

APPLICATION OF SOIL ANALYSES AS MARKERS TO CHARACTERIZE A MIDDLE EASTERN CHALCOLITHIC - LATE BRONZE AGE MOUNDS

YAKIN DOĞU'DA KALKOLİTİK – SON TUNÇ ÇAĞ HÖYÜKLERİNİ NİTELEYİCİ TOPRAK ANALİZLERİNE DAİR BİR UYGULAMA

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Key words: Lebanon, Middle East, Chalcolithic, Late Bronze Age, soil analysis, phosphorus, organic matter, weathering, human activity, stratigraphy

Anahtar sözcükler: Lübnan, Orta Doğu, Kalkolitik, Son Tunç Çağ, toprak analizleri, fosfor, organik madde, ayrışma, insan etkinlikleri, tabakalanma

ÖZET

Lübnan'da Bekaa Vadisindeki El-Ghassil Höyüğü Suriye, Türkiye ve Irak'taki tipik höyüklerden biridir. Bu gibi alanlarda değerlendirme yapılırken çalışmaların ağırlığı daha çok tabakalanma ve çeşitli arkeolojik buluntulara verilmekte ve toprak analiz yöntemleri çoğu kez göz ardı edilmektedir. Bu çalışma yüzeyden yaklaşık 6 ile 7 m derinliklere kadar alınan örneklerle, höyük yakınlarından alınan örnekleri içermektedir. Böylece sağlanan organik madde, toplam ve alınabilir fosfor ve demir oksitlerin oranları gibi parametrik verilerden alandaki toprak oluşumunu ve yerleşmenin yoğunlaştığı veya höyüğün terk edildiği dönemleri, dolayısıyla höyükteki insan yaşamının gelişimini aydınlatmak için yararlanılabilir. Ayrıca bir höyüğün ayırt edilmesi zor ve karışık arkeolojik tabakaları -höyük stratigrafisi de, toprak analizleri kullanılarak aydınlatılabilir.

ABSTRACT

Tell El-Ghassil in Lebanon's Beka'a Valley is typical of mounds, in Syria, Turkey, and Iraq. While stratigraphy and human artefacts are used in archaeological investigations of such sites, soil analysis is a less frequently used. This study involved sampling to a depth of about 6 to 7 meters on exposed surfaces of a vertical transect, as well as away from the mound. The data show that parameters such as organic matter, total and available phosphorus, and the proportion of iron oxides are potentially useful indicators of soil weathering and the intensity of human occupation of the site, as well as periods of abandonment, and thus in charting the human evolution of the mound. The diffuse archaeological layers, i.e., the stratigraphy of the mound, which is difficult to distinguish, may also be elucidated with soil analysis.

INTRODUCTION

Archaeologists have long-relied upon artifacts associated with human activity to document the patterns, chronologies and pottery technologies of past civilizations (Henderson 1989: 311, Tite 1989: 116-118, Paynter et al. 2004: 422-425) as well as the soils these materials were extracted from (Kapur et al. 1998: 183-184, Tite 2008: 220-222). Ample attention was also given to the study of the soils to include micromorphology as a powerful tool. Relatively recent work undertaken at excavations dealing with the characterisation and dating of soil horizons developed in archaeological sections has contributed to the significance of soil development and weathering/decomposition of soils at well known excavation sites of man-made mounds (Eidt 1984: 150). The Middle Eastern region has been the context for examining the civilizations since the beginning of history, with studies conducted in North Mesopotamia-Iraq and Turkey (Stoops and Nijs 1986: 331-333, Weiss et al. 1993: 997-999), the eastern Khabour Basin- Syria (Courty et al. 2008: 215-219), the Madaba-Dhiban Plateau-Jordan (Cordova et al. 2005: 36-40), and the Tigris and Euphrates river basin (Morozova 2005: 41-45).

The approach for this study of an abandoned mound in the Middle East is based on the premise that soil analysis, especially phosphorus (P) as a chemical marker, can complement the conventional archaeological investigations in order to unravel the history of human habitation. The awareness that soil science can add to the archaeologist's endeavors has developed in comparatively recent times (Eidt 1984: 150, Sanchez et al. 1996: 156-160, 1998: 345-350). Recent studies further elucidate phosphorous as a marker in determining degraded archaeological sites with their diffuse stratigraphy/layers incorporated in presently cultivated historical land (Terry et al. 2000: 153-156, Akça et al. 2008: 87). The foregoing study sought to examine an archaeological site in the Middle East using conventional soil analysis with special significance on the phosphorous status of the excavation soils without the use of thin sections regarding the difficulties encountered during the collection of the soils and preparation of the thin sections. These difficulties primarily concern the sampling

of the undisturbed soils, that might cause undesired damage at the sampling surface of the selected profile, followed by the tedious thin section preparation methodology that is closely related to the ever-changing composition of the resins used effecting the period and quality of the thin section. Moreover, the cutting (excavation pit) subsequent to sampling has been filled in, thus the mound is no longer available for sampling. The co-author Prof. S. Kapur from the University of Çukurova and the principle author Dr. John Ryan have collaborated in this paper in an attempt to point out the benefit of simple soil chemical analysis in revealing the soil-bound stratigraphy, that would also serve as a preliminary study in the beginning of a mound excavation that should be followed by the ultimate tool of micromorphology. Ultimately, this paper calls for a greater synergy between Soil Scientist and Archaeologist.

