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GEOLOGY AND ANTHROPOLOGY: A CASE STUDY FROM JORDAN

ABSTRACT: The geological survey at the archaeological site of Ya'amun in northern Jordan has yielded very rich data on the local lithology and its relationship with tomb locations and other archaeological features. The results show different lithology of the used structures at the site and at the same time very well correlated with the time of occupation. Specific rock types were favoured throughout the history of the site for carving tombs, which resulted in tombs arranged in rows according to the geological beds. The chronological variations in the geology of the tombs were probably associated with the development of hardness of tools. Understanding the relationship between geology and tomb location has resulted in the recovery of further tombs and structures at the site in the proceeding seasons of excavations. The investigation of the skeletal biology at the site shows that the people during the Middle and the Late Bronze Ages were healthy. Most of the paleopathological lesions in these periods were myositis ossificans *and* osteophytosis*; typical lesions in elderly and hard workers.* Cribra orbitalia *and* periostitis *were the common paleopathological lesions during the Roman and the Byzantine periods.*

KEY WORDS: Jordan – Geology – Tombs – Anthropology – Paleopathology

INTRODUCTION

Ya'amun is one of the largest archaeological sites in northern Jordan. It has witnessed continuous occupation since the Early Bronze Age. The consecutive archaeological excavations have revealed many cemeteries of different chronology as well as many other archaeological features. The most significant of these features are the Byzantine church on the main Tell and the very large wine presses that were used for exporting purposes.

During the past four years of archaeological work at the archaeological site of Ya'amun in northern Jordan, a major research question has been addressed: why do tombs exist in certain locations. So the efforts then were devoted toward examining factors that might influence the choice of tomb location, which would enrich the collected mortuary data (Rowland 2003). This examination is complicated because the site was occupied over a long span of time and thus by many different cultures ranging from the Early Bronze Age to modern times (Burke, Rose 2001). The variables that we expected to influence tomb locations were tomb reuse, visibility, slope, aspect, and geology.

It was expected that tomb reuse would be a factor that contributed to the choice of tomb location. We assumed that reusing an existing tomb would have saved effort, time and energy. For example the people of the Byzantine period continued to use the Roman tombs (Rose *et al.* 2004, Rose, El-Najjar 2004) leading us to wonder if there were any cultural factors that were being set aside in difference to the ease of tomb reuse. This takes us back to the same argument that when tombs were first carved, what were the factors that determined their locations? So we concluded that the reuse of tombs is not a factor that could be studied.

Visibility or viewshed, as established using GIS parameters, tries to answer the question of why the choice of certain locations (Wheatly, Gillings 2002). For example, Baldia (1995) in his study on the 'Trichterbecher Kulture' found that the tombs' visibility and accessibility imply that prehistoric roads determined their location and orientation. The GIS analysis on the landscape of Ya'amun shows that

