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MATERIAL ASPECTS OF BUILDING AND CRAFT TRADITIONS

SPATIAL PROGRAMME – BUILDING MATERIAL – NATURAL ENVIRONMENT

A HIMALAYAN CASE STUDY

Hubert Feiglstorfer

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Front cover: Uru Katsel Temple in Tibet. Women creating a shiny surface on top
of the clay plaster by burnishing with round stones (Hubert Feiglstorfer).

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CONTENTS

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GENERAL REMARKS

Abbreviations

app.	approximate
c.	circa (used for dates; e.g. c. 19th century)

Institutions:

ACDH / ÖAW	Austrian Centre for Digital Humanities
ASI	Archaeological Survey of India
FWF	Austrian Science Fund
GBA	Geologische Bundesanstalt in Vienna
IAG / BOKU	Institute of Applied Geology / University of Natural Resources and Life Sciences in Vienna
IKGA / ÖAW	Institute for Cultural and Intellectual History of Asia / Austrian Academy of Sciences
IPM / BOKU	Institute of Physics and Materials Science / University of Natural Resources and Life Sciences in Vienna
ISA / ÖAW	Institute for Social Anthropology / Austrian Academy of Sciences
ÖFG	Österreichische Forschungsgemeinschaft
TASS	Tibetan Academy of Social Sciences in Lhasa
TUW	Vienna University of Technology

Abbreviations used in Chapter III:

AB	Adobe brick
BMA	Bulk mineral analysis
BMD	Bulk mineral distribution
CMA	Clay mineral analysis
EP	Exterior plaster
FG	Fine gravel
GSD	Grain size distribution
IP	Interior plaster
IRS	Infrared spectroscopy
RM	Raw material
STA	Simultaneous thermal analysis

Abbreviations used in BMA tables, in alphabetical order:

Amph	Amphiboles
Calc	Calcite
Dol	Dolomite
Goeth	Goethite
Gyps	Gypsum

Hem	Hematite
K-fsp	K-feldspar
Phy	Phyllo silicate
Quar	Quartz
Plagio	Plagioclase
Pyr	Pyrite
7Å	7Å mineral

Abbreviations for languages:

Ger.	German language
Gr.	Greek language
Kash.	Kashmiri language
Kt.	Kati language (Nuristan)
Nep.	Nepali language
Pash.	Pashto language
Tib.	Tibetan language
Skt.	Sanskrit
Turk.	Turkish language
Wg.	Waigal language (Nuristan)

Field research and related projects

Field research in the Himalayas, conducted by the author, started about twenty years ago. First financial support was given by a scholarship from the University of Technology in Graz in 2002. Field research in Iran was conducted in 2003. From June 2005 until December 2006, field research was conducted in the Indian Himalayas, also in Pakistan and Nepal. In March and April 2010, field research to Central and West Tibet, Xinjiang, Qinghai and Gansu was undertaken as part of an Austrian Science Fund (FWF) project P21806-G19 "Society, Power and Religion in Pre-Modern Western Tibet: Interaction, Conflict and Integration". In July and August 2011, field research to Kashmir and Ladakh was conducted as part of the same project P21806-G19, which was also sponsored by the Österreichische Forschungsgesellschaft (ÖFG). In December 2011 / January 2012, field research was conducted to Ankara and Safranbolu region in Turkey. In June 2014 and also in November and December 2015, field research enabled studies in Central Tibet, both expeditions being part of the Austrian Science Fund (FWF) project P 25066 "The Burial Mounds of Central Tibet". In December 2014 / December 2015, field research was conducted to Bulgaria. From September 2014 until February 2015, the project "Clay mineral analysis" under the leadership of the author was granted by the Institute of Social Anthropology at the Austrian Academy of Sciences in Vienna (ÖAW) and The Austrian Research Promotion Agency (FFG) in cooperation with the Institute of Applied Geology at the University of Natural Resources and Life Sciences in Vienna (IAG / BOKU). In November 2015, field research was undertaken to Albania. In July and August 2018, the author conducted field research in the Indian Himalayas within the project "Materiality and Material Culture in Tibet" funded by the ÖAW-Innovation Fund "Research, Science and Society". In May 2019, field research was undertaken to Central Tibet as part of an Austrian Science Fund (FWF) project P30393.

Methods of survey

In the context of a field survey, common tools utilised for on-site architectural survey include measuring, taking pictures, and oral documentation by conducting interviews. Building research within a scientific scope is heavily based on field research, which relies on the documentation of three-dimensional objects. This also includes objects no longer or only partially existing and having to be reconstructed.

Working with vernacular architecture often leads to remote locations. In an article on field documentation (cf. Feiglstorfer 2008), the author attempted to touch upon a topic, with which he is continuously being confronted: How to act in remote areas, partially as a single surveying researcher, and possibly also with restrictions in applying highly technical equipment. Such circumstances make it particularly challenging to establish methods of survey capable of being conducted by a single person (ibid. 96). In the amount and size of portable equipment we can distinguish between a survey conducted within a survey team and a survey conducted by one's self as an individual (if necessary, with local support). Besides simple equipment such as a hand laser measuring tool, a measuring tape, a bubble level, and a plumb, digital methods for processing image data are helpful. Examples include photogrammetry or Image Based Modeling (IBM) also known as Structure from Motion (SfM), for which in the field primarily digital equipment of photography is required. In Feiglstorfer (2008), the author applied photogrammetry for several surveys. Survey techniques are continuously improving, and the former photogrammetric method shown in Feiglstorfer (2008: 99−111) was expanded with SfM. This enables the generation of three-dimensional models out of two-dimensional overlapping pictures. It is one of the methods that can in the field easily be conducted by one person with the use of a digital camera. In the case of using a drone or kite, a second person is needed to assist. Within the study on burial mounds in the FWF project "The Burial Mounds of Central Tibet" (P 25066), this technique was used, for example, for smaller artefacts like a seal with a diameter of about 12 mm. Also, for further analysis of constructions in a three-dimensional view, this method was suitable. GPS is another important tool that is frequently used within this research (ibid. 98). In order to generate maps, GPS data are merged with GIS data. This method can be seen, for example, in a map of historical Western Tibet and Purang (cf. Feiglstorfer 2012b).

Conventions

Common local terms are presented in phonetic transcription. Their transliteration is given in brackets when first noted. Tibetan terms have been transliterated according to the system of Turrel V. Wylie (1959).

Source references in the text are placed directly following the text passage concerned before the following punctuation character. In case the given source refers to more than one successive sentence, the source reference is given after the punctuation character of the last sentence concerned.

INTRODUCTION

Categorised within the field of building history and material culture, the current topic of interest includes the disciplines of technique, natural science and humanity. The applied methodology spans between "classic building technique research" with social anthropological components and material research including laboratory analysis.

Research on building history is based on a maximum dense net of material cultural markers. Their nature is complex and linked to a variety of locally and regionally connoted material aspects. Exploration of such markers is a main focus of this study. As a case study, the Himalayan region has been chosen, and the applied methodology is transferable to other areas of research. The research question within the area of study concerns interrelations between architectural macro and micro components ranging between the materialisation of ideological programmes, building techniques and building material properties. The outline of the method can be found in the structure of the chapters.

Chapter I concerns architectural methods for the materialisation of spatial concepts in accordance with religio-political programmes. The second and third chapters are both concerned with material research. Chapter II shows the relation between traditional crafts and vernacular architecture regarding technical properties of raw material and methods of processing. Chapter III goes into detail of the applied mineralogical research methods to analyse relations between the compositions of different types of clay used for crafts and building purpose. Chapter IV concerns natural resources and climate conditions and their impact on Himalayan composite constructions embedded in a Eurasian context.

Chapter I: On the materialisation of a religious programme

The question of spatial programmes, in this context of early Central and West Tibetan religious structures, requires a unification of material and religious programmatic concepts. Initially, the question for the essence of a religio-political program is raised. Universal programmes are defined and supported by canonical architectural features. Buddhist monastic structures follow geometrical and proportional concepts. Their three-dimensional design focuses on an ideal and geometrically defined common pivot and stands in an inseparable spatial relation to behavioural patterns of pilgrims and devotees. The materiality of such structures becomes part of a larger whole and extends to the spatial organisation of the surrounding settlement and beyond. Particular markers within the village compound follow this spatial concept and define the pilgrims' movements.

Analysis and comparison of religious structures provide insight into architectural methods for the materialisation of religious concepts. Besides geometric and proportional concepts, the definition of the orientation of religious structures is also of importance. Based on a reconstruction of the Khorchag Monastery, located in West Tibet, a hypothesis for celestial dependence between the layout of religious structures and a cosmological unification is emphasised. In concluding, this chapter and bridging to the following chapter, the question is raised of the impact of building materials within such spatial programmes.

Chapter II: Material traditions – Raw material and techniques

Changing the scale by moving from spatial programmes towards material qualities leads into the topic of material research, with mineral-based materials being the focus. Regarding materials for building purposes, in addition to their use for primary constructions like walls or roofs, use for architectural surfaces plays an important role in the processing of different material qualities. According to use, we may distinguish between a quality used for simple functional local building purpose and such used for representation of a higher social status. In most cases, this difference becomes visible through the quality of the selected raw material and its processing. For a comparative purpose, different crafts have been chosen for this study – the making of flat roofs, of clay sculptures and of pottery – enabling the examination of relations between mineral compositions of particular raw materials used for different crafts. An aspect within the current research is the questioning of still existent material traditions with a purpose being to learn and understand local approaches to finding and processing proper materials.

Chapter III: Earth building traditions in Basgo and Likir

In this chapter, the research conducted in Chapter II is continued on an analytical level. The research area includes the villages of Basgo and Likir, both located in Ladakh, and their close surroundings, where earth building traditions are still alive. Particular clay samples used for adobe bricks, flat roof constructions, clay plaster, pottery and also the *tab* (Tibetan stove) are analysed regarding their mineralogical composition and methods of processing. Results will be juxtaposed. Some of the samples are related to historical sites, others to contemporary constructions and building techniques. A variety of different compositions and applications enables the study of relations between historical use and living traditions. Local terms for clays are included in the comparative research so as to search for particular relations between local traditions.

Chapter IV: Himalayan composite constructions and environmental influences

Over the Western Himalayas, composite constructions have a long tradition reaching back at least into the 8th century CE. Initially, this chapter questions in a regional context transmission of particular composite techniques, which are traditionally used for wall constructions. The combination of different materials makes necessary the observation of natural influences on single components of the structure such as wood, stone and clay. A range of natural factors influencing the development of single techniques becomes evident. As a further step, material resources and climate conditions are defined for the research area. Based on these conditions, certain developments in construction are explained. For the development of particular technical features of composite constructions, their impact on a 'seismic culture' is discussed.

In order to obtain an idea of early traditions and the development of composite constructions, the investigation of historical structures is an essential part of this study. The development of certain techniques in accordance with environmental conditions is analysed. A continuous change of composite constructions can be monitored, showing their transformation in a regional context.

PRELIMINARIES

1. Interdisciplinarity

Crucial matters such as tradition or vernacular are common basic frames within material cultural research, and as such are applied within this study. They accompany most discussions on this topic in a theoretical and practically applied manner, and are crucial not only in a Himalayan relation but for building research in general. Their basic definitions and relations to building research are at first treated in a theoretical form, which is thought to be a humanistic introduction to material cultural matters. Traditions are locally determined and in their general existence follow particular general patterns that are looked at from different angles. Materiality and architecture in particular are just components within the matter of tradition and vernacular, which may partially be explained by a material approach. Tradition and vernacular are deeply linked to humans as social beings within a social structure, and studying tradition and vernacular is closely related to the field of social anthropology. As a researcher trained in the field of architecture, this relation seems basic to understanding wider contexts. Nevertheless, this research focuses on the author's field of expertise. The following explanations show an interdisciplinary setting of tradition and vernacular, including material cultural and social anthropological aspects.

2. Treatment of research information

Use of an appropriate building construction is an essential part of primary human needs. A wide range of construction typologies was invented, developed, adopted, transformed, and over the course of time, neglected or destroyed – i.e. subjected to continuous change[2], thereby continuously moving its architectural character. Construction is the backbone of any building structure as a carrier of material qualities.[3] Its existence and design are interwoven into a wide range of human actions, resulting in constructional decisions. In any case, constructions communicate in a material form with the particular local environment, and are to be mentioned as an essential material-cultural[4] fingerprint.

2 Characteristics of traditional types of construction are directly related to its single components; the quicker the change of an object, the more short-dated the single components will be (Lehner 2008: 14).

3 In this context, *material quality* refers to information on its physical existence given by and about the object itself, such as technical properties, e.g. which kind of construction or which materials were used. This may also be related to further information – sensual and associative – on non-technical properties, e.g. which social class did the builders belong to or what may have been the environmental conditions. The summary of all the information given by and about the particular construction defines its material quality: i.e. the information necessary to describe the single parameters, which are relevant for the material existence of an object including any information given by the related environment on the object and vice versa.

4 *Material culture* in general is related to objects and, regarding the present topic, to architecture in particular. Speaking in an architectural relation may too much constrain the wide field of materialised parameters and might exclude objects that are not preliminarily architectural but are possibly used in an architectural context. Of the

Dealing with traditions requires scientific options to reconstruct incomplete historical data, since our understanding of historical facts depends on possibilities of reconstruction within a certain frame of understandable reference and period.[5] History is used as a collection − and for the analysis of data − to get answers for comparable historical incidents. By using contemporary data to the greatest extent possible, the use of the present point of view to explain the past should not be attempted (Rapoport 1990: 80, 81).

This perception may lead to relativising and self-critical insight that results from the fact that research on traditions is dependent on society, its conceptual framework and the period of time, in which a researcher acts. An example of an allegorical depiction of a kind of *Ur*-structure and a related question of whether every structure may be defined as such is given in Schoper (2009: 63, 64) by providing a drawing as example concerning an allegorical change from nature into a simple building structure. The drawing depicts four trees grown in a rectangular position to each other. Their opposing branches form a gable roof in such a way that it seems as if the top of a simple hut has been constructed (as interpreted by Charles Eisen[6]). This example provides the opportunity to discuss the interrelation between how one interprets certain pre-information and the particularly given intellectual and cultural background.

Field research, documentation and the study of architecture and constructions on-site and at the living object reveal sensitivity for local varieties and related circumstances of possible genesis and change. This kind of on-site-research presupposes not only the examination of the construction but in a much wider sense the environmental, social and historical parameters, in which the object is embedded. This approach seems to be preliminary for conducting building research, no matter if the object is still in use, ready for use or already in ruins.

Typologies of building constructions are generally systematised parameters to make certain aspects comprehensible within a certain scientifically ascertainable pattern. It is the research on site that supports the understanding of constructive varieties within categories and different stages of transformation. This instance requires a closer examination and a constant questioning of existing rigid categorisations, and treatment stages of transformation on a same categorical level. One must be aware of mentioning particular methods in "making", for example, an earth roof or wall, a plaster, a stove, etc. as regionally typical building methods, since constructions are often local variations and strongly dependent on local material resources.

Single aspects of construction techniques have to be studied in a respective cultural context with the respective particular relation and not as a separated momentum, as emphasised by Eriksen

main materials used for vernacular structures, i.e. stone, wood, clay, and fibres, none are primarily created for an architectural use as long as man defined them by a particular use as an architectural object. The particular use of these materials makes their integration within a particular culture physically evident. An essential aim in this debate is the closer examination of the essence of materials used as building materials within culturally distinct and differentiable human creativity.

5 The ability and the way to reconstruct depend on the given ability within a particular society and epoch (Assmann 1988: 67, 68). He mentions this fact as *Rekonstruktivität* (Ger.) as one of six features of cultural memory.

6 Front cover by Charles Eisen (1720−1778) in Marc-Antoine Laugier (1755).

(2001: 200).[7] Techniques[8] aimed at creating a certain product work within a certain local customary frame.

A detailed study of various material cultural case examples given in this contribution enabled the understanding of their local relevance. Comparative studies within a wider focus – also in a regional context – revealed fresh insight into possible regional relations. Studying the object itself is one matter, which is followed by the study of the object's interrelations. Individual constructive features and their comparison within a local and regional[9] context are questioned and linked to a search for their material cultural impact.

It is awareness towards certain interrelations by comparing the particular significant parameters to each other and looking for a thread of transmission or diffusion. The possible range of synergies between the reasons for the existence of constructions is diverse. They either directly influence each other or have grown independently from each other. In any case, arguing within a certain predefined matrix of evaluation should guarantee a proximate objective approach.

Traditional building constructions are as such objects defined by humans and are to be seen as a product within a continuous process of change. This results in positioning objects of research into a living, not only object- but process-orientated continuity. Regarding this aspect, Allen Noble (2007: 1) relates "traditional" to processes and material objects as carriers of material cultural aspects, always to be understood within a processual context. Since traditions are related to historic structures, the process-generating facts are only evident in fragments. Mention of them may not be seen as exclusive but as a result of availability within the research work.

The process itself is hard to explain as something complete and finished but, au contraire, as an infinite summary of various parameters, depending on limited possibilities during field research. Conditions during field research are not always the same due to different circumstances, like accessibility, resources in time, unfavourable climate conditions, or high costs – practical reasons that may explain a kind of incompleteness of field sources.

In this regard, the possible objectivity of the relevance of single parameters within a whole process of the genesis of a particular type of construction has to be understood within a net of available and non-available information. Missing information may result in the vanishing of certain preceding structures or in not available written evidences. This has to be considered individually in the translation of the semiotics of an object. An example is the circumstance of non accessible parts of a wall construction, such as the constructive core of a stone wall. Even knowledge that a

7 With reference to Pfaffenberger (1988: 241).

8 Techniques are a social product learnt through tradition and are also part of a material culture (Lemonnier 2007: 544). As one characteristic of technique, Lemonnier differentiates between two dimensions of technical behaviour: physical and communication.

9 *Local* and *regional* are used as relative terms; *local* is defined by characteristics of a place, while *regional* defines a wider area defined by a certain geographical extension and particular characteristics. In this regard, their use depends on the context, not on a preliminary spatial limitation. Achleitner (1997: 111) points out that the changeability of a region is based on the abilities of the people settling there and also that a region exists in a continuous state of draft.

wall's external appearance is similar to that of a neighbouring wall – for which we possibly have detailed evidence of methods used for its construction − does not give full certainty to the conclusion that both walls' constructions are the same. The right choice of tools for the translation of semiotic parameters[10] is needed for a successful approach.

Objectivity is the central aim within scientific work. Formulations and interpretations, choice of comparison samples, particularly within a comparative study, have to follow this ideal. However, contrary to *hard* sciences, a comparative study as a *soft* science is based on a relativity already defined by the choice of the examples of comparison. This situation potentially leaves unclear aspects and, based on subjective experience, a certain relativisation may be needed. The choice of comparative objects and of the used methods in analysis and interpretation are to a certain extent based on subjective experience. By giving all the related decisions in a most objective and comprehensible manner, the aim is again focussed on the *scientific*.[11]

Regarding this concern, it has to be pointed out that most of the empiric material used is based on primary sources collected by the author. This bears advantages in originality compared to secondary sources. Several of the documented, primarily vernacular[12] objects were as such changed or have already vanished completely over the course of preparing this book. In this regard, parts of the presented material are unique and of high value as architectonic contemporary witnesses. The critical side of this circumstance is that with continuously ongoing change – or much worse with the disappearance of witnesses – material sources have vanished and may not be understood in the here documented way during further field research. In many cases the treated vernacular examples are not repaired or rebuilt in a traditional way after their partial or complete change or after destruction but are either replaced by 'modern' constructions that do not follow preceding building tradition or remain unreplaced.

3. Aspects of tradition

Tradition can be explained as the living process of interpreting the past. One can also follow a definition given by Rieger-Jandl (2008: 26): Tradition defines "an anonymous product of a collective sub-consciousness" (transl. author). Another definition according to Shils (1981: 12) mentions tradition as "anything passed down within a group or society with symbolic meaning or special significance with origins in the past". A literal meaning directly translated from Latin is "to transmit" in the sense of "passing down". These definitions are not necessarily related to

10 The relationship between a sign and its object is understood by speakers of the same language (Beeman 2002: 421). The operating radius of local terms and related social communities are linked to this matter as seen in the following.

11 Beckwith (2009: xi) points out the need for acceptance of the importance of one's own experience made, which in its nature is subjective but still integral in an objective scientific process.

12 *Vernacular* (Ger. *vernakulär*) is used as a native language pattern versus the standardised and polite (*lingua franca*) architecture, and is based on local traditions and needs (Oliver 2006). The endemic existence of vernacular structures is limited to a certain region, possibly also to several regions. Indigenous patterns rely on continuous change. Aigner (2010: 27) mentions possible changes as adaptation to new living conditions by a process of modernisation, including structures, which were translated with new materials, different constructions or scale, or by immingling with different forms and cultures.

Himalayan culture and will primarily be treated here in a general discourse. The explanations given in the following context for "tradition" and "traditional" are again based on experiences from field research. When talking about traditions, their possible change and loss inevitably become a matter of discussion.

It is unclear when some traditions began. We may distinguish between the diffusion of traditions due to external influences and such, which are related to a common local aim of adopting and optimising. As an example, a particular method of using timber lacing in solid wall structures is evident along a route from the Himalayas via Pakistan, Iran, and Turkey towards East Europe. Its constructional coherence over such a wide distance is evident, and a local random development may be excluded. In the case of local knowledge on particular local methods in making timber-laced constructions, a diffusion of building traditions over a distance of hundreds of kilometres paired with local adaptations may be suspected (cf. Feiglstorfer 2009). A mixing of external respectively local reasons is supposed for the diffusion of a particular building method over hundreds of kilometres.

Within the material focus of the present research, knowledge of building techniques plays an essential role when "embedded in the habitus and in knowledge systems, and technologies may be studied as ideology" (Eriksen 2001: 201). The use of a technique has to be understood in local communities differently to consideration outside a vernacular context. In case of a loss of a local community, the choice of techniques becomes more variable, and from a builder's individual decision in a vernacular context we see a strong relation to customs of the community. The vernacular system itself becomes a kind of reminder of accepted socio-cultural rules and conventions (Sanders 1990: 45), and its understanding is dependent on the "level of redundancy and way of transmission" (ibid. 47).

Hobsbawm (2007: 2) views the invariance and use of fixed practices as important facts for the existence of traditions, and points out the difference between tradition and custom. In his definition, tradition does not preclude innovation and changes that directly influence tradition (ibid. 3) as a continuous updating of order structures. Custom is mentioned as an expression of tradition being in a continuous confrontation with ingenuity (Lawrence 2006: 126).

Individual structures are interwoven within a local pattern language and the question of who founded a tradition may in general be answered by looking at a collective influence. Possibilities to change or add customs in a traditional system exist for a coordinating elite.[13] Noyes and Abrahams (1999: 92) mention that customs and traditions may also be invented by using already existing models, and that the success of invented traditions "depends on the sensitivity of elite readings." Traditional building techniques that developed over a long period of time and are based on environmental preconditions are to a certain extent related to functional necessities that

13 In this context, Herrle (2008: 12) differentiates in a generalising manner between adaption and usurpation related to exercise power based on the consciousness of those who are the users and those who are the builders. Herrle emphasises the importance of cohesiveness: "'Cohesiveness' in this context can then be defined as the degree to which the amalgamation of cultural elements of various origins has led to generally accepted norms and standards. […] identity depends on a certain level of cohesiveness, on commonly shared values (at least in a particular reference group) and thereby allows a reassurance from the 'other' vis-à-vis the 'self'" (ibid. 11).

define the design of a building. One meaning of tradition includes the existence of past practices and their continuity and relation to something authentic. Past practices in the present meaning are related to material knowledge, in particular techniques with a strong socio-cultural relation[14] (Barfield 1997: 470). Until the start of a modernisation era, knowledge had been handed over within a particular community and from generation to generation. The process of collective learning is a non-genetically predefined process of 'social learning', by which a predefined behavioural pattern is acquired by an individual (Baumann 1996: 34). Further it is emphasised that people learn as individuals (ibid. 37).[15]

Traditional constructions were proven by the related society for their efficiency and may have been adapted to changes, if necessary. This process of adaption can last as long as this particular property of regeneration is not overwhelmed by external influences, such as the introduction of so-called "Western standards". A continuity of a particular building culture depends on the construction itself in terms of its adaptability in a functional and technical context and on the acceptance of the society concerned (Lehner 2008: 16).[16] Among four different stages[17] within a design theory as described by Skibo and Schiffer (2009: 9–11), the behavioural chain and technical choices are of particular interest within this study. The behavioural chain contains the manufacturing process that is related to the availability of raw material and possibilities in its processing. The latter aspect, i.e. technical choices, is related to generation of an adequate construction and finding of a representative design. Throughout this contribution, these aspects are a basic guide.

4. Aspects of vernacular

Vernacular includes a huge variety of different constructions and designs. Its complexity is given by its interdisciplinary entity in a quantitative and qualitative relation. Vellinga (2006) raises in the chapter "The end of the vernacular" the question for the need of a categorisation of vernacular. To get close to a definition, several interpretations will be given. An early use of the term vernacular in context with vernacular architecture can be traced back to 1839 (Green 2007; according to Vellinga 2011: 176), although the term *vernacular* originates from the Latin *vernaculus* (Ger. *einheimisch*, *inländisch*, Engl. *indigenous*, *native*).[18] Vernacular may be understood as native or unique and linked to a certain place (AlSayyad 2006: xvii). In earlier days the term *vernacular* was used "to describe buildings that were built according to local custom to meet the personal requirements of the individuals for whom they are intended" (Noble 2007: 6). Rapoport (2006: 177) refers to early use of the term *vernacular* in the 19th century: Vernacular architecture may

14 According to a definition by Tim Ingold (1979) in (Eriksen 2001: 200), technology is "a corpus of culturally transmitted knowledge, expressed in manufacture and use".

15 In this text referring to Goodenough 1981: 54.

16 Regarding *Regionales Bauen* (Ger.) and a related process of change, Achleitner (1997: 105) distinguishes between two influencing factors: "the more stable 'local' and the more dynamic 'exterior' with a systematised character […]" (transl. author).

17 The four different stages within design theory by Skibo and Schiffer (2009: 9) are: life history / behavioural chain, activities and interactions, technical choices, and performance characteristics.

18 According to the Merriam Webster dictionary.

be explained because of actions taken due to local needs and given natural resources based on a collective decisional level.

Vernacular is related to a social structure and defines a system, of which materiality and in particular architecture and crafts are components. Polite architecture, in contrast, is defined by non-local styles and does not follow local traditions. The expression “vernacular architecture” may vaguely signify the merging of expressions such as “indigenous, anonymous, spontaneous, native or related to the countryside” (transl. author), which are used, according to Rudofsky (1993: 1), due to a lack of a related generic expression. Modern does not exclude vernacular, as long it remains part of a vernacular social context. Also a particular functional association or a particularly related social hierarchical status does not necessarily exclude an object from being vernacular, again, as long as it remains part of a vernacular social context. Based on this premise, all kinds of buildings, even palaces, monasteries, or residential and utilitarian structures may all be connected to the vernacular. In the following, a differentiation of architecture within vernacular systems is conducted by referring to “simple” vernacular structures and elite structures or structures of a higher social status. According to traditions and their continuous adaptation to changing local conditions, vernacular patterns of architecture can be transformed. AlSayyad (2006: xvii) defines a gradual change in vernacular architecture primarily as an adaption to geographic and economic conditions. An adaptation is also related to language that defines architectural components within a vernacular social context.

Vernacular design is based on local material resources and naturally given influences. Methods in joining and processing the single parts of a building or artefact are carriers of symbolic meaning and vernacular identity. Rapoport (1982: 43) mentions a symbolic approach mainly approved in traditional cultures, where a built environment is able to express strong and clear schemata. Tapering of walls can be given as a Himalayan example. In Tibetan culture a method for stabilising walls and preventing them from tipping over towards the outside involves sloping from the bottom towards the top. In Lhasa, we find this method applied with stone walls, in Spiti in Himachal Pradesh with rammed earth walls, and in Ladakh with adobe walls. Each material shows its own design pattern, which can be read via the surface of the wall. The static function of this technique and the general appearance remain similar within the Tibetan cultural zone. Particularly Central Tibetan walls show a design pattern that results from the laying of the stones. The recognition value of this technique is high. One symbolic effect of this traditional building method is its more powerful and fortress-like appearance, for example, the Potala in Lhasa. Size, location, colour and inter alia the tapering of walls denote a particular meaning and, in the words of Eco (1980: 214), act as a “sign-vehicle”.

Regarding the design of vernacular architecture, Broadbent (1980: 139, 143) distinguishes between “pragmatic design”, “typical design”, “analogical design” and “canonical (geometric) design”. The stage of “pragmatic design” as a state of trial and error is to be classified as pre-historical. The stage of “typical design”, where the community shares particular images, is a frequent design aspect in the Himalayas that expresses vernacular design. On the other hand, the “canonical (geometric) design” concerns us in the context of universal, political and religious concepts that are also expressed in design – in a spatial and constructive context. To go with Broadbent’s definition, this contribution is placed within the wide field between “typical design” and “canonical (geometric) design”.

I. UNIVERSAL CONCEPTS: ON THE MATERIALISATION OF A RELIGIO-POLITICAL PROGRAMME

In various cultures, political and religious ideologies found their expression in the manifestation of certain ideological programmes, and were canonically materialised in architecture. Such canonical patterns were best planned modularly and applicable throughout cultural zones. An aim of such an installation of a canonical programme is the spread of a certain ideology by manifestation of power and the representation of a related universal concept. Stek (2013: 345) discusses the shaping of the material environment according to political power and raises important questions for 'common languages and symbols of success, victory and dominion' hidden behind the use of the materialisation of such programmes. An ideologic concept holds the whole programmatic system upright. For example, regarding the Tibetan house such concepts are prevalent in vernacular architecture, although dwellings of the social middle and lower class have to adapt to continuous change (Lehner 2009: 20). The aim for changelessness and imperishability are programmatic features of elite architecture (ibid. 20).

Based on a politically and religiously dominated architectural concept, a particular identity-establishing design pattern may be regionally extended – inter alia to extend a sphere of influence. In the case of 'simple' vernacular structures, their appearance is much dependent on local resources, while in the case of representative monumental structures, e.g. monastic structures, material resources from outside the immediate vicinity may be preferred. Such elite architecture with wide-spread interrelations is adjusted to the spread of a particular cultural programme.

As a research example for the examination of the materialisation of an ideological programme, early Tibetan religious architecture was chosen and will be treated in this chapter. Analysis of religious structures of the imperial Central Tibetan period (7th to 9th century) and of the early West Tibetan period (10th/11th century) uncovered several of such canonical typologies, which were locally applied in variations. In the Tibetan cultural zone, such concepts act in a universal manner and aim to combine terrestrial and celestial components. Before concentrating on various methods to materialise a particular Tibetan Buddhist programme in the imperial Central and early West Tibetan period, outlines of the religio-political programme will be given.

1. Imperial Central Tibetan period (7th–9th Century CE)

The structural and territorial organisation of the Tibetan imperial polity (7th–9th century) is based upon an integration of old territories, which were headed by ruling families, who formed the core of the civil and military elite in the time of the Tibetan empire. The emperors, after having been successful in forging a federation with the old 'lineage'-organised families, expanded their power by marriage with lineages, enabling themselves politically influential positions.

Most likely Buddhism was not fully established during this early period, as can be seen in the form of pre-Buddhist burial rites practised during the imperial time. However, from the late 8th

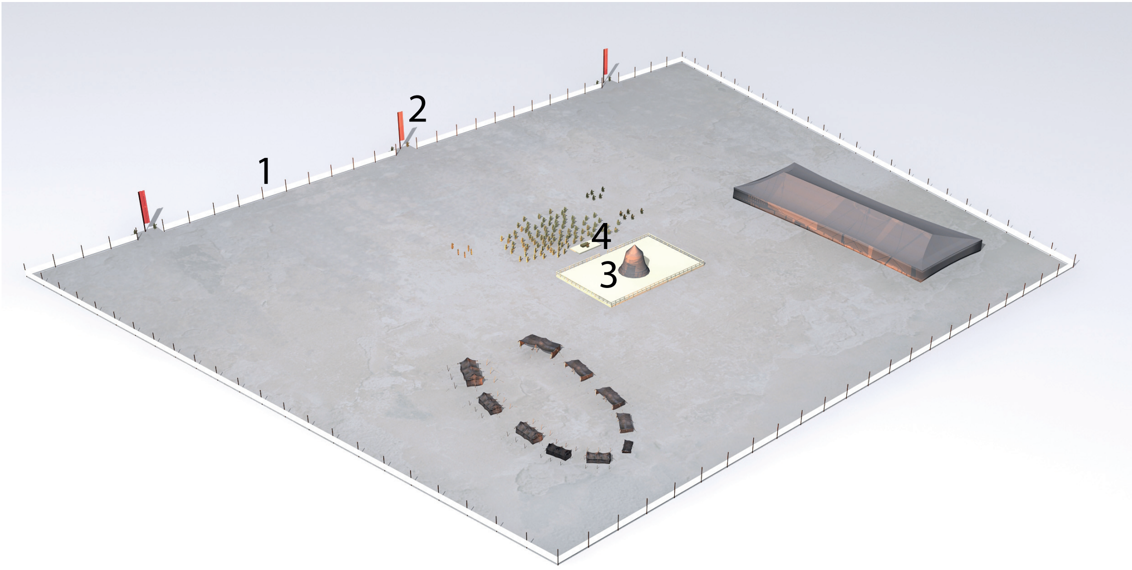


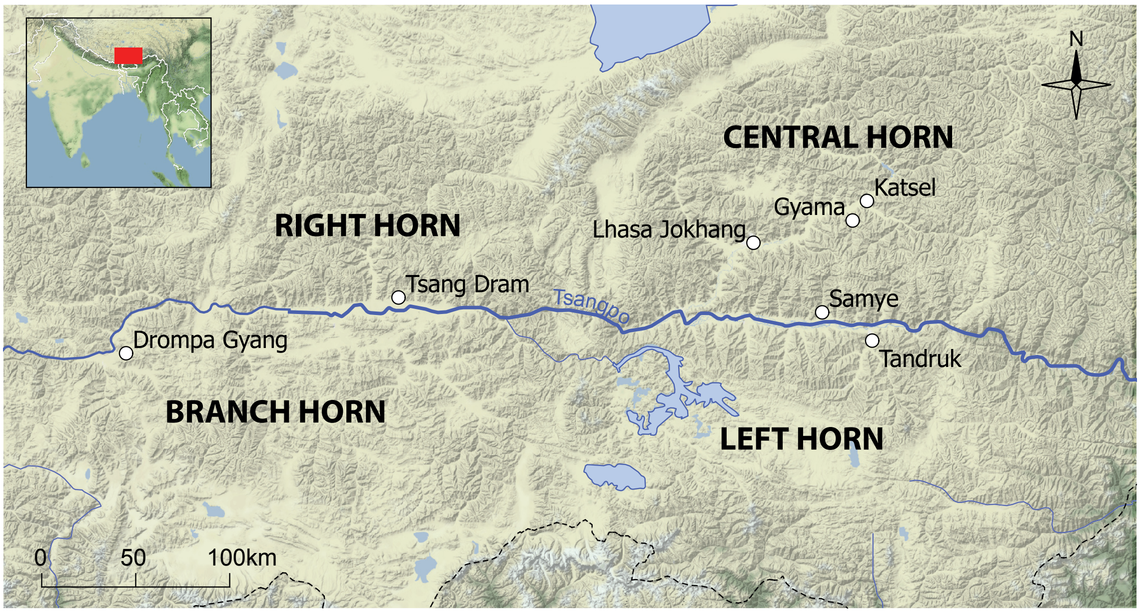
Fig. 1.1 Gyama. Summer camp of the Tibetan king. 1 = 100 lances; 2 = Three gates; 3 = Central platform; 4 = Altar. CAD: author. Rendering: Ferenc Zamolyi.

century on, changes in the area of rituals and also externally in the form of *stupa*-shaped burial mounds (or also mounds with Buddhist clay tablets (Tib. *tsha tsha*) bricked in the walls) can be observed (cf. Feiglstorfer 2018).

1.1 Mobile camps and courtly assemblies

The early emperors' residences largely consisted of mobile campsites (Tib. *pho brang*), where the emperor and his family resided. We know of courtly assemblies (Tib. *'dun ma*) that were held at various locations in Central Tibet. The example of Gyama (Tib. Rgya ma) appears to be the only one, where some reconstruction of the original design is possible on a textual source (namely the Tang Annals relating to the treaty ceremony held in 821 CE), where the campsite is mentioned as the principal summer camp of the Tibetan king (Tib. *btsan po*) (Hazod 2014: 21). The residence and campsite actually refer to the later centre of the Gyama myriarchy (Tib. Rgya ma khri khang).

Figure 1.1 provides a reconstruction of a surrounding enclosure that measured 100 long lances (see number 1 in Fig. 1.1) at a distance of ten paces; it had three gates (2), each with standards in front and guarded by armed soldiers. The central platform (3) had high-ranking ministers stationed at its foot and the emperor's tent at its top. In front, indicated with number (4), is the altar for oath taking, a ceremony headed by the Tibetan monk minister Pal Chenpo (Tib. Dpal chen po) and accompanied by animal sacrifice. The orientation of the residence, whose ground plan is the shape of a trapezium, was towards the north, facing orthogonally towards the Kyichu (Tib. Skyid chu) River (Hazod 2014: 29, 30).



Map 1.1 Central Tibet. The Four Horns.
GIS data based map: Jakob Gredler. Final graphics: author. Map based on data from Vector data (VD) and Basemaps (BM). Citations of VD and BM also see: Chapter IX, list of illustrations.

1.2 Towards monastic establishments

Until the establishment of monasteries, the *lhakhang*s (Tib. *lha khang*, "temple") were related to the court, i.e. to a small elite group of people. The early imperial establishment of four provinces, the Four Horns (Tib. *ru*[18] (*bzhi*) *gnon*), encompasses the empire's territorial core. A territorial division of the Central,[19] Left, and Right Horn formed the first Horn system (Dotson 2009: 39). The first evidence of the Central Horn is given in 684 CE, and the Horns together are mentioned first in 712 CE (Uray 1960: 53, 54). By suppression of the demonic territory, a symbolic centre was symbolically stabilised and the territory of the empire defined. Its territorial extension is expressed by the suppression of the Horns (Hazod, Sørensen 2005: 179).

The erection of four "Temples Taming the Border" (Tib. *mtha 'dul gyi gtsug lag khang*) is a materialisation of a territorial definition of the empire. The border protecting temples of the Four Horns (Tib. Ru bzhi)[20] erected under Songtsen Gampo (605–649) are as follows (see Map 1.1):

18 According to Tsering Gyalpo, the Tibetan word for horn *"ru"*, which serves as the name for an administrative territorial division, is related to the life of nomadic people in Tibet. It designates the point at the top of the four pillars, where the black tent is fixed with a rope (evidence by Christian Jahoda in 2012).

19 The Central Horn was the core region, containing many of the regularly visited imperial residence and council places; in this region it was mostly used as a summer dwelling (Hazod 2015: 192).

20 The list of geomantic temples contains three versions with four central temples in order to suppress shoulders and hips (version 1) or the four limbs (version 2). The four mentioned central temples follow version 1 (Hazod, Sørensen 2005: 184–198).

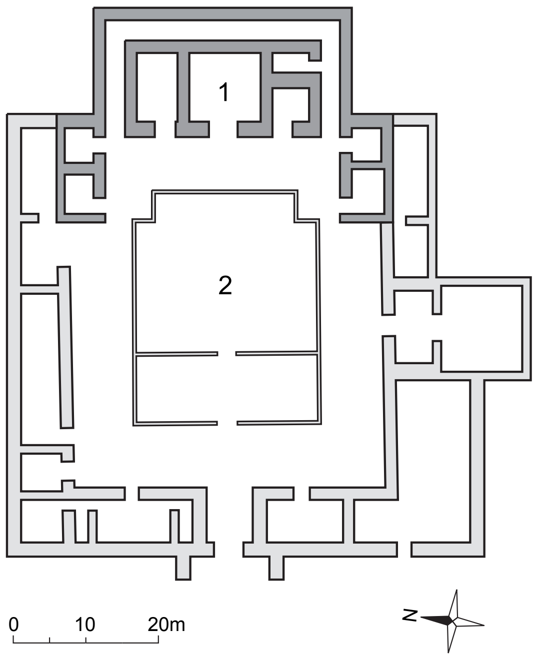


Fig. 1.2 Tandruk. Monastery.
1 = Early core (dark grey);
2 = Later addition (light grey).
After Herdick in Hazod et al. 2005a: 325–327. Cf. Feiglstorfer 2011b: 26.

Tandruk (Tib. Khra ’brug) in the Left Horn (Tib. G.yo ru), Katsel (Tib. Ka rtsal) in the Central Horn (Tib. Dbu ru), Tsang Dram (Tib. Gtsang ’gram) in the Right Horn (Tib. G.yas ru), and the Drompa Gyang (Tib. Grom pa rgyang) Temple in Tsang (Tib. Gtsang), in the area of the Lhatse (Tib. Lha rtse) District of the Additional Horn (i.e. Tib. Ru lag). A later anthropomorphisation integrated these early border taming temples as the two shoulders and the two hips, which were part of the mythological taming process of the supine demoness imagined as covering the Tibetan territory. With the foundation of twelve (or more) border *vihāra*s with the Lhasa Jokhang in the centre, the body of a demoness (Tib. *srin mo*, Skt. *rākṣasī*) depicting the Tibetan territory was nailed down (Hazod et al. 2005b: 5).

Beginning with Trisong Detsen (Tib. Khri srong lde’u btsan), under whom a minister for religious purposes was introduced, assembly places were established for a religious purpose. This had probably been done since the foundation of the first Tibetan monastery at Samye.[21] According to Dunkardzigdzö Chenmo dictionary (Tib. Dung dkar tshig mdzod chen mo), this monastery belongs to the *chökhor sum* (Tib. *chos ’khor gsum*), the three *chökhor* Samye (Tib. Bsam yas), Lhasa (Tib. *Lha sa*) and Tandruk (Tib. Khra ’brug) (Dungkar 2002: 838). These *chökhor* share a common ancient festival tradition, i.e. the “Flower Offering” festival (Tib. Me tog mchod pa[22]). They are part of “Five Great Offerings” of Central Tibet, including Tandruk Chöpa (Tib. Khra ’brug mchod pa), Lhasa Chonga Chöpa (Tib. Lha sa bco lnga mchod pa), Samye Dode Chöpa (Tib. Bsam yas mdo sde mchod pa), Gungthang Metog Chöpa (Tib. Gung thang me tog mchod pa) and Namgang Chöpa (Tib. Gnam gang mchod pa) of Lo. (Hazod 2005b: 290)

21 The foundation of Samye Monastery as a royal temple may have been influenced by the use of summer and winter court sites in Bälpo (Tib. Bal po) and Dragmar (Tib. Brag dmar), respectively, for many years during the reign of Tritsug Detsen (Tib. Khri Gtsug lde btsan) (712 to c. 755 CE) (Dotson 2009: 46).

22 The *Me tog mchod pa* (Tib.) was a great public festival including a *cham* (Tib. *’cham*) performance with the presence of the local dignitaries (Hazod 2005b: 289).

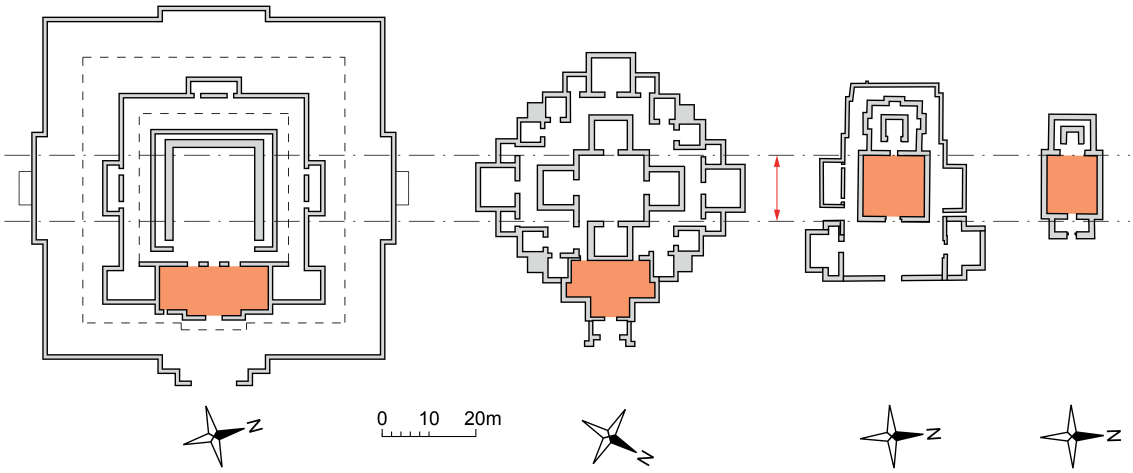


Fig. 1.3 Ground plans of *chökhor* main temples from left to right: Samye, Tholing, Nyarma and Tabo. Development of the position of the assembly hall. Samye after ACP (2007: 39) and Chayet 1988. Tholing after ACP (2007: 46). Cf. Feiglstorfer 2011b: 36.

Money for the upholding of monasteries was collected from lay people via payment of taxes. This was a consequence of the donation of royal land, and the yield was used for monastery maintenance and financial support for each individual monk. This is mentioned for the first time in the case of Samye[23] (Dba' bzhed 2000: 74, 75). Already during Songtsen Gampo (605–649), land was given to vassals, the so-called *"dren"* (Tib. *bran*) (Ronge 1978: 26). The idea of establishing sacred centres for the study of the *dharma* – which follows Thrisong Detsen's (ruled in the 2nd half of the 8th century CE) adaptation of Buddhism as the religion of the court in 761/762 (Kapstein 2000: 60) – and the idea of enabling religious gatherings brought about a change in architectural concepts. The concept of the open, Indian influenced *vihāra* courtyard – as found in the Jokhang of Lhasa (Tib. 'Phrul snang) or the temple of Tandruk (Fig. 1.2) – was changed into the concept of the roofed assembly hall (Tib. *'du khang*). The *dukhang* became successively standardised with the foundation of the Samye Monastery in Central Tibet and in succession in the layout of the early West Tibetan monasteries. This change in architecture of the assembly space (Fig. 1.3) signifies the provision of an appropriate type of space for such gatherings, completely defined as a sacred space, and including the *dukhang* into a proportionally and geometrically defined superior religious programme (Feiglstorfer 2011b: 169ff.).

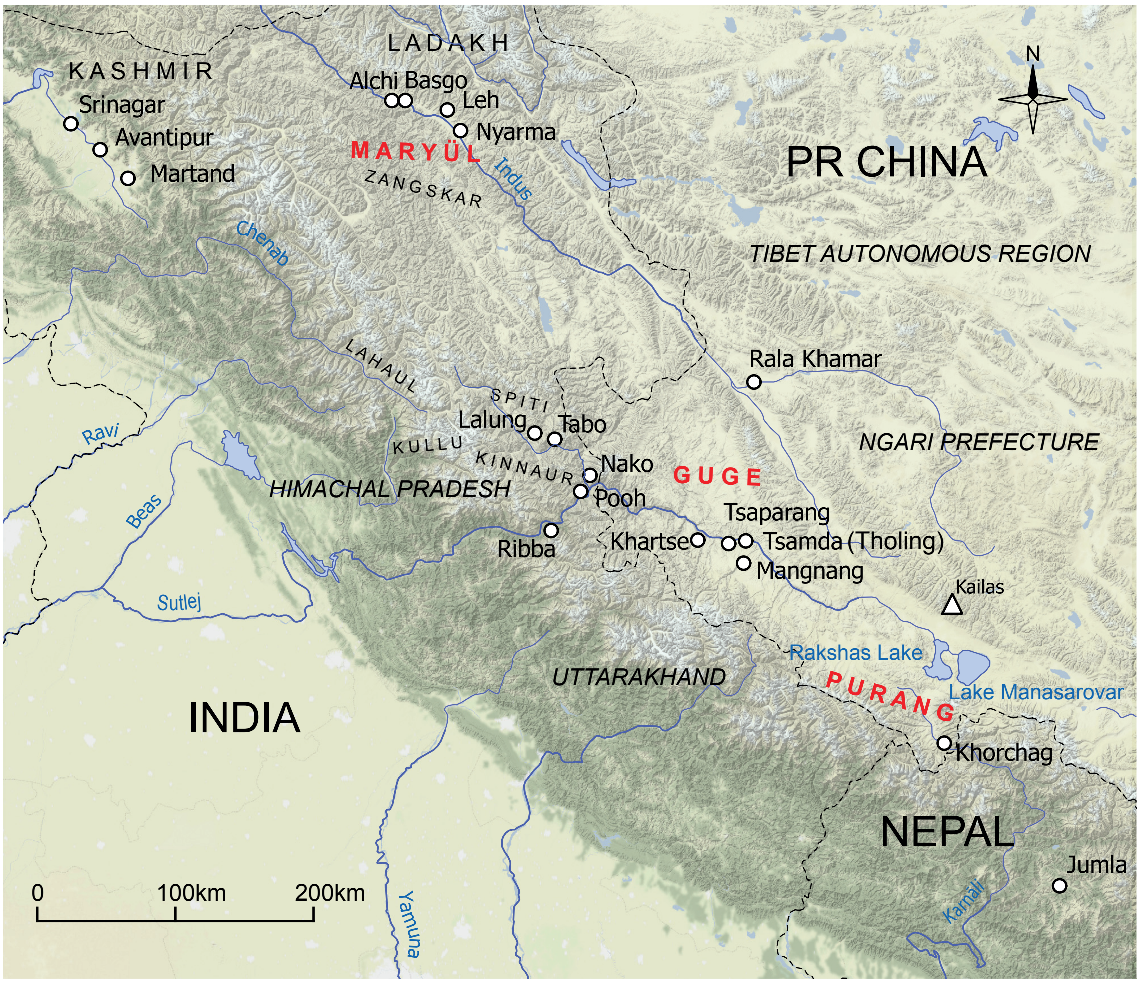
In contrast, in the early West Tibetan system of the 10th/11th centuries, the newly founded monasteries were not linked to the court but functioned as institutions of central importance for the West Tibetan kingdom, not only in religious terms, but on account of their role within a superior religio-political concept. The debut of this development can be equally found with the foundation of Samye in 775 CE. As seen in Samye, in the late 8th/early 9th century, Mahāvairocana appears to have become the central religious figure in a new state cult in Central Tibet (Richardson 1990: 272). The emperor himself appears to be homologous with Vairocana, bringing the ordering of the

23 According to *Sba 'bzhed* (2000: 74, 75), for the maintenance of the monastic community of Samye, seven subject-households were assigned by the emperor to each monk.

empire in relation to the generation of a *maṇḍala* (Kapstein 2000: 60; cf. Feiglstorfer 2013), denoting and underlying as a conceptual principle the course of Tibetan politics.

2. Early West Tibetan period (10th/11th century)

The foundation of the West Tibet kingdom by Kyide Nimagön (Tib. Skyid lde Nyi ma mgon) (903–961 hypothetical after Jahoda and Kalantari 2016: 79, fn. 4) – who originated from the Central Tibetan royal family (Vitali 1996: 90) – together with ministers belonging to aristocratic clans, took place at the beginning of the 10th century (cf. Jahoda, Kalantari 2016: 80). This kingdom seems to have been conceived as a "continuation of the grand empire", which is also suggested by the name "Ngari", i.e. today's designation of Western Tibet. After Nimagön's death, the kingdom was divided under his three sons, who received Purang, Guge and Maryul (Maps 1.2 and 1.3) as well as minor areas such as Spiti, Zangskar, and Garsha (or Lahaul) (Vitali 1996: 159, 160). There is little evidence for the presence of Buddhism in Western Tibet before this time. The inscribed stone stele in Chogro Village in Purang is probably the earliest evidence of Buddhism in this region (Jahoda, Papa-Kalantari 2010; Jahoda, Kalantari 2021).



The fact that Tashigön (Tib. Bkra shis mgon) (born in the early 2nd quarter of the 10th century; Jahoda, Kalantari 2021) is mentioned as having donated a Champa (Tib. Byams pa, Skt. Maitreya) to the temple in Yudra (Tib. G.yu sgra) (Vitali 1996: 107), which is located on the Mapcha (Rma bya, lit. "Peacock") River, indicates the practice of Buddhism in Western Tibet before Yeshe Ö (renounced the throne in favour of his brother in 988 CE; cf. Vitali 1996). Kyide Nimagön is also mentioned in Tibetan historiographical sources as builder of fortresses and castles such as Rala Khamar (Tib. Ra la mkhar dmar) and Tshetho Gyari (Tib. Rtse tho rgya ri).

These fortresses may have constituted the earliest foundations within the West Tibetan empire. The main seat of the empire during Nimagön until the division of the empire was Nyisung (Tib. Nyi bzung) (Vitali 1996: 154, 315). Later, during Khore (Tib. Khor re; reg. 988–996 CE; cf. Vitali 1996), the major political centre of the kingdom changed to Kardung (Tib. Dkar dung) in Purang, and in the 13th century to Gyalti (Tib. Rgyal ti) (ibid. 391). Gyalti's foundation possibly also refers back to an earlier period (ibid. 393).

In addition to the royal dynasty, aristocratic clans – such as the Chogro (Tib. Cog ro) clan, the possible descendant of the mother of Rinchen Sangpo, or the Dro (Tib. 'Bro) clan, whose members may have managed to preserve their influence over areas under their control from

Map 1.2 (Left) Historical Western Tibet.
GIS data based map: Jakob Gredler.
Final graphics: author.
Map based on data from Vector data (VD) and Basemaps (BM). Citations of VD and BM also see: Chapter IX, list of illustrations.

Map 1.3 (Right) Purang. Detail of Historical Western Tibet (Map 1.2). GIS data based map: Jakob Gredler. Final graphics: author. Map based on data from Vector data (VD) and Basemaps (BM). Citations of VD and BM also see: Chapter IX, list of illustrations.

pre-imperial Central Tibetan times – exerted considerable influence within the West Tibetan kingdom (Vitali 1996: 123, 171f.; remarks on the Dro clan see Vitali 1996: 275, fn. 416).[24]

Several emperors' residential foundations are related to the 10th century period of historical Western Tibet.[25] Kukar Nyisung (Tib. Sku mkhar nyi bzung; foundation 912 CE after Vitali 2003: 54f.), located in Upper Purang, is related to Nimagön and was also used as a residence or royal palace by his son Tashigön (Vitali 1996: 155). It is mentioned as a nine-storey building, possibly meant as a family tower. In Guge, Khartse Chiwang Namgyel (Tib. Mkhar rtse phyi dbang rnam rgyal) is also attributed to Nimagön (Bellezza 2010) as well as three fortresses to the south-west of Tholing (the Upper, Lower and Middle Fortress). The monastic complex to the north of the Lower Fortress (Tib. *mkhar 'og ma*) further down the hill is related to Tashigön,[26] the father of Yeshe Ö.

2.1 'Mobile' rulers and religious gathering places

Also in Western Tibet, hereby continuing similar earlier practices of Central Tibet, assemblies of leading members of the royal family or branches were held in order to agree upon major political decisions. At such a meeting that took place in 987 in Purang, the foundation of a temple (Tib. *gtsug lag khang*) in the castle of Kyaru (Tib. Skya ru mkhar) was decided on by Yeshe Ö alias Trisong Tsungtsen (Tib. Khri sde srong btsug btsan) (GP 2011: 290; cf. Jahoda 2016). According to Vitali (1996: 251), the Pagam Chamnyom Ling (Tib. Pa sgam byams snyoms gling) Hermitage was established in 992 at Pekhar (Tib. Spe mkhar) in Rumyül (Tib. Rum yul) of Chogla (Tib. Cog la) for a *molla* (Tib. *mol ba*), which is a decision-making gathering of the leading members of the royal dynasty (Jahoda 2016). After being ordained, ruler Song nge (Tib. Song nge; 947–1019, after Jahoda, Kalantari 2016: 79, fn. 4; Drongshar, Jahoda 2021) was known as the royal Lama Yeshe Ö. To some degree, he can still be regarded as a "mobile" ruler, at least until the late 10th century. According to the record of places under his control and those he visited over the course of many years until the turn of the millennium, it is clear that he was not associated with just one residence during this time.[27] Mobility, which eliminated the need for the king to settle at only

24 A stele, which was erected by a member of the Dro clan in Purang, points towards an early pre-10th century presence (cf. Vitali 1996: 168–169). A wife of Kyide Nimagön ('Bro za 'Khor skyong; a "Bro-wife" with the name Khorkyong (Tib.'Khor skyong) originated from the Dro clan (Vitali 1996: 172, fn. 233). Also a wife of Song nge (Tib. Srong nge) / later Yeshe Ö (Tib. Ye shes 'od) originated from the Dro clan: "The clan affiliation of Yeshe Ö's wife is doubly significant because, on the one hand, it confirms the close association of the Dro*s* with the Ngari Korsum (Tib. Mnga' ris skor gsum) royal family in no lesser a case than that of the great Yeshe Ö and, on the other hand, it is the earliest instance around Later Dissemination (Tib. *bstan pa phyi dar*) documenting the presence of the Sengkar (Tib. Seng dkar) group among the Dro*s* of Tö (Tib. Stod)" (Vitali 1996: 178).

25 In this text, historical Western Tibet and early West Tibet both describe the same period.

26 An account in Vitali (1996: 239) shows that Tholing had been a royal residence before its temple was built by Yeshe Ö in 996. The relation of the Lower Fortress to Tashigön was mentioned in a personal conversation by Tsering Gyalpo in 2011.

27 Song nge may have become known as Yeshe Ö immediately after his ordination. His earliest title (inscription in Tabo entrance hall, Tib. *sgo khang*) is not certain (cf. Jahoda, Kalantari 2016: 87, 88, fn. 37). The mobility during the time of his kingship (until 988; 989 he took orders) may be seen from the instance of the point of assemblies at different sites, where political decisions may have been made.

Fig. 1.4 Khorchag.
Namtong festival. Dorje Chenmo riding on her horse in all directions.

one permanent residence, allowed him to show his physical presence at various places within the kingdom. With the foundation of monastic establishments in 996 CE, the recruitment of young village men for monastic service started (Vitali 1996: 234). This fact is significant for his power as royal Lama, as such he was obviously acting as ruler over a religious dominion.

2.2 Protecting temples

The demoness, spanning over Central Tibet, was fixed with certain temples, with several temples acting as border protecting temples (as mentioned before). Similar to Central Tibet, in Western Tibet border protecting temples from the early West Tibetan period are also known. They mark the areas of possibly hostile aggressors, particularly along the western border towards Kunu, along the Sutlej and the Karnali. They were strengthened with temples in Kanam in the historical region of Nara, and with temples in Ropa, Mona and Poo located in Ronchung, with the later also having a palace for royal residence, and in Tsawagang in Purang. The temple at Tiyag associated with Rinchen Sangpo may also belong to these ancient border protecting temples (today located about 15 km from the present Indian border).

Dorje Chenmo, riding on her horse in all directions, suppressing the demons and clearing the space below the monastery, as observed at the Namtong festival at Khorchag (Fig. 1.4), took over the role of a great protectress and was associated with all major early royal foundations of monasteries. Rituals dedicated to her are known from various places all over the area of historical Western Tibet.

2.3 A religio-political programme

The monastic sites of Nyarma in Maryul, Khorchag in Purang and Tholing in Guge follow a particular architectural concept, which allows to bring the whole kingdom together under one superior religious programme. This programme follows a main characteristic for the all-including religious doctrine under Yeshe Ö, subordinating the whole country's political administration. The Central Tibetan monastic idea of the *chökhor* as a *dharma*-related facility for religious assemblies

Fig. 1.5 Khorchag. Layout of the monastery. 1 = Lhakhang Chenmo; 2 = Jokhang.
Layout of structures based on: Google Earth, DigitalGlobe © 2016. Cf. Feiglstorfer 2017a.

was continued in the early West Tibetan foundations. It was seen as a sacred place for the study of the doctrine as well as for major conferences in the following years, e.g. Tholing in 1076 (Vitali 1996: 320).

According to legend, the famous Jowo silver statue of Khorchag Monastery was ordered by Khore to be cast in Sher in Lower Purang with the aim of being errected in the Serkhar Tsuglagkhang (Tib. Gser mkhar gtsug lag khang), the courtly fortress temple in Kardung. While being transported to Kardung, the statue refused to move and and remained on an *amolika* stone. This stone base was surrounded by a *lhakhang* as the central core of the Khorchag Monastery (Pranavānanda 1949: 64; Vitali 1996: 260, fn. 381). The foundation of the Khorchag Monastery describes a separation of a monastic complex from the imperial residence (Fig. 1.5) and the religio-political centre of Purang. Similar to the legend of the silver statue of Khorchag – which should have been brought to the *lhakhang* of the king's residence high above on the hill – the former main statue of Tholing (Vitali 1999: 90), a Śākyamuni Buddha, was brought up into the *lhakhang* of the palace, located on the hill to the south-east of the monastery.[28]

Three protecting Buddhas are each associated with one of the three earliest monastery foundations. Maitreya is associated with Khorchag,[29] Śākyamuni with Tholing,[30] and Dīpaṃkara with Nyarma.[31] They can be identified as a trinity of the Future, Present and Historical Buddha.[32] Based upon information contained in the Biography of Yeshe Ö,[33] this trinity spans and combines the three domains of the whole West Tibetan kingdom or "Ngari Korsum" (Tib. Stod Mnga' ris skor gsum) (Feiglstorfer 2021b: 225).

3. Ritual space and sacred plan

Defining religious structures using canonical patterns is a globally known method. It ensures recognition value within a particular religious community and the possibility of application of certain religious practices in a regional context. An important question concerns architectonic patterns being applied as representation of a particular religio-political elite, which is strongly related to the introduction of Buddhism into Tibet. What architectonic features and planning tools within a Tibetan Buddhist culture were applied to the embedding of early religious sanctuaries in a ritual context? Concerning this matter, canonical features are relevant in finding an answer. This includes a particular geometric and proportional order, a general spatial organisation, and tools of geomantic divination – features that distinguish religious from 'simple' vernacular architecture. Further, the use of certain materials also implicates the representation of a higher social status.

28 According to Tsering Gyalpo, a red temple (Tib. Lha khang dmar po) had already existed below the so-called "Middle Fortress" before the foundation of the *tsuglagkhang* by Yeshe Ö. According to oral tradition, which was recorded by Tsering Gyalpo around 1989, the main cult statue looked like a unique, colossal and larger than life-size Buddha Dīpaṃkara statue. It is said that some time after the foundation of the *dukhang* of Tholing (also Dzamling Gyen), this statue was invited to this temple and placed in its *cella* (evidence by Christian Jahoda and after a personal conversation of him with Tsering Gyalpo in 2006). Among or in addition to the three larger than life-sized Buddha statues assigned to the past, present and future (Skt. Dīpaṃkara, Śākyamuni, Maitreya) – which existed in the main temples of Nyarma, Tholing and Khorchag, respectively – one notable one-storey-high statue of Dīpaṃkara (Tib. Mar me mdzad) was placed in the main temple of Tholing (Vitali 1999: 90).

29 Cf. Vitali 1996: 259; Drongshar, Jahoda 2021.

30 ibid. 258, fn. 377.

31 ibid. 265, fn. 397.

32 In an e-mail exchange with Christian Jahoda (June 2016), he hypothetically mentions Maitreya, Dīpaṃkara and Tholing in relation to the monasteries of Khorchag, Nyarma and Tholing as a possible concept of a trinity.

33 Maitreya, as the main figure in Khorchag, is mentioned in the biography of Yeshe Ö (Drongshar, Jahoda 2021). Also posed was the idea that Dīpaṃkara was the central figure in Nyarma and that in the centre of Tholing Tsuglagkhang there was a Śākyamuni (Tib. Bstan pa'i gtso bo) statue (cf. Vitali 1996: 258, fn. 377).

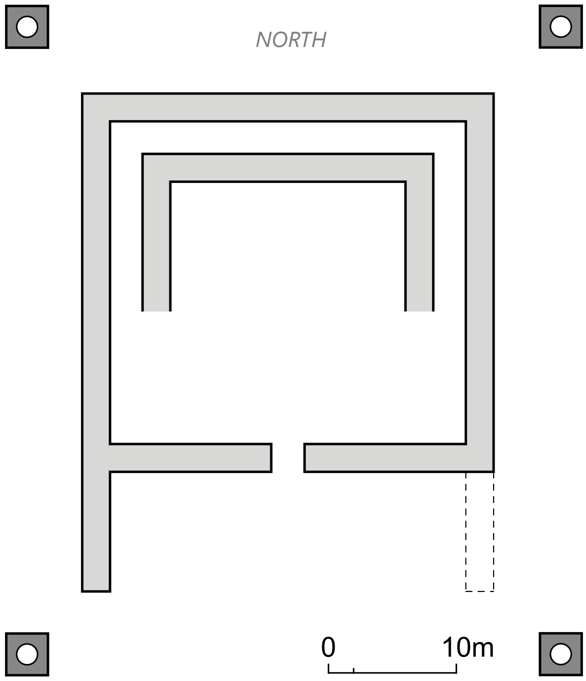


Fig. 1.6 Old Khartse.
Ruins of the *tsuglagkhang* with an internal circumambulation path and four corner *chorten*.
Measurements provided by Tsering Gyalpo in 2010.

The temple and the monastic compound are part of a sacred landscape defined by certain markers of worship. In the early imperial phase in Central Tibet, the Tibetan territory is defined with the twelve immovable bolts pinning down a demoness on Tibet. These bolts are materialised by the so-called "border taming temples" (Hazod et al. 2005b: 5). Within this Tibetan territory, several architectural structures point towards an early definition of a quadripartite concept as a kind of spatial order. An example is the erection of four Rigsum Gönpo (Tib. Rigs gsum mgon po) protector chapels (cf. Feiglstorfer 2011a: 91, fn. 135) around the centre of Lhasa into the four cardinal directions during the rule of emperor Songtsen Gampo in the 7th century. These protector chapels mark a pentalic system in Lhasa, with the Jokhang Temple as its centre. Later, four further chapels were installed at an equidistance along the intermediate directions (Tib. *mtshams*) (Alexander 2005: 91). The central temple of this constellation is the Jokhang in Lhasa, which is also the centre of four monk congregations (Tib. *dge 'dun gyi sde*) erected in the 9th century (Sørensen 2007: 401). They were built as chapels for the purpose of religious services to the Jokhang (ibid.). The quadripartite scheme defined by the four Lhasa *deshi* (Tib. Lha sa *sde bzhi*; later known as the Four Horns / Banners or the Lha sa ru bzhi) is a centre-periphery, originally cosmogonic, model (Sørensen 2007: 411). Around the Jokhang as the centre point, a so-called "Lhasa Maṇḍala zone" (Tib. Lha sa dkyil 'khor steng) was developed in the 11th century and demarcated by four mountains (Hazod, Sørensen 2007: 19). The term Kyilkhor ding (Tib. *dkyil 'khor steng*) used for the courtyard of the Jokhang (Sørensen 2007: 453, fn. 93) refers to its centre position as a cosmocentric concept.

An early pentalic monastic model of cosmogonic nature can already be found in the concept of Samye, the first Tibetan monastery founded in c. 775 CE. This follows a three-dimensionally materialised religious programme. It was as a whole architecturally effectuated with the square as the intended basic geometrical shape of the general layout (Feiglstorfer 2011b: 216). In this architecture the trapezoid as a basic design feature is already completely absent. Such intermedial and pentalically organised layouts can be found at several early Tibetan religious structures, besides the monastery of Samye in Central Tibet also at several monasteries in historical Western Tibet. Early West Tibetan examples include the geometrical constellation of the *tsuglagkhang*s (Tib. *gtsug lag khang*, “main temple”) of Tholing, of Old Khartse (Fig. 1.6) or of Tabo. In these layouts the *tsuglagkhang* is situated in the geometrical centre, and the four corner *chorten* define the outer boundary again surrounded by an enclosure wall.

In the example of Tholing, the *tsuglagkhang* (also known as Gyatsa due to the fact that it forms an enclosure around a multitude of small surrounding *lhakhang*s) shows four integrated corner *chorten* along its outer boundary, and four further *chorten* on the same intermedial axes, with the latter detached from the built structure. Vitali describes this design as a possible arrangement of two interlaced *maṇḍala*s (Vitali 1999: 120, 121). An overlay with a programmatically pentalic structure – as can be found in the four Buddha families around Vairocana – becomes obvious in certain early *tsuglagkhang*s, like at Tholing or Nyarma, but appears in a further design, which may have to do with a change of the religious programme. In contrast, at early *tsuglagkhang*s, having Vairocana as part of the central religious programme does not necessarily mean a pentalic design as stated at the *tsuglagkhang* of Tabo.[34] In this structure the central statue is Vairocana, but the surrounding four Buddha families have not been constructively defined by cardinally projecting niches (as is the case at Tholing or Nyarma).

Following local variations, various canonical patterns were applied at early Tibetan monasteries. A general feature is the repeating use of such patterns over a preferably wide area within a particular religio-political programme. Contrary to ‘simple’ vernacular and secular structures, canonical structures carry a certain aim for representative cultivation over a wide territory. In Tibetan regions, secular architecture is difficult to detach from a religious context. Buddhist belief defines particular ritual practices, such as circumambulation, which interweaves activities of daily life with religious rites and related architectural infrastructure, such as temples in public spaces or private houses.

One of the main drivers for conducting certain deeds that within the Buddhist community have positive connotation, is gaining merits for reincarnation within *saṃsāra*, the cycle of rebirth. Any donation to the monastery – be it in the form of land by an emperor, the form of butter by pilgrims, the erection of religious structures, or circumambulation around such structures – is done to gain merits for one’s future. This Buddhist attitude shapes the Buddhist culture and positions its single components within a spiritual overall standing religious programme. In this concern, the design of architectural components and the material and spatial definitions utilised are subjected to the religious programme. In this context, artefacts designed within a Tibetan Buddhist community are connected with particular ritual practices. The ritual of circumambulation is focused on a centralistic concept with a surrounding concentric structure. The ritual and the definition of the

34 An example of idealisation of a pentalic structure based on a religious programme is even evident at the Candi Sewu Temple (8th century CE) in Java. This temple is representative of a tantric development in the 8th and 9th centuries. The pentalic structure also seems to have been used as an ideological basis for particular South Asian political systems (cf. Feiglstorfer 2013).

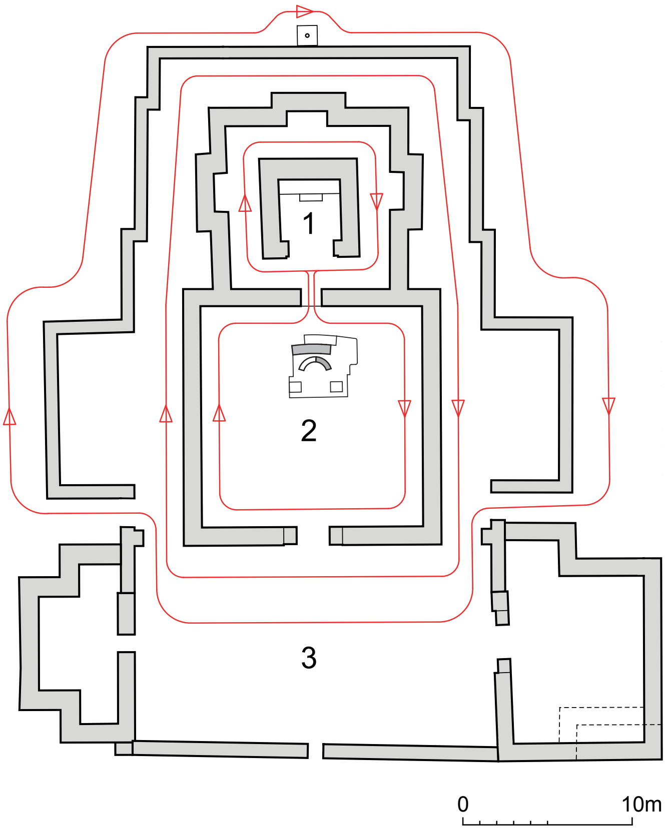


Fig. 1.7. Nyarma. Tsuglagkhang. Circumambulation paths according to Joseph Gergan from 1917 (cf. Jahoda 2021):
1 = *Cella*; 2 = Assembly hall; 3 = Courtyard. Cf. Feiglstorfer 2011b: 51.

related concentric space are dependent on each other, and the central pivot is materially defined, for instance, by a votive object or on an immaterial philosophical level. An example would be Mount Sumeru in the Abhidharmasamuccaya (Asaṅga 2001: 82). According to this philosophical treatise, the world is described as a container based on concentric circles of atmosphere, water, and earth, with Mount Sumeru located in the centre. Mount Sumeru is surrounded by seven mountains, four continents, eight intermediate islands, the inner and outer oceans and a circular mountain chain (Skt. *cakravāḍaparvata*) girdling the earth […] (cf. Feiglstorfer 2011a: 139). This philosophical interpretation of the universe is geometrically based on concentrical rings, with Mount Sumeru as the central pivot.

The layout of the geometrically centralised early Tibetan monastic structures as mentioned before is also organised in concentric horizontal layers. Towards the centre, the structure increases in height. The earth in the philosophical model is protected by a circular mountain chain, which correlates with the function of an enclosure wall (Tib. *lcags ri*). This wall appears as an important architectonic feature in the form of enclosure walls, which were erected around early Tibetan *tsuglagkhang*s, such as at Samye, Tholing, Tabo or Nyarma. The enclosure wall itself is again incorporated in the system of circumambulation paths.

In an architectural concept, circumambulation is the behavioural materialisation of a concentric layout. Different circumambulation paths (which will be mentioned in detail in the following) lead around a central core and are defined as *nangkor* (Tib. *nang skor*), i.e. the inner circumambulation path, the *barkor* (Tib. *bar skor*), i.e. the middle circumambulation path, the *chikor* (Tib.

phyi skor), i.e. the outer circumambulation path, the *tsekor* (Tib. *rtse skor*), which is to be found as a path leading around the district of Marpori in Lhasa (Larsen, Sinding-Larsen 2001: 77), and the *lingkor* (Tib. *gling skor*), which describes the outermost circumambulation around a sacred district.

Samye Monastery is a rigorously organised sacred space and was built from the centre concentrically towards the outer periphery. Monastic functions and ritual movement along particular paths are defined by the architectural body. A mutual interference between this kind of materialised ritual space and the user determines its organisation. An early West Tibetan example is the *tsuglagkhang* of Nyarma, which is organised by interlaced concentric walls in a horizontal as well as vertical composition (Feiglstorfer 2009: 132). According to an account by Joseph Gergan from 1917,[35] the architectonic programme of this temple conforms to the four different paths of pilgrims' circumambulations (Feiglstorfer 2021b: 253f.). The single parts of the building are attuned with the circumambulation route of the pilgrim and vice versa – thus defining an inseparable interaction between architectural space and pilgrims' ritual movements.

Additions to these early concentric layouts specify the development of the sacred space up to the present, and as a result still show the circumambulation rituals of the devotees. The pilgrim is aligned to and integrated in a superior sacred space. Today, in Nyarma, one remaining *nangkor* still circumambulates the *tsuglagkhang* and the adjoining lake (Fig. 1.8). Over the course of time, the concentric temple structure has expanded with the growth of the surrounding sacred and residential structures, basically integrating into the landscape all the *yülsa* (Tib. *yul sa*), *chökhang*s (Tib. *mchod khang*, "family prayer room" or "shrine room") in local residences and various markers of the sacred territory used for worship. The *lingkor* at Nyarma, i.e. the outer circumambulation path, is defined by various such markers of worship (to be explained in the following). The route itself is locally known and can be walked along different paths. The first half of the route leads through the village towards the west, passing a lake, the fortress, a Buddha stone relief and a streamlet, which leads north along the Hemis-Leh road. This path passes another Buddha stone relief and a *chorten* group and leads up to the Thikse Monastery, which is located opposite the Nyarma Monastery at the northern pole of this route. From here two routes lead back south along the second half of the route to the Nyarma Monastery. One passes through desert land, finally leading to *chorten* and *chorten* groups, and to the lake inside the former *chökhor* (which today is in ruins). The second route that runs a little further west, more or less between cultivated and desert land, passes ruins of lhakhang*s*, *chorten* and *chorten* groups, the foot of a cliff with the *lhatho* on top, the fortress, a *mani* wall, a cemetery and a Rigsum Gönpo (Tib. Rigs gsum mgon po) before arriving back at the *nangkor*. This second route passes a variety of historical religious structures, many of them being in ruins. Partially this route overlaps with the *öngskor* (Tib. *ʾong ʾkhor*), which is in Ladakh known as *bumskor* (cf. Feiglstorfer 2021a and Forthcoming).

A similar constellation of a concentrically organised sacred space can be found in Tabo, with the *nangkor* and the *barkor* relating to the temple structure including its surrounding wall (cf. Feiglstorfer 2011b: 47, 48). The *tsekor* is defined by a new *chorten*, a new monastery, the *chorten* of the Serkhung Rinpoche, the new monks' hostel, a row of *chorten* and a monastery enclosure wall. The outermost *korlam* (Tib. *skor lam*), the *lingkor*, is defined by several *chorten*, *yülsa*, a

35 This concept was presented together with Christian Jahoda at the EASAA conference in 2010 in Vienna.

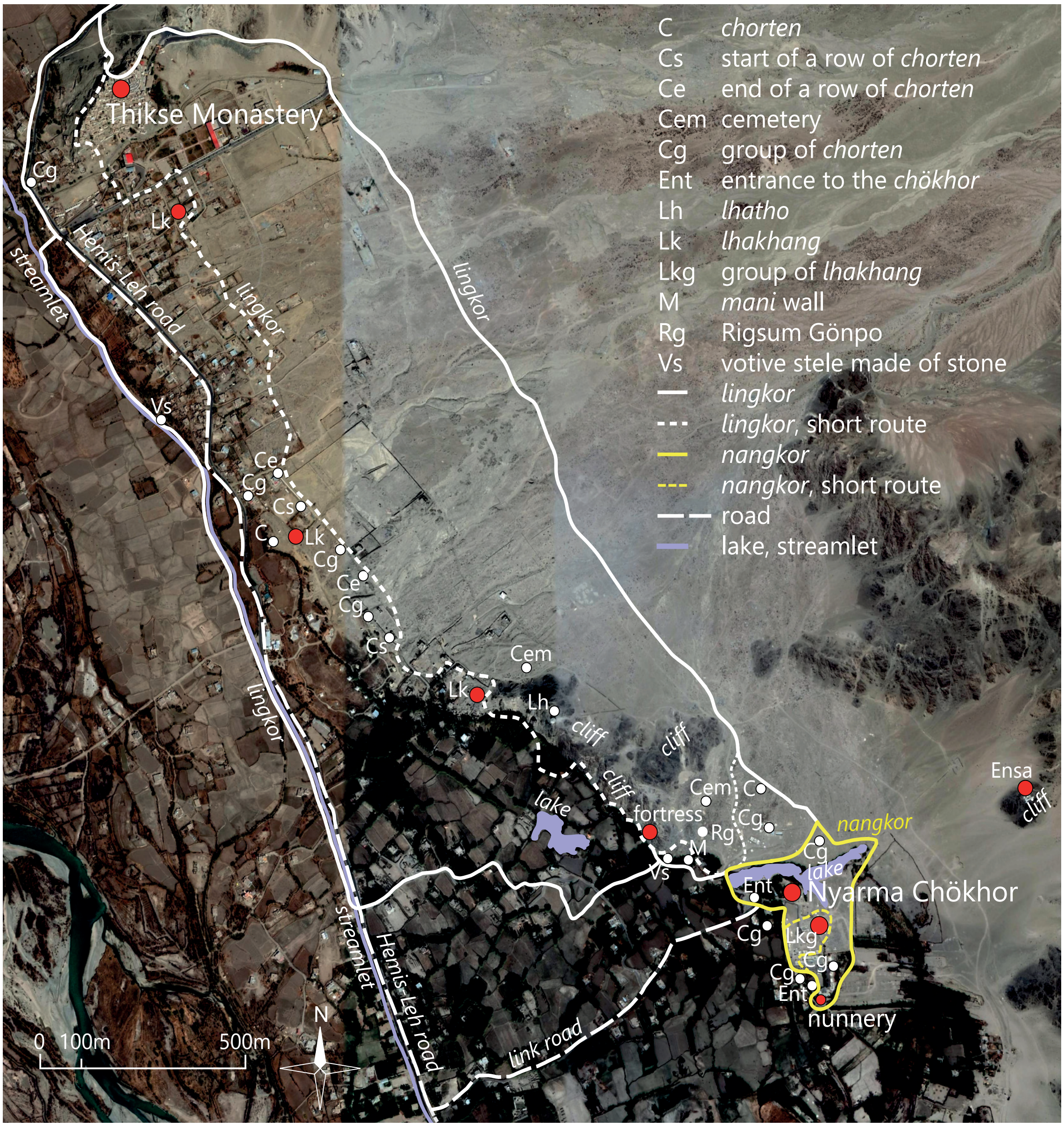


Fig. 1.8 Nyarma. Circumambulation routes marked by religious objects and places, with the *chökhor* located in the south and the Thikse Monastery in the north. Map based on: Google Earth. Image © 2019 Maxar Technologies and Image © CNES / Airbus (see Feiglstorfer 2021a: 160).

cave temple *gompa*, and the Tschagsalang Chorten (which is in the first position). From here it is possible to see the monastery and remains of a 108-*stupa* wall. One may describe this kind of sacred space as a system of circumambulation paths defined by religious structures and a corresponding hierarchy of religious landscape markers.

At Alchi, in Ladakh, we find a further example of a concentric concept of circumambulation paths (Fig. 1.9). The entrance to the village is marked by a Rigsum Gönpo. Similar to Nyarma, one direction of this route follows approximately the flow direction of the Indus, though it is still some distance away. The route is again marked by *chorten* and *chorten* groups, *mani* walls, Kakani Chorten, *lukhang*s (*klu khang*), prayer flags, prayer wheels and a *tsatsakhang*. This circumambulation route encloses a quadrilateral division of the Alchi village along the four cardinal directions.

Up to the present, we can find the practice of quadrilateral positioning of four protecting Rigsum Gönpo (see previous explanation of the Lhasa Maṇḍala), as the example of Alchi shows. In this village, the four hamlets, namely Yülkhor (north), Gompa (south), Chökhor (east) and Shangrong (west), are protected and integrated in a common sacred space (cf. Feiglstorfer 2021a and Forthcoming). The external border of the hamlets is marked by several Rigsum Gönpo. One Rigsum Gönpo is located at the village entrance in the north, one at the very southern end of the village, one close to the Druggyeling Gompa in the west and one in the east at the entrance gate to the historic monastery compound.

In each quarter we find religious structures, for instance, a *lhakhang* in the palace in Yülkhor, the historical monastic compound in Chökhor, the Tsatsapuri Gompa in Gompa and the Shangrong Gompa in Shangrong. Since the monastery compound, which contains some of the oldest structures, is part of this quadrilateral composition, the question arises if there is a geographical centre of this composition. A hypothetical answer may be given by a simple drawing by Morup Dorje, a local teacher of Alchi (cf. Feiglstorfer 2011b: 14). In his drawing, which is based on a traditional local understanding, he depicts the Kumbum Chorten as the village's centre, which would also correlate with the geographical centre, since this stone *chorten* is located in a central area of Yülkhor, Chökhor, Gompa and Shangrong.

Such programmatic overlays of religious objects or buildings and landscape bound to pilgrims' ritual movement are part of the Tibetan Buddhist landscape and thus not solely bound to Himalayan but to Tibetan Buddhist customs. As an example of such a materialised programme outside the Himalayas, the Baldan Bereeven Monastery may be mentioned, apart from various other examples. It is a Gelugpa monastery in the east of Mongolia (48°12′8.78″N, 109°26′20.41″E) established in 1654 (Sanders 2010: 110). A concentrically organised pilgrim's route leads around the main temple and the surrounding temple compound. At the cardinal points this route is marked by votive Buddhist structures. Related to this cardinally divided circumambulation path is the fact that the monastery is embedded in a cardinal intersection among four sacred mountains, which are in the landscape associated with features of a Buddhist *maṇḍala*.

Regarded as a sacred landscape composition, the monastery defines the central pivot within a cardinally organised surrounding net of religious artefacts and mountains, and thus resembles essential features of the afore-described early Tibetan ritual spaces. The monastic structures are embedded in the centre of a *lingkor,* which is again quadrilaterally composed, and together with the monastery in the centre forms a pentalic structure. Along the outer circumambulation path the four cardinal orientations are marked by religious structures.

As shown by means of the Mongolian examples, not only building structures like Rigsum Gönpo, *yülsa*, *chorten* or *lhatho*, but also natural phenomena such as mountains (a famous example being

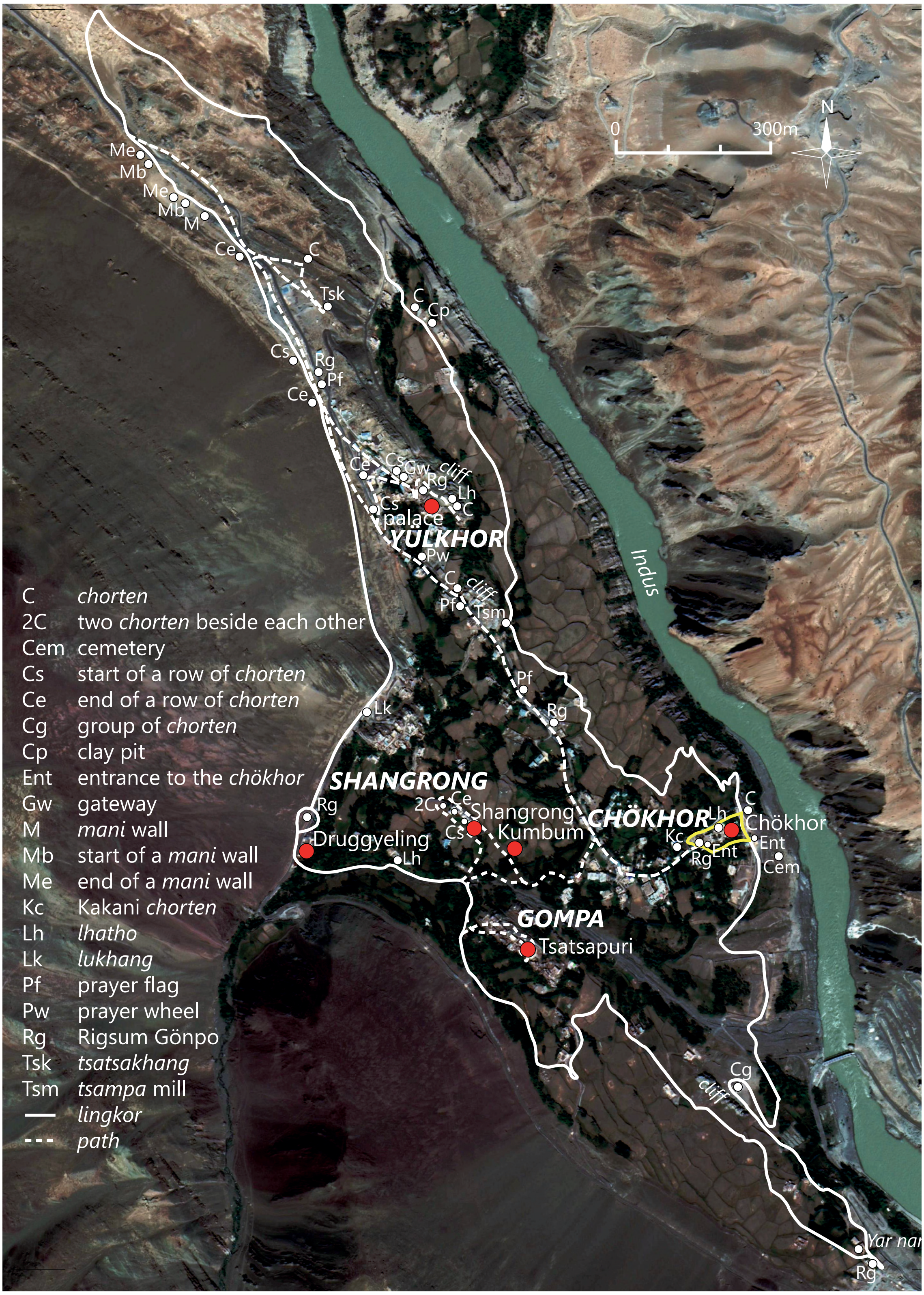


Fig. 1.9 Alchi. Circumambulation paths marked by religious objects and places. The four directions define the four parts of the village. Map based on: Google Earth. Image © 2019 Maxar Technologies and Image © CNES / Airbus.

the *korlam* around Mount Kailas), lakes (e.g. Nyarma *lingkor*) or certain trees are used as central pivots. This system – which along with the above given examples primarily is related to outdoor landscape markers – finds its continuation in the interior space, which is often defined by the *nangkor* leading around a religious artefact. Buddhist activity is expressed by the body, speech and mind, all of which find expression in particular materialisations. As an example, a *künga-rawa*[36] (Tib. *kun dga' ra ba*) symbolises the trinity of all the three activities:[37] Body is expressed by sculptures, speech by written texts, and the mind by *chorten*. These artefacts may all be arranged on a bookshelf or find their particular place within a *lhakhang*.

3.1 Geometry and proportion

The implementation of certain architectonic patterns depends on a cultural affiliation defining certain geometrical and proportional rules. Geometrical and proportional patterns applied at early Tibetan sanctuaries are closely related to Indian predecessors, but not necessarily identical. The way they are applied within a Tibetan Buddhist canon was finally redefined and applied with local variations, and as such maintained the individual character of each religious structure.

A main aspect by which religious structures differ from 'simple' secular vernacular structures is the precision of building construction (see Fig. 1.7). High precision is needed to follow a certain geometric pattern based on the definition of a centre and related concentric circles, diagonals and intersections (for instance, for erecting right angles). Early structures built with adobe bricks, such as at Tabo or Nyarma, show high precision.[38] In Nyarma, the laying of bricks followed a particular method for the construction of sloping walls by introducing holes between bricks, which were filled with stones or earth as filling material and whose width was varied from layer to layer.[39]

Before the primary use of the square as a basic geometrical design, the trapezoidal shape seems to have been of particular relevance in the imperial Tibetan period. The trapezoid may already have been a commonly used shape in pre-Buddhist times, as shown at the layout of Tibetan burial mounds ranging in the centuries before or at least during the Central Tibetan imperial period (7th–9th century CE) (cf. Feiglstorfer 2015). The outer enclosure of emperor Namri Songtsen's (Tib. Gnam ri Srong btsan; died early 7th century CE) mobile residence at Gyama (Tib. Rgya ma; Hazod 2014: 24) is an early imperial example of a still prevalent trapezoidal design. The Gyama Trikhang (Rgya ma khri khang) – which is known to have served as a residence of the court in the 9th century CE – was enclosed by a fence in a trapezoidal shape (see Fig. 1.1) (cf. Hazod 2014: 30). The former shape of this kind of mobile residences is visible in the still existent trapezoidal

36 *Kun dga' ra ba* may be translated as "an enclosure that is totally joyful". This term has several meanings, all referring to some kind of enclosure that is well regarded. One meaning is the enclosure for housing representations of enlightened body / speech / mind usually as found in a religious institution (cf. Feiglstorfer 2011a: 113). This could be shelves for books, a housing for statues, etc. The name is also given to a library containing the sacred texts of the Tripitaka in a monastery, etc. (Duff 2004).

37 Communication with Christiane Kalantari at the Austrian Academy of Sciences (ÖAW), 21/01/2011.

38 At Khorchag, several renovations changed the early structure in a way that this precision could no longer be observed during our field research in 2010.

39 Presented at the 12th TERRA Conference in Lyon in 2016.

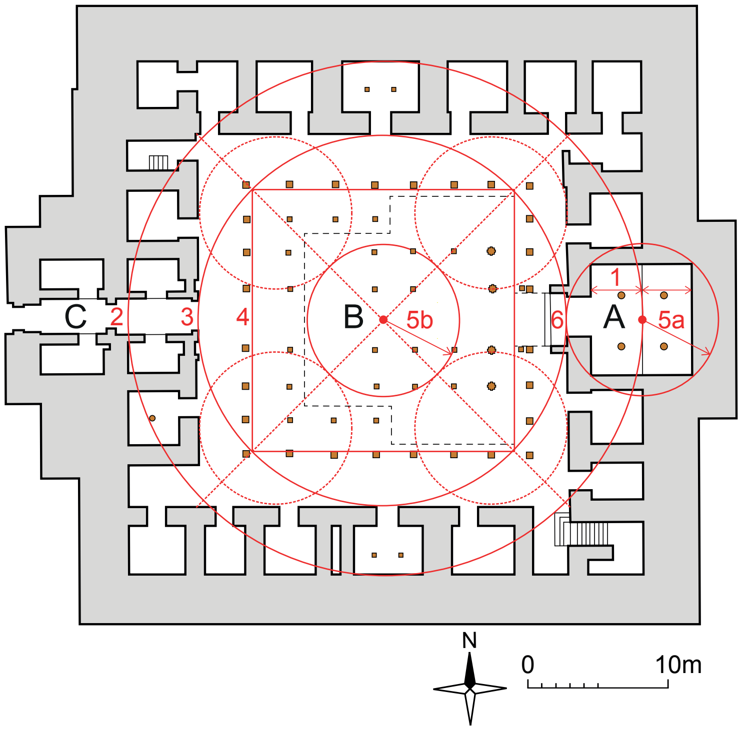


Fig. 1.10 Lhasa. Jokhang. Hypothetical study of geometry and proportions. Ground plan of Jokhang after: XWD 2010: 125, ACP 2007: 33–35, Alexander 2005:40.

A = *Cella*.
B = Assembly hall.
C = Entrance.

shape of a later erected enclosure wall, which is still today marked with a *chorten* at each of its four corners. This layout formally shows the well-marked corner points located on the intermediate axes of the whole structure, and marks a type of a centralised layout with protective structures at its four corners, which we find as part of a design pattern of several early monastic sites. Previously, the trapezoidal shape had subordinate relevance within the layout of a geometrical canon used for Buddhist sanctuaries.

Measurements follow body measures such as *sormo* (Tib. *sor mo*, Skt. *aṅgula*, "width of a finger"), *kru* (Tib. *khru*, Skt. *hasta*, "cubit"), *tho* (Tib. *mtho*, "span") or *dom* (Tib. *'dom*, "fathom"). The use of body measurements was in general wide-spread, and the system applied in Tibet correlates with the Indian system of measurement. Supposedly as in early West Tibetan monasteries such as Nyarma, for short dimensions, proportions from the upper body were used and possibly applied to a rope or a measuring stick.[40] For longer distances, such as the length of enclosure walls, stepping-measures were used. The basic measures must have been individually defined for each structure or at least for each site, since no comprehensible proportional connection applicable to all early West Tibetan *tsuglagkhang*s has thus far been found (cf. Feiglstorfer 2011a: 592–618). Accordance between several of these structures points towards the use of commonly valid units for measures of length (ibid. 618).

Also stated in detailed examinations (cf. Kozicz 2007; Feiglstorfer 2011a, 2011b) is a geometrical and proportional relation between single parts of early West Tibetan temples, in particular

40 In Tibet the use of a measuring stick with a length of 182 cm was reported until the 1960s, without giving data for earlier history. The length of 182 cm (*'dom*) is divided by notches on the stick in the following manner: 12 *sor mo* = 1 *mtho;* 2 *mtho* = 1 *khru;* 4 *khru* = 1 *rang 'dom* or *'dom* (Zhongyi et al. 2000: 272; Schuh 2010).

between *dukhang* (assembly hall) and *tsangkhang* (*cella*). For early West Tibetan temples, four proportional strategies in relating these two building parts can be categorised (cf. Feiglstorfer 2011b: 99–102) using the perimeter around corners in most cases, or the incircle connected with the centre of the assembly hall as a common pivot.

A study of the geometry of Central Tibetan temples[41] states the use of similar proportional schemata already in the imperial Tibetan period. An observation of the Lhasa Jokhang shows that most probably the centre of the assembly hall was fixed first. Next, with concentrical circles and diagonals of squares, the corner points of the assembly hall and the position of the *cella* were defined. This result would indicate the assembly hall as the origin of all further planning in a geometrical context, and the *cella* as proportionally dependent.

The Jokhang in Lhasa, one of the first Buddhist temples in Tibet, is of particular interest for the examination of internal proportions (Fig. 1.10).[42] Since we know from West Tibetan temples that the use of the perimeter was important, the possibility of its use was also examined at this object. Regarding the ground plan of the Jokhang, we have to think in various building phases. The first (mid-7th century) contained just 64 pillars, and at that time the Jowo Lhakhang (= *cella*) – which was transformed during a building phase in the 11th century CE when the *cella* was enlarged towards the outside at the east side of the building (Alexander 2005: 35) – showed no outward-protruding extension. According to the ground plan this extension was a doubling of the room depth (see Fig. 1.10 [1]). During another building phase in the 14th century, the courtyard was covered by a roof, and additional pillars were introduced.

Since the basic structure of the ground plan was not seriously changed but rather adapted, this means that the essential proportions were already defined during the first building phase. The courtyard shows a relatively precise square geometry. All further demarcations of the ground plan, i.e. the location of the walls of the chambers (towards the courtyard and also towards the outside), approximately follow a square shape but not with the same precision as the courtyard-square. Thus the drawing of a circumscribing circle around the courtyard square approximately defines the location of the outer walls of the lateral cells (see Fig. 1.10 [2]). Inscribing a circle in the courtyard-square [3] and inscribing a further square into this circle [4] defines the position of three sides of the pillar rows (north, west and south).

When drawing a circumscribing circle around the inner corners of the early shape of the Jowo Lhakhang (see Fig. 1.10 [5a]) – with its centre located on its rear wall – we obtain a particular diameter. When drawing three tangent circles having this diameter along the diagonal of the courtyard [5b], we can construct the square of the courtyard. The resulting geometry of this

41 This study on early imperial religious structures in Central Tibet was conducted within the FWF-project P25066 "The Burial Mounds of Central Tibet" in spring 2014 at the Austrian Academy of Sciences in Vienna. The results are not yet published.

42 The plan used for this study was drawn according to Alexander (2005: 40) aligned with a plan published in XWD (2010: 125). Since the correctness of the reference plans can not be proven, certain deviations may not be excluded. The method of observation, however, is hypothetical and may only be proven by a quantitative research and the comparison of various results. Nevertheless, also in this case the use of circumscribing circles seems to have been of relevance.

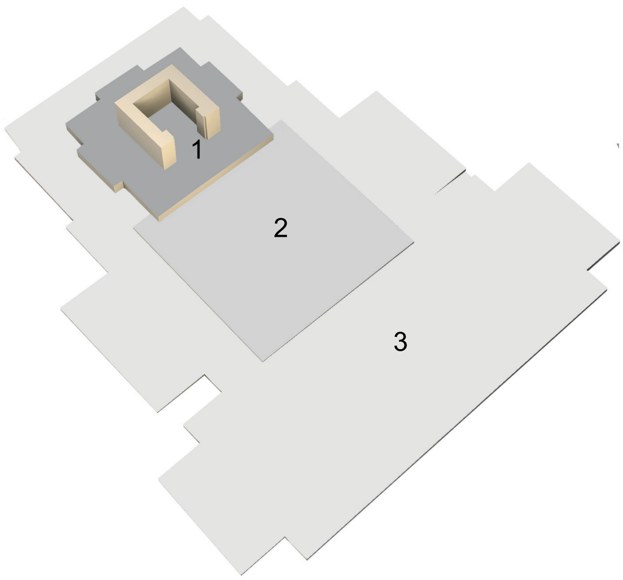


Fig. 1.11 Nyarma. Tsuglagkhang. Vertical layering of the building site.
1 = *Cella*.
2 = Assembly hall.
3 = Courtyard and outer circumambulation path.

method would be a pentalic structure of five circles inscribed in the square of the courtyard. The easternmost point of the courtyard circle would define the position of the entrance of the Jowo Lhakhang [6]. The hypothetical character of this study has already been pointed out and only further examinations on this matter will create a clearer picture. These results indicate the use of a concentric geometry based on circles and diagonals, with their intersection point being the centre of the courtyard square. The Jowo Lhakhang and the courtyard (which is the *dukhang* in a later phase) would be proportionally related to each other. Considering the whole structure of the Lhasa Jokhang as a mandalic composition, its pivot is defined by the centre of the courtyard, and the *cella* is shifted sideways – probably for functional reasons such as guaranteeing enough space for assemblies in the courtyard. Today, for the pilgrim a connection between assembly hall and *cella* may again be experienced by circumambulating the assembly hall and on the east side passing the Jowo Lhakhang, where the Jowo itself can be circumambulated.

The term "mandalic" in general refers to a geometric shape containing a centre and an outer periphery, which can be related to a *maṇḍala* as an ideological programme. For a painted *maṇḍala*, Luczanits mentions a direct relation between the drawn *maṇḍala* and the geometry "used"; the drawn *maṇḍala* refers to the deities, which are to be visualised, while the geometry used defines the purified ritual sphere (Luzcanits 2006: 74). In an assigned three-dimensional architectural meaning, objects of visualisation and the geometry of the ritual space might correlate with this description and by that involve those believers, who access this sacred space in the *maṇḍala*-space.

Moving towards historical Western Tibet (see Map 1.2), the *tsuglagkhang* in Nyarma is the biggest and probably the oldest structure at this temple site. The centre of the construction is the *tsangkhang* (*cella*), which is surrounded by a roof-covered ambulatory. Due to missing archaeological data it remains unclear, which of the two parts – *tsangkhang* and surrounding ambulatory or *dukhang* – were erected first. According to the proportional coherences and the topographically highest location of the *tsangkhang*, it might have been the first erected structure within the *tsuglagkhang* (main temple) to attach further building parts (Fig. 1.11). We can talk at least of three parts of the most early layout: 1) the square *tsangkhang* (= *cella*) surrounded by the cruciform-shaped boundary of the inner circumambulation path, 2) the square *dukhang* and 3) the stepped-shaped boundary of the outer circumambulation path and a forecourt with two attached *lhakhang*s. This early structure was in later building phases extended, e.g. with a second storey on top of the *tsangkhang* (Feiglstorfer 2021b: 251).

Regarding the result of the proportional analysis of the Jokhang in Lhasa, its proportional arrangement hypothetically describes the centre of the courtyard as the starting point for measurements and proportional definition. In Nyarma, this starting point within the planning process might also have been the *dukhang,* on which the layout of the basis of the single attached structures was fixed. The hierarchy of the ambulation paths as part of the horizontal order of the *tsangkhang* correlates with its vertical shaping, which increases from the forecourt towards the central core. Following these facts in combination with a possible start of the planning process in the courtyard of the Lhasa Jokhang, the question is raised whether the starting point of design and the starting point of constructing may have been different. Hypothetically, the design may have started in the *dukhang* but the building process of making the walls itself may have started with the *tsangkhang*. Regarding the process of fixing the layout, another matter remains for future archaeological research: The above-mentioned three building parts (1 to 3) of the earliest structure are arranged on different levels (see numbers in Fig. 1.11). Either the layout was fixed on a common level, from where the single platforms were raised according to the plan, or the single platforms were raised and served as platforms on which to fix the final layout.

At Samye the main temple is organised above a central square of a 3 x 3 grid, which is bordered by the monastery enclosure wall (cf. Feiglstorfer 2011b: 216). For the manifestation of a certain geometrical and proportional concept, axis, diagonals and circles were used, and particular intersections mark the location of certain parts of the compound. A feature found in earliest West Tibetan temples is the use of a modular system. In the *tsangkhang* of the *tsuglagkhang* in Nyarma, a *modulus* seems to have been defined as a kind of measuring unit by dividing the area of the *tsangkhang* into nine squares of equal size by drawing a 3 x 3 grid (Tib. *re'u mig dgu pa*) (ibid. 224). In this *tsangkhang* the geometrical order of the 3 x 3 grid determines the location of the niche on the western wall. The star-shaped pattern is formed by a 3 x 3 grid expressed by one centre and four flanks attached in the four directions. This star-shaped formation finds its designation in the location of the niches of the *tsangkhang* of the Nyarma main temple. Similarly, we can interpret the star-shaped central core of the *tsuglagkhang* in Tholing (see Fig. 1.3) with Vairocana at its centre. The mandalic shape of the central temple is formed by the central *lhakhang* (*tsangkhang*) with four attached *lhakhang*s, i.e. the surrounding *lingshi* (Tib. *gling bzhi*) as the four divisions (Vitali 1999: 256). The core structure also hypothetically follows a 3 x 3 grid of a pentalic order, which defines the *modulus* for generating the layout of the whole temple (cf. Feiglstorfer 2011b: 111).

Following the formal pattern of an Indian *vihāra* (for example, in the 6th century in Nalanda), several early Central Tibetan temple structures are based on a symmetric, mostly square geometric plan. The layout of Indian *vihāra*s is based on an open square court, surrounded by the cells for the monks and a votive cell opposite the doorway. At the Jokhang in Lhasa or at the Tandruk Vihāra (see Fig. 1.2), we find Central Tibetan successors of this functional pattern. The original structures are reduced to the arrangement of votive cells facing towards a central open courtyard.

At early West Tibetan monastic sites like Nyarma, the pattern of the Indian *vihāra* is designed by transforming the central court into a roofed central assembly hall, and the votive cells are reduced to a *tsangkhang* as one adjoined smaller cell. Regarding the layout, the square shape of the *dukhang* of Nyarma is still close to the square (at least rectangular) shaped courtyard of the Indian *vihāra*s. The *dukhang* located in front of the inner core of the *tsuglagkhang* in Tholing shows an uncommon early West Tibetan pattern in that it is integrated into the geometric super-structure. This pattern is closer to the spatial relation between the *dukhang* and the *utse* (Tib. *dbu rtse*) of Samye than between the *dukhang* and the *tsangkhang* at Nyarma, which shows a much more separated structure. The two *tsuglagkhang*s of Samye and Tholing probably show the closest spatial formal definition of a built centralised mandalic-shaped super-structure with both representing early monastic examples of Central and West Tibet, respectively (see Fig. 1.3).

In the early Central and West Tibetan phase – e.g. at the Lhasa Jokhang, at Nyarma or at Tabo – the *tsangkhang* is expressed as an architectural body with its own ambulatory. Nyarma, with its closed ambulatory around the central core, has its own feature in the architectural definition of a *nangkor*. There are only a few early West Tibetan temples equipped with this kind of an internal ambulatory: the *tsuglagkhang*s of Nyarma, of Tabo and of Tholing. All three are known as *chökhor* and were built at a similar time around 996 CE. The Nyarma one-*cella*-type can be typologically better related to the early Central Tibetan one-*cella*-structure of Ramoche or Uru Katsel than to the Central Tibetan triple-*cella*-structure of the Tandruk Vihāra or the Lhasa Jokhang. In later developments of the historical Western Tibetan region, we can no longer find the Nyarma-type with the central core as an internally ambulated *cella* attached to the *dukhang* as a common design. The further development of this early West Tibetan ambulatory structure as an architectural body on its own appears in the reduction of the ambulated *cella* into a *cella* niche, shown at one of the earliest examples of this development, namely the *dukhang* of Alchi. A significant feature of several of the early Central and West Tibetan main temples is the existence of a *nangkor* around the *tsangkhang*.

3.2 Orientation as a tool within canonical architecture

A further way to distinguish an architectural layout with a universal demand is to define the orientation of particular elite structures by following geomantic systematics. In a religious setting the orientation of a structure is defined by the direction, in which the central statue in a temple faces. This orientation equals in most cases the direction of the entrance opening or, in the case of a *stupa,* the orientation in which the hole of the vase is facing. In general in the Asian region, Buddhist temples follow cardinal directions. Early Central and West Tibetan temple structures differ from such a kind of absolute standardising of their orientation, and the feature of an absolute orientation is not the rule. As will be seen in the following, different orientations have been used, raising the question of common valid rules in their determination.

At most early Tibetan monastic sites, not only one but several religious structures can be located. Within these ensembles, the question is raised if there is a correlation between the orientation of the main temple and secondary temples (which in most cases – like at Tholing, Tabo or Alchi – have been erected chronologically after the main temple). Since an absolute cardinal orientation was followed at only a few sites, for the others a relative concept must have been relevant.

Relative concepts of orientation depend on the definition of a reference point. In early Tibetan Buddhist structures, we find orientations towards the west or east as absolute directions. This is the case at the Jokhang or the Ramoche Temple in Lhasa, respectively. In other cases, as relative points of reference we find an orientation towards a specific natural phenomenon, towards specific artefacts, or towards a particular political centre.[43]

In the Tibetan region, dealing with orientations is not a Buddhist invention. It can be observed earlier in pre-Buddhist times, for instance, in the position of burial mound positions. The beginning of Tibetan burial mounds is related to the development of Tibetan chiefdoms app. in the 4th century CE. The burial mounds follow the topography of the place, on which they are erected, commonly in parallel to the mountain slope and facing towards the valley (cf. Feiglstorfer 2015). As shown in a presentation by William Romain, Tibetan tombs in many cases differ from absolute orientations and show relations to particular spots in the landscape (Romain 2019). In contrast, Chinese or Mongolian burial mounds from the Tang period do not follow the topography in this continuously changing manner but show much more absolute cardinal orientations. Examples include the 7th century CE Mongolian tomb, which was excavated at Shoroon Bumbagar burial site at Ulaan Kherem (Erdenebold 2017), and Li Xian's tomb (as a Central Chinese example).

Observations within the FWF project "Burial mounds of Central Tibet" stated the construction of tombs in different shells (cf. Feiglstorfer 2015, 2018). The orientation explained before of the mound following the topography concerns the outer shell of the visible mound. The next inner shells are the burial chamber and the coffin. At a mound at site 0131 (Lo-3c, Tagtse (Tib. Stag rtse) County)[44], it was possible for the author to prove that the orientation of the chamber differs from the orientation of the outer shell of the mound. Due to several foregoing studies on the orientation of Tibetan temple structures (as described later in this text), a cosmic relation becomes possible and the question is raised if there is also such a relation for the inner core of burial mounds. Hazod (Interview 2016) describes particular parameters based on literature, which point towards a determination of orientations by particular celestial bodies.

For the imperial Central Tibetan period (in the Central Himalayas) and the following West Tibetan period (in the Western Himalayas), certain patterns of orientation become obvious. The latest state of research shows an individual strategy for the determination of orientations for each structure. Only in a few cases a hypothesis of a correlation of orientations between a group of temples can be given. The orientations of several early imperial Central Tibetan and early West Tibetan temples and monastic sites will be discussed and juxtaposed with the central task of finding methods for defining particular reference points. What can be stated at the moment is a range of various methods in defining orientations (cf. Feiglstorfer 2017a), and it is possible to give the following state of research.

43 Presented at the winter retreat at the ISA / ÖAW in 2014.

44 The site numbers follow a categorisation according to the TTT (Tibetan Tumulus Tradition) website http://www.oeaw.ac.at/tibetantumulustradition/de/startseite/, access: 08/2019.

The Jokhang in Lhasa and its so called "sister" temple, the Ramoche Temple, were founded in the 7th century CE (Alexander 2005: 88, fn. 3). The Jokhang is the central temple of Lhasa, and for the definition of the Tibetan territory in the 7th century, border taming temples (possibly twelve; see description afore) have been founded. André Alexander investigated these temples and shows on a map six of these border taming temples including their orientation.[45] All the depicted border temples do not show an absolute orientation. Just the Jokhang, which is the centre of this border taming temple constellation, is absolutely orientated towards the west. With its opposite orientation towards the east, the Ramoche Temple relates to the Jokhang. As a hypothesis, this order may point towards a categorisation between marking the centre with absolutely orientated structures and border structures as relatively orientated. Regarding east and west orientation, Alexander (2005: 277) mentions such orientations as relevant for the imperial period, while in the post-imperial period the southern direction became the standard.

The earliest Central Tibetan monastery of Samye is often described as east orientated but actually shows a deviation of app. 8° towards the south (according to Google Earth), which is too much to simply be the result of a measuring inaccuracy. All the single structures on this temple site follow a strict geometrical order according to the main temple. At this site it becomes clear that an individual orientation was determined and all the related structures rigorously subordinated to it.

The main temple of Nyarma in Ladakh was founded in 996 CE. According to satellite images from Google Earth, it shows an absolute orientation towards the east, with a slight deviation towards the north. Temple IV shows a similar orientation and correlates with the main temple, while the orientations of Temples II, IIIa and IIIb do not show an absolute orientation but rather intersect approximately at one point on the shore of the lake in front of the entrance of the main temple (Feiglstorfer 2011b: 239). The absolute orientation of the main temple would hypothetically correlate with the above given hypothesis of the absolute orientation of the Lhasa Jokhang as the central temple. Small deviations of up to app. 4° may either be a measurement inaccuracy or intentional (Feiglstorfer 2011a: 582). The 'secondary' temples in contrast would again be relatively orientated. In this case the question is raised whether there is a historical and hierarchical relation between the main temple and Temple IV, since both show the same (absolute) orientation.

The main temple of Tabo in Spiti was also founded in 996 CE. According to satellite images from Google Earth, it shows an absolute orientation towards the east with a slight deviation towards the south. Compared with the Nyarma compound at the monastery of Tabo, the orientation of the other temples besides the main temple also follows an approximate orientation towards the east and not an orientation related to each other, as is the case at Nyarma. Similar to the temples of the monastic compounds (Tib. *chos 'khor*) of Alchi and Tholing, which are located close to the rivers Indus and Sutlej, respectively, the orientation of the Tabo temples follows the course of the Spiti River.

45 Unpublished project report by André Alexander for the Gerda-Henkel-Stiftung, titled *Die Kulturbauten aus der Gründerzeit des tibetischen Reichs (siebtes Jahrhundert n. Chr.): Eine kulturgeographische, architektonische und ethnographische Dokumentation*. He also presented a paper on this matter at the IATS conference in Vancouver in 2010.

At other early West Tibetan monasteries we may find a similar relation between the orientation of the temple structures within one compound. This is the case in the Alchi Chökhor (orientation of the temples between 145° and 159° south-east; according to Google Earth), or at the temples of Nako, where two temples point in a similar direction (app. 114° / 118° south-east), each with an opposite orientated temple as a counterpart facing app. 296° north-west. Also at Tholing the single temples follow the orientation of the main temple towards app. 63° north-east. At these temple sites the main temple seems to be relevant for the determination of the chronologically later erected temple structures. What we cannot find at these sites is an absolute cardinal orientation. The orientation of the main temples of the given sites is roughly just towards the east but is actually either north-east or south-east. In particular at the monastery of Tholing, which like the monasteries of Tabo and Nyarma was founded in 996 CE, one should expect the application of a similar method for defining orientation. But contrary to the main temples of Nyarma and Tabo, which show absolute orientation, the main temple of Tholing shows relative orientation.

Following these examples of the orientation of main temples and their relation to temples within the respective compound, some other constellations between different sites should be mentioned. Over time, several hypotheses have been generated for relations between temples and, e.g. a political centre, or other temple sites (cf. Feiglstorfer 2017a). An example is the Tandruk Vihāra (oriented 261° W), probably the earliest Central Tibetan *vihāra*. Founded in the 7th century CE, the Tandruk Vihāra faces towards Kathmandu or, as another example, the Uru Katsel (Dbu ru Ka rtsal), which was also founded in the 7th century, faces towards the Tandruk Vihāra (according to Herdick in Hazod et al. 2005a: 267). An example from early West Tibet is the orientation of the Nako, Alchi and Mangyu temples towards the *chökhor* of Tholing, possibly to demonstrate Tholing's central role among the earliest West Tibetan temples (Feiglstorfer 2011b: 241).

These examples show possible relations between particular sites determined by definition of their orientations. On the other hand, we should not overlook the hypothetical character of these statements and cannot exclude a possible coincidence. Furthermore, even in the case that these statements are exactly correct, they primarily state the strong tendency in the imperial Central Tibetan and early West Tibetan period to define connecting orientations individually for some particular sites. At this state of research, all these facts do not show a particular homogenous interrelation to explain an overall connected political or religious system.

Referring back to the introduction of this chapter, a possible cosmic relation of orientating structures towards celestial constellations cannot be excluded, and with some ongoing observations a rather untouched field of research in Tibetan culture has been opened. A recent finding in 2014 started with an examination of the orientation of the Khorchag Monastery. Here for one of the original early West Tibetan temples it was possible to identify for the first time an orientation towards several celestial phenomena (cf. Feiglstorfer 2017a). The temples of Khorchag, which are both within one monastery compound (at least one was founded in 996 CE), the Lhakhang Chenmo and the Jokhang, are approximately in an orthogonal position to each other: the first with an orthogonal position to the passing Peacock River, the second with a parallel position to the river (see Fig. 1.5). With an orientation of 78° north-east for the Lhakhang Chenmo, and an

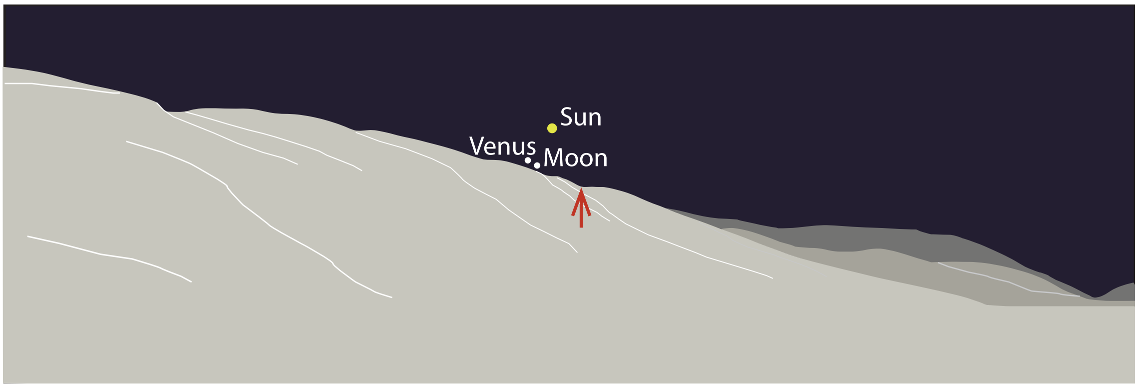


Fig. 1.12 Khorchag. Monastery. View from the Maitreya statue of the Lhakhang Chenmo along the central axis of the temple. The intersection of the main axis of the temple with the mountain shape is shown by an arrow. In 996, a rise of the moon and the Venus occurred on the 19th of June at 9:29 am (Julian calendar), shortly after the rise of the sun. Software used: Stellarium (version 0.13.0, 2014). Landscape source: Google Earth (access: 12/06/2014), DigitalGlobe 2014, satellite recording in 2005. For better visibility of celestial bodies, the background of the sky was darkened (cf. Feiglstorfer 2017a).

orientation of 353° north-west for the Jokhang, an absolute orientation can be excluded. A reconstruction of celestial constellations of the Lhakhang Chenmo – which might be the earlier of these two temples (cf. Feiglstorfer 2017a) – was conducted for the year 996 CE, when the temple was reportedly founded. The temple's orientation was brought in relation to its intersection using a profile of the horizon, wherein the track of particular celestial bodies also crossed.

The result of this study shows an interesting constellation of celestial bodies on the 19th of July, 996, which is just three days after the summer solstice (Fig. 1.12). On the same day it was possible to observe the new moon rising just five minutes after sunrise and two minutes after the rise of Venus. On the same day Mercury and Mars also rose close to this point of intersection. All this happened between 8:11 and 11:41 in the morning of the same day. The amount of celestial activities in that short time span points towards the existence of a particular knowledge on the calculation of celestial activities in advance. Thus, the hypothesis can be given that the orientation towards celestial bodies played a role in the orientation of the temples of Khorchag. Celestial relations for other early West Tibetan temples cannot be excluded and will be a target of further research.

4. Prestigious building material to represent a social status

"Canonic" in the present architectural context equals a kind of standardisation, and it implicates reproducibility on a modular basis. Particular canonical layouts are reserved to an elite group and a particular representative purpose. Canonical structures implicate particular behavioural patterns. They are able to represent a certain dominance over 'simple' vernacular structures. A representative status in a religious context can be expressed by the afore-discussed methods in defining a sacred space. However, the influence of the building material used has so far not been considered. This chapter points towards two categories of building materials. The first category includes locally available material needed to fulfil certain basic essentials of construction common for vernacular architecture. The second category expresses a certain elite status. In this case building material can be longer lasting, more precious or originate from further away.

In the Himalayas, some of the earliest remains of still used architecture are religious structures. Due to maintenance efforts being more focused on such religious structures as compared to the preservation of residential or farming constructions, such structures show higher longevity. It may be the interest of a particular community, e.g. village members or monks, to take care of proper maintenance.

But also the use of different constructions and materials and possibly higher efforts in processing are basic for gaining a representative character. In general, Tibetan houses are technically simple constructions of high ecological value regarding short distances of transport and long durability. Apart from constructive differences, such as thicker and higher walls for representative structures than for vernacular residential structures, what are the differences in the material used?

At least for the basic structure of religious buildings similar material qualities are used compared to 'simple' vernacular structures. For the latter, earth and stones are collected in the close vicinity. With the wood that has been used we find some differences. For 'simple' vernacular structures, wood is also sourced from areas nearby, while wood for structures of a social representative status may originate from areas further away (also see Chapter IV), similar to other natural resources. A main difference to the building material used for 'simple' vernacular structures lies in the material used for representative surfaces of roofs, floors, ceilings and walls. Here the materials used represent a higher status, since they may be rare, transported over a long distance or require expensive and high effort for processing. What we can hypothetically state at this point is that the use of non-local materials points towards the aim to represent a particular higher social status. In the following, examples for commonly used surface materials are given.

4.1 Roofs and floors

The basic construction of roofs and floors is rather similar between 'simple' vernacular and structures of a social representative status. The wood for beams and pillars is cut in the near vicinity or transported over longer distances, as might be the case when using cedar or *shukpa* (see Chapter IV). For 'simple' vernacular, a commonly used wood is poplar. Compared to cedar, which is often used for structures of a higher social status and which grows higher, poplar wood is commonly used for 'simple' vernacular structures, and it is softer and not antifungal.

Ceilings at buildings representing a higher social status are in general much more carefully processed (cf. Feiglstorfer 2012a). The earliest known ceilings of religious structures in historical Western Tibetan were made with wooden planks hewn with an adze. Moreover, at several religious structures, ceilings were painted or covered with painted textiles, as is the case in the Tabo Tsuglagkhang (Fig. 1.13). Another representative method is the laying of straight and decorticated twigs next to each other, either in an orthogonal or fishbone pattern.

There are different qualities associated with processing of the upper layers of the roof. In the case of an earth roof, a simple method of construction involves using only one layer of earth, while for longer lasting structures two or more layers of clay of particular qualities are used. Use of the

Fig. 1.13 Tabo. Tsuglagkhang. Painted textiles on wooden planks hewn with an adze.

Fig. 1.14 Lhasa. Jokhang. Shiny surface of an oiled and burnished *arga* floor.

arga stone (cf. Feiglstorfer 2019) is a method with a high representative character and primarily used for prestigious (religious and aristocratic) structures (Fig. 1.14) (see Martin 2013). An early reported use of *arga* goes back to the imperial period, where it was applied as flooring material in a burial chamber (Sonam Wangdu, Hou Shizhu 1985: 38). This kind of use also refers to the representation of high social status. Its processing needs dozens of workers, and in some cases the material has to be transported over long distances (see Chapter II; Feiglstorfer 2019: 139ff.). Different colours of minerals allow for the processing of a colourful design, and the use of certain minerals and vegetable additions also turns the floor into a reddish colour suitable for religious structures.

4.2 Wall surfaces

In the Himalayan regions, particularly for religious structures, mural paintings developed as a traditional craft. Covering walls with mineral and vegetable colour pigments, specifically over a white sublayer, requires a smooth surface of the wall plaster below. The plaster has to be of a cohesive and non-cracking nature, and its capillary suction should be low. Therefore a particular material for the plaster has to be chosen, and surfaces should be burnished before being painted (Fig. 1.15). This procedure is labour-intensive and makes the surface harder, more durable, more impact-resistant, slightly hydrophobic and levelled for mural-paintings. Such a quality cannot be achieved by just preparing a simple plaster or in the simplest manner by just whitewashing the subconstruction.

The application of a high-quality plaster was not only known for mural-paintings but also for application on wooden pillars with a finishing monochrome red colour, as is still present in rather good condition in the Maitreya Lhakhang in Basgo (see Chapter III) (Fig. 1.16). For this application, know-how in processing a specific grass as an undercoat layer was also needed. Such grass processing has similarities to practices used for clay sculptures (see Chapter II).

Fig. 1.15 Uru Katsel. Assembly hall. Shiny surface of a burnished clay plaster.

Fig. 1.16 Basgo. Maitreya Lhakhang. Painted clay plaster on round-shaped wooden pillars.

Besides the preparation of a proper subconstruction, only specialists can create a mural painting. The raw material, inter alia mineral and vegetable colours have to be processed in a rather labour-intensive manner so as to reach the desired pigments. Some of the raw material is partially still available in Tibetan regions, and some had to be brought from Central China or even from Nepal, Bhutan or India.

