RELATING THE

SOUTH AFRICAN SOIL TAXONOMY

TO THE WORLD REFERENCE BASE FOR SOIL RESOURCES

CW van Huyssteen

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ACRONYMS AND SYMBOLS

BS	Base saturation percentage
CEC	Cation exchange capacity per kilogram soil
CEC_{clay}	Cation exchange capacity per kilogram clay
EBS	Effective base saturation
ECEC	Effective cation exchange capacity
ESP	Exchangeable sodium percentage
Fe_{dith}	Dithionate-citrate-bicarbonate extractable iron
Fe_{ox}	Ammonium oxalate extractable iron
m/m	Mass fraction
OC	Organic carbon
rH	Negative logarithm of the hydrogen partial pressure: (Eh / 29) + (2 x pH)
S	Sum of basic cations
SAT	South African soil taxonomy
sc	Soft carbonate
USDA	Unites States Department of Agriculture
v/v	Volume fraction
WRB	World Reference Base for Soil Resources

PREFACE

The South African Taxonomic Soil Classification System (SAT) is a well-considered and well-used system, which is based on the morphology of the soil. The advantage of a soil classification system being based on morphology, is that most soil profiles can be classified in-field with great accuracy and with far less laboratory analyses. The SAT is therefore an excellent tool for communicating soil properties. The disadvantage is that it differs substantially from international soil classification systems, like the World Reference Base (WRB) or the USDA Soil Taxonomy. Since the South African soil science community is part and parcel of the international soil science community, there is a need for South African soil maps and soil profile descriptions to also be linked to an international soil classification system like the WRB or Soil Taxonomy.

As this book indicates, many similarities exist, but many differences also exist between the SAT and the WRB. There is therefore a need to note the applicable soil properties in order to classify the soils according to the WRB and to provide the equivalent WRB classification. When the equivalent is provided, the interpretation of the information may be valuable for the broader soil science community as well.

This book provides the best equivalent of the SAT to the WRB. This makes it possible for the average South African pedologist (with little or no training of the WRB) to provide the WRB equivalent of the SAT classification in their soil profile classifications and/or soil map legends.

This is a long awaited and overdue book, suitable for the practicing South African pedologist as well as for undergraduate students studying soil science. The soil science community of South Africa hereby thanks Professor Cornie van Huyssteen for his effort to compile this book.

MJ du Plessis (Pr.Sci.Nat)
President of the South African Soil Science Society of South Africa

22 November 2020

CHAPTER 1

SOIL CLASSIFICATION SYSTEMS

Soil classification aims to organise knowledge, organise data, aid recollection and assist in the generation of knowledge (Fanning & Fanning, 1989; Rossiter, 2001; Arnold & Eswaran, 2002).

As such, soil classification can serve a theoretical purpose, emphasising soil formation and relationships; or it can fulfil a valuable role for practical application in agriculture or technological utilisation of soils (De Bakker, 1970).

1.1 National soil classification systems

A myriad of national soil classification systems exists internationally, for example:

- Australia (Isbell, 2016);
- Brazil (Dos Santos et al., 2018);
- Canada (Agriculture Canada Expert Committee on Soil Survey, 1987);
- China (CRG-CST, 2001);
- England & Wales (Avery, 1980);
- France (Baize & Girard, 1998);
- Germany (Arbeitskreis für Bodensystematik der Deutschen Bodenkundlichen Gesellschaft, 1998);
- New Zealand (Hewitt, 1993);
- Polish (Marcinek & Komisarek, 2011);
- Russia (Stolbovoi, 2000); and
- South Africa (Soil Classification Working Group, 1991; 2018).

Eswaran et al (2002) and Krasilnikov et al (2009) provide an overview of these systems. According to Krasilnikov et al (2009), this myriad of systems probably came about because soil science is a relatively new science, having come into existence only with the publication of Dokuchaev's seminal work *Russian Chernozem* in Dokuchaev (1967).

This situation resulted firstly because the world was largely colonised *before* soil classification could be adopted and similarly spread across the world. A second reason might be due to the vast differences in soils throughout the world and therefore, the differences in soil properties relevant for land use interpretation in these environments.

1.2 International soil classification systems

Internationally, soil classification was formalised by Dokuchaev (1967) in Russia, followed by Hilgard (1906), Marbut (1913), Jenny (1941), Smith (1986), and Brewer (1964) in the USA, and Kubiena (1953) in Europe.

The development of soil classification in the international arena is reviewed by Schaetzl and Anderson (2005) and Brevik et al (2015). The history of soil classification in South Africa is excellently reviewed by the Soil Classification Working Group (2018).

Recent developments on soil classification in South Africa is the excellent book of Martin Fey (Fey 2010) discussing the classification (including the potential WRB classification), properties, and geographic distribution on the soils of South Africa. This was followed by the Field book for the classification of South African soils (Le Roux et al., 2013) and Soil Classification - A Natural and Anthropogenic System for South Africa (Soil Classification Working Group, 2018).

There is, however, also a need for international scientific communication and correlation. To this extent, the USDA Soil Taxonomy (Soil Survey Staff, 2014) and World Reference Base (IUSS Working Group

WRB, 2015) have been adopted by the International Union of Soil Sciences as official international soil referencing systems (IUSS, 2020). The stated aims of these two international systems are not to replace the international soil classification systems, but to serve as an international reference. National soil classification systems can, however, not fail to recognise the diagnostics adopted by these international systems and should preferably aim to align their diagnostics to the international systems, to facilitate better correlation and communication.

1.3 The objective

Fanning and Fanning (1989) build on the contention of Cline (1949) that soil classification should have a specific objective. These objectives can broadly be grouped into practical objectives or basic objectives. Practical objectives serve a specific land use, such as agriculture, while basic objectives aim to understand soils and their behaviour. Therefore the classification systems employed also differ between these two objectives: interpretive systems (giving for example suitability classes) are commonly used to address practical objectives, while taxonomic systems (describing soil properties) are used to address basic objectives.

Both Soil Taxonomy and the WRB were developed following a need to group or classify existing soil data: Soil Families in the case of Soil Taxonomy and national soil maps into a World Soil Map Legend in the case of the WRB. Both systems, therefore, had ample access to existing soil data that could be interpreted to make the final soil classification. This situation is, however, not always true for taxonomists making detailed soil maps in the field. As such, they (soil taxonomists) predominantly have to rely on soil morphological criteria and personal experience – to the extent that this is permitted by the classification system used. Rossiter (2001) states that the WRB should be used to group locally defined soils to aid correlation and communication. A schematic (or system) is therefore required to group the national South African taxa into the WRB. Fey (2010) also related the South African Taxonomy to the WRB, but failed to motivate or substantiate his correlations. He also applied qualifiers not currently recognised in the WRB.

Additional to the above, few South African soil taxonomists have the training and/or experience in either of the two international taxonomies. The need does, however, exist to intermittently make international soil classifications. This might be, because a client has requested such, or because a paper might ensue from the data gathered. This book therefore aims to address this knowledge gap to provide South African soil taxonomists with a tool to convert their national South African soil taxa to those of the World Reference Base.

As such, it does not replace the need to peruse the WRB, but aims to assist the pedologist with the creation of a WRB classification, based solely on the South Africa Taxonomy. To this extent, **Figure 1** provides a simplified key for the WRB reference soil groups. Additional WRB qualifiers can, and should be added by the pedologist as analytical data for the soil being studied, becomes available. In this manner, it is envisaged that the WRB classification made from the South Africa Taxonomy should reflect at least 80% of that which would have been possible if all requisite data was available.

This hypothesised relation is, however, not alike for all soil forms and reference soil groups. Therefore, the nature of the relation is elucidated in this book. It is furthermore strongly recommended that at least the qualifiers denoting leaching status (dystric/eutric) and texture (arenic/clayic/loamic/siltic) should be added to the final classification.

It is also foreseen that this document would be a valuable guideline for the education of the WRB to South African students.

Lastly, a comparison such as this inevitably shows areas of correlation and areas of diversion between the classification systems. The latter can be due to inherent national biases, or it might simply be national dogma. It is hoped that this document will assist in aligning SAT diagnostics, where possible to those of the WRB, while at the same time providing examples where the WRB can consider regional peculiarities.

1.4 Highest level soil groups

Highest level soil groups (**Table 1**) should have ease of recognition (deduction from the soil forms) and should preferably be related to the international taxonomies (WRB and/or Soil Taxonomy). Cognisance should also be given to grouping terms currently being used (**Table 1**), to aid correlation but also to avoid confusion. An assumed process (or processes) and properties should also be attributable to this highest category.

1.5 How to use this book

This book provides an overview of soil classification, followed by the methodology employed in making the comparisons between the SAT and the WRB, the classification of the diagnostic horizons and family criteria are then discussed, before focussing on the classification of the individual soil forms and their families. Lastly, some recommendations, stemming from these comparisons are discussed. The sequence of diagnostics and soil forms as presented here follows that of the SAT.

The discussion presented in this book assumes that the reader is familiar with the terms and diagnostics of the SAT. It is further strongly advised that the reader peruse the WRB text to elucidate WRB diagnostics. **Figure 1** provides a schematic of the WRB Reference Soil Group key, **Appendix A** presents a more detailed description of the same, while **Appendix B** presents a synoptic description of the WRB diagnostic horizons, material, and properties.

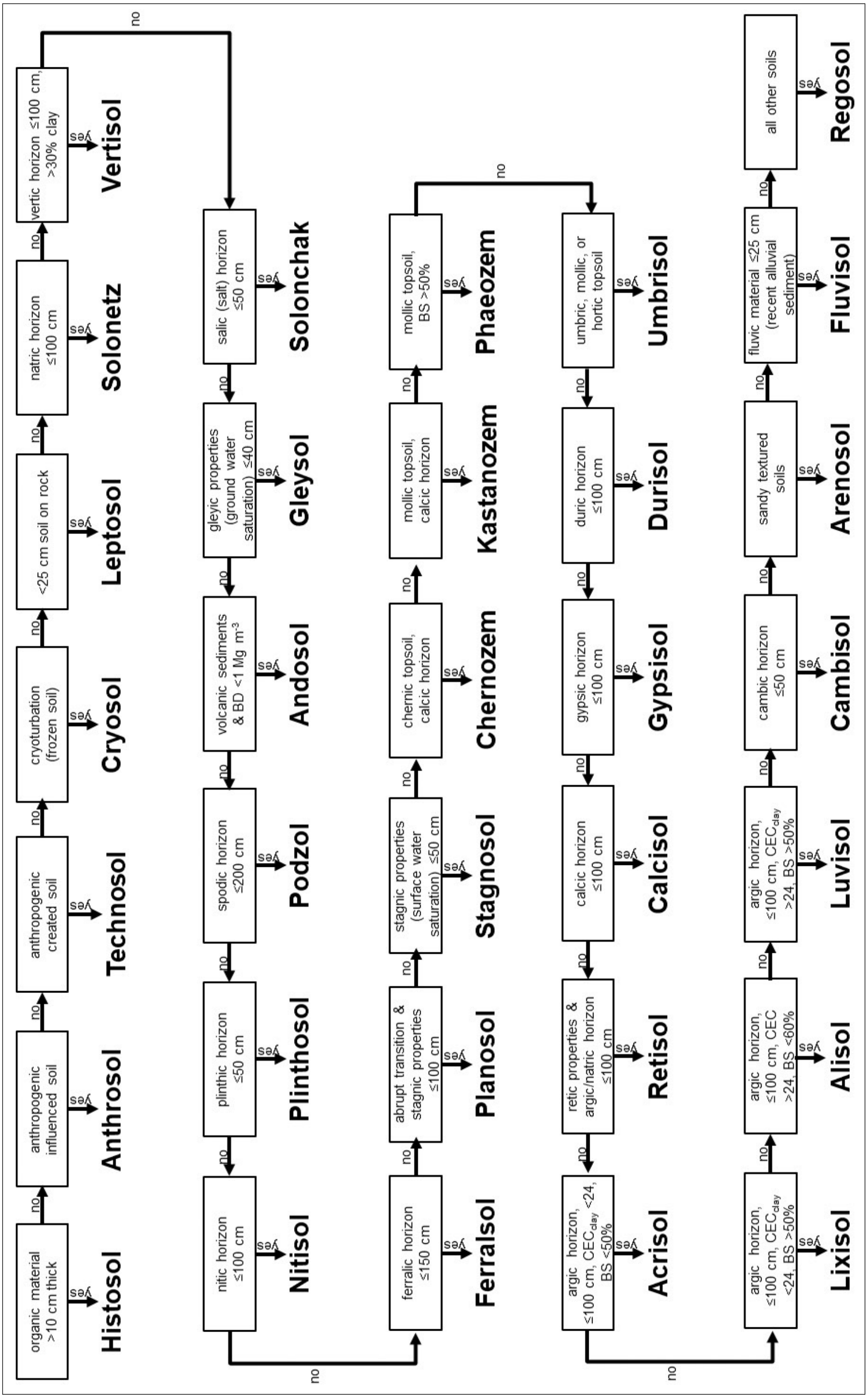

FIGURE 1 Simplified key for the WRB reference soil groups (IUSS Working Group WRB, 2015). A more detailed description of the WRB reference soil groups is presented in Appendix A and of the WRB diagnostics in Appendix B.

TABLE 1 Taxa at the highest level of selected international soil classification systems[1]

WRB[2]	Soil Taxonomy[3]	SiBiCs[4]	Australia[5]	France[6]	Russia[7]	Poland[8]
Histosols	Gelisols	Organossols	Anthroposols	Alocrisols	Al-Fe-humus soils	Organic soils
Anthrosols	Histosols	Neossols	Organosols	Andosols	Svetlozems	Anthropogenic soils
Technosols	Spodosols	Vertissols	Podosols	Vitrosols	Texturally-differentiated soils	Swelling soils
Cryosols	Andisols	Espodossols	Vertosols	Anthroposols	Alkaline-clay-differentiated soils	Black soils
Leptosols	Oxisols	Planossols	Hydrosols	Arenosols	Meta-morphic soils	Clay-illuvial soils
Solonetz	Vertisols	Gleissols	Kurosols	Brunisols	Humus-accumulative soils	Podzolic soils
Vertisols	Aridisols	Latossols	Sodosols	Chernosols	Low-humus-carbonate-accumulative soils	Gleyzemic soils
Solonchaks	Ultisols	Chernossols	Chromosols	Colluviosols	Organo-accumulative soils	Brown earths
Gleysols	Mollisols	Cambissols	Calcarosols	Cryosols	Humus-accumulative hydrogenically transformed soils	Weakly developed soils
Andosols	Alfisols	Plinthossols	Ferrosols	Fersialsols	Gleyzems	
Podzols	Inceptisols	Luvisols	Dermosols	Fluviosols	Cryozems	
Plinthosols	Entisols	Nitissols	Kandosols	Thalassosols	Lithozems	
Nitisols		Agrissols	Rudosols	Grisols	Agrozems	
Ferralsols			Tenosols	Gypsosols	Argoabrazems	
Planosols				Histosols	Abrazems	
Stagnosols				Lepti-smectisols	Halomorphic soils	
Chernozems				Llthosols		
Kastanozems				Luvisols		
Phaeozems				Rganosols		
Umbrisols				Pelosols		
Durisols				Peyrosols		
Gypsisols				Phaeosols		
Calcisols				Planosols		
Retisols				Podzosols		
Acrisols				Rankosols		
Lixisols				Regosols		
Alisols				Salsodic Sola		
Luvisols				Salisols		
Cambisols				Sodisols		
Arenosols				Thiosols		
Fluvisols				Sulfatosols		
Regosols				Yeracrisols		
				Yertisols		

1 Note that taxa are listed in the order of the relevant taxonomic system. Taxa that occur in the same row are therefore not equivalents
2 IUSS Working Group WRB (2015)
3 Soil Survey Staff (2014)
4 Dos Santos et al (2018)
5 Isbell (2016)
6 Baize & Girard (1998)
7 Shishov et al. (2001)
8 Kabała (2019)

CHAPTER 2

MATERIAL AND METHODS

Soil profile description and analytical data from the *Land Type Survey of South Africa* (Land Type Survey Staff, 2004) has been used in the evaluation of the relations and correlations between the SAT and WRB (IUSS Working Group WRB, 2015) diagnostics. Subdivisions of master horizons were counted separately during the calculation of statistics. Horizons that had only partial data were included (where feasible), while those that have all data fields empty were excluded from the analysis. Obvious extraneous values were deleted.

Effective base saturation (EBS) was calculated as the (sum of the basic cations x 100) / (Sum of basic cations + Exchangeable Al). An inherent shortcoming of using the land type database is that the land type survey was done using the Binomial classification (Macvicar et al., 1977), while the discussion here focuses on the Taxonomic classification (Soil Classification Working Group, 1991). This was considered a minor drawback since the majority of the horizon diagnostics remained fairly similar between the 1977 and 1991 versions, while the biggest change was at the soil form and soil family level.

In the discussion that follows, the soil family descriptions have been simplified and grouped in the results tables, to improve legibility, but without negating the connotation thereof. This does not imply a change in the diagnostics or nomenclature of the classification system (the SAT should still be consulted for diagnostic criteria).

The numerical and geographic place names have been omitted since these would be superfluous. The diagnostic criteria for the WRB horizons, properties and materials have similarly been condensed.

Qualifiers separated by a slash (/) symbol denote that either option is possible and thus require a choice by the user, typically based on analytical data.

Other qualifiers should be added on the user´s own initiative by following the WRB criteria, and typically after chemical and physical analyses are available: *e.g.* arenic/clayic/loamic/siltic; sodic; sulfidic; technic; and toxic. As an absolute minimum, it is recommended that at least the leaching status (dystric/eutric) and profile texture (arenic/clayic/loamic/siltic) must be added.

Reference soil groups defined by chemical analyses, *e.g.* Anthrosols and Solonchaks are excluded from this analysis since these cannot be deduced from the SAT.

CHAPTER 3

DIAGNOSTIC HORIZONS

3.1 Organic O horizon

The organic O horizon has >10% organic carbon through a vertical distance of at least 200 mm, is saturated with water unless drained, and overlie horizons with signs of wetness. Organic O horizons, therefore, meet the thickness criterion (>10 cm) for Histosols in the WRB, but not the OC content [≥20% (m/m) soil organic carbon]. However, organic O horizons with ≥20% OC would equal organic material and therefore Histosols.

Organic O horizons with 10-20% OC might classify as chernic, mollic or umbric horizons. Chernic, mollic or umbric horizons all require a moderate to strongly developed structure, a dark colour (moist value and chroma ≤3), ≥0.6% OC (≥1% for chernic); base saturation ≥50% (<50% for umbric), a thickness ≥20 cm (≥25 cm for chernic). It is therefore argued that organic O horizons will meet the structure, OC, colour, and depth criteria, but will classify as chernic or umbric horizons, based on the base saturation. Chernic is given precedence over mollic since it has a higher OC content. Umbric is the only option for high OC, low base saturation organic O horizons. Only five Champagne soils were described during the land type survey (Table 2). Of these, all meet the thickness criterion of the WRB; only one meets the OC limit, while two do not even meet the OC limit of the SAT - one of these should be considered an extraneous classification or analysis.

TABLE 2 Depths, moist colour, and organic carbon content of the five Champagne soils described during the land type survey.

Master horizon	Depth (mm)		Moist colour	OC (%)
	Upper	Lower		
O	0	800	10YR2/1	1.6
O	0	600	10YR2/1	9.4
O	0	300	10YR2/1	12.5
O	0	900	2.5Y2.5/0	18.3
O	0	1200	2.5Y2.5/0	28.4

3.2 Humic A horizon

Humic A horizons have high OC (>1.8% OC), have leached (<4 $cmol_c$ bases per kg clay per percentage OC) topsoils, and may not overlie horizons with signs of wetness. These horizons, therefore, do not have a logic equivalent in the WRB. Instead, these horizons will classify as umbric horizons [moderate to strongly developed structure; a dark colour (moist value and chroma ≤3); ≥0.6% OC; base saturation <50%; and thickness ≥20 cm]. All humic A soil forms will, therefore, key out as Umbrisols because of the 69 humic A horizons, only 5 have moist value >3, while 8 have chroma >3, and all are >20 cm thick. All humic A horizons (Table 3) are considered to be hyperdystric (effective base saturation <50% and <20% in some parts), also because these soils typically occur on the high-rainfall areas on acidic parent material. Only 3 of the 67 described soils have base saturation ≥50%.

TABLE 3 Summary statistics of selected soil properties for the 69 humic A horizons described during the land type survey.

	Moist colour		%			$cmol_c\ kg^{-1}$		
	Value	Chroma	Clay	OC	BS	S	CEC	CEC_{clay}
Avg	2.9	2.3	33.7	13.6	3.6	2.2	15.4	53.0
Min	2.0	0.0	13.4	1.0	1.3	0.1	7.0	19.4
Max	5.0	6.0	68.4	84.5	11.1	25.7	45.6	194.2
Std	0.6	1.2	14.9	14.9	2.3	3.6	7.7	33.7

3.3 Vertic A horizon

All vertic A horizons would equate to vertic horizons since the vertic A has ≥30% clay, wedge-shaped soil aggregates, slickensides, shrink-swell cracks, and are normally >25 cm thick (Table 4). All 71 vertic A horizons described during the land type survey had ≥30% clay with an average thickness of 525 mm, while 48 (68%) have few or many slickensides described. Vertic horizons key out before the melanic A and mollic horizons, in both the SAT and WRB.

TABLE 4 Summary statistics of selected soil properties for the 71 vertic A horizons described during the land type survey.

	Thickness (mm)	%			$cmol_c\ kg^{-1}$		Plasticity index
		Clay	OC	BS	S	CEC	
Avg	535	52.2	1.1	102.5	36.3	41.6	40
Min	30	32.5	0.1	10.1	9.6	11.0	22
Max	1200	70.4	2.8	234.4	117.7	500.0	69
Std	304	10.0	0.5	29.5	15.0	56.9	11

3.4 Melanic A horizon

The melanic A horizons (Table 5) relates primarily to the chernic horizons. The chernic horizon requires ≥20% (v/v) of fine earth (presumed to be true for melanic A horizons), granular or fine subangular blocky structure (true for all melanic A horizons), ≥1% soil organic carbon (presumed to be true; Table 5), Munsell colour value of ≤3 moist, and chroma of ≤2 moist (the colour requirement for the melanic A is more restrictive since it has value and chroma ≤3 in the dry state), base saturation ≥50% (presumed to be true), thickness ≥25 cm (presumed to be true).

