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The Effect of Atlantic and Monsoon Variability on a Neolithic site in Upper Mesopotamia

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Abstract

In this study, stable isotope analyses of calcium carbonate soil samples detected in Neolithic fillings at Sumaki Höyük were performed to determine the causality of climate variability. Approximately 2000-year cycles have been 9000-8000, 6000-5000, 4200-3800, 3500-2500, 1200-1000, and 600-150 years BP, with a current total of six occurrences which are called Rapid Climate Change (RCC). Additionally, since the beginning of the early Holocene, at least eleven similar events with much more effective and rapid climatic changes, such as the 10.2, 9.2, and 8.2 ka events, have been defined. The most discussed climate change event in the Holocene occurred 8200 years ago, known as the 8.2 ka event. There are variations in dating among many studies concerning the 8.2 ka event. While numerous studies have focused on the impact of the 8.2 ka event on Neolithic cultural changes, "collapse," and migration phenomena, the potential impact of the 9.2 ka event on culture has been rarely explored. The focus is on determining the global and local events of the climatic changes in Northern Mesopotamia in the period between 9.2 and 8.2 ka. The global climate data were analysed separately with data from various areas and in each phase, the scale representing the Neolithic period at Sumaki Höyük and macro-micro factors were discussed. It was therefore attempted to interpret the presence or effects of the Monsoon and Atlantic interactions on Neolithic climatic anomalies of the Sumaki Höyük settlement. As a result, the causality of the settlement and its abandonment, along with changes in the settlement strategy, were interpreted.

Keywords: *Rapid Climate Change, Neolithic, Monsoon, Atlantic, Upper Mesopotamia.*

Resumen

En este estudio, se realizaron análisis de isótopos estables de muestras de suelo de carbonato de calcio detectadas en rellenos neolíticos en Sumaki Höyük para determinar la causalidad de la variabilidad climática. Los ciclos de aproximadamente 2000 años han sido 9000-8000, 6000-5000, 4200-3800, 3500-2500, 1200-1000 y 600-150 años AP, con un total actual de seis ocurrencias que se denominan Cambio Climático Rápido (RCC). . Además, desde principios del Holoceno temprano se han definido al menos once eventos similares con cambios climáticos mucho más efectivos y rápidos, como los eventos de 10,2, 9,2 y 8,2 ka. El evento de cambio climático más discutido en el Holoceno ocurrió hace 8200 años, conocido como el evento 8,2 ka. Existen variaciones en la datación entre muchos estudios sobre el evento de 8,2 ka. Si bien numerosos estudios se han centrado en el impacto del evento de 8,2 ka en los cambios culturales, el "colapso" y los fenómenos migratorios del Neolítico, el impacto potencial del evento de 9,2 ka en la cultura rara vez se ha explorado. La atención se centra en determinar los eventos globales y locales de los cambios climáticos en el norte de Mesopotamia en el período comprendido entre 9,2 y 8,2 ka. Los datos climáticos globales se analizaron por separado con datos de varias áreas y en cada fase se discutió la escala que representa el período Neolítico en Sumaki Höyük y los factores macro-micro. Por lo tanto, se intentó interpretar la presencia o los efectos de las interacciones monzónicas y atlánticas en las anomalías climáticas neolíticas del asentamiento de Sumaki Höyük. Como resultado, se interpretó la causalidad del asentamiento y su abandono, junto con los cambios en la estrategia de asentamiento.

Palabras claves: *Cambio climático rápido, Neolítico, Monzón, Atlántico, Alta Mesopotamia.*

1 Introduction

Several studies (Flohr et al., 2015; Bar-Matthews et al., 1999; Landmann et al., 1996; Migowski et al., 2006; Stein, 2001) have been carried out to determine the past climate changes in Mesopotamia and its vicinity in the last two decades. In this study, carbon and oxygen isotope analysis and the effect of the Atlantic-Monsoon variability are informative on climate changes between the 9.2 and 8.2 ka events in the mountainous-plain zone of Upper Mesopotamia, where Sumaki Höyük is located. Average weather conditions that do not change for many years within a wide region are called “climate”. During the geological processes, significant changes were experienced in the climate. In the past, as today, the areas in the middle latitudes with climate variability were the highest. This is globally significant and is particularly more noticeable in semi-arid regions like Mesopotamia. The increases in sunshine duration in and around the equator in the early Holocene caused the position of the Intertropical Convergence Zone (ITCZ) to change. With increasing isolation, the position of the ITCZ has shifted from its present position to more northern latitudes. Due to this change, the rainy period in the summer affected the northern latitudes more than today and caused some important changes on the climate of these areas (Haug et al., 2001; Fleitmann et al., 2007). Although the Holocene globally has a warming trend, warming was not incessant and cooling processes were also effective in some periods. These fluctuations in temperature change led to the shaping of the natural environment and affected human lifestyle.

