DETERMINATION OF LAKE LEVEL AND CLIMATE CHANGE BY GRAIN SIZE DISTRIBUTION OF SUBLACUSTRINE CHANNEL DEPOSITS (KARASU-LAKE VAN-TÜRKİYE)

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Abstract: *The objective of this study is to determine the grain size distribution of a sediment core extracted from sublacustrine channels situated on the eastern shelf of Lake Van, extending from the Karasu River, and utilize this distribution to identify changes in lake water levels. The dating of the core was conducted using the varve counting method. According to the results obtained from the research, the 2 meter long core sediment sequence represents 2400 years of history. The clay content of the sediment sequences ranges from 7.06% to 85.1%, the silt content from 12.8% to 90.7%, and the sand content from 0% to 11.2%. The mean grain size ranges from 5.4 to 9.4 Ø. It was determined that during warm, humid periods, the mean grain size decreased and the lake level rose. During cold and dry periods, however, the mean grain size increased, and the lake level decreased. Consequently, six climatic phases were identified during the 2400 years BP, consisting of three cold and dry periods and three warm and humid periods. These phases correspond to the North Hemisphere's climatic phases, which are named in chronological order from oldest to youngest: the Near Aridification Phase, the Roman Warm Period, the Dark Ages Cold Period, the Medieval Warm Period, the Little Ice Age and the Modern Warm Period.*

Keywords: **Climate change, Mean grain size, Lake level changes, Lake Van, Sublacustrine channel**

1. INTRODUCTION

The phenomenon of global climate change has reached a stage where it is creating non-reversable impacts on ecosystems, water cycles and human life. In this context, lakes are among the ecosystems that have been most severely impacted. Temperature increases and alterations in precipitation patterns are causing disruptions to the hydrological equilibrium of lakes, resulting in substantial declines in water levels. Increased evaporation rates and irregular feeding sources are causing many lakes to shrink and some small lakes to dry up completely. In addition, the decrease in dissolved oxygen levels accompanying the rise in temperature negatively affects water quality through processes such as algal blooms and eutrophication, threatening the life cycles of fish and other aquatic organisms living in lakes. The current changes in lake levels impact ecology, water quality and supply, recreation and economy, as well as flood and erosion risks.

Understanding past lake water level changes is essential for comprehending the mechanisms behind current water level changes and making accurate future predictions. Lake sediments are excellent archives of past climate changes, preserving detailed records of environmental conditions over the thousands of years. The grain size in lake sediments is closely linked to lake level fluctuations and can provide valuable insights into past environmental conditions. Grain size distribution in lake sediments has been utilized to reconstruct the hydrological history of lakes related to regional climatic and environmental conditions [1]. Research indicates that larger grain size suggest a dry climate during periods of low lake levels, while small grain size indicates a humid climate during the periods of high levels [2].

Lake Van, the world's largest soda lake, has been the subject of numerous paleoclimatic studies since the 1960s [3, 4, 5, 6, 7]. The most comprehensive of these studies was conducted in 2010 as part of the ICDP PaleoVan Project, recognized in the literature as Anatolia's longest paleoclimatic archive [8, 9, 10, 11, 12, 13, 14, 15, 16]. The PaleoVan (2010) Project and the Bathyvan project (2012) revealed the existence of two sublacustrine channels in the eastern shelf of Lake Van [17]. The present study aimed to investigate past lake water level changes by measuring the grain size of a sediment core taken from one of these channels (Karasu River).

2. Study Area

Lake Van, located on the eastern Anatolian high plateau of eastern Turkey at an altitude of 1648 meters above sea level, is the world's largest soda lake in terms of surface area and the largest lake in terms of volume [18]. Lake Van is situated the Arabian and Eurasian Plates collision zone [19; 20]. The region experiences a lot of seismic activity. The active stratovolcanoes Nemrut and Süphan are located on the western and northern edges of Lake Van, respectively (Figure 1). The southern side of Lake Van is composed of metamorphic rocks belonging to the Bitlis Massif, while the north and northwest is characterized by volcanic rocks, and the east by ophiolitic rocks and lacustrine sediments [21, 22, 23, 24]. The basin is therefore characterized by regional volcanism, seismic and hydro-thermal activity [5, 6, 17, 19, 20, 25]. The Lake Van Basin is influenced by the Siberian High-Pressure System, the Mid-Latitude Subtropical High-Pressure System, and the Monsoon System [6, 26]. It typically exhibits continental climate characteristics, such as cold, snowy winters and hot, dry summers.