If the chernic horizon is disqualified, then the melanic would relate to the mollic horizon, the melanic A has a sufficiently strong soil structure, (≥0.6% soil organic carbon is presumed), Munsell colour value and chroma ≤3 moist (true, as discussed above), [≥0.6% (absolute) more organic carbon than the parent material, if present, and a base saturation ≥50%], and a thickness ≥10 cm if directly overlying continuous rock, technic hard material or a cryic, petrocalcic, petroduric, petrogypsic or petroplinthic horizon, or ≥20 cm (valid in the majority of cases). Of the 114 melanic A horizons described during the land type survey only one had moist colour value >3 and only two had moist colour chroma >3, only one had OC <0.6%, and only 4 had BS <50%.

TABLE 5 Summary statistics of selected soil properties for the 114 melanic A horizons described during the land type survey.

	Thickness (mm)	Moist colour		%			$cmol_c\ kg^{-1}$	
		Value	Chroma	Clay	OC	BS	S	CEC
Avg	421	2.5	1.1	41.5	2.2	82.5	20.3	24.2
Min	100	2.0	0.0	6.5	0.5	27.7	2.3	3.0
Max	800	4.0	4.0	70.5	5.8	166.3	49.4	49.8
Std	145	0.5	0.8	12.1	1.1	20.3	9.3	8.3

3.5 Orthic A horizon

Orthic A horizons in the SAT are defined as not qualifying as an organic O, humic A, vertic A or melanic A, and therefore do not have an equivalent in the WRB. The orthic A horizon should also not be confused with the WRB ochric qualifier. The latter is defined as having ≥0.2% OC. Orthic A horizons *per se*, therefore, do not relate to any diagnostics within the WRB. As such, it can thus be argued that it is not the orthic A horizons, but rather the underlying horizons that are diagnostic for the relevant soil forms.

3.6 E horizon

The SAT defines E horizons as horizons that are grey, may be mottled, is friable with weak structure and has undergone removal of colloidal iron, clay, and organic matter. Most of the E horizons would qualify as albic material (dry colour: value 7 or 8 and chroma ≤3, or value 5 or 6 and chroma ≤2; and moist colour: value 6, 7 or 8 and chroma ≤4, or value 5 and chroma ≤3, or value 4 and chroma ≤2). Of the 325 E horizons described during the land type survey, 108 (59% of 182 described) meet the WRB dry colour criteria, 191 (69% of 280 described) meet the WRB moist colour criteria, while only 58 (41% of 140 described) meet the WRB dry and moist colour criteria (Table 6). These discrepancies can be related to the difference in the colour criteria, and to the yellow E horizon of the SAT that is yellow in the moist state and grey in the dry state. The SAT E horizons, therefore, relate quite poorly to the WRB albic material but are considered similar in this discussion due to the underlying assumed soil-forming processes and for the sake of simplicity. Stolk and Van Huyssteen (2019) discuss the properties of and differentiation between E, soft plinthic B, G, and prismacutanic B horizons.

TABLE 6 Summary statistics of selected soil properties for the 325 E horizons described during the land type survey.

	Thickness (mm)	Dry colour		Moist colour		%			cmol$_c$ kg^{-1}	
		Value	Chroma	Value	Chroma	Clay	OC	BS	S	CEC
Avg	266	6	2	5	3	13.2	0.5	65.2	3.0	5.1
Min	30	3	1	2	0	0.0	0.0	2.0	0.1	0.0
Max	875	8	6	8	8	47.6	2.2	233.3	17.2	21.8
Std	160	1	1	1	1	9.1	0.4	35.9	2.6	3.7

3.7 G horizon

Neither stagnic nor gleyic properties or reducing conditions were described during the land type survey of South Africa. During the land type survey of South Africa, 189 G horizons were described. These had an average clay content of 39±18%. Faint, distinct or prominent mottles were described for 26, 76, and 39 horizons respectively. The majority (106) had clay described as the dominant cutan type; four had sesquioxide cutans, while only one had silica cutans. Oxidised iron and manganese or reduced iron and manganese mottles were only described for 34 G horizons. Thus it was practically impossible to relate the SAT G horizon to the WRB horizons, based on the land type data. However, the SAT specifies that a G horizon "is saturated with water for long periods" and "is dominated, especially on macro-void and ped surfaces, by grey, low chroma matrix colours". These diagnostics would relate to WRB stagnic properties and reducing conditions, more than it would relate to WRB gleyic properties. Profiles with G horizons might also have a WRB abrupt textural difference, which does not reflect in the SAT taxonomy.

TABLE 7 Summary statistics of selected soil properties for the 189 G horizons described during the land type survey.

	Depth (mm)			Clay (%)	Fe (%)
	Upper	Lower	Thickness		
Count	187	178	179	168	159
Avg	650	1034	404	38.7	1.54
Min	30	250	100	2.0	0.00
Max	1800	2401	1540	88.5	16.58
Std	276	345	233	18.2	1.70

3.8 Apedal horizons

The SAT defines the red apedal B, yellow-brown apedal B, neocutanic B, and neocarbonate horizons primarily on colour and the presence or absence of lime, but secondarily these horizons share the criterion that the structure must be weaker than moderate blocky or prismatic in the moist state, and that if the structure is borderline, has a CEC <11 $cmol_c$ kg^{-1} soil.

The red apedal B, yellow-brown apedal B, neocutanic B, and neocarbonate horizons of SAT do not have direct equivalents in the WRB. This is because the SAT classifies these horizons primarily on colour and only recognises clay luviation and leaching status at the family level. This is in contrast to the WRB that primarily use clay luviation and negates colour and structure development for these horizons. There is also no equivalent for the neocarbonate B horizon in the WRB. The latter is therefore included here under the apedal horizons.

From the land type database, about half of the apedal soils have low activity clays (CEC <24 $cmol_c$ kg^{-1} clay), while the other half has high activity clays. This diagnostic is, therefore, something that the taxonomist needs to determine. Another possible argument is that apedal horizons are defined in the SAT to have CEC_{soil} <11 $cmol_c$ kg^{-1} soil.

Thus for an average clay content of 29% (Table 8), this would equate to CEC_{clay} = 37 $cmol_c$ kg^{-1} clay, implying that the average apedal horizon would have high activity clays. Low activity clays can, however, be assumed for apedal horizons with <45.8% clay since the CEC_{soil} <11 $cmol_c$ kg^{-1} soil for apedal horizons.

The calculated sum of exchangeable cations ($cmol_c$ kg^{-1} clay) relates very poorly (Figure 2) to calculated effective base saturation [sum of exchangeable cations / (sum of exchangeable cations + exchangeable aluminium]. However, according to this calculated relationship, an effective base saturation of 50% would more or less relate to 5 $cmol_c$ kg^{-1} clay sum of exchangeable cations. Dystrophic apedal soils are therefore interpreted in this document to have an effective base saturation <50%, while mesotrophic and eutrophic soils are interpreted to have an effective base saturation ≥50%. According to this assumed relationship, 26 mesotrophic and eutrophic apedal horizons would classify with low base status, 251 dystrophic apedal horizons will classify with high base status, 246 dystrophic apedal horizons will classify with low base status, while 1148 mesotrophic and eutrophic apedal horizons would classify with high base status. This relationship should receive more research attention and should also be addressed by the SAT, as also instructed in the SAT.

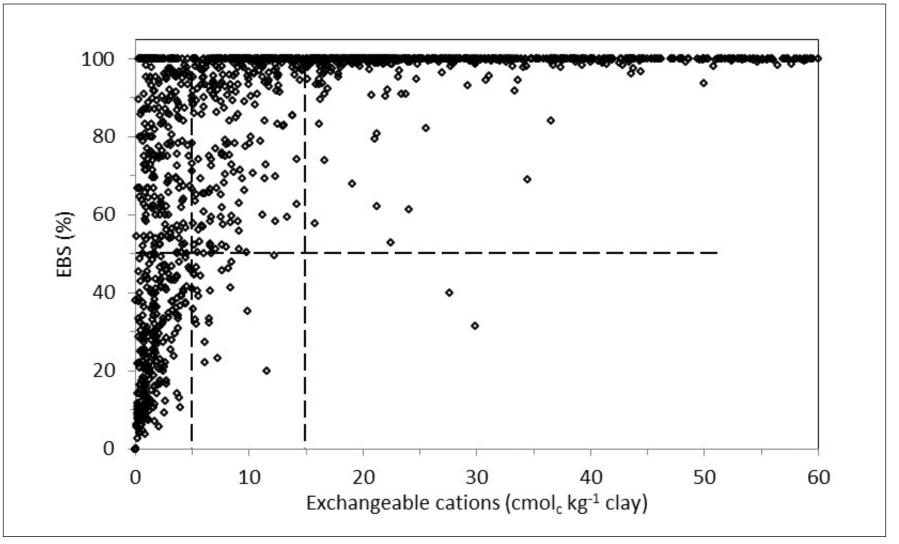

FIGURE 2 Sum of exchangeable cations ($cmol_c$ kg^{-1} clay) against calculated effective base saturation [EBS; exchangeable cations / (exchangeable cations + exchangeable aluminium)] for the apedal (red apedal B, yellow-brown apedal B, neocutanic B, neocarbonate) horizons described and analysed during the land type survey (Table 8). Dashed lines indicate the pertinent WRB and SAT limits.

Clay illuviation in the apedal horizons of SAT is captured through the luvic B family criterion: if the overlying horizon has ≤15% clay, then the B1 horizon must contain ≥5% (absolute) more clay; if the overlying horizon has >15% clay, then the ratio of clay percentage must be ≥1.3. This relates quite well to the WRB criteria for the argic horizon: if the overlying horizon has <10% clay, then the argic horizon has ≥4% (absolute) more clay; if the overlying horizon has ≥10 and <50% clay, then the ratio of clay in the argic horizon to that of the overlying horizon is ≥1.4; if the overlying horizon has ≥50% clay, then the argic horizon has ≥20% (absolute) more clay. Argic horizons require a thickness greater than one tenth of the overlying mineral or ≥15 cm. It can thus be assumed that these conditions will be met for the majority of luvic red apedal B, yellow-brown B, neocutanic B, and neocarbonate horizons.

TABLE 8 Summary statistics of selected soil properties for the 1881 apedal (red, yellow-brown, neocutanic) horizons described during the land type survey.

	Depth (mm)			$cmol_c\ kg^{-1}$			%	
	Upper	Lower	Thickness	S	Al	CEC	BS	Clay
Count	1880	1873	1845	1673	1610	1685	1685	1686
Avg	450	898	458	5	0	8	65	29
Min	0	20	20	0	0	0	0	1
Max	2031	3000	2300	41	10	50	750	694
Std	283	348	244	6	1	5	61	24

3.9 Red structured B horizon

The red structured B largely relates to the nitic horizon, although the latter is much more strictly defined (has ≥30% clay, silt:clay <0.4, <20% relative clay content difference to layers directly above and below, has moderate to strong blocky structure with shiny faces, ≥4% Fe_{dith}, ≥0.2% Fe_{ox}, active:free Fe ≥0.05, does not form part of a plinthic horizon, ≥30 cm thick). Almost all of the 100 red structured B horizons described during the land type survey (Table 9) have clay contents ≥30% (only eight have <30% clay and 6 of these eight have >27% clay). However, only 60 of the 100 red structured B horizons have ≥4% Fe_{dith}, while only 70 have silt:clay <0.4. Since only 32 of the 100 red structured B horizons have CEC_{clay} <24 $cmol_c\ kg^{-1}$ clay, it was concluded that two-thirds of the red structured soils have high activity clays. None of the horizons has an effective base saturation <50%. The principal qualifier would therefore predominantly be luvic (68%), with alic occurring secondarily (32%).

TABLE 9 Summary statistics of selected soil properties for the 100 red structured B horizons described during the land type survey.

	Si:Cl	EBS	%		$cmol_c\ kg^{-1}$			
			Fe	Al	EBS	S	CEC	CEC_{clay}
Avg	0.4	98.6	5.2	0.1	98.6	11.6	18.9	34.5
Min	0.1	54.1	0.0	0.0	54.1	2.2	6.5	10.1
Max	1.5	100	12.8	1.9	100.0	42.5	291.0	418.1
Std	0.2	5.7	2.7	0.3	5.7	6.5	28.0	40.9

3.10 Soft plinthic B horizon

The soft plinthic B largely relates to the ferric horizon [≥5% red to black concretions and/or nodules (≥2 mm), or ≥15% red to black coarse mottles (≥20 mm), due to the accumulation of Fe (and Mn) oxides, and ≥15 cm thick] since the SAT diagnostic specifies >10% (v/v) sesquioxide mottles. Soft plinthic B horizons also qualify as stagnic properties and reducing conditions, given the SAT diagnostic: "has grey colours caused by gleying, either in the horizon itself or immediately beneath it". Only 21 soft plinthic B horizons have their upper boundary >100 cm and all, except 4 are described as B2 or B3 horizons. It would, therefore, be safe to conclude that all soft plinthic B horizons have their upper boundary ≤100 cm from the surface.

Mottle occurrence for the 224 soft plinthic B horizons described (Table 10) during the land type survey was described as: 16 as few (<2%), 71 as common (2-20%), and 107 as many (>20%). Mottle size was described as follows: 52 as fine (<2 mm), 112 as medium (2-5 mm), 0 as coarse (>5 mm). Mottle contrast was given as follows: 23 as faint, 85 as distinct, and 81 as prominent. Mottle colour (primary and associated colour) was described as follows: 14 as grey, 61 as yellow, and 98 as red.

TABLE 10 Summary statistics of selected soil properties for the 224 soft plinthic B horizons described during the land type survey.

	Depth (mm)		Clay (%)	Fe (%)
	Upper	Lower		
Count	224	224	209	203
Avg	677	1038	31.3	2.3
Min	100	370	2.5	0.2
Max	1400	2401	80.4	8.9
Std	264	325	14.7	1.7

3.11 Hard plinthic B horizon

Hard plinthic B horizons largely qualify as petroplithic horizons [indurated yellowish, reddish and/or blackish concretions and/or nodules; a penetration resistance ≥4.5 MPa; ≥2.5% (m/m) Fe_{dith} in the fine earth fraction; or ≥10% (m/m) Fe_{dith} in the concretions, nodules and/or concentrations; Fe_{ox} to Fe_{dith} ratio <0.112; vertical fractures ≥10 cm apart and occupy <20% (v/v); ≥10 cm thick]. The hard plinthic B is only defined as being indurated with iron and manganese oxides which cannot be cut with a spade. Data from the land type survey also provides few of the criteria required by the WRB (Table 11). Although 41 hard plinthic B horizons were described, only 12 were analysed. Of the 12 analysed, only four of these had ≥2.5% (m/m) Fe_{dith} in the fine earth; however, it is hypothesised here that the concretions would have ≥10% (m/m) Fe_{dith}, allowing for the recognition of a petroplinthic horizon.

TABLE 11 Summary statistics of selected soil properties for the 41 hard plinthic B horizons described during the land type survey.

	Depth (mm)		Fe (%)	Clay (%)
	Upper	Lower		
Count	41	41	12	12
Avg	639	914	2.02	17.4
Min	100	520	0.69	5.9
Max	1350	1800	6.16	42.3
Std	260	281	1.68	9.9

3.12 Prismacutanic B horizon

The prismacutanic B horizon largely relates to the natric horizon (≥8% clay; underlies a coarser textured horizon; evidence of illuvial clay; columnar, prismatic or blocky structure; ESP ≥15; ≥7.5 cm or ≥15 cm thick), and an abrupt textural difference (doubling of clay within 5 cm, if overlying layer <20% clay or ≥20% clay increase if the overlying layer has ≥20% clay).

Only 42 prismacutanic B horizons have ESP ≥15%; however, 126 have Na+Mg > Ca, and an additional 6 have ESP ≥15% (Table 12). Therefore 132 of the 190 prismacutanic B horizons would meet the Na criteria of the natric horizon. All prismacutanic B horizons have ≥8% clay and are ≥15 cm thick.

TABLE 12 Summary statistics of selected soil properties for the 42 prismacutanic B horizons described during the land type survey.

	Depth (mm)		$cmol_c\ kg^{-1}$						%	
	Upper	Lower	Na	K	Ca	Mg	S	CEC	ESP	Clay
Count	190	188	190	190	190	190	190	190	190	190
Avg	354	704	1.6	0.6	7.3	6.6	16.1	16.9	10.5	44.9
Min	70	200	0.1	0.0	0.0	0.0	0.2	5.1	0.5	10.4
Max	1100	1650	16.8	4.1	69.6	38.0	76.2	35.5	92.4	82.3
Std	172	246	1.8	0.7	6.5	4.1	9.0	6.0	11.7	14.9

3.13 Pedocutanic B horizon

The pedocutanic B horizon relates to an argic horizon, due to the clay increase, clay cutans and the presumption that pedocutanic B horizons have high activity clays (CEC ≥24 $cmol_c\ kg^{-1}$ clay) and high effective base saturation (≥50%). Of the 373 horizons described during the land type survey, 346 have CEC ≥24 $cmol_c\ kg^{-1}$ clay, while 371 have an effective base saturation ≥50% (Table 13).

TABLE 13 Summary statistics of selected soil properties for the 373 pedocutanic B horizons described during the land type survey.

	Depth (mm)		%			$cmol_c\ kg^{-1}$		
	Upper	Lower	Clay	EBS	BS	S	CEC	CEC_{clay}
Avg	324	681	43.9	99	95.6	18.2	18.9	45.8
Min	0	80	4.8	27	5.4	0.8	4.0	13.8
Max	1500	1601	82.1	100	241.9	60.9	48.7	133.3
Std	212	287	13.6	6	30.6	9.0	7.1	18.0

3.14 Lithocutanic B horizon

Lithocutanic B horizons do not relate directly to any WRB diagnostics. However, the lithocutanic B horizon would equate to skeletic properties if it has ≥40% (v/v) coarse fragments to the solid rock or to a depth of 100 cm; and it can be considered continuous rock if the cracks into which roots can enter are ≥10 cm apart and occupy <20% (v/v); and it can be considered as an argic horizon since it has *tongues* of illuviated clay and soil into the unweathered rock. These criteria were only partially described during the land type survey (Table 14; Table 15).

TABLE 14 Summary statistics of selected soil properties for the 243 lithocutanic B horizons described during the land type survey.

	Depth (mm)		Clay (%)
	Upper	Lower	
Count	243	243	185
Avg	400	663	29
Min	0	60	3
Max	1200	2000	62
Std	227	316	13

TABLE 15 Summary statistics of selected morphological properties for the 243 lithocutanic B horizons described during the land type survey.

Property	Count	Quantity and denomination			
Rock occurrence	219	46 few	70 common	56 many	40 none
Rock kind	191	126 gravel	30 stones	1 boulders	34 none
Rock size	147	71 fine	20 medium	2 coarse	54 none
Rock shape	207	27 angular	26 flat	41 round	76 none
Cutan occurrence	170	69 few	68 common	16 many	17 none
Cutan type	157	138 clay	1 carbonates	5 skeletans	10 none

3.15 Podzol B horizon

The podzol B qualifies as a spodic horizon. The spodic horizon has a pH <5.9; ≥0.5% OC; is overlain by albic material, has dark red moist colours; ≥2.5 cm thick. Only 14 podzol B horizons were described and analysed during the land type survey (Table 16). Ten of these meet the dark red colour criteria of the WRB spodic horizon (of the four not meeting the colour criteria, all have a hue of 10YR and are only one value unit too light). Eight do not meet the ≥0.5% OC criterion.

TABLE 16 Summary statistics of selected soil properties for the 14 podzol B horizons described during the land type survey.

	Depth (mm)		Thickness (mm)	%				$pH_{(H0)}$
	Upper	Lower		Clay	Fe	Al	OC	
Count	14	14	13	14	14	14	14	14
Avg	502	742	258	8.5	1.04	0.70	1.8	5.5
Min	200	450	150	1.4	0.02	0.01	0.1	4.5
Max	900	1100	550	18.3	3.83	3.04	7.6	6.6
Std	234	206	115	5.3	1.16	0.86	2.1	0.5

3.16 Regic sand

Regic sand does not relate to a diagnostic in the WRB. However, regic sands would key out as Arenosols since they have a texture of loamy sand or coarser and are presumed to have <40% (v/v) coarse fragments ≤100 cm from the surface. Of the 47 regic sand horizons described, only six of these had few gravel coarse fragments described, while the texture was predominantly sandy (Table 17).

TABLE 17 Summary statistics of selected soil properties for the 47 regic sand horizons described during the land type survey.

	Depth (mm)		%		
	Upper	Lower	Sand	Silt	Clay
Count	47	47	47	47	47
Avg	574	1214	94.2	2.4	3.3
Min	150	450	77.6	0.1	0.0
Max	2200	2201	100.7	11.6	17.6
Std	381	400	5.7	2.8	3.8

3.17 Stratified alluvium

The stratified alluvium (Table 18) would relate to fluvic material (of fluviatile, marine or lacustrine origin; obvious stratification in ≥25% of the soil volume; does not form part of a spodic or sombric horizon).

TABLE 18 Summary statistics of selected soil properties for the 28 stratified alluvium horizons described during the land type survey.

	Depth (mm)		%		
	Upper	Lower	Sand	Silt	Clay
Avg	516	929	72.5	12.5	13.9
Min	100	300	22.0	0.4	2.3
Max	1300	1801	97.0	35.5	42.8
Std	321	347	20.9	11.3	11.2

3.18 Placic pan

The placic pan will qualify for the placic qualifier (0.1 to 2.5 cm thick, cemented by organic matter, Fe, Mn and/or Al, and has vertical fracture spacing ≥10 cm). No placic pans were described or analysed during the land type survey.

3.19 Dorbank

The dorbank almost directly relates to the petroduric horizon since it has cementation in ≥50% (v/v); has silica accumulation; has vertical fractures ≥10 cm apart that occupy <20% (v/v); cannot be penetrated by roots; ≥1 cm thick. Only 13 dorbank horizons were described during the land type survey, and only 6 of these were analysed (Table 19).

TABLE 19 Summary statistics of selected soil properties for the 16 dorbank horizons described during the land type survey.