On a global scale, climate changes in the Plio-Quaternary began with a clear difference from the evaporitic conditions of the Upper Miocene geological era. After this period under the effect of warmer conditions, a colder climate cycle occurred, especially in the Upper Pliocene. Generally, with a falling temperature trend, occasional short intervals of warm or more freezing oscillations were observed. Cycles periodically occurring of 100,000 or 41,000 or 19,000-23,000 years defined in different models led to warmer and colder climate variations following each other. These cyclical climate changes continued in the Holocene in various forms. A warming trend beginning after the Last Glacial Maximum occurred about 14,000 years ago. This trend was partly broken by active cooling immediately afterwards with a thousand-year scale called the ”Younger Dryas”, and periodically continues with sudden climatic changes in the Holocene (Staubwasser & Weiss, 2006: 372). In consideration of orbital factors, the last cyclical variability (Hoek & Bos, 2007: 1904) in summer solar energy in the northern hemisphere rose in 12,000 BP to reach a peak at 9000 BP. A state like the present climate structure was reached in 6000 BP (Hoel, 1997: 41).Since the Last Glacial Maximum, the climate is known to have changed to a significant degree (Weninger et al., 2009: 8; Bar-Matthews et al., 1999: 89) and our knowledge has been enriched by numerous climate change studies. Sudden climate changes occurring at approximately 2000-year periods are defined as Rapid Climate Change (RCC) (Hughen et al., 1996: 96; Migowski et al., 2006: 427; Staubwasser & Weiss, 2006: 378-379; Weninger et al., 2009: 48; Weninger et al., 2014: 8). These cycles have been calibrated to 9000-8000, 6000-5000, 4200-3800, 3500-2500, 1200-1000 and 600-150 BP, with a current total of six (Mayewski et al., 2004: 244-246; Migowski et al., 2006: 427) Since the beginning of the early Holocene, at least eleven similar events with a much more effective and rapid climatic change (the 10.2, 9.2 and 8.2 ka events) are defined (Berger et al., 2016:1848; Park et al., 2019:9 fig. 7). However, the greatest climate change most discussed in archaeological literature that occurred in the Holocene is the 8.2 ka event of 8200 years ago (Morrill & Jacobsen, 2005: 1). Many studies on the 8.2 ka event show differences in terms of dating (Ahn et al., 2013: 605; Barber et al., 1999: 346-347; Berger et al., 2016: 1849 fig.1; Thomas et al., 2007:75 Table 1). Although there are many studies about the effect of the 8.2 ka event (Staubwasser & Weiss, 2006; Flohr et al., 2015) on the Neolithic cultural changes and/or “collapse” and the phenomenon of migration, the potential impact of the 9.2 ka event on the culture has rarely been explored (Berger et al., 2016: 1848; Flohr et al., 2015: 24; Zhang et al., 2018: 2767).

A series of paleoclimate record data shows that 9.2 ka in the northern hemisphere is a common and important climate anomaly. This phenomenon is very similar to the climatic anomalies experienced in 8.2 ka. The 9.2 ka event is characterized by a cold climate in high and medium latitudes and by an arid climate in lower latitudes and in the tropic zone (Fleitmann, 2008: 1) Furthermore, based on the synthesis of other Holocene climate records from the Asian summer monsoon region, it was realized that the 9.2 ka event also constituted the strongest sudden “collapse” of the Asian monsoon system (Zhang et al., 2018: 2767). In addition, samples taken from the Hoti cave to the north of Oman where the monsoon climate region dominated showed that $\delta 18O$ values changed during the 9.2 ka event (Fleitmann et al., 2007: 176). Although it is difficult to estimate the duration of this climate anomaly, the process seems to be less than 150-200 years (Fleitmann, 2008: 1). The relationship between cultural differentiation and the timing of the climate changes of the 9.2 ka and 8.2 ka events are still questioned. This suggests that there may be a relationship between cultural changes and sudden climatic events (Berger et al., 2016: 1859, 1860).

2 Methodology

Description and Paleoenvironmental Features of Study Area Sumaki Höyük is located 1 km east of Beşiri district in Batman province in the southeastern part of Turkey. It was first discovered in 2002 during a surface survey and then excavated for 5 seasons between the years 2007-2014 within the framework of the Ilısu Dam Salvage Project. The site is positioned in the northern portion of the Lower Garzan Valley, nearly 2.5 km east of Garzan Stream, which is one of the main branches of the Tigris River (Fig. 1). The settlement was founded on ground slightly sloping in a southwest-northeast direction on an erosion surface with an elevation of 700-710 meters. According to the excavation data, the settlement seems to have been bordered by seasonal streams or tributaries with marshy areas to the north and south and had the character of a settlement placed on southeast-northwest oriented natural terraces. The dimensions of the settlement, positioned on the mountain-plain transition zone (namely, the "Hilly Flanks" of Braidwood's), are approximately 160 m (N-S) to 140 m (E-W), with its deepest fill thickness being approximately 2.4 meters (Erim-Özdoğan & Sarıaltun, 2018).

Although Sumaki Höyük was mainly occupied during the Early Pottery Neolithic Period, it had a phase with LPPNB features and a limited phase with shallow fillings dated to 833 cal AD. An area of 2180 m2 was exposed and seven Neolithic phases were detected from the natural soil (from bottom to top phases N7-N1) dated to 9084 – 8123 BP. The seven phases, which were sometimes interrupted by natural events such as floods and torrents, displayed a different character not only in the settlement patterns but also in other assemblages. While phases N7, N3 and N1 are temporary campsites with pottery, Phase N6 is a permanent settlement without pottery, whereas during Phase N5, the settlement seems to be occupied by both sedentary and mobile people using pottery in small numbers. Phase N4 has a permanent character, however, it was not long termed because of frequent flood and torrent events. Phase N2 is an intensively occupied temporary campsite with some parts that seem to display relatively permanent features. Although Phase N1 is a temporary campsite, it resembles a different culture with a different pottery tradition than in phases N7 and N3 (Sarıaltun, 2019).

