



Sedimentological processes in cultural deposits of a Neolithic settlement in Upper Mesopotamia: a microarchaeological case study of Sumaki Höyük

Savaş Sarıaltun¹

Received: 13 January 2021 / Accepted: 1 March 2021 / Published online: 28 March 2021
© Saudi Society for Geosciences 2021

Abstract

This paper presents direct and indirect evidence of the sedimentological processes at the Neolithic cultural deposition of Sumaki Höyük in Upper Mesopotamia. The main scope of this study should be considered not only as a means to reveal the physical structure of external factors experienced in the past but also as part of the process of understanding the extent and variability of human-environmental interaction in the context of time-space. Here, various natural and cultural effects on the stratigraphy of Sumaki Höyük Neolithic settlement and its close environs are discussed in relation to its seven phases. XRD and SEM/EDX analysis shows that during the uninhabited periods of the settlement, deposits of different mineralogical composition were transported there by external factors. EDX data revealed the enrichment of Si to be 21.58%, Ca 14.93%, Fe 8.53%, and C 8.73% in the elemental composition of all phases of Sumaki Höyük. However, in the phase N3 fill, the carbon element proportion (C 11.14%) is higher compared to the fill of other phases, while the silicon proportion (Si 18.16%) is lower. In phase N4, iron (Fe 12.11%) is higher compared to the others. In the phase N5 fill, the calcium proportion is noticeably higher. From XRD data, the brucite and sphalerite are related to an aqueous environment. The presence of kyanite and chalcopyrite, sourced in volcanic formations, indicates that these minerals were probably transported by slope flows from the Kıradağı basalts.

Keywords Geoarchaeology · Neolithic · Sediment · Mesopotamia · Sumaki Höyük · Turkey

Introduction

Sumaki Höyük is located 1 km east of Beşiri district in Batman province in the southeastern region of Turkey (Fig. 1). The site was first discovered in 2002 during the surface survey and excavated 5 seasons between the years 2007 and 2014 within the framework of Ilısu Dam Salvage Project. The settlement is situated in the northern part of the Lower Garzan Valley, nearly 2.5 km east of Garzan Stream, a tributary of the Tigris River. The settlement was founded on ground slightly sloping in a southwest-northeast direction on an erosional surface with an elevation of 700–710 m (Erim-Özdoğan and Sarıaltun 2018).

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 low natural terraces. Basically, the Neolithic topography seems to have an undulating surface. To the southwest of the settlement is the volcanic Mount Kıradağ, with basalt flow. The dimensions of the settlement, positioned on the mountain-plain transition zone, are approximately 160 m (N-S) to 140 m (E-W), (Erim-Özdoğan and Sarıaltun 2018) with its deepest fill thickness being approximately 2.4 m (Fig. 2).

Sumaki Höyük was mainly occupied during the early Pottery Neolithic, although it has a phase with FPPNB features. The settlement has been dated between 9084 and 8123 cal BP (Table 1). An area of 2180 m² was exposed and seven Neolithic phases were determined from the natural soil. These seven phases were sometimes interrupted by natural events such as floods and torrents and each phase displayed a different character, not only in settlement pattern but also pottery and other assemblages. While phases N7, N3,

Responsible Editor: Attila Ciner

✉ Savaş Sarıaltun

¹ Çanakkale, Turkey

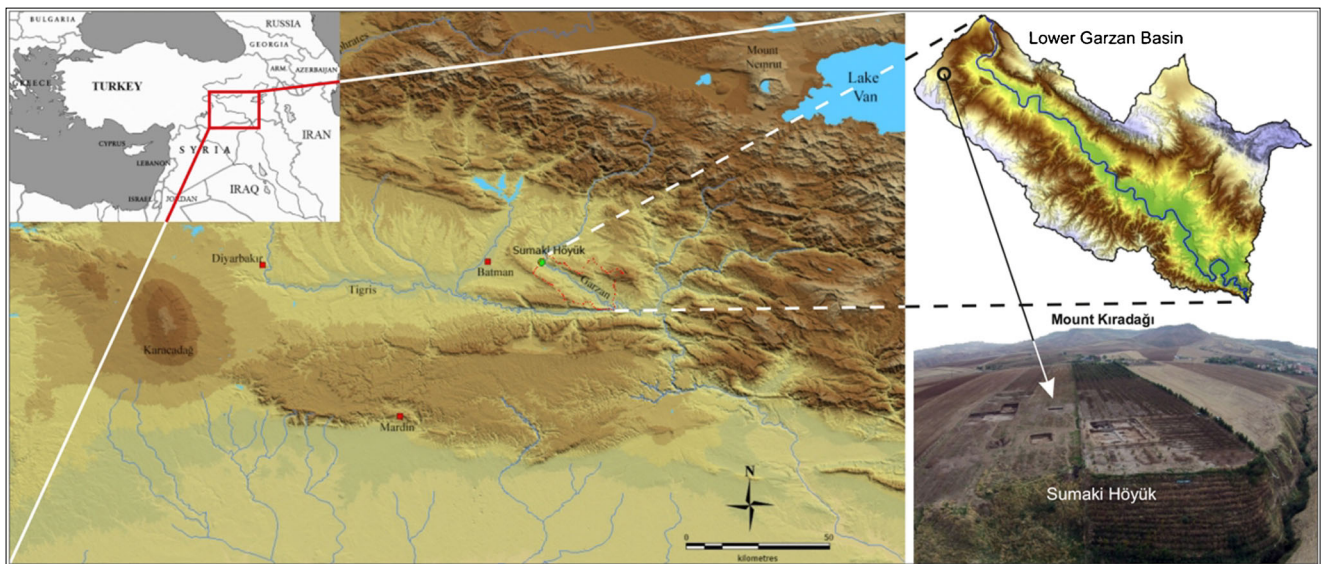


Fig. 1 Map of study area, showing location of Sumaki Höyük

and N1 are temporary campsites with pottery, phase N6 is a permanent settlement without pottery that mainly resembles LPPNB features, whereas during phase N5, the settlement seems to be occupied by both sedentary and mobile groups using pottery in small quantities. Phase N4 has a permanent character although not a long-term one because of frequent flood and torrent events. Phase N2 is an intensively occupied temporary campsite with some parts displaying relatively permanent features. Although phase N1 is a temporary campsite, it resembles a different culture with a different pottery tradition from those in the preceding phases (Sarıaltun 2019).

The main building material is earth and organic material such as reeds and branches in phases N6, N5, N4, and N2. Buildings, which were constructed using the piled earth technique, were erected directly on the ground without stone footings by leaving spaces in between low terraces of the natural topography in areas A and B. The only remains of phases N7 and N3 are post holes, hearths, and ash pits while phase N1 is represented by row of stones and hearths.

The most abundant material excavated or obtained in an archaeological excavation is not lithic items, pottery, or architectural structures. The most common thing is the cultural filling, i.e., the soil (Banning 2000). These sedimentological units are not a passive element to be ignored as they preserve unique evidence of the formation of the archaeological site, paleoenvironmental conditions (Dincauze 1987; Grayson 1981; Hoel 1997), and the chronological processes (Reynolds and Catt 1987) of the settlement. The meaning of the sedimentological content can also be detected in geoarchaeological data sources such as soil profiles and microstratigraphy from archaeological deposits (Hill and Rapp 2014; D’Amore 2014; Matthews 2003; Matthews et al. 1997) Therefore, sediments may be documented and examined by sedimentologists and micromorphologists to understand the deposition’s character. Geoarchaeological survey procedures include sediment classification, micromorphology, particle size analysis, and multicellular geochemistry (Branch 2014; Missiaen et al. 2017; Sarris et al. 2018) and also geophysical methods such as geomagnetic

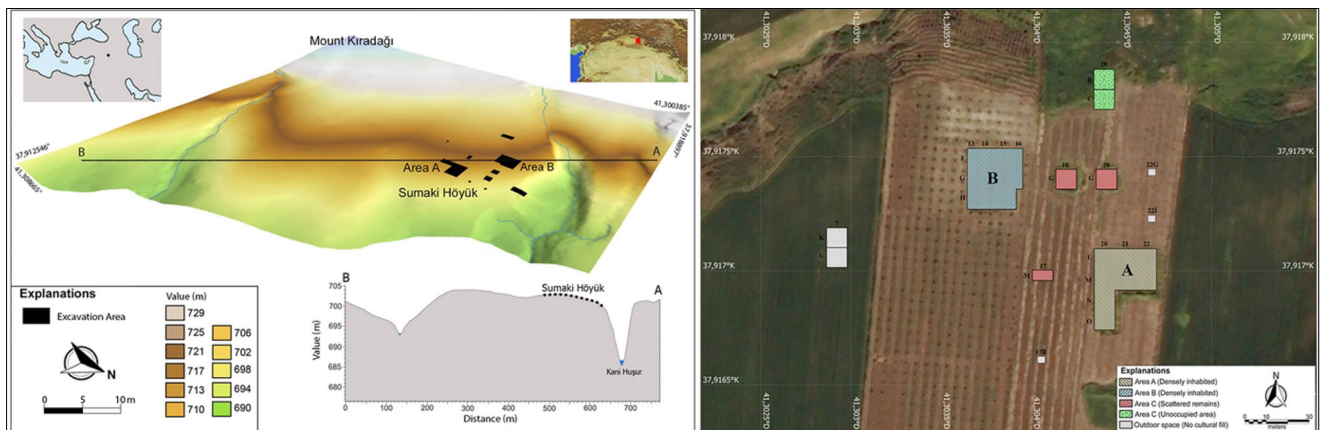


Fig. 2 Excavation area of Sumaki Höyük

Table 1 Chronological stratigraphy of Sumaki Höyük

Level	Period	Phase	CalPal calibration (cal BP)	CEDAD C14 Date (BP)	CEDAD Code
1	Middle Ages	M1	1116 ± 52	1186 ± 40	LTL15185A
		M2			
2	Neolithic	N1	8123	Comparative Chronological Data	
		N2	8258		
		N3	8395±28	7584 ± 50	LTL15193A
			8436±52	7613 ± 60	LTL15187A
			8459±49	7645 ± 50	LTL15194A
		N4	8461±49	7647 ± 50	LTL14406A
			8491±50	7700 ± 50	LTL15192A
			8501±56	7712 ± 60	LTL14408A
		N5	8518±54	7741 ± 50	LTL15190A
			8526±60	7752 ± 60	LTL15186A
			8594±49	7810 ± 50	LTL14407A
			8629±80	7821 ± 60	LTL15189A
		N6	8715±113	7859 ± 60	LTL15191A
			8708±90	7871 ± 50	LTL15188A
9084±57	8127 ± 50		LTL14409A		

