Landscape, Landforms and Geomorphic History of a Semi-arid area along the Euphrates River in northern Syria

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A dissected plateau has developed on sub-horizontal Tertiary limestones and dolomites along the Euphrates River in northern Syria. Modern conditions are semi-arid, with little vegetation, thin slope mantles, and salt-affected shallow stony soils with a wind-borne silt content. A sequence of silt and gravel terraces along the Euphrates River and its main tributaries provides a record of past climatic conditions.

Archaeological sites in the area include Bronze Age, Hellenistic, Roman and Byzantine settlements and tombs. The siting of these features, the materials used for their construction, and the nature of the artefacts discovered are closely related to the geomorphology of the area.

In 1953 Edwin Hills worked for UNESCO in Egypt, and also visited Syria, Lebanon, and Israel. On his return to Australia he suggested that one of the classic problems of the Near East was the need for the "correlation of Pleistocene and Recent events with cultural stages of human development" (Hills, 1954 p.4), a problem which he believed was "of outstanding interest throughout the whole region".

This study described here was carried out to provide archaeological workers associated with a University of Melbourne project with background information on the geology and geomorphology of an area with several major archaeological sites. The field work was carried out between 5th and 27th August 1986, in conjunction with that year's archaeological work.

The area of interest is on the west bank of the Euphrates River, about 55 km south of the Turkish – Syrian border, and mapping was carried out of an area extending north-south some 8 km and east-west 4 km, including areas on both sides of the river (Fig. 1).

High summer temperatures, over 40° (104° F) on many days, limited work to mornings and late-afternoons. Traverses were carried out on foot, after transport by car from the base camp at the village of Joussef Pasha (Plate 1).

Air photos helped in the preparation of the map, and during the 1986 season a geological team of Syrian and Russian geologists were working on the selection of a new dam site in the southern part of the area, and provided helpful information during several discussions. Large trenches and pits excavated for the dam study provided access to useful exposures, and several proved suitable for detailed studies.

Topographic maps of the Upper Euphrates Region were prepared at 1:5,000 by EIRA (Italia) in 1961–1962 as part of the work for the Tabqa Dam, some 50 km downstream (Fig. 1). These maps cover the central part of the area. Syrian Arab Republic (Syria) topographic map sheets at 1:25,000 also cover the area, and were used as the base for Fig. 2.

The most detailed geological map available is that of Oufland (1966) at 1:200,000. A bibliography of geology is provided in Aunimelech (1965 & 1969), and further references are given by Ala & Moss (1979).

The area lies in northern Syria, centred approximately at 36° 22' N and 38° 10' E, and forming part of the northern plateau, bordered to the east by the south-flowing Euphrates River. The plateau stretches westwards to Aleppo while to the east across the river lie the higher plateaus of Mesopotamia. The river is