Clay sculptures, which are immovable and attached to the wall or ground, can be seen as part of the architecture. Their processing is a craft of its own and in general disconnected from 'simple' vernacular architecture (except for small and transportable clay sculptures) and primarily related to religious architecture. For the study of earth buildings, knowledge related to the quality of the raw material used for other crafts, such as making clay sculptures, Tibetan stoves or for pottery seems to be basic for a comprehensive understanding and will be examined in Chapter II and Chapter III.

5. Discussion

In this first chapter it was possible to connect earlier research material with recent research results and to find a superior correlation. The integration of the religio-political programme into earlier architectural research brings the single architectural tools in relation to each other and explains their use in a modular and canonical context. This extended approach gives fresh insight into the interrelation of architecture as a tool of programmatic representation.

Geometry and proportion are mentioned as major tools to define early Buddhist architecture in the Himalayas. They are used for the materialisation of a specific religious programme, which is defined by how it is experienced by the believer. In contrast, 'simple' vernacular structures are based much more on local decisions, and tools for generating a canonical order are less needed. The representation of vernacular structures is primarily connected to a local community. Contrarily, canonical structures in an elite context are defined for a regional representation of a particular ideology.

For ‘simple’ vernacular structures, geometrical and proportional order imply a higher need for precision in construction. Two basic tools were applied as units of measurement. One is the use of absolute measurement units, which are defined by body measures, possibly by applying them to a rope or a stick. The other is the use of relative measuring units, which are defined by the use of *moduli*. In this case, certain *moduli* are used for the geometric organisation of the whole layout. This approach enables a proportional interrelation of single architectural elements and brings it in relation to a superior programmatic idea.

This kind of modularity is the basis of further proportional relations between the single parts of early Tibetan religious structures. The applied method shows hypothetical similarities between early Central Tibetan temples (7th to 10th century CE) and early West Tibetan structures (late 10th to c. 12th century CE). A basic feature of early Tibetan geometric order is the proportional relation between the *dukhang* (assembly hall) and the *tsangkhang* (*cella*). The latest examinations raise the hypothesis that the application of the layout may have started with the geometric centre of the *dukhang,* from where the whole *dukhang* and also the position of the *tsangkhang* were geometrically defined.

The trapezoidal shape seems to have been a kind of predecessor of the rectangular shape, in particular of the square. Features like the enclosure wall or the marking of the four corner points by *chorten* in a centralised layout were already part of trapezoidal-shaped settlement layouts in early imperial Central Tibet (7th to 10th century CE). Main forms, which were often used as ground plans for religious structures, are absolute geometric forms, primarily the circle, and rectangular shapes, mainly the square. The shape of the trapezoid loses its importance in the design of Buddhist structures.

In Tibetan Buddhism, the concentric organisation around a central pivot became a common feature, which correlates with the circumambulating movement of the pilgrim. The circumambulation is a common ritual practice and is spatially defined by particular routes such as the *nangkor*, the *barkor* or the *lingkor*. As we know from today’s use, the concentric design defines the routes of circumambulating pilgrims and becomes another kind of a canonical feature for the definition of sacred space. The definition of such structures connected, e.g. to the position of protectors’ chapels, is already existent in the early imperial period of Central Tibet.

Related to the central core, a cardinal and intermediate location of protecting artefacts – such as Rigsum Gönpo – or natural phenomena – such as mountains as protecting elements – are tools to define a sacred space, e.g. in Lhasa this space is denoted as the “Lhasa Maṇḍala”. Protection on a philosophical level seems to be a main driver for the erection of early religious edifices. Examples are the border protecting temples around the Lhasa Jokhang, the erection of Rigsum Gönpo or of enclosure walls, which due to their small size can be primarily interpreted as fulfilling a religious and not a mundane defensive purpose. Protection of a religious centre or a religious programme in a philosophical context was materialised with protecting enclosure walls surrounding the monastic compounds. The erection of an enclosure wall defines a basic part of the layout of several early Tibetan religious sites. The enclosure wall is one kind of structure within a set of different artefacts and natural phenomena, which define markers along pilgrim routes. They are basic for the definition of a sacred space, which is connected to Tibetan cultural zones.

In religious programmes, protection is an essential matter that is expressed by particular religious protecting figures. These figures have their particular position within a sacred space in a painted, modelled or sculpted form. The position of particular artefacts within a religious structure and the related architectural plan follow a specific religious program. This results in various kinds of inter alia mandalic and pentalic shapes. The pentalic structure is one of the basic design patterns used to define the ritual space of the core temples of early Tibetan religious structures. Such pentalic designs are connected with ideological programs and social structures.

Another tool for the definition of a universal concept is the choice of particular orientations of structures. In Tibet use of relative orientations can already be observed in pre-imperial time at the construction of burial mounds, which primarily follow relative orientations contrary to Mongolian and Central Chinese comparative examples from a similar period. A certain trend of using relative orientations was maintained at early Central and West Tibetan temple structures. The use of an absolute orientation seems to be of importance for some of the *tsuglagkhang*s, while some of the secondary temples within temple compounds or the group of border taming temples follow a pattern of its own (with some evidently related to a central temple). Evidence is given for an inter-relation between orientations of building structures within monastic structural compounds.

In general, in the Tibetan cultural zone we can not deduce an all-over method of defining a temple's orientation. The results of research state different methods applied for certain temples and temple compounds. The introduction of the orientation of celestial bodies can hypothetically be stated as a research result at the Lhakhang Chenmo of Khorchag. The observation of celestial bodies regarding the definition of the position and orientation of religious structures can be assumed to play a particular role. In this field, further research is needed.

Besides a difference in the strength of constructions, the use of particular materials and knowledge of material processing is another tool used to define architecture of a particular representative social status. This differentiation shows a strong impact on the quality of surfaces of the building. The import of minerals for painting, quarrying and transporting *arga* or burnishing wall plasters are not part of the common vernacular material culture but rather of a certain social representation.

On the other hand, the raw material needed for processing a specific plaster may overlap with other building purposes such as making bricks, preparing a flat earth roof, plastering pillars, making a traditional Tibetan stove or even making clay sculptures and pottery. The appropriate raw materials are not strictly separated from each other, and specifically needed technical properties of raw materials may overlap and support each other. The use of particular clay is not primarily reserved for the elite, as is the case for specific kinds of wood or *arga* stone. It is their processing in particular, which shapes a difference between 'simple' and elite representation of a social status.

In order to get closer to this complex matter in material culture, the following chapter on material traditions discusses several of the locally available materials, their processing and possible methods of investigation.

II. MATERIAL TRADITIONS: RAW MATERIAL AND TECHNIQUES

This chapter examines the interrelation between properties of raw materials and the applied processing methods. The first part offers a general overview of the importance of the use of local terminology within the scientific research of materials. Scientific efforts are specifically emphasised. Three different crafts are discussed, i.e. construction of a flat roof, making of pottery and making of clay sculptures, all of which are based on mineral raw material. Raw materials and related processing methods are juxtaposed in a historical and present context.

1. Significance of local terminology within the study of building traditions

Building traditions are carriers of information on functional aspects and social needs based on a particular agreement within a certain community. From a social-anthropological point of view, such information may give answers to questions on technical and related social conditions and developments at a certain time or over a certain period of time and within a certain local or regional context.

One approach to moving closer to a broad material understanding is research on technological and social aspects using local terminology. An example is the terminology used for specific types of clay that are known as fine material for plasters or roofs within the Himalayas. One material that is widely known as *markalak* in Ladakh (Feiglstorfer 2014: 378) is known by the similar term of *narkalak* several hundreds of kilometres further away in Purang, while in Upper Kinnaur, an area in northern India located between Ladakh and Purang, this material is known as *tua*. Further to the east, in Central Tibet, it is referred to as *thigsa*. Locally used terms support research on particular material properties and construction methods. They give evidence of the origin of materials and their use and become a local marker in a material and social-anthropological context. A striking result of this research (Feiglstorfer 2019: 252ff.) was the conclusion that over such a wide distance the material, which was described partially under a similar name, also shows similar material properties suitable for particular technical needs.

Regarding material properties, with this step in research on transmission of traditional knowledge, similarities in the use of particular materials become evident. It invites further investigations into the field of clay, since this material, due to its locally varying compositions and its characteristic to be mixed, is more complex to terminologically categorise compared to building materials such as metal or wood. Nevertheless, within historical sites, in particular religious buildings, which in many cases in the Himalayas are some of the oldest witnesses of local building traditions, we have to regard the complexity of local material specifications. Studying the network of origins of used materials such as clay, wood, stone, metal, etc. supports the understanding of traditional methods of processing and improves insights into crafts and craft traditions. Using local terminology is part of a building material's local identity and essential for further understanding of material properties in a coherent material-cultural context.

2. Earth roofs and *arga* roofs: a continuity of a flat roof tradition

2.1 Two different types of a flat roof

Besides protection from natural elements, a roof also represents a social status. In the case of flat roof constructions, representation may be given by the selection of particular raw materials and a higher quality of the applied method of construction. Particular methods, which are applied for making flat roof constructions, are similar to those used for floor constructions. The use of *arga* as a specific stone instead of clay was historically mainly employed for structures belonging to a religious and aristocratic society. At several buildings in Tibet, we still observe the application of this technique. The need arises for an examination of the construction of such stone roofs and their juxtaposition to common flat roofs made of clay.

A current topic in the conservation of earth buildings is the leakage of traditional flat roofs. Over the last decades in regard to vernacular structures, several problematic measures have been taken due to a loss of knowledge on the right construction process, lack of understanding of the proper raw material, or simply due to a lack of time. Examples include the use of plastic sheets for water proofing, bringing too much load onto the roof or using improper raw material. By learning from traditions, we receive the necessary information on the proper way to construct a long lasting flat roof. It is not just a question of the appropriate quality of clay, but all the single components of construction go hand in hand to create the best possible structure.

In general, there are two different kinds of flat roof constructions in the Himalayas: the flat earth roof with clay as the uppermost layer, and the *arga* roof with a specific kind of stone as the uppermost layer (Feiglstorfer 2012a: 5–8). The earth roof can be found all over the Himalayas with regional and local specifications given by the available raw material. Such an earth roof may differ from the *arga* roof, for example due to a less heavy subconstruction. The use of stones as load-bearing subconstruction could be examined at various *arga* roofs. The *arga* tradition is still practised in Tibet, primarily for structures representing a higher social status. In a recent research project at the IAG / BOKU, *arga* raw material was examined and basic material features analysed (cf. Feiglstorfer 2019: 139ff.).

In the following, some basic features of a Central Tibetan earth roof are juxtaposed to a Central Tibetan *arga* roof construction. For both methods, a similar subconstruction is used.[47] Within the subconstruction, the basic carrier is a wooden construction consisting of *dungma* (Tib. g*dung ma*, “main beams”) and *cham* (Tib. *lcam*, “secondary beams”), with an initial layer of *delma* (Tib. *dral ma*, small pieces of wood of a tree or a bush) on top. This layer is used in such an amount that the *cham* is no longer visible. Previously, *tsherma* (Tib. *tsher ma*, “thorns” or “bush”), which is laid as loose pieces onto the wooden subconstruction, was commonly used, but today any species of wood is applied. If less *cham* is used, a larger amount of *delma* is necessary and vice versa. The use of an organic layer on top of the *cham* and below a next upper layer of clay is widely known in the Himalayas. The type of organic materials depends on the local availability. In the Western

47 At some examined *arga* roofs, the subconstruction is made with a higher content of stone to increase resistance against strong vibrations during ramming (see Fig. 2.2).

Himalayas for this organic layer materials, for example, grass such as *yakses* or *burze* are used (cf. Feiglstorfer 2019: 150).[48] The use of *yakses* and *burze*, in contrast, is not so common for building purpose in Central Tibet as it is in the Western Himalayas. When using stones for making the subconstruction, a layer of stones in varying sizes covers the layer of *delma* (cf. Feiglstorfer 2019: 145ff.). Not just flat but also round stones are used with the aim to press down on the layer of *delma.* In the case, where the layer of *delma* already shows high compression, fewer stones are necessary and vice versa. In-between the big stones rather small stones or sand (Tib. *sil bu*, "bits" or "pieces")[49] are placed into remaining holes.

A layer of a slightly sticky clay taken from the field covers the layer of stones. Such clay has no particular required property, though, if possible, a reduced content of stones is preferred. On the one hand, it has to cover the stones below; on the other hand, it is the layer that carries the upper mineral layer, which consists either of clay or of *arga*. The clay on top of the subconstruction is of *earth-moist* (Ger. *erdfeucht*) consistency, and it is thrown over the layer below, which is either a stone or an organic layer, where it remains either uncompressed or is compressed by beating, e.g. with wooden sticks. When drying, resulting cracks are covered and closed by the next upper layer. Up to this layer, construction remains similar for both flat earth roofs and *arga* roofs.

2.2 Earth roof construction

For the earth roof on top in Central Tibet, a specific type of clay, the *thigsa* (Tib. *thigs sa*)*,* is used (Fig. 2.1; Interview Penba Tashi 2015). It is much finer than the clay below and does not easily crack. It is compressed with wooden branches used as beaters. Whether or not the earth roof is waterproof depends on this layer. Before it starts raining, *thigsa* is applied onto the roof on a date chosen according to the Tibetan calendar. In relation to the orientation of the nest of the magpie, a differentiation is made between *tschogtsang* (Tib. *mchog tshang*, "best nest or house") as the clean and good orientation, and *bumdong* (Tib. *bum stong*) as the "empty vase", respectively, the wrong orientation.[50] These orientations influence the side of the roof, on which to start adding

48 The tradition of using organic insulation layers is not restricted to the Himalayas. In particular organic substances are connected to specific local building traditions. In Bam in Iran, for example, the bark of the date palm tree is used to waterproof the roof.

49 The term *'silbu'* (Tib. *sil bu*) describes small pebbles; also known as *toshug* (Tib. *tho shrug*).

50 According to an interview with Penba Tashi in Lhasa on December 3rd 2015. He mentions the magpie (Tib. *skya ga*, written form; *kre skag*, spoken form), which lives in the close vicinity to settlements and builds a nest in the trees. The form of the nest is ball-like with one or two entrances. It is a common belief that, similar to humans, these birds have to protect their 'home' from precipitation. The entrance of the nest opens contrary to the main direction of the rain. For the builder, the choice of the right time to make the nest and the nest's orientation are of high importance. Related to this traditional belief is the expression *"kyaka thigsa",* which is also used for the application of *thigsa* according to this bird observation.

In the event of a roof leak, one can make a pilgrimage to Drag Yerpa (Tib. Brag Yer pa) in Phenpo. Legend says that the roof of the Lhasa Jokhang was not made of *arga* but also of clay, i.e. *thigsa,* and that the first material, which was used at the Lhasa Jokhang, originated from Drag Yerpa. On the one hand, this description emphasises the religious importance of Drag Yerpa also on a material-cultural level; on the other hand, it points towards a more common use of earth roofs in the imperial period of Central Tibet and a subordinate meaning of *arga* as roofing material.

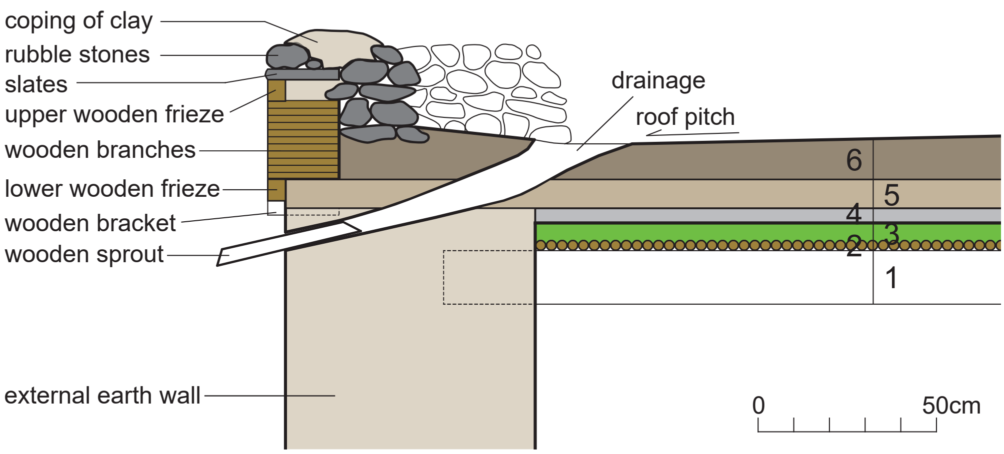


Fig. 2.1 Fig. 8.3 Section of a traditional flat earth roof construction.
CT = Central Tibet; WT = Western Himalayas (cf. Feiglstorfer 2019: 146).

1 = *cham* (Tib. *lcam*, secondary beam), often placed on the *dungma* (Tib. *gdung ma*, main beam), the latter resting on one or more *kawa* (Tib. *ka ba*, pillar).
2 = *delma* (Tib. *dral ma*, small pieces of wood of a tree or a bush), e.g. willow branches are commonly used in WT.
3 = organic layer; specific types of grass like *yakses* used in WT; the use of an organic layer is commonly known in WT, but not everywhere in CT.
4 (ground layer) = *yamba* (Tib. *gyam pa*, flat stones); often used in combination with an *arga* roof; often used in CT or Purang; rarely used in WT.
4 (upper layer) = *dorug* (Tib. *rdo hrug*, small stones); used in combination with the *yamba* below to fill gaps between the bigger stones.
5 = *thogdag* (Tib. *thog 'dag*); is the first layer of clay.
6 = *thigsa* (Tib. *thig sa*); upper and fine layer of clay, which is in some areas traditionally replaced or simply added every year and maintained before rain falls.

clay. When of an *earth-moist* consistency, but not sticky enough to stick to one's fingers, *thigsa* is spread over the roof in a thickness of app. 2 cm to 4 cm. This layer remains uncompressed. *Thigsa* does not contain stones and is known all over Central Tibet. It is still common, e.g. in Lhundrup County and in Tölung (Tib. Stod lung), from where most of the *thigsa* for Lhasa comes from. Locations, where one can dig up *thigsa,* are locally known as *thigsa lensa* (Tib. *thigs sa len sa*). Penba Tashi explained *thigsa* in relation to his home village Grib in Lhundrup that it is commonly a material that is washed down from the hills by rain and that during rainfall, such places become muddy and slippery. This description points towards a type of clay with a high content of clay minerals. For maintenance of the roof, fresh *thigsa* is spread over the roof one to two times a year, while the layer of clay below remains unmaintained. Some families keep fresh *thigsa* for the next season at an edge of their roof. In winter, melting snow in particular has to be removed from the roof. Tashi Penba described this process of snow removal as being necessary as soon as shoe prints are visible in the snow. If not removed in time, the *thigsa* becomes moist and may leak in following seasons.

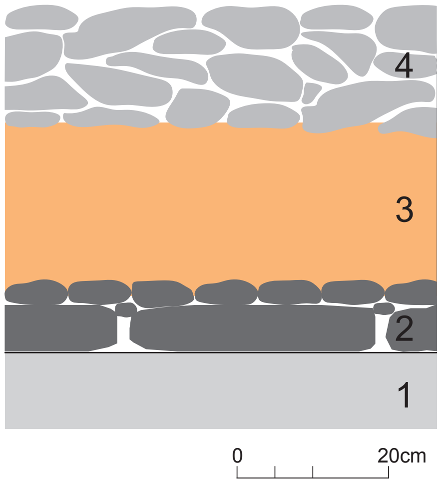


Fig. 2.2 Section of an *arga* roof. Showing a state before mixing clay and *arga* stones by ramming.
1 = Organic layer; 2 = Layer of stones; 3 = Layer of clay; 4 = Layer of *arga*.

2.3 *Arga* roof construction

The second preparation method for a flat roof in Central Tibet is applying *arga* stones in several layers, with the stones becoming finer towards the top layer (Fig. 2.2). Up to the top of the first layer of clay, the subconstruction remains similar as described for flat earth roof constructions. In some cases a stone subconstruction was made between the wooden rafters and the layer of clay on top without using organic fibres as insulation layer in-between. It is said that the quality of an *arga* roof increases from the bottom to the top, and it is the top that protects the roof from total collapse even in the case of the collapse of a pillar (Interview Kelsang 2014). A high-quality *arga* roof lasts many years, according to Grothmann (2011: 23) app. ten years, before the need for renovation arises.

In Feiglstorfer (2012a), a method for making an *arga* roof is described. After having collected the raw material and having crushed the *arga* stones into varying sizes, the work process is conducted in the following described steps (cf. Feiglstorfer 2019: 155ff.). With this technique, we also find several variations and descriptions about the size and preparation of the single layers. Fig. 2.2 shows average dimensions of surveyed *arga* roofs.

- A. Clay is spread out onto the roof in one layer of up to 35 cm (Alexander 2011: 71) and levelled (number 3 in Fig. 2.2).
- B. *Arga* is spread out layer by layer onto the roof, with each layer reducing the size of the pieces. The final *arga* will be between 10 cm and 20 cm (ibid. 71) (number 4 in Fig. 2.2). Each layer of *arga* is levelled, watered and compressed.
- C. The compression starts with a roller. Compression continues with use of the *bogdo*, a ramming tool with a stick to hold it in an upright position and a stone at its bottom end for crushing the *arga*. The surface is continually watered.
- D. As soon as the complete clay-stone mixture is saturated with water and water pressed above the surface of the upper *arga* layer, the ramming process is finished.
- E. In a further step the surface is burnished with stones to make it smooth. After finishing this step, the roof is ready for completion.
- F. The finishing is conducted with particular substances: first oil, followed by the use of vegetable substances. Mixtures and layers of finishing vary locally.

Map 2.1 Western and Central Himalayas. Sites related to *arga*.
GIS data based map: Jakob Gredler. Final graphics: author. Map based on data from Vector data (VD) and Basemaps (BM). Citations of VD and BM also see: Chapter IX, list of illustrations.

Construction can be explained in single steps but has to be understood as a composite construction, and as such it is efficient in a static and hydrophobic manner. The static effect is given by strong areal compression. Due to ramming and watering (steps A to C) that lasts several days, the compound of clay and *arga* becomes more and more homogenised. The small *arga* particles are pressed into the clay, and the clay from below is pressed towards the top, thus forming a homogenous mass (Feiglstorfer 2019: 191, 192). The quality of clay does not have any required specification, thus any clay with a low amount of stones can be used. As a result, up until now no hydraulic influence by the clay could be proven. Since not all examined types of *arga* contained smectite, its influence can also be excluded.

The hydrophobic effect is given by treatment of the surface, which starts with burnishing. Similar to what was mentioned for the finishing of pottery ware, the black paint used for window frames (*nagtsi*, Tib. *nag rtsi*) and wall plasters, by burnishing the surface is compressed, porosities are closed and the surface levelled. The substances used close the porosities and must be resistant to UV light and strong climatic changes. They must further be elastic and non-porous. These features are achieved with a combination of different fluid substances.

According to information given by two monks in December 2015 at the Uru Katsel Temple, *arga* was used for preparation of the monastery's new roof, but there are no *arga* quarries in the close vicinity. They received the *arga* raw material for recent reconstruction of the main temple from the Dogde (Tib. Dog sde) Valley, close to the Sera Monastery. Other places for quarrying *arga* include the village of Serme[51] (Tib. Sa smad; see Hazod 2007: Map 2), which is close to the end of the Chuchod (Chu shul, also Chu shur) District on the way to Nyemo (Tib. Snye mo), Drag Yerpa (Drag Yer pa) in the Kyichu (Skyid chu) region, and several places are located in Phenpo ('Phan po) (Map 2.1).

Seven *arga* samples originating from pits in Central Tibet, West Tibet and Indian Himalayas were analysed regarding their bulk and clay-mineral composition, grain size distribution and colour (see Feiglstorfer 2019: 181). Marl, which is used as *arga,* shows a content of calcite, ranging between 46% and 80% with the highest amount in the Indian Himalayas and the lowest in Central Tibet. Minerals like dolomite, hematite, gypsum or pyrite were absent in general, and minerals like 7Å and 14Å minerals, mica, amphiboles, phyllo silicates, quartz, Kali-feldspar or plagioclase are either absent or available only in small amounts. Regarding the clay mineral analysis conducted for all four of these samples originating from Central Tibet and Indian Himalayas, the following was determined: Two samples show a rather high content of smectite, which supports the absorption of water during ramming and compressing. For three samples, the content of illite ranged between 17% and 42%, while the sample from Phugtal in Zangskar reached 100%, which differs strikingly from the other examined samples. A content of iron oxides, exemplarily of goethite in the sample from Phugtal, adds a yellowish colour. Inclusion of hematite, lepidocrocite or manganese adds a red, orange or black colour, respectively. This aspect seems important in a context of representing a particular social status, with a reddish colour being favoured for religious structures, for instance.

An important fact is that different crafts such as plastering of a wall or the preparation of the surface of pottery, of a clay sculpture or of an *arga* roof, are technically related to each other, even when they are connected to different crafts. Regarding the treatment of surfaces, these mineral-based crafts are interrelated regarding the use of similar raw material and the way of processing. An examination, which has so far not been conducted for the Himalayas, involves finding synergies between methods of construction and the raw material used. Such a study is inter alia connected to the correlation between raw material resources and methods of processing. This method of examination requires a higher level of research effort than just focusing on technical aspects of roof constructions, for instance, since a high effort in interdisciplinary exchange is needed. For that purpose, methodologically an architectural and natural scientific background complement each other well, as demonstrated in particular in Chapter III.

Bellezza (2015) describes the method of burnishing pots in the Chugong period in Central Tibet around 4,000−3,500 BCE. This technique is globally well known, leading us to further investigate this method of treatment of the upper surface of plasters. In research at the IAG / BOKU, experiments focused on this field showed clear differences in the burnishing behaviour of different mixtures. Further it turned out that the raw material used for plaster of the Nyarma Tsuglagkhang (founded in 996 CE) showed an ideal mineral composition for this treatment (Feiglstorfer 2019:

51 The village of Serme has not yet been clearly localised and will be part of future research.

Fig. 2.3 Uru Katsel Temple. Women creating a shiny surface on top of the clay plaster by burnishing with round stones.

33ff.). The same clay, which was collected from places close to the building site, was used for bricks and also for the lower and the upper plaster layer. For the single components, the clay was treated in different ways, by sieving, desludging and mixing with straw. In this way, the properties of the clay could be adjusted to its use.

Due to large wall surfaces within temple halls, the method of burnishing is rather time consuming. In 2014, the author observed this method at the Uru Katsel Temple in Central Tibet (Fig. 2.3). Here women standing beside each other in a row burnished the expansive wall surfaces to prepare them to be painted in the next stage. In 2015, the author examined the same surfaces at the Uru Katsel Temple again, which were now evenly burnished with a shiny mirror-like surface, and still free of cracks (see Chapter I, Fig. 1.15).

This brief review of burnishing brings us back to the treatment of the *arga* roof, for which a similar method is applied. Contrary to the surface of clay, which is burnished to a *leather hard* (Ger. *lederhart*) consistency in order to be used for pottery, plaster, or clay sculptures, the surface of the *arga* roof needs more humidity, in particular during the process of mixing and compacting the clay and stone layer. Before the application of water proofing fluids on the *arga*, burnishing is a proper method to compress the supporting material and to close its porosities. At the IAG / BOKU, material tests for the *arga* were performed to observe its behaviour after burnishing.

Several features are crucial for the functioning of the burnishing process. The grain size distribution of the burnished material is balanced between fine and coarse material. The results of the

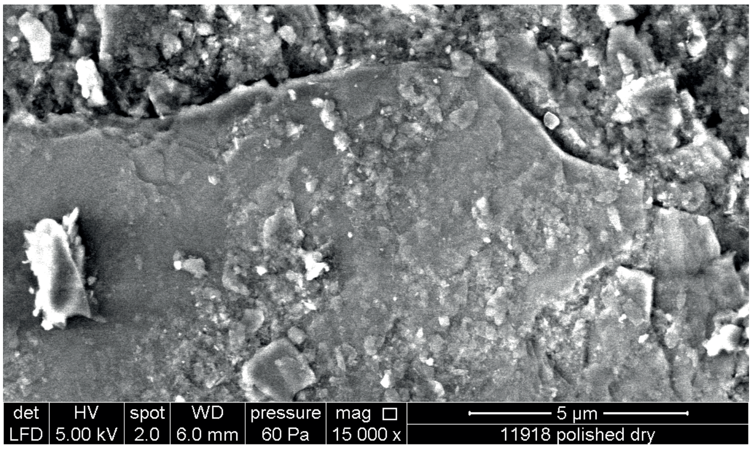


Fig. 2.4 Burnished surface of a clay plaster under the REM with 15,000 times magnification. Silicate sheets are homogenously compressed over a large part. Observation conducted at the IPM / BOKU in 2015.

test show that a too high content of clay minerals turns the surface of the substance into a greasy layer. An REM (scanning electron microscope) picture shows that for the burnished surface silicate sheets are laid horizontally and homogenously compressed (Fig. 2.4). Due to a high amount of phyllo silicates, these sheets slide onto each other and do not show cohesion. On the contrary, clay with a higher content of fine sand keeps the surface homogenous and stops the continuous sliding of the silicate sheets.

With proper grain size distribution, the time and pressure of burnishing becomes relevant. Application of pressure that is too high results in the effect described above, i.e. moving of silicate sheets against each other, leading towards a cracking of the surface. With a decrease of the water content, the pressure can be increased. The so-called *"*leather hard*"* consistency is an elastic term and is very much related to the particular use. The content of water leads us to another important precondition for the burnishing process. In general, it is material-related and certainly related to the craftsman's experience. Under the REM, a humid clay mixture shows rather big channels between the silicate leaves for water transport – a condition being not ideal for burnishing. In such a case, the pressure leads to removal of water but not to a stabile compression of the mixture. For wall plaster or the surface of pottery, burnishing under such conditions causes unevenness. The surface must reach such a low water content that the pressure does not cause displacements of clay particles. This can be used as a simple explanation of the term *'leather hard'* in the context of reaching a certain stage of compaction and dewatering (cf. Feiglstorfer 2019: 103ff.).[52]

2.4 Discussion

Traditional Central Tibetan flat roofs include two different types of making: a flat earth roof and an *arga* stone roof. The *arga* roof is of a higher quality when it comes to longevity, and due to the great amount of needed construction effort and high costs, it is reserved for the upper social class, aristocracy and monasteries. Use of such roofs is related to the representation of a particular social status. By that, the short distance of transport is not of primary relevance, though of high importance is the representative quality. It is not clear when this tradition began. An early finding

52 In contrast to the process of a simple compression of the clay-*arga* mixture, according to Satish (2003: 528), burnishing with oil based on natural organics causes a chemical interaction with a hydrophobic effect.

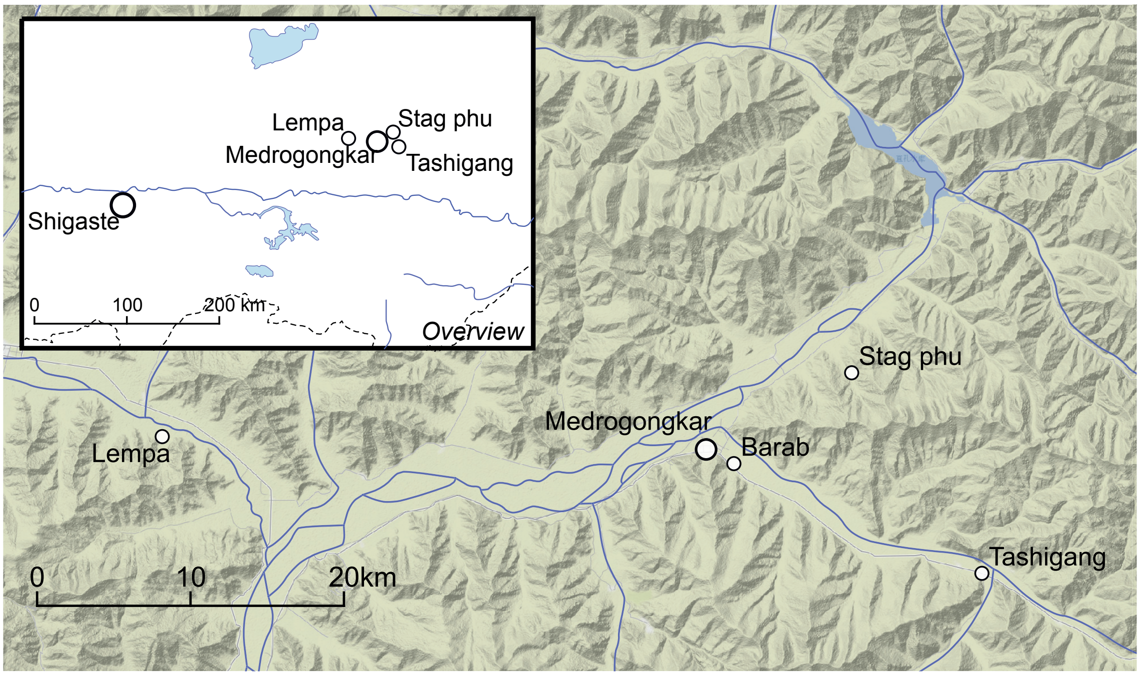
of *arga* used for a floor construction dates back to the imperial period of Central Tibet (Martin 2013). There is evidence that in the original state of the Jokhang in Lhasa, for example, the roof was simply made of clay.

Arga stone itself shows a relatively high content of calcite, and, to the best of today's knowledge, no hydraulic properties. The way in which one stratifies and treats the single layers enables a compaction and conglomeration of the single components between the layers from below to the top and vice versa. In the course of ramming, fineness and density of the single layers are changed. The processing of the surface layer with burnishing correlates with methods we find in other crafts, for example, for clay plasters, pottery or stoves. This aspect clarifies the material relation between different crafts – an aspect that points towards an open border concerning the exchange of information between the craftspeople. A terrazzo-like pattern is given by the colour of the minerals, dominated by colours of iron oxides. Since mineral colours vary between the single quarries, the visual features of *arga* roofs show slight differences, though this can be controlled by choosing specific material from certain quarries. Local variations also derive from naturally changing mineral compositions. For example, some samples show a content of smectite and others do not.

Construction of an *arga* roof follows an economic and functional principle. The basic structure of the roof is kept simple, and follows the same pattern of construction of an earth roof. The upper levels are changed and combined with the bottom layers in a most efficient physical manner. The involvement of the observation of the behaviour of birds in the process of construction and the use of the Tibetan calendar to define dates of construction show the complex relationship between construction, nature and timely regulation within a Tibetan year.

The making of traditional flat roofs based on clay is in general decreasing. Flat earth roofs are dominant in the countryside, while *arga* roofs are related to social representative sites. Flat earth roofs are easier to make, and no special skills are required for processing, while *arga* roofs are technically more sophisticated and need to be supervised by a master. A labour force of up to eighty workers, as was the case for the renovation of the *arga* roof on the Gyümed Dratsang in Lhasa, comes with high costs. After the Chinese Cultural Revolution, *arga* roofs were substituted by cement, however, over the last years the tendency has shifted to a revival of traditional crafts. Concrete floors are being demolished and replaced with *arga* floors. However, some disturbing factors of modernisation remain and show the sensitivity of the whole compound towards modernising interventions, as the following example shows: During a visit at the Gyümed Dratsang in 2015, the *arga* roof, which was erected in 2014, showed cracks, which is atypical for *arga* roofs. In an interview in December 2015 with Jampa Kelsang, who coordinated the process of making the *arga* roof, he explained that contrary to the traditional method the clients wanted him to introduce a plastic sheet below the layer of clay. This sheet interrupts the air and moisture exchange between in- and outside and leads to different surface tensions. Humidity, which remained in the construction, was not able to circulate in all directions but was instead led to the surface, where it caused cracks during a process of drying and freezing.

From a technical point of view, the *arga* roof is not necessarily limited to Himalayan regions, and the adaptation of current modern resources and tools to these traditional material qualities is a further aim of research.



Map 2.2 Central Tibet. Sites related to pottery. GIS data based map: Jakob Gredler. Final graphics: author. Map based on data from Vector data (VD) and Basemaps (BM). Citations of VD and BM also see: Chapter IX, list of illustrations.

3. Earth building material: Pottery and stove making traditions

3.1 Regional setting of this study

In Central Tibet we can still today find villages like Barab (Tib. Ba rab), which is located in Medrogongkar County, where pottery making is a living craft tradition (Map 2.2). In earlier days this craft was more common in centres of pottery such as in Lempa (Tib. Len pa) close to the village of Gyatso Shöl[53] (Tib. Rgya mtsho zhol) or in Kyilung (Tib. Skyid lung) Village in Phenpo (Tib. 'Phan po). In Barab, pottery ware was produced and sold in Lhasa, where the guild of potters was located along the Barkor until the Cultural Revolution when the central bazaar closed. Today, mobile traders coming from around Lhasa sell much of the pottery ware that is available in Lhasa. To sell pottery ware, potters either bring their products to Lhasa or customers, who trust in their potters' good quality, buy directly at their workshops. In Lhasa, along the Sangra road (near the Ngachen road), it is still possible to buy pottery ware at a fix-installed shop. Traditional pottery craft is also alive in the Shigatse region, but unlike in Barab, where natural colour use is common, the Shigatse region mostly does not utilise natural colours anymore. The use of natural colour is one essential criterion for the quality of the pottery produced in Barab and surrounding settlements. Chemical colours commonly used in central Chinese factories may spall easier when fired in comparison to natural colours. For the potter of today, the production of pottery is a side business in addition to farming and preferably conducted in winter on sunny days. In earlier days some potter families settled close to the observatory in Tagphu (Tib. Stag phu), which is about 9 km from Barab in a north-east direction, but in this village this craft is no longer alive.

53 The village of Gyatso Shöl has not yet been clearly localised and will be part of future research.

Fig. 2.5 Pottery wheel with a ceramic mould before being covered with fresh clay.

In the nearby village of Thaba[54], one or two families still practice the pottery craft. In contrast, in the village of Barab itself in 2015 about fifty families still kept this tradition alive.[55]

The village of Barab, where field research was conducted, has a long history in pottery. Tashi,[56] a potter from this village, produces his pots in the courtyard (ground plan with app. 20 m x 15 m) of his house. In a northern corner of the courtyard, pottery ware is kept for drying, while finished pots are stored inside. The potter's wheel is fixed in the ground of the higher section of the courtyard that adjoins the house. From this position, it is possible to face the direction of the sun while working and to look out over the courtyard's walls to the mountains located in the south. Such a southern orientation of the house and the courtyard accelerates the drying process of the pottery ware.

3.2 Raw material for pottery and processing

Raw material for pottery is brought from different sites: From the village of Baklog (today: Tashigang; Tib. Bkra shis sgang) one type of red coloured clay is collected, known as *khampa* (Tib. *kham pa*). Ser (Tib. *gser*), which is locally described as yellow, originates from the hills south of Old Barab. Old Barab's ruins are located directly to the south of the new village of Barab. In order to process the basic material, these two types of clay have to be mixed to avoid later cracks. The proportion of the mixture depends on the kind of red of the *ser*. In the case of a strong red colour, the proportion of the mixture is 1:1, and if the red colour appears light, the proportion is changed to 1:½. Sand is added in a small amount to further avoid cracking in the case that the pottery is to be fired without glaze. This fine sand is brought from Tsangthog[57], a village that is mentioned by the potter Tashi to be also close by. In the case of glaze being used, sand is not added, since the colour would not remain on the sandy surface. Mixing different ingredients

54 The village of Thaba has not yet been clearly localised and will be part of future research.

55 Information given by the potter Tashi from Barab in December 2015.

56 In December 2015, the author had the chance to observe the working process of the Tashi family in Barab, being very thankful to Tashi and his family for their hospitality and support of this research.

57 The village of Tsangthog has not yet been clearly localised and will be part of future research.

for preparation of basic pottery material is commonly known in the Himalayas. In the Western Himalayas in the village of Likir in Ladakh (see Chapter III), a specific fine sand is mixed with a specific type of clay. In Nixi in the north-western region of Yunnan Province, so-called "black pottery" is prepared from three different substances (Zhang, Gu 2009: 13, 14).[58]

At the Barab workshop, the mixture is sieved using very fine nets. Today the method is done with a sieve made of cloth, known as *sangre* (Tib. *sang re*), which are fine blue plastic coats, primarily made for building purpose. In earlier days, finely woven textiles, for example *khatak*s (Tib. *kha btag*), were used (as described by Tashi's wife). In Nixi, for comparison, a fine mesh of wooden baskets is used for sifting red clay and white sand (Zhang, Gu 2009: 16, 17). In general, before processing the mixture, it is kneaded and has to rest for a while in a covered condition. For that purpose plastic sheets are currently used. In earlier days, specific pots were prepared, in which the clay was stored and covered by a lid.

In Barab, pots are made in an economic fashion, wherein a series of pots is formed using a ceramic mould (Fig. 2.5).[59] The wheel itself is turned by hand, contrary to using a stick, which we know, for example, from Himachal Pradesh in India (Perryman 2000: 23), or one's feet below ground, as we have seen, for example, from Maroc.[60] In Ladakh, in contrast, pottery made in the 1980s was still primarily moulded by hand (Bhan 1990: 190), contrary to the author's observation in Likir in 2018, when the pottery wheel was commonly in use.

The use of a pottery wheel in Tibet goes back to c. 4000 BCE (Interview Shaki Ongdu 2015), while the pottery found along the Neolithic site at Karub (c. 4700 BCE) was at this time still formed by hand. Pottery at the archaeological site of Chugong at the periphery of Lhasa was already in c. 4000 BCE produced on the wheel, particularly in an advanced phase, while in an earlier state, pottery was produced by hand without using a wheel. Chugong pottery was fired at a higher temperature, resulting in a shiny black surface. A further feature of advanced technology in Chugong compared with Karub is the rounded bottom and the addition of three small feet instead of the preparation of a flat bottom (Chayet 1994: 55). The colour was primarily dark red.

John Bellezza (2015) also mentions a dark-grey ware. He describes a finer quality in a later phase of Chugong pottery ware and attributes this increase in quality to the advancement of the process of firing from open pits to kilns.[61] As of recently, burnishing,[62] which he mentions for Chugong pots, is no longer practiced in Barab, as such a process would greatly extend the processing time. These developments point towards a high standard of know-how during the Chugong period. In Central China, the first evidence of ceramic production goes back to c. 18,300 to 15,400 BCE in

58 At Nixi workshops, the three substances are explained as coarse red clay, a white sand (Zhang, Gu 2009: 16, 17) and quartz, which is heated until turning into a grey or black colour. It is thereafter cooled and pulverised (Elliott 2011: 11). All ingredients are gathered from nearby hills (Zhang, Gu 2009: 13, 14).

59 The use of a mould is also common in Nixi (Elliott 2011: 11).

60 In Nixi, only a banding wheel for modelling but not a pottery wheel is used (Elliott 2011: 12).

61 This indication is hypothetical. The finer quality of the pottery may also be related to the use of different raw materials or a development in the methods of processing.

62 For the method of burnishing mineral surfaces, see the information given on *arga* roofs in this publication.

Yuchanyan Cave and to c. 20,000 BCE in Xianrendong (Shelach-Lavi 2015: 57).[63] In the early Neolithic period, the earliest ceramic vessels were moulded by hand (ibid. 87), while already during the late phase of the Neolithic period the use of a potter's wheel was known. In contrast, in Kashmir, Bhan (1990: 191) describes the introduction of the potter's wheel to have occurred around 3000 BCE.[64]

In Barab, at the beginning of the process on the potter's wheel, a small amount of finely crushed fired pottery material is spread over the mould to keep it from sticking together. In order to compress the clay onto the mould (see Fig. 2.5) and to bring it into form, a wooden paddle is used (Fig. 2.6).[65] The pot is continuously kept humid with brushes of different sizes made from pig's hair (2.7).

In order to smooth the surface, a certain pressure is applied onto the pot with pieces of soft yak leather.[66] Processing of one of the small incense holders takes app. 15 minutes. Thereafter the pot is covered with a textile to decelerate the speed of drying, thus avoiding cracks. Many pots are used just being fired but without a glaze. If the pot is to be glazed, the glaze is applied after drying and before firing. The mineral traditionally used throughout the region is *shado* (Tib. *zha rdo*), which in earlier days was collected at Muning[67]. Today it originates from a valley called Ba located in Medrogongkar. Graining of this mineral is conducted without water, as it is necessary for minerals used for painting colours to be grained in trays of stone (Fig. 2.8). *Shado* is grained onto a stone plate after being crushed into small pieces. The whole process of graining *shado* to the size of a few cubic centimetres takes app. one hour. After graining, it is applied onto the pot with a brush.

In Barab, pots are fired only once, either with or without glaze. Without glaze the pot appears red (Fig. 2.9), while the surface colour turns light dark-dotted brown, when the traditional glaze is added. In order to fire the pots in the courtyard, an oven is erected temporarily with *lamak* (Tib. *la mag*) (Fig. 2.10), which is a substance with a slight amount of clay and a large amount of organic tubular stems. This material is obtained in the close vicinity to the settlement from a marshy terrain (Fig. 2.11). The *lamak* is filled into the gaps between and over the pots before setting the fire.[68] Small ceramic tripod spacers are put below the pots to lift them from the ground. The fire is kept for about 24 hours. On the following day, the fired pots are checked and, if necessary, fresh *lamak* is added.

63 According to Boaretto et al. 2009 and Wu et al. 2012 (in Shelach-Lavi 2015: 57), this is the earliest evidence of ceramic production in the world.

64 Until the introduction of the potter's wheel in Kashmir, kneaded *karewa* clay has been put in layers around a mass and the surface had been finished with wooden sticks or pieces of bone and at least with a dabber (Bhan 1990: 190).

65 For Nixi pottery, wooden paddles of different sizes are also frequently used tools (Elliott 2011: 16).

66 For Nixi potters, the use of deer skin chamois is common (Elliott 2011: 14).

67 The village of Muning has not yet been clearly localised and will be part of future research.

68 The use of peat is mentioned as fuel for potters in the Pulwana District in Jammu and Kashmir (GSI 2012b: 49), which points towards the use of a similar technique as used in Tibet. This material contains 10.4% moisture, 32.4% volatile matter, 4.21% ash and 11.99% carbon (ibid.).

Fig. 2.6 (Top) Use of a wooden paddle to mould the clay.

Fig. 2.7 (Below) Brushes made from pig's hair.

Fig. 2.8 (Top) Tools and minerals (*shado*) for graining.

Fig. 2.9 (Below) Fresh pots covered with textiles to prevent drying at too fast a rate.

Fig. 2.10 (Top) *Lamak* stacked in front of the potter's house.

Fig. 2.11 (Below) Marsh land in front of the village of Barab, from where *lamak* is collected.

Form and method of making are related to particular needs, one being the need for the *surkhok* (Tib. *zur khog*, "burning giving offering"), which is ritually used when someone passes away. The pot is filled with sweets, barley or *tsampa* and hung on the door of the respective family.[69] Other types of pottery ware include the following:

- Incense holder (Tib. *bsang phor*).
- Incense burner. For installation on the roof, some incense burners are home made from stones or clay, or bought as ready-made pottery ware.
- Butter lamp (Tib. *mar me*).
- Chang (Tib. *chang*) pot, also known as *zama* (Bhan 1990: 190). These kinds of pots are also used for storage of food like grains. For this purpose, the pots are of a bigger size.
- Teapot (Tib. *khog ldir*) with a bottom part that keeps the tea hot and the actual teapot as the upper covering portion.
- A *bumpa* (Tib. *bum pa*) is filled with five different kinds of grains, five different kinds of cloths, and five different kinds of minerals, (etc.) together with a religious text. It is taken to a monastery to be blessed. This kind of pot is known as *nönbum* (Tib. *gnon bum*). After the blessing it is hidden within one's house in a position and orientation that, according to astrological prediction, is a carrier of wealth. The same kind of a *bumpa* may also be used as *lukhang* (Tib. *klu khang*), locally also-called "naga-pot". In this case, it may have a snake painted upon its side.

In the village of Likir in Ladakh, the tradition in pottery has existed for generations. A son of the family Langdopa (house name) is still involved in production, and he explains the individual types of raw material (Feiglstorfer 2014: 372). As a material-cultural aspect, it is again the availability of clay with specific properties, which makes a particular clay appropriate for pottery making. At the IAG / BOKU, the material properties of the used raw material were examined. The use of a particular species of sand from a pit along the west side of the village helps to avoid the occurrence of cracks in the ceramics. This sand contains a small amount of smectite that enables better cohesion with the clay and supplements properties of the clay such as swellability (see Chapter III).

3.3 *Thab* and its material relation to pottery

This study has revealed similar clay properties between pottery and clay stove and furthermore between the two different settlements Likir and Basgo. This leads us to another important topic related to Himalayan pottery and architecture: the production of clay stoves, the so-called *"thab"*[70] (Tib.; "stove"). There are not many elders left to pass on this dwindling knowledge related to the *thab*. These massive stoves (see Chapter III) are produced in situ and become a non-moveable part of the building. They are modelled of clay and not fired. Their surface is treated with specific substances and burnished to make them waterproof. The clay itself must be fire-resistant, meaning it must not shrink or swell and be free of any cracks. In this matter, several places in Likir and Basgo have a specific clay, the so-called *"thabsa"* (Tib. *thab sa*). A description of the process of making a *thab* is given in Feiglstorfer (2014: 383, 384). Following further material research at

69 Interview with Penba Tashi from Nyemo on the way from Lhasa to Medrogongkar on December 18th, 2015.

70 Another matter in earth architectural materials is tiles. Their use in the Himalayas is of subsidiary importance due to the large amount of fire wood. Ceramics used in architecture we find in lower mountainous regions of the Himalayas – in China, Nepal or Jammu and Kashmir.

the IAG / BOKU on clay used for traditional Tibetan stoves and on the inner coating of a *tandoor* stove, it was possible to explore the basic material properties of specific proper kinds of clay. Knowledge of these properties enables us to reflect on their behaviour during processing and to categorise the requirements needed to reach particular qualities, for example fire resistance or low shrinkage. A detailed description of the used method of investigation is given in Chapter III.

In Central Tibet, a *thab* is commonly known, but how to process a high-quality *thab* is not as clearly observed in Ladakh. When talking to Penba Tashi[71] from Nyemo, a 30-year-old Tibetan, who was our guide during field research in 2015, he did not indicate any differences between a stove made of 'any' kind of clay easily available from the surrounding areas and a stove produced with a specific kind of clay with particular properties, as the author could observe, for example, for the stoves made in Ne in Ladakh (see Chapter III). Just in reference to the material's use, for Penba Tashi from Nyemo the term *"thab sa"* had no further meaning in terms of particular material quality. Another Penba Tashi, a Tibetan of around forty years of age from Phenbo,[72] explained that in his village in Phenbo anyone can produce a *thab* whenever the need arises, which means that making a *thab* continues to be a living tradition in the countryside and the knowledge needed to construct a *thab* is still existent. In his description he mentioned a particular type of clay, of which he provided a sample for testing.

3.4 Discussion

The essence of the involvement of knowledge of the raw material of pottery and different methods in processing in regard to the building material is closely related to earth building methods. Regarding the vernacular use of raw material for waterproofing or heat resistance, surfaces such as roofs or stoves have not been fully examined. A technical understanding of these traditions can improve awareness of specific material and social preconditions needed to keep such traditions alive.

The way, in which pottery ware in Barat is fired, is an ecologic model for a sustainable approach in that it uses the material from the marshy terrain adjoining the village. This material and the short distance of transport is cheap and the energy required low. Similarly, the pottery material itself, i.e. clay and sand, is collected from a site that is as close as possible. In present day Barab, pottery tradition seems unaffected by tourism but suffers from reduced sales due to the import of cheap Central Chinese pottery ware and the use of chemical glaze for imported ware. In Ladakh, in comparison, the pottery tradition has decreased, with only one pottery village in Likir. For Yunnan, as another Himalayan example, Elliott (2011: 23–34) mentions tourism to Nixi in the east of Tibet as a main factor for change. In this case, the request for pottery does not necessarily correlate with traditional forms. In Nixi, firing is conducted with wood, which is rather valuable compared to the marshy terrain used in Barat. At this place, government regulations such as restrictions on wood harvesting have been endangering pottery tradition.

71 Penba Tashi describes the quality of clay from ruins to be better for making a *thab*, though this has yet to be verified. This information might point towards the preference of sticky clay for a better modelling with a certain proportion of sand as commonly used for building purpose.

72 Interviews with Penba Tashi from Phenbo in Lhasa on November 29th and December 18th, 2015.

For the *thab* made of a specific clay, we learn about a sustainable form of a firing place within a residential building. The stoves are located in the living room and serve as a kind of centre for social life and communication within the living and cooking space. The *thab* itself is a fixed piece of furniture. Other rooms in the house such as sleeping rooms are not heated, and the author observed for certain families that members sleep in the *chensa* (Tib.), which is a combined living / kitchen area. For warmth, thick blankets are used during the night and clothing is not necessarily changed for sleeping. Energy consumption for heating coincides with meal preparation. This situation also promotes communication within the family and with guests, since the main activities take place in the living room. A further social aspect is the operation of such stoves from a sitting position. On its top, several holes are made for the placement of pots, and side holes are needed for firing, air-conditioning and collecting ash. This work integrates elder family members, who operate the firing of the stove.

Maintaining such traditions is related to social conditions and constitutes an ecological way of living. Different changes may endanger the necessary social preconditions. At the end of the 19th century, Moravian missionaries introduced the metal stove to Ladakh (Clarke 1995: 10). This introduction is an example of early Western material-cultural influences.

An importance to keep pottery and stove traditions alive is the preservation of local knowledge of local material resources and of properties of materials. This knowledge is the main source for further use of the appropriate material for contemporary construction in a sustainable context. With today's open market, it is easy to introduce artificial and not sustainable building materials, for example for waterproofing flat roofs. Having the proper knowledge of local clay and related traditions of processing is essential for an ecological and sustainable approach. It emphasises the need to understand the specific properties of materials used for local crafts.

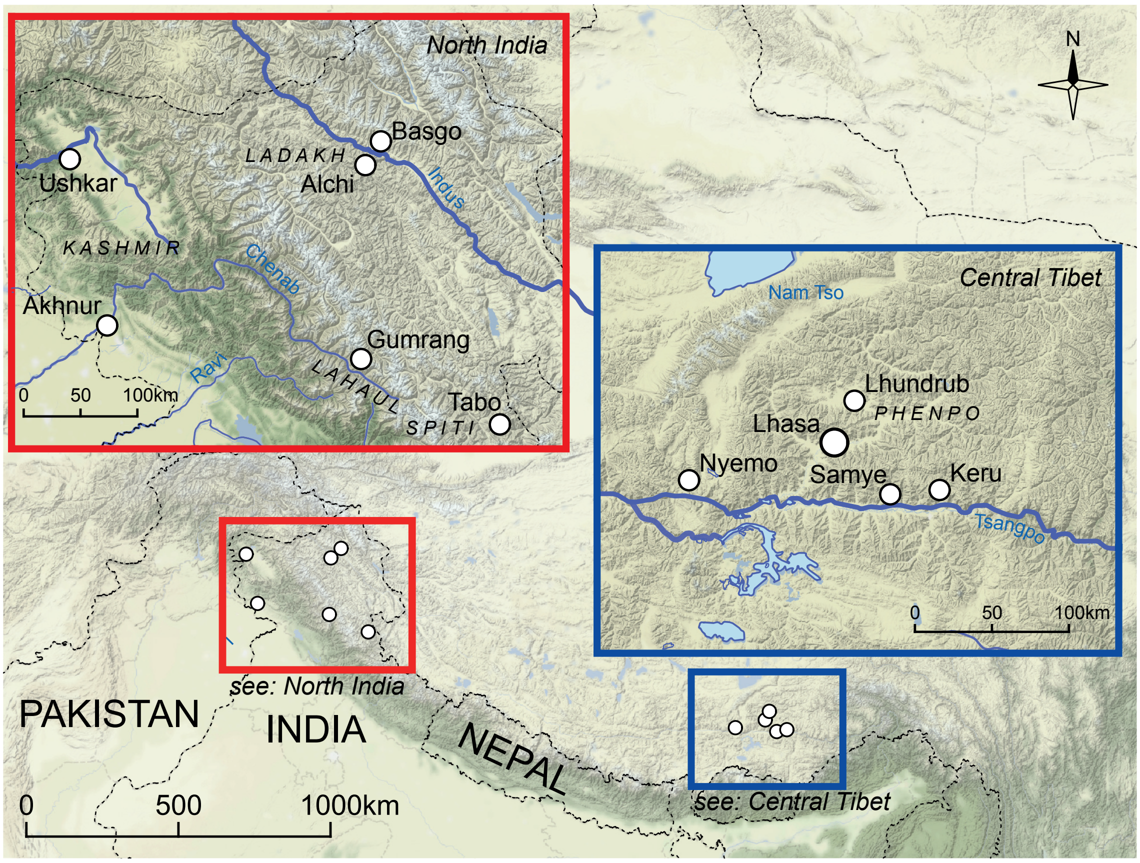
4. Earth building material and Buddhist clay sculptures

4.1 Regional and historical setting

Methods of making clay sculptures in Central Tibet follow a long tradition reaching back to at least the construction of the Samye Monastery in the 8th century CE. Using clay for sculptures shows a highly developed understanding of raw material and its processing, an aspect, which encourages the study of clay as a building material and to gain insight into different processing methods. The craft of the clay sculptor requires a particular high understanding of both the needed material and the great skills essential for its handling.

Clay sculptures from Akhnur (6th century CE) and Ushkar (8th century CE) as dated by Varma[73] (1970: 179–184) belong to the earliest examples of clay sculptures in the north-west Indian region

73 In his publication on *The Indian Technique of Clay Modelling,* Varma (1970: 2–4) uses several ancient texts. Among those are the *Kaśyapaśilpa* from the 11th/12th century, the *Vīmānārcanākalpa* from the 8th century, the *Kaśyapajñānakāṇḍa* from a period earlier than the 16th century and the *Samūrtārcanādhikaraṇa* from the 16th/17th century CE.



Map 2.3 Western Himalayas and Central Tibet. Places mentioned in the text, being related to traditions of making clay sculptures. GIS data based map: Jakob Gredler. Final graphics: author. Map based on data from Vector data (VD) and Basemaps (BM). Citations of VD and BM also see: Chapter IX, list of illustrations.

(Map 2.3). Along the northern Central Asian silk route, clay sculptures are predominant, while for the southern route, stucco – a mixture of gypsum dust, sand and calcite – was primarily used for the heads of sculptures, and clay was preferably used for the bodies (Yaldiz 1987: 143, 212). Yaldiz also argues for the use of clay due to a lack of durable materials in this arid loess-dominated zone. Varma (1970: 116) describes a separate firing of the heads in a kiln and their attachment with a wooden peg to the relievo. In contrast, most of the mural decoration was modelled and fired in situ, mentioning that the quality of firing decreased towards the wall (ibid.).

In Central Tibet, sculptures in the Keru (Tib. Ke ru, former Kwa chu) Lhakang located east of Samye date back to the imperial period, and clay has been used as material for sculptures since early times (Chayet 1994: 203, 204) (Map 2.3). Contrary to the method described for the Western Himalayas – where a compact mass is modelled around a supporting construction – Chayet describes the sculptures as being made of a thin layer of clay around a wooden armature (see description below). Luczanits (2004: 18) mentions the statues of the Keru Lhakhang being partially hollow between clay and armature. This description refers to a method contrary to the one used in the Western Himalayas, in Kashmir or in Fondukistan. This method is still practiced today in a Lhasa workshop and possibly points towards a more than thousand years old Central Tibetan tradition. The description of sculpture construction at Tsaparang – with straw first wrapped around a wooden subconstruction, which is covered with a textile before finally overlaying with clay (Chayet 1994: 204) – shows the application of a similar technique.

The tradition of making clay sculptures was continued in the Western Himalayas beginning in the late 10th century (Heller 1999: 61), and the highly sophisticated Western Himalayan technique ends with the sculptures of the late Alchi temple group (c. 1220 CE) (Luczanits 2004: 17). Compared to the amount of clay sculptures, the production of stone sculptures in Central Tibet was of a subordinate relevance, contrary to metal sculptures made of beaten brass.

Following a stagnation in carrying on the craft of clay sculpturing in Lhasa in the 1950s, various techniques have again been being practised since at least the 1990s. For the arid Himalayan zone, clay is a well-suited material. On the other hand, for the living clay sculpture tradition in areas with a humid climate, in particular in Bengal, the durability of the sculpture is subordinated to aspects like the ritual process of making or finally having the clay sculpture dissolved in a river. Regarding this concern, in Bengal the process of dissolution of the sculpture is to be seen as a favoured aspect, and sculptures are often immersed into water at the end of ritual ceremonies. In the Tibetan cultural zone, in contrast, clay sculptures aim for long durability.

As a support for this research, Könchog Tsering (Dkon mchog tshe ring)[74] gave permission to the author to study his methods of making unfired clay sculptures (Tib. *’jim sku*) at his workshop in Lhasa. In this contribution, recent techniques of clay sculpturing conducted as performed in his workshop are documented and juxtaposed to historical activities in Central Tibet and adjoining regions in the west.

4.2 Different techniques in clay modelling

First, we distinguish between sculptures made with a mould and those without, both methods following a predefined iconography. The use of a mould is mentioned for clay sculptures along the northern Central Asian silk route. Due to close regional similarities in the design of heads, the hypothesis is proposed that the production of clay sculptures for most monasteries in this area occurred in just a few workshops (Yaldiz 1987: 143). The use of moulds enables a quicker production of a given series of sculptures, and the following of a predefined design facilitates the work process; however, regional characteristics may appear in an attenuated form.

For such historical sculptures, of which no description about their production is available, it is difficult to be certain whether moulds were used. Similarities in the shapes of certain parts of the body between different sculptures may give evidence of the use of a mould. For this reason, for

74 The author is very grateful to Könchog Tsering for his hospitable support. At the time of the interview on the 4th of December, 2015, he was 48 years old. As a young man he worked as a house and furniture painter and started following his passion for clay modelling about 30 years ago. He went to a Tibetan master, where he learned and worked without payment for about ten years. At that time no school for clay modelling existed in Lhasa. Governmental support of this trade is today given by the acceptance of the production of sculptures for a monastery, which is today treated as a form of setting of taxes. According to Könchog Tsering, a new activity in traditional Buddhist crafts started in Tibet in the late 1990s.

Fig. 2.12 Mould used for a part of the clay sculpture.

Fig. 2.13 After moulding the front and back side of the sculpture, the two halves are combined as shown. Along the right shoulder of the sculpture, the joint can still be seen.

Fig. 2.14 The master himself moulds the face with wooden sticks.

Fig. 2.15 Back side of a Tara sculpture head. In a separate working step, the crown is attached to the head. A hole on top of the head is left for a later filling of the sculpture with sacred goods.

Tabo clay sculptures, the proposed hypothesis asserts the use of a mould for faces and main features of the body, including hair (Luczanits 2004: 270). In Fondukistan and in the Kashmir area, there is no evidence of the use of a mould for the preparation of the head (Varma 1970: 155), and in the entire Indo-Afghan regions no mould has been found (ibid. 156).

For several sculptures in the Lhasa workshop with a height of up to app. 80 cm, the torso was made with a mould, while all the other parts were modelled by hand, with small decorative details of moist clay applied onto the prepared sculpture. The moulds are prepared from gypsum into two parts (Fig. 2.12), a front and a back part, not including the head. Varma (1970: 206) describes the preparation of a mould either in stucco or in unfired clay itself, and the sprinkling of ash onto the inside surface of the mask for easier detachment from the cast.[75]

The master models the head by hand without a mould, while the torso is prepared with a mould by his apprentice. The two sides are prepared separately, first the front followed by the back side. After stripping the front side from the mould, it is put onto the back side, which still remains in the mould, and the two parts are pressed together. The remaining joints are closed carefully after stripping the model from the mould as a whole, and the joints remain invisible after final treatment (Fig. 2.13). In general, the openings left at the bottom or at the top of sculptures are necessary such that the sculpture can be filled with sacred goods in a later step. Under a plastic sheet the torso is kept slightly humid so that the head does not have to be attached immediately. The result of this method resembles casted metal sculptures, which are hollow and free standing with a shell of a rather constant thickness.

The head is modelled in two stages. First, the face is treated with extreme care (Fig. 2.14), and thereafter the head is attached to the torso.[76] As a last step the back side of the head is modelled. A second method is free-hand modelling of the whole sculpture (not only of the head – which is applied for bigger sculptures – and masks – which are made without a mould). The use of a model is certainly a facilitation of Könchog Tsering's work, in particular for the production of a series of similar sculptures, but has nothing to do with the inability to create a sculpture (as is also emphasised by Varma 1970: 205, 206). Varma (ibid.) mentions that it is the choice of the sculptor to use a mould or to model by hand. In the Lhasa workshop, only additional elements like horns or crowns are attached as a final step (Fig. 2.15). Particularly, this has been described for a crown made for clay sculptures in Tabo, which was loosely affixed to the head (Luczanits 2004: 271).

Another differentiation influencing the method of production is if the clay sculpture is free standing without any further support – as in the case of Buddhist sculptures, which are often placed on a lotus base – or if the sculpture needs a wooden subconstruction due to its predefined iconographic design. This differentiation is basic for a method of clay modelling and done using a wooden subconstruction. The clay sculpture of a Yamāntaka as a standing figure with a height of app. 1.6 m is an example exhibited in the Lhasa workshop. Also early West Tibetan examples such as the ones from the main temple in Tabo belong to this category (Fig. 2.16).

75 For this kind of clay modelling, the term "cast" is not precise, since the clay is pressed into the mould in a viscous consistency and not cast with fluid consistency.

76 Casts are set in place by pressure after applying a still slightly moistened slurry to the splice (Varma 1970: 159).

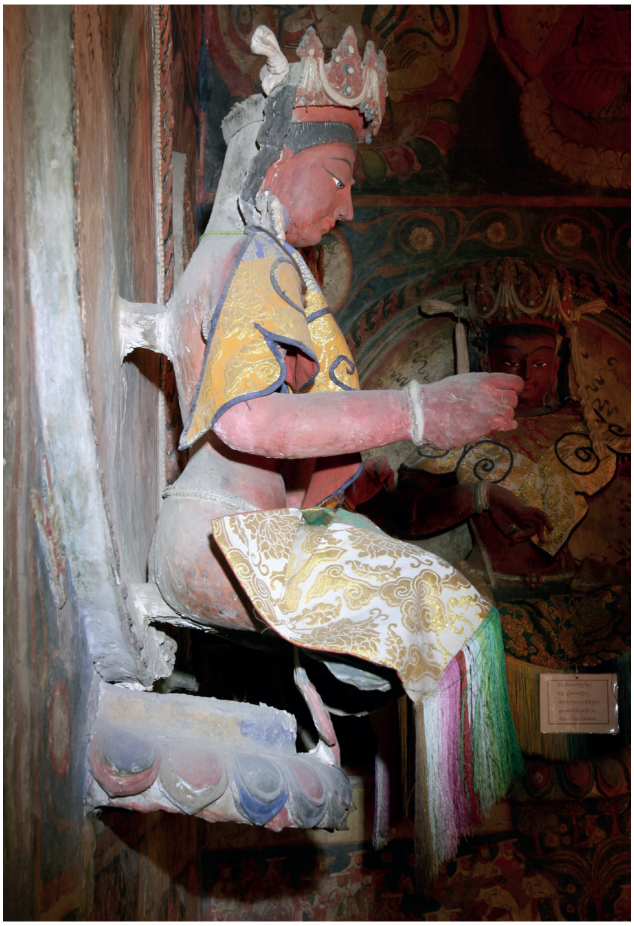


Fig. 2.16 The vertical *vaṃśadaṇḍa* (inside the sculpture) is connected with the two horizontal *upaśūla*s, which are fixed in the wall.

Each of these clay sculptures has one vertical wooden brace, the *sogshing* (Tib. *srog shing*, Skt. *vaṃśadaṇḍa*), which refers to a tree of life as described by Könchog Tsering. This connotation is critically rejected by Varma (1970: 42). He argues that the *vaṃśadaṇḍa* (Skt.) is indeed also known as *Brahmadaṇḍa* but refers to *Brahman* as anything basic and not to a *Supreme God* or a *Universal Soul*.

Some sculptures additionally have a so-called *"rüshing"* (Tib. *rus shing*) as a wooden brace, possibly along the neck and elongating laterally with another vertical wooden brace on each side. *Rüshing* in its meaning as "tree of bones" refers to a kind of skeleton made of wooden sticks used to brace the statue. It is organised around the central vertical *sogshing*, and different *daṇḍa*s and *śūla*s (Skt.) represent different kinds of bones.[77]

77 Besides the use of a wooden support for bigger sculptures, the use of a core prepared of stone is known in the area of the Central Asian silk route (Yaldiz 1987: 143). Also the use of iron rods is known for Nepalese clay sculptures in the 12th/13th century (Luczanits 2004: 12, 305, fn. 36). Another technique is the use of straw added to a core of wood, for instance in Bengal. According to Varma (1970: 42, 43), *śūla*s – also called *"daṇḍa*s*"* – define parts of the armature. In addition to the *vaṃśadaṇḍa* as the vertebral column, several other *daṇḍa*s are known, including *vakṣodaṇḍa*, the stick across the chest, the *kaṭidaṇḍa*, the stick across the hips, or the *upaśūla* as a supporting part describing essential elements of the wooden armature.

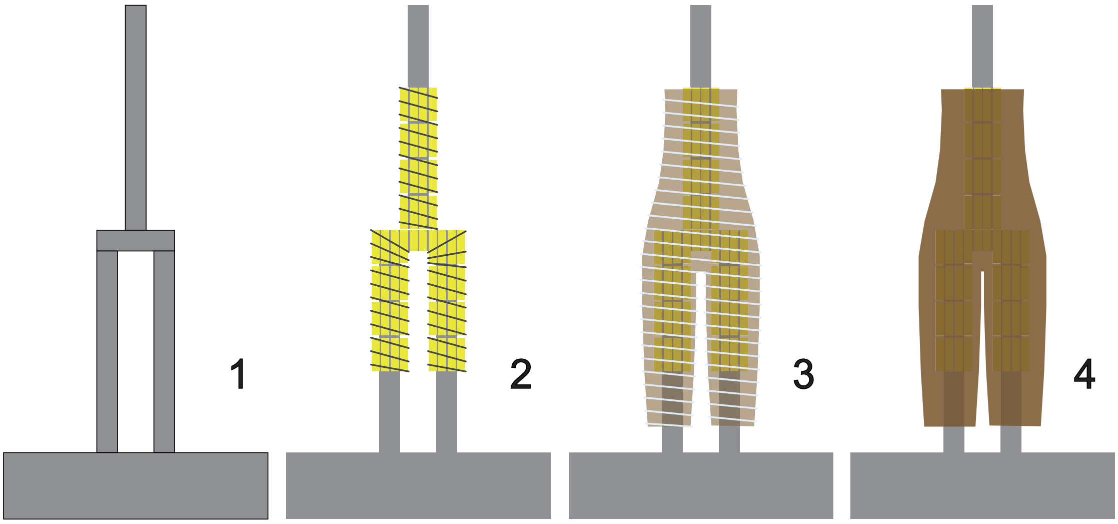


Fig. 2.17 Method of making the torso and head of a life-sized clay sculpture: 1 = Wooden subconstruction; 2 = Fixing rolls with mantras by wrapping textiles around the subconstruction; 3 = Twigs of *penma* are fixed with a rope onto the layer of mantra rolls; 4 = The *penma* is covered with clay.

Different materials were applied to clay sculptures, such as strips of hide and vegetable fibre cords for joining parts of the armature, as known from Western Himalayan sculptures. Vegetable fibre cords were furthermore wrapped around wooden parts as support for the clay (Luczanits 2004: 266, 267). In the ancient texts, ropes applied in two layers play an essential role in a functional and symbolic context. In the preparation of Bengal clay sculptures, ropes are replaced by a layer of straw and, particularly in the Lhasa workshop, vegetable fibres of the *somaradza* (Tib. *so ma ra dza*) are used. The length of this grass extends up to app. 4 m to 5 m. The preparation of a rope of grass (Tib. *dras thag*)[78] is similar to what could be found in Basgo in Ladakh.[79] This specific grass from Ladakh is locally known as *busho* (Lad.; see Chapter III). There it is twisted into a rope, which is also used to be wrapped around the pillars in the Maitreya Lhakhang in Basgo as a base for the application of plaster. This architectural use is close to the method described for clay sculptures. In Central Tibet in earlier days, the so-called *"tsadrema"* (Tib. *rtsa bre ma*) was brought from the mountains to be used in the construction of clay sculptures.

In the Lhasa workshop, a particular technique of using grass is known for larger statues (Fig. 2.17): Rolls with mantras (Tib. *gzungs*, Skt. *dhāraṇī*) are wrapped around the central pillar, the *sogshing*, together with yellow textiles, whereon they are pressed with *penma* (Tib. *spen ma*)

78 In earlier days a *dratag* (Tib. *dras thags*) was also made of animal hair.

79 In South Indian texts treated by Varma (1970: 13), the use of coconut fibres is mentioned, and a possible symbolic meaning of the ropes used is described with *nāḍī* (Skt.), arteries or veins. The three most important ropes are *suṣumnā*, *iḍā* and *piṅgalā* (ibid. 80). They are applied tight together at the point of the navel and run vertically in parallel to the armature before being tied horizontally (ibid.). There, after clay is applied onto the ropes and a second layer of ropes is fastened to the armature and again covered with clay, a following step includes repeating this process a third time (ibid. 86).

twigs[80] by fixing them with a rope of *somaradza* grass. In-between and upon this layer made of rope, clay is applied. This method, i.e. a wooden skeleton on which ropes and clay are added, resembles the traditional method as described for Western Himalayan and Kashmir sculptures. For this method, sacred texts are additionally mounted in the sculpture's centre. The wooden subconstruction is wrapped with long ribbons often made of paper and being printed with sacred texts. Hollow free-standing clay sculptures without any support (as mentioned above) or sculptures that are cast or wrought of metal, are filled with sacred scriptures and precious goods.

In Central Tibet we find another method for the preparation of clay sculptures. In this case a modelled block of clay is used as a stay-in-place formwork model, around which the actual sculpture is designed. This method is appropriate for bigger constructions, the weight of which would become too heavy to carry. Such sculptures are relatively light-weight and, according to Könchog Tsering, these kinds of sculptures were prepared for the Jokhang in Lhasa in earlier days. For this kind of construction, a scarf was twisted about seven times around the central model of clay. This base construction is covered with a mixture of glue (Skt. *aṣṭabandha*, "binding medium") produced from yak skin (*pin yak kowa*; Tib. *spin g.yag ko ba*) and wheat flower. After drying for approximately one week, hardness is tested by knocking on the sculpture with one's fingers. A particular bright sound signals having reached the required hardness. Thereafter, the newly produced subconstruction for the sculpture is knocked until the clay model inside breaks and drops out.[81] A light construction remains, on which the actual sculpture is again modelled without the use of clay. The substances used are a mixture of *shukpa* powder and *wanglag* (Tib. *dbang lag*, "particular herbs"), which are together with water put into a pot for ten minutes. The resulting mixture is a kind of a glue that is the base material for modelling the statue. Due to the use of herbs, such statues are also called *"mendam"* (Tib. *sman 'dam*, "clay of herbs"), and the final result is a sculpture made of glue and herbs. At first glance, this technique has from the point of processing – apart from its central clay block, which is in a first step used as formwork – nothing in common with a clay sculpture as described before. Upon further observation, this method, as it is described in the Lhasa workshop, seems to follow a long lasting tradition of preparing a clay sculpture, possibly dating back to early Central Tibetan imperial temple foundations. For the construction of the main statue in Samye in the Washe (see *Sba bzhed* 43–45 as mentioned in Chayet 1994: 204), this method is described. For this technique, grass or straw is covered with a textile of cotton, which is then held in place by fluid clay and covered with seven layers of yellow[82] clay. Upon finishing the sculpture, the surface appears shiny and stone-like, which implies that the method of surface treatment potentially involves the use of a particular burnishing method.

80 The use of twigs is also reported for a Western Himalayan sculpture from Gumrang in Lahaul. In this case, the twigs are fastened around the central shaft (Luczanits 2004: 266).

81 A description given by Chayet (1994: 203) for a recent production of a clay mask is similar. The core of clay is used as a kind of mould, on which a layer of a mixture of glue and flour is applied and upon which a textile is modelled. This layer is repeated several times and after drying, the mask is detached from the core with a spatula and prepared with yak skin glue and chalk powder before being painted and lacquered.

82 The described golden colour may actually refer to a yellow colour, possibly related to the content of particular ferric oxides but perhaps also referring to any additives.

4.3 Quality of the clay

Regarding the base material in the Lhasa workshop, the clay originates from the village of Dreb[83] (Tib. Sgreb grong tsho), a village in Phenpo, and for the purpose of clay modelling it is said to be the best material available.[84] Its quality differs from that of a *thigsa* (Tib. *thigs sa*), which is used for roofs, in that the former is smoother. Similar, it is used for pottery[85] but it is still finer than commonly used pottery clay, and it does not show any content of sand.[86] Also in Lhundrub (Tib. Lhun grub) in Phenpo, the same type of clay is used and brought to Lhokha. The uppermost layer was not applied as an additional fine slurry or mixed with fine fibres as described for Western Tibetan sculptures (Luczanits 2004: 268). In the Lhasa workshop, the clay was applied as a single and rather fine layer, which is contrary to the description given for Tabo sculptures, wherein at least two layers of extremely fine clay are mentioned (ibid. 270). According to archaeological evidence, Varma (1970: 150) mentions difficulty in comprehending the number of clay layers that are used, and following his examination of heads from Tarimia, he hypothesises that the core was made of one piece, while the body was made in several layers. A clay mineralogical method of examination as described in Chapter III gives evidence about the quality of the materials and layers used. In the Lhasa workshop, various methods are practiced to avoid cracks, particularly for pieces up to about two metres in size. For larger pieces, reinforcement may be neglected. In this case cracks are filled in a semi-dry or dry state with fresh material. The following mixtures are used in the Lhasa workshop:

· *pödam* (Tib. *spos 'dam*)	Clay mixed with *shukpa*-powder.
· *shagdam* (Tib. *shag 'dam*)	Clay mixed with fine pieces of Tibetan paper.
· *tsadam* (Tib. *rtsa 'dam*)	Clay mixed with long fibres of *somaradza*.

The ingredients are mixed with the clay as a kind of sheeting. This mixture has to be beaten intensely for a long period. For the sculptures of Tabo, Nako and the Alchi Sumtseg, a content of thin vegetable fibres is reported, while for the sculptures of Gumrang and the Alchi Mañjuśrī Lhakhang, the content of hair is described (Luczanits 2004: 268). For the northern silk route in Central Asia, the use of a mixture of clay with chopped straw (Ger. *Häcksel*) and animal fibres is mentioned (Yaldiz 1987: 143), similar to the use of chopped straw for Tabo sculptures (Luczanits 2004: 268).

83 The village of Dreb has not yet been clearly localised and will be part of future research.

84 According to the ancient texts treated by Varma (1970: 19), three different kinds can be distinguished, i.e. an arid clay (Skt. *jāṅgalā*), which is strong and too hard to dig, a damp clay (Skt. *anūpa*), which is easy to dig and contains black sand, and a mixture of both (Skt. *miśrā*) showing both qualities and containing a small amount of sand or stickiness. Following ancient texts, the three types of clay should be prepared each in twelve steps, which sounds rather ambitious and questionable from a practical point of view.

85 In general, pottery clay seems rather close to the quality of clay needed for clay modelling. For the extremities of sculptures made in Bengal, the clay is described as sticky, without sand or small stones, and ready to model the whole piece in one step (Varma 1970: 211).

86 For sculptures from Tabo, the use of purified clay and the addition of sand are mentioned, and for sculptures from Tabo and Gumrang, also the addition of chopped straw is described (Luczanits 2004: 268). Contrarily, the clay used in the workshop of Lhasa was described without the addition of sand, straw or further purification. This may simply have to do with different local raw material resources but does not enable any qualitative comparison.

At the Lhasa workshop straw was not added; instead just the described *pödam*, *shagdam* or *tsadam.* In this workshop, within one sculpture the use of several of these ingredients can be applied for different parts. For the Tara sculpture[87] with a height of app. 1.4 m – which was at the time of the author's visit standing in the workshop and whose production took about two weeks – the torso was made with *tsadam*, delicate parts like the face were made with *shagdam,* and delicate decorative parts such as the extension of hair over the shoulders were created with *pödam.* A long history of incense powder made of *shukpa* is said to exist at Nyemo.[88]

4.4 Surface of the sculpture

At the Lhasa workshop, in a semi-dry state the surface is pressed and smoothed with a wooden stick (see Fig. 2.15). A preferred stick is made of *depam* (Tib. *sde pam*), a hard wood. Remaining cracks and unevenness are smoothed but not burnished. After smoothing, a sublayer for the following layer of paint – particularly when adding gold colours – is applied with a brush. This fine layer is a mixture of a specific clay called *"serdam ngenpa"* (Tib. *gser ldam ngan pa*) with yak skin glue. *Serdam ngenpa* relates to the mode of painting and also the name of a colour. For the glue used, today we can distinguish between a modern artificial and the traditional version made of yak skin. For Western Himalayan sculptures, in particular from Tabo and Gumrang, the application of a white priming coat was common (Luczanits 2004: 275). For Gumrang, the use of a considerably thick limestone paste is described (ibid.). This paste is also mentioned as *śarkarā* or *śarkarākalka*[89] (Skt.) in early texts treated by Varma, and translated as limestone paste of which it is not clear if the limestone was burnt (Varma 1970: 24, 28, 29). Varma hypothesises that unburnt limestone was used, and he gives a translation of *śarkarākalka* as "a finer variety of clay" (ibid. 29), which would also correlate with its use in the Lhasa workshop.

According to Varma (1970: 153), two different methods in applying the final layers for coating are explained either as one single layer on the core with the second layer used for burnishing; or as two applied layers with one layer as the base for the application of a slurry (also known as "slip" or "thin clay wash"; ibid: 164). For the Bengal sculptures, after modelling the head, just a thin layer of silt from the Ganges is added (ibid. 210). According to the method, which was shown in the Lhasa workshop, no additional final layer for burnishing was applied. The core material already had the fineness needed for the uppermost layer. This method correlates with a method used for traditional Tibetan wall plasters. Examinations of Tibetan wall plasters at Nyarma show that the upper plaster layer after desludging the base material is capable of being burnished (Feiglstorfer 2019: 103ff.). In the case of the Lhasa workshop, the upper surface remained unburnished. The conducted smoothing left a homogenous and levelled but not shiny surface.

87 To carry the Tara sculpture, at least two strong men are needed, for the Yamāntaka sculpture, at least three.

88 A traditional method of producing the powder is with a water wheel. By activating the rotation of a wooden stick, a continuous beating on the piece of *shukpa* takes place. Due to the rubbing of the *shukpa* along the hard ground, the wood is powdered.

89 For the application of *śarkarākalka* (Skt.)*,* two layers having thickness of two to three *yava*s are used. With the second, holes or cracks should be avoided. After one to two months, another three layers should be applied until the prescribed measurements are obtained (Varma 1970: 88). These layers are the last possibilities for adjustments to any measures or proportions to be made.

4.5 Discussion

The study of Sanskrit literature conducted by Varma (1970) gives rather detailed information on Indian clay sculptures. His comparative analysis by including ancient Indian texts of early examples of clay sculptures from Indo-Afghan regions, and Jammu and Kashmir, shows similarities with traditions in processing the clay and in making clay sculptures over the Tibetan cultural zone in a number of aspects. A comparison with Western Himalayan, Bengal and Central Tibetan methods of making clay sculptures provides insight into historical working processes. The connotation of the single parts of the clay sculpture with parts of the human body as described in Indian literature stands in a specific religious context. Comparison with present-day methods of making clay sculptures in Lhasa provides evidence of still remaining traditional knowledge. Since techniques used for modelling are related to a deep understanding of properties of the base material, clay sculpturing can be considered a highly developed skill. Various aspects seem to be of relevance also for studying traditions in Himalayan earth architecture.

Early findings of clay sculptures from the 6th century in the Kashmir / Fondukistan region, from the 8th century in Central Tibet, and the 10th and following centuries in the Western Himalayas show the long tradition of this craft. In Central Tibet, a tradition of clay sculpture modelling remains today and reflects historical methods through the use of moulds or modelling in thick layers by hand or preparation of thin-skinned hollow sculptures. A continuous transfer of knowledge from generation to generation and master to scholar shows a continuity of traditions such as particular modelling methods. This continuity in the transfer of related traditions is seen in the still existent knowledge in a Lhasa workshop being related to knowledge gained from the renovation of historical clay sculptures in the Jokhang in Lhasa.

The single methods can be ascribed as prevalent to particular regions between Fondukistan in the west and Central Tibet in the east. Using a mould or modelling in thick layers is found as a commonly used method in several regions (Western Himalayas, Kashmir, Bengal or Central Tibet), while the technique of processing thin layers around an armature and making hollow shells seems to be concentrated in Central Tibet. On the other hand, we can distinguish between different local technical variations based on varying local raw material conditions, such as the use of different kinds of materials for making the subconstruction, the firing of sculptures, or the use of different fibres to prepare stabilising ropes.

For vernacular architecture, an important fact seems to be that there is not just one solution for solving a technical problem, but rather there are local solutions dependent on local resources. Such problems concern a) the prevention and repair of cracks, b) the preparation of a proper adhesion of clay on wood, c) the collection and preparation of clay in general, or d) the treatment of surfaces.

a) Prevention of cracks: At the Lhasa workshop, three clay mixtures are described by using *shukpa*-powder, paper, and fibres. In a historical context, the use of straw or animal and vegetable fibres is also stated. In order to repair cracks in the Lhasa workshop, hair cracks are closed with a fine slurry of clay and compressed with a wooden stick.

b) Preparation of a proper subconstruction on wood: Using a wooden brace with ropes (or as seen in Bengal, the use of straw as an alternative to ropes) as a subconstruction for clay modelling is similar to the architectural problem of application of clay on wood. For example, this issue is known from wattle and daub or half-timbered constructions, where technical problems are experienced regarding how to fix clay on wood, and how to avoid cracks due to the different tensile moduli of the combined materials. An answer to this technical problem is the introduction of elastic fibres to improve the adhesion of clay on wood. A related example (which was found in Basgo in Ladakh) involves the use of ropes twisted around pillars to guarantee plaster without cracks (see below for technical analysis). This application shows close similarities to the technique used for sculptures with ropes twisted around the armature. Also the use of two layers of clay, each fixed on a rope, is a method known from clay sculptures that is used to reduce the possibility of cracks and to increase the technically possible thickness of the layer of clay.

c) Collection and preparation of clay in general: Places for collecting the proper clay are traditionally known over a wide region. The very fine material quality at the Lhasa workshop is similar to the material used for pottery. Historical evidence for clay sculptures indicates the mixing of clay with sand. After mixing the clay with additives as given under (a), it has to be compressed by beating to maximise a consistent mixture. In the Lhasa workshop, for the preparation of hollow light-weight clay sculptures (similar to Tibetan clay masks), a mixture of clay, *shukpa* powder, herbs and water is modelled around a solid core of clay. According to a historical mentioning for Samye in Central Tibet, a block of grass or straw is covered with a textile of cotton, followed by a layer of fluid clay, which is covered by further layers of clay. Both techniques show similarities, and future examination should demonstrate their suitability for architectural purpose.

d) Treatment of surfaces: Surfaces are in general reworked in a semi-dry state. At the Lhasa workshop, burnishing was not conducted but the last upper layer of clay was compressed with a wooden stick before covering it with a mixture of clay and yak skin glue (for glue in Indian texts, a limestone paste is described). For Indian sculptures, the application of a clay slurry and its burnishing are mentioned. The method of burnishing in general is conducted with rounded stones on interior wall plasters, particularly at religious Tibetan structures. For the plaster used at Nyarma, laboratory tests showed that the mixture used for the ground plaster was refined most probably by desludging to guarantee a burnishable upper surface (Feiglstorfer 2019: 103ff.). More so, a small content of fine sand on the upper layer of plaster increases the ability of being burnished (ibid.). Also this method seems to depend on the quality of the available raw material. Today in Bhutan, for example, the application of a fine slurry on the upper layer of plaster is used as a layer for burnishing (Interview Meingast 2015).

Several of the techniques, which teach us about the historical use of clay for sculptures, can be compared with recent application, a tradition being based on the fine balancing of raw material and applied techniques. In need of further examinations are possibilities for present-day use of such techniques in the creation of earth constructions and conservation.

III. EARTH BUILDING TRADITIONS IN BASGO AND LIKIR / LADAKH

1. Introduction

Within the field of material culture, the determination of material properties by examination of an object's single components is an essential aspect for proving the quality of the raw material, verifying places of origin, and understanding methods of processing. In the Himalayas, clay is still an important building material. The material characteristics of different types of clay and processing techniques follow traditional and locally defined patterns. Local knowledge on particular properties of clay, based on local experience, overlaps with regional knowledge with particular local adaptations. Today, general knowledge on locally available types of clay and processing practises is decreasing, and it is primarily various elders, who keep such information.

In researching this topic for the last 20 years, the author has collected and documented samples of clay from various sites in the Himalayas. These samples are the carriers of information on particular material qualities related to the use of specific material for different constructive purposes. The samples are either raw material collected from locally known pits known for their uses for specific building purpose or originate from damaged parts of certain building components. According to their material properties, they were analysed and compared. For comparison, material-specific properties, such as colour, grain size distribution, grain shape, hardness, organic additives and mineral properties were analysed and juxtaposed. Individual properties are examined in relation to their constructive uses. In the present study, locally used materials for adobe bricks, flat earth roof constructions, rammed earth floors, clay plaster, pottery and also the *thab* (Tibetan stove) are analysed. Some of the samples, in particular those of plasters and bricks, are related to historical sites; others are related to recent constructions and crafts. Traceable material properties were analysed based on analytic parameters – constructively and material-orientated. For the single techniques of construction, the results of the laboratory tests are juxtaposed, and analysed and additional examinations of selected samples were conducted. The analysis follows a categorisation specifically given by the single techniques, the place of material origin, and the local names of the raw material.

1.1 Research questions

Regarding the wide field of this study, the following research questions are posed with a primary focus on material research:

- What are the particular properties used to categorise specific commonly used earth building materials? What are the material properties, which support a particular building material's use for the building purposes mentioned?
- If there are any regional relations in the knowledge transfer about a particular material, in what way can they be related to specific locally conventional terms?
- In what way are building techniques and crafts related to each other and how can the knowledge gained be useful for future applications?

1.2 Origin of the samples

Samples originate from clay pits or particular parts of buildings, such as the roof, interior and exterior plaster, adobe bricks or rammed earth walls. Many of the clay pits are difficult to find without local help, as they are often integrated into the surrounding natural environment such as agriculturally utilized fields. The choice of particular samples is to a certain extent dependent on factors such as proper information from the local population, accessibility of the pit or object, and, if needed, particular local permission. Samples of loose earthen debris lying on the ground at various spots along building structures were collected without digging or applying any invasive impact on the structures.

As far as the collected type of samples has a particular local designation, all names were documented, same as the recording of the particular use and processing of each material. The sampling points were documented on a map and by photographs. The collected samples give a unique outline of clay as material used for building and crafts. The aim of such a variety is to keep a wide range of comparable samples with high diversity.

For the next chapter on building traditions in Basgo and Likir in Ladakh, samples were collected in these two villages, which are located about 10 km from each other along the Leh-Kargil Highway NH 1D (Map 3.1) at an altitude of app. 3,200 m and above. Over the course of field research, Basgo, Likir and the surrounding settlements stood out due to their wide range of different locally available and still used types of clay and living clay traditions. For several of the locally known types of clay, local names were available, which could be linked to a particular use or meaning within the field of building techniques.

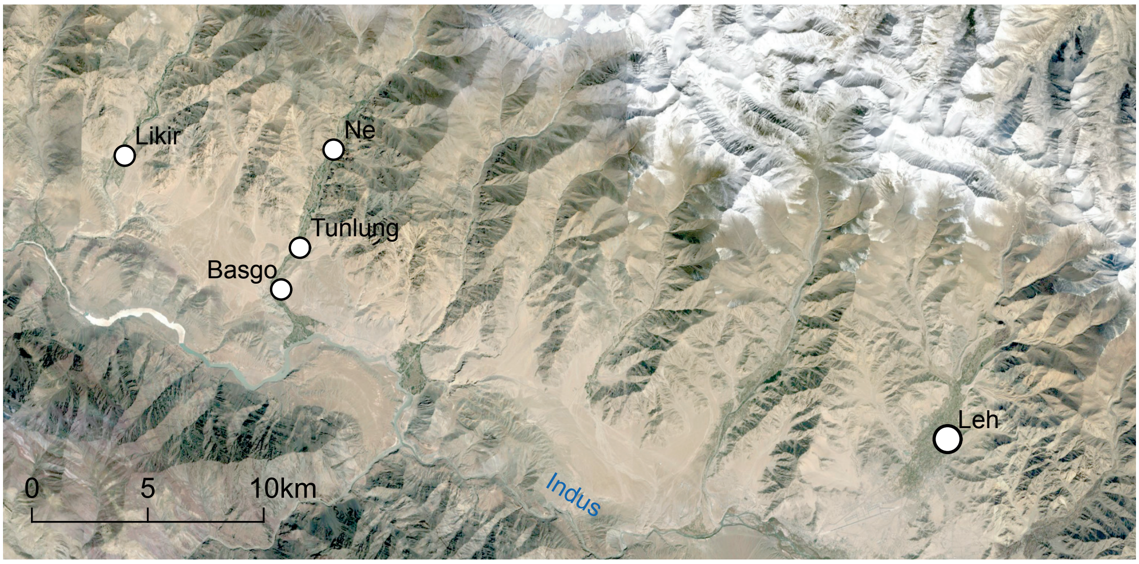
In Basgo, several temples of different ages were built on top and along the foot of the temple-hill and also in the close vicinity to Basgo. For building purposes, the local tradition differentiates between clay used for roof constructions, interior and exterior plaster, and the plaster applied to pillars and bricks. Particular mixtures are known for particular building purposes, and the related raw material was collected for examination. For construction of a Tibetan clay stove (Tib. *thab sa*, which is a proper clay for building a clay stove), local knowledge still exists, and related samples of different kinds of clay were collected. Likir is well known as a village with a pottery tradition, and is further known as a source for not only pottery clay, but for good quality clay for building purposes. This functional interrelation between the properties of clay for different kinds of uses within one village, and even more so between these two villages, is the aim of this observation.

Several of the samples were collected at building structures at Basgo, as shown in Map 3.2. According to Table 1, the samples of the following structures will be examined:

Basgo: Maitreya Lhakhang, Lotsāba Lhakhang, Lhakhang 'close to the road' (Leh-Kargil Highway NH 1D), building raw material, clay stove (Tib. *thab*).

Basgo / Likir: Stove and pottery clay. Likir: Adobe brick, clay pit and sand.

Map 3.1 Basgo and Likir. Origin of the samples. GIS data based map: Jakob Gredler. Final graphics: author. Map based on: Google Earth. Image © 2016 TerraMetrics.



Map 3.2 Building structures at Basgo related to the examined samples. GIS data based map: Jakob Gredler. Final graphics: author. Map based on: Google Earth. Image © 2016 TerraMetrics.

Table 3.1 List of the samples.

Sample	**Country**	**Province/prefecture**	**Settlement**	**Origin**	**Local name**
			Basgo – Maitreya Lhakhang		
8469	India	Ladakh	Basgo	plaster on pillar	---
8479	India	Ladakh	Basgo	plaster on pillar	---
8496	India	Ladakh	Basgo	int. wall plaster	---
			Basgo – Lotsāba Lhakhang		
8482	India	Ladakh	Basgo	int. wall plaster	---
8483	India	Ladakh	Basgo	int. wall plaster	---
11946	India	Ladakh	Basgo	int. wall plaster	---
11948	India	Ladakh	Basgo	adobe brick	---
			Basgo – Lhakhang close to road (Highway NH1D)		
8475	India	Ladakh	Basgo	int. wall plaster	---
11928	India	Ladakh	Basgo	int. wall plaster	---
8499	India	Ladakh	Basgo	ext. wall plaster	---
8472	India	Ladakh	Basgo	adobe brick	---
11933	India	Ladakh	Basgo	adobe brick	---
			Basgo – building raw material		
15410	India	Ladakh	Basgo	clay pit	*dzasa,* red clay
11915	India	Ladakh	Basgo	clay pit	*thetsa*
15411	India	Ladakh	Basgo	clay pit	*thetsa*
8465	India	Ladakh	Basgo	clay pit	*thetsa* + *dzasa*
11952	India	Ladakh	Basgo	adobe brick	---
			Basgo – clay stove (*thab*)		
11748	India	Ladakh	Tunlung	clay pit	*thabsa*
15412	India	Ladakh	Tunlung	clay pit	*thabsa*
11919	India	Ladakh	Ne	clay pit	*thabsa*
			Basgo / Likir – stove and pottery clay		
15515	India	Ladakh	Basgo	clay pit/cave	*thabsa*
11751	India	Ladakh	Likir	clay pit	*thabsa, dzasa*
11752	India	Ladakh	Likir	clay pit	*dzasa*
			Likir – adobe brick and clay pit		
11763	India	Ladakh	Likir	adobe bricks	---
11921	India	Ladakh	Likir	clay pit	---
			Likir – sand		
11749	India	Ladakh	Likir	sand pit	*jema* (Tib.)

1.3 Structure of this chapter

Part 1: Mineralogical analysis of the clay samples.
Part 2: Additional examinations on selected samples.
Part 3: Discussion.
Grain size classes and results of bulk and clay mineral analysis are given in Tables 3.2, 3.3 and 3.4 at the end of Part 2 of this chapter. Further tables, graphics and related documents are attached in the Appendix of Chapter III.

2. Research method

2.1 Documentation

During the expeditions the samples were numbered, catalogued and described in detail. Before examining the samples in the laboratory of the IAG / BOKU (Institute of Applied Geology / University of Natural Resources and Life Sciences in Vienna), they were numbered once more. The label of the samples in this text is related to this numbering at the laboratory, and for further identification in the text, the samples are listed in a table (Table 3.1).

The following parameters are part of the research on site:

· Locally specific names of the samples: Local names of specific types of clay were used for further identification of the particular material, since the names may indicate a certain location of where to find the clay or give information about a certain material quality. Local names were not existent for all types of clay. For further identification of each sample, the number entered in the book of samples will always enable its identification related to any further test.

· Description of where material was found: Contains the region, the place's name, the name and type of building and the location within the building. In the case of material collected at clay pits, the location of the pit is described and the locally known use of the material documented.

· General description of the material appearance of the samples, such as colour, taste and smell, haptic perception, grain size, and additives used: These parameters follow a testing with all senses, primarily conducted on site. The importance of citing such parameters lies in the practical importance for the builder, who is not primarily confronted with scientific data but with what can be immediately perceived about the material properties on site.

· General description of constructions: Local earth building traditions are documented descriptively. Their features are described, and structures as a whole and in detail will be visualised as drawings, plans and photographs. For proper analysis, the following documentation is required:
  – Architectural survey
  – Description of the natural environment
  – Description of the constructions and the materials' processing
  – Plans (ground plans, sections, elevations)
  – Drawings of the technical properties and details
  – Photographs
  – GPS position of the single objects
  – Interviews and local reports on the use and processing of building materials

· Constructions: Based on the collected material, examinations were conducted regarding the choice of the material for particular constructions and the material's particular processing. Technical parameters of the constructive typologies and their dependence on particular clay are discussed. Analysis focuses on the following points:
  – Detailed observation of the single constructions and crafts
  – Comparative constructive traditions
  – Technical properties
  – Local particularities
  – Impact of the natural environment on the use of these constructions
  – Possible relation between the use of a particular clay and the type of construction

2.2 Laboratory methods[89]

2.2.1 Grain size analysis (GSA)

Particle size analysis was carried out as a combination of wet sieving (fractions >20 μm) along with sedimentation analysis with Micromeritics Sedigraph III (fractions <20 μm). 50 g of air-dried clay was treated for dispersion and destruction of organic substances over several days with app. 200 ml of 10% hydrogen peroxide. After completion of the reaction, excess oxygen was removed by boiling in a water bath. After sonication, the sample was sieved. Residues of sieving (>2,000 μm, >630 μm, >200 μm, >63 μm and >20 μm) were dried and weighed. The fraction <20 μm is used for the sedimentation analysis in the sedigraph after sonication. Results from sieving and sedigraph are combined.

2.2.2 Grain shapes

Grain shapes are determined according to Tucker (1985:17, 18) according to the following code:

0	very angular
1	angular
2	angular with beginning rounding
3	slightly rounded
4	rounded
5	well-rounded

2.2.3 Bulk mineral analysis (BMA) by XRD

Evaluation of an average amount of certain minerals is conducted according to peak intensity in relation to the general peak intensity. The intensities in the BMA tables are given with the following categorisation. Attention is also paid to amounts that deviate from the average. This semi-quantitative evaluation is given in proportional relation of the samples to each other. Since calcite and gypsum can be added for strengthening constructive features of particular clay mixtures, their amount is given quantitatively with the following symbols: . = traces, * = small amount, ** = medium amount, and *** = high amount. To determine the bulk mineral content, the samples were dried at 70°C and ground to a flour-like consistency (≤20 μm) in a vibratory disc mill. The ground powder was prepared in a 'backload' procedure. Until 2010 X-ray analysis was conducted using a Philips X-ray diffractometer PW 1710 with a divergence slit (Cu-K α-rays (45kv, 40mA) 2° to 70° 2θ, 1 step per second, step size 0.02° 2θ). The semi-quantitative determination

89 The description of laboratory methods is based on the methods given by Karin Wriesnig (2013: 57, 58 and 60).

of mineral contents was conducted according to Schultz (1964). For samples analysed after 2010, a Panalytical XPert Pro MpD diffractometer with automatic divergent slit, Cu LFF tube 45 kV, 40 mA, and an X'Celerator detector was used. The measuring time was 25s, with a step size of 0.017° 2θ. Using a Scheibler aparatus, the content of carbonate was measured according to Ö-Norm L 1084 by destroying the carbonates with 15% HCl and determining the volume of the CO_2 in consideration of air pressure and temperature. The inorganic content of carbon was calculated by multiplying the content of carbonate by 0.12.

2.2.4 Clay mineral analysis (CMA)

The sample preparation was carried out according to Whittig (1965) and Tributh (1970). The destruction of organic substances was the same as with the GSA. The preparation of the sample was conducted in parallel to the GSA. The clay fraction was a result of centrifugating (five minutes at 1,000 rpm) from the <20 µm fraction. The complex of sorption of the clay fraction was exchanged by shaking with 4 N MgC_{l2-} or 4 N KCl solutions, respectively. An X-ray analysis was conducted using a Philips X-ray diffractometer PW 1710 until 2010, and with a Panalytical XPert Pro MpD diffractometer after 2010 (as described before). Each porous ceramic plate carries 20 mg of clay (Kinter, Diamond 1956). These texture specimens were dried over night in a dessicator above a saturated NH_4NO_3-solution before being X-rayed. Thereafter, for the determination of swellable clay minerals (smectite, vermiculite), all ceramic plates were put into an atmosphere saturated with ethylene glycol. Subsequently, for the identification of well-crystallised kaolinite, these plates, which had already been preprared with potassium, were additionally treated with dimethyl sulfoxide (DMSO). In addition to this process, the plates were tempered at 550°C for two hours to determine primary chlorite. After each treatment the samples were X-rayed (K and Mg plates from 2° to 40° 2θ, with ethylene glycol treated plates from 2° to 32° 2θ, with dimethyl sulfoxide (DMSO) treated plates from 2° to 26° 2θ, and tempered plates from 2° to 14° 2θ). The identification of clay minerals is conducted according to Thorez (1975), Brown (1980), Moore & Reynolds (1989) and Wilson (1987). For the semi-quantitive evaluation, the areas of characteristic peaks in combination with empirical correction factors were used (Riedmüller 1978). The untreated remaining clay fraction is freeze-dried for further investigation.

2.2.5 Simultaneous Thermal Analysis (STA)

50 mg of the grounded and at a relative humidity of 65% equilibrated sample were heated from 25°C to 1,000°C in a Pt-Rh crucible at a heating rate of 10°K per minute. Measurement was conducted using an instrument of Netsch (Luxx 429) at a flow of 15 ml of nitrogen and 50 ml air per minute. As a correction, an empty crucible was used. STA results were used for the determination of the content of gypsum and calcite. Several peaks resulting from an endothermic or exothermic process were typical for most of the samples and not additionally quoted.

– a peak at around 75°C points towards the escape of adhesive water.
– a peak at around 120°C to 180°C indicates the escape of water of crystallising gypsum.
– a peak at around 350°C to 450°C indicates the combustion of organic material.
– a peak at around 573°C points towards quartz inversion.
– a peak at around 750°C shows the release of CO_2 from carbonate minerals.

2.2.6 Infrared Spectroscopy (IRS)

Compacted samples were composed of 250 mg potassium bromide and 1 mg clay, or 1 mg of grounded and at 70°C dried clay. IR-spectra were measured with a Bruker spectrometer Tensor 27 between wave numbers 4,000 cm^{-1} and 500 cm^{-1}.

2.2.7 Sample colours

Sample colours were determined in a dry and semi-dry state according to the Munsell Soil Colour Chart. In the following detailed mentioning of the single samples' colours, further explanation is only given in the case of deviation from the average appearance of samples within one region. For the determination, the colours in the chart mentioned with the appendix YR (Yellow-Red) are used. Munsell categorises between five hues: R (Red), Y (Yellow), G (Green), B (Blue) and P (Purple); and intermediate hues: YR, GY (Green-Yellow), BG (Blue-Green), PB (Purple-Blue) and RP (Red-Purple). The resulting ten hues are again divided into ten increments, in total resulting in 100 hues. Practically, only forty are used, containing four charts titled as 2.5, 5, 7.5 and 10. The two following numbers, which are divided by a dash, categorise the lightness between 0 (black) and 10 (white) and the chroma, which is measured radially. The 10YR chart most often used within the current research, followed by 7.5YR. This designation is followed by two numbers, e.g. 10YR 5/2. The first number ranges between 0 (absolute black) and 10 (absolute white), and the second number indicates clay colour ranges app. between 2 and 8 in the current research. For all samples, the dry and also semi-dry colours were measured.

2.2.8 Shrinkage

The value of the geological shrinkage refers to the weight of the humid sample as 100%, while the geotechnical shrinkage refers to the dried sample as 100%. In the following, geotechnical shrinkage is given.

3. Mineralogical analysis of clay samples

Basgo – Maitreya Lhakhang. Sample 8469

Fig. 3.1 (Left) Basgo. Palace and monastery. Picture on the top right: Maitreya Lhakhang.
Fig. 3.2 (Right) Basgo. Maitreya Lhakhang with plastered round-shaped pillars.

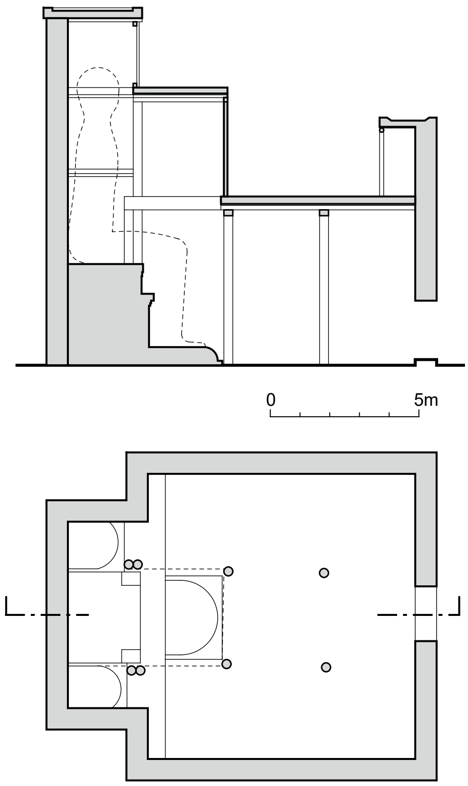


Fig. 3.3 (Left) Basgo. Maitreya Lhakhang. Ground plan and section. The ground plan shows the position of the round-shaped pillars.
Fig. 3.4 (Right) Basgo. Maitreya Lhakhang. Damage at the plaster on a pillar.

Sampling point

Ladakh, Basgo, Maitreya Lhakhang (upper temple), located app. at 34°13'27.62"N, 77°16'36.22"E (see Map 3.2, Figs. 3.1 to 3.3). The name of this temple follows a locally common designation. The pillars are plastered and painted red. Debris was collected by a worker from the floor during renovation work, originating from a deep crack in the plaster of a pillar (Fig. 3.4). The plaster is composed of two layers, a levelling (lower) layer and an upper layer, on which the red paint was applied. This sample belongs to the levelling layer (= ground layer), which was applied onto and between a rope-like bunch of fibres. The rope has a diameter of app. 1 cm and was helically twisted around the wooden pillars (Fig. 3.5). In Ladakh, plastering of a wooden pillar is a rarely used technique. Commonly, wooden pillars, which are round or angular, are directly painted but not plastered. The diameter of these pillars including the plaster is app. 30 cm, and the plastering was conducted along the full height of the pillar at app. 5.30 m. The thickness of the full plaster compound is app. 3 cm to 4 cm, and the thickness of the levelling layer is app. 2 cm. Sample number in the field: 34 BA/IP II. Additives: Straw with a length of up to 3 cm is present in a small amount. Constructive use: Levelling layer of plaster on a round wooden pillar. The organic fibres originate from the *busho* grass, which grows in the fields of Basgo. It becomes elastic when moistened, and reaches lengths of up to three metres. Furthermore, this grass is known for being twisted into a rope. Today it is used as animal feed and for making fire. June and July are the best months to harvest this grass.

Fig. 3.5 (Left) Basgo. Maitreya Lhakhang. Fibres visible due to a damage of the plaster.

Grain size distribution

As a plaster levelling layer, the material is relatively fine (biggest fraction: fine gravel). The median is located at app. 22.0 µm; the <2 µm fraction contains app. 12% of the whole sample. Fractions >20 µm amount to about 88% of the whole material. The maximum peak is 20.4% medium silt, and the whole sample is dominated by the silt and sand fractions. The sharp break in the grain size distribution between fine silt and coarse clay points towards the addition of coarse material or the desludging of fine material to avoid cracks.

	Gravel	Sand	Silt	Clay [%]
8469	0.8	32.2	55.2	11.8

Grain shapes

Grain size is up to 8 mm. Grain shapes >2,000 µm and also between 40 µm and 2,000 µm are dominantly 'angular-shaped'. This fact does not support the hypothesis that the material can be a mixture of two different types of clay (Fig. 3.6).

Bulk mineral analysis

The sample contains a small amount of amphiboles, 7Å minerals, phyllo silicates, quartz, K-feldspar, plagioclase and calcite, but no gypsum. 14Å minerals, mica and hematite are present in trace amounts. The content of calcite is 8%.

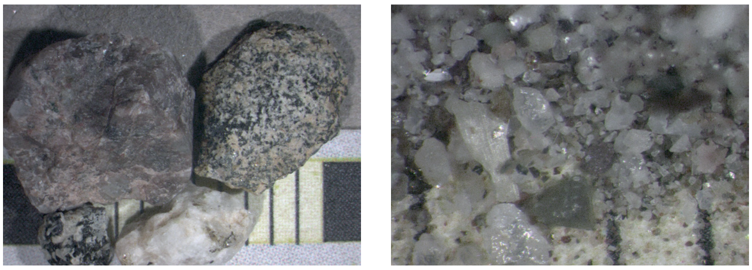


Fig. 3.6 Shape of grains in sample 8469. Scaled in millimetre. Shape of fraction >2,000 µm (left), 40–2,000 µm (right).

Clay mineral analysis

The CMA shows a scattered content of clay minerals. Comparison with other samples shows this sample to be equal with sample 8479, i.e. the sample of the upper layer of the plaster in the Maitreya Lhakhang. This indicates that for the levelling plaster of the pillar and the interior wall plaster, the same material (possibly from the same pit) was used (see sample 8496). At 44% (of the clay fraction), the sample shows a relatively high content of swellable clay minerals (22% smectite and 22% vermiculite). According to most of the samples within this region, the content of kaolinite is rather low.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
8469	22	22	37	3	16

Basgo – Maitreya Lhakhang. Sample 8479

Sampling point

Ladakh, Basgo, Maitreya Lhakhang (upper temple). Debris was collected by a worker from the floor during renovation work, originating from along a deep crack in the plaster of a round and red coloured pillar (like sample 8469 located app. at 34°13’27.62”N, 77°16’36.22”E). The plaster is composed of two layers: the levelling (lower) layer and the upper layer, on which the red paint was applied. The thickness of the red-painted upper layer is app. 1.5 cm. This sample is related to sample 8469 (levelling plaster on a pillar) and is the second and upper fine plaster layer not reinforced with fibres like the levelling layer. Sample number in the field: 38 BA/IP IV. Constructive use: Upper layer of a pillar plaster.

Grain size distribution

The material is relatively fine, with the biggest fraction being fine gravel. The median is located at app. 70 µm; the <2 µm fraction contains app. 17% of the whole sample. Fractions >20 µm together make up about 81% of the whole material. The maximum peak is 19.6% medium sand, and the whole sample is dominated by sand followed by silt and clay fractions. Interestingly, the fine layer is coarser than the levelling layer. An explanation for this may be the fact that the less coarse material in the levelling layer adheres better to the fibres below than the coarse material. Since the amount of swellable clay minerals (smectite and vermiculite) is relatively high, the addition of sand seems to be useful against cracking. Nevertheless, the 2 µm fraction is with 17% more present as is the case in the levelling layer. The grain size distribution graphics do not show such an immediate break between silt and clay, as is the case in the levelling layer. This would point towards a reduction of the fine material by desludging of the levelling material but an addition of coarse material in the sand and fine gravel fractions.

	Gravel	Sand	Silt	Clay [%]
8479 (upper plaster)	2.7	48.9	31.8	16.6
8469 (ground plaster)	0.8	32.2	5.2	11.8

Grain shapes

The grain size is up to 4 mm. Grain shapes >2,000 µm are ‘angular-shaped’ and partially show ‘beginning rounding’ (Fig. 3.7), while for the fractions below, primarily ‘angular-shaped’ grains are available. Compared with the coarse layer from sample 8469, an additional grain shape appears in the gravel fraction with a finer shape towards ‘beginning rounding’. The ‘angular-shaped’ material becomes less in the finer upper layer. This fact may emphasise the hypothesis of separating the very coarse and adding finer material for the upper plaster layer.

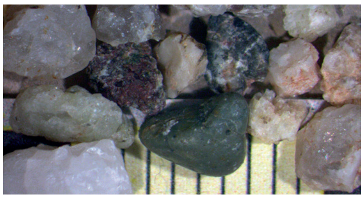


Fig. 3.7 Shape of grains in sample 8479. Shape of fraction >2,000 µm.

Bulk mineral analysis

The BMA shows mineral contents very similar to sample 8469, with just a slightly higher content of quartz and plagioclase. The content of calcite is 11%, as shown in Table 3 given at the end of this chapter. It was possibly used as a base layer before the addition of red paint. The colours, particularly in a semi-dry state, are the same in the samples 8469 and 8479. Traces of hematite explain the light reddish colour, though not the red paint as shown in the picture.

Clay mineral analysis

The CMA shows a scattered content of the clay minerals, similar to sample 8469. The much higher content of illite is a striking difference.

	Smectite	Vermi18°	Illite	Kaolinite	Chlorite [%]
8479	18	16	52	0	14

Additives

Straw with a length of up to 1 cm is minimally present. The content of straw seems less than we find in the levelling layer, and the fibres are much shorter.

Basgo – Maitreya Lhakhang. Sample 8496

Sampling point

Debris was collected by a worker from the floor during renovation work, originating from a deep crack along the left wall (view towards central statue). The thickness of the full plaster compound was app. 3 cm. Sample number in the field: 36 BA/LS. Constructive use: Interior plaster on the left wall in the assembly hall. Additives: A small amount of fine fibres of straw and small pieces of wood are present, though not as coarse as found in samples 8469 and 8479. Thus a different way of processing between the plasters used on the pillars and the plaster used on the wall is shown.

Grain size distribution

The material is relatively coarse, with the biggest fraction composed of medium gravel. The median is located at app. 130 µm; the <2 µm fraction contains app. 11% of the whole sample. These data are similar to levelling plaster 8469. A big difference is the high content of coarse material in sample 8496, in particular a high amount of coarse sand and fine gravel as well as medium gravel. Fractions >20 µm together make up about 89% of the whole material, which is also similar to sample 8469. The whole sample is dominated by the sand fraction followed by silt and clay fractions. Also in this case, the amount of swellable clay minerals (smectite and vermiculite) is relatively high, and the addition of sand seems to be useful against cracking. Since the basic material contains the whole plaster compound (levelling and fine plaster) and seems to be similar to what was used for the plaster of the pillars, this sample represents an average of the added data gathered at the pillar plaster samples 8469 and 8479.

Taking into account the fact that the CMA of samples of the Maitreya Lhakhang show a slight similarity to sample 8475 (plaster in the 'Lhakhang close to the road'; explained in the following), grain size distributions will be compared. Regarding the median and 2 µm of samples 8475, 8469 and 8496, we state the following:

8469: The median is located at app. 20 µm; the <2µm fraction at app. 12%.
8496: The median is located at app. 130 µm; the <2µm fraction at app. 11%.
8475: The median is located at app. 20 µm; the <2µm fraction at app. 18%.

This comparison shows a close similarity between the grain size distributions of samples 8469 and 8475, while sample 8496, the interior wall plaster in the Maitreya Lhakhang, is much coarser.

	Gravel	Sand	Silt	Clay [%]
8496 (interior wall plaster)	17.3	41.9	30.0	10.8
8469 (levelling pillar plaster)	0.8	32.2	5.2	11.8
8479 (upper pillar plaster)	2.7	48.9	31.8	16.6
8475 (interior wall plaster)	6.5	33.1	42.6	17.8

Grain shapes

Grain shapes between 2,000 µm and 200 µm are dominantly 'angular-shaped', similar to sample 8479. This is possibly a result of desludging or separating the raw material and adding the leftover sand to the plaster.

Bulk mineral analysis

The BMA shows a mineral content similar to sample 8469, i.e. the levelling plaster in the Maitreya Lhakhang, but with a slightly higher content of K-feldspar and a much higher content of plagioclase. An 8% content of calcite is similar to the levelling layer 8469. An anthropogenic addition cannot be excluded, possibly as a base layer for the addition of red painting, or the use of a content of *martsi* (Tib.; is a red colour clay with a high content of calcite) for the red painting. *Martsi* shows a high content of calcite, which explains the slightly higher amount of calcite in sample 8479, i.e. the upper and finer plaster layer of the pillar. Compared with sample 8475, i.e. the interior wall plaster in the 'Lhakhang close to the road', similarity is found, though not as strong as with sample 8469, which is a material from the same temple. The colours, particularly in the semi-dry state, are similar for samples 8469, 8479 and 8496. Traces of hematite explain the light reddish colour.

Clay mineral analysis

The CMA shows a scattered content of the clay minerals. A difference in comparison to samples 8469 and 8479 (pillar plasters) is the much higher content of smectite (44% of the clay fraction) and swellable clay minerals (60% of the clay fraction), which makes this sample much more swellable. This justifies the higher amount of coarse material – particularly gravel – that acts against cracking. Regarding comparison with sample 8475 (plaster in the 'Lhakhang close to the road'), similarities are obvious, pointing towards a similar basic material.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
8496	44	16	24	0	16

Basgo – Lotsāba Lhakhang. Sample 8482

Sampling point

The Lotsāba Lhakhang is located at app. 34°13'26.64"N, 77°16'30.96"E. The name used for this Basgo temple follows a locally common designation. Remains of the interior upper plaster carry remnants of a white layer. The thickness of the whole plaster is 2.5 cm, and the thickness of the upper layer is app. 1 cm. Sample number in the field: 35 BA/IP III. Additives: Long pieces of straw up to 2 cm and also very short pieces (<2 mm) are present in small amounts. Constructive use: Interior wall plaster; upper layer (Figs. 3.8 to 3.11).

Grain size distribution

The material is relatively fine, with the biggest fraction being fine gravel (very small amount). The median is located at app. 5.5 µm; the <2 µm fraction contains app. 24% of the whole sample. At 62.5%, the silt content is relatively high and may be relevant for the compensation of the high content of swellable clay to avoid cracks. Fractions below 63 µm (silt and clay) together make up about 81% of the whole material. Silt and clay together compose 92.5% of the whole sample. The maximum peak clearly corresponds to medium and fine silt (together 56.7%). Since the amount of swellable clay minerals (smectite and vermiculite) is relatively high, the addition of sand seems to be useful against cracking. The grain size distribution graphics do not show an immediate break or a bimodal distribution – a possible evidence for the use of the desludging method and a lack of

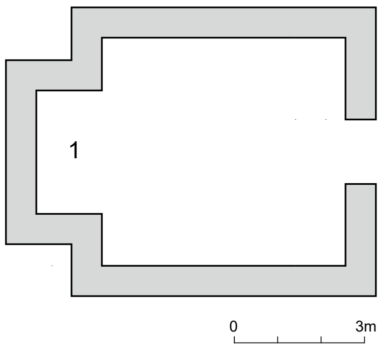


Fig. 3.8 (Top, left) Basgo. Lotsāba Lhakhang. Ground plan. 1 = *cella* niche.
Fig. 3.9 (Top, right) Basgo. Lotsāba Lhakhang. View towards *cella* niche.
Fig. 3.10 (Bottom, left) Basgo. Lotsāba Lhakhang. Brick bond.
Fig. 3.11 (Bottom, right) Basgo. Lotsāba Lhakhang. Layers of plaster next to a wooden bracket.

addition of coarse material. This is particularly seen when compared to the brick sample from the same wall (11948), which shows a much higher content of coarse material.

	Gravel	Sand	Silt	Clay [%]
8482 (upper layer incl. white layer)	0.5	7.0	67.7	24.8

Grain shapes

Grain shapes between 2,000 µm and 200 µm are dominantly ‘angular-shaped’ and give no evidence for the addition of another material.

Bulk mineral analysis

The sample contains a small amount of amphiboles, 7Å minerals, phyllo silicates, quartz, K-feldspar, plagioclase, and calcite. 14Å minerals, mica and hematite appear as traces – generally similar to samples 8469, 8479 and 8496. The content of calcite is 6%, as shown in Table 3. Compared to other Basgo samples, the content of calcite is evident in most of the samples and an average amount of app. 8% seems to be naturally given. Regarding this fact, the white layer seems to be the result of slight remains of a layer of gypsum, as shown in the BMA.

The content of gypsum was measured at 2%. A content of gypsum was also traced by X-ray diffraction within a slower measurement. Since there is no evidence of gypsum in sample 11946 (plaster without white coating) or sample 11948 (adobe brick) – both of which have a similar content of calcite – the hypothesis of a gypsum layer upon the plaster may be emphasised. The colours, particularly in the semi-dry state, are the same for samples 8465, 8469, 8496 and 8482. Traces of hematite explain the light reddish colour.

Results measured with STA
- A peak at 132°C points towards the transformation of gypsum to hemihydrate.
- A peak at 141°C points towards the transformation of hemihydrate to anhydrite.
- The residual mass at 1,000°C is 93.09%.

Clay mineral analysis

The CMA shows a scattered content of the clay minerals with a relatively high content of illite.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
8482	9	14	51	4	22
8479	18	16	52	0	14
8465	18	11	51	4	16

The CMA of sample 8482 (plaster from the 'Lotsāba Lhakhang') shows similarities with samples 8479 (plaster on the pillar in the Maitreya Lhakhang) and 8465 (mixture for flat roof construction). At 23% of the clay fraction, smectite and vermiculite are similarly present as swellable minerals for sample 8482. This is lower than for samples 8479 and 8465 with 34% and 29%, respectively. The amount of illite is nearly the same, and the amount of kaolinite is in general small. Also the content of chlorite is rather similar to samples 8479 and 8465. All these samples do not really show a clear marker for their local assignment.

A comparison of the grain size distribution shows the interior plaster in the Lotsāba Lhakhang being by far the finest of the examined plasters, followed by the plaster on the pillar in the Maitreya Lhakhang and further by the material used for a flat roof. Regarding the content of clay, these three samples are relatively close to each other, in particular sample 8482 (interior plaster in the Lotsāba Lhakhang) and sample 8479 (material used for a flat roof).
- 8482: The median is located at app. 5.5 µm; the 2 µm fraction at app. 24%.
- 8479: The median is located at app. 70 µm; the 2µm fraction at app. 17%.
- 8465: Material used for a flat roof: The median is located at app. 210 µm; vs. 240 µm at sample 15411 (*thetsa* sand) and 2,000 µm at sample 15410 (*dzasa*); the 2 µm fraction is at app. 11%.