and geoelectrical resistivity (Balkaya et al. 2021; Ekinci et al. 2014). Sediment classification using XRD and SEM/EDX analyses was carried out to understand the sedimentation process (Marathe 2012; Patil and Shrivastava 2005; Pattnayak et al. 2019) of the soils in the Neolithic layers of Sumaki Höyük and to determine their properties, resulting in several conclusions.

Archaeological stratigraphy and sedimentological change at Sumaki Höyük

The Neolithic phases of Sumaki Höyük, mainly the architectural remains, accumulations in open areas, pottery distribution, and natural effects of the deposition process, were taken into consideration. Other materials such as clay objects, and stone tools were also noted for detailed examination of the layers (Fig. 3).

The earliest occupation of Sumaki Höyük phase N7 is dated to 9084 cal BP. The remains of the occupation are post holes, hearths, firepits, and mobile artifacts such as pottery sherds, stones, and bone tools. The deposit of phase N7 was grey-colored earth mixed with small stones, random lime fragments, and ashy areas. Calcified organic material traces in different parts of the open areas are indications that the phase N7 settlement was affected by drought and evaporation after experiencing an aqueous environment. In the succeeding phase N6, which is dated to 8708–8594 cal BP, the area was densely inhabited and there was a radical change in the settlement pattern. Buildings were erected directly on the ground without stone footings and were positioned by leaving spaces in between low terraces of the natural topography (Fig. 4). The

primary plan type is Cell Buildings, with “L” or “T”-shaped long rooms (corridor) in the middle and almost-square cells on either wing. There are also smaller single-roomed dwellings. All buildings were constructed using the piled earth technique. The walls were covered by knitted reed and branch surroundings (Sarıaltun 2019).

The archaeological deposit of the open areas in phase N6 was light grey, occasionally yellowish-grey, hard, lime-rich fill with low ash content. Its other distinctive character was that it had a layered appearance. The primary cause of this layering was the formation of surfaces with a different character linked to wet and dry levels due to external factors such as rain and sun. Furthermore, occasionally intense ashy and limey fills are noteworthy in the trench sections. The ashy fills, which are not widely distributed, and very thin, not more than 1 cm thick, notably increased in the areas surrounding hearths. The lime-rich fill is possibly the remains of organic material from either architectural elements or waste. The lime fragments are hazelnut-sized, and there is no trace of plaster on any of their edges.

As documented in the winter quarters of semi-nomads in the Lower Garzan Basin, similar organic material was distributed randomly within the settlement or more densely around structures which had been disturbed. Accordingly, these separate lime areas in the open areas of phase N6 may be the traces of dispersed structures. In the southeastern part of the settlement, a mixed fill level with dense lime-rich, ash-rich fill containing small pebbles was identified. Blue-grey filling with a diameter of 3 m was identified within the virgin soil layer. According to geomorphological investigations, this natural depression with blue-grey fill formed due to the accumulation of watery mud in this area over a specific period. Similar traces in the eastern part of this site were also identified

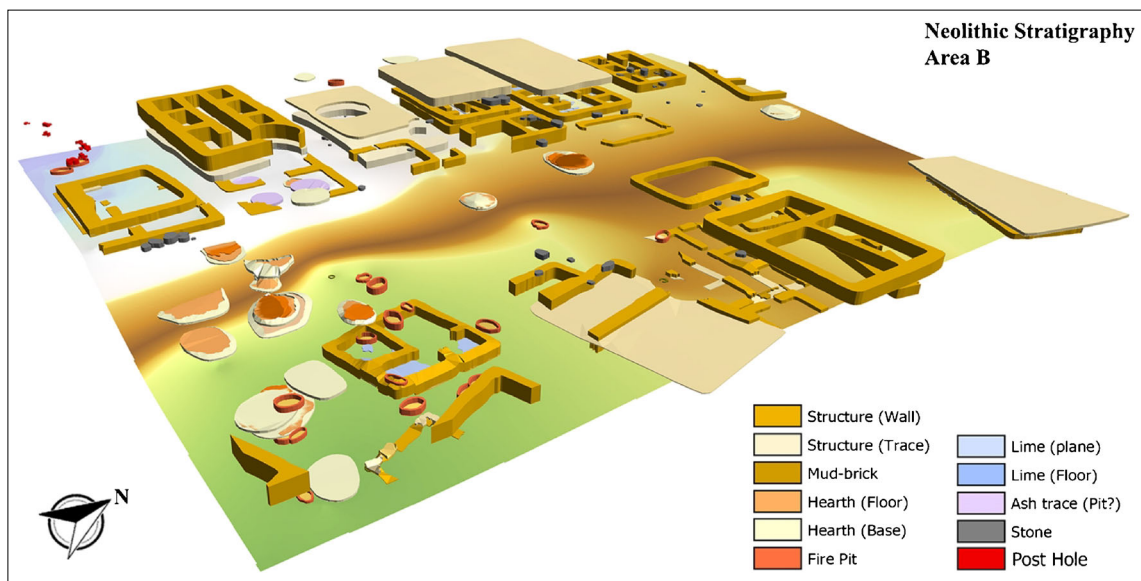


Fig. 3 Architectural stratigraphy at Sumaki Höyük Neolithic settlement

immediately beside an area where the natural soil exhibits a vertical slope in a section where the surface partially flattens out. The topography of phase N6 therefore displays rows of natural terraces with southwest-northeast and east-west orientation. In relatively flat areas, the surface has a slightly undulating appearance.

The investigation by XRD analysis of earth samples taken from phase N6 deposit determined calcite with a calcium carbonate composition and the organic carbon mineral of graphite along with cliftonite, silica, and quartz crystals. Both field observations and SEM images show that these samples have different grain sizes and different mineralogical composition. SEM images of samples identified micritic envelopes on the sand and stone grains, and also scalenohedral and rhombohedral crystal structures were observed together with acicular crystals. Calcium carbonate minerals were also clearly seen around tubes formed by organic remains. Additionally, samples were identified with SiO₂ gels filling the natural cavities. The

clearest one is of the silicon dioxide gel filling a *Panicum* plant remnant (Fig. 5).

The succeeding phase N5, dated to 8526–8491 cal BP, has a similar settlement character to the previous phase. The western part of this site seems to be more intensively occupied than before, keeping the same pattern on low terraces of the natural topography as it was in phase N6, while the eastern part of this site was less settled. Either in building layout or construction technique, notable changes are recognized in phase N5. While the practice of Cell Building and single-roomed structures continued, multi-roomed and double-roomed buildings appeared.

The fill of phase N5 was grey-colored, ashy and contains carbon fragments. Additionally, in the southeast corner of trench 14H, northwest of trench 20M and southwest of trench 20L, dark-grey fill with dense carbon fragments was observed while in different areas, a heterogeneous fill with mixed sequences of stones, pottery sherds, bones, and obsidian tool fragments was identified. This heterogeneous fill was

