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Al-Lāhūn : A Geo-Archaeological Approach of the Belgian Excavations in Jordan [1]

Introduction

A geo-archaeological project started in autumn 1994 at al-Lāhūn and was continued in spring 1995. It examined the archaeological site and the surrounding region of the Wādī al-Mūjib valley (biblical Arnon), east of the Dead Sea. This region corresponds to the ancient Moab kingdom, often mentioned in the Bible and in the Assyrian texts in the first millennium BC.

The geomorphological part of this investigation was done by Morgan De Dapper with the assistance of Beata-Maria De Vliegher, in connection with the archaeological excavations at al-Lāhūn, directed by Denyse Homès-Fredericq.

Geo-archaeology is the study of the mutual relationship between man and his environment in the past: what was the influence of the physical environment on the activities of man and what was the influence of man on changing the physical environment?

The latter took place in this area since the Neolithic Revolution, some 10,000 years ago and continues till now, as is attested by the ancient caves of al-Lāhūn, used as shelter in Antiquity and still in use as a granary today. The influence of man on nature led to one of the oldest humanised landscapes in the world.

However, the change of man's environment is in fact the result of a complex interplay between natural factors (such as climatic shifts leading to changes in the vegetation pattern) and human factors (such as deforestation accelerating soil erosion). The assessment of the contribution of both parts is of utmost importance in the frame of the International Global Change Investigations. The al-Lāhūn area offers a unique chance for such an assessment. To achieve these goals Archaeology and Earth Sciences have to combine in a joint interdisciplinary effort: geo-archaeology.

Location and Archaeo-Environmental Settings of the al-Lāhūn Area

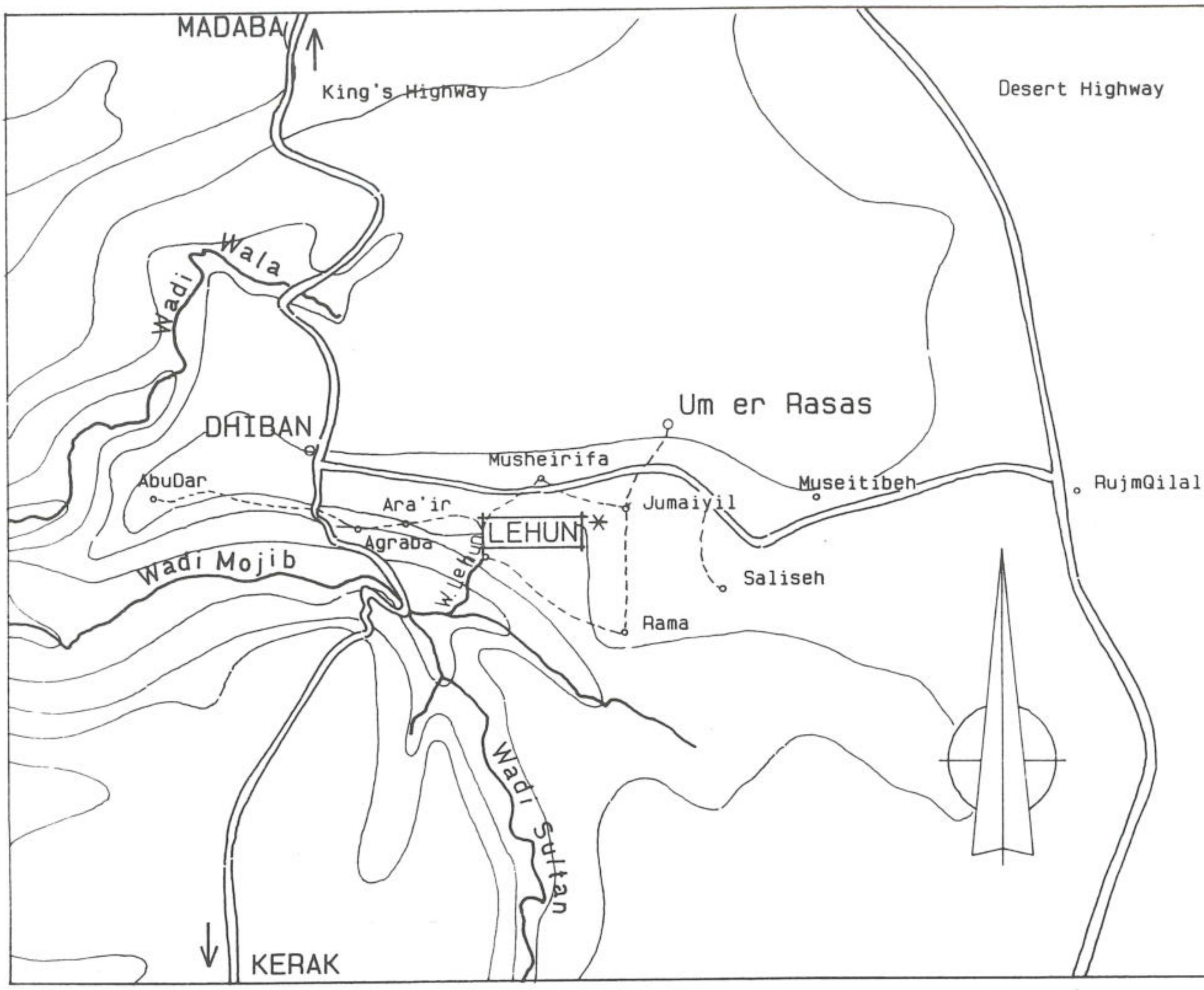
Al-Lāhūn is located in the Mādabā district between the King's Highway and the Desert Highway, some 80 km south of 'Ammān (FIG. 1). It lies 7 km east of Dhibān, the former capital of King Mesha of Moab (850 BC), who was a contemporary of Salmanasar III of Assyria, and 3 km of this military fortress of Ara'ir (the biblical Aroër). When we visited the site for the first time, we followed an ancient track along the border of the Moabite plateau, probably used by king Mesha's soldiers. It passed through Ara'ir and reached al-Lāhūn with its fortress built for military and economic purposes, and as a granary to collect the caps of the surrounding area. Now, a modern asphalt road leading to the site changes completely the aspect of the landscape.

