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The Environmental History of the Azraq Basin

Introduction

The arid lands of Jordan, to the east of the rift valley, can be divided into three major lithological/ecological units; basalt in the north, limestone/chalk/flint in the centre, and sandstone/granite in the south (see FIG. 1). Only very basic Quaternary palaeoenvironmental work has so far been conducted in these areas, of which the most notable was the study of the pluvial lake basin at El Jafr by Huckriede and Wiesemann (1968), the overview of Jordanian geology by Bender (1974), and the recent work of Henry (1983) and Osborn and Duford (1981) in the Hisma. A number of other projects are in progress at the present time which may yield data of palaeo-environmental significance; especially that of Betts and MacDonald in the basalt, Rollefson, Muheisen, Kennedy/Gilbertson, and Besancon/Hours/Copeland in the Azraq Basin, Rolston in the Wadi Bayir drainage system and Jobling and Eadie in the Hisma.

The limestone/chalk/flint desert contains two huge depressions, each of about 12,000 sq. km., which formed as a result of subsidence in the Palaeozoic, Cretaceous and possibly early Tertiary period (Bender, 1974). These are the El Jafr and Azraq Basins (see FIG. 1).

The El Jafr Basin was the subject of a detailed environmental and archaeological investigation by Huckriede and Wiesemann (1968) in the mid 1960s. They found evidence of a Pleistocene lake which covered up to 1,000 or 1,800 sq. km. at its maximum. During this time 25 m. of limestones and marls were deposited and these contain freshwater ostracods and molluscs. A single radiocarbon date of 24,450 ± 870 BC (Hv 1719) was obtained from the upper part of the limestone. During the succeeding period the lake appears to have become brackish and sheets of gravel spread across the basin. A period of extreme aridity followed, with sandstorms more intense that those of today. Finally a moister phase led to the re-solution of a portion of the limestones and the formation of the present mud-flat, Qa el-Jafr. The process of desiccation is likely to have begun in the Middle Palaeolithic since Levallois–Mousterian as well as early Upper Palaeolithic implements were found on the surface of the pluvial limestone. The date of the re-solution of the limestones is uncertain at present.