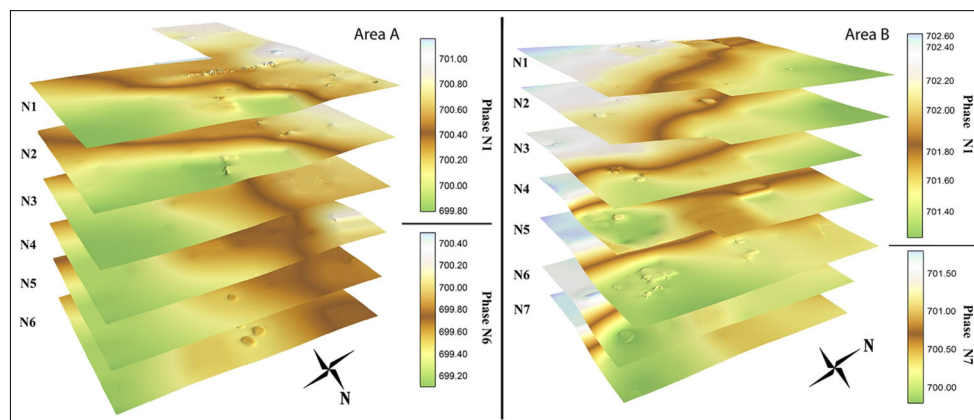


Fig. 4 Changes in topography by phase at Sumaki Höyük

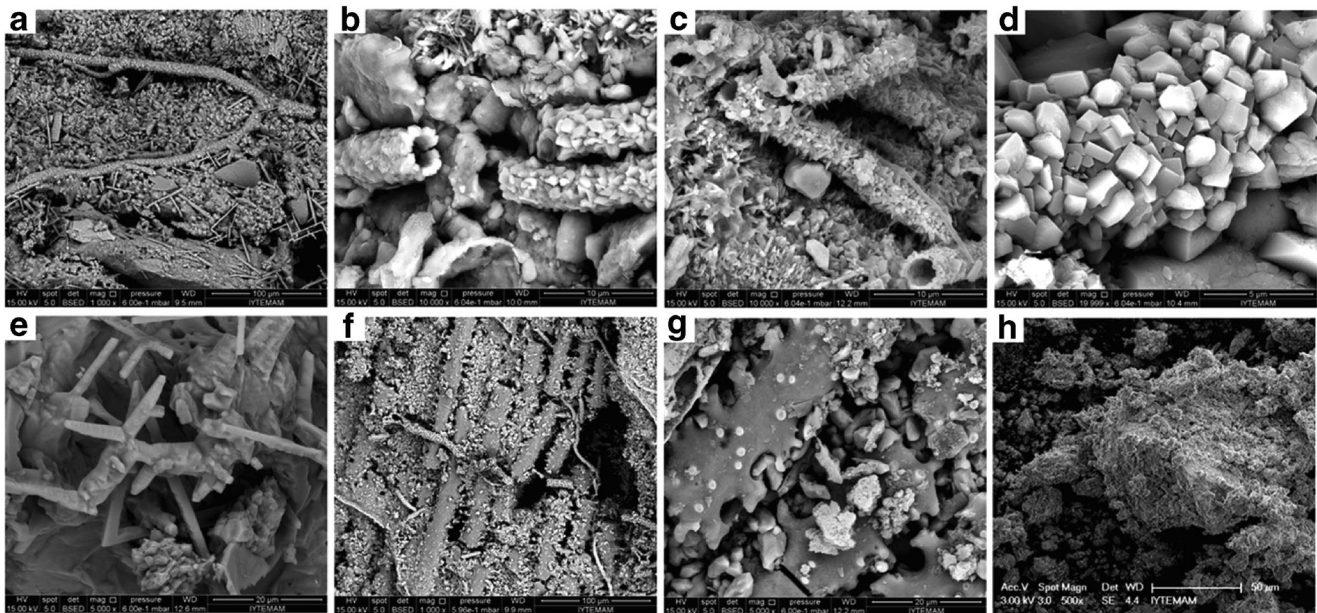


Fig. 5 SEM images of lime and soil samples taken from Neolithic culture deposits at Sumaki Höyük

concentrated mainly in the east-northeast part of trench 15F (Fig. 6d), although it was occasionally scattered between the structures in trenches 14G and 14F, and also in trenches 18G, 20G, and 22M. This heterogeneous fill is directly related to the torrents that occurred by the end of phase N5.

When the relationship between the torrent accumulation areas and the topography of the period is addressed, it is natural that geographic events occurring between the years 8491 and 8461 cal BP would deposit material in areas permitted by the topography. The irregular characteristics identified in the

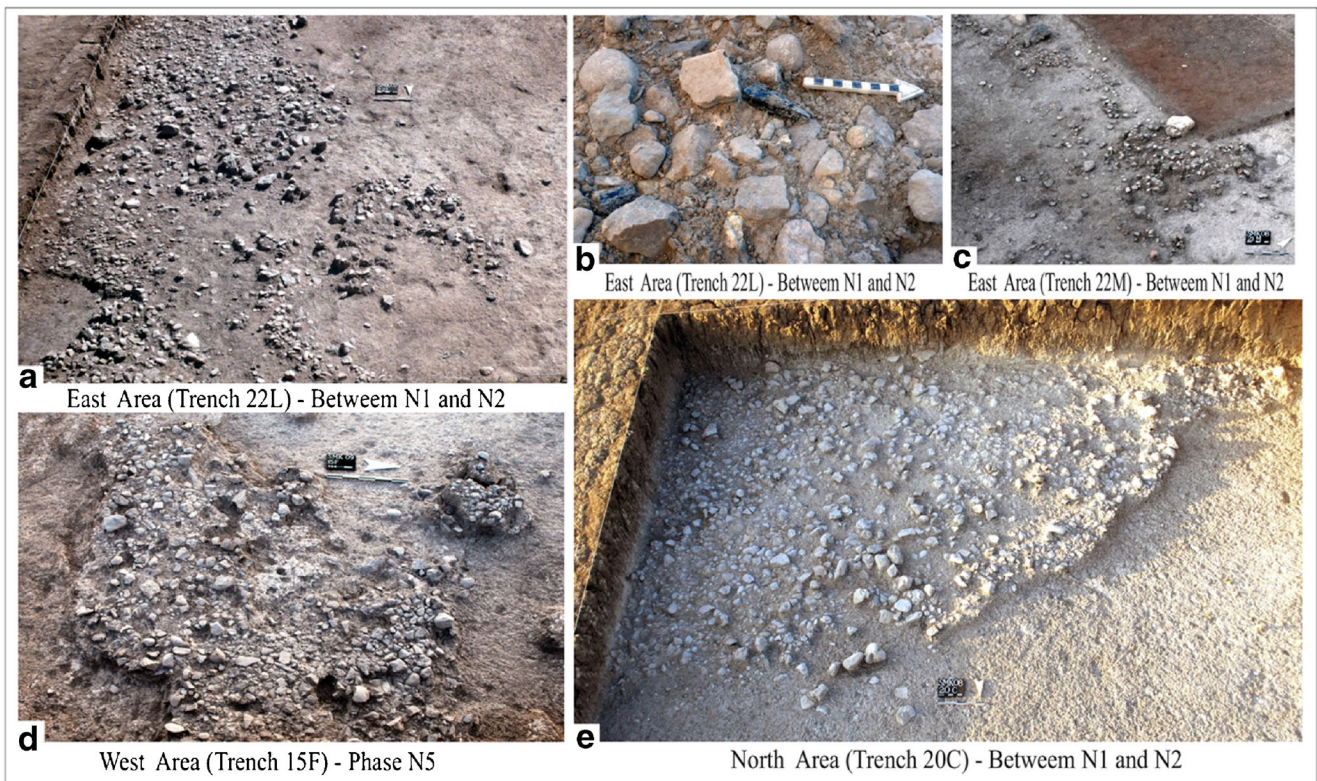


Fig. 6 Flood/torrent remains at different phases of Sumaki Höyük

sequential accumulation areas of the archaeological layers show that these torrents occurred suddenly. Regarding the torrent geometry in tandem with the archaeological material, it was found that obsidian and flint tools and flakes, animal bones, ground stone fragments, and a few pottery sherds were deposited in a disorderly manner. Apart from XRD and SEM/EDX analyses, algae traces on the surface of the pottery sherds (Fig. 7) and many animal bones remains agglutinated to lime showed that the archaeological material remained in water for a long time (Fig. 8). Likewise, in some samples, examples were found in which meniscus bridges were formed indicating that various stones adhered to the bones. With evaporation and the rising limey water (Gönül and Çelebi 2003), the cohesion and adhesion forces of objects approach each other. Investigation of soil samples taken from the deposit of phase N5 using the XRD method identified them as having a calcium carbonate composition, calcite minerals, and the organic carbon mineral of graphite along with cliftonite, sphalerite, silica, and quartz crystals.

The following occupation, phase N4, is dated to 8461–8436 cal BP. In phase N4, there is a change in both architectural conception and settlement pattern. The Cell Building tradition ended. However, the construction of multi-roomed and double-roomed buildings with piled earth walls continued, and the number of temporary single-roomed short-duration dwellings with reed surroundings/walls, probably covered by tents or flimsy material, increased.

The deposit of phase N4 in the west excavation area is generally grey with thin lines formed of occasionally dense hazelnut-sized lime fragments without any traces of plaster on

their edges. The grey fill is sometimes mixed with dense ash, mainly concentrated around hearths and fire pits. The phase N4 filling in the east excavation area is generally light buff and light grey. Contrary to the grey and occasionally lime fragment-rich fill identified in the west area, the proportion of lime fragments in the cultural deposit from the east area is relatively less.

The light brown soil line of 3–4-cm thickness identified in various trench sections, for example, in the western section of trench 15G in the west excavation area (Fig. 9) and western section of trenches 20L–20M in the east excavation area, above the phase N4 deposit, shows that geomorphologically, this area was not used for a specific period. Accordingly, after phase N4, Sumaki Höyük was not occupied. The settlement organization of the newcomers was different from the phase N4 inhabitants.

Phase N3 is dated to 8395 cal BP according to a single C14 dating. The settlement pattern and architectural tradition of phases N6–N4 disappear. Lasting for nearly 250 years, the permanent settlement transforms into a temporary “campsite” with features partly similar to phase N7. Oval tents now replace the practice of permanent buildings, and according to the distribution of artifacts, there was intensive usage of open areas.

Although the phase N3 deposit is very shallow compared to the fill of other phases, it is incredibly varied. The fill generally has the appearance of thin consecutive beds with a light grey and occasionally lead-grey color. Dense lime fragments and stony mixed fill were also identified. Scattered ash-rich fill was determined in different areas around hearths and fire pits.