Al-Lāhūn is quite extensive with its 66 ha of surface area. The hilly landscape has a denivellation of nearly 40 m. Small natural sectors are delimited north-south by the Wādī al-Lāhūn and a seasonal wadi, and east-west by other rivers. The site has been almost continuously inhabited, with more or less intensive occupation, from the Palaeolithic till modern times. The ancient settlers chose various sectors to built their dwellings. In the southern part, well protected by the cliffs of the Wādī al-Mūjib plateau, we find the earliest remains, including prehistoric artefacts, an Early Bronze Age town and cemetery (contemporary with the Mesopotamian Djemdet-Nasr period), a Late Bronze/Iron Age I village (end of the Medio-Assyrian and Neo-Assyrian period) and an Iron Age 2 fortress of the period of the Neo-Assyrian kings of the ninth century (FIG. 2). In the northern part, near the fertile fields and the antique trade roads of the Moabite plateau, as well as along the slopes of the Wādī al-Lāhūn (where the humidity and the vegetation are longer kept), settlements appeared in more peaceful and commercial periods: Nabataean and Roman temples, a Mamluk mosque near a small agricultural village of the same period, Ottoman houses and modern constructions were successively built.

An excellent satellite photograph recently published in the *National Geographic*,[2] shows clearly the physical

[1] We would like to thank Dr G. Bisheh, Director-General of the Department of Antiquities and his staff, who encouraged us greatly in our investigations as well as the different institutions who gave us financial and logistic support since the beginning of the excavations, as the National Foundation of Scientific Research Flanders, the Free University of Brussels, the University of Ghent, the Royal Museums of Art and History, the Ministry of the French Community and the Ministry of the Wallonne Community.

[2] *NGM* 187/6, June 1995:100-101.



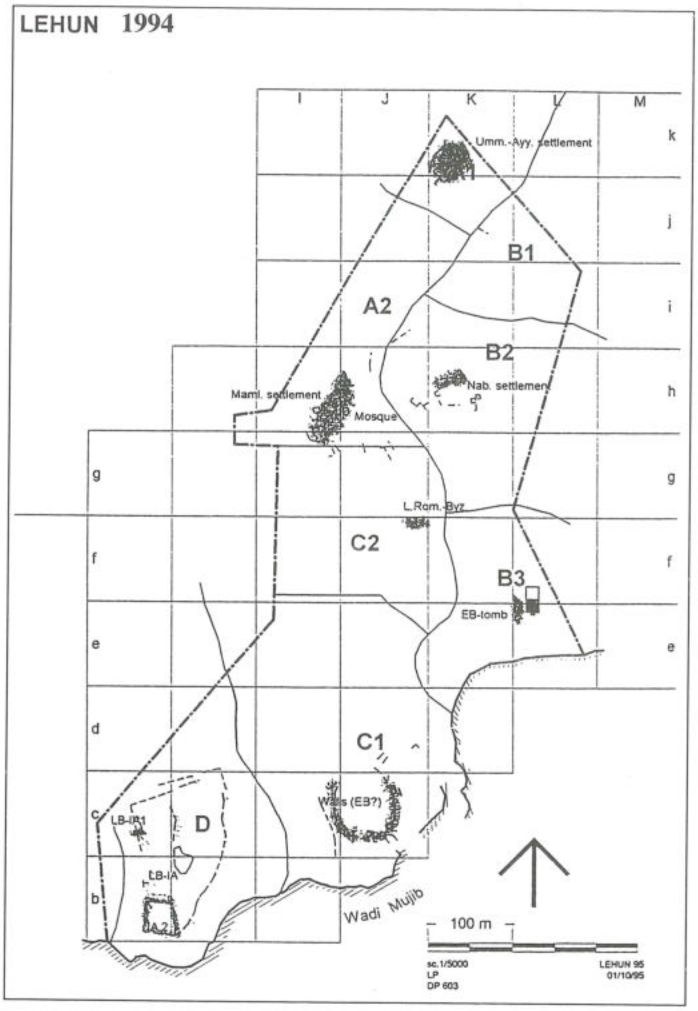
1. General map of the region of al-Lāhūn.

