

# 20 GIS and Archaeology in Jordan

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## 20.1 INTRODUCTION

This paper introduces the Southern Transjordan Geographic Information System (GIS) Mapping Project (STGMP) which was initiated in 1989 as the first Geographic Information System in the Middle East dedicated to addressing archaeological questions.

The long-term goals of the Project are to test hypotheses regarding specific, ecologically-based aspects of the growth and collapse of urban life in Early Bronze Age Transjordan.

## 20.2 BACKGROUND CULTURAL-HISTORICAL SUMMARY

The Early Bronze Age (ca. 3400–2000 B.C.) is the first period of urbanization in Palestine–Transjordan. The most recent subdivision of the period, following Richard (1987) is as follows:

3600–3400 B.C.	Late Chalcolithic
3400–3100 B.C.	Early Bronze (EB) I
3100–2700 B.C.	EB II
2700–2350/2300	EB III
2350/2300–2000	EB IV

The EB I period and antecedent Late Chalcolithic period, circa 3600–3400 BC, are seen as the beginning of a social growth trajectory which culminated in EB II and early EB III circa 2700–2600 B.C. Over the span of some one thousand years, an egalitarian, village society was sustained by a mixed economy of sheep and goat herding as well as cereal cultivation, and then changed to a complex “city–state” system (Richard 1987:27) of large fortified towns, whose economy was supported by intensive agriculture and a network of international trade. By late EB III many of these urban centres had been abandoned, and by the end of the period circa 2400 B.C., this highly inte-

grated culture had dissolved to a loosely organized society of semi–nomadic pastoralists, identified by but a few villages, hamlets and transient campsites.

This picture of growing socio–political complexity is often linked to the Egyptian and Syro–Mesopotamian economic spheres. Influence from Egypt during the Old Kingdom Dynasties I–V, took the form of export–trade in wine, oil, and agricultural products from Palestine (Joffe 1991) and perhaps the exertion of direct political control over resource rich areas of the Sinai Peninsula (Richard 1987). Closer relations and shared traditions in ceramics and architecture indicate the influence of the Syrian sphere, also in its ascendancy during the contemporaneous Jemdet Nasr and Early Dynastic I–III periods.

The Early Bronze IV period of Palestine, circa 2350–2000 B.C. has been referred to variously as a “dark age” or non–urban interlude (Dever 1980, Palumbo 1991) in which the subsistence system shifted dramatically from that of sedentary, intensive agriculture in arable regions in EB II–III, to a semi–nomadic pastoral subsistence in environmentally marginal areas incompatible with dry farming. This picture is an outgrowth of the available evidence:

- 1) a gap in habitation at large tells previously occupied in EB III
- 2) the presence of vast EB IV cemeteries in Central Palestine not associated with habitation sites
- 3) the discovery of campsites in so–called “marginal” areas such as the Negev, and of sedentary villages in Transjordan.

This period of collapse and social disintegration corresponds to the Old Kingdom–First Intermediate Dynasties of Egypt, ca. 2315–1992 (Dever 1980:37; Richard 1987:22), and the Ur III period of Mesopotamia. Although Syria flourished at this

time, there is little evidence of increased trade with Palestine during the period. EB IV culture in Palestine seems to have followed more closely that of Egypt, then in decline.