ARCHAEOLOGICAL BACKGROUND

Mound represent an example of such former settlement peculiar to the Middle East/Western Asian region (Wilkinson 1976: 280). Some of the major tells in the region are depicted in Fig. 1. The well known fact, that mound are created by the accumulation and weathering of successive levels of human occupation using alluvial clays to construct the walls and roofs of buildings and stables and to enclose courtyards, neighborhoods, and settlements, by the archaeologists is highly intriguing for Earth and Soil Scientists in terms of soil formation. When mud-brick structures reach the end of their usefulness for humans and livestock and/or collapse and are abandoned by their inhabitants, they are often stripped of scarce wood and stone and exposed to weathering (Bullard 1985: 111) or filled in and used as well-drained compact foundations for the next level of structures, all being of strong interest as soil bound natural materials to Soil Scientists, as also exposed to climatic changes in their course of abandonment.

As the build-up of organic materials on site from human and animal waste can make the underlying clay debris unsuitable as a construction material, fresh supplies of well weathered alluvial clays from

outside the site tend to be brought in for further building. After several hundreds or thousands of years, a mound is formed from successive phases of building, rebuilding, abandonment and re-occupation superimposed on the rubble of earlier settlements on the same site (Davidson 1976: 261-263). This build-up of sealed deposits provides an opportunity to investigate the development of soils within a closely dated chronological sequence (Haidouti and Yassoglou 1982: 1049).

SOIL INVESTIGATIONS

Soil studies of archaeological sites range from potential and actual erosion (Thornes and Gilman 1983: 93-107), morphology and horizon identification (Haidouti and Yassoglou, 1982: 1048), and chemical analysis (Eidt 1985: 158, Beach and Beach 2008: 420). Analyses that reflect weathering intensity and nutrient accumulation can augment evidence from other approaches. Iron (Fe) solubility in solutions of ammonium oxalate (amorphous) and citrate-dithionite-bicarbonate ("free" or crystalline) reflects weathering intensity in soils, and, by inference, the duration of exposure of a particular surface to the elements of weathering. The ratio of these fractions has been used to indicate relative weathering intensity as a supplement to other criteria (Alexander 1974: 122, Ahmad et al. 1977: 1164).

While "available" phosphorus (P) can build up due to decomposition of plant materials, all of which contain P, as well as ash which is a rich source of P, this fraction tends to "revert" over time to a less soluble fraction. As P is immobile in soils, unless subject to surface erosion, total soil P values reflect accumulation due to plant debris, human and animal excreta, ash, bones, etc (Eidt 1984: 150, 1985: 162-163). Organic carbon (C) and nitrogen (N), as components of organic matter (OM) or material of plant origin, are possible indices of soil change, but are less reliable than P. These elements may disappear from the soil by oxidation, and subsequent volatile loss as carbon dioxide in aerobic and as methane (CH₄) in anaerobic conditions in the case of carbon and ammonia and nitrous oxide in the case of nitrogen, and mineralization to mobile nitrate which may be leached or lost in surface runoff.

The rate as well as the extent of these chemical transformations depends on the environment (though ¹⁴C dating has been used to establish approximate age of plant remains in soil layers, the presence of known artifacts, i.e., coins and pottery of known historical period, can also be used to define soil age alongside an interpretation of the processes such as bioturbation that may affect any residual soil stratigraphy). Similarly, soluble salts may be ephemeral. Major changes associated with weathering and organic matter accumulation should be reflected in variation in soil color with depth of the accumulated soil (Fitz Patrick 1993: 255-260).

MATERIALS AND METHODS

TELL EL-GHASSIL

Tell El-Ghassil, a mound of approximately 12m in height (Plate 1) above the surrounding ground level, or an elevation of 88 to 100 meters above sea level and one square hectare in area and a slope of up to 35%, is located in the Bekaa Valley, Lebanon, 50 km east of Beirut (Fig. 2). The mound is on the boundary of 100-ha farm of the American University of Beirut's Agricultural Research and Education Center and adjacent private property—the latter half of the mound is off limits to examination and excavation. The climate of the area is typical of the semi-arid Mediterranean agro-ecological zone (Kassem 1981: 11-13), with cold wet winters (mean annual rainfall of 400-500 mm and mean winter temperature of about 5°C) and hot (30°C) dry summers. The mound has been cultivated since it was abandoned as an occupation site many centuries ago.

The site was included as a separate "soil unit" in the map prepared by Sarsam (1975: 24). The predominant soil type is a very fine clayey, mixed, mesic, Vertic Xerochrept, developed on alluvium derived from limestone. Nutrient distribution for the farm soil was described by Ryan et al. (1980: 22-30). The adjacent soils exhibited considerable physical and chemical spatial variation consistent with alluvial/colluvial deposition.

The mound owes its existence to human settlement attracted to the perennial spring, 'Ain El-Ghassil' at the foot of the mound at the south side (Fig. 2). The archaeological sequence of the site has been

established during excavations between 1956 and 1974 (Baramki 1961: 91, Badre 1982: 126-128). The earliest occupation, during the Bronze Age, extended from about 1200 BC, and lasted until about 600 BC, when the site was finally abandoned. Although clearly stratified deposits from the earliest phases of occupation at the site have not been reached, significant Middle and Late Bronze Age burials (1750-1325 BC ca) and several phases of Iron Age temples have been excavated.