✱ Lehun : 714 to 748 m asl

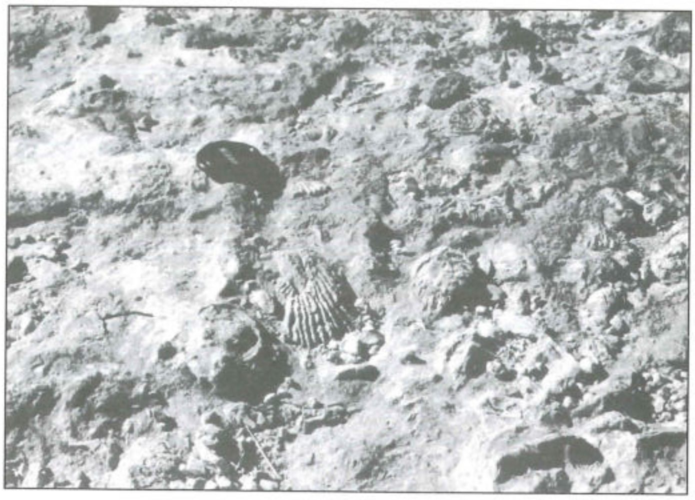
environment of the area: it is dominated by the canyon of the Wādī al-Mūjib which was deeply incised during the Quaternary in subhorizontal layers of marine sediments of Late Cretaceous age, with younger local basalt sheets on top.

On the northern rim of Wādī al-Mūjib, at an altitude around 700 m asl, al-Lāhūn overlooks the canyon of the river which is some 500 m deep and 5 km wide. 25 km further to the west the Wādī al-Mūjib flows into the Dead Sea at an altitude of 400 m below sea level. The river bed drops 600 m over a distance of 25 km. This means that it has a mean slope of 2.4 %, which is quite important. The depth of the canyon and the steep profile of the river bed are indicators of the high geomorphodynamic forces involved in the al-Lāhūn area. They are enhanced by the fact that the area (close to the rift) is tectonically unstable.

This deep natural incision separates two very contrasting environments: on the one hand the "man-friendly" plateau covered with fertile soils and the terra rossa typical of the Mediterranean region, expressed by the brown colours on the satellite image; on the other hand the "man-hostile" canyon, expressed by the grey colour of the bare rocks. Al-Lāhūn is situated at the very boundary of those two extremely opposite environments and has been, without doubt, selected for this double function; in the oldest period, during troubled times for its man-hostile character, at the rim of a steep escarpment allowing a strategic position, overlooking the southern Moabite plateau and the Dead Sea; and in peace time for its man-friendly function, with its good climatological conditions and its average rainfall of about 200-300 mm per year in this region. After a rainy season, the northern part of the site is very fertile, allowing barley and wheat to grow. Al-Lāhūn has also a semi-arid Mediterranean micro-climate, between the mild coastal and the dry desert climate. This is certainly one of the reasons why al-Lāhūn has been chosen alternatively by nomads and agricultural populations during the ages: even at the end of the last century



2. General map with sectors and periods represented in al-Lāhūn till 1994.



3. Bank of oyster fossils of Late Cretaceous age exposed in the bed of the Wādī al-Lāhūn.

the site was again settled by some nomads coming from the Wādī al-Mūjib: ancient prehistoric caves were used as the main chamber while some front wall enlarged their houses.

Al-Lāhūn: A Journey in Time and Space

The sediments which form the geological substratum of the whole al-Lāhūn area were deposited in a sea during the Late Cretaceous some 100 million years ago.[3] Their marine nature is testified by numerous fossils. Some of them have conspicuous sizes such as the oysters of the *Actinostreon species* (FIG. 3). Banks of those shells may be easily observed in the bed of the Wādī al-Lāhūn, close to the Dighouse. Those marine sediments consist of an alternation of harder rocks like limestone and softer rocks like marls. The limestone blocks were often used by man in the different periods: for instance in the walls of the Late Bronze Age village or of the Iron Age Fortress (FIG. 4) or for making their tools (grindstone etc.). In the Nabataean temple of the first century AD with embossed façade (as the stone is easy to cut) the inclusions of marine fossils are still visible in the Cretaceous limestone, while the interior walls (which were once plastered) expose now the formation of the fallen, local blocks.