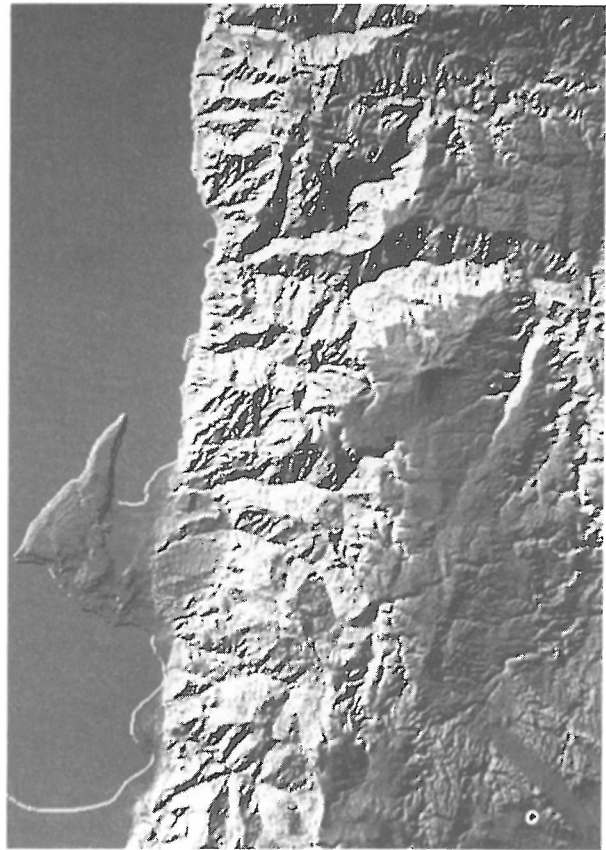
The stresses which caused or accompanied the Early Bronze Age collapse are poorly understood. Nomadic invasion theories have long been discounted (Dever 1980), although Egyptian raids during the III–VI Dynasties have been noted. Recent syntheses (Dever 1980; 1987; Richard 1987) suggest a complex interaction of agents, all of which (except Egyptian interference) are environmentally linked, e.g. famine or pestilence, resource exhaustion (Dever 1987; Weippert 1988) or shifts in climate (Richard 1987).

Although subsistence data have been collected (at varying levels of precision) at a few Bronze Age sites excavated in Jordan, there has been no systematic study of Early Bronze Age sites and settlement patterns in relation to environment and landscape whatsoever. Thus, while shifts in subsistence and landuse are closely held as both cause and effect of EB growth and collapse, assessments of both have been uneven and wholly subjective. Similarly, while the terms of “marginal” and “non-marginal environments” have entered the accepted vocabulary of systemic models, there is an often-ignored, striking void in our knowledge of the ecological and landscape data upon which such models ultimately depend.

### 20.3 GIS AND ARCHAEOLOGY OF THE LEVANT

Geographic Information System technologies have provided the capacity to investigate the relationships between landscape, ecology and Early Bronze Age growth and collapse. The Project’s use of this tool is grounded in the fundamental anthropological premise that human behaviour is patterned, and the process of decoding those patterns can yield greater understanding of cultural change. In this case, Bronze Age site locations themselves have left us a record of patterned human behaviour, which can be decoded using environmental correlates.

At this point, I have chosen not to digress and explain in greater detail what GIS is, how it works, and what it may do in terms of statistical modelling for research, and modelling for cultural resource management purposes. Certainly those who have attended the CAA Conference in recent years have some knowledge of GIS, but unfortunately this is not the case for those doing research in the Middle East. Many of our senior



*Figure 20.1: IDRISI-generated ‘optimal shading’ image of the STGMP study region northwest quadrant, including the east bank of the Dead Sea. The various scales of gray indicate values of shade or sunlight assigned to ground units of the digital elevation image (64 km north–south; 48 kilometers east–west), based on a sun azimuth of 315 degrees at 30 degrees above the horizon.*

generation of scholars have expended themselves on texts – biblical or otherwise – and a notable few still think archaeology in the Levant is for the purpose of Biblical illustration or proof. As a result the younger generation has been trained by those who are largely technologically illiterate. Therefore, many computer applications for archaeology — like GIS — have been late in coming to anthropological research in the Levant.

Regrettably, this general situation is even more pronounced in the local universities — at least in Jordan. Here, there simply are no academic specialists or generalists in GIS or remote sensing, much less in archaeological GIS, quantitative methods for the archaeologist or even mundane computer applications such as using a computer assisted drafting (CAD) system to draft site maps. Consequently, this situation is reflected at the governmental level, with a Department of Antiquities already suffering from inadequate fund-

ing. There have, however, been some interesting developments here with dramatic potential (see Palumbo in this volume).

#### 20.4 THE STGMP STUDY AREA

The Project's study region encompasses some 6000 square kilometers directly south east of, and including the shores of the Dead Sea in the Hashemite Kingdom of Jordan (Figure 20.1). Included in the GIS are the "Biblical landscapes" of the Lisan peninsula and the Dead Sea, the territory of Moab, and the Biblical Arnon river, known today as the Wadi Mujib. The Bronze Age site of Bâb edh-Dhrâ, occasionally mis-identified as the Biblical site of Sodom or Gomorrah, is just to the east of the base of the Lisan peninsula.

