A SEDIMENTOLOGICAL PATTERN OF A COASTAL TRANSITIONAL ENVIRONMENT: FROM THE EASTERN MEDITERRANEAN SEA SHORELINE THROUGH THE LAKE BAFA

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Abstract – Lake Bafa is located in a marine to terrestrial transitional area on the coastal Aegean plain. It has been under the influence of different sedimentological systems over the last 3.5 ka, namely fluvial, delta frontal, swamp and lagoon. This study is based on the lithological study and correlation of six sediment cores (*BAF*35, - 37 - 39 - 41, - 42, - 46) distributed over the Lake Bafa basin.

Concerning the main depositional characteristics and radiocarbon chronology, we aim at reconstructing the fundamental characteristics of local abrupt and gradual environmental fluctuations in this coastal study site. The gradual changes reflect four main environmental phases: the present isolated lacustrine stage (last 0.8 ka), a lagoon stage (0.8÷1.75 ka BP), a coastal marine-fluvial interaction stage (1.75÷2.7 ka BP) and the earliest marine-dominated stage is (before 2.7 ka BP). Further sedimentological markers points to abrupt geo-events, mainly controlled by the local hydro-climate, geomorphology and geo-tectonic processes.

Introduction

Several lagoons and coastal lakes were formed on the Anatolian coastal plain of the Aegean Sea in the Eastern Mediterranean, following the Holocene transgression. Sedimentary successions of these coastal aqueous environments constitute important archives for the Holocene coastal evolution, including the sedimentological processes and geomorphological changes [1, 7].

Both an west to east directed transect from a marine to an inland and a core-depth profile in a recent lacustrine or lagoon system potentially allow us to understand the nature of the corresponding environmental and ecosystem changes in these rapidly evolving coastal aquatic systems, such as the coastal plains of the Eastern Mediterranean during the Holocene [5,7]. In this respect, we conducted a paleo-limnological study on the Lake Bafa basin, representing a current terrestrial lacustrine geo-setting (Figure 1). During the middle to late Holocene, the basin has gradually evolved geo-morphologically from an open marine gulf-estuarine environment (Aegean Sea), through a lagoon and to its current isolated lacustrine geo-setting [2-7]. Lake Bafa basin is currently classified as a completely isolated fresh lacustrine system near the present Aegean Sea coastal plain. These rapid environmental changes, which are taken place over a geologically short time scale, are mainly driven by the deltaic progradation of a dominant river system, following the early Holocene transgression (E-W trending Buyuk Menderes River) [1-3]. As such, Lake Bafa basin sedimentary

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succession represents an important archive for both paleo-limnologists and paleoceanographers. Our main purpose is to reconstruct the general sedimentological pattern of lake Bafa basin, illustrating the geo-markers of the abrupt and gradual environmental changes and fluctuations occurred during the late Holocene.

Materials and Methods

Several sediment cores were retrieved along E-W and N-S transects in the lake's basin, using water-sediment interface piston and hammer-piston coring methods. The six sediment cores include *BAF*35, -37, -39, -41, -42, -46, which range in length from 1.5 m to 4.5 m long (Figure 2).

Litho-stratigraphical characterisation of the cores mainly were defined based on the macro-sedimentological properties (i.e. sediment colour, sediment size, structure and abundance and the types of the shell content).

Selected *Cerastoderma glaucum* shells were analysed in Beta Analytical Laboratories for AMS radiocarbon age determinations [6-7]. These data were calibrated to calendar ages using CALIB v.5 software [8-9], applying a reservoir age correction of 400 years.

Grain size analyses were carried out at the EMCOL Laboratories in Istanbul Technical University. Samples were treated with HCl and KOH, before the analysis. The grain size distribution of the sediment samples was determined at 5 cm resolution using sieve analysis for coarse-grained fraction (>63 μm) and a Frisch Analysette22 laser grain size analyser for fine-grained (<63 μm) fraction of lake sediments.

Results

This study represents the lithological characteristics of the lake Bafa sediments and overall spatial distributions, in accordance to the cross-correlation of several sediment cores *BAF*35, - 37 - 39 - 41, - 42, - 46 (Figure 2). Detailed stratigraphy of *BAF*37 taken from the basin centre was previously documented in several publications [4-7]. Further sedimentological characterisation of *BAF*35, -42, -46 cores and detailed litho-stratigraphy of *BAF*39, - 41 cores were represented in this study for the first time (Figure 3).

In a basic frame, sedimentary succession of the different cores reflects similar lithological characteristics (Figure 3). The topmost unit of the cores consists mainly of homogeneous clayey silt deposited in the last 1.0 ka BP. A laminated sediment unit was deposited during 1 to 1.5 ka BP time interval. The laminated unit is followed downwards by a mainly homogeneous to thickly banded sediment unit accumulated from 1.5 to 2.2 ka BP. The oldest sediments investigated in this study consist of laminated clay to sand layers, which accumulated approximately during 2.3 to 3.5 ka BP period. The depositional system characteristics of these individual sedimentological units were classified basically as the current lacustrine stage (S-I: last 0.8 ka), lagoon-dominated stage (S-II.: 0.8–1.75 ka BP), marine-river interaction stage (S-III: 1.75–2.7 ka BP) and marine-dominated stage (S-IV: earlier than 2.7 ka BP), as discussed below [6-7].