Basgo – Lotsāba Lhakhang. Sample 8483

Sampling point

Ladakh, Basgo, ruin of the Lotsāba Lhakhang, like sample 8482 it is located at app. 34°13'26.64"N, 77°16'30.96"E. Remains of the interior fine plaster carried remnants of a white layer (probably lime or gypsum). This sample was found in the same chamber as sample 8482 but along a different section of the wall. The results are expected to be similar to those of sample 8482. The thickness of the upper layer is about 1 cm. Sample number in the field: 30 BA/IP. Additives: Long pieces of straw up to 1 cm and also very short pieces (<2 mm) are present in a relatively small amount, similar to sample 8482. Constructive use: Interior wall plaster; upper layer.

Grain size distribution

The material is relatively fine, with the biggest fraction being fine gravel (very small amount). The median is located at app. 4.8 µm; the <2 µm fraction contains app. 26% of the whole sample (a quarter of the whole sample). At 64.9% the content of silt is relatively high and may be relevant for the compensation of the high content of swellable clay to avoid cracks. Fractions <63 µm (silt and clay) amount to about 91% of the whole material. The maximum peak corresponds to medium and fine silt, together equalling 56.3%. Since the amount of swellable clay minerals (smectite and vermiculite) is relatively high, the addition of sand seems to be useful against cracking. The grain size distribution graphics do not show an immediate break or valley between two fractions – a possible evidence for the use of the desludging method and lack of the addition of coarse material. This is seen in particular when compared to the brick sample from the same wall (11948), which shows a much higher content of coarse material.

	Gravel	Sand	Silt	Clay [%]
8483 (upper layer incl. white layer)	0.9	8.1	64.9	26.1
8482 (upper layer incl. white layer)	0.5	7.0	67.7	24.8

Grain shapes

The size of the grains is up to app. 7 mm. The grain shapes between 2,000 µm and 200 µm are dominantly 'angular-shaped' and give no evidence for the addition of another material. Desludging of the material cannot be excluded.

Bulk mineral analysis

The BMA shows more or less the same result as sample 8482, and emphasises the similarity between these two samples and the fact that for one interior plaster the same raw material qualities and refinements of the material were chosen. The content of calcite was measured at 6%. The content of gypsum was measured at 2%, same as for sample 8482. A content of gypsum was also traced in the X-ray diffraction as a result of a slower measurement. The colours, particularly in the semi-dry state, are the same for samples 8465, 8469, 8496, 8482 and 8483. Traces of hematite explain the light reddish colour.

Results measured with STA
- A peak of 137°C points to the transformation of gypsum to hemihydrate.
- The residual mass at 1,000°C is 89.69%.

Clay mineral analysis

The CMA shows a scattered content of the clay minerals with a relatively similar proportion of the single minerals compared with sample 8482. Only the amount of smectite strongly varies between 9% and 20% (of the clay fraction) – possibly due to the use of different layers within the clay pit or the use of material from clay pits close to each other.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
8483	20	15	44	3	22
8482	9	14	51	4	22

Basgo – Lotsāba Lhakhang. Sample 11946

Sampling point

The ruin of the Lotsāba Lhakhang, like sample 8482, is located at app. 34°13'26.64"N, 77°16'30.96"E. Remains of the interior plaster (levelling and upper layer) carry no remnants of a white layer. This sample was found in the same chamber as samples 8482 and 8483 but at a different section of the wall. It contains a levelling layer and a fine upper layer. The thickness of the plaster is about 2.5 cm. Sample number in the field: 69. Additives: Straw of a length of up to 3 cm is present in a medium amount. Constructive use: Interior wall plaster; levelling and upper layer.

Grain size distribution

The material is relatively fine but in general coarser than samples 8481 and 8483 (previously examined); biggest fraction: medium and fine gravel. The median is located at app. 9 µm; the <2 µm fraction contains app. 17% of the whole sample. The content of silt at 62.9% is relatively high and may be relevant for the compensation of the high content of swellable clay to avoid cracks. Fractions <63 µm (silt and clay) amount to about 78.5% of the whole material. The maximum peak corresponds to medium and fine silt, with both together equalling 51.8%. The amount of swellable clay minerals (smectite; no vermiculite) is much less than for samples 8482 and 8483, which may indicate that the material for the interior plaster was not taken from only one particular pit and may have been added at a later time. The grain size distribution graphics do not show an immediate break or valley between two fractions – evidence for the use of the desludging method and lack of addition of coarse material. This may be seen in particular when compared to the brick sample from the same wall (sample 11948), which shows a much higher coarse content and a valley in the grain size classes, likely related to a material mixture. For this sample, a lesser content of clay and a higher content of sand may be due to a higher amount of parts of the levelling layer, a similarity to samples 8482 and 8483.

	Gravel	Sand	Silt	Clay [%]
11946 (full plaster without white layer)	5.2	16.3	62.9	15.6
8482 (upper layer incl. white layer)	0.5	7.0	67.7	24.8
8483 (upper layer incl. white layer)	0.9	8.1	64.9	26.1

Grain shapes

Grain shapes between 200 µm and 6,300 µm are dominantly 'angular-shaped' with a tendency towards 'angular with beginning rounding', which occurs fluently as opposed to abruptly (Fig. 3.12). This fact emphasises the hypothesis that the addition of another material was probably not relevant, but possibly desludging and the addition of desludged material may have had an impact.

Bulk mineral analysis

The BMA shows more or less the same result as samples 8482 and 8483, and emphasises its similarity and the fact that for one interior plaster the same raw material qualities and refinements of the material were chosen. Contrary to samples 8482 and 8483, gypsum is present only in trace amounts, which may indicate the use of gypsum for the upper layer as a base for mural paintings. The content of calcite follows with 10% the average indicated amount of calcite within the Basgo samples. No gypsum is present. The colour of this sample varies slightly from the samples before due to its higher content of coarse material and shows a tendency towards grey with no red, same as the previous samples. This is also due to the absence of hematite.

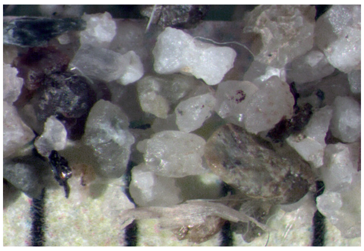



Fig. 3.12 Shapes of grains in sample 11946. Scaled in millimetre.
Shape of fraction >2,000 μm (left), >200 μm (right).

Clay mineral analysis

The CMA shows a scattered content of the clay minerals with a relatively similar proportion of the single minerals to samples 8482 and 8483. It shows similarities to the CMA of samples 8482 and 8483 but also clear differences, like a smaller content of smectite, the lack of vermiculite and a higher content of illite (65% of the clay fraction), both of which might indicate the use of a different clay pit. At 6%, the amount of swellable material is comparatively low.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11946	6	0	65	2	26
8482	9	14	51	4	22
8483	20	15	44	3	22

Basgo – Lotsāba Lhakhang. Sample 11948

Sampling point

Ladakh, Basgo, ruin of the Lotsāba Lhakhang, like sample 8482, it is located at app. 34°13’26.64”N, 77°16’30.96”E. Sample of an adobe brick found along the rear wall. Sample number in the field: 68. Additives: Pieces of straw up to a length of app. 3 cm as well as very short pieces are present. In this area, it is rare to find straw content within an adobe brick. Constructive use: Adobe brick.

Grain size distribution

The material is relatively coarse, particularly when compared to plaster samples 8482, 8483 and 11946; biggest fraction: fine gravel. Compared with interior plaster sample 11946, no medium gravel is available. The median is located at app. 220 μm; the <2 μm fraction contains app. 10% of the whole sample. Together equaling 68.3%, the content of gravel and sand together is relatively high and may be relevant for the compensation of the amount of swellable clay minerals (28%

smectite of the clay fraction). Additionally, it clearly shows a distinction between plaster and brick material. For binding a content of about 10% <2 µm is needed. The grain size distribution graphics show a bimodal distribution between fine gravel and medium sand – possible evidence for mixture with another material. In the case of the brick, the material is much more equal to the raw material or the added coarse material.

	Gravel	Sand	Silt	Clay [%]
11948 (adobe brick)	17.2	51.0	21.8	10.0
8482 (upper layer incl. white layer)	0.5	7.0	67.7	24.8
11946 (full plaster without white layer)	5.2	16.3	62.9	15.6

Grain shapes

The size of the grains is up to 2 cm. Grain shapes >6,300 µm and >2000 µm show 'beginning rounding' and are also 'angular-shaped', while for fractions below 200 µm, 'angular-shaped' is dominant. This change in shape at around 2,000 µm may be an indication of the addition of coarse material (Fig. 3.13).

Fig. 3.13 Shapes of grains in sample 11948. Scaled in millimetre.
Shape of fraction >2,000 µm (left), >630 µm (centre), >200 µm (right).

Bulk mineral analysis

The BMA shows similar results to plaster samples 8482, 8483 and 11946 with slightly less amphiboles. Also present is an 11% content of calcite, which follows the average amount of calcite found within the Basgo samples. No gypsum is present. Traces of hematite explain the light reddish colour. As a darker sample, this sample differs from samples 8482, 8483 and 11946.

Clay mineral analysis

The CMA shows a scattered content of the clay minerals with relatively few similarities amongst the single minerals compared with samples 8482, 8483, 11946 and 11948. Apart from similarities, it also shows clear differences like the higher amount of smectite. However, similar to plaster 11946, there are no indications of a content of vermiculite. The amount of illite, in contrast, is similar to plaster samples 8482 and 8483 but differs from plaster sample 11946, which stands out at 65% of the clay fraction. Within all Basgo-Likir samples, two further samples, i.e. 11752 and 11952, show similarities to sample 11948 (as shown below). These similarities are no vermiculite and a strongly marked chlorite. The differences between samples 11946 (interior plaster) and 11948 (adobe brick) result in a different geological mechanism of transport.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11948	28	0	44	2	27
8482	9	14	51	4	22
11946	6	0	65	2	26
11752	0	0	38	0	62
11952	20	0	47	2	31

Basgo – 'Lhakhang close to the road'. Sample 8475

Sampling point

Ladakh, Basgo, ruin of a temple, is located along the left side of the road to Leh, and located at app. 34°12'45.09"N, 77°17'41.99"E. The names of the afore-treated temples, mentioned as Maitreya Lhakhang and Lotsāba Lhakhang, follow a locally common designation. In the case of this temple (which is related to sample 8475) no such obvious designation is available. For further treatment of this temple within this contribution, its location along the National Highway NH1D towards Leh is used as further designation and we simply refer to it as 'Lhakhang close to the road'. The sample shows remains of the interior plaster. The thickness of the plaster is app. 2.5 cm. Sample number in the field: 37 BA-RZ/IP. Additives: Very long fibres of straw of up to 6 cm are present partially in a high amount. Constructive use: Interior wall plaster (Figs. 3.14 to 3.17).

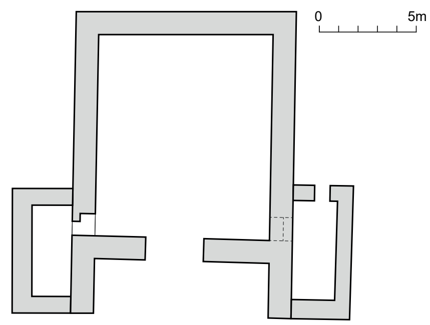


Fig. 3.14 (Top, left) Basgo. Lhakhang. Ground plan.
Fig. 3.15 (Top, right) Basgo. Lhakhang. View from the entrance towards the rear wall.
Fig. 3.16 (Bottom, left) Basgo. Lhakhang. Interior plaster (B/W).
Fig. 3.17 (Bottom, right) Basgo. Lhakhang. Exterior plaster.

Grain size distribution

The material is relatively fine, with the biggest fraction being fine gravel, which equals an amount relatively high for plaster. The median is located at app. 20 µm; the <2 µm fraction contains app. 18% of the whole sample. Together with the content of fine gravel, this amount may be relevant for the compensation of the high content of swellable clay to avoid cracks. The distribution curve shows a bimodal distribution with peaks of fine sand and fine silt – a possible evidence of a mixture with another clay or sand.

	Gravel	Sand	Silt	Clay [%]
8475 (plaster)	6.5	33.1	42.6	17.8

Grain shapes

Grain shapes between 200 µm and 6,300 µm are dominantly 'angular-shaped' without any evidence of a change in shape. This fact may indicate that the material is raw and unmixed.

Bulk mineral analysis

The sample contains a small amount of mica, amphiboles, 7Å minerals, quartz and K-feldspar. Plagioclase and calcite appear in a medium amount. Traces of 14Å minerals, phyllo silicates and hematite are available. The content of gypsum was measured at 2%, a possible indication for its use upon the plaster. A content of gypsum was also traced in the X-ray diffraction within a slower measurement. It is the only sample of the five examined samples of this temple with a conspicuous content of gypsum. Sample 11928 – also an interior plaster – only shows traces of gypsum. It is likely that the gypsum has already been washed out. The content of calcite of sample 8475 was measured at 13%. Compared to other Basgo samples, the content of calcite is evident in most of the samples, and an average amount of app. 8% to 10% seems to be naturally given. The colours are within the investigated range of Basgo samples. Due to traces of hematite, the sample is slightly red coloured.

Results measured with STA
· A peak at 128°C points towards the presence of gypsum.
· The residual mass at 1,000°C is 88.98%.

Clay mineral analysis

The CMA shows a scattered content of clay minerals with a relatively high content of illite and a high content of swellable clay minerals (33% of the clay fraction). The clay contains smectite and vermiculite. This sample shows similarity to the Basgo samples in general.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
8475	24	9	43	3	21

Basgo – 'Lhakhang close to the road'. Samlpe 11928

Sampling point

Ladakh, Basgo, ruin of a temple along the left hand side of the road to Leh. Like sample 8475, it is located at app. 34°12'45.09"N, 77°17'41.99"E. Remains of the interior plaster. The thickness of the plaster is app. 2.5 cm. Sample number in the field: 47. Additives: Very long fibres of straw of up to 6 cm are partially present in a high amount. Constructive use: Interior wall plaster, similar to sample 8475 but from a different location within the wall.

Grain size distribution

The material is relatively fine; biggest fraction: fine gravel. The amount of gravel is relatively high for a plaster. The median is located at app. 15 µm; the <2 µm fraction contains app. 21% of the whole sample. The content of silt and sand together at 71.4% is relatively high and, together with the content of fine gravel, may be relevant for the compensation of the high content of swellable clay to avoid cracks. The peaks correspond to fine sand and fine silt – all data are relatively similar to sample 8475. Even the grain size distribution remains similar. The grain size distribution graphics shows a bimodal distribution – a possible evidence for the mixture with another material, similar to sample 8475.

	Gravel	Sand	Silt	Clay [values given in %]
11928 (plaster)	7.3	29.7	42.1	20.9
8475 (plaster)	6.5	33.1	42.6	17.8

Grain shapes

Grain shapes between 200 µm and 6,300 µm are dominantly angular-shaped without evidence of a change in shape. This fact may indicate the material as raw and unmixed.

Bulk mineral analysis

The sample contains a small amount of amphiboles, 7Å minerals, quartz, and K-feldspar (marked in Table 3 with *); dolomite at 2% and calcite at 12% is also indicated. 14Å minerals, mica, phyllo silicates, gypsum and hematite appear as traces. The amount of 12% of calcite follows an average quantity within the Basgo samples. The colours are within the investigated range of Basgo samples. Due to traces of hematite, the sample is slightly red coloured.

Clay mineral analysis

The CMA shows a scattered content of clay minerals with a relatively high content of illite and a slightly smaller content of swellable clay minerals in comparison to sample 8475. In this case the clay contains only smectite, and no vermiculite. It clearly shows similarity to the Basgo samples in general.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11928	18	0	41	5	37
8475	24	9	43	3	21

Basgo – 'Lhakhang close to the road'. Sample 8499

Sampling point

Ladakh, Basgo, ruin of a temple located along the left hand side of the road to Leh. Like sample 8475, it is located at app. 34°12'45.09"N, 77°17'41.99"E. Remains of the exterior plaster. The thickness of the plaster is app. 4 cm. Sample number in the field: 33 BA-RZ/AP. Additives: Fibres of straw of up to app. 3 cm are present in a high amount. Constructive use: Exterior wall plaster.

Grain size distribution

The material is coarser than interior plasters 8475 and 11928; biggest fraction: fine gravel. The median is located at app. 50 µm; the <2 µm fraction contains app. 12% of the whole sample. The content of sand at app. 39.6% and gravel at 7.5% shows a high amount of coarse material. For the exterior plaster, a higher content of coarse material makes the plaster more resistant to precipitation. As a comparison, in Austria a thick layer of clay plaster ("fir-coat"), locally also known as "Åu-glehnert", is known to be mixed with cow dung. Whether or not this was the case at early Himalayan temples cannot be stated within this study. Since in the Himalayas dung is traditionally known as an additive for earth constructions, we cannot exclude a particular use for plasters. In this sample the content of binding material seems to have been reduced to a small but still binding amount. The grain sizes show a wide range in their distribution. The amount of clay in sample 8499 (exterior plaster) is much smaller than for interior plaster samples 8475 and 11928.

	Gravel	Sand	Silt	Clay [%]
8499 (ext.plaster)	7.5	39.6	41.3	11.6
8475 (int. plaster)	6.5	33.1	42.6	17.8
11928 (int.plaster)	7.3	29.7	42.1	20.9

Grain shapes

Grain shapes between 200 µm and 6,300 µm are dominantly 'angular-shaped' without any evidence of a change of shape. This fact may indicate the material as raw and unmixed.

Bulk mineral analysis

The sample contains a small amount of mica, amphiboles, 7Å minerals, quartz and K-feldspar (in Table 3 marked with *); plagioclase appears in a medium amount (in the table marked with **). 14Å minerals, phyllo silicates and hematite appear as traces. Calcite is available at 15% and dolomite at 3%. The relatively high amount of calcite fits into the range of samples of this temple with a content between 12% and 15%. No traces of gypsum are present. It is similar to sample 8499. The colours are within the investigated range of Basgo samples. Due to traces of hematite the sample is slightly red coloured.

Clay mineral analysis

The CMA shows a scattered content of clay minerals with a relatively high content of swellable clay minerals. Smectite and vermiculite together make up 51% (of the clay fraction). Together with the content of fine gravel, the high amount of coarse material may be relevant for the compensation of the high content of swellable clay to avoid cracks. The following list shows a comparison with samples 8475 and 11928, with both coming from the same building and both showing similarities to sample 8499. The CMA of sample 8499 (exterior plaster) shows slight similarities to sample 8483 (interior plaster in the Basgo Lotsāba Lhakhang) regarding a high content of swellable minerals (35% of the clay fraction) and the proportion of smectite and vermiculite. The amount of smectite is clearly higher in sample 8499. In sample 8483, a mixed layer shows a marker for its clearer local assignment.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
8499	30	21	29	3	16
8475	24	9	43	3	21
11928	18	0	41	5	37
8483	20	15	44	3	22

Basgo – 'Lhakhang close to the road'. Sample 8472

Sampling point

Ladakh, Basgo, ruin of a temple located along the left hand side of the road to Leh. Same as sample 8475, it is located at app. 34°12'45.09"N, 77°17'41.99"E. Remains of an adobe brick. Sample number in the field: 32 BA-RZ/LS. Constructive use: Adobe brick.

Grain size distribution

The material is relatively coarse, with the biggest fraction being coarse and medium gravel (in the graphics, the total amount of gravel is shown in the FG (fine gravel fraction). The median is located at app. 550 µm; the <2 µm fraction contains app. 8% of the whole sample. The content of gravel at 35.8% and of sand at 42.5%, in summary 78.3%, shows a dominance of coarse material. The high amount of coarse material indicates a different treatment of the adobe brick material compared to the plaster samples. In this sample the content of binding material seems to have been reduced to a very small but still binding amount.

	Gravel	Sand	Silt	Clay [%]
8472 (adobe brick)	35.8	42.5	14.2	7.5
8475 (int. plaster)	6.5	33.1	42.6	17.8
8499 (ext.plaster)	7.5	39.6	41.3	11.6

Grain shapes

Grain shapes between 200 µm and 6,300 µm are dominantly 'angular-shaped' without any evidence of a change of shape. This fact indicates that the material is raw and unmixed.

Bulk mineral analysis

The sample contains a small amount of amphiboles, 7Å minerals, quartz and K-feldspar (marked in Table 3 with *); plagioclase and calcite appear in a medium amount (marked in the table with **). A content of gypsum was also found in trace amounts in the X-ray diffraction within a slower measurement. The content of calcite was measured at 12%, which compared to other Basgo samples is within an average amount. The colours are within the investigated range of Basgo samples. Since no hematite could be traced, the sample does not show any red colour.

Clay mineral analysis

The CMA shows a scattered content of clay minerals with a relatively high content of illite and a content of swellable clay minerals, in this case smectite and vermiculite. A relatively high content of these two minerals, together equally 23% (of the clay fraction), may explain a still available effect of binding despite a content of 35.8% gravel and 42.5% sand, together equalling 78.3% of coarse material. The result of the CMA fits well into basic features of most of the Basgo-Likir samples, i.e. a clear appearance of illite, up to a medium amount of smectite and vermiculite, a strong appearance of chlorite, and a few kaolinites. For the present sample, the amount of smectite is much less. This fits well for its use as material for the production of adobe bricks, since a minimal amount of smectite helps to avoid a high rate of deformation and cracks within the brick.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
8472 (adobe brick)	9	14	50	4	23
8482 (int. plaster)	24	9	43	3	21
8499 (ext. plaster)	30	21	29	3	16

Basgo – Lhakhang 'close to the road'. Sample 11933

Sampling point

Ladakh, Basgo, ruin of a temple along the left hand side of the road to Leh. Same as sample 8475, it is located at app. 34°12'45.09"N, 77°17'41.99"E. Remains of an adobe brick. Sample number in the field: 45. Constructive use: Adobe brick.

Grain size distribution

The material is relatively coarse, with the biggest fraction being medium gravel (in the graphics the total amount of gravel is shown in the FG fraction). The median is located at app. 180 µm; the <2 µm fraction contains app. 10% of the whole sample. The content of gravel at 10.4% and of sand at 60.4%, together equalling 70.8%, shows a clear dominance of coarse material. The high amount of coarse material indicates different treatment of the adobe brick material. In this sample the content of binding material seems to have been reduced to a very small but still binding amount.

a. Since with the CMA a strong similarity to sample 11946 (plaster in the Lotsāba Lhakhang) is stated, the grain size distributions will be compared. Regarding the grain size distribution, the two samples show similarity in the clay fraction and partially in the gravel fractions, but the silt and illite fractions appear completely different. The adobe brick is much coarser than the plaster.

b. Since with the CMA a strong similarity to sample 11928 (plaster in the 'Lhakhang close to the road') is stated, grain size distributions will be compared. Regarding grain size distribution, the adobe brick is much coarser than the plaster. As comparison with another adobe brick, the data of sample 8472 will be added.

	Gravel	Sand	Silt	Clay [%]
11933 (adobe brick)	10.4	60.4	18.8	10.4
11928 (int. plaster)	7.3	29.7	42.1	20.9
8472 (adobe brick)	35.8	42.5	14.2	7.5
11946 (int. plaster Lotsāba Lk.)	5.2	16.3	62.9	15.6

Grain shapes

Grain shapes between 200 µm and 6,300 µm are dominantly 'angular-shaped with a beginning rounding' (Fig. 3.18). This fact may indicate the material as raw and unmixed.

Fig. 3.18 Shapes of grains in sample 11933. Scaled in millimetre.
Shape of fraction >2,000 µm (left), >630 µm (centre), >200 µm (right).

Bulk mineral analysis

The sample contains a small amount of amphiboles, 7Å minerals, quartz and K-feldspar (marked in Table 3 with **); plagioclase appears in a medium amount (marked in the table with **). The amount of calcite was measured at 13% within the average range of Basgo samples. Dolomite, 14Å minerals, mica and phyllo silicates are all available in trace amounts. No gypsum could be detected. The colours are within the investigated range of Basgo samples. Since no hematite was identified, the sample does not show any red colour. The adobe brick was produced without any additives, similar to sample 8472.

a. A comparison of the BMA of sample 11933 with sample 11946 (plaster in the Lotsāba Lhakhang) shows great similarity between these two samples, contrary to differences in the grain size fractions.

b. A comparison of the BMA of sample 11933 with sample 11928 (plaster in the 'Lhakhang close to the road') also shows great similarity between these two samples, contrary to differences in the grain size fractions.

Clay mineral analysis

The CMA shows a scattered content of clay minerals with a relatively high content of illite and a small content of swellable clay minerals (in this case of smectite). The amount of kaolinite at app. 7% is relatively high compared to the other samples from this temple. The strong variation in the content of clay minerals between sample 8472 and 11933 indicates that they did not originate from the same clay pit. For comparison, sample 11946 (plaster from the Lotsāba Lhakhang) is listed below and shows close similarities to sample 11933. A close relation between samples

11933 and 11928 (respectively brick and plaster) points towards the possibility of the use of a particular basic material. The other samples (see the following listed samples) from this building (i.e. samples 8482, 8499 and 8472) show clear differences in comparison to sample 11933.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11933 (adobe brick)	9	0	53	7	32
11928 (int. plaster)	24	9	43	3	21
8472 (adobe brick)	9	14	50	4	23
11946 (int. plaster Lotsāba)	6	0	65	2	26

Basgo – Building raw material. Sample 15410

Sampling point

Ladakh, Basgo. Red coloured clay from north of the Maitreya Lhakhang (upper temple) (Fig. 3.19), located at app. 34°13'28.78"N, 77°16'38.23"E. The local terminology is *dzasa* (Tib. *rdza sa*), which possibly derives from pottery clay. An area, which is located about 2 km north of the temple hill, is called *"zasna"* (pronounced) and points towards the influence of local clay on toponymies. This material is one of the basic types of clay for building purposes in the area around the monastery hill. Along with the sandy *thetsa* (Tib. *'phred sa*), it is used as part of a mixture for the preparation of plasters. As mentioned by locals, this plaster is applied in two layers. The lower (levelling) layer is mixed with straw. For the upper (fine) layer, the same mixture is used without straw. Such a two-layer plaster is found throughout this region with changing thickness and a variable amount of straw. Sample number in the field: 74 BA/LG.

Fig. 3.19 Basgo. Sample 15410. Sample colour (after Munsell): Dry 10YR 6/2 light brownish grey. Semi-dry 10YR 4/2 dark greyish brown.

Grain size distribution

The material is coarse, with the biggest fraction being medium and fine gravel. The median is located at app. 2,000 µm; the <2 µm fraction contains app. 8% of the whole sample. The gravel fractions together equal about 53.9% of the whole sample. The maximum peak is 41.2%, with medium gravel dominating the whole sample. The distribution curve shows a bimodal distribution with a deep valley between fine gravel and fine sand. Due to this valley the fractions of fine sand and smaller parts are easily separated from the whole sample, and the finer portion of material can be used for another purpose. This silt-dominated portion of the sample, which includes some clay, is appropriate for the mixing of plaster with coarse material such as *thetsa*. Instead of desludging, the gravel fraction and the fine material can be separated from each other by sieving. Nevertheless, due to the gravel-fraction, the coarse content must be separated to achieve a material much finer than shown by samples of *thetsa* (described with samples 11915 and 15411). Perhaps pits exist with only the fine content and without the content of gravel. Another hypothesis can be that the rather high content of gravel shows a relatively high amount of coarse material in laboratory research, but the haptic impression in the field differs due to a high content of silt. This may also be the reason why locally it is known as a fine material. Apart from the high amount of gravel, the grain size distribution shows a well-sorted curve. On the other hand, we may not exclude the possibility that coarse material was added to a fine and silt dominated *dzasa* sample.

	Gravel	Sand	Silt	Clay [%]
15410 *dzasa*	53.9	8.7	30.7	6.9

Bulk mineral analysis

The sample contains a small amount of 7Å minerals, quartz and plagioclase (marked in the table with *). Traces of 14Å minerals, mica, amphiboles, phyllo silicates, K-feldspar and dolomite (1%) appear as traces without indications of a content of gypsum. At 10%, the amount of calcite is average.

Clay mineral analysis

Similar to samples 15411 and 11915, this sample shows a high content of the swellable mineral smectite (see Fig. CMA 3.28 in the Appendix of Chapter III).

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
15410 (*dzasa*)	30	0	32	2	36

Basgo – Building raw material. Sample 11915

Sampling point

Ladakh, Basgo, like sample 15410, is located at app. 34°13’28.78”N, 77°16’38.23”E. The local terminology is *thetsa* (Tib. *’phred sa*), also known as “*thetsa* sand”, which already points towards its use as an additive locally mixed with the *dzasa* (Tib. *rdza sa*) (Fig. 3.20). Sample number in the field: 20. Constructive use: Raw material for the sandy additive for the preparation of a plaster.

Grain size distribution

The material is coarse, with the biggest fraction being fine gravel. The median is located at app. 250 µm; the <2 µm fraction contains app. 9% of the whole sample. The gravel and sand fractions amount to about 77.9% of the whole material. The maximum peak is 41.1% of medium sand. Sand dominates the whole sample. This sample shows no bimodal distribution. This may be a hint that this material was not separated from another sample but used as a homogenous material with sandy dominance – contrary to the *dzasa,* which was separated and of which the finer fractions were probably preferred for the preparation of plasters. The high content of sand is clearly visible.

Fig. 3.20 Basgo. Sample 11915.
Sample colour (after Munsell):
Dry 10YR (6)7/1 light grey.
Semi-dry 10YR 4/1 dark grey.

	Gravel	Sand	Silt	Clay [%]
11915 (*thetsa*)	3.8	74.1	14	8.2
15410 (*dzasa*)	53.9	8.7	30.7	6.9

Bulk mineral analysis

The BMA shows clear differences to the *dzasa* (15410): The sample contains only traces of 7Å minerals. It also contains a small amount of quartz but a higher amount of plagioclase. Compared to sample 15410, no traces of dolomite are present, and further no traces of 14Å minerals or amphiboles are present. The K-feldspar is available in a small amount, while for sample 15410 it appears only in lesser trace amounts. Small reddish spots point towards a content of hematite. The amount of calcite at 7% is below the average level (10%−11%) for the samples in this region. Since this sample is used as raw material for mixing, we can assume that an average content of calcite is stated as naturally given. The sample does not show any content of gypsum. It is relatively greyish and shows reddish spots, probably traces of hematite.

Clay mineral analysis

The CMA shows a scattered content of the clay minerals. Compared with sample 15410, the content of clay minerals is clearly different. The content of illite and chlorite is much less compared to sample 15410. Regarding the CMA, in particular the high amount of swellable minerals – 53% (of the clay fraction) for sample 11748 (used for making a clay stove) – shows similarities to sample 11915 – which contains 72% swellable material (i.e. a *thetsa,* which is not used for making a stove). Due to this analysis we can state that the *thetsa* potentially gives an optic and haptic impression of being coarse and thus may be known as a sandy material. Additionally, the content of clay minerals is similar to *dzasa* sample 15410, and furthermore the content of swellable minerals at 72% (of the clay fraction) is more than double compared to sample 15410 at 30%. This emphasises once more the hypothesis that sample 15410 shows an amount of gravel above average for *dzasa* raw material.

Regarding the rather high content of swellable clay minerals, this high amount we know from bentonites with a content of app. 60% to 80% of clay minerals, in this case montmorillonite, which belongs to the smectite group that is a 2:1-clay mineral classified by a layer charge of 0.25 to 0.6. Montmorillonites also show a content of mica and chlorite. At this point, the question for a vulcanic indicator arises. The 2 µm CMA-graphics shows a di-octachedric smectite at app. 62°. Since the quartz peak at app. 60° is higher than the one at app. 50°, the additional share may be described as content of mica. The sample may speculatively be described as a volcanic ash of old age. With a content of app. 80% of framework material and 20% of binding material, this material can be described as a building material with a high binding effect in spite of its rather coarse appearance.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11915 (*thetsa*)	72 (smec + verm)		13	6	8
15410 (*dzasa*)	30	0	32	2	36
11748 (*thab*)	11	42	10	37	0

Basgo – Building raw material. Sample 15411

Sampling point

Ladakh, Basgo, similar to sample 15410, is located at app. 34°13'28.78"N, 77°16'38.23"E. The local terminology is *thetsa* (Tib. *'phred sa*) (Fig. 3.21). This is another sample of this material for further comparison. As mentioned before, this material is known for the preparation of a plaster but it is also recognised for the preparation of flat roofs and floors, in particular for the lower (first) layer, which can also be mixed with very coarse material with a size of up to 1 cm to 2 cm. The uppermost layer used for flat roofs was mentioned either as *markalak* (Feiglstorfer 2019: 199ff.) or as *khusa* (Feiglstorfer 2014: 378), which is a kind of sooty material (mostly a recycled plaster from kitchens)[90]. For the preparation of adobe bricks, this kind of *thetsa* is used without any further mineral addition. If needed, straw can be added. Sample number in the field: 75 BA/LG. Constructive use: Raw material for the sandy additive for the preparation of a plaster. It is also used for the lower layer of flat roofs and the preparation of adobe bricks without any further mineral addition.

Grain size distribution

The material is coarse and as expected similar to the *thetsa* sample 11915; biggest fraction: fine gravel. The median is located at app. 240 µm versus 250 µm for sample 11915; the <2 µm fraction contains app. 9% of the whole sample, same as for sample 11915. The gravel and sand fractions amount to about 74.8% of the whole material versus 67.9% for sample 11915. The maximum peak is 32.7% medium sand. Sand dominates the whole sample. There is no bimodal distribution as in sample 15410. This may indicate that the material was not separated but rather used as a homogenous material with sandy dominance. This is contrary to the *dzasa*, which may have been separated and of which finer fractions were preferred for the preparation of plaster. The sample is obviously sandy.

90 Interview with Sonam Dawa in Leh, August 2002: When using 'high-quality' clay for the top roof layer and eventually adding ash, daily clearing of the snow from the roof is not required.

Fig. 3.21 Basgo. Sample 15411.
Sample colour (after Munsell):
Dry 10YR 6/2 light brownish grey.
Semi-dry 10YR 4/2 dark greyish brown.

	Gravel	Sand	Silt	Clay [%]
15411 (*thetsa*)	6.0	68.8	16.5	8.7
15410 (*dzasa*)	53.9	8.7	30.7	6.9
11915 (*thetsa*)	3.8	74.1	14	8.2

Bulk mineral analysis

With slight differences, the BMA shows close similarities to sample 11915: The differences are the content of 7Å minerals in small amounts as opposed to trace amounts, and amphiboles and 14Å minerals as traces. In sample 11915 amphiboles and 14Å minerals are missing; a higher content of K-feldspar appears in a medium amount (marked in Table 3 with **), contrary to sample 11915, which shows only a small amount. The content of calcite in sample 15411 is 11% compared to 7% in sample 11915. Similarly, no dolomite and gypsum were traced. The content of calcite was measured at 11%.

Clay mineral analysis

The CMA shows a scattered content of clay minerals. A comparison with *thetsa* sample 11915 shows similarities but also differences. These differences emphasise the fact that two materials with the same local name and a high similarity in their grain size distribution and in their bulk mineral consistency must not necessarily follow a similarity of clay mineral content. Simply having clay from a different clay pit may change the clay mineralogical composition and by that also its particular behaviour as a building material. In this particular context, the 38% content of smectite as a swellable material in sample 15411 compared with 72% of smectite and vermiculite in sample 11915 must result in a different behaviour regarding swellability. The high content of chlorite indicates the metamorphic character of this material differing from smectite and mica, possibly due to a different means of geological material transport.

Both *thetsa* samples (11915 and 15411) are relatively similar regarding the BMA but show differences when comparing their CMA, as shown in the following juxtaposition.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
15411 (*thetsa*)	38 (smec + verm)		26	0	36
15410 (*dzasa*)	30	0	32	2	36
11915 (*thetsa*)	72 (smec + verm)		13	6	8

Basgo – Building raw material. Sample 8465

Sampling point

Ladakh, Basgo, a clay pit located beside the Maitreya Lhakhang at 34°13'27.07"N, 77°16'36.70"E. This material is mixed and ready for application on a roof (Fig. 3.22). In a further step, this material is mixed with straw. General local information designated this material as a high-quality building material. The two afore-mentioned types of clay, *thetsa* and *dzasa*, are mixed. On wooden stretchers the final mixtures were carried along steps onto the roof and sectionally poured onto the afore-applied layer of *jakses* (Figs. 3.23, 3.34). After a short drying process the applied and still humid sediment was compressed and flattened with wooden beaters. These beaters had a similar form to what is known from the construction of the *arga* roof (cf. Feiglstorfer 2019).
Sample number in the field: 31 BA/LG. Additives: Pieces of wood and long pieces of straw. Constructive use: Mixture of *thetsa*, *dzasa* and straw for flat roof construction.

Fig. 3.22 Basgo. Sample 8465.
Sample colour (after Munsell):
Dry 10YR 7/2 light grey.
Semi-dry 10YR 5/3 brown.

Fig. 3.23 (Left) Basgo. Maitreya Lhakhang. New roof construction.
Fig. 3.24 (Right) Basgo. Maitreya Lhakhang. One layer of a mixture of *thetsa* and *dzasa*.

Grain size distribution

The material is coarse and shows similar qualities to a mixture of the *thetsa* and *dzasa* samples; biggest fraction: fine gravel. The median is located at app. 210 µm versus 240 µm for sample 15411, and 2,000 µm for sample 15410; the <2 µm fraction contains app. 11% for the whole sample, compared to 9% for sample 15411, and 8% for sample 15410. The gravel and sand fractions amount to about 63.3 % versus 74.8% of the whole material for sample 15411, and 62.6% for sample 15410. The maximum peak is 24.5% medium sand. The coarse fractions of sand and gravel dominate the sample.

	Gravel	Sand	Silt	Clay [%]
8465 (*dzasa+thetsa*)	12.5	50.8	25.8	10.9
15410 (*dzasa*)	53.9	8.7	30.7	6.9
15411 (*thetsa*)	6.0	68.8	16.5	8.7

Grain shapes

The size of the grains is up to 14 mm. The >2,000 µm fractions are 'slightly rounded shaped' and also 'angular-shaped', while the fractions below are dominantly 'angular-shaped'. The change in the shape at around 2,000 µm may be an indication of the addition of a coarse material (Fig. 3.25). Regarding the two different grain shapes, the grain size distribution points to the use of two different kinds of raw material and not being a natural mixture.

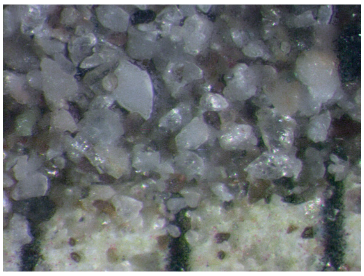


Fig. 3.25 Shapes of grains in sample 8465. Scaled in millimetre.
Shape of fraction >2,000 µm (left), >200 µm (right).

Bulk mineral analysis

The BMA clearly shows properties of both types of clay: *thetsa* and *dzasa*. 14Å minerals, hematite and mica occur as traces, while amphiboles, 7Å minerals, phyllo silicates and quartz appear in a small amount (marked in Table 3 with *). K-feldspar and plagioclase are present in a medium and relatively high amount, respectively. Calcite ranges from 10% to 11%, with 10% being the average level. Traces of gypsum are present.

Results measured with STA

- A peak at 117°C points towards the presence of gypsum.
- The residual mass at 1,000°C is 92.03%.

Clay mineral analysis

The CMA shows a scattered content of clay minerals. A comparison with *thetsa* sample 15411 and *dzasa* sample 15410 regarding swellable clay minerals provides the following results: 29% for sample 8465, slightly above 30% for sample 15410, and 24% for sample 15411. The content of kaolinite is comparably low, while the value for illite is with 51% above the values of samples 15410, 11915 and 15411.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
8465 (*dzasa+thetsa*)	18	11	51	4	16
15410 (*dzasa*)	30	0	32	2	36
15411 (*thetsa*)	38 (smec + verm)		26	0	36

Basgo – Building raw material. Sample 11952

Sampling point

Ladakh, Basgo, new adobe brick. The material was found along a building site beside the *chorten* close to the Lotsāba Lhakhang, located at app. 34°13'26.12"N, 77°16'31.26"E. The brick is a recent production (Fig. 3.26). Sample number in the field: 70. Additives: Short pieces of straw and pieces (up to app. 5 cm) of small branches were detected. For the preparation of adobe bricks in this area, straw was perhaps added due to the high content of clay and swellable clay minerals. Constructive use: Adobe brick.

Fig. 3.26 Basgo. Sample 11952. Sample colour (after Munsell): Dry 10YR 6/2 light brownish grey. Semi-dry 10YR 3/2 very dark greyish brown.

Grain size distribution

The material is obviously a mixture of coarse and fine material. The intention of the producers must have been a wide range of fractions but does not follow the kind of flat roof mixture of the *thetsa* and *dzasa* (which we observed with sample 8465). The distribution of fine and coarse is much more homogenous than found in flat roof sample 8465 or in plaster sample 15410. Biggest fraction: fine gravel. The median is located at app. 31 µm versus 210 µm for flat roof sample 8465; the <2 µm fraction contains app. 19% of the whole sample versus 11% for flat roof sample 8465. The content of clay and silt (together equalling 58%) is relatively high compared to the other samples within this group of building raw materials. Compared to bricks from the Maitreya Lhakhang and the Lotsāba Lhakhang, this mixture is particular with a clear difference in the choice of the raw materials. The following list compares sample 11952 with other samples of this group, and with sample 11948, i.e. the brick sample from the Lotsāba Lhakhang.

	Gravel	Sand	Silt	Clay [%]
11952 (adobe brick)	6.7	35.3	38.7	19.3
15410 (*dzasa*)	53.9	8.7	30.7	6.9
8465 (*dzasa+thetsa*)	12.5	50.8	25.8	10.9
11948 (adobe brick Lotsāba Lk.)	17.2	51.0	21.8	10.0

Grain shapes

The size of the grains is up to 17 mm. The >6,300 μm and >2,000 μm fractions are 'slightly rounded-shaped' and also 'angular-shaped', while the fractions below are dominantly 'angular-shaped'. This change in the shape at around 2,000 μm may be an indication for the addition of coarse material (Fig. 3.27). Regarding the grain shapes, the grain size distribution points to the use of two different kinds of raw material and not a natural mixture. According to the grain shapes, the grain size distribution points to the use of two different kinds of raw material.

Fig. 3.27 Shapes of grains in sample 11952. Scaled in millimetre.
Shape of fraction >2,000 μm (left), >630 μm (centre), >200 μm (right).

Bulk mineral analysis

The BMA clearly shows properties close to those of this group of raw materials. 14Å minerals, mica, hematite and amphiboles occur as traces, while dolomite (app. 1%), 7Å minerals, phyllo silicates, quartz, K-feldspar and plagioclase occur in small amounts (marked in Table 3 with *). The content of calcite was measured at 11%, and no gypsum was traced.

Clay mineral analysis

The CMA shows a scattered content of the clay minerals. In comparison with the other samples of this group of building materials, sample 11952 shows the lowest content of swellable clay minerals. On the other hand, a relatively high content of silt is present. This lower content of swellable minerals may explain why this sample, which has such a high content of clay minerals, does not shrink much or crack. The content of sand and gravel (together 42%) supports this behaviour, which is the aim for adobe brick material.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11952 (adobe brick)	20	0	47	2	31
15410 (*dzasa*)	30	0	32	2	36
15411 (*thetsa*)	38 (smec + verm)		26	0	36
8465 (*dzasa+thetsa*)	18	11	51	4	16

Basgo – clay stove (Tib. *thab*). Sample 11748

Sampling point

Ladakh, Tunlung near Basgo. The pit is located along the slope of a hill at app. 34°14’9.79”N, 77°16’50.22”E. Small digging holes indicate that this place has been known for the collection of raw material (Fig. 3.28). It is said that the proper material can be crumbled between the fingers of one hand. Furthermore, a dark colour indicates higher humidity and by that easier crumbling. At first glance the collected samples seemed to be a kind of stone material. After several attempts, the material crumbled between the fingers into small sandy pieces, giving the impression that it did not contain enough binding material. The right proportion of water is required to reach the state of ‘norm stiffness’ (Ger. *Normsteife*) so that the raw material becomes smoother, and capable of binding and processing. Sample number in the field: 5. Constructive use: Clay for the production of a clay stove (Figs. 3.29 to 3.34).

Fig. 3.28 Tunlung. Sample 11748. Sample colour (after Munsell): Dry10YR 7/6 yellow.
Semi-dry 10YR 5/6 yellowish brown.

Grain size distribution

The material is relatively coarse, with the biggest fraction being coarse and medium gravel. In the grain size graphics, fine and coarse gravel are displayed together in the FG peak. The median is located at app. 650 µm; the <2 µm fraction contains app. 9% of the whole sample. The content of gravel is 31.8% and the content of sand 44.7%. Together at 76.5%, this sample shows a relatively high content of coarse material. This may be relevant for the compensation of the high content of swellable clay to avoid cracks and also for reduced elongation during heating. The maximum peak corresponds clearly to the gravel fraction. The grain size distribution graphics do not show an immediate break or bimodal distribution. Since the material was taken from the pit, the addition of material to this sample can be excluded.

	Gravel	Sand	Silt	Clay [%]	
11748	31.8	44.7	15.6	7.9	(raw material)

Grain shapes

The grain shapes between 200 µm and 6,300 µm are dominantly ‘angular-shaped’ and continuously display the same rounding, thus giving no evidence of mixing.






Fig. 3.29 (Top, left) Ladakh. Basgo. In a Tibetan farmhouse, a *thab* is a social centre of daily life.
Fig. 3.30 (Top, right) Ladakh. Basgo. A *thab* still in use.
Fig. 3.31 (Centre, left) Ladakh. Basgo. Serzang Lhakhang. Broken *thab*.
Fig. 3.32 (Centre, right) Ladakh. Basgo. Serzang Lhakhang. Broken *thab*.
Fig. 3.33 (Bottom, left) Ladakh. Taktok. Former monastery kitchen in a cave with a broken *thab*.
Fig. 3.34 (Bottom, right) Ladakh. Taktok. Former monastery kitchen. Broken *thab*.

Bulk mineral analysis

The sample contains a small amount of 14Å minerals mica, phyllo silicates, quartz, K-feldspar, and plagioclase, and a higher amount of 7Å minerals. Goethite and hematite were found in trace amounts. The stove clay does not contain calcite. The lack of calcite also supports the material's use at higher temperatures, similar to *thabsa* samples 11748, 15412 and 11919. Contrarily, pottery clay samples 15515 and 11752, i.e. also for use at higher temperatures, contain calcite. No gypsum could be traced, contradicting use at high temperatures, similar to samples 15412 and 11919, which are also used for stove production. The colours are outside the investigated range of Basgo samples, since they are relatively yellowish, and in a dry and also a semi-dry state. The X-ray diffraction shows a clear peak at 17.8° (2θ).

Results measured with STA
- A peak at 301°C points towards the content of goethite.
- A peak at 537°C points towards a dehydroxilation of kaolinite.
- The residual mass at 1,000°C is 92.44%.

Clay mineral analysis

The CMA shows a scattered content of clay minerals with a relatively high content of kaolinite and swellable clay minerals (smectite and in particular vermiculite at 42% of the clay fraction). It generally does not show similarity to the Basgo samples, with an exception being the other *thabsa* samples. The high content of kaolinite is a factor for increasing resistance against the high temperature that occurs when firing a stove. Chlorite is missing. The high content of smectite and vermiculite in combination with kaolinite shows a technical conflict regarding heat resistance. While smectite and vermiculite enable swelling, kaolinite supports a form of stability. A content of well-crystalised kaolinite is found in this sample.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11748 (*thabsa*)	11	42	10	37	0

Basgo – clay stove (*thab*). Sample 15412

Sampling point

Ladakh, Tunlung near Basgo. The pit is located along the slope of a hill at app. 34°14'9.79"N, 77°16'50.22"E (Fig. 3.35). Small digging holes along the road indicate that this place has been known as a location for collecting raw material. The material is similar to sample 11748, which was taken about one metre to the side. Sample number in the field: 76 BA/LG. Constructive use: Clay for the production of an oven. Its use for roofs is problematic, since it becomes a clayey mass when getting in contact with water, although it is mentioned as a material for making floors (Feiglstorfer 2014: 372).

Fig. 3.35 Tunlung. Sample 15412.
Sample colour (after Munsell):
Dry 10YR 7/6 yellow.
Semi-dry 10YR 5/6 yellowish brown.

Grain size distribution

The material is relatively coarse, with the biggest fraction being medium and fine gravel. The median is located at app. 180 µm, much lower than for sample 11748; the <2 µm fraction contains app. 14% of the whole sample. In general this material has a higher content of fine material than sample 11748. The content of gravel is 23.7%, and the content of sand 39.6%. In combination giving 63.3%, the material is relatively coarse. This may be relevant for the compensation of the high content of swellable clay to avoid cracks and also to reduce elongation during heating. The maximum peak corresponds to the gravel fraction. The grain size distribution graphics do not show an immediate break or bimodal distribution. Since the material was taken directly from the pit, the addition of material in this sample can be excluded.

	Gravel	Sand	Silt	Clay [%]
15412 (*thabsa*)	23.7%	39.5%	22.8%	13.9% (raw material)
11748 (*thabsa*)	31.8%	44.7%	15.6%	7.9% (raw material)

Bulk mineral analysis

The sample, which is very similar to sample 11748, contains a small amount of 14Å minerals, mica, 7Å minerals, phyllo silicates, quartz, plagioclase and K-feldspar, and no calcite or gypsum. The colours are outside the investigated range of Basgo samples, since they are relatively yellowish in a dry and also semi-dry state. The BMA shows a clear peak of 17.8° (2θ) and the STA shows a peak of 302°C. The content of a goethite could be proven.

Results measured with STA (Fig. 3.36)

- A peak at 302°C points towards the content of goethite.
- A peak at 526°C points towards a dehydroxilation of kaolinite.
- The residual mass at 1,000°C is 93.3%.

Clay mineral analysis

The CMA shows a scattered content of clay minerals with a relatively high content of kaolinite and swellable clay minerals, i.e. smectite and in particular vermiculite at 42%. It does not show similarity to the Basgo samples in general. In the stove clay samples, chlorite is missing. The CMA of this sample along with the content of swellable clay minerals is similar to sample 15412.

Kaolinite could be identified as well-crystallised in the CMA and the IRS. Morever, with the IRS analysis, several other minerals, such as smectite and quartz, were proven (see Fig. IRS 3.1 in the Appendix of Chapter III).

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
15412 (*thabsa*)	20	28	19	33	0
11748 (*thabsa*)	11	42	10	37	0

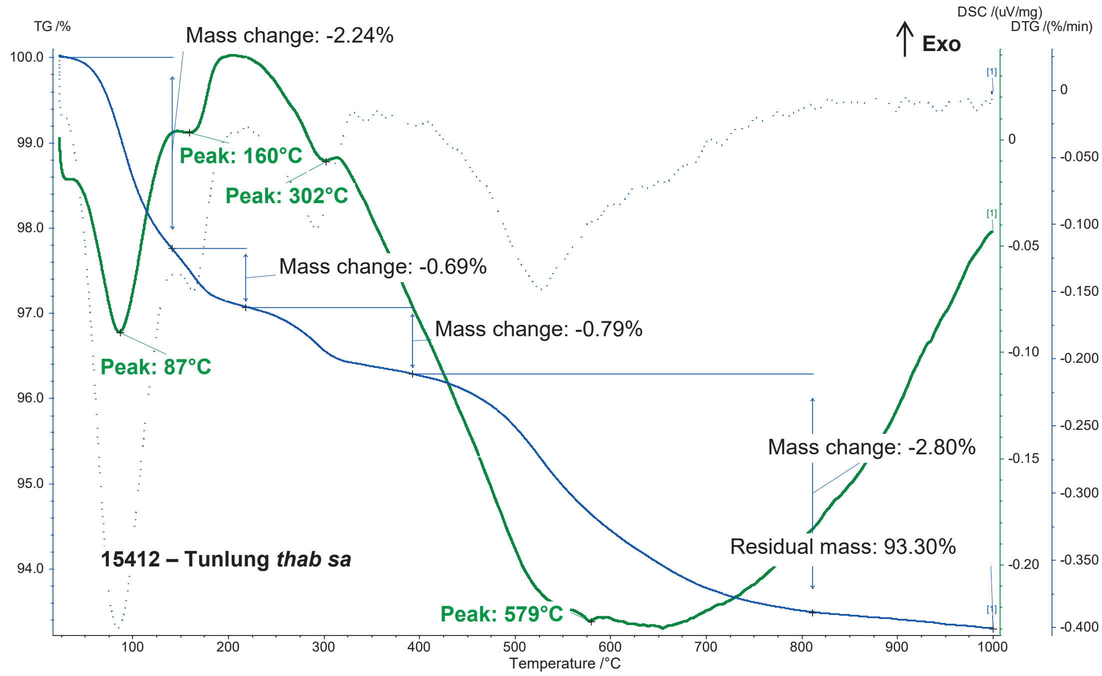


Fig. 3.36 Tunlung. Sample 15412. STA showing a content of goethite.

Basgo – clay stove. Sample 11919

Sampling point

Ladakh, Ne (34°16'39.44"N, 77°17'57.91"E) located about 7 km north of Basgo. The material was collected at the foot of the 'temple hill' opposite the village of Ne (Fig. 3.37). Tsewang Norbu, a stove maker from Ne, collected the material and spoke of it as a better processable material than the material collected for samples 11748 and 15412. He also explained the procedure of making a stove from this material.[91] Sample number in the field: 32. Constructive use: Clay stove.

Grain size distribution

The material is relatively coarse, with the biggest fraction being fine gravel. The median is located at app. 380 µm; the <2 µm fraction contains app. 10% of the whole sample. The content of gravel is 21.2% and the content of sand is 44.1%, which together at 65.3% show a relatively high content

91 A detailed documentation of the method for preparation of a clay stove is given in Feiglstorfer 2014: 383–386.

Fig. 3.37 Tunlung. Sample 11919.
Sample colour (after Munsell):
Dry 10YR 8/1 white.
Semi-dry 10YR 8/2 very pale brown.

of coarse material. This may be relevant for the compensation of the high content of swellable clay to avoid cracks and also for reduced elongation during heating. The peak clearly corresponds to the gravel fraction. The grain size distribution graphics do not show an immediate break or a bimodal distribution. Since the material was taken directly from the pit, the addition of material in this sample can be excluded. Generally speaking, this material is much more similar to sample 11748 than it is to samples 11748 and 15412, although the latter two were collected close to one another and look very similar to each other. Grain shapes between the 200 µm and 6,300 µm fractions are dominantly 'angular-shaped', giving no evidence of a mixture.

	Gravel	Sand	Silt	Clay [%]	
11919 (Ne)	21.2	44.1	24.3	10.3	(raw material)
11748 (Tunlung)	31.8	44.7	15.6	7.9	(raw material)
15412 (Tunlung)	23.7	39.5	22.8	13.9	(raw material)

Bulk mineral analysis

The sample differs from samples 11748 and 15412 in that the mica is only available in trace amounts. Furthermore, the content of K-feldspar is much higher in sample 11919 (marked in Table 3 with ***). Compared to most of the other Basgo-Likir samples, but unlike stove samples 11748 and 15412, the stove clay contains traces of calcite, measured at 3%. Like stove samples 11748 and 15412, this sample does not contain gypsum. Besides proving the content of well-crystallised kaolinite, several other minerals such as smectite and quartz could be determined. The colours are outside the investigated range of Basgo samples and also differ from the two other stove samples in that they are much brighter. A slight content of hematite may be responsible for some reddish spots within the sample.

Results measured with STA

- A peak at 526°C points towards a dehydroxilation of kaolinite.
- The residual mass at 1,000°C is 95.1%.

Clay mineral analysis

The scattered content of clay minerals is similar to stove samples 11748 and 15412. At 57%, the content of swellable clay minerals is the highest compared to samples 11748 and 15412. The kaolinite could be identified as well-crystallised in the CMA, and was also recognised with the IRS (see Fig. IRS 3.2 in the Appendix Chapter III). It is significant to note that the content of chlorite in the oven material is also 0%.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11919 (Ne)	38	19	7	36	0
11748 (Tunlung)	11	42	10	37	0
15412 (Tunlung)	20	28	19	33	0

Basgo / Likir – stove and pottery clay. Sample 15515

Sampling point

Ladakh, Basgo, collected at two small caves of an app. size of 2 x 2 x 1 m (L/B/H). These caves are located at the foot of the temple hill with the monastery and palace on top, just beside Highway NH1D, on the left side when moving towards Leh. The surface of the cave walls was dark, shiny and showed traces of recent digging. Apparently this material (Fig. 3.38) is still collected for its special qualities. It can be dug in layers by breaking the layers by hand. Sample number in the field: 81 BA/LG. Constructive use: This clay is known as *thabsa*. After ramming and compressing, water is added. Thereafter it is said to have the characteristic of 'stone'-like hardness. It is different to sample 15412 from Tunlung, which is also known for its use for making floors. According to the potters from Likir, this material is used for the production of *tandoor* stoves. It is simply made by covering the inside of metal barrels.

Fig. 3.38 Basgo. Sample 15515.
Sample colour (after Munsell):
Dry 10YR 8/1 white.
Semi-dry 10YR 8/2 very pale brown.

Grain size distribution

Compared with the *thabsa* (samples 11748, 15412, and 11919), the material is much finer with nearly no sand and gravel and a much higher content of silt and clay. The biggest fraction is medium sand (not including the 0.6% amount of only coarse sand). The median is located at app.

2.5 µm; the <2 µm fraction contains app. 42% of the whole sample. The content of gravel is 0.1% and the content of sand is 3.2%. Together equalling 3.3%, the sample shows a very small content of coarse material (fine gravel and sand) versus a very high content of fine material (silt and clay) at 96.7%. This may be relevant for the processing of the material with the aim to create a fine layer important for its later use in the construction of a stove. On the other hand, to avoid shrinkage, a relatively high content of silt (54.5%) is available. At 42.9%, the maximum peak clearly corresponds to the fine silt fraction. The grain size distribution graphics do not show an immediate break or bimodal distribution. Since the material was taken directly from the pit, an addition of material in this sample can be excluded.

	Gravel	Sand	Silt	Clay [%]
15515	0.1	3.2	54.5	42.2 (raw material)

Bulk mineral analysis

In general the sample shows similarities to the appearance of most of the samples in this region. There is no content of amphiboles and K-feldspar, and only traces of 14Å minerals. Mica, 7Å minerals, phyllo silicates, quartz and plagioclase occur in small amounts (marked in Table 3 with *) and dolomite makes up 2%. The content of calcite was measured at 4% (as shown in Table 3). This value is lower than the average content of calcite measured in this region. No gypsum could be traced. A content of hematite gives this sample a reddish appearance.

Clay mineral analysis

The CMA of this sample shows a less scattered content of clay minerals as observed in most other Basgo-Likir samples, and no swellable clay minerals (smectite or vermiculite) can be traced. This points towards the quality of remaining free of cracks when firing. The content of chlorite is the highest for the Basgo-Likir samples, and differs from *thabsa* samples 11748, 11919 and 15412 from Tunlung and Ne, which show no content of chlorite. On the other hand, kaolinite cannot be traced, which is different to the *thabsa* samples with a content of kaolinite between 12% and 57%. All three samples used for pottery or the interior panelling of *tandoor* stoves show a content of corrensite, which is a mixed layer mineral of chlorite and smectite, and a marker for these samples. At app. 3°θ the curve shows a small peak. This peak is a result of the widening (swelling) due to the swellable content, which shifted from the chlorite peak at app. 6°θ in a left direction.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
15515 (Basgo cave)	0	0	31	0	69
11748 (Tunlung)	11	42	10	37	0
11919 (Ne)	38	19	7	36	0

Basgo / Likir – stove and pottery clay. Sample 11751

Sampling point

Ladakh, Likir Village is located at 34°15'56.20"N, 77°11'53.88"E. This material (Fig. 3.39) is locally known as *thabsa* (oven clay) under the local term *dzasa* (Tib. *rdza sa*), also pronounced as 'sesa' or 'sersa'. Sample number in the field: 31. Constructive use: A potter family from Likir[92] showed the different kinds of clay and explained their particular uses. It was explained as material to make a *thab* (Tibetan stove), meant for interior panelling of *tandoor* stoves. Contrary to sample 11752, this material is mixed with coarse material and appears to be ready for application. The used clay has to fulfil several tasks such as resistance to heat, more or less no shrinkage, no cracking, and no addition of fibres or other organic materials.

Fig. 3.39 Basgo. Sample 11751.
Sample colour (after Munsell):
Dry 10YR 7/2 light grey.
Semi-dry 10YR 6/3 pale brown.

Grain size distribution

Compared with *thabsa* sample 15515, the material is also very fine with just a small amount of sand and gravel, and a high content of silt and clay; biggest fraction: fine gravel. The median is located at app. 3 µm, similar to sample 15515 with app. 2.5 µm; the <2 µm fraction contains app. 38% of the whole sample, similar to sample 15515 with app. 42%. The content of gravel is 1.8%, and the content of sand is 13.2%. Equalling 15%, the sample shows a small content of coarse material (fine gravel and sand), but this content is still higher than sample 15515 with 3.3%. This may be relevant for the processing of the material with the aim to create a fine layer important for its later use for stove construction. On the other hand, to avoid shrinkage, a relatively high content of silt of 46% is available. The maximum peak again clearly corresponds to the fine silt fraction with 31% versus 42.9% at sample 15515. The grain size distribution graphics show a bimodal distribution with a valley between medium sand and medium silt, which may point towards the addition of sand.

92 The house name of the potter family is Langdopa. The interview with the potter Rigzen Wangyal, his brother Rigzen Angdu and their mother, and Tsering Norbu was held in August 2011 and interpreted by Sonam Wangchuk (cf. Feiglstorfer 2014).

	Gravel	Sand	Silt	Clay [%]	
11751 (*dzasa,* Likir)	1.8	13.2	46	39	(mixed material)
15515 (*thabsa*, Basgo)	0.1	3.2	54.5	42.2	(raw material)

Grain shapes

The examination of the grain shape shows a continuous change of the dominant rounding from 'angular-shaped' and a 'beginning rounding' in fractions >2,000 µm, 'angular' with a slight tendency towards 'beginning rounding' in fractions >630 µm, and 'angular-shaped' in fractions >200 µm. This fact emphasises the addition of sand to the raw material, probably to avoid cracks after drying and during heating (Fig. 3.40).

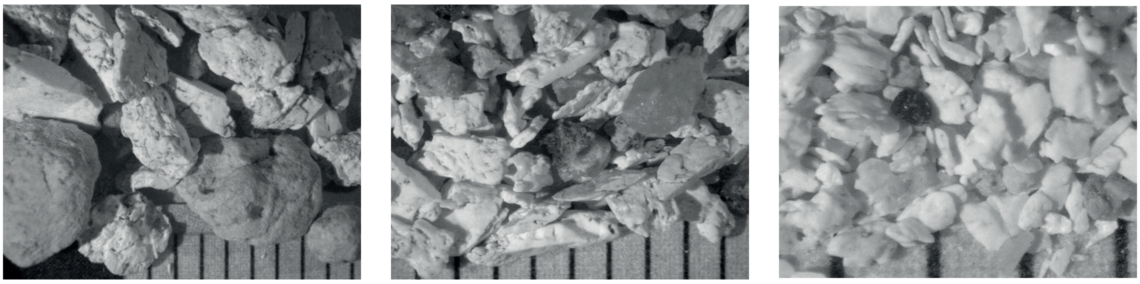


Fig. 3.40 Shapes of grains in sample 11751. Scaled in millimetre (B/W).
Shape of fraction >2,000 µm (left), >630 µm (centre), >200 µm (right).

Bulk mineral analysis

In general the sample is very similar to *thabsa* sample 15515. Only the 7Å minerals and mica are available in trace amounts, as opposed to the small amount found for sample 15515. The amount of calcite was measured at 12%. The sample has a rather greyish appearance without any traces of a red colouring ferric oxide. The content of gypsum at 12% is rather high and not suitable for the use as a stove or for pottery ware. This relatively large amount does not fit into the picture of clay used for continuous heating (as is the case with a stove). At temperatures of about 100°C to 110°C, gypsum changes into a hemihydrate, and at a temperature of about 200°C, it changes into an anhydrite. When cooling down, humidity is absorbed and recrystallisation occurs.

Either the explanation given to the author about this material was not correct or the collected sample contained some gypsum or was contaminated with gypsum. Since the other material parameters seem to fit to clay used for pottery or stoves, an unwanted collection of a gypsum contaminated material seems obvious. In consideration of this finding, further analysis of this sample is needed. The collection of a new comparable sample from Likir is necessary to verify this examination.

Results measured with STA
· Peaks at 138°C and 145°C point towards the presence of gypsum, measured at 12%.
· The residual mass at 1,000°C is 86.09%.

Clay mineral analysis

The CMA shows a less scattered content of clay minerals as observed in most other Basgo-Likir samples, and generally shows similarities to the two other pottery and *thabsa* samples, i.e. 15515 and 11752: Swellable clay minerals and kaolinite are not present, but a big amount of chlorite was determined.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11751 (Likir *dzasa*)	0	0	43	0	57
15515 (Basgo *thabsa*)	0	0	31	0	69

Basgo / Likir – stove and pottery clay. Sample 11752

Sampling point

Ladakh, Likir Village, located at 34°15'56.20"N, 77°11'53.88"E. This material (Fig. 3.41) is locally known as pottery clay under the local term *dzasa* (Tib. *rdza sa*). Contrary to sample 11751, this is an unmixed raw material. Sample number in the field: 26. Constructive use: Clay used for pottery and for the production of a *thab*.

Fig. 3.41 Likir. Sample 11752.
Sample colour (after Munsell):
Dry 10YR 5/1 grey.
Semi-dry 10YR 4/1 dark grey.

Grain size distribution

Compared with *thabsa* sample 15515, the material is also very fine with just a small amount of sand and gravel, and a high content of silt and clay; biggest fraction: medium sand. The median is located at app. 2.8 µm, similar to sample 15515 with app. 2.5 µm, and sample 11751 with 3 µm; the <2 µm fraction contains app. 38% of the whole sample, similar to sample 15515 with app. 42%, and to sample 11751 with app. 38%. In this sample gravel is not present and only 0.2% of sand versus sample 11751 with a content of gravel at 1.8% and a content of sand at 13.2%. At 0.2% the total amount of coarse material is very low versus 15% for sample 11751. Again a relatively high content of silt at 60.3% is present compared to 46% for sample 11751, and 54.5% for sample 15515. The maximum peak again corresponds to the fine silt fraction at 36.3%, compared to 31% for sample 11751, and 42.9% for sample 15515. The grain size distribution graphics show no valley as in sample 11751. Since the material was taken directly from the pit, the addition of material in this sample can be excluded. According to the results of the grain size analysis, pottery clay sample 11752 seems to be equal to pottery clay sample 11751 but without the addition of sand.

	Gravel	Sand	Silt	Clay [%]
11752 (*dzasa, Likir*)	0	0.2	60.3	39.5 (raw material)
15515 (*thabsa*, Basgo)	0.1	3.2	54.5	42.2 (raw material)
11751 (*dzasa, Likir*)	1.8	13.2	46	39 (mixed material)

Grain shapes

Grain shapes between 2,000 µm and 200 µm are dominantly ‘angular-shaped’ and continuously have the same rounding, indicating no evidence of a mixture.

Bulk mineral analysis

The results of the BMA are more or less the same as for pottery clay sample 11751. Just the gypsum is missing, which may emphasise the afore-mentioned hypothesis that sample 11751 may have been contaminated with gypsum and was originally similar to sample 11752, i.e. without a content of gypsum. The content of calcite was measured at 8% and a content of dolomite at 2%, as shown in Table 3. A content of hematite gives this sample a reddish appearance.

Clay mineral analysis

The CMA shows again close similarity between sample 11752 and sample 11751. Within the Basgo-Likir samples, two further samples, i.e. 11948 (adobe brick from the Lotsāba Lhakhang in Basgo) and 11952 (new brick from Basgo), show similarities to sample 11752. Such similarities are a corrensite mixed layer, no vermiculite and a strongly marked chlorite.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11752 (Likir *dzasa*)	0	0	38	0	62
15515 (Basgo *thabsa*)	0	0	31	0	69
11751 (Likir *dzasa*)	0	0	43	0	57

In consideration of the fact that these samples are too coarse, such similarities can also lead to the assumption that samples 11948 and 11952 (both samples used for adobe bricks, in short mentioned as AB) are useful as pottery clay in the case that the fine material can be separated.

11952 (AB Basgo)	20	0	47	2	31
11948 (AB Lotsāba Lk.)	28	0	44	2	27

After analysis, we can state that sample 11752 and 11751, both of which are used for pottery, are very similar, with the difference being that the latter was mixed with a small amount of sand (13.2%) for stabilisation purposes.

Likir – clay pit and adobe brick. Sample 11763

Sampling point

Ladakh, Likir Village, the pit is located at app. 34°15’28.53”N, 77°12’31.30”E. At the entrance to the village, a clay pit was dug for the primary use of collecting water and not for the collection of raw material. Since this water hole enabled access to material from the area of the ground water, a sample was taken and examined (Fig. 3.42). Sample number in the field: 27.

Fig. 3.42 Likir. Sample 11763.
Sample colour (after Munsell):
Dry 7.5YR 5/1 grey.
Semi-dry 2.5YR 2.5/1 black.

Grain size distribution

The material is relatively coarse, with the biggest fraction being fine gravel. The median is located at app. 130 µm; the <2 µm fraction contains app. 14% of the whole sample. At 60.9%, the total amount of coarse material (gravel and sand) is relatively high. At 22.7%, the maximum peak again corresponds to the medium sand fraction. The grain size distribution graphics show no valley or sharp break. In regard to this grain size distribution, one cannot assume addition of coarse material. A comparison with the samples of the Basgo-Likir group is given below. The results show a close similarity to mixture 8465 from Basgo which was used for making the flat earth roof on the Maitreya Lhakhang.

	Gravel	Sand	Silt	Clay [%]
11763 (Likir clay)	7.1	53.7	25.5	13.7
8465 (*dzasa*+*thetsa*)	12.5	50.8	25.8	10.9

Grain shapes

The grain shapes were examined as ‘very angular’ and do not give any evidence of a mixture of different materials.

Bulk mineral analysis

The results of the BMA fit into the general appearance of clay in the Basgo-Likir region. Compared with sample 8465 (*dzasa* + *thetsa*: flat roof material from Basgo), which shows similarities in grain size distribution (see analysis before), there are only slight differences in the missing of 14Å minerals or in the slightly less availability of 7Å minerals and phyllo silicates. The content of calcite was measured at 8%, as shown in Table 3; gypsum and dolomite are not present. The sample material is relatively dark, particularly already appearing almost black in the semi-dry constitution, a possible indicator of organic content.

Clay mineral analysis

The CMA shows with 6% a relatively low content of swellable clay minerals but it stands out with a relatively high amount of illite. The list given below again shows a comparison with samples of the Basgo-Likir group. The sample has with 63% (!) a significantly high amount of illite, some chlorite and kaolinite, and a small amount of smectite.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11763 (Likir clay)	6	0	64	14	16
8465 (*dzasa+thetsa*)	18	11	51	4	16

Likir – clay pit and adobe brick. Sample 11921

Sampling point

Ladakh, Likir Village, the pit is located some metres beside the water whole, from where sample 11763 was taken at app. 34°15'28.53"N, 77°12'31.30"E (Fig. 3.43). Beside this clay pit, adobe bricks, which were processed from this material, are stacked. Sample number in the field: 28. Constructive use: Raw material for adobe bricks.

Fig. 3.43 Likir. Sample 11921.
Sample colour (after Munsell):
Dry 7.5YR 7/3 pink.
Semi-dry 7.5YR 5/3 brown.

Grain size distribution

The material is relatively fine, with the biggest fraction being fine gravel. The median is located at app. 8.5 µm versus app.130 µm for sample 11763; the <2 µm fraction contains app. 29% of the whole sample versus 14% for sample 11763. At 10.6%, the total amount of coarse material (gravel and sand) is relatively low versus 60.9% for sample 11763. At 27.3%, the maximum peak corresponds to the coarse silt fraction. The grain size distribution graphics show a bimodal distribution. The addition of coarse material can be excluded regarding this material as raw material taken from the pit. The raw material seems to be rather fine for the preparation of adobe bricks, which must be the reason for its later mixture with sand.

	Gravel	Sand	Silt	Clay [%]
11921 (Likir clay pit)	0.5	10.1	60.3	29.1
11763 (Likir clay)	7.1	53.7	25.5	13.7

Grain shapes

With 'very angular' shapes, the grain shape follows the result observed for sample 11763, giving no evidence for a mixture.

Bulk mineral analysis

The results of the BMA fit into the general appearance of clay of the Basgo-Likir samples. Compared with sample 11763 (adobe brick from Likir), the appearance is similar, although some differences can be traced: 14Å minerals appear as traces, phyllo silicates appear in small amounts instead of traces, and plagioclase appears in a smaller but still high amount when evaluated against sample 11763. Compared with sample 11763, calcite is not present.

Clay mineral analysis

The CMA shows a much higher content of swellable clay minerals (smectite with just 35%) than found in sample 11763 from Likir. Significant for this sample is a clear amount of illite, no vermiculite, a small amount of kaolinite, and chlorite of a subordinate amount.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11921 (Likir clay pit)	35	0	49	6	10
11763 (Likir clay)	6	0	63	14	16
11752 (Likir *dzasa*)	0	0	38	0	62

In comparison with another type of clay from Likir (sample11752) known as *dzasa* (pottery clay), sample 11921 shows much more smectite, much less chlorite, more illite and a coarser grain size distribution as shown in a juxtaposition of the grain sizes and CMA of both samples.

· 11921 (GSD) The median is located at app. 8.5 µm; the <2 µm fraction contains app. 29%.
· 11752 (GSD) The median is located at app. 2.8 µm; the <2 µm fraction contains app. 38%.

Likir – sand. Sample 11749

Sampling point

Ladakh, Likir Village, located at 34°15'56.20"N, 77°11'53.88"E. This type of sand (Tib. *bye ma*) can be found close to the pits for *thabsa* sample 11752 (Fig. 3.44).[93] It is locally known as sand for mixing with pottery clay for adobe bricks. For these mixtures not just any sand is used; instead this sand in particular is preferred. Sample number in the field: 23. Constructive use*:* Sand for mixing for pottery ware, and sand to be mixed with clay for adobe bricks.

Grain size distribution

As 'sand', the material is dominated by medium and fine sand, with the total amount being 74.3%. However, a small amount of silt and clay is also present. The median is located at app. 150 µm; the <2 µm fraction contains app. 7% of the whole sample. At 0.6%, the amount of gravel is very low. The peak corresponds to the fine sand fraction. Compared with *thabsa* sample 11752, with which it is originally mixed on site, and *thabsa* sample 15515, with which it is mixed for the test within this study (see below), these comparative samples are also relatively fine with just a small content of sand and gravel and a high content of silt and clay. Both samples 11752 and 15515 show their biggest fraction as being medium sand and their smallest fraction also as fine clay. In this relation, the sand (sample 11749) seems to be an appropriate complementation.

93 The sample's origin is described in Feiglstorfer 2014: 369.

Fig. 3.44 Likir. Sample 11749.
Sample colour (after Munsell):
Dry 5YR 5/3 and 5YR 6/3 olive and pale olive.
Semi-dry 5YR 6/3 pale olive.

	Gravel	Sand	Silt	Clay [%]
11749 (Likir sand)	0.6	78.5	14.8	6.1

Grain shapes

The grain shapes were examined as 'angular' and do not give any evidence for a mixture of different materials.

Bulk and clay mineral analysis

The results of the BMA show traces of mica, small amounts of quartz and K-feldspar (marked in Table 3 with *), and medium amounts of amphiboles and plagioclase (marked in the list with **). Results of the BMA and of the CMA show close similarities to the clay collected from the water hole.

The clay mineral analysis shows a small amount of swellable clay minerals, which influence the behaviour of the mixture. This may be the reason why potters from Likir prefer this sand. It may also be the suitable material for preparation of a clay plaster. The content of smectite indicates this material being of a rather young genesis. At 4%, the content of kaolinite is relatively small. The content of illite points towards an older material as opposed to young material, which was probably crunched during the Ice Age.

	Smectite	Verm18°	Illite	Kaolinite	Chlorite [%]
11749 (Likir sand)	4	0	66	4	26
11763 (Likir clay)	6	0	63	14	16

The trace content of calcite may give an answer to the continuously recurring question of whether calcite was added by humans or if it was an already naturally given component. To get closer to an answer, an observation of calcite as anthropogenically added or naturally mixed is conducted in the following.

4. Additional examinations of selected examples

4.1 Behaviour of stove material during heat treatment

Tandoor stoves are widely known throughout the Asian continent. Heat is produced with wood or charcoal and reaches temperatures of up to 600°C−800°C (Katz, Weaver 2003: 254). Temperatures for preparing meat and bread (e.g. Indian *nan* or *chapatti*) must be much lower. Om Gupta (2006: 2393) describes the heat used for firing a clay stove being at a temperature of up to 480°C. Since the temperature has to be kept for an extended period of cooking, a long lasting heat resistance is important. Essential is the heat, not the flames, the latter of which should be avoided as much as possible. Also the design and material of *tandoor* stoves differ widely. *Tandoor* stoves are popular among members of the Indian army based in Ladakh.[94] The given form is that of a cylindrical oil barrel with the inside coated with clay. According to local saying, before processing of the clay, it is mixed with fine sand at a ratio of app. 1:2 (Feiglstorfer 2014: 370).

For a traditional *tandoor* stove, the fire is made through a bottom hole. The food for cooking is put into the oven from the top. A traditional *tandoor* stove made of clay is also widely known. In Punjub (e.g.) the tradition of using clay stoves is still vivid, and the same can be said for the Lower Himalayas, e.g. in the area of Manali. Since the practice of preparing *tandoor* stoves in metal barrels is relatively young, the *tandoor* made from an oil barrel can be explained as a composite development of the *tandoor* tradition from other areas of India – possibly transferred to Ladakh by soldiers – and the old Ladakh stoves tradition of working with heat resistant clays (*thabsa*).

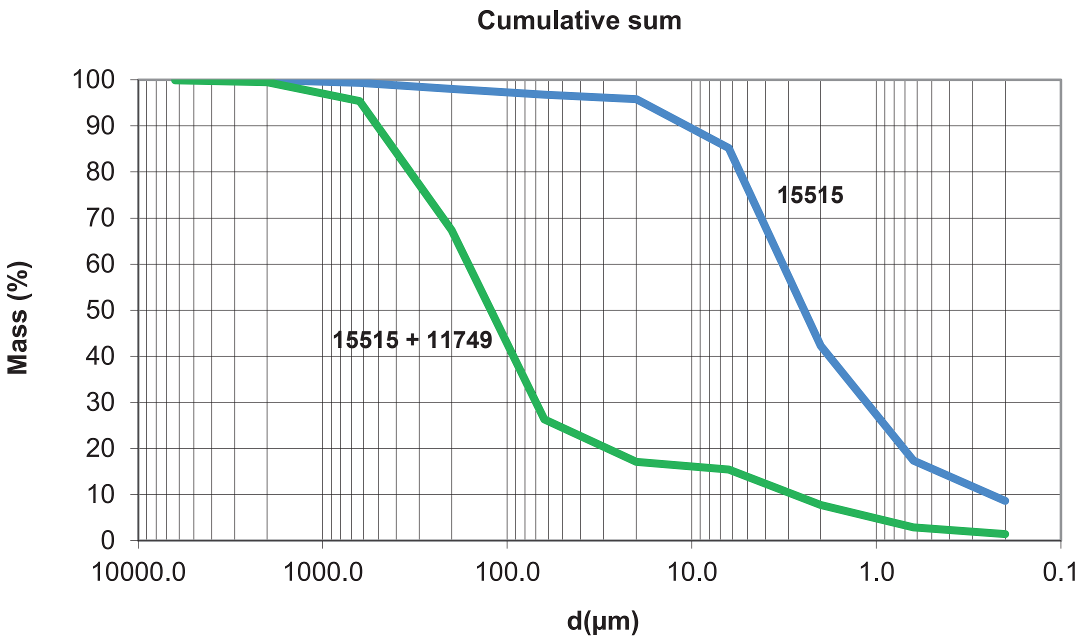
For sample 11751, we find a *tandoor* stove clay mixture with material properties that appear similar to sample 15515 but with a slightly higher content of sand. Since the use of sample 11751 was only uncovered from interviews with locals and not seen when mixed or further processed, the following examinations should provide an insight into the material's shrinking behaviour at different temperatures, i.e. 240°C, 480°C, 600°C and 950°C.[95] For further comparison, the tests will be conducted with two different kinds of stove material (*thabsa*):

· With the raw material of sample 15412 from Tunlung near Basgo (see mineral analysis).
· With the raw material of sample 15515 from Basgo (see mineral analysis).
· With a mixture of the raw material (sample 15515) and the fine sand of Likir – which is known as material for mixing for the preparation of clay for an oven or for pottery ware and which was locally used to prepare sample 11751 – we receive the finally processable material from Likir.

In order to find the right proportion in the addition of sand from Likir (sample 11749) so that we achieve a *dzasa* mixture similar to sample 11751, the following experiment was conducted.

94 The use of a particular clay for coating the inside of an oil barrel was described by locals, and raw material for that purpose was given to the author by the potter's family from Likir.

95 240°C was chosen as average cooking temperature, which ranges in a clay stove between 200°C and 240°C. 480°C was chosen as the temperature described by Om Gupta (2006) for a clay oven. 600°C was mentioned by Katz and Weaver (2003) as a temperature reached with coal and charcoal. 950°C is the temperature at which sintering begins.



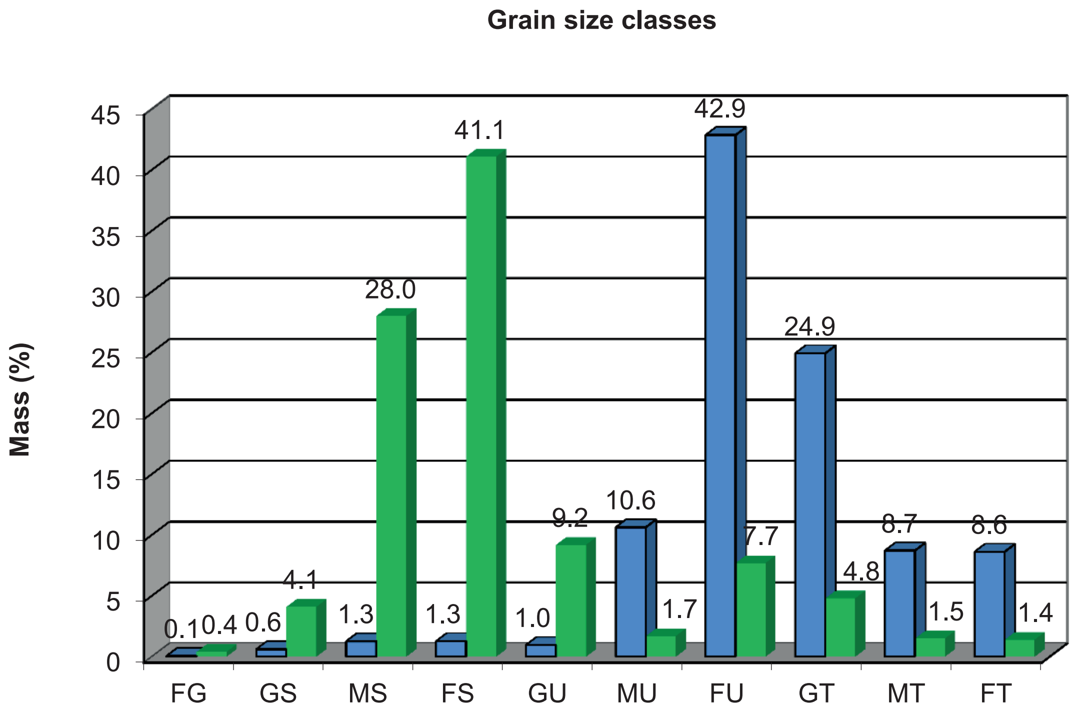


Fig. 3.45 *Tandoor* stove clay: Sample 15515 (raw material; blue colour) in comparison to a mixture with sample 11749 (sand; green colour).

Comparing the grain size distributions between samples 15515 and 11751, the main difference is in the fractions sand and gravel (see Appendix Chapter III). The calculation shows effects on the whole mixture by changing the ratio of these two fractions.

	Gravel	Sand	Silt	Clay	[%]
15515 (*thabsa*, Basgo)	0.1	3.2	54.5	42.2	(raw material)
11749 (sand, Likir)	0.6	78.5	14.8	6.1	(raw material)
11751 (*dzasa, Likir*)	1.8	13.2	46	39	(mixed material)

Content of grain sizes ≥ (sand and gravel), same as > coarse silt (in Fig. 3.45 marked with GU):
· Sample 15515 contains app. 3.3%.
· Sample 11749 contains app. 79.1%.
· Sample 11751 contains app. 15%.

About 12% of the total mass of the whole sample with a grain size > GU has to be added to sample 15515 to achieve a mixture with a grain size distribution in the fractions > GU, similar to sample 11751. As a first attempt, estimated 15% of the total mass of the fractions > GU of sample 15515 were taken from Likir sand sample 11749 and added to sample 15515. The resulting grain size distribution as given in Fig. 3.45 shows a considerable increase of sand, on the one hand, and of silt and clay, on the other hand: The amount of sand in sample 15515 mixed with sample 11749 rises up to 73.6%, which is close to sample 11749 with 78.5%, while the content of silt decreases from 54.5% (in sample 15515) to 27.5% (in the mixture) and the content of clay from 42.2% to 7.7%, respectively. A comparison with the *dzasa* (i.e. sample 11751) shows that the addition of 15% of the total mass of the fractions > GU of sample 15515 was too much and needs to be reduced to receive a proper mixture, which is equivalent to the *dzasa* from Likir.

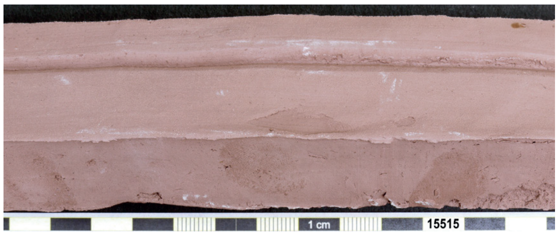
The following juxtaposition shows the different shrinkage behaviour for three selected samples, i.e. 15412 (*thabsa* / Tunlung), 15515 (*thabsa* / Basgo) and 15515 + 11751 (*thabsa* / Basgo + sand / Likir as shown in Fig. 3.45). Figs. 3.46 to 3.55 show a juxtaposition of the visual appearance of samples 15412 (*thabsa* / Tunlung) and 15515 (*thabsa* / Basgo) after firing. In the following table, columns marked with Dry* give the values for drying shrinkage, and those marked with °C give the values for firing shrinkage.

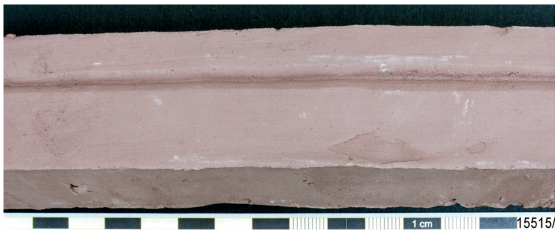
Shrinkage; change of the length of the samples [cm]:

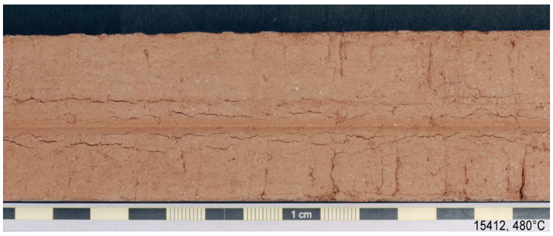
	Wet	Dry*	240°C	480°C	600°C	900°C
15412	20	19.50	19.50	19.45	19.45	19.45
15515	20	18.10	18.10	18.07	18.00	17.65
15515+sand	20	18.30	18.30	18.30	18.30	18.05

Shrinkage [%]

	Dry*	240°C	480°C	600°C	900°C
15412	2.50	2.50	2.75	2.75	2.75
15515	9.5	9.5	9.65	10.0	11.75
15515+sand	8.5	8.5	8.5	8.50	9.75







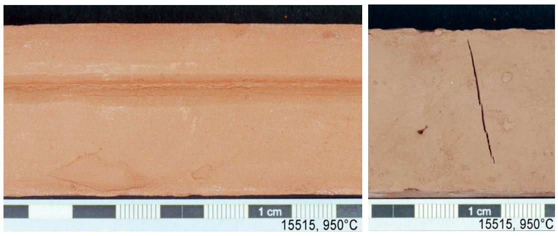


Fig. 3.46 (Top left) 15412. Unfired.
Fig. 3.48 (Second left) 15412. Fired at 240°C.
Fig. 3.50 (Third left) 15412. Fired at 480°C.
Fig. 3.52 (Fourth left) 15412. Fired at 600°C.
Fig. 3.54 (Bottom left) 15412. Fired at 950°C.

Fig. 3.47 (Top right) 15515. Unfired.
Fig. 3.49 (Second right) 15515. Fired at 240°C.
Fig. 3.51 (Third right) 15515. Fired at 480°C.
Fig. 3.53 (Fourth right) 15515. Fired at 600°C.
Fig. 3.55 (Bottom centre / right) 15515. Fired at 950°C:
Front side of the sample (centre) / back side of the sample (right).

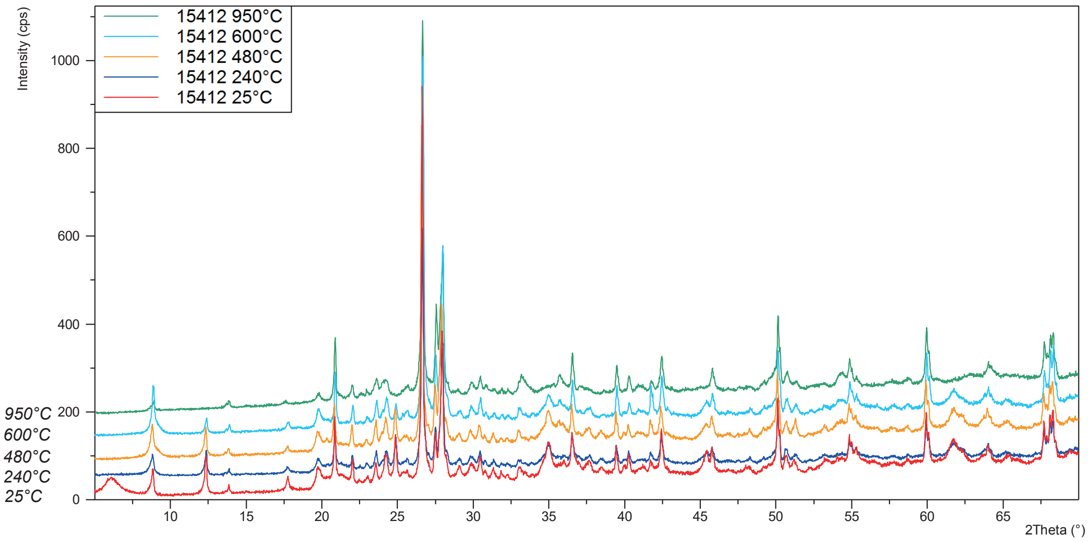
4.1.1 Analysis of the shrinkage

- Sample 15412 (*thabsa* / Tunlung) shows the ideal behaviour after three days of drying and then firing. Shrinkage after drying is 2.5% and remains nearly the same (2.75%) until the end of firing when temperatures reach 900°C. Regarding shrinkage behaviour, this material from Tunlung is ideal for making a stove.
- Sample 15515 (*thabsa* / Basgo) shows shrinkage of 9.5% after three days of drying, while the addition of sand reduces the shrinkage to 8.5%. After firing at 900°C, shrinkage is 11.75%, while the addition of sand reduces this shrinkage to 9.75%. During the different steps and after three days of drying and then firing up to 600°C, nearly no change in shrinkage is visible. This continuity changes between 600°C and 900°C, where further shrinkage is visible. The main shrinkage with and without adding sand happens during the change from the wet state into the dry state but not during firing. Shrinkage during the whole firing process was between app. 1% (with sand) and 2% (without sand).

In this context, sample 15515 (used for *tandoor* stove) shows no firing shrinkage from the point of being in a dry state to firing up to 600°C. In this case the material in an unaltered state would already be suitable in view of its shrinkage. In the case of pottery and stove making, this would mean a possible appearance of cracks due to shrinkage during the drying process, not during firing. In the case of making a stove, these cracks can be filled with moistened clay, though this is not the case for pottery making, where the unfired pottery ware has to be free of cracks. For that reason, the amount of sand has to be slightly increased. Regarding the shrinkage behaviour in a laboratory test, the addition of sand with 15% of the whole mass of the sample appeared as too much. The content of sand within the sample increases and in contrast the content of silt and clay dercreases – all these deviations being too high when comparing the result to the values given in the *dzasa* sample 11751. The examination of various mixtures of different types of clay with varying amount of sand should be the aim for future tests.

4.1.2 Behaviour of the surface during the shrinkage test

- For sample 15412 (*thabsa* / Tunlung), during firing at 240°C the colour changes from ochre to a relatively dark grey, and for firing at temperatures up to 950°C, the colour becomes more reddish in appearance (Figs. 3.46, 3.48, 3.50, 3.52, 3.54). The surface is more porous and coarser than in sample 15515. Cracks are visible and must be filled with moistened clay. Cracks appear stable throughout the entirety of the shrinkage test. Cracks that appeared before firing do not change until the end of heating.
- Sample 15515 behaves partially differently. It also reaches its darkest stage at 240°C with a reddish-purple appearance. When firing above 240°C, the colour brightens, becomes more red and remains similar until the end of firing at 950°C (Figs. 3.47, 3.49, 3.51, 3.53, 3.55). It feels smooth, and the sound is high when knocking with one's fingernail on the surface. Between 600°C and 950°C, one crack occurred at the back side of the sample (Fig. 3.55).



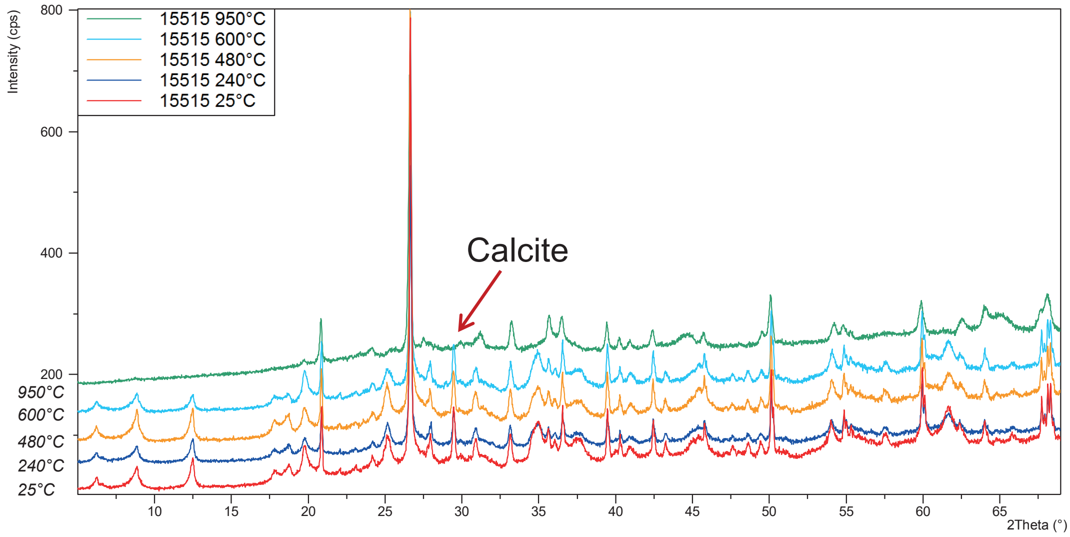


Fig. 3.56 (Top) BMA of sample 15412 at different stages of firing.
Fig. 3.57 (Below) BMA of sample 15515 at different stages of firing.

4.1.3 Influence of minerals on the samples' behaviour during firing

- Comparing the diffractograms of the single stages of firing, the following results can be given (Figs. 3.56, 3.57).

  - For sample 15412, when firing up to 240°C, the peaks become generally slightly smaller and remain similar up to 600°C. Above 600°C, quartz remains unchanged. This sample does not contain calcite. For sample 15412, smectite and vermiculite disappear when firing at 240°C.
  - For sample 15515, the resulting curve remains constant up to 600°C. Above 600°C, quartz and some mica remain, along with K-feldspar and plagioclase. Calcite disappears at app. 800°C (Lasser, Redl 2013: 29).

- Sample 15515, which is used for pottery, shows a content of calcite. For the firing process this content may be one essential factor for heat resistance. In comparison, according to Noll (1984), the clay used in ancient times was rich in calcite to increase strength when fired at low temperatures and to reduce the danger of layers of paint spalling off (Rösch 2010: 8 according to Noll 1984: 43).

As is the case for sample 15412 (*thabsa* / Tunlung), the content of kaolinite influences the behaviour of the clay during firing. Also an increased content of ferric oxides, which is present in sample 15515 as hematite and in sample 15412 as goethite, enables firing at higher temperatures (Wimmer-Frey et al., forthcoming). Phyllo silicates are dispersed at 900°C, while K-feldspar remains stable up to 1100°C (Lasser, Redl 2013: 29).

A high content of quartz is a disadvantage if the stove is often fired. Due to an increase in volume during recrystallisation at the quartz inversion, an increasing content of quartz needs more space. Both samples (15412 and 15515) contain a small amount of quartz.

4.1.4 Content of humidity to reach the 'norm stiffness'

The following list shows the content of humidity in the state of its 'norm stiffness'.

	15412	15515	15515+11749	11748
A. Sample wet in %	44.8	38.4	11.3	22.5
B. Sample dry in %	37.7	27.2	8.2	19.1
C. Humidity in gram	7.1	11.2	3.1	3.4
D. Humidity in % (geotechnical)	19	41.5	37.7	17.8

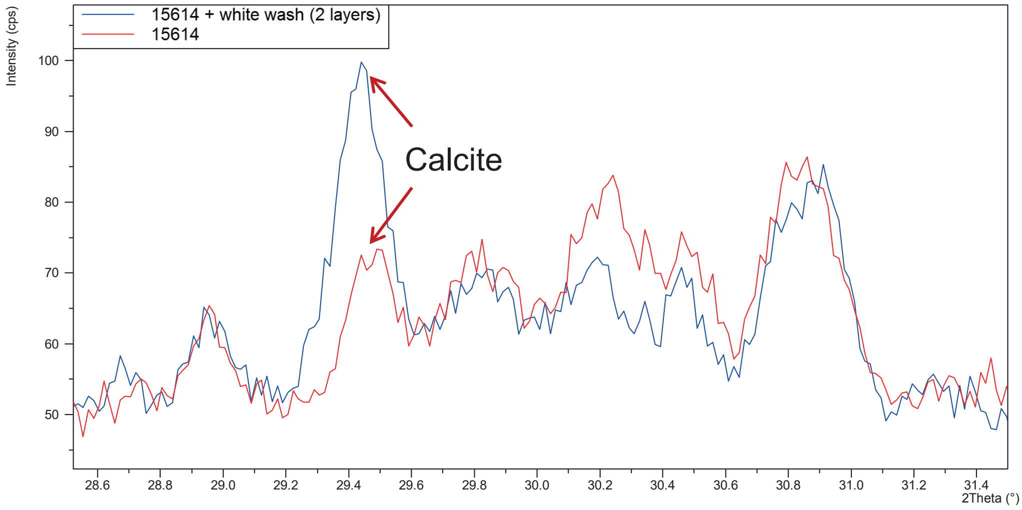


Fig. 3.58 Sample 15614 is a modern plaster produced according to DIN requirements. The curves show one sample without the addition of whitewash compared with a sample with two layers of whitewash.

4.2 Calcite as an anthropogenic or natural factor

A question arises whether the necessary content of calcite in a sample is the result of an anthropogenic addition of calcite or naturally given. Reasons for an anthropogenic addition are whitewashing, preparation of the base layer for a mural painting or stabilisation of clay. During analysis, all samples containing possible remains of whitewashing or a base layer for mural paintings were ground together with the whole sample of clay. Meaning, the analysed contents of calcite were part of the whole anaylsed sample, which itself could contain natural deposits of calcite. A content of calcite in a sample of a plaster may originate from a natural deposit but also could be remnants of former whitewashing.

Thus, plaster sample 15614 was first measured without whitewashing and subsequently ground and analysed. Thereafter, sample 15614 (1.3 cm thick) was prepared with two layers of a whitewash made of calcite. A comparison of the content of calcite in both samples is given in Fig. 3.58. The measured difference of the content of calcite between the two samples (with and without whitewash) is app. 1%. Since most of the examined Himalayan layers of plasters are of a thickness of up to app. 4 cm with a layer thickness of whitewash of up to app. 50 µm, the measureable content of calcite of the whole plaster sample shrinks proportionally. On the other hand, we may also state that in general the whitewashing was and still is part of a collective annual renewing process – also used in a ritual context – and over dozens and even hundreds of years many layers of whitewash may have been applied but also washed away by precipitation and disappeared as a result of weathering. Nevertheless, according to the given result of this examination, we can state a difference of calcite between the raw material and the state of being whitewashed with two layers of app. 1% for a 1.3 cm thick plaster after graining the whole sample (i.e. clay plaster + two layers of whitewash). This also means that a content of calcite in the range of more than app. 1% on a whitewashed plaster of a thickness of 1.3 cm may already result from a natural deposit in the raw material. As long as we do not separate the calcite layer from the plaster layer below in separate examinations, it is not possible with methods of BMA, Scheibler test and STA, to give a more

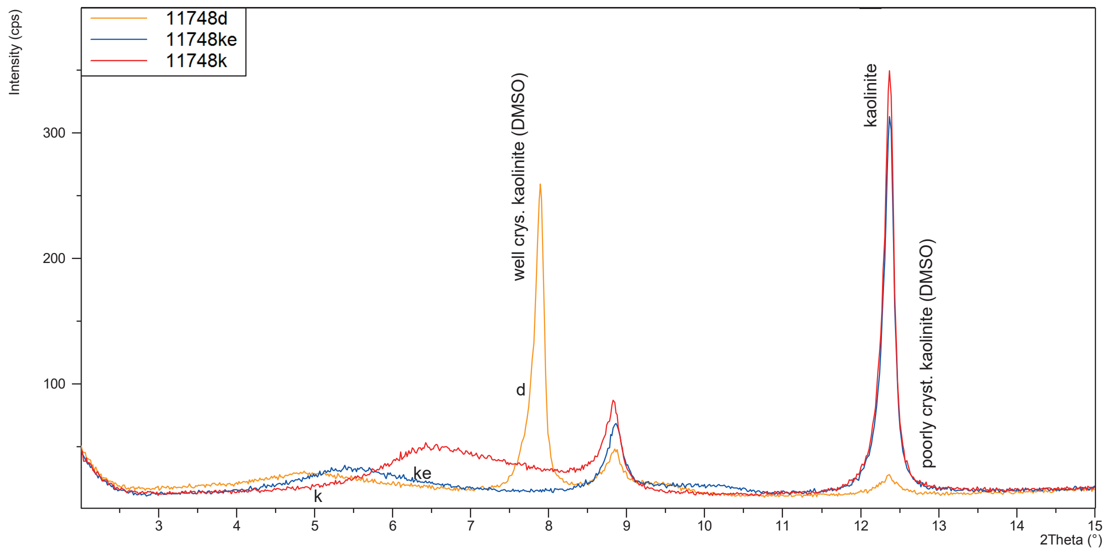


Fig. 3.59 GMA. Sample 11748. Content of well-crystalised kaolinite.

detailed statement regarding the content of anthropogenically applied calcite. As an example, the BMA of sample 8479 (pillar plaster) shows a calcite amount of 11%. In this case we can state that a naturally given content of calcite is existent, but we may not also exclude an anthropogenic addition. White layers on plasters may point towards the use of calcite in a comparably small amount, as shown in Fig. 3.58. Indications for an anthropogenic addition would result from a case, for example, where the lower layer of the plaster is prepared without calcite and the fine upper plaster layer with calcite. Since some samples of interior plasters originate from ruins without a roof, weathering is a reason for the disappearance of calcite from the surface, even of former interior plasters. Being that weathering due to precipitation is not uniform over the whole surface of the wall, results of mineral analyses may vary.

Gypsum in comparison: In the case of gypsum as a base layer for a mural painting, the influence of weathering is similar but with an even quicker effect. This is particularly true at ruins without a protective roof. Since in one liter of water two grams of gypsum can be dissolved, in the case of precipitation the weathering of a gypsum surface happens rather quickly.

4.3 Content of kaolinite

A relatively high content of kaolinite was stated for the samples from Tunlung and Ne, as shown in the CMA graphics (Fig. 3.59). In the X-ray diffraction, the kaolinite peaks in the potassium and potassium-ethylen curve at about 7Å split up in the DMSO curve. The high peak at 11.2Å (7.8°) points towards the content of well-crystalised kaolinite, and the remaining broader and much smaller peak at 7Å (12,5°) points towards the content of poorly crystallised kaolinite. This could be proved for all stove samples (11748, 15412 and 11919). The IRS analysis confirms the X-ray measurement. Figs. 3.60 and 3.61 show the results for the IR-measurements. The four peaks at a wave number between about 3694 and 3620 cm^{-1} are evidence for a well-crystalised kaolinite (cf. van der Marel and Beutelspacher 1976). With the Infrared Spectroscopy (IRS) analysis several other minerals such as smectite and quartz were also traced.

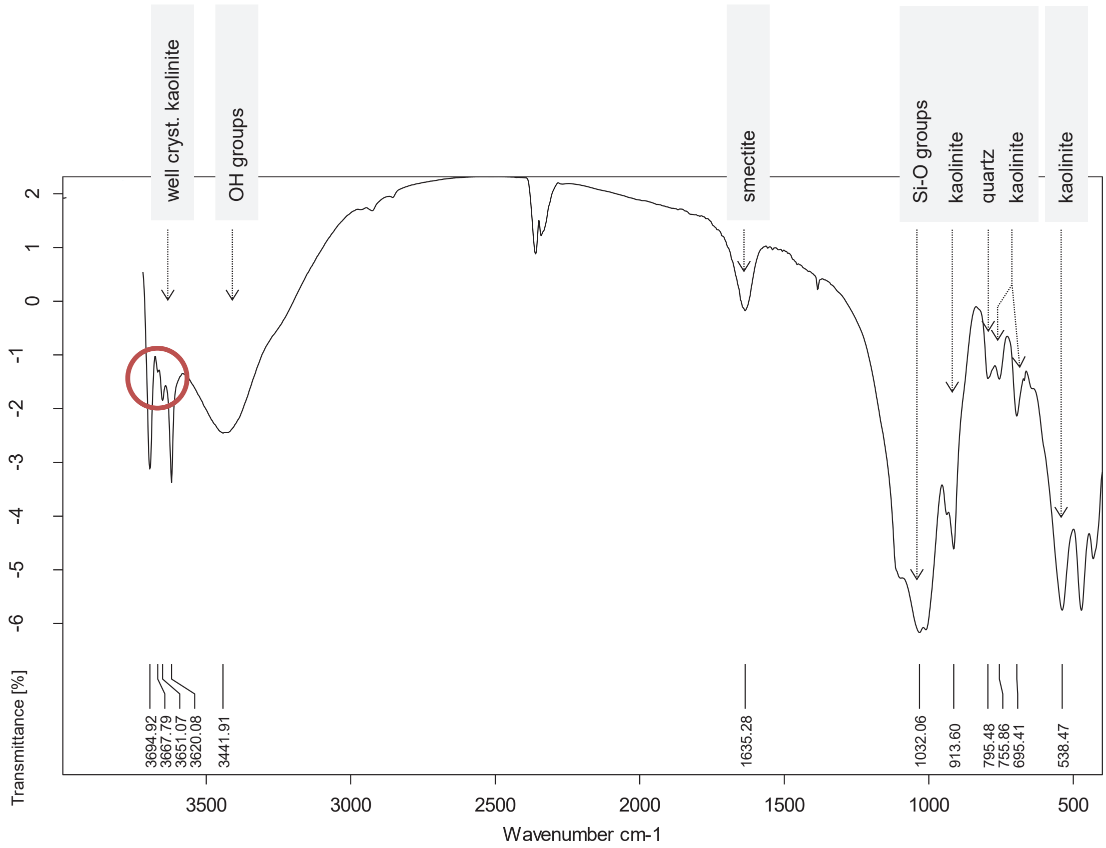


Fig. 3.60 Sample 11748. IRS analysis. See Fig. 3.61 for the detail of the molecular structure marked by a circle.

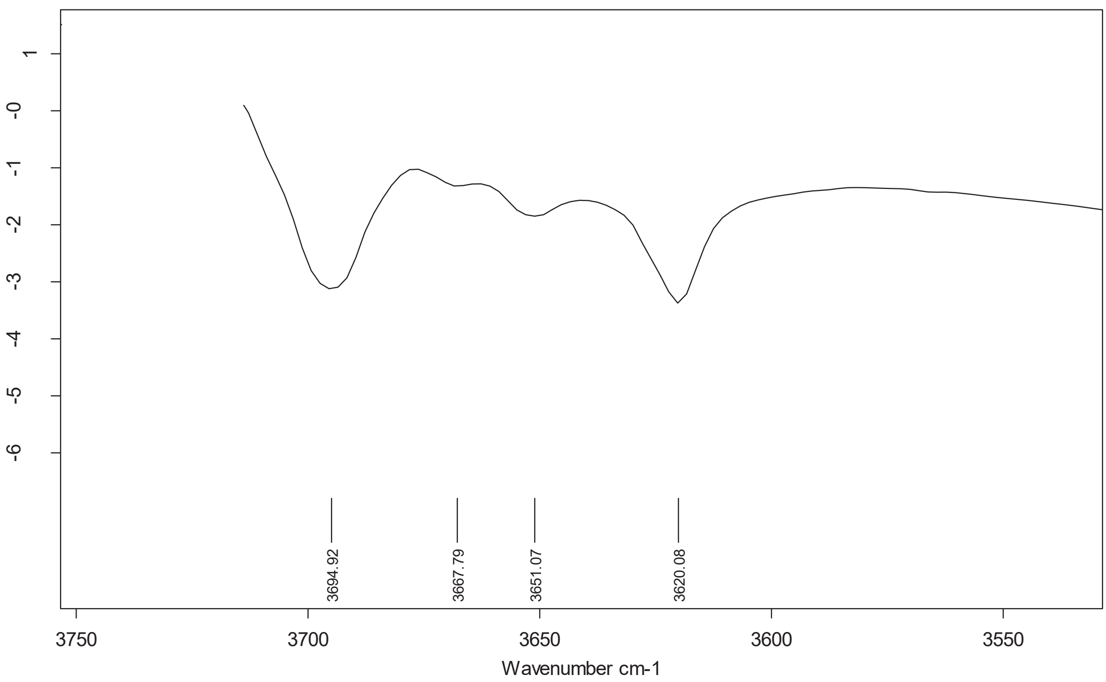


Fig. 3.61 Sample 11748. IRS analysis. Detail of Fig. 3.60. Content of well-crystalised kaolinite according to van der Marel and Beutelspacher 1976.

4.4 Tables of results

Table 3.2 Grain size classes.

Sample	Gravel [%]	Sand [%]	Silt [%]	Clay [%]	Median [µm at 50%]	<2µm [%]
Basgo – Maitreya Lhakhang						
8469	0.8	32.2	55.2	11.8	22	12
8479	2.7	48.9	31.8	16.6	70	17
8496	17.3	41.9	30.0	10.8	130	11
Basgo – Lotsāba Lhakhang						
8482	0.5	7.0	67.7	24.8	5.5	24
8483	0.9	8.1	64.9	26.1	4.8	26
11946	5.2	16.3	62.9	15.6	9	17
11948	17.2	51.0	21.8	10.0	220	10
Basgo – Lhakhang close to road (Highway NH1D)						
8475	6.5	33.1	42.6	17.8	20	18
11928	7.3	29.7	42.1	20.9	15	21
8499	7.5	39.6	41.3	11.6	50	12
8472	35.8	42.5	14.2	7.5	550	8
11933	10.4	60.4	18.8	10.4	180	10
Basgo – building raw material						
15410	53.9	8.7	30.7	6.9	2000	8
11915	3.8	74.1	14	8.2	250	9
15411	6.0	68.8	16.5	8.7	240	9
8465	12.5	50.8	25.8	10.9	210	11
11952	6.7	35.5	38.7	19.3	31	19
Basgo – clay stove (*thab*)						
11748	31.8	44.7	15.6	7.9	650	9
15412	23.7	39.5	22.8	13.9	180	14
11919	21.2	44.1	24.3	10.3	380	10
Basgo / Likir – stove and pottery clay						
15515	0.1	3.2	54.5	42.2	2.5	42
11751	1.8	13.2	46	39	2.5	38
11752	0	0.2	60.1	39.5	2.8	38
Likir – adobe brick and clay pit						
11763	7.1	53.7	25.5	13.7	130	14
11921	0.5	10.1	60.3	29.1	8.5	29
Likir – sand						
11749	0.6	78.5	14.8	6.1	150	7

Table 3.3 Results of the bulk mineral analysis.

Sample	14Å	Mica	Amph	7Å	Phy sil	Quar	Goeth	K-fsp	Plagio	Calc	Dol	Hem	Gyps	Pyr
Basgo – Maitreya Lhakhang														
8469	.	.	*	*	*	*	---	*	*	7.8%	---	.	---	.
8479	.	.	*	*	*	**	---	*	**	11.3%	---	.	---	---
8496	.	.	*	*	*	*	---	**	***	8%	---	.	---	---
Basgo – Lotsāba Lhakhang														
8482	.	.	*	*	*	*	---	*	**	6%	---	.	2%	---
8483	.	*	*	*	*	*	---	*	**	6%	---	.	2%	---
11946	---	.	*	*	.	*	---	*	**	10%	---	---	.	---
11948	.	.	---	*	.	*	---	*	*	11%	---	---	---	.
Basgo – Lhakhang close to road (Highway NH1D)														
8475	.	*	*	*	.	*	---	*	**	13%	.	.	2%	---
11928	.	.	*	*	.	*	---	*	*	12%	2%.	.	.	.
8499	.	*	*	*	.	*	---	*	**	15%	3%.	.	---	---
8472	.	.	*	*	.	*	---	*	**	12%	.	---	.	.
11933	.	.	*	*	.	*	---	*	**	13%	1%.	---	---	.
Basgo – building raw material														
15410	.	.	.	*	.	*	---	.	*	10%	1%.	.	---	---
11915	---	.	---	.	.	*	---	*	**	7%	---	.	---	---
15411	.	.	.	*	.	*	---	**	**	11%	---	.	---	---
8465	.	.	*	*	*	*	---	**	***	10%	.	.	.	---
11952	.	.	.	*	*	*	---	*	*	11%	1%.	.	---	---
Basgo – clay stove (*thab*)														
11748	*	*	---	**	*	*	.	*	*	---	---	.	---	---
15412	*	*	---	*	*	*	.	*	*	---	---	.	---	---
11919	.	.	---	*	*	*	---	***	*	3%	---	.	---	---
Basgo / Likir – stove and pottery clay														
15515	.	*	---	*	**	*	---	---	*	4%	2%.	*	---	---
11751	.	.	---	.	*	*	---	---	.	12%	---	---	12%	---
11752	.	.	---	.	**	*	---	.	*	8%	2%.	.	---	---
Likir – adobe bricks and clay pit														
11763	---	.	*	.	.	*	---	**	***	---	---	.	---	---
11921	.	.	*	.	*	*	---	*	**	---	---	---	---	---
Likir – sand														
11749	---	.	**	---	---	*	---	*	**	.	---	---	---	---

Table 3.4 Results of the clay mineral analysis.

Sample	**Smectite**	**Vermiculite 14Å/18Å**		**Illite**	**Kaolinite**	**Chlorite**	**Mixed layer**
Basgo − Maitreya Lhakhang							
8469	22	---	22	37	3	16	
8479	18	---	16	52	0	14	
8496	44	---	16	24	0	16	
Basgo − Lotsāba Lhakhang							
8482	9	---	14	51	4	22	
8483	20	---	15	44	3	19	
11946	6	---	---	65	3	26	
11948	28	---	---	44	2	27	
Basgo − Lhakhang close to road (Highway NH1D)							
8475	24	---	9	43	3	21	
11928	18	---	---	41	5	37	
8499	30	---	21	29	3	16	
8472	9	---	14	50	4	23	
11933	9	---	---	53	7	32	
Basgo − building raw material							
15410	30	---	---	32	2	36	
11915	72			13	6	8	
15411	38			26	0	36	
8465	18	---	11	51	4	16	
11952	20	---	---	47	2	31	
Basgo − clay stove (*thab*)							
11748	11	---	42	10	37	0	
15412	20	---	28	19	33	0	
11919	38	---	19	7	36	0	
Basgo / Likir − stove and pottery clay							
15515	0	---	---	31	0	69	ML corrensite
11751	0	---	---	43	0	57	ML corrensite
11752	0	---	---	38	0	62	ML corrensite
Likir − adobe brick and clay pit							
11763	6	---	---	63	14	16	
11921	35	---	---	49	6	10	
Likir – sand							
11749	4	---	---	66	4	26	

Discussion

5.1 Research question 1: What are the particular properties used to categorise specific commonly used earth building materials? What are the material properties, which support a particular building material's use for the building purposes mentioned?

The examined samples are designated for specific interior and exterior use. Most common plasters are made as two-layer plasters with a lower layer (also ground or levelling layer) and an upper plaster layer. Other samples are connected to the use as adobe bricks, the construction of a flat roof, the making of pottery ware, or the creation of a stove. According to the results of this research, the local tradition of Basgo and Likir has a long history and particular types of clay and mixtures for each of these purposes. Also the single sites, where the materials were applied, vary from each other, leaving a rather complex network of different material applications. The main general features will be given in the following.

Grain size distribution

- The levelling layer of the pillar plaster in the Maitreya Lhakhang is rather fine and applied onto the pillar using organic fibres fastened around the pillar. These fibres are introduced as a layer for the compensation of different expansions of the wooden pillar and the plaster. The levelling layer for the pillar plaster is dominated by silt and sand fractions. It is rather fine, which may result in its ability to be easily pressed between the fibres. The upper layer contains a larger amount of clay. The need for adding coarse material in both layers may result in a relatively high content of swellable clay minerals. Compared to the pillar plasters, the interior plaster in the Maitreya Lhakhang shows a much higher content of gravel and less clay. The general composition, in particular concerning the content of sand and silt, is similar but coarser compared to the upper plaster layer.
- The upper layers of the interior plaster used in the Lotsāba Lhakhang are much finer than those used in the Maitreya Lhakhang. The levelling layer applied in the Lotsāba Lhakhang is more similar to the upper layer used in the Maitreya Lhakhang. Contrary to the Maitreya Lhakhang, in the Lotsāba Lhakhang there is no evidence of the addition of coarse material. For the adobe bricks, coarse material seems to have been added, and this material shows similarities to the interior plaster found in the Maitreya Lhakhang.
- The examined adobe brick from the 'Lhakhang close to the road' shows strong similarities to the adobe brick in the Lotsāba Lhakhang. Nearly all analysed data match. In the 'Lhakhang close to the road' the exterior plaster seems to be made with a similar raw material as used for the interior plaster. A close similarity in different properties between samples 8469 (pillar plaster from Maitreya Lhakhang) and 8475 (interior plaster from the 'Lhakhang close to the road') is given. The matching properties point towards the use of a rather similar raw material.
- A similar result is also stated for samples 11933 and 11928 (brick and plaster from the 'Lhakhang close to the road', respectively), leaving for sample 11933 open the changing rounding of grains being the result of an anthropogenic act via the preparation of a similar mixture, or the result of a natural process caused by geologic transport. Such slight differences also show that the basic material used within the same temple structure was not necessarily from the same clay pit. Specific evidence for this fact is that samples 8575, 8499 and 8472 – which are samples of further plasters and bricks within the 'Lhakhang close to the road' – obviously differ from sample 11933.

- Evidence for a mixing of two or more types of clay or sand is given by a bimodal grain size distribution and by the use of different grain shapes within the same building material.
- The locally available *dzasa* is rather coarse and is the basic material for further mixtures of plasters and clay used for flat roofs. The *dzasa* is mixed with *thetsa*, increasing the content of sand. The mixture of *dzasa* and *thetsa* is similar to the interior plaster in the Maitreya Lhakhang. This mixture was also applied to the roof of the Maitreya Lhakhang and to the adobe brick in the Lostāba Lhakhang. This fact points towards a commonly known use of the *dzasa* / *thetsa* mixture.
- Raw material for stoves from Basgo show a rather high content of gravel and sand and a lower content of silt and clay with an average ratio of app. 3:4:2:1 in the given order. Several materials are known in Basgo for the construction of a stove. Samples from Tunlung and Ne are similar to each other but vary strongly from the *thabsa* found along the highway. This much finer sediment from Basgo with a proportion of 0 (gravel) : 0.5 (sand) : 5.5 (silt) : 4 (clay) or 0:1:11:8 shows much more similarities to the clay from Likir, which is used for pottery and stoves. The *thabsa* from Likir has to be mixed with a specific type of sand, while the *thabsa* from Ne and Tunlung remains unmixed. Some of the clay from Likir, which is used for pottery ware, can also be used for the production of a stove.

Grain shapes

- Observed is the dominance of 'angular-shaped' grains with a partial tendency towards 'beginning rounding'. This points towards a rather short distance of geologic transport.

Bulk mineralogy

- Some mineral features have strong similarities with the examined building materials. The average amount of 14Å minerals and of mica appears as traces, while 7Å minerals, quartz and K-feldspar appear in small amounts. The average content of plagioclase is medium. A few samples contain dolomite. About two thirds of the samples contain traces of hematite, which is manifested in the reddish colour of the Basgo clay. The two samples from Tunlung contain traces of goethite, giving them a yellowish colour. Gypsum was found as traces in interior plasters of the Lotsāba Lhakhang and the 'Lhakhang close to the road'. This points towards the use of gypsum as a base layer for mural paintings in these early temples in Basgo. The content of calcite ranges between 6% and 15%, pointing towards a natural deposit of calcite in the raw material. In the samples of Tunlung, no calcite is present, and in the sample of Ne only 3% calcite was identified. This points towards its qualification as heat-resistant stove material, since the lesser amount of calcite results in higher flexural strength. On the other hand, the samples from Likir – which are known for their use in making stoves or pottery ware – do not follow these ideal properties and show a content of calcite between 4% and 12%.
- As an example, the content of amphiboles in the pottery sand of Likir (sample 11749) indicates the content of a metamorphic stone being related to the formation process of clay. Based on the existence of amphiboles, in the 2 µm CMA-graphics, a peak of app. 62°θ (app. 1.49 Å) shows a di-octahedral structure. The peak at 61°θ shows a tri-octahedral structure. These are the weathering-resistant components kaolinite, muscovite and muscovitic illite. Amphiboles weather easier and convert into smectite in a further stage (see Fig. CMA 3.27 in the Appendix of Chapter III).

Clay mineralogy

- In general, the Basgo-Likir samples show a rather high amount of swellable clay minerals (up to 72%), on average between 20% and 40% of the clay fraction. In 23 of the 26 samples swellable clay minerals are present: 23 with smectite and 14 also with vermiculite 18Å. The content of swellable clay minerals is rather high in the interior plaster of the Maitreya Lhakhang, which explains the addition of a high amount of coarse material. In the Lotsāba Lhakhang and in the 'Lhakhang close to the road', the content of swellable clay minerals is less. This explains the difference in the use of coarse material compared to the Maitreya Lhakhang.
- The CMA of the *dzasa* / *thetsa* mixture (sample 8465) shows strong similarities to the pillar plaster in the Maitreya Lhakhang (sample 8479), in particular in regard to the content of smectite, illite and chlorite. Sample 8479 was collected from a clay pit close to the Maitreya Lhakhang, and the matching results of the CMA might be an evidence for using clay from close to the temple for various applications, like making plasters or flat roofs. This fact strengthens the hypothesis that certain clay mixtures, which are considered to be technically optimised for certain applications, are by tradition used for different craft activities, be it in this specific case the use as roofing clay or as plaster clay. Both types of clay are likely to have been produced during various periods of time, the roofing plaster being a contemporary mixture and the processing of the pillar plaster probably dating back a long time. The comparison of these two materials seems to strengthen the hypothesis of traditional knowledge in a continuity in the application of technically optimised clay building techniques and in the selection of particular locally available raw materials. Comparing the grain size distribution of both samples, 8465 and 8479, we find the mixture of the two clay types being adapted to the particular technical needs. For that reason the clay used as plaster was adapted by using much less gravel, keeping the content of sand similar and raising the content of silt and clay. This result given in numbers: the median of sample 8479 is located at app. 70 µm and the 2 µm fraction ranges at around 17%. Sample 8465 is much coarser due to the addition of *thetsa* sand shown by a much higher median of app. 210 µm.
- The *thetsa*, which shows a high content of swellable clay minerals between 38% and 72%, compensates for its tendency towards cracks due to its natural high content of coarse material. The same is true for the clay from Tunlung and Ne, which is used for stove construction with an amount of swellable clay minerals between 48% and 57% in the clay fraction.
- The samples from Tunlung and Ne, which are used for making a stove, show a relatively high content of vermiculite, thus being in contrast to most of the other samples. The high content of vermiculite acts as a binder, while the high content of kaolinite is responsible for a refractory property. For the samples from Tunlung and Ne, a well-crystallised kaolinite was identified.
- In contrast, the Likir samples used for the making of pottery and stoves, and also the Basgo sample collected along the highway, are the only samples without a content of swellable clay minerals and therefore with a low content of coarse material. Besides this feature, these three samples show a content of a mixed layer corrensite marker. A secondary crystallised chlorite can also be found for samples of the 'stove and pottery group'.
- The sand, which is preferably used by the potters from Likir for mixing, also shows a 4% content of swellable clay minerals in the clay fraction.
- The content of illite is in general high and constitutes up to 66% of the clay fraction. Kaolinite is in general low and ranges on average around 5%. Only in the samples from Tunlung and Ne, which are used for the preparation of a stove, does the content range between 33% and 37%,

pointing to their qualification as stove material, since a high amount of kaolinite makes it more resistant to heat. Concerning this aspect, the samples from Likir and the sample from Basgo, which are known for their use in stove construction, do not correlate with this material quality.