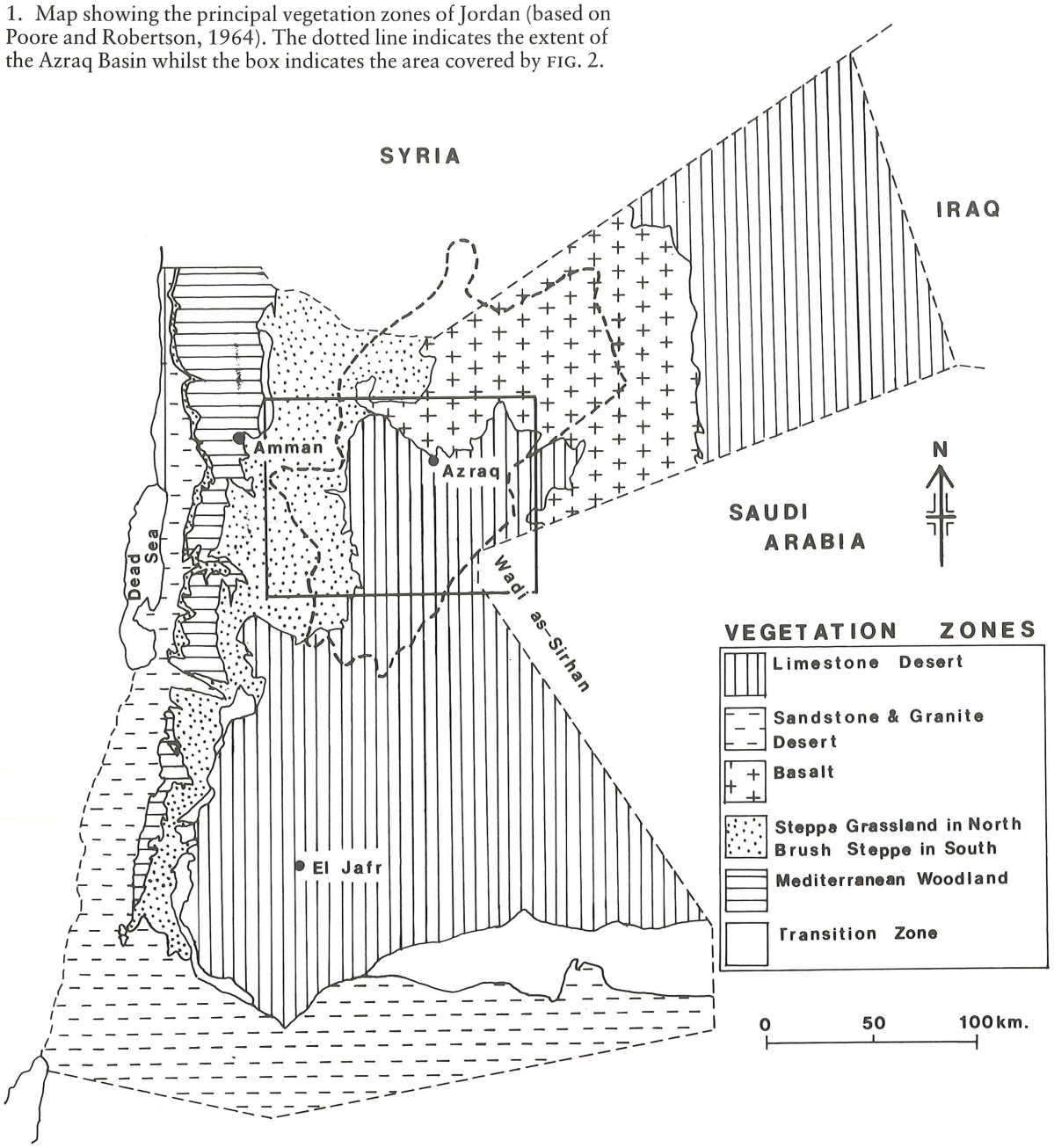
The Azraq Basin has been less well studied. Most of our knowledge of the Quaternary and Recent environment has been acquired by hydrologists working in the region. In the 1950s the Baker and Harza Engineering Company (1958) made a survey of the ground and surface water potential of the Azraq area and in the course of their investigations discovered sedimentary evidence of a Pleistocene lake, which they described as covering 4,500 sq. km. They also uncovered two prehistoric sites near Azraq Shishan which were investigated by Kirkbride (Harding, 1958; Kirkbride p.c.). One of these, at Ain el-Assad or Lion Spring, produced several hundred handaxes as well as Neolithic artifacts. This site was recently re-examined by Rollefson (1980, 1982) and the earlier material is thought to date to the penultimate glaciation or the last interglacial. A second site uncovered by the Baker Harza project and dating to the Yabrudian and Levallois–Mousterian (C Spring) produced a rich faunal assemblage which was identified by Clutton Brock (1970) as containing rhinoceros, European and Asiatic ass, camel, hartebeest and bovids.

Van Liere (1960–61), reinterpreting the geological findings of the Baker Harza project, suggested a three phase lake, the earliest phase being represented by lacustrine marls, the second by gypseous marl and the third and latest by clay and loam. However, he was unable to date these sedimentary episodes.

Other work of a more archaeological nature was undertaken in the region between the 1920s and 1950s by Rees (1929), Waechter *et al.* (1938), Zeuner *et al.* (1957) and Field (1960). They found sites dating from the Lower Palaeolithic to recent times, indicating that even if marginal, this region was habitable through much of man's history. However, although archaeologically important, their work tells us little more of past environments in the region.