Moreover, the variable sedimentation rates were observed in cores located in different parts of the basin. Higher sedimentation rates were observed in cores from the basin depo-centre and in north-western parts of the lake's basin compared to those in the cores taken from the eastern parts of the basin, particularly for the lacustrine-lagoonal phase.

Detailed grain size distributions were illustrated through the *BAF*46 core (Figure 3). Furthermore, the represented time interval extended along with the lowermost units of the core *BAF*37, exhibiting the additional older layers. *BAF*46 sediments consist of clay in a ratio between 0 % to 40 %, sand in a ratio between 0 % to 20 % and an average of 60 % silt. General fluctuations of the grain size distribution of sediments collected from the various cores reflect similar tendencies through the depth profile. Hence, a similar shift through the enhanced clay-sized material was observed in the 55-110 cm depth of the *BAF*35 core, 120÷140 cm depth of the core *BAF*37 and 90÷120 cm depths of the core *BAF*46. Similarly, an increase of the relative contribution of the sand-size grains was either observed in 10÷60 cm and 110÷230 cm depths of the core *BAF*35 and 20÷80 cm and 140÷220 cm depths of the core *BAF*37.

Discussions

The main sedimentology of various cores exhibits similar lithological properties. However, the correlated lithological succession of cores *BAF*39, -41, -42 recovered along the east-west transect indicates distinct changes in the sedimentary facies of the neighbouring geological sub-settings (i.e. marine, fluvial, etc) and in the proportion of the endogenic material during the marine, lagoon, lacustrine stages. The gradual transition from –coastal marine to lagoonal and lacustrine facies were observed in the eastern parts of the lake basin (in the depositional boundary of the S-I-II-III versus S-IV stages). Hence, the gradually reduced amounts of the lacustrine and lagoon originated sediment deposition was observed through the eastern parts of the lake basin, during the last 1.75 ka. The cores taken from the easternmost parts of the lake's basin include the most distinct evidence of marine sedimentation compared to the cores taken from the western-central parts (Figure 3). These spatial variations potentially either caused by the material supply amount from the neighbouring geological sub-settings (i.e. marine, fluvial) or variations of spatial boundaries of the primary depositional sub-basins (i.e. marine, lagoon, lacustrine stages).

Cross-correlation of the cores reflects a sum of the characteristic properties of paleo-environmental stages (I) or geological events (II).

(I) Lithological characteristics of the environmental stages from past to recent term are summarized as followingly: (1) the older marine sediments were observed either as grey coloured well-washed sands or massive sand deposits intensively rich in marine shell residues; (2) the transition from a lagoon to the lacustrine environment is characterized by a characteristic thin unit with laminated or varved layers; (3) flood events particularly occurred in the marine-river interaction stage, reflect beige coloured massive sand size depositional pattern; (4) Lacustrine stage reflects mostly massive clay-silt size in lithology.

(II) A sum of continuous signals of the coarse event deposits was also detected along with the north-south transect, considering the lithological indicators and grain size distribution data. The normal sedimentary succession in the cores (in particular core *BAF46*), with its different facies, is interrupted by two types of event deposits in the form of coarse (sandy) grained sedimentary units or sand-clay intercalations.

The first type of event deposits become especially frequent during the last 2.5 ka years. These units are half to few cm thick and are characterized by coarse detrital fraction intercalated with clays. These event deposits reflects mass flow characteristics considering the lithological indicators, grain size distribution data and their continuous signals along with the north-south sedimentary profile (i.e. 3÷10 cm; 43÷50 cm; 150÷160 cm; 190÷205 cm; 227÷234 cm depths of for *BAF*37 core and 10÷20 cm; 85÷92 cm; 243÷252 cm, 290÷300 cm and 357÷370 cm depths of *BAF*35 core). The respective age determination of these event sediments reflects a positive correlation with the geological dates of the significant local ancient earthquake events, occurred during the last 2.5 ka years. The respective dates for these ancient earthquakes are 1955 Soke, 399 AD Izmir, 468 AD Aydın, 68 BC Millet, 350 BC Priene. Therefore, we suggest classifying these mass flow units as seismo-turbidite layers (Figure 3).

The second type of event deposits is massive sandy layers, which particularly observed in the *BAF*46 core. The radiocarbon ages of these layers are not correlated with historical earthquake records. Only other possible origins for this rapid deposition of these coarse units are the storm surges and floods. Based on their highly variable grain-size distribution characteristics and cyclic pattern over time, we tentatively suggest that a high number of these layers represent paleo-flood deposits of the Buyuk Menderes River in the basin. These interpretations are also supported by the palaeontological and geochemical data of our previous studies on *BAF*37 core [6-7].