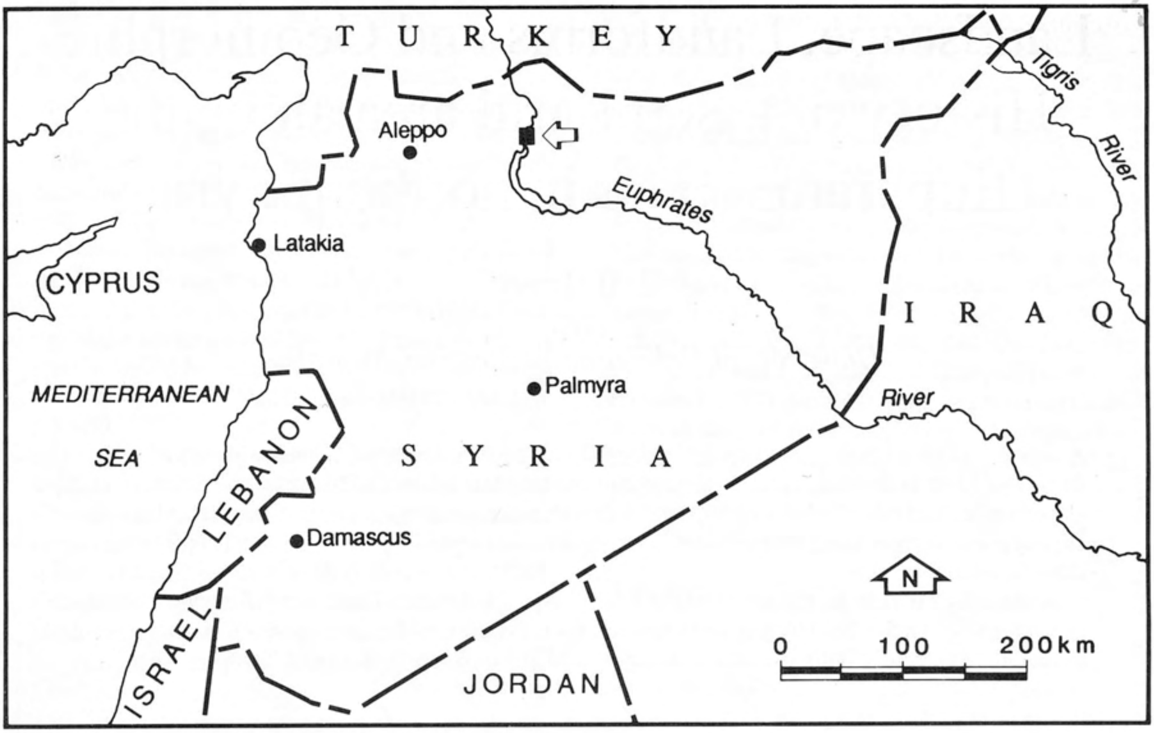

Fig. 1 Syria and adjacent countries, with arrow indicating study area (see Fig. 2).

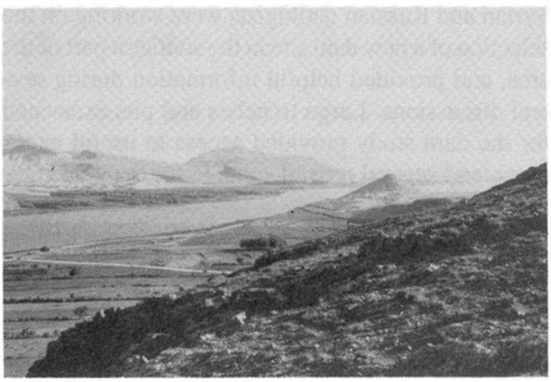

Plate 1 The Euphrates River, looking north from Jebel es-Soda, showing irrigated river terraces, and dip slopes north of Joussef Pasha in upper unit calcarenite.

locally at 299 m above sealevel, with the plateau rising to over 380 m. A Bronze Age fortress and other buildings are found on el-Qitar, at 379 m, and a Hellenistic fortress and town on Jebel Khalid, at 427 m (Fig. 2). Bronze Age tumuli, a Roman villa, Byzantine tombs and Islamic building remains are also found, and artefacts of Palaeolithic and Neolithic age are widespread (see Table 1).

The area is semi-arid, with a rainfall of 250 mm per year, mainly in winter, and a dry summer. The mean January temperature is 4.5° to 6° C and the mean in July is 30° C (Wolfart, 1967).

In summer dust storms occur, and the landscape is dry, with sheep and goats grazing on the stubble, and most human activity occurring on the irrigated terraces where crops and fruit trees are cultivated, with poplars grown to provide house rafters, and firewood. Wadis do not flow unless fed by springs, and the Euphrates is at its lowest in September and October.

Rain, occasionally heavy, and some snow occur in winter, and the river may rise, flooding the cultivated terraces. Most wadis are still however dry. Total annual rainfall may vary greatly, giving drought years. A high annual evaporation gives very dry summers, and soil moisture may be low for much of the year.

In spring the landscape has a sparse cover of flowering plants and low bushes, and the cereal crops are maturing, to be harvested, mostly by hand, in early summer. Snow melt in Turkey gives a peak run-off in April and May. River level varies seasonally by 1 to 6 m (Wilkinson, 1978).