Thus in 1975, I began a project with the purpose of reconstructing the environmental, demographic and subsistence history of the region through the Upper Pleistocene and early Holocene. I was particularly interested in obtaining biological evidence pertinent to the origins of pastoralism in the southwest Asian arid zone, a field which had hitherto been

1. Map showing the principal vegetation zones of Jordan (based on Poore and Robertson, 1964). The dotted line indicates the extent of the Azraq Basin whilst the box indicates the area covered by FIG. 2.



neglected by prehistorians concerned with the origins of animal and plant husbandry in the Near East. Before I go on to discuss the result of the work to date it would be useful to outline the present environmental features of the Azraq Basin.

The present environmental features of the Azraq Basin

The Azraq Basin is an irregularly shaped depression covering about 12,000 sq. km. and stretching from the Jebel Druze area of southern Syria to the Saudi border and then west to within 20 km. of Amman (see FIG. 1). The elevation at the centre of the depression is about 500 m. whilst along its northern boundary it reaches 1,800 m., along the west 900 m. and to the south and east between 600 and 900 m. The southern half of the depression is composed of Cretaceous and Tertiary limestones, chalks and marls and the surface is coated with a flint hammada. The northern part is covered by basalts and tuffs which were emitted from volcanoes and fissures between the Miocene and Pleistocene (Bender, 1974). One flow at Kheurbet el-Ambachi in southern Syria has been dated to 2125 ± 160 BC (de Vries and Barendsen, 1954) suggesting that localised volcanic activity continued until quite recently. The older basalts are covered by a hammada of boulders and cobbles making access extremely difficult.

Geological surface mapping suggests that the Azraq Basin is a structural extension of the Wadi es-Sirhan, an inland depression which runs southeast for 300 km. into Saudi-

Arabia. However, seismic surveys and test drilling by the Yugoslav company, Industrija Nafte, has shown that the Azraq Basin is separated from the Wadi es-Sirhan by an east–west subsurface structural divide. Block faulting occurred beneath both the Azraq Basin and the Wadi es-Sirhan in the late Cretaceous, and in the case of the former, individual displacements of 50–1,500 m. have been detected. Consequently there are over 3,000 m. of Cretaceous and lower Tertiary marine sediments in the Azraq Basin in contrast to 150–800 m. in many other areas of the Jordanian plateau (Bender, 1974).

The temperature regime at Azraq village, for the period for which we have records, varies between 45° and −10° (Nelson, 1973), whilst precipitation over the basin as a whole varies between 200 + mm. in the NW and less than 50 mm. in the SE. The overall precipitation averages 84 mm. per year most of which falls in erratic, unevenly distributed storms between November and March (UN Development Programme, 1966). There are no perennial streams or permanent bodies of surface water except for the springs and pools at Azraq. After storms, some water runs off in intermittent stream channels and eventually collects in topographic depressions (or playas) where it evaporates within a few months. The largest of these is at Azraq, and covers about 50 sq. km. A very small percentage of the rainfall, estimated to be less than 2 per cent per annum, seeps down through the surface material of the uplands and stream beds (particularly in the basalt area) and replenishes the ground water in the underlying geological formations. The ground water flows slowly through the rocks in a down gradient direction and eventually is discharged through springs and seeps into the freshwater pools at Azraq.

Permanent vegetation in the basin is largely limited to the wadis, the silty surrounds to the major qas or playas and the wetlands at Azraq. There is however a spring bloom of annuals on the basalt and flint hammada. The recent fauna of the basin has been described by Nelson (1973) and probably included herbivores such as oryx, gazelle, ass and ostrich, and carnivores such as lion, leopard, cheetah, hyaena, wolf, jackal and fox, the last of which is still common in the area.

The results of my own survey work

Turning now to the results of my own survey work. I have so far had two field seasons in the region; the first in 1975 with Dr Nicholas Stanley Price and Mr Mufleh Khuraibi, and the second in 1982 with Mr Paul Harvey (geomorphologist), Dr Francoise Hivernel and Mr Brian Byrd (lithics specialists) and Mr Khalid Abu Ghanimeh (Department of Antiquities representative). The recent work was supported by grants from the Wainwright Committee, the British Academy, the British Institute at Amman and the Palestine Exploration Fund.