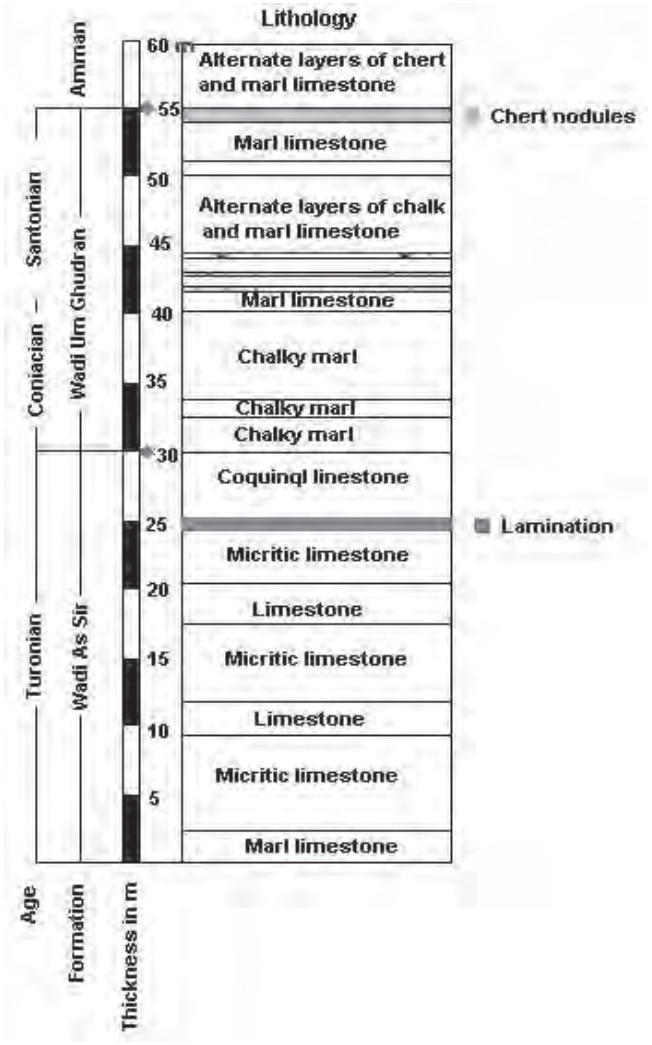

FIGURE 1. The geological columnar section of Ya'amun area. Created by Ahmad Al-Shorman.

the visibility from the tombs was generally limited and only included small portions of the opposing slopes. It also shows that areas visible from the tombs contained no primary archaeological features that would permit to say that the tombs were carved so that they could be seen from these features. This analysis did not fulfil the role of common visibility and thus excluded the effect of visibility on tomb location.

The terrain of Ya'amun is dominated by steep slopes especially on the main Tell, which provides good locations for carving. This is mainly due to the absence of soil cover on the steepest slopes and to the fact that tombs are more easily carved into such slopes. If steep slopes were necessary for tomb construction then we would not find tombs carved into flat terrains. Since we do find tombs in flat locations then steep slopes were not necessary conditions.

Aspect is the surface orientation of an area in terms of North, South, East, and West (Wheatley, Gillings 2002). Until today, archaeological studies in the region have not shown any effect of aspect on the geographical distribution of sites or features within sites. The tombs in Ya'amun were not uniformly established on any certain aspect even during a given particular occupational period. Having eliminated the above variables we chose to collect the necessary data to test the influence of geology upon tomb location.

The geology of tombs has not been explored independently in the Levant; few studies were carried out in Egypt, like for example Fornabager (2002), who studied the geology of tombs for the purpose of conservation, Lucas and Harris (1962), who found that ancient Egyptians favoured limestone hills to produce chambers for tombs. Rickerby (1999) noted that there is a relationship between the rock type and the tomb design and construction in the Theban tombs of Egypt.

METHODS

To date the known tombs of Ya'amun are located on the slopes of the central Tell and the hill slopes that surround the Tell on all sides. This area and the surrounding hills were geologically and archaeologically surveyed by a skilled team consisting of an archaeologist, a bioarchaeologist, a landscape surveyor and two archaeology graduate students. The area was divided into 4 zones that were surveyed separately and strip by strip. The surveyor and the 'Total Station' were situated on the Tell and the coordinates of each archaeological feature including tombs, and the geological beds were recorded and later plotted on the main contour map of the site. The rock types of tombs, walls, cisterns, and pavements were also individually recorded. The contoured map of the site was digitized using ArcGIS 9.2 to create a 20 m Digital Elevation Model. The DEM was then modelled to create a travel time map using the model after Gorenflo and Gale (1990) $v=6e^{-3.5|s+0.05|}$, where $\underline{v}$ is the velocity and $\underline{s}$ is the slope in percent.