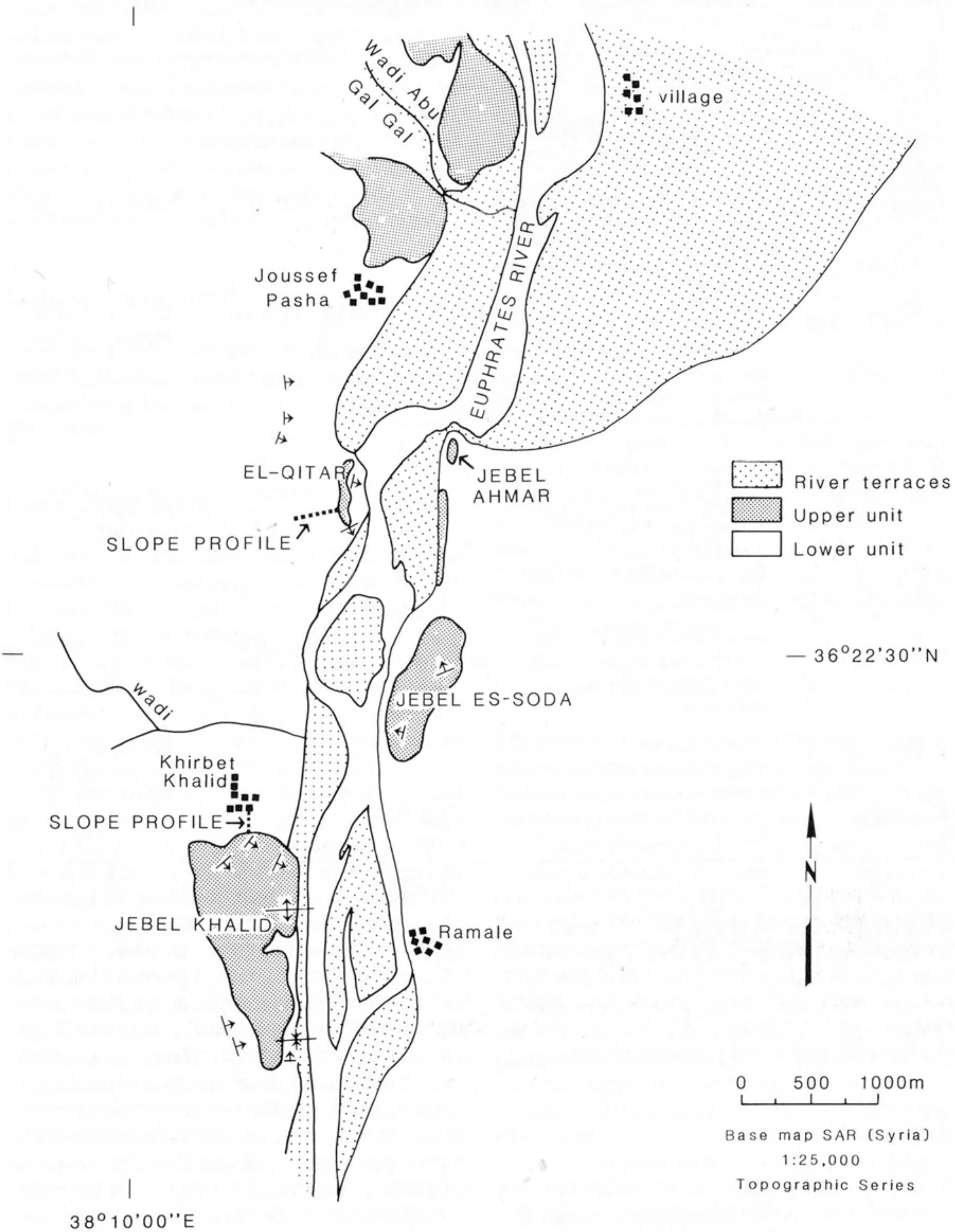

Fig. 2 Geological sketch map of the el-Qitar area, from Wadi Abu Gal Gal in the north to Jebel Khalid in the south, and showing the Euphrates River and the locations of slope profiles on el-Qitar and Jebel Khalid.

Table 1 Age sequence of archaeological sites and artefacts in the el-Qitar and Jebel Khalid area, northern Syria. Based on Van Loon (1967).

Period	Sites and Artefacts	Pottery	Age	
7. Islamic	Khirbet Meushrag site NE of Joussef Pasha	blue & green glazed pottery	Mediaeval, 11th to 13th century	900 to 700 BP
6. Byzantine	tombs near Joussef Pasha; Christian hermits' cave dwellings on Jebel Khalid	dark red & black ribbed pottery, roof tiles	330 to 638 AD	1,600 to 1,300 BP
5. Roman	villa at Khirbet Matbukh	bright red slipped ware	64 BC to 330 AD	2,000 to 1,600 BP (possibly 1,500 BP)
4. Hellenistic	defensive wall and building remains on Jebel Khalid	black-glazed & red-glazed ware; West Slope ware; imported wine amphorae	331 to 46 BC	2,300 to 2,000 BP
3. Middle and Late Bronze Age	fortress walls and building remains on el-Qitar; tumuli to northeast of Joussef Pasha; basalt grinding stones	fine-gritted cream pottery	2,000 to 1,000 BC	4,000 to 3,000 BP (probably 3,500 to 3,000 BP)
2. Neolithic (Halafian)	surface artefacts at Jebel Haloula & generally distributed in study area	broad-band linear design in dark paint	5,000 to 3,500 BC	7,000 to 5,500 BP
1. Palaeolithic	artefact found within Wadi Abu Gal Gal upper terrace & generally distributed in study area	—	—	140,000 to 20,000 BP (possibly 100,000 BP)

On the plateau and slopes wheat and barley are grown as dry-farming crops, with barley favoured because of the low rainfall. On the irrigation terraces cotton, wheat, maize, sugar beet, and in past times rice, are amongst the crops grown. Near Joussef Pasha, cucumber, tomato, and fruit trees including pomegranate, apricot and peach were noted.