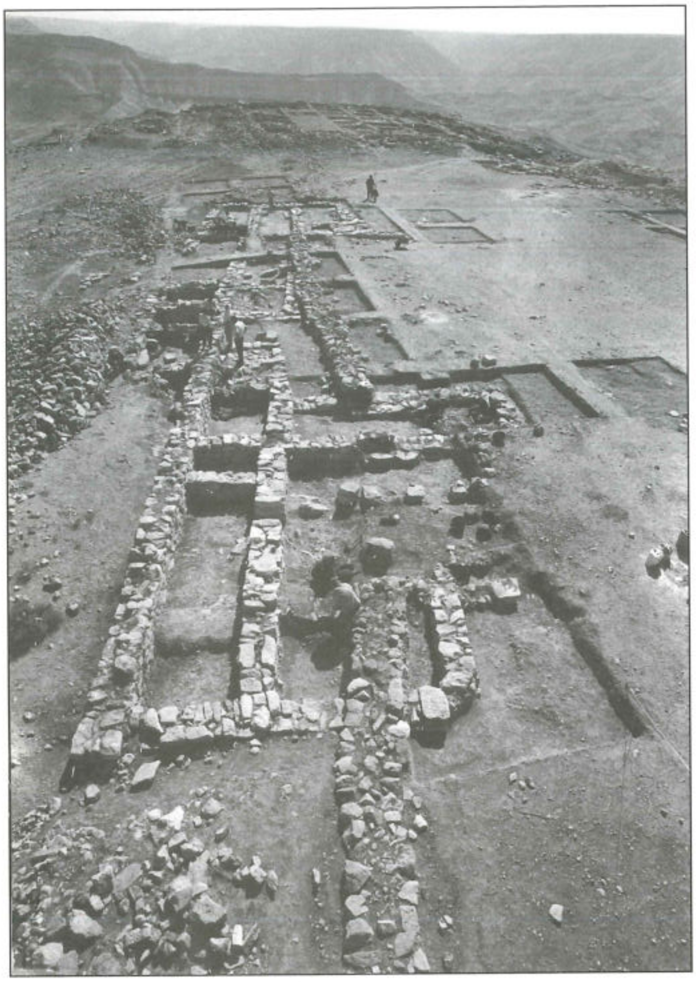
The geological strata underwent only minor folding and faulting. They show an almost horizontal layer, corresponding to the original deposit by the sea. In some layers cherts and flints are included (FIG. 5). They formed an important raw material for prehistoric toolmakers. Scrapers, blades, points and other tools were surely locally made. They proved a long, but often discontinuous occupation of the site, till the beginning of sedentarisation in Jordan, as proved by the survey made by G. Rollefson at al-Lāhūn, where he gathered nearly 1000 flints on an area of 225.000 sq. m.[4]

From the Lower Miocene, 25 million years ago, till the Pliocene, 3 million years ago, large tectonic crustal movements led to the progressive sinking of the Jordan rift and the rising of the marine deposits. On the newly formed landsurface a drainage network was formed including the proto-Wādī al-Mūjib.

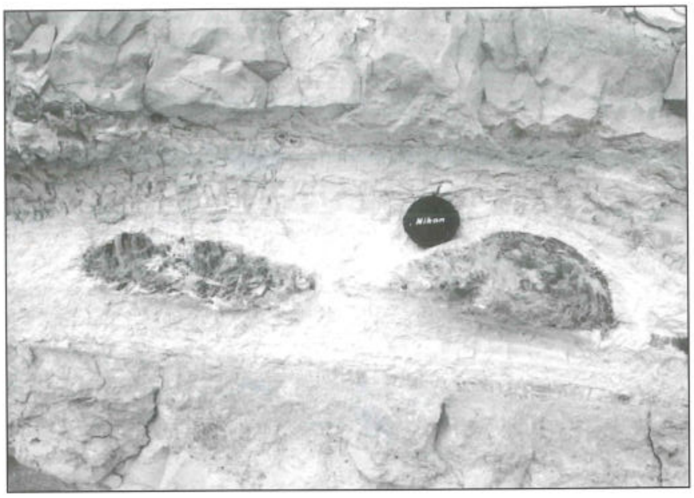
During the Early Quaternary, some 1.8 million years ago, sheets of molten basalt lava poured out in fissure eruptions. Part of them were flowing into the shallow valley of the proto-Wādī al-Mūjib and baked the marine sediments (FIG. 6). They solidified and since then rest on the Cretaceous substratum. Those basalt sheets occur on the southern rim of the canyon almost opposite of al-Lāhūn (FIG. 7). Since the molten lava has not streamed into the canyon, the deep incision of the Wādī al-Mūjib canyon must be younger than the basalt formation itself. One can conclude that the canyon and the landforms within it are

3 Bender, F. *Geologie van Jordanien* . Berlin-Stuttgart: Geber. Borntraeger.

4 We take this opportunity to thank Prof Dr G. Rollefson and Dr G. Finkhauser who made a survey at al-Lāhūn in 1980. (see also D. Homès-Fredericq and H.J. Franken, eds, *Pottery and Potters. Past and Present. 7000 Years of Ceramic Art in Jordan.* Tübingen 1986:66-67; D. Homès-Fredericq and P. Naster, *Rapport préliminaire sur la deuxième campagne de fouilles belges en Jordanie (automne 1980)*, Bruxelles 1981:13-14 (Unpublished manuscript at the Registration Centre, Department of Antiquities).



4. Late Bronze Age village and Iron Age fortress.



5. Chert and flint formation included in marine marls of Late Cretaceaous age.

6. Baked horizon on the contact between Early Quarternary basalt and the Late Cretaceous substratum.

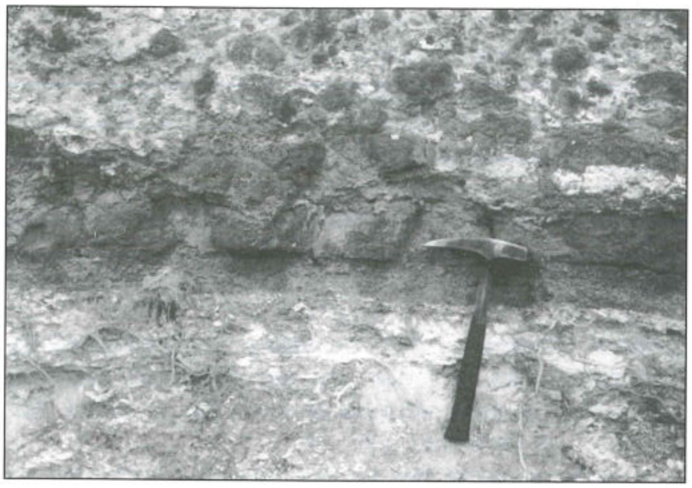
Pleistocene. It is a quite young geological and geomorphological phenomenon linked to the formation of the Jordan rift system. Those basalt stones, too, were often used by the inhabitants of al-Lāhūn to make mortars for their daily life or to consolidate their walls.