All of the recovered human skeletal remains were cleaned and sorted according to tomb number and locus number. They were dated based on the associated pottery sherds and other artifacts like the scarabs of the Bronze Age tombs. Each identified bone was sided and investigated anthroposcopically for any paleopathological lesions. The minimum number of individuals MNI was determined based on the highest count of one side of a bone type (for example: right femur). Sex was estimated in few cases; complete pelvises and skulls. The anthropological data recording and analysis were done after Buikstra and Ubelaker (1994). The paleopathological lesions were identified after Ortner (2002) and Roberts and Manchester (1999).

SITE GEOLOGY

The geological structure of Ya'amun is a continuation of the Ajloun Dome Structure accompanied by a number of fault systems; the East-West fault system with minor Northeast-

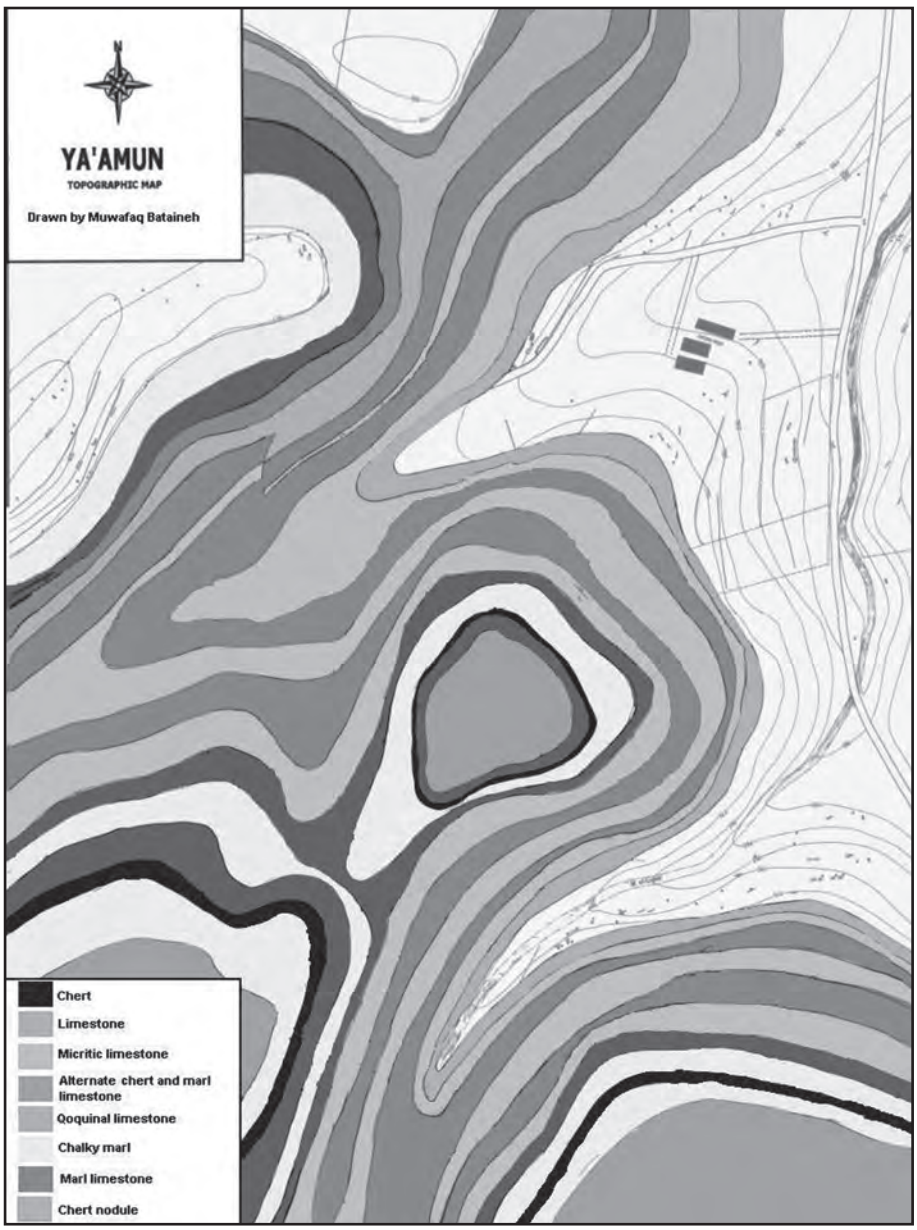

FIGURE 2. The local lithology of Ya'amun. Created by Ahmed Al-Shorman.