Regional Geology

Northern Syria lies above a broad Tertiary and Cretaceous shallow marine carbonate sedimentary basin, deepest below Aleppo where it reaches more than 4000 m, and extending eastwards to the area of interest, where a total depth of 1300 m is estimated (Wolfart, 1967). The basin shallows to the north and the south, and deepens to the east.

Pleistocene terrestrial gravels are found on plateau surfaces in northern Syria, and extensive salt lakes have developed in depressions on the plains to the south, but are not been seen in the study area. There have been few changes to the original marine surface apart from erosional reworking by rivers and wind. Terraces have formed along the rivers, and gravel fans are forming along the adjacent mountain fronts in modern semi-arid conditions. Wind is eroding and redepositing the thin soils developed on the rocky hills, gravel fans and terraces.

There have been extensive young basaltic eruptions in Syria and adjacent countries. Basalts of Upper Pliocene and Lower Pleistocene age are found to the east of the Euphrates valley, 35 km to the north and northeast of the study area. Upper Pliocene and Miocene basalts are 55 km to the northwest, and 80 km to the southwest, beyond Lake Aj Jaboul, the Upper Miocene basalts of Jebel el Hass are found. Basalts are also interbedded with the Helvetien (Miocene) limestones and may be outcropping along the river to the north. To the north across the border into Turkey young basaltic activity has occurred.

Lithology and Stratigraphy

The bedrock of the study area is made up of two main units (Fig. 2) with an angular unconformity between, representing a local regression and trangression in the Tertiary.

Lower Unit Mudrock

The lower unit consists of massive to bedded white limestone, with a chalky appearance, glaringly white in the sun (Plate 2) but with a pronounced yellow colour when moist. Soil cover is generally thin, and exposed rock weathers mainly by disintegrating into a powder due to salt crystallization. This rock generally forms rounded hills and flat areas on either side of the river, and also forms the long, gentle lower slopes of the main mesas and the plateau.

This lower unit is given as Palaeogene age, and specifically Eocene, on the Geological World Atlas sheet 9 (UNESCO, 1976). The same unit is identified by Ala & Moss (1979) as Palaeocene and Lower Eocene, and consisting of marly limestone of less than 100 m thickness, becoming marl further south, and underlain by less than 200 m of older marl and limestone.

Wolfart (1967) shows this area as a Palaeogene marl–chalk deposit some 300 m thick. The most detailed account is that of Oufland (1966 p.14) who described Upper Eocene to Oligocene limestones, clayey limestones and marls from this area.

In hand-specimen this rock is seen to consist mainly of calcareous clay-size material, originally a lime-mud, with small calcareous gastropod shells, foraminifera and ostracods. The composition indicates either a deep-water deposit below wave-base, or shallow quiet water, but in either case near land, as included fragments of plant remains are present, now

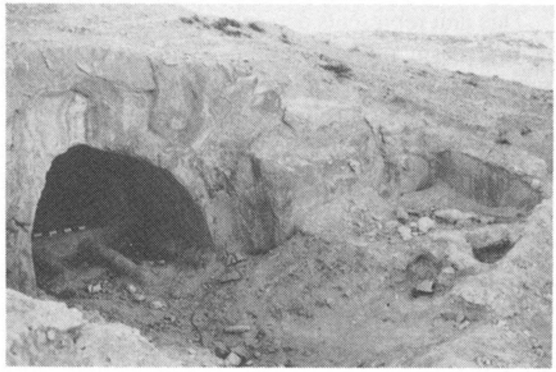

Plate 2 Tomb of perhaps fifth century AD cut in lower unit mudrock; exposed by recent robbing.

preserved as pyrite and indicating anerobic conditions during deposition. These oxidize to give rusty spots in the otherwise white rock. Oufland (1966) described the depositional basin in Oligocene times as probably shallowing to the south, i.e. around this area.

This unit could be referred to as a chalk, (as is done by the local dam geologists) but will here be called the "lower unit mudrock".

Upper Unit Calcarenite

The upper unit is a grey to white limestone, which becomes yellow when wet. Beds average 0.5 m thick. Bedding and well-developed vertical jointing in two directions at right angles control outcrop of resistant beds, which characteristically form scarps, and the cappings of mesa-like mountains, particularly along the river.

Outcrops show a case-hardened surface overlying a softer interior. The harder beds commonly weather by granular disintegration and the formation of flakes 1–2 mm thick, particularly in protected overhangs, and salt weathering may be again a major factor. Minor solution pitting and joint enlargement occurs, with rare karren development on flat to rounded surfaces, and the formation of occasional tafoni and minor caverns.