The aim of the 1975 season was to assess the potential of the region for a large scale study of environment, demography and subsistence through the Upper Pleistocene and Holocene. During the survey, fifteen areas were surveyed archaeologically, these being chosen so as to sample as many of the geomorphological features and biological habitats present in the basin as was possible. During the three weeks, over fifty occurrences of prehistoric material were recorded, ranging in date from Lower Palaeolithic to Chalcolithic (Garrard and Stanley Price, 1975, 1977). The survey demonstrated the period and density of occupation and indicated the potential for future research.

Consequently in 1982, I undertook a second season with the aims of:

1) Making a geomorphological survey of the central lake area and of two of the wadis draining into the western side of the basin. This was in order to begin a reconstruction of the hydrological and climatic history of the basin.
2) Trying to locate stratified sites of Upper Palaeolithic to Chalcolithic date, which could after excavation, help in the dating of geomorphological features and provide data on cultural and economic developments through to the early pastoralist period.
3) Increasing our knowledge of past settlement patterns in the Azraq Basin.

Given the nature of this volume I will concentrate on the results of our environmental enquiries.

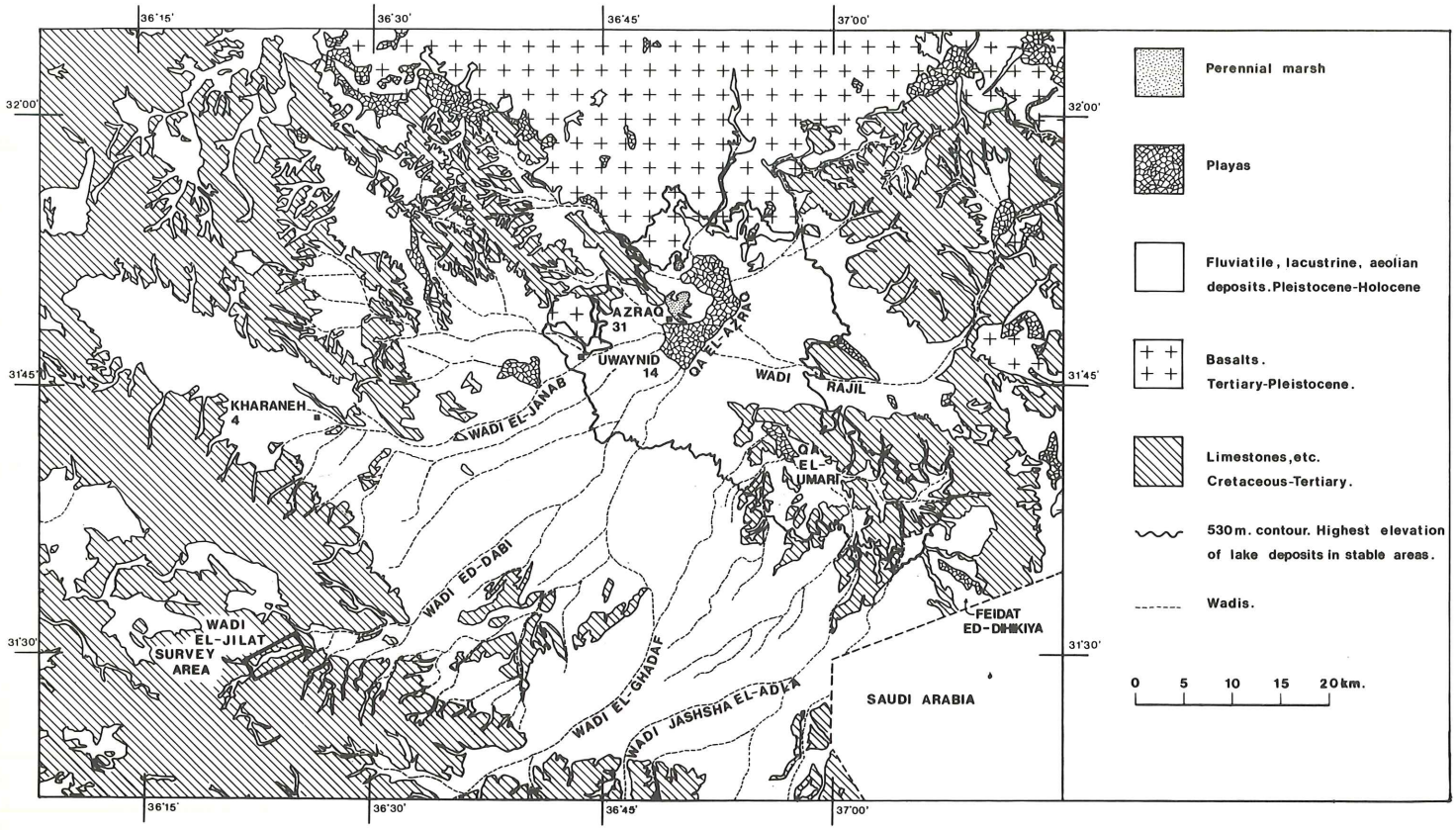
The Western Wadis

We spent the first half of the field season examining the environmental history of two wadis running into the western side of the basin, the Wadi el-Jilat and the Wadi el-Kharaneh (see FIG. 2). Since the western wadis receive the most precipitation, it seemed likely that they would provide the most information concerning the history of water inflow into the central basin.

Wadi el-Jilat

Wadi el-Jilat itself was selected because it was a valley in which Waechter *et al.* (1938) had located and partially excavated several impressive sites in the 1930s. It is a tributary of the Wadi Dabi (or Dhobai) after which Waechter's sites were named. During the course of the survey we made systematic surface collections from Waechter's sites, and also walked several transects across the valley, both in Waechter's area and to the east and west recording all prehistoric occurrences. The prehistoric sites discovered by Waechter and ourselves appear to belong to three major periods, the late Upper Palaeolithic (*c.* 25–17,000 BC), the Kebaran (*c.* 17–12,000 BC) and the Pre-Pottery Neolithic B (*c.