Southeast fault systems. There are three geological formations at Ya'amun: Wadi Essir Formation, Wadi Umm Ghudran Formation, and Amman silicified limestone Formation (Abd Alhamid 1995: 16–20; *Figure 1*).

The local lithology sequences of the southern and western areas of the site are mainly alternative layers of marl limestone (medium hardness) ranging from 0.5–2.5 m in thickness and micritic limestone (very hard but subject to concoidal fractures) ranging from 0.3–3 m in thickness. This sequence is usually located in the bottom of the wadis upward extending approximately to the last quarter of the hills. Situation above this sequence is a hard limestone of 0.5–1 m in thickness and a clayey chalk layer of about 1–2 m in thickness. The hill tops of the southern and western areas have layers of marl limestone (0.2–1 m), thin chert beds (0.1–0.6 m), and silicified limestone (0.5–1.5 m). The eastern area has also a layer of marl limestone (0.2–1 m), thin chert beds (0.1–0.6 m), and silicified limestone (0.5–1.5 m) (*Figure 2*).

RESULTS

All of the surveyed tombs and archaeological features are located within one-hour distance walk from the main Tell, which was the administrative centre throughout the history of the site. The people of Ya'amun then had to utilize this limited area for constructing the various mortuary, ritual, social and habitation structures. Although the area was limited, it has a varied local lithology, which consequently resulted in an enforcement of where to establish a certain structure (*Figure 3*).

The data suggests that tombs form all time periods at the site are located in horizontal rows situated mostly in the

FIGURE 3. Travel time map represented by contour lines generated using GIS. Each contour represents 6 minutes of travel time starting from the church on top of the hill.

same geological beds. The Late Bronze Age tombs (e.g. Tomb 158) were carved in a clayey chalk limestone bed, which is very soft and very easy to work. We did not find any Bronze Age tombs within hard geological beds such as micritic limestone. The walls of the Late Bronze Age structures on the Tell were built of moderate sized stones compared to those of the Iron Age and the Byzantine walls. Also the majority of these stones were not shaped, but probably collected locally from the surface. The shaped stones from the Late Bronze Age structures are few and when they do exist they are of marl limestone. The few basalt stones found in the structures were reused grinding stones. The area does not have local basalt beds and the closest available basalt stones are about 3 hours walk from the site (Ramtha region).

Unfortunately, no Iron Age tombs have been recovered yet. The stones that were used in the Iron Age walls on top of the Tell at Ya'amun are large boulders shaped on the side exposed on the wall. Most of these are micritic limestone. The western area of the site has many quarries for micritic limestone probably used during the Iron Age. Smaller unshaped chert stones were also found in the walls.

The Roman tombs were found in two geological beds: the nodular micritic limestone and marl limestone. Tomb 159, for example, was carved in a nodular micritic limestone, but 10 cm above the roof a layer of chalk was found. The three loculai inside the tomb were carved in a marl limestone layer. Leaving 10 cm of hard nodular limestone to compose the roof protects it from collapse and suggests the method of tomb carving. Inhabitants knew the geology of the area and selected locations so that they could carve the tomb in softer rock leaving the harder layer as the roof. The two sarcophagi inside the tomb were made of clayey chalk limestone possibly quarried from the clayey chalk limestone bed few metre east of the tomb. We noted that the doorway of this tomb is very wide so that the sarcophagi can be easily brought inside. On the other hand, other Roman period tombs carved into marl limestone beds have sarcophagi made from marl limestone, but here the doors were too small for a sarcophagi to be brought from outside. We have archaeological evidence that these latter sarcophagi were quarried and cut inside the tomb itself; the evidence is the small door of the tomb through which a sarcophagus could not pass.