	Depth (mm)		%						
	Upper	Lower	Sand	Silt	Clay	OC	Fe	Al	Mn
Count	13	13	6	6	6	5	5	5	5
Avg	508	597	54.0	24.5	20.5	0.29	1.23	0.08	0.03
Min	0	-	22.0	16.8	3.7	0.03	0.50	0.03	0.01
Max	1300	1500	77.8	48.4	52.5	0.50	1.72	0.13	0.05
Std	383	525	21.4	12.1	21.3	0.24	0.60	0.04	0.02

3.20 Saprolite

Saprolite, similar to the lithocutanic B does not relate easily to diagnostics in the WRB. Saprolite could, therefore, be considered similar to the lithocutanic B horizon and would thus equate to skeletic properties if the saprolite has ≥40% (v/v) coarse fragments to solid rock or to a depth of 100 cm; and the saprolite can be considered continuous rock if the cracks into which roots can enter are ≥10 cm apart and occupy <20% (v/v). Eighty-six saprolite horizons were described during the land type survey, but only 22 of these were analysed (Table 20).

TABLE 20 Summary statistics of selected soil properties for the 104 saprolite horizons described during the land type survey.

	Depth (mm)		Clay (%)
	Upper	Lower	
Count	104	104	24
Avg	681	1102	28
Min	260	280	5
Max	1500	9501	62
Std	268	1625	19

3.21 Soft carbonate horizon

The soft carbonate horizon (if ≥15 cm thick) equate to a calcic horizon [calcium carbonate equivalent ≥15%; ≥5% (v/v) secondary carbonates; calcium carbonate equivalent ≥5% (m/m) than an underlying layer; is not a petrocalcic horizon; ≥15 cm thick] and an assumed base saturation >50%. The soft carbonate horizon also qualifies for protocalcic properties [disrupt the soil structure; or occupy ≥5% (v/v) of the soil with masses, nodules, concretions; or cover ≥50% of structural faces, pore surfaces or undersides of rock fragments; or form permanent filaments (pseudomycelia)]. Only eight soft carbonate horizons were described during the land type survey, and only two of these were analysed.

3.22 Hardpan carbonate horizon

The hardpan carbonate horizon (if ≥10 cm thick) equates to a petrocalcic horizon [very strong effervescence; induration by secondary carbonates; vertical fractures ≥10 cm apart and occupy <20% (v/v); cannot be penetrated by spade or auger; ≥10 cm thick], and an assumed base saturation >50% throughout. Twelve hardpan carbonate horizons were described during the land type survey, but only three of these were analysed. The upper boundary of these horizons was 200 mm ±150 mm. Thicknesses varied from 100 to 1 000 mm, where these were described.

3.23 Unconsolidated material without signs of wetness

Unconsolidated material without signs of wetness does not relate to any diagnostic in the WRB.

3.24 Unconsolidated material with signs of wetness

Unconsolidated material with signs of wetness can only relate to stagnic properties (oximorphic mottles, concretions, or nodules; reductimorphic colours; or albic material) and reducing conditions (rH <20; or Fe^{2+}; or FeS; or CH_4).

3.25 Unspecified material with signs of wetness

Similar to unconsolidated material with signs of wetness, unspecified material with signs of wetness can only relate to stagnic properties (oximorphic mottles, concretions, or nodules; reductimorphic colours; or albic material) and reducing conditions (rH <20; or Fe^{2+}; or FeS; or CH_4).

3.26 Hard rock

Hard rock directly relates to continuous rock [if vertical cracks ≥10 cm apart and occupy <20% (v/v)]. The land type survey described 43 hard rock horizons, which on average started at 186 ±123 mm from the surface.

3.27 Man-made soil deposit

Man-made soil deposit would relate to artefacts (created or substantially modified by humans) or technic hard material [consolidated from an industrial process, and properties substantially different from natural material; and <5% (v/v) vertical cracks] if the man-made soil deposit is hardened.

CHAPTER 4

FAMILY CRITERIA

4.1 Fibrous and humified organic material

Fibrous organic material refers to well preserved (identifiable) plant remains while humified organic material refers to composed plant remains. Greater than 2/3 (v/v) recognizable plant material is assumed for the fibrous organic O (diagnostic for the WRB fibric qualifier); while <1/3 (v/v) recognizable plant material is assumed for the humified organic O (diagnostic for the WRB sapric qualifier).

4.2 Thin and thick humic A horizons

Since the humic A horizon does not have a logic equivalent in the WRB, the thin (≤450 mm) and thick (>450 mm) humic A horizons also do not relate to any diagnostic in the WRB. The pachic qualifier can, however, be used in the case of Umbrisols to denote a thick (>50 cm) umbric horizon.

4.3 Dark and light coloured A horizons overlying the E horizon in Fernwood form

Darker coloured orthic A horizons refer to moist colour value ≤4 and chroma ≤1 due to organic matter accumulation. Dark coloured orthic A horizons can thus most probably be related to the WRB ochric qualifier (≥0.2% OC from 0-10 cm), humic if it has ≥1% OC from 0-50 cm, and hyperhumic if it has ≥5% OC from 0-50 cm. The ochric qualifier is assumed here for the dark coloured orthic A horizons.

4.4 Bleached orthic A horizon

Bleached orthic A horizons refer to A horizons that have undergone reduction and removal of iron, while non-bleached orthic A horizons have no marked reducing conditions. As such it can *senso stricto*, and for the extreme examples, be interpreted as reducing conditions, albic material, and even a stagnic colour pattern. Non-bleached orthic A horizons might also be interpreted as having ≥0.2% OC from 0-10 cm, which would give rise to the ochric qualifier. However, it is argued here that all these deductions are weak and that the bleached orthic A horizon should rather be regarded as not relating to any diagnostic in the WRB.

4.5 Dark, red and other colours found in vertic A horizons and in pedocutanic B horizons which occur beneath melanic A horizons

Dark colours have moist value ≤4 and chroma ≤1 and values ≤4 with chroma ≤2 if the hue is 10YR or 7.5YR. Red colours have of a hue 5YR, 2.5YR, 10R or 7.5R. The dark colours, therefore, relate to the ochric qualifier (≥0.2% OC from 0-10 cm), similarly to the dark and light colours overlying the Fernwood E horizon. Red colours relate to the WRB rhodic qualifier (moist colour hue redder than 5YR, moist value <4, and dry value not more than one unit higher than the moist value).

4.6 Grey and yellow E horizons

Grey and yellow E horizons do not relate to any diagnostic in the WRB. However, the diagnostics for the WRB albic material state moist

Munsell colour value of 6-8 and chroma ≤4, or value 5 and chroma ≤3, or value 4 and chroma ≤2. This is largely in line with the dry colours for the E horizon and therefore yellow E horizons do not qualify as albic material.

4.7 Presence and absence of lamellae in the E horizon of Fernwood form

Lamellae in the E horizon relate to the WRB lamellic qualifier [≥2 lamellae (0.5-7.5 cm thick), with higher clay contents than the matrix, a combined thickness ≥5 cm, and starting ≤100 cm from the surface].

4.8 Dystrophic, mesotrophic, eutrophic

Differentiation between dystrophic, mesotrophic, and eutrophic B horizons are discussed under the apedal horizons in Chapter 3.

4.9 Non-red and red colours in B horizons, stratified alluvium and regic sand

Red colour families have hues of 5YR, 2.5YR, 10R, or 7.5R and thus correlate with the WRB rhodic qualifier (moist colour hue redder than 5YR, moist value <4, and dry value not more than one unit higher than the moist value).

4.10 Luvic B horizon

Luvic and non-luvic B horizons are discussed under the apedal horizons in Chapter 3.

4.11 Subangular/fine angular and medium/coarse angular structure in pedocutanic B and red structured B horizons

Structure size and type do not relate to any diagnostics in the WRB.

4.12 Continuous black cutans in prismacutanic B horizons

The SAT defines black cutans as an indication of wet soils. These families are therefore related to the stagnic qualifier (stagnic colour pattern and reducing conditions), although the presence of black cutans is not a criterion for stagnic properties.

4.13 Ortstein hardening of podzol B horizons

The ortstein hardening relates to the WRB ortsteinic qualifier (cemented in ≥50% of its horizontal extension).

4.14 Hard and not hard lithocutanic B horizons and saprolite

The non-hard and hard lithocutanic B and saprolite do not easily relate to WRB qualifiers. The best options are densic (root-limiting compaction) and fragic (structural units that do not allow roots to enter and ≥10 cm vertical separations, evidence of alteration, <0.5% OC, ≥50% slaking, does not cement, penetration resistance ≥4 MPa, no effervescence, ≥15 cm thick).

4.15 Signs of wetness

Signs of wetness relate to stagnic properties (oximorphic mottles, concretions, or nodules; reductimorphic colours; or albic material) and reducing conditions (rH <20; or Fe^{2+}; or FeS; or CH_4). (Thus quite similar to the unconsolidated and unspecified material with signs of wetness.)

4.16 Calcareous horizons and layers

Calcareous horizons effervesce visibly when with cold 10% HCl and thus correlate with calcaric material (should preferably only be for strong effervescence). It is important to note that within the geologically extremely old South African landscape these lime accumulations most probably almost always refer to secondary lime (i.e. segregated and redistributed) and are not necessarily inherited from the parent material.

4.17 Podzolic character beneath a diagnostic yellow-brown apedal B horizon

Podzol horizons occurring beneath a diagnostic yellow-brown apedal B horizon at best correlate to Entic Podzols. The entic qualifier is used for Podzols to denote weakly developed spodic horizons that do not have overlying albic material.

4.18 Friable and firm C horizons

Friable refers to soils that have a loose to slightly firm consistence (and thus increased permeability), while firm refers to soils with a firmer consistence (and thus reduced permeability). Firm saprolite horizons are therefore interpreted to relate to the densic qualifier (compaction to the extent that roots cannot penetrate).

4.19 Material underlying organic O horizons

Material underlying organic O horizons refers to solid rock and saprolite on the one hand and unconsolidated material on the other hand. If the bedrock or saprolite occur ≤100 cm from the surface, then the WRB leptic qualifier would be satisfied.

CHAPTER 5

SOIL FORMS

5.1 Champagne

(Organic O): The organic O of Champagne soils meets the thickness criterion of the WRB (the >20 cm assumed depth limit for Champagne soils is more restrictive than the ≥10 cm required for Histosols), but not the OC content [≥20% (m/m) soil organic carbon]. Thus organic O horizons with ≥20% OC would equal organic material and therefore Histosols. Champagne soils are therefore differentiated here into two classes: those with ≥20% OC and those with <20% OC. The fibric qualifier is implemented for the fibrous organic O, while the sapric qualifier is implemented for the humified organic O. It is assumed that if bedrock or saprolite is present it would occur ≤100 cm from the surface, thus enabling the leptic qualifier.

Champagne soils with ≥20% OC in the organic O:

Fibrous organic O, bedrock or saprolite underlying Champagne	Leptic Fibric Histosol
Fibrous organic O, unconsolidated material underlying Champagne	Fibric Histosol
Humified organic O, bedrock or saprolite underlying Champagne	Leptic Sapric Histosol
Humified organic O, unconsolidated material underlying Champagne	Sapric Histosol

Champagne soils with <20% OC on bedrock or saprolite (≤25 cm from the surface) would key out as Leptosols, while those on unconsolidated material would key out as Gleysols (for organic O horizons <40 cm thick or Stagnosols for organic O horizons <25 cm thick) since groundwater saturation can be assumed. Organic O horizons are saturated with water for long periods and have evidence of wetness in the subsoil. Organic O horizons with 10-20% OC might also classify as chernic, mollic or umbric horizons. Chernic, mollic or umbric horizons all require a moderate to strongly developed structure, dark colour (moist value and chroma ≤3), ≥0.6% OC (≥1% for chernic); high base saturation ≥50% (<50% for umbric), a thickness ≥20 cm (≥25 cm for chernic). It is therefore argued that organic O horizons will meet the structure, OC, colour, and depth criteria, but will classify as chernic or umbric horizons, based on the base saturation. Chernic is given precedence over mollic since it has a higher OC content. Umbric is the only option for high OC, low base saturation organic O horizons. Champagne soils with <20% OC on bedrock or saprolite (>25 cm from the surface) would key out as Leptic Phaeozems or Umbrisols, if it is assumed that the high OC content would result in dark topsoils, leading to the mollic horizon.

Champagne soils with <20% OC in the organic O:

Fibrous organic O, bedrock or saprolite underlying Champagne	Chernic/Umbric Leptosol (Humic, Stagnic)
Fibrous organic O, unconsolidated material underlying Champagne (organic O horizon <40 cm thick)	Chernic/Umbric Gleysol (Humic)
Fibrous organic O, unconsolidated material underlying Champagne (organic O horizon ≥40 cm thick)	Gleyic Chernozem (Hyperhumic)
Humified organic O, bedrock or saprolite underlying Champagne	Chernic/Umbric Leptosol (Humic, Stagnic)
Humified organic O, unconsolidated material underlying Champagne (organic O horizon <40 cm thick)	Chernic/Umbric Gleysol (Humic)
Humified organic O, unconsolidated material underlying Champagne (organic O horizon ≥40 cm thick)	Gleyic Chernozem (Hyperhumic)

5.2 Kranskop

(Humic A / yellow-brown apedal B / red apedal B): Luvic families of the yellow-brown and red apedal B horizons qualify as argic horizons. The acric qualifier (CEC <24 $cmol_c\ kg^{-1}$ clay and effective base saturation <50%) is presumed since humic A soils typically occur on the high-rainfall areas on acidic parent material. The maximum base saturation recorded during the land type survey is 11.1% (Table 3). Rhodic is used to denote the red apedal B and endorhodic is used since it is assumed that the upper boundary of the red apedal B2 would typically occur deeper than 50 cm. Pachic refers to a thick (>50 cm) umbric horizon, used here to relate to thick (>450 mm) humic A horizons.

thin A, non-luvic B1 Kranskop	Haplic Umbrisol (Hyperdystric, Endorhodic)
thin A, luvic B1 Kranskop	Acric Umbrisol (Hyperdystric, Endorhodic)
thick A, non-luvic B1 Kranskop	Haplic Umbrisol (Hyperdystric, Pachic, Endorhodic)
thick A, luvic B1 Kranskop	Acric Umbrisol (Hyperdystric, Pachic, Endorhodic)

5.3 Magwa

(Humic A / yellow-brown apedal B / unspecified): Magwa soils will classify similar to Kranskop soils, except for the exclusion of the red apedal B2 (endorhodic) in Magwa soils. Pachic refers to a thick (>50 cm) umbric horizon, used here to relate to thick (>450 mm) humic A horizons.

thin A, non-luvic B1 Magwa	Haplic Umbrisol (Hyperdystric)
thin A, luvic B1 Magwa	Acric Umbrisol (Hyperdystric)
thick A, non-luvic B1 Magwa	Haplic Umbrisol (Hyperdystric, Pachic)
thick A, luvic B1 Magwa	Acric Umbrisol (Hyperdystric, Pachic)

5.4 Inanda

(Humic A / red apedal B / unspecified): Inanda soils will also classify similar to Kranskop soils, except that the red apedal B (endorhodic) now occurs higher up in the profile; thus endorhodic becomes just rhodic. Pachic refers to a thick (>50 cm) umbric horizon, used here to relate to thick (>450 mm) humic A horizons.

thin A, non-luvic B1 Inanda	Haplic Umbrisol (Hyperdystric, Rhodic)
thin A, luvic B1 Inanda	Acric Umbrisol (Hyperdystric, Rhodic)
thick A, non-luvic B1 Inanda	Haplic Umbrisol (Hyperdystric, Pachic, Rhodic)
thick A, luvic B1 Inanda	Acric Umbrisol (Hyperdystric, Pachic, Rhodic)

5.5 Lusiki

(Humic A / pedocutanic B / unspecified): The humic A horizon still results in Lusiki soils keying out as Umbrisols (Hyperdystric), but in this case, the pedocutanic B horizon lead to the recognition of an argic horizon, due to the clay increase and clay cutans. The luvic qualifier is used since pedocutanic B horizons (Table 13) have high activity clays (CEC ≥24 $cmol_c$ kg^{-1} clay) and an assumed high effective base saturation (≥50%). Pachic refers to a thick (>50 cm) umbric horizon, used here to relate to thick (>450 mm) humic A horizons.

thin A, non-red, subangular/fine angular B1 Lusiki	Luvic Umbrisol (Hyperdystric)
thin A, non-red, medium/coarse angular B1 Lusiki	Luvic Umbrisol (Hyperdystric)
thin A, red, subangular/fine angular B1 Lusiki	Luvic Umbrisol (Hyperdystric, Rhodic)
thin A, red, medium/coarse angular B1 Lusiki	Luvic Umbrisol (Hyperdystric, Rhodic)
thick A, non-red, subangular/fine angular B1 Lusiki	Luvic Umbrisol (Pachic)
thick A, non-red, medium/coarse angular B1 Lusiki	Luvic Umbrisol (Hyperdystric, Pachic)
thick A, red, subangular/fine angular B1 Lusiki	Luvic Umbrisol (Hyperdystric, Pachic, Rhodic)
thick A, red, medium/coarse angular B1 Lusiki	Luvic Umbrisol (Hyperdystric, Pachic, Rhodic)

5.6 Sweetwater

(Humic A / neocutanic B / unspecified): Sweetwater soils will classify similar to Kranskop soils, except that the rhodic qualifier, denoting the red apedal B in the case of Kranskop soils, is replaced by cambic representing the neocutanic B of Sweetwater soils. The luvic B1 horizon families are assumed to be acric (CEC <24 $cmol_c$ kg^{-1} clay and effective base saturation <50%), similar to the argument for Kranskop soils, while the red neocutanic B1 families have rhodic qualifiers. Pachic refers to a thick (>50 cm) umbric horizon, used here to relate to thick (>450 mm) humic A horizons.

thin A, non-red, non-luvic B1 Sweetwater	Cambic Umbrisol (Hyperdystric)
thin A, non-red, luvic B1 Sweetwater	Cambic Acric Umbrisol (Hyperdystric)
thin A, red, non-luvic B1 Sweetwater	Cambic Umbrisol (Hyperdystric, Rhodic)
thin A, red, luvic B1 Sweetwater	Cambic Acric Umbrisol (Hyperdystric, Rhodic)
thick A, non-red, non-luvic B1 Sweetwater	Cambic Umbrisol (Hyperdystric, Pachic)
thick A, non-red, luvic B1 Sweetwater	Cambic Acric Umbrisol (Hyperdystric, Pachic)
thick A, red, non-luvic B1 Sweetwater	Cambic Umbrisol (Hyperdystric, Pachic, Rhodic)
thick A, red, luvic B1 Sweetwater	Cambic Acric Umbrisol (Hyperdystric, Pachic, Rhodic)

5.7 Nomanci

(Humic A / lithocutanic B): If the humic A horizon is <25 cm thick, then Nomanci soils will key out as Umbric Leptosols (Humic). However, for this discussion humic A horizons ≥25 cm thick is presumed since humic A horizons were initially defined (MacVicar et al., 1977) to be >45 cm thick (see also Table 3). An argic horizon reflates to the lithocutanic B (Table 14). The acric / lixic / alic / luvic qualifiers can, however, not be estimated since these would be a function of parent material and climate. The leptic qualifier (hard rock ≤100 cm from the surface) can be assumed in most cases and should be included for the thin families. The tonguic qualifier denotes tonguing of the umbric horizon into the lithocutanic B. Pachic refers to a thick (>50 cm) umbric horizon, used here to relate to thick (>450 mm) humic A horizons.

thin A, non-hard B1 Nomanci	Acric/Lixic/Alic/Luvic Leptic Umbrisol (Hyperdystric, Tonguic)
thin A, hard B1 Nomanci	Acric/Lixic/Alic/Luvic Leptic Umbrisol (Hyperdystric, Tonguic)
thick A, non-hard B1 Nomanci	Acric/Lixic/Alic/Luvic Leptic Umbrisol (Hyperdystric, Pachic, Tonguic)
thick A, hard B1 Nomanci	Acric/Lixic/Alic/Luvic Leptic Umbrisol (Hyperdystric, Pachic, Tonguic)

5.8 Rensburg

(Vertic A / G): Rensburg soils have a vertic horizon, while the G horizon implies stagnic properties and reducing conditions. Rensburg soils would, therefore, key out as Vertisols since the vertic horizons would be ≤100 cm from the surface; have ≥30% clay; and shrink-swell cracks. The calcareous G horizon families reflect through the calcaric qualifier.

Non-calcareous Rensburg	Haplic Vertisol (Stagnic)
Calcareous Rensburg	Haplic Vertisol (Calcaric, Stagnic)

5.9 Arcadia

(Vertic A / unspecified): Arcadia soils have a vertic horizon and thus key out as Vertisols since the vertic horizons would be ≤100 cm from the surface; have ≥30% clay; and shrink-swell cracks. The calcareous A horizon families are reflected through the calcaric qualifier, while red families result in the chromic qualifier (rhodic would be preferable, but is not available for Vertisols). The dark coloured families lead to the pellic qualifier (value ≤3 & chroma ≤2), while other coloured families result in the haplic qualifier.

Dark coloured, non-calcareous Arcadia	Pellic Vertisol
Dark coloured, calcareous Arcadia	Pellic Vertisol (Calcaric)
Red coloured, non-calcareous Arcadia	Chromic Vertisol
Red coloured, calcareous Arcadia	Chromic Vertisol (Calcaric)
Other coloured, non-calcareous Arcadia	Haplic Vertisol
Other coloured, calcareous Arcadia	Haplic Vertisol (Calcaric)

5.10 Willowbrook

(Melanic A / G horizon): The melanic A equate to a mollic horizon, while the G horizon relates to a stagnic colour pattern and reducing conditions. If the melanic A horizon is ≤25 cm thick and if the G horizon is ≥50 cm thick or ≥25 cm thick and directly overlies continuous rock, this would lead to Stagnosols. Fey (2010) classify shallow (<50 cm to G horizon) Willowbrook soils as Gleysols, however, as discussed in Chapter 3, the G horizons would rather relate to stagnic properties, than to gleyic properties.

Non-calcareous G Willowbrook	Mollic Stagnosol
Calcareous G Willowbrook	Calcaric Mollic Stagnosol

If the above conditions are not met, then the melanic A horizon is >25 cm thick, and Willowbrook soils will key out as Phaeozems (mollic horizon; and base saturation ≥50%). If the base saturation of the topsoil is <50% (which is doubtful), then these soils will key out as Umbrisols.