· In general, the high content of chlorite of the Basgo-Likir samples indicates the metamorphic character of this material differing from smectite and mica, possibly due to a different mode of geological material transport. In relation, the stove samples from Tunlung and Ne differ from the rest of the samples in that they have no content of chlorite. Completely different to the stove samples from Tunlung and Ne are the stove and pottery samples from Likir and the sample from Basgo from along the highway, all of which show the highest content of chlorite (between 57% and 69%).

Organic additives

· The use of straw is widely common and differs not only locally but also from object to object and even within objects, particularly when an object is erected in different building phases.

· The levelling plaster (= ground plaster) used on the pillars in the Maitreya Lhakhang is reinforced by the fibres of the rope fastened around the pillars. This is why the content of additional straw fibres is kept low in this plaster. The length of fibres is found to be up to app. 3 cm. The upper layer shows an even smaller content and shorter fibres with a length of up to app. 1 cm. In this upper layer reinforcement is still required, but since the attempt seems to have been to keep the surface smooth, the tendency is to reduce the amount of fibres. The wall plaster in contrast to the pillar plaster shows fewer and smaller fibres, even in the levelling layer, which points towards chronologically different stages of preparation between wall plaster and pillar plaster.

· The upper layer in the Lotsāba Lhakhang, in contrast, shows a much higher content of straw with a length of up to 2 cm, which was coated with a thin base layer for the mural paintings without using straw but rather gypsum. In this case, the levelling layer contains a higher amount of straw than the levelling layers used for interior plaster or pillar plaster in the Maitreya Lhakhang. This also points towards the use of different methods of application. Rather unusual is the use of straw (with a length of up to 3 cm) in adobe bricks.

· For the plaster in the 'Lhakhang close to the road', the amount of fibres used is high and their length ranges up to 6 cm. For the exterior wall plaster with a rather similar mineral composition to the interior wall plaster, the fibres used are slightly shorter (up to 3 cm) but the general mixture appears similar. Contrary to the Lotsāba Lhakhang, no fibres were used for the preparation of adobe bricks.

· For recent plasters in Basgo, the *dzasa* is mixed with the sandy *thetsa*, which is a commonly known method. In this case, the levelling layer is mixed with straw and the upper layer remains without fibres. A recently prepared adobe brick (sample 11952) keeps the tradition of adding organic material to the bricks. In this case, small branches were used. Material used for the preparation of stoves remains without the addition of any organic fibres.

· Specifications for a *thabsa*:
  - In the case of the locally available *thabsa* from Likir, a mixture of 2:1 (clay:sand) is recommended by Rigzen Wangyal and his family (the potters from Likir) (Interview Rigzen Wangyal in August 2011). The laboratory test using a ratio of 6:1 (clay:sand) showed that the shrinkage during a three-day drying process was still 8% and that the content of sand needed to be increased for less shrinkage. For potters and *thab* makers, it is essential to

reduce shrinkage as much as possible during the drying process. The addition of sand fulfils this need. As the examination shows, the firing process with a maximum shrinkage of 2% is not as problematic.

- Furthermore, the quantity of water used for processing the clay influences the processability and quality of the result. Each type of clay has its own features. In the case of the clay used for stoves, a variety between 15% and 29% was determined. With the *thabsa* from Basgo (sample 15515), the highest content of water (29%) was needed in order to achieve norm-stiffness. Adding app. 15% of sand to the raw material changed the need for water to only 27%.

5.2 Research question 2: If there are any regional relations in the knowledge transfer about a particular material, in what way can they be related to specific locally conventional terms?

For the samples collected in the Basgo-Likir region, several local terms are known. This is primarily the case for raw material and less for processed objects. The mixtures themselves follow local traditions without any further conceptual classification. This makes their scientific differentiation much more difficult than is the case with raw materials, which cannot be mixed, such as wood or stone.

The terms are not only commonly known locally; *thabsa* (Tib. *thab*, “stove”; Tib. *sa*, “earth”) is a Tibetan term and is commonly known in Tibet. Its designation defines its use and by that a particular quality of clay. Until now, no data have been available on the earliest development of a traditional Tibetan stove. It is related to fixed settlements as well as to nomadic households (Interview Tsering Drongshar 2016). The stoves examined by the author were either still in use or demolished. All of them showed reliefs of auspicious Tibetan symbols on their surface. Since the beginning of this tradition, knowledge about particular properties of clay must have been given. As seen in the preceding analysis, it is difficult to determine a particular material quality of clay just by its colour. The *thabsa* samples from Ne, Tunlung, Basgo and Likir are very different in their visual and haptic appearance. A resident of Basgo drew the author’s attention to the use of the Basgo *thabsa* for making smoke pipes, since this material is heat-resistant. This information shows that technical development was not necessarily restricted to a search for particular stove material but also arose from daily life experiences in the use of heat-resistant materials.

Local traditions in using particular terminologies for clay used as building material are connected to a particular use and to sense-perceivable properties as generally standardisable technical specifications. Such standardised specifications are based on the empirical understanding of technical properties of clay. The process of assigning a particular term to a particular type of clay may strongly be shaped by its individual use, for example, by mixing, desludging, adding water or any other additives. This individual use connected with an individual perception may differ for a clay with one particular designation by showing different mineralogical properties when being dug at different sites. This fact turns the individual perception of the craftspeople into a central ability in keeping and adapting technical characteristics.

A variety in understanding properties of one specific type of clay is shown with a clay known as *dzasa*. The term *dzasa* (Tib. *rdza sa*) is known at various places in Ladakh, like Basgo, Likir or Shey (Feiglstorfer 2014: 372). In Basgo, traces of hematite in this clay are responsible for colouring the temple hill red. According to the Tibetan dictionary (www.thlib.org), various translations for *rdza* are given, such as "clay" or "earthenware" (Jim Valby), "clay-slate" (Ives Waldo) or "terracotta" (Rangjung Yeshe). When speaking about its designation as clay, according to the results of research it can be catergorised as clay of a certain fineness and processability used for a range of crafts. Earthenware and terracotta are fired materials and show a terminological relation to pottery ware. According to Tsering Drongshar, who grew up in Central Tibet (correspondence in March 2016), the Tibetan term *rdza sa* simply describes a clay without any further specification. Contrarily, a clay known as *thetsa* (Tib. *'phred sa*), which in the Basgo region refers to a clay collected along the slope of a hill (Feiglstorfer 2014: 373), is not known to Tsering Drongshar.

5.3 Research question 3: In what way are building techniques and crafts related to each other and how can the gained knowledge be useful for future applications?

In vernacular architecture the use of raw materials follows an economically optimised way of processing and use. Regarding clay in the Himalayas, the raw material is part of the natural environment. Its sustainability after use is given either by its recycling into new objects made of clay or simply adding it to the soil of the surrounding environment. For recycling, it can be mixed with other mineral or organic materials to improve particular qualities. In the case of plasters, we know of the traditional reuse of sooted kitchen plaster to make flat roofs waterproof. In the case of plasters, adobe bricks, and flat earth roofs the reuse of clay at other building sites is an option with the positive side effect that this reuse may reduce the mixing effort. In the case of fired clay, such as pottery ware, the crushed objects can be again mixed with clay or reused after grinding them into powder as base material for further mixtures.

This study showed that within craft traditions the same type of clay can be used for various craft techniques. In this respect, knowledge of the making of a plaster, a clay stove, a flat roof or pottery ware is, on the one hand, connected to the single crafts and allows for the technical understanding of related craft techniques. On the other hand, it is connected to a general understanding of optimising material qualities and techniques as a general knowledge far beyond a focus on just one single craft.

This holistic approach in vernacular building techniques is also visible in the use of particular terms. *Dzasa*, for example, is used for the raw material of pottery ware, plaster and flat roofs but in each method of processing it is related to a specific technique of mixing and applying additives. The term *thabsa*, for example, is not only used for stoves; some species of *thabsa* are used for making pottery. Another example is a specific type of sand from Likir, which, due to its mineral qualities, is not only used for pottery but also for making clay stoves and for processing adobe bricks.

Due to their ecological qualities, the materials mentioned are highly sustainable, which can be a future challenge for their use beyond existing traditions. Changes of traditions are initiated when they begin to be neglected by the local community. Clay traditions, as we find them at Basgo and Likir in Ladakh, are locally determined due to particular locally available material properties and commonly applied processing methods. They are part of the material culture of a local community. Their application to other places or societies is in most cases connected to changes or a loss of these traditions. Learning from traditions means gaining a general understanding of basic properties of materials and processing techniques, and applying this knowledge to particular new situations.

From techniques used to make a flat roof or plaster, for example, we may learn about coordinating different types of clay in several layers and about the technically optimised use of additives. However, local recipes are hardly to be transferred from one site to another without any loss but they rather have to be adapted. As far as known, the making of a clay stove in a Tibetan manner is not existent in Western traditions. In this respect, apart from its materiality its social connectivity has to be taken into account. In this regard, the complexity in the interaction of knowledge and practice according to traditional patterns of the use of materials needs to be questioned, researched and be brought into relation to particular local resources and traditions.

IV. Himalayan composite constructions and environmental influences

This chapter is subdivided into four parts:

- In the first part (1), the chapter begins by presenting certain types of composite constructions. In this part, first a general historical context of timber frame structures (1.1) and, secondly, of the bracing of solid walls (1.2) is discussed, both also looking beyond the borders of the Himalayas. In part (1.3) of this chapter, the relation of composite constructions to building traditions in the Himalayas, and in part (1.4) the diffusion of composite constructions are observed. In part (1.5) the relation between the evolution of composite constructions and seismic culture is treated.
- The second part (2) of this chapter deals with a general consideration of the importance of the material diversity of vernacular architecture with reference to the Himalayan region.
- This leads to the third part (3), which focuses on material diversity in vernacular structures.
- In the fourth part (4), constructive developments are shown under the influence of climatic conditions and the local availability of raw material.

1. Composite constructions: a general view

The roots of composite constructions[96] extend into the early beginnings of building culture. In this context, wood has played a central role from the very beginning. For early dwellings, wattle with clay or hide as composite structures were used. In Kastoria in West Macedonia, pole foundations of wooden huts with probably wattled walls have been found dating between 4570 and 4330 BCE (Hatzitrifon 2016: 6). According to secondary literature sources (ibid. 8), the use of wattle and daub during the time of ancient Greece is evident. Archaeological remains of stilt houses, e.g. along the lake side of Lake Constance (Fig. 4.1), demonstrate an early use of wattle as infill material. Wattle and daub constructions also point towards an understanding of the positive aspects of the flexibility of structures related to an early awareness of seismicity. In Caral in Peru, for example, from about 3000 BCE we know of a flexible technique using wattle and daub besides solid structures made of rope bags filled with stones – both techniques showing an awareness of structural movements (Baca, Neumann 2015: 61, after Vargas et al. 2011; Fig. 4.2). As a kind of wattle and daub, in Venezuela, Uruguay, Colombia, Costa Rica, etc. we find clay-pocket-walls in the form of pre-Columbian construction called *bahareque*. This is similar to *quincha* in Peru (Fig. 4.3) and Chile, and similar to *taquezal*[97] in Nicaragua and *tabique* in Portugal. This technique is widely used and occurs in Europe predominantly in southern and south-eastern Europe. In particular, such use is found in north-western Europe, its verifiability starting in the late 16th century and onwards (Hatzitrifon 2016: 13, after Swindells 1987: 68), in the Iberian region

96 *Composite constructions* are mentioned as a constructive family and not as a particular single type of construction. Within this family, particular constructive typologies have become evident.

97 Cf. Langenbach 2000: 5.

Fig. 4.1 Unteruhldingen. Germany. Pfahlbau Museum. Reconstruction of wattled walls of sunken structures of a lake dwelling settlement (975–953 BCE). The reconstruction of the technique is based on remaining imprints.

Fig. 4.2 Caral. Peru. Example of the early use of wattle and daub (*quincha*) (c. 3000 BCE).

Fig. 4.3 (Below) Lima. Peru. *Quincha* wall.

towards the Balkans, and in Turkey (known as *bağdadi*[98]). Wattle was consistently used for infill and still is today, and may be considered as the oldest, most widely used and still commonly used building technique.

The origin of the German word "Wand" for wall as a constructional boundary of a space, which derives most probably from "winden" ("braiding") (Kluge 1989: 776), refers to an early distinction between the light-weight, braided boundary within a load-bearing timber frame construction and a "Mauer" ("wall"; Lat. *murus*), i.e. a solid, walled boundary. The development of the wall in general is connected to a technology development, and following the given terminological interpretation, a "Mauer" (solid wall) is generally more rigid than a "Wand" (light wall construction), which does not have high load capacity to tensile stress and torsion. This circumstance may have supported an evolution leading to these two design principles being connected to each other for mutual support.

1.1 Timber frame structures

Early evidence for timber frame structures found over parts of the later Turkish territory are timber frame constructions used in the second millennium BCE during the Hittites. Their defence walls are known to have been built with a lower stone part of a height of app. 3 m to 4 m and an upper timber frame construction with adobe bricks of a similar height (Nossov 2008: 16). For residential houses, the use of framework construction on a solid base is reported (Burney 2004: 25). In early Greece until the 1st century CE, the use of timber for construction was common (Hatzitrifon 2016: 8).

98 At the *bağdadi* (Turk.) technique, the space between the timber elements is filled with light material, or with a kind of plaster / lime rendering on wooden lath (Gülhan, Özyörük 2000: 4). The use of laths (or reeds) either mounted on one side or on both sides of the vertical timbers is known as *shanashil* (Hatzitrifon 2016: 6).



Fig. 4.4 Herculaneum. Italy. Casa a Graticcio. Photo: Erich Lehner.
Fig. 4.5 Quedlinburg. Germany. Post and beam construction (c. mid 14th century CE) filled with wattle and daub.
Fig. 4.6 Vacha. Germany. Side wall of a four-storey half-timbered house.

Early discovery of a half-timbered structure is reported in Herculaneum where it was conserved after the eruption of Mount Vesuvius in 79 CE (Fig. 4.4). This Roman half-timbered construction was erected without diagonal bracing. Such bracing was also not mentioned by Vitruvius for the *opus craticium* (Osthues 2014: 306). The infill of this half-timbered house was carried out with stones. The word *cratitii* (cf. *opus craticium*) does not refer to the framework of the construction but to the infill, and we can conclude that a wattle and daub construction is being referred to.[99] The half-timbered building in Herculaneum, which was built of stone on the ground floor and half-timbered on the upper floor (Osthues 2014: 304–306), is an early version of the later development of European *Fachwerk* constructions. During the Roman era, an additional use of diagonal bars was also practised, as found in the upper level of the Diomedes Villa in Pompeii (Hatzitrifon 2016: 9, after Adams 2007: 134).

The combination of a solid basement and an upper flexible construction brings an additional structural requirement. It has several advantages, for example, saving timber, making the basement fireproof or giving the upper half-timber construction a solid basement. On the other hand, the rigid stone construction has to be braced with timber.

In Central Europe, half-timbered construction represents the development of building on stilts (Ger. *Fachwerk*). Between the 13th and 15th century, different regional building types developed (described for the Czech Republic by Kuklik 2008: 5). In Germany, the early form of a half-timbered house is the post and beam construction (Ger. *Ständerbau*) that appeared in Germany at the beginning of the Late Middle Ages (13th century; Steiner-Welz 2007: 10).[100] This technological

99 Huts in early Rome during Roman rule may have primarily been made of wattle and daub (Edlund-Berry 2013: 413). Already the houses of the early Creatans at Knossos were wattle and daub huts (Rider 1965: 266). The use of clay for Greek houses is reported for structures on the Pnyx Hill in Athens during the 5th and 4th century BCE, where walls, floors and roofs were made of clay (ibid. 212).

100 Forster (2004: 96) reports on early wattle and daub techniques connected to post and beam constructions in Austria in the 12th/13th century.

development enabled the increase of the building height (Fig. 4.5). The posts were set on a beam, making them more durable. In Great Britain, two-storey buildings have been reported since the 15th century (Hatzitrifon 2016: 18, after Swindells 1987: 15, 17).

In the north-western part of Austria in the Late Middle Ages and during the Early Modern Age, a development from light constructions (including timber and wattle and daub) to solid structures (including stone and later fired bricks) took place (Forster 2004: 96). Stone constructions for rural houses and also the beginnings of fired brick constructions can be traced back to the Middle Ages (Kühnel 1984: 254–257). Timber constructions still remained common in the 19th century (Forster 2004: 96).

Around the end of the Middle Ages (15th–16th century) in Central Europe, the post and beam technology was replaced by a half-timber construction, where at each floor the posts were separated by horizontal beams (Ger. *Rähmkonstruktion*; Fig. 4.6). Each floor was a separate segment of construction. This enabled better utilisation of trees and increasing the building height. A common infill-method was the use of wattle and daub. In addition, adobe brick, fired bricks and stones were frequently used. The choice of the infill material was related to the expression of social status.

Between the 2nd and the 16th century, for the region spanning over the Balkans and today's Turkey, insufficient scientific facts allow us only to speculate about the transmission of the half-timber frame construction, e.g. in Constantinople in the 4th, 11th or 13th century as described by Hatzitrifon (2016: 10). Returning to the Roman half-timbered construction, it seems to anticipate a development seen again in the Balkans and the Ottoman region. It remains unclear if transmission of this type of construction had already settled in the Balkans and / or Anatolia before the spread of the Ottoman Empire, or if the main phase of transmission followed the expansion of Ottoman influence. Contrary to the early post and beam development in central Europe, the Balkan-Ottoman building type shows a solid basement and a half-timbered upper floor, similar to the house mentioned in Herculaneum. Therefrom this it is not possible to exclude a different technical development.

Derivation of the Balkan-Ottoman building type (Figs. 4.7, 4.8) from a post and beam construction is not evident. The half-timbered construction in the upper floor is in Turkey known as *himiş*[101] (in Macedonia known as *bondruk*[102]) and is close to what we know in German as *Fachwerk* or in French as *colombage*. The oldest testimonies of this Roman-Balkan-Ottoman building type in Turkey have been found to exist starting in the 17th century (Günay 1998: 16). An example is the Sofa Kosku building in the Topkapi Palace in Istanbul (Ahunbay 2000). According to historical reports for Istanbul in the 16th century, Hatzitrifon (2016: 11) mentions simple, one-storey houses and representative buildings made of wood besides other materials like stone. In addition, paintings may point towards the use of simple, one-storey buildings in Istanbul and Anatolia during the 16th century, and a common development of the multi-storey type in the 17th century (ibid.). The

101 Cf. Langenbach 2002b: 3. The Turkish term depends on the filling: *himiş* for a filling with masonry, *bağdadi* for a filling with bulk material (*vrac* in French) and *dizeme* when filled with wood (*rondins* in French) (Caimi 2006: 499). According to Poletti (2013: 114), the kind of infill changes the behaviour of the wall, ranging from flexural to shear predominance.

102 Cf. Gramatikov 2000: 1.

Fig. 4.7 Safranbolu. Turkey. View over the mostly two- or three-storey *himiş* constructions of the city.

Fig. 4.8 Ankara. Turkey. *Himiş* structure on top of a solid ground floor.

oldest remaining buildings in Kastoria in Greece from the 18th century follow a similar typology with stone walls in the lower level and the upper level constructed with wood (Hatzitrifon 2016: 13).

The vertical structural division is a feature of Balkan-Ottoman buildings from the 17th century onwards. In the first half of the 17th century, not only the ground floor, but also three facades of the upper floors were erected in stone and do not project beyond the ground floor (Günay 1998: 72). The ground floor was mostly made of rubble stone, with dressed stones rarely used. Today and since at least the 17th/18th century, this type of solid construction with a half-timbered upper floor can be found all over the Balkans from Albania in the west and Romania in the north, via Greece, North Africa in the south and Central Asia in the east (ibid. see Map 1). Syrian influence can be attributed with having a significant impact on the development of stone construction techniques (ibid. 19).[103]

Moving eastwards into the Himalayas, half-timber frame constructions developed primarily in Kashmir. A dating of the origin of this tradition is difficult and we cannot exclude influence from western regions. An early development of timber-framed structures as we know from Europe under the Greek or the Romans is not evident in the Himalayas or the Indian subcontinent. A common use of structural timber started in Kashmir at least in the 12th century CE. King Jayasimha (1128–1140) allowed the citizens a free supply of forest wood, which increased the common use of timber for building construction, which peaked between 1420 and 1470 (Kachru, Thapalyal 1990: 103). Langenbach (2009: 5) mentions historical sources such as Kalhana in 1148 and Tímúr the Tátár in 1398 CE, both of whom refer to the large amount of timber constructions in Kashmir (after Elliot 1867). According to Langenbach, the two vernacular main building techniques in Kashmir, *dhajji-dewari* and the *taq,* may have evolved much later at the beginning of the 19th century (Langenbach 2015: 84). This seems to be a late dating, in particular for the use of *taq,* for which earlier use cannot be excluded (see below in parts 1.3 and 4 of this Chapter).

103 At this point we need to emphasise that we have to differentiate between a standardised building type, which may span over a transnational area and local variations, for instance, due to particular local material resources and climate conditions. For example, the type of timber for Ottoman buildings is addressed to the respective local availability: chestnut at the Black Sea, oak and yellow fir in Western and Northern Anatolia, and cedar, cypress and juniper in Mediterranean areas up to the Taurus Mountains (Günay 1998: 30). The widespread use of wood shingles for roofing is determined by the availability of wood (ibid.).

1.2 Bracing of solid walls

Structures found in Orchomenos in Greece, which were dated c. 3000 BCE, show a succession of different types of walls made either round or oval in their ground plan (Rider 1965: 45). These wall shapes oppose an early use of timber-lacing at this time in this region. Throughout Minoan era, timber structural systems were continuously used for about 1,300 years (Tsakanika-Theohari 2009: 129). In different levels of the walls, unworked timber trunks or branches were laid as reinforcement transversally and longitudinally into the wall. This technique was developed during the Minoan era with vertical timber components (ibid. 130, 131).

The bracing of solid stone walls is traditionally made with timber lacing,[104] and in many cases ring beams are used. A kind of timber lacing is the use of a 'ladder'-like timber construction placed on the wall at a certain height, e.g. on top of each floor, but also placed within a storey. It is composed of a pair of runner beams facing the inner and outer surface of the wall. They are connected by wooden cross-pieces, which resemble a ladder (in the following also called "'ladder'-like timber lacing"). Ring beams in general work only in a force-fitting manner, in particular at the corner joints. The efficiency of the ring beam is substantially increased if it is not only linear along the wall, but covering the whole area on top of the wall. This may be one reason for the development of the 'ladder'-like timber lacing. Moreover, it facilitates the connection of the solid wall portion with the floor beams on top.

Traditionally, the wooden joints were made as pure wooden constructions, e.g. with pegs and lap joints. Early examples of timber lacing may date back to 9,000 years ago in Anatolia[105] (Hughes 2000a). In Akrotiri of Santorin (c. 1500 BCE), an early type of a wooden timber lacing was found (Touliatos 1996: 78–81). Buildings each with two to three-storeys were mainly made of rubble stone, in which horizontal timber lacing made of tree branches with cross-pieces on top had been placed as a kind of 'ladder'-like construction (Vintzileou 2011: 169). We can describe this construction as an early form of timber lacing. However, as shown by Vintzileou (2011: 172), several buildings had the horizontal lacing connected to a vertical timber structure and by that formed a framework construction for the reinforcement of stone walls.

Julius Caesar mentions the "Gallic wall", wherein straight beams were placed (with a length of about 12 m) lengthwise connected at a distance of about 60 cm. Distance between the beams was about the same and the beams were held in position by a load of stones on top. Advantages of this technique are its strength as a defensive construction and fire safety resulting from the high content of stone. (The Gallic Wars; pictures of reconstruction see Caimi (2006), after G.A. Rondelet (1832) in Barucci (1990)).

The use of timber in combination with solid structures such as walls and domes is reported from the Roman and Byzantine period. During this time, timber belts were used at the bases of domes for stabilisation during earthquakes (Gavrilovič at al. 2003: 64). For the Byzantine era, different structures with timber reinforcement have been found (Vintzileou 2011: 172). In this context,

104 Timber lacing is a horizontal bracing of solid walls (made of, e.g. stone or clay) with wooden elements, beams or scantling, also seen with logs.

105 Following Hughes (2000a) where no further source for this dating is given.

Fig. 4.9 Baldan Bereveen Khiid. Mongolia. Vertical and horizontal timber lacing in a solid wall.

Fig. 4.10 Kashmir. India. *Dhajji dewari* (1) and *taq* (2) constructions along the banks of the Jhelum River.

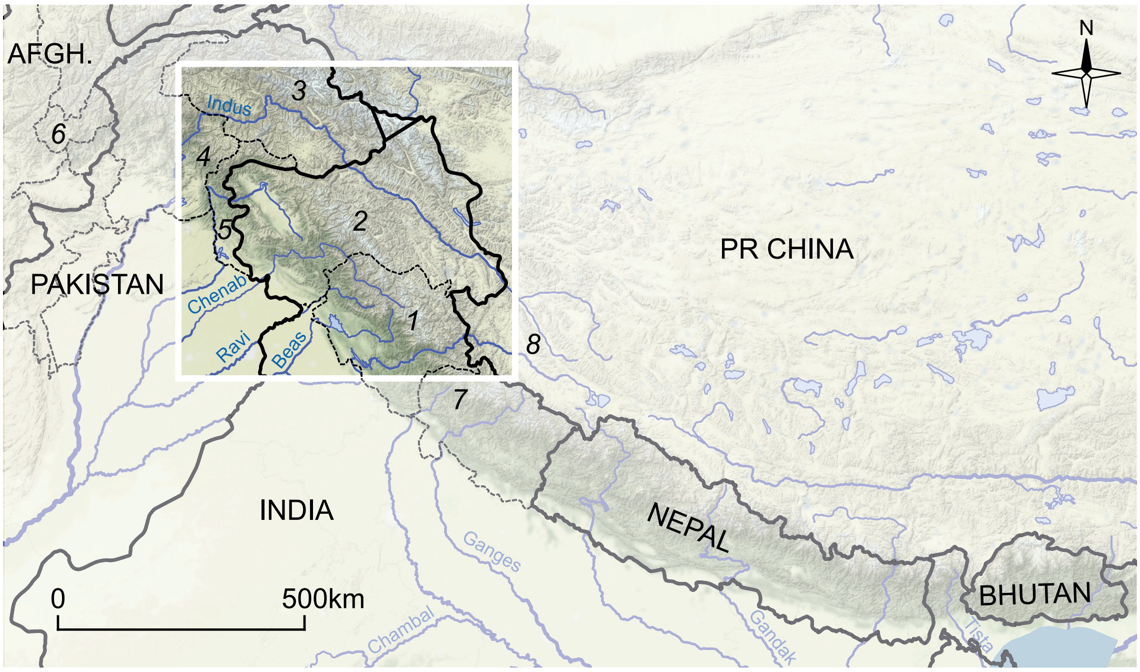
the term *imandosis*[106] (*imantodi* after Hatzitrifon 2016: 20), deriving from the Greek language, is used. According to two dictionaries – one from the 9th century and the other from the 10th century – the term *imandosis* is defined as a tying system, i.e. to tie timber components inside masonry construction, arches and vaults using diagonal timber bracing (ibid. 173, 174). An early example of timber lacing is known from Khorezm in Central Asia and dates back to the 8th century CE (Günay 1998: 32, after Yazicioğlu-Mustafa 1982: 37–38)[107]. In the Greek, Balkan and Ottoman constructions, since at least the 18th century, the use of timber lacing is reported for solid ground floors made of stone.

Moving eastwards into the Himalayas, early dating for the use of timber lacing is given by Darragon (2015: 42). She specifically refers to one 12-cornered tower dating to the 4th century CE. It is located in the higher reaches of the Nyangchu River of present day Gyamda (Tib. Rgya mda') County in East Tibet. Another early East Tibetan example is found in the chamber of the burial mound M-3 at the burial ground in Reshui. Here, walls in the east and west chambers were made of stone using a kind of 'ladder'-like timber lacing dating between the 7th and 9th century CE (SAM 2004: 63). We can also mention Mongolian sites to show the far-reaching use of timber lacing in solid structures, e.g. at the Baldan Bereeven Monastery in the east of Mongolia (48°12'8.78"N, 109°26'20.41"E), where the use of timber lacing in combination with vertical timber bracing in an earth structure has been observed (Fig. 4.9).

Timber lacing in solid walls is traditionally used worldwide in many regions. This building technique is spread throughout Europe along the Mediterranean region, the Balkans, Greece across Turkey (here known with the term *hatil*, cf. Langenbach 2002b: 3), North Africa, Syria or Jordania (e.g. used along the inner surface of well-dressed stone walls of Qasr el-Bint in Petra), the mountainous region of Iran (e.g. used in the adobe brick walls of Abyaneh; alt. 2,230 m, 33°35'9.92"N, 51°35'29.99"E), North Pakistan (here known by the Pashto term *bhatar*, cf. Dipasquale, Mecca 2015: 85), Kashmir (here known by the term *taq*) (Fig. 4.10), along the Himalayan region into East Tibet and Mongolia.

106 Hatzitrifon (2016: 20) mentions the incorporation of Greek terms into Turkish and also the replacement thereof by Turkish terms. This includes a Greek term for "timber ladder-type stretching bars in stone walls" as ιμάντωδη.

107 Günay mentions in his book the place as Harzem. Mrs. Zeynep Ahunbay was so kind as to verify Harzem as Khorezm in Central Asia in an e-mail on Oct. 13th, 2016.



Map 4.1 Core region and extended core region.
GIS data based map: Jakob Gredler. Final graphics: author. Map based on data from Vector data (VD) and Basemaps (BM). Citations of VD and BM also see: Chapter IX, list of illustrations.
1 = Himachal Pradesh;
2 = Jammu and Kashmir;
3 = Gilgit-Baltistan;
4 = Khyber Pakhtunkhwa;
5 = Azad Jammu and Kashmir;
6 = Nuristan;
7 = Uttarakhand;
8 = Ngari.

1.3 Composite constructions in the Himalayan region

The core region of further investigation is located in the Himalayas in the states of Jammu and Kashmir, and Himachal Pradesh. The expanded core region extends into the adjacent region of North Pakistan, which is included in this study because of essential comparison features, although it is already part of the Karakoram region (Map 4.1). In the core region, we find distinct traditions of composite constructions. In this section, the relevant structures are shortly presented. The composite constructions of the core region are covered in greater detail in the following parts of this chapter. The mentioned constructions represent commonly occurring composite techniques, which should not be understood as exclusively the only types of constructions in these regions. Furthermore, different variations of the mentioned composite techniques are treated below.

1.3.1 Core regions Himachal Pradesh, Jammu and Kashmir and North Pakistan

The majority of the population in Himachal Pradesh belongs to the *Khash*, whose settlement in the Indo-Gangetic plains dates back to the time before the *Aryans* (Handa 2008b: 137). For the high quality, wood-stone-composite multi-storey construction, the *Khash*[108] are considered predominant, in particular for the use of the *kath-kuni* composite technique (explanation of the technique below). Before using this composite technique, *Khash* buildings had mainly been made of wood (Handa 2006: 49). Other major population groups in Jammu and Kashmir, and Himachal Pradesh are the *Gujjar* (mainly building with clay) and the *Gaddi*, the latter having settled in the Indian mainland since the early Middle Ages (Handa 2008b: 137). The *Gaddi* use the *farque* composite construction technique for their buildings (ibid. 140; explanation of the *farque* technique below in part 4 of this chapter). Both *Gaddi* and *Khash* constructions are also found with a cantilevered upper floor.

In the Transhimalayan part of Himachal Pradesh (Upper Kinnaur, Lahaul and Spiti; detailed map of Kinnaur see Map 4.7), we find stone and earth buildings with a relatively small content of wood, primarily used as timber lacing. In some areas in Himachal Pradesh, in particular in some parts of the districts Chamba, Shimla, Kullu and Kinnaur, dry stone walls (not as composite) are common due to the availability of river stones and a local scarcity of wood (cf. Sood et al. 2013), although app. one third of Himachal Pradesh is forested (see Map 4.5).

In Ladakh (located in Jammu and Kashmir), we primarily find clay and stone structures. Different techniques for using 'simple' timber lacing or 'ladder'-like ring beams are known. From Ladakh to North Pakistan, the design changes with a significantly higher content of wood. In North Pakistan, we find composite constructions such as *bhatar,* and *cator and cribbage*, the latter being from a construction-typological point of view related to the *kath-kuni* construction in Himachal Pradesh.[109]

From Ladakh to Kashmir, a substantial change of structures is obvious. On the one hand, we find solid constructions with 'ladder'-like timber constructions (in Kashmir known as *taq*), similar to the *hatil* in Turkey; on the other hand, we find half-timbered buildings (in Kashmir known as *dhajji-dewari*), similar to the *himiş* in Turkey. Concerning strong similarities between construction techniques used in Kashmir and in Turkey, we cannot exclude mutual influences or even a primary influence, as already mentioned, between Kashmir and its western regions. The 'ladder'-like development, which we find in Kashmir with *taq,* is also evident in Himachal Pradesh and Uttarakhand, and further east just scattered, rarely as a main building type and often reduced to 'simple' timber lacing without the use of pairs of runner beams. The Ottoman-Kashmir half-timber type (*dhajji-dewari*) with diagonal components finds its core area in the Himalayas in Kashmir with some remains of *dhajji-dewari* in Himachal Pradesh and the *rabsey* in Bhutan.

108 Negi Loktus (2015: 361) gives a vague hypothesis of a possible link between the *'Khash'* and the Tibetan designation of Kashmiri people as *'Khashe'*.

109 For further explanations of the mentioned techniques see below in part 4 of this chapter.

1.3.2 Himalayan regions outside the core region

Fig. 4.11 West Bhutan. Located close to Paro along the road to the Tagtshang Monastery. Traditional *rabsey* construction. Photo: Roland Meingast 2016.

Fig. 4.12 Tawang. Arunachal Pradesh. Stone, clay and bamboo mats used side by side.

Fig. 4.13 Rumtek. Sikkim. Monks' residences close to the monastery. The building type is locally referred to *Bhotia* people.

In Bhutan we find varying altitude-differentiated thatched bamboo houses in the south, rammed earth in the west and stone architecture in the east. Stone buildings are made with rubble stone in a random bond. Timber lacing is rather uncommon. Wood is primarily used for the projecting upper storeys, the so-called *"rabsey"* (Fig. 4.11). They are connected to solid subconstructions made of rammed earth or stone. The supporting beams are placed on projecting wooden brackets. The *rabsey* construction is a wooden framework infilled with wattle and daub or wooden panels (cf. Potocnik 2007). A stone building tradition continues in the east of Bhutan in Arunachal Pradesh in Tawang and Bomdilla, where besides solid stone structures we find 'simple' timber frame buildings with walls of bamboo mats (Fig. 4.12). Their frequency increases towards Assam.

To the west of Bhutan in Bengal in Kalimpong and the surrounding area as well as in Sikkim, different cultural influences meet. In this region we find solid constructions, mainly of stone, e.g. at religious Tibetan Buddhist structures. Attributed to the ethnic group of the *Bhutia* is a type of building with a ground floor used for storage and made of well-dressed stones, and an upper floor made of wattle and daub as a living floor. An example is the monk's accommodation beside the Rumtek Monastery (Fig. 4.13). Similarly, another example is the nun accommodation near the Ralang Monastery, in which even the upper floor was partially built in stone, and open wall sections were closed with wattle and daub. Traditional architecture of the *Lepcha*, found in Bhutan, Sikkim and West Bengal in the area of Kalimpong, is a stilt construction on stone bases. The ground floor is open, and the upper living floor is closed with wattle and daub panels, similar to *Bhutia* houses.

Fig. 4.14 Lhasa. Tibet. Traditional technique of stone laying shown at the Shide Lhakhang.

In the timberless West and Upper Tibet regions, stone and earth buildings are prevalent. A variety of different stone bonds were used. The ruins of the ancient monastery of Chekha (Tib. Chad kha) in Central Tibet are an example of the diversity (cf. pictures in Feiglstorfer 2015: 77–81). The ruins of the Shide Lhakhang in Lhasa show typical banded stone masonry (ibid. 82–83). This technique uses large (mostly dressed) stones on the outer and inner surfaces of the walls placed side by side in a row in clay mortar (Fig. 4.14). Cavities between the large stones are filled with smaller stones. At certain vertical distances, cross-stones connect the outer and inner wall shell. The reduction of the cavities to a minimum increases the friction between the stones and by that the ability of distributing pressure within the wall. The use of two shells of stone with a vertical infill layer and the type of layering of the stones ensure flexibility in the wall in the case of structural movements.

The outer surfaces of the walls are inclined, whereby the amount of building material is reduced towards the top, which also reduces the labour force required to lift the stones. Furthermore, the mass of the wall is reduced in the upper part, which is positive in the case of structural movements. The inclination of the wall shifts the centre of gravity of the wall to the inside, which in the case of movement makes outward tilting more difficult. These stone structures are entirely without wood. In contrast, in East Tibet wood is much more common, primarily for timber lacing in stone walls with clay mortar, for timber frames, or for log buildings (Ryser 1997: 54).

Fig. 4.15 Kathmandu Valley. Nepal. 1 = Wooden wedges as a traditional technique to stabilise walls. 2 = Wooden components destroyed during the earthquake in 2015.
Photo: Christof Ziegert.

In Nepal, at Newar structures in the Kathmandu Valley, in many cases the outer walls of a house are made of fired bricks, while the interior structure is divided by timber frames (Tavares et al. 2014: 15). In the case of structural movements, ceiling beams are chocked with wooden wedges (Nep. *chokus*; cf. Bonapace, Sestini 2003: 66; Fig. 4.15). These wedges secure against slipping out of the hole in the wall. In prestigious buildings, ceiling beams are often placed relatively close to each other (with a distance of app. the width of one beam), whereby a bracing along the floor surface is increased (cf. Feiglstorfer 2011b: 130). In Nepal, timber lacing and ring beams are known by tradition, however, they seem to have a minor role in Newar vernacular buildings. Section drawings of the Basantpur Tower (from 1770 CE; Le Port 1991: 103–105) show a vertical and horizontal timber lacing, a characteristic not present in many other buildings of this form. A *Kashia* house in Nepal does not differ much from a *Khash* House in Himachal Pradesh or Uttarakhand (Handa 2008b: 140). In western Nepal, the use of timber lacing in stone buildings is common. It follows a type also known from East Tibet (Ryser 1997: 54, after Kleinert 1983: 19). *Khash* people, who still live in Jumla District in Nepal, may have brought composite building techniques to Nepal.

1.4. Diffusion of composite constructions

In addition to local developments, specific types of construction were spread over long distances. The channels of dissemination of composite constructions, in particular half-timber and timber-laced walls that are commonly used over a wide region stretching from the Balkans towards Kashmir, are difficult to determine and can here only be called hypothetical. Even more so, we find similarities in the materials and techniques used, and this may point towards a common development or mutual influences. In addition to the mentioned types of construction, numerous others, which we have yet to consider, exist in the discussed regions, including monolithic (non-composite) types of construction. The diffusion of techniques can be linked to different parameters such as trade, war or peoples' relocation. Local resources, environmental conditions and building traditions are opposed to imported expertise.

Based on the aforementioned historical markers of half-timbered buildings, early roots in a Greek-Roman-Balkan-Ottoman cultural zone can be seen, with diffusion over the European and Ottoman regions to Kashmir. At this point, strong constructive similarities between Kashmir construction and technical developments to the West can be drawn, such as a particular type of half-timber construction and methods of infill, the vertical separation between a solid ground floor and light-weight upper storey or the cantilevered half-timber storeys. Towards the Far East, presently no direct influence can be stated. Central Chinese timber frame constructions show individual features and point towards a cultural development of its own.

The use of timber lacing in solid buildings in general has a much earlier development than the framework tradition, and its diffusion is considerably more extensive. Timber lacing belongs to a type of construction that spread not only through knowledge transfer, but may have developed as it was locally adapted to specific technical requirements. Again, a certain unifying characteristic between the 'ladder'-like timber lacing in Kashmir and Western cultures (e.g. Balkans or Turkey) becomes obvious.

The dissemination of knowledge was supported by imperial political structures and ethnic-religious affiliation. The construction of defence structures, for example, was concerned with continuous technical progress (see "Gallic Wall" described afore) as well as the construction of buildings with a claim to represent a higher social status, as related to rulers or religious communities. Belonging to certain population groups and religions may also contribute to such widespread dissemination. A diffusion of certain constructive features of identity by Muslims in the Late Middle Ages can be suspected.

The dissemination process is complex and cannot be reduced simply to a religion as a priority transporter of knowledge. For example, we find constructive parallels to Islamic North Pakistan in Hindu dominated Himachal Pradesh. According to a hypothesis by Handa (2001: 97), no structural temple existed in the Western Himalayan region up until the 7th century, except possibly several Deva Temples in Kullu. For the Śakti Devī Temple (late 7th/early 8th century) in Himachal Pradesh, construction is described as "made by the usual timber-bonding method that combines layers of stone with a framework of wood" and points towards the use of a *kath-kuni* or a similar building technique (Bernier 1989: 38). The Buddhist temple of Ribba built in the 9th/early 10th century (Klimburg-Salter 2002: 21; Luczanits 1996: 71) follows a type of construction similar to the *cator and cribbage* technique found in North Pakistan; the same can be said for the Hinduistic Mirkulā Devī Temple in Udaipur in Himachal Pradesh built in the 11th century (acc. to Handa (2006: 180) in the 8th century). The local non-Muslim population of *Khash* primarily propagated the *kath-kuni* technique (as it is known in Himachal Pradesh).[110]

The Islamisation of Kashmir, which peaked in the 13th to 15th centuries, started in the 11th century during the Lohara-Dynasty. In the 11th century, Turkish influence in Kashmir may have existed. Tunga, who led the war under the Kashmiri ruler Saṃgrāmarāja (1003–1028 CE), was defeated in 1013 by Turkish troops (Handa 2006: 47). This is evidence of contacts between Kashmir

110 In Uttarakhand, the *Khashia* could not evolve as had been the case in the rest of the Western Himalayas, which lead to a neglect of the development of wooden architecture (Handa 2006: 47). For further explanations of the techniques mentioned see below in part 4 of this chapter.

and western territories. During the foundation of Chamba (c. 1025 CE), a mixture of Pratihāra Renewal (10th to 12th century) and the Kashmiri style is evident in artistic products (Bernier 1997: 132).

The conquest of Chamba by King Lalitāditya (ruled 724–760 CE) after the reign of Chamba's King Meruvarman (680–700 CE, Singh 1999: 74) probably extended influence to southern Lahaul, Kullu and Kangra by rulers of Kashmir's Karkoṭa Dynasty (Bernier 1997: 132; cf. Handa 2001: 104). Muslim rulers followed this dynasty. Because of the increase of the dominance of Muslim culture in Kashmir, Hindu stone carvers had to leave to the Hindu kingdom of Chamba, resulting in a lack of carvers in Kashmir (Handa 2006: 97). Under Sultan Zain-ul-Abidin (1420–1470 CE), wooden architecture flourished in Kashmir (Handa 2001: 107). Handa (2006: 26) points towards political and socio-economic factors in Kashmir during the 14th century as influencing those of Himachal Pradesh and Uttarakhand. Specifically, the *kath-kuni* technique was of more strength for defence, and displaced the earlier full-wooden structures. Additionally, an over-exploitation of deodar wood may have caused restrictions to be put into place by the local rulers regarding cutting of deodar trees (ibid.).

At this point of research, we cannot state a primary Kashmir and / or Muslim influence on the development of the *kath-kuni* technique in Himachal Pradesh. As shown in the following, the *kath-kuni* technique seems to be a logical continuation in the development of timber lacing in solid walls in Himachal Pradesh. This seems to differ from the *dhajji-dewari* technique, which has its eastern limit of extensive influence in the Himalayas in Kashmir.

Important for diffusion is also the willingness of the ruling class to accept new influences. Langenbach (2002b: 3) hypothesises that Nepal remained a protected kingdom isolated from cultural influences from the Ottoman Empire (or earlier Muslim craft traditions, AN), and thus a diffusion of the 'ladder'-like timber lacing was excluded from Nepal. However, we need to consider that Nepal was known for its exchange of various goods and craftspeople already in the imperial period in Central Tibet in the 7th century. Literature sources for Nepal between the 8th and 12th century are very limited. At least in the late 10th/early 11th century, we know that craftspeople from Nepal were in high demand in the Western Himalayas and must have been in contact with craftspeople from Kashmir. Thus at this early time an exchange of the latest technical standards in Kashmir must have existed in Nepal. One of the earliest strong earthquakes reported in Nepal occurred in 1255 CE (cf. Pradhan 2000), and the occurrence of earlier earthquakes is likely. The questions still remain of why 'ladder'-like timber lacing was not introduced to a much higher degree into vernacular Newar architecture, and why a technique using wedges at the ends of the floor beams to stabilise the walls in case of structural movements was preferred.[111]

For Western Gujarat in the Khuch area, where a seismic building culture is also absent, Langenbach (2002b: 3) argues that the Moguls' influence was too minimal for this sizable Hindu region. In Ahmedabad in Central Gujarat, in contrast, where a timber-composite tradition is existent the period of Islamisation was in parallel to the Ottoman Empire, facilitating cultural exchange.

111 Research conducted after the Nepal earthquake in 2015 reported that wedges and wooden components were strongly weathered and had lost their static strength (Telephone conference in spring 2016 with Christoph Ziegert, who conducted a post-earthquake survey). This may have supported the collapse of many historical Newar structures.

Fig. 4.16 Mandriza. Bulgaria. Adobe brick walls with timber lacing and a projecting upper floor.

Fig. 4.17 Mandriza. Adobe brick walls with 'ladder'-like timber lacing.

1.5 Relation between diffusion of composite constructions and seismic culture

Sensitivity of building traditions to foreign influence is well expressed by a Bulgarian example from the Ottoman period: Mandriza, a village in the far east of Bulgaria (alt. 81 m; 41°23'30.32"N, 26° 7'59.58"E) located close to the Greek and Turkish borders, gives evidence of a mixture of different building traditions. During the Ottoman rule, Albanian shepherds from the south-east of Albania founded this village, following an adobe brick culture (Figs. 4.16, 4.17).[112] Until the 1970s, they were silk farmers, and during its economical peak, the village had about 3,000 inhabitants. Today, it is nearly abandoned. Surrounding villages like Dolno Lukovo follow a widespread spread Bulgarian tradition of building with rubble stone in a random bond with 'ladder'-like timber lacing (Figs. 4.18, 4.19). Interior walls were made as timber frame constructions with wattle and daub infill. In Mandriza, in contrast, which is said to be the only Albanian village in Bulgaria, buildings are made of adobe bricks – surrounded by villages following stone architecture. This means that the Albanian settlers may have brought their building traditions with them. However, what remains the same in the neighbourhood is the use of timber lacings, which obviously follows a local building tradition. Several of the lacings were made like 'ladders', as found in the

112 Personal information given by Hristo Peev in Mandriza in December 2014. The following data were collected by the author during field research:

Ad Mandriza (an adobe village): In earlier days, a centre for education on silk production was situated in Bursa; old buildings were erected in app. the 17th century, new buildings around 1850 CE; the width of adobe walls is app. 64 cm; the brick size is about 29 x 14.5 x 7 cm; the width of the brick bond is either 2 x 29 cm or 4 x 14.5 cm, with a bed joint of 2.5 cm; the use of ring beams as timber lacing is common; timber lacings are app. 8 x 8 cm in profile; the common length of houses along the road is app. 8 m to 9 m; during earthquakes, buildings survived without significant damage; houses were built in cooperation of all village members; nails were forged in the village.

Ad Dolno Lukovo (a stone village): Stone walls are made as double shell constructions with well-dressed outer faces using smaller rubble stones as filling material; stones were chiselled out of big boulders; the wall thickness is app. 50 cm; about three 'ladder'-like timber lacings are laid within the height of each floor; walls are straight with well-dressed corner stones; oak wood is used as structural timber; during earthquakes a few buildings showed cracks, most survived without any damage; the tradition of making stone constructions ended with the beginning of the socialist era changing to fired bricks.

Villages towards the north between Mandriza and Ivanova: The villages contain remaining stone and adobe buildings. Some of the stone buildings show timber lacings, others are built without.

Fig. 4.18 Dolno Lukovo. Bulgaria. Stone walls with timber lacing.

Fig. 4.19 Dolno Lukovo. Corner half lap joints.

neighbouring stone constructions; others were made of 'simple' ring beams with just one runner beam. Mandriza is a good example of both the assimilation of a foreign building tradition and the use of proved local techniques in wall stabilisation. This example is strongly related to the matter of timber lacing in regard to structural movements, which have become a part of the traditional knowledge on building technique in particular regions. In context with earthquake endangered regions, this technical evolution has become part of a seismic culture.

In addition to historical references to the correlation of influences concerning either the diffusion or the independent local development of techniques in different places, particular types of construction may help to find consistencies. The global field of vernacular development appears extremely diverse. Considering the aforementioned region spanning from the Balkans to the Himalayas, clear technical measures are present for the strengthening of buildings in the case of structural movements. Structural movements can result from ground settlement and earthquakes, the latter being much more extensive over wide areas. Globally, some regions have been more affected by earthquakes due to their tectonic preconditions. Damages are an essential parameter for the development of buildings. In particular, people have learned and developed from the effects of earthquakes.

The development of a seismic culture in affected areas and of related local building traditions is likely. Regarding the aforementioned Balkan-Ottoman-Kashmir-Himalayan zone, connecting principles of techniques used in a seismic culture along the west-east zone from the Balkans to the Himalayas become obvious. Several striking coherences are mentioned at this point: The fact that composite structures have been deliberately applied to counter earthquakes is shown in the following two examples: 1) After the city of Lefkas in Greece was destroyed in 1825, the British, who occupied the island (1810–1864), introduced new regulations with timber framed constructions, which today are still in common use (Touliatos 1996: 78–81). 2) Another example is the *Construção Pombalina* (after the Marquis of Pombal) in Portugal. Knowledge of the development of a timber frame construction was collected from the surviving buildings of the 1755 earthquake, and new building rules including a framework construction were established and followed for about eighty years after the earthquake.[113]

113 During the mid 19th century, these constructions were progressively abandoned and a simple type of this building technique (known as *gaioleiros*) developed (Simões et al. 2012).

Earthquakes pose a widespread threat to buildings. Today, earthquake zones are determined over the globe and divided by earthquake intensities. The map "Earthquake danger zones around the world"[114] includes all earthquakes measuring 6.0 and more on the Richter scale over the past 40 years. The affected regions are mostly located in areas of plate tectonic activity. Looking at the further region adjacent to the Himalayas in a Eurasian context, a zone of strong activity becomes evident (after Richter ≥ 6.0) from west to east, and from Italy across the Balkans (to Romania in the north; cf. Hărmănescu, Georgescu 2015), Greece, Turkey, Iran, Afghanistan, Pakistan, Himalaya and adjacent regions.

This zone corresponds approximately to the main distribution area of composite structures, i.e. solid walls with timber lacing. Half-timbered structures, however, show a different main distribution area, namely across a large part of Europe towards Kashmir. In Kashmir and North Pakistan, we find a focal point of different composite techniques: on the one hand, half-timbered buildings, on the other hand, solid constructions with timber lacing. In further parts of the Western Himalayas (e.g. Himachal Pradesh), the half-timbered building tradition is no longer being practised. With the introduction of the *cator and cribbage* technique, North Pakistan and the Western Himalayas show a cultivation of a technical development of a solid wall composite technique with an extremely high content of timber. In some rural areas, these traditions are still alive.

The Himalayan fold mountains are the largest and youngest mountain range. They developed from the collision of the Indian and Eurasian plates. These activities are still in progress. The "Seismic Hazard Maps of the World"[115] shows the peak ground acceleration (PGA) that a site can expect during the next 50 years with ten percent probability. On the 5-point upward rising scale of the "Seismic Hazard Maps", the Himalayas are marked with level 4. The high risk of earthquakes in the Himalayas and historical disasters must have been a major reason for the development of certain composite constructions.

Historical sources on Himalayan earthquakes in the 18th century and earlier are scarce. According to Bilham et al. (2001: 1442; adjusted by the author according to Sood et al. 2013), great earthquakes occurred in 1255 (Nepal)[116], 1555 (Kashmir), the 16th century CE (Kashmir), 1720 (Kumaon), 1803 (Garhwal; it caused great damage between Delhi and Lucknow), 1833 (Nepal), 1855 (Srinagar), 1897 (Bhutan), 1905 (Kangra), 1934 (Nepal-Bihar), 1950 (Assam), 1974 (Pattan), 1975 (Kinnaur and Spiti; it caused damage (e.g.) in the villages of Nako, Shelkhar and Chango), 1981 (Karakoram, Darel, Tangir, Khanbari Valleys), 1991 (Uttarkashi), 1999 (Chamoli in Gharwal region), 2005 (Muzzafarabad in Kashmir), and 2015 (Nepal).

114 Map: *Earthquake danger zones* around the world: http://www.cbc.ca/news2/interactives/world-quakes, access: 05/2016.

115 Seismic Hazard Maps of the World: http://geology.about.com/od/seishazardmaps/ss/World-Seismic-Hazard-Maps.htm#step15, access: 05/2016.

116 This seismic activity is reported according to the Gopalrajbamsabali (a fifteenth century chronology) and caused the collapse of temples and the death of one third of the population (Pradhan 2000).

Certain features such as the use of locally available materials, simple floor plans, small window openings or the use of pure wooden joints are generally part of vernacular architecture and do not necessarily point towards characteristics of a seismic culture. There are some technical features that can be an indication of additional seismic measures, and which may also show up in particular details of construction. Ortega et al. (2015) mention some characteristics of vernacular seismic-resistant constructions like elevation configuration, use of timber elements, connection between structural elements, stabilisation of floors and roofs, and reinforcement of the openings. Some of these characteristics are explained in the following in relation to the Himalayan regions.

1.5.1 Quality of the ground

Within an earthquake zone, the consistency of the ground is striking for its behaviour during vibrations. It is not an anthropogenic feature, like the following described technical aspects of seismic culture, but a crucial natural circumstance, on which culture concerning developments are based.

During an earthquake, due to a sudden displacement, the ground accelerates, and shear waves (S-waves) and primary waves (P-waves) are produced (Hettler 2000: 407). This happens along the surface and underground, and is followed by accelerating foundations and constructions (Gasparini 2000: 5). How vibrations during an earthquake are absorbed depends on the quality of the ground, which is an essential criterion for the impact of an earthquake on a building. A soft, sandy ground can be regarded as particularly critical. It can lead to vibration amplification, liquefaction or sudden subsiding (Adam, Paulmichl 2010: 67). Excessive vibrations significantly change the behaviour of a soft ground. Its properties are similar to liquefaction (Tabet 2016: 4).

The ground directly influences the building's foundation, which in turn has to work as a shear component. In order to form a rigid foundation plate, a bedrock is suitable as a stiff base. Solid floors have a positive impact on the resilience of a building against earthquake forces. They increase the range of the excitation frequency and divide the energy released on several frequencies. In a reverse sense, this effect could be observed in the 1985 earthquake in Mexico City. The soft ground contributes to a filtering of vibrations and results in an amplification of a smaller frequency range. (Interview with Adam in 2004)

In South America and, indeed, in Kashmir, we find a soft ground, as opposed to rocky mountain ground (cf. Langenbach 2005: 15). Schick (1997: 64–66) also mentions the ground as an important parameter in the examination of earthquake resistance. Specifically, in regard to earthquakes, alluvial ground is ideal for settlement, and uncompressed mixtures of sand and clay problematic. In the Himalayas, as an example, in particular in the Tibetan cultural areas, many of the settlements have been founded on alluvial fans.

1.5.2 Structural timber elements

As seen from the previously given overview of composite constructions in the Himalayas, we are basically concerned with two types: 1) solid walls with timber lacing, and 2) half-timber frame constructions. The wood in both applications is characterised by properties such as tensile strength or resistance against flexure and torsion. Such attributes are in contrast to some of the poor qualities of pure solid wall structures without timber lacing.

Timber elements generally behave elastically in a linear direction under alternating loads (Ceccotti, Thelandersson 2000: 3). This is in consideration of failures due to natural defects like knots and also of dissipation energy in areas of the timber components that are perpendicularly compressed (ibid.). According to Cokcan (2001: 53), during an earthquake we find a concentration of tensions along the corners.

At flexible vernacular constructions, the natural frequency may be higher than the stimulating frequency; however, having both equal to each other can be crucially influential. (Schick 1997: 64−66) Soft structures may be forced to take over natural frequency, while rigid constructions such as earth buildings are not endangered by this effect, as they shake rather quickly and do not show such clear deformations. Since the direction of acceleration is random, they have to be strengthened properly. (Gasparini 2000: 5) "Strength and rigidity are less effective in ordinary and unregulated construction than is flexibility, ductile behaviour, and cumulative non-destructive damping" (Langenbach 2002b: 9). Regarding weak half-timber frame constructions without rigid components, Langenbach (ibid. 5) differentiates between strength and lateral capacity, and takes note of their ability to withstand lateral forces for a longer period of time without collapsing (Langenbach 2000: 15). The strong bond between solid structure and timber would suggest using "membrane" instead of "frame" (Langenbach 2015: 87).

Over the course of history, the use of timber constructions has proven to be a common measure in earthquake prone zones. As an example, in the Marmara earthquake in 1999, timber elements in buildings performed positively (Gülhan, Özyörük 2000). In addition, some negative aspects go along with the use of timber. The higher the content of timber, the more forest land is required and the higher is the risk of fire and weathering. Half-timbered houses are found in areas with relatively high resources of timber[117] and not in arid zones. Timber lacing in solid structures, however, is also found in arid zones, e.g. in Ladakh.

Half-timbered structures are made as a kind of stabilising and flexible cache. Their connection to supporting constructions such as plinths or solid walls also remains flexible. To achieve a box-like structure, floors strengthen the horizontal surface areas, and diagonal bracings and infills strengthen vertical surface areas. Timber lacings in solid walls, in contrast, are held in position by the load of the wall on top, and wall and lacing stabilise each other.

1.5.3 Solid walls and timber lacing

One of the essential static tasks of a 'ladder'-like timber lacing (known as *taq*, *bhatar*, or *cheol*)[118] is its performance as a ring beam, i.e. a kind of belt to hold the construction together in the case of structural movements (Fig. 4.20). Ring beams have to be joined at their corners. Further, as an advantage of 'ladder'-like *taq* constructions, this joint may be connected at each corner at both

117 Traditions of timber lacing are not dependent on a particular altitude, much more on the availabilty of timber. We also find a timber lacing culture at low altitudes close to sea level, as examples from the Balkans show.

118 The wooden framework is in Himachal Pradesh also known as *chzalairi* or *patari* (Handa 2008b: 144).

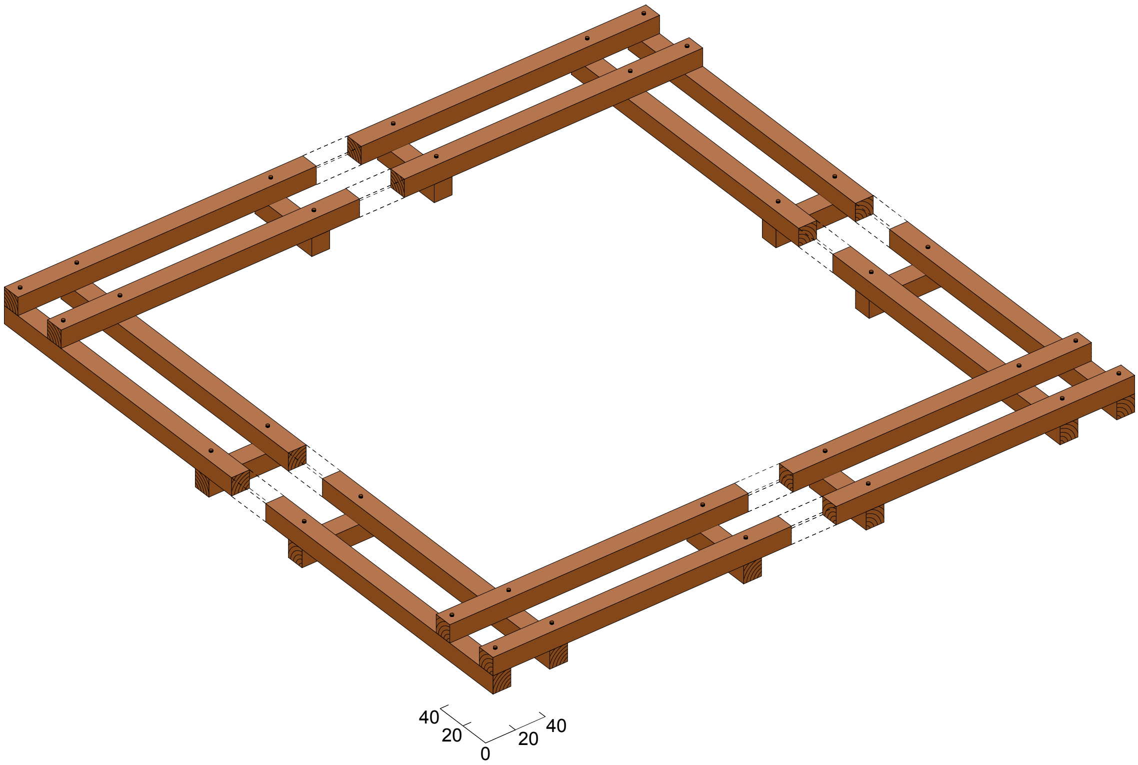


Fig. 4.20 System of ring beams.
CAD: Martin Pospichal. Details provided by the author.

facing runner beams of the 'ladder'. It does not act only linearly, but over the whole corner area. Specifically, in the case of a 40 cm strong wall, there is an area of app. 0.16 m² at each corner. An advantage of timber runners is the additional and by that increasing ductility that augments the capacity to absorb energy and increase earthquake resistance (Langenbach 1989; referring to Gosain, Arya 1967: 29).

In general, foundations, walls, ceilings and roofs are as much as possible designed as shear components.[119] In the case of an earthquake, this box-like structure supports the stabilisation of the walls in position. This method requires an appropriate structural connection of the floors with the support wall and a stability of the walls on each floor. The floor beams at each floor are connected to the ring beams and by that form a reinforced horizontal shear component. For a stable structure, it is important to ensure that floor beams, roof beams, and ring beams are firmly bonded with each other to absorb the shear forces of the floor and roof in conjunction with the walls. This rigid diaphragm allows the distribution of loads to relatively rigid vertical elements on the basis that the relative rigidity of the vertical and horizontal elements correlate with each other (Ambrose, Vergun 1999: 63).

119 For floor beams in Newar structures, which are often laid rather close to each other, the single parts of the floor or flat roof form a two-dimensional shear component for strengthening the whole structure.

During an earthquake, the vibration frequencies of the roof and the walls are different (cf. Minke 2001). This means that, in the case of a non-flexible joint between roof and walls, additional force is placed on the walls. Their connection should be of such strength that the risk of the walls drifting outwards and causing a collapse of the roof onto the inhabitants is reduced.[120] This depends on a proper structural connection of the floor and roof beams with a ring beam. A ring beam is a proper support for the floor and roof beams. For the *kath-kuni*[121] technique in Himachal Pradesh or the *cator and cribbage* technique in North Pakistan, roof beams are integrated into the wall structure and connected to the ring beams. For the *taq* system in Kashmir, floor beams are placed between a double layer of runner beams. Similar is the *dhajji-dewari* construction in Kashmir and the *himiş* construction in Turkey. For several examples, the floor beams are sandwiched between two runner beams facing the outside of the facade. These sandwich techniques support the stabilisation of the floor beams in position.

In the case of movements within solid structures, an important aspect for keeping the construction in position is the friction between timber elements and the wall, and the denticulation of these two constructive elements (Gasparini 2000: 2, 3). At various examples in the Himalayas, as shown below, timber lacing was placed in dry stone walls without the use of mortar. According to Minke (2001: 35), it is recommended to cover ring beams, which are best located centrally over the wall, with app. 2 cm of mortar having good adhesion values. In the case of 'ladder'-like timber lacings, which are kept in position by the load of the wall on top, this method seems to not have been of striking relevance in vernacular Himalayan examples.

As we know from 'simple' building structures in Ladakh, in the case of solid earth and stone structures, floor beams are laid into a wall niche and not fixed on a ring beam. In some cases within the niche, beams are placed on a supporting stone. One method to reduce the possibility of slipping out of the wall during an earthquake is to let the beams protrude outside of the wall. Also in this case, the beams remain slidable. This method brings us to the structural influence of protruding components such as verandas or upper storeys, as we find them in the Ottoman architecture, in Kashmir, in Himachal Pradesh, in Gujarat and in Bhutan. In contrast to the mentioned technique, by placing floor and roof beams without using ring beams, protruding constructions are commonly connected to ring beams. These protruding components press onto the structure below and support stabilisation (Langenbach 2002b: 3). An observation made after the earthquake in 2001 in Gujarat was that the buildings with balconies were more resistant to earthquakes (Langenbach 2002a: 120). This may explain the advantage of beams that extend through the rubble stone walls against joists, which terminate in pockets (ibid.).

Ring beams in stone structures are a common feature throughout the Himalayas. To keep a theoretical box-like structure, the horizontal timber lacing is usually mounted over the entire height

120 During an earthquake in Upper Kinnaur and Spiti in 1975, strong damage was caused to residential and religious buildings, including the temple in Nako and structures in Shelkhar and Chango. As locally reported, at the monastery of Shelkhar, due to the drifting outwards of walls, several monks were sepulchered and trapped below the collapsing roof.

121 *Kath-kuni* (for further explanation see Handa 2006: 102): *Kunā* meaning "corner" and *kātth* meaning "wood"; translated as "forming corners of the square-cut wooden sections" (ibid.) or meaning that the corners were all made of wood.

of the building at similar vertical intervals so that the mentioned belt-effect is active not only on top of the structure, but across the structure. In case of an adobe brick structure (e.g. in Tibet or Ladakh) or a half-timber structure (e.g. in Bhutan or Turkey) on top of a building, the most upper part of the solid structure below is separated from the following upper structure by a ring beam. In contrast, within 'simple' adobe brick structures in Ladakh, the use of ring beams is not as common as at stone structures.[122] In the aforementioned case of floor beams, which are not connected to a ring beam, in the case of an earthquake, the single beams do not give the needed stabilisation over the floor surface area. On the contrary, they increase the mass[123] by acting as point loads on the wall construction, resulting in increased vibration of the wall (Interview with Adam in 2004).

For that purpose, in the Tibetan cultural zone, the introduction of a tapering of the outside of walls may have been a result of development. Their load decreases from bottom to top, and by that reduces the load vibrating in the upper section of the building. By shifting the centre of gravity towards the interior due to tapering, the chance of collapse towards the outside is reduced. This tapering also provides improved rigidity in the corners. If the wall were made with the full wall thickness upwards, this would not only reduce the geometric rigidity, but also increase the mass of the wall and thus lower the natural frequency of the wall. These tapering walls also increase the horizontal rigidity, which is a decisive factor for the establishment of an earthquake-resistant building. (Interview with Adam in 2004) For early West Tibetan religious adobe brick structures, wall thickness reaches up to 1.3 m with wall inclinations deriving up to 2°.[124] In general, for prestigious structures, the thickness is rather high. In contrast, for 'simple' vernacular two-storey structures, the thickness of the wall is mostly the length of one brick and tapering is not possible. Interior walls are often made as light-weight constructions, e.g. as timber frame constructions with wattle and daub infill. They are not primarily acting to transfer load like shear walls, but "as energy dissipaters and sway dampers" (Langenbach 2000: 19).

A development in the Tibetan cultural zone, which ignores the aforementioned importance of strengthening corners, are the open corners at rammed earth constructions. At several rammed earth constructions in Spiti and in Central Tibet, rammed earth walls that are part of a simple rectangular ground plan are just 'leaned' towards each other in the corners without any further joint, and by that a gap is left over the whole height of the wall. It remains unclear whether this method is thought to create separation joints. In this case, the mentioned advantages given by the tapering of the wall become evident by pressing the walls together in the corners. In the case that the flat roof collapses, its stabilising load is missing and the walls may collapse easily (see collapsed walls at the Chakyung Babsa Tower in Chekha; cf. Feiglstorfer 2015: 74).

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122 In the Tibetan cultural zone, at adobe brick structures with high social status, such as the main temples at Nako, Tabo and Khorchag, timber lacing is used in the walls. Many of the investigated 'simple' vernacular adobe structures have rather thin walls with the length of a brick as thickness and even no space for timber lacing.

123 The weight of a 20 cm thick flat earth roof is app. 400 kg/m². Problematic for the structure during an earthquake is the high mass on top of the building, which results from a continuous addition of earth for the renovation of a roof without exchanging layers.

124 Wall inclinations of the monastery of Nyarma (earliest parts from 996 CE) were presented by the author at the TERRA 2016 conference in Lyon.

1.5.4 Elevation configuration

Another aspect of vernacular buildings in earthquake zones is their vertical segmentation between a solid lower part (higher mass) and a lighter and more detailed upper part (lower mass). Thus, the centre of gravity is lowered (cf. Dipasquale, Mecca: 2015). Already at the Minoan house, which was made of several storeys, a division of the lower part made of stones and the upper part made of adobe bricks is reported (Rider 1965: 142, 143). In several early cases – e.g. at Ottoman houses before the 17th century or at early West Tibetan temples – a single-storey structure was common, while at later multi-storey structures, we find the load of the used materials often reduced towards the top of the building.

Also in multi-storey buildings[125] from the Balkans to the Himalayas, the lower floor is usually built with the largest mass, in most cases as stone masonry. Such a change between lower and upper floors is also found at timber-laced structures in Kashmir (see Bhushan 2016: 55) or in Himachal Pradesh (see Dave et al. 2013: 34ff.). In most of these regions, the solid ground floor is preferably built of stone. The lacing is an essential technical marker within this seismic cultural region from the Balkans to the Himalayas. In the case that the solid walls are built of rammed earth, as we can find in Tibet or Spiti, such timber reinforcement is not common.

The upper floors of the Ottoman house are built as half-timber structures. Also in Kashmir or Himachal Pradesh, in many cases, timber frame and timber-laced constructions, respectively, are placed on top of a solid basement. According to particular building traditions, the floors on top of the solid (plinth) structure are built with lighter and handier materials. On the one hand, this reduces the load of the building from bottom to top and facilitates the transport of the material to the upper floors. On the other hand, in the case of earthquakes, the upward reduction of the mass has a positive effect on the vibration behaviour of the wall. Also, at many structures in Himachal Pradesh, the *kath-kuni* construction was placed on top of one or more storeys made of stone (ibid.). In the Tibetan cultural zone, it is common to place adobe walls on top of solid walls made of stone or rammed earth. In Bhutan, the wooden *rabsey* is set on a solid substructure, also either made of stone or rammed earth. Besides the structure, where a *dhajji-dewari* construction is placed on top of a solid plinth, several *dhajji-dewari* buildings in Kashmir are raised as half-timber structures over the full height of the building. In the case of *taq* constructions, if bigger openings are introduced, they are usually placed in the upper floors. In strong contrast to the examples using stone for the plinth, in North Pakistan, e.g. at the tower of the Altit Fort or at the Baltit Fort, where the *cator and cribbage* technique is applied, the lower part of the construction is made with a much higher content of timber than the upper part.

1.5.5 Material and joints

The use of proper materials and joints is not primarily a statement of a seismic culture, but for vernacular architecture in general. Their efficiency has to be understood as part of an earthquake-proof structure. The quality of the building material – brittle like mineral-based materials or flexible like timber – influences behaviour during an earthquake. Weak mortar (lime or clay mortar)

125 This change between solid lower and light upper constructions is related to a change between winter and summer places within residential buildings, as we know this, for example, from Safranbolu houses (cf. Bammer 1980: 49).

is essential for the transmission of forces into the whole structure (Langenbach 2000:8). For his observations of the architecture of the Mirkulā Devī Temple at Udaipur in Himachal Pradesh, Nocci (1994: 101, fn. 8) mentions the use of clay mortar and points out its low binding power in the case of an earthquake.

For stone walls, for example as observed at the Old Monastery in Chekha in Central Tibet, clay mortar was used. Neve (1913: 38) talks about the use of clay instead of mortar for traditional Kashmir buildings to enable elastic bonding. With an increasing rigidity of a structure, the necessity for a stronger avoidance of fracture rises (Langenbach 1989: 11). At flexible traditional structures, the rigidity of joints is limited. Minke's objection is the often-used low quality of clay mortar. He argues that the typical diagonal cracks result from the use of a poor mortar (Minke 2001: 13). This would be the case when a clay with too low a binding power, e.g. when containing not enough clay minerals, is used. At various Himalayan examples, simple dry stone walls were erected and no mortar seems to have been used. According to Dave et al. (2013: 73), this has been the case at *kath-kuni* constructions in Kinnaur.

Shaking during an earthquake affects the junctions between materials to a certain degree of deformation, followed by a collapse. The vibration period of structures increases with the slenderness of a structure, and the rigidity becomes more important (Cokcan 2001: 47). In particular, constructive joints in the upper storeys are more stressed due to higher shear forces, and the lower weight of wooden ceilings keeps the horizontal shear low (ibid.). The absorption of tensile forces by wooden joints is of crucial relevance. To fulfill this requirement, traditional techniques for joining wooden components were introduced – for ring beams, e.g. the use of wooden pegs in combination with halving lap joints, dovetail or mortise, and tenon joints. Since they weaken with age, they have to be maintained and, if necessary, replaced after a certain period.

One possibility of stabilisation would be the use of anchoring devices such as brackets. Such brackets are inserted at the outer wall through the ends of the protruding beam. In this way, brackets serve as a tie rod and make a firm connection between the roof and the outer wall. This construction technique can be found in several earth building cultures, for example in the mountainous regions of Iran in Abyaneh, in Himachal Pradesh in the Upper Temple at Nako, in the Skurbuchan Temple in Ladakh (Nako and Skurbuchan see below) or at the castle-temple of Shani Maharaj at Kharshali in Uttarakhand (cf. Handa 2008b: Fig. 35).

1.5.6 Wall openings

The methods used for fixing window frames within masonry walls may point towards awareness of seismicity; more so, the way of fixing may be such an indication. Concerning structural movements, each opening is a weak spot, and cracks in a wall often start in the corners of openings. Horizontal components of window frames often project deep into the adjoining brick wall. They allow an efficient interlocking of the window member with the surrounding masonry, and prevent cracks in the corners of the openings in case of movements. Inserting a wooden lintel, which protrudes into the adjacent wall, reduces the transmission of forces in the wall along the edges of the masonry wall opening. Examples of big-sized window frames with horizontal wooden components in the lintel and parapet area developed during the Newar period in Nepal.

Fig. 4.21 Gondhla. Lahaul. Placing wooden window frames in a stone construction with ‘ladder’-like timber lacing.

This type of window construction is widely used and we find it in some Western Himalayan buildings, for example, in the tower of Gondhla in Lahaul, which was built with timber-laced stone walls as opposed to Newar brick walls (Fig. 4.21). Another possibility to reduce cracks in walls along openings is to reduce the size and amount of openings. As an example, early West Tibetan religious structures had only one storey and one door opening, no windows. Openings in solid walls at vernacular structures are in general small, which makes the rooms rather dark. In contrast, openings in half-timber frame structures can be designed larger without interfering with the static system.

1.6 Discussion

The Western Himalayas can be regarded as a “transition” zone of different vernacular building techniques. A significant proportion assumes composite constructions, in particular combinations of stone / clay and wood, and timber frames with different kinds of infill material. In principle, we have to distinguish between timber frame constructions and solid walls with timber lacing. These two basic types show different distribution areas and historical developments. Their development can geographically only be assessed approximately and they are subject to different local and regional adaptations. Local adjustments are found, for example, in the choice of locally available raw materials. Regional common terms show the embedding of certain techniques in the respective architecture.

Timber frames already appear as an early development among the Hittites, Greeks and Romans. Wide dissemination took place in Europe, and Asia Minor to Kashmir in the Western Himalayas. The development of solid walls with timber lacing is more difficult to grasp. Again, early discoveries were made in Greece and in Central Asia. The distribution is significantly over a wide area. It is found in various forms over the entire Himalayas – from the Western Himalayas to East Tibet. Timber lacing can be as simple as a crack stopper not being joined at the corners of the building, or technically more elaborated as ring beams – either with just one facing runner beam or as a 'ladder'-like ring beam. The latter describes a technique found over a wide area from the Balkans into the Himalayas. Dominant distribution areas are in the regions of the Balkans, Turkey, Iran, Kashmir, the Western Himalayas and North Pakistan, including Himachal Pradesh in northern India.

The change from single-storey buildings to several storeys is connected to particular technical developments, for example, the differentiation between a massive lower building zone and a timber frame structure in the upper zone. Early examples among the Hittites or Romans show similarities to 'ladder'-like ring beams.

Cultural influence by certain ethnic groups including the acceptance of wood as a construction material and its release by a ruling elite for general use have a significant impact on the spread of timber building techniques. The dissemination is a combination of imported and local traditional knowledge, as the Albanian influence in Mandriza shows. Why certain techniques, such as the use of timber lacing, despite high earthquake hazard, are not rooted in the vernacular architectural Newar culture remains unclear.

From the Himalayas in the east to the Mediterranean area in the west, there are wide regions exposed to strong seismic activity. Certain extensive constructive developments point to the development of a seismic culture. Techniques that have also been applied in the Western Himalayas are the vertical layout of buildings with a solid lower level and light-weight upper level, reinforcement via timber lacing and ring beams, and integration of floor beams into the wall construction to avoid a drifting outwards of the wall or to withstand tension, shear and torsional forces by appropriate materials and compounds.

2. The importance of material diversity

Several parameters, such as topography and morphology, ethnic-cultural aspects, and environment and raw material resources, are strongly involved in the process of determining the vernacular features of a given building. One of the most essential factors is the dependence on local availability of certain materials. In this part (4.2), general aspects of the importance of material diversity and its impact on processes of vernacular architecture, including some Himalayan specifications, will be discussed.

Vernacular architecture in general originates locally and within a certain reachable distance from raw material sources, such as timber, stones, and clay. Considering the available range of materials, constructions are adjusted according to particular local living conditions, like climate, protection against enemies, soil characteristics, earthquakes, and fire or flood protection. Rural architecture in the Himalayas, in particular in remote areas, is still based on the most essential needs, resulting in rather simple and functional construction techniques. The core matter for dimensioning the thickness of walls, as an example, is primarily static strength, while heat insulation is subordinate (cf. Künzel 2014: 27). Means of heating are dependent on the heating and cooling phases that result from the thermal conductivity of the used constructions (ibid. 41, 42).

Local material resources are processed in a most efficient way, and they are collected from close distances. Ideally, clay is available from one's own land, stones also may originate from one's own land or a particular quarry in the close vicinity, lime or gypsum originate from the mountains, and certain organic materials like timber or grass also from places nearby. In Central Tibet the saying *sana dona* (Tib. *sa sna rdo na*) reduces material diversity into two words, and can be translated with "different kinds of earth and different kinds of stones", with *sana* (Tib. *sa sna*) meaning "different kinds of earth" and *dona* (Tib. *rdo sna*) meaning "different kinds of stones". This saying points towards a traditional variety of building materials and an awareness of material diversity. For each type of stone, one has to know the right place to collect, also to purchase, and to trade it. This ability involves detailed understanding of local structures in all their facets, be it economical, social, technical, etc. If not, building may become more expensive, there may be a misuse of the proper technique necessary to process local materials, or building may not be adequate for a particular social status. In this context, a free interpretation may read *sana dona* as expression of a basic understanding of the correlation between the availability of local resources and an ecological sustainability. Economic conditions may be valid within a certain community – be it a neighbourhood, a settlement or particular personal relationships – close to what we understand as "local". In general, regarding a relation between ecological conditions and social organisation, these relations may not be comparable over certain regions (Eriksen 2001: 193).

In traditional belief, materials may be more than simply functional goods. They can be classified as male and female, which we know from different kinds of *arga* or bricks.[126] Furthermore, they may also be respected in a religious context. The Buddhist worship of a *shukpa* tree, which provides a high-quality structural timber, is one example within the Tibetan culture. The term

126 Personal information on "male and female" bricks given by Tashi Tsering at the IATS conference in Vancouver in 2010.

for the Himalayan cedar (Cedrus deodara), which is locally known as *deodar,* derives from the Sanskrit term *devadāru*, meaning “wood of gods”. Such connotations of materials connect them with a certain awareness and respect. The professional processing of particular materials is connected to a particular social status. In Tibetan tradition, the carpenter, for example, belongs to the highest-ranked craft while the blacksmith to the lowest. Not only building material but the whole building process is part of religious life. In Buddhist regions like Tibet, Bhutan or Ladakh as well as in Hindu dominated regions like Himachal Pradesh, a building process takes place under the protection of a local deity.

Not using material that originates from nearby would probably point towards the use of a material in a decorative, technical or functional relation to represent a higher social status. An example of a decorative reason would be the use of particular mineral colours for mural paintings, for example, that have to be brought from other countries like India, Nepal, Tibet or Bhutan. An example of a technical functional aspect would be the use of *arga* stone instead of a commonly used flat earth roof construction. The use of *arga* as is the case in Ladakh and Tibet means heavier transport over longer distances and a more complicated process in quarrying this material than simply digging for earth. The gain for this higher effort is longer durability of the roof related to a higher social status (cf. Lehner 2009: 83). This basic precondition for the use of locally available raw material − which is inseparably connected with perpetuating of particular traditions – interferes with the need to overcome uneconomically long distances with high loads. In the context of representing a higher social status, increased effort in organising building material across longer distances would mean a differentiation between those of a common or lower social status and those of a higher social class. In earlier days, *arga* was – and even in remote Himalayan areas still is – either transported on the backs of carriers or with the help of animals. Long-distance transport to Ladakh and Tibet of *arga* stones and proper high quality timber, such as cedar, was primarily conducted by yaks. In the case of buildings representing a higher social status, such as monasteries, higher requirements in the quality of building material increased the length of transport distance. Having the financial means to afford such transport was beyond the means of a simple farmer, who was dependent on nearby resources of building material. In breaking the forces of dependence on local products and customers, a further step is the use of motor ability going hand in hand with the easier availability of goods from an external market (cf. Feiglstorfer 2012a: 3). Thus, reliance on locally available building material was reduced. In this regard, motorised transport assistance facilitated a termination of the concept of pre-modernity[127].

An early example from the late 10th century CE in Ladakh of acting economically is provided by one of the three earliest monasteries of West Tibet located in Nyarma in Ladakh. In the course of a study at the IAG / BOKU it was proven that the clay used for the entire construction of the monastery was collected nearby, even for a building of such high social status. With the thus obtained clay, bricks were produced with the minimum amount of additives possible. The material was even ideal for use as a plaster ground layer. At this example, only the upper plaster layer was either sieved or desludged. Both methods do not need any addition of a second material, only the

127 The delimitation itself of ‘modern’ and ‘premodern’ according to the Querelle des Anciens et des Modernes (1687) is still related to ancient times, while in later use, since the second half of the 19th century, the term *modern* has started to be commonly used in Europe (Barnard, Spencer 1996: 377).

separation of fine from coarse material. With this seemingly simple approach, a rather economic and material-efficient procedure was possible. Further, a rather high knowledge of clay within an economical as well as ecological context becomes obvious.

This interrelation between local material resources and applied techniques marks the kind of construction used and the choice of material within composite constructions. There are several parameters that define the availability of certain natural materials, like altitude and climate as well as vegetation and geological zones, which are up to a certain point interrelated with each other. These generalising statements are explained in detail in part 3 of this chapter, and the effects of changes of these parameters on the particular local material composition are analysed in part 4 of this chapter.

Workers are in a vernacular context predominantly relatives, neighbours and as much as possible people out of the local context. In a modernised context they become predominantly paid workers from outside the vernacular community. It is relevant if a personal relationship exists between workers and house owners in that they may see their personal effort to produce a high-quality product as an honour. In a vernacular community, local builders with specific knowledge and interest in certain techniques, such as stone cutting, masonry or carpentry, and also people with a related profession share their skills with relatives, friends and those related to a certain local community. In remote Himalayan areas, people have to cooperate on the building site, and this is only possible at specific times in the year, since many of the labourers are primarily farmers. Their year is structured by the seasons and related social events. For example, for a traditional earth roof of a residential building in Himachal Pradesh we can find up to twenty people on the roof preparing insulation or thereafter compressing the clay, similar to the ramming of walls.

In the case of brick laying, an effort depends on whether the bricks are fired or sunburned. Firing of bricks is related to a high-energy input and much higher costs than using adobe bricks. The latter have to be prepared quite early within a year, as soon as the earth is no longer frozen, so that they can dry and be ready for processing in another season within the same year. In Tibet, construction of a residential house in general does not take longer than two seasons (Alexander 2011: 70). The system of seasonal construction work influences the private sector but also public construction work, for instance, at monasteries. Again, in the Himalayas, traditional work at monasteries is (or in Tibet was) executed by either monks, persons directly related to the monastery, locals with a certain duty towards the monastery or by paid external workers. Workers were commonly recruited from the rural area.

The survival of knowledge of traditional techniques also depends on their complexity. To keep with the example of making a rammed earth wall or an *arga* roof, the need exists for someone who has knowledge of the individual working steps, their duration, their need in human and material resources, and specific technical features. At least one person, for example, the supervisor, has to be aware of all these facets of construction. However, some of the work itself can be conducted by labourers with no specific knowledge or education. In Tibet for the case of repairing an *arga* roof, the process has to be conducted in several steps guided by at least one supervisor, who precisely knows the individual working steps.

While ramming a roof requires no special training, specific knowledge is essential for the work of a carpenter or mason. The quality of work is not dependent only on having a good supervisor but on the skill of the single worker. Today in Ladakh or Spiti, skilled stone carvers are locals but also workers from Kashmir or Nepal. Another recent example of employing workers from outside the village community concerns the renovation of the village temple of Lalung (alt. 3,650 m) in Spiti in 2006. Here construction of a flat roof is a tradition related to a shortage of timber in this region. Contrary to tradition, a sloping roof was installed on the former flat roof by carpenters originating not from the village but from outside Spiti. For such specific crafts, the limits of neighbourly help are evident.

With the use of particular materials and related building techniques, a specific demand for labourers follows. Depending on the complexity of the work, it can either be conducted by lay- or semi-skilled workers or just by skilled workers. Knowledge is passed on from one generation to the next, within a master-apprentice-relation or within a specific group of workers in a kind of craft guild. Crafts are not necessarily inherited, as shown by the example of Könchog Tsering, a clay sculptor in Lhasa, who the author visited in December 2015 (see Chapter II). As a young man, Könchog Tsering worked as a house and furniture painter. About 30 years ago, he followed his passion and was trained in clay modelling by a master in Lhasa. In his case he did not follow a family tradition. Up until 1959, besides the clergy and aristocracy, sub-categories of commoners can be mentioned according to their social rank. A differentiation of these categories correlates with freedom of movement, ownership of land, economic status and a specifically regulated duty to pay taxes. Among these, we find a guild of artisans similar to a social group of its own, which formed under the Fifth Dalai Lama's government in the 17th century (Ronge 1978: 86, 102). This Tibetan guild included a builders' community called *doshing zokhang* (Tib. *rdo shing bzo khang*) or *doshing chipa* (Tib. *rdo shing spyi pa*), which before 1959 had included up to 500 regular members and more, if required (Alexander 2011: 62). In major Tibetan monasteries, this guild was employed to engage in the maintenance, repair and restoration work of major monasteries. This guild also included experts responsible for plaster and clay, and the *shepön* (Tib. *zhal dpon*, "leader of the flooring"), which included female members. In this community of masons, the *shepön* had the lowest social status, contrary to the carpenters who had the highest. Living and working as an artisan in Lhasa required joining of a guild (ibid. 62, 63).

In Himachal Pradesh, building works, like the erection of a new house, are conducted within customary community participation (locally known as *kewar* or *saret*) (Handa 2008b: 138). Related customs are different in the case that someone within the community is not able to conduct a specific task. At the *Gaddi* in Himachal Pradesh, for example, a carpenter is a skilled person by choice, not by compulsion or inheritance (ibid. 138); this is contrary to the *Gujjar*s, who do not accept anyone from outside kith and kin as part of customary community participation (ibid. 150).

Primarily in the so-called "Western world", the loss of building traditions has already strongly progressed. In most of the rest of the world, tendencies are orientated towards that loss. Today, as a result of naturally defined forces, the following of traditions has changed into a voluntary decision. Modern building materials are advertised with a longevity and less time resources of individuals for maintenance. In rural areas, building with 'modern' materials generates a lack of skilled workers with knowledge of certain traditionally predetermined qualities. This change towards the 'modern era' has even reached remote places in the Himalayas.

With the neglect of certain natural material resources and the loss of related traditions, evidence of their existence is disappearing. Earlier clay pits in large settlements, for example, in Leh in Ladakh, are reported to have been built over and are no longer accessible. This results in either accepting building material of lower quality or investing in higher quality with higher costs for a longer distance of transport. With opening of the market and the need for innovations, renunciation of local resources is a way to keep pace or dominate a market. As comparison, in the Western sphere during the 18th and 19th century, continental and American traders started to look for new manufacturing methods, with Great Britain as the first industrialised power (Jeremy 1991: 2). Decisions for development changed from a local level towards a state level. Technologies were imported, transformed and modified by cultural features (ibid. 1991: 3).[128] Governmental building structures installed by the British in Indian Himalayan settlements in Himachal Pradesh, for example in Shimla or in Kaza (the latter located in Spiti), stick out with corrugated iron roofs or massive stone walls erected against local building traditions. Within this process, external influences become a driving force for further changes of the 'local', which is – regarding building traditions – dwindling over time.

On the Himalayan plateau, over the centuries the availability of wood has decreased and this point needs to be considered during research on historical structures. It should not be excluded that centuries ago the use of timber was much more common in the Himalayas than it is the case today. Scientific reports state that the aridity within Central Tibet is primarily caused by deforestation and high-quality timber such as cedar was much more easily available in earlier days. Recent research shows that "the present high mountain deserts of southern Tibet are the result of deforestation due to centuries of woodcutting, use of incense, and grazing"[129] (Miehe et al. 2003). Previously, around 3,000 years ago, the Muktinath Valley in Mustang, as an example, was much more densely settled with a higher number of livestock. This may have resulted in an overexploitation of the land (Kriechbaum 2002: 82). Examinations of the vegetation have shown that the vegetation cover of the whole valley was strongly changed by human activities (ibid. 81) and resources of structural timber may have continuously decreased.

2.1 Discussion

Vernacular is a social concept tightly related to local conditions of raw material resources. Diversity of local building materials and expertise in processing is a crucial factor for keeping a vernacular system alive. In Central Tibet, the saying *sana dona* points towards this material diversity of different kinds of stones and clay, their different qualities and different ways of processing. In this context, diversity of raw materials becomes essential with their use. For the maintenance of diversity, certain preconditions need to be held in balance. To keep the use of local materials economic and ecological, availability must be secured within a certain distance. This fact determines the means of transportation. Materials for a representative purpose for a wealthy society are not

128 A further development that diverges inevitably from traditional local standards is based on a technology transfer, which may explain further dynamics in import and transformation of technologies. Jeremy (1991: 4) mentions the following parameters: Vehicles of transfer, networks of access to the originating economy, information goals of acquirers, methods of information collection, and speed of transfer of a given technology.

129 Sir Charles Bell (1924: 16) reports a traditional saying that in earlier times there were much more cypress trees in Tibet.

bound in the same way to local availability, justifying transport over a longer distance.

Substitution of local materials for products from external markets influences the vernacular system, possibly irreversibly. Transmission of knowledge of materials is primarily given by oral and inherited means. Work is basically conducted by the house owners and the local community. A distinction is to be made between crafts capable of being conducted by semi-skilled labourers, and those requiring a specifically trained skill. This difference influences the complexity in transmission of certain skills. In vernacular systems, only in particular cases and communities are specialists brought into the local community from outside. In the Himalayas, dependent on cultural and in particular religious affiliation, materials are connoted with a certain meaning beyond their simple functional use. This fact integrates them into customs of a village community.

Composite constructions, which follow a particular content of raw materials, for instance, stone, clay or wood, are based on material diversity and sensitive to changes in the local availability of raw material components. In the following parts 3 and 4 of Chapter IV, this matter leads us from material diversity towards diversity of constructions.

3. Environmental aspects: climate and raw material

Building traditions follow particular cultural patterns and are subject to change over time (see *Preliminaries*). On the one hand, changes may be regarded as culturally determined, and traditions may remain the same, change or vanish due to a variety of reasons. On the other hand, variations may result from certain local preconditions. Thus, mentioned here are naturally given aspects,[130] which in general are fixed and change only over a rather long time span (climate, vegetation, geology, etc.). Such change (e.g. precipitation or availability of natural resources) may induce a change of building traditions.

Environmental, socio-cultural and socio-economic are described as the three main attributes of sustainable architecture (Guillaud et al. 2014: 6). Vernacular architecture in general follows these aspects. Specifically, environmental preconditions and their impact on Himalayan composite constructions are treated in the following.

Inhabitants of former times did not have knowledge of statics calculations, e.g. concerning seismic motions or statics and static collaterals. The high durability of the building materials used shows that they understood the qualities of regionally available building material and were well aware of their constructive use. This also points towards an awareness of earthquake-resistant structures. Historical structures were not built on the basis of a unified building codex, but followed knowledge transmitted over generations and which grew empirically through experience.[131] Posing the question for the use of particular constructions is based on the existence of knowledge related to environment-behaviour interaction (Rapoport 1990: 245). People are not settled in a particular influencing environment; they instead search for the proper environment (ibid. 246).

In the Himalayas, we find great diversity in different naturally given preconditions and related building traditions. Within several field studies in the Himalayas, a coherent picture of existing building traditions was gained. We can distinguish between a generalised and a detailed categorisation of features of vernacular architecture. With the general categorisation we can refer to general features of construction, such as the use of particular raw materials related to particular altitudes over a wide region, for example, the Himalayas in general. This approach is rather inaccurate. With detailed categorisation, in addition to the assignment of particular features of construction to a certain altitude, it is possible to relate specific constructions and related variations to a particular local influence. This approach considers local variations and is essential for the following study.

130 Sanders (1990: 44) mentions in his study on "behavioural conventions and archaeology" seven factors that shape a house: climate, topography, available materials, level of technology, available economic resources, function, and cultural conventions. According to his categorisation three of these factors, namely climate, topography and raw materials, are fixed influences and naturally determined (ibid. 1990: 45).

131 These traditional and commonly accepted practices stand in contrast to today's building codes. In a Kashmir context there are four essential aspects mentioned by Langenbach (1989: 10): 1) small strength of the mortar; 2) no bonding between infill walls and piers; 3) weak bond between the wythes of the masonry in the walls; and 4) frequent (historical) use of heavy sod roofs.

Map 4.2 Elevation within the core region.
GIS data based map drawn by: Jakob Gredler. Final graphics: author. Map based on Vector data (VD) and SRTM digital elevation data (SR) adapted from Jarvis et al. 2008. Citations of VD and SR also see: Chapter IX, list of illustrations.

The present study concerns primarily composite constructions with wooden components in the Western Himalayas. In the field of structural engineering, a composite construction is given when two different materials (in the particular case of this contribution i.e. clay and / or stone and wood) are bound together in such a way that they ‘collaborate’ as a single structure. This includes, e.g. framework constructions or solid walls with timber lacing, i.e. materials that work as a constructive unit. At least two materials have to be bound to gain a new unified structural unit and in doing so the materials support each other, for instance, concerning their energy effort in processing or their physical or mechanical properties, like insulation, thermal storage, water repellence etc.

Composite constructions are a synergy of several materials. This may be a solid wall construction as a combination of different components, e.g. a stone wall, a brick wall or a rammed earth wall, all of which in this study are combined with wooden lacing; in this study it may also be a skeleton construction of wood with infills of clay, bricks or stone. The way of combining materials and the proportional distribution of each material component depends on particular technical parameters.

The Himalayas have to be mentioned as having a great variety of different building traditions. A large number of these traditions are still practised and include a great variety of composite constructions. Various forms of timber lacing were treated in the literature, e.g. Randolph Langenbach covered various regions such as Pakistan and India, in particular Kashmir, and Turkey (see http://www.conservationtech.com), and Richard Hughes focused on vernacular architecture in Pakistan (see Hughes 2000a, 2005, 2007) or Turkey (see Hughes 2000b). For the Indian Himalayas, Neil Howard (1989) looked at fortress architecture in Ladakh, and O.C. Handa (2001) examined particular local constructions in the Western Himalayas. One of the main criteria for a continuous change of resources is a changing altitude, correlating with changes in temperature and precipitation. These are some of the crucial parameters for technical building decisions. They are in direct relation to local availability of particular raw materials, and availability changes with increasing altitudes (Map 4.2). Composite constructions in the Western Himalayas are found in mountainous areas within a certain altitude range. Related areas reach from lower altitudes of app. 1,585 m in Srinagar up to altitudes of app. 3,600 m in Ladakh. This study concerns environmental influences primarily within these app. 2,000 metres difference of altitude.

For the reason that early structures provide a good picture of later developments, such early structures are emphasised. Several of the representative objects of research are religious structures. They represent a hierarchically high social status within the related local community, were maintained with most care, and erected with building techniques following a high technical standard. Of relevance in this study are local technical authenticities, which in some examples still remain as local traditions or have either vanished or changed over centuries, e.g. were replaced by modern structures. The names of the builders of vernacular architecture are in many cases not known.[132] Material resources exert influence on the design of a building. The final design decision is not solely material, but culturally related. Certain timber-laced techniques show both local affiliation and an integration into a wider typological context. Finding an origin of timber lacing traditions seems to be difficult, but looking for early technical developments may help to understand historical and in particular function-based developments.

132 Basically, we are talking about architecture without architects following Rudofsky’s (1993) core message, with patterns of construction as communal achievement, related to a particular region. For a further discourse on vernacular architecture, see above under *Preliminaries*.

3.1 Research question and method

What influence has the changing altitude in the Western Himalayas in correlation with environmental influences on the technical development of traditional composite wall constructions? Traditional composite wall constructions and their material components will be examined according to altitude-related environmental parameters.

3.2 Research area

A core region of this examination within the Western Himalayas stretches from Ladakh (which is located in the province Jammu and Kashmir) in the north and the districts Chamba, Lahaul & Spiti, and Kinnaur (which are located in the province Himachal Pradesh) in the south. Comparative examples from the mountainous Pakistan provinces Gilgit-Baltistan, Khyber Pakhtunkhwa and Azad Jammu and Kashmir are given (see Map 4.1).

3.3 Natural preconditions related to altitude

Regarding environmental changes due to changing altitude, both temperature and precipitation are of central importance for vernacular building traditions. Temperatures may influence the thickness of walls. Wall structures affect the heat insulation and the dispersion of humidity in a fluid or gaseous aggregate phase inside the wall structure as well as inside the building. Persistent humidity negatively affects the construction. At cold temperatures, water that has frozen within the construction may lead towards the effect of congelifraction and by that open cracks for further water intrusion. Persistent moisture penetration of wooden parts of the building may result in rotting. Precipitation concerns primarily the protection of the surface to make the wall repellent against or closed off from water intrusion. Making a stone plinth up to a certain height above ground level is the most common method to break the capillary moisture rising from the ground below. Aside from the wall construction, the roof is primarily affected by precipitation, and using a pitched roof instead of a flat roof can roughly be ascribed to different influences like rain or snow or the changing amount of precipitation in higher altitudes and less forested areas.

Another vulnerability of constructions is caused by water along the outer surface of the wall, in particular when using wooden components. This problem is evident in the framework or in timber-laced buildings, where the wooden components are often visible along the outer surface of the wall. Plastering of the whole wall can easily result in cracks in the plaster in the area covering the junction between the wood and other material components. In a traditional way, the use of vegetable or animal fibres helps to reduce or even to avoid cracks. Different methods in using such fibres are shown with techniques of processing clay for sculptures (see Chapter II). As soon as a crack occurs, humidity is able to enter the construction. In the case of frost, a congelifraction can result with the crack eventually enlarging and causing weakening of the particular wall structure. In the case of plaster avoidance, as is the case at many vernacular structures, the circulation of air, water and damp within the construction is not impeded and the chance of quicker drying of the infiltrated humidity is given. Avoidance of plastering outer wall surfaces can be found in many vernacular structures all over the Himalayas. The adobe brick temples of Tabo can be mentioned as early examples. The foundation of the earliest core of this monastery dates back to 996 CE. In pictures published by Romi Khosla in the course of a conservation project by the ASI

(Khosla 1979: pictures 42–45), we can see the documentation of their unplastered state before plastering. In arid zones rainfall may also be strong, but not of such a duration that the saturation of the unfired bricks leads to the danger of a loss of stability of the construction. This changes with an increase of the duration of rainfall in that stability would be negatively affected. The strong rainfalls in August 2010 in Ladakh and Spiti showed the dramatic effects of a climatic change with long lasting precipitation on adobe constructions.

The primary function of exterior walls of vernacular structures in the Himalayas is related to stability. This concerns carrying both a static load (e.g. a roof) and a dynamic load (e.g. by ground settlement or earthquakes). Within traditional village life, the insulation of stone, wood and earth walls of vernacular structures is not of striking relevance for the inhabitants since most activities during the day happen outside the building, and heating is reduced, primarily to the preparation of food. Clothing and not buildings is the main heat regulator. In a traditional Himalayan house, the intermittent way of heating results in dependence on the heating and cooling phases from the thermal conductivity of the used constructions (cf. Künzel 2014: 41, 42).

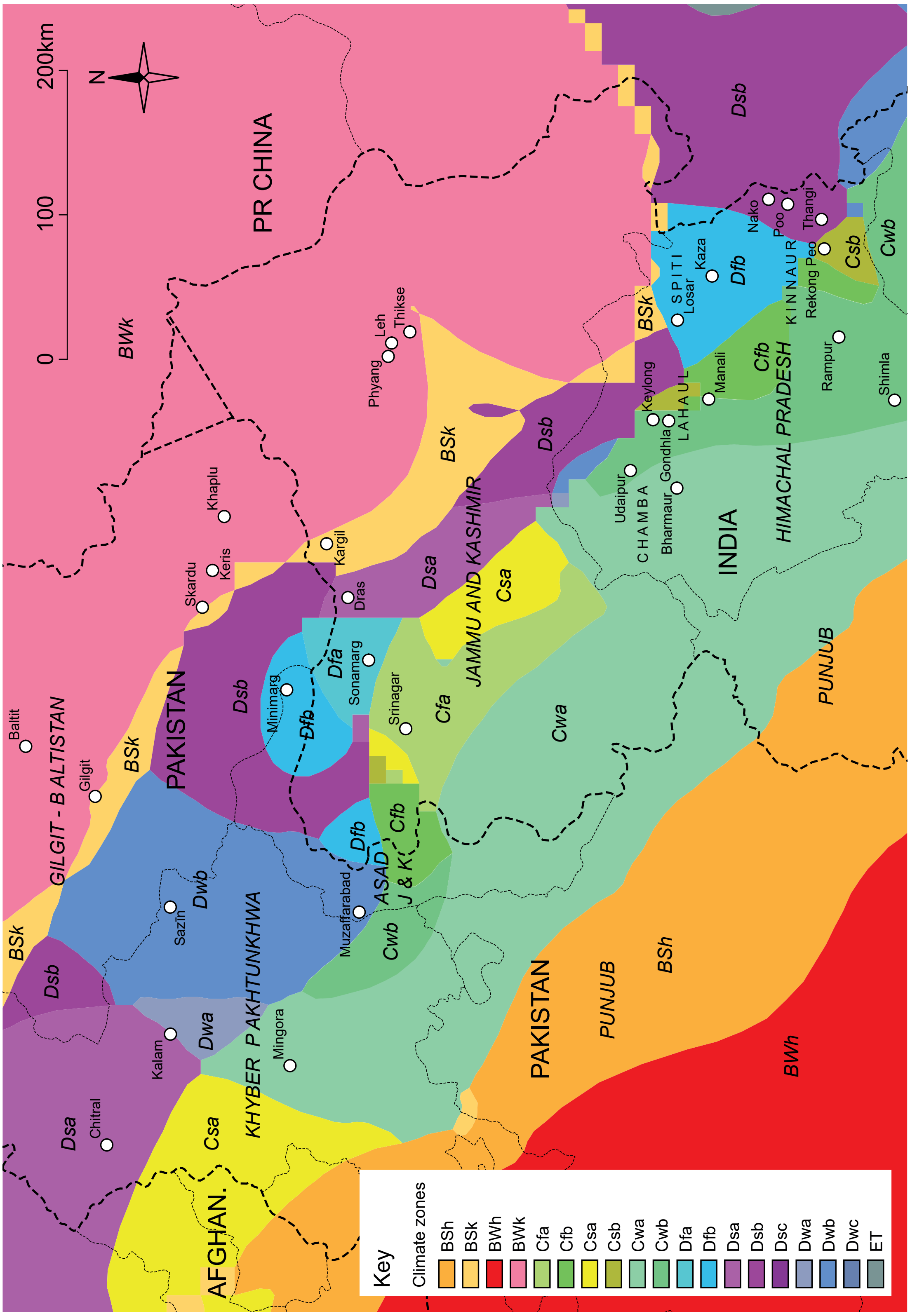
The thermal conductivity (measured in W/mK) of building materials and the degree of moisture penetration are essential parameters for the insulating effect of building components. Compared with mineral building materials such as clay or stone, wood has a relatively low thermal conductivity. The content of wood at composite constructions is rather low, and an increasing content of wooden elements increases the heat insulation of the wall but also the amount of joint gaps to adjoining wall materials. Insulation with clay is worse than with wood, but still more efficient than with stone. In the case of rain, the insulation is strongly reduced due to temperature transmission supported by sorption. An unplastered wall, for example, may contribute to a quicker removal of water stored inside the wall compared to a plastered wall.

Before analysing single structures, temperature and precipitation are to be summed for the research areas. This step supports getting insight into the dependence of a particular type of building technique on environmental conditions and the local availability of particular raw materials. Vegetation is mainly influenced by changing temperatures and precipitation. The particular type of locally available clay is also influenced, for example, by wind or water erosion. Available species of stone are primarily related to geological factors.

3.4 Western Himalayan climate in general

Himalayan altitudes of the core region of this study (mountainous regions of Jammu and Kashmir, and Himachal Pradesh) range between app. 1,800 m and 3,600 m. Climate plays a crucial role in the availability of specific raw materials for building purpose, in particular, timber, stone and clay. The climate diversity of the Himalayas, which act as climate barriers, reflects the variety of natural building resources in this region. In the following, an overview is given of the different climate types in the core region. Table 4.2, which contains altitudes and climate data, is shown in the Appendix of Chapter IV. According to a detailed global climate classification by Köppen-Geiger (WMKG), the present area of study within the Western Himalayas will be classified according to Peel et al. (2007)[133].

133 Cf. map by Peel et al. 2007. Online: http://people.eng.unimelb.edu.au/mpeel/koppen.html, access: 05/2016.



Map 4.3 Climate classification.
GIS data based map drawn by: Jakob Gredler. Final graphics: author. Map based on Vector data (VD) and Climate map (CM) adapted from Peel et al. 2007. Citations of VD and CM also see: Chapter IX, list of illustrations.

Of the five climate types given by Peel et al. (2007), three stretch over the Western Himalayas: arid [B], temperate [C] and cold [D]. The orientation of the different climate types in the Western Himalayas follows the orientation of the topography from north-west to south-east. The north-eastern region with Ladakh is assigned to the arid zone [B]. The cold zone [D] continues to the west, stretching from Chitral in North Pakistan in the north to Moorang in Kinnaur in the south. Further west the temperate zone [C] continues from Nuristan in Afghanistan in the north to Uttarakhand in the south. These three climate types are subdivided into several categories, as described in the following from north-east to south-west (Map 4.3). Abbreviations for climate types are given in square brackets according to Peel et al. (2007).

3.4.1 Arid climates [B]

- Arid, desert, cold [BWk]: This climate type stretches over Ladakh (Leh) to the north into North Pakistan (Khaplu).
- Arid, steppe, cold [BSk]: This climate type stretches from Skardu to the south towards Kargil located in Ladakh, Karsha and the Markha Valley in Zangskar, and ends at the north of Spiti.

3.4.2 Cold climates [D]

- Cold, dry and hot summers [Dsa]: This climate type stretches from west of Kalam (located in Khyber Pakhtunkhwa) to the west via Chitral into eastern Afghanistan. A second zone of this climate type stretches from Dras (located in Ladakh) to the northern border of the Chamba District.
- Cold, dry winters and warm summers [Dwb]: This climate type stretches from Muzaffarabad (located in Kashmir) in the south towards Gilgit (located in Gilgit-Baltistan) in the north-east and Kalam (located in Khyber Pakhtunkhwa) in the north-west.
- Cold, dry and warm summers [Dsb]: This climate type stretches west of Skardu (located in Gilgit-Baltistan) and west of Kargil (located in Ladakh) and is westwards connected to the climate type [Dwb]. A second zone with this climate type is located further south, stretching from Upper Kinnaur south via Lippa, Spillo and Thangi to Charang.
- Cold, without dry season, warm summers [Dfb] or hot summers [Dfa]: Both climate types are partially surrounded in the north by climate type [Dsb]. Climate type [Dfb] is found in the area to the south surrounding Minimarg in Kashmir, and climate type [Dfa] is described by the area surrounding Sonamarg in Kashmir. Further south, climate type [Dfb] stretches from Losar to Kaza in Spiti towards Poo and further south to Asrang in Kinnaur.

3.4.3 Temperate climate [C]

- Temperate, dry winters, warm summer [Cwb]: This climate type stretches over most of the eastern part of Himachal Pradesh from Udaipur (located in Chamba) in the north to Keylong (located in Lahaul) in the south-east and to the south to Manali, Shimla and further on to Uttarakhand. To the west, the climate type [Cwb] is flanked by the large climate type [Cwa] and along its east flank smaller climate types are embedded, in particular the climate types [Cfb] and [Csb].
- Temperate, without dry season, warm summers [Cfb]: This climate type stretches from Manali in the west over a large part of Kullu in the east.
- Temperate, dry and warm summers [Csb]: This climate type is attributed to a region in Kinnaur, which stretches from Kalpa to Sangla.

· Temperate, dry winters, hot summers [Cwa]: This climate type stretches over the largest region within the area of study, from Mingora (located in Khyber Pakhtunkhwa) in a southern direction via Jammu to the west of Shimla. Another climate type [Cfa] is embedded along the north-eastern part of climate type [Cwa].
· Temperate, without a dry season, hot summers [Cfa]: This climate type includes Srinagar and the Kashmir Valley.

3.5 Climate in the areas of study: Jammu and Kashmir, Himachal Pradesh, North Pakistan, Central and West Tibet

When not further mentioned, the summary follows the data given in Table 4.3 in the Appendix of Chapter IV according to *Climate data for cities worldwide* according to Köppen and Geiger (in the following briefly mentioned as "CD"). Altitudes are given in metres. The given data are based on an annual average, and maximum and minimum peaks in temperature may differ from the given average data. In an architectural context, precipitation stresses the need for the proper protection of roofs and walls regarding water ingress into the construction. In the case of snowfall, besides water ingress as a result of melting, the increasing weight from snowfall is of particular relevance. A high difference between daily minimum and maximum temperatures will strain the ability of materials to increase or decrease their volumes. In this relation, cracks become an important matter of construction. Varying conditions influence local techniques of construction. Altitudes above sea level are given in metres [m]. The altitude data of Köppen and Geiger (CD) are compared with and, if necessary, adjusted to the data given in Google Earth.

3.5.1 Jammu and Kashmir

Ladakh

In Ladakh, minimal precipitation over the year is the norm. The data for Leh (alt. 3,520 m), Phyang (alt. 3,510 m) and Thikse (alt. 3,250 m) are similar. Low temperature is on average app. -9°C, and the difference between minimum and maximum temperature goes up to app. 26°C, which is comparatively high. Precipitation increases in the west towards Kargil (alt. 2,700 m). This is visible by the increase of vegetation. (CD) Over the course of a single year, there is more snowfall (maximum app. 15 cm) than rain (Cunningham 2005: 179). In Dras (west of Kargil), strong snowfall may start in November (ibid. 180). In Leh, rainfall is limited to short showers usually between July and September. In Kargil, in summer, there are just a few days with rainfall and lots of snow in winter. (Negi 1998: 68)

Srinagar

A strong change occurs from Ladakh towards Srinagar in Kashmir (alt. 1,590 m). Precipitation occurs throughout the entire year, and even in the driest month it is still relatively high. Annual precipitation is about twice as high as in Kargil (alt. 2,700 m) and six times as high as in Leh or Phyang. Also in winter precipitation is rather high. Temperatures go down to around 0°C. (CD) Precipitation is higher in winter than in summer (Negi 1998: 69). Summers in Kashmir Valley are temperate with severe winters (GSI 2012b: 2).

3.5.2 Himachal Pradesh

Lahaul

In Lahaul (Keylong, alt. 3,100 m; Gondhla, alt. 3,170 m; Udaipur, alt. 2,650 m), the amount of precipitation is much higher compared to the data given for Leh and Phyang, but still rather low. Precipitation is higher in summer than in winter. While maximum temperature in Lahaul is similar to Leh and Phyang, the minimum temperature is higher (CD), and in Keylong it may severely drop below the freezing point (Negi 1998: 70). Snow may fall already in October (Cunningham 2005: 180). Snowfall is much stronger than in Spiti (see below) (Bajpai 1987: 5).

Spiti and Upper Kinnaur

In Spiti (Kaza, alt. 3,660 m), annual precipitation is lower than in Lahaul, but still higher compared to Leh or Phyang. Climate in Upper Kinnaur (Nako, alt. 3,630 m) is similar to the climate of Kaza. Precipitation is still higher in summer than in winter. (CD) The biggest amount of snow is mentioned with a height of app. 75 cm. The season for snow is between November and February (Cunningham 2005: 181). For Spiti, Verma (1997: 13) reports heavy downpours, e.g. in September 1988 with 140 mm, in July 1989 with 110 mm and in August 1990 with 100 mm, and that snow may remain on the surface until April.

Middle and Lower Kinnaur

In Middle and Lower Kinnaur (Spillo, alt. 2,400 m; Rekong Peo, alt. 2,420 m; Kalpa, alt. 2,760 m), annual precipitation is similar to Lahaul (Keylong, alt. 3,100 m), and temperatures in winter drop to close to 0°C. From Upper Kinnaur to Middle Kinnaur, winter instead of summer is the season with the most precipitation. (CD)

Shimla District

In Shimla District (Rampur, alt. 960 m), precipitation clearly increases compared to Kinnaur. From Kinnaur to Middle Kinnaur, summer instead of winter is the season with the most precipitation. (CD) In Shimla (alt. 2,100 m), frost is frequent in winter, while in summer temperatures rise to app. 20°C (Negi 1998: 70).

Kullu

Further north towards Kullu (Manali, alt. 2,000 m), annual precipitation is nearly double compared to Rampur and twenty times more compared to Leh. The average minimum temperature ranges around 0°C. The North Indian districts Lahaul, Spiti, Upper Kinnaur and Ladakh have less precipitation and are on average colder, while towards Chamba (Bharmaur, alt. 2,170 m), precipitation and temperature are rather similar. (CD) Winter in Manali can be severe (Negi 1998: 70). Kullu is located at a frontier of two climatic zones, i.e. the south zone with monsoons and the continental zone with a cycle of seasons (Postel et al. 1985: 287).

Chamba

In Chamba (Purthi, alt. 2,460 m; Bharmaur, alt. 2,170 m; Chamba, alt. 950 m), the climate is similar to regions west of Kinnaur with less precipitation in winter compared to summer. This changes again further north in Lahaul. In Purthi, precipitation occurs throughout the whole year. (CD) In the upper valleys of the Chandra and Bhaga Rivers, during the season from app. the end of the year until May, a small amount of snow may be experienced (Bajpai 1987: 5).

3.5.3 North Pakistan

Gilgit-Baltistan

In the province of Gilgit-Baltistan, a climate with low precipitation throughout the year is prevalent (CD). Altitudes of the observed areas range between 1,470 m in Gilgit and 2,430 m in Baltit. (CD) In Baltit (alt. 2,430 m), Skardu (alt. 2,250 m), Keris (alt. 2,310 m) and Khaplu (alt. 2,600 m), temperatures range between -9°C and 23°C. The difference between minimum and maximum temperature is up to app. 30°C. Annual precipitation is about twice as high as in Ladakh (see Leh and Phyang). Minimum temperatures are similar to Ladakh (see Leh and Phyang), while in comparison maximum temperatures are higher. The highest precipitation occurs in the warm season. In Gilgit (alt. 1,470 m), which is about 1,000 m lower than, e.g. Baltit, it is much warmer, while precipitation remains similar. (CD) As reported by Hughes (2005: 22), in Hunza rainfall can be quite intense and damaging, but not frequent.

Khyber Pakhtunkhwa

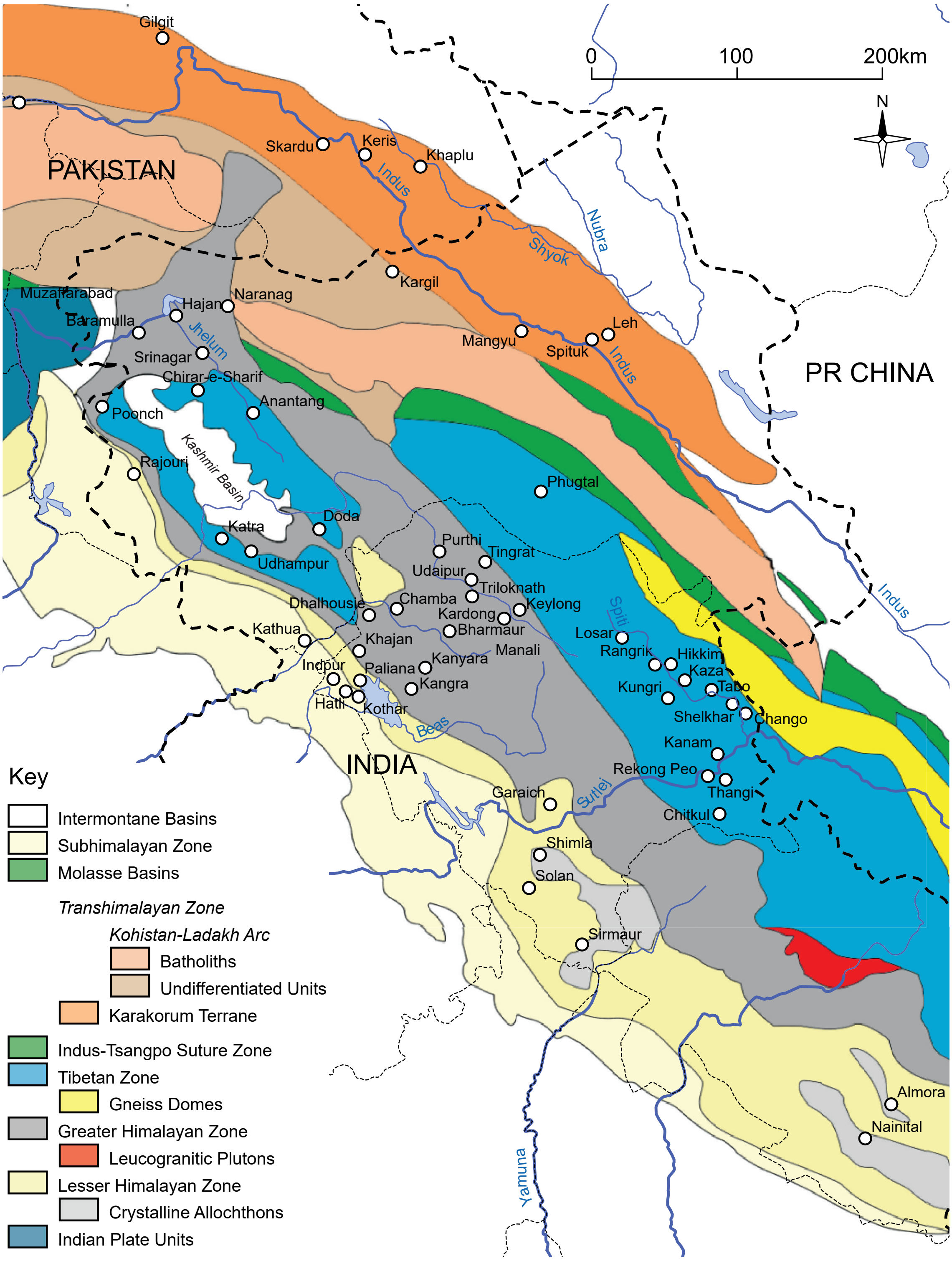
Further west in the province of Khyber Pakhtunkhwa, we also find low precipitation over the course of the year. In Sazīn (alt. 1,000 m), which is app. 470 m below the altitude of Gilgit, maximum temperature is similar, but low temperatures are in comparison higher and not below 0°C. Annual precipitation is about three times as high. At Kalam (alt. 2,000 m), which is app. 250 m lower than Skardu, we find a similar relation with minimum temperature ranging above 0°C. In Kalam, the climate is moderate, but warm. Precipitation is observed throughout the year, with even the driest month experiencing high precipitation. (CD)

3.5.4 Central and West Tibet

In comparison with Tibetan climate conditions, Lhasa (alt. 3,660 m) has an annual precipitation of app. four times of Leh or Phyang. Maximum temperatures are about similar to those of Leh, but minimum temperatures are higher than those of Ladakh. The difference between minimum and maximum temperature is app. 18°C, which is lower than the data given for Ladakh. Purang (alt. 3,890 m) in West Tibet has higher precipitation and lower temperatures compared to Lhasa. The climate in Purang is moderate and cold. The amount of precipitation in winter is higher compared to summer. (CD)

3.6 Raw material for building purpose

Raw material resources strongly relate to climatic conditions and altitudes. For vernacular architecture in general, nearby materials with a short distance of transport – if necessary with animals – are chosen. The choice of building materials and of appropriate methods of processing depend on social status, which is expressed by increased effort and by increasing the final building quality. The following data on wood, earth and stone are summarised for the research area to provide possible interrelations between climate and material resources, and the development of building techniques.



Map 4.4 Tectonic map of the core region.
GIS data based map by: Jakob Gredler. Final graphics: author. Map based on Vector data (VD) and Tectonic map (TM) adapted from Hodges 2000: 239. Citations of VD and TM also see: Chapter IX, list of illustrations.

According to Gansser (1964), the Himalayas can be divided into the following geological belts: Transhimalaya, Higher Himalaya, Lower Himalaya and Siwalik Himalaya. Following a categorisation after Negi (1998: 106), we can reduce this division into three belts, correlating with a biophysical graduation between these belts (Handa 2008b: 130). Map 4.4 is based on a tectonic map published by Hodges (2000: 329). The Geological Survey of India published the following categorisation (2012b: 2, 3).

Shiwalik or Sub- or Outer Himalaya: 600 m to 1,200 m; "structural and denudational hills separated by sub-latitudinal flat bottomed valleys" (cf. GSI 2012b).

- Lower or Lesser Himalaya: also "structural and denudational hills", but higher elevations from 3,500 m to 5,000 m (ibid. 2).
- Greater or Higher or Main Himalaya: heights exceeding 6,000 m; rising steeper than the Lesser Himalaya; located above snowline except for deep ravines (cf. GSI 2012b: 2).
- Trans- or Tibetan or Tethyan Himalaya: Zangskar and Karakorum Range; Ladakh Range between Indus and Shyok Rivers up to 6,529 m; Indus Valley as erosional and depositional terraces, flood plains, palaeolake and aeolian surfaces located between Ladakh and Zangskar with a valley floor between 3,195 m and 3,395 m at Upshi and the Shyok Valley between Ladakh and Karakorum (cf. GSI 2012b: 2, 3).