During the geomorphological field surveys of autumn 1994 and spring 1995 at least three river terrace levels could be distinguished within the canyon: T1, T2 and T3. At the al-Mūjib-Nukhayla confluence (close to the new bridge on the King's Highway) the erosive base of the oldest terrace (T3) stands some 40 m above the present-day 'talweg' (T0). The alluvial deposits are at least 40 m thick and are composed of a large amount of well-rounded basalt boulders set in a matrix of finer gravel and sand showing current bedding features. The lower parts of those fluviatile deposits are cemented by calcium carbonates. It is obvious that the basalt boulders were transported by the Wādī al-Bālū' whose catchment comprises extensive outcrops of basalt sheets.

The base of the youngest river terrace (T1) is at the level of the 'talweg' but its top stands 5 to 10 m above it. The river deposits are mainly composed of gravels and sands with only a minor amount of boulders. Most of the material was transported by the upstream section of the Wādī al-Mūjib. Only few basalt boulders are present here. This is due to the fact that no basalt outcrops occur in the upstream reaches of the Wādī al-Mūjib. The few basalt boulders which are present are derived from the erosion of the oldest terrace level.

An intermediate river terrace level (T2) could be traced 2 km upstream in the Wādī al-Mūjib. It is composed of boulders, different kinds of gravel and sand. These coarse deposits are well cemented by calcium carbonates and therefore take the aspect of conglomerates (FIG. 8). This level is not present at the al-Mūjib-Nukhayla confluence but is testified by huge conglomeratic boulders present in the youngest terrace deposits. The "conglomerate"- terrace was also observed in the lower reaches of the Wādī al-Qaṭṭār and at the Nukhayla-al-Bālū' confluence. In the latter, important travertine formations are linked to it.

Till now, only a relative terrace chronosequence (T1, T2, T3) could be established. However, it is obvious , as argued above, that the observed terraces are all Quaternary and date most probably from the Middle to



7. Thick basalt sheet of Early Quaternary age exposed on the southern rim of the Wādī al-Mūjib canyon.

8. Conglomeratic aspect of the intermediate river terrace T2 incised by the present-day river bed T0 at the Wādī al-Mūjib.

Late Quaternary. Absolute dating of the terraces will probably be difficult due to the lack of absolute dating evidence. However, it must be possible to frame the terrace sequence, by comparison with other regional studies, into the general Quaternary geological history of Jordan.

The gentle sloping top surfaces of the terraces are used for irrigated cultivation. The basalt boulders of the oldest terrace show a typical black colour when they are exposed at the surface. The specific spectral reflectance of those phenomena may be useful to trace the river terraces on aerial photographs and satellite imagery, thus allowing for efficient geomorphological mapping.

The Holocene legacy of the Wādī al-Mūjib valley is present, amongst others, in numerous small patches of loose fine alluvial deposits along the 'talweg', testifying to repeated deposition and erosion. Those alluvial deposits are without any doubt closely linked to environmental changes due to the impact of man. Those took place almost continuously in the area since the Neolithic Revolution 10,000 years ago.

In some of those alluvial patches, organic materials such as charcoal and shell fragments could be sampled. Radiocarbon dating of those materials will allow for absolute dating. The bed of the Wādī al-Mūjib and its tributaries such as the Wādī al- Lahūn, is in many cases cut in hard rock and shows the typical riffle-and-pool morphology. In the pools flacks of water remain long after the end of the winter rainy season. In those temporary closed systems special micro-environments develop, including a typical micro-fauna. Those micro-organisms are very sensitive to environmental changes and thus may serve as indicators. Moreover, their fossil remains are conserved for a long time. As a result their study, as well in present-day environments as in stratigraphic sequences, may be an important tool for reconstruction of environmental history.

After important rainfall, muddy water stays in the pools allowing for sedimentation of the clay. This natural phenomenon allowed people to use this clay to produce their local hand-made ceramics: in the Early Bronze I A-B period, the fact is demonstrated by the analyses of Prof. H.J. Franken (of the "Instituut voor Aardewerktechnologie", University of Leyden), proving that the clay was extracted from the potholes in the riverbed of the Wādī al-Lāhūn. This was also the case in the Late Islamic period, where the pottery was hand-made, too. Sedimentation of clay in the Wādī al-Mūjib is, of course, far more important. In the Late Bronze and Iron Age the inhabitants of the fortified village and of the fortress selected the more convenient clay of the Wādī al-Mūjib to throw their wheel-made pottery.

The canyon walls are very steep and show a dynamic equilibrium: material which is accumulated at the foot of the slope is carried away by the river and is replaced by new material eroded from the top of the canyon wall. For that reason there is a continuous transport of material along the slope ("dynamic"). At the same time the canyon is widening and the slope conserves its steepness ("equilibrium").