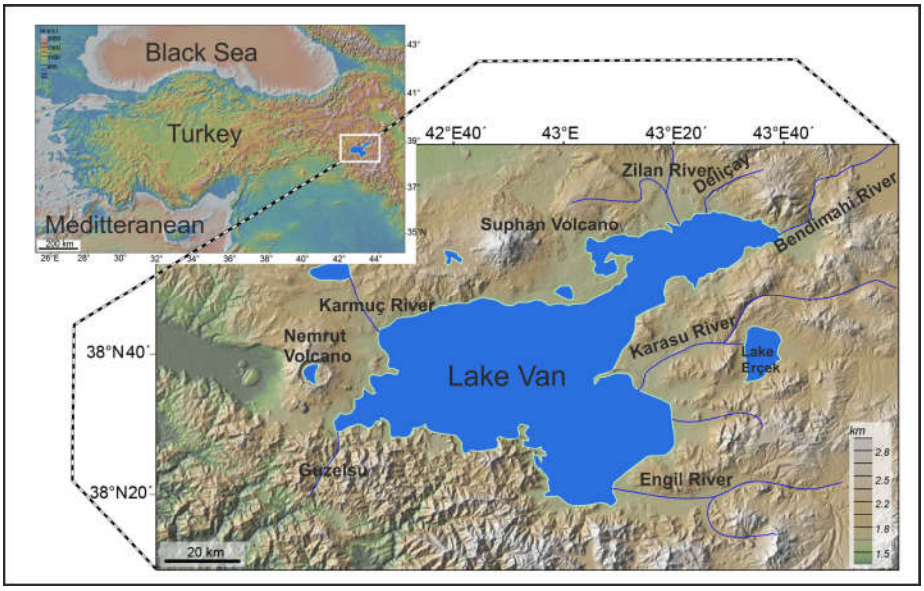

Figure 1. Lake Van and drainage area map (modified from [17]).

Due to its potential for reconstruction, the paleoclimate and palaeoecological development of Near East, Lake Van hosted the International Continental Scientific Drilling Program (ICDP) PaleoVan Project in 2010 [6]. Prior to this project, very limited information was known regarding the morphology about the Lake Van bottom structure [3]. High-resolution profiles and bathymetric data obtained in 2004 and 2012 have revealed the existence of sublacustrine channels on the eastern shelf of Lake Van [17]. One of these channels corresponds to the Morali River, the other to the Karasu River, and they are located on the eastern side of the lake at a water depth of 50-150 m (Figure 2) [7]. These channels can be to 0.5 km wide [17]. They have been interpreted as fluvial-deltaic systems that developed on land during periods of low lake water levels and were subsequently submerged when the lake level rose [17].

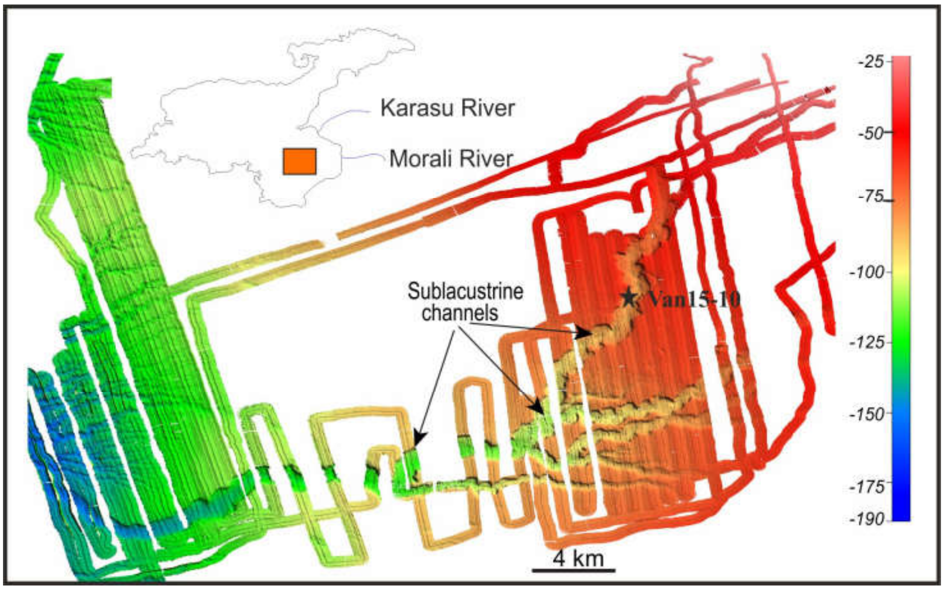

Figure 2. Bathymetry map on eastern shelf of Lake Van showing the Van15-10 core location (modified from [17]).