Non-calcareous G Willowbrook	Stagnic Phaeozem
Calcareous G Willowbrook	Calcaric Stagnic Phaeozem

5.11 Bonheim

(Melanic A / pedocutanic B): The melanic A equates to a mollic horizon, while the calcareous pedocutanic B equates to protocalcic properties (since it refers to secondary carbonates) and thus implies a base saturation ≥50%, leading to the Kastanozems. The luvic qualifier denotes the clay increase in the pedocutanic B, while rhodic refers to the red coloured B. No distinction is drawn in WRB between dark and other coloured B horizons or the nature of the blocky structure. The non-calcareous families would key out as Phaeozems (mollic horizon and a base saturation >50% throughout and no secondary carbonates). If the base saturation of the mollic horizons <50% (which is doubtful), then these soils will key out as Umbrisols. Bonheim soils cannot be Chernozems (Fey, 2010) since there is no protocalcic horizon. Similarly, it cannot be Luvisols since the Kastanozems and Phaeozems key out first.

Dark, subangular/fine angular, non-calcareous B Bonheim	Luvic Phaeozem
Dark, subangular/fine angular, calcareous B Bonheim	Luvic Kastanozem
Dark, medium/coarse angular, non-calcareous B Bonheim	Luvic Phaeozem
Dark, medium/coarse angular, calcareous B Bonheim	Luvic Kastanozem
Red, subangular/fine angular, non-calcareous B Bonheim	Luvic Phaeozem (Rhodic)
Red, subangular/fine angular, calcareous B Bonheim	Luvic Kastanozem (Rhodic)
Red, medium/coarse angular, non-calcareous B Bonheim	Luvic Phaeozem (Rhodic)
Red, medium/coarse angular, calcareous B Bonheim	Luvic Kastanozem (Rhodic)
Non-Dark, non-Red, subangular/fine angular, non-calcareous B Bonheim	Luvic Phaeozem
Non-Dark, non-Red, subangular/fine angular, calcareous B Bonheim	Luvic Kastanozem
Non-Dark, non-Red, medium/coarse angular, non-calcareous B Bonheim	Luvic Phaeozem
Non-Dark, non-Red, medium/coarse angular, calcareous B Bonheim	Luvic Kastanozem

5.12 Steendal

(Melanic A / soft carbonate horizon): The melanic A equates to a chernic horizon, while the soft carbonate horizon (if ≥15 cm thick with secondary carbonates) equates to a calcic horizon and an assumed base saturation ≥50%, leading to the Chernozems. Steendal soils where the melanic A horizon does not relate to a chernic horizon (as discussed in the diagnostic horizons section) will become Kastanozems, with the same prefix qualifiers than the Chernozems.

Non-calcareous A Steendal	Calcic Chernozem
Calcareous A Steendal	Calcic Chernozem

5.13 Immerpan

(Melanic A / hardpan carbonate horizon): The melanic A equates to a chernic horizon, while the hardpan carbonate horizon (if ≥10 cm thick secondary carbonates, assumed here) equates to a petrocalcic horizon, and an assumed base saturation ≥50% throughout, leading to the Chernozem. Immerpan soils where the melanic A horizon does not relate to a chernic horizon (as discussed in Chapter 3) will become Kastanozems, with the same prefix qualifiers than the Chernozems.

Non-calcareous A Immerpan	Petrocalcic Chernozem
Calcareous A Immerpan	Petrocalcic Chernozem

5.14 Mayo

(Melanic A / lithocutanic B): The melanic A equates to a mollic horizon, while the lithocutanic B equates to the leptic qualifier (hard rock ≤100 cm from the surface, which can be assumed in most cases). This leads to Phaeozems (a base saturation ≥50% throughout is assumed, but this assumption may not be valid in acidic parent material and high rainfall areas). Luvic is assumed from the cutanic nature of the lithocutanic B, while densic is assumed for the "hard" lithocutanic B families. [If the melanic A horizon is ≤25 thick (unlikely according to Table 5), then Mayo soils will key out as Leptosols]. The skeletic qualifier can be used if the soil has ≥40% (v/v) coarse fragments <100 cm or to hard rock (this is assumed here to denote the cutanic nature of the lithocutanic B). The tonguic qualifier denotes tonguing of the melanic A horizon into the lithocutanic B. [The leptic and densic qualifiers can be considered mutually exclusive, since leptic refers to rock occurring ≤100 cm from the surface (with implied rooting limitation) while densic refers to compaction that roots cannot penetrate occurring ≤100 cm from the surface. Both qualifiers are, however, used here since the rock may not necessarily be root limiting. See also the discussion on the family criteria in Chapter 4.]

Non-hard, non-calcareous B Mayo	Skeletic Luvic Leptic Phaeozem (Tonguic)
Non-hard, calcareous B Mayo	Calcaric Skeletic Luvic Leptic Phaeozem (Tonguic)
Hard, non-calcareous B Mayo	Skeletic Luvic Leptic Phaeozem (Densic, Tonguic)
Hard, calcareous B Mayo	Calcaric Skeletic Luvic Leptic Phaeozem (Densic, Tonguic)

5.15 Milkwood

(Melanic A / hard rock): The melanic A equates to a mollic horizon, while the hard rock relates to leptic properties (if the hard rock ≤100 cm from the surface, which can be assumed in most cases). This leads to Phaeozems (a base saturation ≥50% throughout is assumed from Table 5, but this assumption may not be valid in acidic parent material and high rainfall areas). [If the melanic A horizon is ≤25 thick (unlikely according to Table 5), then Milkwood soils will key out as Leptosols].

Non-calcareous A Milkwood	Leptic Phaeozem
Calcareous A Milkwood	Calcaric Leptic Phaeozem

5.16 Inhoek

(Melanic A / unspecified): The melanic A equates to a mollic horizon, while a base saturation ≥50% throughout is assumed (Table 5; this assumption may not be valid in acidic parent material and high rainfall areas). This leads to Inhoek soils keying out as Phaeozems. Signs of wetness lead to the stagnic qualifier, while the calcareousness results in the calcaric qualifier.

Fluvisols can be considered (Fey, 2010) if the melanic A horizon <25 cm thick; however, this is doubtful (Table 5). The fluvic qualifier may, however, be considered for Phaeozems if the unspecified underlying (parent) material is stratified and from alluvial origin.

Non-wet, non-calcareous A Inhoek	Haplic Phaeozem
Non-wet, calcareous A Inhoek	Calcaric Phaeozem
Wet, non-calcareous A Inhoek	Stagnic Phaeozem
Wet, calcareous A Inhoek	Calcaric Stagnic Phaeozem

5.17 Katspruit

(Orthic A / G): The G horizon relates to stagnic properties, reducing conditions, and most probably an argic horizon (Table 7). Katspruit soils may thus most probably have an abrupt textural difference (doubling of clay within 5 cm, if the overlying layer <20% clay or ≥20% clay increase if the overlying layer has ≥20% clay) <100 cm from the surface and would, therefore, key out as Planosols. Other Katspruit soils with a thin orthic A (≤25 cm thick) would key out as Stagnosols. The remainder of the Katspruit soils would key out as Acrisols, Lixisols, Alisols or Luvisols (depending on the clay activity and base status of the G horizon). It is argued here that few if any G horizons in South Africa would qualify to have gleyic properties and hence Katspruit and Kroonstad soils would not qualify as Gleysols, as indicated by Fey (2010). Gleysols are, however, technically possible and should therefore not summarily be excluded.

Katspruit soils with an abrupt textural difference from the orthic A to the G horizon:

Non-calcareous G Katspruit	Acric/Lixic/Alic/Luvic Planosol
Calcareous G Katspruit	Calcaric Acric/Lixic/Alic/Luvic Planosol

Katspruit soils with an orthic A ≤25 cm thick and no abrupt textural difference:

Non-calcareous G Katspruit	Acric/Lixic/Alic/Luvic Stagnosol
Calcareous G Katspruit	Calcaric Lixic/Luvic Stagnosol

Katspruit soils with an orthic A >25 cm thick and no abrupt textural difference:

Non-calcareous G Katspruit	Stagnic Acrisol/Lixisol/Alisol/Luvisol
Calcareous G Katspruit	Calcic Stagnic Lixisol/Luvisol

5.18 Kroonstad

(Orthic A / E / G): Kroonstad soils would classify much the same as Katspruit soils, with the exception that the probability of an abrupt textural difference would be much greater due to the presence of the E horizon. The E horizon would in this case relate to albic material, but also stagnic properties. Therefore, Kroonstad soils with an orthic A horizon ≤25 cm thick would key out as Stagnosols. The grey E horizons would relate to albic material (Table 6), while yellow E horizons do not.

Kroonstad soils with an abrupt textural difference from the orthic A or E to the G horizon:

grey E Kroonstad	Acric/Lixic/Alic/Luvic Albic Planosol
yellow E Kroonstad	Acric/Lixic/Alic/Luvic Planosol

Kroonstad soils with ≤25 cm to the G horizon and no abrupt textural difference:

grey E Kroonstad	Acric/Lixic/Alic/Luvic Albic Stagnosol
yellow E Kroonstad	Acric/Lixic/Alic/Luvic Stagnosol

Kroonstad soils with >25 cm to the G horizon and no abrupt textural difference from the orthic A or E to the G horizon:

grey E Kroonstad	Albic Stagnic Acrisol/Lixisol/Alisol/Luvisol
yellow E Kroonstad	Stagnic Lixisol/Luvisol

5.19 Longlands

(Orthic A / E / soft plinthic B): Similar to the Kroonstad soil, most grey E horizons would qualify as albic material (Table 6), while yellow E horizons do not. The soft plinthic B horizon (Table 10) is for the most part similar to the ferric horizon [≥15% (v/v) mottles and/or concretions], or [≥5% (v/v), ≥2 mm diameter mottles and/or concretions], and/or stagnic properties (or gleyic properties in extreme cases), and reducing conditions. The soft plinthic B horizon does not relate to the WRB plinthic horizon [≥15% (v/v), ≥20 mm diameter mottles and/or concretions; ≥2.5% (m/m) Fe_{dith} in the fine earth, or ≥10% (m/m) Fe_{dith} in the concentrations; and ≥15 cm thick] since the Fe content is too low (Table 10) and since there is no hardening in soft plinthic B horizons. Longlands soils would, therefore, key out as Stagnosols, if the orthic A horizon is ≤25 cm thick since the E horizon can be considered as part of the stagnic properties. Longlands soils with orthic A horizons >25 cm thick would key out only as Cambisols since clay luviation cannot be assumed (as indicated by Fey, 2010) for the majority of Longlands soils, especially not for the E horizon. If the soft plinthic B horizon starts <100 cm from the surface and if the soft plinthic B horizon has illuvial clay, then Longlands soils can key out as an Albic Stagnic Acrisol, Lixisol, Alisol, or Luvisol.

Longlands soils with orthic A horizon ≤25 cm thick:

grey E Longlands	Albic Stagnosol (Ferric)
yellow E Longlands	Stagnosol (Ferric)

Longlands soils with orthic A horizon >25 cm thick:

grey E Longlands	Stagnic Cambisol (Ferric)
yellow E Longlands	Stagnic Cambisol (Ferric)

5.20 Wasbank

(Orthic A / E / hard plinthic B): The E horizon qualifies as albic material (Table 10), while the hard plinthic B largely qualifies as a petroplithic horizon (Table 11). Wasbank soils, therefore, key out as Plinthosols, provided that the hard plinthic B starts ≤50 cm from the surface. Stagnic properties can be assumed if the hard plinthic B horizons are actively forming (*i.e.* not relict), which should be true for the majority of cases (Le Roux et al., 2005).

grey E Wasbank	Albic Stagnic Petric Plinthosol
yellow E Wasbank	Stagnic Petric Plinthosol

5.21 Constantia

(Orthic A / E / yellow-brown apedal B): The E horizon qualifies as albic material (Table 6), while the luvic yellow-brown apedal B horizons would qualify as an argic horizon (Table 8). Non-luvic yellow-brown apedal B horizons would qualify as cambic horizons and thus Cambisols, if the A horizon plus E horizon <50 cm thick, else it would be Regosols (Cambisols and Regosols do not have an albic qualifier). The podzolic character below the yellow-brown apedal B of Constantia soils would probably qualify as spodic horizons [pH (<5.9, ≥0.5% OC, dark red colours, ≥2.5 cm thick)] and would, therefore, key out as Podzols since the spodic horizon would start ≤200 cm from the surface (Table 16).

Non-luvic B, non-podzolic Constantia	Cambisol or Regosol
Non-luvic B, podzolic Constantia	Albic Podzol (Neocambic)
Luvic B, non-podzolic Constantia	Albic Acrisol/Lixisol/Alisol/Luvisol (Neocambic)
Luvic B, podzolic Constantia	Albic Podzol (Neocambic)

5.22 Tsitsikamma

(Orthic A / E / podzol B with placic pan): The E horizon qualifies as albic material (Table 6), while the podzol B qualifies as a spodic horizon (Table 16). Tsitsikamma soils would, therefore, key out as Podzols since it can be assumed that the spodic horizon would occur ≤100 cm from the surface.

Non-wet Tsitsikamma	Albic Podzol (Placic)
Wet Tsitsikamma	Stagnic Albic Podzol (Placic)

5.23 Lamotte

(Orthic A / E / podzol B / unconsolidated material with signs of wetness): Similar to discussed for Tsitsikamma, the E horizon qualifies as albic material (Table 6), while the podzol B qualifies as a spodic horizon (Table 16). The unconsolidated material with signs of wetness will probably qualify as stagnic properties with reducing conditions. Lamotte soils would therefore also key out as Podzols since it can be assumed that the podzol B would occur ≤100 cm from the surface. Ortstein hardening is captured by the ortsteinic qualifier, while the friable and firm saprolite (C) horizons are captured by densic qualifier.

non-hard B, friable C Lamotte	Stagnic Albic Podzol
non-hard B, firm C Lamotte	Stagnic Albic Podzol (Densic)
hard B, friable C Lamotte	Stagnic Albic Ortsteinic Podzol
hard B, firm C Lamotte	Stagnic Albic Ortsteinic Podzol (Densic)

5.24 Concordia

(Orthic A / E / podzol B / unconsolidated material without signs of wetness): Similar to the Tsitsikamma and Lamotte, the E horizon qualifies as albic material (Table 6), while the podzol B qualifies as a spodic horizon (Table 16), but in this case without the underlying material with signs of wetness. Concordia soils would therefore also key out as Podzols since it can be assumed that the spodic horizon would occur ≤100 cm from the surface.

friable C Concordia	Albic Podzol
firm C Concordia	Albic Podzol (Densic)

5.25 Houwhoek

(Orthic A / E / podzol B / saprolite): The E horizon qualifies as albic material (Table 6), while the podzol B qualifies as a spodic horizon (Table 16). The non-hard and hard saprolite families do not easily relate to any WRB qualifiers. Therefore, the best qualifier options are densic (root-limiting compaction) and fragic (structural units that do not allow roots to enter and ≥10 cm vertical separations, evidence of alteration, <0.5% OC, ≥50% slaking, not cemented, penetration resistance ≥4 MPa, no effervescence, ≥15 cm thick).

non-hard C, non-wet Houwhoek	Albic Podzol
non-hard C, wet Houwhoek	Stagnic Albic Podzol
hard C, non-wet Houwhoek	Albic Podzol
hard C, wet Houwhoek	Stagnic Albic Podzol (Densic)

5.26 Estcourt

(Orthic A / E / prismacutanic B): The E horizon qualifies as albic material (Table 6), while the prismacutanic B qualifies as a natric horizon (Table 12). Estcourt soils will, therefore, key out as Solonetz, if the prismacutanic B starts ≤100 cm from the surface (which can safely be assumed; Table 12). Families with black cutans are interpreted to have stagnic conditions since the SAT diagnostic criteria state that "The presence of (continuous) black (as opposed to other dark colours) cutans is usually an indication of a wet soil climate". Estcourt soils that do not qualify for the natric horizon might key out as Planosols (as in Fey, 2010), if stagnic properties are present, else they would probably be Luvisols.

grey E, non-black cutanic B Estcourt	Abruptic Solonetz (Albic, Cutanic)
grey E, black cutanic B Estcourt	Stagnic Abruptic Solonetz (Albic, Cutanic)
yellow E, non-black cutanic B Estcourt	Abruptic Solonetz (Albic, Cutanic)
yellow E, black cutanic B Estcourt	Stagnic Abruptic Solonetz (Albic, Cutanic)

5.27 Klapmuts

(Orthic A / E / pedocutanic B): The E horizon relates to albic material (Table 6), while the pedocutanic B horizon relates to a luvic argic horizon, due to the clay increase, clay cutans and the presumption that pedocutanic B horizons have high activity clays (CEC ≥24 $cmol_c$ kg^{-1} clay) and a high (≥50%) base saturation (Table 13). This would lead to Klapmuts soils keying out as Albic Luvisols if the pedocutanic B starts ≤100 cm from the surface (which can safely be assumed; Table 13). Red families qualify for the chromic qualifier, while no differentiation in the WRB is possible for the other SAT families. Lixisols (Fey, 2010) are therefore a doubtful option for Klapmuts soils since the CEC_{clay} is >24 $cmol_c$ kg^{-1} (Table 13).

grey E, non-red, subangular/fine angular B Klapmuts	Albic Luvisol (Cutanic)
grey E, non-red, medium/coarse angular B Klapmuts	Albic Luvisol (Cutanic)
grey E, red, subangular/fine angular B Klapmuts	Chromic Albic Luvisol (Cutanic)
grey E, red, medium/coarse angular B Klapmuts	Chromic Albic Luvisol (Cutanic)
yellow E, non-red, subangular/fine angular B Klapmuts	Albic Luvisol (Cutanic)
yellow E, non-red, medium/coarse angular B Klapmuts	Albic Luvisol (Cutanic)
yellow E, red, subangular/fine angular B Klapmuts	Chromic Albic Luvisol (Cutanic)
yellow E, red, medium/coarse angular B Klapmuts	Chromic Albic Luvisol (Cutanic)

5.28 Vilafontes

(Orthic A / E / neocutanic B): The E horizon relates to albic material (Table 6), while the neocutanic B relates to a cambic horizon. The albic qualifier is not available for Cambisols, but is included here as a supplementary qualifier, in line with WRB specification. Luvic Vilafontes families relate to an argic horizon, but this can be acric / lixic / alic / luvic. The latter can, however, not be estimated from the SAT since it would be a function of the parent material and climate and should be decided by the taxonomist. Luvic B horizon Vilafontes soils would, therefore, key out as Acrisols, Lixisols, Alisols or Luvisols (if the neocutanic B horizon starts ≤100 cm from the surface – which can safely be assumed; and depending on the clay activity and base status in the B horizon), while the remainder would key out as Cambisols (if the neocutanic B starts ≤50 cm of the surface, else they would key out as Regosols – also no albic qualifier is available for the Cambisols or Regosols). Red families would relate to the chromic qualifier.

grey E, non-red, non-luvic B Vilafontes	Cambisol (Albic) Haplic Regosol
grey E, non-red, luvic B Vilafontes	Albic Acrisol/Lixisol/Alisol/Luvisol (Neocambic)
grey E, red, non-luvic B Vilafontes	Chromic Cambisol (Albic) Haplic Regosol
grey E, red, luvic B Vilafontes	Chromic Albic Acrisol/Lixisol/Alisol/ Luvisol (Neocambic)
yellow E, non-red, non-luvic B Vilafontes	Cambisol (Albic) Haplic Regosol
yellow E, non-red, luvic B Vilafontes	Albic Acrisol/Lixisol/Alisol/Luvisol (Neocambic)
yellow E, red, non-luvic B Vilafontes	Chromic Cambisol (Albic) Haplic Regosol
yellow E, red, luvic B Vilafontes	Chromic Albic Acrisol/Lixisol/Alisol/ Luvisol (Neocambic)

5.29 Kinkelbos

(Orthic A / E / neocarbonate): E horizons relate to albic material (Table 6), while the neocarbonate does not equate to protocalcic properties [since it does not have carbonate accumulations that disrupt the soil structure, or occupy ≥5% (v/v), or cover ≥50% of structural faces, pore surfaces or rock fragments, or form permanent filaments]. The albic qualifier is not available for Cambisols, but is included here as a supplementary qualifier, in line with WRB specifications. Luvic B horizon Kinkelbos soils would, therefore, key out as Acrisols, Lixisols, Alisols or Luvisols (if the B horizon starts ≤100 cm from the surface – which can safely be assumed; and depending on the clay activity and base status in the B horizon). Alisols and Acrisols are excluded here, since they are unlikely to occur in calcareous material. The remainder would key out as Cambisols (if the neocarbonate B starts ≤50 cm from the surface, else it would key out as Regosols. (No albic qualifier is available for the Cambisols or Regosols.) Red families would relate to the chromic qualifier, but this is not available for Regosols. Kinkelbos soils, therefore, classify exactly similar to Vilafontes soils in WRB.

grey E, non-red, non-luvic B Kinkelbos	Cambisol (Albic) Haplic Regosol
grey E, non-red, luvic B Kinkelbos	Albic Lixisol/Luvisol (Neocambic)
grey E, red, non-luvic B Kinkelbos	Chromic Cambisol (Albic) Haplic Regosol
grey E, red, luvic B Kinkelbos	Chromic Albic Lixisol/Luvisol (Neocambic)
yellow E, non-red, non-luvic B Kinkelbos	Cambisol (Albic) Haplic Regosol
yellow E, non-red, luvic B Kinkelbos	Albic Lixisol/Luvisol (Neocambic)
yellow E, red, non-luvic B Kinkelbos	Chromic Cambisol (Albic) Haplic Regosol
yellow E, red, luvic B Kinkelbos	Chromic Albic Lixisol/Luvisol (Neocambic)

5.30 Cartref

(Orthic A / E / lithocutanic B): E horizons equate to albic material (Table 6), while lithocutanic B horizons equate to an argic horizon because the lithocutanic B has tongues of illuviated clay and soil into the underlying parent material. Acric / Lixic / Alic / Luvic can, however, not be estimated since it would be a function of the parent material and climate. The leptic qualifier is included here since the lithocutanic B must "merge into underlying weathering rock" and it is hypothesised that this continuous rock would start ≤100 cm from the surface. These soils do not qualify as Leptosols (Fey, 2010) since it is doubtful if continuous rock (having cracks into which roots can enter ≥10 cm apart and <20% in volume) occurs <25 cm from the surface in Cartref soils.

grey E, non-hard B Cartref	Albic Leptic Acrisol/Lixisol/Alisol/Luvisol (Cutanic)
grey E, hard B Cartref	Albic Leptic Acrisol/Lixisol/Alisol/Luvisol (Cutanic)
yellow E, non-hard B Cartref	Albic Leptic Acrisol/Lixisol/Alisol/Luvisol (Cutanic)
yellow E, hard B Cartref	Albic Leptic Acrisol/Lixisol/Alisol/Luvisol (Cutanic)

5.31 Fernwood

(Orthic A / E / unspecified): The grey E horizon qualifies as albic material (Table 6) but does not determine the WRB reference soil group. If the E horizon has a texture class of loamy sand or coarser, then Fernwood soils would key out as Arenosols, else they would key out as Regosols. Fernwood soils might, therefore, key out as Arenosols since E horizons can have low clay content (Table 6). Fernwood soils with a podzol B horizon ≤200 cm from the surface, but >150 cm (to be excluded in the SAT) would key out as Podzols. The hyperdystric qualifier (effective base saturation <20%) is assumed due to the leached nature of E horizons (Table 6). Fernwood soils that do not have a texture class of loamy sand or coarser would classify as Stagnic Regosols. Fey (2010) classified all Fernwood soils as Arenosols.