Though the site at Tell El-Ghassil is only partially excavated to a depth of 6-7m (Fig. 2), the purpose of this study was to integrate soil analysis data with previous archaeological observations in order to more accurately establish the site's chronology. A secondary purpose was to evaluate soil chemical data as indices for archaeological work under semi-arid environments. Unfortunately due to logistical constraints in the area, more complete morphological examination was not possible.

PROCEDURE

The 1-ha site was sampled on the surface in each direction of the compass from its center, i.e., north, south, east and west. The samples were taken at the ridge of the tell, the mid and toe slopes, and in the adjacent field or non-tell area on the northern side. In each case, surface debris was cleared away and a composite sample was obtained from 15-20 sub-samples. Samples were also obtained from the vertical sections of the cutting or excavation facing east and west. Samples were taken on systematic basis every 50 cm to a depth of about 6-7m based on the average depths encountered in the previous mound studies and experience of the authors obtained at field studies on the stratigraphic distributions/depths at relevant conditions. They were obtained by scraping away the exposed/weathered surface layer and taking a core sample at about 10 cm into the excavated pit face.

The samples were then taken to the laboratory, air-dried, and passed through a 2-mm sieve for subsequent chemical and physical analysis, as follows by standard procedures (Black 1965: 1572). Soil pH was conducted by the glass electrode (soil: solution, 1:2.5); electrical conductivity (EC) by a resistance bridge from a similar soil solution

extract; total calcium carbonate (CaCO_3) equivalent by acid neutralization followed by titration; organic matter by potassium dichromate digestion; total soil nitrogen by the Kjeldahl digestion procedure; total P by perchloric acid digestion followed by colorimetric determination with vanado-molybdate; available phosphorous by extraction with 0.5 M sodium bicarbonate (NaHCO_3) and determination with ascorbic acid; soil texture by the Buoyoucos hydrometer; and soil color according to the Munsell colour chart. Soil iron was extracted with acid ammonium oxalate (amorphous) and a solution of citrate-dithionite-bicarbonate ("free Fe - iron"-mainly crystalline) as described by Alexander (1974: 123).

RESULTS

The impact of occupation on the mound can be seen by considering surface soil properties in each direction from the top of the mound to adjacent non-tell fields (Table 1). Differences between the tell and the fields were evident for some parameters, but not for others. There was no difference in soil texture (most samples were clay), pH or soluble salts. With the site's elevation and the moderate rainfall (400-500 mm) any build up of salts was unlikely. As might be expected, pH values were relatively constant due to the solid-phase calcium carbonate. However, while N and organic matter data were variable, calcium carbonate values tended to be higher on the mound than in adjacent fields, but considerable variation in calcium carbonate is a feature of such colluvium/alluvium derived from limestone (Badre 1982: 128). Similarly, most values for both available phosphorous and total phosphorous were higher on the mound.

The inherent variability in the data was reduced by averaging the depth-wise values at both sides of the excavation as well as all surface samples and by comparing them with average field values (Table 2). Thus, more reliable conclusions could be drawn. When surface samples from the tell were compared with depth, the only obvious differences were with organic matter, which were higher, and sodium bicarbonate-phosphorous values which were lower than average values with depth. There were no consistent differences in other properties between surface and depth wise samples on the mound.

Clear differences were evident between average mound and non-mound values. The mound had considerably higher levels of calcium carbonate, both available and total phosphorous, soluble salts, and proportionately more sand and silt. As expected, pH values did not differ between the mound and the field. However, the mound had lower levels of organic matter and consequently lower nitrogen levels. Both forms of iron (i.e. amorphous and “free”) were also lower, with proportionally less clay. It is of interest to note that the proportion of amorphous to “free” iron was relatively constant between the tell and adjacent fields, ie at 0.36 to 0.38, indicating similar weathering intensities in the soil of the tell and that of the surrounding field.

In view of these differences in soil enrichment or depletion, the distribution of these parameters with excavation depth was presented. Not only were differences with depth evident (Fig.'s 3 and 4 -broken and solid lines stand for either sides of the Tell) but also depending on the location of the depth-wise probe (ie at opposite sides of the excavation separated by a distance of about 10 m). The fluctuation of some of the contents of the soil attributes with depth, such as the available and total phosphorous, organic matter, nitrogen and the salt as well as the clay contents, around the depths of 1, 3 and 4 m may well be the markers of archaeological stratigraphy/layering.

Consistent with soil having solid-phase calcium carbonate, soil pH showed little depth-wise distribution. Though somewhat erratic, both calcium carbonate and clay values tended on average to be relatively uniform with depth. This is consistent with the notion that the materials used to build the mound came from the same source, with a relatively constant amount of CaCO_3 in the clay-sized fraction. Though the distribution of sodium bicarbonate-phosphorous was highly erratic, the average values from both sides of the excavation tended to range from 100 to 150 mg.kg^{-1} with no evident decrease with depth. The two-to three fold increase in available P due to man's activity, eg. ash from burning organic materials-food residues- and bones, both being rich sources of phosphorous, can be seen from a comparison of unfertilized adjacent soil phosphorous values (Ryan et al., 1980: 33-38) and from the ancient bones found in the burials of the mound (Badre

1982: 129-130). Exhibiting a similar erratic distribution, total phosphorous values tended to increase with depth.