3.6.1 Methods of processing raw material for vernacular structures

Today, in remote Himalayan areas, logs are still sawn by hand with a bucksaw (Ger. *Rahmensäge*). This tool needs two workers who alternately pulling the saw. One method in Ladakh involves the log being stabilised in a vertical, slightly inclining position while (as shown in the picture) the two workers – husband and wife – sit opposite each other (Fig. 4.22). Another method is the use of a two-men crosscut saw as found in Tawang in Arunachal Pradesh, where the log is kept in a horizontal position and two male workers stand above each other (Fig. 4.23). In both cases, the log is cut at the same time into several boards in a longitudinal direction. An early method of processing the surface of a board, e.g. for historical ceiling boards in Nako in Upper Kinnaur, involved use of an adze. The planks and beams are straight and cut very precisely,[134] requiring a high processing effort. Thus cutting is done only to meet real needs. In 'simple' building structures beams can be found uncut and in some cases even unpeeled (cf. Feiglstorfer 2012a).

Figures opposite page:

Fig. 4.22 (Top, left) Kaza. Ladakh. Buck saw.

Fig. 4.23 (Top, right) Tawang. Arunachal Pradesh. Two-men crosscut saw used in a vertical position.

Fig. 4.24 (Centre, left) Nyarma. Ladakh. Mould for producing sun-dried adobe bricks.

Fig. 4.25 (Centre, right) Sangnam. Spiti Valley. Wooden shuttering for rammed earth walls made on top of a stone basement.

Fig. 4.26 (Bottom, left) Central Tibet. Close to the Chekha Monastery. Villages along the river show a dominance of rounded river stones, which are used for house constructions.

Fig. 4.27 (Bottom, right) Gondhla. Lahaul. Stone carver using hammer and chisel.

134 The early history of the use of a handsaw made of bronze in East Asia goes back to the Zhou Dynasty (1122/1045–770 BCE), while the use of a bucksaw started in the Song Dynasty (960–1279 CE) (cf. Li Zhen 2004).






Adobe bricks are usually processed in bottomless moulds (just with four sides) (Fig. 4.24). Sieving is conducted with metal sieves. A traditional method is the use of sieves made of fibres or the use of textiles to gain fine engobe for slurries used for upper layers of wall surfaces. The method of desludging may have also been used (Feiglstorfer 2019: 48ff.). For rammed earth walls, shuttering made of boards or wattled willow mats are commonly used (Fig. 4.25). Mortar is applied by hand. Fired bricks are of negligible importance in the research area except for Srinagar, where a particular small brick size, the so-called *"maharaji"* brick, was produced. In the Srinagar District, plentiful wood resources allow for the firing of kilns.

Boulders are either collected when loose – e.g. as rounded river stones (Fig. 4.26), which are from a static point of view less appropriate than quarried angular-shaped stones – or they are quarried with simple tools, such as a pickaxe, iron hammer, wedge or crowbar (Atkinson 2002: 267). For a random stone wall, the effort to dress the stones is less than in the case of ashlars (square hewn blocks), which are often used as corner stones or for lined stone walls (Fig. 4.27). Different qualities of processing can be distinguished, e.g. a simple dressing as widely used in Lahaul or more sophisticated methods for processing of rectangular hewn blocks. An example of the latter is the Bhīmā Kālī Temple in Sarahan in Himachal Pradesh. The kind of stone plays an essential role in the effort and labour costs. We may differentiate between random stone walls and banded masonry, with or without the use of mortar. The term "banded masonry" follows Howard's description (Howard 1989: 218) with a first layer of large stones followed by a second layer for filling the gaps and for levelling of the next layer of large stones. Alexander (2011: 35) calls this texture a "galleted rubble texture".

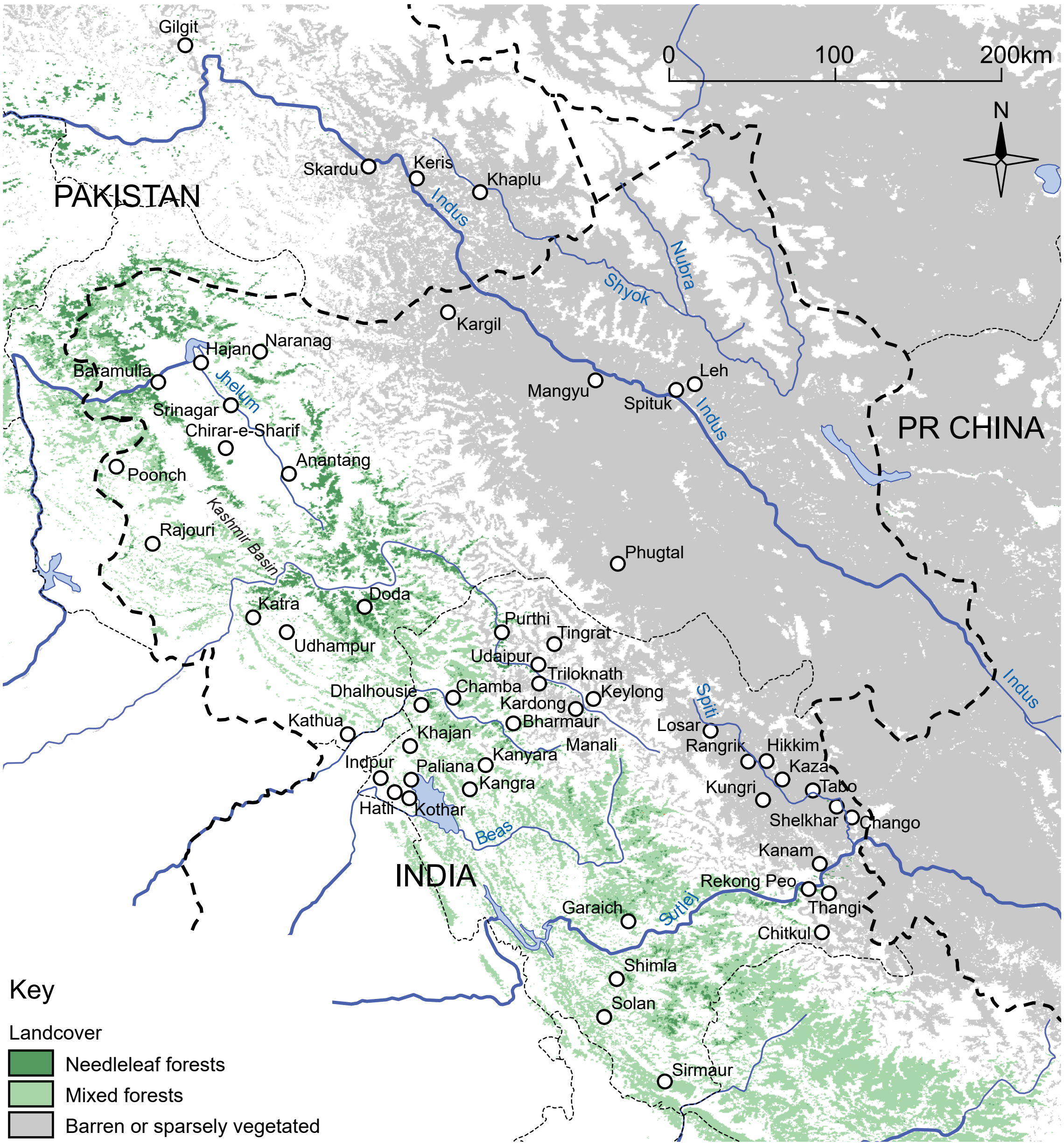
3.6.2 Timber

Regions like Chamba, Kashmir or Kinnaur are well known for a long tradition in wood carving and carpentry. The availability of appropriate timber is an essential precondition. One parameter for the availability of wood is the tree line. In arid zones, trees are primarily available in river valleys as groups. All the highest records for treelines in High Asia above 4,850 m consist of Juniperus species (Farjon 2005: 170). Found even at 4,900 metres in south-eastern Tibet, the highest tree species known in the Himalayas in general is Juniperus tibetica (Miehe et al. 2007: 169). In the following, the most common types of trees used for structural timber in the Western Himalayas are matched with altitude related climate features (Map 4.5). Given in italics are the local names of trees as collected in the field and adjusted with literature. The local terms may vary between different places. For a comprehensive summary of further local terms, compare Gamble (1984).

3.6.2.a Jammu and Kashmir

Ladakh

- In higher altitudes with less precipitation than we can find in Ladakh, Lahaul, Spiti, or Upper Kinnaur, i.e. all areas at an altitude of app. 3,100 m and above, willow, poplar, *takpa* (Betula utilis; Hindi *bhujpatra*; "white Himalayan birch") and *shukpa* (Juniperus macropoda or Juniperus excelsa; in Himachal Pradesh known as *lewar* or *shur*, Handa 2006: 42; "Himalayan pencil cedar") are commonly used for construction. Throughout the Himalayas, *takpa* is known for its bark, which is used for flat roof insulation between the wooden subconstruction and the



Map 4.5 Forest landcover.
GIS data based map: Jakob Gredler. Final graphics: author. Map based on Vector data (VD) and MODIS Land Cover (LC) according to Friedl, Sulla-Menashe (2015). Citations of VD and LC also see: Chapter IX, list of illustrations.

earth layer on top (cf. Feiglstorfer 2019: 145ff.). Due to its elasticity, its branches are also known for their use for bridges made of twigs. *Takpa* rarely grows below 3,050 m (Gamble 1984: 668). Birch forests are found at altitudes between 200 m and 2,000 m, a precondition, which is not dependent on monsoon rains, but on the amount of water occurring during the snowmelt (Holzner, Kriechbaum 1998: 63). According to Negi (1998: 193), it is associated with the category of sub-alpine forest.

· *Shukpa* is known as a hard wood used for carving, and it is preferably used for religious structures. Its needles are collected and used as incense. Since forest decimation in the past has greatly impacted this wood, cutting is currently prohibited, and in some areas such as in Lahaul, even the collecting of its needles is not allowed. According to Negi (1998: 193, 212), *shukpa* is found in the dry zone of the Higher Himalaya and the Transhimalaya between 2,700 m and 4,300 m. It is reported to have a height of up to 21 m and a girth of up to 6 m (Gamble 1984: 699).

· For 'simple' vernacular structures, poplar with its long and straight growth is commonly used. *Yarpa* (Populus balsamifera) and *makkal* (Populus nigra; according to Handa 2006: 42 locally also known as *yarpa*) are mentioned as common at high altitudes. Gamble (1984: 691, 692) describes the *yarpa* as available between 2,450 m and 4,250 m in arid zones of the Himalayas. He describes the *makkal* as present only in a cultivated form and with growth at altitudes up to 3,800 m. As a further species of poplar, Gamble mentions *hodung* (Populus euphratica). This species is found at high altitudes up to 4,100 m, like in Ladakh (ibid. 691). It is common in Nubra along the Shyok River, and grows in pure sand (Brandis, Stewart 1874: 474, 475). The *safedar* (Populus alba) grows wild and is cultivated at an altitude between 1,200 m and 3,650 m with a height up to 12 m and a girth up to 2 m (ibid. 473). Willow is commonly used for wattled objects. Handa (2006: 42) also mentions the Salix alba ("white willow", see Gamble 1984: 687), locally known in Himachal Pradesh as *chung*. Besides the above mentioned locally available species of wood, for elite building constructions *devdar* is brought from lower elevated regions in Kashmir or Himachal Pradesh.

Kashmir

· Kashmir is a centre for wooden architecture and arts. In Kashmir along the rivers Vitasta and Jhelum, pine forests are predominant (Kachru, Thapalyal 1990: 103). *Kail* (Pinus wallichiana or Pinus excelsa; "blue pine") is commonly used for constructions in Kashmir and Punjab (Gamble 1984: 704). For its use for planking, doors, windows or furniture, it is said to be superior to the deodar, since *kail* is not brittle, contains no oil and is free of scent (ibid. 705). Deodar is strongly present in Kashmir (ibid. 710). Throughout the Himalayas, it was commonly used for religious buildings. In Kashmir, besides various other examples, it was used for the Nund Rishi Mosque in Chirar-e-Sharif (Kachru, Thapalyal 1990: 109). In western regions such as Jammu and Kashmir and Himachal Pradesh, deodar grows within a wide altitude range between app. 1,370 and 3,350 m (Handa 2008b: 136). In the area of Jammu and an adjoining part of western Himachal Pradesh, there are sub-tropical semi-desert forests, inter alia, containing *shisham* (Dalbergia sissoo) (Negi 1988: 191). At lower altitudes, insects endanger wooden building structures. In the lower areas of the Jammu-Kangra region, for example, termites are a problem (Handa 2008b: 164).

3.6.2.b Himachal Pradesh

Lahaul and Kullu

- Lahaul differs from the southern district of Kullu due to a smaller variety of species of trees. S*hukpa* can be found here (Sudershan Vashishtha 2003: 186) and was in former times used for processing house beams (Gamble 1984: 699). Small groves of *takpa* are common.
- The *devdar* (Cedrus deodara, "deodar") is one of the main timbers for construction in Lahaul and Kullu and, according to Gamble (1984: 710), the most important and valuable timber in the whole of North India. It grows, e.g. at higher altitudes along the Chandra, Bhaga, Ravi, Beas, Sutlej, Yamuna and Ganges Valleys (Handa 2008b: 136). According to Negi (1998: 203, 211), in the Western Himalayas deodar is associated with the categories of Himalayan moist deodar forest between 1,700 m and 2,500 m and the dry deodar forest between 2,000 m and 3,200 m. During British rule, *deodar* was an important good for export from Kullu (Minhas 1998: 131). It grows with a height of up to 45 m and a girth from 2 m to 13 m (Gamble 1984: 712). The deodar can be found in Jammu and Kashmir via Uttarakhand to Nepal (Handa 2008b: 130).
- In Lahaul, two species of poplar are predominant: *yarpa* and *makkal*. *Yarpa* grows high and straight. The *makkal* is often cut, making it look smaller and broader (correspondence with Tsering Dorje 2005). In lower regions towards Kullu *kail*, walnut and spruce fir can be found. Walnut trees grow, e.g. in the area of Gondhla (Postel et al. 1985: 291), located about 7 km south of Keylong.
- The *kail* is associated with the categories of the Himalayan moist temperate forest, which is found between 1,500 m and 3,300 m. The Himalayan dry temperate forest and *kail* forests can be found in the moist temperate zone above 2,100 m and 2,500 m (Negi 1998: 192, 193), inter alia, in Kashmir, Punjab, Chamba, Dalhousie, Shimla and Kinnaur (cf. Negi 1998: 209). The *kail* is superior to the *chīr* (both belonging to the family of the Pinus) and reaches a height of up to 45 m and a girth of up to 3.5 m (Gamble 1984: 704, 705).

Spiti

- For Spiti, Verma (1997: 9, 10) mentions northern slopes as the location of *takpa growth,* and moist irrigated locations for willow and poplar. In the temple of Lalung in Spiti (12th century CE; Luczanits 2004: 106), primarily two different types of wood were used, i.e. *devdar* and *shukpa*. *Devdar* was used for the ground floor and contains the earliest structure from the 12th century. For this prestigious structure, this points towards an import of deodar wood from lower areas of Himachal Pradesh. Today, the nearest place for Spiti to collect deodar is Mandi (150 km) or Rampur (100 km) (correspondence with Dechen Lundup in 2015). *Shukpa* was used in the temple of Lalung for the upper floor. This floor was added in the 20th century and is most likely of local origin. The use of different kinds of wood within one building is found not only in Spiti, but is in general rather common in the region.

Kinnaur

- In Kinnaur, *shukpa* was commonly used for religious structures (Gamble 1984: 699). Species of poplar (e.g. *safedar*) and willow (e.g. *malchang*, Salix daphnoides; in arid zones of the Himalayas growing up to 4,500 m) are found here (Royle 1979: 344). In Lahaul, willow is rarely used as wood for construction, but is utilised more commonly in Kinnaur, Spiti, Zangskar and Ladakh (Interview with Tsering Dorje in 2005).

- According to local information, *devdar* is the wood used in the temples of Nako (in Kinnaur also known as *kelmang*; Handa 2006: 24). Deodar forests are still widespread in Kinnaur, where wood, also known as *kelo* or *diar*, from these forests is the main timber for construction (Dave 2013: 13). It grows, for example, in the Sutlej Valley. Deodar is considered sacred (cf. Handa 2006, Belz 2012: 64) as expressed by its name *devdar* (on the terminology of *devdar* see part 2 of Chapter IV).
- Another wood used for construction in Kinnaur is *kail* (Gamble 1984: 705). Today, for constructions in Nako, the primarily used wood comes from the *kail* tree (Tib. *gsom shing*) from the Ropa Valley and Rekong Peo, the latter of which is at a lower altitude in Kinnaur and further south from Nako. Together with the *devdar,* the *kail* is the most commonly used tree for building construction (Dave 2013: 69). Deodar is a very durable wood and used for various purposes in architecture. Due to the release of oil, it is not suitable for polishing and painting (ibid. 69).
- *Spun* or *tosh* (Abies pindrow, "silver fir") is used for making wooden shingles and grows at altitudes of up to 3,000 m with a height of up to 42 m and a diameter of up to 76 cm (Gamble 1984: 719, 720). The *thelu* (Juniperus communis), which grows between 2,750 m and 3,350 m, is found in Kinnaur (Gamble 1984: 697, 698). In Kinnaur, *chīr* (Pinus roxburghii) is available up to app. 2,000 m (Negi 1998: 252; Interview with Tsering Dorje in 2005). Besides its use for structural purposes, it is known for the extraction of resin. It is resinous and highly inflammable, thus it is not popularly used as structural timber (Handa 2008b: 132). Brandis and Stewart (1874: 506, 507) mention extensive use of *chīr* wood in the hills for buildings and add that in Kumaon, roof timbering takes a period of two generations.
- Oak is known as a good firing wood (Belz 2012: 64), in addition to its use for structural purpose. Oak trees are associated with the category of temperate forests (Negi 1998: 192–203). In Kinnaur, the *bān* (Quercus leucotricophora or Quercus incana, "oak") appears between 900 m and 2,400 m. It is known as hard wood, but "liable to warp and decompose on exposure to wet." During the British rule in India, the British used oak beams and rafters in their residences. (Indus Publishing (ed.), *Gazetteer of the Kangra District* 1994: 28). Another species of oak is the *mohru* (Quercus dilatata), which grows between 1,800 m and 2,700 m. Contrary to the *bān* tree, it prefers moist forests (Gamble 1984: 673). Other trees used for building purposes are the *akhrot* (Juglans regia; "walnut"), which grows between 900 m and 3,000 m (ibid. 663), and the *parong* (Acer oblongum, "Himalayan maple"), which grows between 600 m and 1,800 m (ibid. 199).

Chamba

- In the Chamba District settlements of Chhatrari, Bharmaur, Tisa, and Chamba Town, the presence of highly experienced carpenters (Hindi *badhai*) is widely known (Bharti 2001: 177). In Chamba District, close to Kangra District, one of the main tree species is *chīr* (Pinus roxburghii). The area close to Dalhousie is associated with the *bān* tree, and the main species used for structural timber are *kail* and *deodar*. According to Bharti (2001: 185, 186), deodar is the main timber for construction in Chamba (ibid. 177). In the Ravi Valley, for example, pine trees are common, also towards Udaipur and Triloknath (Postel et al. 1985: 291).

Kangra

- In the Gazetteer of the Kangra District (1994), a relation between species and altitude is mentioned. Trees grow predominantly along the northern slopes of hill ranges (ibid. 26). Most common is the *chīr,* which grows under different climate conditions at altitudes between 500 m and 2,100 m. Its wood is hard. It grows straight and reaches a height of up to 10 m with planks that have a width of up to 60 cm. Above Dharamsala, we find the *rai* (Picea smithiana, "Himalayan spruce"). Here altitude reaches between 2,400 m and 3,200 m. Wood from this altitude is mentioned as inferior to the wood of the *chīr,* and is used only for the construction of shingles. (ibid. 27) Lower regions of Kangra are much richer in wood, e.g. in *toon* (Gamble 1984: 157).

- Montane sub-tropical forests are situated between 500 m and 1,500 m with hot summers of up to 40°C (Negi 1988: 191). Negi describes the *sāl* (Shorea robusta) as dominant in the Shiwalik and Himalayan foothills. It grows to a length of 35 m or even higher (ibid. 194). It is one of the most commonly used types of wood in Northern India. For example, it is employed as piles, beams, planks or bridge rails. Its height reaches app. 45 m and its girth is app. 2.4 m. (Gamble 1984: 78) Its quality as structural timber is below the deodar, but due to availability and affordability, it is often preferred to deodar (Handa 2008b: 132).
- The *shisham* is preferably used for carpentry. It is spread throughout the whole district, and was reserved for the British during their reign. It is also known as durable, and used for construction, furniture, carvings and boats (Gamble 1984: 247). Its height is reported to be up to 18 m and its girth is up to 3 m (ibid. 248).

Uttarakhand

- In areas west of the Yamuna in Himachal Pradesh and in parts of Uttarakhand, the *toon* (Toona ciliate or Cedrela toona; "red cedar") is commonly used, e.g. as beams. In addition to *deodar* and *chīr,* it is also used for making planks (Handa 2008b: 148). *Toon* is durable and grows up to 1,200 m. It is also used for furniture, door panels and carvings (Gamble 1984: 157).

3.6.2.c North Pakistan

Gilgit-Baltistan and Kyber Pakhtunkhwa

- In a description given by Hunzai and Beg (2005: 54), elaborate decorative timber work is mentioned for Baltistan, using local walnut, mulberry, juniper, cedar, apricot and poplar wood. For Kyber Pakhtunkhwa (the former North Western Frontier), Schacher (1998: 3) mentions cedar (*deodar* in Urdu and Pashto), blue pine (*pavich* in Urdu; *biar* in Pashto) and Himalayan poplar in northern areas as the types of wood used for beams. In the Karakorum region, pine, walnut, mulberry and apricot are commonly used for structural elements. In Hunza and Baltistan, juniper is in high demand for beams in the *cator and cribbage* construction (Hughes 2007: 109).

3.6.3 Stone

According to Map 4.4 showing the tectonic structure of the Western Himalayas within the core region of this study, an allocation primarily to four different tectonic zones becomes evident. North Pakistan and Ladakh in the area between Leh and Gilgit are located in the Karakorum Terrane, which bellongs to the Transhimalayan zone. The area from Zangskar via eastern Lahaul and Spiti to Kinnaur belongs to the Tibetan zone, while the area of western Himachal Pradesh (Chamba and Kangra) belongs to the Greater Himalaya. The area between Srinagar and Udhampur belongs to the Kashmir Basin, which is surrounded by the Tibetan zone.

- In many parts of the Western Himalayas, a proper stone building material is available (Atkinson 1993: 296). Among these are granite, gneiss, volcanic rock, sandstone, limestone, dolomite, shale, schist, slate, siltstone, quartzite and various conglomerates. The quality for building purposes between the stones varies, and in certain cases stones must be transported over long distances to ensure a certain quality. Transport to remote places is still conducted by pack animals. Today, stone is free when it can be quarried from one's own land (Belz 2012: 159).

· According to Atkinson (1993: 207, 208), in the sub-Himalayan zone, sediments are predominant, while in the Lesser Himalaya, crystalline rocks (gneiss and granite) are prevalent, and in the Tibetan zone, highly fossiliferous sediments such as limestone are reported.
· Stones with a content of mica (such as gneiss) are preferred for building purposes, since these are easier to cut. From stone sculptures produced in North India, we know of the origin of the material that is of interest as building material. In the Gandhara period, mainly carbonaceous chloritoid phyllite and chlorite schist were used, while in the Gupta period metasiltstone was preferred and in the Gujara-Pratihara period chlorite-quartz-mica schist was commonly used (Satish 2003: 288). During all periods, sandstone (e.g. from Himachal Pradesh) was used and in a later phase also metasiltstone, limestone, or chlorite schist from Almora (ibid.). Sandstone in particular is widely available in the Central Himalayan region (Handa 2008b: 137).
· Stones for building purpose of different qualities are found all over Jammu and Kashmir, and Himachal Pradesh. Certain types of stones are known as predominant in various regions. In the following, an overview will be given of structural stones and related geology in Himachal Pradesh, and Jammu and Kashmir in order to determine further relations between locally available raw materials and local building techniques.

3.6.3.a Stones commonly used as building material

Slates

· Over the Western Himalayas, several deposits of slates are commonly known and used as building material. The use of schist as roof material is locally associated with a particular social status. In various regions with high precipitation, slates are predominantly used as roof covering and for paving. The use of slates as roofing material increases from the cold climate zone [B] towards the temperate climate zone [D] (for climate data see Map 4.3)
· In Jammu and Kashmir, slates used for roofing are quarried in the Chhongthash area in Leh District and in the districts Udhampur-Rajouri-Poonch (GSI 2012b: 42).
· In Himachal Pradesh, slates of a high quality for building purpose originate from the Dhauladhar Range between Kangra and Chamba. Slate is also quarried in the Shimla region. It is of lesser quality to that found in the Chamba District. (Cunningham 2005: 229) Further slate belts in Himachal Pradesh exist in the Kangra District (GSI 2012a: 36–37; in Kangra near Kanyara, see Burrard, Hayden 1908: 265) and in the area to the south-east of Himachal Pradesh in Garhwal (GH 1993: 296). In Garhwal, high-quality slates are reported (ibid.).

Gypsum and limestone

· In Jammu and Kashmir, gypsum is available in the districts of Baramulla, Kargil and Doda.
· In Himachal Pradesh, gypsum is available at deposits in the districts of Kinnaur, Lahaul and Spiti, Sirmaur, and Solan. (GSI 2012a: 25ff.; GSI 2012b: 34ff.) In Spiti, gypsum is found in the Gyundi sub-valley and in an area near Losar (Verma 1997: 9).
· In Jammu and Kashmir, limestone is available in the districts of Anantnag, Baramulla, Srinagar, Kargil, Leh, Doda, Kathua, Udhampur, Rajouri, and Poonch (GSI 2012a: 25ff.;

GSI 2012b: 34ff.). In Himachal Pradesh, limestone is available as deposits in the districts of Bilaspur, Chamba, Kangra, Kinnaur, Kullu, Mandi, Shimla, Sirmaur and Solan (ibid.). Also for Garhwal, gypsum deposits and the manufacturing of limestone are reported (GH 1993: 294, 295; Verma 1997: 8).

3.6.3.b Stones following a geographical order

Jammu and Kashmir

· In the Jammu-Kangra region, many of the buildings are made of sandstone (Handa 2008b: 126), which is a commonly used building stone in the Shiwalik Himalaya in Jammu and Kashmir. However, in the Lesser Himalaya, limestone, slates, shales und schists can be found (Negi 1998: 105–111). As building material in Jammu and Kashmir, inter alia, granite is used in the Panjal Trap, sandstone is common in the Murrees, marble is used in the region of Jammu, and limestone is prevalent in the Kashmir Valley (GSI 2012b: 29). From Kashmir towards Kaghan Valley in North Pakistan, gneiss is reported, though this resource is extinct at the Zoji La. From here to Tibet, limestone and schists are prevalent. (GH 1993: 151) In the Transhimalayan Zangskar crystalline formation gneiss and granite can be found (Negi 1998: 112). In Ladakh – which is part of the Transhimalayan zone, separating it from Jammu and Kashmir (GSI 2012b: 1) – a large variety of stones exists, inter alia, granite (e.g. along the southern slope of the Karakorum), gneiss, schist, shale, limestone (marble in Kupwara and Leh District; GSI 2012b: 40), volcanic stones (e.g. in the areas of Shyok or Dras), conglomerates, and fine sediments (e.g. in the Indus Flysch zone; cf. Negi 1998). According to the Geological Survey of India, local building materials in Ladakh include, inter alia, volcanic stones, limestone and granite (GSI 2012b: 29). Deposits of *arga* stone (highly carbonatic) are known in Mangyu and Phugtal (cf. Feiglstorfer 2016, 2019).

Himachal Pradesh

· Geology in Spiti (part of the Transhimalayan zone) is similar to the geology of north-eastern Kullu, but differs from the rest of Kullu. It contains marine deposits, shale, limestone, Giumal sandstone (Sudershan Vashishtha 2003: 255, 257), and conglomerates (Atkinson 1993: 207, 208). Most of Lahaul is made up of metamorphic and crystalline rocks. Just a small part close to the crossing of the Bhaga and Chandra Rivers consists of volcanic rocks. (Sudershan Vashishtha 2003: 185) In Kullu, crystalline stones (granite, gneiss, schist) and unfossiliferous rocks are available. Further south, unfossiliferous sedimentary rocks stretch from Chamba via Kangra and Shimla Hills to Garhwal. These consist of limestones, slates, quartzites and conglomerates. (ibid. 9) For Garhwal, close to Almora, fine-grained quartzites and mica schist are present, and at Nainital limestone and clay schist are reported as well as gneiss, sandstone and chlorite-schist (GH 1993: 296). For Kinnaur, Handa (2008b: 137) mentions the availability of high-quality structural sandstone. In the Sangla Valley, slates, quartz schists, phyllite, garnetiferous schists, quartzite and lenticular limestone are reported (Devi et al. 2014: 740).

North Pakistan

· In North Pakistan, the use of granodiorites and gneiss is common, along with slate, marble or basalt (Hughes 2007: 108). Atkinson (1993: 207, 208) mentions a preferred use of limestone for Chitral and Afghanistan.

West and Central Tibet

- In West Tibet, Atkinson (1993: 207, 208) reports limestone in Ngari and volcanic stone in the area of Lake Manasarowar. Deposits of *arga* stone (see Chapter II) are known in the Purang region. In Central Tibet, granite, slate, schist and quartz stones are commonly used for construction (Alexander 2011: 35). From Central Tibet to the source of the rivers Indus and Sutlej, granite, schist, mica-schist, gneiss and beds of highly crystalline limestone are stated (GH 1993: 152). Deposits of *arga* (highly carbonatic) are known in the region of Leh and the surrounding area (Feiglstorfer 2019: 139ff.).

3.6.4 Clay

In Himachal Pradesh, and Jammu and Kashmir, clay is traditionally used for a variety of construction and crafts purposes. Places related to clay examination within this study are given in Map 4.6. Table 4.1 and Table 4.2 contain clay samples, which are mentioned in the text. The samples with a sample number were examined at the IAG / BOKU. Data on grain size distribution and bulk and clay mineral analysis are given in Table 4.4, Table 4.5 and Table 4.6 in the Appendix of Chapter IV. Various types of clay for different use were examined by the author:

Walls:	rammed earth walls
	wattle and daub walls
	bricks (primarily adobe; rarely fired)
	clay mortar and clay plaster
Roofs / floors:	flat and rarely pitched earth roofs
	rammed earth floors
Other use:	clay stoves
	clay sculptures
	pottery ware
	painting

In order to change the binding behaviour of clay, different additives are traditionally known in the Himalayas (ibid.). These include anorganic additives, e.g. lime or sand, and organic additives, e.g. fibres, needles from trees, straw, pieces of twigs, salt, gum, rice starch, or the juice of apricots. In Ladakh, Chamba and Kinnaur, apricots are locally known as *chulli*. The *chulli* (Prunus armeniaca) grows at altitudes between app. 1,200 m and 3,000 m (cf. Kureel et al. 2007: 2). In general, clay is processed in a moistened state and has to dry after being processed. Usually local clay that has been sourced nearby is used. Only for a particular purpose, e.g. clays for waterproofing of a roof, does transport over longer distances occur. Whether clay is used at all for building purposes generally depends on environmental conditions such as local availability, the quality of the raw material, and climate conditions, e.g. the amount and strength of precipitation.

Clay of different qualities for building purposes is found all over Jammu and Kashmir, and Himachal Pradesh. Certain types of clays are known by local terms, and these terms may point towards their place of origin, or specific properties and purpose. In the following, an overview is given of clay deposits in Himachal Pradesh, and Jammu and Kashmir so as to find further relations to other locally available raw materials and building techniques. Samples of clay were collected in Himachal Pradesh, and Jammu and Kashmir. Results of these examinations – conducted at the IAG / BOKU – are presented below.[135]

135 See Appendix of Chapter IV for grain size classes and results of bulk and clay mineral analysis.

Map 4.6 The map shows sampling points of clay samples and settlements related to part 3.6.3 (“Stone”) and part 3.6.4 (“Clay”) of Chapter IV.

GIS data based map: Jakob Gredler. Final graphics: author. Map based on Vector data (VD). Citations of VD also see: Chapter IX, list of illustrations.

Table 4.1 List of clay samples

Sample no.	Place	State	Origin	Use	Local name
			Chamba		
8506	Purthi	HP	clay pit	roof, plaster	*sho*
8510	Purthi	HP	clay pit	field clay	*kit-jan*
8528	Purthi	HP	clay pit	whitewash	
	Purthi	HP	clay pit	whitewash	*makol*
	Purthi	HP	clay pit	whitewash	*golu*
	Purthi	HP	clay pit		*kosti* (also *losti*)
			Kinnaur		
8467	Ribba	HP	clay pit	roof, plaster	
8493	Ribba	HP	clay pit	painting	
8492	Chulling	HP	old house	interior plaster	
8511	Thangi	HP	clay pit	roof, plaster	*cham*
8518	Thangi	HP	stable	roof	
8529	Thangi	HP	entrance gate	plaster	
8513	Moorang	HP	clay pit	exterior plaster	*chit*
		HP	clay pit	roof	*kum-mating*
	Shelkhar	HP	clay pit	roof, plaster	*tua*
			Spiti		
6041	Tabo	HP	old house	interior plaster	
6053	Tabo	HP	old house	brick	
	Tabo	HP	clay pit	brick, rammed earth, roof	*duksa*
	Tabo	HP	clay pit	rammed earth, roof, plaster	*shaksa*
	Tabo	HP	clay pit	painting	*tsak*
6048	Sangnam	HP	residential building	roof	
6049	Kungri	HP	old house	roof	
6050	Dhankhar	HP	old house	roof	
8507	Rangrik	HP	old house	exterior plaster	
8515	Rangrik	HP	old house	rammed earth	
8512	Lalung	HP	clay pit	mortar, plaster	
8527	Hikkim	HP	ruins of an old house	adobe brick	
8530	Hikkim	HP	ruins of an old house	interior plaster	

Table 4.2 List of clay samples

Sample no.	Place	State	Origin	Use	Local name
			Lahaul		
8480	Keylong	HP	clay pit	building purpose	*sakalak*
6057	Keylong	HP	old house	brick	
8478	Tingrat	HP	clay pit	roof, plaster	*talba*
			Kashmir		
11755	Srinagar	J&K	Jalali Haweli	interior plaster	
11916	Srinagar	J&K	Jalali Haweli	mortar, roof	
11757	Naranag	J&K	stable	flat roof, brick, plaster	
			Ladakh		
	Spituk	J&K	clay pit	roof, plaster	*markalak*
	Basgo	J&K	clay pit	roof, plaster	*dzasa*
	Basgo	J&K	clay pit	roof, floor, brick, plaster	*thetsa*
	Likir, Ne	J&K	clay pit	stove	*thabsa*
			North Pakistan		
	Hunza	Gilgit-B.	clay pit	roof, floor	*damul*
			West Tibet		
	Khorchag	Ngari	clay pit	roof, plaster	*narkalak*

3.6.4.a Jammu and Kashmir

Kashmir

- In the Srinagar District in Karewas in Kashmir Valley, and also at Wuyan and near Hajan Har, deposits of clays, used for cement manufacturing, are reported (GSI 2012b: 29ff.). During field research, samples were collected at Srinagar (samples 11755 and 11916) and Naranag (sample 11757).
- Sample 11755 from Srinagar is an interior plaster (5cm)[136] from the Jalali Haweli and was given to the author by the owner. This plaster contains 62.8% silt, 34.9% clay and hardly any-coarser grains.
- Sample 11916 was also collected from the Jalali Haweli in Srinagar, but this clay is used for mortar and the flat roof covered by a gable roof. The grain size distribution of these two materials is rather similar. Since the technical standard of this building is high and may be counted as a residential elite structure, the materials used can be expected to follow a high technical standard. From the roof material we know that it was not sieved and that it is locally available with this fine consistency. Both samples show a content of smectite as swellable clay mineral.
- Sample 11757 from Naranag in Kashmir, which is located about 30 km north of Srinagar, originates from a flat roof of a stable used by nomads during summer. This clay is locally universally used, inter alia, for bricks and plaster. It is coarser than the afore-mentioned material used at the Jalali Haweli and contains no swellable clay minerals. All samples taken in Kashmir, similar to Spiti, show a content of calcite.
- In the Udhampur District, clay shale bands in rocks close to Katra-Reasi and Tikri have been identified. This clay is used for the manufacturing of Portland cement. In Jammu District in the Bameal-Dhun sector, clay for a refractory use is known, but due to a high content of Fe_2O_3, it is unsuitable for the ceramic industry (GSI 2012b: 29ff.).

Ladakh

- In Ladakh, white bentonitic lacustrine clays at Lamayuru and Spituk are locally known as *markalak* (Feiglstorfer 2019: 199ff.). Further locally available types of clay, such as *dzasa* or *thetsa*, and their use for plaster, roofs, bricks, stoves or pottery are discussed in Chapter III. A geological profile was conducted when carrying out pollen analysis from a 23 m core dating from about 30,000 to 9,000 BCE at the Tso Kar in Rupshu in Changtang at about 4,572 m (cf. Bhattacharyya 1989: 28, 29). Seventeen different layers are reported within these 23 m, primarily showing sediments with a content of varying types of clay (ibid.).
- East of the Jammu-Kangra region, *chik* clay (red-ochre clay) is known for its structural qualities for building purposes (Handa 2008b: 169). In Uttarbaini in Jammu District, deposits of bentonite are reported (GSI 2012b: 28).

136 The interior plaster is applied in three layers all using the same red clay: The 1st layer is clay mixed with grass growing at the lake close to the building (known as *kalrun*); the 2nd layer is clay mixed with paddy straw; the 3rd layer is clay applied after drying of the 2nd layer and mixed with *kalrun*; finally finished with a trowel. The exterior plaster (app. 3 cm) is a clay mortar mixed with lime without grass. In side rooms the plaster is made with two layers: The 1st layer is app. 1 cm with mixed straw; the 2nd layer (very fine) is app. 1 cm mixed with paddy straw.

3.6.4.b Himachal Pradesh

Chamba

- In Chamba, a particular white clay is known as *makol* or *golu,* and a red clay is referred to as *losti* (Handa 2005: 61; Handa 2008b: 176). Handa (2008b: 169) reports the use of *makol* or *golu* (a white clay) for whitewashing. *Makol* or *golu* is mixed with salt and gum or *pitchh* (rice starch) after having been dissolved in water. For traditional paint, *geru* (Eng. *raddle*) is dissolved in water. Next, a coat of mustard oil is added to the exterior, or oil of the seeds of *chulli* or *sahare* (apricots) is applied to the interior (ibid.). Red-coloured clay is used for painting, similar to ochre. During field research the author collected clay samples in Chamba, inter alia, in Purthi.
- Sample 8506 from Purthi is a red clay, sample 8510 is a grey clay, and sample 8528 is a white clay, the latter of which is used for whitewashing. The red clay (sample 8506) was collected at a clay pit along the road. Its local designation is *sho* (spoken: *shau*). It is used as a roof layer with a thickness of app. 30 cm. For plaster it is mixed with cow dung and needles of the *kail* tree. It is applied with a thickness of app. 5 cm to 8 cm. The material contains 27.6% of gravel and sand and a rather high amount of silt with 51.9% and a median of 17 µm.
- Sample 8510 from Purthi is a grey clay that was also collected along the road. Its local designation is *kit-jan*. It is a material, which is also collected from the fields and rarely used as building material. This clay is much coarser than the *sho* clay, in particular due to a higher content of gravel.
- Sample 8513 from Purthi is a white clay also collected along the road. It is mixed with water and used for whitewashing on interior and exterior walls. This clay is even coarser than the *kit-jan* clay and has to be sieved before processing.
- In Purthi, having all locally known types of clay available along the road points towards short distances of transport and central availability of the material. The bulk mineral analysis of the Chamba samples shows, inter alia, mica, quartz and plagioclase. In general, these samples are rather poor in swellable clay minerals and show a high content of illite and partially also of chlorite. The content of kaolinite is present only as traces.

Middle Kinnaur

- In Middle Kinnaur at Kanam, a peach-coloured clay, known as *kum mating* or *kum pating*, is placed at roof constructions on the birch bark, preferably used for waterproofing of roofs (Negi Loktus 2015: 324). East of Lipa, also in Middle Kinnaur, deposits of kaolin clay are reported (GSI 2012a: 21ff.). Samples were collected at Ribba (samples 8467 and 8493), at Thangi (samples 8511, 8518 and 8529), at Moorang (sample 8513) and at Chulling (sample 8492).
- Sample 8467 from Ribba was taken from a clay pit in the village close to the Ribba Temple. It is locally known as a good building material used as plaster or for the roof. Its grain size distribution is similar to the *sho* clay from Purthi, which was also used as plaster and roof clay.
- Sample 8493 from Ribba was taken from a clay pit in the village close to the Ribba Temple. It is used for plaster and particularly for wall painting. For further building purpose, it is considered too weak. With a median of 5 µm, it is much finer than sample 8467 from Ribba.
- Sample 8511 from Thangi is a red clay collected from a local clay pit. Its local designation is *cham*. It is mixed with the needles of the *chilgoza* pine tree (Pinus gerardiana) or with chopped chaff and used as plaster. A better quality is obtained when mixed with cow dung.

- Sample 8518 from Thangi originates from the roof of an app. 80 years old collapsed stable. It was placed and compressed on top of the birch bark. The raw material was sieved up to app. 2 cm grain size, as explained by the owner of the stable.
- Sample 8529 from Thangi originates from the wall of the entrance gate to the village. The grain size distribution and also the clay mineral properties are very similar to sample 8518.
- Sample 8513 from Moorang is taken from a clay pit and has to be sieved before use. Its local designation is *chit*. It is locally described as clay with good quality for application of an upper plaster layer. It colours the wall white and thereafter there is no need for further whitewashing.

Upper Kinnaur

- In Upper Kinnaur, lacustrine clays are found at Shelkhar and Chango (GSI 2012a: 21ff.). The local designation is *tua,* and it is used for flat roofs and plaster (cf. Gruber 2011; cf. Feiglstorfer 2019: 139ff.). The fine *tua* clay from Shelkhar, which is used for plaster and roofs, is mixed with a dark, coarse clay to create a mixture locally described as "hard as concrete" and which is used for rammed earth walls. The *tua* clay alone is too fine for ramming. In the Spiti area, ramming is a widespread traditional building technique.
- In Chulling (Upper Kinnaur), sample 8492, which is a part of the interior plaster of an old village house, fits in the mineral range of clays from Kinnaur. At 44%, its grain size distribution has a rather high content of silt compared to a content of just 5.6% of clay.
- The bulk mineral analyses of the samples of Kinnaur show values similar to those from Chamba, inter alia, with a content of mica, quartz and plagioclase. Except for sample 8493, no swellable clay minerals could be found.

Spiti

- In Spiti, deposits of lacustrine clay at Kioto and Atargoo are reported (GSI 2012a: 21ff.). In Tabo and its surroundings, several other types of clay are known, e.g. *duksa*, *shaksa* or *tsak* (Dechen Lundup 2015).
- Earth floors are made of *shaksa,* which is covered with a liquid paste and then burnished. This liquid paste consists of *duksa* mixed with water and cow dung. Bricks are also made with *duksa* without mixing any further clay or additives. For a rammed earth wall, *shaksa* and *duksa* are mixed. For the roof, first a layer of *duksa* (also known as *shodam*) is covered with *shaksa* and then again covered with *duksa,* which is burnished with a mixture of *duksa* and cow dung. Plaster on rammed earth walls is made of sieved *shaksa* to create a sand-powder-like material, which is then mixed with straw. The *tsak* is reported as a clay used for painting. It is collected from Pin Valley or Lidang Village[137], the first being at a distance of 30 km from Tabo.
- During field research, samples were collected in Spiti and Lahaul (for these samples, see Appendix of Chapter IV). Sample 8515 is debris which originates from a damaged part of a wall of an old village house in Rangrik, which is located close to Kaza. It is an example of clay used for rammed earth. For a clay used for rammed earth, a median of 35 µm is rather fine and the content of clay relatively high. In fact, the content equals the grain size distribution of the exterior plaster (sample 8507). Thus we can suspect that a similar raw material was used for plastering and ramming.
- The clay used for adobe bricks at an old house at Tabo (see sample 6053, i.e. debris from the floor along the wall) has a rather coarse median of 260 µm. Compared to this adobe brick sample, the interior plaster used on this brick, as described with sample 6041, has a very small

137 The village of Lidang has yet not been clearly localised and will be part of future research.

median of 3 µm. A comparison of their bulk and clay mineral properties shows strong similarities. Regarding the grain size distribution, the plaster may be the sieved portion of sample 6053.

- Sample 8512 from Lalung in Spiti was collected from a local clay pit and is locally described as universally used clay, used for plaster, mortar and ramming. For plaster, sieving thereof is necessary. The contents of clay and silt are similar to the clays used in Rangrik for ramming and plastering. Only the content of gravel is higher.
- Roof clays from Spiti originate from damaged parts of a ten-year-old residential building in Sangnam (sample 6048), of an old house in Kungri (sample 6049) and an old house in Dhankar (sample 6050). The grain size distribution of these three examples shows similarities, in particular, the sand, silt and gravel fractions. The content of gravel and sand is rather high. The content of clay ranges between 13.4% and 19.2%, and the medians range between 65 µm and 150 µm. These results point towards a similar base material used for the roofs between Sangnam and Dhankar. The content of silt is between 23.4% and 33.8%, and the content of clay is between 13.4% and 19.2%. These similarities point towards the use of locally available clay without mixing, since the content of gravel is still between 18.4% and 26.4%.
- Another comparison is made between samples 8527 (adobe brick) and 8530 (interior plaster) from the ruins of an old house in Hikkim in Spiti. At 30 µm, the median is the same and the content of clay and silt is rather similar. The difference is in the gravel and sand fractions. In the brick, with 19.5% a much higher content of gravel is available compared to 5.7% in the interior plaster, while in the interior plaster the content of sand is higher. According to the grain size distribution, the base material for bricks and plaster seems to be similar, but for the use as plaster it was sieved. The clay used for the bricks shows a rather similar grain size distribution compared to the clay used for rammed earth at Rangrik (sample 8515). The bulk mineral analysis is basically similar to those shown for Chamba and Kinnaur, but in contrast, calcite is a content of all samples in Spiti, which is missing in the samples of Chamba and Kinnaur.

Lahaul

- From Lahaul, sample 8480 is clay from a pit commonly used for building purpose. Its local designation is *sakalak*. With a content of 31.2% of gravel and 4.4% of clay, it is a rather coarse material.
- Sample 6057, which originates from a damaged adobe brick in a wall of an old house in Keylong, shows a different grain size distribution and seems to be a sieved *sakalak* clay, as emphasised by the similar bulk and clay mineral properties. The bulk mineral analysis with the higher content of plagioclase and a lower content of calcite shows more similarities to samples taken in Chamba or Kinnaur than those taken in Spiti.
- Sample 8478 from Tingrat was taken from a clay pit in the village. Its local designation is *talba*. Its grain size distribution is similar to sample 8467 from Ribba, and is also used as clay for plaster and roofs. This sample shows, in contrast to the other samples from this region, a 14Å vermiculite and a smaller content of illite.

Kangra

- In Kangra District, deposits of clay are reported: yellow-coloured clay west of Shahpur; light grey clay in the Middle and Upper Shiwaliks at Khajan, Indpur, Paliana, Kothar (a composition of montmorillonite, kaolin, quartz, carbonates, and Fe-oxides), and Hatli (GSI 2012a: 21ff.).

Kullu

- In Kullu District, kaolin clay near Bathua used for whitewashing is reported. In Mandi District, a variety of deposits, which are commonly used for plastering and whitewashing, is reported; clays from Garaich and Negi Nal are suitable for the manufacturing of stoneware. In Shimla District north of Shimla, clay is found and used for the manufacturing of bricks, tiles and pottery. In Sirmaur District, a variety of deposits of varied lacustrine clay is reported and commonly used for making bricks. Some clay pockets contain a kaolin clay and also clay that is sticky when wet and powdered when dry. (GSI 2012a: 21ff.)

3.6.4.c North Pakistan

Hunza and Karakorum region

- In Hunza in North Pakistan, a fine grained lacustrine clay, known as *damul,* is used for waterproofing of flat roofs and compacted floors (Hughes 2007: 109). Clay in the Karakorum region, used for adobe bricks, is characterised by a high content of silt, sand, quartz, biotite mica and a lack of clay minerals (ibid.).

3.7 Discussion

The orientation of the mountains from north-west to south-east influences the orientation of the climate zones. Arid, cold and temperate zones follow this pattern in elongated bands. A change from zone to zone correlates with a change of altitudes. This influences the vegetation zones and the availability of particular trees. In turn, these factors influence architectural developments, which are dependent on the orientation of these zones.

In the arid zone, precipitation is rather low, while in the cold zone we can distinguish between dry and humid regions. Further, in the temperate zone, precipitation also changes between dry and rather humid areas. This goes hand in hand with the development from the flat earth roof towards the pitched roof covered with wood or stone. This change also follows a north-east to south-west direction within the temperate zone and in the area, where the cold zone [D] changes into a temperate zone [C] (see Map 4.3). This goes hand in hand with the development of a high culture of wooden architecture in the north-west to south-east stretching zone from North Pakistan via Kashmir, Chamba, and Kinnaur into Uttarakhand. This zoning also describes the direction of the increase of structural timber in composite constructions from the north-east towards the south-east and may be mentioned as a prime reason for certain material changes within traditional buildings.

The above given association of trees with particular regions and altitudes shows a relation with a change of the tree population and of a local availability of species of trees. This becomes mainly the case in sparsely wooded higher altitudes. The given tree species are those, which are commonly used for constructions. For elite structures, wood is brought from outside a given region with a high effort of transport.

The historical use of various species of trees differs partially from present use. Primarily, hard wood, which grew straight and long, was used, while today poplar and willow have become predominant over mountainous regions from Baltistan over Ladakh, Lahaul and Upper Kinnaur. The high availability of structural timber may have supported its intense use, particularly in Kashmir and Himachal Pradesh, where, from a historical point of view, use was supported by the agreement of the regional ruler.

Today, large forest areas still exist in Himachal Pradesh. Of a total area of 14,353 km² for Himachal Pradesh, 811 km² are covered by different species of deodar, 809 km² by *kail*, 1,436 km² by *chīr*, 1,343 km² by fir spruce, 183 km² by *sāl* and 540 km² by *bān* (GSI 2012a: 38). About one third of the whole area of Himachal Pradesh is covered with forest – mostly mixed forests and a small amount of needleleaf forests. This is contrary, e.g. to Ladakh, where in higher arid regions only groups of trees exist.

Most populated are valleys connected to a water supply and timber resources. Stones may be collected along riverbeds. A structurally good stone has to be quarried and is in general not rounded, as stones found in rivers would be. Structural stone is found all over the Western Himalayas in different qualities. In some areas of the Western Himalayan region and up to the Yamuna eastwards in Uttarakhand – areas with a strong population of deodar trees – a good structural stone is rare (Handa 2006: 26). In settlements, where material of particular good quality is quarried in the close vicinity, such as slates in Bharmaur, its popularity in vernacular use is obvious. At such places, thick and large pieces of slate can be found stapled by the villagers along the road or at building sites. The availability of slate in the area close to Leh did not change the vernacular flat roof tradition, since the timber resources for roof timbering to carry heavy slates are too scarce. For wall structures, e.g. for religious structures or fortress structures, inter alia, stones were used for solid walls.

The general content of mica, which we can refer to in the examined clay samples (see Appendix of Chapter IV), may support a favourite use of stone due to its easier cutting. The use of timber implicates, on the one hand, knowledge of movements within building structures and, on the other hand, a possible support of structures made of stone. It may also correlate with the need for a strengthening of the mica-laden stone in solid walls (Handa 2008b: 136). In lower regions, the increase of termites is an indicator for less use of wood and a preference for stone.

For commonly known clays, their location along routes of transport is evident and points towards an economical and collective use. A short distance of transport is in general an important condition for the use of particular clay. On the other hand, clays such as the *tsak,* which is used in Tabo in Spiti for painting, is collected at places, which are located a longer distance away, similar to limestone, which often has to be collected at mountainous sites.

Making of fired bricks depends much on the availability of proper clay, in addition to the availability of wood or peat for firing. According to reports by the Geolocical Survey of India (GSI 2012a,b), deposits of fireable clay for the ceramic industry are found in Jammu or in the Shimla District.

The samples from Spiti and Kashmir point towards a carbonatic mineral geology in these regions, which influences the properties of the clay. Also the low content of swellable clay minerals – except for lacrustrine clays – in the clays over the Western Himalayas determines a technically possible range of application. Rather coarse material in Spiti containing calcite and no swellable minerals shows its proper use for rammed earth. An economic approach makes it necessary to use the same base material for ramming, bricks and also for plaster. The availability of different kinds of clay, e.g. as shown for Tabo, made possible the development of different mixtures customised to particular needs. The use of organic additives shows the deep understanding and high development of locally available material resources. These developments have to be regarded from a local point of view and may change in detail from village to village. The use of local terms for clays points towards their use as rooted in traditional knowledge.

At the high altitudes of Ladakh, an earth building tradition still exists. Connected to the minimal resources of wood, this region shows a weathering of the soil of a characteristic that differs from forested areas. In the high-altitude arid zone, transport by glaciers, rivers and wind indicates the given properties of the clays and the availability of some very fine and silty lacustrine clays (cf. Feiglstorfer 2019: 24ff.).

4. Aspects of construction

The present research focuses on indigenous building traditions, whose building material qualities are primarily dependent on local material resources. Application of particular materials follows environmental preconditions, such as climate and local raw material resources, while processing is strongly related to cultural parameters. In the case of changing raw material resources, local techniques were adjusted.

If possible, solid walls were reinforced with timber lacing to make them more stable. Different methods of strengthening solid constructions with wood as a flexible additive were developed as composite constructions. Stone, clay and wood were optimised for mutual support. The different environmental parameters for stone, clay and wood in accordance with climate conditions imply a large variety of different local reactions, which are an essential part of defining local identity. A peculiarity in the Western Himalayas is the large variety of different local traditions based on a large variety of different natural preconditions and cultural influences. The aim of this last part of Chapter IV is to delve deeper into different local variations in order to get closer to an understanding of regional changes.

In regions with less timber resources, the method of construction was adjusted. Adjusting is not to be mainly understood as simply adding or omitting wood but rather creating a homogenous construction that fulfils particular architectural needs. At higher altitudes, the use of clay or stone or both in combination with a less content of wood is obvious, while in lower and more wooded areas with higher precipitation, the content of timber in constructions increases. Regarding these naturally predefined circumstances, we can state a detailed hypothesis for the predominance of raw material resources in predefining local building techniques. The way of processing and assembling the raw material in contrast is dominated by local cultural traditions. In this respect, this study involves two basic aspects, i.e. natural environmental preconditions, which are more or less fixed, and local material-cultural traditions, which are adaptable.

Over the last decades, due to continuous changes of and additions to constructions, at a single site different techniques of constructions may have been introduced. Continuous transformations of techniques are found all over the Himalayas. The ruins of the Old Monastery of Chekha in Charado (Tib. Chad kha in Bya ra mdo) in Central Tibet are a Central Tibetan example of such a mixture of different technical applications at one site. The monastery was founded by the Kadampa master Ja Chekhapa Yeshe Dorje (Tib. Bya ’Chad kha pa Ye shes rdo rje; 1101–1175) in 1164 CE.[138] Different methods of existing wall constructions situated beside each other indicate different ages of the single constructions. Constructions range from pure rammed earth, adobe bricks as single and double-shell constructions, stone walls with flat stones and a rather thin layer of clay mortar, and dry stone walls without mortar (cf. Feiglstorfer 2015: 74).

Starting at high altitudes and continuously descending within the given research area, locally predominant wall constructions are categorised and juxtaposed. The chosen examples give evidence only in a qualitative, but not in a quantitative context. Except for the region of Gilgit-Baltistan, the examined regions have been visited several times for field research in the years between 2001 and 2015. The remaining witnesses of early constructions clearly show local knowledge of a differentiation between various technical methods in using timber. Several of the given examples are elite structures such as fortresses, *shikari*-towers, religious buildings (Buddhist and Hindu temples and mosques), shrines or palaces. Examples for Himachal Pradesh may date back more than 1,000 years. The given examples, which have been well maintained over centuries, provide an idea of developments in structural engineering in the Himalayan Middle Ages, and leave space for hypothesising on indigenous developments and historical technology transfer. An interest of the builders of elite structures must have been the production of a long lasting shell to protect, e.g. precious religious goods, like wall paintings or sculptures, and to represent a particular social status. Techniques and materials of high quality were adjusted to local possibilities.

Climate data in the following analysis are given according to *Climate data for cities worldwide* according to Köppen and Geiger[139]. Basic data for the regional availability correlate with previously given analysis. The single regions (Ladakh, North Pakistan, Kashmir, Himachal Pradesh) are analysed in the given sequence (Map 4.7).

138 Available at: http://www.oeaw.ac.at/tibetantumulustradition/sites_by_id/0104/

139 See part 3 of this Chapter and Table 4.3 in the Appendix of Chapter IV.

Map 4.7 Sites related to part 4 of Chapter IV "Aspects of Construction".
GIS data based map: Jakob Gredler. Final graphics: author. Map based on Vector data (VD).
Citations of VD also see: Chapter IX, list of illustrations.


0
100km
N
K2
Shigar
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Shahi Kangri
Nubra
Shyok
PR CHINA
Kargil
Chigtan
Skurbuchan
Timogang
LADAKH
Wanla
Saspol
Basgo
Leh
Shey
Thikse
Nyarma
Alchi
Spituk
Nun
KARGIL
JAMMU AND KASHMIR (J&K)
Kangju Kangri
Padum
Indus
Purthi
CHAMBA
Udaipur
Chamba
Keylong
Gumrang
Taryul
Spiti
Hansa
Gondhla
Losar
Chhatrari
LAHAUL AND SPITI
Manali
Kaza
Dhankar
Tabo
KANGRA
Sangnam
KULLU
Nako
Beas
Ropa
Spillo
Chaini
HIMACHAL PRADESH
Rekong Peo
Tholing
Sutlej
Sarahan
KINNAUR
SHIMLA
Dharali
UTTARKASHI

4.1 Ladakh

This part concerns composite wall constructions containing wood in the province of Ladakh with a closer look at the vernacular architecture in the Indus Valley.

As given in the table with climate data (see Table 4.3 in the Appendix of Chapter IV), the altitude of settlements along the Indus Valley changes from around 3,520 m at Leh, Phyang and Thikse, and decreases by app. 800 m to Kargil with an altitude of app. 2,700 m to the Pakistan border. The average annual temperature in Leh, Phyang and Thikse ranges from 4.7°C to 6.8°C. This is comparable to Spiti, which is located at a similar altitude. Temperatures increase towards Kargil by app. 2°C to 4°C. Compared to North Pakistan, temperatures are close to those in Kargil. In Leh, the difference between annual minimum and maximum temperature is 26°C, which is relatively high. In Kargil, the temperature is even higher at 32°C. The resulting stretching of material is a factor to be considered in regard to combinations of different materials within a composite construction. Annual precipitation increases in Leh at around 100 mm, and moving towards Kargil, precipitation is about three times higher. Towards North Pakistan, it increases slightly compared to Leh. Snowfall can already start in October and last until April. Snowfall has also been recorded at passes during the summer months. Extreme temperature may decrease below -40°C and increase above 30°C. Traditional architecture is not prepared for strong rainfall such as occurred in 2010. At this time small creeks became powerful streams that swept away trees and rocks, forming damaging mud slides.

Correlating with the given climate data, the timber population for building constructions in Ladakh is low compared to the environmental conditions of the adjoining territories Khyber Pakthunkhwa, Lahaul and Kashmir (see Map 4.5). These conditions are reflected in the vernacular architecture of Ladakh. In recent constructions similar to traditional building techniques, adobe bricks were primarily used; the use of timber was widely neglected. In contrast, regarding historical composite wall constructions, the use of timber was widely known, as shown in the following research on historical structures.

The traditional roof construction in Ladakh is a flat roof made of clay on an organic layer. In arid zones the flat roof is the predominant roof form. The upper and heavy constructive layer is in most cases a compressed earth construction, which is typically constructed using several layers of a different homogeneity. The upper layer is the water-bearing layer, which is prepared according to particular local methods (see material analysis in Chapter III). In various areas of the Himalayas, some types of clay used for the upper layers are easily repaired, for example, with a silty clay known as *markalak*. If this is not the case, at least the upper layer has to be replaced after several years as soon as the roof starts to leak. At this point, a concern is the possibility of overstraining the timber subconstruction in the case that the old soaked clay is not exchanged, but instead new heavy material is loaded on top. In several cases, damage to the subconstruction was found and attributed to this kind of continuous overloading.

4.1.1 ‘Simple’ timber lacing (horizontal timber straps along wall faces)

This technique uses the timbers as scantling placed on stone or brick walls, horizontally running along the facade. No cross-pieces are evident. Wooden lacing is in general made of cut wooden beams. Their use in an uncut form or even with bark would not enable the necessary friction resistance between the wood and the adjoining stone or brick.

With this kind of construction, the adobe bricks are the primary load-bearing part and not the wooden component, as would be the case with a much higher content of wood. A reason for the use of the 'simple' timber lacing is its impact as a crack stopper.[140] In the case of static movements within the wall, either by wall settings or due to earthquakes, these inlays avoid cracks crossing along the whole height of the wall and destruction of the wall. In the case of using a 'ladder'-like system as shown with the following technique, a drifting apart of the wall can also be avoided.

There are two ways to use this kind of 'simple' timber lacing: (a) as a simple inlay or (b) as a ring beam.

a) Single beams are laid, and the lacing does not work as a ring beam (Fig. 4.28). It acts as a crack stopper and as a levelling layer for the following top row of bricks or stones. As a levelling layer it also impedes a collapse of the masonry. In this function, it is commonly used in plinths of stone walls and in adobe brick walls.

b) The lacing as a ring beam needs a connection between the single runner beams along the facade, at the corners, for example, by using wooden pegs (Fig. 4.29). Effects of external forces due to earthquakes or uneven subsidings of walls and also internal forces due to the wall's dead load related to its height are reduced. The wooden inlays also act as a reducer of the buckling length along the height of the wall. It stabilises the whole structure and not just the single wall. Drifting inwards is prevented by the existence of floor and roof constructions acting as stabilising plates. Such ring beams may be erected on the floor level and combined with the floor beams to avoid a drifting outwards of parts of walls.

Howard (1989: 221) differs the size of the used timbers for fortress constructions according to their use: for a banded texture timber, width is up to 25 cm, and for a random texture wall, width is app. 10 cm. His description that adjacent timbers may be simply butted together or joined by halving joints, which are sometimes dowel pegged, points towards the timbers' use as 'simple' lacings without a primary static function as ring beams. An early example of this technique is described with mixed-stone masonry with timber lacing at the tower of Hankar in Zangskar dating to the 12th/13th century (Devers, Vernier 2011: 85).

4.1.2 'Ladder'-like timber lacing

This technique consists of runner beams placed in pairs along the in- and outside faces of a wall (see Fig. 4.20). They are connected by cross-pieces and stabilised by the masonry on top (Langenbach 2010: 2). It is similar to the system known as *taq* in Kashmir. The Kashmir version in contrast shows a 'ladder' consisting of two facing beams above each other with the floor beams in-between. The technique commonly used in Ladakh shows a 'ladder' with only one facing beam along the facade.

140 We often find such crack stoppers above wall openings to strengthen wall corners. Crack stoppers consist of runner beams along the surface of a wall. This prevents cracks disseminating over a wider area of the wall.

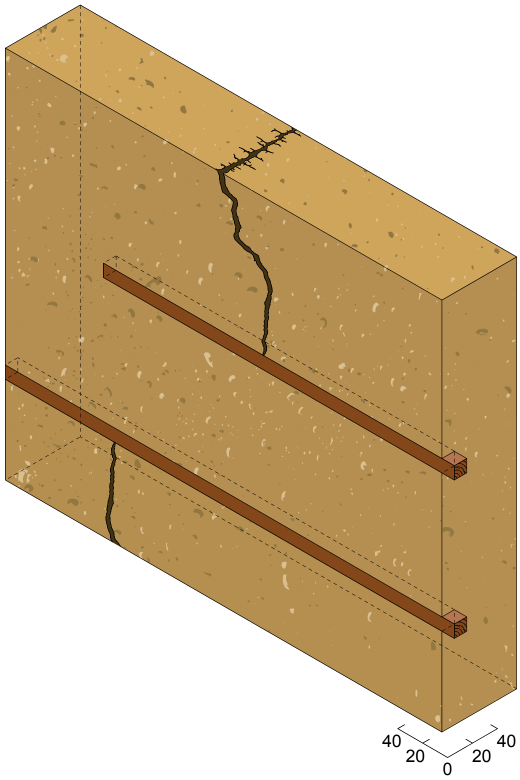


Fig. 4.28 System of 'simple' timber lacing acting as a crack stopper.
CAD: Martin Pospichal.
Details provided by the author.

Generally, the heads of the cross-pieces and the exterior beams running along the facade are visible from outside the building. 'Ladder'-like constructions connected with the floor beams mark the position of the storeys, as long as they are not covered along the facades. In most cases the runner beams are scantlings, while the cross-beams may also be round in shape. In addition to the beams' function as crack stoppers and levelling support for the following row of bricks or stones, two crossing 'ladders' may easily be closed at the building's corners and act as a ring beam. Since the timber lacing covers the whole width of the wall, it is more efficient as a stabiliser than 'simple' timber lacings (as mentioned above).

4.1.3 Wattle and daub

Apart from timber lacing constructions, Ladakh is home to other composite techniques that use wood. Wattled mats are widely used and often made of willow branches. A traditional use of such mats is as shuttering for rammed earth walls, as shown in a picture by Khosla (1979: Fig. 179) from Padum in Zangskar. In an interview in 2005 with Mr. Wangchuk in Leh, he mentioned the uppermost storey of the Sumtseg in Alchi (c. 11th century CE) having been built as a wattle and daub construction (Interview with Mr. Wangchuk in November 2005). He supposed that such a lighter weight construction technique was chosen because of the reduction of the load on top of the two storeys and also the reduced effort needed for lifting the material.

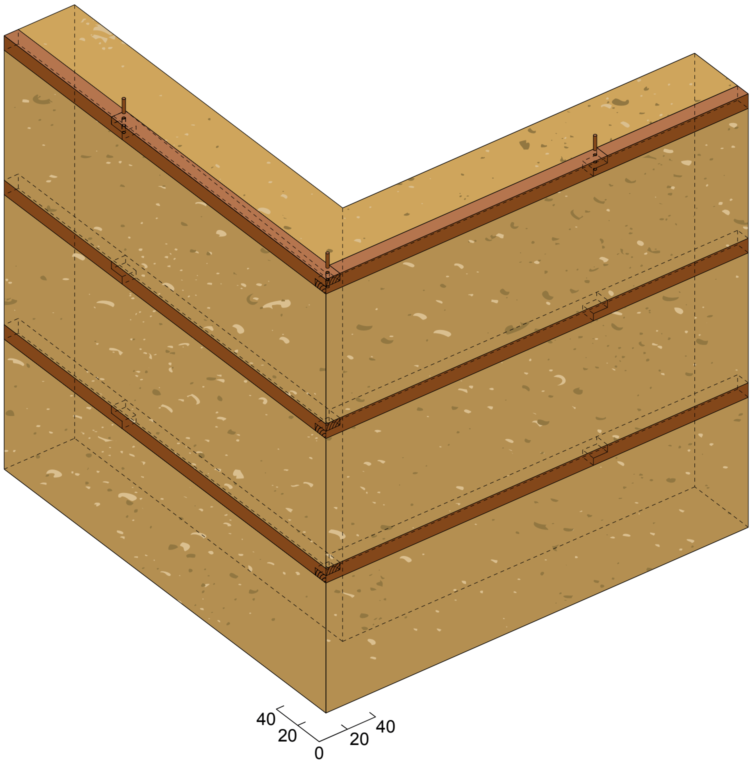


Fig. 4.29 System of 'simple' timber lacing acting as a crack stopper. CAD: Martin Pospichal. Details provided by the author.

4.1.4 Bracing of rammed earth lintels

Another composite technique using wood is known by its use as tensile reinforcement of rammed earth lintels (Fig. 4.30). During field survey at an entrance to the central tower of the fortress in Saspol (for further description of this fortress, see Howard 1989: 282ff.), Sonam Wangchuk pointed towards the existence of bendable and elastic twigs (Interview with Sonam Wangchuk in August 2011). Before ramming, these twigs were laid into the clay. This technique is also known for recent rammed earth constructions, in particular at the corners and along the edges of the rammed layer.

4.1.5 Investigated objects

Nyarma, Temple VIa

Alt. 3,264; 34° 2'21.64"N, 77°41'3.37"E. Up until now, this building has not been dated (Fig. 4.31). It may date back to the end of the first millennium if erected together with the main temple. Along the eastern adobe brick wall, a notch for the former position of a timber lacing was found. The thickness of the wall is app. 115 cm (cf. Feiglstorfer 2011: 8, 28).

Fig. 4.30 (Left) Saspol. Ladakh. Rammed earth lintel of an entrance gate of the fortress reinforced with twigs.
Fig. 4.31 (Right) Nyarma. Ladakh. Structure in front of the *tsuglagkhang* with notches of former timber lacing.

Leh, Old Town

Alt. 3,520 m; 34°9'54.25"N, 77°35'9.20"E. Houses in the Old Town of Leh, located at the foot of the palace (foundation date around 1600 CE), are built of stone and clay using different composite techniques, including components of timber lacing. Several of the housing structures in the old town of Leh show different techniques within one and the same structure.

In a facade as shown on Fig. 4.32, the use of 'simple' timber lacings connected to each other by halved joints is evident (Figs. 4.33, 4.34). This example shows the effect of timber lacings as crack stoppers. Below the upper storey, several cracks end at the lacing. The ring beam is laid between a stone basement and an adobe brick wall on top. Lintels project a long distance into the laterally adjoining stone wall. Thereby, they act as crack stoppers, in particular in the corners of the window openings. The banded stone walls are made with clay mortar. Using stone for the plinth results in a higher strength thereof compared to adobe bricks. The latter, in contrast, are of less weight and easier to carry on top.

Wanla, Fortress tower

Alt. 3,175 m; 34°14'58.71"N, 76°49'50.02"E. As an example, on top of the ridge where the temple is situated, a tower-shaped building of three storeys made of stone faces north-west. It may be dated to the 11th century (Howard 1989: 260). Along its plinth on the north-west side, a kind of retaining wall with a 'simple' timber lacing was used. In this case, the primary function of the wood is to hold the front wall together and to avoid lateral outside drift.

Leh Palace

Alt. 3,540 m; 34°9'57.52"N, 77°35'11.69"E. Along the southern front of the palace of Leh, we can observe six storeys (Jest, Sanday 1983: 8). The front wall tapers from a width of app. 1.75 m at the base to app. 0.5 m at its top. For the walls in the lower storeys, granite stone was

Fig. 4.33 (Top) Leh. Old Town. Corner half lap joint.
Fig. 4.34 (Below) Leh. Halving joint.

Fig. 4.32 (Left) Leh. Stone wall in the Old Town topped with an earth wall, both using timber lacing as crack stopper.

used and adobe bricks for the upper storeys. For the lower levels in a vertical distance of app. 3 m, 'ladder'-like timber lacing made of *shukpa* was introduced and connected through the wall with round cross-pieces. (ibid.)

Basgo, Serzang Lhakhang

Alt. 3,270 m; 34°13'25.59"N, 77°16'33.92"E. The stone basement of the Serzang Lhakhang in Basgo has a height of app. 2 m at the south wall and carries an adobe brick wall on top. Two 'ladder'-like constructions are introduced within the stone basement and two further within the adobe brick wall. Most of the cross-pieces are round-shaped. They are not related to the position of a floor. The width of the wall is app. 67 cm. Howard (1989: 234) associates this temple with the reign of King Dragpa Bum (Tib. Grags pa ʼbum). Bellini (2014: 226) gives the time of his reign as roughly 1450–1490.

Timogang, Maitreya Lhakhang and palace

Alt. 3,350 m; 34°19'38.55"N, 76°59'29.35"E. The Maitreya Lhakhang and the opposite located palace which are both close to the fortress of Timogang, were built with a similar 'ladder'-like timber lacing technique as we can find in the Serzang Lhakhang in Basgo. Both structures are dated to the same building period (Howard 1989: 254). The Serzang Lhakhang in Basgo, the Maitreya Lhakhang and the palace, which in Timogang were built with random texture and clay mortared stone (ibid).

Spituk Monastery

Alt. 3,240 m; 34°7’31.62”N, 77°31’36.17”E. Along parts of the facades of the monastery in Spituk, similar ‘ladder’-like lacings with round cross-pieces were used. The monastery was rebuilt in the second half of the 15th century during the reign of King Dragpa Bum (Bellini 2014: 226). In contrast to the main building, the *gönkhang* (“protectors’ chapel”), which is much smaller, does not show any timber lacing. The walls are built with a high random stone plinth and an adobe brick wall on top. Along the south facade of the main monastery, the stone plinth reaches partially up to the level of the ground floor, which is up to app. 2 m above ground. The walls of the three storeys on top are made with adobe bricks. In each floor a timber lacing was introduced. The lacing supports the floor beams, which project over the front of the facade. A lacing was introduced as a flexible partition layer between the stone basement and the adobe wall on its top.

Phyang Monastery

Alt. 3,590 m; 34°11’11.53”N, 77°29’21.53”E. The walls of the main building of the Phyang Monastery (founded in the 16th century) show a plinth going up to the second floor. They are made of random stone with mortar. The two upper storeys on top of the stone plinth are made of adobe bricks (Figs. 4.35, 4.36). Similar to the given example of Spituk, the ‘ladder’-like lacings are at floor level. The wall thickness along the west facade is app 73 cm on the 2nd floor. Stone walls on the ground level reach up to 150 cm. In some of the cross-pieces, a notch is cut to improve their connection with the front facing beams. Halving lap joints connect them.

Skurbuchan Khar

Alt. 2,960 m; 34°26’4.50”N, 76°42’26.40”E. In front of the rammed earth defence tower, an extension towards the Indus River was built with random stone walls. Their round shape points to them being brought from the riverbed below. The rounding of the stones reduces the stability of the bond. A part of the front of the whole structure was made with angular rubble stone. Each of the single horizontal sections of the stone walls was individually made with ‘ladder’-like timber lacings (Fig. 4.37). Between these wall sections, the single lacings are not connected to each other. At the corners the lacings were connected with corner half lap joints. Round cross-pieces hold the facing runner beams in position by applying two different methods. One method is to use a lap joint, similar to what is seen in Phyang. The other method is to fix the cross-piece with wall brackets (shear keys) – a kind of wooden nail (or stick). In the latter case, with some examples the cross-piece was laid into a notch in the upper surface of the front beam, possibly to keep the level for the stone wall above in one line (Figs. 4.38, 4.39). The width of the rammed earth entrance wall leading to the temple is 72 cm, and the width of the entrance wall made of stone and leading to the ante-chamber is 94 cm.

Saspol Monastery

Alt. 3,110 m; 34°14’46.19”N, 77°10’0.81”E. Along the outer face of the rear wall of the tower-like part of the Saspol Monastery, the use of ‘ladder’-like timber lacing is evident. Due to an uneven and whitewashed surface it is not easy to detect. It shows fewer cross-pieces than the previously mentioned examples.

Fig. 4.35 Phyang. Two storeys with stone walls topped with two storeys of adobe brick walls. Timber lacing at floor level carries the floor beams. Along the facade runner beams are connected to halving joints.

Fig. 4.36 Phyang. Floor beams are connected to the runner beams by lap joints.

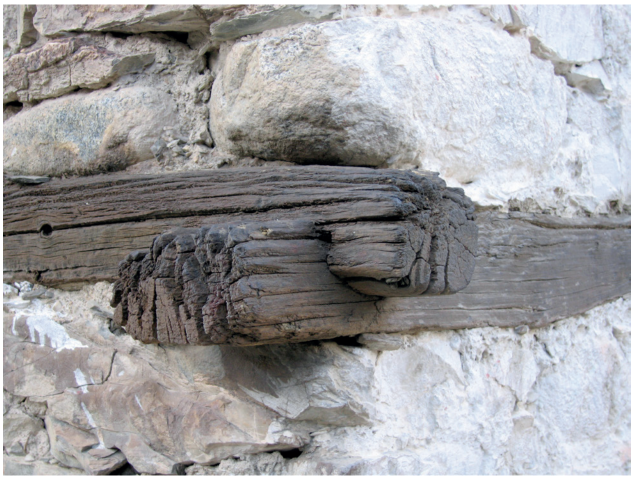


Fig. 4.37 (Top) Skurbuchan Khar. Timber lacing in the lower stone part of the wall.
Fig. 4.38 (Bottom, left) Skurbuchan Khar. Corner half lap joint.
Fig. 4.39 (Bottom, right) Skurbuchan Khar. Wall bracket (shear keys).

Chigtan Castle

Alt. 3,290 m; 34°27’28.84”N, 76°31’10.12”E. The castle dating back to possibly the 16th/17th century, shows several stages and techniques of construction (cf. Khan et al. 2014: 254ff.). Two of these techniques show different ways of using timber in composite constructions: (a) situated in the core of the castle with closely-laid timbers and (b) situated with timbers laid at a greater distance from each other. According to Khan et al. (2014: 266), the latter (i.e. construction b) chronologically follows the first mentioned wall construction (a). Francke (1994: Plates XLIIa and XLIIIa) shows the position and also a detail of the closely-laid stone-timber construction (a), while parts of the latter construction (b) still partially exist (Fig. 4.40).

Construction (a):

The closely-laid timber construction shows traces of a building tradition using more wood, a technique that is common in wooded zones. This points towards a higher availability of wood. Using ‘ladder’-like timber lacing with round cross-pieces connected using lap joints is widely known for Ladakh constructions (see above). In this regard, the structure within the castle of Chigtan follows a similar pattern with a difference being that the timbers were laid at a much closer vertical distance to each other (based on proportions in the picture, the distance between the timbers can roughly be estimated between 30 cm to 40 cm). The stones show a well-dressed outer surface. They are relatively flat and long and in this aspect similar to the timber-laced outer walls of Chigtan Castle (see construction b; Fig. 4.41). They are laid in a thick mortar bed. This technique increases the stability of the stone construction and together with the closely laid timbers, the builders’ intention of giving the inner core of the castle a superior strength becomes evident. Easily cutting the stone into this flat shape is enabled by its mineralogical composition.

What this construction has primarily in common with vernacular composite constructions in the northern adjoining region of Gilgit-Baltistan (see below) is the increased use of wood, but not necessarily the technique itself, as mentioned in Khan et al. (2014: 264). Examples like the Kharmag Castle[141] follow a *cator and cribbage* technique, which is common in the region of Baltistan (see below), and similar to the techniques applied at the fortresses of Baltit or Shigar. They seem basically to be a different type of construction technique, as is the case in the closely-laid composite construction (a) in Chigtan. As far as can be seen in Francke’s detailed photograph of a piece of the facade of this building, there is no evidence of a *cribbage* structure and the facing beams are simply resting on the stone walls. A tapering of this wall, according to Tibetan building tradition, cannot be excluded.

Construction (b):

Parts of the outer walls of the castle are still standing in-between a big amount of rubble from collapsed walls (Figs. 4.41, 4.42). At the time of visit in 2011, it was possible to enter the western part of the fortress for observations. Some of the free standing walls are still of a height of more than 6 m, of which the upper part of app. 2 m to 3 m is made of adobe bricks placed on the stone wall below. Parts of these free standing stone walls continue downwards as retaining walls. The total height (= plinth and retaining wall together) rises up to app. 10 m above the rubble-covered ground. From downhill, when approximating the castle, these walls impressively rise against the sky.

141 Compare photographs at http://www.tibet-encyclopaedia.de, access: 05/2016.

Fig. 4.40 Chigtan. Fortress made of rubble stone.

Fig. 4.41 Chigtan. Fortress. The stones are relatively flat. Corner half lap joint.

Fig. 4.42 Chigtan. Fortress. Timbers are laid on a plane stone level and covered by one layer of flat stones. Surrounding stones are pressed to the timber using a clay mortar.

Some of these walls show a tapering that we know from Tibetan structures. 'Ladder'-like timber lacing can still be found along the western and southern flanks of the castle, though less along the eastern flank. The construction of the walls is a random double-shell stone structure with an inner core filled with rubble. Some of the stones are rather flat and of a kind we may also find in a wall structure (a). Particularly the stones, which are on top or below bordering the timber lacing, are relatively long and well-processed. The stones are laid in a mortar bed. The lacings are connected with halving lap joints. The round cross-pieces are connected with lap joints similar to the ones found at the closely laid timber wall structure (a). In both structures, they are also laid rather tightly to each other (at structure (b) with a distance of app. 60 cm to 80 cm). Wall thickness ranges between app. 40 cm and 60 cm. For small wall openings, lintels are made of stone, and for longer lintels wood is used.

Chigtan Monastery

Fragments of several adobe brick walls of the former Chigtan Monastery are located in today's village of Sgang, which is in the close vicinity of the castle of Chigtan, located in a plain area (Figs. 4.43, 4.44). Francke (1994: Plate XLII) shows the Chigtan Monastery in a photograph, and it resembles in shape, topography and mountain rocks in the background the ruins, which the author found in the village of Sgang (local pronounciation).[142] Francke (1994: 100) states the temple's size to be 14 x 15 paces (app. 10.7 x 11.4 m)[143] with a height of 24 ft (app. 7.3 m). The interior size of the measured temple is (after conversion into paces) 13 paces (9.9 m) x 16.6 paces (12.7 m), which does not prove identicalness with the taken measurements. The entrance porch is of a lower height than the temple chamber.

From the point of construction, this temple – in particular remains of its best-preserved wall (see Fig. 4.44) – is of importance for further observations. It shows a timber-laced structure in an adobe wall of a width of app. 86 cm. This equals the length of two bricks (brick size 43 x 29 x 11 cm) (Figs. 4.45, 4.46). The wall's facade is divided into three sections by the horizontally running lacings' positions. Today, no timber remains and only the notches of the former runner beams are left. The wall is vertically straight and shows no tapering. A kind of double-shell construction with infill of pieces of clay and small stones resembles a technique known from the temples of Nyarma[144] and also from Ladakh stone constructions. Regarding the 'ladder'-like timber lacing and the unusually thin West Tibetan adobe brick wall – which is also much more similar to stone constructions – structural similarities to the stone walls found at Chigtan Castle can be hypothetically stated (see Chigtan Castle construction b). Francke (1994: 100) dates this temple hypothetically to the Kadampa period in the 11th century CE, i.e. at least 500 to 600 years earlier than the construction of the castle of Chigtan. The transfer of particular techniques from stone to earth constructions regarding wall thickness and the use of timber lacing is known from other examples in cultural transfer zones (e.g. see afore-given explanations for Mandriza in Bulgaria in the context of a transfer zone). Concerning the walls of the Chigtan Temple, the basic features can be found at various early West Tibetan religious structures, but certain influences point towards an adaption of techniques, which may derive from this and / or adjoining regions possibly up to about 900 years ago.

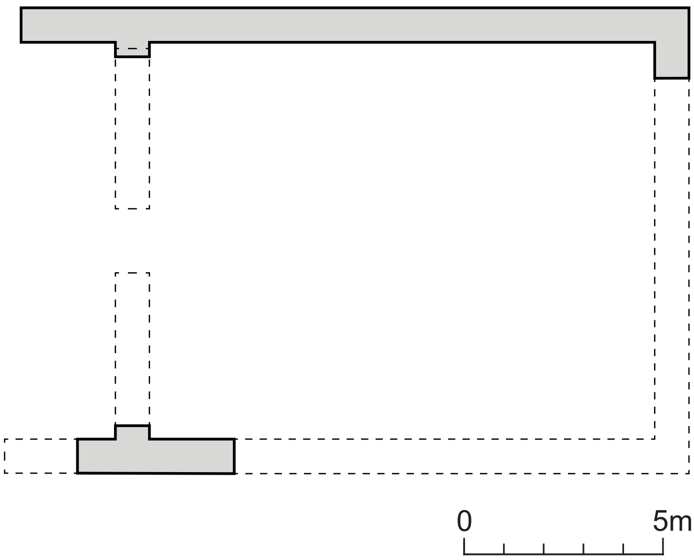
142 Brick bonds of early temples in Ladakh were shown on a poster presented by the author at the TERRA 2008 conference in Bamako.

143 The conversion from paces into metres was made using the factor 0.75. This remains hypothetical since for this measurement given by Francke, his definition of paces remains unclear.

144 Methods of construction were presented by the author at the TERRA 2016 conference in Lyon.

Fig. 4.43 Chigtan (Sgang). View from the south onto the ruins of a temple with notches of former timber lacing.

Fig. 4.44 Chigtan (Sgang). Ground plan.



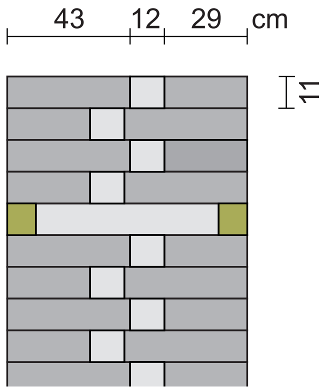


Fig. 4.45 Chigtan (Sgang) (Left). View from the former verandah onto the interior surface of a wall.
Fig. 4.46 Chigtan (Sgang) (Right). Double-leaf wall filled with clay mortar.

4.2 North Pakistan and Nuristan

This part concerns composite wall constructions containing wood in the province Gilgit-Baltistan with a closer look at the vernacular architecture in the valleys of Hunza and Indus and in the province Khyber Pakthunkhwa, with a closer look into the Swat Valley. The province of Nuristan, which is located in eastern Afghanistan, is mentioned as a comparison. In 2006, the author conducted field research in the valleys of Swat and Kunar. For data on the architecture in Gilgit-Baltistan and Nuristan, the author is dependent on literature sources and personal information.

As given in the table with climate data, the altitude of settlements along the valleys Indus and Hunza (e.g. Baltit with an altitude of 2,430 m) is roughly 1,000 m below settled areas in Central Ladakh. The altitude of Kalam, with an altitude of 2,000 m, is even 1,400 m lower. From Kalam to the south in the direction of the Swat Valley towards Mingora (alt. 930 m), altitude decreases rapidly. At app. 4°C, the average annual temperature in Gilgit-Baltistan is above the comparable data of Leh, while at Kalam, the difference to Leh is already app. 8°C. Annual precipitation is higher in the Indus and Hunza Valleys compared to Leh, while the precipitation in Kalam is more than four times compared to Baltit or Khaplu. Compared to Leh, maximum temperatures are higher in the Indus and Hunza Valleys in Pakistan. These differences between Baltistan and Ladakh become much smaller when compared with western parts of Ladakh, i.e. in the area of Kargil (alt. 2,700 m). The climate conditions in the valleys Hunza, Indus and Swat may explain the higher population of timber as compared to most places in Ladakh. This fact implicates a higher amount of wood used in building constructions, and by that a different development of building techniques. Concerning a regional type of roof construction, a flat roof is the traditional roof in Gilgit-Baltistan and Khyber Pakthunkhwa, and also further west in Nuristan.

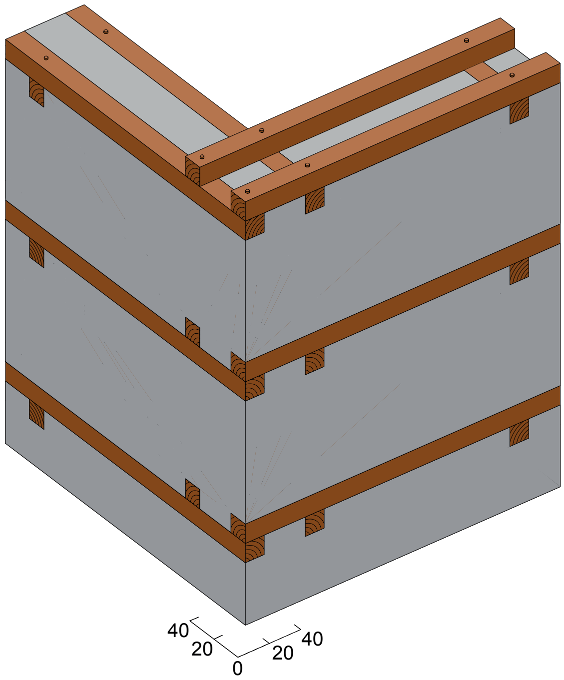


Fig. 4.47 System of a *bhatar* construction.
CAD: Martin Pospichal. Details provided by the author.

4.2.1 *Bhatar*

At the *bhatar* construction, the 'ladder'-like timber lacing is not only at floor level, but at a certain distance along the whole height of the wall (Fig. 4.47). The vertical distance between the timber lacings ranges between 30 cm and 60 cm. Beams are in profile between 10 x 10 cm and 12 x 12 cm, and the facing runner beams are connected with cross-pieces every 90 cm to 150 cm (Schacher 1998: 3). Stone structures are made with or without mortar. Cross-pieces are in general placed below the runner beams (ibid). In contrast to the *cator and cribbage* technique (see below), the vertical 'column'-like timber-stone structures (*cribbage*) are missing and just the *cator*-construction remains. Vertical timber elements are also not used. Commonly used timbers include deodar, blue pine and, at higher altitudes, also poplar (ibid.).

In Kalam and the surrounding area, the main construction of vernacular buildings is the 'ladder'-like timber lacing in combination with stone walls (Fig. 4.48). This technique is locally known as *bhatar*[145] and is similar to the 'ladder'-like construction at floor level. In Indian Kashmir, this technique is known as *taq*, in Turkey as *hatil* or *dugmeli* (Schacher 1998: 2; Hughes 2000b; Langenbach 2007), and in the Greek Middle Ages as *imantodi*. In North Pakistan, it is commonly used between Chitral in the west to Besham in the east, in Nuristan and in the northern provinces of Pakistan (Schacher 1998: 2). In Keshtagrom in Nuristan, Edelberg (1984: 6) shows examples of

145 Schacher (1998: 2) describes the *bhatar*, on the one hand, as wooden laths reinforcing a stone wall and, on the other hand, as the whole construction, which includes this kind of timber lacing.

Fig. 4.48 Kalam. North Pakistan. *Bhatar* construction.

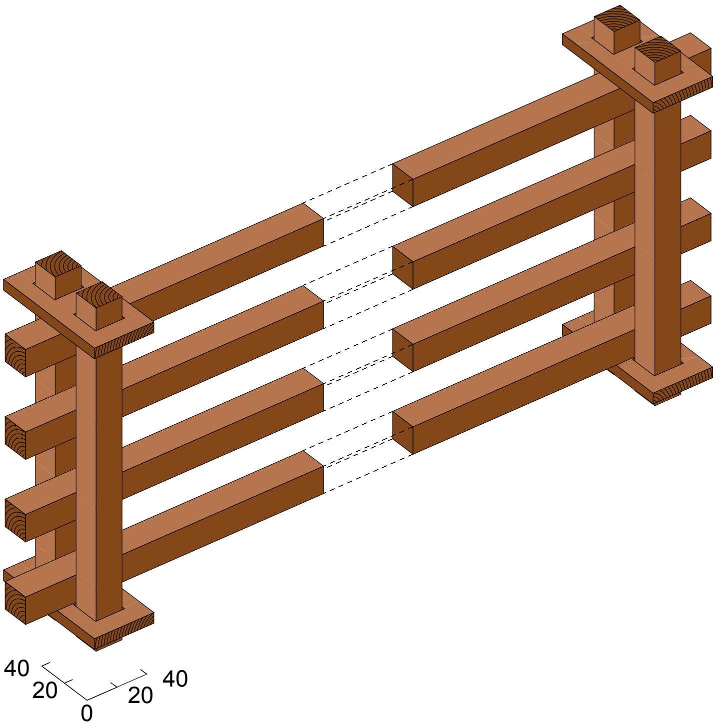


Fig. 4.49 Nuristan. Afghanistan. System of a *pik'ū* construction.

CAD: Martin Pospichal. Details provided by the author, according to a picture given in Edelberg 1984.

'ladder'-like constructions with about two layers of stones above the runner beams notched at the corners. The stones are described as being rendered with clay, while the runner beams (Kt. *makř'ik*) are placed without such a rendering.

A common tradition for making walls is mentioned with the *pik'ū* (Wg.) construction (Fig. 4.49). The *pik'ū* or *pik'ū-nakur'ä* construction resembles the *bhatar* construction as it also changes layerwise between wooden runner beams and stone-clay infill. However, striking differences do exist: The layers of timber runners (Wg. *ban-ē*) are not laid as pairs but rather as single beams and are kept in position by vertical poles (Wg. *pik'ū*) at the inside and outside of the walls. These poles pass through wooden clamps (Wg. *nakur'ä*) that protrude from the wall both inside and outside. (cf. Edelberg 1984: 4ff.) Such poles are rarely used in Himachal Pradesh, while in Uttarakhand they appear as wall brackets or shear keys to stabilise walls.

4.2.2 *Cator and cribbage*

A traditional technique in this region is the combination of the 'ladder'-like timber lacing (known as *cator*) as the horizontal component – as mentioned for structures in Ladakh – with a stone-filled timber column-like system (*cribbage*) as the vertical component (Fig. 4.50). In the ground plan, square-shaped column-like components (known as *cribbage*[146]) are made by piling up logs two by two, with each layer rotated by 90°. For Ladakh, the use of the *cribbage* technique is not common and no historical data exists showing its use. Hughes (2000a) mentions its common use between Nuristan and Baltistan; this system was already used in Mohenjodaro (app. 3,500 BCE), in Roman and Medieval London for quay construction, and at the Baltit Fort already app. 800 years ago (ibid.).

The combination of the *cribbage* construction with the *cator* construction changes the static role of the wood. In the simple *cator* system – as described afore for Ladakh – the wooden components are integrated into the solid wall construction, which may be of stones or adobe bricks. In this case, the solid wall component (stone or brick) is the prime carrier of the load and we can still talk of a solid wall construction. In contrast, the *cator and cribbage* technique as described for North Pakistan is from a static point of view closer to a wooden skeleton construction. This is emphasised by the fact that parts of this construction, in particular the *cribbage* components, may be erected as 'simple' wooden constructions first and filled with stones in a later phase.

The solid component of this construction is primarily stone. Fired bricks would be too energy-intensive and, from a static point of view, would mean no improvement. On the other hand, adobe bricks are not common, possibly due to the unsuitable properties of local clay (see aforementioned material resources). The strength of adobe bricks in general is lower than stone, which may result in cracks due to tensions in the wooden part of the construction. In particular, strength for adobe bricks is low against shear forces and tensile loads.

In a drawing, Hughes (2000a: Fig. 1) shows standards for the *cator and cribbage* construction, where the *cribbage* columns are set at a distance of app. 2 m to 4 m from each other. This refers to the available average length of structural timber. The runner beams (*cator*) are placed with a

146 Hughes (2007: 102) describes cribbage as a "vertical timber box frame".

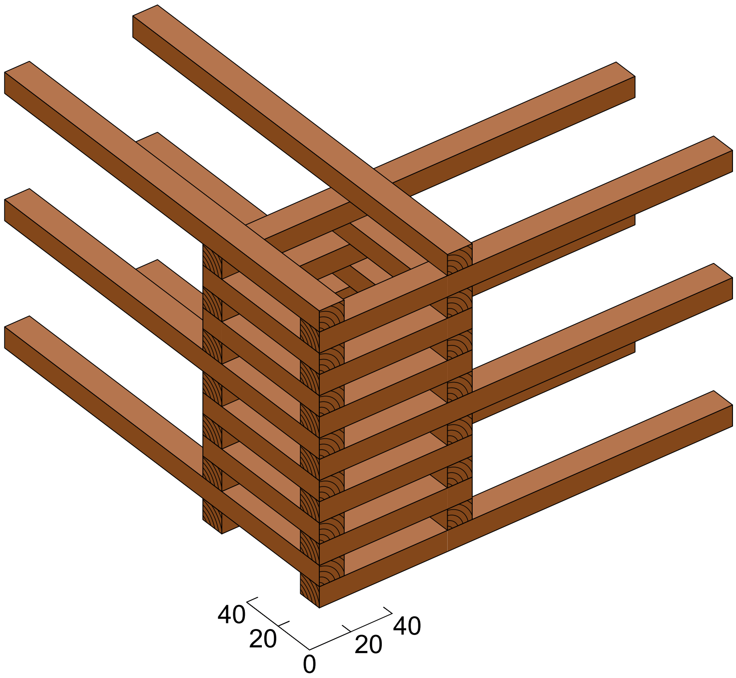


Fig. 4.50 System of a *cator and cribbage* construction.
CAD: Martin Pospichal. Details provided by the author.

vertical distance of max. app. 1 m from each other. They are connected with each other at the corners by wooden pegs. Timbers are in profile 5 cm to 12 cm square. Timber length is not always jointed or nailed together. To reach a better quality, runner beams are tied together through the wall thickness with cross-pieces at 1 m to 4 m intervals.

This technique enables rather slim and high wall proportions, as is seen at the facade of the Baltit Fort, which is just app. 40 cm thick, but 10 m high (Hughes 2007: 112). Historical monuments of these regions, as shown in photographs by Dani (1989), are mainly built with the *cator and cribbage* system. This concerns forts and palaces (*khar*s), mosques (*masjid*s) and tombs of saints (*astana*s); the artistic style related to this construction is locally known as *thatar*[147] (Klimburg 2007: 151). For an additional strengthening of the corners in the *cribbage* system, wooden boards were introduced between two rows of *cator* beams covering the end of the wall (cf. Dani 1989: Plate Xa, Tower of Dost Mohammad in Tangir Valley). This technique is also practiced in Himachal Pradesh, e.g. in Chamba and Middle Kinnaur (see Fig. 4.79).

147 The North Pakistan term *thatar* is used in Chamba (as *thathar*) to describe the single horizontal pieces used in the *farque* construction (cf. Handa 2008b: 101).

4.3 Kashmir

This chapter concerns composite wall constructions containing wood in Kashmir. In 2006 and 2011, the author conducted field reseach in Srinagar and surrounding areas. The altitude of Srinagar is about 1,585 m, which is roughly 2,000 m below settled areas in Ladakh, 1,000 m below settled areas in Chamba and Baltit, and 500 m below Kalam.

At 13.6°C, the average annual temperature in Srinagar is, besides Chamba Town, the highest within the reached North Indian settlements. It is about 8°C higher compared to Leh and similar to Kinnaur and Chamba. At 23.1°C, the maximum temperature is, besides Chamba Town, the highest within the researched North Indian settlements, while the difference between annual maximum and minimum temperature is 23.1°C, which is the highest after the Ladakh region. This high difference means a particular high stress of the building material over the seasons of a year, resulting in the need of flexible behaviour. The climate conditions in the Kashmir Valley may explain the relatively high population of timber. This fact implicates a higher amount of wood used in building constructions compared to higher altitudes and regions with less tree population. Such conditions support the development of some particular building techniques. Low temperatures around 0°C in winter may bring big amounts of snow.

A pitched roof is the traditional roof construction in Srinagar and the hilly surrounding region. At a few historical building sites in the Srinagar region, we find a mixture of sloping and green roofs. The *khanqah* in Pampur (alt. 1,620 m; app. 10 km south-east of Srinagar) or the Madeen Saheb (15th century CE, INTACH 2010b: 480) located near Nowshohar are good examples, and from a constructive point of view related to what we find at the Sumtseg in Alchi located in Ladakh at an altitude of 3,020 m. This is one of the few examples in Ladakh influenced by Kashmir in regard to art history and building structure. In a picture by Kak, the *khanqah* in Pampur is shown with a sloping grass roof (Kak 1933: Plate XLVI). In the meantime, it has been changed to a tin roof.

The sophisticated roof timbering shows a construction typical for many of the mosques in Kashmir and North Pakistan. The part of the roof next to the eave is made with a gentle slope in a single- or multi-tiered pyramidal shape (Kash. *chaar baam*). The central part of the roof is a steep sloping spire. A small open pavillon (Kash. *brangh*) is often integrated between the spire and the *chaar baam* (Fig. 4.51). Similar types of roofs with a central steep sloping portion on top of an open roof pavillion and covered with wooden shingles are also found at Buddhist structures, e.g. in Middle Kinnaur, specifically in Ropa, Sunnam or Karla.

In Srinagar, a particular composite building culture developed with buildings of a common height of up to three and four storeys. Srinagar appears as a kind of transition zone of different building techniques with light-weight as well as solid structures, and those resulting from a combination. As a light-weight construction, the *dhajji-dewari* is predominant; as solid structures the *taq* is predominant and the *cator and cribbage* construction frequently used. All these constructions are closely related to the availability of structural timber. The *dhajji-dewari* is widely used over Kashmir (in India and Pakistan as well), while further north in North Pakistan and in Himachal Pradesh, we find it occasionally. In Chamba, which is close to Kashmir, the *dhajji-dewari* is still more prevalent than in the districts of Shimla or Kinnaur. *Cator and cribbage* constructions are

Fig. 4.51 View over the city of Srinagar. In the centre of the picture, four pyramidal-shaped roofs (*chaar baam*) are visible.

widely used in Kashmir, North Pakistan and Himachal Pradesh. *Bhatar* constructions are widely known in the Himalayas. Historical monuments are mainly from the last two centuries, in particular *taq* constructions, although some historical monuments can also be mentioned for the 13th/14th century. In particular, some historical *cator and cribbage* constructions reach back to this period.

4.3.1 *Taq*

It is a 'ladder'-like timber lacing similar to the *bhatar* in Pakistan or the *hatil* in Turkey (Fig. 4.52). The 'ladders' are primarily laid on floor level and connected to the floor beams to strengthen the wall against lateral forces (cf. Langenbach 1989). Together, *taq* and floor beams form a horizontal rigid membrane (Fig. 4.53). Floor beams are in most cases visible from the outside. 'Ladder'-like timber lacings (in Kashmir known as *ker*, Langenbach 2009: 8; in Himachal Predesh as *cheol*) act as ring beams and are joined at the corners. The lacing is not vertically connected. The runner beams are app. 10 cm to 15 cm square (ibid. 5). The *taq* may also be introduced in the wall between the floors for additional strengthening (as it is common with *bhatar* constructions). The runner beams are stabilised by the load on top, a technique as already described by Julius Caesar for the Gallic walls (see part 1 of this Chapter). Besides the timber's use as a reinforcing component, the *taq* also describes a modularity alternating between masonry piers (*tshun*, 45 cm to 60 cm) and window bays (*taqshe*, 90 cm to 120 cm) (ibid. 8). The amount of bays is used to describe a building's size (ibid. Forword). The rhythmical change between masonry piers and window bays is also known from Turkish buildings, for example, from Safranbolu (cf. figure in Caimi 2006: 465). In Srinagar, some of the buildings are vertically divided into a solid masonry part with timber lacing in the lower part of the building and a *dhajji-dewari* construction on top. The cross-pieces within the 'ladders' are preferably below the runner beams, and in earlier days

Fig. 4.52 Kashmir. India. *Taq* constructions along the banks of the Jhelum River.

notches instead of nails were preferred.[148] An early example for the use of a *taq* construction in Srinagar is the Syed Shah Niamatullah Qadri's Shrine (13th/14th century CE, INTACH 2010a: 55, 306), though the majority of historical monuments using *taq* are not older than the 19th century, as described by Langenbach (2015: 84).

In Srinagar, fired bricks are commonly used for wall constructions. A special size for fired bricks was used in Kashmir in the 19th and 20th century, and relates to the Maharaja of Dogra (Langenbach 2009: 8). These bricks are known as *maharaji* bricks (Kash. *maharaji seer*) and had already been used at earlier structures such as the Syed Shah Niamatullah Qadri's Shrine (13th/14th century CE, INTACH 2010a: 306) or the Aastan-i-Syed Mohammad Hussain Baladur (14th century CE, ibid. 188). They were placed as a protecting cover in front of adobe bricks (*khaam seer*) (ibid. 8). They are also known as Lachania bricks with a size of 23 x 10 x 2.5 cm (Interview with Saleem Beg in 2011). Lachan[149], which is located south of Srinagar, is where the clay for the bricks was collected and where the bricks were fired. Their low height means various advantages such as a higher brick stability and a bigger amount of flexible joints between the bricks. The bricks were modelled by hand and fired at a rather high heat (Seminar held by Langenbach in 2008). In the city museum of Safranbolu in January 2012, two traditionally used bricks were exhibited – one as an adobe brick with a size of app. 30 x 14 x 7 cm and one as a fired brick of app. 20 x 10 x 5 cm. The size of the fired brick shows close similarity to the *maharaji seer*. For solid walls, besides bricks also stones are used, in particular in the countryside, as seen at local houses in Naranag, north of Srinagar.

148 Information given at a seminar held by Randolph Langenbach, 22/09 to 26/09/2008 in Brescia, Italy (see under "Correspondence and Interviews").

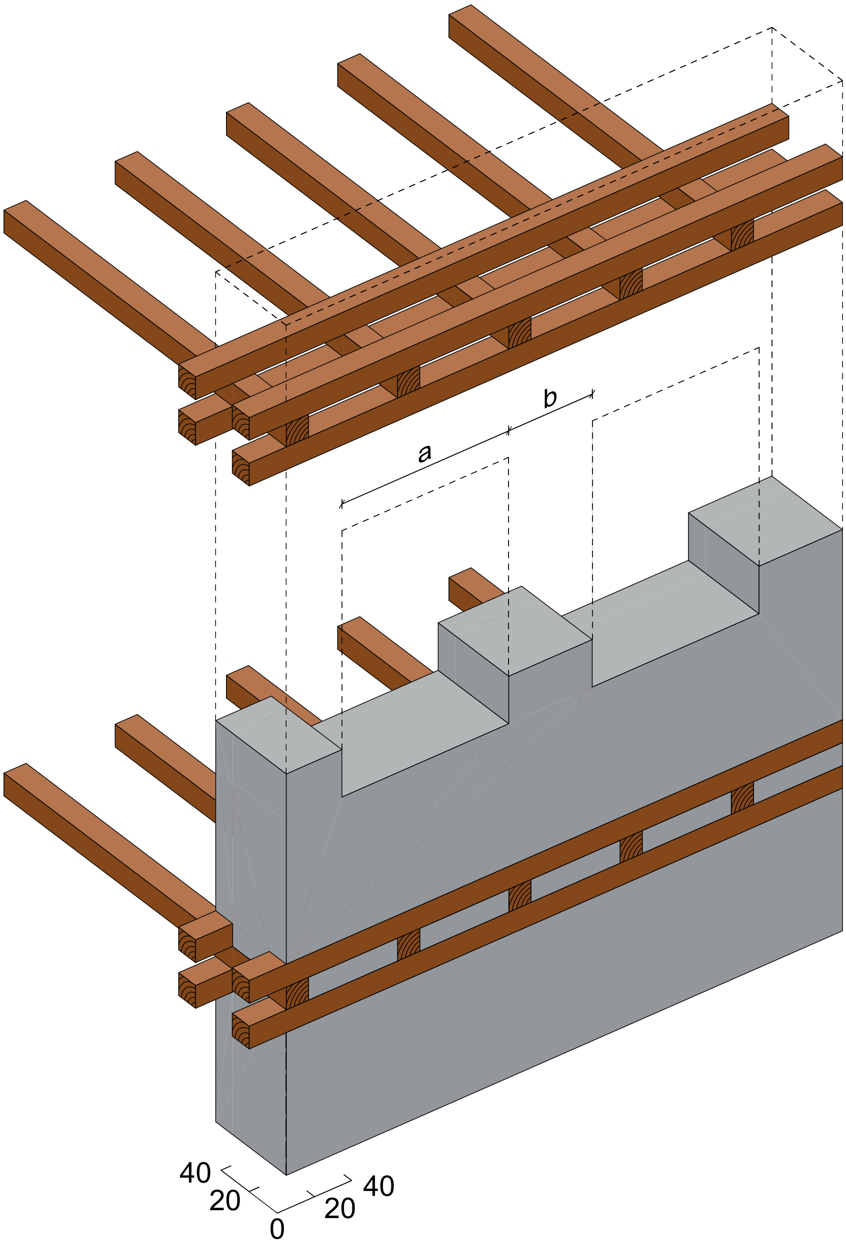


Fig. 4.53 System of a *taq* construction. a = *taqshe*, b = *tshun*, both based on proportions given in Langenbach 2009: 8. CAD: Martin Pospichal.

149 Lachan has not yet been clearly localised and will be part of future research.

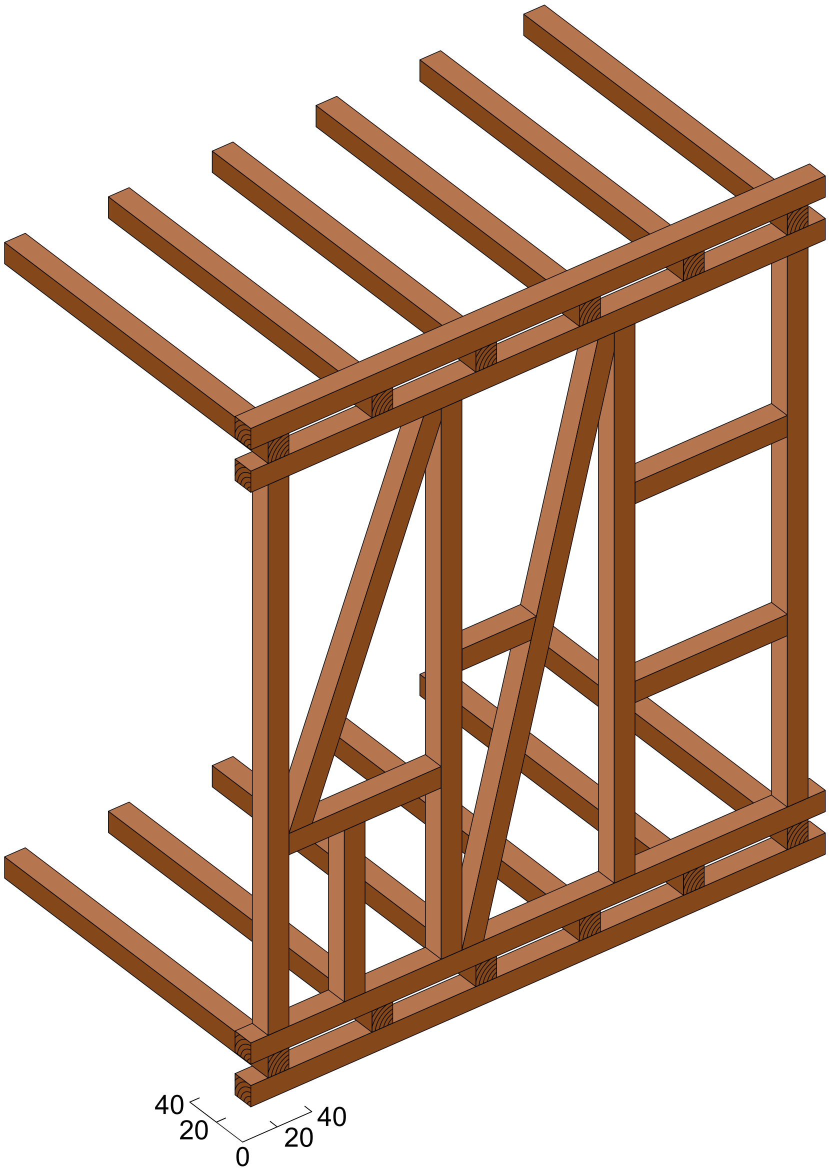


Fig. 4.54 System of a *dhajji-dewari* construction. Compare a structural model given in Langenbach 2009: 17. CAD: Martin Pospichal.

4.3.2 *Dhajji-dewari*

The term *dhajji-dewari* deriving from the Persian meaning "patchwork quilt wall" (Schacher, Quaisar 2009: iii) is a half timber frame construction, which may either rise over the whole height of a building or be placed on top of solid walls (Fig. 4.54). Kashmir (in India and Pakistan as well) is one of the main regions of dissemination of this technique. Commonly used timbers are blue pine, deodar and *chīr* pine (Arup 2011: 10). The timber frame consists of vertical and horizontal members. Within the facade – except at its corners – the vertical members do not necessarily have to be placed above each other. The frames are divided for later wall openings and are commonly filled with adobe or fired bricks having a wall thickness of app. 12 cm to 14 cm, which remains unplastered (Seminar held by Langenbach in 2008). The frames may be subdivided by several horizontal wooden members over one storey. In many cases, but not in general, diagonal members are introduced. In villages the use of wooden boards instead of square timber elements is common and the frames are divided into smaller frames with stone infill. Also among Turkish half-timber frame structures (*himiş*), we find many examples without diagonal bracing.

Dhajji-dewari walls are independent structures for each floor. The floor beams are clamped (pressed together) between the upper runner beam of the lower part of the wall (i.e. the storey below) and the lower runner beam of the upper part of the wall (i.e. the storey on top). Further, the parts of the wall are connected to each other in a 'cage'-like manner. Floor beams remain in general visible along the front and rear facade. In the case of structural movements, the single storeys of *dhajji-dewari* move partially independently from each other. The high amount of joints increases a structure's flexibility.

4.3.3 *Cator and cribbage*

In Kashmir, several *cator and cribbage* constructions follow the type as described for North Pakistan. The *khanqah* in Pampur is one of the impressive examples in Kashmir (Figs. 4.55, 4.56). It was built with deodar wood. The wood construction remained widely open, and only at some parts it was filled with stones. Big parts of the load-bearing walls of this *khanqah* are built without stone infill and show the statical independence of the timber structure in this construction. Several examples show the early development of this technique in Srinagar. Among them are the 14th century examples like the Aastan-i-Syed Mohammad Hussain Baladur, the Kanqah-i-Muallah (INTACH 2010a: 366) or the Ratqail Mosque (INTACH 2010b: 805).

Another representative example in Srinagar is the Khanqah-i-Naqshbandi built app. in the 17th century (INTACH 2010a: 205) (Fig. 4.57). The wall thickness is app. 90 cm. The runner beams made of deodar are app. 12 x 16 cm (W/H), and the bricks used in the exterior wall are of a size 17 x 13 x 3 cm (L/W/H) following in height a *maharaji* brick size. The width between the *cator* ranges between 50 cm and 160 cm, with the latter larger width used for window openings. The interspaces along the facade between the wooden components are filled with small-sized bricks (Fig. 4.58). The construction at the corners shows that the position of the runner beams is around the whole building kept at the same level (Fig. 4.59) and not displaced with the height of one beam at each corner, as known from North Pakistan *dhajji-dewari* buildings.

4.4 Eastern Lahaul, Spiti, Upper Kinnaur and northern region of Middle Kinnaur

This chapter concerns composite wall constructions in Himachal Pradesh in the east part of the province Lahaul (village of Keylong, alt. 3,100 m) and Spiti (village of Kaza, alt. 3,660 m and Tabo, alt. 3,285 m), in Upper Kinnaur (villages of Nako, alt. 3,630 m and Chulling, alt. 3,200 m) and in Ropa Division as a northern region of Middle Kinnaur (village Ropa, alt. 3,030 m). Altitude ranges between 3,030 m and 3,660 m and separates this region of study from the following lower altitude region of Middle Kinnaur.

Fig. 4.55 (Top, left) Pampur. Kashmir. Prayer room of the *khanqah*.
Fig. 4.56 (Top, right) Pampur. Kashmir. Open and filled spaces between the cross-pieces.

Fig. 4.57 (Centre, left) Srinagar. Khanqah-i-Naqshbandi.
Fig. 4.58 (Centre, right) Srinagar. Kanqah-i-Muallah. Small bricks are used to fill the holes between the cross-beams.

Fig. 4.59 (Bottom) Srinagar. Khanqah-i-Naqshbandi. Corner construction: Runner beams (a) and layers of brick infill (b) are layerwise alternatingly kept on the same level around the whole building.

4.4.1 *Eastern Lahaul*

Regarding climate data of Keylong in Lahaul, Kaza in Spiti and Nako in Upper Kinnaur, we find close similarities between Spiti and Upper Kinnaur. At app. 5.2°C, the annual temperature is similar to Leh, whereas the annual precipitation in Spiti and Upper Kinnaur is much higher compared to Leh and similar to Kalam in the Swat Valley. At app. 19.5°C, the difference between minimum and maximum temperatures during one year is much lower than in Leh with 26°C or Gilgit-Baltistan with between 27°C (Baltit) and 30.6°C (Khaplu), and similar to Kalam with 22.6°C. Keylong (alt. 3,100 m) and its surrounding, like Gondhla (alt. 3,170 m), show a slightly higher average annual temperature and precipitation compared to Spiti and Upper Kinnaur. Snowfall during winter can be strong, in particular in the southern regions of Lahaul.

From Ladakh (Leh, alt. 3,520 m) towards Lahaul (Keylong, alt. 3,100 m) as well as from Zangskar (Padum, alt. 3,570 m) towards the Chenab Valley in the south, we observe a move from predominant earth constructions towards stone and earth constructions as well as a higher content of wooden components. Forestration is higher than in Ladakh, in particular in the foothills of this area of study between Lahaul and Middle Kinnaur. In the west in the areas of western Lahaul and towards Kullu and in the east towards Middle Kinnaur, the availability of timber increases. These areas seem to be a transition zone towards stone constructions with an increased content of wooden components. The transition between such zones is gradual and not precisely defined. In general we find regionally determined types of construction with local variations. The stone walls in general are plastered at the inside and in several cases also outside.

The traditional roof construction around Keylong, Spiti and Upper Kinnaur is a flat roof covered with clay, often placed on a layer of birch bark. Exceptions exist, for example, the fortress tower of Gondhla, which is today covered with a slightly inclined roof of stone slates, or the temple of Guru Ganthal, which had a sloping wooden roof in earlier days similar to what we find at wooden temples in Chamba District or at the Hadimba Temple in Manali in Kullu (see Khosla 1979: 92).

4.4.1.a Investigated objects in Eastern Lahaul

Gondhla, Fortress tower

Alt. 3,180 m; 32°30'29.38"N, 77°1'33.76"E. Located about 15 km south of Keylong in Gondhla in the Chandra Valley, it is an eight-storey high fortress tower formerly belonging to the Thakurs (Fig. 4.60). It was founded in app. 1700 CE (cf. Handa 2008a) as a royal residence and watch tower with a shrine upstairs (Bernier 1989: 82).

It is a construction made with rather flat stones in-between a 'ladder'-like construction without the use of vertical wooden elements. This construction is known as *dhol-maide*. Parts of the facade between the *cheol* (which is a local term for the runner beams) still bear plaster. The brown wooden lacings and the bright appearing plaster show a relatively conspicuous linear pattern. The flat stones are an additional factor in stabilising the wall. The stones are set in a clay mortar (ibid. 1989: 82).

In Himachal Pradesh, most fortress towers are placed on a high plinth reinforced with a *dhol-maide* construction (e.g. the fortress tower in Labrang, see below), and the walls in the upper

Fig. 4.60 Gondhla. Lahaul.
Fortress tower.

part typically continue as *kath-kuni* constructions (in Kinnaur also known as *doriyā*[150], Handa 2008b: 145).[151] The fortress tower in Gondhla diverges from this typology, since its plinth is rather low and the whole construction follows the *dhol-maide* type. Handa (2001: 184) describes roughly between one and one-and-a half metres of wall thickness for fortress towers. Towers in general may raise up to 45 metres, as shown with the five-storeys-high tower at Chaini (31°37'38.79"N, 77°21'29.60"E), c. 17th/18th century CE (Handa 2001: 188).

In the case of Chaini, the high plinth is made as a *dhol-maide* construction with a height of 15 m (Handa 2008b: 75). The fortress tower in Gondhla, in contrast, does not follow this pattern, since it rises over its full height with a *dhol-maide* construction.

Johling Temple

Johling is a small village located on the left banks of the Bhaga River before reaching Keylong. At this temple, which dates back to the early West Tibetan period (11th century, Luczanits 2004: 68), the walls are rubble stone constructions. Here it is possible to find a few wooden lacings, in particular fixing one corner, but a ring beam was not used. Some of the beams show slits, which points towards their former use within another construction or at another position within this temple. Two runner beams are connected at the corner by a half lap joint.[152]

150 According to Dave et al. (2013: 67), different other local terms for the *kath-kuni* technique are known: *katth ki kanni* in Sarahan region or *kashth kona* at other places.

151 At the *kath-kuni* construction, as described for the Koti Banal architecture in Uttarakhand, the timber structure was built first and thereafter filled with stones (Rautela, Joshi 2008: 476).

152 Presented by the author at a lecture at the Vienna University of Technology in January 2011 on "Constructive

Fig. 4.61 Taryul. Lahaul.
Village houses built with stone.

Gumrang Temple

Alt. 3,300 m; 32°34'13.82"N, 77°2'49.59"E. Gumrang is a small village located on the right banks of the Bhaga River before reaching Keylong. At least the lower portion of this temple's walls was made of stones. The upper portion was difficult to investigate due to its irregularly thick plaster and changes due to a possible former repair. The wall thickness of the stone wall is app. 38 cm and was covered by a concrete wall of a similar thickness. No wooden lacing could be found. Around 1973 an avalanche destroyed the early temple of Gumrang (Luczanits 1994: 84) and a new temple was erected. This temple shows the erection of a later concrete wall around the original wall.[153]

Taryul, village houses

Alt. 3,450 m; 32°34'10.69"N, 77°3'45.32"E. Taryul is a small village on the right banks of the Bhaga River above the village of Satingri on the way to Keylong. In this village the walls are traditionally made of stone with wooden 'ladder'-like timber lacing. The thickness of these walls ranges around 45 cm. Recent structures in this village were erected with stone walls without timber lacing, which compared to early structures shows a change towards reducing timber (Fig. 4.61). Khosla (1979: 118) states that clay mortar was not used for the traditional timber-bonded walls since the shear compression held the stones in place. However, for new stone walls, clay mortar is used for levelling instead of timbers. In this village some of the upper walls – most probably for economic reasons and to reduce the load onto the walls below – wattle and daub walls were erected. Wattle constructions are primarily made of willow twigs and plastered at the outside and inside.

Traditions in the Western Himalayas". Analysis of the walls of this temple is based on pictures from the Western Himalaya Archive Vienna. Online: https://whav.aussereurop.univie.ac.at/ic/4610/#page=1), access: 06/2016.

153 In order to strengthen the original stone structure, a second wall was partially erected in front of the original wall and strengthened with columns of steel concrete.

4.4.2 Spiti

The altitude increases from Lahaul towards the south-east in Spiti. Here, e.g. at the villages Losar and Hansa (alt. 4,000 m) and Kaza (alt. 3,660 m), one enters a traditionally predominated rammed earth region, which also includes adobe brick structures. As described by Khosla (1979: 120), a method of making window and door holes is first to ram the walls without openings, but with the door and window frames already placed in the correct position. After the ramming is finished, the openings are gouged out. At several structures, such as the ruins of the Hikkim Monastery, rammed earth walls and adobe walls were erected beside each other, both on stone plinths.

For rammed earth constructions, saw wood to produce boards for the scaffolding is needed. This need is specific in arid zones, where timber in general is scarce. In this case, wattled mats made of branches – similar to what is used for wattle and daub constructions – were used as shuttering in earlier days (cf. Khosla 1979: Fig. 179). The rods to produce such mats must be flexible and are made primarily from the twigs of the willow tree. The walls of some of the rammed earth buildings follow the method of tapering the outer surface of the wall by reducing its thickness from a thicker base towards a thinner top and reducing the load of the wall towards its top. For the erection of a tapering rammed earth wall, towards the wall's top, the distance between the scaffolding boards is reduced layer by layer. The height determined of the shuttering boards in Dhankar and Sangnam was on average 60 cm.

Besides a predominance of rammed earth constructions as a local tradition, as is the case in the Spiti Valley or the Pin Valley, adobe brick buildings are also present. In this regard we state a relative predominance that may continuously change or has been changed, and we are certainly not talking of an exclusive and pure rammed earth region.

4.4.2.a Investigated objects

Even today, the method of ramming walls is common, as can be observed in Dhankar or Tabo village. Common wall thickness, as observed in Tabo, Dhankar and Sangnam ranges between 35 cm and 45 cm. Besides residential buildings, religious structures were also rammed. Only the very early temples of the West Tibetan empire were exclusively made of adobe bricks. Two structures are given as examples for a later development of an extensive rammed earth building culture: the village temple in Rangrik (appr. data: alt. 3,685 m; 32°15'20.22"N, 78° 1'28.23"E) and a ruined monastery in Hikkim (appr. data: alt. 4,400 m; 32°14'48.01"N, 78° 5'45.47"E).