Some of the Roman Period tombs had been reused during the Byzantine Period, while others were carved in beds of marl limestone and few in micritic limestone. The majority of the stones used in building the Byzantine Church on the Tell are well shaped limestone boulders. There are few moderately shaped micritic limestone blocks as well as unshaped chert. Two baptismal fonts were found at the church; one of them is of micritic limestone and the other of fossiliferrous limestone. The alley on the southern portion of the church was made of micritic limestone pavers, which usually stand erosion and abrasion.

FIGURE 4. Osteophytosis; a vertebra of a young female. Photographed by Hussien Deebajah.

THE SKELETAL BIOLOGY AT YA'AMUN

The osteological analysis comprised 42 tombs of different time periods as shown in *Table 1* below. The Middle Bronze age tombs (e.g. Tomb 1) yielded significant amounts of bone and bone fragments representing a MNI of 18 individuals. The nature of the bones (comingled and fragmented) hindered the detailed demographic analysis such as ageing by skeleton and sexing. Most of the recorded bone pathologies were *myositis ossificans*, *arthritis* and *osteophytosis* (*Figure 4*). The pathologies from the Late Bronze Age skeletons (MNI=27) were very similar to those of the Middle Bronze Age. The pathologies are typical to those usually found among hard working groups and the elderly. One can conclude that the people during the Bronze Ages at Ya'amun were healthy and probably enjoyed sufficient quantities and qualities of food as there were no nutritional related pathologies.

TABLE 1. Pathologies according to tomb number, where MNI denotes to Minimum Number of Individuals, MBA denotes to Middle Bronze Age, LBA denotes to Late Bronze Age, R denotes to Roman Period, B denotes to Byzantine Period, and % is the percent of bones with lesions from total bones in the same tomb.

Tomb no.	**MNI**	**Date**	**Paleopathology**	**%**
1	18	MBA	*Myositis ossificans*, *osteophytosis*	3.4
2	1	MBA	*Arthritis* in phalanges, *osteophytosis*	–
3	1	MBA	None	–
Total	20			–
4	1	LBA	None	–
55	1	LBA	None	–
158	22	LBA	*Arthritis*, *osteophytosis*	–
164	1	LBA	None	–
165	1	LBA	None	–
6	1	LBA	None	–
Total	27			–
25	10	R	*Cribra orbitalia*, *arthritis*, *Schmorl's node*	7.4
31	3	R	*Cribra orbitalia*, *arthritis*, *Schmorl's node*	3.2
41	1	R	None	–
43	3	R	*Periostitis*, *arthritis*	–
45	3	R	*Periostitis*, *arthritis*	–
46	1	R	*Osteophytosis*	–
47	1	R	None	–
48	4	R	*Myositis ossificans*	–
50	1	R	None	–
51	1	R	None	–
52	1	R	None	–
53	3	R	*Arthritis* in phalanges	–
56	1	R	None	–
78	7	R	*Periostitis*, *arthritis* in phalanges	–
107	4	R	None	–
108	1	R	None	–
109	1	R	Abnormal curvature in tibia	–
122	1	R	None	–
127	2	R	None	–
129	1	R	None	–
154	1	R	None	–
159	2	R	None	–
167	1	R	None	–
170	2	R	None	–
171	1	R	None	–
172	1	R	None	–
Total	58			–
116	21	B	*Myositis ossificans*, *osteophytosis*	2.5
117	18	B	Rib fracture, *periostitis*, *osteophytosis*	1
118	27	B	*Arthritis*	2
120	2	B	None	–
122	1	B	None	–
168	1	B	None	–
176	1	B	None	–
Total	71			–

FIGURE 5. A healed fibula fracture; adult male. Photographed by Hussien Deebajah.

