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Earthquake Records of North Anatolian Fault From Lake Sapanca Sediments, NW Anatolia

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INTRODUCTION

Lake Sapanca is a pull-apart basin located along the North Anatolian Fault Zone (NAFZ) in NW Anatolia, Turkey (Fig. 1-a,c). The lake has a maximum depth of 53 m and a surface area of 46.8 km^2, measuring 16 km in E-W and 5 km in N-S directions. Large earthquakes are common along the NAFZ in this area. The objective of this study is to determine and date the records of past earthquakes in the lake's sedimentary sequence, which is important for earthquake risk assessment for the area. The earthquake records are represented by mass-flow deposits accumulated in the form of Turbidite-Homogenite (TH) units, which often consist of multiple sand-silt lamine above a sharp base in the lower and a homogeneous mud at the top.

We carried out a systematic study of the sedimentological, physical and geochemical analyses of three water-sediment interface cores, recovered along a depth transect to study mass flow events triggered by earthquakes over the last 250 years (Fig. 1-b). The analytical methods involved particle size analysis using laser diffraction, physical properties analysis using Multi Sensor Core Logger (MSCL), total organic carbon (TOC) and total inorganic carbon (TIC) analyses using Shimadzu TOC Analyzer, and high resolution digital X-Ray radiography and μ-XRF elemantal analyses using Itrax Core Scanner. The geochronology was established using radionuclide (^{210}Pb,^{137}Cs) and accelerator mass spectrometry (AMS) radiocarbon analyses.

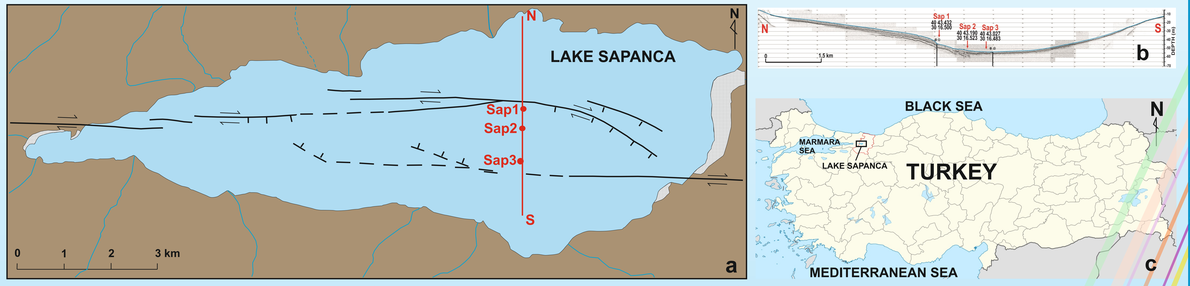


Fig. 1:a)Map showing location of studied cores, faults and position of cores on N-S seismic profile (b). c) Map showing the location of the Sapanca Lake in NW Turkey.

TIC-TOC ANALYSIS

Total organic (TOC) and inorganic (TIC) carbon contents decrease in the mass flow (TH) (Fig. 4).

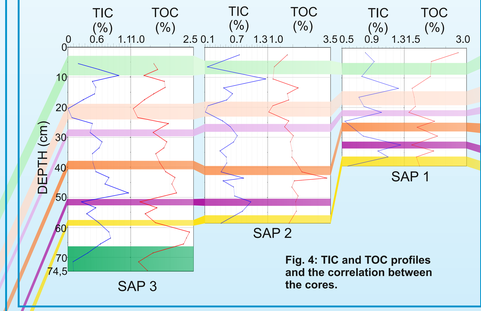


Fig. 4: TIC and TOC profiles and the correlation between the cores.