This entire area has been surveyed for archaeological sites in recent years by the Wadi al-Hasa Survey (MacDonald 1989), the Central Moab Survey (Miller 1991), the Southern Ghor and North-east 'Araba Survey (MacDonald 1992), and others (Rast & Schaub 1978; McConaughy 1981). These surveys have provided the Bronze Age site data from which empirical models have been developed.

#### 20.5 DETAILS OF THE STGMP GIS DATABASE

##### 20.5.1 Areal coverage and considerations

First some minor details on the GIS itself. The Project's database is founded on two available map coverage's; the 1959 1:25,000 scale Palestine Grid series, and the 1987 1:25,000 French Mapping Group Series. The reference grid has thus been linked to the 1000 meter Palestine Belt Grid, which is based on the Transverse Mercator projection and the Clarke 1880 ellipsoid. Maps were chosen for the basis of the GIS rather than remotely sensed data for a variety of reasons. Factors included outright cost, availability of map data, and access to remote sensing.

##### 20.5.2 Complicating factors

One of the realities of the Middle East is that until recently remotely sensed data was controlled by the military, and in many instances maps are still considered military documents. In the case of this project, liaison with the military was deemed unnecessary and unacceptable. This has, of course, lengthened the process of finalizing the basic data set, and has mitigated against integrating remotely sensed data into the GIS, at least for the time being.

Another complicating factor for GIS in Jordan is that two differing map grid reference systems are used simultaneously — that of the Universal Transverse Mercator (UTM) and the Palestine Grid, both of which are based on differing map projections, ellipsoids and datum points. There are even rumours of a third system being introduced, the Jordan Transverse Mercator (JTM) which consists of a grid "normalized" from UTM Zones 36 and 37! Finally, the delta co-ordinates for conversion between the differing ellipsoids (Clarke 1880 for Palestine Grid; and International for UTM Zone 36) are held as military information. Clearly there will be a problem when archaeologists in this tiny piece of the Middle East begin to use UTM-based Global Positioning System (GPS) units for survey, and when only Palestine Grid or JTM grid maps are used as the basis for an integrated GPS-GIS mapping system.

##### 20.5.3 Software and database building

Terrain modelling as the database initial layer, was accomplished through manual digitizing of contours on a one-meter grid using the ROOTS digitizing software, produced by the Harvard Graphics and Spatial analysis Laboratory (Corson-Rikert 1990). Vector-to-Raster conversion was accomplished on a 50 x 50 meter grid cell size (Chan & White 1990). The sample universe thus comprises some 1.7 million units, excluding areas not digitized and portions of the Dead Sea. The Project therefore bears the perhaps dubious distinction of having nearly half of its elevation values below sea level, in some cases as much as minus 393 meters.

##### 20.5.4 Landscape variables

Some fifty environmental variables have been produced using the IDRISI GIS software from Clark University (Eastman 1990). In addition to the usual variables of slope, aspect and the "distance to resource" themes, the project produced some special landscape variables with the TerrainPac (Kvamme 1990b) and TERRA (Kvamme 1991) terrain modelling software produced by Dr. Kenneth Kvamme of the University of Arizona Spatial Analysis Lab.

In particular, elevations were produced from rasterized vector and point data using a non-weighted, 8-directional, "steepest ascent" raster interpolation algorithm (Kvamme 1990a, 1990b). This was used especially to mitigate against loss of smaller valleys during terrain interpolation, in the highly dissected terrain of the study area.

Another landform variable generated by TerrainPac is the peak-valley index (Kvamme

1990b). The peak–valley algorithm calculates the volume of a cylinder of specified radius around each ground unit of an elevation image — thus creating a new, secondary image identifying peaks and valleys. High volumetric measures indicate peaks; and low measures indicate valleys.

Another variable which has proven to be important in the analytical stage is that of the ridge–drainage index (Kvamme 1990b). In this case, reclassifying values can quickly lead to the identification of drainage as well as ridge networks.

One final variable is that of the terrain texture index (Kvamme 1990b). This last variable gives a measure of landscape roughness by indicating the standard deviation of values of maximum elevation change within a specified radius.

## 20.6 INTEGRATING GIS AND STATISTICAL ANALYSIS

Now that the GIS details have been dealt with, we shall move on to the data. In examining Bronze Age III sites (tells, village sites and sherd scatters, excluding tombs, cemeteries and caves) in relation to the current, normal year isohyets, what we have found is a dispersion of sites across the highland areas well within the 200 mm. isohyet.