* 7,500–6,000 BC). The only later site was a substantial dam of probable Roman–Byzantine date, which is now completely silted up (Waechter *et al.*, 1938). Several of the Upper Palaeolithic and Kebaran sites were 5–10,000 sq. m. in area and reminiscent of small tells—broad dome shaped structures with 1–3 m. of stratigraphy. They were also rich in bone and charcoal and therefore good candidates for excavation.

2. Map showing the geology of the central Azraq Basin (based on Bender, 1974) and the possible extent of the late glacial and early Holocene lake.



Whilst archaeological work was continuing we made a geomorphological survey of the 8 km. of valley in which the sites were found. In the central stretch, where Waechter's sites were located, the wadi has cut a gorge through the consolidated sediments of the valley floor and Upper Palaeolithic to Pre-Pottery Neolithic sites were preserved in the shallow soil on either side. Given the age span of the sites, it seems likely that the wadi has been entrenched in the gorge for over 25,000 years. Upstream of the gorge, the wadi has been capable of lateral as well as vertical erosion, but an alluvial terrace has survived and in its upper levels a substantial late Upper Palaeolithic site was found (Wadi el-Jilat 9). As the wadi is presently cutting through this terrace and there has been no detectable tectonic activity downstream, it seems likely that the terrace formed during a period of wetter conditions than the present, when there was also slightly more vegetation. The late Upper Palaeolithic site suggests that the terrace was forming up until *c.* 20–17,000 BC, but we need to undertake a small-scale excavation and obtain material for C14 dating before we can give a reliable date. As will be seen later, there is evidence for increased precipitation during this period from elsewhere in southwest Asia. Across the wadi from this site, eroding from the surface of the equivalent terrace, we found a site containing a mixture of Upper Palaeolithic and Kebaran elements (Wadi el-Jilat 10). Parts of this site were covered by the remnants of a layer of homogeneous sandy loam, very reminiscent of wind blown loess and some of the artifacts may be derived from this. Others appeared to be eroding from the terrace beneath this deposit. If it proves to be loess, it would suggest arid conditions following terrace formation and probably dates to the late glacial between 16–12,000 BC, when most evidence from SW Asia suggests very dry conditions. Again, excavation is necessary before a detailed environmental chronology can be established.