Fernwood soils with a texture class of loamy sand or coarser throughout the profile:

light A, grey, non-lamellae E Fernwood	Hyperdystric Albic Arenosol
light A, grey, lamellae E Fernwood	Hyperdystric Lamellic Albic Arenosol
light A, yellow, non-lamellae E Fernwood	Hyperdystric Albic Arenosol
light A, yellow, lamellae E Fernwood	Hyperdystric Lamellic Albic Arenosol
dark A, grey, non-lamellae E Fernwood	Hyperdystric Albic Arenosol (Ochric)
dark A, grey, lamellae E Fernwood	Hyperdystric Lamellic Albic Arenosol (Ochric)
dark A, yellow, non-lamellae E Fernwood	Hyperdystric Albic Arenosol (Ochric)
dark A, yellow, lamellae E Fernwood	Hyperdystric Lamellic Albic Arenosol (Ochric)

Fernwood soils lacking a texture class of loamy sand or coarser throughout the profile:

light A, grey, non-lamellae E Fernwood	Hyperdystric Stagnic Regosols
light A, grey, lamellae E Fernwood	Hyperdystric Stagnic Regosols (Lamellic)
light A, yellow, non-lamellae E Fernwood	Hyperdystric Stagnic Regosols
light A, yellow, lamellae E Fernwood	Hyperdystric Stagnic Regosols (Lamellic)
dark A, grey, non-lamellae E Fernwood	Hyperdystric Stagnic Regosols
dark A, grey, lamellae E Fernwood	Hyperdystric Stagnic Regosols (Lamellic)
dark A, yellow, non-lamellae E Fernwood	Hyperdystric Stagnic Regosols
dark A, yellow, lamellae E Fernwood	Hyperdystric Stagnic Regosols (Lamellic)

5.32 Westleigh

(Orthic A / soft plinthic B): Westleigh soils have a ferric horizon, stagnic properties and reducing conditions. These soils would, therefore, key out as Stagnosols if the ferric horizon (soft plinthic B) starts ≤25 cm from the surface. However, the average upper depth of soft plinthic B horizons for Westleigh soils is 396±190 mm. The majority of Westleigh soils are therefore excluded from Stagnosols. The average clay content in Westleigh soils increases from 19±10% in the orthic A (Table 21) to 38±14% in the soft plinthic B (Table 22). The soft plinthic B would therefore quite likely qualify as an argic horizon if the profile lacks a lithological discontinuity (assumed to be true). Westleigh soils, therefore, key out as Luvisols since the soft plinthic B has an average base saturation of 81% and an average CEC of 468 $cmol_c\ kg^{-1}$ clay (Table 22). Non-luvic B Westleigh soils can by definition not have an argic horizon and therefore does not qualify for Luvisols. These soils, therefore, become Cambisols. Westleigh soils do not qualify, as indicated by Fey (2010), as Plinthosols (B horizon does not harden irreversibly), Stagnosols (B horizon starts too deep), Acrisols or Lixisols (high activity clay in the B), or Arenosols (B horizon too clayey).

TABLE 21 Summary statistics of selected soil properties for the orthic A horizons of Westleigh soils described during the land type survey

	Depth (mm)		$cmol_c\ kg^{-1}$		%		
	Upper	Lower	CEC	CEC_{clay}	BS	Fe	Clay
Count	38	38	33	33		33	34
Avg	0	321	7.3	28	76	1.2	19.7
Min	0	100	2.6		46	0.2	6.6
Max	0	580	23.2			4.4	55.7
Std	0	107	4.7			1.0	

TABLE 22 Summary statistics of selected soil properties for the soft plinthic B horizons of Westleigh soils described during the land type survey

	Depth (mm)		$cmol_c\ kg^{-1}$		%		
	Upper	Lower	CEC	CEC_{clay}	BS	Fe	Clay
Count	44	43	40	40		39	40
Avg	396	819	10.6	468	81	2.3	38.1
Min	100	370	1.0	357	160	0.3	3.5
Max	1100	2000	22.3	352	131	6.3	65.7
Std	190	335	4.6	289	104	1.6	13.8

non-luvic B Westleigh	Stagnic Cambisol (Ferric)
luvic B Westleigh	Ferric Stagnic Luvisol

5.33 Dresden

(Orthic A / hard plinthic B): The hard plinthic B (Table 11) relates quite well to a petroplinthic horizon. Some hard plinthic B horizons might also have stagnic properties and reducing conditions if actively forming. Dresden soils, therefore, key out as Plinthosols (which keys out before Stagnosols). The bleached nature of the A horizon is not recognised by the WRB.

non-bleached A Dresden	Stagnic Petric Plinthosol
bleached A Dresden	Stagnic Petric Plinthosol

5.34 Avalon

(Orthic A / yellow-brown apedal B / soft plinthic B): The luvic yellow-brown apedal B horizon relates to the argic horizon, non-luvic variants relate to cambic horizons or to Regosols, while the soft plinthic B relates to a ferric horizon. The B1 horizon must start ≤100 cm from the surface – this can safely be assumed (Table 8). Although a few Avalon soils might have a ferralic horizon (required for a Ferralsol), the majority would not since the average base saturation of dystrophic yellow-brown apedal B horizons in Avalon soils is 14±10% and the average CEC is 21±5 $cmol_c$ kg^{-1} clay. Avalon soils also do not qualify, as indicated by Fey (2010), as Plinthosols (since soft plinthic B horizons do not relate to the plinthic horizons) or Arenosols [too much clay in the soft plinthic B horizons (30±12%)].

Dystrophic, non-luvic B1 Avalon	Stagnic Plinthic Cambisol/Regosol
Dystrophic, luvic B1 Avalon	Stagnic Plinthic Acrisol/Alisol
Mesotrophic, non-luvic B1 Avalon	Stagnic Plinthic Cambisol/Regosol
Mesotrophic, luvic B1 Avalon	Stagnic Plinthic Acrisol/Alisol
Eutrophic, non-luvic B1 Avalon	Stagnic Plinthic Cambisol/Regosol
Eutrophic, luvic B1 Avalon	Stagnic Plinthic Lixisol/Luvisol

5.35 Glencoe

(Orthic A / yellow-brown apedal B / hard plinthic B): The luvic yellow-brown apedal B horizon relates to the argic horizon, non-luvic yellow-brown apedal B horizons relate to cambic horizons or to Regosols, while hard plinthic B horizons relate to the petroplinthic horizons. Glencoe soils would, therefore, key out as Plinthosols if the hard plinthite starts ≤100 cm from the surface, else Glencoe soils would key out as Acrisols/Alisols/Lixisols/Luvisols for the luvic families (if the B1 horizon starts ≤100 cm from the surface) or they would be Cambisols or Regosols for the non-luvic families. Glencoe soils would not qualify, as indicated by Fey (2010), as Arenosols since the other possible RSGs key out first and since the required low clay content is doubtful.

Hard plinthic B ≤100 cm deep:

Dystrophic, non-luvic B1 Glencoe	Stagnic Plinthosol (Acric/Alic)
Dystrophic, luvic B1 Glencoe	Stagnic Plinthosol (Acric/Alic)
Mesotrophic, non-luvic B1 Glencoe	Stagnic Plinthosol (Acric/Alic)
Mesotrophic, luvic B1 Glencoe	Stagnic Plinthosol (Acric/Alic)
Eutrophic, non-luvic B1 Glencoe	Stagnic Plinthosol (Lixic/Luvic)
Eutrophic, luvic B1 Glencoe	Stagnic Plinthosol (Lixic/Luvic)

Hard plinthic B >100 cm deep:

Dystrophic, non-luvic B1 Glencoe	Stagnic Plinthic Cambisol/Regosol
Dystrophic, luvic B1 Glencoe	Stagnic Plinthic Acrisol/Alisol
Mesotrophic, non-luvic B1 Glencoe	Stagnic Plinthic Cambisol/Regosol
Mesotrophic, luvic B1 Glencoe	Stagnic Plinthic Acrisol/Alisol
Eutrophic, non-luvic B1 Glencoe	Stagnic Plinthic Cambisol/Regosol
Eutrophic, luvic B1 Glencoe	Stagnic Plinthic Lixisol/Luvisol

5.36 Pinedene

(Orthic A / yellow-brown apedal B / unspecified material with signs of wetness): The luvic yellow-brown apedal B horizon relates to the argic horizon, non-luvic yellow-brown apedal B horizons relate to cambic horizons or to Regosols, while the unspecified material with signs of wetness relate to stagnic properties and reducing conditions. Pinedene soils would, therefore, key out as Stagnosols if unspecified material with signs of wetness ≤25 cm (which is highly unlikely and thus excluded here). It is more likely that Pinedene soils would key out as Acrisols/Alisols/Lixisols/Luvisols for the luvic families (if the B1 horizon starts ≤100 cm from the surface), or Cambisols or Regosols for the non-luvic families. Ferralsols as an option for Pinedene soils (Fey, 2010) is doubtful, similar to the argument made for Avalon soils, while Arenosols are also doubtful since the required low clay content is uncertain and since Cambisols key out before Arenosols.

Dystrophic, non-luvic B1 Pinedene	Stagnic Cambisol/Regosol
Dystrophic, luvic B1 Pinedene	Stagnic Acrisol/Alisol
Mesotrophic, non-luvic B1 Pinedene	Stagnic Cambisol/Regosol
Mesotrophic, luvic B1 Pinedene	Stagnic Acrisol/Alisol
Eutrophic, non-luvic B1 Pinedene	Stagnic Cambisol/Regosol
Eutrophic, luvic B1 Pinedene	Stagnic Lixisol/Luvisol

5.37 Griffin

(Orthic A / yellow-brown apedal B / red apedal B): The luvic yellow-brown apedal B and red apedal B horizons relate to the argic horizon, while the non-luvic yellow-brown apedal B and red apedal B horizons relate to cambic horizons (and thus Cambisols) or to Regosols. Griffin soils, therefore, key out as Acrisols/Alisols/Lixisols/Luvisols for the luvic families (if the yellow-brown apedal B1 horizon starts ≤100 cm from the surface, which can be safely assumed) or Cambisols or Regosols for the non-luvic families. The chromic qualifier is used to denote the red apedal B horizon. Ferralsols and Arenosols as options for Griffin soils (Fey, 2010) are doubtful, as discussed for Pinedene soils.

Dystrophic, non-luvic B1 Griffin	Chromic Cambisol/Regosol
Dystrophic, luvic B1 Griffin	Chromic Acrisol/Alisol
Mesotrophic, non-luvic B1 Griffin	Chromic Cambisol/Regosol
Mesotrophic, luvic B1 Griffin	Chromic Acrisol/Alisol
Eutrophic, non-luvic B1 Griffin	Chromic Cambisol/Regosol
Eutrophic, luvic B1 Griffin	Chromic Lixisol/Luvisol

5.38 Molopo

(Orthic A / yellow-brown apedal B / soft carbonate): The luvic yellow-brown apedal B horizon relates to the argic horizon, non-luvic yellow-brown apedal B horizons relate to cambic horizons or to Regosols, while the soft carbonate relates to a calcic horizon. Molopo soils, therefore, key out as Calcisols, if the soft carbonate starts ≤100 cm from the surface and also only for the non-luvic families (Calcisols must have a calcic horizon and no argic horizon above the calcic horizon). Molopo soils where the soft carbonate starts >100 cm from the surface and for the luvic families (with the B1 horizon starting ≤100 cm from the surface) key out as Acrisols/Alisols/Lixisols/Luvisols. Lixisols, and most probably Luvisols can be presumed because Molopo soils would not be well leached since they occur primarily in arid environments. This is largely in agreement with Fey (2010).

non-luvic B1, dry carbonate Molopo	Cambic Calcisol
non-luvic B1, wet carbonate Molopo	Cambic Calcisol (Stagnic)
luvic B1, dry carbonate Molopo	Haplic Lixisol/Luvisol
luvic B1, wet carbonate Molopo	Stagnic Lixisol/Luvisol

5.39 Askham

(Orthic A / yellow-brown apedal B / hardpan carbonate horizon): The luvic yellow-brown apedal B horizon relates to the argic horizon, non-luvic yellow-brown apedal B horizons relate to cambic horizons (and thus Cambisols) or to Regosols, while the hardpan carbonate relates to a petrocalcic horizon. Askham soils, therefore, key out as Calcisols, if the hardpan carbonate starts ≤100 cm from the surface. Askham soils where the hardpan carbonate starts >100 cm from the surface key out as Acrisols/Alisols/Lixisols/Luvisols for the luvic families and as Cambisols or Regosols for the non-luvic families. Lixisols, and most probably Luvisols can be presumed because Askham soils would not be well leached since it occurs in arid environments. Fey (2010) only has the Calcisol option, which does not always hold true, as discussed for Pinedene soils.

Hardpan carbonate ≤100 cm:

non-luvic B1 Askam	Cambic Petric Calcisol
luvic B1 Askam	Lixic/Luvic Petric Calcisol

Hardpan carbonate >100 cm:

non-luvic B1 Askam	Eutric Cambisol/Regosol (Bathycalcic)
luvic B1 Askam	Haplic Lixisol/Luvisol (Bathycalcic)

5.40 Clovelly

(Orthic A / yellow-brown apedal B): The luvic yellow-brown apedal B horizon relates to the argic horizon (Table 8), while the non-luvic yellow-brown apedal B horizons relate to cambic horizons or Regosols. Clovelly soils, therefore, key out as Acrisols, Alisols, Lixisols, Luvisols, Cambisols, or Regosols, if the yellow-brown apedal B horizon starts ≤100 cm from the surface, which can safely be assumed. Ferralsols and Arenosols as options for Clovelly soils (Fey, 2010) are doubtful, as discussed for Pinedene soils.

Dystrophic, non-luvic B1 Clovelly	Haplic Cambisol/Regosol
Dystrophic, luvic B1 Clovelly	Haplic Acrisol/Alisol
Mesotrophic, non-luvic B1 Clovelly	Haplic Cambisol/Regosol
Mesotrophic, luvic B1 Clovelly	Haplic Acrisol/Alisol
Eutrophic, non-luvic B1 Clovelly	Haplic Cambisol/Regosol
Eutrophic, luvic B1 Clovelly	Haplic Lixisol/Luvisol

5.41 Bainsvlei

(Orthic A / red apedal B / soft plinthic B): The luvic red apedal B horizon relates to the argic horizon, non-luvic variants relate to the cambic horizons or Regosols, while the soft plinthic B relates to a ferric horizon. The B1 horizon must start ≤100 cm from the surface and can safely be assumed (Table 8). Bainsvlei soils do not qualify, as indicated by Fey (2010), as Ferralsols (BS and CEC too high), Plinthosols (soft plinthic B horizons do not relate to the plinthic horizons) or Arenosols (too much clay in the soft plinthic B horizons).

Red apedal B horizon soils will classify very (almost precisely) similar to the yellow-brown apedal by horizon soils since the WRB does not differentiate horizons based on colour, excluding for the albic material. The only difference would be the inclusion of the rhodic qualifier to denote the red coloured subsoils and some soil forms that do not have red/yellow-brown equivalents. Chromic (moist colour redder than 7.5YR and chroma >4) is used in preference to rhodic (moist colour redder than 5YR and value <4) to denote the red apedal B since chromic is less restrictive than Rhodic and thus more likely. Rhodic and chromic are, however, not allowed for Regosols.

Dystrophic, non-luvic B1 Bainsvlei	Chromic Stagnic Plinthic Cambisol/Regosol
Dystrophic, luvic B1 Bainsvlei	Chromic Stagnic Plinthic Acrisol/Alisol
Mesotrophic, non-luvic B1 Bainsvlei	Chromic Stagnic Plinthic Cambisol/Regosol
Mesotrophic, luvic B1 Bainsvlei	Chromic Stagnic Plinthic Acrisol/Alisol
Eutrophic, non-luvic B1 Bainsvlei	Chromic Stagnic Plinthic Cambisol/Regosol
Eutrophic, luvic B1 Bainsvlei	Chromic Stagnic Plinthic Lixisol/Luvisol

5.42 Lichtenburg

(Orthic A / red apedal B / hard plinthic B): The luvic red apedal B horizon relates to the argic horizon, non-luvic variants relate to the cambic horizons or Regosols, while the hard plinthic B relates to the petroplinthic horizon. Lichtenburg soils would, therefore, key out as Plinthosols if the hard plinthite starts ≤100 cm from the surface, else Lichtenburg soils would key out as Acrisols/Alisols/Lixisols/Luvisols for the luvic families (if the B1 horizon starts ≤100 cm from the surface) or they would be Cambisols or Regosols for the non-luvic families. Lichtenburg soils would not qualify, as indicated by Fey (2010), as Arenosols since the other possible RSGs key out first and since the required low clay content is doubtful.

Hard plinthic B ≤100 cm deep:

Dystrophic, non-luvic B1 Lichtenburg	Chromic Stagnic Plinthosol (Acric/Alic)
Dystrophic, luvic B1 Lichtenburg	Chromic Stagnic Plinthosol (Acric/Alic)
Mesotrophic, non-luvic B1 Lichtenburg	Chromic Stagnic Plinthosol (Acric/Alic)
Mesotrophic, luvic B1 Lichtenburg	Chromic Stagnic Plinthosol (Acric/Alic)
Eutrophic, non-luvic B1 Lichtenburg	Chromic Stagnic Plinthosol (Lixic/Luvic)
Eutrophic, luvic B1 Lichtenburg	Chromic Stagnic Plinthosol (Lixic/Luvic)

Hard plinthic B >100 cm deep:

Dystrophic, non-luvic B1 Lichtenburg	Chromic Stagnic Plinthic Cambisol/Regosol
Dystrophic, luvic B1 Lichtenburg	Chromic Stagnic Plinthic Acrisol/Alisol
Mesotrophic, non-luvic B1 Lichtenburg	Chromic Stagnic Plinthic Cambisol/Regosol
Mesotrophic, luvic B1 Lichtenburg	Chromic Stagnic Plinthic Acrisol/Alisol
Eutrophic, non-luvic B1 Lichtenburg	Chromic Stagnic Plinthic Cambisol/Regosol
Eutrophic, luvic B1 Lichtenburg	Chromic Stagnic Plinthic Lixisol/Luvisol

5.43 Bloemdal

(Orthic A / red apedal B / unspecified material with signs of wetness): The luvic red apedal B horizon relates to the argic horizon, non-luvic red apedal B horizons relate to cambic horizons (and thus Cambisols) or to Regosols, while the unspecified material with signs of wetness relate to stagnic properties and reducing conditions. Bloemdal soils would, therefore, key out as Stagnosols if the unspecified material with signs of wetness starts ≤25 cm (which is highly unlikely and therefore excluded here). It is more likely that Bloemdal soils would key out as Acrisols/Alisols/Lixisols/Luvisols for the luvic families (if the B1 horizon starts ≤100 cm from the surface), or Cambisols or Regosols for the non-luvic families. Ferralsols and Arenosols as options for Bloemdal soils (Fey, 2010) are doubtful, similar to the arguments made for Avalon soils.

Dystrophic, non-luvic B1 Bloemdal	Chromic Stagnic Cambisol/Regosol
Dystrophic, luvic B1 Bloemdal	Chromic Stagnic Acrisol/Alisol
Mesotrophic, non-luvic B1 Bloemdal	Chromic Stagnic Cambisol/Regosol
Mesotrophic, luvic B1 Bloemdal	Chromic Stagnic Acrisol/Alisol
Eutrophic, non-luvic B1 Bloemdal	Chromic Stagnic Cambisol/Regosol
Eutrophic, luvic B1 Bloemdal	Chromic Stagnic Lixisol/Luvisol

5.44 Kimberley

(Orthic A / red apedal B / soft carbonate horizon): The luvic red apedal B horizon relates to the argic horizon, non-luvic red apedal B horizons relate to the cambic horizons (and thus Cambisols) or to Regosols, while the soft carbonate relates to a calcic horizon. Kimberley soils, therefore, key out as Calcisols, if the soft carbonate starts ≤100 cm from the surface and also only for the non-luvic families (Calcisols must have a calcic horizon and no argic horizon above the calcic horizon). Non-luvic Kimberley soils where the soft carbonate starts >100 cm from the surface will become Cambisols or Regosols. Luvic Kimberley soils where the soft carbonate starts >100 cm from the surface, with the B1 horizon starting ≤100 cm from the surface, key out as Acrisols/Alisols/Lixisols/Luvisols. Lixisols, and most probably Luvisols can be presumed because Kimberley soils would not be well leached since they occur in arid environments. This is largely in agreement with Fey (2010).