The slope dynamics are testified by numerous minor

9. Minor landslide on the canyon wall of the Wādī al-Mūjib; the landslide breaks the continuity of a hard limestone bank.

landslides (FIG. 9). Some landslides, however, involve huge volumes of rocky material and may have been triggered by earthquakes which, without doubt occur in this tectonically active area (FIG. 10). However, deforestation may have accelerated the process.

Due to the fact that the Cretaceous substratum shows an alternation of harder and softer rocks, erosion on the slopes works selectively. Softer parts are easily eroded while harder banks resist longer. As a result "abris sous roche" are formed which served, and still serve, as shelter for man (FIG. 11). Banks of hard rock which are undermined, finally detach and tumble down. Those huge blocks eventually come to rest in a chaotic stapling at the foot of the canyon wall. Also here the space below the blocks is arranged by man to serve as a shelter (FIG. 12). He builds little walls to protect himself and his presence is still attested by black smoke stains. This kind of shelter has not yet been excavated in the al-Lāhūn area and their investigation may lead to interesting results.

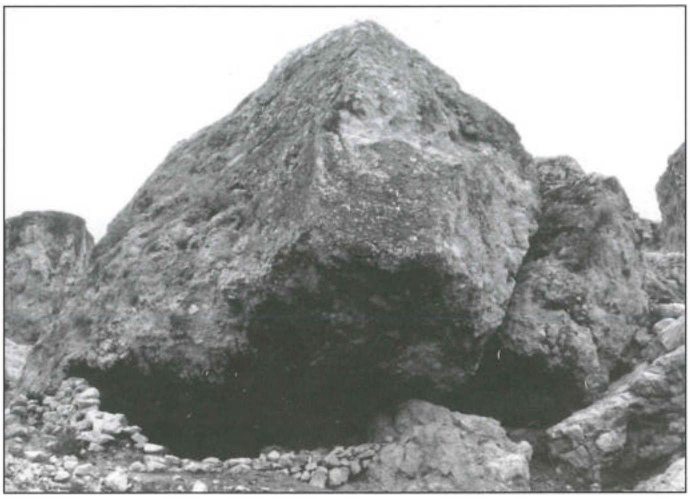
A special form of chemical weathering leads to the formation in the rock of hollows, called "taffoni". Some become so huge that they too may be used as shelter or a granary (FIG.13).

One of the most destructive geomorphological forces on the canyon walls are formed by man's herds of goats and sheep which graze even on the steepest slopes. The daily passage of the cattle, and this since centuries, is a tremendous form of accelerated slope erosion. Every slope is attacked by their trampling: vegetation and the few remainders of fertile soil are destroyed and their tracks form a dense network of scars, the so called "terracettes", on the slopes (FIG. 14).

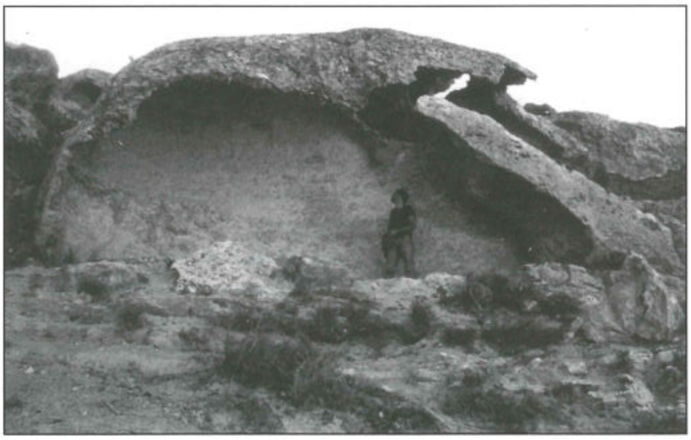
Collecting water has always been of life-importance for man in the al-Lāhūn area. Most of the water storage works are mere adaptations of the physical terrain features. Caves and cisterns make use of the regular subhor-

10. Major landslide on the canyon wall of the Wādī al-Lāhūn. This landslide involves an important volume of rock which blocked the course of the river bed. Such landslides may be trigged by earthquakes.

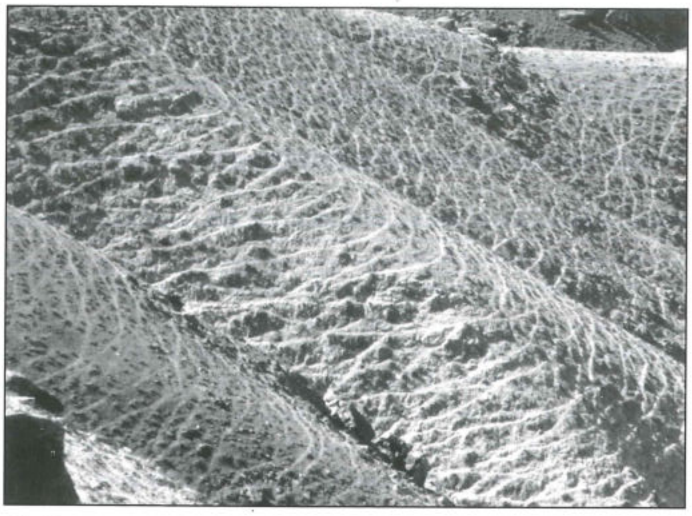
11. Formation of "abri sous roche" by differential erosion of alternating harder and softer rocks of the late Cretaceous substratum.