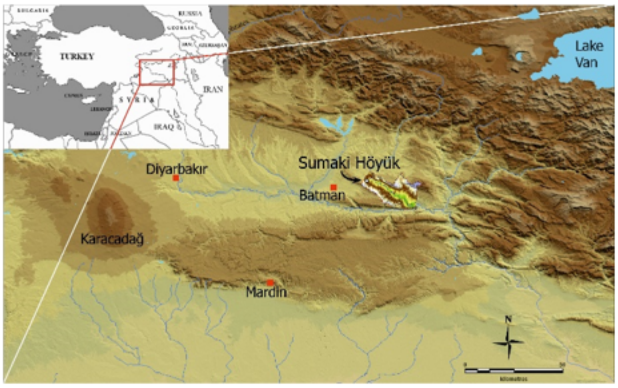

Figure 1: Location of Sumaki Höyük Neolithic settlement.

In the Neolithic layers of Sumaki Höyük, many flood/inundation/soil flow traces have been identified, with two particularly well-defined. Due to these external factors, the settlement was abandoned at intervals. Abandonment of the settlement was not only determined by archaeological data but also geological processes. In the upper levels of Phase N4 fill, a 2-3 cm-thick soil formation was identified which occurred after a probable flood, creating an aqueous environment. Pottery sherds in some of the Neolithic layers (e.g., phases N7, N5 and N4) have greenish-coloured oxidized surfaces (Fig.2a) and many animal bones agglutinated to lime (Fig.2b) show that the archaeological material remained affected for a long duration under water.

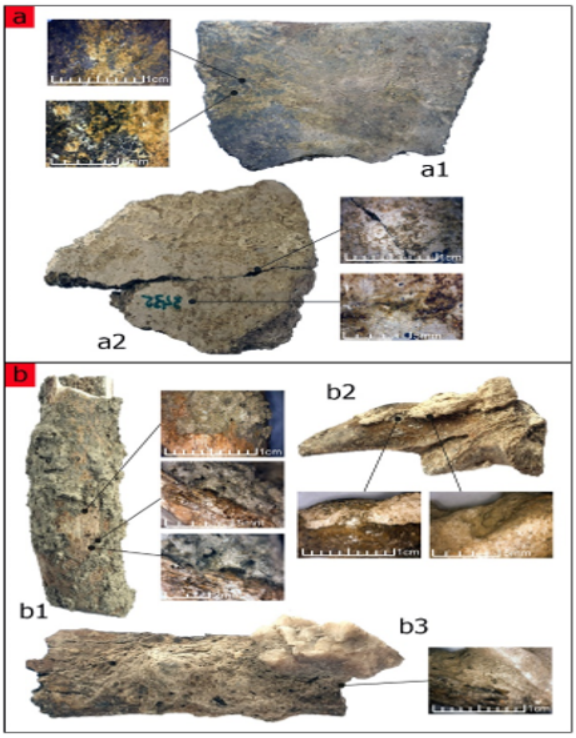

Figure 2: Archaeological fragments found in Sumaki Höyük Neolithic.

Archaeological material such as sherds, figurines, chipped stone tools, etc. that were swept away by torrents or inundations have accumulated in depression areas, particularly at the end of phases N5 and N2 (Fig. 3) Since heavy materials like ground stone objects were not exposed to this motion, it is understood that the carrying capacity of the flow rate of inundation or soil flows in the Neolithic period was relatively low. Heavy flooding or soil flows that disturbed or covered the structures entirely did not occur at Sumaki Höyük and its environs, at least in the Neolithic period.

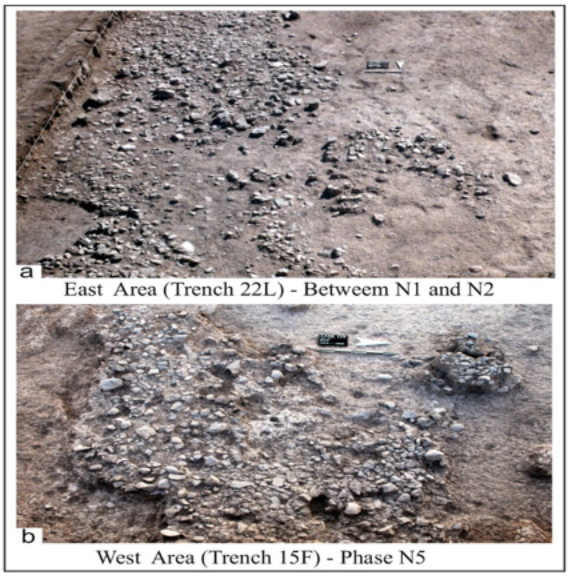

Figure 3: Flood/torrent remains at different phases of Sumaki Höyük Neolithic settlement.

Examination of various organic materials in sediments and soils provides information about the climatic conditions for the study area. Both stable (H, O, C, N, Ca, Sr, Cu, Pb, S) and unstable (U, Th, K, Ar) isotope techniques have been analysed as part of archaeological research (Maoffat, 2014: 106). Isotope analyses are quite prevalent for defining climatic and environmental conditions in the past and for establishing the paleo-environment of the study area. Stable isotope analyses of calcium carbonate soil samples detected in Sumaki Höyük Neolithic fillings were performed to determine the causality of the climate variability. Thirty calcium carbonate samples taken from Neolithic layers were sent to the Environmental Isotope Laboratories at Arizona University for isotope analysis. δ18O and δ13C of the carbonates were measured using an automated carbonate preparation device (KIEL-III) coupled to a gas-ratio mass spectrometer (Finnigan MAT 252) by Dr. David Dettman. Powdered samples were reacted with dehydrated phosphoric acid in a vacuum at 70°C. The isotope ratio measurement is calibrated based on repeated measurements of NBS-19 and NBS-18, and the precision is ± 0.10 ‰ for δ18O and ± 0.08 ‰ for δ13C.