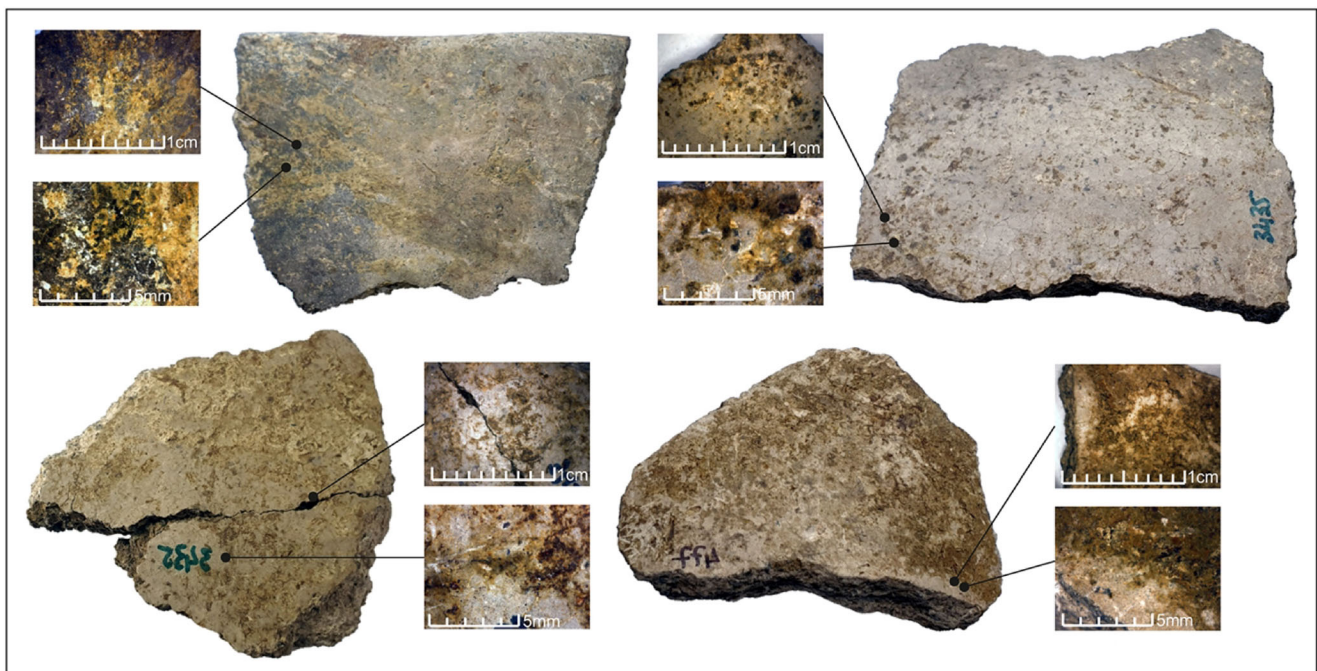


Fig. 7 Algae traces on the surface of pottery from Sumaki Höyük

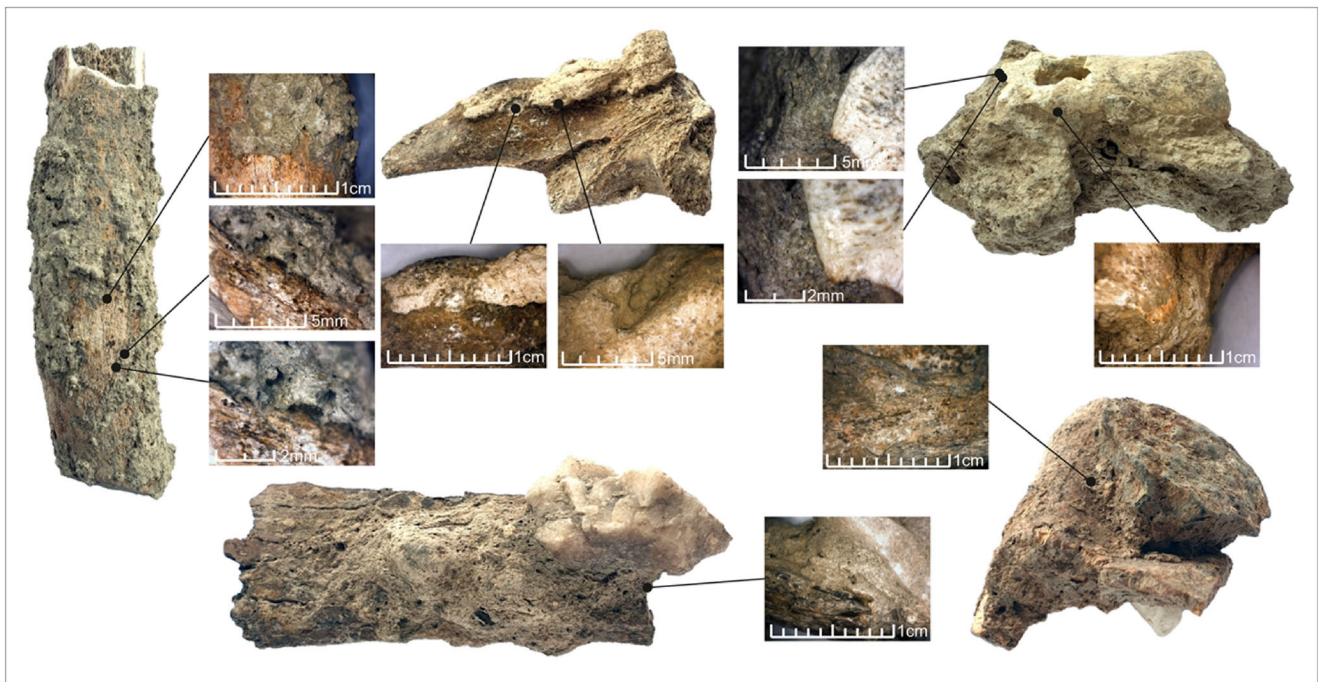


Fig. 8 Animal bone remains with lime attached and showing meniscus bridges

Samples taken from the east excavation area examined with XRD analysis were found to contain anorthite (calcium feldspar), calcite, silicon, and quartz minerals. Their chemical composition is calcium carbonate, silicon dioxide, and calcium aluminum silicate compounds. Samples from the west excavation area were identified as containing cliftonite, graphite, calcite, and quartz minerals. Their chemical composition is calcium carbonate, carbon, and silicon dioxide compounds.

Phase N2 was relatively dated to about 8250–8200 cal BP. The settlement pattern and spatial distribution density were recreated similar to phases N6 and N4. In this phase, the temporary circular structures from phase N3 are replaced by temporary single-roomed rectangular structures. The buildings were located beside each other and built following the topography of the period.

The deposit of phase N2 is generally grey-buff, occasionally with dense stones, and partly ashy. Towards the end of

this phase, a flood level was identified which greatly disturbed the ground, with inundated buildings and other features. Affecting nearly the whole settlement, flow and sedimentation data indicate that the flood had a southwest-northeast orientation. The east area is where the flood/torrent left the most sedimentation (Fig. 6a, c, e). When the accumulation areas due to this flood/torrent are assessed in terms of the topography of the period, it is evident that the settlement's topography allowed accumulation in areas due to geographic events occurring in about 8200–8150 BP. Soil samples from phase N2 deposit were seen to contain calcite, silicon, quartz, and anorthite minerals, as determined by XRD analysis (Table 2)

The torrent fills have a more complex mineral composition. Samples from these fills were determined to contain calcite, quartz, and silicon along with sphalerite, brucite, altaite, and chalcopryrite. The similarity between the mineral composition of the flood in this phase and the floods of phase N5 indicates

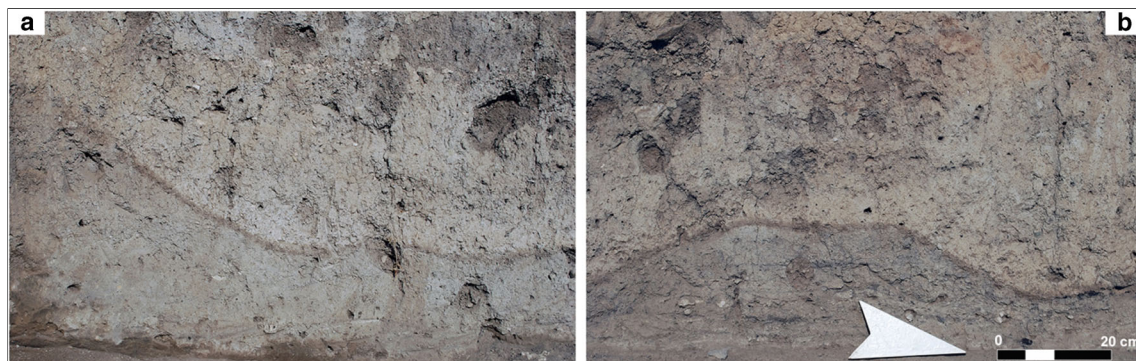


Fig. 9 Thin earth line between phases N4 and N3 in west area

that the direction and triggering factors were the same. Pottery sherds, obsidian/flint tools (Fig. 6b) and flakes, animal bones, and ground stone fragments in the archaeological layers were deposited in a disorderly manner in the heterogeneous sedimentation area, as they were in phase N5. This heterogeneous fill with plenty of stones is directly associated with the flood/torrents occurring in the later stages of this phase. Since there is no regular surface, the flooding probably happened more than once. The settlement was abandoned sometime after the torrent event(s), and the spatial perception and settlement strategy radically changed in the following phase N1.