3. Material and Methods

This study focuses on a short sediment core (Van15-10) collected from one of the sublacustrine channels (Karasu) of Lake Van within the scope of project number 2015-MİM-B106 (Figure 2).

A hammer corer mounted on a floating platform was used for coring during the field trip. The corer was fitted with liners with an outer diameter of 90 mm. The length of the Van15-10 core is 200 cm.

The core was split in half longitudinally. Then the split sections were divided into two parts using two metal plates along the separation line. Metal plates were slide along the same line to prevent surface contamination, enabling the core surface to be split without damage.

The varve counting method was used to establish an absolute chronology for the Van15-10 sediment core. The sediment core was split into 10 mm segments, and the number of varve within each segment was counted under high magnification. The sedimentation rate (SAR) was calculated using the annual sediment laminae. The time interval represented by each segment could then be calculated once the SAR had been determined for each one. This is achieved by dividing the fixed segment length (10 mm) by the SAR to provide a precise time interval length for each segment.

Grain size analysis was performed at 3 cm intervals along the Van15-10 sediment core. A laser diffraction method was employed to determine the grain size distribution, allowing precise measurement across a wide range of particle sizes. Samples were carefully extracted with a toothpick to prevent contamination and preserve the structure of the sediment. Each sample was dispersed in distilled water by stirring and ultrasonication to break down any aggregates and ensure accurate measurements. A laser beam passed through the sample, and the resulting scattering pattern was recorded by detectors. These patterns were processed using specialized software to calculate the grain size distribution. After each analysis, the system was thoroughly cleaned with distilled water to prevent cross-contamination.

4. Results and Discussion

4.1. Age-Depth Model

Data obtained from the varve counting method shows that the sediment sequence in the core Van15-10 covers a period of 2400 years BP. The age-depth model is illustrated as follows (Fig. 3). Although the sedimentation is not uniform throughout the core, an average sedimentation rate of 1.23 mm per year has been determined. This variation in sedimentation rate indicates changes in depositional processes and environmental conditions over the time period.

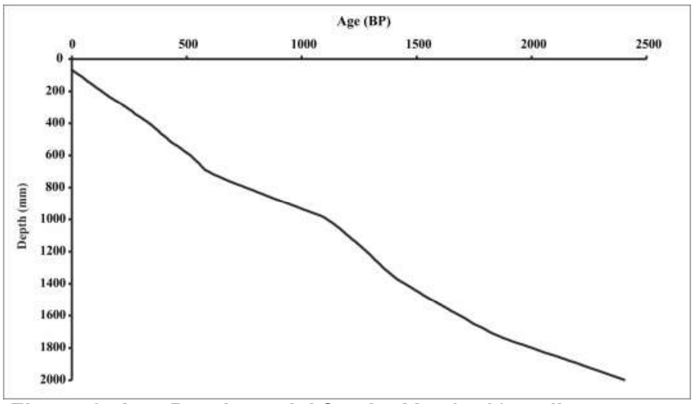

Figure 3. Age-Depth model for the Van15-10 sediment core.

It is important to note that the radiocarbon ages may be inaccurate dure to the presence of carbonate rocks in Lake Van drainage basin, which can result in the reservoir effect. The varve counting method was used as the dating method because previous studies in Lake Van have highlighted the reservoir effect in bulk sediment ^{14}C AMS dating methods [27, 28]. According to these studies, the reservoir effect is not constant and can increase or decrease with depth, which complicates the interpretation of past climate changes in the region.

4.2. Grain Size

Figure 4 illustrates the results obtained from the grain size analyses. The clay content throughout the core ranges from 7.06% to 85.1%, the silt content from 12.8 to 90.7%, and the sand content from 0% to 11.2%. Sediments are predominantly silt sized.