This unit is given on the Geological World Atlas sheet 9 (UNESCO, 1976) as Neogene, and specifically Pliocene. Ala & Moss (1979) described 100 m of dolomitic limestone in this area, of Middle and Upper Eocene age; elsewhere they gave a figure of "more than 600 m".

This unit represents deposits accumulating as the marine basin of northeastern Syria continued to subside during the Middle and Upper Eocene (Ala & Moss, 1979, p.13). Towards the Turkish border, the unit becomes dolomitic and anhydritic.

Sanlaville (1985), working in the upper Euphrates and Sajour area to the north, described a lower unit along the river as "Calcaires marneux de l'Eocene at de l'Oligocene", with an upper unit of "Calcaires de l'Helvetien", i.e. lower middle Miocene. These probably correspond to the lower and upper units in the study area.

Wolfart (1967) described this unit as a Miocene limestone and chalk–marl–limestone. The most detailed account is by Oufland (1966 p.17) who recorded this unit as a Miocene (Helvetian) coquina and detrital limestone, locally dolomitic, and varying in average thickness from 30 to 90 m.

Hand specimens show this unit to be a marine calcarenite composed of skeletal carbonate grains including calcareous shells and smaller organisms, with occasional pebbles of other material. Originally porous, this unit is generally now cemented, and in some areas is recrystallized. This unit is very high in magnesium (J. Tarboush, pers. comm.) and like other units described to the south is apparently dolomitized.

It will be referred to here as the "upper unit calcarenite".

Late Tertiary and Quaternary Rocks

Late Miocene to Pliocene folding movements led to a further uplift of northeast Syria, and in some areas coarse continental sediments were deposited. Extensive basaltic lava flows were erupted in north, west and southern Syria. Neither of these units occurs in the study area.

Alluvial and slope deposits of Quaternary age are extensively developed. They are discussed later in the section on geomorphology.

Stratigraphic Summary

Although suggested ages for the lower and upper units described above vary with the author, the following general summary can be made:-

1. Deposition of extensive Eocene to Oligocene lower unit mudrock, overlying older Tertiary marine carbonate units (outcropping only further to the south and west).
2. Uplift and regression of the Tertiary sea, and subaerial erosion during the Oligocene.
3. Transgression and renewed deposition, above an angular unconformity, of the Miocene upper unit calcarenite, which now forms hill cappings in the area (and outcrops more widely to the east across the Euphrates River).

Structure

Gentle folds with mainly shallow dips are noted in the upper unit calcarenite, which overlies the softer lower unit mudrock with an angular unconformity (Plate 3). The Euphrates River appears to follow a synclinal fold axis running north–south along the centre of the study area; de Heinzelin (1967 p.22) noted a faulted syncline at Joussef Pasha which he suggested controls the course of the river. The gentle dip of the upper hard units towards the river from each side, as at Jebel Khalid to Jebel es-Soda, and el-Qitar to Jebel Ahmar, has caused narrow rock-walled sections to form along the river; these are currently being investigated as possible dam sites.

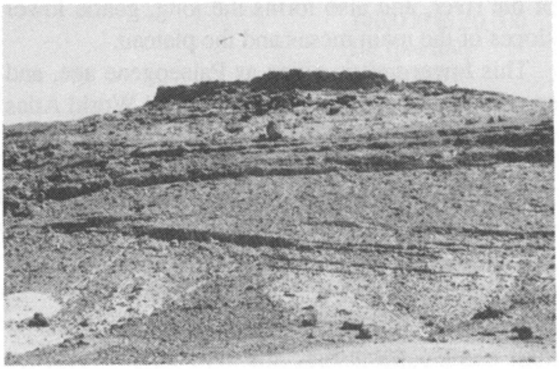

Plate 3 Angular unconformity between lower unit mudrock and upper unit calcarenite, exposed on east side of Wadi Abu Gal Gal. Apparent stone wall on skyline is natural outcrop of calcarenite.

The Russian/Syrian dam team believes that up to 70 m of river gravels can be found along the course of the Euphrates in the study area, with a structural trench controlled by a fracture zone underlying the river course (J. Tarboush, pers. comm.).

Geomorphology

The area shows excellent examples of structural control by dipping hard and soft beds, the landscape expression being most obvious in the local semi-arid conditions with little vegetation and soil cover. Jebel Khalid and Jebel es-Soda are mesas capped by resistant upper unit calcarenite, and el-Qitar is a steep cuesta where the upper unit has a dip of 30°. Tilted upper unit calcarenites are found to the north of the village of Joussef Pasha (Plate 1). To the west and east away from the river a plateau has developed, largely on the lower unit mudrock, and dissected by wadis, especially close to the Euphrates River itself.