Soft carbonate ≤100 cm deep:

non-luvic B1, dry carbonate Kimberley	Cambic Calcisol (Chromic)
non-luvic B1, wet carbonate Kimberley	Cambic Calcisol (Chromic, Stagnic)
luvic B1, dry carbonate Kimberley	Haplic Lixisol/Luvisol (Chromic, Bathycalcic)
luvic B1, wet carbonate Kimberley	Stagnic Lixisol/Luvisol (Chromic, Bathycalcic)

Soft carbonate >100 cm deep:

non-luvic B1, dry carbonate Kimberley	Chromic Cambisol/Regosol (Bathycalcic)
non-luvic B1, wet carbonate Kimberley	Stagnic Chromic Cambisol/Regosol (Bathycalcic)
luvic B1, dry carbonate Kimberley	Haplic Lixisol/Luvisol (Chromic, Bathycalcic)
luvic B1, wet carbonate Kimberley	Stagnic Lixisol/Luvisol (Chromic, Bathycalcic)

5.45 Plooysburg

(Orthic A / red apedal B / hardpan carbonate horizon): The luvic red apedal B horizons relate to the argic horizon, non-luvic red apedal B horizons relate to the cambic horizons (and thus Cambisols) or to Regosols, while the hardpan carbonate relates to a petrocalcic horizon. Plooysburg soils, therefore, key out as Calcisols, if the hardpan carbonate starts ≤100 cm from the surface. Plooysburg soils where the hardpan carbonate starts >100 cm from the surface key out as Acrisols/Alisols/Lixisols/Luvisols for the luvic families and as Cambisols or Regosols for the non-luvic families. Lixisols, and most probably Luvisols can be presumed because Plooysburg soils would not be well leached since it occurs in arid environments. Fey (2010) only has the Calcisol option, which does not always hold true, as discussed above.

Hardpan carbonate ≤100 cm:

non-luvic B1 Plooysburg	Cambic Petric Calcisol (Chromic)
luvic B1 Plooysburg	Chromic Lixisol/Luvisol

Hardpan carbonate >100 cm:

non-luvic B1 Plooysburg	Eutric Cambisol/Regosol (Bathycalcic)
luvic B1 Plooysburg	Haplic Lixisol/Luvisol (Bathycalcic)

5.46 Garies

(Orthic A / red apedal B / dorbank): The luvic red apedal B horizon relates to the argic horizon, non-luvic red apedal B horizons relate to cambic horizons (and thus Cambisols) or to Regosols, while the dorbank relates to the petroduric horizon. Garies soils, therefore, key out as Durisols if the dorbank occurs ≤100 cm from the surface. Luvic families of the Garies soils where the dorbank occurs >100 cm would be Lixisols/Luvisols, while the non-luvic families would be

Cambisols or Regosols. Lixic, and most probably Luvic can be presumed because Garies soils would not be well leached since they occur in arid environments. The occurrence of the dorbank >100 cm is denoted by the bathyduric qualifier. Fey (2010) only has the Durisol option, which does not always hold true, as discussed above.

Dorbank ≤100 cm:

non-luvic B1 Garies	Lixic/Luvic Petric Durisol (Chromic)
luvic B1 Garies	Lixic/Luvic Petric Durisol (Chromic)

Dorbank >100 cm:

non-luvic B1 Garies	Chromic Cambisol/Regosol (Bathyduric)
luvic B1 Garies	Chromic Lixisol/Luvisol (Bathyduric)

5.47 Hutton

(Orthic A / red apedal B): The luvic red apedal B horizon relates to the argic horizon, and the non-luvic red apedal B horizons relate to the cambic horizons (and thus Cambisols) or to Regosols. Non-luvic Hutton soils, therefore, key out as Cambisols or Regosols, while the luvic Hutton soils key out as Acrisols, Alisols, Lixisols, or Luvisols, if the red apedal B horizon starts ≤100 cm from the surface, which can safely be assumed. Ferralsols and Arenosols as options for Hutton soils (Fey, 2010) are doubtful, as discussed above.

Dystrophic, non-luvic B1 Hutton	Chromic Cambisol/Regosol
Dystrophic, luvic B1 Hutton	Chromic Acrisol/Alisol
Mesotrophic, non-luvic B1 Hutton	Chromic Cambisol/Regosol
Mesotrophic, luvic B1 Hutton	Chromic Acrisol/Alisol
Eutrophic, non-luvic B1 Hutton	Chromic Cambisol/Regosol
Eutrophic, luvic B1 Hutton	Chromic Lixisol/Luvisol

5.48 Shortlands

(Orthic A / red structured B): The red structured B relates to the nitic horizon. Shortlands soils, therefore, key out as Nitisols since it can be assumed that the red structured B (nitic) horizon would start ≤100 cm from the surface. No option exists in the WRB to capture the calcareousness or structure size and type of the red structured B. The eutric qualifier is used since none of the red structured B horizons have effective base saturation <50% (Table 9). The luvic qualifier would predominate (68%), with alic only valid for the minority (32%; Table 9). Fey (2010) list Alisols, Acrisols, Luvisols, Lixisols, and Cambisols as alternatives for Nitisols. These can certainly be considered in the unlikely situation where the red structured B does not qualify as a nitic horizon.

Dystrophic/mesotrophic, non-calcareous, non-luvic, subangular/fine angular B Shortlands	Eutric Luvic/Alic Nitisol
Dystrophic/mesotrophic, non-calcareous, non-luvic, medium/coarse angular B Shortlands	Eutric Luvic/Alic Nitisol
Dystrophic/mesotrophic, non-calcareous, luvic, subangular/fine angular B Shortlands	Eutric Luvic/Alic Nitisol
Dystrophic/mesotrophic, non-calcareous, luvic, medium/coarse angular B Shortlands	Eutric Luvic/Alic Nitisol
Eutrophic, non-calcareous, non-luvic, subangular/ fine angular B Shortlands	Eutric Luvic/Alic Nitisol
Eutrophic, non-calcareous, non-luvic, medium/ coarse angular B Shortlands	Eutric Luvic/Alic Nitisol
Eutrophic, non-calcareous, luvic, subangular/ fine angular B Shortlands	Eutric Luvic/Alic Nitisol
Eutrophic, non-calcareous, luvic, medium/ coarse angular B Shortlands	Eutric Luvic/Alic Nitisol
Calcareous, non-luvic, subangular/ fine angular B Shortlands	Eutric Luvic/Alic Nitisol
Calcareous, non-luvic, medium/ coarse angular B Shortlands	Eutric Luvic/Alic Nitisol
Calcareous, luvic, subangular/ fine angular B Shortlands	Eutric Luvic/Alic Nitisol
Calcareous, luvic, medium/ coarse angular B Shortlands	Eutric Luvic/Alic Nitisol

5.49 Jonkersberg

(Orthic A / podzol B & placic pan): Jonkersberg soils have a spodic horizon and a placic horizon and will, therefore, key out as Podzols since the podzol B must occur ≤150 cm from the surface to be diagnostic for the SAT. The entic qualifier is included to denote Podzols that lack an E horizon. The classification of Jonkersberg soils as Podzols is in agreement with Fey (2010), except for the change of the gleyic for the stagnic qualifier and the inclusion of the entic qualifier.

Non-wet Jonkersberg	Entic Podzol (Placic)
Wet Jonkersberg	Stagnic Entic Podzol (Placic)

5.50 Witfontein

(Orthic A / podzol B / unconsolidated material with signs of wetness): Witfontein soils have a spodic horizon, stagnic properties and reducing conditions and therefore key out as Podzols since the podzol B must occur ≤150 cm from the surface to be diagnostic for the SAT. The entic qualifier is used to denote Podzols that lack an E horizon, while the ortsteinic qualifier denotes the ortstein hardening of the podzol B, and the densic qualifier denotes firm C horizons. The classification of Witfontein soils as Podzols is largely in agreement with Fey (2010), except for replacing the gleyic with the stagnic qualifier and the inclusion of the entic qualifier.

non-hard B, friable C Witfontein	Stagnic Entic Podzol
non-hard B, firm C Witfontein	Stagnic Entic Podzol (Densic)
hard B, friable C Witfontein	Stagnic Entic Ortsteinic Podzol
hard B, firm C Witfontein	Stagnic Entic Ortsteinic Podzol (Densic)

5.51 Pinegrove

(Orthic A / podzol B / unconsolidated material without signs of wetness): Pinegrove soils have a spodic horizon and therefore key out as Podzols since the podzol B must occur ≤150 cm from the surface to be diagnostic in the SAT. The entic qualifier is used to denote Podzols that lack an E horizon, while the densic qualifier denotes firm C horizons (unconsolidated material). The classification of Pinegrove soils as Podzols is in agreement with Fey (2010).

friable C Pinegrove	Entic Podzol
firm C Pinegrove	Entic Podzol (Densic)

5.52 Groenkop

(Orthic A / podzol B / saprolite): Pinegrove soils have a spodic horizon and therefore key out as Podzols since the podzol B must occur ≤150 cm from the surface to be diagnostic in the SAT. The entic qualifier is used to denote Podzols that lack an E horizon, the densic qualifier denotes hard C horizons, while the stagnic qualifier denotes the signs of wetness immediately beneath podzol B. [Leptic can be included, before entic, if the saprolite or rock parent material occurs ≤100 cm from the surface; while skeletic can be included, before leptic or entic, if the profile has ≥40% (v/v) coarse fragments]. The classification of Groenkop soils as Podzols is largely in agreement with Fey (2010), except for replacing of the gleyic with the stagnic qualifier and the inclusion of the entic qualifier.

non-hard C, non-wet Houwhoek	Entic Podzol
non-hard C, wet Houwhoek	Stagnic Entic Podzol
hard C, non-wet Houwhoek	Entic Ortsteinic Podzol
hard C, wet Houwhoek	Stagnic Entic Ortsteinic Podzol

5.53 Sterkspruit

(Orthic A / prismacutanic B): Sterkspruit soils have a natric horizon and therefore key out as Solonetz since the prismacutanic B (natric) horizon occurs ≤100 cm from the soil surface. The abruptic qualifier denotes the abrupt transition from the orthic A to the prismacutanic B horizon, the chromic qualifier denotes the red prismacutanic B horizons, while the cutanic qualifier denotes the illuvial clay in the prismacutanic B horizon. Fey (2010) classifies Sterkspruit soils as Solonetz or Planosols. Planosols require stagnic properties and reducing conditions, in addition to an abrupt textural difference and therefore the Planosol option is excluded here.

Non-bleached A, non-red B Sterkspruit	Abruptic Solonetz (Cutanic)
Non-bleached A, red B Sterkspruit	Chromic Abruptic Solonetz (Cutanic)
Bleached A, non-red B Sterkspruit	Abruptic Solonetz (Cutanic)
Bleached A, red B Sterkspruit	Chromic Abruptic Solonetz (Cutanic)

5.54 Sepane

(Orthic A / pedocutanic B / unconsolidated material with signs of wetness): Sepane soils have an argic horizon, which would most probably be Luvic (Table 13), with underlying stagnic properties and reducing conditions. Sepane soils would, therefore, key out as Luvisols. The endocalcaric qualifier is used to denote the calcareous B horizons, the cutanic qualifier denotes the "clearly expressed cutanic character" of the pedocutanic B, while the haplic qualifier denotes the "normal" condition. No option exists in the WRB to capture the bleached A, or structure size and type of the pedocutanic B. Fey (2010) classifies Sepane soils as Luvisols or Lixisols. The former option is given preference here since by far the majority of pedocutanic B horizons (Table 13) have high base saturation and high activity clays

(BS >50% and CEC_{clay} ≥24 $cmol_c$ kg^{-1} clay). Lixisols, Alisols, and Acrisols (in that order) may be possible in extreme cases.

Non-bleached A, subangular/ fine angular non-calcareous B Sepane	Haplic Luvisol (Cutanic)
Non-bleached A, subangular/ fine angular calcareous B Sepane	EndocalcaricLuvisol (Cutanic)
Non-bleached A, medium/ coarse angular, non-calcareous B Sepane	Haplic Luvisol (Cutanic)
Non-bleached A, medium/ coarse angular, calcareous B Sepane	EndocalcaricLuvisol (Cutanic)
Bleached A, subangular/fine angular non-calcareous B Sepane	Haplic Luvisol (Cutanic)
Bleached A, subangular/fine angular calcareous B Sepane	EndocalcaricLuvisol (Cutanic)
Bleached A, medium/ coarse angular, non-calcareous B Sepane	Haplic Luvisol (Cutanic)
Bleached A, medium/ coarse angular, calcareous B Sepane	EndocalcaricLuvisol (Cutanic)

5.55 Valsrivier

(Orthic A / pedocutanic B / unconsolidated material without signs of wetness): Valsrivier soils have an argic horizon, which would most probably be Luvic (Table 13). Valsrivier soils, therefore, key out as Luvisols since the pedocutanic B (argic) horizon starts ≤100 cm from the soil surface. The chromic qualifier is used to denote red pedocutanic B horizons, the protocalcic qualifier to denote the calcareous B horizons (although the diagnostic criteria for protocalcic are strictly not met), while the cutanic qualifier denotes the "clearly expressed cutanic character" of the pedocutanic B horizon. No option exists in the WRB to capture the bleached A or structure size and type of the pedocutanic B. Similar to Sepane soils, Fey (2010) classifies Valsrivier soils as Luvisols or Lixisols. The former option is given preference here since by far the majority of pedocutanic B horizons (Table 13) have high base saturation and high activity clays (BS >50% and CEC_{clay} ≥24 $cmol_c$ kg^{-1} clay). Lixisols, Alisols, and Acrisols (in that order) may be possible in extreme cases.

Non-bleached A, non-red, subangular/fine angular non-calcareous B Valsrivier	Haplic Luvisol (Cutanic)
Non-bleached A, non-red, subangular/fine angular calcareous B Valsrivier	Protocalcic Luvisol (Cutanic)
Non-bleached A, non-red, medium/ coarse angular, non-calcareous B Valsrivier	Haplic Luvisol (Cutanic)
Non-bleached A, non-red, medium/ coarse angular, calcareous B Valsrivier	Protocalcic Luvisol (Cutanic)
Non-bleached A, red, subangular/fine angular non-calcareous B Valsrivier	Chromic Luvisol (Cutanic)
Non-bleached A, red, subangular/fine angular calcareous B Valsrivier	Protocalcic Chromic Luvisol (Cutanic)
Non-bleached A, red, medium/ coarse angular, non-calcareous B Valsrivier	Chromic Luvisol (Cutanic)
Non-bleached A, red, medium/ coarse angular, calcareous B Valsrivier	Protocalcic Chromic Luvisol (Cutanic)
Bleached A, non-red, subangular/fine angular non-calcareous B Valsrivier	Haplic Luvisol (Cutanic)
Bleached A, non-red, subangular/fine angular calcareous B Valsrivier	Protocalcic Luvisol (Cutanic)
Bleached A, non-red, medium/ coarse angular, non-calcareous B Valsrivier	Haplic Luvisol (Cutanic)
Bleached A, non-red, medium/ coarse angular, calcareous B Valsrivier	Protocalcic Luvisol (Cutanic)
Bleached A, red, subangular/fine angular non-calcareous B Valsrivier	Chromic Luvisol (Cutanic)
Bleached A, red, subangular/fine angular calcareous B Valsrivier	Protocalcic Chromic Luvisol (Cutanic)
Bleached A, red, medium/ coarse angular, non-calcareous B Valsrivier	Chromic Luvisol (Cutanic)
Bleached A, red, medium/ coarse angular, calcareous B Valsrivier	Protocalcic Chromic Luvisol (Cutanic)

5.56 Swartland

(Orthic A / pedocutanic B / saprolite): Swartland soils have an argic horizon, which would most probably be Luvic (Table 13). Swartland soils therefore key out as Luvisols since the pedocutanic B (argic) horizon starts ≤100 cm from the soil surface. This classification is exactly similar to the Valsrivier soils since no distinction is made in the WRB on the nature of the underlying material (saprolite vs. unconsolidated material). The chromic qualifier is used to denote red pedocutanic B horizons, the protocalcic qualifier to denote the calcareous pedocutanic B horizons (although the diagnostic criteria for protocalcic are strictly not met), while the cutanic qualifier denotes the "clearly expressed cutanic character" of the pedocutanic B horizon. No option exists in the WRB to capture the bleached A or structure size and type of the pedocutanic B. Fey (2010) classifies Swartland soils, similar to Sepane and Valsrivier soils as Luvisols or Lixisols. The former option is given preference here since by far the majority of pedocutanic B horizons (Table 13) have high base saturation and high activity clays (BS >50% and CEC_{clay} ≥24 $cmol_c$ kg^{-1} clay). Lixisols, Alisols, and Acrisols (in that order) may be possible in extreme cases.

Non-bleached A, non-red, subangular/ fine angular non-calcareous B Swartland	Haplic Luvisol (Cutanic)
Non-bleached A, non-red, subangular/ fine angular calcareous B Swartland	Protocalcic Luvisol (Cutanic)
Non-bleached A, non-red, medium/ coarse angular, non-calcareous B Swartland	Haplic Luvisol (Cutanic)
Non-bleached A, non-red, medium/ coarse angular, calcareous B Swartland	Protocalcic Luvisol (Cutanic)
Non-bleached A, red, subangular/fine angular non-calcareous B Swartland	Chromic Luvisol (Cutanic)
Non-bleached A, red, subangular/fine angular calcareous B Swartland	Protocalcic Chromic Luvisol (Cutanic)
Non-bleached A, red, medium/ coarse angular, non-calcareous B Swartland	Chromic Luvisol (Cutanic)

Non-bleached A, red, medium/ coarse angular, calcareous B Swartland	Protocalcic Chromic Luvisol (Cutanic)
Bleached A, non-red, subangular/fine angular non-calcareous B Swartland	Haplic Luvisol (Cutanic)
Bleached A, non-red, subangular/fine angular calcareous B Swartland	Protocalcic Luvisol (Cutanic)
Bleached A, non-red, medium/ coarse angular, non-calcareous B Swartland	Haplic Luvisol (Cutanic)
Bleached A, non-red, medium/ coarse angular, calcareous B Swartland	Protocalcic Luvisol (Cutanic)
Bleached A, red, subangular/fine angular non-calcareous B Swartland	Chromic Luvisol (Cutanic)
Bleached A, red, subangular/fine angular calcareous B Swartland	Protocalcic Chromic Luvisol (Cutanic)
Bleached A, red, medium/ coarse angular, non-calcareous B Swartland	Chromic Luvisol (Cutanic)
Bleached A, red, medium/ coarse angular, calcareous B Swartland	Protocalcic Chromic Luvisol (Cutanic)

5.57 Tukulu

(Orthic A / neocutanic B / unspecified material with signs of wetness): The non-luvic neocutanic B relates to a cambic horizon (Table 8), the luvic neocutanic B would relate to an argic horizon, and the unspecified material with signs of wetness would relate to stagnic properties and reducing conditions. Non-luvic Tukulu families, therefore, key out as Cambisols, while the luvic Tukulu families would key out as Acrisols/Lixisols/Alisols/Luvisols. No option exists in the WRB to capture the bleached A horizon, while the red neocutanic B horizons will qualify for the chromic qualifier. For Cambisols, the neocutanic B must start ≤50 cm from the surface and its lower boundary must be ≥25 cm from the surface (these options are assumed here). For Acrisols/Lixisols/Alisols/Luvisols the argic horizon must start ≤100 cm from the surface (which can also safely be assumed). Fey (2010) also lists Arenosols as an option for Tukulu soils. This is not considered a viable option here since the Cambisols key out first, and soil with such low clay content would probably classify as Namib soils in SAT.

non-bleached A, non-red, non-luvic B Tukulu	Stagnic Cambisol
non-bleached A, non-red, luvic B Tukulu	Stagnic Acrisol/Lixisol/Alisol/Luvisol
non-bleached A, red, non-luvic B Tukulu	Chromic Stagnic Cambisol
non-bleached A, red, luvic B Tukulu	Chromic Stagnic Acrisol/Lixisol/Alisol/Luvisol
bleached A, non-red, non-luvic B Tukulu	Stagnic Cambisol
bleached A, non-red, luvic B Tukulu	Stagnic Acrisol/Lixisol/Alisol/Luvisol
bleached A, red, non-luvic B Tukulu	Chromic Stagnic Cambisol
bleached A, red, luvic B Tukulu	Chromic Stagnic Acrisol/Lixisol/Alisol/Luvisol

5.58 Etosha

(Orthic A / neocutanic B / soft carbonate): The non-luvic neocutanic B (Table 8) relates to a cambic horizon, the luvic neocutanic B would relate to an argic horizon, and the soft carbonate horizon relates to a calcic horizon. Therefore, non-luvic Etosha families key out as Calcisols if the soft carbonate starts ≤100 cm from the surface; else these families would be Cambisols since it is assumed that the neocutanic B (cambic) horizon starts ≤50 cm from the surface, while the luvic Etosha families would key out as Acrisols/Lixisols/Alisols/Luvisols because neocutanic B (argic) horizon starts ≤100 cm from the surface. Acrisols and Alisols can be disregarded since they would be highly unlikely in this environment. The red neocutanic B horizons will qualify for the chromic qualifier and the wet soft carbonate horizons for the stagnic qualifier. Dystric/eutric qualifier options are included since no other qualifier option exists. Fey (2010) lists Calcisols, Luvisols, and Lixisols as options for Etosha soils, but these would not hold true for all families, as discussed above.

non-bleached A, non-red, non-luvic B, non-wet carbonate Etosha	Cambic Calcisol [if sc ≤100 cm] Dystric/Eutric Cambisol [if sc >100 cm]
non-bleached A, non-red, non-luvic B, wet carbonate Etosha	Cambic Calcisol (Stagnic) [if sc ≤100 cm] Stagnic Cambisol [if sc >100 cm]
non-bleached A, non-red, luvic B, non-wet carbonate Etosha	Haplic Lixisol/Luvisol
non-bleached A, non-red, luvic B, wet carbonate Etosha	Stagnic Lixisol/Luvisol
non-bleached A, red, non-luvic B, non-wet carbonate Etosha	Cambic Calcisol (Chromic) [if sc ≤100 cm] Chromic Cambisol [if sc >100 cm]
non-bleached A, red, non-luvic B, wet carbonate Etosha	Cambic Calcisol (Chromic, Stagnic) [if sc ≤100 cm] Chromic Stagnic Cambisol [if sc >100 cm]
non-bleached A, red, luvic B, non-wet carbonate Etosha	Chromic Lixisol/Luvisol
non-bleached A, red, luvic B, wet carbonate Etosha	Chromic Stagnic Lixisol/Luvisol
bleached A, non-red, non-luvic B, non-wet carbonate Etosha	Cambic Calcisol [if sc ≤100 cm] Dystric/Eutric Cambisol [if sc >100 cm]
bleached A, non-red, non-luvic B, wet carbonate Etosha	Cambic Calcisol (Stagnic) [if sc ≤100 cm] Stagnic Cambisol [if sc >100 cm]
bleached A, non-red, luvic B, non-wet carbonate Etosha	Haplic Lixisol/Luvisol
bleached A, non-red, luvic B, wet carbonate Etosha	Stagnic Lixisol/Luvisol
bleached A, red, non-luvic B, non-wet carbonate Etosha	Cambic Calcisol (Chromic) [if sc ≤100 cm] Chromic Cambisol [if sc >100 cm]
bleached A, red, non-luvic B, wet carbonate Etosha	Cambic Calcisol (Chromic, Stagnic) [if sc ≤100 cm] Chromic Stagnic Cambisol [if sc >100 cm]
bleached A, red, luvic B, non-wet carbonate Etosha	Chromic Lixisol/Luvisol
bleached A, red, luvic B, wet carbonate Etosha	Chromic Stagnic Lixisol/Luvisol