Wadi el-Kharaneh

Having obtained this data from Wadi el-Jilat, we turned our attention to the Wadi el-Kharaneh lying further north, and also flowing into the western side of the Azraq Basin. This is an area were Besancon, Hours and Copeland also worked in 1982. Whilst they concentrated on the Middle Pleistocene sites and deposits, we examined the Upper Pleistocene and recent evidence. Wadi el-Kharaneh was one of the areas where I undertook survey work in 1975 (Garrard and Stanley Price, 1975, 1977) and is the location of one of the best known Stone Age sites in Jordan. The site in question, which we labelled Kharaneh 4, was found by Harding (1959,

Kirkbride p.c.) about 1 km. south of Qasr Kharaneh. It was the subject of a small-scale excavation by Mujahed Muheisen of the Department of Antiquities in Amman in 1981, and I am presently studying the vast quantity of faunal remains which he obtained (predominantly *Gazella subgutturosa* and *Equus hemionus*). The industries appear to belong to the Geometric Kebaran and early Natufian and I have obtained four C14 dates on the bone ranging from 12–8,000 BC; 12,020 ± 150 BC (Q 3075), 10,250 ± 140 BC (Q 3074), 8,670 ± 126 BC (Q 3073) and 7890 ± 120 BC (Q 3072) (my thanks to Dr V. R. Switsur of the University of Cambridge radiocarbon laboratory).

The site itself lies on a terrace in the Wadi el-Kharaneh. At the base of the terrace there are gravels deposited by the former wadi which contain 'Upper Palaeolithic-like flints' (Besancon, Hours and Copeland—this volume). Superimposed on these are clays which may be of lacustrine origin. There is no bedrock barrier which could have acted as a dam, but it is possible that calcreted wadi gravels served this function. Above the clays are the remnants of an homogeneous layer of sandy loam very similar to the loess-like deposits in Wadi el-Jilat. A number of Epipalaeolithic sites were found on the surface of this deposit and the major 20,000 sq. m. site of Kharaneh 4 was amongst these. Thus this deposit must have collected prior to the earliest C14 date from this site of 12,020 ± 150 BC, and if it proves to be wind blown loess, indicates arid conditions in the late glacial. Either during or since this material accumulated, incision took place in the wadi and its tributaries, and this was followed by renewed terrace formation and further incision. It seems likely that terrace formation occurred during wetter periods when there was more vegetation and whilst the earlier terrace is probably of Upper Palaeolithic date, the later may be contemporary with the late glacial—early Holocene expansion of the Azraq lake described below.

The Azraq Lake

Moving east to the central Azraq Depression, we undertook geomorphological surveys in three areas to examine the history of the former lake—these being Wadi el-Uwaynid, Wadi el-Rajil and Feidhat ed-Dihikiya (see FIG. 2).

Wadi el-Uwaynid

In Wadi el-Uwaynid, along the southwestern side of the basalt outlier bearing the same name, we found a well-preserved terrace. At the base of its sequence were semi-consolidated wadi gravels and above were lake clays, silts and evaporites. Lacustrine sediments were found up the wadi as high as the 530 m. contour, but not beyond. Moving downstream to the Qasr Uwaynid promontory, at the southern point of the jebel, we found a number of *in situ* epipalaeolithic sites eroding out from beneath these lake deposits. We checked this by digging a small sondage at Uwaynid 14. This site contains an assemblage very reminiscent of the Moshabian industry of Sinai (Phillips and Mintz, 1977) which has been dated to 12–10,750 BC (Bar-Yosef, 1981). The exact dating of this site will however depend on further excavation and obtaining material for C14 dating. The site is contained in a grey clay suggesting a swampy environment. Above this are gypsums, brown silts and evaporites marking the rise and fall of the Azraq lake.