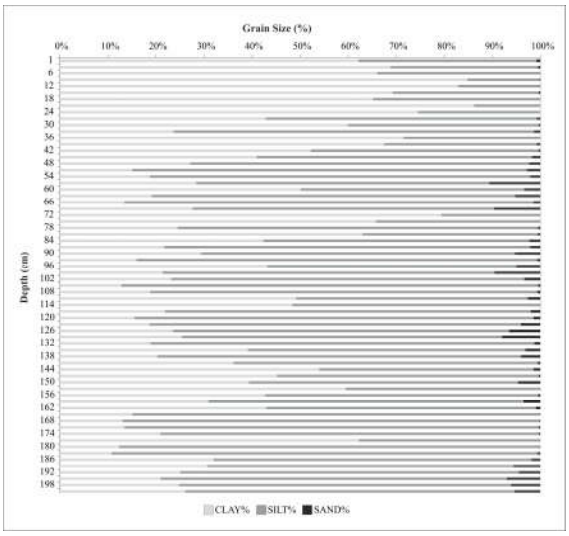

Figure 4. Grain size distribution of Van15-10 sediment core

The mean grain size is presented in Figure 5 and ranges from 5.4 Ø to 9.4 Ø. According to the classification by [29], the grains fall within the medium silt to clay size range.

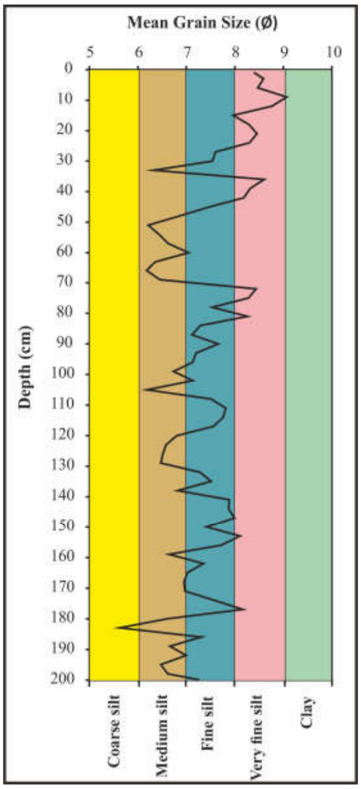

Figure 5. Mean grain size of Van15-10 sediment core

The mean grain size varies between medium silt and coarse silt at a depth of 200-180 cm in the Van15-10 sediment core. At 180 cm, the mean grain size abruptly changes from coarse silt to very fine silt, and up to 140 cm, the mean grain size is predominantly fine silt. Mean grain size shows a uniform coarsening from fine silt to medium silt between 140-105 cm. Between 105-70 cm, the mean grain size shifts from medium silt to very fine silt. The mean grain size changes abruptly at 70 cm, shifting from very fine silt to medium silt size. It remains constant at medium silt size up to the 50 cm level, then abruptly drops back to very fine silt size. Between the 38 and 32 cm levels, the silt size suddenly increases from very fine to medium. From the 32 cm level to the top of the sediment core, the grain size decreases, reaching fine silt and clay.

4.3. Lake Level Fluctuations During the Last 2400 Years

In order to determine changes in lake water level over the last 2400 years, the mean grain size obtained from this study is presented according to the calculated varve ages (Figure 6). The green shaded areas indicate humid, warm periods and consequently high lake levels, while the yellow shaded areas indicate cold and dry periods and consequently low lake water levels.

The mean grain size data obtained from the core indicates variations in sediment deposition processes that are driven by climatic conditions. During warm and humid periods, the grain size tends to be smaller. Conversely, during drier periods, reduced water flow allows the deposition of coarser materials, resulting in larger grain size.

Between 2400-2000 years BP (200-180 cm), the grain size was relatively large, indicating a period dominated by dry conditions. Coarser sediments generally settle during periods of reduced river flow, when the transport of fine particles is more difficult. This suggests that, although sediments are generally coarse grained, finer particles are still present in significant quantities due to intermittent but intense sediment flows. These remarks make it clear that arid climatic conditions prevailed, and the lake water level decreased accordingly between 2400-2000 years BP. This period roughly coincides with the "Near Eastern Arid Phase", a global climate change with solar variability spanning 2925-2200 years BP and affecting regions such as the Aegean, Mediterranean, and Western Asia [30, 31, 32]. This period in Anatolia is characterized by arid conditions in many places [31, 33, 34, 35, 36, 37, 38]. Similar arid conditions are observed in the Near East, at Soreq Cave, Mirabad and Zeribar Lakes [39, 40]. Furthermore, the flow of the Euphrates and Tigris rivers reached its minimum level 1150-950 years ago [41, 42, 43].