Careful attention was paid to sterilization during sampling and different elevations were selected from the same area, especially to give a consecutive sequence. Calcium carbonate samples were selected with particular attention to both the sedimentological depositional data and historical succession. In addition, each sample group was analysed and interpreted in comparison with the archaeological data, both horizontally and vertically. Samples were selected from the two areas of the settlement where the most sterile and cultural fill data are most consistent. One of these areas is Trench 14G and the other is Trench 15G (Fig. 4). The most important reason for taking samples from the building walls is to avoid comparisons with possible later or earlier fills in open areas and to identify the historical data with the utmost precision.

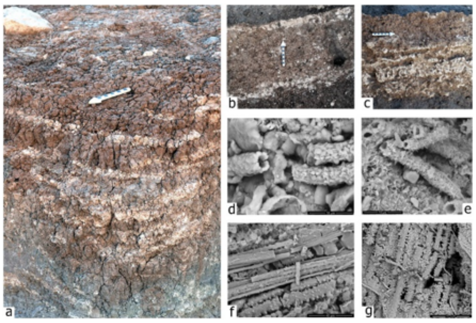

Figure 4: Lime pieces in structure wall sections from Neolithic Period of Sumaki Höyük (a-c) and their SEM images (d-g).

Climatic conditions of Near East between 9.2 and 8.2 ka events

The Near East's climate is affected by a mutual relationship between the dominant climate types in Europe, North Africa, and Asia (Bar-Matthews et al., 1999: 86; Gat & Magaritz, 1980: 82). For example, storms arising in the Atlantic Ocean noticeably affect the Near East (Gat & Carmi, 1987: 515 Fig. 1) (Fig. 5). Being a transition region between humid climates to the north and dry climates to the south, and despite this unique location, paleoclimatic or paleo-environmental research (Caneva et al., 1993; Doğan, 2002; Marcollongo & Palmieri, 1992; Kuzucuoğlu, 2002; Özdoğan, 1997; Pustovoytov et al., 2007; Riehl et al., 2009) in northern Mesopotamia is insufficient. The long-term trend toward arid conditions in the Near East is related to regionally complex monsoon evolution (Gat & Carmi, 1987: 522; Staubwasser & Weiss, 2006: 372; Weninger et al., 2009: 17).

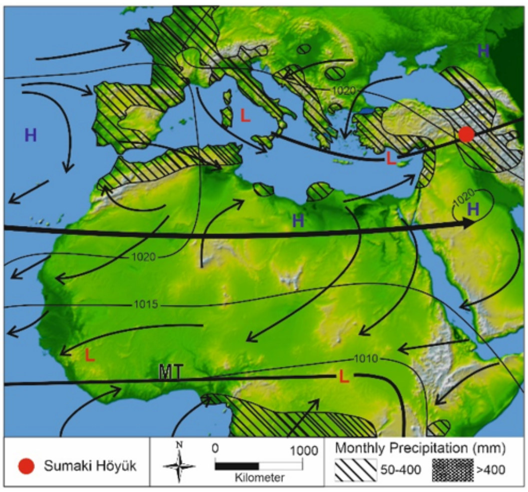

Figure 5: January average surface pressure, surface and upper atmospheric winds and rainfall in North Africa and Mediterranean basin (adapted from Barry and Chorley, 2003).

In areas where the monsoon effect prevailed, a reduction in the northward migration of the Intertropical Convergence Zone (ITCZ) balanced the air column over the Eastern Mediterranean region and prevented the formation of rain clouds. Due to this ITCZ effect, aridity was experienced in the Near East throughout the whole year, especially in the summer months (Alley & Águstsdóttir, 2005: 1130; Haug et al., 2001: 1307; Rohling & Palike, 2005: 975) (Fig. 6). As a result of the southward movement of the subtropical belt, the Mediterranean basin was invaded by Atlantic air currents, causing significant cooling. The combination of cold and dry weather with relatively warm sea water partly destabilized evaporation and formed cyclones (Gat & Carmi, 1987: 514).

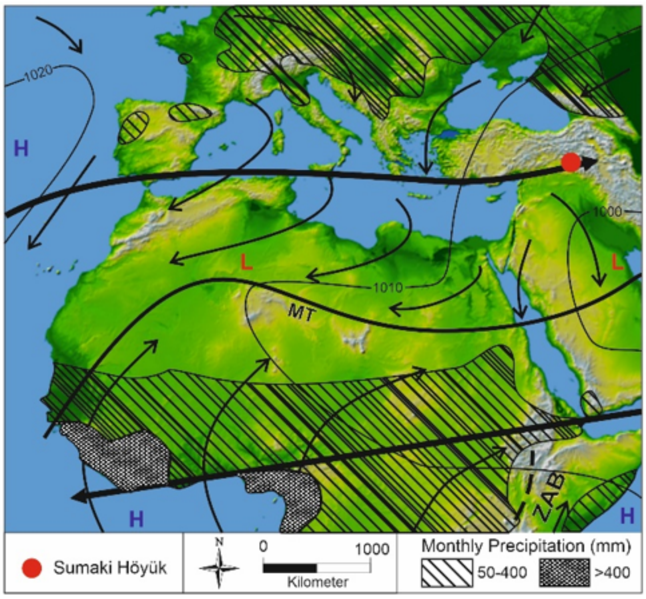

Figure 6: July average surface pressure, surface and upper atmospheric winds and rainfall in North Africa and Mediterranean basin (adapted from Barry and Chorley, 2003).