Moving along the north bank of the Wadi el-Uwaynid to within 200 m. of the present Qa el-Azraq, we found an impressive site which we called Azraq 31. This appears to be late Pre-Pottery Neolithic date (7–6,000 BC) but it may also contain Pottery Neolithic or Chalcolithic elements. The position of this site at 1–2 m. above the present playa and within 200 m. of its shoreline, suggests that the lake had retreated to more or less its present level by this time. The site itself was located on a hard travertine cap belonging to a former spring. Unfortunately, due to salt encrustation, organic remains are poorly preserved and it will be very difficult to excavate.

Other sites indicating low lake levels include the Acheulian, Yabrudian and Levallois–Mousterian sub-surface sites found by the Baker and Harza Engineering Company (1958) to the immediate south and southwest of the Azraq Shishan Marshes (Ain el Assad, C and B Springs), the two Kebaran and one Natufian site (Azraq 17, 20 and 18 respectively) found in the Shishan marshes and to the immediate south during my own 1975 survey (Garrard and Stanley Price, 1977), and the Roman–Byzantine walls which enclose the freshwater marshes and pools at Azraq Shishan, which extend down to the edge of the present playa. Of these, the Natufian site (Azraq 18), is particularly interesting as it dates to the period between the occupation of Uwaynid 14 and Azraq 31 (12–10,000 and 7–6,000 BC) when we have assumed that there was a high lake. It suggests that the period of high water may have been shorter than suggested, but the site will require further investigation before reaching conclusions.

A number of boreholes have been drilled in the central lake basin of which thirteen have been described by the United Nations Development Programme (1966) from the area of the present playa. The depth of Quaternary deposits varies considerably (from 2–30 m., 7 being the average), but the records are not detailed enough to allow palaeoclimatic reconstruction.

Wadi el-Rajil

Moving across Qa el-Azraq to Wadi el-Rajil, which flows into its eastern side, we found similar evidence of lake deposits in a terrace running up to 530 m. contour. In this terrace, the clays and evaporites of the lake were sandwiched between alluvial gravels. Like the Wadi el-Uwaynid, the Wadi el-Rajil is presently undergoing incision, which is presumably related to the retreat of the lake and drier conditions.

Evidence that the terminal glacial lake rose to 530 m. was also found in several other localities in the northern basin. If one measures the area enclosed by the present 530 m. contour, the lake would have had a coverage of *c.* 700 sq. km. and a maximum depth of *c.* 20 m. However, there is a need for caution with these figures. Firstly, alluvial deposition and

erosion make it impossible to establish the exact outline of the high lake and thus its area. Secondly, both these factors and wind deflation have affected the contours of the former lake bottom, making it difficult to estimate depth. Thirdly, it is possible that there has been tectonic activity in the southern basin since the lacustrine sediments were deposited.

Feidhat ed-Dihikiya

Moving south to Feidhat ed-Dihikiya on the Saudi frontier, there has been considerable tectonic activity both within and possibly since the Pleistocene. Feidhat ed-Dihikiya is a 'V' shaped depression which cuts back from the northern Wadi es-Sirhan into the Azraq Basin through the shallow anticline which divides the two. The depression is defined by near vertical cliffs of 30 to 50 m. At the base of the cliffs brilliant white Tertiary marls and limestones are exposed. However above these are chocolate brown sandy clays with rock salt, and marls with thin gypsum layers, which are of lacustrine origin. Moving back from the cliffs to the highest point of the anticline are lacustrine sandstones with conglomerates, thin bedded limestones and finally a 5 m. thick layer of the brackish water mollusc *Cerastoderma edule paladosa*. The maximum overall thickness of these lake deposits is 55 m. (Bender, 1974), which compares with 18 m. for the maximum thickness of lacustrine sediments from boreholes in the Azraq area (UN Development Programme 1966—well AZ 9). The thickness of the deposits combined with the high elevation (up to 570 m.), suggests that they belong to an earlier lacustrine phase than that observed at Azraq, and could well be Middle Pleistocene in date. A sample of shells was collected by us for Uranium–Thorium dating. The major depression at Feidhat ed-Dihikiya would appear to postdate these lake sediments and results from considerable downfaulting. Lake sediments were found in the depression but there were few good exposures in which they could be observed.