However, some parameters showed some consistent changes. Organic matter was uniform with depth, i.e., at about 0.8% at 2.5 to 3.5 m. At lower depths, the organic matter content showed a peak of about 2.75% at 2.5m for one side of the excavation and a similar peak at 4.0 m at the same side. As nitrogen is a relatively constant constituent of organic matter, its distribution followed that of organic matter, with increases from 0.08% to about 0.15% at the 3 and 4-m peaks. Though average salinity values were relatively low, i.e., about 0.2 ds.m^{-1} , the distribution showed peaks together with the clay percentage at the 3 to 4-m depth, similar to, but not coinciding exactly, with those for organic matter and nitrogen.

Measurements of soil colour with excavation depth and on the surface showed little variation in this property. Cultivated surface samples were brown (10 YR 5/6) to pale brown (10 YR 6/3). The peaks for organic matter at 3 to 4 m depth showed a slight color change to dark brown (10 YR 3/3) to grayish brown (10 YR 5/2).

DISCUSSION

This study of a partial excavation of a typical mound in the Middle East region indicated that in the absence of apparent physical differentiation in soil properties within the mound, some chemical indices served as indicators of man's activities during the various phases of its evolution. This also yielded clues/markers to the probable diffuse archaeological stratigraphy, i.e., the long-standing layers of human settlement rather than the features of soil development, primarily of soil structure and abrupt changes in color, as observations of the face of the exposure indicated no evidence of pedogenesis or horizon development. Not surprisingly, Eidt (1985: 150) in his overview of such a pre-historic settlement indicated that because of the low weathering intensity, mound in arid/semi-arid areas are unlikely to exhibit features of normal soil development due to the low rainfall; the constant mixing due to human traffic would cause homogenization and prohibit any differentiation to occur, thus, implying to the effect of human activities

causing the formation of the different layers.

The sampling procedure applied in this study is different compared to the well-known drilling method that would need deep augering through the mound causing some destruction, which is unacceptable in archaeological investigations. Moreover, the soil samples were collected simultaneous to the excavation study adding value to archaeological study in need of utmost care in preserving the nature of the mound. On the other hand, the sampling procedure may also help archaeologists, facing difficulties in determining the diffuse stratigraphy of the mound, to start off with some guiding information provided by soil analyses as stated above.

The weak weathering intensity and limited exposure to the elements for a short period of time (from 7000 to 3200 yr BP/ from Early to Late Holocene) in terms of soil development and uniform climate (of that part of the Holocene prevailing at the site) are also reflected in the low ratio of oxalate to citrate-dithionite-bicarbonate iron in the samples. It can be assumed that the chemical and physical composition of the mound is similar to the surrounding soil, since the mound would most probably have been built with local materials. This is in contrast to sites when buildings were made of stone, which often were transported great distances. Examples of such sites are the Greek-Roman site in nearby Baalbek to the north and in Anjar to the east.

Despite this similarity, some physical differences might be expected between mound and the soil of the surrounding area. As the edges of mound are steeply sloping (over 12%), erosion is likely to occur, thus depleting the finer clay fraction and enrich the foot slope with finer depositional material. Despite such expectations, no clear catenary differences in texture were detected. If there were indeed any textural changes with slope position it might have been masked by the mixing effect of cultivation of the surface soil on and around the mound. These probable and expected changes of the surface soil after cultivation, need to be defined as the changing parameters of the inhabited areas (Akça 2008: 89-92), whereas it is well known that the ephemeral characteristics such as organic matter, nitrogen and carbon, as well as available phosphorous have been influenced by centuries of human cultivation, especially in the recent decades of fertilizer use.

Of the chemical parameters used to characterize the evolution and build-up of the mound, the most sensitive indicators are phosphorous and organic matter. Much has been written about phosphorous in mound development (Eidt 1985: 150). In this case, it was clear that the available phosphorous levels are derived from ash from burning of fuel wood, as well as from mineralization of organic material and decomposition of bones (Badre 1982: 127-130). The values of 100-250 mg kg⁻¹ throughout the 6-7 m transect are 10-20 times higher than in the corresponding soil in the field without any history of fertilization. The high values in the topsoil surrounding the mound were due to over-fertilization with superphosphate for many years at the research station where the mound is located. The phosphorous enrichment in the tell itself obviously came from mans activity.

Due to the dynamics of soil phosphorous in which relatively soluble "available" P gradually reverts to insoluble forms, total phosphorous, which encompasses both soluble and the much larger insoluble fraction, total phosphorous values showed "peaks" and "troughs" at various depths, but a general increase with depth. It might be reasonable to assume that these peaks may reflect periods of extensive human occupation.

Other measurements also showed distinct peaks with depth. For example, there was a threefold increase in organic matter at around 3 to 4 m and the discrepancy between the two samplings was due to the variation at the north and south faces of the excavation. As nitrogen is related to organic matter, the peaks were similar. Those peaks may reflect a time when the site was abandoned and given over to natural vegetation which would enhance the soil organic matter content through root biomass and incorporation of surface biomass. While electrical conductivity did show some peaks, the actual values were low, but could have indicated a dry period when some salts from natural soil weathering or by the input of salt-laden windblown material would accumulate, as has been the case throughout the Eastern part of the Mediterranean Basin and the Middle East since the Early Holocene (Kubilay et al., 1997).