The final habitation of the Neolithic settlement, represented by phase N1, was relatively dated to about 8150-8100 BP according to comparative chronological data. The architectural tradition in this phase displays a different style to nearly all the previous phases. Stone is the dominant building material and the occupation is represented by rows of large, left-over basalt grinding stones placed in different directions, sometimes forming corners. These rows may have surrounded the tents or reed dwellings of the semi-nomads.

All the hearths of this phase have stone pavements. Except for one hearth, the others have only a single-plastered floor on the stone pavements. As with the architecture, noteworthy changes are also observed in artifact assemblages.

The deposit of phase N1 consists of light brown, grey, and light grey earth and contains a higher density of walnut-sized pebbles compared to other phases. However, the numerous lime fragments observed in previous phases are virtually non-existent in the fill from this phase. All fills of phase N1 are heterogeneous. Immediately above phase N1 and below the Middle Age layers, there is a swamp-like fill containing no

archaeological material. The fill was identified as being nearly 35-cm thick in the southern part of the site (Fig. 10). The existence of this fill suggests that Sumaki Höyük was uninhabited until the Middle Ages (1116 cal BP).

Landslides around Sumaki Höyük

In any geographical area, geological and/or geomorphological masses change their location not only through erosion. Other elements that cause such a movement are mass movements which begin when the weight of the mass and the forces holding the mass in place reach a certain level. The degree of slope, robustness of geological structure, and weak plant cover, as well as precipitation, are the main elements determining mass movements and their effects (Ekinçi et al. 2013; Siler and Şengül 2016; Sunkar and Tanbul 2009). This movement may be in the form of mass falls, landslides, or rockfalls. Masses moving as a result of sliding down a slope due to gravity form surface landforms such as landslide toes and debris accumulation (Elias and Dias 2009; Erginal et al. 2009; Göktürkler et al. 2008; McClain et al. 2021).

Mass movements around Sumaki Höyük are triggered by three primary mechanisms. The first one is in the form of a collapse or slips, flows, and falls. Collapsing generally occurs in areas with large-scale landslides, while slips affect relatively smaller areas. Collapse movements consist of more than one step, and with landslide toes, specifically on the slopes of Mount Kıradağ. The sliding surface is generally flat and curved. The flow form of mass movements is observed more often in areas with a clayey, sandy, or clastic structure. It is

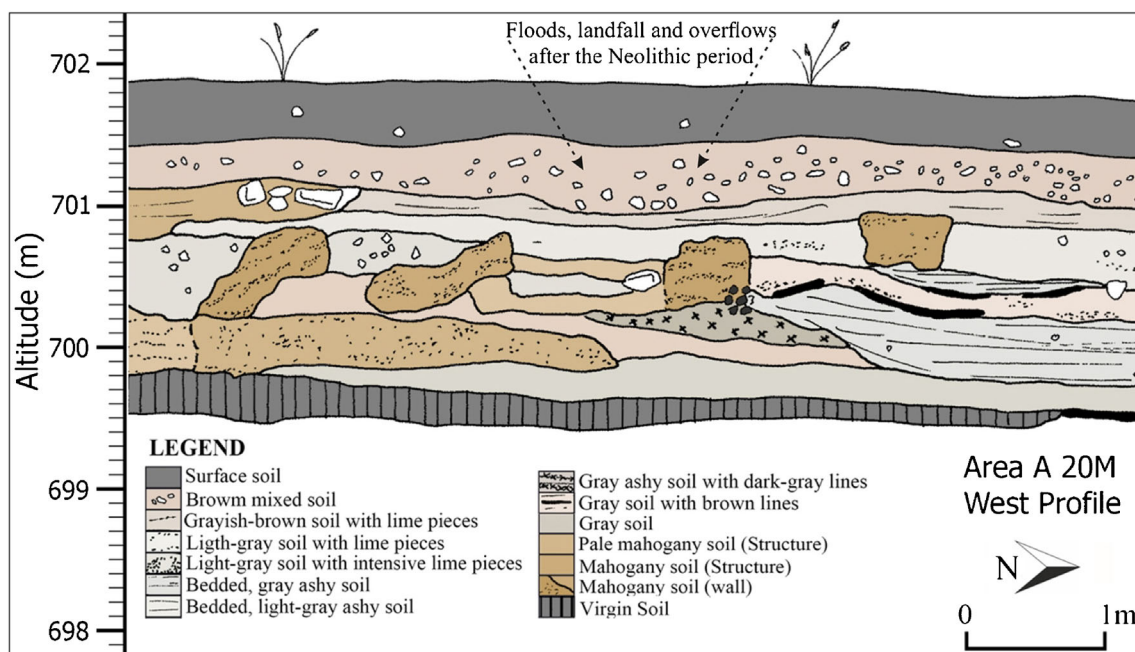


Fig. 10 West profile of trench 20M at Sumaki Höyük

particularly effective on the west side of Garzan Stream where the Upper Miocene-aged Şelmo Formation is predominant (Yeşilova and Helvacı 2011; Yılmaz and Duran 1997). Since fall mechanisms occur in movements where hard rocks like limestone or basalt break away, it is therefore evident in the Mt. Kıradağ basalt and Mt. Mare conglomerate in the form of fragmented blocks that have been dragged.

Linked to the topographic structure and slope of the basin and considering the amount of precipitation, its form, and duration/season, it is necessary to state the following. Precipitation falling during the winter and spring in our study area seeps underground or joins the surface flow and acts as a trigger for mass movements. Clayey-sandy-silty geological units saturated with water from precipitation may be a source of mass movements. In periods when precipitation increases, the groundwater accumulating under the cover of the Kıradağ Basalt, acting as a reservoir, either reaches the surface through slope springs or passes into the surface flow on the slopes, causing occasional landslides (Sunkar and Tonbul 2012). Accordingly, mass movements affecting large areas are widely observed on the east slopes of Mount Kıradağ.

Generally, due to the heavy, dense basalt mass above loose units and the instability of a slope, mass movements occur very frequently and the material is carried over large distances.

The best example of this is observed near Tepecik village about 9 km from Mount Kıradağ where basalt blocks from the mountain have accumulated on the slope of Garzan Stream. In front of both these accumulations, two settlements were detected, Gre Şavo and Gre Keleke, with habitation beginning in 5000–4000 BP (Erim-Özdoğan and Sarıaltun 2011). This indicates conclusively that a large-scale landslide with fragmentation and movement occurred sometime before 5000 BP.

Landslides and soil flow at Sumaki Höyük and its environs were spatially modeled with GIS techniques and correlated to the geomorphological dynamics and processes effective on the area. The erosion-deposition surfaces where Sumaki Höyük is located were generally formed in Quaternary, but more predominantly in Holocene. Due to the high siltation of this area, sloping piedmont morphology and geological structures as well as landforms such as dense slides, collapses, and soil flows occurred extensively (Fig. 11). During the archaeological excavations and geomorphological field investigations that we carried out around Sumaki Höyük, many new landslide fractures were identified.

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

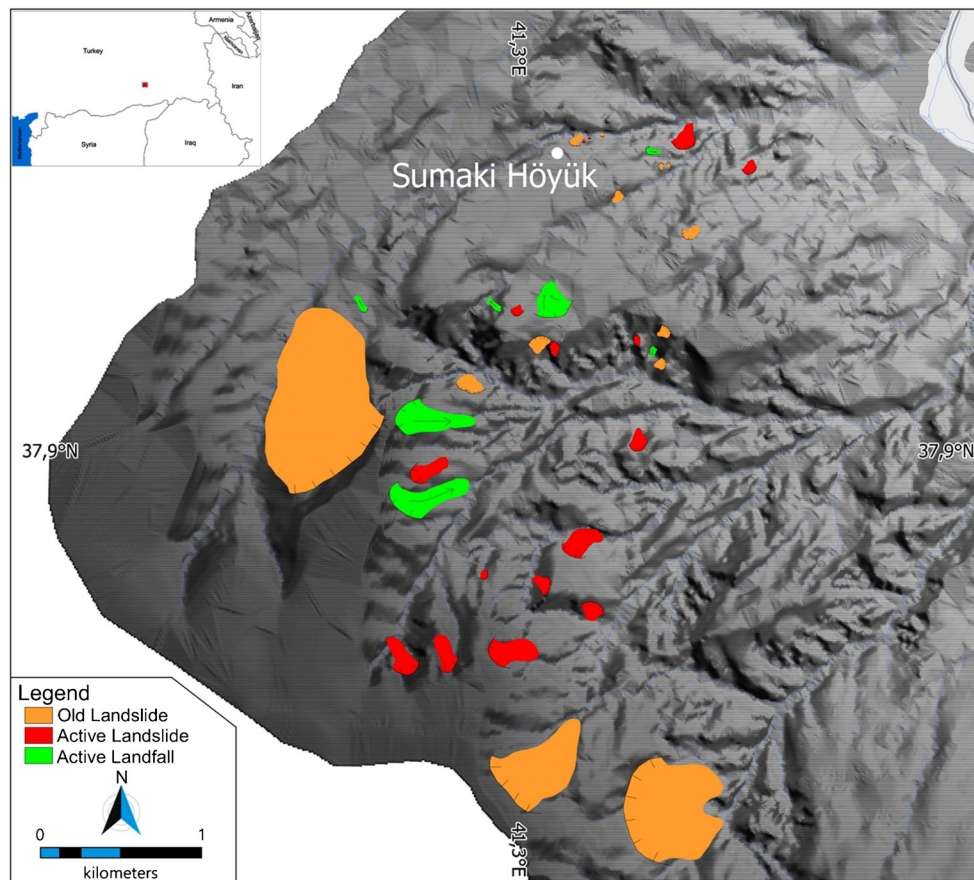


Fig. 11 Landslides and landfall modeling in the vicinity of Sumaki Höyük

was abandoned at intervals; however, abandonment of the settlement was not only determined by archaeological data. In the upper levels of phase N4 fill, as mentioned above, a 2–3-cm-thick soil formation was identified which occurred after a probable flood, creating an aqueous environment. XRD and SEM/EDX analysis shows that during the uninhabited periods of the settlement, deposits of different mineralogical composition were transported there by external factors. For example, brucite and sphalerite are related to an aqueous environment. The presence of kyanite and chalcopyrite, sourced in volcanic formations, indicates these minerals were probably transported by slope flows from the Kıradağı basalts.