12. Chaotic stapling of huge blocks detached from the upper canyon wall after undermining of banks of massive limestone underlain by more erodible soft marls. After tumbling down the blocks came to rest at the foot of the canyon wall close to the river bed of the Wādī al-Mūjib. The spaces below the blocks are arranged by man to serve as shelter.



13. Formation of hollows called "taffoni" by dominantly chemical weathering. They may serve as shelters or granaries.



14. Dense network of "terracettes" on steep slopes. Those microsteps are due to the daily passage and trampling by sheep's and goats and are an important form of accelerated soil erosion.

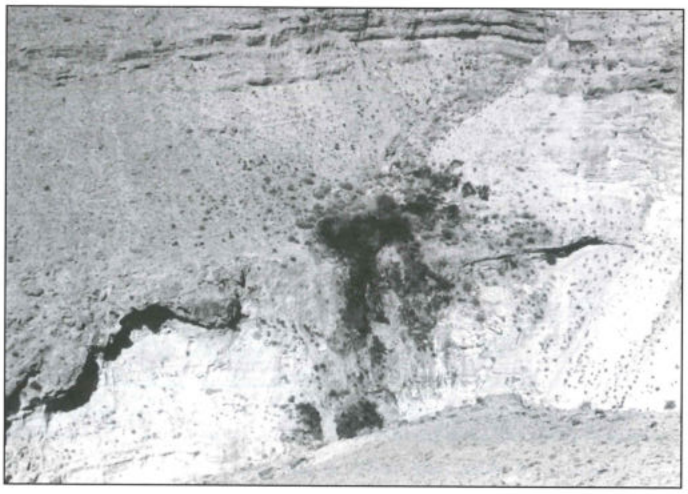
izontal alternation of softer and harder layers of the almost tectonically undisturbed marine Cretaceous sediments which form the geological substratum of the al-Lāhūn area. Caves are excavated areas below massive limestone bedrock shelves which are originally the result of "abri sous roche" formation due to differential weathering and erosion or the formations of "taffoni" due to dominantly chemical honeycomb-weathering.

For the construction of cisterns – covered water storage areas, at al-Lāhūn usually underground chambers – massive limestone and chert layers may serve as "roofs", whereas the marly sediments are excavated to form the "bell" of the cisterns.

Waterpools – open reservoirs which rely on seasonal rain and run off collection – are in most cases located where natural closed terrain depressions occur. In some cases, the natural depressions are in fact well developed dolinas (FIG. 15). One occurs at the rim of the escarpment, east of the Iron Age fortress at al-Lāhūn, and is the result of a karstic solution of the carbonatic bedrock. The rainwater which infiltrates follows planes of weakness such as fissures and joints in the bedrock whereby the solution of the carbonates takes place. As a result an intricate network of small and large subterranean hollows is formed. Some of those hollows may become quite large and form natural caves (FIG. 16). In some cases the roof of large caves may collapse leading to the formation of closed depressions at the surface: these are the dolinas. In the escarpment just below the dolinas several karstic hollows developed along dominantly vertical fissures were observed. On the lower parts of those slopes important travertine accumulations are formed along seepage lines (FIG. 17). Those accumulations are due to precipitation of the calcium transported in solution in the groundwater. The travertine is still formed at present day, showing that the process of karstic solution and precipitation is still active. Those

15. Dolina or closed karstic depression developed by solution of the underlying limestone on the rim of the Wādī al-Lāhūn east of the Iron Age Fortress. The dolina was arranged to serve as a pool.

16. Natural cave developed along a fissure in the limestone below the dolina shown on FIG. 15.



17. Travertine formation due to seepage of calcium-rich groundwater on the slope below the dolina and cave shown in FIGS. 15 and 16. The travertine is still formed at present-day showing that the process of karstic solution and precipitation is still active.

travertines can be dated by radiometric methods. Moreover they contain fossil pollen which can help us for environmental evolution reconstruction.

Dams may be constructed where the wadi valley is narrow and the catchment area is large enough. Valleys are in most cases narrow where the bedrock is harder and more resistant to erosion. Those outcrops of harder rock offer at the same time a solid base for the wall of the dam. In most cases the walls have disappeared but part of the dam lake infill is still conserved (FIG. 18). Careful study of the infill stratigraphy and its sedimentological, mineralogical and microfaunal characteristics may help to reconstruct the dam history.

The al-Lāhūn GaIS Project

In order to link the geographical knowledge from al-Lāhūn and its surroundings with the archaeological information in an efficient way, a GIS (Geographical Information System) project was built up. The aim of this project is to establish more specifically a Geo-archaeological Information System (LEHUN-GaIS) for al-Lāhūn.

The GaIS comprises on one side a list of data which can be stored in a database (such as a list of observation points stating the artefacts found on that place plus typical characteristics such as the altitude, lithology, slope and aspect, era, etc.). On the other side, it comprises spatial data stored as digital maps (such as lithological maps, geomorphological maps, land-use maps, maps of the archaeological sites, etc.).