Rangrik Temple

In Rangrik Village the Old Temple was built as a rammed earth construction. It follows the design concept of a centralised Buddhist temple with an internal circumambulation corridor (Figs. 4.62, 4.63). The rammed earth walls are plastered. As shown with an old village house, the same raw material was used for the rammed earth and for the plaster (see before). The thickness of the rammed earth walls is app. 50 cm.

Hikkim Monastery

At the Hikkim Monastery, of which only remains of walls exist, rammed earth walls were erected along with adobe brick walls at the first floor level. Walls were plastered. Similar to

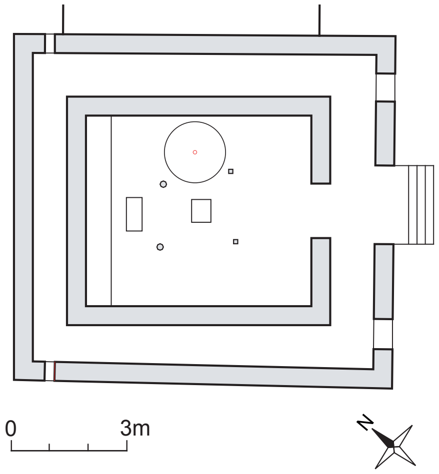


Fig. 4.62 Rangrik. Spiti. Ground plan.

Fig. 4.63 Rangrik. Spiti. Temple walls made of rammed earth.

the results of the material analysis for the old house in Rangrik – as shown with an old house in the surrounding of Hikkim for ramming, brick making and plastering the same raw material was used. Wall thickness of rammed earth walls ranges between app. 40 cm and 50 cm.

Tabo Monastery

Alt. 3,285 m; 32°5'37.27"N, 78°23'2.04"E. Founded in 996 AD, the monastery of Tabo is the oldest known religious architectural structure in Spiti. It was built with adobe bricks. Its walls (thickness at the main temple app. 120 cm) were kept unplastered for nearly 1000 years until renovation work in the 1970s.[154] Still, many of the wall paintings on the interior wall surfaces are well preserved. Photographs of the unplastered walls published by Khosla (1979) show no wooden inlays. On the other hand, according to reports (cf. Luczanits 2004: 263), wooden planks of a thickness of 8 cm to 10 cm were inserted into the adobe brick walls with a vertical distance of app. 1.5 cm to 2 m.[155] The description points towards the existence of timber lacing within the adobe wall structure, and draws a picture of a far uncommon construction in Spiti.

4.4.3 Upper Kinnaur (Hangrang Division) and Middle Kinnaur (Ropa Division)

In Kinnaur in pre-collonial times, under the earlier ancient kingdom of Bashahr, near total control of the forests belonged to the villages (Belz 2012: 64; cf. Bajpai 1981; cf. Cranney 2001). Concerning building material features, Upper Kinnaur is more related to the Spiti and Lahaul region than to the southern regions of Kinnaur. This district is divided into Upper, Middle and

154 A paper titled "Tabo Tsuglagkhang – various aspects of integrative conservation" was presented by the author at an international seminar in January 2014 in Krakow.

155 Since the inner surface of the walls is plastered and mostly painted, the use of timber lacing could only be reconstructed with the help of conservation reports.

Lower Kinnaur, which are again subdivided into the following regional divisions:[156]

- Upper Kinnaur: Poo-Namgia, Hangrang
- Middle Kinnaur: Baspa, Sairag and across, Jangram, Upper Tukpa, Sumcho, Ropa
- Lower Kinnaur: Atharabees, Pandrabis-Bhaba, Pagramang-Rajgram

Upper Kinnaur and Ropa, which is the northern division of Middle Kinnaur, are located to the east and south of Spiti. In this northern part of Kinnaur (located at an altitude of 3,000 m and above), the tradition of building with stones is present, similar to Lahaul, but with an even less content of timber. Due to these features, Upper Kinnaur and the northern region of Middle Kinnaur are close to each other and differ from constructions further south. This may be explained by changes in geological characteristics and timber resources. Since river stones were also used for construction, a general tendency towards the use of stones is indicated. The region of Upper Kinnaur shows less precipitation and much lower temperatures, as is the case in lower areas of Middle Kinnaur.

From Upper Kinnaur southwards (towards Middle and Lower Kinnaur) and to the west and south of Lahaul, a change towards an increased use of stone becomes evident. In contrast, Spiti shows an exception with a preference for earth constructions. On the other hand, the amount of wood used for buildings increases in these directions and is used in different composite ways, primarily together with stone. In transitional zones being home of establishments of different building techniques, like in Hangrang in Upper Kinnaur, in Ropa in the northern part of Middle Kinnaur, or in Lahaul, we find pure stone constructions as a traditional way of building. There is a change from Upper Kinnaur to Middle Kinnaur from solid structures of stone and clay towards the use of *dhol-maide* constructions (cf. Handa 2001: 108f.), which resembles the *bhatar* construction in North Pakistan.

A main feature of this construction is the still high amount of stones used in relation to the whole construction as well as the technique of stone laying and the absence of vertical wooden structural wall components. Stone is still not just an infill, but the primary load-bearing material, although the timber components take over important static features of the construction.

4.4.3.a Investigated objects

Nako, village buildings

The village houses of Nako are in most cases either pure stone constructions of quarried stone, or the ground floor is stone and the upper floor constructed of adobe bricks. The use of wooden bracings is uncommon.

Nako, temple compound

Alt. 3,628 m; 31°52'53.88"N, 78°37'33.80"E. Contrary to the stone building tradition of the village houses, the four temples of the temple compound are all built with adobe bricks. The two earliest temples of this compound are the Lotsāba Temple, which is dated to the first decades of the 12th century, and the Upper Temple, which at the earliest is dated to the middle of the 12th century (Luczanits 2004: 84, 88). The thickness of the walls of these two temples is app. 80 cm. At some parts of the facade of these two temples, 'simple' timber lacings, but no

Fig. 4.64 Nako. Wooden bracket.

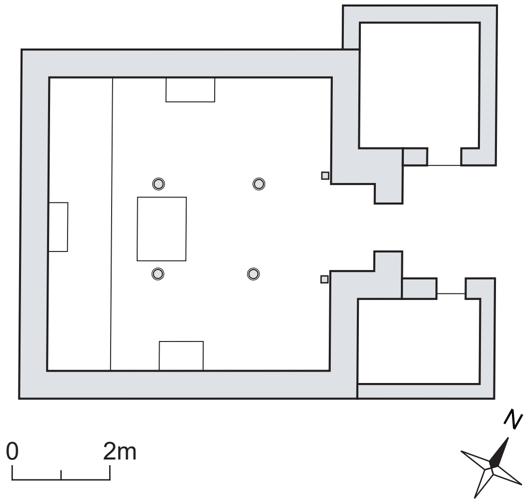


Fig. 4.65 Chulling. Temple. Ground plan.

'ladder'-like construction could be traced. At the northern corner of the Upper Temple (front left corner with view towards the temple), a wooden bracket was used to keep the lacing in position (Fig. 4.64). The random stone structures with the use of a 'simple' timber lacing resemble stone constructions, for example, in Lahaul as found at the Johling Temple. In general, this approach seems to be related primarily to a stone building tradition. The use of clay as a building material within a region, which is today shaped by a stone building culture, may either refer to a change of a building tradition in the past or to the establishment of a doctrinal ideology, by which the use of adobe bricks may have been favoured for early West Tibetan structures (see 4.4.3.b below).

Chulling Temple

Alt. 3,200 m. The village-temple in Chulling in Hangrang is made as a random stone structure similar to the temples in Johling with no wooden lacing found (Fig. 4.65). At the example of Chulling in Upper Kinnaur, the stones used have a rounded shape, probably from the river nearby, while at the Johling example, quarry stones were used. At both constructions no mortar was found between the stones.[157] The technique of using round-shaped stones correlates with the simplicity of the geometry of the ground plan.

156 The partition of Kinnaur into three internal regions, Upper, Middle and Lower Kinnaur, follows the systematisation given by Sanan and Swadi 1998:18–20, 107, 108.

157 Presented by the author at a lecture at the Vienna University of Technology in January 2011 on "Constructive Traditions in the Western Himalayas".

Ropa, Lotsāba Temple

Alt. 3,030 m; 31°47'47.59"N, 78°25'15.69"E. In the case of the Lotsāba Temple in Ropa (Figs. 4.66, 4.67; 10th or 11th century CE, Luczanits 2004: 62), the 'simple' timber lacing as found in the temples of Nako changes into a 'ladder'-like construction known as *"dhol-maide"*[158]. App. 15 km further west from Chulling and about 140 m below the Lotsāba Temple of Ropa, a change in construction occurs, similar to what was observed for the change from Lahaul towards western and southern located lower areas. The mentioned construction in Ropa, which is still primarily a solid structure with wooden lacing, already shows a clear tendency towards the increasing use of timber and a related increasing share of wooden components in the construction. Wooden components exist not only as reduced to 'simple' timber lacing, as we know from the temples of Nako, but as successively approaching a distinct structural and load bearing body.

The stone wall of this *dhol-maide* construction with a width of app. 70 cm is built in vertical segments, with each segment having a height of about 50 cm to 90 cm. To hold the runner beams in position, wooden cross-pieces are alternately placed below and on top of the runner beams with a horizontal distance of about 1.5 m to 2 m. This technique increases the stabilising efficiency of the *dhol-maide.* The method of joining runner beams and cross-pieces varies locally and even among single objects within the same village.

In order to reconstruct the process of construction, the first layer of cross-pieces is laid across the wall with a certain protrusion that is to be later used to fix the beams with a lap joint to the runner beams. The space between the cross-pieces is filled with stones. After bringing the runner beams into position on top of the first layer of cross-pieces, the space between the runner beams is filled with stones. Thereafter, the second layer of cross-pieces is placed on top of the runner beams, again with a certain protrusion, and joined to them with lap joints. The horizontal position of this second layers of cross-pieces is between the cross-pieces of the first layer.

In the case of Ropa, the profile of these cross-pieces is rectangular. As shown at examples in Ladakh (see above), the wooden cross-pieces may also be round, pointing towards a simpler version with less availability of cutting timber. However, in regard to the static system, they show a similar function. The runner beams are always cut and treated carefully regarding size, dimension and straight growth.

In the case that the wall is longer than the average length of beams – which in the Himalayan zone is about four metres – the beams have to be joined. In the case of Ropa, this joining was conducted by half lap joints. Also at the *cator and cribbage* structures as shown by Hughes (2000a: Fig. 1) or at the *kath-kuni* structures as shown by Rautela and Joshi (2008: 477), maximum length is given with four metres. Special care is given to the corners with larger stones used along the wall. At the corners the crossing 'ladders' are supported by a piece of a beam of a length slightly more than the width of the wall. This corner piece keeps the top beams in a levelled position.

158 The system of a *dhol-maide* (= *bhatar*) construction is depicted in Fig. 4.47.

Fig. 4.66 Ropa. Lotsāba Lhakhang. South-east corner.
Dhol-maide construction. The detail shows a strengthening of the corners by supporting the *cheol* (1) with wooden beams (2).

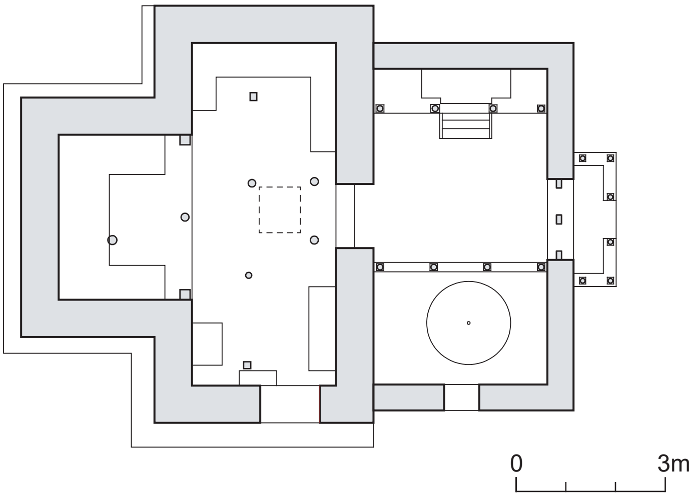


Fig. 4.67 Ropa. Lotsāba Lhakhang. Ground plan.

The stone wall of the *dhol-maide* construction traditionally remains unplastered. In the case of the Ropa Temple, even after app. 900 years, precipitation is not to such an extent that the wooden construction is rotting. Since the outer walls are plastered only inside, the unplastered facade supports air circulation within the walls and drains water inside the walls to the outside. Further, dampness is easily moved from the inside towards the outside due to the open construction caused by a plurality of gaps between the stones.

Compared to solid and plastered walls, at timber frame buildings the amount of building moisture is quite minimal and the drying time short (cf. Künzel 2014: 31). A similar idea may be behind keeping the outside walls unplastered. Clay mortar as it is used at the Ropa Temple is in general permeable to water vapour. Air circulation by openings and air leakiness of the walls support the drying process. A quickly drying wall is necessary so as to not affect the plaster and the wall paintings on the inner surfaces of the wall.

4.4.3.b Construction of early West Tibetan monasteries for comparison

Since with early Buddhist temples in Tabo and Nako a close relation to early West Tibetan structures is given, before moving further to southern regions in Kinnaur, the significance of adobe bricks for the earliest West Tibetan monasteries is discussed (see Map 1.2 in Chapter I). This concerns the following monasteries: Nyarma in Ladakh (alt. 3,264 m; 34°2'21.96"N, 77°41'2.27"E), Tabo in Spiti (alt. 3,285 m; 32°5'37.19"N, 78°22'55.43"E), Nako in Upper Kinnaur (alt. 3,628 m; 31°52'53.88"N, 78°37'33.80"E), Tholing in West Tibet (alt. 3,730 m; 31°28'59.51"N, 79°47'50.31"E) and Khorchag in Purang in Tibet (3,721 m; 30°11'47.28"N, 81°16'4.66"E). From Kinnaur along the Sutlej towards the east into Ngari (West Tibet), we find the early historical West Tibetan centre of Tholing. Here the altitude increases and an arid zone is present. Further, in an easterly direction into Purang, we find Khorchag (app. 3,730 m), another early West Tibetan centre. The whole area shows a predominance of earth construction. Today, clay is the predominant building material. These monastic centres are located at an altitude between 3,264 m and 3,730 m. In Purang, the annual average precipitation is slightly higher compared to Spiti and Upper Kinnaur, while the annual average temperature is similar. Due to the influence of the monsoon, precipitation in this area is much higher than in Leh.

At several of these sites, we find the original constructions of the early religious structures embedded in an environment of different technical developments:

- Today, Nyarma (main temple founded in 996 CE) is embedded in a region of adobe tradition, though the fortress erected on top of a rock in the north of the monastery compound and also some *stupa*s within the compound show the remains of a stone building tradition. All five temples of the monastery were erected with adobe bricks and just one wall shows a notch in the wall, which may point to a former timber lacing (see Fig. 4.31).
- In the case of Tabo Monastery (main temple founded in 996 CE), all temples were built with adobe bricks within a region partially dominated by rammed earth constructions. According to renovation reports, timber lacing was used (Luczanits 2004: 263).
- Today, moving further east from Tabo towards Nako in Upper Kinnaur, stone constructions are predominant within the village. Contrary to current local tradition, all temples within the temple compound were not erected in stone but rather in adobe with partial wooden bracing using lap joints and wooden pegs.
- Further east, the cores of the main temples of the monasteries of Tholing and Khorchag in West Tibet (main temples founded in 996 CE) show an adobe brick construction. Khorchag is located close to the Nepalese border in the east of the Western Himalayas with closer access to timber. Today, villagers report of former transports of wood from Nepal up into the arid zone of Purang. At Nyarma, Tabo, Nako and Tholing, access to timber in surrounding regions means a high effort of transport.
- In the Khorchag Monastery, the central core of the two temples, Lhakhang Chenmo and Jokhang, was erected with adobe bricks, while later additions were built as rammed earth walls on the ground floor. These rammed earth walls were again topped with adobe bricks to reduce the load of the wall and minimise transport effort of building material onto the upper floor. In this temple, adobe bricks with wooden bracing are found at the rear side of the Maitreya Lhakhang – the earliest part of the monastery (cf. Feiglstorfer 2017a). According to written sources, the decision to extend the monastery with rammed earth constructions may have resulted from flooding, which endangered the monastery, particularly its sacred core (ibid.). Reasons for a traditional use of rammed earth versus adobe

bricks are potentially various, such as the availability of the proper clay for adobe bricks, the need for a defensive structure against enemies, flooding as a natural catastrophe or quick processing of the clay without a preceding time-consuming drying process. The need for a certain form of representation could also have been a reason for the decision in the choice between rammed earth and adobe bricks. A rammed earth construction has a dominant and fortress-like appearance, in particular with tapering walls.

· The selection of one of the two building methods (rammed earth or adobe bricks) is related to the availability of a proper quality of clay.[159] In the case of the availability of coarse clay with a content of just a few clay minerals as binders, the material is appropriate for the use of rammed earth constructions. In the opposite case, where finer material with a higher content of clay minerals is available, the production of adobe bricks would be a consequence. Also the content of calcite reduces the strength of the clay, which is the case, for example, in the regionally available clay in Spiti (see Table 4.5 in the Appendix of Chapter IV).

It becomes obvious that over the distance of about 500 km, main temples of early monasteries of the West Tibetan kingdom under Lama Yeshe Ö (late 10th century CE), namely Nyarma, Khorchag, Tholing and Tabo, were all built with adobe bricks – partially contradicting earlier or later regional developments. This seems not to have been a coincidence, but was most probably part of a general concept also concerning layout and construction of the main temples of these compounds. The layout of the temples is related to a geometrical and proportional pattern. For the precise realisation of such concepts, adobe bricks seem to be an appropriate building material. The use of adobe bricks was also appropriate for keeping a certain accurate precision in building right angles, and in keeping the walls straight and of a relatively consistent thickness, i.e. with a thickness reaching up to 130 cm (for example, at Temple II in Nyarma; cf. Feiglstorfer 2011b).

4.4.4 Middle Kinnaur (Sairag, Jangram, Upper Tukpa, Sumcho)

Districts/regions:	Places:
· Sairag and across	Rekong Peo (alt. 2,420 m), Kalpa (alt. 2,760 m), Kothi (alt. 2,450 m)
· Jangram	Lippa (alt. 2,700 m)
· Upper Tukpa	Ribba (alt. 2,720 m), Thangi (alt. 2,820 m)
· Sumcho	Labrang (alt. 3,000 m), Kanam (alt. 2,800 m), Spillo (alt. 2,400 m), Karla (alt. 2,780 m)

From Nako in Upper Kinnaur towards Middle Kinnaur in the south and along the Sutlej towards Shimla District, the altitude decreases continuously (Map 4.8), correlating with an increase in the use of timber. In Nako in Upper Kinnaur compared to Spillo in Middle Kinnaur, the average annual temperature decreases from 12.2°C to 4.8°C in Nako. Also annual precipitation increases, and the difference between minimum and maximum temperature decreases. The amount of snow is higher than in Upper Kinnaur. Towards Rampur (alt. 970 m), these differences obviously increase.

159 Important factors for easy availability are criteria like less effort in digging and short ways of transport.

Map 4.8 Sites related to Kinnaur and Spiti.
GIS data based map: Jakob Gredler. Final graphics: author. Map based on data from Vector data (VD) and Basemaps (BM). Citations of VD and BM also see: Chapter IX, list of illustrations.

A traditional roof construction in Middle Kinnaur is a flat roof covered with clay, often on a layer of birch bark (Fig. 4.68). Several residential and also temple structures, e.g. around Rekong Peo or the temples of Kothi, have slate roofs (Fig. 4.69), and a few buildings, like the central temple of the monastery in Labrang or a roof over the central *stupa* of a *stupa* ensemble in Karla, are covered with a steep roof with wooden slats (Fig. 4.70). As an example, the sixth floor of the fortress tower at Labrang was covered with a pitched wooden roof, before the top floor was removed, and the fifth floor was covered with a flat roof (Negi Loktus 2015: 318).

The Bhīmā Kālī Temple in Sarahan in Shimla District follows a similar slate covered roof pattern. With a decreasing altitude towards lower regions of Rampur and increasing precipitation, the traditional sloping roofs become more common. Using wood for covering the most holy part of a shrine or temple is said to be an old tradition (Handa 2001: 111). This may be the reason that, for example, in Middle Kinnaur, such wooden roof coverings appear in regions, where slate is commonly used to cover inclining roofs. According to Belz (2012: 164, 167), in Kinnaur slate has been used as a roofing material since the 1920s, and even more commonly starting in the 1930s after flat roofs, as the ancient roof type, were partially replaced by pitched wooden slats.

4.4.4.a From dhol-maide to kath-kuni

Moving further south in Middle Kinnaur along the Sutlej Valley, the amount of timber within stone-timber composite constructions increases and the structural timber elements become statically more relevant as autonomous constructions within the whole composite compound. The timber components are not just reduced to wooden horizontal layers, as we know from a *dhol-maide* construction, but increasingly more wooden components are introduced primarily at the corners. For the *kath-kuni* technique, beams are placed within a smaller vertical distance (in general the height of one beam) to each other (Fig. 4.71). The wooden framework (known as *cheol*) is either filled with stone or rubble masonry. *Kath-kuni* refers to all the corners made of wood (Handa 2001: 108). This meaning points to a change from the 'simple' timber lacing via the *dhol-maide* construction towards the *kath-kuni* construction. Within these gradual variation from 'simple' lacing towards the *kath-kuni* composite system, stone takes over the position of an infill material. An important factor of stone infill is the stabilisation of the whole construction in that the stone keeps the timber components in position. Their mass is a factor for the stabilisation of the elastic timber construction. Equally tight placing of stones and timber decreases the possibility of later movement of parts of the construction, and keeps the construction flexible in the case of structural movements, caused, for example, by earthquakes.

The resulting construction equals the *cator and cribbage* technique as already described for North Pakistan. An average length of residential *kath-kuni* structures ranges between 4 m and 8 m (Dave et al. 2013: 75), which is similar to the average length given for runner beams at *cator and cribbage* constructions (cf. Hughes 2000a). The average width of *kath-kuni* walls ranges between 50 cm and 60 cm (Dave et al. 2013: 75). The layer of stone is locally known as *mait* (Handa 2008b: 145). Fixing the runner beams with cross-pieces, which is known as being dove-tailed,[160] is an option to keep the beams in position (Thakur 1996: 30; Handa 2001:108). The horizontal timber components of the *cator* in many cases remain unplastered and give the wall a horizontally striped appearance.

160 Local term for cross braces or dove tail is *maanvi* (Dave et al. 2013: 73).

Fig. 4.68 (Top) Labrang. Middle Kinnaur. View over the flat roofs.
Fig. 4.69 (Bottom, left) Kalpa. Middle Kinnaur. Slate covered roof.
Fig. 4.70 (Bottom, right) Karla. Middle Kinnaur. Wooden slat covered roof.

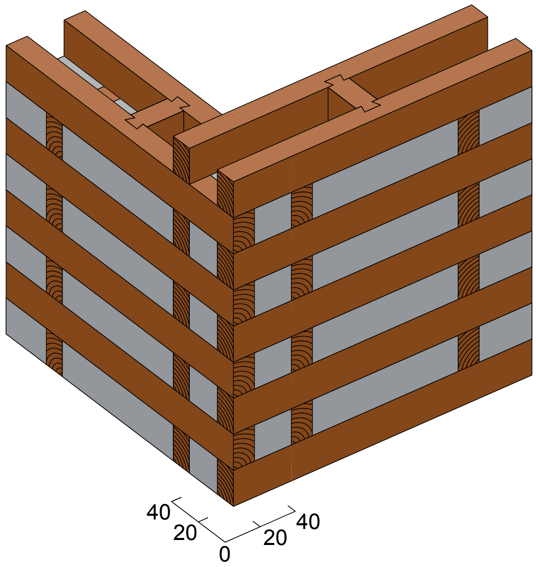


Fig. 4.71 System of a *kath-kuni* construction.
CAD: Martin Pospichal. Acc. to: Handa 2001: 109. Details provided by the author.

4.4.4.b Farque

For the vertical 'column'-like members of the *cribbage,* either squared timber or thick planks are piled upon each other, with each layer rotated by 90° (Fig. 4.72). In Chamba, this technique is known as *farque* (Handa 2001: 108). The single wooden pieces, which are laid as facing pairs at each layer, are known as *thathar* (Handa 2008b: 101). This technique can also be found in Kinnaur as a subordinate type of construction.

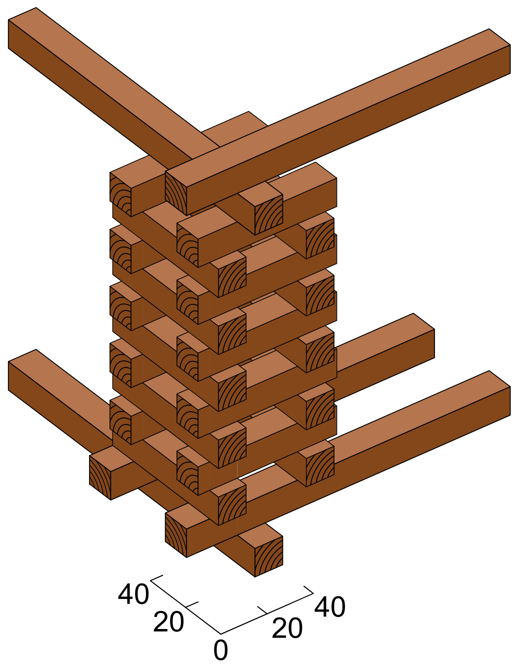


Fig. 4.72 System of a *farque* construction.
CAD: Martin Pospichal. Details provided by the author.

4.4.4.c Dhajji-dewari

Another technique, which is compared to *kath-kuni* rarely used in Kinnaur, is the so-called *"dhaji-dewari"* (see Fig. 4.54). This technique is mainly found in Kashmir or North Pakistan, though several examples can also be found in Himachal Pradesh, e.g. in Kanam in Kinnaur. In Kinnaur, this technique plays a subordinate role. The type of *dhaji-dewari* wall as it is shown in Kanam (see Fig. 4.86) consists of a wooden frame structure (foundation beam, roof beam, square-shaped pillars) divided into smaller frames by horizontal boards and diagonally placed boards. The amount of wood is high, but the dimension of the single wooden pieces is small.

4.4.4.d Observed objects in Middle Kinnaur

Karla, village

Alt. 2,780 m; 31°39'57.62"N, 78°26'4.26"E. Karla is a small village located north of Spillo. Several examples show the diversity of constructions to be found in this village. Close to the village temple, there is a *stupa* group covered by a roof supported by pillars, which follow a *kath-kuni* technique. At the front the supporting construction is made with pillars following the *farque* technique, but without stone infill. This example shows the timber construction as the primary load-bearing component of a *farque* construction (Fig. 4.73). The stone walls of the village temple in Karla follow the *kath-kuni* technique (Fig. 4.74). An old decayed house beside the temple shows a similar construction technique, but the content of timber is reduced to a *dhol-maide* construction (Fig. 4.75). In the latter example, two different techniques (*kath-kuni* and *dhol-maide*) are located beside each other.

Labrang, Fortress tower

Alt. 2,865 m; 31°40'44.45"N, 78°26'26.45"E. Labrang is a village close to Spillo located opposite to the village Kanam (Fig. 4.76). Its monastery is located at a higher altitude of app. 3,000 m. The village stretches downwards below the monastery to an altitude of app. 2,830 m. A fortress tower is located in the south-western section of the village. Since Capt. Gerard did not mention this fort after his stay at Kanam and Labrang in 1818, its existence at this early time is doubtful (Negi Loktus 2015: 312). Above the third *cheol* located in the plinth, the tower raises with a *kath-kuni* construction (Fig. 4.77). The beams of the *kath-kuni* portion of the tower are of a height of two layers of stone. The wooden structure of each facade is formed by layerwise piling up runner beams and cross-pieces and interlacing the runner beams at the corners. Structurally, this arrangement forms a column-like reinforcement at each facade's corners (1) and centre (2) (see numbers given in Fig. 4.77), the latter dividing each facade into two symmetrical parts. Each of these two symmetrical parts is structurally again divided into two parts by the placement of wooden cross-pieces between the runner beams (see number 3 in Fig. 4.77). Since the cross-pieces are not connected by lap joints it can be assumed that they are fixed with wooden pegs (locally known as *kadil,* Dave et al. 2013: 75) to the facing beams. The basement of this five-storey tower, which had six storeys in earlier days (Negi Loktus 2015: 317), is a *dhol-maide* construction (Fig. 4.78). The heads of the outside facing runner beams of some *cheol* of the *dhol-maide* construction decoratively protrude from the wall (number 1 in Fig. 4.78). *Cheol* meeting at one corner are vertically offset to each other. Following this offset, cross-pieces are located either below or on top of the runner beam (number 2 in Fig. 4.78). The stones are in general rather flat and carefully dressed. The corner stones are bigger in size. The height of the beams equals the height of two to four layers of stone.

Fig. 4.73 Karla.
Farque construction.

Fig. 4.74 Karla.
In the picture left:
kath-kuni construction (1).

Fig. 4.75 Karla.
In the picture left:
dhol-maide construction (1).
In the picture right (in ruins):
kath-kuni construction (2).

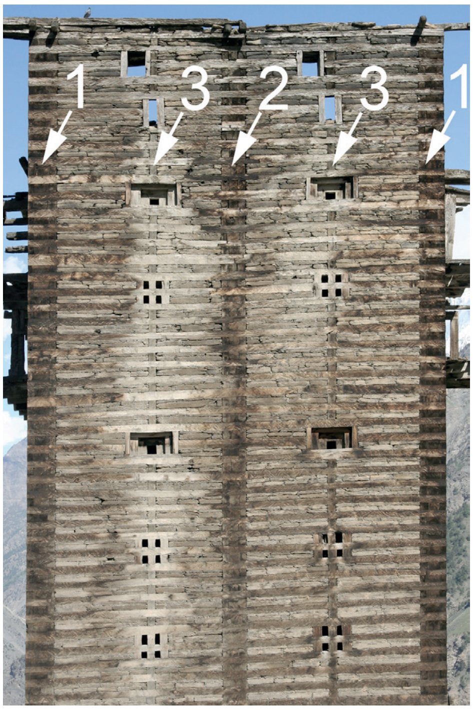


Fig. 4.76 (Top, left) Labrang. Fortress tower.
Fig. 4.77 (Top, right) Labrang. Fortress tower. *Kath-kuni* construction. 1, 2 = Groups of runner beams and cross-pieces; 3 = Single cross-pieces.
Fig. 4.78 (Bottom, left) Labrang. Fortress tower. *Dhol-maide* construction.
Fig. 4.79 (Bottom, right) Labrang. Village house. End of a *kath-kuni* wall.

Labrang, village and Old Monastery

Village houses (alt. 2,830 m to 3,020 m) show stone walls of the two types as already described for the Karla Temple (see Figs. 4.74, 4.75) – one type defined by the *kath-kuni* technique and the other by the *dhol-maide* technique. The stones are dressed, but not as precisely as shown at the Labrang Fortress tower, underlining a particular status of the given workmanship. One example shows beams equalling the height of two layers of stone. Ends of open walls are covered with panels (or beams), which are reminiscent of a *farque* construction (Fig. 4.79). Parts of the Old Monastery also follow this technique, though thick layers of whitewash and plaster make it hard to make definite statements about the technique used. This type of *kath-kuni* with rather high beams used as cross-pieces and for the closing of wall fronts is common at various other places, for example at Lippa, which is located app. 5 km west of Spillo.

Thangi, village and temple compound

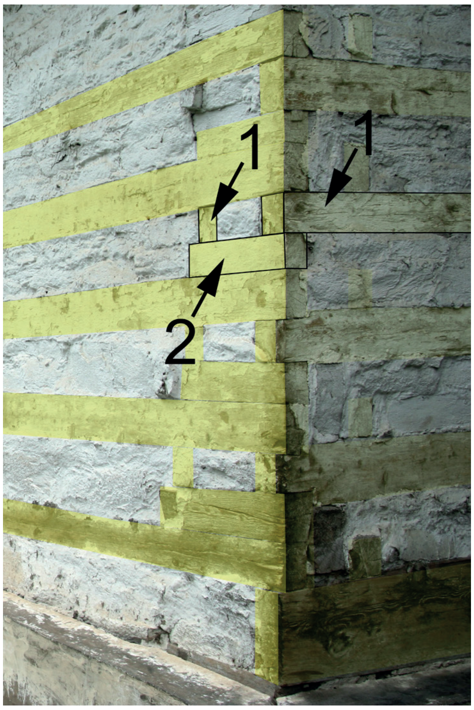
Alt. 2,755 m; 31°33'16.70"N, 78°28'45.84"E. Thangi is a village located on the right banks of the Tedong Valley, which is a side valley of the Sutlej Valley, app. 12 km south of Spillo. Already the entrance gate to the village follows a timber lacing tradition. It is a kind of *dhol-maide* construction with wooden boards closing the open facing ends of the wall between the single *cheol*, similar to the construction from Labrang in Fig. 4.79 but using well-dressed stones. The wall thickness was measured with 41 cm. At 11 x 13 cm (W/H), the timbers are app. square with a vertical distance of 35 cm to 40 cm from each other.

The solid core of village houses (Fig. 4.80) as well as the way the window frames were mounted is close to the technique and precision used at the Labrang Fortress tower. The height of the beams equals the height of several (often two) stone layers (see number 1 in Fig. 4.80). For closing the *cheol* at the corners, various methods were developed: One method that can be found at simple village residential buildings or stables, was already shown for Labrang in Fig. 4.79 by using high wooden boards or beams of the length of the wall thickness. Another method found at *kath-kuni* structures is that the runner beams within the *cheol,* which face inwards, are not of full height filling the vertical interspace between the runner beams (see number 2 in Fig. 4.80). Some of these lower beams are covered with one layer of stones or are laid on top of a layer of stones so as to save wood. Another method is to close the end of a *cheol* with a beam placed between the two runner beams (see number 1 in Fig. 4.81). In this case stones are not visible at the *cheol's* end.

At the temples of Thangi, several layers of stone fill the vertical space between the *cheol* (Fig. 4.82). Since this space is too high to be filled by one beam, a further supporting piece of wood was introduced below each corner crossing of two *cheol* (number 1 in Fig. 4.82). The wall thickness is app. 47 cm. The runner beams are up to 18 cm in height, and the vertical distance between them is also app. 47 cm.

Columns to hold the roof of stables are made as *farque* constructions, not filled with stones, similar as shown at Karla in Fig. 4.73.

Fig. 4.80 (Top) Thangi. Middle Kinnaur. Verandas attached to the *kath-kuni* core of the building.
Fig. 4.81 (Bottom, left) Thangi. A beam fills the interspace between the runner beams.
Fig. 4.82 (Bottom, right) Thangi. Supporting piece (1) of wood below each corner crossing of two *cheol* (2).



4.4.4.e Koti banal (Uttarakhand) for comparison

With a height of up to five storeys, structures in the Yamuna Valley in the Rajgarhi region of Uttarkashi show similarities in shape and building techniques to structures found in several villages of Kinnaur, e.g. in Thangi. As reported by Handa (2008a: 81), in most of the regions of Uttarakhand, the *kath-kuni* wall type is notably uncommon. This type of construction in this region may refer back to app. 1,000 years ago (Rautela, Joshi 2008; Rautela et al. 2008). In Thangi, some parts within one construction may show the use of clay mortar, while other parts appear dry-packed. For this technique at Koti banal (as an example besides other places like Dakhiyatgaon, Guna or Dharali), the use of a paste made of pulses (lentils) as mortar is reported (Rautela et al. 2008). At residential structures in Thangi, wall thickness is between app. 40 cm to 50 cm. Koti banal structures have a wall thickness of app. 50 cm to 60 cm (ibid.). At these structures, a difference to the *kath-kuni* in Kinnaur is the use of wall brackets (also known as shear keys). For a Koti banal construction, the use of lap and nailed joints is documented (Rautela, Joshi 2008: 478).

Kanam, village and temples

Alt. 2,680 m to 2,840 m; 31°40’33.32”N, 78°27’8.93”E. Compared to Labrang, a bigger variety of techniques was found in Kanam. Early residential structures (*khyum*) built of wood and stone go back more than 250 years (ibid. 45, 323). The following examples show a variety of different constructions in this village.

Kath-kuni and *dhol-maide* are commonly used in Kanam. The Palden Lhundup Gephel Monastery (locally known as “Khache Lhakhang”) is situated within a courtyard surrounded by a timber-laced structure, where the vertical interspace between the *cheol* is raised by one or more additional wooden cross-pieces placed at the corners and with a length of the thickness of the wall (number 1 in Fig. 4.83). This method of closing the corner with wooden beams is also shown with an example of a residential structure (Fig. 4.84). At the Kangyur Lhakhang, a *dhol-maide* construction was erected with runner beams of a vertical distance of 80 cm without closing the corners with wooden elements (Fig. 4.85). The wooden cross-pieces (round and square-shaped) were connected with lap joints and alternatingly laid below and on top of the facing beams (number 1 in Fig. 4.85).

A small residential structure was attached to the Kangyur Lhakhang (Fig. 4.86). Walls were built with the *dhaji-dewari* technique on a stone plinth of a height of app. 80 cm above ground level. Wooden pillars were placed at a distance of app. 80 cm on a foundation beam with a beam on top to carry the roof. Each field between these pillars was vertically divided into three smaller fields by horizontal boards, which were fixed with notches in the pillars. In these rectangular frames, two crosswise placed boards diagonally fit into each other. The space in-between the boards is filled with dressed stones and clay mortar. The space between the pillars is partially also used to integrate door and window frames. From a static point of view, the crosswise position of the boards in-between horizontal and vertical elements strengthens the wall against horizontal forces as a kind of ‘wind bracing’. The horizontal timbers keep the construction from falling apart. The *dhajji-dewari* construction can be categorised as ‘restrained’ masonry, pointing to the use of a soft mortar (cf. Langenbach 1989: 24, fn. 22). Wood and stone structures are in general multi-storey with a maximum of three storeys (Negi Loktus 2015: 323).

Fig. 4.83 (Top) Kanam. Middle Kinnaur. Palden Lhundup Gephel Monastery.
Fig. 4.84 (Bottom, left) Kanam. Village house. Timber-laced structure with corners strengthened by additional wooden beams.
Fig. 4.85 (Bottom, right) Kanam. Kangyur Lhakhang. *Dhol-maide* construction.

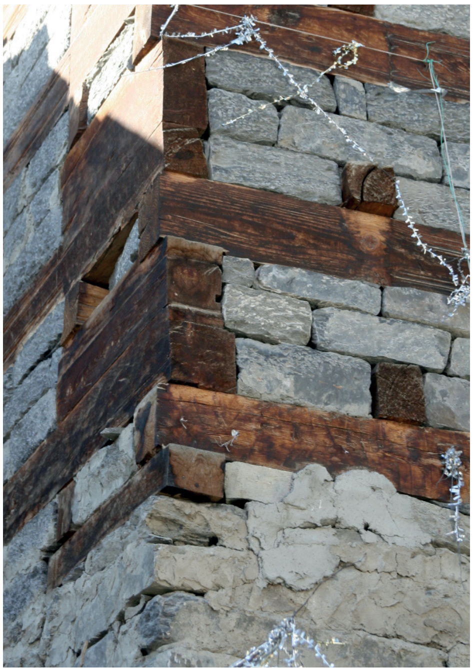


Fig. 4.86 (Left) Kanam. *Dhajji-dewari* structure attached to the Kangyur Lhakhang.
Fig. 4.87 (Right) Kalpa. *Dhajji-dewari* structure on the upper floor of a village house. See arrow.

Kalpa

Alt. 2,760 m; 31°31'53.00"N, 78°15'7.49"E. Kalpa is a hamlet in the close vicinity of Rekong Peo. *Kath-kuni* constructions are traditionally predominant. Some walls are made as *dhajji-dewari*, e.g. as lighter constructions on the second floor of a residential building (Fig. 4.87). The use of *dhajji-dewari* in Kinnaur is in general subordinate to *kath-kuni* constructions. However, for several buildings this technique was also used in this district – similar to the Shimla District located further west, for example, in Sainj according to a drawing given in Dave et al. (2013: 132).

At the ruin of a residential structure, which was made as a *kath-kuni* construction, facing beams (11–14 x 16 cm; W/H) with a height of two layers of stone were documented (Figs. 4.88, 4.89, 4.90). The width of a wall is between 38 cm and 42 cm. The filling between the beams is rubble stone, and ends with a dressed stone.

Ribba Lotsāba Lhakhang (Translator's Temple)

Alt. 2,720 m; 31°34'42.27"N, 78°21'21.06"E. Ribba is a small village on top of the hill along the left bank of the Sutlej River. The Lotsāba Lhakhang was located in a small forest glade with a good view upstream into the river valley. Its foundation can be dated back to the 9th/early 10th century (cf. Klimburg-Salter 2002: 21; Luczanits 1996: 71). In 2006, the author documented the structure of this temple. Unfortunately, it burned down later in the same year. It showed a type of *kath-kuni* construction in a decorative manner – contrary to the commonly simple structural appearance of a *kath-kuni* construction – by using beams protruding from the outer surface of the wall and painting their front black; the rest of the facade was painted white. Just the pillars, window facings and window frames were kept red. A thick layer of whitewash covered the whole facade, while the inside was plastered (Fig. 4.91).

Fig. 4.88 Kalpa. Ruin of a *kath-kuni* village house.

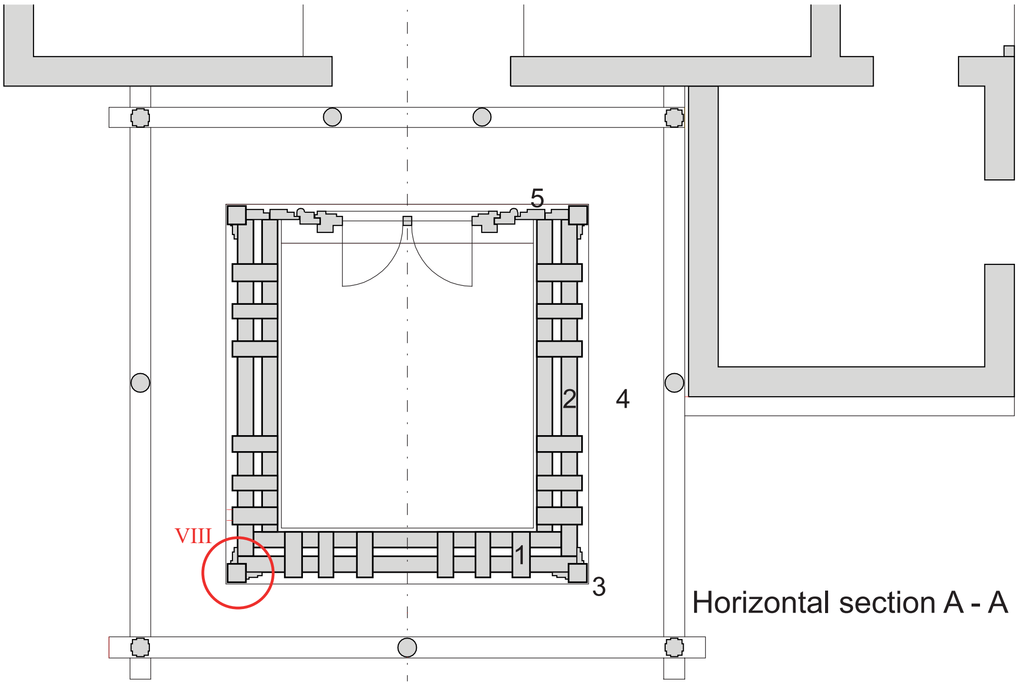
Fig. 4.89 Kalpa. Interior of the *kath-kuni* wall between the runner beams is filled with rubble stone.

Fig. 4.90 Kalpa. Connection of the floor beams to the *kath-kuni* wall structure.

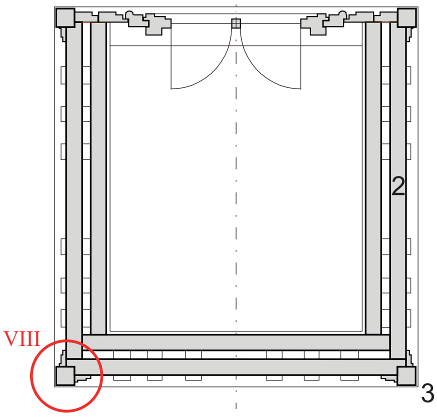
Fig. 4.91 Ribba. Middle Kinnaur. North facade.

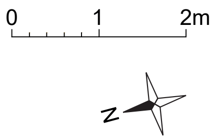
The door entrance was a wooden panel construction. The ground plan of the *garbhagṛha* was app. square with an interior length of the rear wall of 295 cm and an exterior length of app. 390 cm. The wall thickness was app. 47 cm (measured without protrusion of the cross-pieces). The height of the wall measured at its outside app. 4 m (rear wall), at its inside app. 355 cm (Fig. 4.92). Reconstructing the process of construction (from bottom to top), *cheol* were put in position as a plinth layer (see number (I) in the West elevation of Fig. 4.92). In the next layer, cross-pieces (II), which protrude from the outer surface of the wall, were placed on top of the *cheol* and were flush mounted to the inside for later interior plastering. The interspace between these cross-pieces, probably filled with wood, was plastered and whitewashed. A pair of outwardly and inwardly facing runner beams (III) was again laid on top of this layer of cross-pieces, and so on. After the third layer of cross-pieces, the following three layers of runner beams (IV) show carved ornaments. The carved window frame (V) was made as part of the wall construction and fixed between cross-pieces (a) and the heads of runner beams (IV). The window frame at its bottom was connected to the window board (VI). At its top, the window frame was connected to a carved beam, which acted as lintel (VII). The gap between the runner beams at the corner junctions was covered by a corner pillar and adjoining wooden pilaster strips (see number (VIII) in horizontal sections A-A and B-B in Fig. 4.92).

The *kath-kuni* construction at Ribba used timber to a high extent. The roof at the time of survey was a flat roof construction with a covering metal sheet tent roof. Its wooden subconstruction pointed towards a former wooden tent construction, hypothetically covered with wooden shingles as is traditionally common in this region, compared, for example, with the temples in Sunnam or Karla.

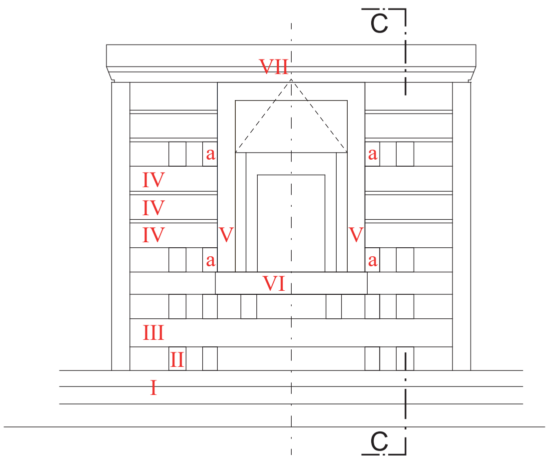


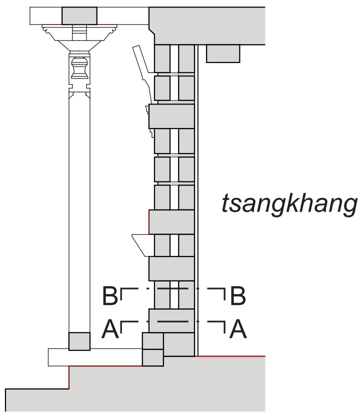
Horizontal section A - A





Horizontal section B - B





West elevation

Vertical section C - C

4.5 Shimla District (Rampur Division)

Sarahan, Bhīmā Kālī Temple

Alt. 2,170 m; 31°30'37.18"N, 77°47'43.15"E. Sarahan is a village embedded in deodar forests. The stones within the *kath-kuni* structure are well dressed. Like in the fortress tower of Labrang (see Fig. 4.77), the high precision of construction has to be emphasised and points towards a way of representing elite status. The front of the stones is precisely flush mounted with the timber construction. As visible at the ends of the *cheol*, the interspace between the runner beams is filled with two further beams – similar to constructions at Thangi (see Fig. 4.81) or at Labrang (see Fig. 4.77). Thus, in a front view there are visible four beams laid beside each other and no further filling material. Lap joints connecting runner beams overlap app. 40 cm.

4.6 Kullu, western Lahaul and Chamba

This part concerns composite wall constructions in the districts Kullu (village of Manali, alt. 1,950 m), western Lahaul (village of Udaipur, alt. 2,650 m) and Chamba (village of Purthi, alt. 2,460 m; Chamba Town, alt. 950 m). The elevation difference ranges at app. 1,700 m and separates this region into different zones regarding availability of particular types of timber and climate conditions. Kangra towards the south continues at low altitude, while towards Zangskar in the north and Lahaul in the east, altitudes increase.

Regarding climate data, Manali in Kullu compared to Spillo in Kinnaur (alt. 2,400 m) shows a higher annual average temperature (15.1°C versus 12.2°C) and about 2.5 times the amount of annual precipitation (1,972 mm versus 710 mm). At 379 mm, the difference between minimum and maximum precipitation during one year in Manali is relatively high compared to the surrounding places: Udaipur in Lahaul with 122 mm, Spillo in Kinnaur with 89 mm and Purthi in Chamba with 157 mm. Places within Chamba District like Chamba Town and Bharmour show higher differences, with 454 mm and 588 mm, respectively. In the whole region, snowfall can be strong. The difference in the annual average temperature between Manali in Kullu and Udaipur in Lahaul with 9.4°C is wider than compared to Spillo in Kinnaur. On the other hand, at 1,057 mm, the difference concerning the annual precipitation in Udaipur is less compared to Purthi and Chamba Town in Chamba District, and Bharmour and Manali in Kullu. Comparing Udaipur in Lahaul and Purthi in Chamba, at app. 2°C the annual average temperature in Udaipur is slightly less and the

Fig. 4.92 Ribba. (Opposite page) Lotsāba Lhakhang. *Kath-kuni* construction.
Top: Horizontal section A-A with a new structure attached to the east.
Centre: Horizontal section B-B.
Bottom left: West elevation.
Bottom right: Vertical section of the west wall.
1 = Cross-piece;
2 = Runner beam;
3 = Corner pillar;
4 = Circumambulation path along the surrounding platform;
5 = Carved door panel.

annual precipitation at 1,299 mm in Purthi slightly higher. A comparison between the annual precipitation in Keylong in eastern Lahaul and Udaipur in western Lahaul shows an increase towards the west, which continues into Chamba District. Due to low altitude, places in Chamba District, like Chamba Town and Bharmour, are warmer with an average annual temperature of 20.7°C in Chamba Town and 15.1°C in Bharmaur. At Purthi, which is located at a higher altitude than Chamba Town and Bharmour, annual precipitation decreases considerably. Of all the discussed places in this region, Chamba Town and Bharmour are hit most by monsoons during July with 480 mm and 609 mm, respectively. All the mentioned regions are forested (see Map 4.5).

Influences on roof constructions by the given climate conditions explain the use of pitched roofs primarily covered with slates in Chamba, Bharmaur and Manali. At higher altitudes, like at Purthi or Udaipur, a change towards flat earth roofs is evident. Exceptions are religious structures such as the Mirkulā Devī Temple in Udaipur or the Hadimba Temple in Manali, which are covered with wooden slats. Handa (2008b: 131) reports of places along the Chamba border on the Jammu and Kashmir side, which prefer flat roofs, although enough deodar would be available. According to Handa (2001: 130), gable roofs may have been a development from a flat roof around the 18th century, and he mentions the Devi-Kothi Temple in Chamba as the earliest example in this region (Handa 2001: 130).

4.6.1 Kullu District

4.6.1.a Investigated objects

Manali, village and Hadimba Temple

Alt. 2,060 m; 32°14'53.73"N, 77°10'50.84"E. Manali is located in the north of Kullu District close to the borders of Lahaul and Kangra. In Kullu *kath-kuni* constructions are common. An example outside of Manali is the castle in Naggar (cf. Bernier 1989: Plate 7). In some parts of Manali (for example, in Vashist and Old Manali) we still find different traditional composite constructions, such as *kath-kuni*, *dhol-maide* or wood frame constructions. In some cases buildings are attached to each other, leaving only a small gap in-between. A connection between two farm houses was simply made by completing the two walls adjoining each other using a *kath-kuni* construction for each of these. At some buildings, the horizontal brown beams between whitewashed filling material increasingly underline the linear structure of the building.

The Hadimba Temple (1553 CE, Handa 2001: 236) is not a *kath-kuni* structure as sometimes propagated, but rather a timber frame structure with wooden pillars and massive horizontal wooden beams in-between.[161] On top of these horizontal beams, which are of the length of the interspace between two posts, wooden cross-pieces are placed, as we know from *cheol* constructions. The filling between the timber elements is either stone or fired brick, though this remains unclear due to the thick layer of whitewash.

161 Cf. pictures (VW02 27,3; VW02 27,4; VW09 1002,1639) in the Western Himalaya Archive Vienna. Online: https://whav.aussereurop.univie.ac.at/ic/, access: 06/2016.

4.6.2 Western Lahaul

4.6.2.a Investigated objects

Udaipur, Mirkulā Devī Temple

Alt. 2,658 m; 32°43'34.32"N, 76°39'44.26"E. Udaipur is a village located along the banks of the Chandrabhaga River. On three sides except along the entrance, the walls of the *garbhagṛha* of the Mirkulā Devī Temple are made as a *kath-kuni* construction using deodar wood. The door entrance is a wooden panel construction. The ground plan of the *garbhagṛha* is app. square with 317 x 306 cm. The interior length of the rear wall and of the lateral walls is 222 cm (Thakur 1996: 95) (Fig. 4.93). The wall thickness is app. 48 cm (similar to Ribba with 47 cm). The height of the wall measured at its outside is app. 257 cm, and at its inside app. 190 cm.

At the corners, wooden pillars are placed overlapping the wall by app. 6 cm (number 1 in Figs. 4.93 and 4.95). The ends of the beams facing one another disappear behind the corner pillars, similar to the Lotsāba Lhakhang in Ribba (see number 1 in Fig. 4.95 and number 3 in Fig. 4.92). The wall is horizontally divided by wooden cross-pieces, which protrude from the wall by app. 6 cm (number 2 in Fig. 4.94). The construction of the layers between the runner beams is hidden behind the wall plaster and the question for the type of building material of this layer remains open. The plaster was not whitewashed and maintains its natural brown colour.

A main difference to the commonly known *kath-kuni* constructions is the use of four corner pillars. These are placed in front of the ends of the outwardly facing runner beams (number 1 in Fig. 4.95), consequently hiding the runner beams' ends. Just beside this pillar the inwardly facing runner beam protrudes from the wall (see number 2 in Fig. 4.95). In comparison, in Ribba the end of the inwardly facing runner beam was covered by a carved blind-wood (compare number VIII in Fig. 4.92).

Since it was not possible to look into the wall construction, these evidences hypothesise, similarly to the wall construction of the Lotsāba Lhakhang in Ribba, that the width of the wall is shaped by the width of two runner beams placed beside each other – keeping the question open for the existence of a horizontal interspace between the runner beams and the type of infill material used for this hypothetical interspace.

This kind of combination of a *kath-kuni* structure and corner pillars shows traces of an early period in the use of the *kath-kuni* system and a possible former use of pillar-based constructions. Regarding the thickness of the walls, the use of corner pillars and of protruding cross-pieces, the building technique applied for making the walls at the Lotsāba Lhakhang in Ribba is close to the one at the Mirkulā Devī Temple. A striking difference between the Mirkulā Devī Temple in Udaipur and the Lotsāba Lhakhang in Ribba is that the builders paid obviously more attention to an artistic appearance of the outer surface at the Lotsāba Lhakhang by carving the outer surface of the runner beams. Conversely, the facade of the *garbhagṛha* at Udaipur remains plain without any further decoration.

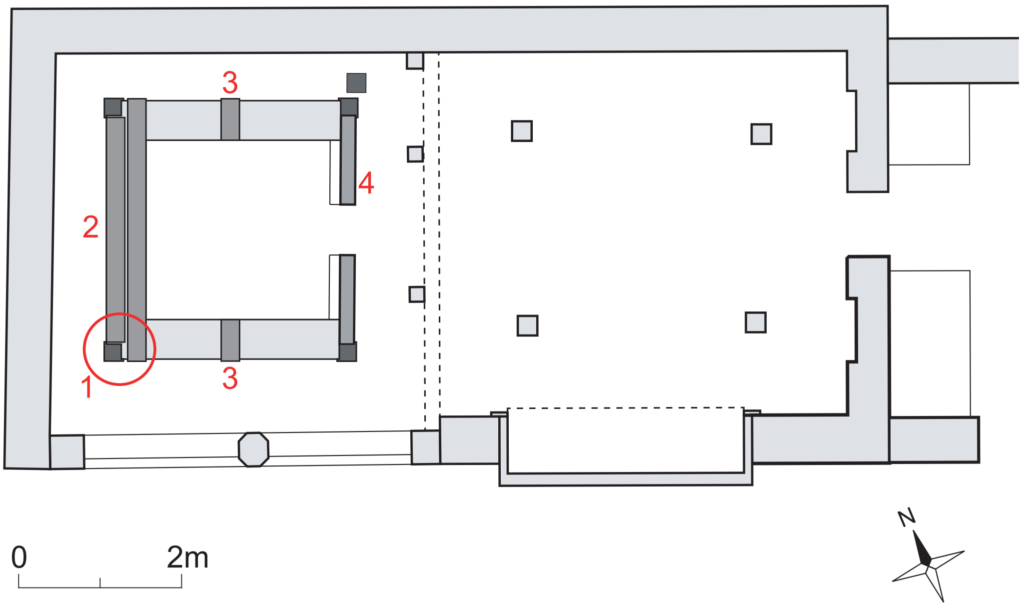


Fig. 4.93 (Top) Udaipur. Lahaul. Ground plan of the Mirkulā Devī Temple with corner pillars at the four corners of the *garbhagṛha*. 1 = Corner pillar; 2 = Runner beams; 3 = Cross-beams; 4 = Wooden door panel.

Fig. 4.94 (Bottom, left) Udaipur. Mirkulā Devī Temple. Circumambulation corridor along a *kath-kuni* wall of the *garbhagṛha* (on the left side of the picture).

Fig. 4.95 (Bottom, right) Udaipur. Mirkulā Devī Temple. Corner pillar at the southern corner of the *garbhagṛha*.

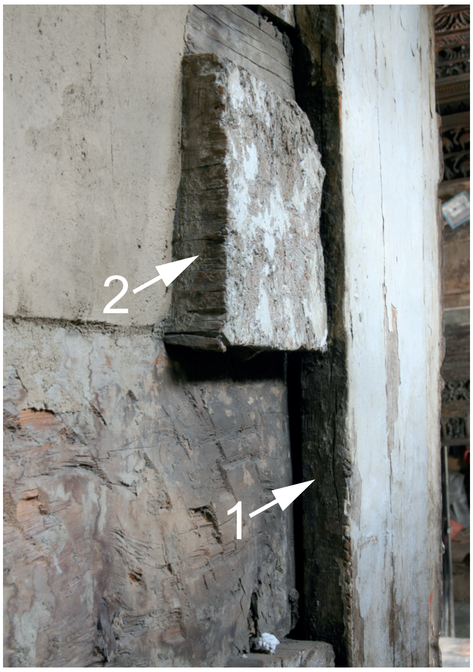


Fig. 4.96 (Left) Purthi. Chamba. Combination of *dhol-maide* and *farque* technique.
Fig. 4.97 (Right) Purthi. Combination of *dhol-maide* and *farque* technique.

4.6.3 Chamba District

4.6.3.a Investigated objects

Purthi

Alt. 2,460 m; 32°54'54.58"N, 76°27'59.15"E. Purthi is a village located in the Chamba District on the route towards Jammu in the north. It is situated along a west-facing slope on the left banks of the Chenab River. At Purthi we find a variety of traditional building techniques. Some recent two-storey buildings were constructed purely with stone without any content of timber. *Dhajji-dewari* constructions show close similarities to those observed in the adjoining province Jammu and Kashmir, where this technique is commonly used. A variation of the *dhajji-dewari* construction as found in Purthi shows diagonally placed boards within a wooden frame, which spans over the whole height of a floor, being vertically divided into several smaller fields – similar to a *dhajji-dewari* construction as observed in Kanam in Fig. 4.86.

The *kath-kuni* technique is widely used. A particular type of a *kath-kuni* construction as found in Purthi shows a mixture of a *farque* construction and a *kath-kuni* construction, with every second or third wooden beam of the *farque* construction running along the whole facade (Figs. 4.96 and 4.97) – similar to the description of the *cator and cribbage* technique given by Hughes (2000a). In some cases the dimension of the single beams is relatively large, as shown in Fig. 4.96.

Ravi Valley

For the Ravi Valley, Postel et al. (1985: 298) describe a common method of construction using the *farque* technique at the corners in combination with *cheol*. Schist quarries in the close vicinity have a strong influence on the design of traditional architecture in Bharmour.[162]

162 Particularly in the close vicinity to Bharmaur (see aforementioned), a schist quarry supplies the whole region with high-quality material.

Fig. 4.98 (Top) Bharmaur. Chamba. Corners made as *farque* construction and the wall in-between as *dhajji-dewari* construction.

Bharmaur

Alt. 2,170 m; 32°26'31.55"N, 76°32'15.96"E. Bharmaur is a village located about 28 km south-east of Purthi. Due to its position on a slope, it faces north into the Chenab Valley and west into the Ravi Valley. The village of Bharmour shows a similar variety of building techniques, as is the case in Purthi. Some buildings show a combination of a *farque* construction at the corners of the building with the walls in-between made as *dhajji-dewari* constructions (Figs. 4.98 and 4.99). The *farque* technique seems to be more common in Chamba than in Lahaul, Kullu or Kinnaur. Several *dhajji-dewari* constructions follow the type as described at Purthi, with diagonally placed boards within a wooden frame, which spans over the whole height of a floor, being vertically divided into several smaller fields. Fig. 4.100 shows the use of a *farque* construction at the corners of a three-storey construction. At houses built adjacent to each other, the *farque* constructions are built close to each other but without any further structural connection.

Also in Bharmaur, *kath-kuni* is a commonly used building technique. The Lakṣaṇā Devī Temple at Bharmaur (c. 680 CE, Handa 2001: 136), whose *garbhagṛha* measures 420 x 300 cm outside and 312 x 200 cm inside with a wall thickness of 80 cm to 85 cm (Thakur 1996: 90), is described as a clay-plastered timber-bonded structure (Handa 2001: 138, after: ASI report by Hargreaves 1929: 17). The mentioned wall thickness of 80 cm to 85 cm appears rather strong compared to an average wall thickness of *kath-kuni* constructions.

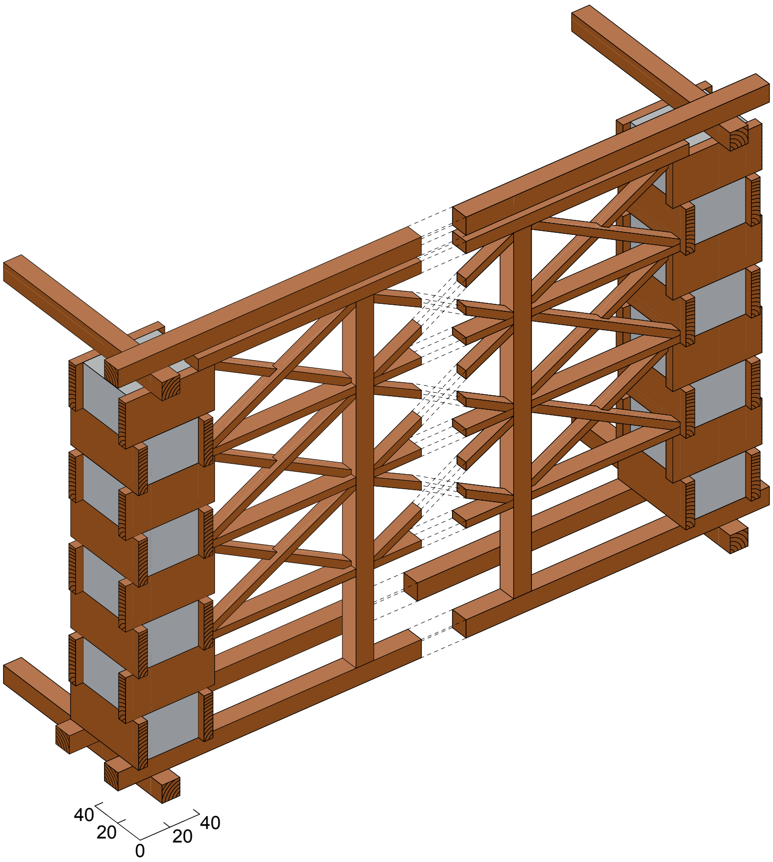


Fig. 4.99 (Below) Bharmaur. Combination of *farque* and *kath-kuni* construction.
CAD: Martin Pospichal. Details provided by the author.

Chhatrarhi

Alt. 1,825 m; 32°26’49.51”N, 76°22’31.10”E. The use of the *kath-kuni* technique at early wooden temples in Himachal Pradesh may point towards an early introduction or development of this technique, with the Śakti Devi Temple in Chhatrarhi in Chamba dating back to the late 7th/early 8th century (cf. Handa 2006: 90; Bernier 1989: 38). The dimensions of the ground plan of the *garbhagṛha* with 314 x 342 cm inside and 438 x 480 cm outside are bigger than those measured at the Mirkulā Devī in Udaipur. Further, the thickness of the clay-plastered walls, which is between 60 cm and 65 cm (cf. Thakur 1996: 92), resembles a size of *kath-kuni* constructions, with a width of the infill space between the facing runner beams being larger than is the case at the Mirkulā Devī Temple in Udaipur or at the Lotsāba Lhakhang in Ribba (where the wall thicknesses are just 48 cm and 47 cm, respectively).

Fig. 4.100 Bharmaur. *Kath-kuni* construction.

4.7 Discussion

The investigation of local building techniques and their structural adaptation to local resources reveals striking facets in the development of building methods. Technical details, choice of materials, quality of workmanship and representation of a particular cultural identity are locally defined. On the one hand, the development and organisation of certain crafts and building techniques are influenced by local and regional parameters and need to be understood in a local context, and on the other hand, they need to be considered as part of a wider context, which even includes neighbouring regions and beyond.

Inter alia, climatic parameters are dependent on altitude, and the respective local material resources are an essential basis for certain technical developments. The availability of wood, stone and clay and the respective quality of the locally-available building materials allow a variety of material combinations and mixtures. The resulting developments in building techniques cannot be understood in a linear way, but as a complex interdependence between natural and cultural preconditions. For example, increasing availability of wood locally resulted in local building techniques going from a 'simple' timber lacing, not using 'ladder-like ring beams, to a *dhol-maide* construction to a *kath-kuni* construction – all three being distinct types of constructions requiring individually-adapted craft techniques.

The intent behind the use of composite constructions is to strengthen a particular structure based on the optimised use of local resources. This technical optimisation responds to specific needs, on the one hand, and is also the product of a trial-and-error approach that yields construction experience and leads to the avoidance of failure. Here, long-term experience with structural movement must have played an important role, and which has led to a common understanding regarding the choice of building techniques. Timber lacing in the walls, for example, is connected to the ceiling and roof system, and together they form a three-dimensional static concept. Spanning thousands and thousands of kilometres from the Mediterranean to the Himalayas along a seismically active zone, such composite constructions developed as culturally-interrelated building traditions. This kind of collective experience and the resulting structural interventions can be considered to be a 'seismic culture'.

Over time, traditional building techniques have been adapted and changed. Viewed over several centuries, a specific building technique cannot necessarily be attributed to an immutable local technique, since it may have changed in the course of time for various reasons. Stone, clay and wooden structures, and the different methods of processing and applying them are evidence of this continuous change in the context of local resources. The main temples of the early historical West Tibetan monasteries are an example of this. They were consistently built with adobe bricks, although the development of vernacular structures in the areas surrounding the monasteries shows the use of different building techniques, as we can see in Tabo in Spiti or in Khorchag in Purang. Early examples of structures give us an idea of traditions in a certain historical period and allow us to make hypotheses regarding possible developments. And similar to a particularly homogenous earth building tradition in early historical West Tibetan monasteries, a particularly homogenous wood building tradition can be observed in early wooden temples in Himachal Pradesh, even though each wooden structure has its own local expression regarding the size and proportion of the individual construction components. As shown with the structures of early wooden temples in Chhatrarhi, Bharmaur, Udaipur and Ribba, the length of timber used for the garbhagṛha ranges between 3 m and 4.8 m. The wall thickness ranges between 47 cm and 85 cm.

In the following list, construction data for early structures are juxtaposed, according to the sources given before:

Site	*Temple*	*Max. length of runner beams*	*Wall thickness*
Chhatrarhi	Śakti Devi Temple	480 cm	60 cm to 65 cm
Bharmaur	Lakṣaṇā Devī Temple	420 cm	80 cm to 85 cm[163]
Udaipur	Mirkulā Devī Temple	317 cm	48 cm
Ribba	Lotsāba Lhakhang	390 cm	47 cm

The local type of roof construction is an indicator of the interplay of environmental factors and material resources. At higher altitudes, the traditional roof is flat and made of clay or *arga*. By contrast, in Himachal Pradesh, at altitudes of about 2,800 m or less, this resulted by tradition in a preference for a pitched roof covered with stone slates, wooden shingles or wooden slats. However, this cannot be considered as a general rule because, for example, in North Pakistan, which borders Ladakh to the north or further west in Nuristan, an east Afghan province, which borders Pakistan, flat roofs are also commonly used at lower altitudes.

In the Western Himalayas, composite constructions were erected in addition to solid stone and earth constructions. For these, the content of wood changes according to local availability, climate conditions and altitude. Several basic types of construction can be observed for the Western Himalayas, being connoted with different local designations. In the following list, the different types of constructions are ranked according to an increasing content of wood.

1. 'Simple' timber lacing (which does not consist of a ladder-like pair of runner beams but only of single runner beams at each layer of timber lacing)
   - Type a. not acting as a ring beam
   - Type b. acting as a ring beam

2. Ladder-like timber lacing acting as a ring beam (local terms: *ker, cheol*)
   - Type a. with the vertical distance between the runner beams of a height of more than one beam ranging up to the height of one storey: using only horizontal wooden components (local terms: *bhatar, taq, dhol-maide*)
   - Type b. with the vertical distance between the runner beams equalling the height of one beam or a multiple of a beam's height: using horizontal wooden components combined with vertically-arranged wooden 'column-like' corner components (known as *cator and cribbage* or locally as *kath-kuni*)

3. Timber frame constructions (local terms: *dhajji-dewari*)

163 A value of 85 cm for the wall thickness, as given by Thakur (1996: 90) for the Lakṣaṇā Devī Temple, seems to be rather high for a timber construction, for example a *kath-kuni* construction, and its verification will be part of further research.

These different types of Western Himalayan constructions show a different content of wood; the amount of load-bearing components such as stone or clay changes. Within this study, in particular for Himachal Pradesh, the author observed that construction methods were adapted very sensitively to keep step with changes in topography, altitudes, and timber requirements. Regarding this step-like change from higher to lower altitudes, as a first step of transformation, solid stone and earth structures with a low content of wooden components become solid structures with an increased content of timber but still working with stone and clay as the primary load-bearing components. In the next topographical-change step, the content of wood increases by such an amount that the load-bearing wall components become free-standing timber skeleton structures with stone infill. The individual phases of structural change are depicted in Fig. 4.101.

The cator and cribbage constructions of *kanqah*s in Kashmir, for example, are referred to as "wooden structures" in a resource mapping conducted by INTACH (2010). This designation corresponds to their structural nature, since, from a static point of view, they act as freestanding wooden structures, in some cases even without a stone infill.

Today, in Ladakh, the use of timber lacing is rare, whereas for historical structures, it was more common. In early West Tibetan temples, the use of 'simple' timber lacing not acting as a ring beam can be traced back to as far back as the 10th century. Regarding the aforementioned examples of early timber lacing, the use of timber lacing acting as a ring beam was already common in Ladakh in the 15th/16th century, and if we look at the construction of the Chigtan Monastery, the use of the latter technique may even go back as far as the 11th century. The construction of the central part of the castle of Chigtan points towards this border region being a transition zone for the assemblage of different building techniques, ranging from a predominant arid zone with solid stone and earth constructions to constructions with a high content of timber.

Wall brackets (or shear keys) are traditional, and in some areas, like Uttarakhand, they are commonly used in vernacular architecture. To the north of Ladakh, close to Pakistan, the use of stone constructions and of solid construction-strengthening timber lacing increases. Crossing the northern border towards Pakistan, this feature exhibits a kind of regularity with local variations, stretching from the Pakistan-Indian border, following the Shyok River into the Skardu district, via the Gilgit district and further on to the west to the Swat Valley, the Chitral district and into Nuristan. Along this route the altitude decreases, the amount of forest area increases, and with this, the increased amount of timber used in solid wall constructions results in timber-rich techniques such as *cator and cribbage*. Along the whole route, stone (primarily quarried stone) is a prime building material.

Similar developments can be observed when crossing the Zoji la from Kargil towards the west and entering the Kashmir Valley. In Srinagar the predominant construction is already primarily a wooden construction with brick infill. Kashmir is another zone of transition and interface of different composite building techniques. Environmental conditions and raw material resources support the development of composite constructions based on wood. Using fired brick is also based on the availability of wood for firing and a suitable quality of clay. *We find cator and cribbage* constructions – similar to those in North Pakistan – dating back to at least the 13th century, and *taq* constructions (similar to *bhatar* in north-western Pakistan) dating back at least 200 years, although the latter were possibly even used much earlier, in the 13th/14th century.

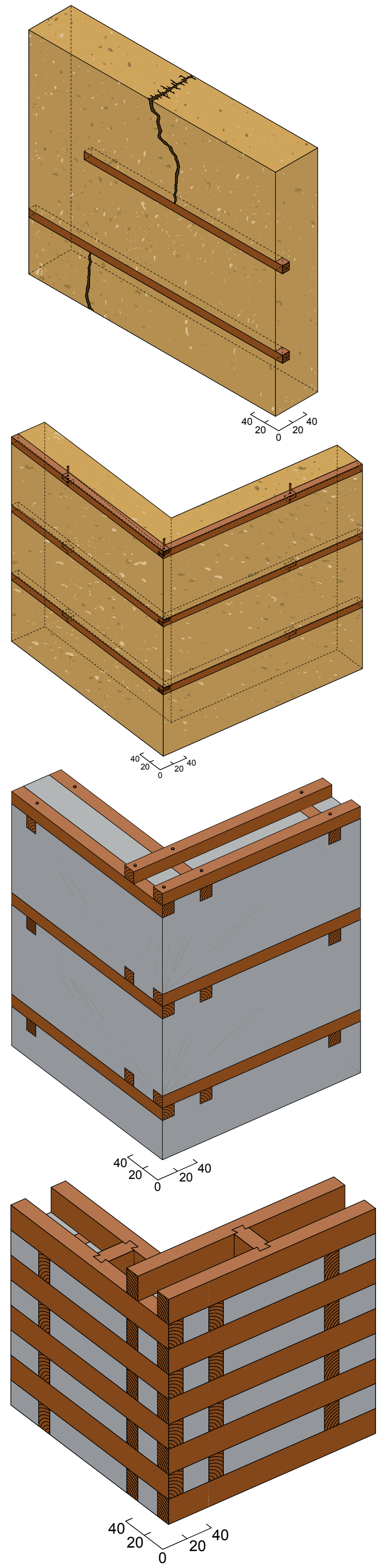


Fig. 4.101 Phases of structural change from solid clay and stone constructions (top) towards timber-based constructions (below). CAD: Martin Pospichal. Details provided by the author.

The ‘ladder-like timber lacing (*taq*) was optimised by modularly alternating between piers and bays within the wall construction. The introduction of fired bricks with a minimised height (similar to findings at Safranbolu in Turkey) allows us to formulate a hypothesis that the builders’ intent was to optimise the solid structures’ earthquake-resistance. *Dhajji-dewari* constructions are often found in Kashmir and can be found as subordinate techniques in surrounding regions such as Chamba, Shimla or Kinnaur. This type of construction is mainly related to a timber frame tradition which extends westwards from the Western Himalayas and continues towards Europe in different local constructive forms. For roof and wall constructions, we can also observe a focal point for various types developing alongside each other or even merging, as they do in Kashmir, for example, where we find earthen flat roofs, pitched roofs covering earthen flat roofs and pitched earthen roofs.

Himachal Pradesh offers a wide variety of facets of Western Himalayan developments in building techniques. At higher altitudes (including early evidence from the period of historical West Tibet in the late 10th century), reduced timber resources supported the development of solid structures made mainly of stone and clay. The availability of suitable raw material enabled this development. In this context, “suitable” in a vernacular context has to be understood to mean “available in the vicinity and capable of being quarried and processed in an energy-efficient manner”.

Structural changes from solid structures into wooden structures occur at higher altitudes, for example, between eastern Lahaul and Middle Kinnaur in the east of Himachal Pradesh, and Chamba and Kullu in the west. A transition zone from purely solid structures with a reduced content of timber towards timber-rich structures such as the *dhol-maide* can be found at an altitude of approx. 3,000 m. Examples of this transition zone are the tower at Gondhla, which is mainly a stone structure combined with the *dhol-maide* technique, the Old Temple of Ropa, which is one of the first villages reached when approaching Kinnaur from the north, where the *dhol-maide* building technique is commonly used, and the village of Labrang in Middle Kinnaur, where *dhol-maide* and *kath-kuni* constructions are found alongside each other.

Many of the traditional constructions – especially at altitudes of around 3,000 m and below – have not been plastered on the outside. One physical aspect of a faster humidity transport and a faster drying process within walls may explain the avoidance of plaster in regions with increasing rainfall below 3,000 m. In structures representing a particularly high social status, timber components were processed in a more elaborate manner. Highly-developed craftsmanship for a particularly well-processed design allows and emphasises this development, which we can observe in solid stone and clay structures as well as in wooden constructions.

With decreasing altitude, the content of wood in wall structures increases and changes from a *dhol-maide* into a *kath-kuni* construction with an increased amount of wood. A *kath-kuni* construction assembles features of a horizontal *dhol-maide* construction and a vertical *farque* construction. In Himachal Pradesh, *farque* constructions are found in Chamba and to a lesser extent also in Kinnaur. The use of the *kath-kuni* technique might date back to the 7th/8th century. Pillars at the corners of some of these early structures (e.g. in Udaipur or Ribba) may hypothetically point towards a more common earlier use of post and beam constructions.

Regarding constructions found within this study at altitudes above 2,000 m, altitude-dependant continuous technical modifications show the local adaptation of construction techniques to local building material resources and environmental conditions. Building cultural transition zones make these developments particularly evident. And tracing developments from higher to lower altitudes shows a smooth transition from solid earth and stone constructions to stone-wood dominated constructions. At higher elevations, we mainly find solid building structures, primarily earth and stone buildings with minimal wood content, but as wood availability continuously increases with the decrease in altitude, construction methods show an increasing proportion of wood – and not just simply more wood, but the timber construction techniques themselves change to adapt to the higher proportion of wood.

V. SUMMARY AND FUTURE PERSPECTIVES

1. Summary

Covering a thematically broad field, this book attempts to examine the material aspects of craft and building traditions approached from different angles: from a micro perspective such as looking at mineral properties, to a macro perspective including looking at the materialisation of spatial programmes. Methodologically, a variety of different tools from the fields of architecture, anthropology and geology, like building survey, interviews, participant observation, and clay mineralogical examinations in the laboratory allowed the author to go beyond mono-disciplinary perspectives.

In Tibetan Buddhist culture, the consideration of objects in a religio-political and ideological context is a trigger for particular material cultural developments, and these express themselves in the spatial-material definition of settlement structures as well as in the design of individual building structures, and in the choice of craft techniques and building materials. Various steps are taken to materialise an ideological programme, such as designing the layout of sacred buildings according to specific proportions and patterns of geometry and orientation. In this context, the selection of materials has a significant impact on the surface design of architecture and artefacts. The choice of raw materials and methods of processing are connected to the representation of a particular social status. This study sheds light on the interrelation between an ideological programme, its spatial manifestation and its interconnectivity with behavioural patterns of the local community such as circumambulation rituals. Not only the use of particular precious materials, such as *arga* for roofs and floors, but also the method of processing the materials connects the process of "making" with a material symbolism within the ideological programme.

Material and materiality in their totality play an essential role in shaping the identity of those who commission or construct a building, as well as of those who use it, such as monks, pilgrims, or farmers, for example. Various crafts are technically related to each other through an exchange of craftspeople and through similarities of material properties and production methods. Vernacular building and craft traditions are based on local knowledge and allow the study of a sustainable construction approach by using a variety of locally-available resources. This vernacular approach shapes various production processes, such as brick-making, the construction of roofs and floors, or the production of plasters. Vernacular knowledge of building and craft traditions have evidently been fused, using as a basis an integral understanding of materials and techniques, as has been demonstrated in this book exemplarily with crafts, such as pottery, clay sculpture production and stove-making. The processability of particular regionally-available materials – for example, polishing the clay surfaces of pottery, sculptures or roofs – led to specific manufacturing standards which, in turn, enabled the codification of certain symbolic and social hierarchical expressions.

Furthermore, by exploring the finest components of materials, we can discover a lot about local building methods. Clay mineralogical research methods allow us to examine building materials and to draw conclusions about the processing techniques used. An understanding of the complex interplay of material components and their processing by different types of craftspeople suggests a lively transfer of knowledge within local communities. This study reveals such complex interrelations by examining mineral components processed in bricks, roofs, plasters, stoves and pottery from two villages in Ladakh.

This study demonstrates the impact of the natural environment on vernacular architecture, on the development of particular building techniques and on building design. Raw material deposits, climate and earthquake zones are interdependently reflected in vernacular decisions on the choice of building techniques and design. Local resources and the material properties of locally-available building materials, and their interaction with climatic conditions and altitude are striking aspects in triggering developments in crafts and building traditions.

An investigation into the Western Himalayas shows fluid transitions in the environmentally-triggered development of stone-clay-wood composite constructions. The respective proportion of material components is rather sensitive to changes in environmental conditions. Connected to this change, an interaction between the local development of building techniques and locally-rooted methods of processing materials go hand-in-hand. Beyond local characteristics, a striking result of this study is that it shows a regionally-superordinate context in the development of a collective understanding of building traditions. One example of this is building techniques in the context of a 'seismic culture', an aspect which suggests that local communities are flexible in how they adapt to environmental changes, over great distances, from the Himalayas to the Mediterranean.

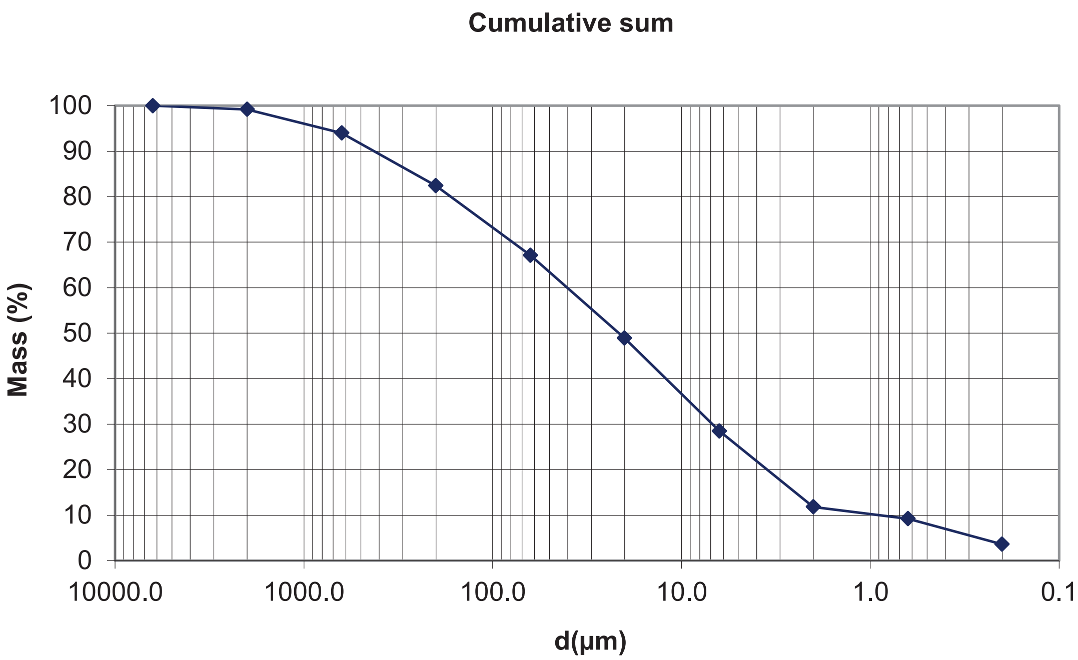
2. Future perspectives

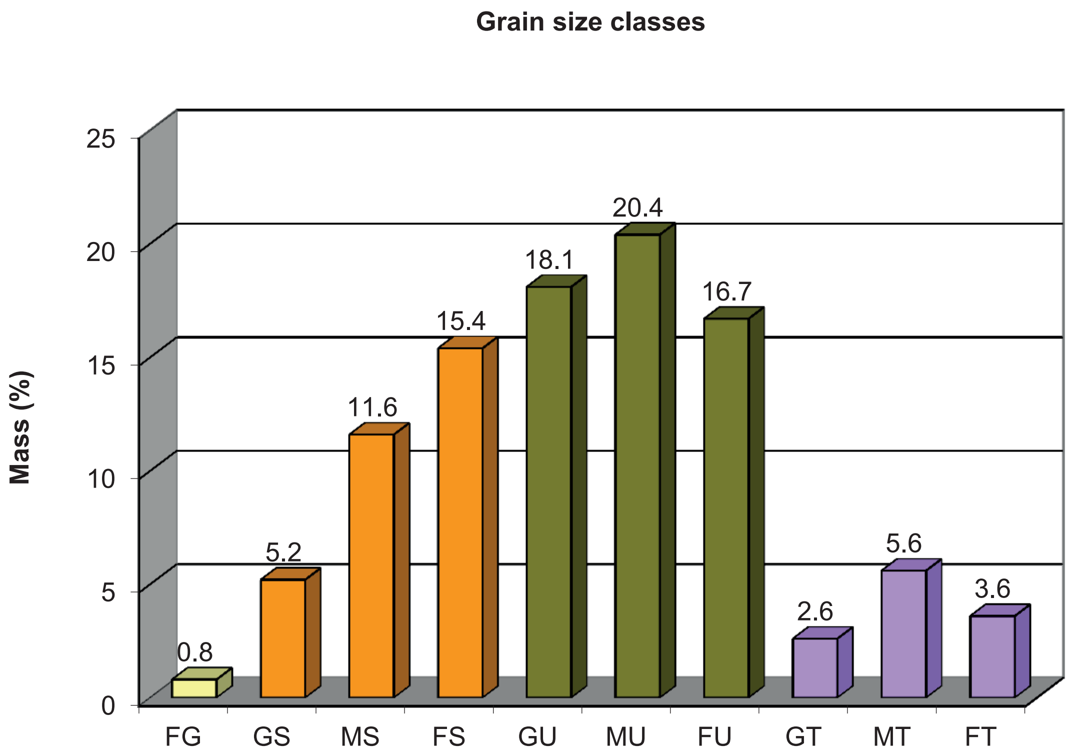
Material culture in a vernacular context is a multi-disciplinary challenge. Based on the research results, further focus on crafts and building traditions in an anthropological context might be promising to achieve a more holistic picture of the interrelation between building materials, building techniques and communities of craftspeople in various regions of the world. The examination of building materials and processing methods requires the interdisciplinary combination of technical and natural sciences, and humanities. The transformations of crafts and crafts(wo)manship, including historical, contemporary and future aspects, are a challenge for future research. Furthermore, research on the sustainability of local traditions in an economic, ecological and social context would allow us to question contemporary developments, to learn from tradition and to direct developments sustainably into the future. Building sites, workshops, transport and trade, or social-status-defining qualities as potential triggers of change are all factors which exert a strong influence on knowledge transfer among craftspeople.

Little is known about the processes and effects of the transformation of craft traditions, not only in terms of technical aspects, but in a wider sense, their impact on social and ecological developments. Each populated area of the globe deals with this topic in its own way. The Himalayas are suitable for investigations of this kind because of their diversity in many aspects. Finally, research on this topic will be needed in a wider and even in a global context.

VI. APPENDIX CHAPTER III

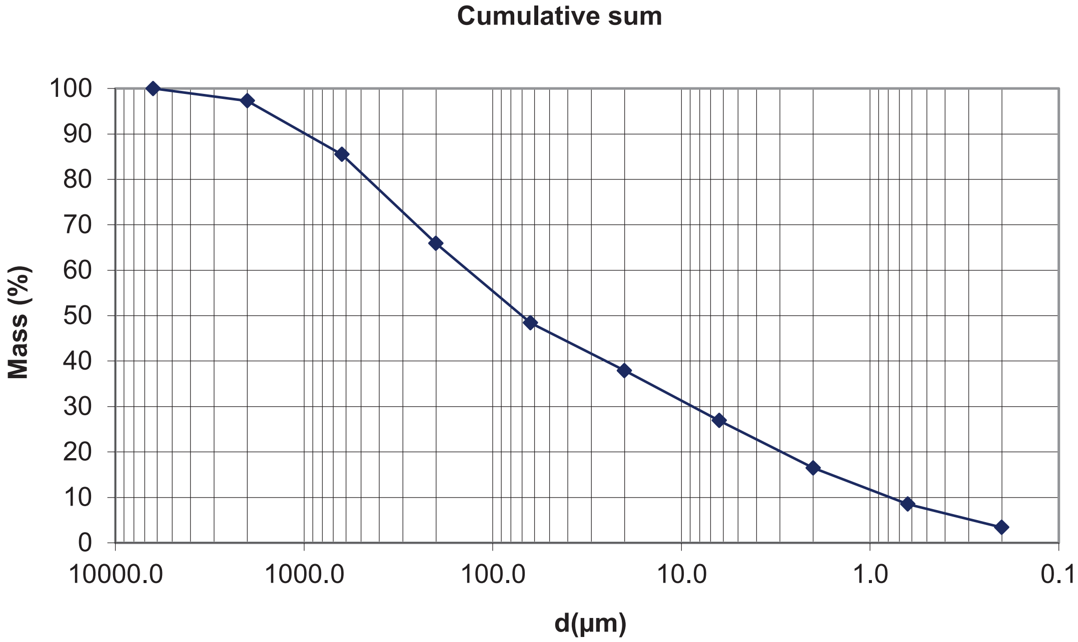
8469 – Basgo
Maitreya Lhakhang. Plaster on pillar.

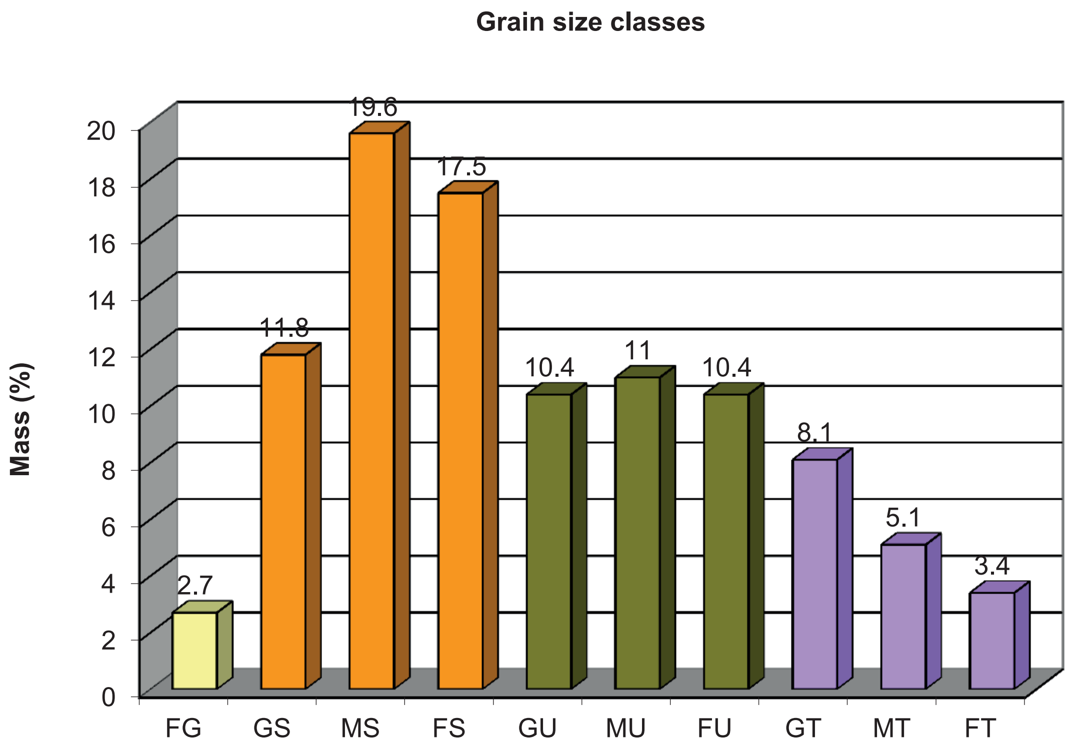




GSD 3.1 Basgo. Maitreya Lhakhang. Sample 8496. Plaster on pillar. Top: Cumulative sum. Bottom: Grain size classes.

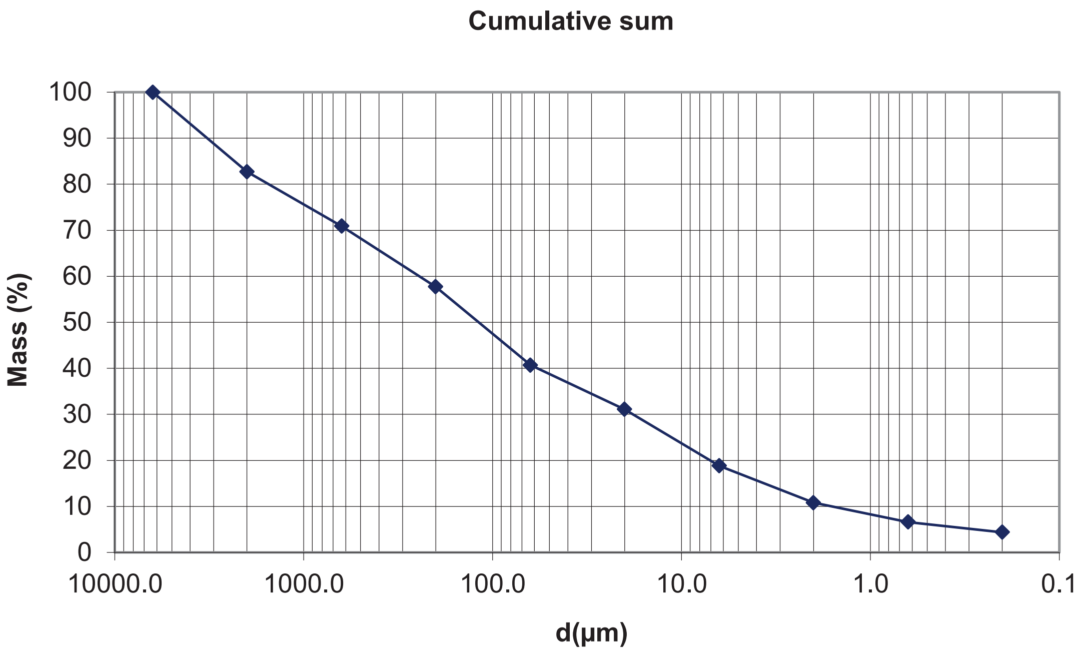
8479 – Basgo
Maitreya Lhakhang. Plaster on pillar.

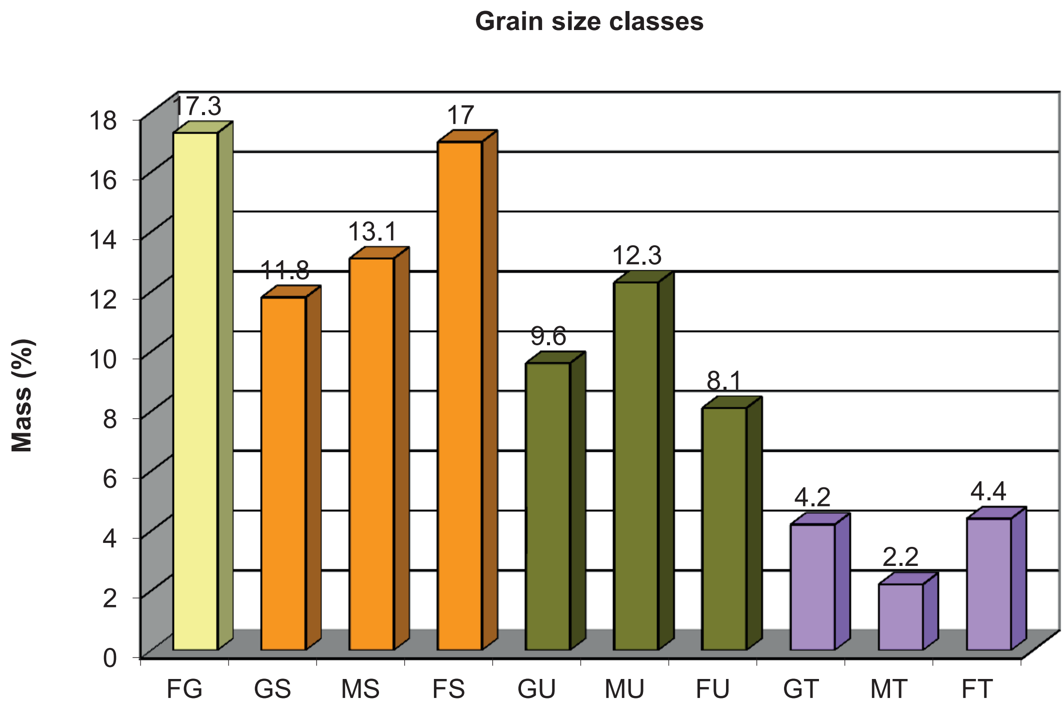




GSD 3.2 Basgo. Maitreya Lhakhang. Sample 8479. Plaster on pillar. Top: Cumulative sum. Bottom: Grain size classes.

8496 – Basgo
Maitreya Lhakhang. Plaster on pillar.

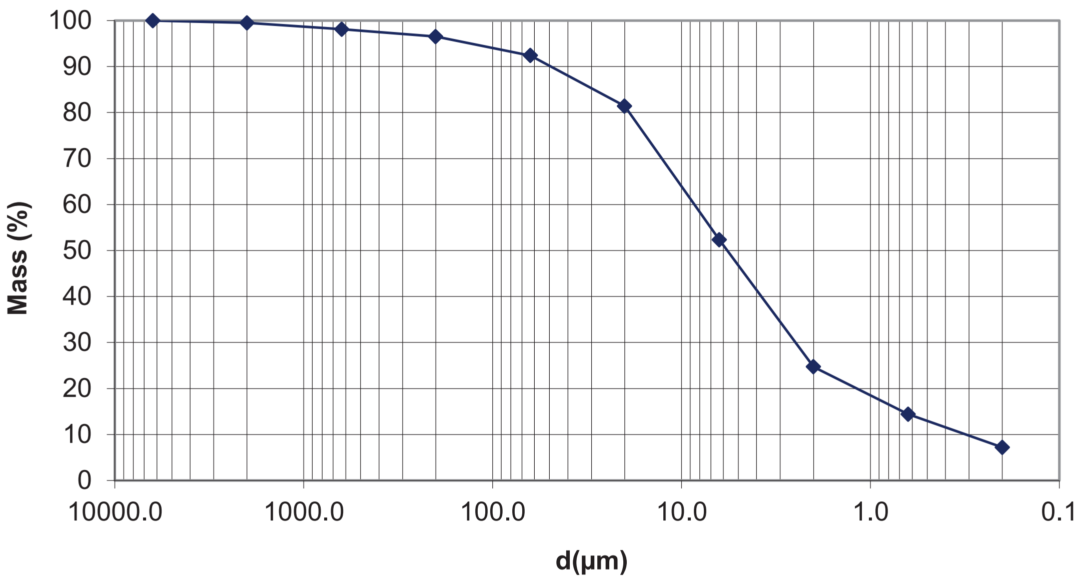




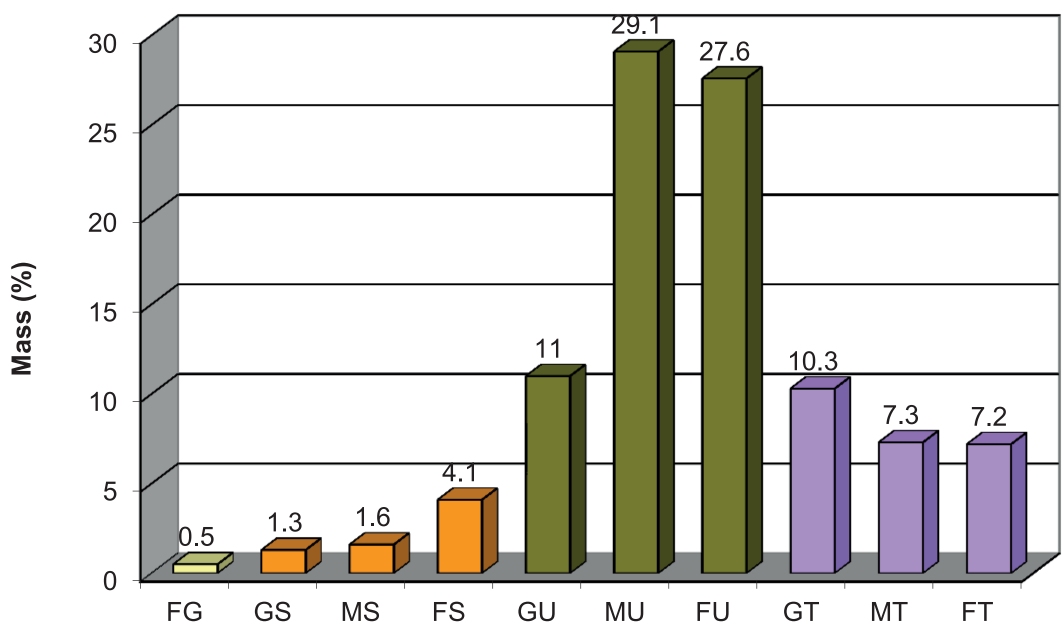
GSD 3.3 Basgo. Maitreya Lhakhang. Sample 8479. Plaster on pillar. Top: Cumulative sum. Bottom: Grain size classes.

8482 – Basgo
Lotsāba Lhakhang. Interior wall plaster.

Cumulative sum



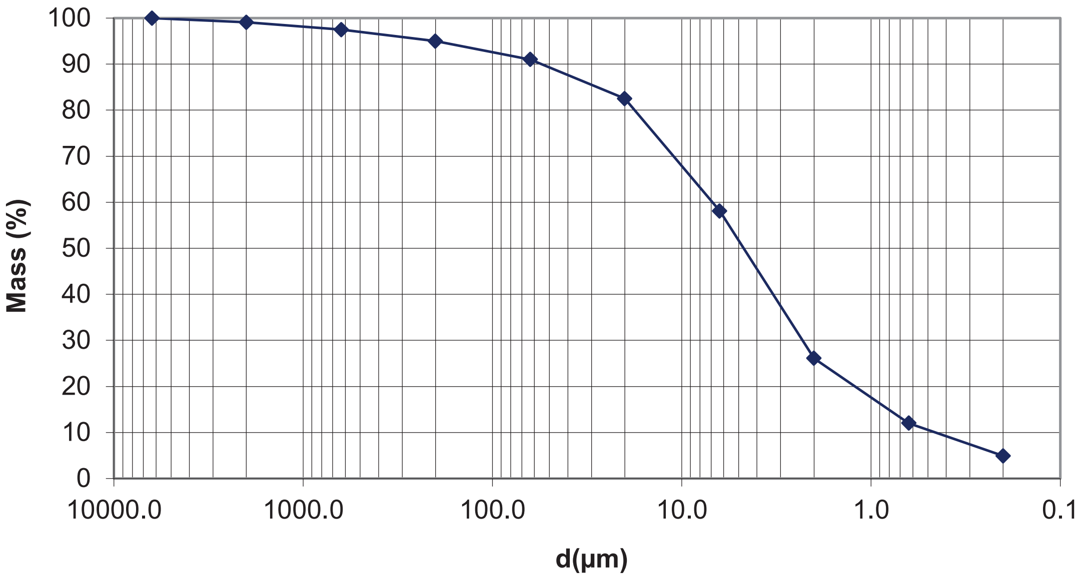
Grain size classes



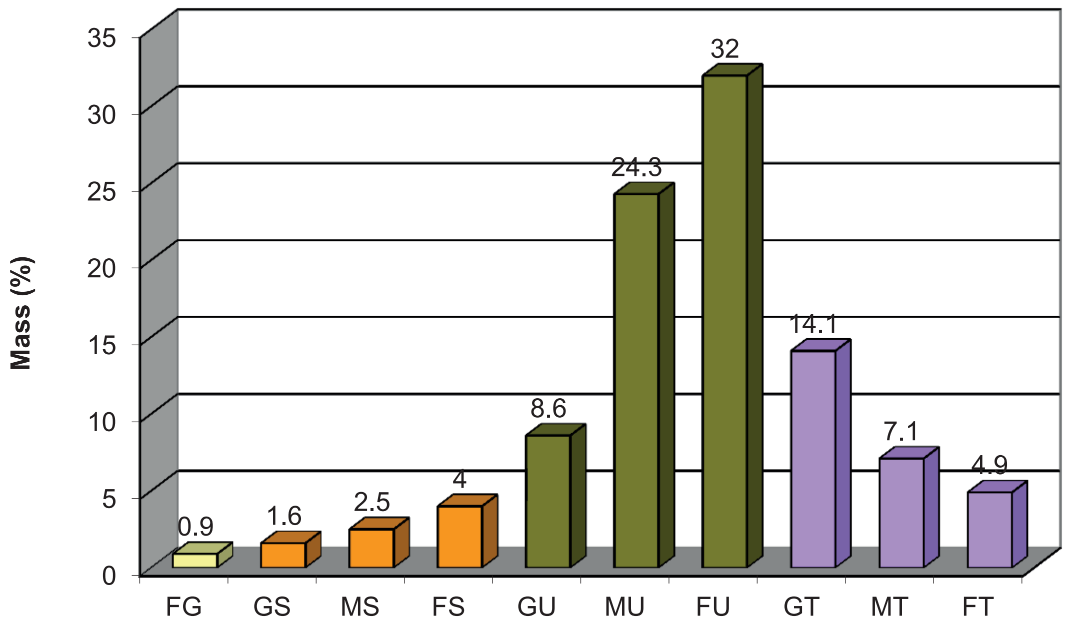
GSD 3.4 Basgo. Lotsāba Lhakhang. Sample 8482. Interior wall plaster.
Top: Cumulative sum. Bottom: Grain size classes.

8483 – Basgo
Lotsāba Lhakhang. Interior wall plaster.

Cumulative sum



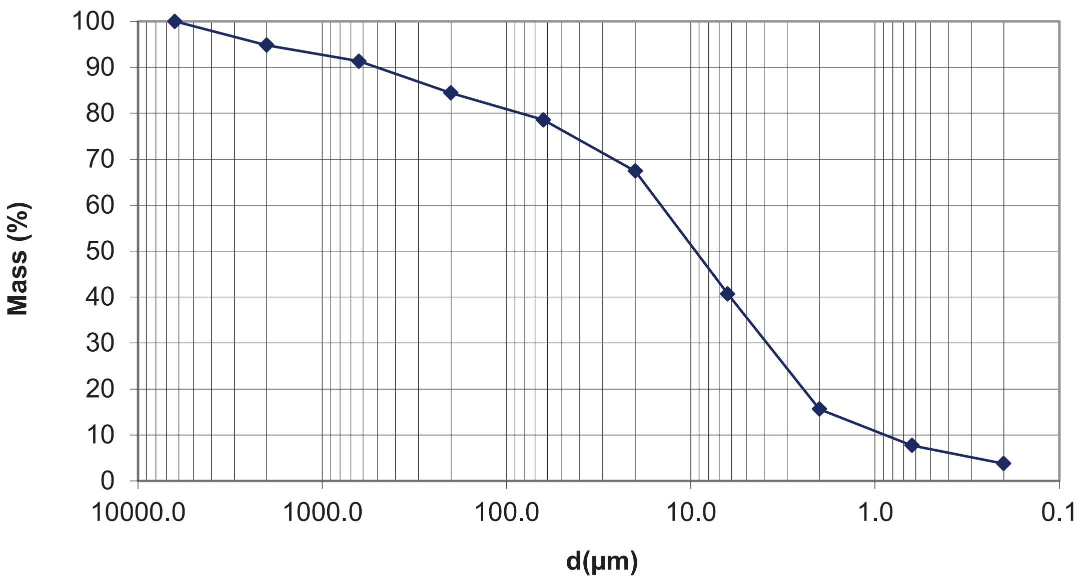
Grain size classes



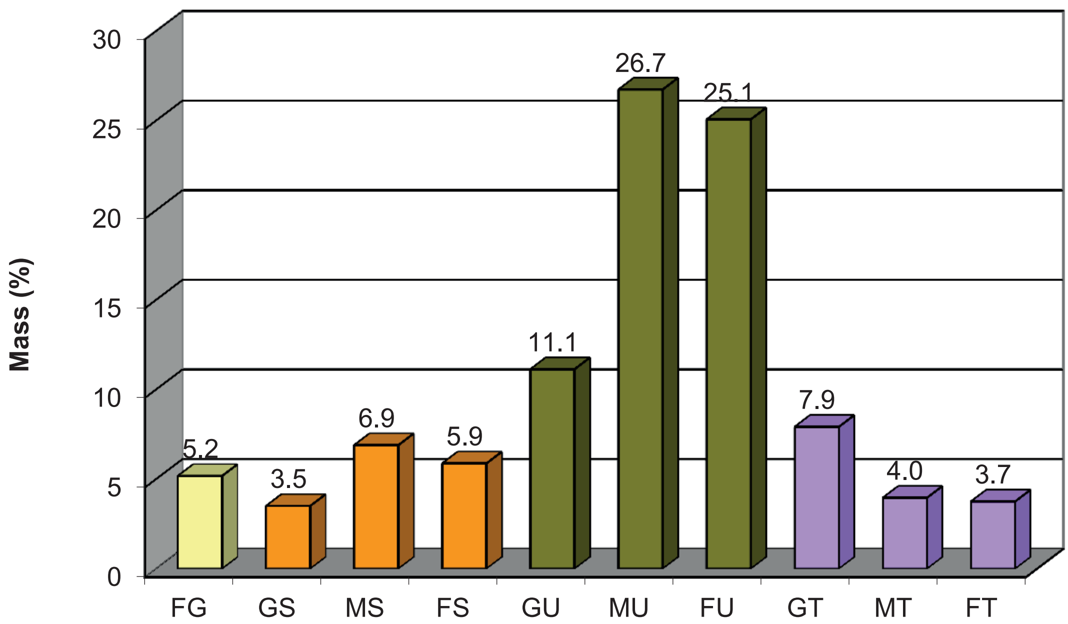
GSD 3.5 Basgo. Lotsāba Lhakhang. Sample 8483. Interior wall plaster.
Top: Cumulative sum. Bottom: Grain size classes.

11946 – Basgo
Lotsāba Lhakhang. Interior wall plaster.

Cumulative sum

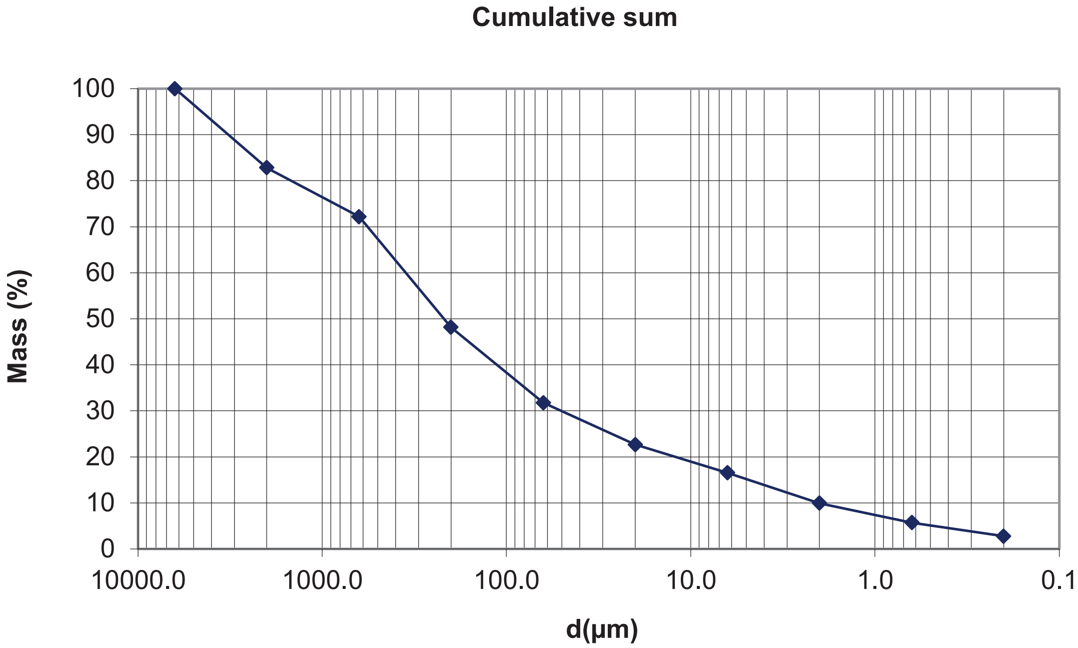


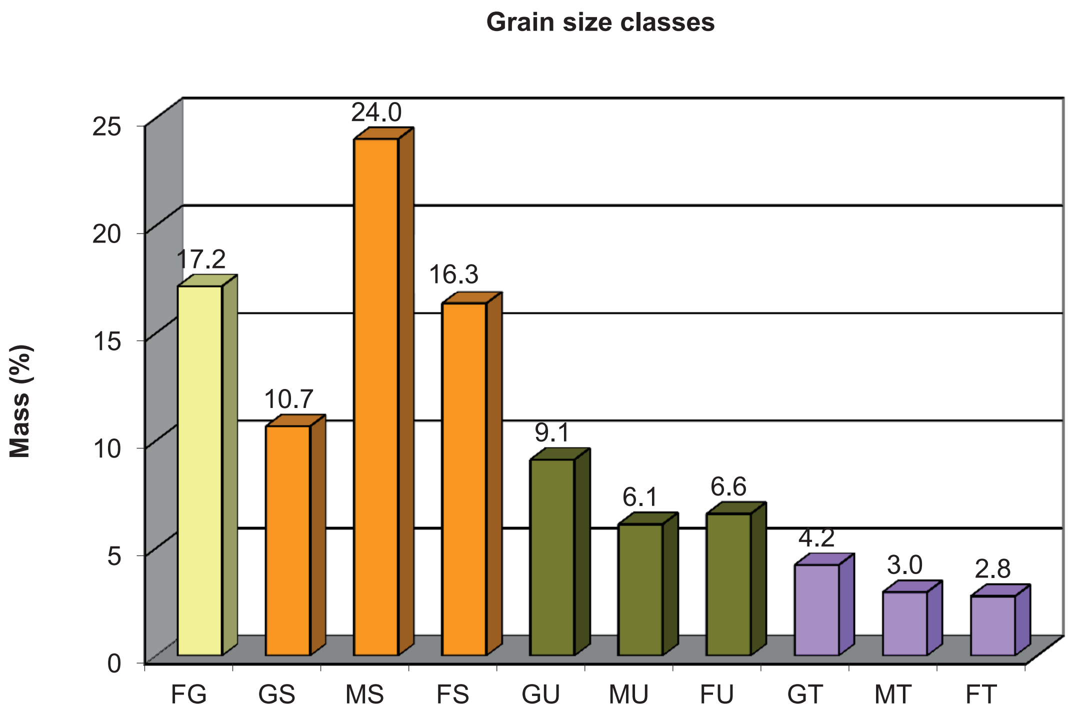
Grain size classes



GSD 3.6 Basgo. Lotsāba Lhakhang. Sample 11946. Interior wall plaster.
Top: Cumulative sum. Bottom: Grain size classes.

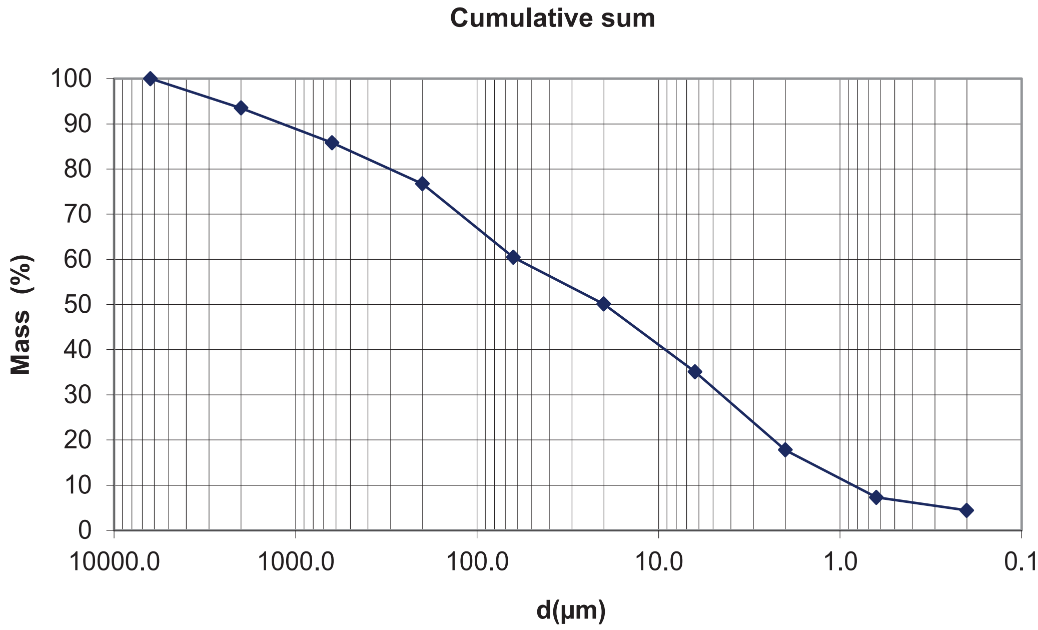
11948 – Basgo
Lotsāba Lhakhang. Adobe brick.

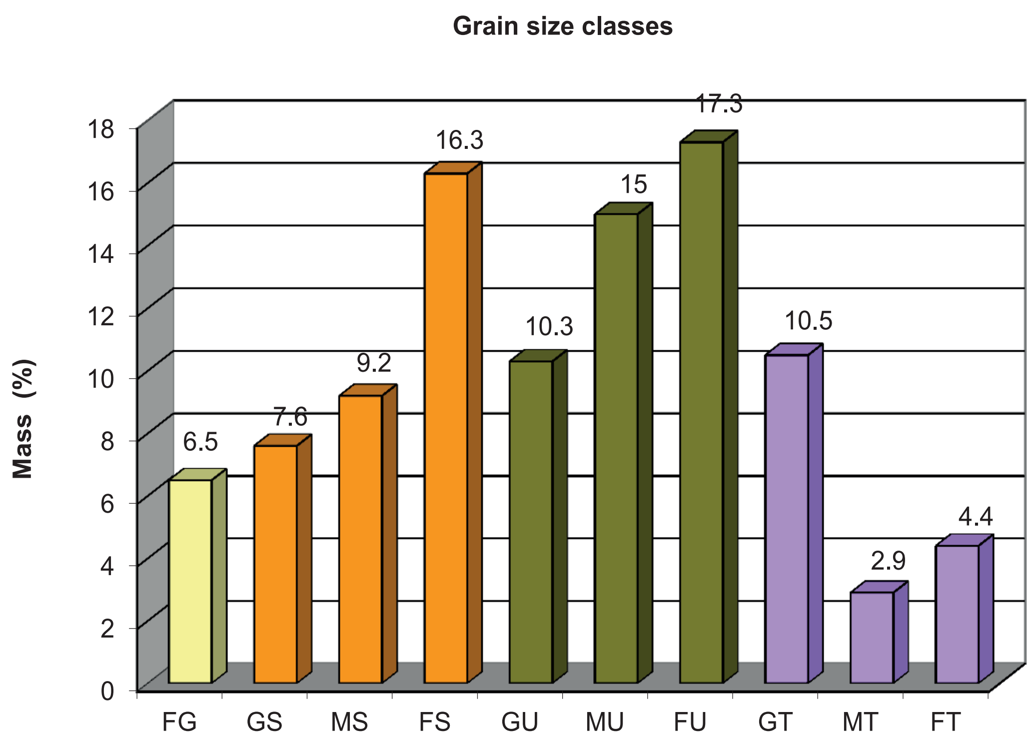




GSD 3.7 Basgo. Lotsāba Lhakhang. Sample 11948. Adobe brick. Top: Cumulative sum. Bottom: Grain size classes.

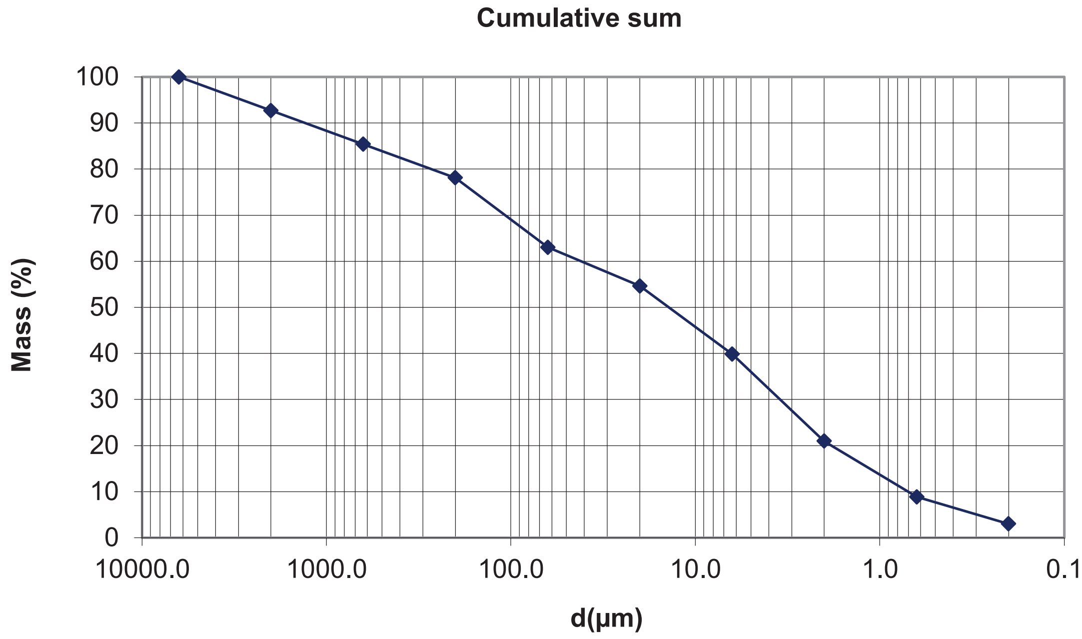
8475 – Basgo
‘*Lhakhang* close to the road’. Interior wall plaster.

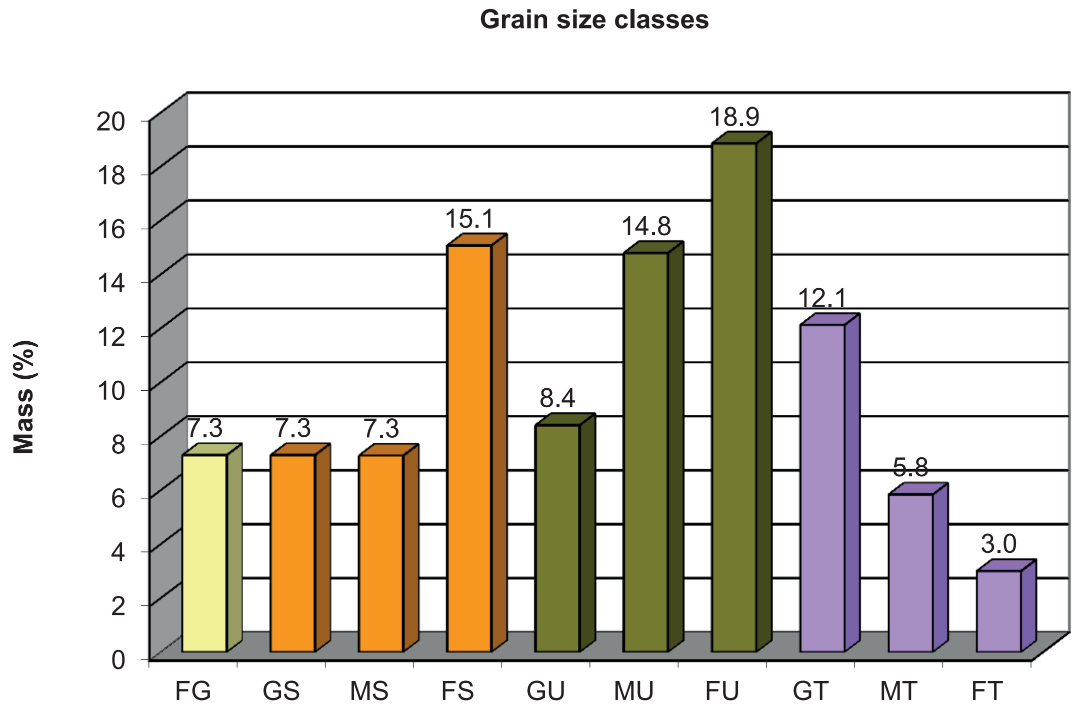




GSD 3.8 Basgo. ‘*Lhakhang* close to the road’. Sample 8475. Interior wall plaster.
Top: Cumulative sum. Bottom: Grain size classes.