Drainage Pattern

A system of usually dry wadis extends across the lower slopes, mostly on the lower unit mudrock, with a generally dendritic pattern which in detail is controlled by the bedding and joint pattern. Several major lineaments can be seen on the aerial photographs, and are well expressed in the drainage pattern, forming prominent north-south margins to the river, as on the eastern side of Jebel Khalid, and on the left bank to the north of Jebel es-Soda (Fig. 2). These may be the expression of faults paralleling the axis of the major syncline which controls the course of the river through the area.

Hillslopes

Below the rocky scarps developed on the upper unit calcarenites the slopes are generally soil-covered, with angular clasts of limestone to 10 cm or so in or on the soil. Large fallen blocks from the scarp above are found on some slopes. Gully erosion has removed the soil from some lower slopes.

Detailed slope profiles showing the soil and slope mantle have been surveyed on the west slope of el-Qitar and the north slope of Jebel Khalid (Fig. 3). The description of these slopes was assisted by the trenching carried out by the Syrian–Russian dam investigation team.

The upper trench on el-Qitar has proved of major interest. Exposed in the trench are 100 to 150 cm of slope deposit consisting of four units. The lowermost unit ca. 20 cm thick is of angular clasts of rock in bedded fine sand, resting abruptly on fresh to weathered bedrock, and representing a similar slope deposit to that found on the surface today. The unit above is a dark to black clayey sand to clay loam, powdery, with root holes, 10YR 3/2 black to brownish black, largely horizontal, and resting directly on bedrock in the upslope part of the trench. It contains pottery, and is mostly clast-free, and can be provisionally equated with a dark horizon in the archaeological excavations on the top of el-Qitar dated by radiocarbon at ca. 3,500 BP (T. McClellan, pers. comm.) and possibly due to destruction by fire.

Above is a unit of vesicular porous silt, 10YR 7/3 dull yellow orange, sometimes reddened, and containing impressions of plant stems; this represents an accumulation some 45 cm thick of fragmental and broken-down mud brick.

The uppermost unit is a silty loam containing rounded and platy fragments of rock, and pottery, and forming a modern slope deposit some 20 cm thick.

On the upper surface of el-Qitar the slope mantle can be seen infilling old buildings and overriding walls almost completely, indicating an accumulation of more than 1 m of further slope mantle in the last 3,500 years or less.

The other feature of note is the development of apparently deep weathered sections on the lower slopes at both el-Qitar and Jebel Khalid. The section at the foot of Jebel Khalid contains some pottery, and may have been a man-made excavation or an erosion gully, later infilled. However the more than 5 m of deep weathering found half way down the west slope of el-Qitar is less easy to explain. A magnetometer survey carried out by Dr E. Polak (pers. comm.) in February 1985 crossed the line along which the trench was later constructed, and located several anomalies on the slope which were suggested as buried walls and man-made trenches, but these do not correlate with this deep weathered section.

The deep weathering may be related to the presence of more susceptible rock, but it is notable that on both el-Qitar and Jebel Khalid it occurs where steeper upper slopes give way to gentler lower slopes (Fig. 3). Although a distinct piedmont angle is not seen, this weathering may be compared with the scarp-foot weathering described by Twidale (1967) in the Flinders Ranges of South Australia. Differential weathering below scarps, particularly in the middle part of the debris slope, was ascribed by Twidale (p.403) to runoff from the bare hillslopes above percolating into