The situation for all Early Bronze IV sites is much the same, with the difference being the presence of far fewer sites. As before, this discounts cemeteries, tombs, and megalithic architecture thought to be associated with necropoli. In any event this decrease in raw numbers of site from EB III to IV generally parallels the shrinkage which previous models have indicated.

The patterning of EB IV sites however, takes on new meaning however, when we disregard EB IV sites which are reoccupied from EB III, and are left with *de novo* EB IV sites — that is to say, locations which became occupied for the first time in EB IV. As it turns out all of these sites have been placed at permanent springs, or near drainage's which provide a year–round water–supply.

Employing an approach to integrate statistics and GIS (see Kvamme this volume), the project has used the Kolmogorov–Smirnov test and the two sample T–Test (Kvamme 1990c) to identify a few landscape variables which are important to Bronze Age III and Bronze Age IV site locations. There are a number of variables which exhibit T–scores greater than 2, and thus are significant against the background samples, in a temporal sense. The first is elevation, which indicates a

rather dramatic shift to lower altitudes from EB III to EB IV.

New site locations in EB IV were also chosen apparently with less regard for low slope areas, as was the case for the preceding EB III. This move to higher slope areas is not correlated to a shift in aspect, or ground facing direction. In EB III as well as EB IV the preference is for southward–facing slopes. The background sample indicates a mean of 177 degrees.

Indices of local relief in areas of differing size reflect the same trends in data. Both 150 and 250 meter relief indices show that low relief areas were preferred site locations in EB III. This was followed by a shift to higher relief areas in EB IV, particularly for new sites.

As we indicated before however, water–related variables take on a special significance. This includes distances to springs, minor and major drainage's which provide low sodium content water, fit for human consumption, irrigation and stock watering.

The distances to major drainage's are nearly halved from EB III to EB IV, and the distances to major as well as minor drainage's has been reduced by nearly a factor of 3 from EB III to EB IV. This situation is again reflected when all water sources are considered. This includes springs, seeps, and drainages where water is present year–round.

Other variables which are of importance are those of the peak–valley index, and terrain texture. *De novo* EB IV sites tend towards more “peak–like” locations, and the terrain texture grows progressively higher from EB III to EB IV.

## 20.7 CONCLUSIONS

Although statistical analysis is not complete, it is possible to make some tentative conclusions from the data just reviewed. It has always seemed clear that water sources became of primary importance at the EB III–EB IV transition, but finally we have some statistical data to support this notion. Although there is little evidence of a dramatic climatic shift in the Levant or of dramatic droughts in the Bronze Age, perhaps what we are looking at now in EB IV is a response to a localized and perhaps short–lived disturbance in rainfall. As those of you who have followed the climatic patterns in the Levant in the last months will know, Jordan has recently been the recipient of similar climatic “disturbances”. Some months ago this so–called “desert country” received the usual annual rainfall allotment in the space of 24 hours,

and received upwards of a meter and a half of snow in some areas. As of the date of this conference (*ultimo March 92 — ed.*), some of the larger snow drifts have still not yet completely melted.

In any event, what we are perhaps looking at in the Bronze Age is exactly the opposite — a short-lived but effective drought in Southern Jordan, and a subsequent cultural response. This is indicated by the shift in settlement to areas near to water, and also by the nature of EB III sites which were thought worthy of continuing occupation in EB IV. Many of these sites at the current edge of the 200 mm isohyet, were also near permanent springs, and indicate reservoirs used in earlier time periods. Obviously a short drought would have also affected permanent as well as temporary spring output, and also affected the viability of dry-farming in the plateau areas. This in turn made areas near drainage's more valuable for subsistence agriculture. With this perspective it would be no surprise to find *de novo* sites located adjacent to, but not on top of areas conducive to cropping. Indeed, this is also what seems to be indicated by indices of terrain texture and slope. Perhaps the downward shift in elevation may also be eventually correlated with the increased exploitation of specialized plant growth communities in valleys at lower elevation. While these preliminary remarks may tend to endorse the characterization of the period as a pastoral-nomadic interlude, more important is the possibility of environmental factors and events acting as one trigger of change in the Bronze Age.