Note: sc = soft carbonate

5.59 Gamoep

(Orthic A / neocutanic B / hardpan carbonate horizon): The non-luvic neocutanic B horizon relates to a cambic horizon, the luvic neocutanic B horizon would relate to an argic horizon (Table 8), while the hardpan carbonate horizon relates to a petrocalcic horizon. Gamoep soils, therefore, key out as Calcisols, if the hardpan carbonate horizon starts ≤100 cm from the surface (which is assumed here). For those soils where the hardpan carbonate horizon starts >100 cm from the surface, the non-luvic Gamoep families would key out as Cambisols (Bathypetrocalcic), while the luvic Gamoep families would key out as Acrisols/Lixisols/Alisols/Luvisols (Bathypetrocalcic). The hardpan carbonate horizons result in the petric qualifier, the non-luvic neocutanic B horizons result in the cambic qualifier, and the red neocutanic B horizons result in the chromic qualifier.

non-bleached A, non-red, non-luvic B Gamoep	Cambic Petric Calcisol
non-bleached A, non-red, luvic B Gamoep	Lixic/Luvic Petric Calcisol
non-bleached A, red, non-luvic B Gamoep	Cambic Petric Calcisol (Chromic)
non-bleached A, red, luvic B Gamoep	Lixic/Luvic Petric Calcisol (Chromic)
bleached A, non-red, non-luvic B Gamoep	Cambic Petric Calcisol
bleached A, non-red, luvic B Gamoep	Lixic/Luvic Petric Calcisol
bleached A, red, non-luvic B Gamoep	Cambic Petric Calcisol (Chromic)
bleached A, red, luvic B Gamoep	Lixic/Luvic Petric Calcisol (Chromic)

5.60 Oudtshoorn

(Orthic A / neocutanic B / dorbank): The non-luvic neocutanic B horizon relates to a cambic horizon, the luvic neocutanic B horizon would relate to an argic horizon (Table 8), and the dorbank to a petroduric horizon. Oudtshoorn soils, therefore, key out as Durisols, if the dorbank horizon starts ≤100 cm from the surface (which is assumed here). For those soils where the dorbank horizon starts >100 cm from the surface, the non-luvic Oudtshoorn families would key out as Cambisols (Bathypetroduric), while the luvic Oudtshoorn families would key out as Acrisols/Lixisols/Alisols/Luvisols (Bathypetroduric). The dorbank horizons result in the petric qualifier, the red neocutanic B horizons will qualify for the chromic qualifier, while lixic/luvic for the luvic family needs to be decided on by the taxonomist. No option exists in WRB to add the cambic qualifier for Durisols, as was possible for the Calcisols.

non-bleached A, non-red, non-luvic B Oudtshoorn	Petric Durisol
non-bleached A, non-red, luvic B Oudtshoorn	Lixic/Luvic Petric Durisol
non-bleached A, red, non-luvic B Oudtshoorn	Petric Durisol (Chromic)
non-bleached A, red, luvic B Oudtshoorn	Lixic/Luvic Petric Durisol (Chromic)
bleached A, non-red, non-luvic B Oudtshoorn	Petric Durisol
bleached A, non-red, luvic B Oudtshoorn	Lixic/Luvic Petric Durisol
bleached A, red, non-luvic B Oudtshoorn	Petric Durisol (Chromic)
bleached A, red, luvic B Oudtshoorn	Lixic/Luvic Petric Durisol (Chromic)

5.61 Oakleaf

(Orthic A / neocutanic B): The non-luvic neocutanic B relates to a cambic horizon and the luvic neocutanic B would relate to an argic horizon (Table 8). The non-luvic Oakleaf families would, therefore, key out as Cambisols, if the neocutanic B starts ≤50 cm from the surface (which is assumed here), while the luvic Oakleaf families would key out as Acrisols/Lixisols/Alisols/Luvisols if the neocutanic B starts ≤100 cm from the surface. The red neocutanic B horizons will qualify for the chromic qualifier. The dystric/eutric qualifier options are included since no other prefix qualifier option exists for the Cambisols, while the haplic qualifier refers to the “normal” condition. Fey (2010) lists Arenosols as an option for Oakleaf soils. This is not considered a viable option here since the Cambisols key out first and soil with such low clay content would probably classify as Namib soils in SAT.

non-bleached A, non-red, non-luvic B Oakleaf	Dystric/Eutric Cambisol
non-bleached A, non-red, luvic B Oakleaf	Haplic Acrisol/Lixisol/Alisol/ Luvisol
non-bleached A, red, non-luvic B Oakleaf	Chromic Cambisol
non-bleached A, red, luvic B Oakleaf	Chromic Acrisol/Lixisol/Alisol/ Luvisol
bleached A, non-red, non-luvic B Oakleaf	Dystric/Eutric Cambisol
bleached A, non-red, luvic B Oakleaf	Haplic Acrisol/Lixisol/Alisol/ Luvisol
bleached A, red, non-luvic B Oakleaf	Chromic Cambisol
bleached A, red, luvic B Oakleaf	Chromic Acrisol/Lixisol/Alisol/ Luvisol

5.62 Montagu

(Orthic A / neocarbonate B / unspecified material with signs of wetness): The non-luvic neocarbonate B horizon relates to a cambic horizon, the luvic neocarbonate B would relate to an argic horizon, while the unspecified material with signs of wetness relates to stagnic properties and reducing conditions. The luvic variants will most probably be Lixisols or Luvisols, depending on the clay activity since Montagu soils most probably have a base saturation >50%. The calcaric qualifier in Cambisols denotes the neocarbonate B, the stagnic qualifier denotes the material with signs of wetness, while the chromic qualifier denotes the red neocarbonate B horizons. Fey (2010) lists Arenosols as an option for Montagu soils. This is not considered a viable option here since the Cambisols key out first and soil with such low clay content would probably classify as Namib soils in SAT.

non-bleached A, non-red, non-luvic B Montagu	Calcaric Stagnic Cambisol
non-bleached A, non-red, luvic B Montagu	Stagnic Lixisol/Luvisol
non-bleached A, red, non-luvic B Montagu	Calcaric Chromic Stagnic Cambisol
non-bleached A, red, luvic B Montagu	Chromic Stagnic Lixisol/Luvisol
bleached A, non-red, non-luvic B Montagu	Calcaric Stagnic Cambisol
bleached A, non-red, luvic B Montagu	Stagnic Lixisol/Luvisol
bleached A, red, non-luvic B Montagu	Calcaric Chromic Stagnic Cambisol
bleached A, red, luvic B Montagu	Chromic Stagnic Acrisol/Lixisol/ Alisol/Luvisol

5.63 Addo

(Orthic A / neocarbonate B / soft carbonate horizon): The non-luvic neocarbonate B horizon relates to a cambic horizon, the luvic neocarbonate B horizon would relate to an argic horizon (Table 8), and the soft carbonate horizon would relate to calcaric material. The wet neocarbonate B families relate to stagnic properties and reducing conditions. Addo soils would, therefore, key out as Calcisols, if the soft carbonate horizon starts ≤100 cm from the surface and because the neocarbonate B has secondary carbonate accumulation. (For soils where the soft carbonate horizon starts >100 cm from the surface, the non-luvic Addo families would key out as Cambisols, while the luvic Addo families would key out as Acrisols/Lixisols/Alisols/Luvisols. Alisols and Acrisols can be excluded, since they are unlikely to occur in calcareous material.) The cambic qualifier reflects the non-luvic neocarbonate B horizons, the luvic qualifier the luvic neocarbonate B horizons, the stagnic qualifier the wet soft carbonate B horizons, while the chromic qualifier reflects the red neocarbonate B horizons. Fey (2010) similarly classifies Addo soils as Calcisols.

non-bleached A, non-red, non-luvic B, non-wet carbonate Addo	Cambic Calcisol
non-bleached A, non-red, non-luvic B, wet carbonate Addo	Cambic Calcisol (Stagnic)
non-bleached A, non-red, luvic B, non-wet carbonate Addo	Luvic Calcisol
non-bleached A, non-red, luvic B, wet carbonate Addo	Luvic Calcisol (Stagnic)
non-bleached A, red, non-luvic B, non-wet carbonate Addo	Cambic Calcisol (Chromic)
non-bleached A, red, non-luvic B, wet carbonate Addo	Calcisol (Chromic Stagnic)
non-bleached A, red, luvic B, non-wet carbonate Addo	Luvic Calcisol (Chromic)
non-bleached A, red, luvic B, wet carbonate Addo	Luvic Calcisol (Chromic Stagnic)
bleached A, non-red, non-luvic B, non-wet carbonate Addo	Cambic Calcisol
bleached A, non-red, non-luvic B, wet carbonate Addo	Cambic Calcisol (Stagnic)
bleached A, non-red, luvic B, non-wet carbonate Addo	Luvic Calcisol
bleached A, non-red, luvic B, wet carbonate Addo	Luvic Calcisol (Stagnic)
bleached A, red, non-luvic B, non-wet carbonate Addo	Cambic Calcisol (Chromic)
bleached A, red, non-luvic B, wet carbonate Addo	Calcisol (Chromic, Stagnic)
bleached A, red, luvic B, non-wet carbonate Addo	Luvic Calcisol (Chromic)
bleached A, red, luvic B, wet carbonate Addo	Luvic Calcisol (Chromic, Stagnic)

5.64 Prieska

(Orthic A / neocarbonate B / hardpan carbonate horizon): The non-luvic neocarbonate B relates to a cambic horizon, the luvic neocarbonate B would relate to an argic horizon (Table 8), and the hardpan carbonate horizon to a petrocalcic horizon. Prieska soils would, therefore, key out as Calcisols, if the hardpan carbonate horizon starts ≤100 cm from the surface and because the neocarbonate B has secondary carbonate accumulation. (For soils where the hardpan carbonate horizon starts >100 cm from the surface, the non-luvic Prieska families would key out as Cambisols, while the luvic Prieska families would key out as Acrisols/Lixisols/Alisols/Luvisols.) The hardpan carbonate (petrocalcic horizon) is reflected through the petric qualifier, the cambic qualifier reflects the non-luvic neocarbonate B horizons, the luvic qualifier the luvic neocarbonate B horizons, while the chromic qualifier reflects the red neocarbonate B horizons. Fey (2010) similarly classifies Prieska soils as Calcisols.

non-bleached A, non-red, non-luvic B Prieska	Cambic Petric Calcisol
non-bleached A, non-red, luvic B Prieska	Luvic Petric Calcisol
non-bleached A, red, non-luvic B Prieska	Cambic Petric Calcisol (Chromic)
non-bleached A, red, luvic B Prieska	Luvic Petric Calcisol (Chromic)
bleached A, non-red, non-luvic B Prieska	Cambic Petric Calcisol
bleached A, non-red, luvic B Prieska	Luvic Calcisol Petric Calcisol
bleached A, red, non-luvic B Prieska	Cambic Petric Calcisol (Chromic)
bleached A, red, luvic B Prieska	Luvic Petric Calcisol (Chromic)

5.65 Trawal

(Orthic A / neocarbonate B / dorbank): The non-luvic neocarbonate B horizon relates to a cambic horizon, the luvic neocarbonate B horizon would relate to an argic horizon (Table 8), and the dorbank to a petroduric horizon. Trawal soils, therefore, key out as Durisols, if the petroduric horizon starts ≤100 cm from the surface and because the neocarbonate B has secondary carbonate accumulation. For soils where the petroduric horizon starts >100 cm from the surface, the non-luvic Trawal families would key out as Cambisols (Bathyduric), while the luvic Trawal families would key out as Acrisols/Lixisols/Alisols/Luvisols (Bathyduric). The pretic qualifier refers to the dorbank (petroduric) horizon, the eutric qualifier to the non-luvic neocarbonate B horizon, the luvic qualifier to the luvic neocarbonate B horizon, while the chromic qualifier refers to the red neocarbonate B horizon. The cambic qualifier is unfortunately not available for the Durisols. Fey (2010) similarly classifies Trawal soils as Calcisols.

non-bleached A, non-red, non-luvic B Trawal	Eutric Petric Durisol
non-bleached A, non-red, luvic B Trawal	Luvic Petric Durisol
non-bleached A, red, non-luvic B Trawal	Eutric Petric Durisol (Chromic)
non-bleached A, red, luvic B Trawal	Luvic Petric Durisol (Chromic)
bleached A, non-red, non-luvic B Trawal	Eutric Petric Durisol
bleached A, non-red, luvic B Trawal	Luvic Petric Durisol
bleached A, red, non-luvic B Trawal	Eutric Petric Durisol (Chromic)
bleached A, red, luvic B Trawal	Luvic Petric Durisol (Chromic)

5.66 Augrabies

(Orthic A / neocarbonate B): The non-luvic neocarbonate B horizon relates to a cambic horizon, and the luvic neocarbonate B horizon would relate to an argic horizon (Table 8). The non-luvic Augrabies families would, therefore, key out as Cambisols, if the neocarbonate B horizon starts ≤50 cm from the surface (which is assumed here), while the luvic Augrabies families would key out as Lixisols/Luvisols, if the luvic neocarbonate B horizon starts ≤100 cm from the surface (which is assumed here). The eutric qualifier is assumed for the neocarbonate B due to the presence of carbonates, while the chromic qualifier reflects the red neocarbonate B horizon. Fey (2010) similarly classifies Augrabies soils as Calcisols.

non-bleached A, non-red, non-luvic B Augrabies	Eutric Cambisol
non-bleached A, non-red, luvic B Augrabies	Haplic Lixisol/Luvisol
non-bleached A, red, non-luvic B Augrabies	Eutric Chromic Cambisol
non-bleached A, red, luvic B Augrabies	Chromic Lixisol/Luvisol
bleached A, non-red, non-luvic B Augrabies	Eutric Cambisol
bleached A, non-red, luvic B Augrabies	Haplic Lixisol/Luvisol
bleached A, red, non-luvic B Augrabies	Eutric Chromic Cambisol
bleached A, red, luvic B Augrabies	Chromic Lixisol/Luvisol

5.67 Brandvlei

(Orthic A / soft carbonate horizon): The soft carbonate horizon relates to a calcic horizon. The wet soft carbonate horizon family relates to stagnic properties and reducing conditions, resulting in the stagnic qualifier. Brandvlei soils would, therefore, key out as Calcisols, if the soft carbonate horizon starts ≤100 cm from the surface (which is assumed here) and because there is no argic horizon occurring above it. Fey (2010) similarly classifies Brandvlei soils as Calcisols.

non-wet soft carbonate Brandvlei	Haplic Calcisol
wet soft carbonate Brandvlei	Haplic Calcisol (Stagnic)

5.68 Coega

(Orthic A / hardpan carbonate horizon): The hardpan carbonate horizon relates to a petrocalcic horizon. Coega soils would, therefore, key out as Calcisols, if the hardpan carbonate horizon starts ≤100 cm (the converse is highly unlikely). The petric qualifier denotes the indurated nature of the carbonate horizon. The occurrence of lime in the A horizon does unfortunately not reflect in the WRB qualifiers. Fey (2010) similarly classifies Coega soils as Calcisols.

non-calcareous A Coega	Petric Calcisol
calcareous A Coega	Petric Calcisol

5.69 Knersvlakte

(Orthic A / dorbank): The dorbank would relate to a petroduric horizon. Knersvlakte soils, therefore, key out as Durisols, if the petroduric horizon starts ≤100 cm from the surface (the converse is highly unlikely). The petric qualifier denotes the indurated nature of the dorbank horizon. The occurrence of lime in the A horizon does unfortunately not reflect in the WRB qualifiers. Fey (2010) similarly classifies Knersvlakte soils as Durisols.

non-calcareous A Knersvlakte	Petric Durisol
calcareous A Knersvlakte	Petric Durisol

5.70 Glenrosa

(Orthic A / lithocutanic B): The lithocutanic B horizon might be considered continuous rock if cracks into which roots can enter are on average ≥10 cm apart and if the cracks occupy <20% (v/v). Glenrosa soils would key out as Leptosols since it is postulated here that the lithocutanic B would have <30% (v/v) fine earth, given the SAT diagnostic that the lithocutanic B "*merges into underlying weathering rock*". Glenrosa soils where these limits are not met would become Leptic Acrisols, Lixisols, Alisols, Luvisols, or Cambisols. The cutanic qualifier reflects the illuvial clay into the lithocutanic B horizon, the protocalcic qualifier reflects the calcareous lithocutanic B horizons, while the stagnic qualifier reflects the wet lithocutanic B horizons. The hard lithocutanic B families [with ≥40% (v/v) coarse fragments throughout or to a depth of 100 cm] equates to skeletic properties and thus the skeletic qualifier. No option exists in the WRB to capture the bleach nature of the A horizon. The calcareous families might qualify for the eutric qualifier. Fey (2010) lists only Leptosols, Acrisols, Lixisols, and Cambisols as options for Glenrosa soils.

non-bleached A, non-hard, non-wet, non-calcareous B Glenrosa	Cutanic Leptosol
non-bleached A, non-hard, non-wet, calcareous B Glenrosa	Cutanic Leptosol (Protocalcic)
non-bleached A, non-hard, wet, non-calcareous B Glenrosa	Cutanic Leptosol (Stagnic)
non-bleached A, non-hard, wet, calcareous B Glenrosa	Cutanic Leptosol (Protocalcic, Stagnic)
non-bleached A, hard, non-wet, non-calcareous B Glenrosa	Cutanic Skeletic Leptosol

non-bleached A, hard, non-wet, calcareous B Glenrosa	Cutanic Skeletic Leptosol (Protocalcic)
non-bleached A, hard, wet, non-calcareous B Glenrosa	Cutanic Skeletic Leptosol (Stagnic)
non-bleached A, hard, wet, calcareous B Glenrosa	Cutanic Skeletic Leptosol (Protocalcic, Stagnic)
bleached A, non-hard, non-wet, non-calcareous B Glenrosa	Cutanic Leptosol
bleached A, non-hard, non-wet, calcareous B Glenrosa	Cutanic Leptosol (Protocalcic)
bleached A, non-hard, wet, non-calcareous B Glenrosa	Cutanic Leptosol (Stagnic)
bleached A, non-hard, wet, calcareous B Glenrosa	Cutanic Leptosol (Protocalcic, Stagnic)
bleached A, hard, non-wet, non-calcareous B Glenrosa	Cutanic Skeletic Leptosol
bleached A, hard, non-wet, calcareous B Glenrosa	Cutanic Skeletic Leptosol (Protocalcic)
bleached A, hard, wet, non-calcareous B Glenrosa	Cutanic Skeletic Leptosol (Stagnic)
bleached A, hard, wet, calcareous B Glenrosa	Cutanic Skeletic Leptosol (Protocalcic, Stagnic)

5.71 Mispah

(Orthic A / hard rock): The hard rock relates to continuous rock if cracks into which roots can enter are on average ≥10 cm apart and occupy <20% (v/v), which can easily be assumed here. Only Mispah soils with A horizons ≤25 cm thick would thus key out as Leptosols. The lithic qualifier can be used if the orthic A horizon <10 cm thick and the nudilithic qualifier can be used if the orthic A horizon is absent. Dystric is assumed for the non-calcareous orthic A horizon families, while Eutric is assumed for the calcareous orthic A horizon families. Fey (2010) similarly classifies Mispah soils as Leptosols. Mispah soils with A horizons >25 cm thick would probably key out as Cambisols or maybe Regosols.

non-bleached, non-calcareous A Mispah	Dystric Leptosol
non-bleached, calcareous A Mispah	Eutric Leptosol
bleached, non-calcareous A Mispah	Dystric Leptosol
bleached, calcareous A Mispah	Eutric Leptosol

5.72 Dundee

(Orthic A / stratified alluvium): The stratified alluvium relates to fluvic material. Dundee soils would, therefore, key out as Fluvisols, if the stratified alluvium starts ≤25 cm from the surface (Table 18), which is assumed here. Dundee soils where the stratified alluvium starts >25 cm from the surface would be Cambisols or Regosols. Dystric is assumed for the non-calcareous orthic A horizon families, Eutric is assumed for the calcareous orthic A horizon families, while the stagnic qualifier reflects the signs of wetness in the stratified alluvium. No option exists in WRB to capture the red B families (chromic qualifier) for Fluvisols. Fey (2010) lists only Fluvisols as an option for Dundee soils.

non-red, non-wet, non-calcareous Dundee	Dystric Fluvisol
non-red, non-wet, calcareous Dundee	Eutric Fluvisol
non-red, wet, non-calcareous Dundee	Dystric Stagnic Fluvisol
non-red, wet, calcareous Dundee	Eutric Stagnic Fluvisol
red, non-wet, non-calcareous Dundee	Dystric Fluvisol
red, non-wet, calcareous Dundee	Eutric Fluvisol
red, wet, non-calcareous Dundee	Dystric Stagnic Fluvisol
red, wet, calcareous Dundee	Eutric Stagnic Fluvisol

5.73 Namib

(Orthic A / regic sand): Namib soils would key out as Arenosols since they would have a texture of loamy sand or coarser (Table 17). Dystric is assumed for the non-calcareous orthic A horizon families, while eutric is assumed for the calcareous orthic A horizon families. Unfortunately, no option exists in WRB to capture the red B families for Arenosols. Fey (2010) similarly classifies Namib soils as Arenosols.

non-red, non-calcareous Namib	Dystric Arenosol
non-red, calcareous Namib	Eutric Arenosol
red, non-calcareous Namib	Dystric Arenosol
red, calcareous Namib	Eutric Arenosol

5.74 Witbank

(Orthic A / man-made soil deposit): Man-made soil deposit would relate to artefacts or technic hard material. Witbank soils, therefore, key out as Technosols. Dystric is assumed for the non-calcareous orthic A horizon families, while eutric is assumed for the calcareous orthic A horizon families. The garbic, spolic, urbic, and linic prefix qualifiers refer to the nature of the deposited material (garbage, industrial waste, human settlement rubble, and geomembrane respectively) and should be determined by the taxonomist.

non-calcareous Witbank	Garbic/Spolic/Urbic/Linic Technosol (Dystric)
calcareous Witbank	Garbic/Spolic/Urbic/Linic Technosol (Eutric)

CHAPTER 6

DISCUSSION AND RECOMMENDATIONS

Not all World Reference Base reference soil groups have the same possibility to be reflected from the SAT classification. This is because some (e.g. Histosols & Andosols) are very rare or simply do not occur in South Africa, others (e.g. Solonchaks) are defined based on soil chemistry, which is not utilised in the SAT, while still others (e.g. Gleysols & Gypsisols) are not yet recognised in the SAT. These RSGs can therefore currently not be recognised from the SAT but should be classified as such if the relevant data is available. Table 23 provides a summary of the correlation and classification elegance of the SAT soil forms.