In the southern part of the site, a nearly 35-cm-thick swamp/wetland layer has been identified (Fig. 12b), which indicates that the settlement was also affected by external factors such as a torrent or landfall after the Neolithic period. Additionally, the steep slope or former river course in the east part of the site (Trench 20G) was filled by a landslide and/or flood (Fig. 12a). Pottery sherds in some of the Neolithic layers have greenish-colored oxidized surfaces from the effect of a long duration underwater. Light archaeological material such as sherds, figurines, and chipped stone tools that were swept away by torrents or inundations have accumulated in depressions in the ground. 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 the 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. It should be noted here that our interpretations are predominantly valid only for Sumaki Höyük and its close surroundings.

Results and discussion

We will here discuss the different natural and cultural effects on the stratigraphy of Sumaki Höyük Neolithic settlement and

its close environs. The data obtained from the geological units and geomorphological accumulation areas in and around the site play an important role in understanding the Neolithic topography of Sumaki Höyük and its environs as well as external factors experienced in the different phases and their effect on settlement strategy and also their material-based choice of architecture. Accordingly, the geomorphological data were investigated by spatial and morphometric distribution, such as the landslide traces around Sumaki Höyük, soil structure and possible vegetation diversity. Analyses of various soil samples taken from the Sumaki Höyük deposit and its surrounding area have been integrated with other data and are discussed in the microarchaeological context.

Landslide events that occurred in clayey units directly affected the settlement of Sumaki Höyük and its surroundings. The erosion-accumulation surface settlement where Sumaki Höyük is located was generally formed in Pliocene-Pleistocene but particularly in Holocene. Flooding, overflow, and earth flow traces, of which two are quite apparent, have been detected in the Neolithic layers of Sumaki Höyük. Due to these external factors, the settlement was abandoned at intervals.

In the environs of Sumaki Höyük, but especially to the south, are dark reddish-colored andosol soils due to the effect of the Kıradağı basalt. In our study area and its surroundings, reddish-brown soils are common with excessive amounts of limestone fragments in their lower layers. A caliche layer is encountered in the lower layer of these soils due to excessive lime forming as a result of serious drought. In soils with excessive evaporation and insufficient rain, salinization may occur due to alkaline reactions (Boggs 2014: 175–179). In other words, with excessive rain, some minerals become chemically soluble in the lower layers of the soil, and tend to rise towards the surface due to capillarity actions in the dry periods after rain (Dal 2010; Erpul et al. 2017) Additionally, at levels where water can rise upward, there is a direct relationship with external factors as in the cavity structure of building materials and evaporation. As the number of cavities in the material increases, the height that water can reach also increases.

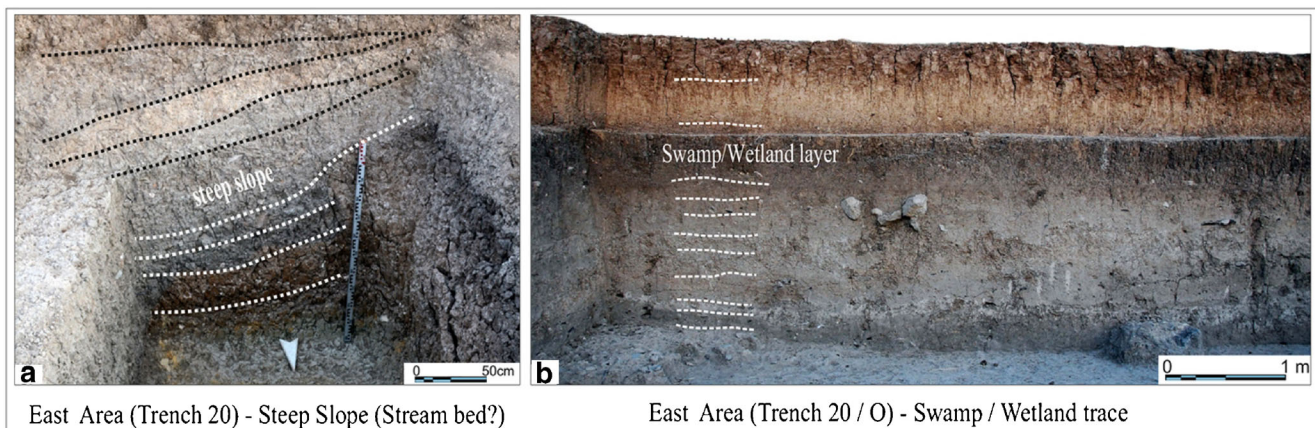


Fig. 12 Natural steep slope in Trench 20G and trace of marshland in Trench 20/O, in east excavation area of Sumaki Höyük

Material such as the reed/herbaceous plants used in the Neolithic structures of Sumaki Höyük has very fine cavities, and limey water may rise significantly due to capillarity action in these cavities. With evaporation and the rising limey water (Gönül and Çelebi 2003), the cohesion and adhesion forces of objects approach each other. In other words, the limey water rising (capillarity) due to evaporation binds to the organic materials used in architecture, or to archaeological materials such as pottery and bones due to the cohesion and adhesion forces, and remains. This process may take several thousands or millions of years. However, accumulations formed in short periods may be observed, as in the Holocene-aged Okavango Delta in Botswana (Graf et al. 2008).

Confirmation of the abandonment of Sumaki Höyük settlement does not rely solely on archaeological evidence. For example, in the uppermost part of phase N4 deposit, 2–3-cm-thick soil lines, possibly after floods or inundation, are observed. XRD (Table. 2) and SEM/EDX analyses (Fig. 13) show that different soils were transported to the settlement and various mineral compositions were formed in periods when habitation was partially interrupted. An approximately 35 cm-thick swamp/wetland fill, clearly detected in the south part of this site, indicates that the site was also affected by external factors such as floods, landfall and overflows after the Neolithic period. Besides this, in the east part of this site, it was determined that the steep slope (stream bed?) on the eastern edge of the settlement was filled with landslide/flood

material. Especially in the phases N4 and N2, greenish oxidation is seen on the surface of pottery sherds from them remaining underwater over a long time. It can be stated that very strong floods, overflows or soil runoff which would dislodge or cover the structures did not take place in the Neolithic period around Sumaki Höyük.

The mineralogical composition of the Neolithic deposits was determined with XRD analysis. The most critical factor in the identification or formation of minerals is an architectural tradition, as much as external factors such as floods, since the percentage of lime in the lime samples from architectural structures as well as the mineral composition of limey fills is almost the same, supporting this argument. The dominant minerals were quartz, calcite, and silicon dioxide. In various fills, differing amounts of carbon, iron oxide, magnesium hydroxide, and aluminum silicate minerals were also determined. The most important reason for this, together with architectural tradition, is due to differences in decomposition/deposition caused by the flood factor. The mineral composition of flood fills shows a heterogeneous accumulation; however, samples from fills that were not affected by floods are relatively more homogeneous. “Sterile” fills are noted for generally being dominated by calcite, silicon dioxide and quartz; while earth samples from flood fills were determined as containing minerals not found in archaeological deposits, such as cliftonite, plumbago/graphite, brucite, sakhite,

Table 2 XRD analysis of Sumaki Höyük Neolithic phases

Phases	Calcite	Quartz	Silicon dioxide	Kyanite	Almandine	Plumbago / Graphite	Cliftonite	Sphalerite	Brucite	Altaite	Chalcopyrite	Anorthite	Carbon	Caminite	Iron	Periclase	Sakhaite
N1																	
Torrent 1																	
N2																	
N3																	
N4																	
Torrent 2																	
N5																	
N6																	
N7	Sediment analysis not done																