Conclusion

We applied an integrated method, useful for investigation of the complete nature of various coastal environments, simply focusing the litho-facies analysis, together with radiocarbon chronology, in a transitional marine-terrestrial setting on the Anatolian coastal plain of the Aegean Sea. The results show the that the coastal geomorphological evolution of the area is controlled mainly by the interactions of the Holocene marine transgression and progradation of riverine sediments. Following the Holocene marine transgression, the prograding deltaic sediments started filling a marine gulf and gradually isolating part of it to form first a lagoon, and then, with complete isolation, form the present Lake Bafa over the last 3.5 ka. In particular, during sedimentary unit the river-marine interaction stage, the lagoon was frequently flooded by the river depositing coarse event deposits, which interrupt the normal sedimentary succession.

The synthesis of the main characteristic environmental phases and geo-events would be summarized as followingly: (1) low energy conditions related homogenous fine-grained material deposition, (2) abrupt geological events related coarse-grained sediment accumulation in massive layers and (3) mass flow pattern of sediment accumulation.

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Figures

Figure 1 - Geographical location of the Lake Bafa Basin (*google earth image*).

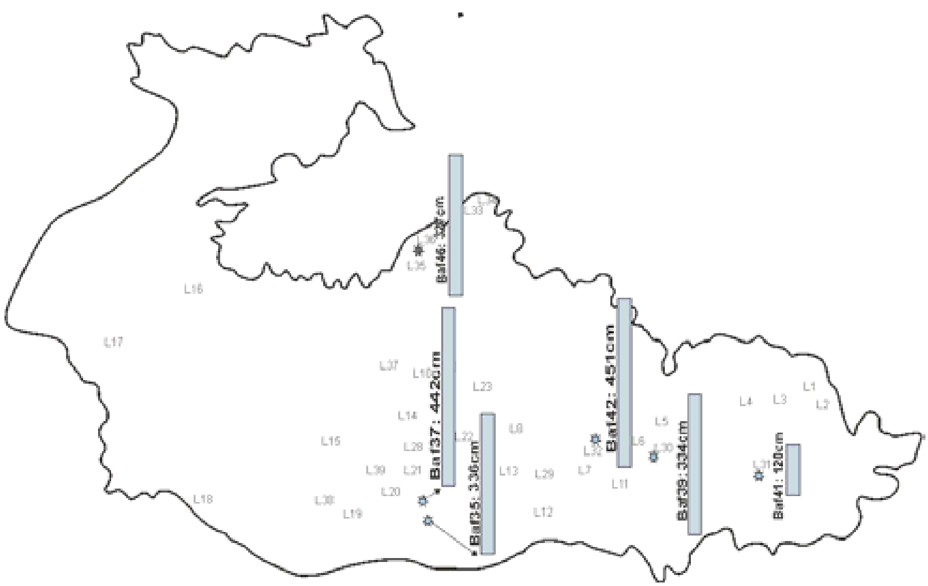

Figure 2 - L1-L39 indicate core locations (sediment-water interface short cores and upto 4.5m depth long piston sediment cores) of the entire project (I.U.BAP Project numbers: 28942; 17828) and studied cores *BAF*35, -37, -39 -41, -42, -46.

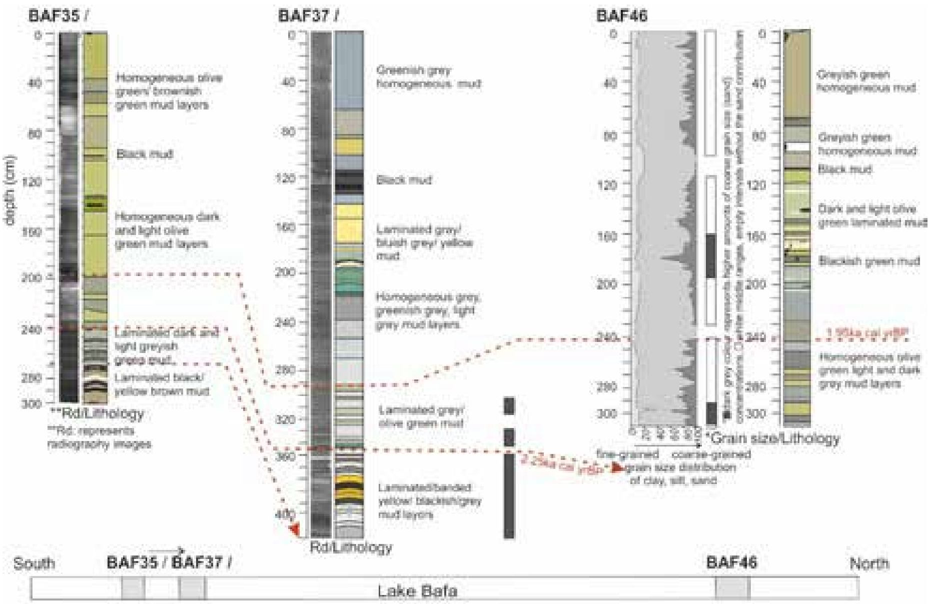

Figure 3 - Litho-stratigraphic corelation of studied cores *BAF*35, - 37, -46 and the detailed grain size distribution of core *BAF* 46. Detailed lithology and age determinations previously published for the core *BAF*37 [6-7].

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