This in a nutshell, is the preliminary work of the project, and some idea of the unique situations we face doing GIS in the Middle East. GIS is certainly in its formative stage in the Levant, but we hope these sorts of studies will prove their worth and potential to the governmental sector as well as the academic community.

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#### References

- Corson-Rikert, J., D. White & K. Chan  
1990 *The ROOTS program for Map digitizing, Editing and Verifying*. Cambridge MA: Harvard University Laboratory for Computer Graphics and Spatial Analysis.
- Chan, Kelly L. & Denis White  
1990 *CHOPIN: A Vector to Raster Conversion Program*. Cambridge MA: Harvard University Laboratory for Computer Graphics and Spatial Analysis.
- Dever, W. G.  
1980 New Vistas on the EB IV ("MB I") Horizon. *Bulletin of the American Schools of Oriental Research* 237:35-64.
- 1987 The Collapse of the Urban Early Bronze Age in Palestine: Toward a Systematic Analysis. in P.de Miroschedji (ed.) *L'urbanization de le Palestine a l'age du Bronze Ancien*, British Archaeological Reports (International Series 527) pp. 225-246 .
- Eastman, R.  
1990 *IDRISI. A Grid Based Geographic Analysis System, Ver. 3.2* Clark University Graduate School of Geography, Idrisi Project, Worcester MA.
- Joffe, Alexander H.  
1991 Early Bronze I and the Evolution of Social Complexity in the Southern Levant. *Journal of Mediterranean Archaeology*. 4(1):3-58.
- Kvamme, Kenneth  
1990a GIS Algorithms and their effects on regional archaeological analysis. in Kathleen M.S. Allen, Stanton W. Green & Ezra B. W. Zubrow (eds.) *Interpreting Space: GIS and Archaeology*. Taylor and Francis, London pp. 112-125.
- 1990b *TERRAIN PAC 1.5 Beta test version*. University of Arizona, Laboratory for GIS and Spatial Analysis, Tucson AZ.
- 1990c *T-Test for Spatial Data Version 1.0*. University of Arizona, Laboratory for GIS and Spatial Analysis, Tucson AZ.
- 1991 *TERRA version 6.91*. University of Arizona, Laboratory for GIS and Spatial Analysis, Tucson AZ.
- MacDonald, B.  
1989 *The Wadi el-Hasa Archaeological Survey 1979-1983, West Central Jordan*. Wilfrid Laurier University Press, Waterloo, Ont.
- 1992 *The Southern Ghors and Northeast Araba Archaeological Survey*. Sheffield Archaeological Monographs 5. J.R. Collins, Sheffield.
- McConaughy, Mark A.  
1981 A Preliminary Report on the Bâb edh-Dhrâc Site Survey. in *The Southeastern Dead Sea Plain Expedition: an Interim Report of the 1977 Season*. *Annual of the American Schools of Oriental Research* 46. American Schools of Oriental Research, Cambridge MA pp. 187-190.
- Miller, J. Maxwell (ed.)  
1991 *Archaeological Survey of the Kerak Plateau*. ASOR Field Reports. Scholars Press, Atlanta.

- Palumbo, G.  
 1991 *The Early Bronze Age IV in the Southern Levant. Settlement patterns, economy and material culture of a "Dark Age"*. *Contributi e Materiali di Archeologia Orientale (CMAO)*, 3. Università di Roma, Roma.
- Rast, W. & T. Schaub  
 1978A Preliminary Report of Excavations at Bâb edh-Dhrâ<sup>c</sup>, 1975. in D. N. Freedman (ed.) *Preliminary Excavation Reports: Bâb edh-Dhrâ<sup>c</sup>, Sardis, Meiron, Tell el Hesi, Carthage (Punic)*. Annual of the American Schools of Oriental Research 43. Annual of the American Schools of Oriental Research, Cambridge MA pp. 1–32.
- Richard, S.  
 1980 Toward a Consensus of Opinion on the End of the Early Bronze Age in Palestine and Transjordan. *Bulletin of the American Schools of Oriental Research*. 237:5–34.
- 1987 The Early Bronze Age: The Rise and Collapse of Urbanism. *Biblical Archaeologist* 50:22–43.
- Weippert, M.  
 1988 *Palastina in vorhellenistischer Zeit*. Beck, München.

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