In conclusion, the study shows that some chemical analyses from Middle Eastern mound, or elevated

human occupation sites, notably forms of phosphorous, organic matter, and iron can serve as useful indicators of how soils have been historically used by man. The conventional archaeological approaches involving the identification of pottery and other human artifacts, in addition to sophisticated soil micromorphological identification conducted by the use of the polarised and electron microscope, together with these simple chemical analyses can help to elucidate the very complex history of evolution of human habitation over the millennia of man's existence in the Middle East region. The approach is but one piece in the puzzle that enables archaeologists to develop a picture of the chronology of mound. The sampling procedure

implemented in this study is also recommended together with the type of soil analyses at similar sites for the preservation of the man-made mounds, determination of the human activities and the tentative determination of the archaeological stratigraphy.

NOTE

Prof. S. Kapur in charge of a thin section laboratory and head of the Archaeometry Department of this University and Dr. John Ryan former Professor of Soil Science in the American University of Beirut, presently working in ICARDA, Syria has collaborated extensively with Çukurova University over the past ten years.

REFERENCES

- Ahmad, M., J. Ryan and R.J. Paeth 1977
 "Soil development as a function of time in the Punjab river plains of Pakistan", *Soil Science Society of America Proceeding* 41: 1162-1166.
- Akça, E. et al. 2008
 "Differentiating the natural and man-made terraces of Lake Van, Eastern Anatolia, utilising earth science methods", *Lakes & Reservoirs: Research and Management* 13: 83-93.
- Alexander, E.B. 1974
 "Extractable iron in relation to soil age on terraces along the Truckee River, Nevada", *Soil Science Society of America Proceedings* 38: 121-124.
- Badre, L. 1982
 "Tell El-Ghassil: Tomb 1", M. Yan (ed.) *Archaeologie du levant*: 123-132. Maison de l'Orient, Lyon.
- Baramki, D. 1961
 "Preliminary report on the excavation at Tell El-Ghassil", *Bulletin du Musée de Beyrouit* 16: 87-97.
- Beach, T. and Sh. Beach Luzzadder 2008
 "Geoarchaeology and Plain Aggradation around Kinet Höyük, an Archaeological Mound in the Eastern Mediterranean, Turkey", *Geomorphology* 101/3: 416-428.
- Black, C.A. 1965
Methods of soil analysis. Agron No. 9, American Society of Agronomy, Madison.
- Bullard, R.G. 1985
 "Sedimentary environments and lithologic materials at two archaeological sites", G. Rapp and J.A. Gifford (eds.) *Archaeological Geography*: 103-133. Yale University Press, New Haven.
- Cordova, C., C. Foley, A. Nowell and M. Bisson 2005
 "Landforms, sediments, soil development and prehistoric site settings in the Madaba-Dhiban Plateau, Jordan", *Geoarchaeology* 20: 29-56.
- Courty, M.A. et al. 2008
 "Regional manifestation of the widespread disruption of soil-landscape by the 4 kyr BP impact-linked dust event using pedo-sedimentary micro-fabrics", S. Kapur, A.R. Mermut and G. Stoops (eds.) *New Trends in Soil Micromorphology*: 211-236. Springer Verlag, Berlin.
- Davidson, D.A. 1976
 "Processes of tell formation and erosion", D.A. Davidson and M.L. Shockley (eds.) *Geoarchaeology*: 255-265. Duckworth, London.
- Eidt, R.C. 1984
Advances in abandoned settlement analysis. Application to prehistoric anthrosols in Colombia, South America. University of Wisconsin, Milwaukee.
- Eidt, R.C. 1985
 "Theoretical and practical considerations in the analysis of anthrosols", G. Rapp and J.A. Gifford (eds.) *Archeological Geology*: 155-189. Yale University Press, New Haven.