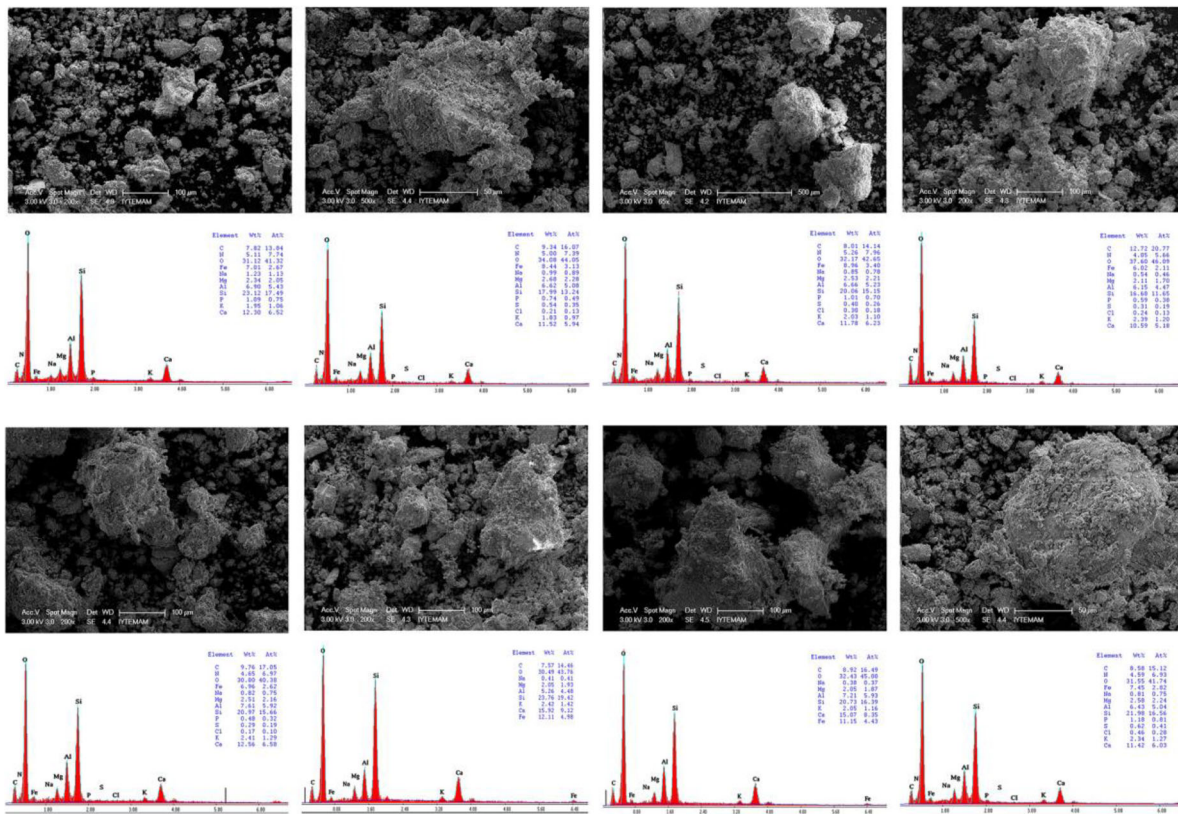


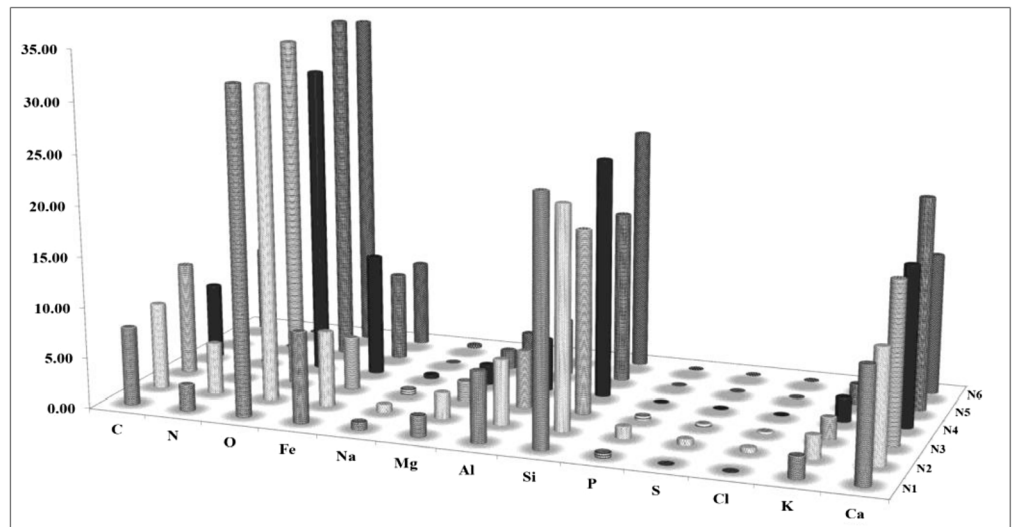
Fig. 13 SEM images and EDX analysis results from Sumaki Höyük

altaite, chalcopyrite, and sphalerite (Table 2). Their mineral combinations show that these fills were transported by external factors.

Soil formation or accumulation in settlements is the result of the mutual interaction of climate-organism-human-topography under certain conditions and within a particular process. The physical and chemical characteristics of soil from the deposits of Neolithic phases were determined. According to EDX analysis, the most common elements are O 32.83%,

Si 21.58%, Ca 14.93%, Fe 8.53%, and C 8.73%. In phase N3 fill, the carbon element proportion (C 11.14%) is higher compared to the fill of other phases, while the silicon proportion (Si 18.16%) is lower. In phase N4, iron (Fe 12.11%) is higher compared to the others (Figs. 13 and 14). In phase N5 fill, the calcium proportion is noticeably higher. These differences are mainly related to climate, the amount of lime in fills, and also to the construction tradition of the site. External factors, for instance floods, are also very important. Flood water and

Fig. 14 Average of EDX analysis of Sumaki Höyük Neolithic phases



wetland areas identified immediately before phase N2 and phase N4 may have affected distribution of the elements.

Based on the soil carbon isotope data of Sumaki Höyük and also some climatic data from Near Eastern caves and lakes such as Lake Van, the Dead Sea, and Soreq Cave, one of the most important factors in the occurrence of landslides is the presence of an unstable climate; cold-and-humid, warm-and-dry alternations were experienced sequentially between 9084 and 8123 cal BP. Based on these data, it is likely that Sumaki Höyük may not be the only Neolithic settlement in the Lower Garzan Basin. Sedentary or temporary Neolithic settlements with a shallow fill would have been completely sealed by more rigorous landslides or similar external factors. The mobility of the communities in the period studied is most likely the result of changes in the physical environment affecting the cultural environment. This process of interaction is mutual. Therefore, changes in the cultural environment as a result of changes in the physical environment also change the appearance of the physical surroundings.

Conclusion

Changes in the physical and cultural environment of Sumaki Höyük are a good example of the interaction of multiple variations. Since the Neolithic topography had an undulating character with southeast-northwest oriented low natural terraces, structures were directly erected on the relatively higher areas without stone footings while the lower areas were reserved for open air daily activities in all phases. The excavation data showed that the effects of the flood/torrent or landslide seem to be primarily limited to the relatively empty spaces outside the buildings but occasionally due to their rate also seriously being destructive on buildings. After these occasions, the area appeared to be unsuitable for occupation.

XRD and SEM/EDX analysis shows that during the uninhabited periods of the settlement, deposits of different mineralogical composition were transported there by external factors. Energy-dispersive X-ray spectroscopy data revealed the enrichment of Si (21.58%), Ca (14.93%), Fe (8.53%), and C (8.73%) in the elemental composition of all phases of Sumaki Höyük. In phase N3 fill, however, the carbon element proportion (C 11.14%) is higher compared to the fill of other phases, while the silicon proportion (Si 18.16%) is lower. In phase N4, iron (Fe 12.11%) is higher compared to the others (Figs. 13, 14). In phase N5 fill, the calcium proportion is noticeably higher. From X-ray diffractometry data, brucite and sphalerite are related to an aqueous environment. The presence of kyanite and chalcocopyrite, sourced in volcanic formations, indicates that these minerals were probably transported by slope flows from the Mt. Kıradağı basalts. These differences are mainly related to climate, the amount of lime in fills, and also to the construction tradition of the site. External factors, for instance floods, are also very important.

Flood water and wetland areas identified immediately before phase N2 and phase N4 may have affected distribution of the elements.

When all these factors are evaluated together, we can say that physical conditions can change the cultural environment, architectural perception, and building materials as well as the physical structure of the natural environment as a result of human influence. This can be described as mutual dialectic change and adaptation between the cultural and physical environment.

Nomenclature N, North; S, South; E, East; W, West; O, Oxygen; Si, Silicon; Ca, Calcium; Fe, Iron; C, Carbon; XRD, X-ray diffractometry; EDX, Energy-dispersive X-ray spectroscopy; SEM, Scanning electron microscopy; FPPNB, Final Pre-Pottery Neolithic B; cal BP, Calibrated years before; CalPal, Cologne Radiocarbon Calibration & Paleoclimate Research Package; CEDAD, CEntro di Fisica applicata, DATazione e Diagnostica

Acknowledgements Sumaki Höyük excavation project was conducted with the permission of the Ministry of Culture and Tourism of the Republic of Turkey. The article benefited from my PhD thesis titled "The Neolithic Architectural Structures and Cultural Landscape of Sumaki Höyük," completed at Paris Nanterre University. I would like to express my gratitude to Prof. Dr. Aslı Erim-Özdoğan for permitted me to do the study of Sumaki Höyük. Mr. Graham Lee is thanked for proofreading the English text of the article. I am also indebted to editorial board member and journal referees for their constructive comments that have greatly improved my paper.

Declarations

Conflict of interest The author declares that there are no competing interests.