Champagne soils classify poorly in the WRB because the OC content is more restrictive in the WRB. It is thus proposed that the SAT adopt family criteria (10-20% OC and ≥20% OC) to better relate to the WRB. SAT should also consider lowering the depth limit to 10 cm and to capture the shallow (≤25 cm) rock or saprolite required for Leptosols as additional soil families.

TABLE 23 Summary of the correlation between the SAT soil forms and the WRB reference soil group(s), and the classification elegance thereof

Soil form	Classification elegance		WRB classification
	Good	Poor	
Champagne		X	Histosols, Leptosols or Gleysol depending on OC content
Kranskop	X		Umbrisols
Magwa	X		Umbrisols
Inanda	X		Umbrisols
Lusiki	X		Umbrisols
Sweetwater	X		Umbrisols
Nomanci	X		Umbrisols
Rensburg	X		Vertisols
Arcadia	X		Vertisols
Willowbrook		X	Stagnosols or Phaeozems, depending on the depth of the G horizon
Bonheim		X	Kastanozems or Phaeozems
Steendal	X		Kastanozems
Immerpan	X		Kastanozems
Mayo	X		Phaeozems
Milkwood	X		Phaeozems
Inhoek	X		Phaeozems
Katspruit		X	Planosols, Stagnosols or Luvisols, depending on the texture difference and thickness of the orthic A
Kroonstad		X	Planosols, Stagnosols or Luvisols, depending on the texture difference and thickness of the orthic A
Longlands	X		Plinthosols
Wasbank	X		Plinthosols
Constantia		X	Cambisols, Regosols, Podzols, Acrisols, Lixisols, Alisols, Luvisols
Tsitsikamma	X		Podzols
Lamotte	X		Podzols
Concordia	X		Podzols
Houwhoek	X		Podzols
Estcourt	X		Solonetz
Klapmuts	X		Luvisols
Vilafontes		X	Cambisols, Regosols, Acrisols, Lixisols, Alisols, Luvisols
Kinkelbos		X	Cambisols, Regosols, Acrisols, Lixisols, Alisols, Luvisols
Cartref		X	Acrisols, Lixisols, Alisols, Luvisols
Fernwood		X	Arenosols if the sandy texture is assumed

Soil form	Classification elegance		WRB classification
	Good	Poor	
Westleigh	X		Plinthosols
Dresden	X		Plinthosols
Avalon		X	Plinthosols, Cambisols, Regosols, Acrisols or Alisols, depending on the depth of the soft plinthic B
Glencoe		X	Plinthosols, Cambisols, Regosols, Acrisols, Alisols, Lixisols or Luvisols depending on the depth of the soft plinthic B
Pinedene		X	Cambisols, Regosols, Acrisols or Alisols, depending on the presence of luviation
Griffin		X	Cambisols, Regosols, Acrisols or Alisols, depending on the presence of luviation
Molopo		X	Calcisols, Lixisols or Luvisols, depending on the presence of luviation
Askham		X	Calcisols, Cambisols, Regosols Lixisols or Luvisols, depending on the depth of the hardpan carbonate
Clovelly		X	Cambisols, Regosols, Acrisols, Alisols, Lixisols or Luvisols, depending on the presence of luviation
Bainsvlei		X	Plinthosols, Cambisols, Regosols, Acrisols, Alisols, Lixisols or Luvisols, depending on the depth of the soft plinthic B and the presence of luviation
Lichtenburg		X	Plinthosols, Cambisols, Regosols, Acrisols, Alisols, Lixisols or Luvisols, depending on the depth of the soft plinthic B and the presence of luviation
Bloemdal		X	Cambisols, Regosols, Acrisols, Alisols, Lixisols or Luvisols, depending on the presence of luviation
Kimberley		X	Cambisols, Lixisols or Luvisols, depending on the presence of luviation
Plooysburg		X	Cambisols, Lixisols or Luvisols, depending on the presence of luviation
Garies	X		Durisols
Hutton		X	Cambisols, Regosols, Acrisols, Alisols, Lixisols or Luvisols, depending on the presence of luviation
Shortlands	X		Nitisols
Jonkersberg	X		Podzols
Witfontein	X		Podzols
Pinegrove	X		Podzols
Groenkop	X		Podzols
Sterkspruit	X		Solonetz
Sepane	X		Luvisols

Soil form	Classification elegance		WRB classification
	Good	Poor	
Valsrivier	X		Luvisols
Swartland	X		Luvisols
Tukulu		X	Cambisols, Acrisols, Alisols, Lixisols or Luvisols, depending on the presence of luviation
Etosha		X	Cambisols, Acrisols, Alisols, Lixisols or Luvisols, depending on the presence of luviation
Gamoep	X		Calcisols
Oudtshoorn	X		Durisols
Oakleaf		X	Cambisols, Acrisols, Alisols, Lixisols or Luvisols, depending on the presence of luviation
Montagu		X	Cambisols, Acrisols, Alisols, Lixisols or Luvisols, depending on the presence of luviation
Addo	X		Calcisols
Prieska	X		Calcisols
Trawal	X		Durisols
Augrabies		X	Cambisols, Lixisols or Luvisols, depending on the presence of luviation
Brandvlei	X		Calcisols
Coega	X		Calcisols
Knersvlakte	X		Durisols
Glenrosa	X		Leptosols, with some assumptions
Mispah	X		Leptosols, with some assumptions
Dundee	X		Fluvisols, with some assumptions
Namib	X		Arenosols
Witbank	X		Technosols
Sum	46	28	

Although the humic A horizon does not relate directly to any WRB horizons, the final classification of soil profiles with humic A horizon soils was quite satisfactory. The majority of the diagnostic horizons and family criteria could be captured in the RSG and qualifiers. More attention should, however, be given to promote the inclusion of the humic A horizon in the WRB, especially since a version of the humic A horizon (dark, leached, high OC) also reflects in the Brazilian system (Dos Santos et al., 2018).

Both Rensburg and Arcadia soils relate very well to the Vertisols of the WRB. Additionally, all the family criteria could be captured through qualifiers. Consideration can be given to rewriting the SAT diagnostics (e.g. include wedge-shaped peds) of the vertic A to be more in line with the vertic horizon of the WRB.

In general, the melanic A horizon soils classified quite easily as Phaeozems or Kastanozems. This was in part because thick (>25 cm) melanic A horizons were assumed, based on the land type data. If the melanic A would be thinner than this criterion, then Mayo and Milkwood soils would key out as Leptosols, while the Willowbrook soils will key out as Stagnosols. A >25 cm thick diagnostic should, therefore, be considered for the SAT melanic A horizons. (Only 5 of the 114 melanic A horizons described during the land type survey are ≤25 cm thick.)

Katspruit and Kroonstad soils relate rather awkwardly to the WRB since they can either be Planosols, Stagnosols, Acrisols, Lixisols, Alisols or Luvisols. This is due to Katspruit and Kroonstad soils that may have an abrupt textural difference from the orthic A or E to the G and thus become Planosols, or if the orthic A ≤25 cm thick they become Stagnosols. Adding these diagnostics (abrupt textural difference and shallow ≤25 cm orthic A horizons) to that of the G horizon (or accommodation thereof at the family level) would therefore greatly improve the relation of Katspruit and Kroonstad soils to the WRB.

Constantia soils classified quite awkwardly as Cambisols, Regosols, Podzols, Acrisols, Lixisols, Alisols, or Luvisols. But in the end, the WRB classification does relate quite well to the families of the Constantia, provided that the clay activity and leaching status of the argic B can be defined.

Soils with podzol B horizons (Tsitsikamma, Lamotte, Concordia, Houwhoek) classify quite well within the WRB since the concept of the

SAT podzol B relates quite well to the WRB spodic horizon and since it was assumed that all podzol B horizons occur ≤100 cm from the surface. The WRB qualifiers were also able to capture the family criteria and occurrence of the E horizon quite well.

Soils with E horizons (Kroonstad, Longlands, Wasbank, Constantia, Tsitsikamma, Lamotte, Concordia, Houwhoek, Estcourt, Klapmuts, Vilafontes, Kinkelbos, Cartref, Fernwood) typically had the albic qualifier, while the B horizons determined the Reference Soil Group. Recognition of albic properties was the result of E horizons being equated to albic properties, based on the concept and not the diagnostics thereof. This implied discrepancy is greater for the yellow E than for the grey E horizons. The majority of these soils therefore key out as Acrisols, Lixisols, Alisols or Luvisols. However, the differentiation between these cannot be captured from the SAT. This should be highlighted for further research, especially given the statement for the Dystrophic, Mesotrophic and Eutrophic family criteria in SAT that "*Once sufficient data are available, it is possible that these criteria will be replaced by percentage base saturation*". In general Klapmuts soils classify quite well in WRB, but the structure size and type (sub/fine/medium/coarse angular) family criteria are not recognised by the WRB. This is a significant shortcoming since it seriously impacts on root development and water movement.

Families of the SAT can easily be converted to qualifiers (of adjectives) of the soil forms. As such it is recommended that these should precede the soil form name, as adjectives of the soil form.

It is also suggested to add depth criteria to the SAT diagnostics. At the same time, it should be recognised that the inclusion of a depth criterion can (and probably would) artificially divide natural soil bodies. This should not be the intention. However, depth criteria will greatly aid in relating SAT soils to the WRB while also providing better differentiation between soil forms: For example, shallow Hutton soils on rock *versus* red Mispah soils. It is proposed that those soils that do not meet a specific depth criterion should still be included in the specific class, but should then be identified as a shallow member of that taxon, through the use of a qualifier such as entic, proto, or raso.

CONCLUSION

The procedure adopted here to provide a WRB classification based on the SAT soil families worked quite well, although certain RSGs and qualifiers were excluded by default. Some of these RSGs are not relevant to South Africa, but some are and should be included by the taxonomist to produce high-quality WRB classifications.

Through the application of this procedure, some peculiarities, omissions and inconsistencies were observed in the SAT and WRB. Addressing these is recommended for future research. These were discussed in detail above, but in summary, simplifying the WRB, firstly through linguistic editing (*i.e.* less verbose text) and secondly by simplifying and standardising the criteria should be considered. Both these recommendations could be done to absurdity, to determine and evaluate the impact thereof. Introduction of depth criteria should be considered for the SAT. This can possibly be a 'soft' criterion (*e.g.* 50±5 cm), to prevent the artificial division of soil forms and/or families. Lastly, a higher level of classification should be included in the SAT. This will formalise the nomenclature already used by taxonomists, e.g. duplex soils, apedal soils, and water table soils. It will also aid in promoting the adoption of soil classification amongst the broader community since it would be less complicated.

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APPENDIX A

Simplified key and general description of the WRB Reference Soil Groups[9]

Histosols	Soils with thick (≥10 cm) organic material
Anthrosols	Soils formed due to long and intensive agricultural use
Technosols	Human-created soils, containing significant amounts of artefacts
Cryosols	Soils with permafrost (cryic horizon)
Leptosols	Thin (<25 cm) soils on rock or with many coarse fragments
Solonetz	Soils with a high exchangeable Na content
Vertisols	Soils formed due to shrink-swell clays and alternating wet-dry conditions
Solonchaks	Soils with a high concentration of soluble salts
Gleysols	Groundwater-affected, underwater and tidal soils
Andosols	Soils formed with allophanes or Al-humus complexes parent material (volcanic ash soils)
Podzols	Soils with subsoil accumulation of humus and/or oxides
Plinthosols	Soils with accumulation and redistribution of Fe
Nitisols	Soils with strong structure, low-activity clays, P fixation, and many Fe oxides
Ferralsols	Soils with dominance of kaolinite clay and Fe/Al oxides
Planosols	Soils with an abrupt textural difference and stagnating water
Stagnosols	Soils formed due to stagnating water
Chernozems	Soils with a very dark topsoil and a subsoil of secondary carbonates, with a high base saturation (≥50%) throughout
Kastanozems	Soils with a dark topsoil and a subsoil of secondary carbonates, with a low base saturation (<50%) throughout
Phaeozems	Soils with a dark topsoil and a subsoil without secondary carbonates, with a high base saturation (≥50%) throughout
Umbrisols	Soils with a dark topsoil and a subsoil without secondary carbonates, with a low base saturation (<50%) throughout
Durisols	Soils with silica accumulation and cementation
Gypsisols	Soils with secondary gypsum accumulation
Calcisols	Soils with secondary carbonate accumulation
Retisols	Soils with interfingering of light-coloured, coarser-textured (albic) material into a finer-textured layer
Acrisols	Soils with a clay-enriched subsoil, low-activity clays (ECEC <24 $cmol_c\ kg^{-1}$ clay), and a low base status (<50%)
Lixisols	Soils with a clay-enriched subsoil, low-activity clays (ECEC <24 $cmol_c\ kg^{-1}$ clay), and a high base status (≥50%)
Alisols	Soils with a clay-enriched subsoil, high-activity clays (ECEC >24 $cmol_c\ kg^{-1}$ clay), and a low base status (<50%)
Luvisols	Soils with a clay-enriched subsoil, high-activity clays (ECEC >24 $cmol_c\ kg^{-1}$ clay), and a high base status (≥50%)
Cambisols	Soils with only moderate profile development
Arenosols	Soils with sandy texture
Fluvisols	Soils with stratification from fluviatile or lacustrine deposition
Regosols	Soils with no significant profile development

9 Source: World Reference Base for Soil Resources 2014, update 2015. International soil classification system for naming soils and creating legends for soil maps.World Soil Resources Reports No. 106. FAO, Rome. http://www.fao.org/3/i3794en/I3794en.pdf. Reproduced with permission.

APPENDIX B

Simplified properties of the diagnostic horizons, properties and materials of the WRB[10]

anthraquic horizon	a layer comprising the puddled layer and plough pan in paddy soils, both showing a reduced matrix and oxidized root channels
hortic horizon	a dark layer, with high organic matter and P content, high animal activity, high base saturation; resulting from long-term cultivation, fertilization, and the application of organic residues
hydragric horizon	the layer below an anthraquic horizon in paddy soils, showing redoximorphic features and/or accumulation of Fe and/or Mn
irragric horizon	a uniformly structured layer, with at least a moderate organic matter content, high animal activity; gradually built up by sediment-rich irrigation water
plaggic horizon	a dark layer, with at least a moderate organic matter content, sandy or loamy texture; resulting from the application of sods and excrements
pretic horizon	a dark layer, with a high organic matter and P content, low animal activity, high exchangeable Ca and Mg contents, with remnants of charcoal and/or artefacts; including Amazonian Dark Earths
terric horizon	a layer showing a colour related to the source material, with high base saturation; resulting from addition of mineral material (with or without organic residues) and deep cultivation
cryic horizon	a perennially frozen layer (with visible ice or, if not enough water, a temperature ≤0°C)
calcic horizon	a non-cemented layer consisting of accumulated secondary carbonates
fulvic horizon	a layer with andic properties, highly humified organic matter, and high ratio of fulvic acids to humic acids
melanic horizon	a layer with andic properties, highly humified organic matter, and low ratio of fulvic acids to humic acids
salic horizon	a layer with high amounts of water soluble salts
thionic horizon	a layer with sulfuric acid and a very low pH
folic horizon	a layer of organic material, not water-saturated and not drained
histic horizon	a layer of organic material, water-saturated or drained
chernic horizon	a thick layer, very dark-coloured, with high base saturation, moderate to high organic matter content, well-structured, with high biological activity

10 Source: World Reference Base for Soil Resources 2014, update 2015. International soil classification system for naming soils and creating legends for soil maps.World Soil Resources Reports No. 106. FAO, Rome. http://www.fao.org/3/i3794en/I3794en.pdf. Reproduced with permission.

mollic horizon	a thick layer, dark-coloured, with high base saturation, moderate to high organic matter content, not massive and hard when dry
umbric horizon	a thick layer, dark-coloured, with low base saturation, moderate to high organic matter content, not massive and hard when dry
argic horizon	a subsurface layer with distinctly higher clay content than the overlying layer and/or the presence of illuvial clay
duric horizon	a layer of concretions or nodules, cemented or indurated by silica
ferric horizon	a layer with ≥5% reddish to blackish concretions and/or nodules or ≥ 15% reddish to blackish coarse mottles, with accumulation of Fe and/or Mn oxides
gypsic horizon	a non-cemented layer with secondary gypsum accumulation
natric horizon	a subsurface layer with high exchangeable Na and distinctly higher clay content than the overlying layer and/or the presence of illuvial clay
petrocalcic horizon	a cemented or indurated layer with accumulation of secondary carbonates
petroduric horizon	a cemented or indurated layer with accumulation of secondary silica
petrogypsic horizon	a cemented or indurated layer with accumulation of secondary gypsum
petroplinthic horizon	a cemented or indurated layer with accumulation of Fe oxides
pisoplinthic horizon	a layer with ≥40% strongly cemented to indurated concretions and/or nodules, yellowish, reddish, and/or blackish in colour, with accumulation of Fe oxides
plinthic horizon	a layer with ≥15% concretions and/or nodules, reddish in colour, with accumulation of Fe oxides
sombric horizon	a subsurface layer with accumulation of organic matter, excluding spodic and natric horizons
spodic horizon	a subsurface layer with accumulation of organic matter and/or Fe and Al
cambic horizon	a layer showing evidence of pedogenic alteration, but that does not meet the criteria of other diagnostic horizons
ferralic horizon	a strongly weathered layer; dominated by kaolinite clays and oxide minerals
fragic horizon	a non-cemented layer with compact structure, preventing roots and water penetration, except along interped faces
nitic horizon	a layer rich in clay and Fe oxides, with moderate to strong structure, and shiny aggregate faces

protovertic horizon	a layer influenced by swelling and shrinking (montmorillonite) clays
vertic horizon	a layer dominated by swelling and shrinking (montmorillonite) clays
aridic properties	soil surface characteristics of soils formed under arid conditions
takyric properties	a heavy-textured soil surface layer formed under arid conditions in periodically flooded soils
yermic properties	a desert pavement and/or vesicular layer in soils formed under arid conditions
abrupt textural difference	a very sharp (abrupt) increase in clay content over a short depth range
albeluvic glossae	vertically continuous interfingering (tongues) of coarser-textured and lighter coloured (albic) material into an argic horizon
retic properties	interfingering (tongues) of coarser-textured and lighter coloured (albic) material into an argic or natric horizon
lithic discontinuity	a change in parent material
continuous rock	consolidated (rock) material, excluding cemented or indurated pedogenetic horizons
andic properties	short-range-order minerals and/or organo-metallic complexes (volcanic ash)
anthric properties	mollic or umbric horizons created or substantially transformed by humans
geric properties	a low effective CEC (<1.5 $cmol_c$ kg^{-1} clay)
gleyic properties	saturation with groundwater and with reducing conditions (bright ped faces and pore linings, with grey ped interiors)
stagnic properties	saturation with surface water and with reducing conditions (grey ped faces and pore linings, with bright ped interiors)
reducing conditions	low rH value (<20) and/or the presence of sulfide, methane or reduced Fe
protocalcic properties	secondary carbonates, excluding calcic or petrocalcic horizons
shrink-swell cracks	cracks that open and close due to the swelling and shrinking of (montmorillonite) clay minerals

sideralic properties	relatively low effective CEC (<1.5 $cmol_c$ kg^{-1} clay)
vitric properties	≥5% volcanic glass and related materials, with limited amount of short-range-order minerals and/or organo-metallic complexes
mineral material	<20% soil organic carbon
organic material	≥20% soil organic carbon
soil organic carbon	organic carbon that does not form part of artefacts
albic material	light-coloured fine earth, with high Munsell value and low chroma
artefacts	created, modified or brought to the surface by humans, with no subsequent pedogenesis
technic hard material	consolidated and relatively continuous material resulting from industrial processes
calcaric material	≥2% calcium carbonate equivalent, inherited from the parent material
dolomitic material	≥2% of a mineral that has a ratio $CaCO_3/MgCO_3$ <1.5
colluvic material	heterogeneous material that has moved downslope
fluvic material	fluviatile, marine or lacustrine deposits with evident stratification
gypsiric material	≥5% gypsum, at least partially inherited from the parent material
sulfidic material	containing detectable inorganic sulfides
hypersulfidic material	sulfidic material capable of severe acidification upon oxidation
hyposulfidic material	sulfidic material not capable of severe acidification upon oxidation
limnic material	material deposited in water through precipitation or through aquatic organisms
ornithogenic material	material deposited by birds or bird activity
tephric material	≥30% volcanic glass and related materials

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The South African Taxonomic soil classification system (SAT) is well established and utilised in South Africa. However, it is not internationally well known and therefore the need arose to provide a tool by which South African soil taxonomists can convert South African soil classifications and profile descriptions to the international classifications of the World Reference Base (WRB) for soil resources.

The diagnostics and tacit knowledge presented in this publication are therefore based on the SAT and the WRB. When necessary, further substantiation was derived from the *Land Type Survey of South Africa*.

The adopted procedure is effective in providing a reasonable classification based on the South African soil forms and families, while excluding certain WRB soil groups and qualifiers, because these are irrelevant to South African taxonomy.

Lastly, this publication also highlights some peculiarities, omissions and inconsistencies observed between the SAT and WRB.

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