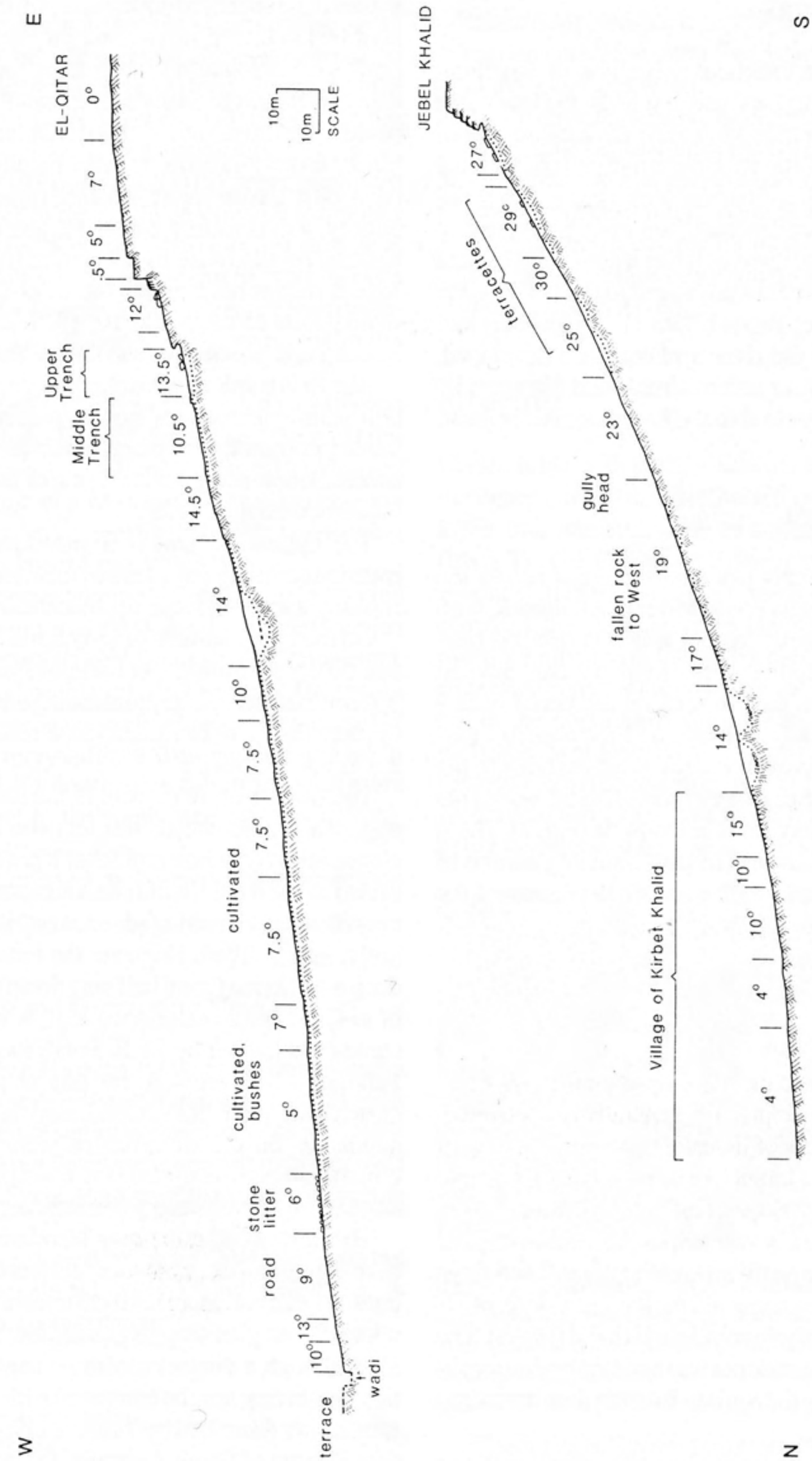

Fig. 3 Slope profiles for el-Qitar and Jebel Khalid (for locations see Figure 2). Rock outcrop at surface except where shallow soils and slope deposits are indicated by dots, or greater depth to bedrock is indicated. Survey by Abney level and pacing.

the rock strata, and also to seepage from the pervious rocks which form the scarp upslope.

The distance between adjacent mesa cappings ranges from less than a kilometre to 2 km or so. Assuming an average retreat rate for the free face of several mm per year (see for example discussion for the Palymra area by Sakaguchi, 1986, p.7) this could represent a period of sub-aerial weathering and erosion of between 125,000 and 500,000 years, rather less than the period of at least 2 Ma for which the area has apparently been above the level of marine deposition.

Wadis and Fans

Stony fans emerge from the hillsides along the main wadis, and the wadi walls show cross-sections of well-bedded coarse to fine angular limestone clasts. In some wadi walls, buried soils and soil calcrete layers are seen, and occasionally massive cementing by carbonate occurs. Wilkinson (1978) has studied sequences in which wadi fans have formed along the Euphrates River in an area some 50 km to the south near Meskene. When a fan is eroded by the main river, renewed local incision occurs along the wadi. Such changes may occur at any time as the main river shifts its course, and so no climatic deductions should be made.

River Terraces

The main river terrace at 4 to 7 m above the present river level is an uncemented grey sandy silt, with occasional clasts of limestone. Small, well-rounded pebbles occur in the river itself. A variety of pebbles, up to 20 cm in diameter, of dense red and black igneous rock, coarse diorite, flint, and rare milky reef quartz, are also found scattered across the landscape, and may have been carried up from the terrace or the river channel.

In the area immediately downstream from Jebel Khalid, and extending to the Tabqa dam site, a terrace sequence was described by de Heinzelin (in van Loon, 1967, p.2, 3 & 22–25). High gravels occur at 60 to 90 m above the flood plain, the main terrace is at 15 to 30 m height, and a lower terrace is at 1 to 10 m.