References

- Balkaya Ç, Ekinci YL, Çakmak O, Blömer M, Amkens J, Kaya MA (2021) A challenging archaeo-geophysical exploration through GPR and ERT surveys on the Keber Tepe, City Hill of Doliche, Commagene (Gaziantep, SE Turkey). *J Appl Geophys* 186: 104272. <https://doi.org/10.1016/j.jappgeo.2021.104272>
- Banning EB (2000) Soils, Sediments, and Geomorphology. In: Jochim MA, Dickens RS (eds.) *The archaeologist's laboratory - the analysis of archaeological data. Interdisciplinary Contributions to Archeology book series (IDCA)*, pp 235-247. https://link.springer.com/chapter/10.1007/0-306-47654-1_12
- Branch N (2014) Agrarian landscapes: environmental archaeological studies. In: Smith C (ed.) *Encyclopedia of global archeology*, Springer Reference, pp 84-90. https://doi.org/10.1007/978-1-4419-0465-2_2263
- Boggs S (2014) *Principles of sedimentology and stratigraphy* (5th Edition). Pearson. http://www.science.earthjays.com/instruction/HSU/2015_fall/GEOL_332/SedimentologyStratigraphy4e.pdf
- Dal M (2010) Trakya Bölgesi Tarihi Yapılarında Kullanılan Karbonatlı Taşların Bozulma Nedenleri. *Vakıflar Dergisi* 34:47–59 <http://hdl.handle.net/11352/832>

- D'Amore L (2014) Stratigraphy in archaeology: a brief history. In: Smith C (ed.) Encyclopedia of global archeology, Springer Reference, pp 7085-7094. https://doi.org/10.1007/978-1-4419-0465-2_1031
- Dincauze DF (1987) Strategies for paleoenvironmental reconstruction in archaeology. *Adv Archaeol Method Theory* 11:255–336. <https://doi.org/10.1016/B978-0-12-003111-5.50008-7>
- Ekinci YL, Türkeş M, Demirci A, Erginal AE (2013) Shallow and deep-seated regolith slides on deforested slopes in Çanakkale, NW Turkey. *Geomorphology* 201:70–79. <https://doi.org/10.1016/j.geomorph.2013.06.008>
- Ekinci YL, Balkaya Ç, Şeren A, Kaya MA, Lightfoot CS (2014) Geomagnetic and geoelectrical prospection for buried archaeological remains on the Upper City of Amorium, a Byzantine city in midwestern Turkey. *J Geophys Eng* 11(1):015012. <https://doi.org/10.1088/1742-2132/11/1/015012>
- Elias RB, Dias E (2009) Effects of landslides on the mountain vegetation of Flores Island, Azores. *J Veg Sci* 20(4):706–717. <https://www.jstor.org/stable/40295784>
- Erginal AE, Öztürk B, Ekinci YL, Demirci A (2009) Investigation of the nature of slip surface using geochemical analyses and 2-D electrical resistivity tomography: a case study from Lapseki area, NW Turkey. *Environ Geol* 58:1167–1175. <https://doi.org/10.1007/s00254-008-1594-4>
- Erim-Özdoğan A, Saraltun S (2011) Inventory of cultural heritage in the environs of Garzan Valley and Batman Stream, Ilisu Dam Area. In: Tuna N, Doonan O (eds.) Salvage project of the archaeological heritage of the Ilisu and Carchemish Dam Reservoirs activities in 2002 (Vol. II). pp 945-1146. ODTÜ-TAÇDAM.
- Erim-Özdoğan, A, Saraltun S (2018) Sumaki Höyük Batman /Beşiri. In: Batman Müzesi Ilisu Barajı Kurtarma Kazıları pp. 55-88. Batman Müzesi Yayınları.
- Erpul G, Deviren-Saygın S, Gabriels D (2017) Toprak, Uygarlık ve Yaşam. 70. Türkiye Jeoloji Kurultayı. TMMOB Jeoloji Mühendisleri Odası Yayınları No:132, pp 772-775.
- Göktürkler G, Balkaya Ç, Erhan Z (2008) Geophysical investigation of a landslide: the Altındağ landslide site, İzmir (western Turkey). *J Appl Geophys* 65(2):84–96. <https://doi.org/10.1016/j.jappgeo.2008.05.008>
- Gönül İA, Çelebi G (2003) Binalarda Zeminden Kaynaklanan Nemlenmeyi Önleme Yöntemleri. *Gazi Üniversitesi Mühendislik ve Mimarlık Fakültesi Dergisi* 18(4):109–122. <https://dergipark.org.tr/tr/pub/gazimmfd/issue/6658/89016>
- Graf MT, Schwadron M, Stone PA, Ross M (2008) An enigmatic carbonate layer in Everglades tree island peats. *EOS* 89(12):117–124. <https://doi.org/10.1029/2008EO120001>
- Grayson DK (1981) A critical view of the use of archaeological vertebrates in paleoenvironmental reconstruction. *J Ethnobiol* 1(1):28–38. <https://ethnobiology.org/sites/default/files/pdfs/JoE/1-1/Grayson1981.pdf>
- McClain KP, Yıldırım C, Çiner A, Sarıkaya MA, Özcan O, Görüm T, ... Öztürk T (2021) River, alluvial fan and landslide interactions in a tributary junction setting: Implications for tectonic controls on Quaternary fluvial landscape development (Central Anatolian Plateau margin, Turkey). *Geomorphology* 376 (Journal Pre-proof). <https://doi.org/10.1016/j.geomorph.2020.107567>
- Hill CL, Rapp G (2014) Geoarchaeology. In: Smith C (ed.) Encyclopedia of global archeology, Springer Reference, pp 3008-3017. https://doi.org/10.1007/978-1-4419-0465-2_812
- Hoel F (1997) Paleoenvironment and human society in the Jezireh of Northern Mesopotamia 20 000-6 000 BP. *Paléorient* 23(2):39–49. <https://doi.org/10.3406/Paleo.1997.4651>
- Marathe RB (2012) XRD and SEM analysis of Tapti River sediment: a case study. *Archiv Appl Sci Res* 4(1):78–84. <https://www.scholarsresearchlibrary.com/articles/xrd-and-sem-analysis-of-tapti-river-sediment-a-case-study.pdf>
- Matthews W, French CAI, Lawrence T, Cutler DF, Jones MK (1997) Microstratigraphic traces of site formation processes and human activities. *World Archaeol* 29:281–308. <https://doi.org/10.1080/00438243.1997.9980378>
- Matthews W (2003) Excavations at Tell Brak, Exploring an Upper Mesopotamian regional centre, 1994-1996. McDonald Institute for Archaeological Research and British School of Archaeology in Iraq 124:344. <https://doi.org/10.2307/4132224>
- Missiaen T, Sakellariou D, Flemming NC (2017) Survey strategies and techniques in underwater geoarchaeological research: an overview with emphasis on prehistoric sites. In: Bailey G, Harf J, Sakellariou (eds.), Under the sea: archaeology and palaeolandscapes of the continental shelf, Springer, pp 21-37. https://doi.org/10.1007/978-3-319-53160-1_2
- Patil BH, Shrivastava VS (2005) XRD and SEM analysis of Tapti River sediments. *Mater Sci Res India* 3(2):175–178 (India). <https://doi.org/10.13005/msri/030212>
- Pattnayak S, Kumar M, Sahu SC, Dhal NK, Behera RK (2019) Comparison of soil characteristics and carbon content of contrastingly different moist-mixed deciduous and evergreen mangrove forest in Odisha, India. *Geol Ecol Landsc* 3(4):239–246. <https://doi.org/10.1080/24749508.2018.1545104>
- Reynolds KS, Catt JA (1987) Soils and vegetation history of abandoned enclosures in the New Forest, Hampshire, England. *J Archaeol Sci* 14(5):507–527. [https://doi.org/10.1016/0305-4403\(87\)90035-5](https://doi.org/10.1016/0305-4403(87)90035-5)
- Saraltun S (2019) The Neolithic architectural structures and cultural landscape of Sumaki Höyük. Dissertation, Paris Nanterre University
- Sarris A, Kalaycı T, Moffat I, Manataka M (2018) An introduction to geophysical and geochemical methods in digital geoarchaeology. In: Siart C, Forbriger M, Bubbenzer O (eds) Digital geoarchaeology - new techniques for interdisciplinary human-environmental research. Springer, pp 215–236. https://doi.org/10.1007/978-3-319-25316-9_14
- Siler M, Şengül MT (2016) Kaman Deresi Havzası (Pütürge-Malatya) Kütle hareketleri. In: Özçağlar A, Türkoğlu N, Bayar R, Yılmaz E, Aydın O, Karabacak K (eds.) TÜCAUM International Geography Symposium proceedings. Ankara Üniversitesi Dil ve Tarih-Coğrafya Fakültesi. pp 126-139.
- Sunkar M, Tanbul S (2009) Baskil Havzası'nda (Elazığ) Doğal Ortam Özelliklerinden Kaynaklanan Sorunlar ve Çözüm Önerileri. *Fırat Üniversitesi Sosyal Bilimler Dergisi* 19(2):83–106. <https://dergipark.org.tr/tr/pub/firatsbed/issue/6328/84526>
- Sunkar M, Tonbul S (2012) Iluh Deresi (Batman) Havzası'nın Jeomorfolojisi. *Coğrafya Dergisi* 24:38–60. <https://dergipark.org.tr/tr/pub/iucografya/issue/25069/264616>
- Yeşilova Ç, Helvacı C (2011) Batman-Siirt Kuzeyi Stratigrafisi ve Sedimentolojisi, Türkiye. *TPJD Bülteni* 23(2):7–50. <http://www.tpjd.org.tr/images/bulneler/pdf/aralik2011.pdf>
- Yılmaz E, Duran O (1997) Güneydoğu Anadolu Bölgesi otokton ve allokon birimlerin stratigrafi sözlüğü. TPAO Araştırma Merkezi, Eğitim Yayınları No:31.