- Fitzpatrick, E.A. 1993
Soil Microscopy and micromorphology. John Wiley & Sons, Chichester.
- Haidouti, C. and N.J. Yassoglou 1982
“The genesis of certain soil profiles on an archaeological site in southern Greece”, *Soil Science Society of America Proceedings* 40: 1047-1051.
- Henderson, J. 1989
Scientific Analysis in Archaeology. University of Oxford, Committee for Archaeology, Monograph 19, Oxford.
- Kapur, A. et al. 1998
“Mineralogy and Micromorphology of Iznik Ceramics”, *Anatolian Studies* 48: 181-189.
- Kassem, A. 1981
“Climate, soil and land resources in North Africa and West Asia”, *Plant and Soil* 58/1: 28.
- Kubilay, N. et al. 1997
“Seasonal chemical and mineralogical variability of atmospheric particles in the coastal region of the Northeastern Mediterranean”, *CATENA* 28/3-4: 313-328.
- Morozova, G.S. 2005
“A review of Holocene avulsions of the Tigris and Euphrates Rivers and possible effects on the evolution of civilizations in Lower Mesopotamia”, *Geoarchaeology* 20: 401-423.
- Paynter, S., F. Okyar, S. Wolf and M. Tite 2004
“The Production Technology of Iznik Pottery-A Reassessment”, *Archaeometry* 46/3: 421-437.
- Ryan, J., G. Musharrafieh and A. Barsumian 1980
Soil fertility characterization at the Agricultural Research and Education Center of the American University of Beirut. Publ. No. 64: 1-47, Faculty of Agriculture and Food Sciences, Beirut.
- Sanchez, A.A., M.L. Canabata and R. Lizcano 1996
“Phosphorus analysis in archaeological sites: an optimization of the method and interpretation of the results”, *Archaeometry* 38: 151-164.
- Sanchez, A.A., M.L. Canabata and R. Lizcano 1998
“Archaeological and chemical research on sediments and ceramics at Polideportivo (Spain): An integrated approach”, *Archaeometry* 40: 341-350.
- Sarsam, A.A. 1975
Map and characteristics of soils on the Agricultural Research and Education Center of the American University of Beirut. M.Sc. Thesis. American University of Beirut, Beirut.
- Stoops, G. and R. Nijs 1986
“Micromorphological characteristics of some tell materials from Mesopotamia”, *Pedologie* 36: 329-336.
- Terry, R.E. 2000
“Quantitative phosphorous measurement: A field test procedure for archaeological site analysis at Piedras Negras, Guatemala”, *Geoarchaeology* 15/2: 151-166.
- Thornes, J.B. and A. Gilman 1983
“Potential and actual erosion around archaeological sites in southeast Spain”, *Rainfall Simulation, Rain off and Soil Erosion*: 91-113. CATENA Supplement 4, Elsevier, Amsterdam.
- Tite, M.S. 1989
“Iznik pottery: An investigation of the methods of production”, *Archaeometry* 31/2: 115-132.
- Tite, M.S. 2008
“Ceramic production, provenance and use - a review”, *Archaeometry* 50/2: 216-231.
- Weiss, H. 1993
“The origin and collapse of Third Millennium North Mesopotamian civilization”, *Science* 261: 995-1004.
- Wilkinson, T.J. 1976
“Soil and sediment structures as an aid to archaeological interpretation: Sediments at Dibsī Faraj, Syria”, D.A. Davidson and M.L. Shackley (eds.) *Geoarchaeology*: 275-288. Duckworth, London.

APPLICATION OF SOIL ANALYSES

Direction from Tell Center	Location	Soil Properties							
		pH	Electrical Conductivity	Calcium Carbonate	Organic Matter	Nitrogen	Phosphorus Total	NaHCO ₃	Texture
			dSm-1	%			mg kg ⁻¹		
East	Top	8.2	0.16	24	1.8	0.12	0.12	0.27	Clay
	Mid-slope	8.4	0.16	29	1.3	0.10	0.10	0.30	Clay
	Foot-slope	8.1	0.17	29	1.6	0.12	0.14	0.32	Clay
	Field	8.3	0.16	15	1.8	0.14	0.12	0.20	Clay
North	Top	7.9	0.16	29	1.7	0.10	0.33	44	Clay
	Field	8.0	0.30	29	1.7	0.10	0.32	70	Clay loam
	Foot-slope	8.1	0.15	31	1.6	0.12	0.32	52	Clay
	Mid-slope	7.9	0.21	28	2.7	0.19	0.27	49	Clay
South	Top	8.3	0.18	34	1.2	0.07	0.43	163	Clay loam
	Mid-slope	8.1	0.21	29	1.4	0.11	0.34	54	Clay
	Foot-slope	8.2	0.14	28	1.5	0.11	0.30	41	Clay
	Field	8.0	0.18	22	2.0	0.14	0.27	39	Clay
West	Top	8.2	0.15	23	2.4	0.17	0.37	54	Clay
	Field	8.2	0.16	30	2.1	0.13	0.39	88	Clay
	Foot-slope	8.1	0.18	26	2.7	0.19	0.34	44	Clay
	Mid-slope	8.1	0.18	20	1.9	0.14	0.27	29	Clay

Table 1. Selected soil properties of the Tell El-Ghassil site.

Çizelge 1. El-Ghassil Höyüğü alanının seçilmiş toprak özellikleri

Property	Tell Surface	Depth*		Average	Non-Mound	Mound: Non-Mound Ratio
		A	B			
CaCO ₃ , %	28.4	29	28.	28.6	21	1.36
OM, %	1.75	1.39	1.07	1.40	2.1	0.67
Total-P, %	0.34	0.37	0.38	0.36	25	1.44
NaHCO ₃ -P, mg kg ⁻¹	2.82	130	130	107	38	62
N, %	0.12	0.08	0.08	0.09	0.15	0.62
pH	8.17	8.1	8.2	8.2	8.0	1.03
E.C. dS m ⁻¹	0.18	0.28	0.29	0.25	0.18	1.39
Fe-oxalate	1.37	1.64	1.66	1.56	2.32	0.67
Fe-CDB, mg kg ⁻¹	5.36	4.28	4.21	4.62	6.45	0.72
Fe-ox/Fe-CDB	0.25	0.38	0.39	0.38	0.36	
Clay, %	43.3	38.7	42.5	41.5	59.2	0.70
Sand, %	29.4	31.8	30.6	30.6	22.8	1.34
Silt, %	29.3	29.5	27.5	28.8	18.0	1.60

Table 2. Surface and depth-wise soil analysis of Tell El-Ghassil site in relation to adjacent non-mound soil.(from the top of the mound).

Çizelge 2. El-Ghassil Höyüğü alanının yüzey ve derinlikten alınan topraklarının yakından alınan höyük dışı topraklarıyla (höyüğün olan ilişkisi)



Fig. 1. The major Mound of the Middle East and Location of Mound El-Ghassil.