MSCL DATA

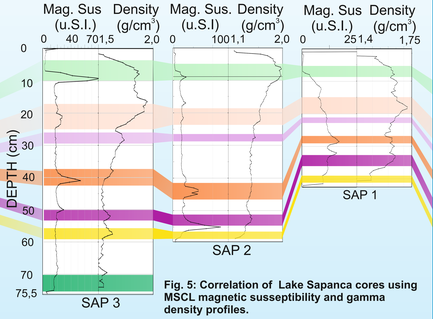


Fig. 5: Correlation of Lake Sapanca cores using MSCL magnetic susseptibility and gamma density profiles.

MSCL gamma density and magnetic susseptibility (MS) were measured at 1 cm resolution (Fig. 5). Increased gamma density and MS values are observed for mass flow (TH) units, suggesting increased detrital mineral input with high ferromagnetic - and para-magnetic mineral content. There are also are two black diagenetic iron monosulfide (greigite) bands at 43 cm in Sap2 and 55 cm in Sap3 that give high MS values.

μ-XRF ELEMENTAL ANALYSIS

μ-XRF elemental analysis show that especially the basal coarse parts of TH units are enriched in lithophile elements (Si,Rb,Ti,K; detrital input proxy) and depleted in Ca (carbonate proxy). Thus, TH units are characterized by lower Ca/Ti values than the normal lake sediments (Fig. 6)

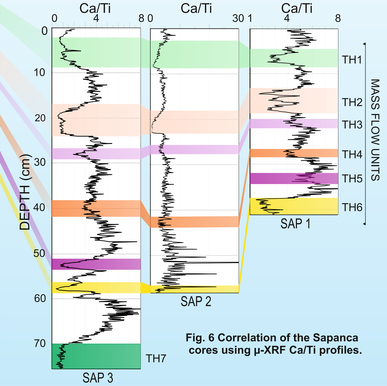
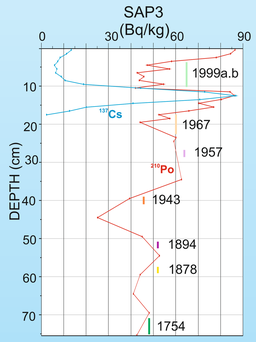


Fig. 6 Correlation of the Sapanca cores using μ-XRF Ca/Ti profiles.

CHRONOLOGY



AMS radiocarbon analysis of plant remain at 37.5 cm at core Sap2, suggest an age between the years 1900 and 1950. Radionuclide analyses (^{210}Pb and ^{137}Cs) were made for core Sap3 (Fig. 7). The results suggest that the average sedimentation rate is 1,87 mm/yr, discarding mass flow units. This result is in agreement with the findings of Schwab et al.(2009) and Leroy et al. (2010). Using this sedimentation rate and the correlation between the cores Sap1, Sap2 and Sap3 suggest that the cores cover the last 135, 135, 250 years.

Fig.7: ^{210}Po and ^{137}Cs profiles and loca- tion of mass flow units correlated with historical earthquakes (see text).

LITHOLOGY

The lake sedimentary sequence consist of light grey clayey silt interrupted by darker grey coarse silt to fine sand mass-flow units which commonly have a sharp lower boundary and a finning upward grain size (Fig. 2). The upper part of mass-flow units are homogeneous clayey silt (homogenite), which together with the coarse basal part (turbidite), has the features of a turbidite-homogenite (TH) unit (Becks et al., 2006; Çagatay et al., 2012)