From 8600 to 8000 BP), the eastern Mediterranean region had a regular winter/spring cycle at intervals but was under the effect of a very cold polar air mass (Hoek & Bos, 2007: 1904). As a result of the strengthening of atmospheric circulation above the North Atlantic and Siberia, in periods with RCC such as the 8.2 ka event (Fig. 7), a regional airflow came directly from Siberia producing days or even weeks of winter and spring onset conditions (Mayewski et al., 2004: 249; Weninger et al., 2009: 17). During the well-known climate oscillation in Holocene of the 8.2 ka event, glaciers advanced in the northern hemisphere according to North Atlantic and Siberian records. However, this period lasted only a short time (Morrill & Jacobsen, 2005: 1; Mayewski et al., 2004: 250). In the accepted approach to the 8.2 ka event is that it is the a result of polar heat transported north, after which meltwater was released and affected the North Atlantic Deep-Water formation and circulation (Alley & Águstsdóttir, 2005: 1133; Hoek & Bos, 2007: 1904; Morrill & Jacobsen, 2005: 1; Rohling & Palike, 2005: 975; Weiss & Bradley, 2001: 610; Wiersma & Jongma, 2010: 547).

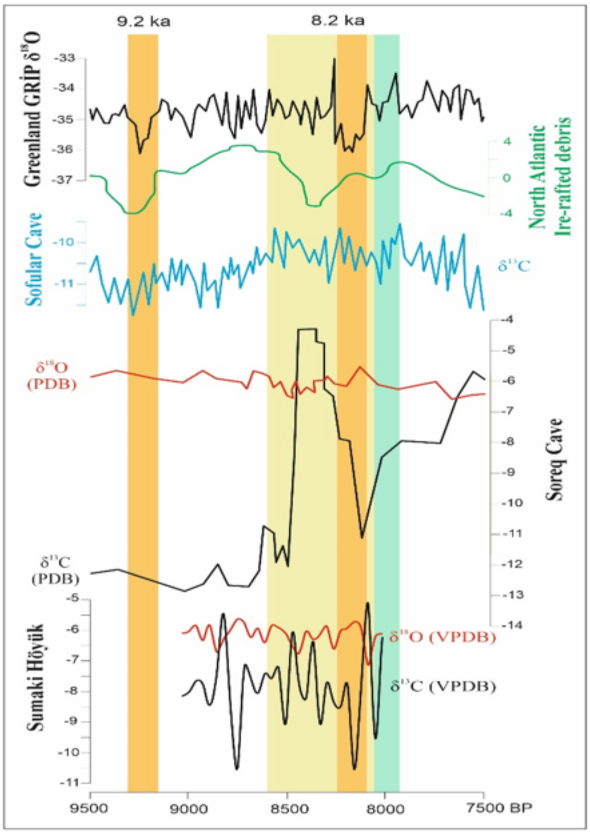

Figure 7: Diagram showing evidence for 9.2 and 8.2 ka events and Sumaki Höyük isotope results integrated with these data (adapted from Berger et al., 2016: 1849 fig. 1; Berger and Guilaine, 2008: fig. 5; Weninger et al., 2009: 16 fig. 5; Bar-Matthews et al., 2003: 3190; Flohr et al., 2015: Fig.1 and Sarıaltun, 2019, Diagram 3.11).

The rapid climate change in the Near East during early Holocene is understood from a range of regional differences. The Jordan Valley experienced a very humid period from about 10,000 to 8600 BP. After nearly a 200-year cold period around 10,200 BP, this short-term cold period was replaced by a milder and humid climate at 10,000 BP. This relatively warmer and more humid period ended suddenly, and a cold period was experienced from 8600 to 8000 BP (Fig. 8). Both RCC cases (10.2 ka and 8.6 - 8.0 ka BP) show that at intervals, the Eastern Mediterranean region was under the effect of cold polar air, although within a regular winter/spring cycle. In parallel with this cold period, there are falls in the water level of the Dead Sea and Lake Van around 8600 - 8000 BP (Fig. 9) When we gather all this data, it is evident that within a certain period the Near East experienced rapid aridity (Landmann et al., 1996: 801; Migowski et al., 2006: 247; Özdemir et al., 2013: 967-968; Weiss, 2000: 76).