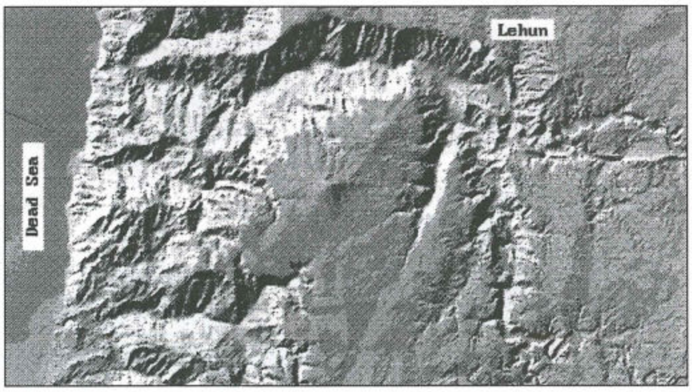
A GaIS is a tool based on computer technology, which makes it possible to link the database with the spatial data, and do as well a combination of database queries and spatial (vertical and horizontal) queries.

18. Remnants of dam lake infill in the upper reaches of Wādī al-Lāhūn.

To feed the GaIS with information, three main sources can be distinguished: (1) the collection of data via field observations, (2) the collection and digitizing of the existing cartographic data and (3) the derivation of information from remotely sensed imagery (aerial photos, satellite images...). In a second stage, a combination of these data can produce more advanced maps, and can be used to build and run models.

It stands to reason that the fundamental prerequisite to build a GaIS is the precise location of the observations in a fixed co-ordinate system. Such precise location can be done by using GPS (Global Positioning System) technology. The GPS technology is based on the NAVSTAR satellite system, which finished its experimental phase in 1994. 24 NAVSTAR satellites are broadcasting waves with a certain frequency from which some are received by the GPS device on the ground. The GPS calculates the time between the broadcasting and the reception of the signal. Knowing the exact position of the satellite and given the calculated distance from at least three satellites, the GPS device calculates the location on the Earth's surface in a chosen co-ordinate system. In the case of the al-Lāhūn survey the GPS location of the observation points is carried out with a compact and light weight hand-held device (The Ensign GPS of Trimble Navigation, USA) (FIG. 19). Since the al-Lāhūn area is almost entirely free of high vegetation, the reception of the satellite signals is almost never hindered. By taking the average of a set of measurements for the same point, the error can be reduced to about 30 m, which is, in general, sufficient to locate the observation points (30 m on a scale of 1/50.000 is the size of a pencil dot !).[5]

The building of LEHUN GaIS was started in December 1994. The digital treatment was performed on an ILWIS (Integrated Land and Watershed Management Information System, developed at the International Institute for Aerospace Survey and Earth Sciences at Enschede, The Netherlands) software package. Following



19. Shadow image of the al-Lāhūn- and Wādī Mūjib area derived from a Digital Elevation Model (DEM), based on the Jordan topographical map on scale 1/50,000.

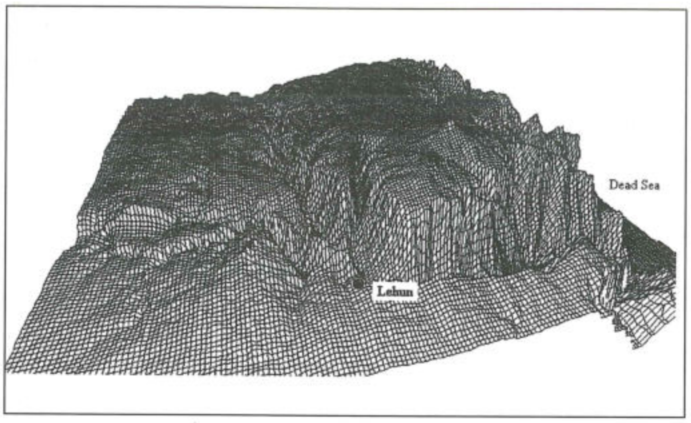
[5] Brackman, P., De Dapper, M., Devreker, J. and Vermeulen, F. 1995. The Use of Geomorphology, Remote Sensing and GIS-Technics for Geoarchaeological Purposes in the Pessinus Area, Central Anatolia (Turkey). *Natuurwetenschappelijk Tijdschrift (Gent)* 75:3-34.

steps were taken during the indoor preparation:

1. The contour lines of the Jordan topographical map on scale 1/50,000 for the area were digitized and consequently rasterized. For steeply sloping parts only the 100 m contour interval was used; for plateau areas the 5 m contour interval was added.
2. From these files a DEM (Digital Elevation Model) was made. This DEM forms the base for the GaIS.
3. From the DEM derivated products were made: slope map, shadow image (FIG. 19), 3D-images (FIG. 20).

Conclusions

By the year 2,000 the al-Lāhūn Dighouse will become a museum. In order to make the richness of al-Lāhūn and its environment available for a larger public the establishment of a geo-archaeological park, wherein archeo-monuments as well as geo-monuments are displayed, is planned as a future project. Better understanding of the natural and cultural patrimony by the local people will lead to consciousness and sustainable use of their cultural and natural resources. In this way a contribution can be made to conserve this unique site and its environment for future generations.



20. 3D-image of the al-Lāhūn-viewed from NNW (vertical angle 30°, vertical exaggeration 10x) - and Wādī al-Mujib area derived from a Digital Elevation Model (DEM), based on the Jordan topographical map on scale 1/50,000.