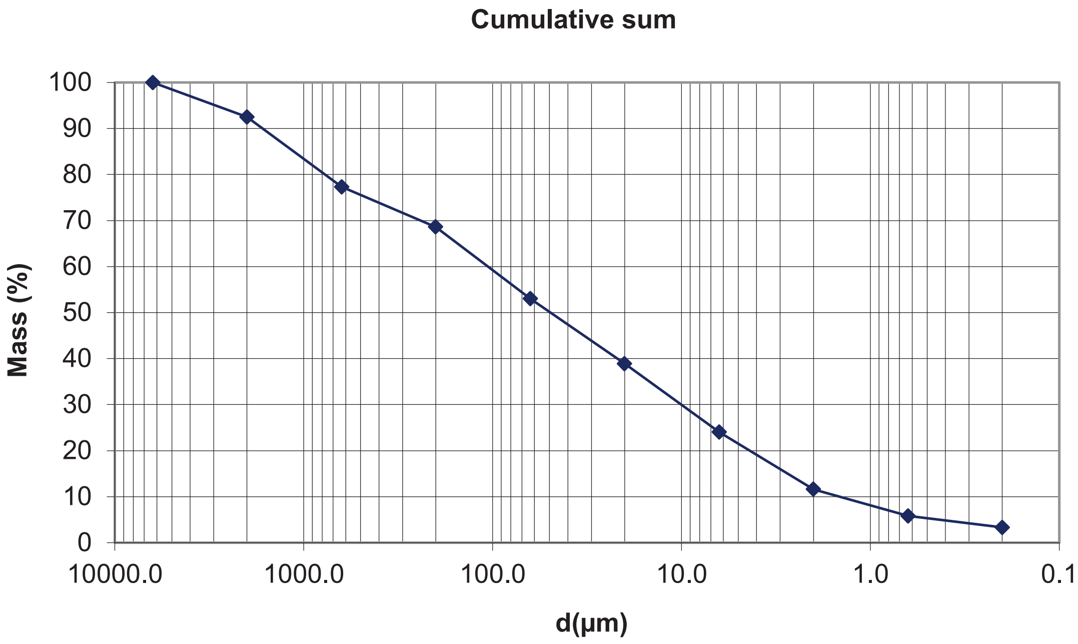
11928 – Basgo
'*Lhakhang* close to the road'. Interior wall plaster.

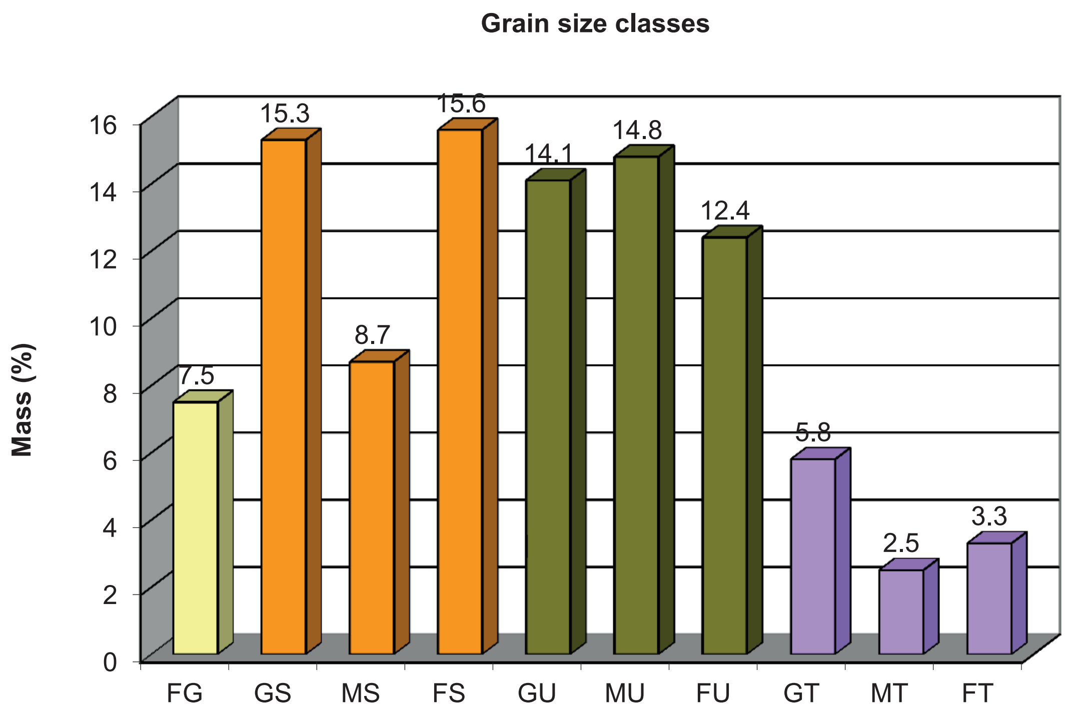




GSD 3.9 Basgo. '*Lhakhang* close to the road'. Sample 11928. Interior wall plaster. Top: Cumulative sum. Bottom: Grain size classes.

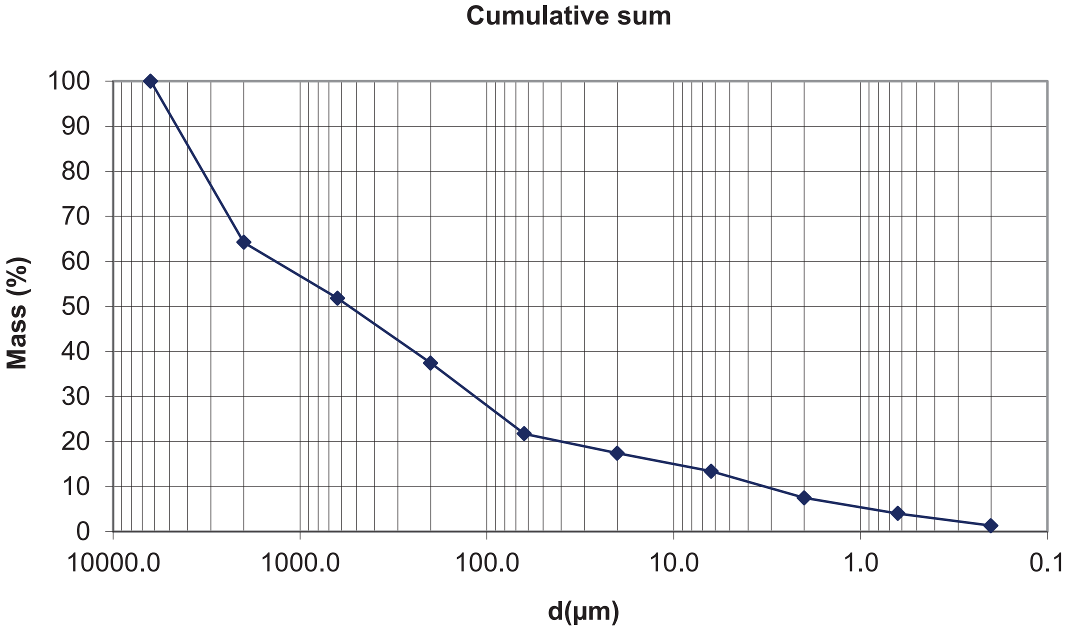
8499 – Basgo
‘*Lhakhang* close to the road’. Exterior wall plaster.

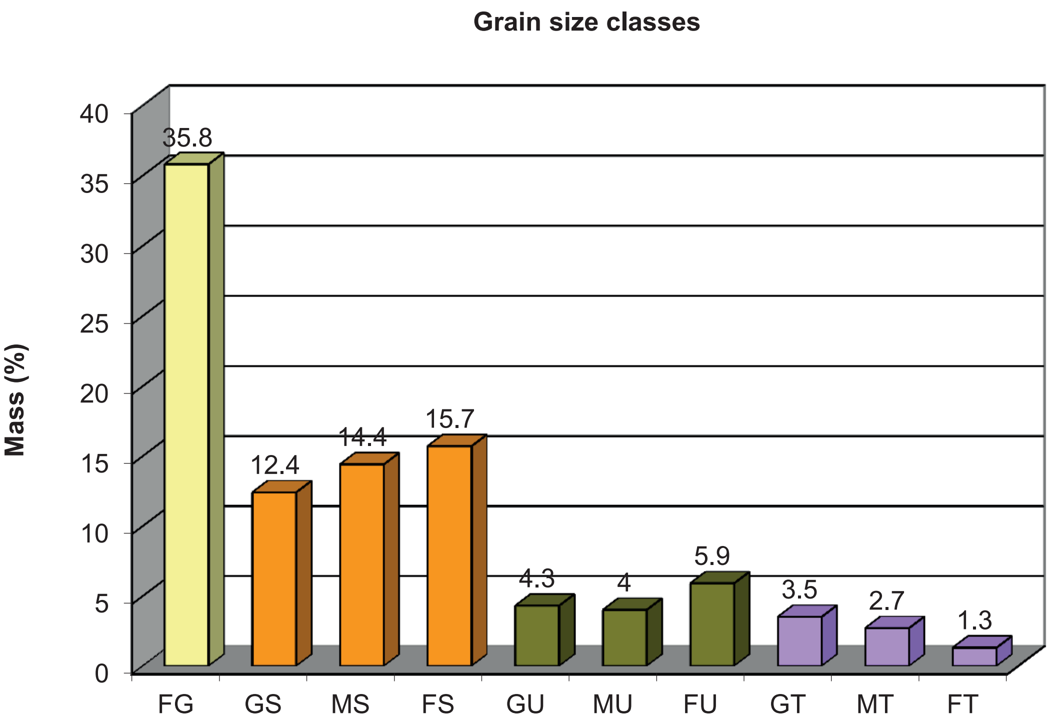




GSD 3.10 Basgo. ‘*Lhakhang* close to the road’. Sample 8499. Exterior wall plaster.
Top: Cumulative sum. Bottom: Grain size classes.

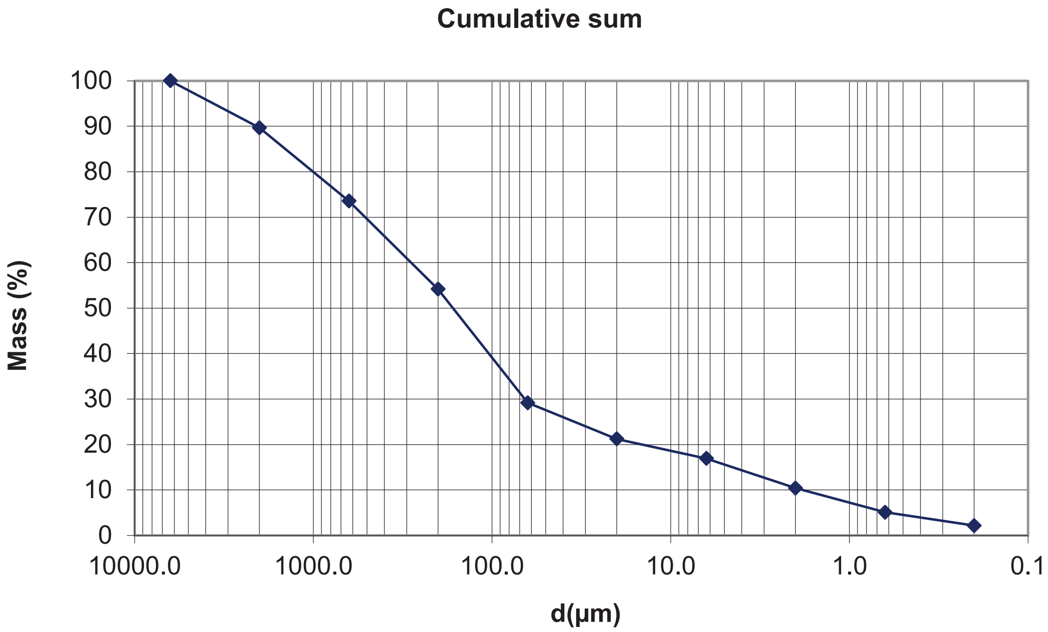
8472 – Basgo
'*Lhakhang* close to the road'. Adobe brick.

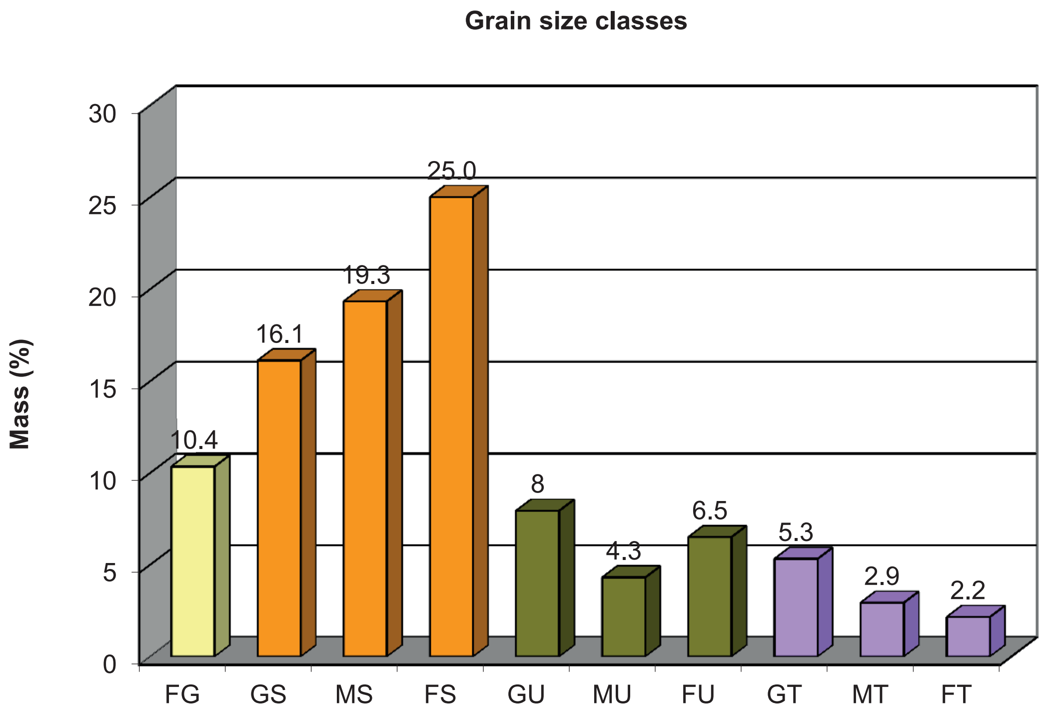




GSD 3.11Basgo. '*Lhakhang* close to the road'. Sample 8472. Adobe brick.
Top: Cumulative sum. Bottom: Grain size classes.

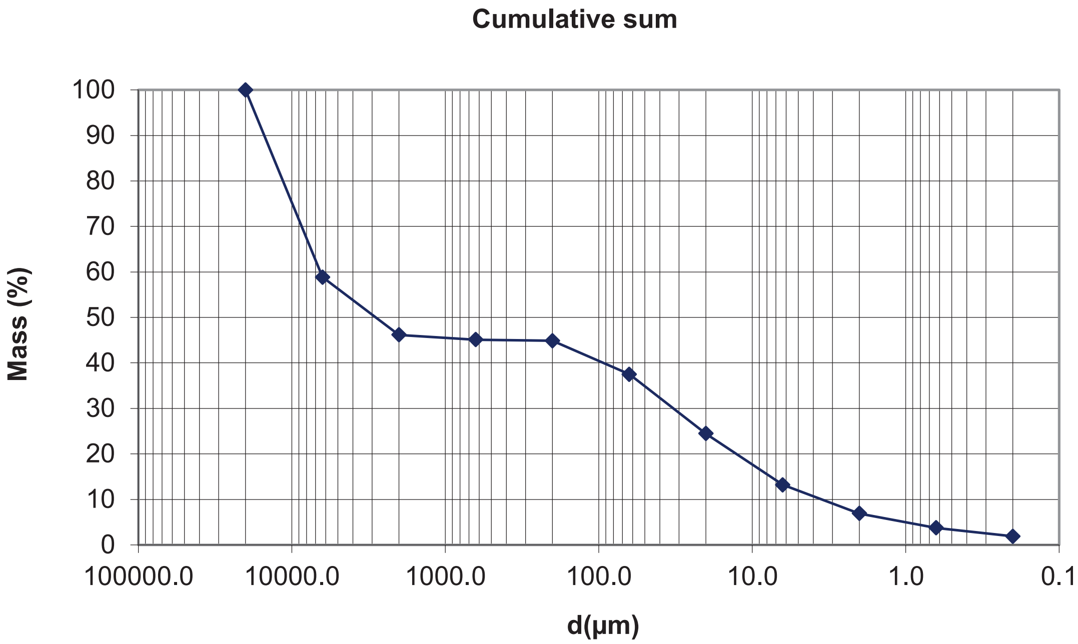
11933 – Basgo
'*Lhakhang* close to the road'. Adobe brick.

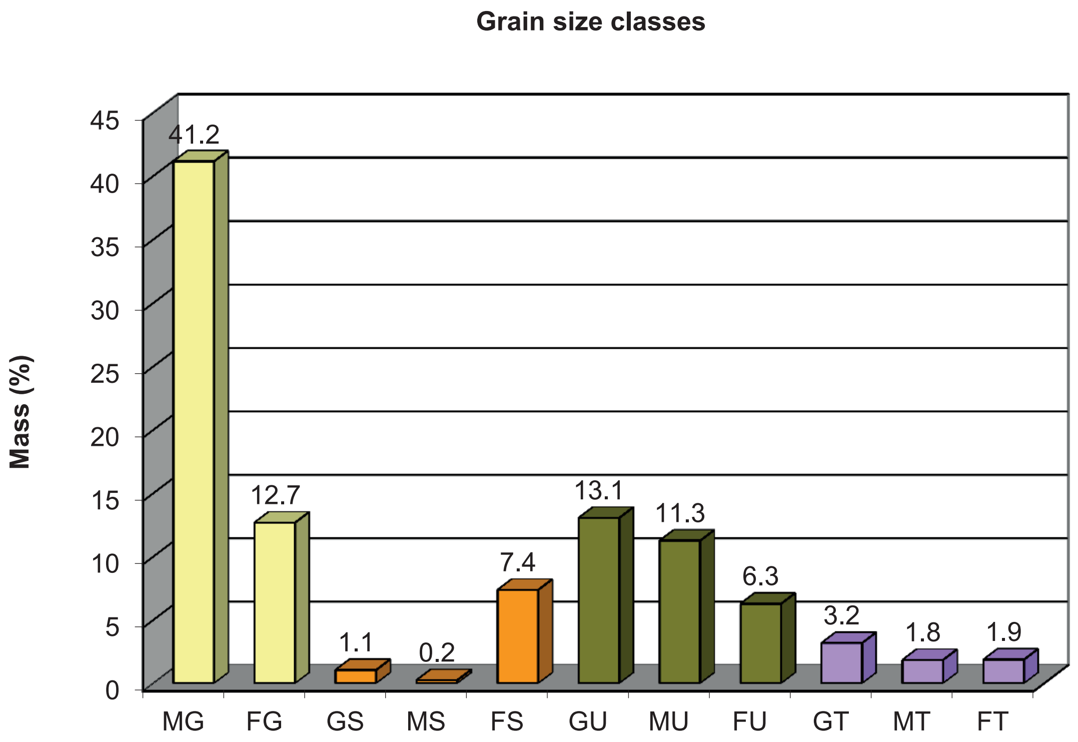




GSD 3.12 Basgo. '*Lhakhang* close to the road'. Sample 11933. Adobe brick.
Top: Cumulative sum. Bottom: Grain size classes.

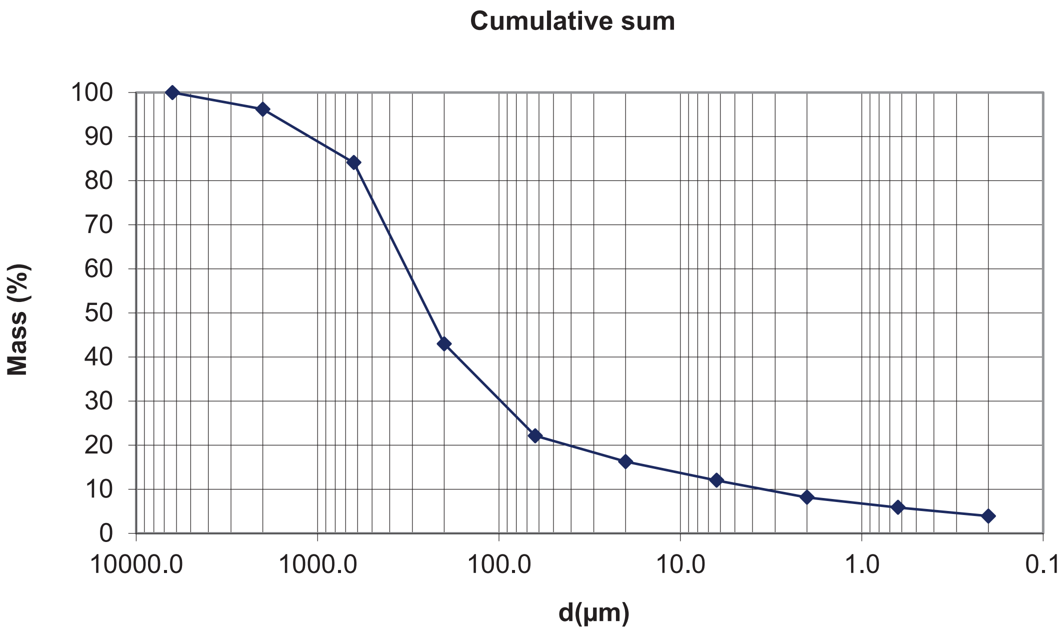
15410 – Basgo
Building raw material. *Dzasa*.

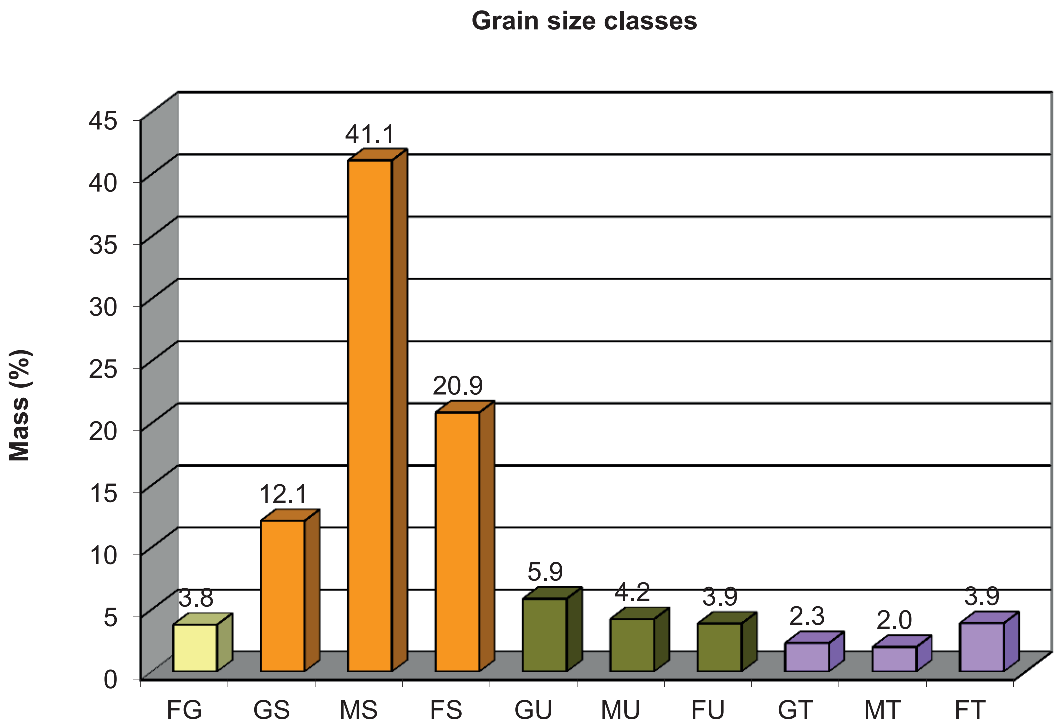




GSD 3.13 Basgo. Sample 15410. Building raw material. *Dzasa*.
Top: Cumulative sum. Bottom: Grain size classes.

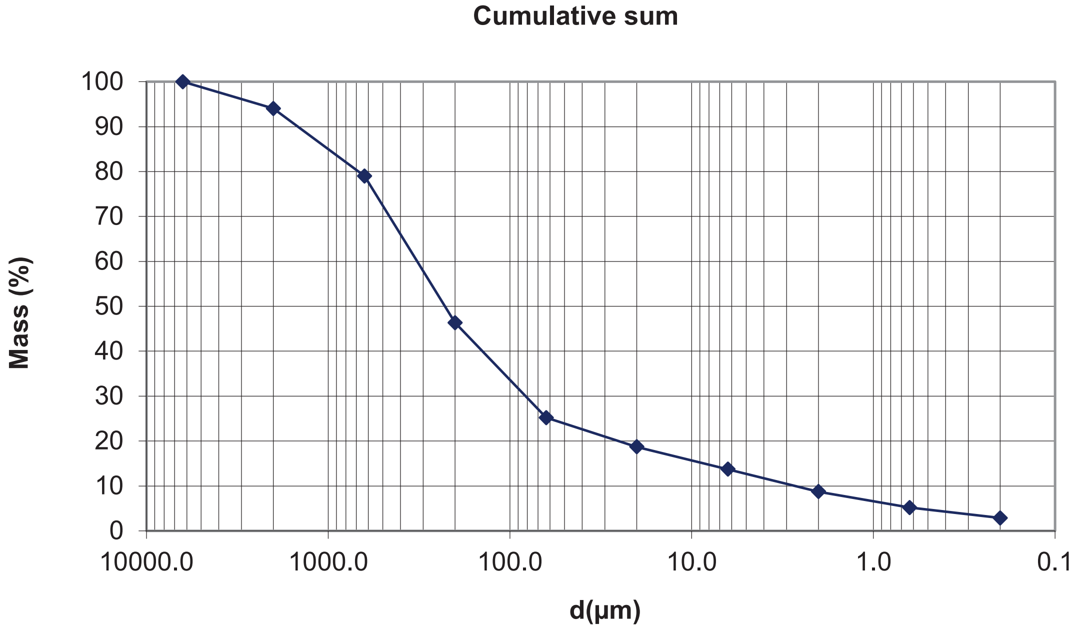
11915 – Basgo
Building raw material. *Thetsa*.

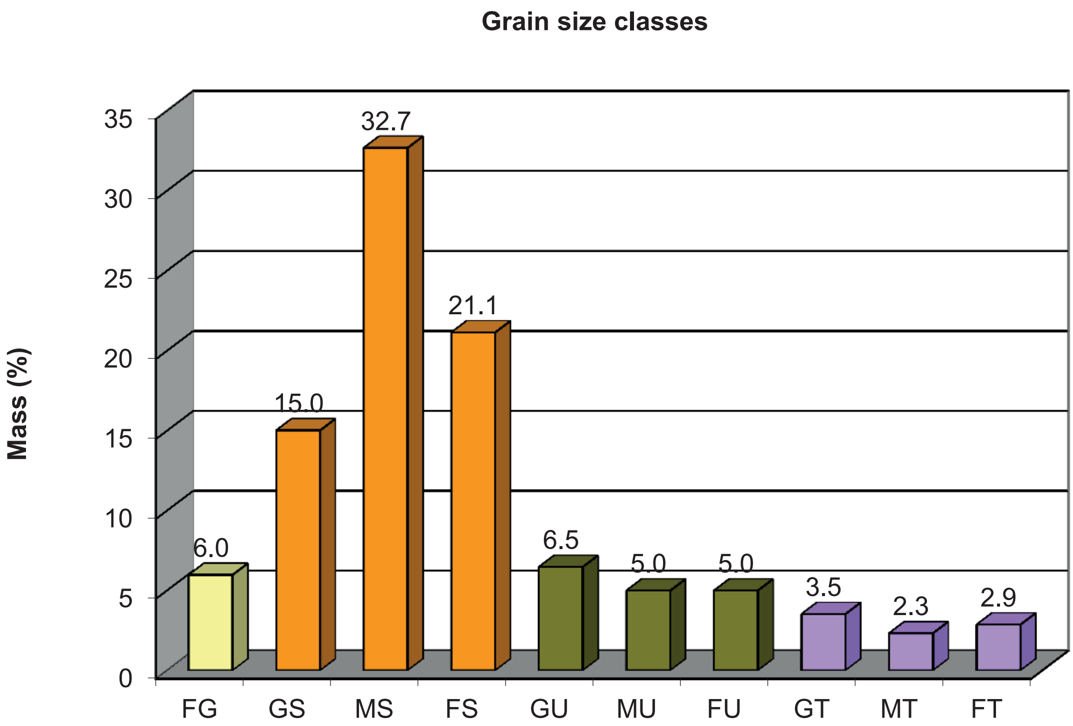




GSD 3.14 Basgo. Sample 11915. Building raw material. *Thetsa*. Top: Cumulative sum. Bottom: Grain size classes.

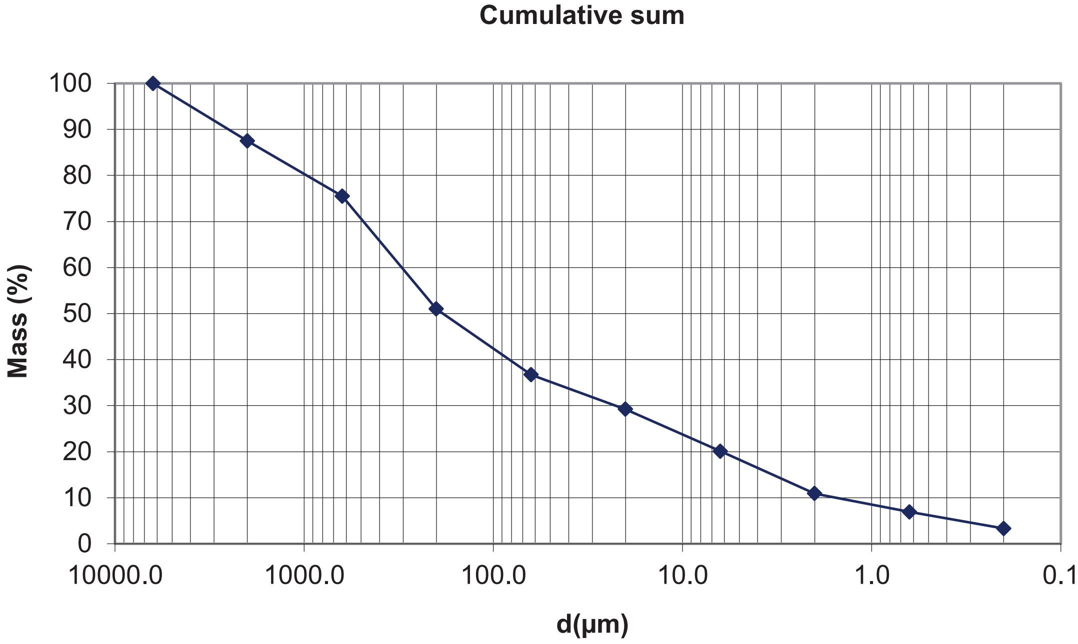
15411 – Basgo
Building raw material. *Thetsa*.

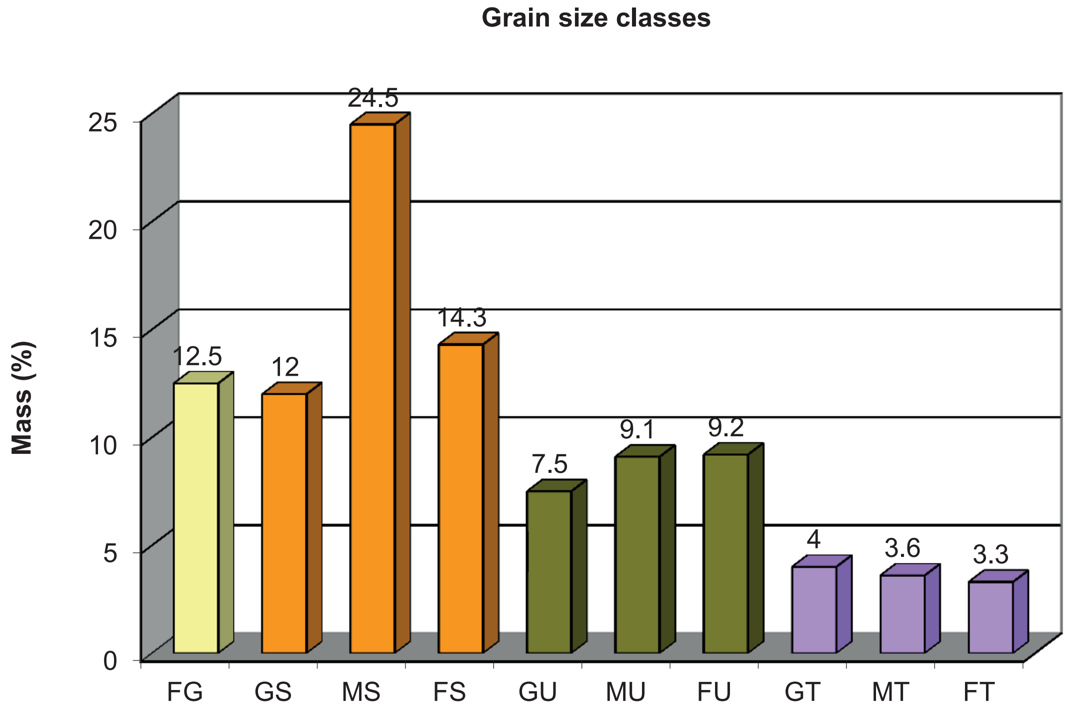




GSD 3.15 Basgo. Sample 15411. Building raw material. *Thetsa*. Top: Cumulative sum. Bottom: Grain size classes.

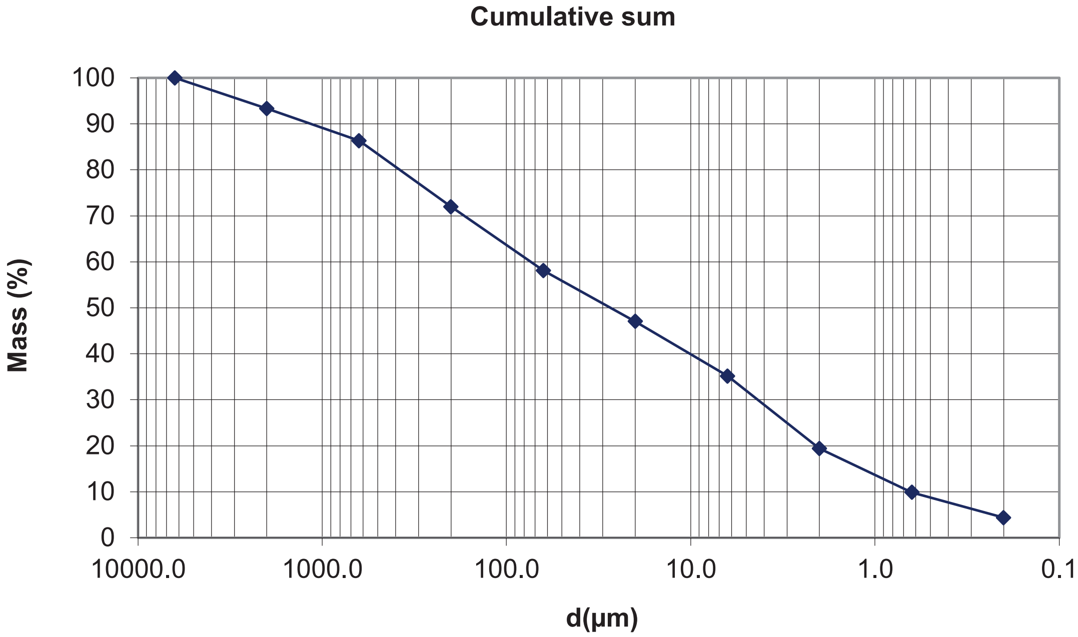
8465 – Basgo
Building raw material. *Thetsa* and *dzasa*.

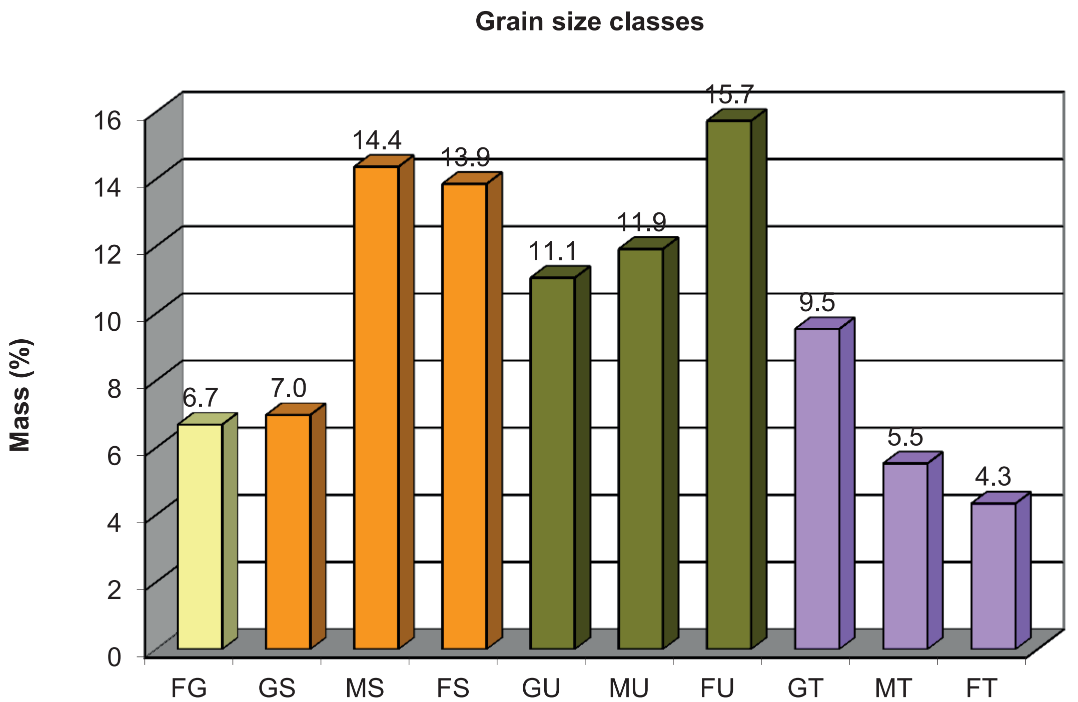




GSD 3.16 Basgo. Sample 8465. Building raw material. *Thetsa* and *Dzasa* mixed.
Top: Cumulative sum. Bottom: Grain size classes.

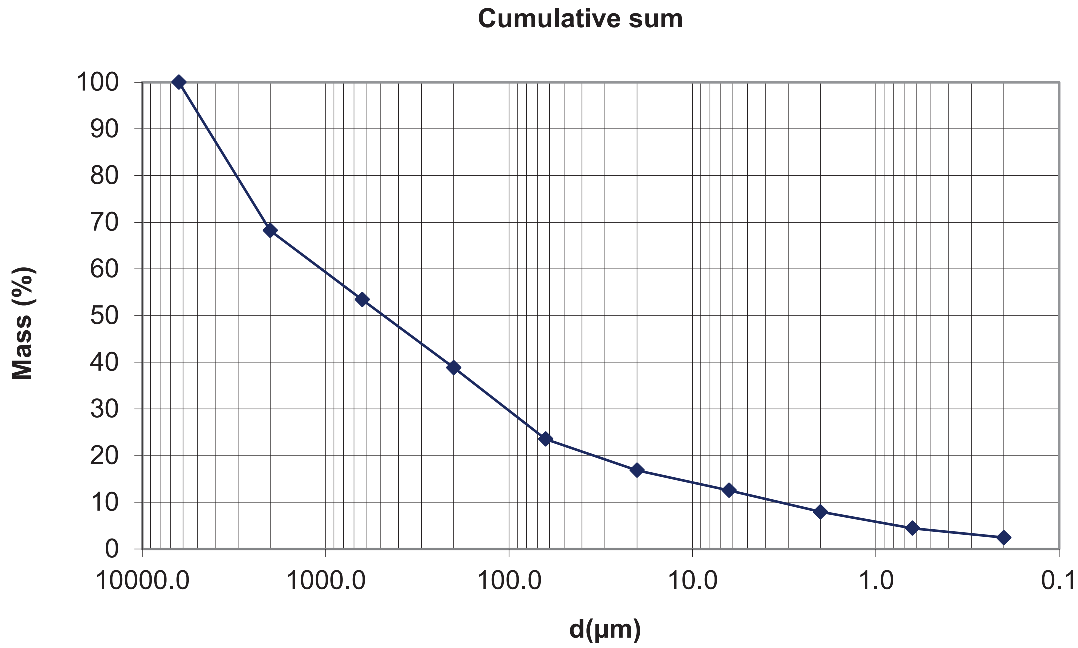
11952 – Basgo
Building raw material. Adobe brick.

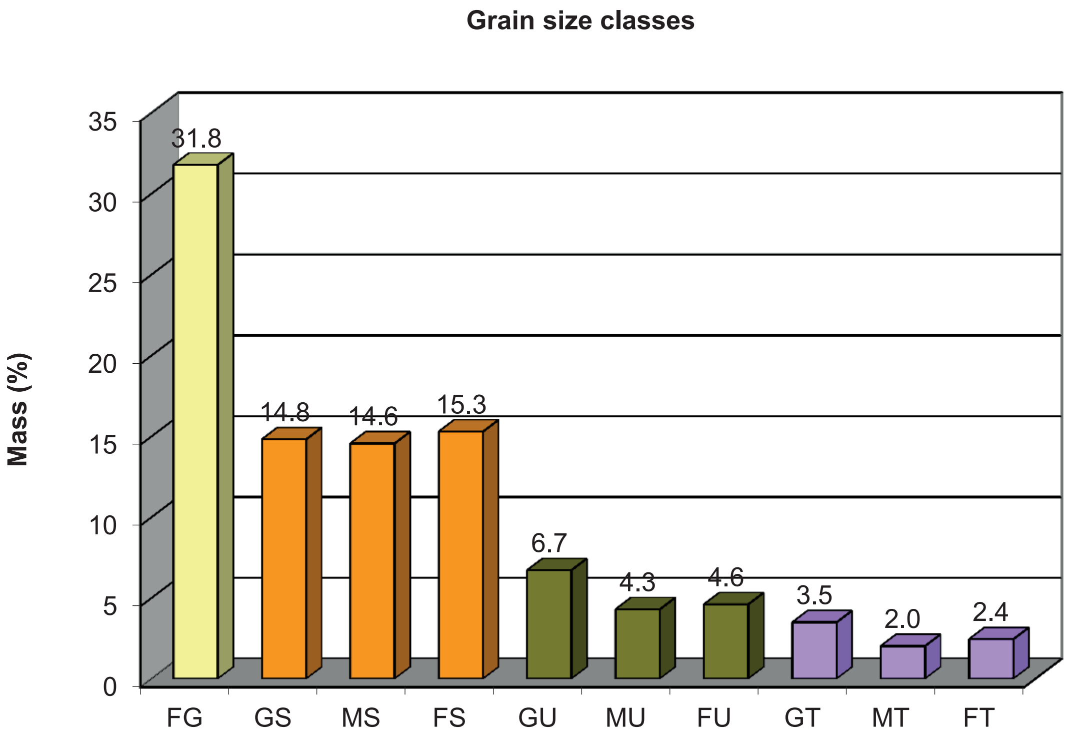




GSD 3.17 Basgo. Sample 11952. Building raw material. Adobe brick.
Top: Cumulative sum. Bottom: Grain size classes.

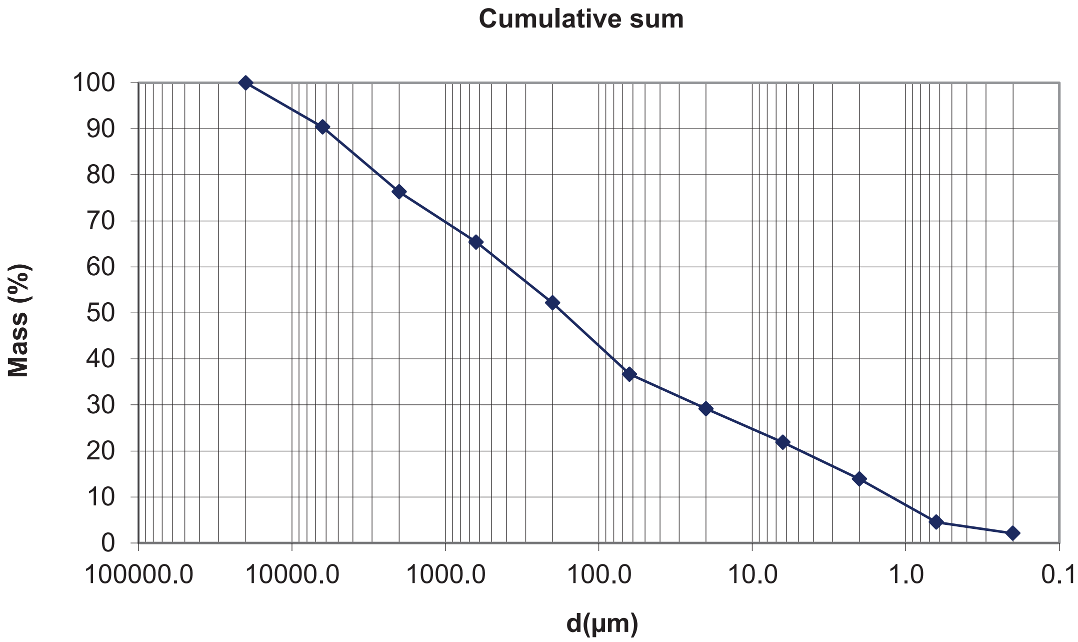
11748 – Tunlung
Clay stove. *Thabsa*.

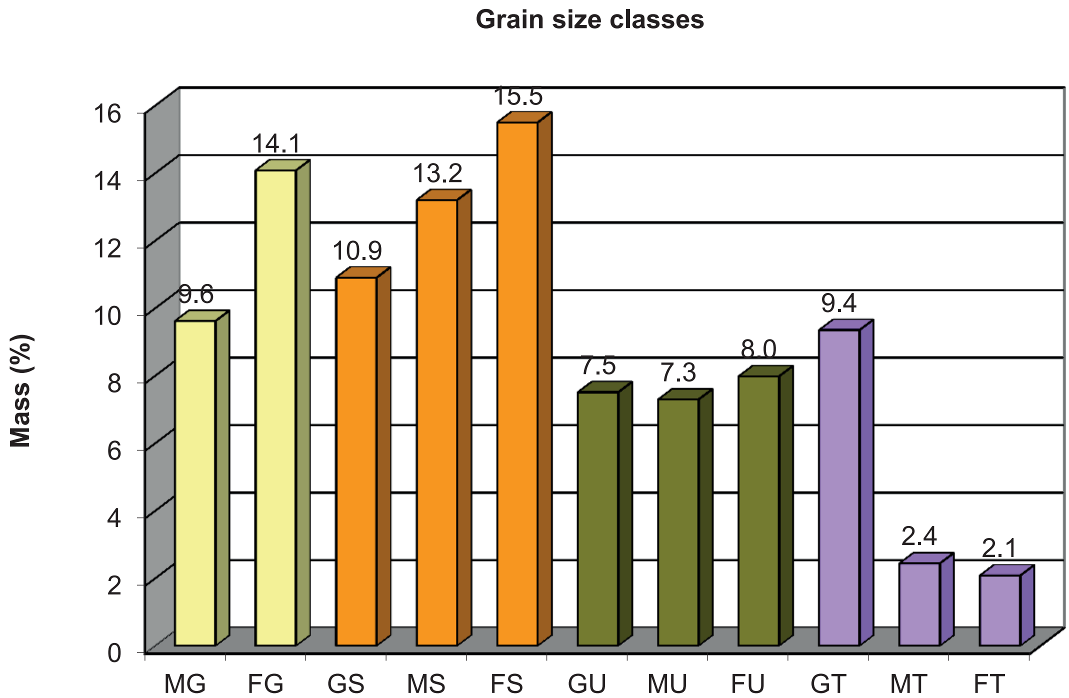




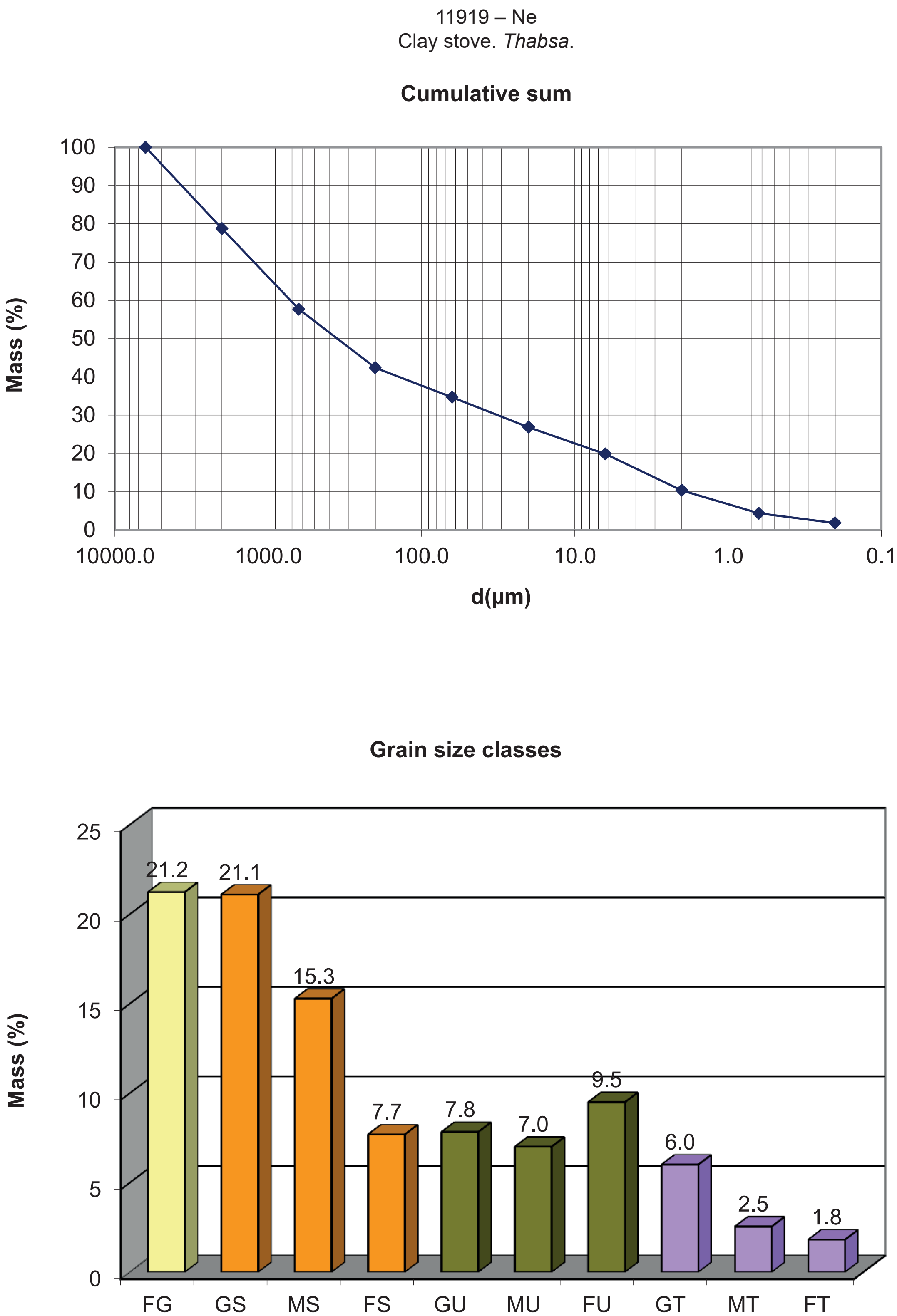
GSD 3.18 Tunlung. Sample 11748. Clay stove. *Thabsa*. Top: Cumulative sum. Bottom: Grain size classes.

15412 – Tunlung
Clay stove. *Thabsa*.



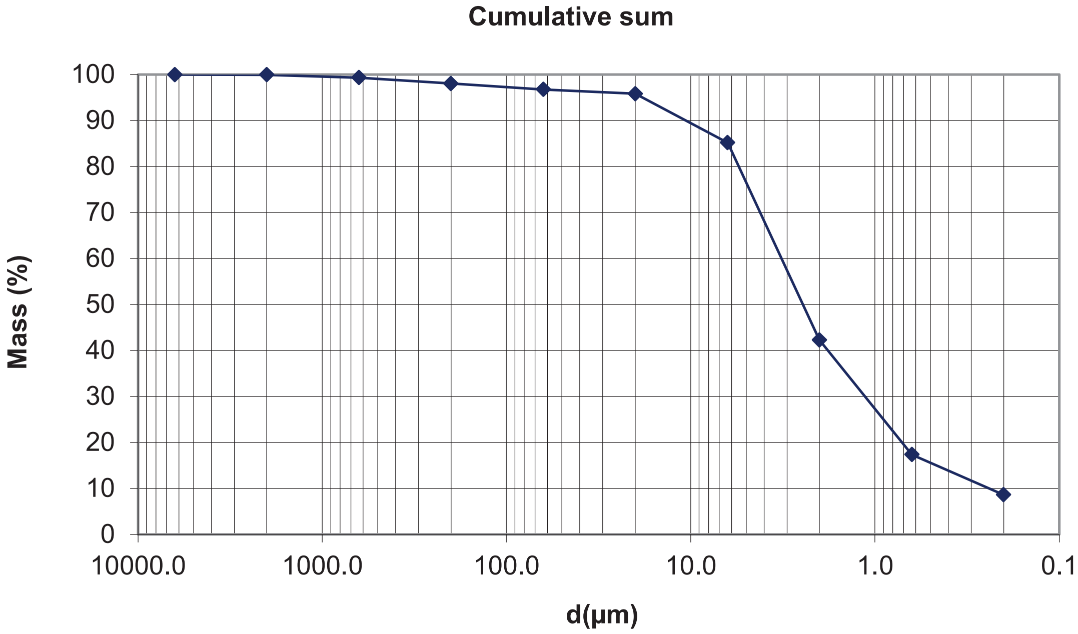


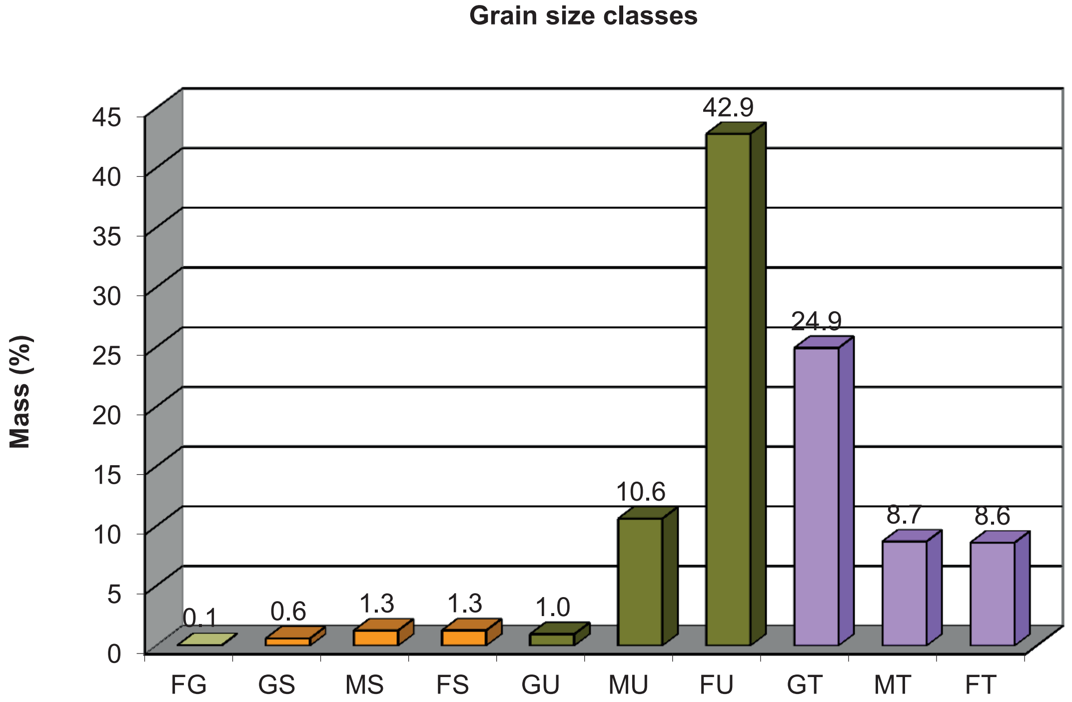
GSD 3.19 Tunlung. Sample 15412. Clay stove. *Thabsa*. Top: Cumulative sum. Bottom: Grain size classes.



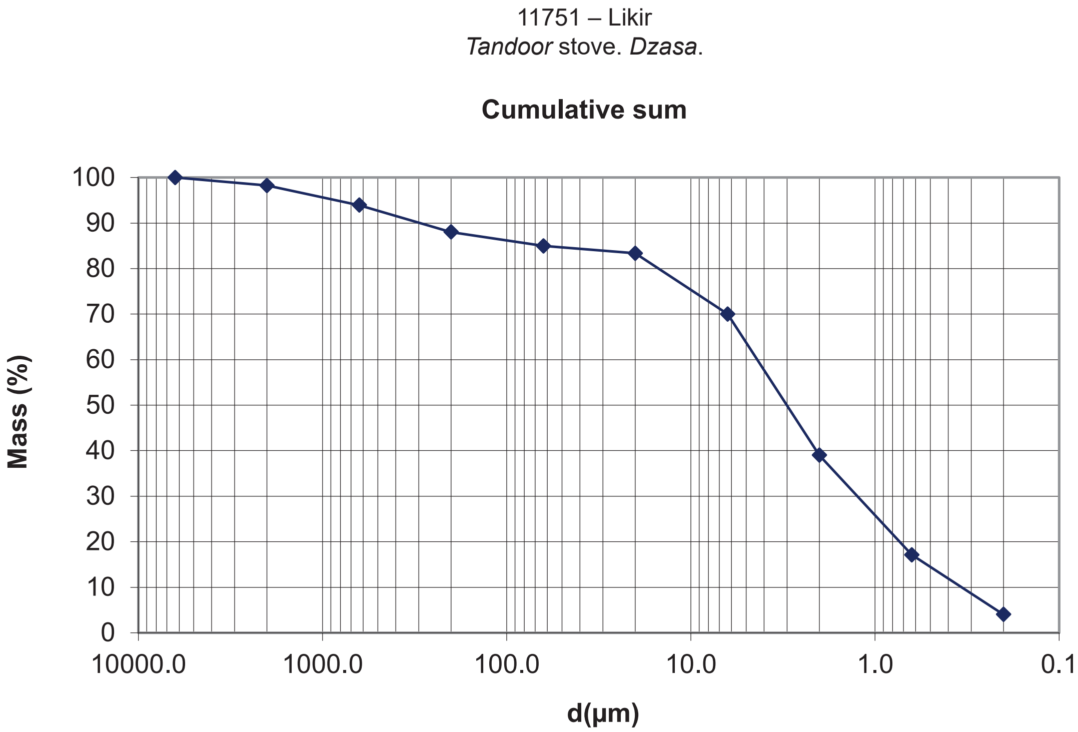
GSD 3.20 Ne. Sample 11919. Clay stove. *Thabsa*. Top: Cumulative sum. Bottom: Grain size classes.

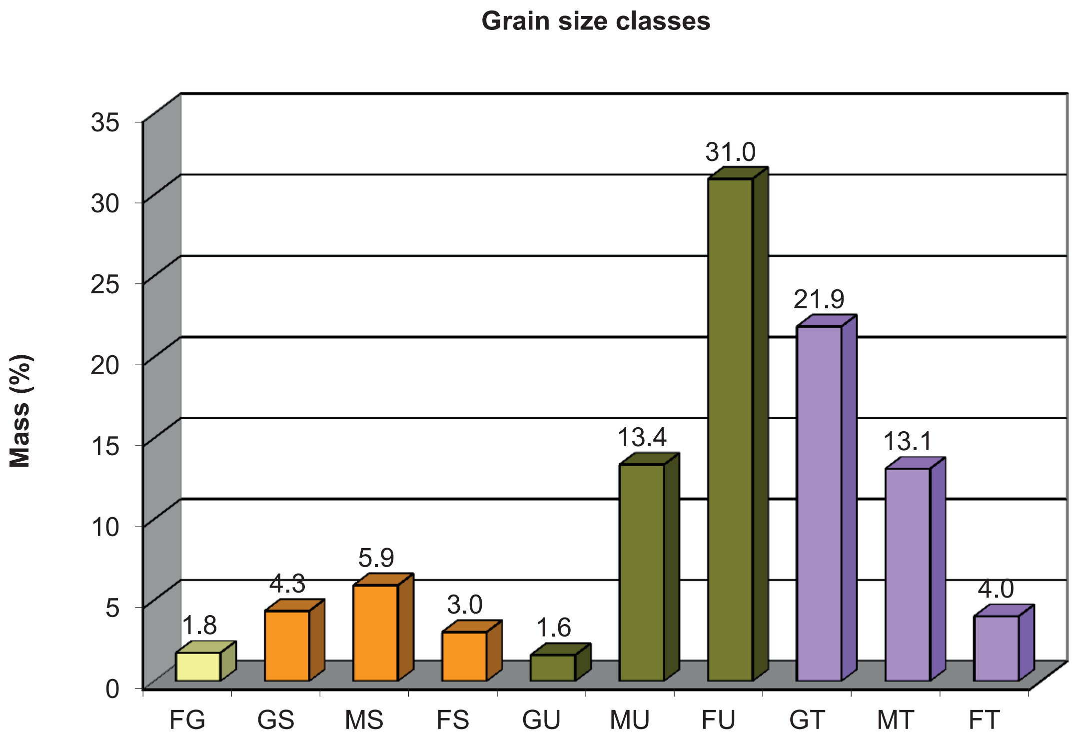
15515 – Basgo
Tandoor stove. *Thabsa*.





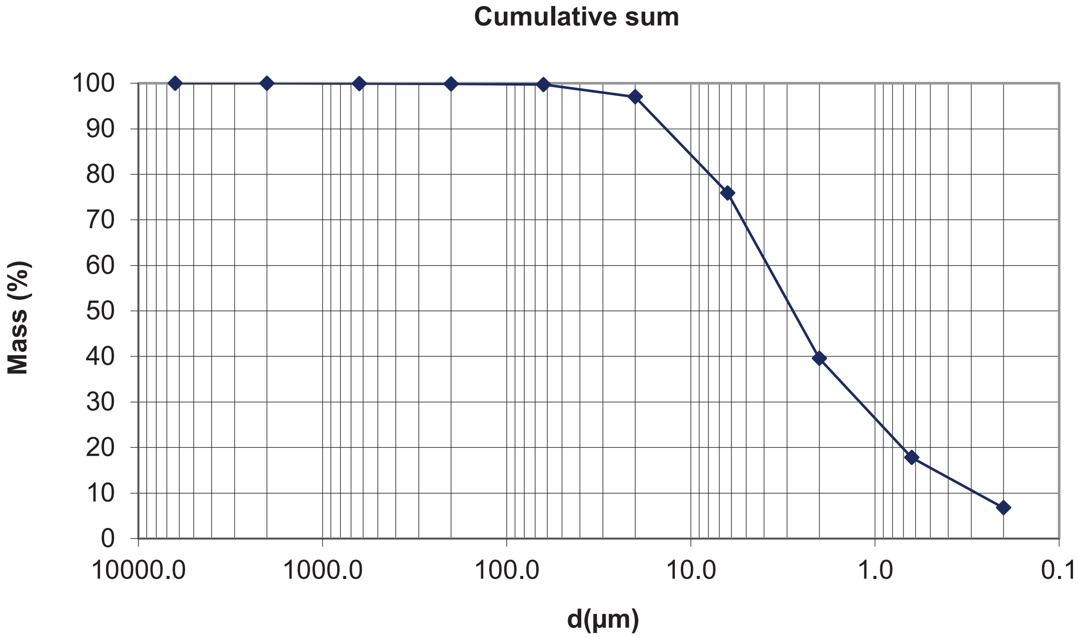
GSD 3.21 Ne. Sample 15515. *Tandoor* stove. *Thabsa*. Top: Cumulative sum. Bottom: Grain size classes.

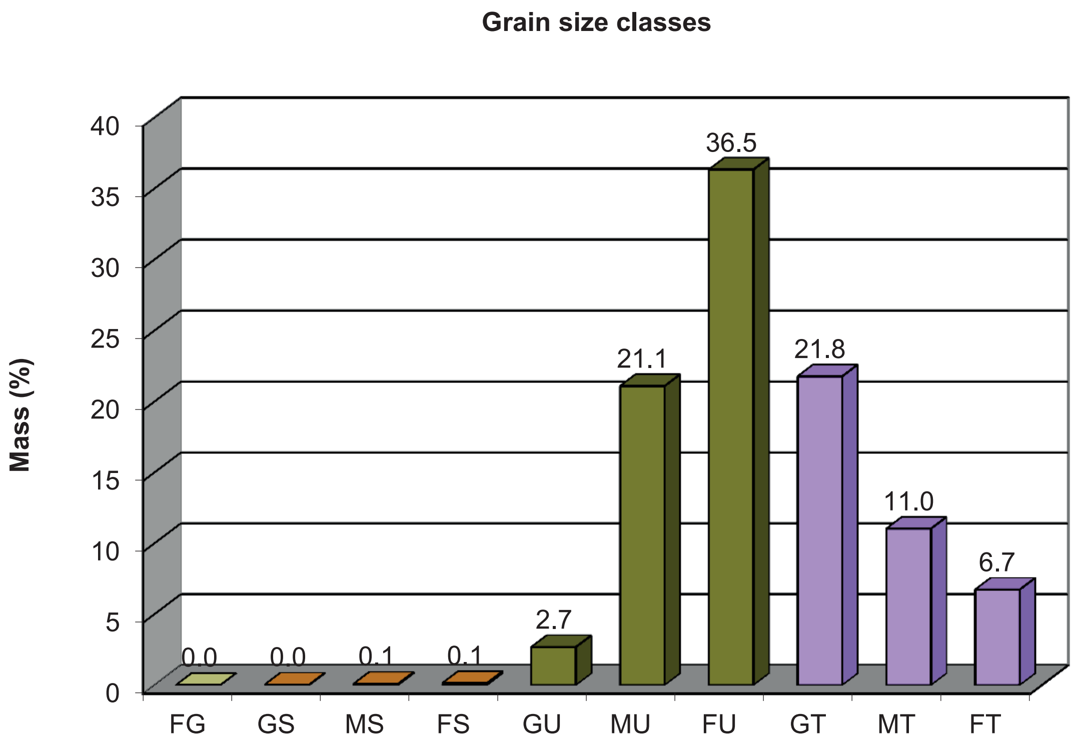




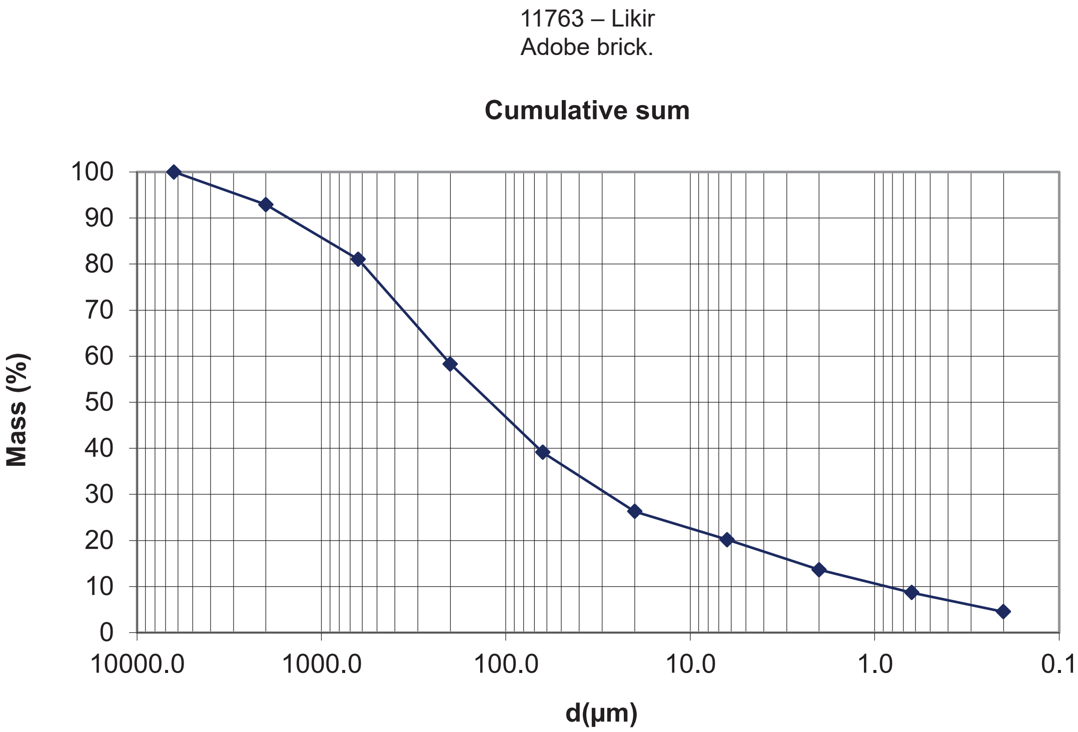
GSD 3.22 Likir. Sample 11751. *Tandoor* stove. *Dzasa*. Top: Cumulative sum. Bottom: Grain size classes.

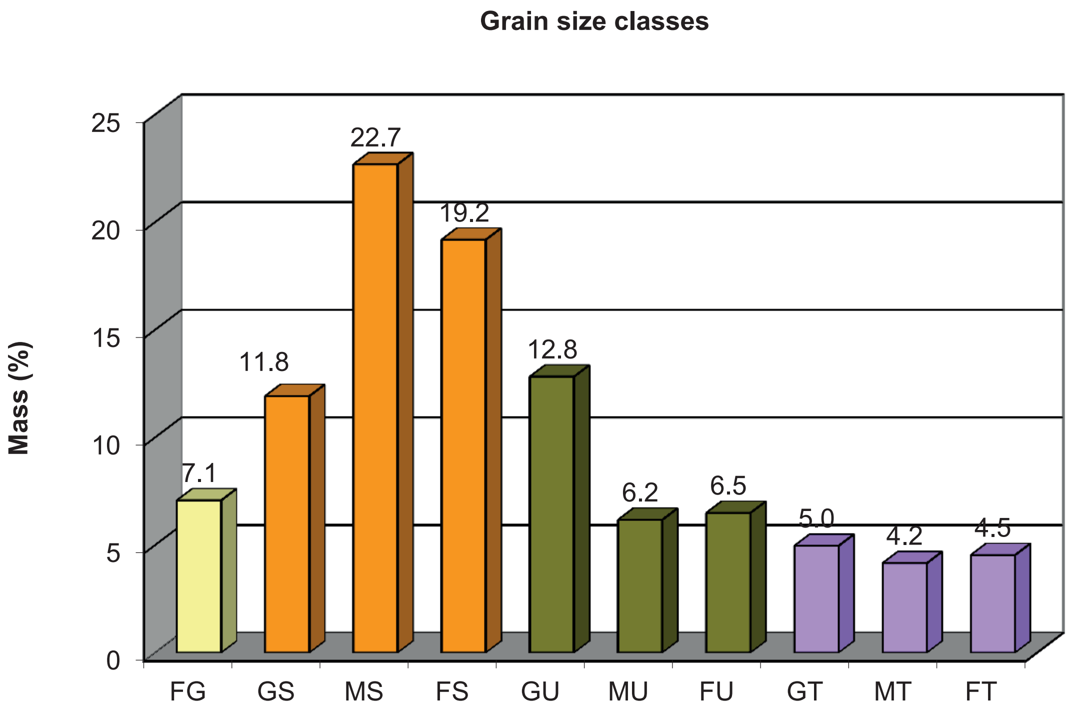
11752 – Likir
Tandoor stove. *Dzasa*.





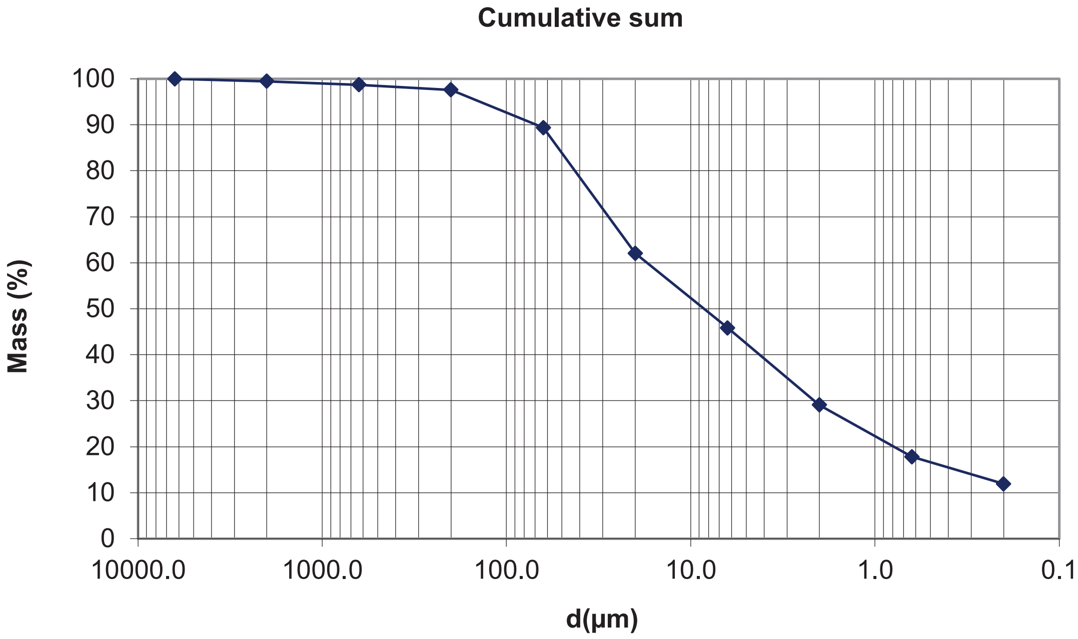
GSD 3.23 Likir. Sample 11752. *Thandoor* stove. *Dzasa*. Top: Cumulative sum. Bottom: Grain size classes.

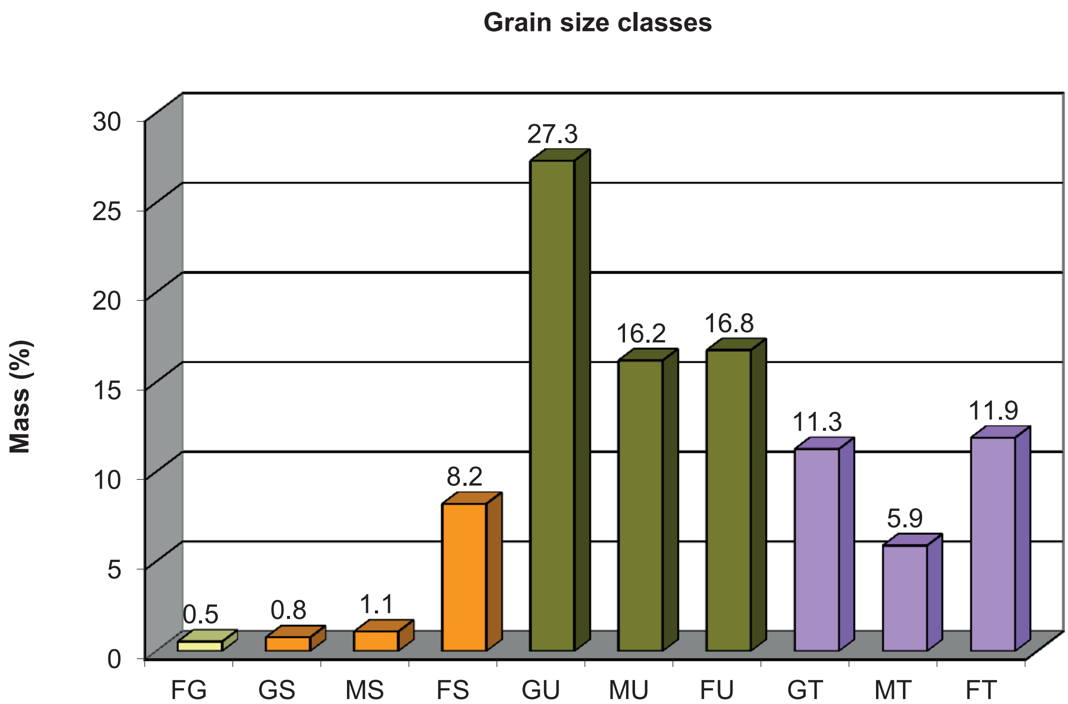




GSD 3.24 Likir. Sample 11763. Adobe brick. Top: Cumulative sum. Bottom: Grain size classes.

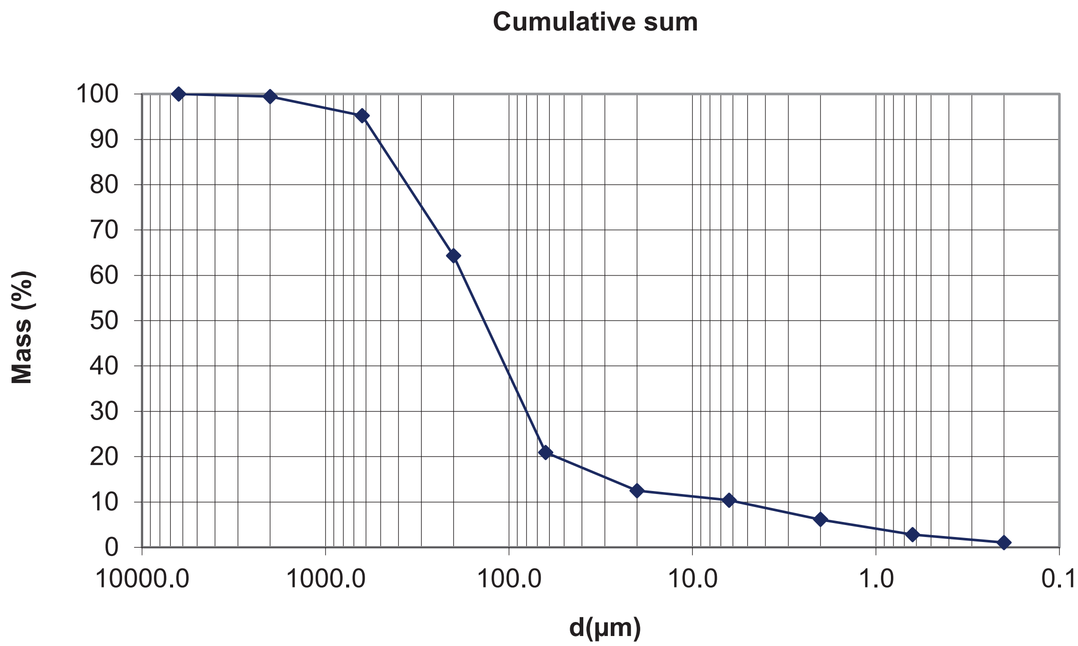
11921 – Likir
Clay pit.

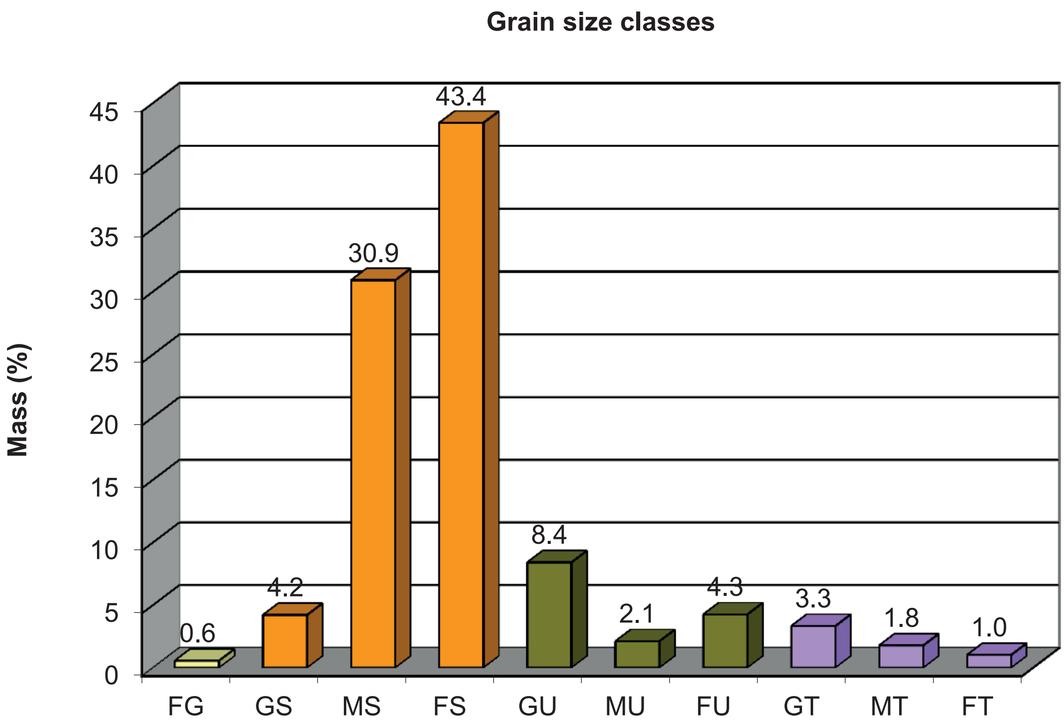




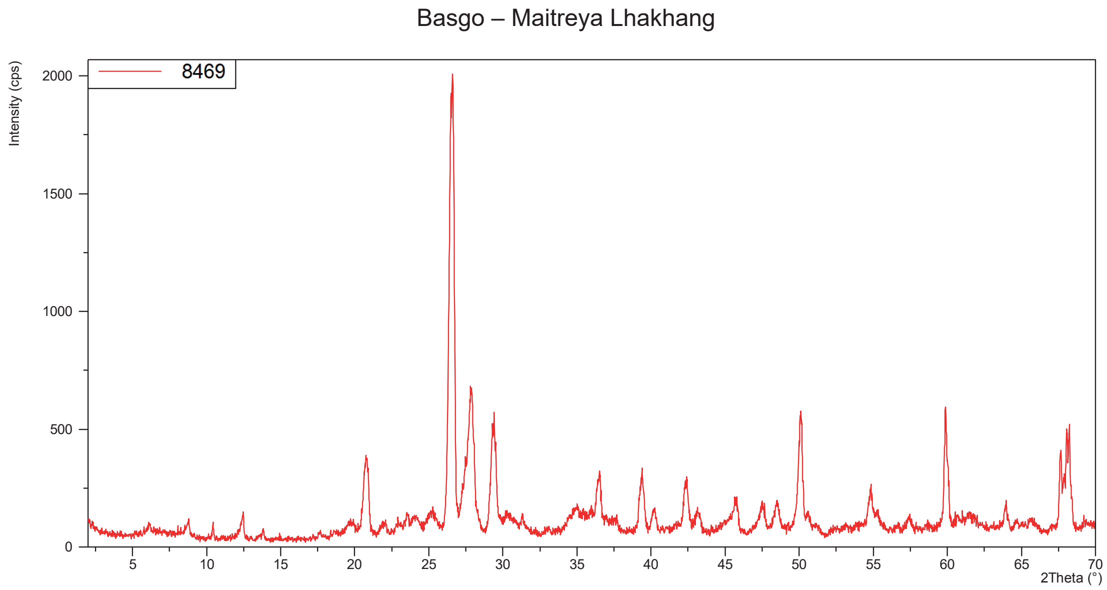
GSD 3.25 Likir. Sample 11921. Clay pit. Top: Cumulative sum. Bottom: Grain size classes.

11749 – Likir
Sand.

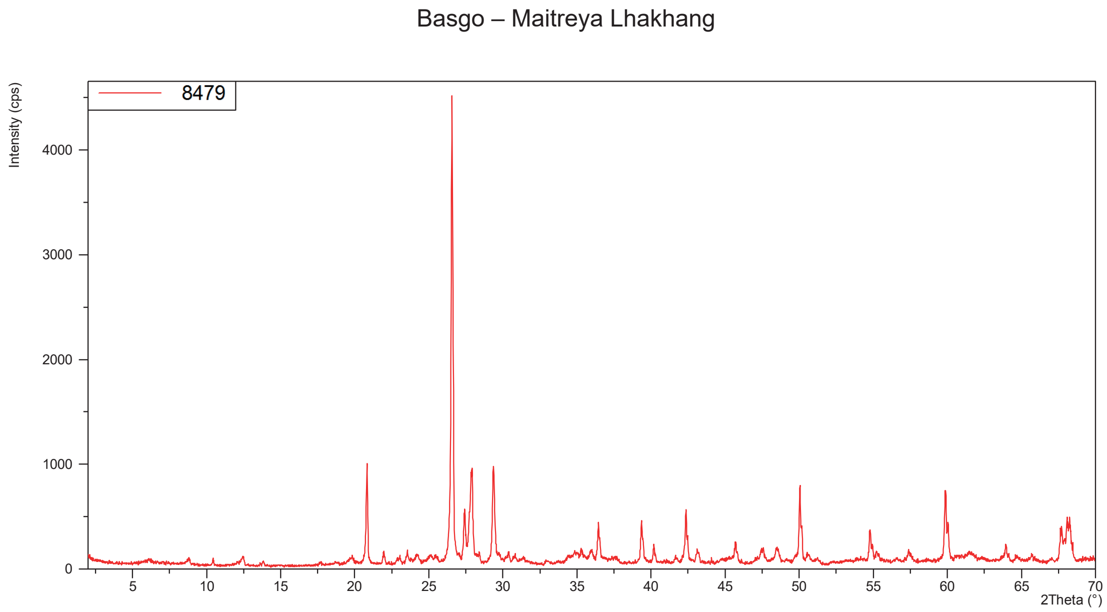




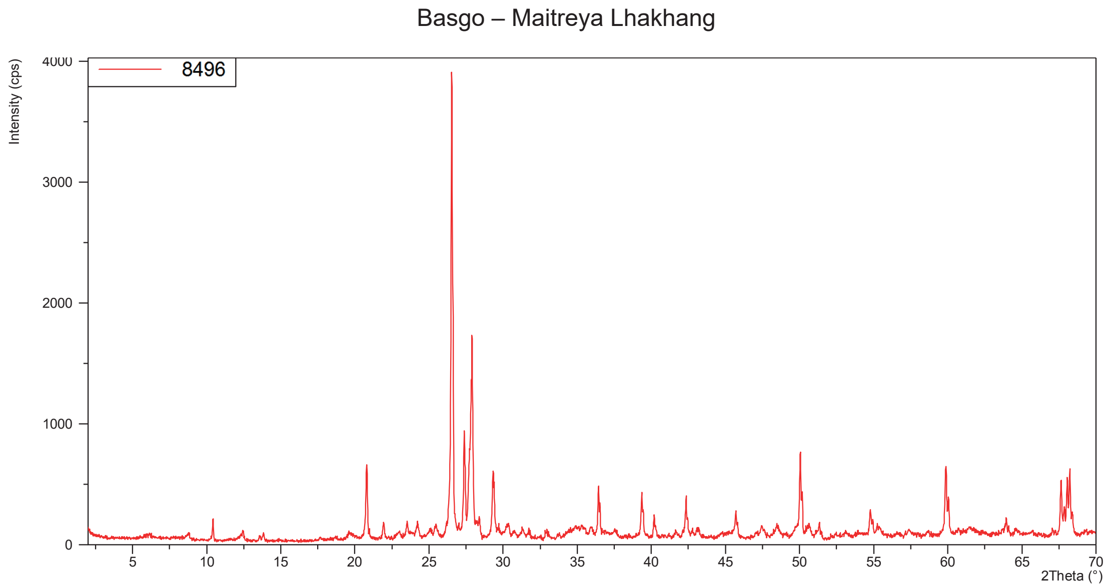
GSD 3.26 Likir. Sample 11749. Sand for mixing. Top: Cumulative sum. Bottom: Grain size classes.



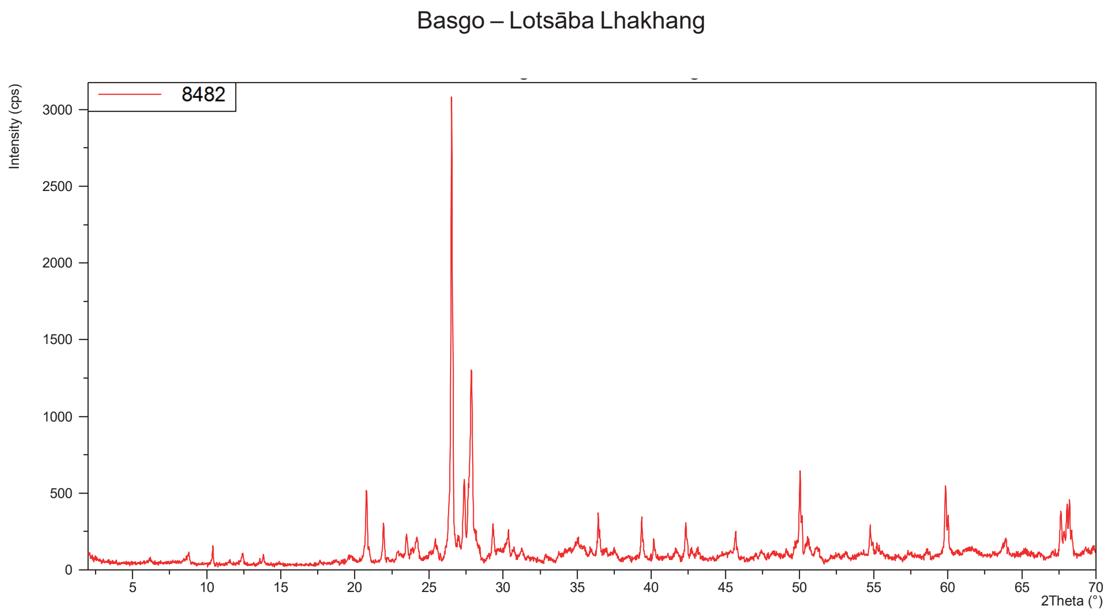
BMA 3.1 Basgo. Maitreya Lhakhang. Sample 8469. Bulk mineral analysis.



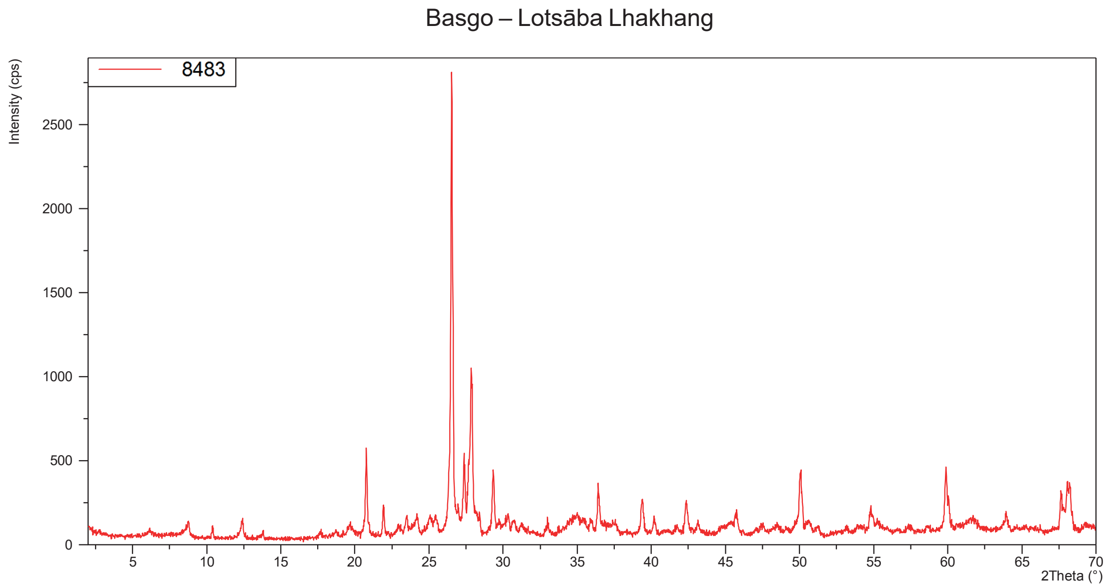
BMA 3.2 Basgo. Maitreya Lhakhang. Sample 8479. Bulk mineral analysis.



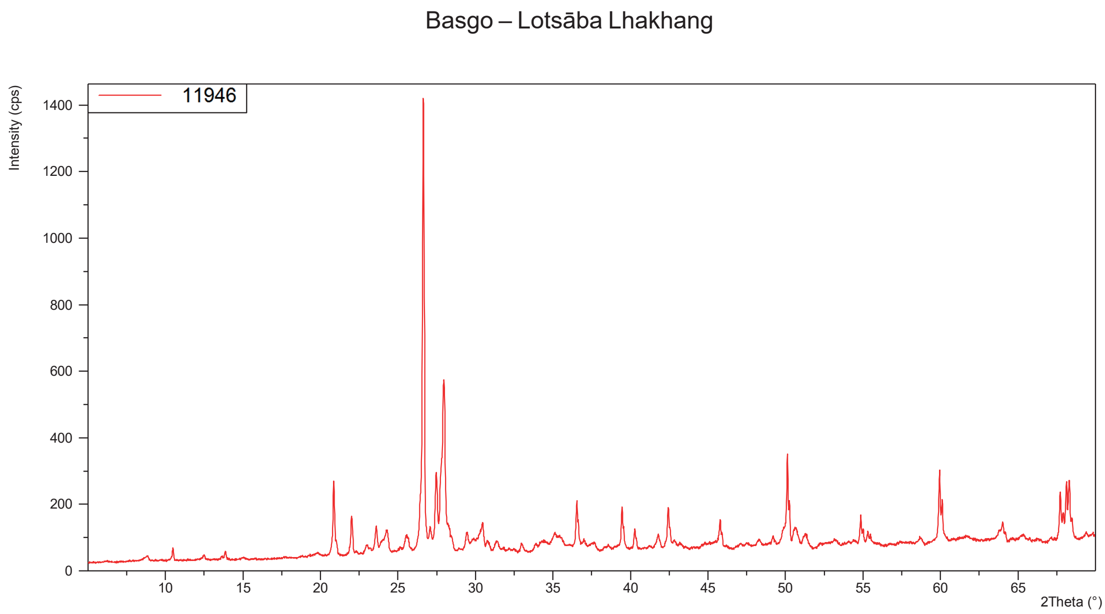
BMA 3.3 Basgo. Maitreya Lhakhang. Sample 8496. Bulk mineral analysis.



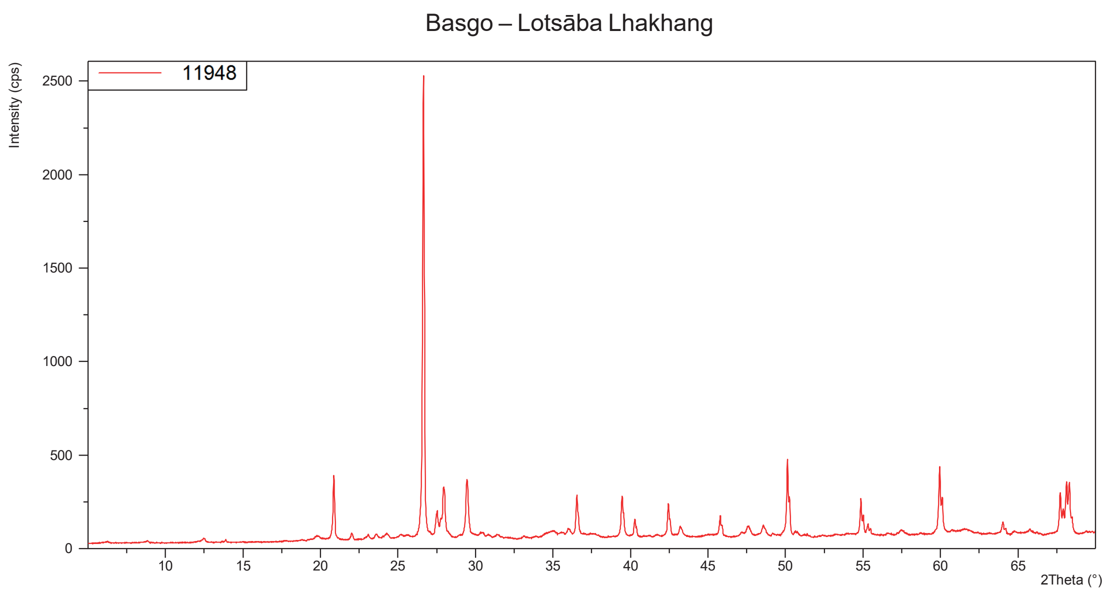
BMA 3.4 Basgo. Lotsāba Lhakhang. Sample 8482. Bulk mineral analysis.



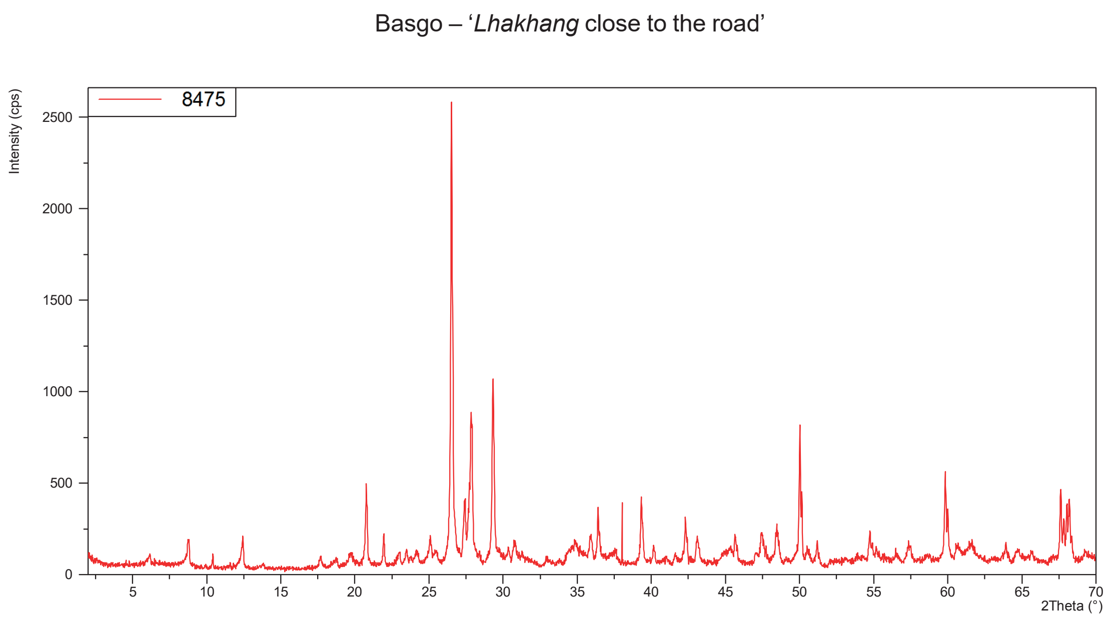
BMA 3.5 Basgo. Lotsāba Lhakhang. Sample 8483. Bulk mineral analysis.



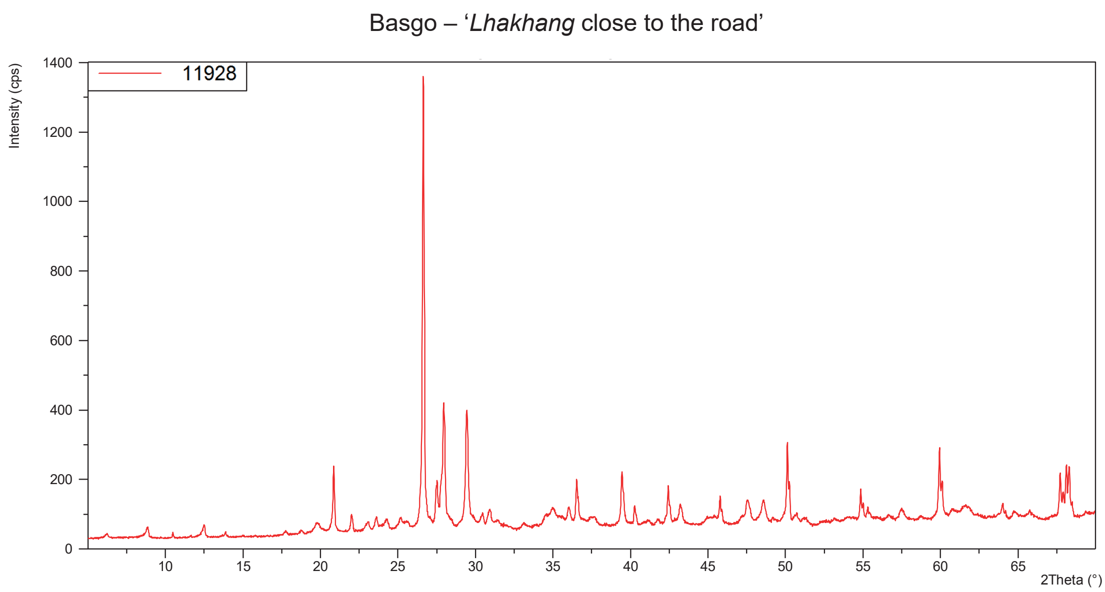
BMA 3.6 Basgo. Lotsāba Lhakhang. Sample 11946. Bulk mineral analysis.



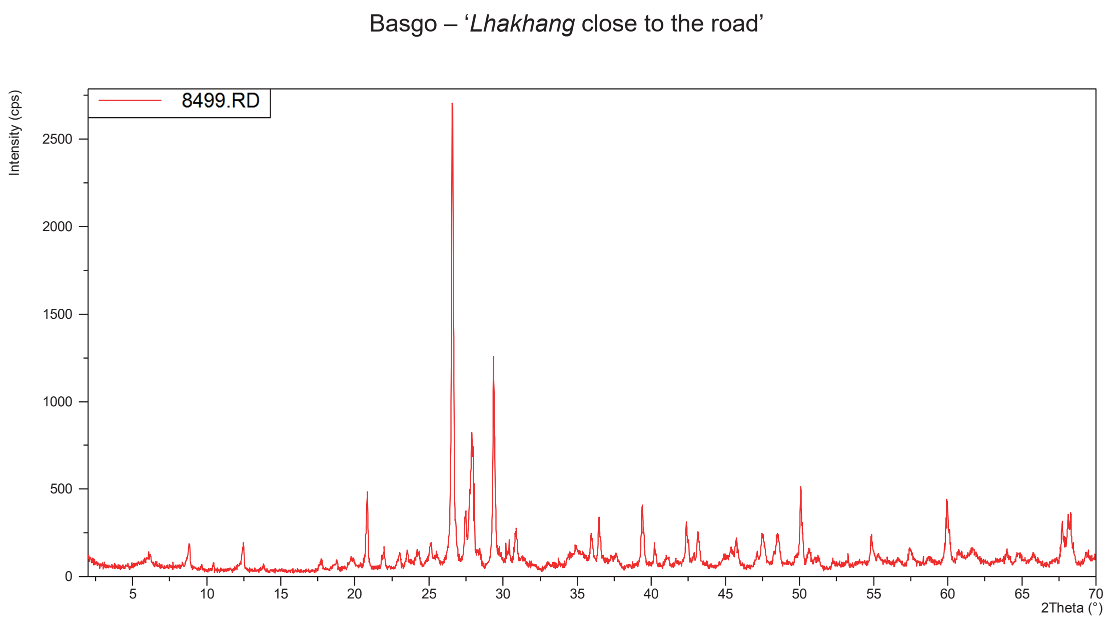
BMA 3.7 Basgo. Lotsāba Lhakhang. Sample 11948. Bulk mineral analysis.



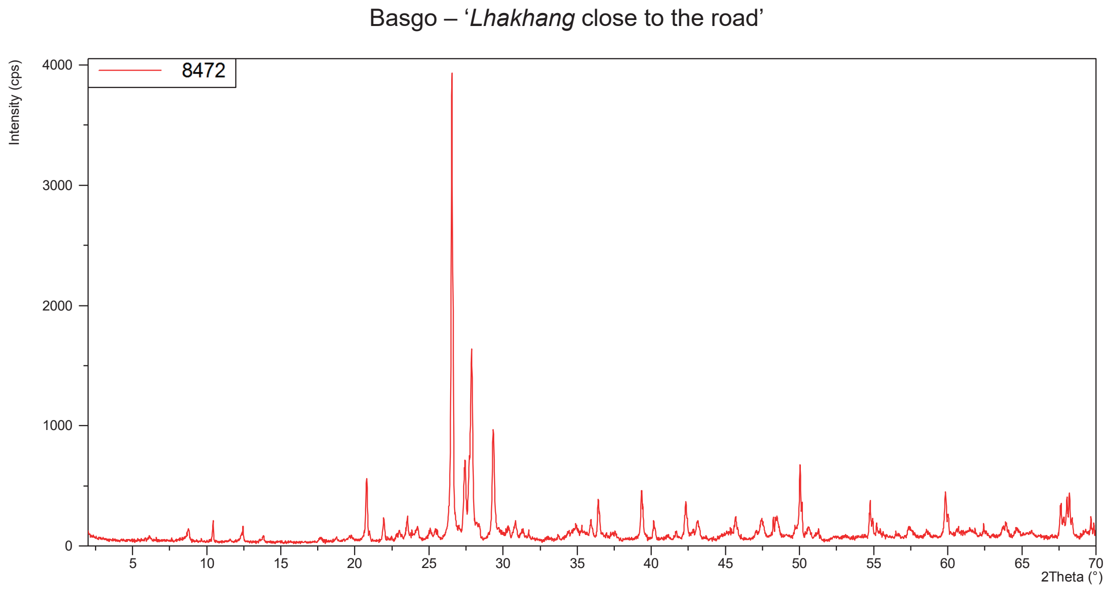
BMA 3.8 Basgo. '*Lhakhang* close to the road'. Sample 8475. Bulk mineral analysis.



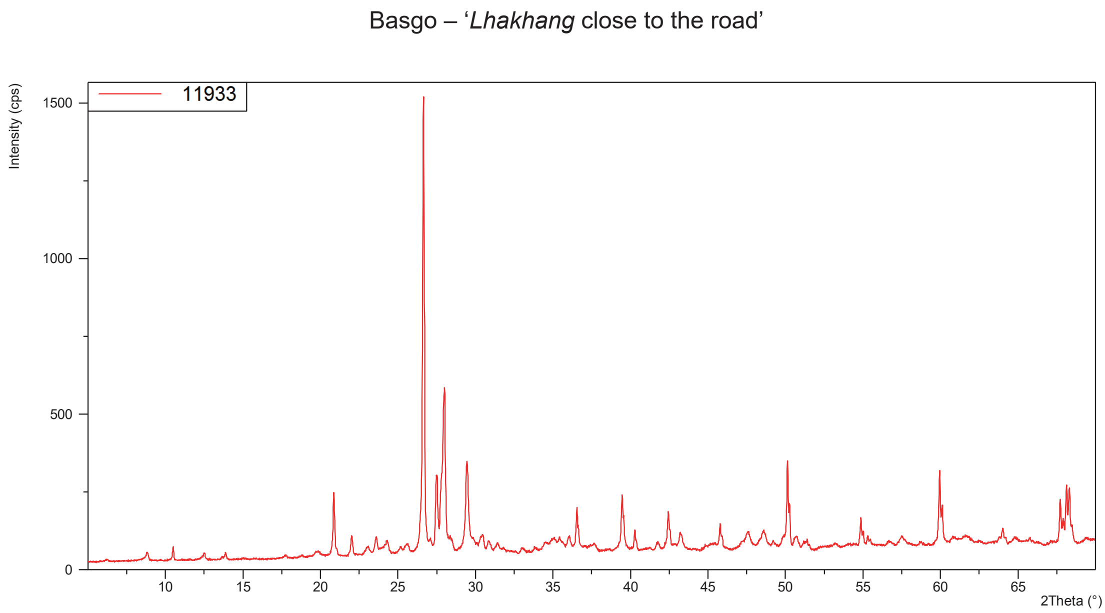
BMA 3.9 Basgo. '*Lhakhang* close to the road'. Sample 11928. Bulk mineral analysis.



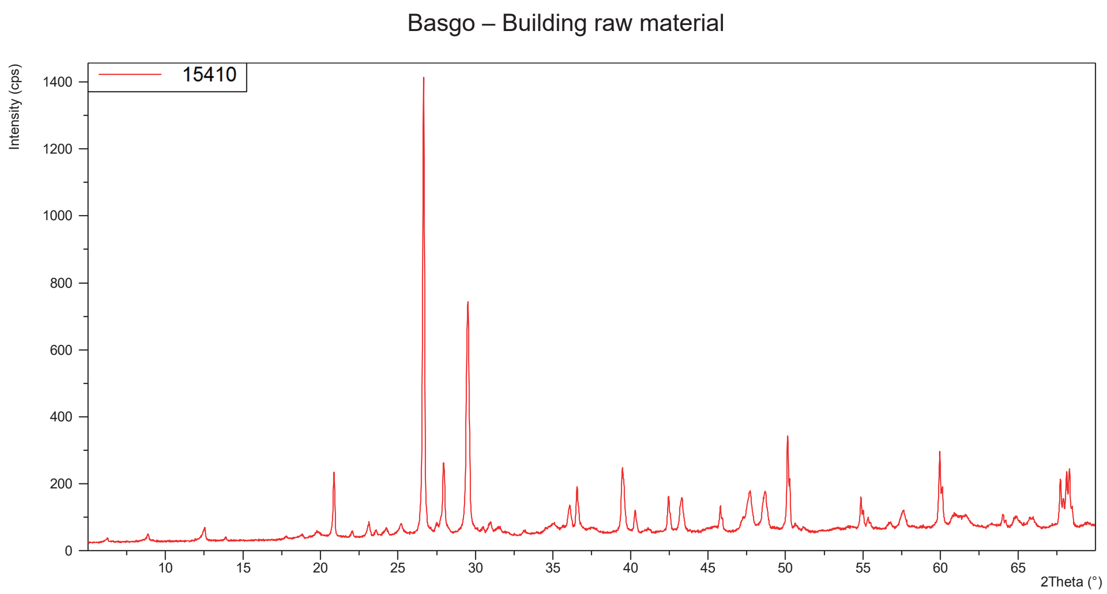
BMA 3.10 Basgo. '*Lhakhang* close to the road'. Sample 8499. Bulk mineral analysis.



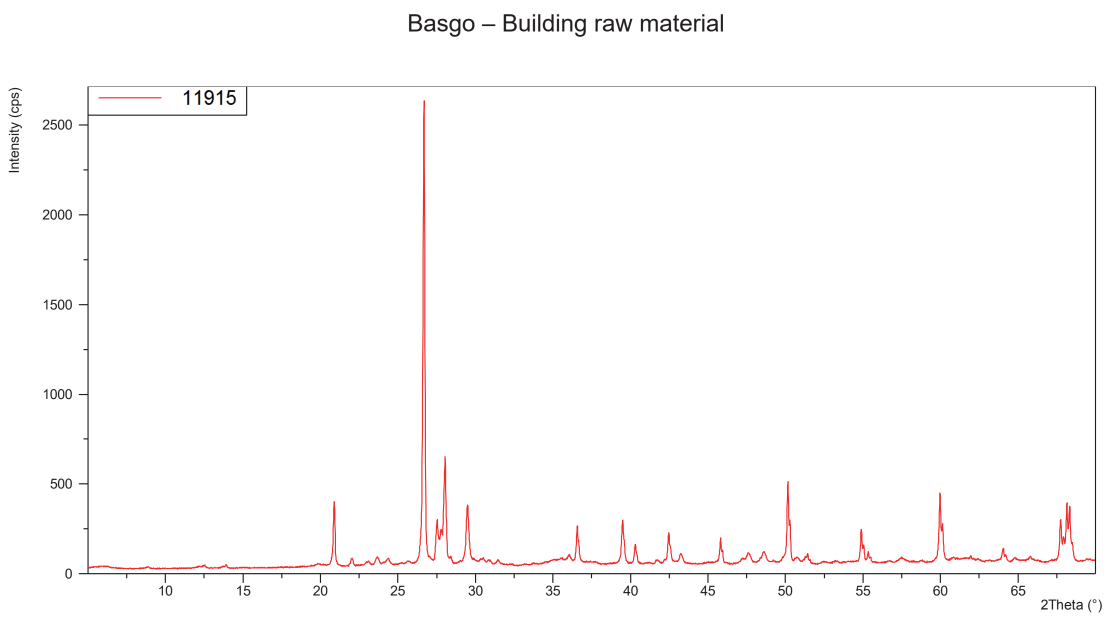
BMA 3.11 Basgo. '*Lhakhang* close to the road'. Sample 8472. Bulk mineral analysis.



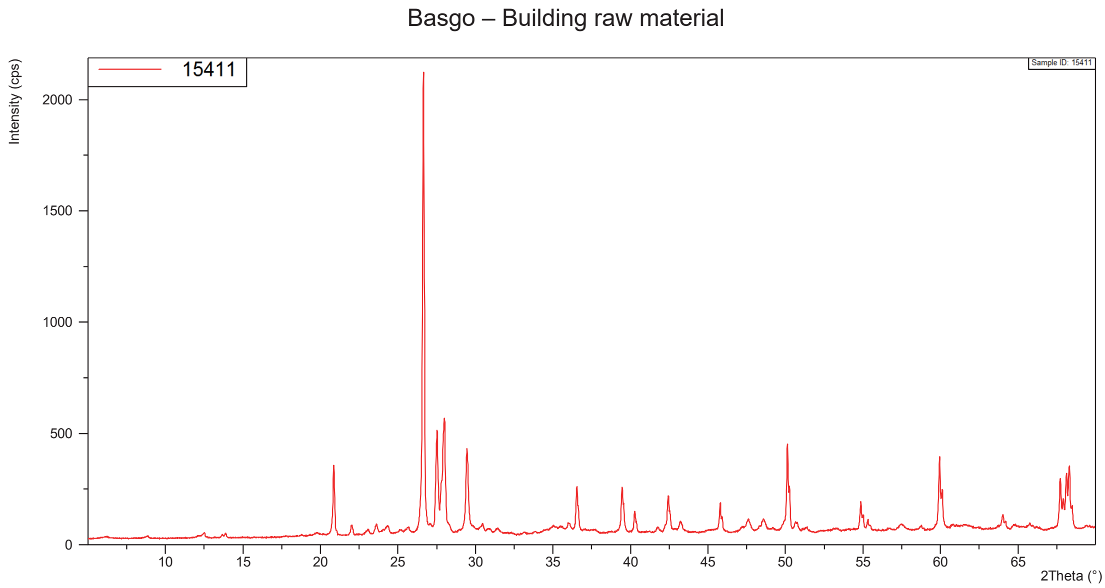
BMA 3.12 Basgo. '*Lhakhang* close to the road'. Sample 11933. Bulk mineral analysis.



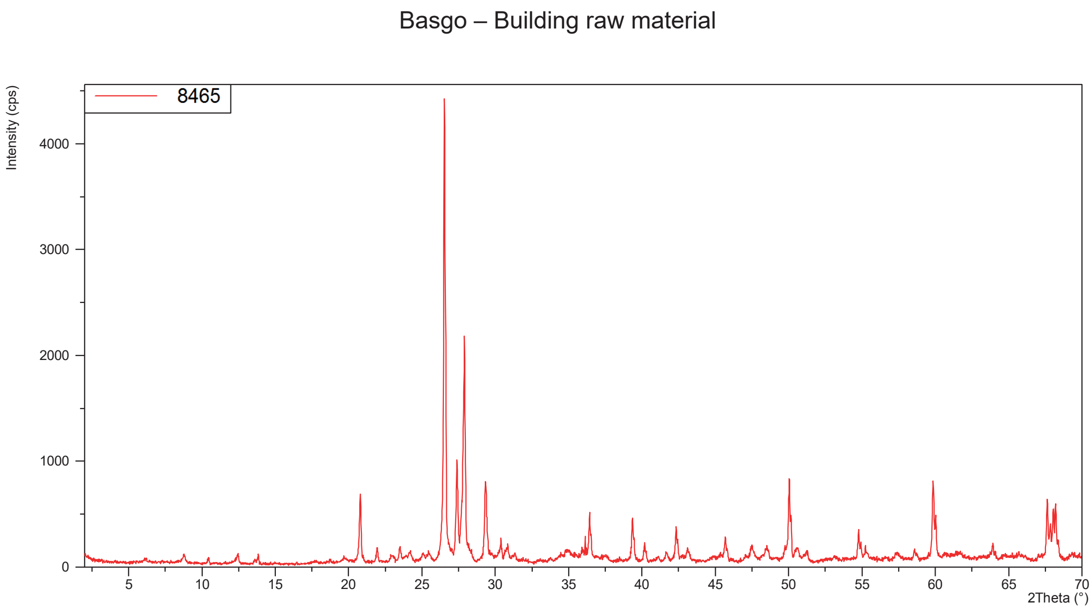
BMA 3.13 Basgo. Building raw material. Sample 15410. Bulk mineral analysis.



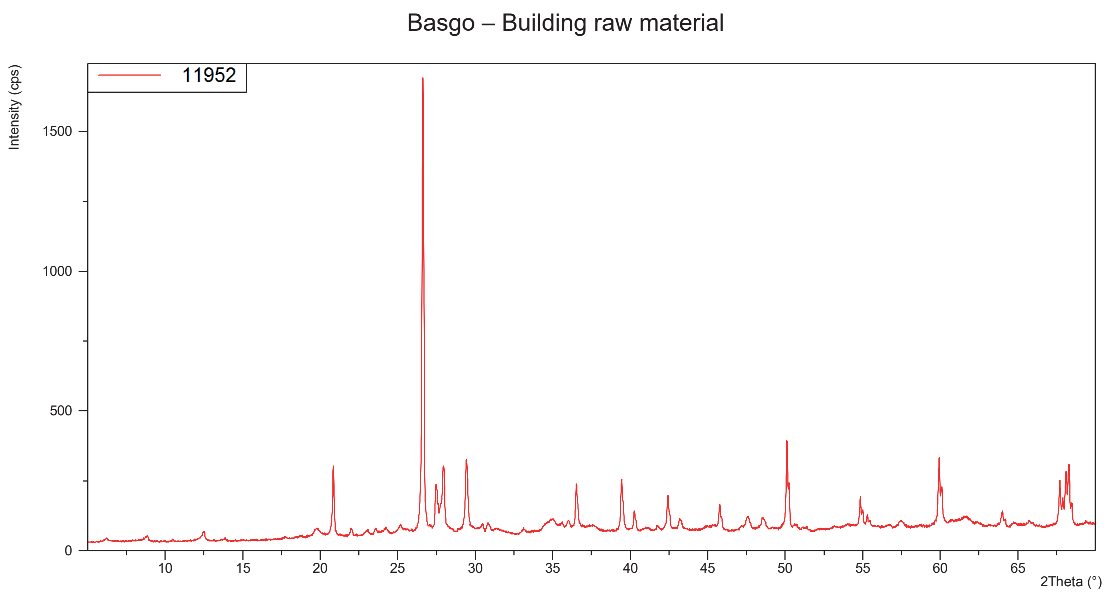
BMA 3.14 Basgo. Building raw material. Sample 11915. Bulk mineral analysis.



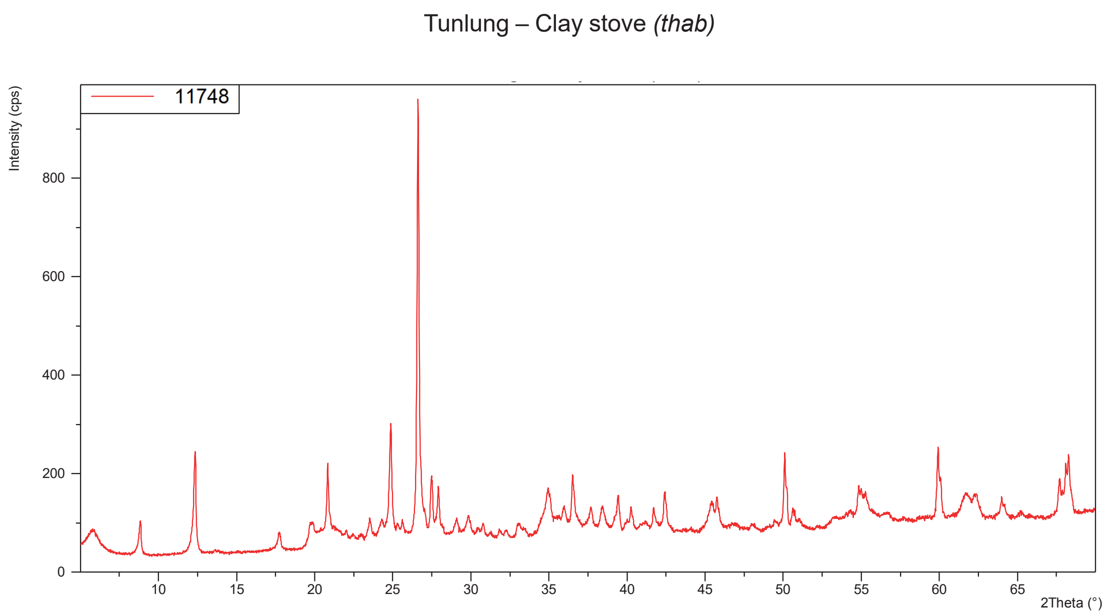
BMA 3.15 Basgo. Building raw material. Sample 15411. Bulk mineral analysis.



BMA 3.16 Basgo. Building raw material. Sample 8465. Bulk mineral analysis.

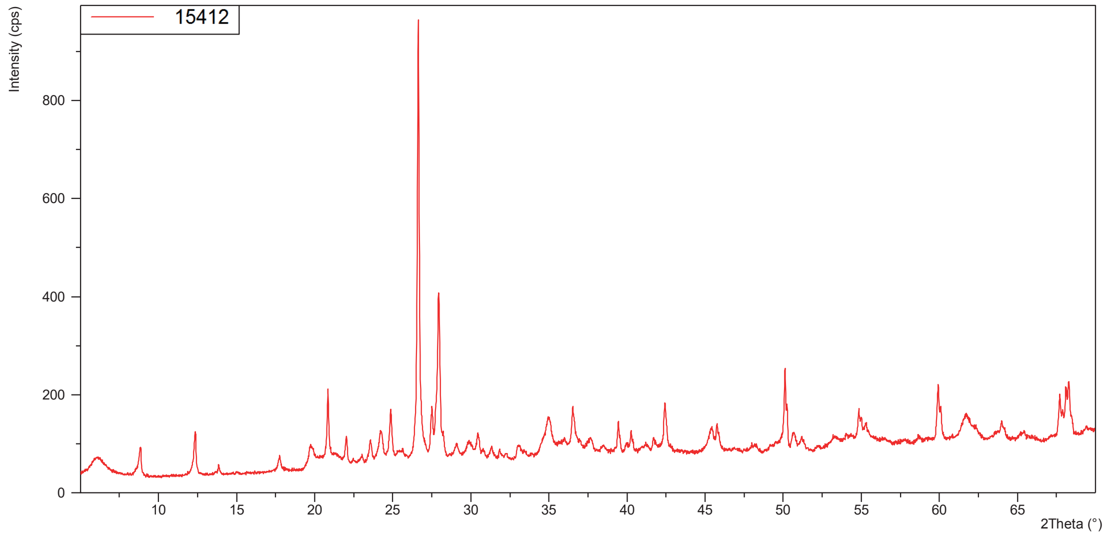


BMA 3.17 Basgo. Building raw material. Sample 11952. Bulk mineral analysis.