However, according to Soreq Cave data, there were occasional severe rains within this arid period (Bar-Matthews et al., 2003: 3182-3185) which can be explained by the monsoons' circulation, with similar precipitation characteristics today. Similar rainfalls are also effective today, depending on effects of the ITCZ during the season, which is called the "monsoon" season. There is a significant change only in areas where precipitation is effective. The short-term dry period at about 8000 BP, which is particularly mentioned in studies based on Soreq Cave data (Bar-Matthews et al., 2003: 3182-3185, 3190; Weninger et al., 2009:16), can be considered as a dry period without monsoon rains. The fact that Sumaki Höyük is located in the impact area of the hot and dry air masses, which form the western end of the monsoonal cycle today, described as the Basra Low-Pressure System, strengthens this prediction. The critical location of Lake Van in the path of the atmospheric southwest jet stream and northern belt of subtropical high pressure enables interpretations of the Near East paleoclimate (Landmann et al., 1996; Wick et al., 2003; Reimer et al., 2009). Core studies of the lake floor and its terraces are understood to reflect an uninterrupted climatic archive from the Late Pleistocene to the Holocene. Dramatic falls in the water level of Lake Van were observed between 9600 and 6400 BP. The primary cause of drops in the water level is reduced humidity and increased evaporation. Accordingly, in the late glacial stage up to 10,000 BP, the lake rose 40+ m above its current level. After this rising stage, rapid falls and small partial rises occurred in the lake level (Pre-boreal, Boreal and Atlantic phases). This fall continued until 6000 BP. According to cores from the lake, the salinity of the lake water reached its maximum level throughout 10,000-6000 BP, which is described as the "Salinity Crisis" (Özdemir et al., 2013: 966).

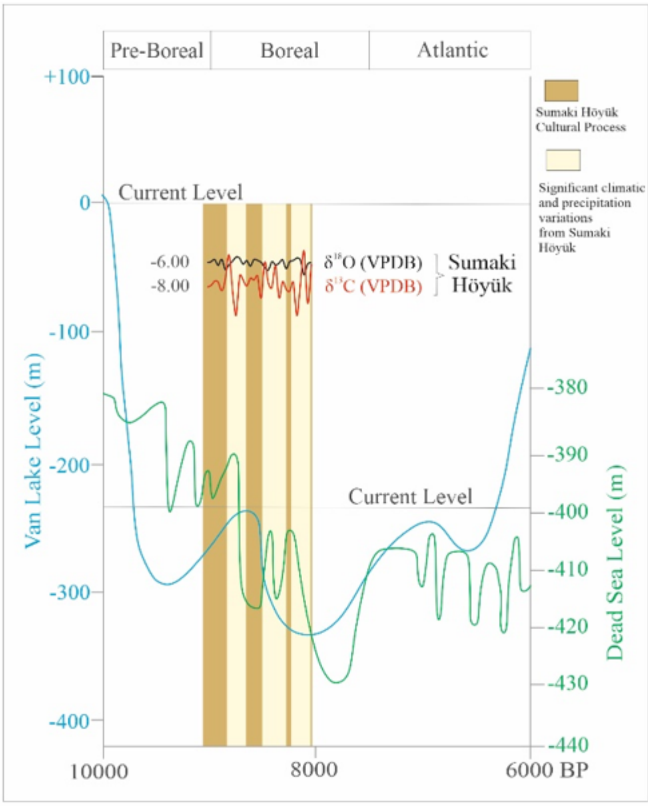

Figure 8: Lake level changes showing evidence of 8.2 ka event and Sumaki Höyük isotope results integrated with these data (adapted from Migowski et al., 2006: 427 Fig. 4; Litt et al., 2012: 101 Fig. 5d; Stein et al., 2001: 279 Fig. 7 and Sarıaltun, 2019: Diagram 3.1).

The Dead Sea data is a critical and sensitive recorder of Quaternary climate variability in the Near East (Migowski et al., 2006: 422). According to sediment traces and lake level data from the watershed of the Dead Sea, two large humid stages and more than one rapid arid event have been documented during the Holocene (10-8.6 ka BP and 5.6-3.5 ka BP) (Stein, 2001: 280). The Dead Sea comprises two sub-basins, and according to a thinner laminated aragonite series in the Ze'elim area between the two basins, humid conditions were dominant from 10 to 8.6 ka BP. However, there appears to be a very long depositional gap between 8.2 and 5.6 ka BP in Ze'elim. According to the Ze'elim sediments, a layer of gypsum and sand was deposited during the 8.2 ka event (Migowski et al., 2006: 425). This fill indicates shallow water conditions, and it is understood that an apparent fall in water level was experienced in the years around 8200 BP. In this period, the lake level fell by about -416 m.

The fluctuations in the lake level of the dry and humid periods are given in the graph (Fig. 8) However, there is a corrolation between humid and dry periods and lake level changes in general, contrary to the common trend. A hort-term partial increase in lake levels in dry periods and decreasing lake levels during humid periods can be explained; the fact that precipitation can be greatly affected by other atmospheric events. But it is emphasized that the process also triggers anomalies caused by the general circulation. This can be explained by the deviation of the ITCZ from its usual cycle and, accordingly, the monsoons' circulation.

Climatic conditions and its probable effect on occupations of Sumaki Höyük in the Neolithic period

The assumption that similar physical factors controlled past variations in δ18O and δ13C up to the present day allows us to reconstruct paleoclimatic conditions. Isotope components and composition may be used to determine the annual precipitation amount and temperature for our study area, and from these, inferences can be made on paleoclimate conditions. In our study, the relationship and process affecting the oxygen isotope composition and meteoric oxygen isotope in soil carbonates were explained in detail.

Carbonate sediment (CaCO3) samples from the Neolithic deposits of Sumaki Höyük were subjected to δ18O and δ13C isotope analyses. Carbon isotope analyses determined extraordinarily high δ13C curves for the years between 9084 - 8123 BP, and especially from 8501 to 8491 BP and from nearly 8200 to 8150 BP (Fig. 7, 8). According to the δ13C isotope values, a clearly arid period was identified between those eras. In those years, there was significant drought at Sumaki Höyük and its surroundings, according to δ13C isotope values. If these maximum δ13C values are compared with δ18O isotope values for the same period, a definite warm period existed, especially around 8501 - 8491 BP (end of Phase N5).