The recorded pathologies from the Roman (MNI=58) and Byzantine (MNI=71) skeletal remains were arthritis in phalanges, *cribra orbitalia*, osteophytosis, periostitis and trauma (long bone fractures) (*Figure 5*). Compared to the Bronze Age the people might have modified their daily activity patterns during the classical period, as surface bone infection started to appear (periostitis). Malnourishment represented by *cribra orbitalia* was very evident. There was one case that showed curvature in the tibia typical to vitamin C deficiency. It is substantial that the health during the Roman and the Byzantine Periods was not better than in the Bronze Age.

Based on the tomb types and architecture, social stratification and/or inequality were very apparent during the Roman and the Byzantine Periods and consequently wealth acquisition is predetermined as well as access to better food qualities and quantities, which in turn might have triggered the deterioration in health status. Despite the time period at Ya'amun, most of the people died at younger ages (around 40 years old). The minimum number of individuals MNI was 198 from all of the periods as shown in *Table 1*, where the total number of the Middle Bronze Age individuals was 20, the total number of the Late Bronze Age individuals was 27, the total number of the Roman Period individuals was 58, and 71 for the Byzantine Period individuals.

DISCUSSION

The people of the Middle and Late Bronze Ages carved their tombs in areas of softer rock types (e.g. clayey chalk). These tombs could not stand the prolonged pressure imposed on their roofs by the overlaying soil and other geological beds. The selection of such a softer rock type was probably influenced by the availability of only softer and pliable bronze tools. In his study on the tombs of ancient Egypt, Stocks (1999) pointed out that the ancient Egyptians probably carved sedimentary rocks using copper and bronze chisels as well as stone hammers.

Avoiding the hardness of micritic limestone, the Middle/Late Bronze Age people of Sahab in Middle Jordan used natural caves to burry their dead (Ibrahim 1972, McNicolle 1992, Potts *et al.* 1985) or cut pits into the thick silt deposits and then lined them with small stones or mud bricks (Tubb 1997). At Tell es-Sa'idiyeh the tombs were constructed of two parallel rows of horizontally laid mud bricks (Tubb 1988). The Middle Bronze Age tombs from Ajjul in Gaza were carved in sandstone (Steel 1998) and the Middle Bronze Age tomb at Tell el-Umayri was cut into chalk (Waheeb 1997: 75).

The Iron Age that was characterized by fortifications and ramparts is often thought of as an age of turmoil, power and violence. Their stronger tools enabled people quarrying harder rocks that could withstand natural and anthropogenic impacts. This new technology using harder and sturdier iron tools contributed to the change in tomb location. The inhabitants must have learned that carving tombs in clayey chalk layers would result in tombs lasting only a short time. So they carved tombs in marl limestone, nodular limestone, and micritic limestone as well but used their knowledge about rock hardness to carve longer lasting tombs. Based on the geological data collected from the sites, it is now evident that they examined the stratification of rocks and chose to carve the tombs below hard rock layers (e.g. chert and micrite) to give the tombs a very hard roof that would withstand the ravages of time.

Even with the presence of hard tools, carving tombs in micritic limestone would have required an extensive amount of labour and energy, which explains the presence of occasional single shaft tombs carved into micritic limestone. Our ethnoarchaeological data from the same area serve as an interpretative model of the above case. The modern inhabitants use steel tools to cut shaft graves where a person can only carve one a day. They have local nomenclature for the different types of rocks; they usually quit carving when they face harder rock types. But unlike the people of late antiquity their graves do not exist in rows because of the limited space in their cemeteries.

CONCLUSIONS

The favour of softer rock types for carving tombs in antiquity had determined the location of tombs; in rows parallel to the softer rock bed. The required sophisticated technology combined with the political and social factors affected the location selection. Knowing and understanding the geology of Ya'amun will ease future surveys and excavations and probably will uncover Iron Age tombs. The health of the people during the Middle and Late Bronze Ages was better than that during the Roman and the Byzantine Periods, where malnutrition and traumas were at best grim.

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