Res 1. Orta Doğu'daki başlıca Höyükler ve El-Ghassil Höyüğü'nün konumu



Fig. 2. The Tell El-Ghassil and the surrounding cultivated soil
Res 2. El-Ghassil Höyüğü ve çevreleyen işlenen topraklar

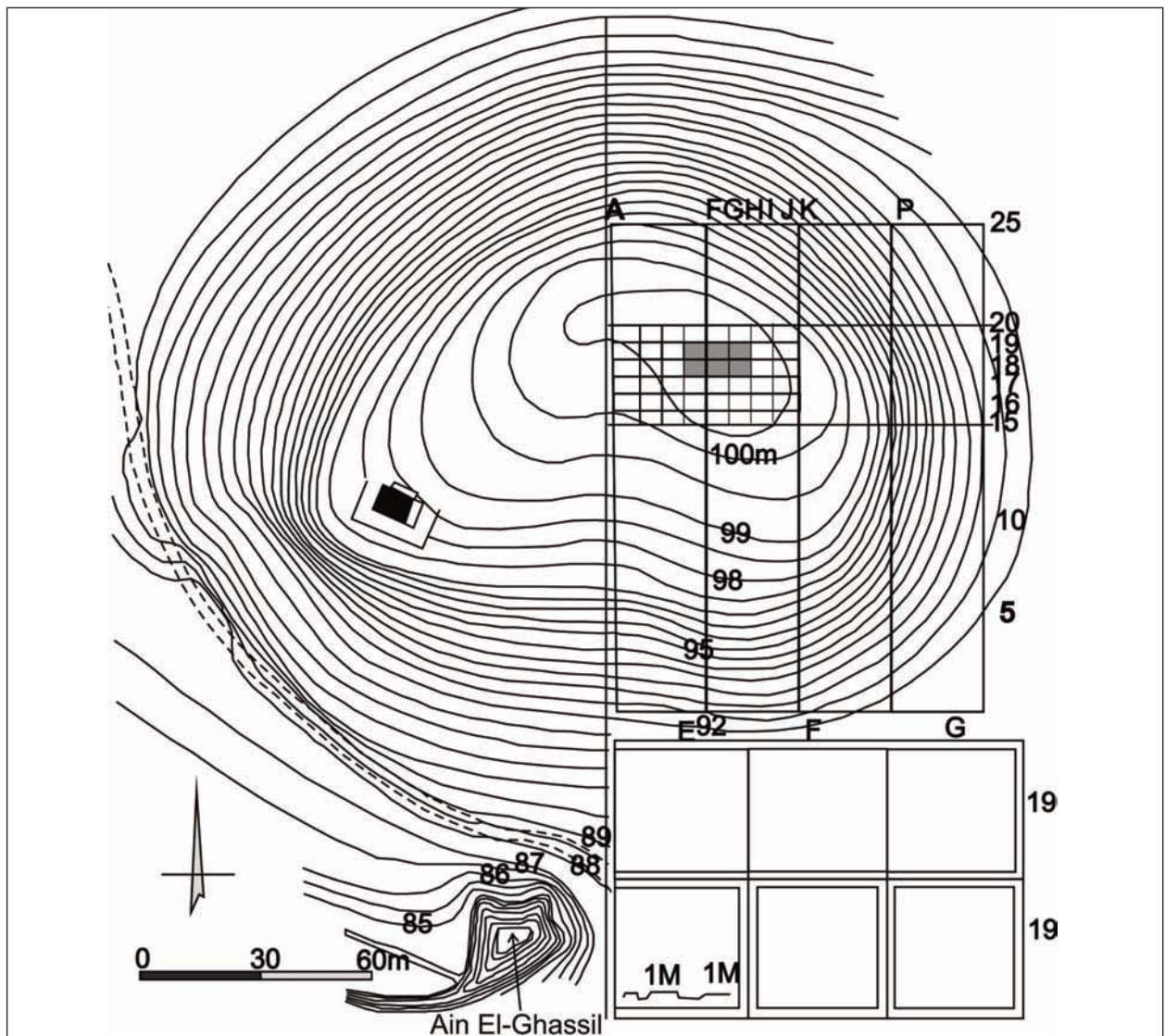


Fig. 3. The topographic setting and excavation of the Tell El-Ghassil.
Res. 3. El-Ghassil Höyüğü'nün topoğrafik konumu ve kazısı.