According to the isotope values and archaeological data, cold and wetter periods were experienced immediately before and after this warm-dry period. These cold and wet periods are better defined for the years 8526, 8491-8461, 8436 BP, and about 8250 - 8200 or 8200 - 8150 BP. Regarding isotope values, after a relatively stable period in Phase N5 between the years 8501 to 8491 BP and in Phase N1 around the years 8123 BP, the δ13C curves invert. It is highly probable that more than one dry-warm period was experienced during these years. A cold-wet period occurred especially between the years 8491 and 8461 (end of Phase 5) and at nearly 8250-8200 BP (end of Phase N2) (Fig. 7, 8).

Accordingly, various analyses indicate that climatic changes such as warm-and-humid, warm-and-dry, cold-and-humid, and cold-and-dry periods were experienced sequentially between 9084 and 8123 BP. In other words, Sumaki Neolithic settlement was understood to be occupied between the 9.2 ka and 8.2 ka events, the time the climate change crises occurred. These climatic fluctuations affected the loose clayey units beneath the Kıradağ basalt flow south of Sumaki Höyük, which resulted in frequent flooding, overflows or earth flows that affected the settlement. This is probably one of the main reasons why the settlements of Sumaki Höyük were partially interrupted, and the area was not occupied permanently. Another fact might be the environmental character of this region; being in the mountain-plain transition zone was favourable for semi-nomadic communities, as it is today. In the Neolithic period, specifically the PPNB, the presence of semi-nomadic communities has been discussed at length; however, most of the time the hypotheses are questionable because of the vague nature of the data. Sumaki Höyük excavations, albeit in a limited area, offer some data on this problematic issue. With the deterioration of a harmonised lifestyle in PPNB settlements due to climatic changes between 9.2 ka and 8.2 ka, the partial or total abandonment of the settlements is what led the PPNB communities to adopt a lifestyle whereby they could maintain their 'long standing' habits.

3 Results and discussion

The general features and climatic characteristics of the mountain-plain zone of southeast Anatolia are high temperatures in summers and low temperatures in winters. Although the annual precipitation is over 500 mm, the amount of precipitation is quite low in warm seasons. The precipitation in winters, when precipitation increases, is mostly in the form of snow. Snow melts rapidly when temperatures increase, sometimes joining surface flows and sometimes flowing along stream beds.

The δ18O and δ13C analysis of the Sumaki Höyük calcium carbonate samples shows that the study area experienced warm-and-cold and dry-and-humid climatic conditions in different periods. According to chronological isotope releases, cold periods were generally humid, and it is seems that there were severe droughts in warm periods. Humid periods identified in the study area display a similarity to the results of the study by Flohr et al. (2015). It is possible to explain these climatic changes in the past by Earth's orbital changes and changes in the solar activity of the sun (Mayewski et al., 2004; Marino et al., 2009). The location of pressure centres in the General Atmospheric Circulation and their displacement across latitudes determine the climate of many areas. This also triggers variations in the circulation between years and accounts for possible long- or short-term differences in climatic conditions. Significant and long-lasting changes in atmospheric circulation have been observed from the past to the present. Paleoclimate simulations have shown that summer temperatures are warmer, warming land surfaces faster than ocean surfaces and increasing the land-ocean temperature contrast. During reduced insolation and cooler summer temperatures, monsoon activity has been simulated to decrease (Chase et al., 2003; de Noblet et al., 1996; Prell and Kutzbach, 1987).

The monsoon circulation and Atlantic-derived circulations play a substantial role in the climatic conditions of the northern hemisphere. It is suggested that the monsoon Circulation oscillates between the southern and northern hemispheres throughout the year, depending on the activity of the Intertropical Convergence Zone (Chao and Chen, 2001; Gadgil, 2003). Similarly, the Atlantic circulation is also reported to be a circulation pattern that varies significantly from past to present due to changes in the depth of the warm ocean layer (Bahr et al., 2022). The most extreme wet periods were also detected by Alley et al. (1997), and were experienced before the short-term cooling. As determined in the archaeological excavations of the study area, it can be argued that the Atlantic circulation became evident in 8200 BP, following the humid periods that caused flood-and-torrent accumulations. According to isotope data, the traces of the long-term dry period that the temperatures decreased due to the effect of the increasing Atlantic circulation are evident. As Mayewski et al. (2004) and Zhang et al. (2014) have mentioned, summer monsoons over the Arabian Sea and Tropical Africa have weakened and fluctuations have been experienced in Alize winds due to Rapid Climate Change. While permanent droughts were experienced in Pakistan, precipitation increased in the Middle East. Considering the location of the study area, the occurance of humid periods might be an increasing effect of the Atlantic circulation. At the same time, the isotope analysis indicates that humid-and-cold seasons were experienced during these periods. In this context, it is suggested that the monsoon circulation is effective from time to time while the northern Atlantic circulation is active occasionally in the study area. The data of humid periods are clear accumulations of the flood-and-torrent fills observed in the site. Designated as 1 and 2 in the chart, flood-and-torrent episodes are evident. During these periods, unlike temperatures between the years 8708-8123 BP, cold periods are more dominant. This can be a micro-scale evidence of the impacts of the North Atlantic and Arctic Oscillations, which are an important determining factor on the study area's climatic conditions. Similarly, the North Atlantic Oscillation / Arctic Oscillation, which has an impact on humid conditions today, is the most reliable explanation of the humid-cold periods in the years 8708-8123 BP.