A major problem is to define the relationship between the Azraq lake and that or those in the northern Wadi es-Sirhan. The altitude of the cliffs at the northern end of Feidhat ed-Dihikiya lies between 520 and 530 m., so it is possible that there was an overflow between the two basins at the time when the Azraq lake reached its maximum of 530 m. The sculpturing of the cliffs at the northwestern end of the depression indicates that there has been considerable fluvial erosion, but because of local tectonic disturbance there is no way we can at present demonstrate a positive link between the two basins.

Conclusions

In TABLE 1 I have outlined the main geomorphological and archaeological evidence for past environments in the Azraq Basin. In the western inflow wadi, Wadi el-Jilat, we found an alluvial terrace with Upper Palaeolithic sites eroding from its surface. Since the wadi is downcutting at the present time and there has been no obvious tectonic activity in the northern Azraq Basin, it seems likely that the terrace formed during a period of increased rainfall prior to 17,000 BC. There is considerable evidence for these conditions from elsewhere in the Levant. It was marked by aggradation in the wadis leading into the Jordan–Arabah rift (Bar-Yosef, Goldberg and Leveson, 1974, Golderg, 1976; Copeland and Vita Finzi, 1978), by high lake levels in the Palmyra, Damascus, El Jafr and Jubbah basins (Huckriede and Wiesemann, 1968; Kaiser *et al.*, 1973; Sakaguchi, 1978; Garrard, Harvey and Switsur, 1981) and by high percentages of arboreal pollen in the Huleh Valley (Horowitz, 1971).

A loess-like deposit accumulated on the alluvial terraces of both Wadi el-Jilat and Wadi el-Kharaneh during the later Kebaran period. A site with a basal C14 date of 12,000 BC was found on the surface of this material in Wadi el-Kharaneh. This suggests an extremely dry glacial maximum, which is supported by data from elsewhere in the Levant. Wadis running into the Jordan–Arabah Valley appear to have cut into their terraces, the lakes mentioned earlier dried up and the pollen from the Huleh Valley indicates more steppic conditions.

Evidence for a return of moist conditions in the very late glacial was found in Wadi el-Uwaynid where a site of 12–10,750 BC was covered by deposits belonging to the expanding Azraq lake. The lake grew to cover an area of approximately 700 sq. km. with a maximum depth of 20 m. before retreating to its present position at *c.* 7,000 BC. At the present time the playa at Azraq covers a maximum area of 50 sq. km. with a depth of up to 1.5 m. Less extensive evidence for late glacial or early Holocene pluvial conditions was also found in the El Jafr and Damascus basins, but unfortunately this is undated. However Goldberg (1981) has

Table 1 Geomorphological and archaeological evidence for past environment in the Azraq Basin

Years BC	*Wadi el-Jilat*	*Wadi el-Kharaneh*	*Wadi el-Uwaynid*
0			
		Wadi incision	Azraq 31 (7–6,000+)
10,000		Alluvial terrace Kharaneh 4 (12–8,000)	Lacustrine deposits Uwayid 14 (12–10,750)
	Loess? Wadi incision Jilat 10	Loess? Wadi incision	
20,000	Jilat 9 (25–17,000) Alluvial terrace	Alluvial terrace	

found indications of extensive lakes in Sinai dating between 12–10,000 BC and there is also evidence for increased humidity in the pollen profile from the Huleh Valley.

I hope in 1984 to undertake further work in the Azraq Basin with the aim of digging small sondages in those sites of key importance to the environmental, cultural and subsistence history. Hopefully organic material will be found and it will be possible to obtain absolute dates for the sequence I have just described.

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