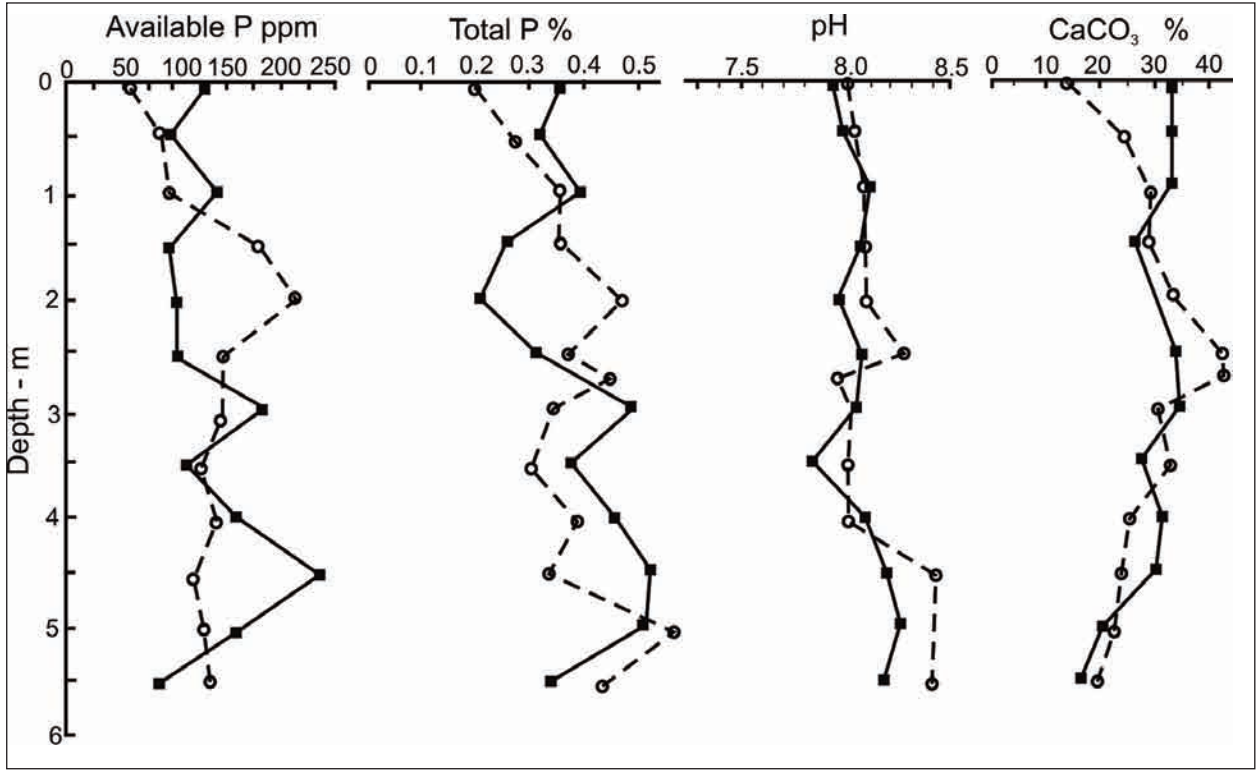


Fig. 4. Some of the depth-wise chemical analyses of the mound soils.
Res. 4. Höyük topraklarının derinliğe bağlı kimi kimyasal analizleri

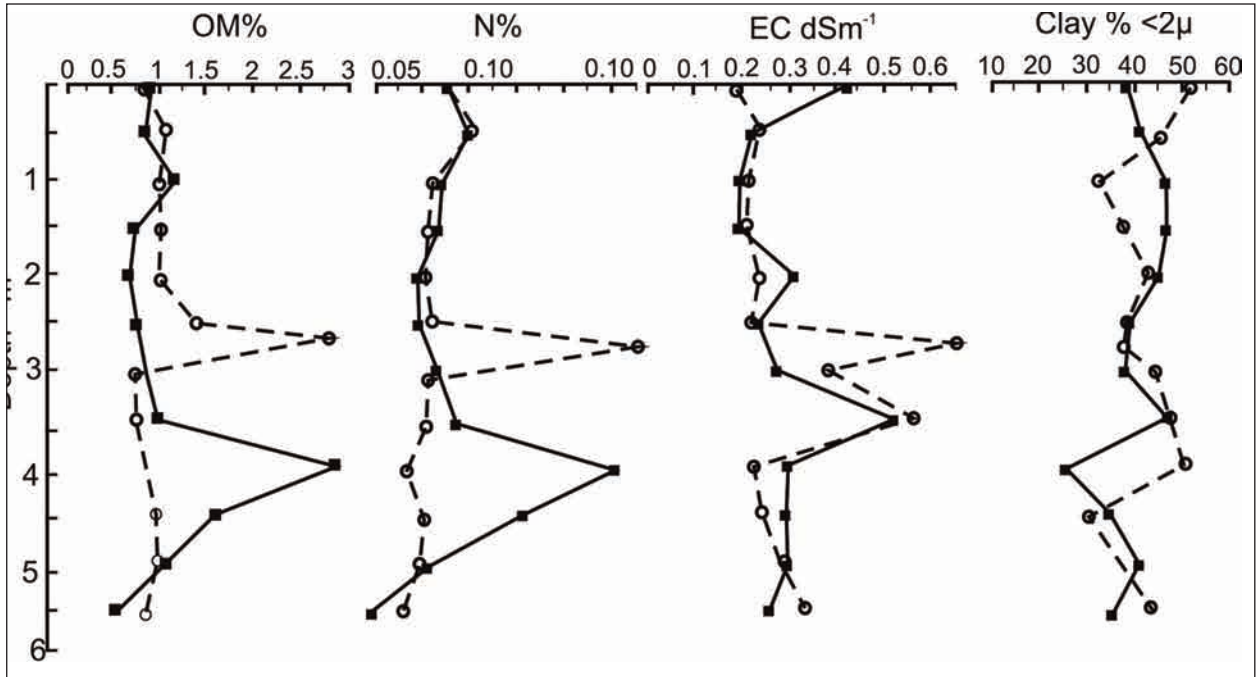


Fig. 5. Some of the depth-wise physical and chemical analyses of the mound soils.
Res. 5. Höyük topraklarının derinliğe bağlı kimi fiziksel ve kimyasal analizleri