The Asian Monsoon, an important component of the global climate system, plays an important role in transporting temperature and humidity from tropical regions to higher latitudes (Yang et al. 2016). Ziv et al. (2004) proved that there was a link between the Asian Monsoon and the Middle Eastern summer regime. Today, as in the past, the climatic conditions of the Near East are controlled by the subsidence structure in the middle levels of the atmosphere due to the monsoon circulation. This circulation is the most important factor leading to the lack of rainy conditions around the study area. As explained in the study by Ziv et al. (2004), the monsoon circulation has caused subsidence in the upper atmosphere, leading to the development of hot and arid conditions in the past as well as in the present. Long-term fluctuations in the monsoon circulation have altered the rainfall pattern. It is understood that the hot and arid period in 8123, 8395 and 8491- 8526 BP when the precipitation anomalies in the study area were in an arid trend, caused the monsoon to form a determinant circulation pattern in the region and led to the development of hot and arid conditions in the climate of the region. This dry period also coincides with the results of Flohr et al. (2015).

It is very likely that the mid-latitude cyclones that developed in the Eastern Mediterranean Basin under the influence of the North Atlantic/Arctic Oscillation caused heavy rainfall in the past as well as today. Flood and torrent events, which are clearly identified in the results of carbon and oxygen isotope analysis and sedimentologically in various areas of Sumaki Höyük, are estimated to be traces of the Atlantic circulation in the past, which is also effective on the climate of the study area in today's conditions and causes heavy rainfall. During the Arctic circulation it was stronger, and it can also be expressed in cold periods, with severe winter conditions. The period between phases N1 and N2 and the cold period at the beginning of phase N5 of Sumaki Höyük indicate that the Arctic circulation strengthened and coincided with the phase of severe winter conditions. The repeated cold weather anomalies effective in the Holocene have been confirmed by terrestrial and marine records in many studies (Weninger et al., 2014; Rohling et al., 2002, 2009; Mercone et al., 2001; Meeker and Mayewski, 2002; Casford et al., 2003; Marino et al., 2009).

Even today, the climate of the Near East is controlled by subduction in the middle levels of the atmosphere due to the monsoon circulation. This circulation leads to arid and hot conditions around Sumaki Mound. In phases or seasons when the Atlantic circulation weakens and the monsoon circulation becomes dominant, a circulation with hot and dry anomalies develops in the study area. In contrast, it is understood that rainy periods develop under the influence of Atlantic circulation. Significant floods in the study area in certain periods can be explained by the Atlantic circulation, and the high-temperature periods accompanying the dry periods can be explained by the dominance of the monsoon circulation over the area.

4 Conclusions

The carbon and oxygen isotope data of Sumaki Höyük, and some climatic data from the Near Eastern caves and lakes such as Soreq Cave, Lake Van and Dead Sea, prove the presence of an unstable climate structure with cold-and-humid, warm-and-dry alternations and dramatic changes in the physical environment that were experienced sequentially between 9.2 and 8.2 ka events. The period that is called the 8.2 abrupt climate change (Alley et al., 1997) in the N1 phase from the results of carbon and oxygen isotope analysis lasted until 8258±44 BP around the study area. It can be ascertained that the atmospheric circulation that led to the development of very humid events (causing floods in the study area) in the N1, N2, N3 and N5 phases, as indicated in the results of carbon and oxygen isotope analysis, was most probably caused by the Atlantic circulation that penetrated the Eastern Mediterranean. The warm and precipitation-free period during the N1 phase reflects the climatic characteristics of the subsidized area of the monsoon circulation, as described in detail in Fleitmann et al. (2007). The effects of the prolonged cold period are evident from the end of the N1 phase (8123±50 cal BP) and most of the N2 phase (8258±44 BP). Similar prolonged cold periods were observed during the N4 phase (8436±52-8526±60 BP). The Inter-Tropical Convergence Zone (ITCZ) which controls the monsoon circulation during cold periods seems to have shifted towards the equator. The convective activity and the release of latent heat within or across the ITCZ pulls the ITCZ northward and intensifies the monsoon circulation in response to stronger surface heating and excess sunlight during the northern hemisphere's Indian Summer Monsoon. At the same time, a stronger monsoon circulation due to greater surface heating of the Eurasian landmass and the resulting increased land-sea thermal contrast (Webster et al., 1998) will increase the transport of equatorial moisture, which in turn intensifies convection within the ITCZ and the Indian Summer Monsoon circulation in summer. This in turn leads to higher monsoon rainfall in other areas close to the summer ITCZ. It can be argued that this rainy area led to a hot and arid climate in Sumaki Höyük and its immediate surroundings, as the subsidized air portion of the circulation remained. The most important feeding mechanism of the heavy rainfall during cold periods can be explained by the dominance of an Atlantic circulation around the study area. During the periods when the Atlantic/Arctic circulation develops, the decrease in temperatures is evident from the end of the N1 phase through the N2 phase and from the end of the N4 phase to the beginning of the N5 phase. During these climatic anomaly periods, the changing atmospheric circulation led to lower temperatures and triggered two major flood events along with other geomorphologic factors. Monsoon circulation and Atlantic circulation are the main mechanisms controlling the temperature/precipitation regime of the study area in the past. Atmospheric conditions in this area during the flood disasters were also shaped by the Atlantic circulation.

5 References

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