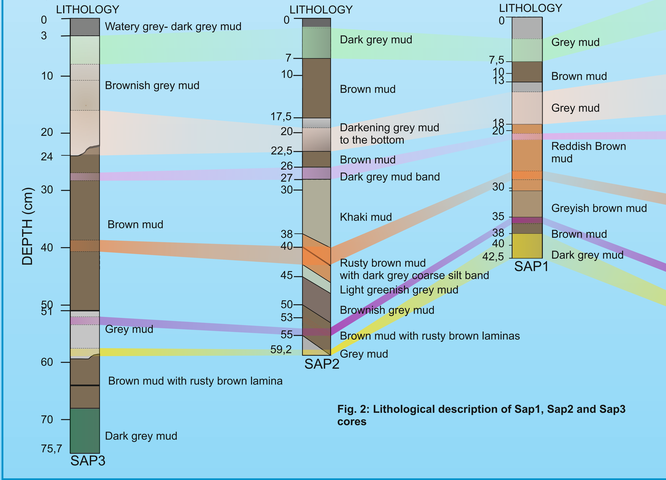
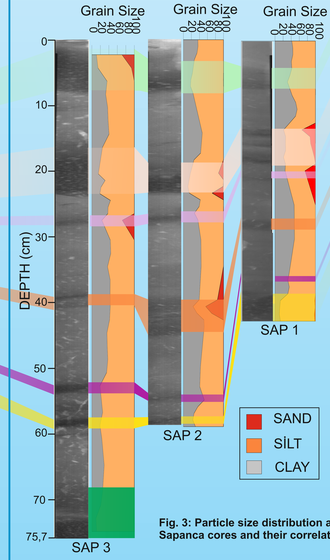


Fig. 2: Lithological description of Sap1, Sap2 and Sap3 cores

GRAIN SIZE ANALYSIS AND RADIOGRAPHY



Analysette 22 Analyzer was used to determine particle size distribution and related parameters (skewness, sorting and mean), at a sampling resolution of 1 cm. The normal lake sedimentary sequence consisting of clay and fine silt is interrupted fine sand and coarse silt intervals representing the mass flow (TH) units. We detected some more TH units in the radiography images, which we could not see by normal visual observation. Such units appear as dark, dense bands in the radiography, corresponding to larger particle size and are shown with dotted lines in Figure 3.

Fig. 3: Particle size distribution and radiography of Lake Sapanca cores and their correlation using these properties

RELATIONSHIP BETWEEN EARTHQUAKE AND MASS FLOW UNITS

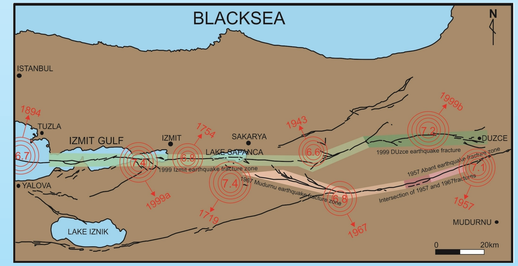


Fig 8: Map of North Anatolian Fault around Lake Sapanca, fracture zones was occured by effected large earthquake and epicenters and magnitudes of historical earthquakes

Mass flow units are characterized in Lake Sapanca sedimentary sequence by sharp basal contact, high gamma and radiography density, coarse grain size, low TOC and high detrital input. Previous studies in similar lake and marine basins show that such units are triggered by earthquakes (Schwab et al., 2009; McHugh et al., 2008; Boex et al., 2009; Çagatay et al., 2012). The topmost mass flow unit (TH1) correlate with the 1999 earthquakes. Conidering the radionuclide chronology,TH2-TH7 units correlate with the 1967, 1957, 1943,1894,1878 and 1754 earthquekes, respectively (Fig 8). Last four earthquakes' fault fractures and epicenters are shown in Figure 8 (Ambraseys et al., 1995; Pantosti et al., 2008; Emre et al., 2013).

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CONCLUSIONS

- Mass flow units in Lake Sapanca cores covering the last 250 years are defined by sharp basal contacts, high detrital input (Si, K,Ti, Rb), low carbonate (Ca) and TOC, high magnetic susseptibility and gamma density, high density in radiography image and increased particle size.
- Based on radionuclide based chronology, sevent mass flow units (TH1-TH7) identified with their special sedimentological, geochemical and physical properties can be correlated with historical earthquakes as follows: TH1: 1999 Izmıt and Duzce Earthquakes, TH2:1967 Mudurnu Earthquake, TH3: 1957 Abant Earthquake, TH4: 1943 Hendek Earthquake, TH5: 1894 Marmara Earthquake, and Th6 and Th7: 1878 and 1754 Izmıt earthquakes.