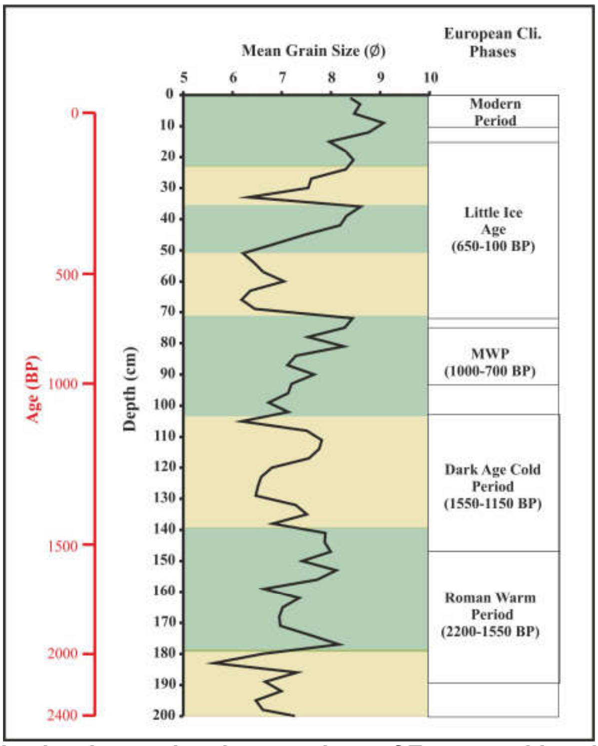

Figure 6. Mean grain size data and and comparison of European historical climate phases (Green and yellow shadows show the warm/humid and cold/dry intervals)

During the 2000-1450 BP interval, the mean grain size decreases, indicating warm and humid conditions. During periods of high lake level, fine grained sediments are transported into the lake. This period roughly coincides with the Roman Warm Period (2200-1150 year BP) in literature [44]. Climate conditions in Anatolia were variable during this interval [37, 38, 48, 49].

Between 1450 and 1160 years BP, the increase in grain size indicates that lake levels were relatively low, suggesting that the conditions returned to a drier state. Larger grains dominated indicated a decrease in sediment transport capacity. This period, known as the Dark Age Cold Period and spanning 1550-1150, is notable for significant transformations in governance, cultural traditions and urbanization within the Eastern Roman and Byzantane Empires [45]. During this period, arid conditions were reported at Lake Salda [46]. Partially arid conditions were recorded at Sofular Cave, Lake Çubuk and Lake İznik. According to previous studies, freezing events occurred in the Black Sea (1150 years BP) and the Nile River (1121 years BP) [47].

The variability in the mean grain size over the period 1160-600 years BP (105-70 cm) indicates changes in climatic conditions. This suggests a transition from drier to wetter conditions, and that the lake's water level is high during this period. This period roughly coincides with the Medieval Warm Period (1000-700 years BP). Lake Salda and Lake

Çubuk are recorded as having experienced a wet-dry-wet cycle during this interval (. Meanwhile, the climate at Sofular Cave, Lake Nar and Lake İznik is reported to have been humid [36, 37, 49]. However, data obtained from Lake Tecer suggested that the climate in central Anatolia was dry [48].

During the 600-150 years BP period, the grain size indicates a shift towards coarser sediment grains compared to previous periods. The region's climate was arid and the lake level was low during this stage. This period corresponds to Little Ice Age (650-100 years BP). Anatolia is cold and dry throughout the Little Ice Age [36, 37, 38, 46, 48, 49].

150 years BP to AD2015, the mean grain size is finer, indicating increased water flow and stable sedimentation conditions. This finer grain size reflects consistent sediment transport processes, typically associated with higher water levels and humid conditions, and corresponds to the Modern Warm Period (AD 1850-present).

5. Conclusion

The 2 meter long core recovered from sublacustrine channels from the eastern shelf of Lake Van represents approximately 2400 years BP. Grain size distributions obtained from this study reveal three cold and dry periods and three warm and humid periods over the last 2400 years. During warm and humid periods, mean grain size is generally fine and lake water levels are high. Conversely, during cold and dry periods, the grain size becomes coarser and the lake water levels are low. The cold and dry periods and the warm and humid periods are consistent with European Climate Stages such as the Near Aridification Phase, the Roman Warm Period, the Dark Age Cold Period, the Medieval Warm Period, the Little Ice Age, and the Modern Warm Period.

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