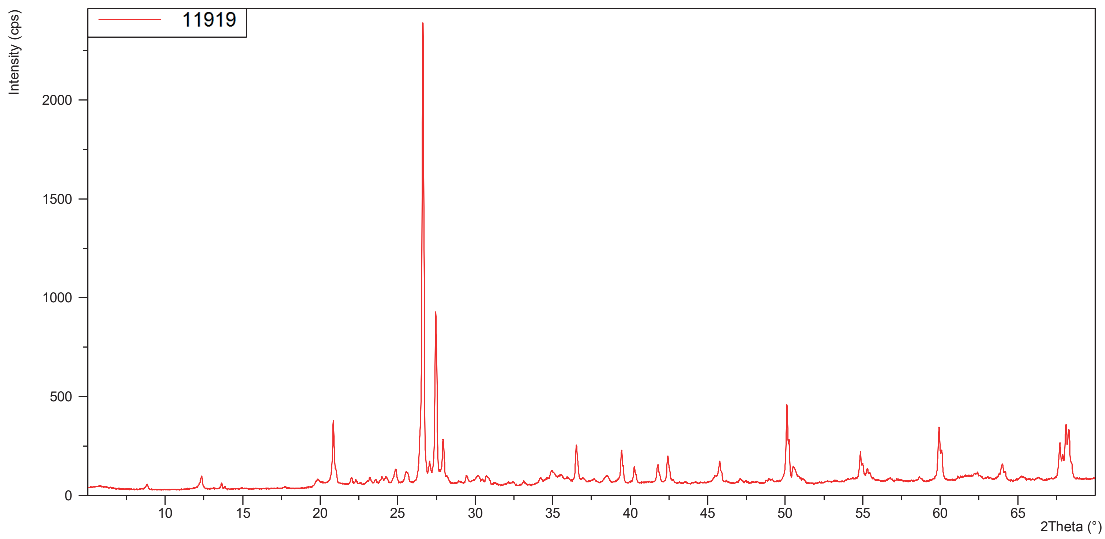
BMA 3.18 Tunlung. *Thabsa*. Sample 11748. Bulk mineral analysis.

Tunlung – Clay stove *(thab)*



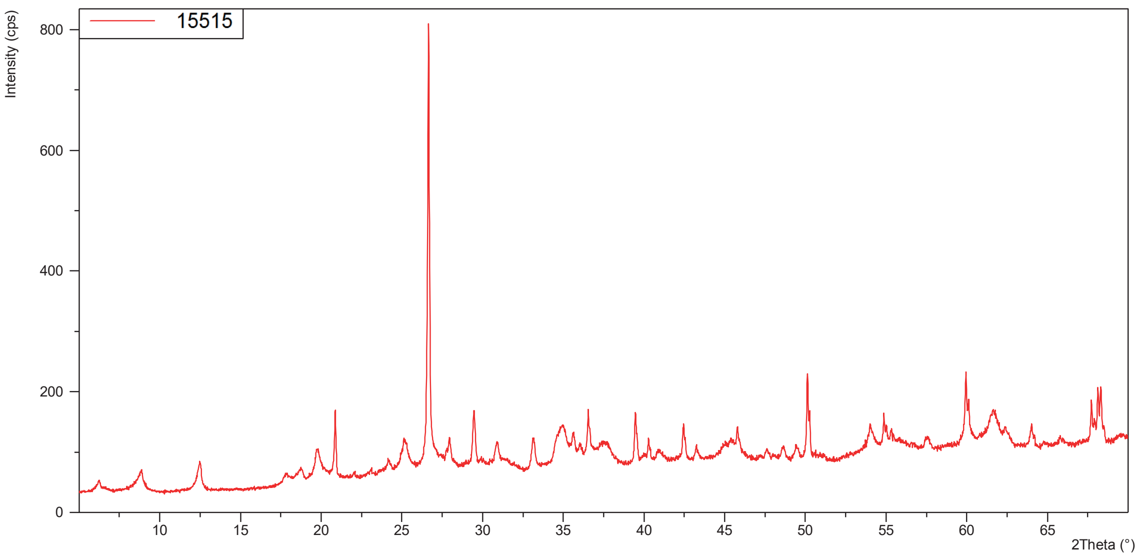
BMA 3.19 Tunlung. *Thabsa*. Sample 15412. Bulk mineral analysis.

Ne – Clay stove *(thab)*



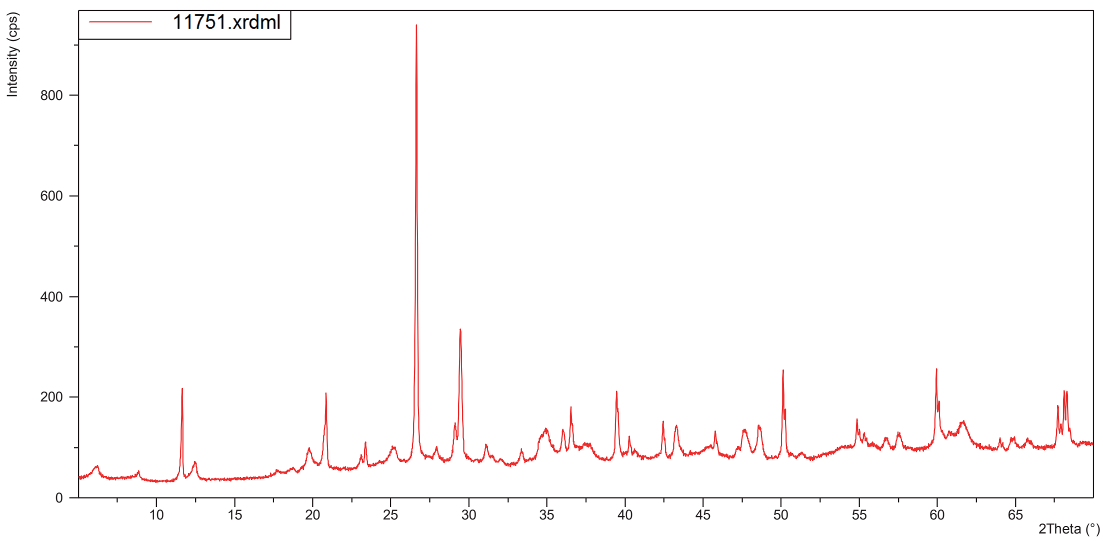
BMA 3.20 Ne. *Thabsa*. Sample 11919. Bulk mineral analysis.

Basgo – Clay stove *(thab)*

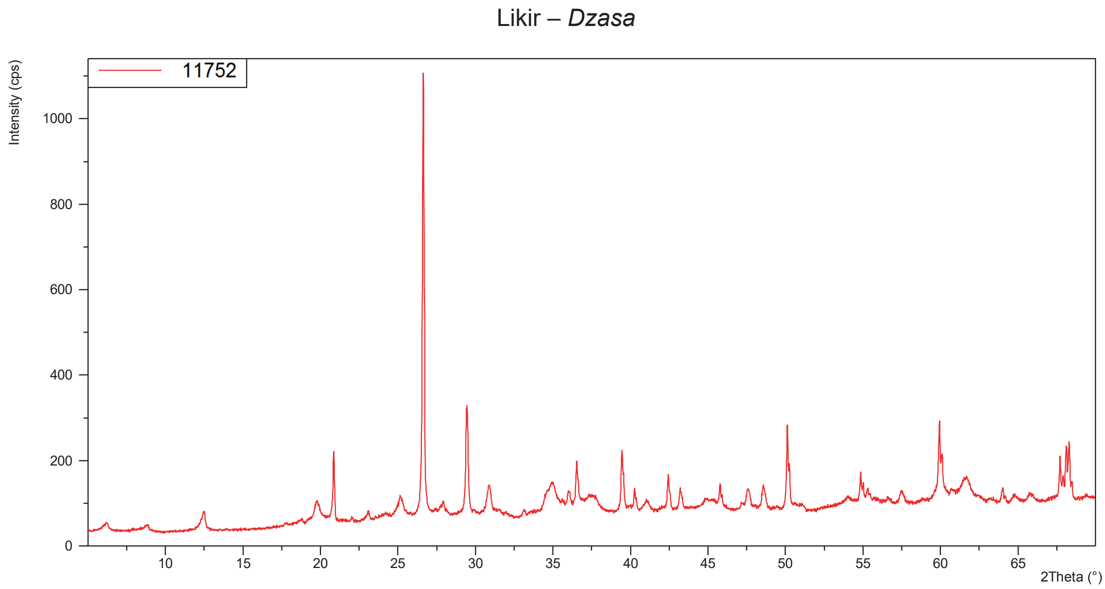


BMA 3.21 Basgo. *Thabsa*. Sample 15515. Bulk mineral analysis.

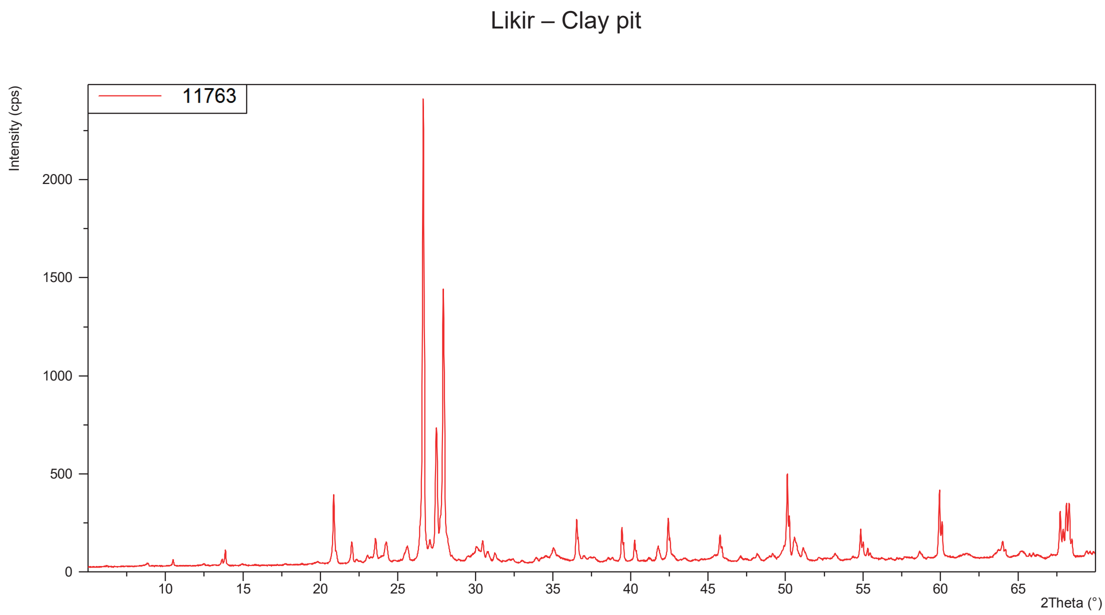
Likir – *Thabsa*



BMA 3.22 Likir. *Thabsa*. Sample 11751. Bulk mineral analysis.

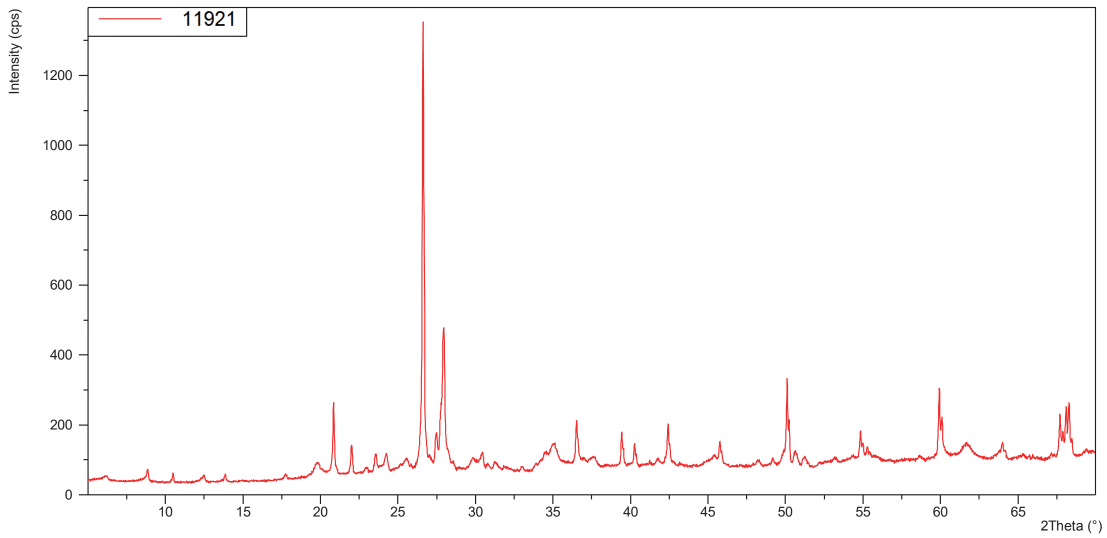


BMA 3.23 Likir. *Dzasa*. Sample 11752. Bulk mineral analysis.



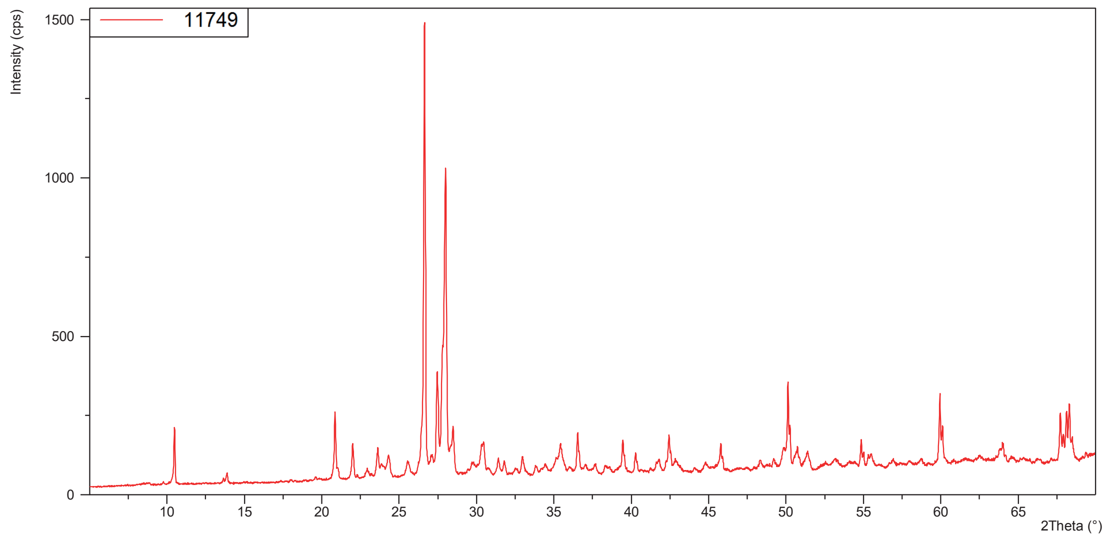
BMA 3.24 Likir. Clay pit. Sample 11763. Bulk mineral analysis.

Likir – Adobe brick

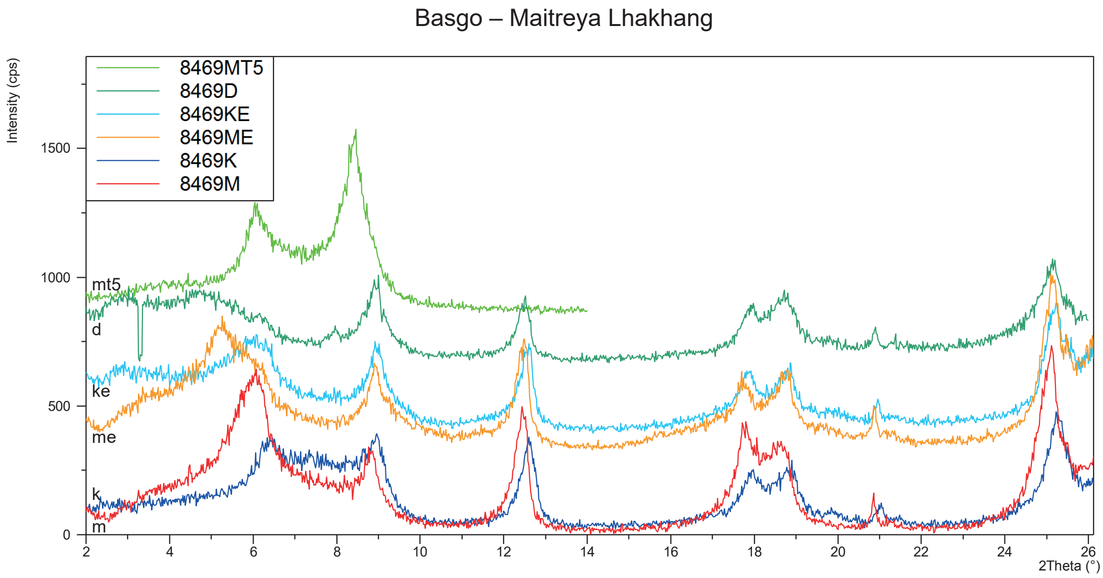


BMA 3.25 Likir. Adobe brick. Sample 11921. Bulk mineral analysis.

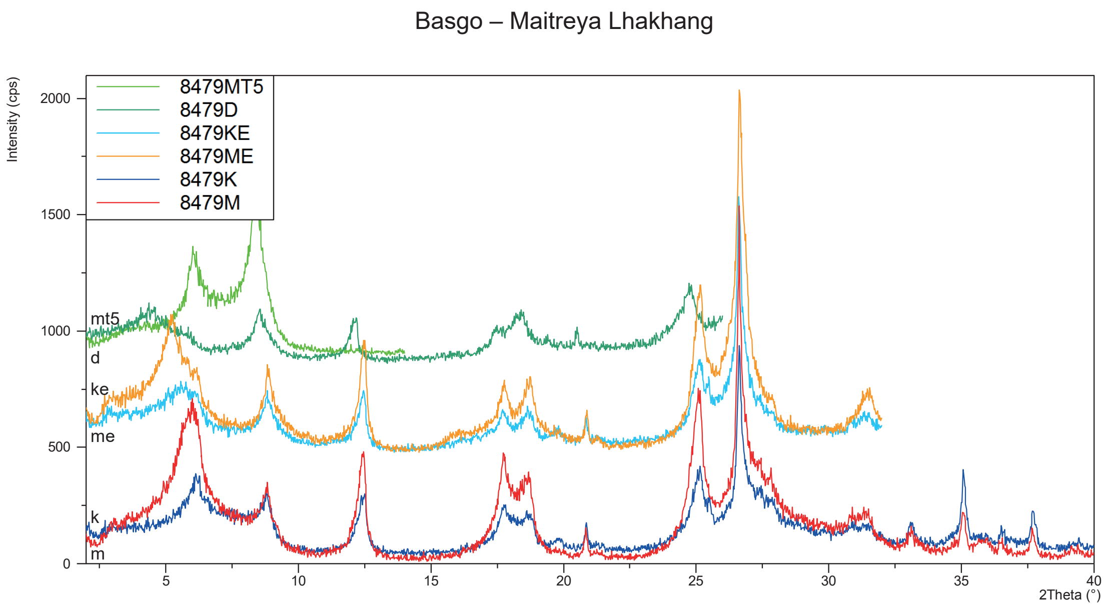
Likir – Sand



BMA 3.26 Likir. Sand. Sample 11749. Bulk mineral analysis.

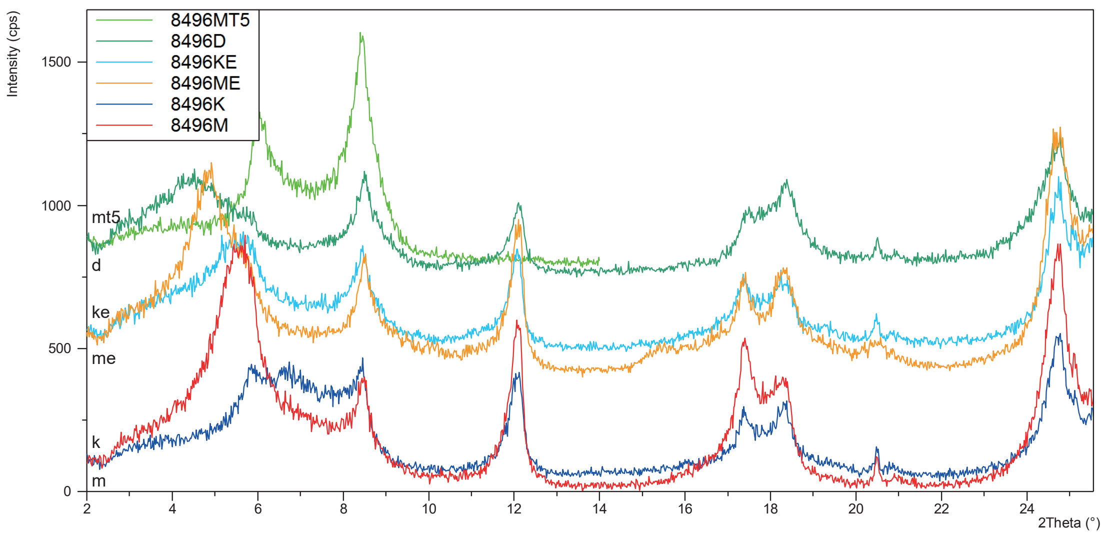


CMA 3.1 Basgo. Maitreya Lhakhang. Sample 8469. Clay mineral analysis.



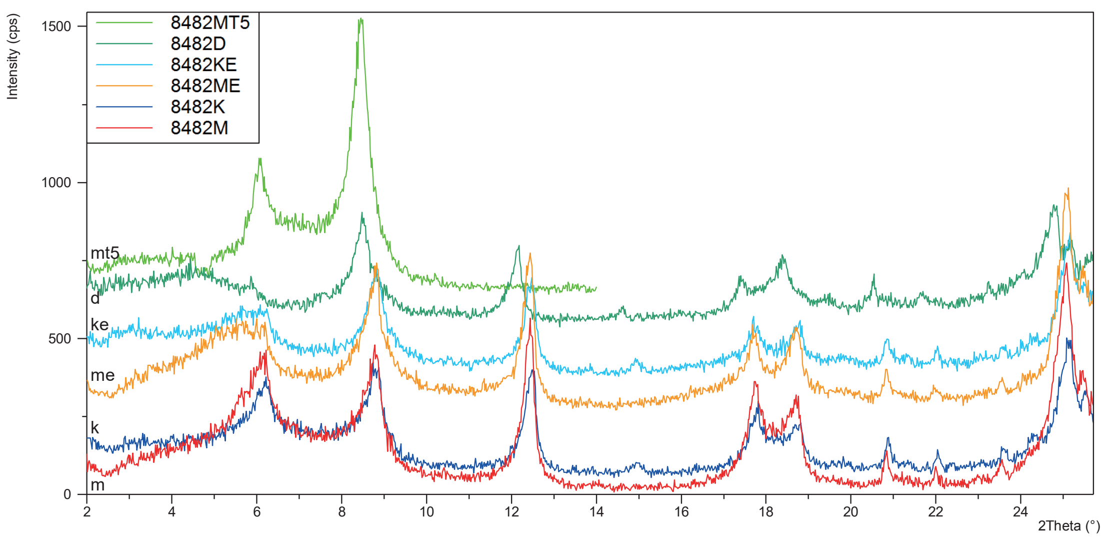
CMA 3.2 Basgo. Maitreya Lhakhang. Sample 8479. Clay mineral analysis.

Basgo – Maitreya Lhakhang

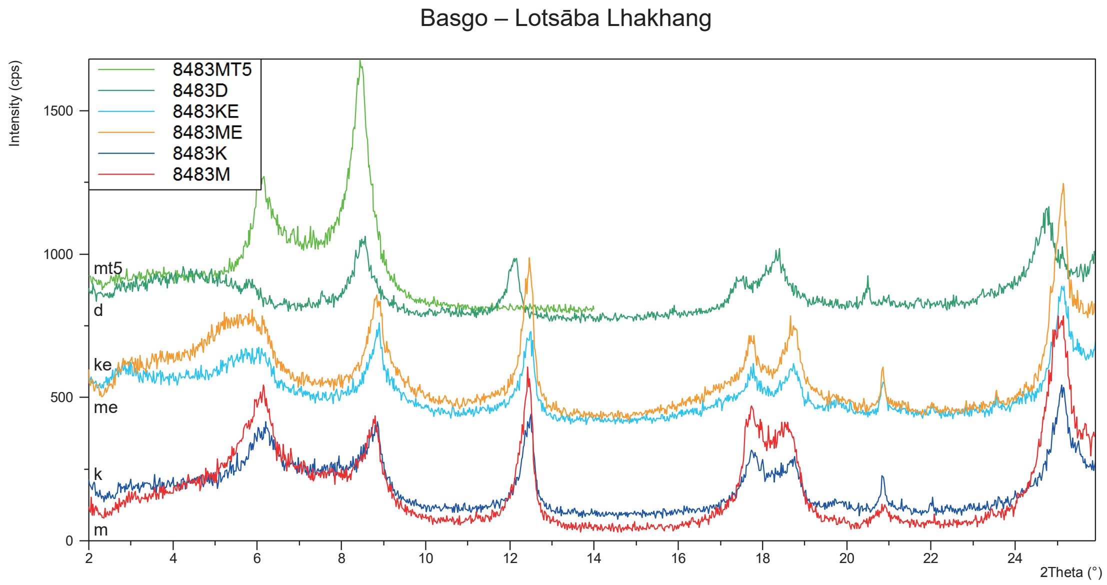


CMA 3.3 Basgo. Maitreya Lhakhang. Sample 8496. Clay mineral analysis.

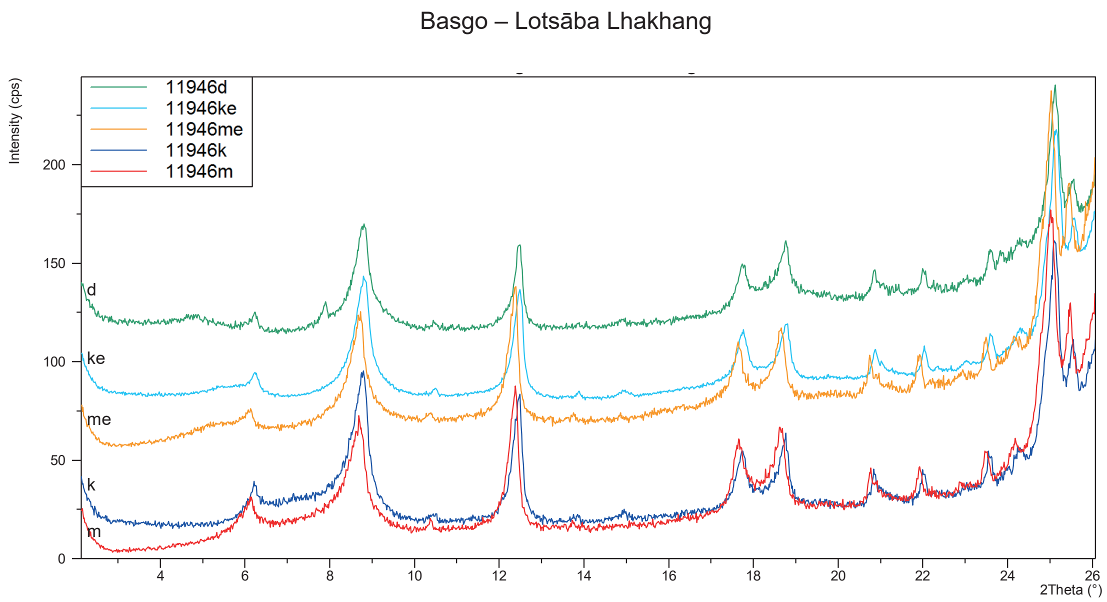
Basgo – Lotsāba Lhakhang



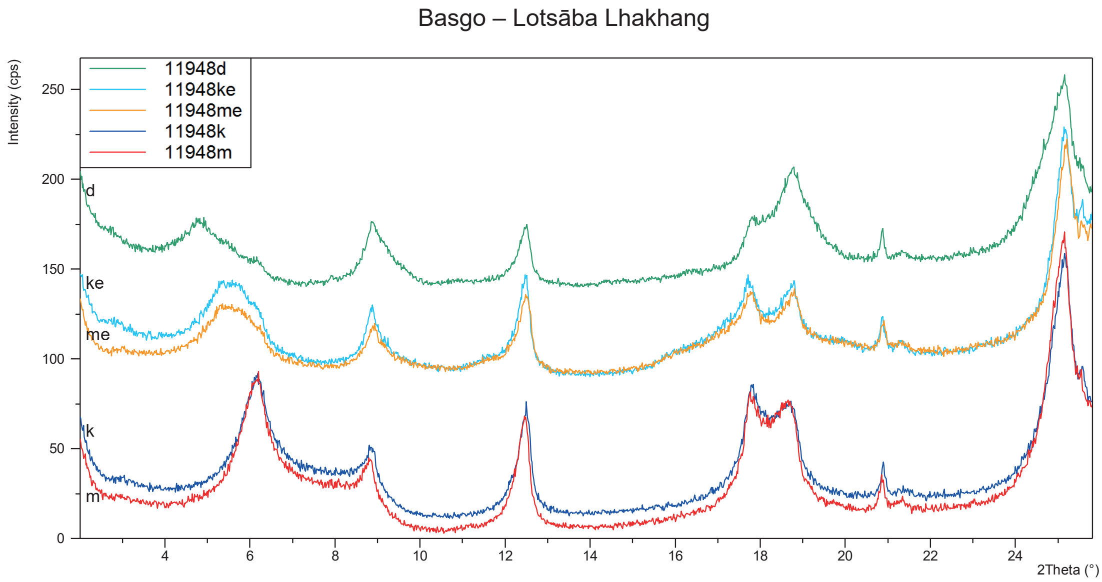
CMA 3.4 Basgo. Lotsāba Lhakhang. Sample 8482. Clay mineral analysis.



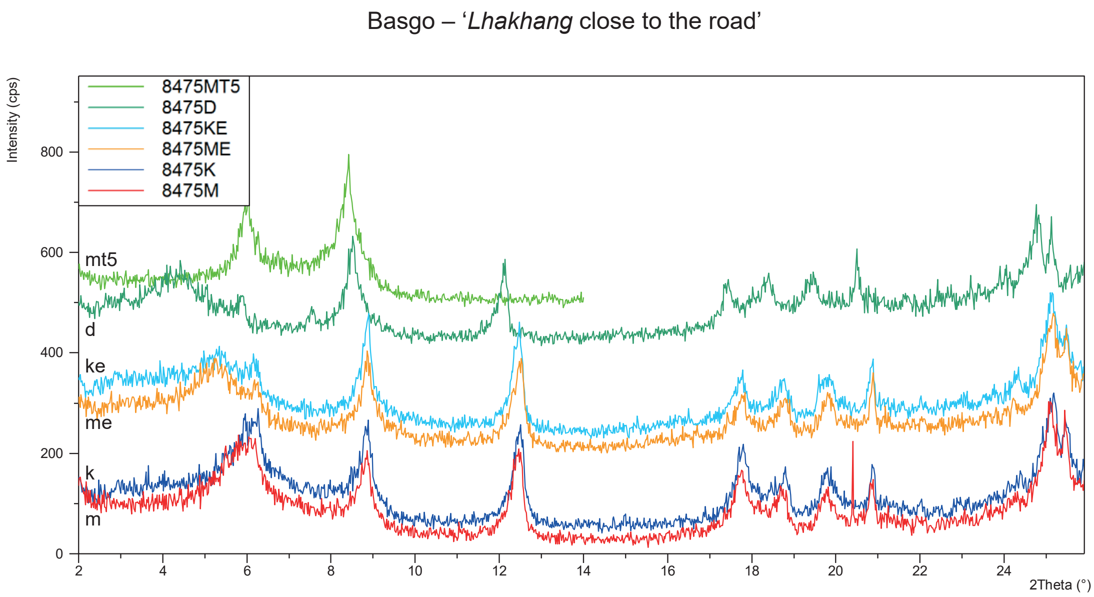
CMA 3.5 Basgo. Lotsāba Lhakhang. Sample 8483. Clay mineral analysis.



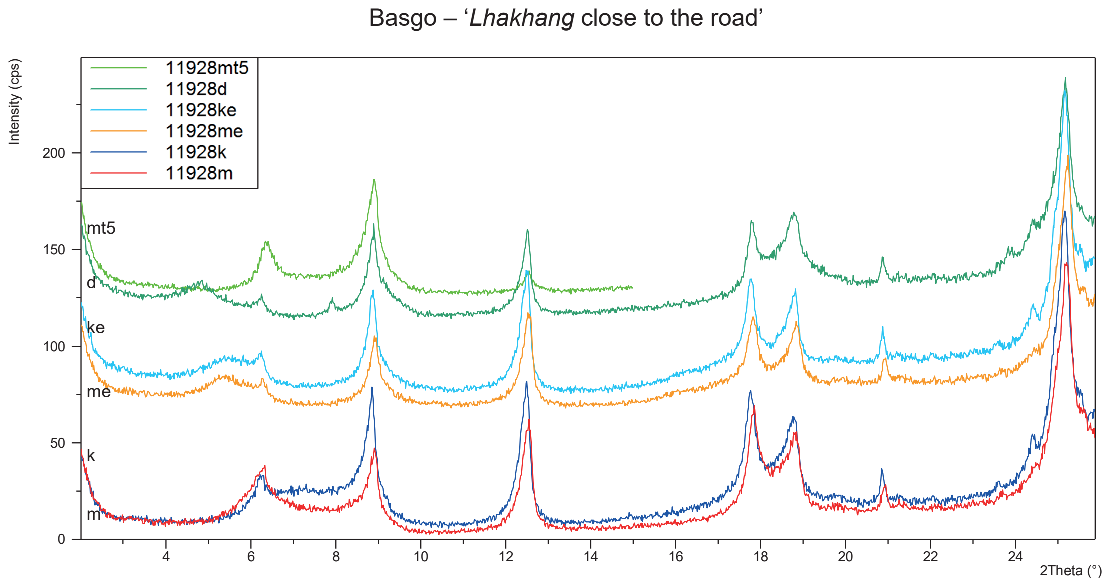
CMA 3.6 Basgo. Lotsāba Lhakhang. Sample 11946. Clay mineral analysis.



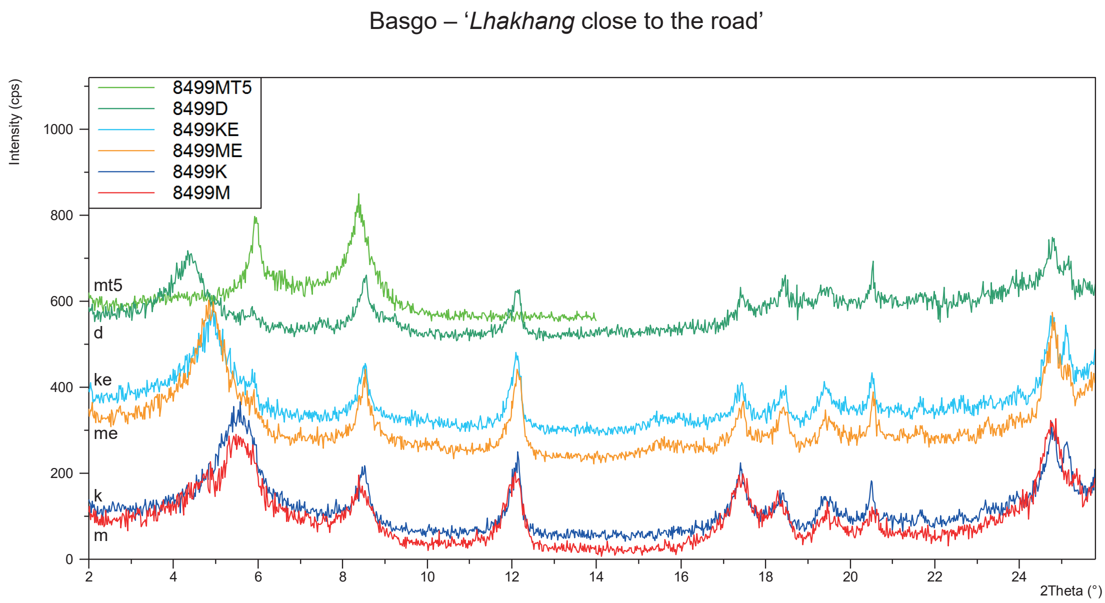
CMA 3.7 Basgo. Lotsāba Lhakhang. Sample 11948. Clay mineral analysis.



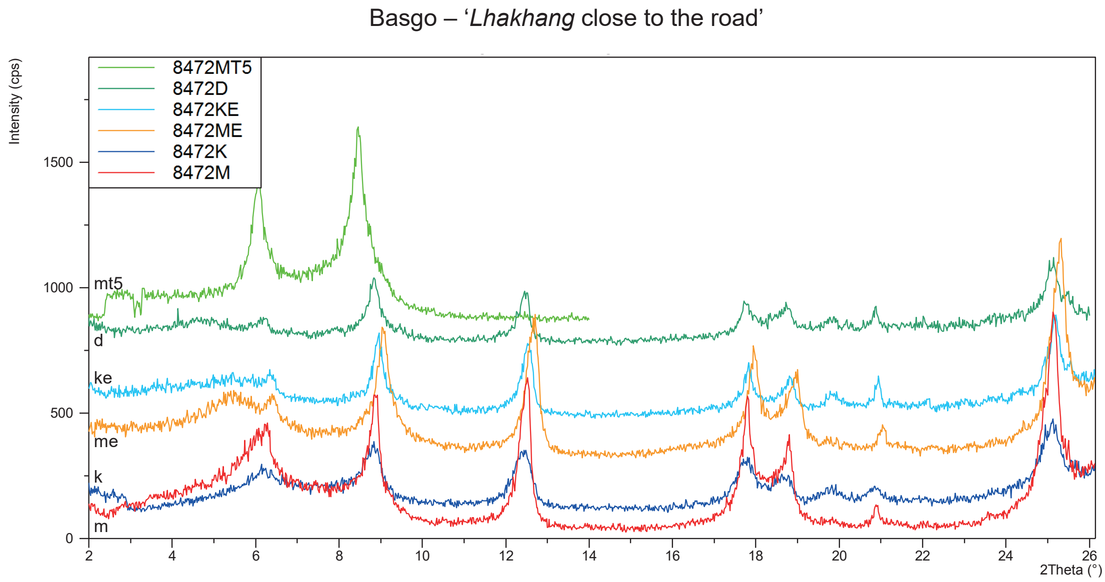
CMA 3.8 Basgo. '*Lhakhang* close to the road'. Sample 8475. Clay mineral analysis.



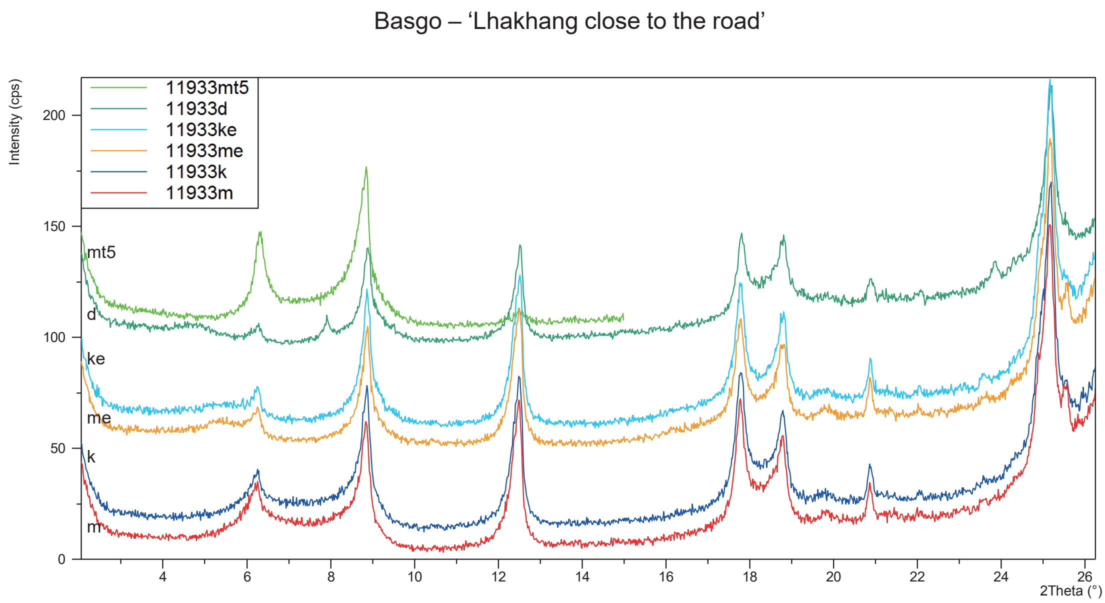
CMA 3.9 Basgo. '*Lhakhang* close to the road'. Sample 11928. Clay mineral analysis.



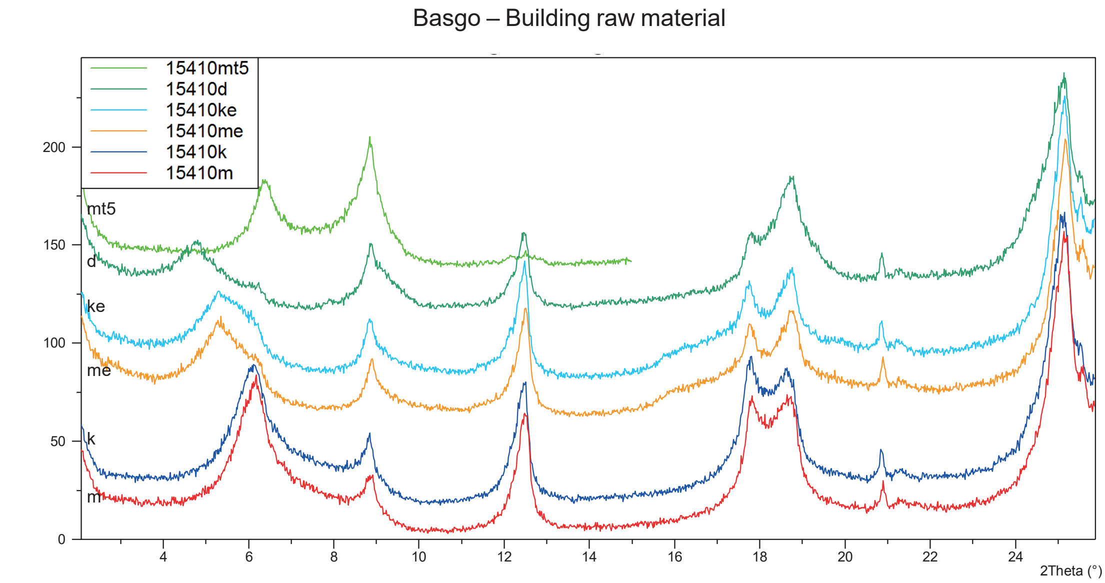
CMA 3.10 Basgo. '*Lhakhang* close to the road'. Sample 8499. Clay mineral analysis.



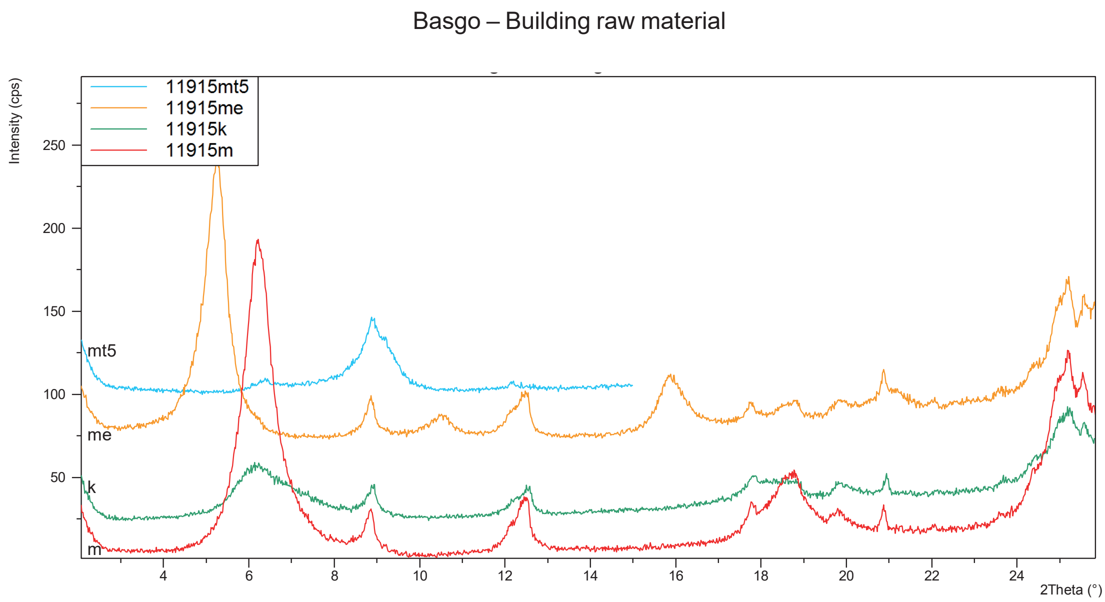
CMA 3.11 Basgo. 'Lhakhang close to the road'. Sample 8472. Clay mineral analysis



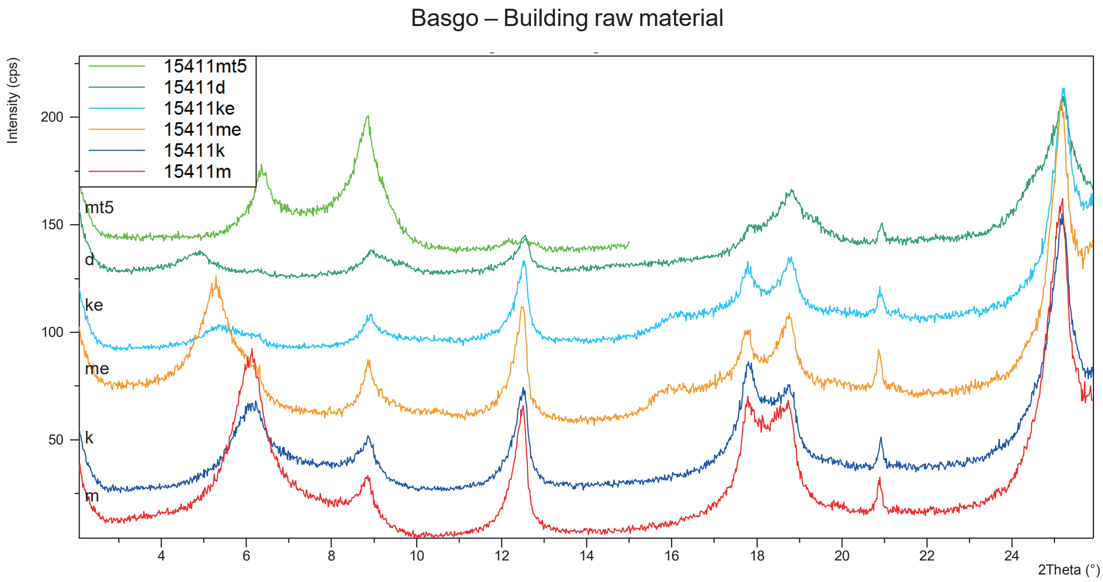
CMA 3.12 Basgo. '*Lhakhang* close to the road'. Sample 11933. Clay mineral analysis.



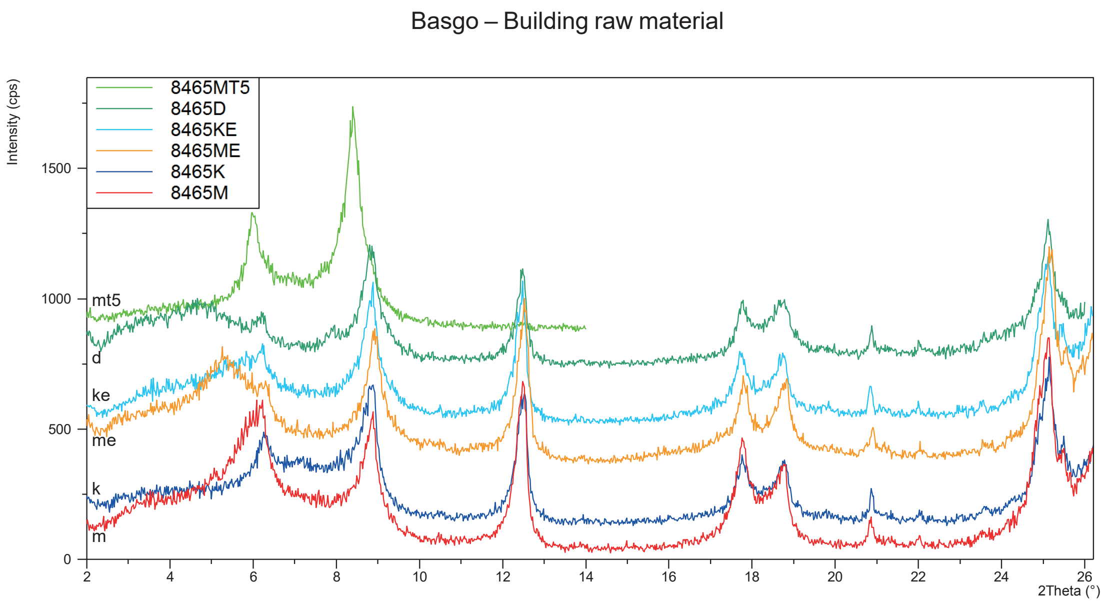
CMA 3.13 Basgo. Building raw material. Sample 15410. Clay mineral analysis.



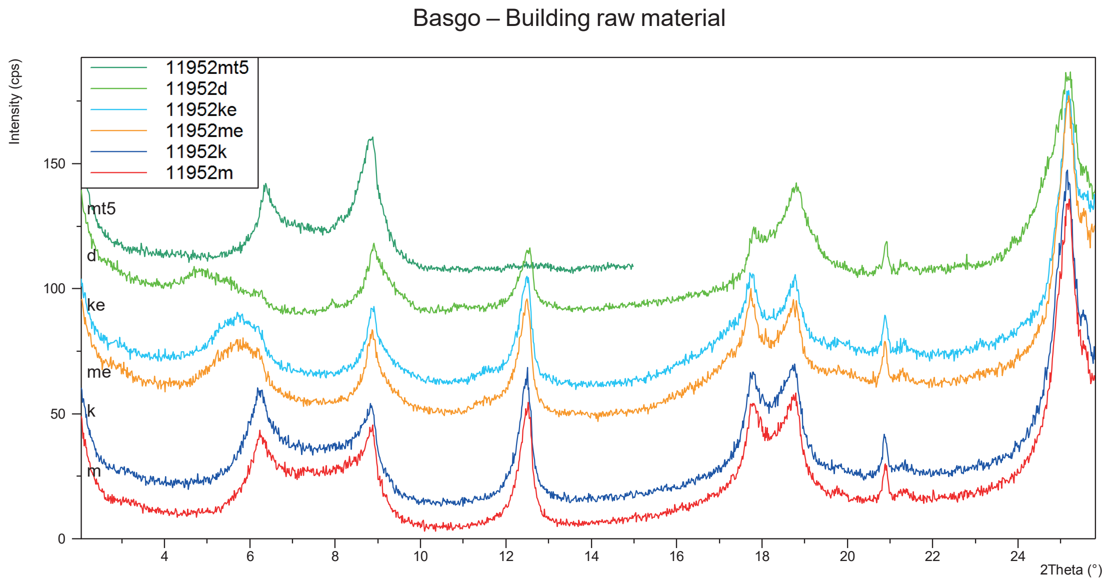
CMA 3.14 Basgo. Building raw material. Sample 11915. Clay mineral analysis.



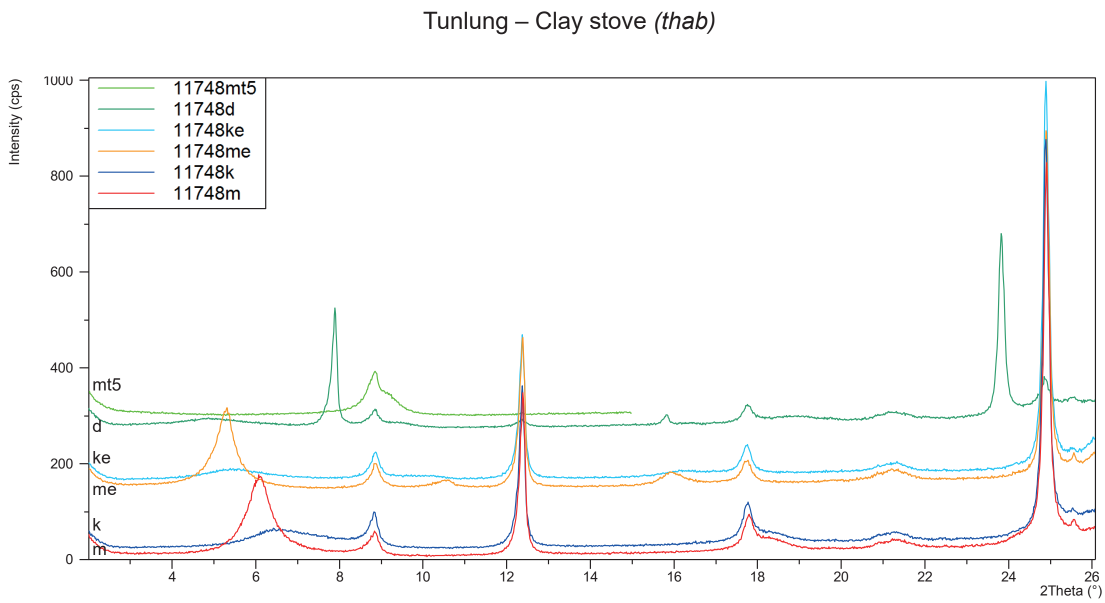
CMA 3.15 Basgo. Building raw material. Sample 15411. Clay mineral analysis.



CMA 3.16 Basgo. Building raw material. Sample 8465. Clay mineral analysis.

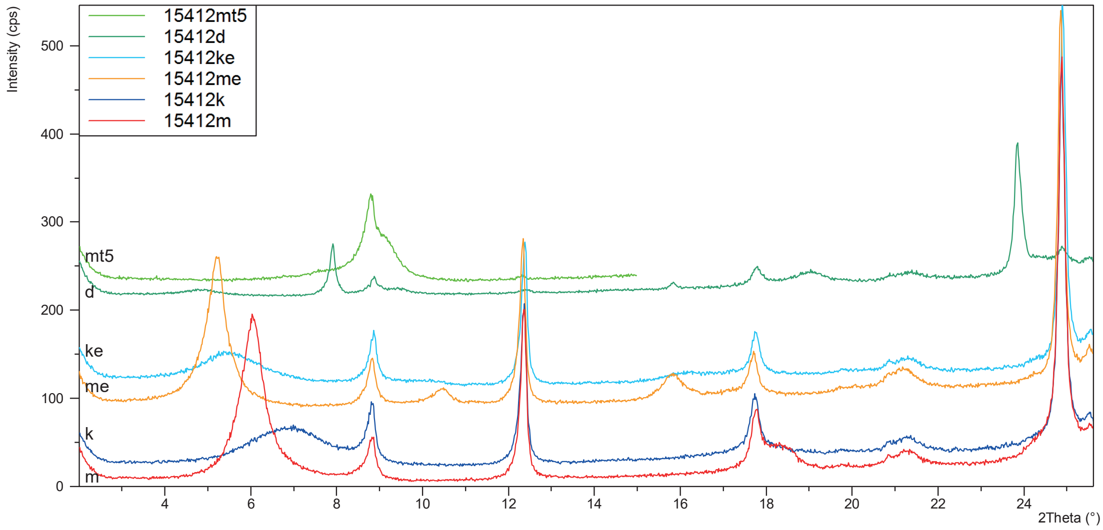


CMA 3.17 Basgo. Building raw material. Sample 11952. Clay mineral analysis.



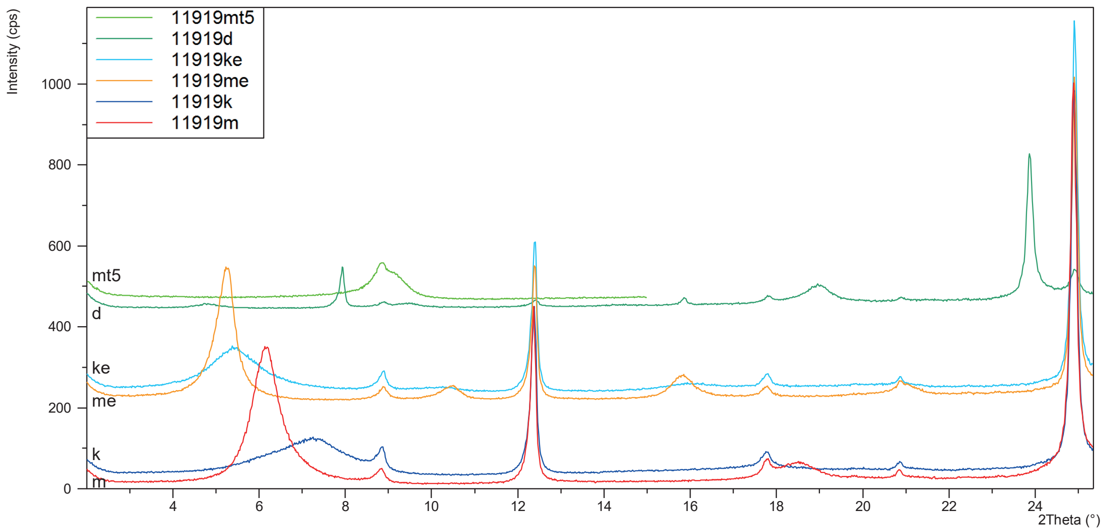
CMA 3.18 Tunlung. *Thabsa*. Sample 11748. Clay mineral analysis.

Tunlung – Clay stove *(thab)*

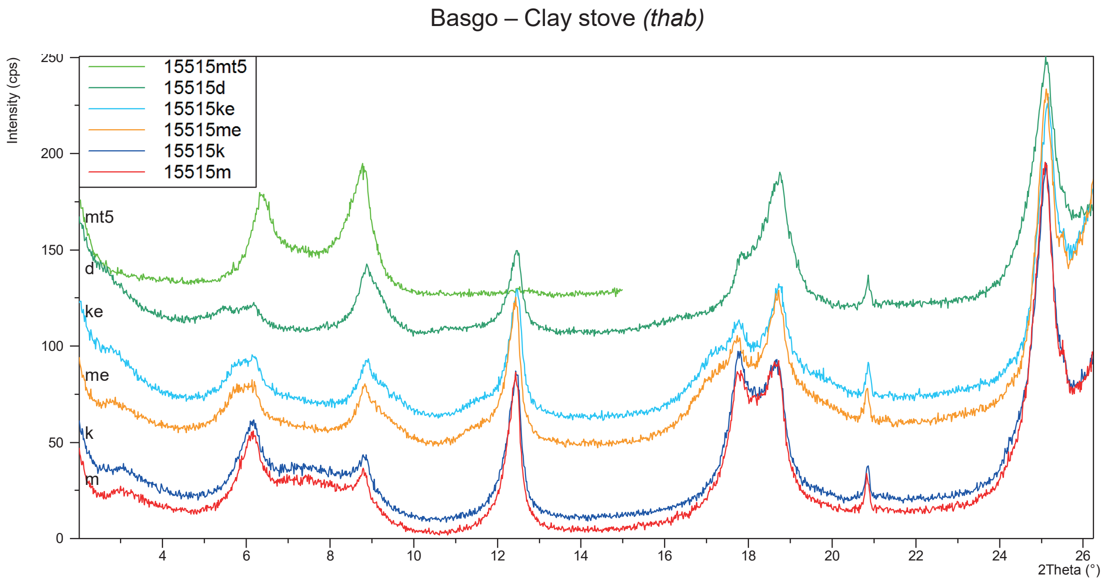


CMA 3.19 Tunlung. *Thabsa*. Sample 15412. Clay mineral analysis.

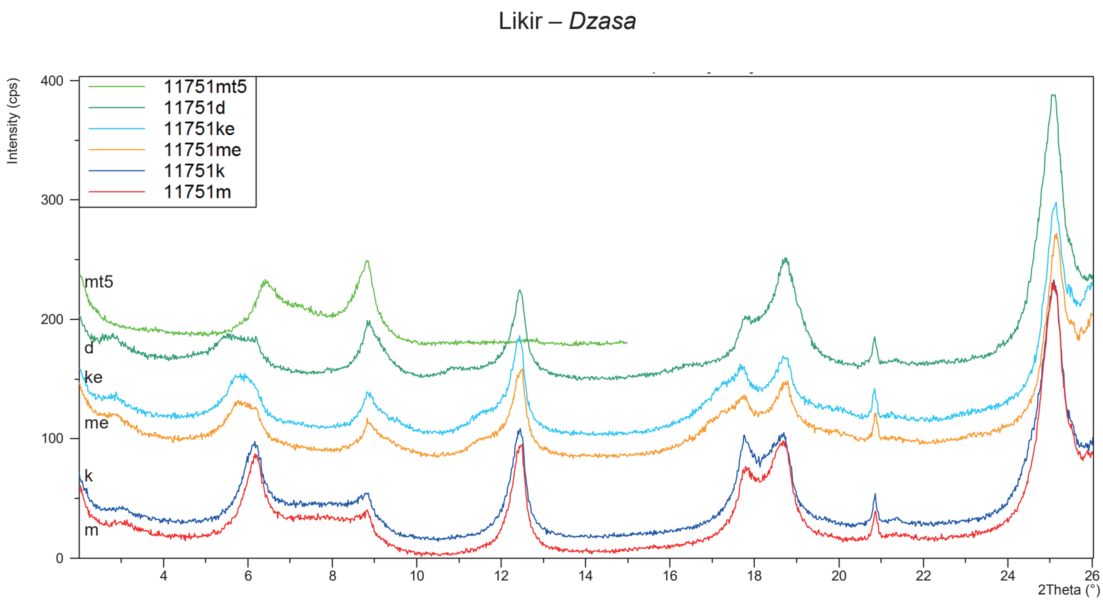
Ne – Clay stove *(thab)*



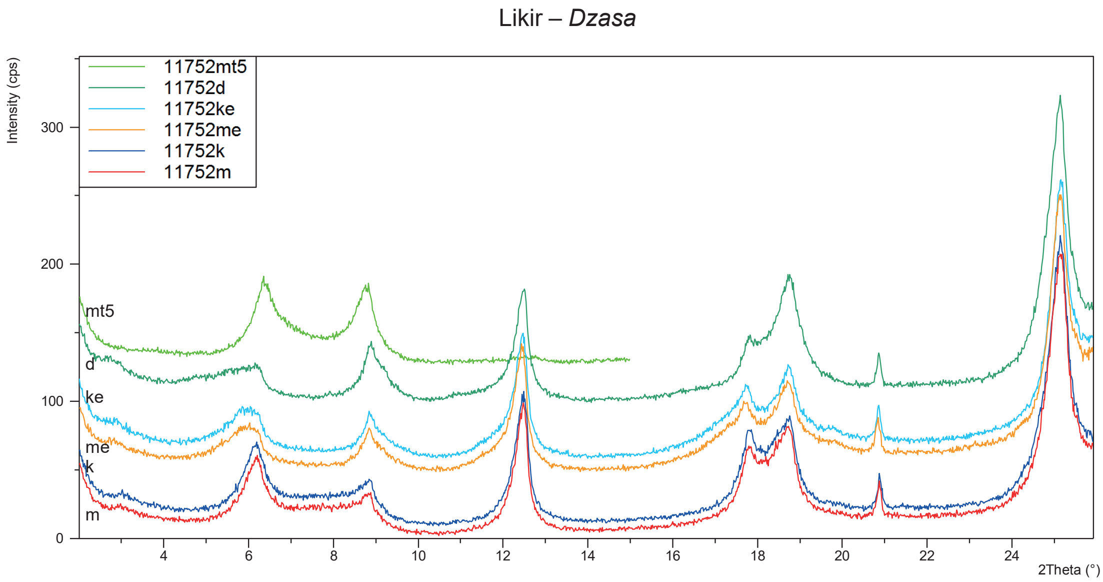
CMA 3.20 Ne. *Thabsa*. Sample 11919. Clay mineral analysis.



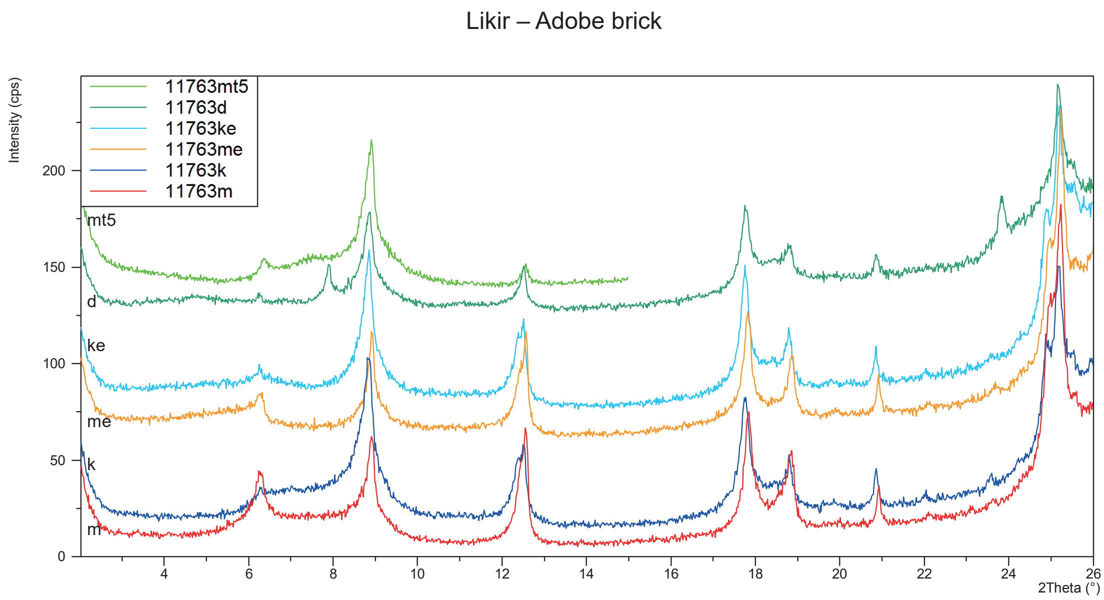
CMA 3.21 Basgo. *Thabsa*. Sample 15515. Clay mineral analysis.



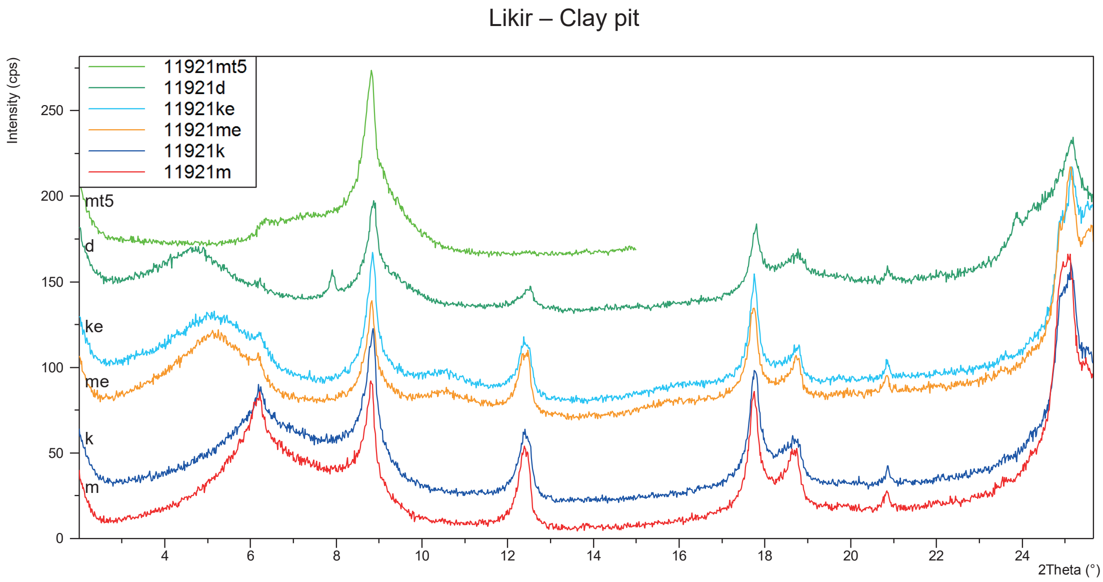
CMA 3.22 Likir. *Tandoor* stove and pottery clay. Sample 11751. Clay mineral analysis.



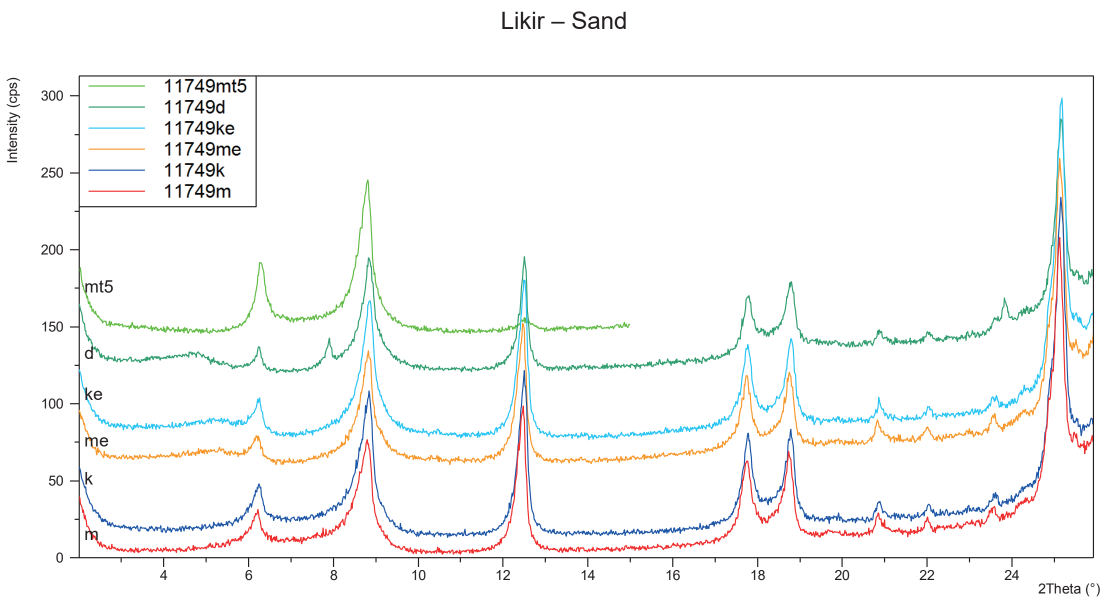
CMA 3.23 Likir. *Dzasa*. Sample 11752. Clay mineral analysis.



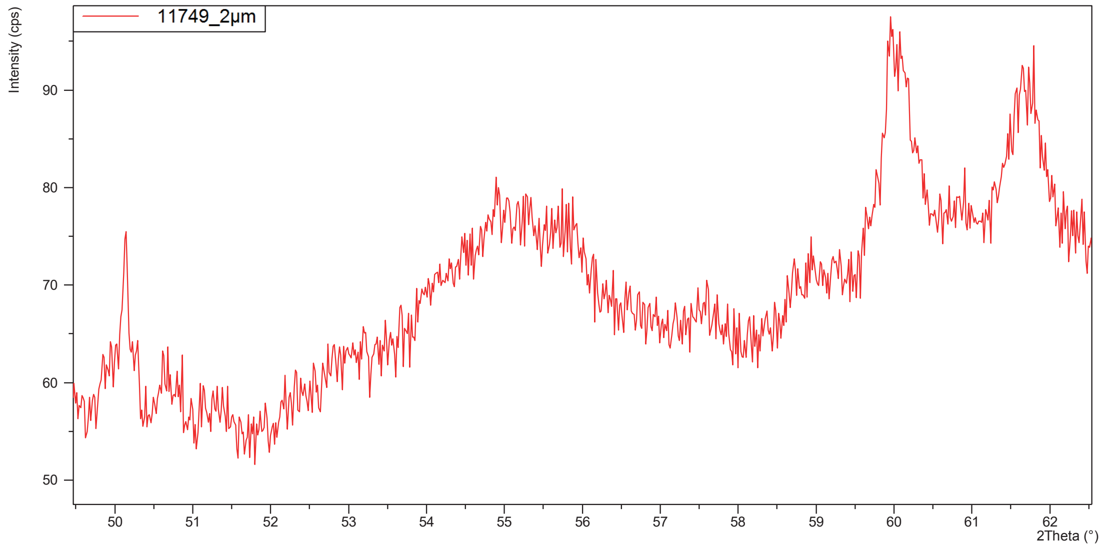
CMA 3.24 Likir. Adobe brick. Sample 11763. Clay mineral analysis.



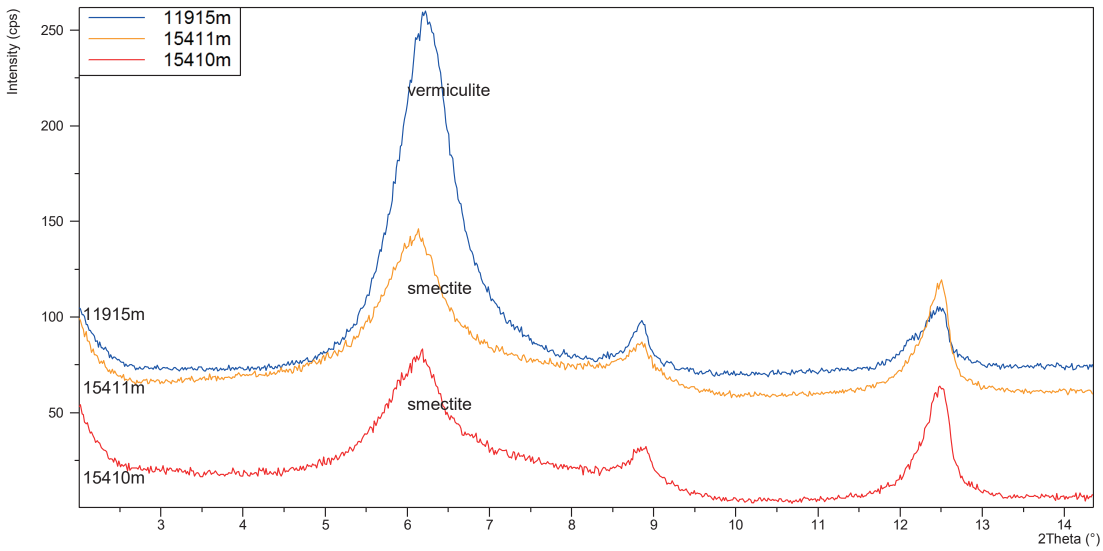
CMA 3.25 Likir. Clay pit. Sample 11921. Clay mineral analysis.



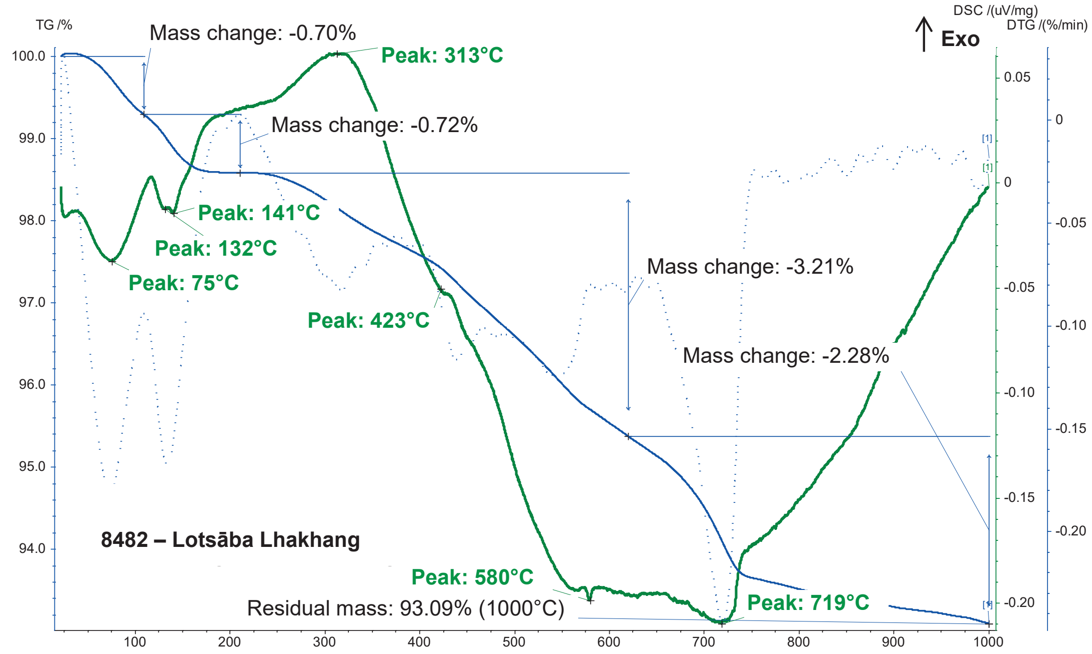
CMA 3.26 Likir. Sand. Sample 11749. Clay mineral analysis.



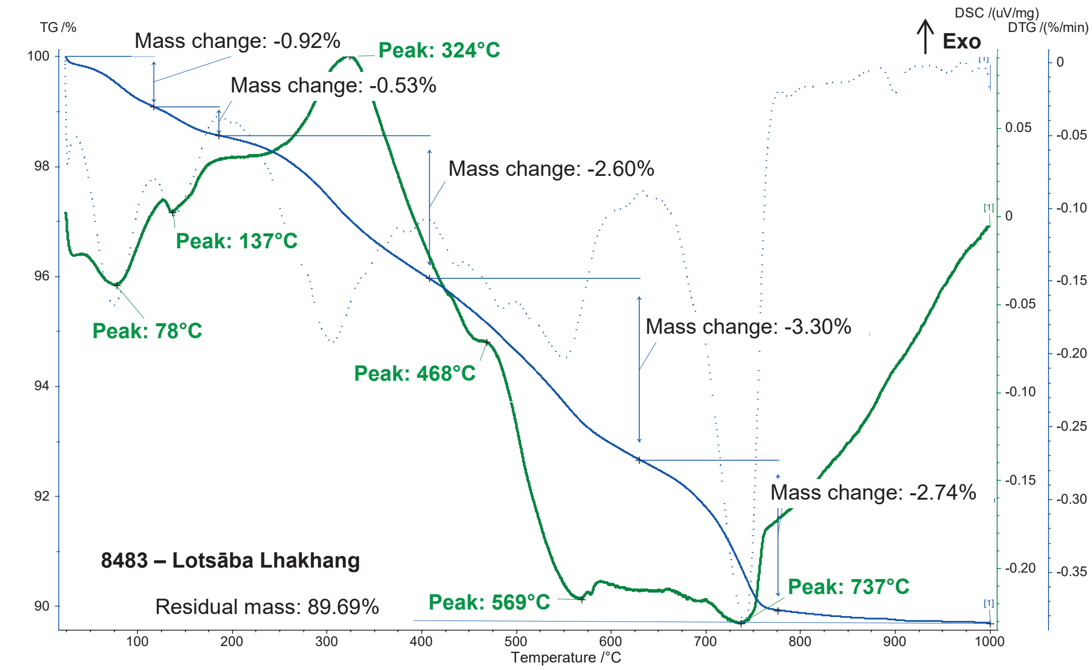
CMA 3.27 Likir. Sand. Sample 11749. Clay mineral analysis. Di-octahedral and tri-octahedral components.



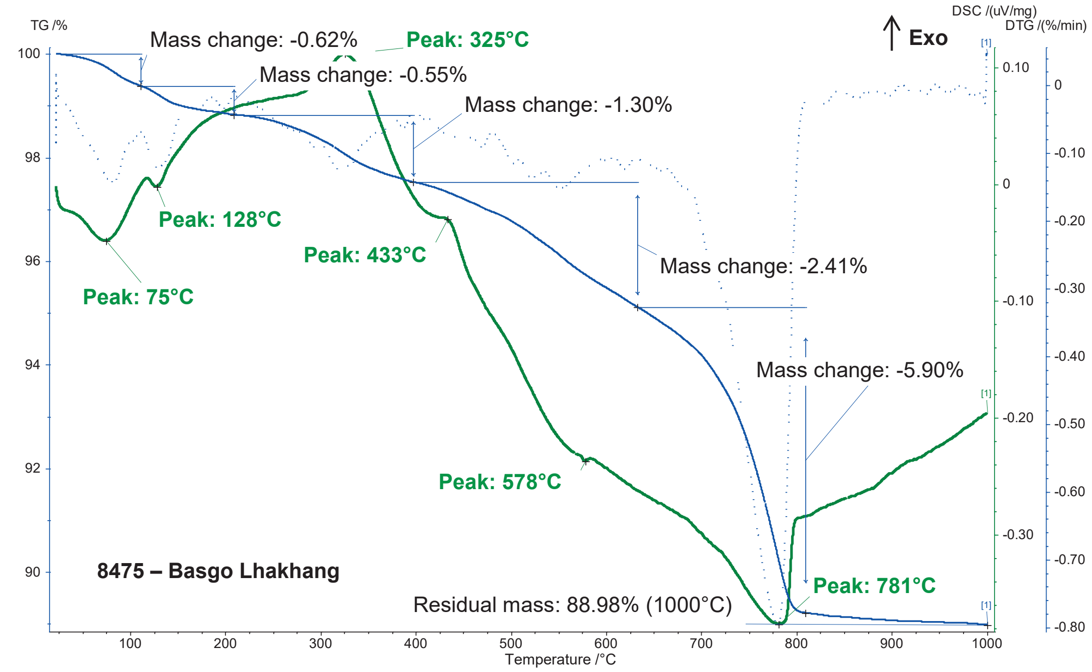
CMA 3.28 Basgo. Samples 15410, 15411 and 15915. Content of smectite and vermiculite.



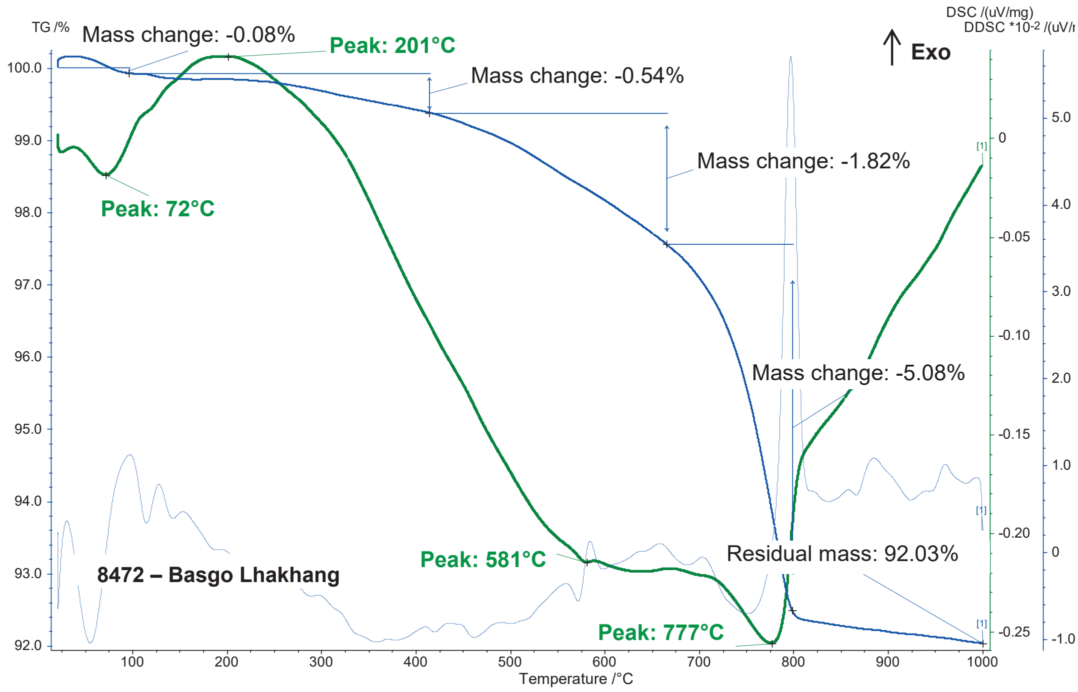
STA 3.1 Basgo. Lotsāba Lhakhang. 8482. Simultaneous thermal analysis.



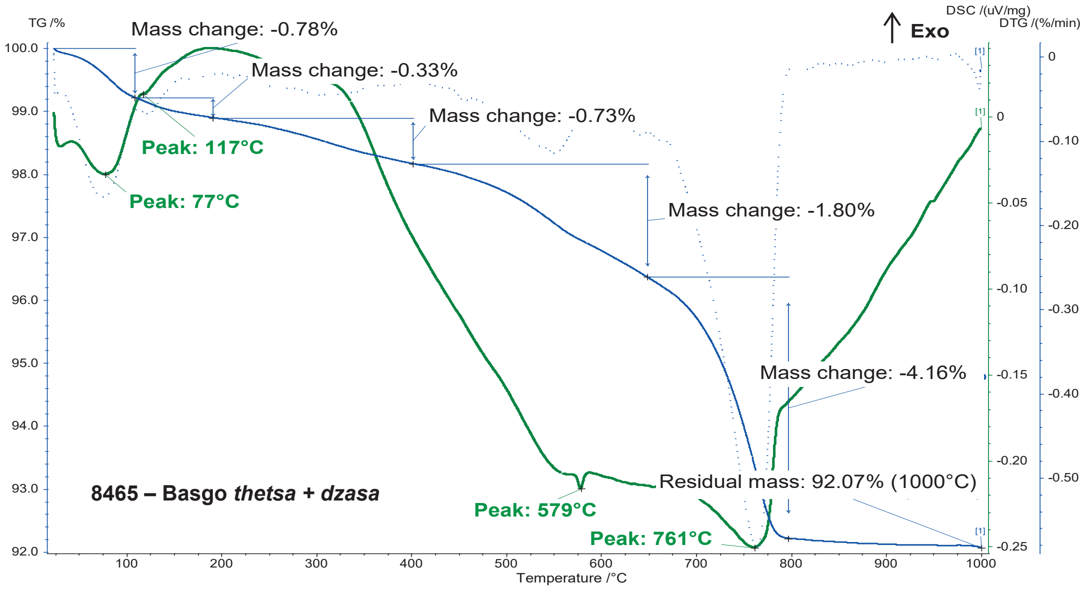
STA 3.2 Basgo. Lotsāba Lhakhang. 8483. Simultaneous thermal analysis.



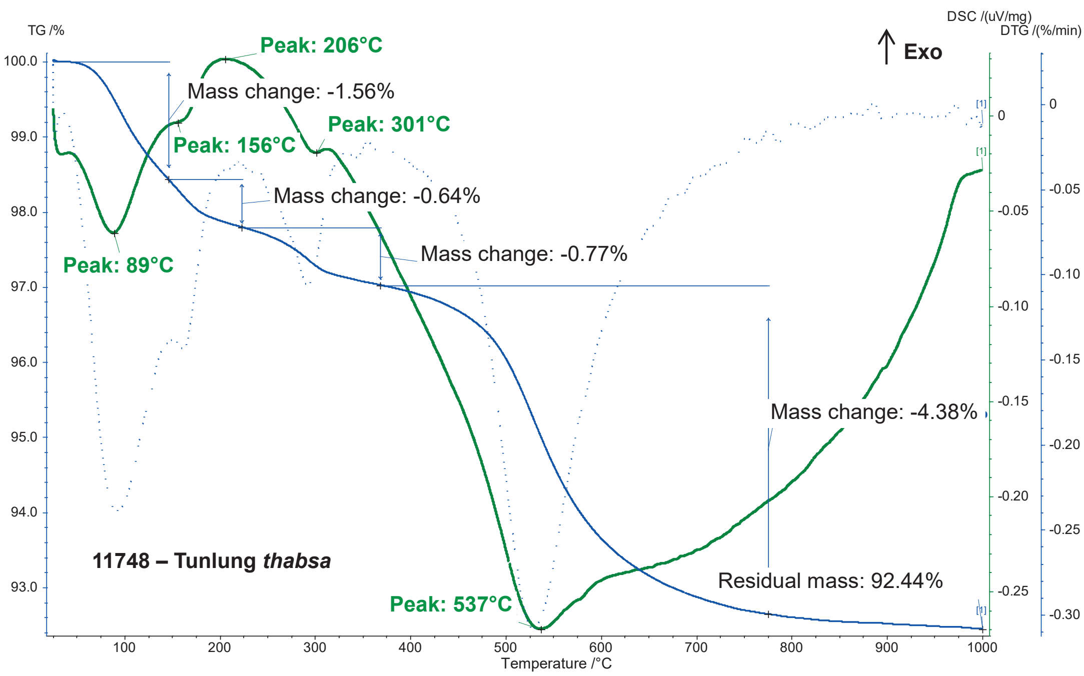
STA 3.3 Basgo. '*Lhakhang* close to the road'. 8475. Simultaneous thermal analysis.



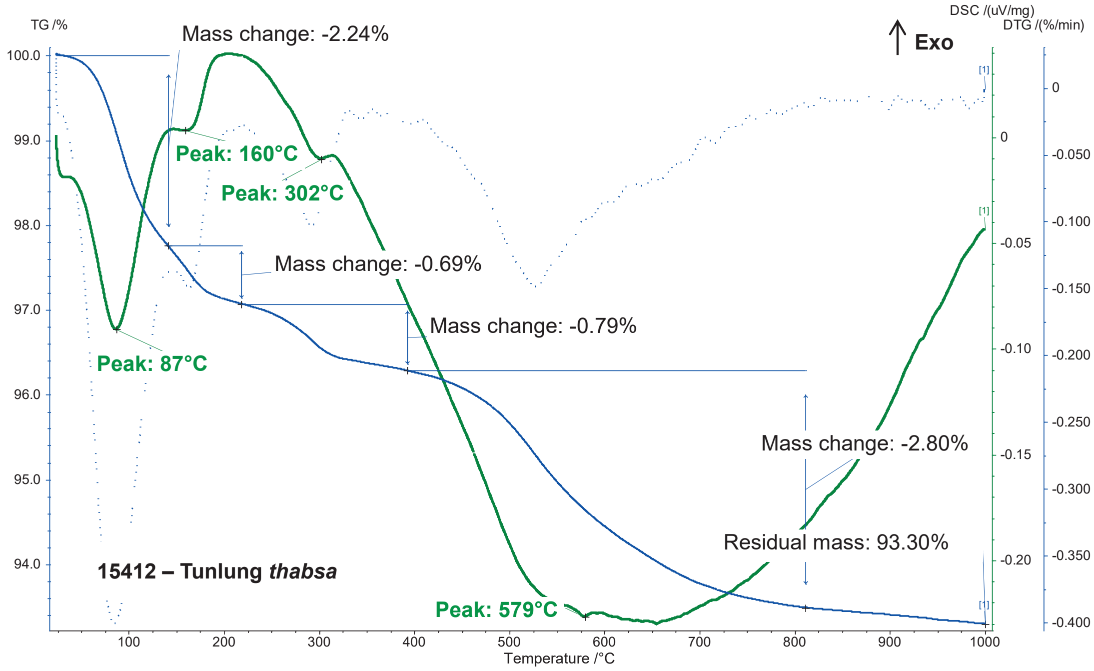
STA 3.4 Basgo. '*Lhakhang* close to the road'. 8472. Simultaneous thermal analysis.



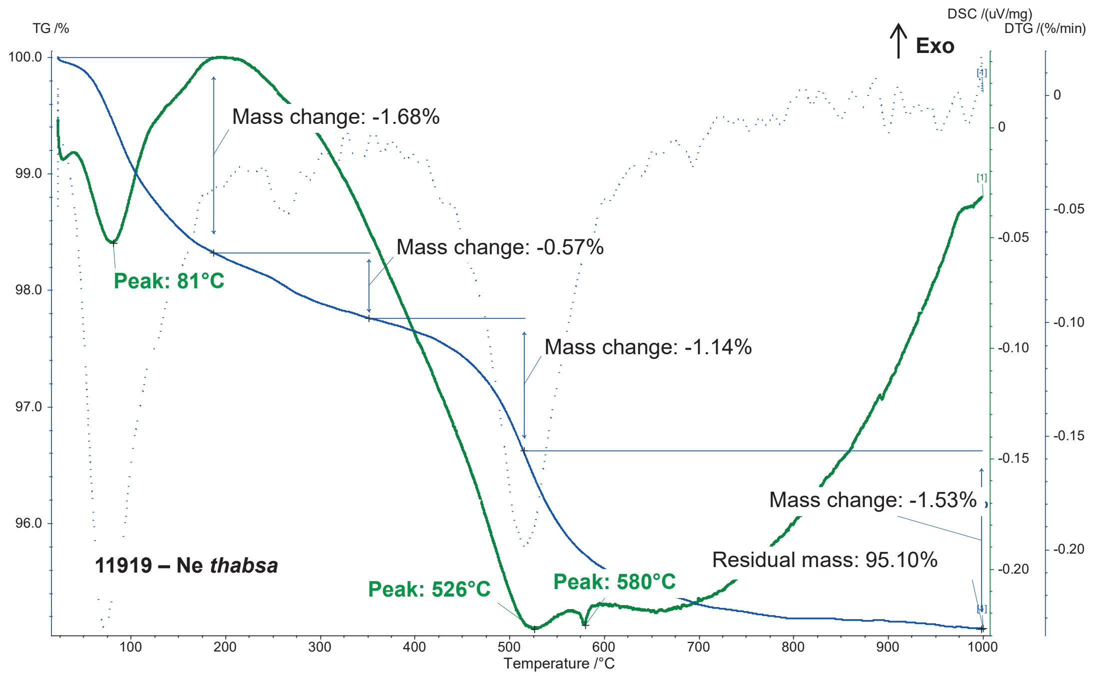
STA 3.5 Basgo. Sample 8465. Raw material. *Thetsa* and *dzasa* mixed. Simultaneous thermal analysis.



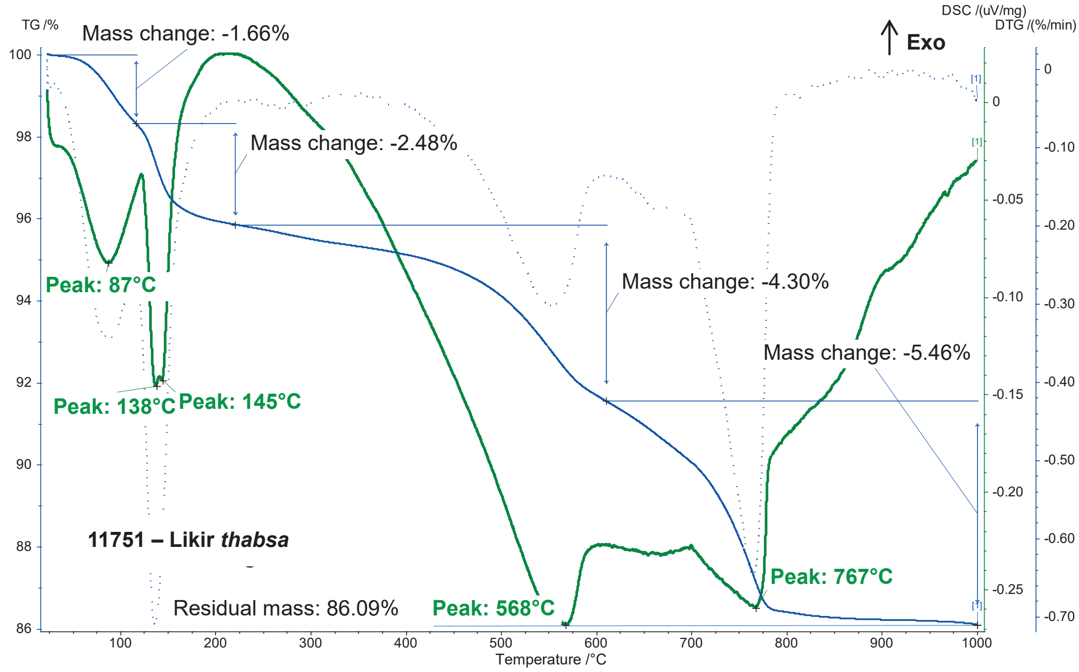
STA 3.6 Tunlung. Sample 11748. Raw material. *Thabsa*. Simultaneous thermal analysis.



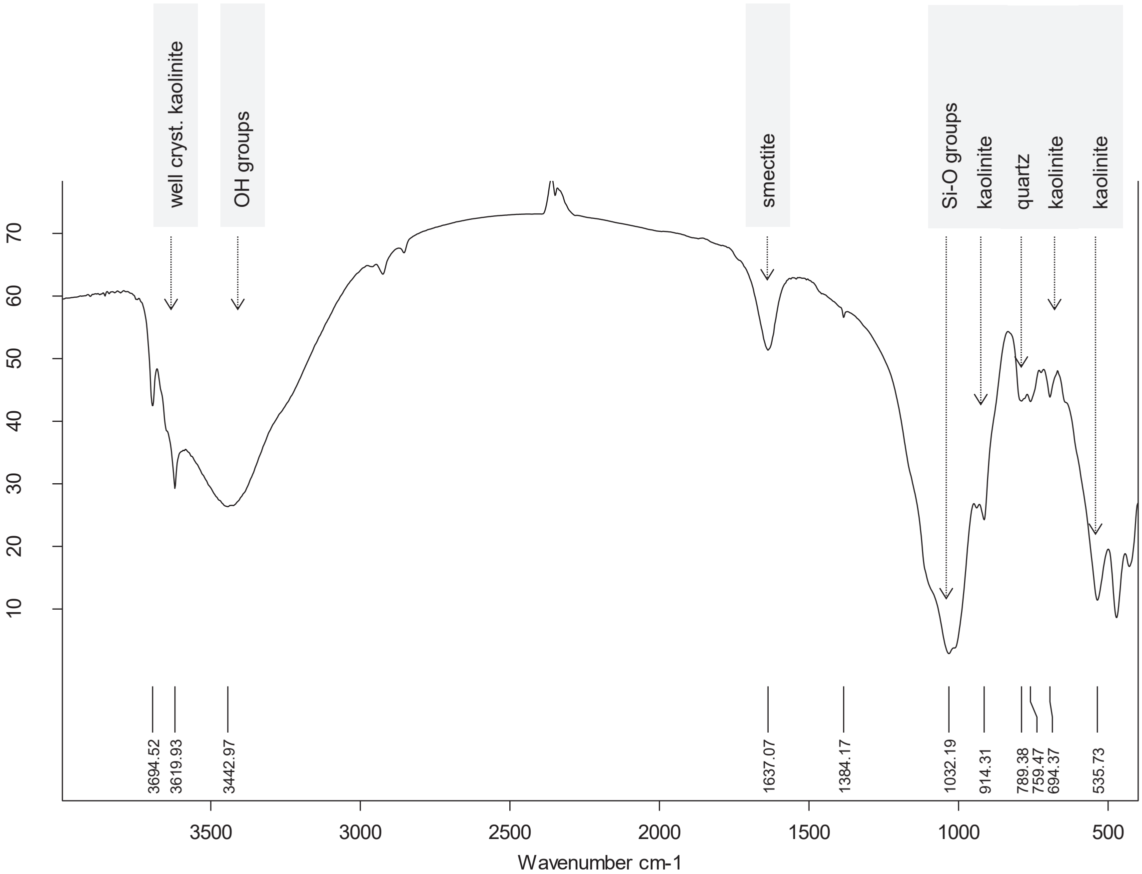
STA 3.7 Tunlung. Sample 15412. Raw material. *Thabsa*. Simultaneous thermal analysis.

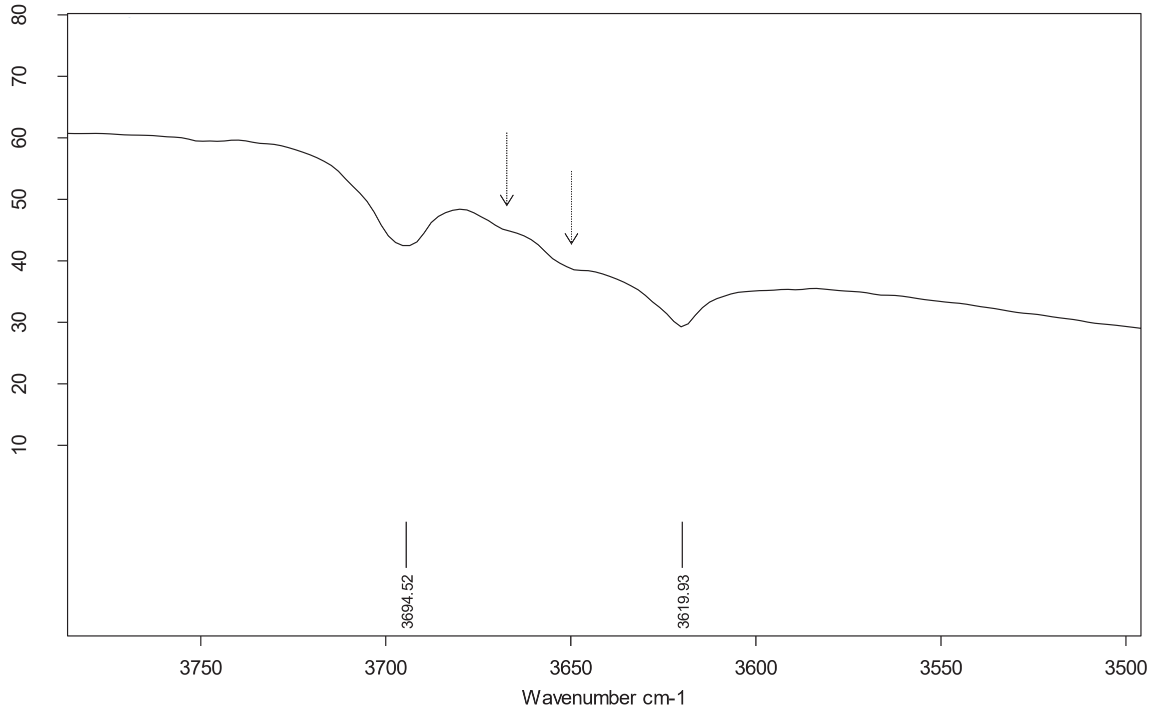


STA 3.8 Ne. Sample 11919. Raw material. *Thabsa*. Simultaneous thermal analysis.

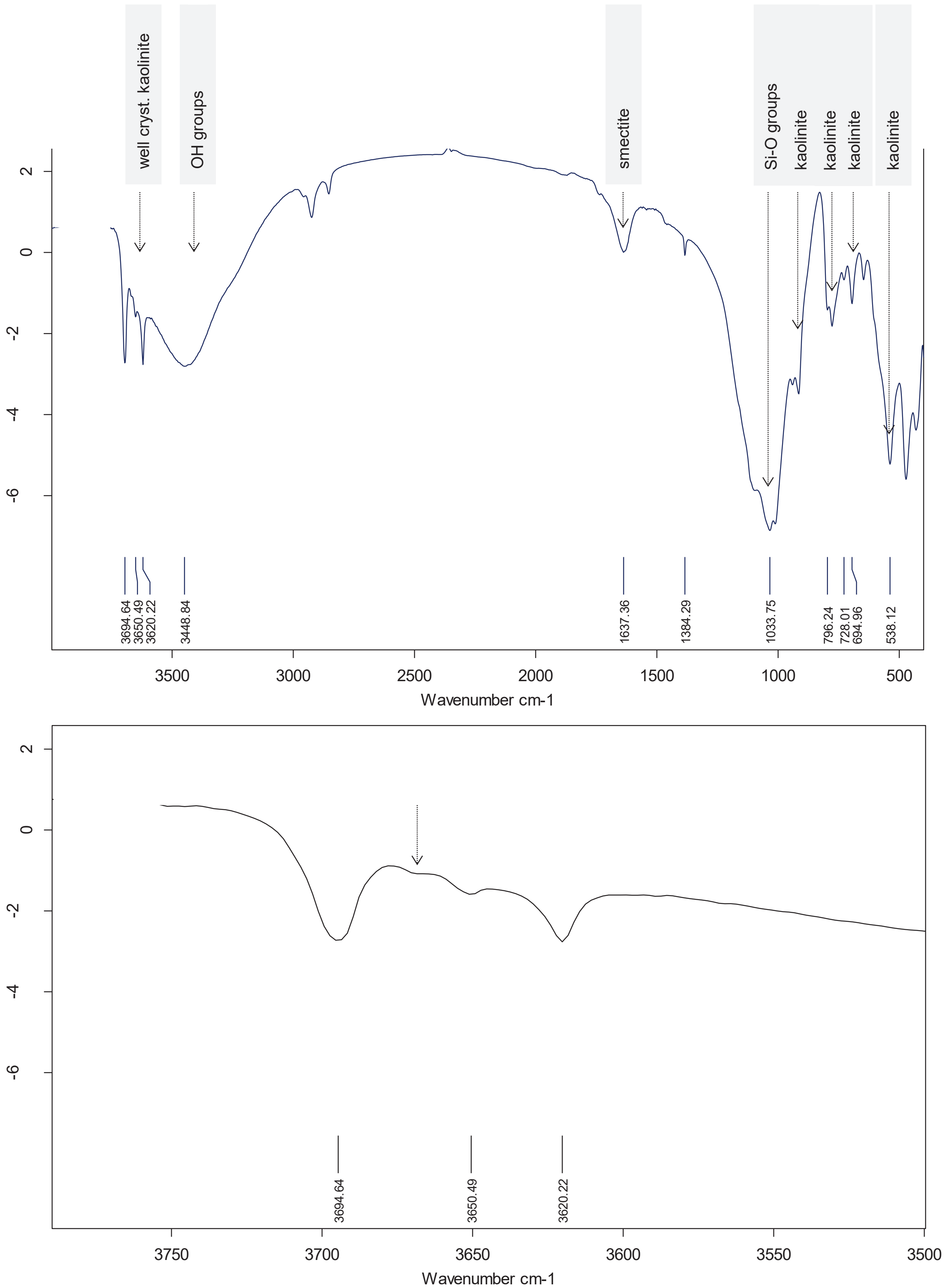


STA 3.9 Likir. Sample 11751. Raw material. *Thabsa*. Simultaneous thermal analysis.





IRS 3.1 Tunlung. Sample 15412. Infrared spectroscopy. Below: Showing the content of well-crystallised kaolinite.



IRS 3.2 Ne. Sample 11919. Infrared spectroscopy. Below: Detail showing the content of well-crystallised kaolinite.

VII. APPENDIX CHAPTER IV

Table 4.3 Climate data.

Abbreviations:
ann. = annual; temp. = temperature [°C]; prec. = precipitation [mm]; altitude in [m]; Δ = difference.

Climate data according to *Climate data for cities worldwide*: online 11.5.2016. Climate data according to http://de.climate-data.org/

	Province / district	Place	Altitude	Temp / ann. average	Ann. prec.	Min prec.	Max prec.	Δ prec. min/max	Min temp.	Max temp.	Δ temp. min/max
INDIA	Ladakh	Leh	3520	5.2	103	Oct: 3	August: 16	13	Jan: -8.6	July: 17.4	26
		Phyang	3510	4.7	105	Oct: 3	August: 15	12	Jan: -9.4	July: 17	26.4
		Thikse	3250	6.8	150	Jun: 4	March: 22	18	Jan: -7.1	July: 18.7	25.8
	Kargil	Kargil	2700	8.6	318	Nov: 6	March: 82	76	Jan: -8.8	July: 23.3	32.1
	Srinagar	Srinagar	1590	13.6	693	Nov: 24	March: 110	86	Jan: 1.5	July: 24.6	23.1
	Lahaul	Keylong	3100	7.6	824	Nov: 23	March: 136	113	Jan: -3.5	July: 16	19.5
		Gondhla	3170	7.7	858	Nov: 24	March: 138	114	Jan: -3.3	July: 15.9	19.2
		Udaipur	2650	9.4	1057	Nov: 26	March: 148	122	Jan: -1.8	July: 17.3	19.1
	Spiti	Kaza	3660	5.1	668	Nov: 16	March: 90	74	Jan: -5.6	July: 14.1	19.7
	Upper Kinnaur	Nako	3630	4.8	651	Nov: 16	Jan: 83	67	Jan: -5.6	July: 13.9	19.5
	Middle Kinnaur	Spillo	2400	12.2	710	Nov: 19	Jan: 108	89	Jan: 2.9	June: 19.3	16.4
		Rekong Peo	2420	12.8	797	Nov: 19	Jan: 108	89	Jan: 3.7	June: 19.8	16.1
		Kalpa	2760	13.2	867	Nov: 19	Mar: 109	90	Jan: 4.2	June: 20.2	16
	Shimla	Rampur	960	19.9	1098	Nov: 18	July: 185	167	Jan: 10.6	June: 27.6	17
	Kullu	Manali	2000	15.1	1972	Nov: 30	July: 409	379	Jan: 5.5	June: 22.6	17.1
	Chamba	Purthi	2460	11.8	1299	Nov: 26	July: 183	157	Jan: 0.5	June: 19.8	19.3
		Bharmour	2170	15.1	2078	Nov: 26	July: 480	454	Jan: 5.4	June: 22.7	17.3
		Chamba	950	20.7	2213	Nov: 21	July: 609	588	Jan: 10.6	June: 29.3	18.7
PAKISTAN	Gilgit-Baltistan	Khaplu	2494	9.2	150	Nov: 3	March: 35	32	Jan: -7.2	July: 23.4	30.6
		Baltit	2430	9.2	128	Nov: 2	May: 28	26	Jan: -9	July: 22	27
		Keris	2310	9.4	176	Nov: 3	March: 36	33	Jan: -6.5	July: 23.2	29.7
		Skardu Town	2250	10.2	204	Nov: 4	May: 35	31	Jan: -4.6	July: 23.3	27.9
		Gilgit	1470	16.5	154	Nov: 2	May: 32	30	Jan: -3.8	July: 28.3	24.5
	Khyber Pakhtunkhwa	Sazīn	1000	16.7	419	Nov: 8	April: 60	52	Jan: 4.7	July: 27.2	22.5
		Kalam	2000	13.4	639	Nov: 15	April: 93	78	Jan: 1.5	July: 24.1	22.6
TIBET	Central Tibet	Lhasa	3660	7.9	438	Jan: 0	Aug: 132	132	Jan: -1.8	June: 15.9	17.7
	West Tibet	Purang	3890	4.4	897	Nov: 9	Aug: 194	185	Jan: -3.5	July: 11.3	14.8
IRAN	Isfahan	Abyaneh	2220	11.9	118	Aug: 0	Jan: 22	22	Jan: -2.5	July: 25.1	27.6
BULGARIA	Haskovo	Mandriza	70	13.5	586	Aug: 19	Dec: 77	58	Jan: 3.2	July: 23.8	20.6
TURKEY	Karabük	Safranbolu	480	12.8	597	Aug: 33	Dec: 70	37	Jan: 2.5	July: 22.4	19.9

Table 4.4 Grain size classes.

Sample	Place	Gravel	Sand	Silt	Clay	Median [µm]
			Chamba			
8506	Purthi	11.6	16.0	51.9	20.5	17
8510	Purthi	34.7	11.8	45.5	8.0	47
8528	Purthi	40.6	20.1	35.9	3.4	700
			Kinnaur			
8467	Ribba	1.3	28.6	53.1	17.0	16
8493	Ribba	0.1	8.8	55.4	35.7	5
8492	Chulling	11.5	28.7	44.2	15.6	30
8511	Thangi	18.1	20.8	51.5	9.6	34
8518	Thangi	15.3	25.3	40.8	18.6	12
8529	Thangi	17.9	31.9	39.0	11.2	65
8513	Moorang	2.2	27.2	56.5	14.1	12
			Spiti			
6041	Tabo	1.1	8.3	50.8	39.8	3
6053	Tabo	27.5	33.8	24.5	14.2	260
6048	Tabo	26.4	22.3	33.8	17.5	65
6049	Kungri	18.4	39.0	23.4	19.2	110
6050	Dhankar	27.5	29.1	30.0	13.4	150
8507	Rangrik	12.1	22.2	46.0	19.7	25
8515	Rangrik	10.1	28.2	43.7	18.0	35
8512	Lalung	20.8	12.9	50.4	15.9	17
8527	Hikkim	19.5	22.8	37.8	19.9	30
8530	Hikkim	5.7	39.1	32.1	23.1	30
			Lahaul			
8480	Keylong	31.2	40.6	23.8	4.4	260
6057	Keylong	0.4	17.1	69.0	13.5	30
8478	Tingrat	1.2	38.4	46.6	13.8	28
			Kashmir			
11755	Srinagar	0.3	2.0	62,8	34,9	4.8
11916	Srinagar	0.9	2.4	68	28,7	5.5
11757	Naranag	10.0	14.2	38,2	37,6	4.4

Table 4.5 Results of bulk mineral analysis.

Sample	14Å	Mica	Amph	7Å	Phy	Quar	Goeth	K-fsp	Plagio	Calc	Dol	Haem	Gyps	Pyr
Chamba														
8506	.	*	---	*	.	*	---	.	*	---	---	.	---	---
8510	*	*	---	**	.	*	---	.	*	---	---	---	---	---
8528	*	*	---	**	.	*	---	.	*	---	---	---	---	---
Kinnaur														
8467	*	*	---	.	---	*	---	*	**	---	---	---	---	---
8493	.	.	---	.	.	*	---	.	.	---	---	---	---	---
8492	.	*	---	*	.	*	---	.	*	---	---	---	---	---
8511	.	*	---	*	.	*	---	.	*	---	---	.	---	---
8518	.	*	---	*	.	*	---	.	*	.	---		---	---
8529	.	*	---	*	.	*	---	.	*	---	---	.	---	---
8513	.	*	---	*	.	*	---	.	*	*	.		---	---
Spiti														
6041	.	*	---	.	.	*	.	.	.	.	.	.	---	.
6053	.	.	.	.	.	*	.	.	.	*	.	.	---	.
6048	.	.	.	.	.	.	---	.	.	**	.	---	.	---
6049	.	.	.	.	.	*	.	.	.	*	.	---	.	---
6050	.	.	.	.	.	*	.	.	.	*	.	---	.	---
8507	.	.	---	.	.	*	---	.	.	*	.	---	---	.
8515	---	.	---	.	.	*	---	.	.	*	---	---	---	---
8512	---	.	---	.	.	.	---	.	.	*	*	---	---	---
8527	---	.	---	.	.	.	.	---	.	**	---	.	---	.
8530	---	.	---	.	.	*	.	.	.	*	---	.	---	---
Lahaul														
8480	.	*	---	*	.	*	---	.	**	.	.	---	---	---
6057	---	*	---	.	.	*	---	.	*	.	.		---	---
8478	.	*	---	.	---	*	---	.	*	---	---	---	---	---
Kashmir														
11755	.	*	.	.	.	*	---	.	.	*	.	.	---	---
11916	.	.	.	.	.	*	---	.	.	*	.	.	---	---
11757	.	*	---	.	.	*	---	.	.	*	---	---	---	---

Table 4.6 Results of clay mineral analysis.

Sample	Smectite	Vermiculite 14Å/18Å		Illite	Kaolinite	Chlorite	Mixed layer
Chamba							
8506	.	*	---	**	.	.	.
8510	---	.	---	**	.	*	.
8528	---	---	---	**	---	**	---
Kinnaur							
8467	---	---	---	***	---	*	---
8493	---	**	---	*	.	---	.
8492	.	---	---	**	.	*	.
8511	---	---	---	***	---	*	.
8518	---	---	---	***	.	.	---
8529	---	---	---	**	.	*	.
8513	---	---	---	**	.	*	.
Spiti							
6041	---	---	---	**	*	*	---
6053	---	---	---	**	*	*	---
6048	.	---	---	**	.	*	---
6049	---	---	---	**	*	*	---
6050	---	---	---	**	.	**	---
8507	.	---	---	**	*	*	.
8515	.	---	---	**	*	*	.
8512	---	---	---	**	.	*	---
8527	---	---	---	*	**	---	.
8530	.	---	---	*	**	.	*
Lahaul							
8480	---	---	---	**	.	*	.
6057	---	---	---	**	*	*	.
8478	---	---	.	***	---	*	---
Kashmir							
11755	*	---	---	**	*	*	.
11916	.	---	---	**	*	*	.
11757	---	---	---	**	*	.	*

VIII. BIBLIOGRAPHY, CORRESPONDENCE AND INTERVIEWS

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Correspondence and interviews

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Dechen Lundup (2015). Postal communication in spring 2015. He is a resident of Tabo in India and was a monk in former days. He supported the author during field research.

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Hazod, Guntram (2016). Personal communication. He is researcher at IKGA / ÖAW.

Kalantari, Christiane (2011). Personal communication on January 21st in 2011 and ongoing communication. She is an art historian specialised in Western Himalayan art.

Kelsang, Jampa (2014). Personal communication in Lhasa during his work on the roof of the Gyüme Dratsang in Lhasa in June 2014. He is master for making *arga* roofs.

Könchog, Tsering (2015). Personal communication in December 2015 in Lhasa, where he ran a workshop for making clay sculptures.

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MEINGAST, Roland (2015). Personal communication in Vienna in April 2015. He is an Austrian specialist on building ecology and earth constructions.

RIGZEN WANGYAL (August 2015). He is a resident of Likir in Ladakh, where at the time of the interview, he was a potter working together with his brother Rigzen Angdu, their mother, and Tsering Norbu.

SHAKI ONGDU (2015). Personal communication in Lhasa on December 17th in 2015. At the time of the interview he was director of the Cultural Relics Office in Lhasa.

TASHI, Penba (2015). Personal communication in Lhasa on November 29th and December 18th 2015. He is a resident of Nyemo.

TASHI, Penba (2015). Personal communication in Lhasa on December 3rd in 2015. He is a resident of the village Grib in Lhundrup.

TSERING Dorje (2005). Personal communication in Keylong on July 28th in 2005. At the time of the interview, he was a resident in Keylong. He has his roots in Tibet, where he was monk at the Tholing Monastery.

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WANGCHUK (2005). Personal communication in Leh on November 7th in 2005. At the time of the interview, he was working at the Archaeological Survey of India, Jammu and Kaschmir Circle in Leh.

WANGCHUK, Sonam and and his wife Rebecca NORMAN. Personal communication in Ladakh in August 2011. They guided the author in Ladakh and interpreted during interviews. At the time of the interview, they ran the SECMOL Campus at Phey in Ladakh.

ZIEGERT, Christof (2016). Telephone correspondence in spring 2016 and ongoing correspondence. He is a resident of Germany and an expert in the field of earth building.

IX. LIST OF ILLUSTRATIONS

The maps are north-oriented. Different sources were used. Several maps are drawn on the basis of satellite images such as Google Earth. Other maps were created with the free and open source geographic information system QGIS Development Team, 2016 (QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://www.qgis.org/). For that purpose, GIS data based maps were created by Jakob Gredler and graphically finalised by the author. Details were provided by the author. For the maps data were downloaded and adapted. The following data were used. The particular sources are mentioned with abbreviations in the caption of each map.

- VD = Vector data (rivers, lakes, mountain peaks, borders, etc.): made with Natural Earth. Free vector and raster map data @ naturalearthdata.com.
- BM = Basemaps: made with maps.stamen.com. Map tiles by Stamen Design, under CC by 3.0. Data by OpenStreetMap, under ODbL.
- SR = SRTM4 digital elevation data. Adapted from Jarvis et al. 2008.
- CM = Climate map. Adapted from Peel et al. 2007.
- TM = Tectonic map. Adapted from Hodges 2000: 329.
- LC = MODIS/Terra and Aqua Combined Land Cover Type CMG Yearly Global 0.05 Deg - MCD12C1.006, Friedl, Sulla-Menashe (2015).

Chapter I

Chapter II

Chapter III

Chapter IV

Fig. 4.93 (Top) Udaipur. Lahaul. Ground plan of the Mirkulā Devī Temple with corner pillars at the four corners of the *garbhagṛha*. 1 = Corner pillar; 2 = Runner beams; 3 = Cross-beams; 4 = Wooden door panel.
Fig. 4.94 (Bottom, left) Udaipur. Mirkulā Devī Temple. Circumambulation corridor along a *kath-kuni* wall of the *garbhagṛha* (left).
Fig. 4.95 (Bottom, right) Udaipur. Mirkulā Devī Temple. Corner pillar at the southern corner of the *garbhagṛha*.
Fig. 4.96 (Left) Purthi. Chamba. Combination of *dhol-maide* and *farque* technique.
Fig. 4.97 (Right) Purthi. Combination of *dhol-maide* and *farque* technique.
Fig. 4.98 (Top) Bharmaur. Chamba. Corners made as *farque* construction and the wall in-between as *dhajji-dewari* construction.
Fig. 4.99 (Below) Bharmaur. Combination of *farque* and *kath-kuni* construction. CAD: Martin Pospichal. Details provided by the author.
Fig. 4.100 Bharmaur. *Kath-kuni* construction.
Fig. 4.101 Phases of structural change from solid clay and stone constructions towards timber-based constructions. CAD: Martin Pospichal. Details provided by the author.

Appendix Chapter III

Grain size distribution analysis

GSD 3.1 Basgo. Maitreya Lhakhang. Sample 8496. Plaster on pillar. Top: Cumulative sum. Bottom: Grain size classes.
GSD 3.2 Basgo. Maitreya Lhakhang. Sample 8479. Plaster on pillar. Top: Cumulative sum. Bottom: Grain size classes.
GSD 3.3 Basgo. Maitreya Lhakhang. Sample 8479. Plaster on pillar. Top: Cumulative sum. Bottom: Grain size classes.
GSD 3.4 Basgo. Lotsāba Lhakhang. Sample 8482. Interior wall plaster. Top: Cumulative sum. Bottom: Grain size classes.
GSD 3.5 Basgo. Lotsāba Lhakhang. Sample 8483. Interior wall plaster. Top: Cumulative sum. Bottom: Grain size classes.
GSD 3.6 Basgo. Lotsāba Lhakhang. Sample 11946. Interior wall plaster. Top: Cumulative sum. Bottom: Grain size classes.
GSD 3.7 Basgo. Lotsāba Lhakhang. Sample 11948. Adobe brick. Top: Cumulative sum. Bottom: Grain size classes.
GSD 3.8 Basgo. '*Lhakhang* close to the road'. Sample 8475. Interior wall plaster. Top: Cumulative sum. Bottom: Grain size classes.
GSD 3.9 Basgo. '*Lhakhang* close to the road'. Sample 11928. Interior wall plaster. Top: Cumulative sum. Bottom: Grain size classes.
GSD 3.10 Basgo. '*Lhakhang* close to the road'. Sample 8499. Exterior wall plaster. Top: Cumulative sum. Bottom: Grain size classes.
GSD 3.11 Basgo. '*Lhakhang* close to the road'. Sample 8472. Adobe brick. Top: Cumulative sum. Bottom: Grain size classes.
GSD 3.12 Basgo. '*Lhakhang* close to the road'. Sample 11933. Adobe brick. Top: Cumulative sum. Bottom: Grain size classes.

Appendix Chapter IV

X. INDEX

The index refers to terms used in the text including footnotes and captions, not including terms used in maps. The symbol → refers to a further mentioning of the concerned term in the index.

The index is divided into four categories:

1. Architecture and crafts related terms

1.1 Tools for building construction

2. Raw and building materials

2.1 Timber

2.1.1 English terms

2.1.2 Local terms

2.1.3 Scientific terms

2.2 Organic materials

2.3 Stones / Minerals / Mineral products

2.4 Clay

3. Names

3.1 Places / Regions / Countries

3.2 Mountains / Rivers / Passes

3.3 Persons / Families

3.4 Religious figures

3.5 Population groups

The manual production of objects and buildings significantly shapes the material culture of societies. Knowledge concerning the ideal properties of materials obtained from nature, techniques of processing raw materials, and the skills needed to manufacture certain products have been passed down from generation to generation over the centuries. Many buildings, as well as objects in daily use, which we consider cultural heritage today, have their origin in the skills of crafts(wo)men and the craft traditions to which they belong. In contrast to workers in the industrial prefabrication of products, craftspeople have to be able to react flexibly to different natural conditions. The properties of naturally occurring raw materials such as clay, stone or wood can vary greatly. Craftspeople must constantly draw upon and adapt the knowledge, skills and techniques they have learned in order to optimize the quality of their products.

The author of this book is an architect and architectural historian, which is why his research makes a strong reference to craft traditions in construction. In addition, he researches building materials, their properties and processing methods, with a focus on clay and clay building techniques. Bringing these main research areas together enables the observation of building craft traditions from different perspectives.

The social status of materials and processing methods can differ greatly between societies. This book focuses on Buddhist architecture in the Himalayas, where the author has been conducting research for over 20 years. Certain behavioural patterns, such as ritually walking around the perimeter of religious buildings and objects, reinforce their symbolic value in the respective community. These meanings, in turn, are made tangible through certain materials, shapes, colours, or textures used in the buildings themselves.

In the course of the research, it became clear that particular traditional processing methods can be found in various craft disciplines. For example, the method of burnishing roofs or walls is used in the manufacture of certain religious objects such as clay sculptures, and also in the manufacture of everyday objects such as clay ovens or pottery. Traditional knowledge about such processing methods is spread over large parts of the Himalayas and is regionally adapted to the respective crafts.

The Himalayan region is ideal for this research due to its diverse natural conditions. Different altitudes, topographies, vegetation, climatic and geological conditions have shaped building and craft traditions across this region. This book clearly shows the interconnectivity between natural conditions and regional building and craft traditions, as well as their combined influence on material culture in the Himalayas.

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