Of these only the lowermost terrace, the Mureibit Formation of de Heinzelin (1967), is well-developed in the study area, with terraces generally at about 5 to 6 m above the present river level, and sometimes 1 or 2 m higher. At the ancient Bronze Age river gates below el-Qitar the terrace is about 4.5 m above river level.

Due to the influence of the Tabqa dam, there has probably been some minor drowning of the floodplain of the Euphrates in this area, with a consistently higher level than in the past. Occasionally also the level may rise and fall suddenly by several metres when water is stored and then released upstream in Turkey and the original floodplain gravels, now usually underwater, may be temporarily exposed.

A high level terrace is found along Wadi Abu Gal Gal, a right bank tributary to the Euphrates in the north, beyond Joussef Pasha. 15 to 20 m of gravels and finer sediment have been hardened in the upper 4 m, apparently by silicification, and form a major bench along the valley side. A Middle or Upper Palaeolithic artefact of flint was found within this terrace sequence (here called the Gal Gal unit) below the hard capping, which suggests an age of perhaps 100,000 years for this terrace. Buried soils occur within the terrace deposit.

A lower terrace along the downstream part of the same wadi at an elevation of 2 m is not cemented, and is mainly blue-grey clay (one of the few clay deposits in the area); it has a major calcrete horizon with massive carbonate up to 1 m thick as well as other calcrete layers, suggesting a complex soil history. The presence of a Roman villa site on the lower terrace surface at Khirbet Matbukh gives a minimum age of 1,500 BP for its formation.

Further upstream at Jebel Haloula on the Wadi Abu Gal Gal upper and lower terrace deposits can be seen resting on eroded lower unit mudrock with elevations of 20 m and 6 m respectively; the upper terrace has an extensive surface deposit of Neolithic Halafian pottery (M. Mottram, pers. comm.) which may be 7,000 to 5,500 BP (Van Loon, 1967, p.3).

A terrace at 16 m above the river on the west bank of the Euphrates River just upstream from Joussef Pasha contains rounded river pebbles of many varieties, cemented together, including sub-rounded to rounded, elongate to spherical pebbles of creamy brown flint, white quartz, red jasper, and dark igneous and metamorphic rock pebbles. This is apparently the only representative in the study area of a high level terrace along the main river. The archaeological site of Khirbet Meushrag, a predominantly

Table 2 Alluvial terrace units on the Euphrates River and tributary wadis in the el-Qitar and Jebel Khalid area, northern Syria, and suggested correlation with other areas.

Study Area			Glacial terminology	Other Areas			
Euphrate units	Wadi units	Probable age		De Heinzelin (1967)	Van Liere (1960)	Ponikarov et al. (1964)	Vita-Finzi (1972)
16 m	15-20 m	100,000 BP & >7,000 BP	Last Glacial >30,000 BP to 10,000 BP	Shajara Fm 15-30 m Mid-Pleistocene?	Middle Pleistocene valley fill and Main Terrace to 45 m	Third Terrace 25-35 m Middle Palaeolithic, and Second Terrace 12-15 m Upper Palaeolithic	Fill I 50,000 to 10,000 BP
4-7 m	2-6 m						
		>1,500 BP	Post-Glacial or Holocene <10,000 BP	Mureibit Fm 1-10 m >5,000 BP plus flood-plain deposits	Lower Terrace, Holocene and prehistoric to Byzantine, plus post-mediaeval floodplain	First terrace & floodplain 3-6 m Holocene	Fill II 2,000 to 300 BP

Hellenistic and Islamic settlement, with some prehistoric material (Sagona & Sagona, 1988) lies just above this terrace (see Table 1).

Detailed correlation with the complex terrace sequences developed by Van Liere (1960), and Ponikarov et al. (1964) will not be attempted here. However the conclusions of Vita-Finzi (1972) that in Syria, Turkey, Iran and most of the Mediterranean area alluvial deposits and related marine sedimentation can be explained in terms of only two main alluvial "fills" in the last 50,000 years may provide a useful framework. Fill I was deposited from 50,000 to 10,000 BP and was followed by a period of erosion and down-cutting. Fill II was deposited from 2,000 to 300 BP, and then modern erosion and down-cutting began.

Table 2 summarizes the sequence of terraces in this and adjacent areas along the Euphrates River.

Soils

The soils of the slopes and plateaus on the west side of the Euphrates are generally thin and stony, averaging 15 to 30 cm deep, and passing abruptly down into rock. Rock outcrops in places, and elsewhere areas of soil up to 1m deep are found. The parent rock consists of the lower unit mudrock, with its occasional harder limestone beds. The soil contains many platy to rounded rock clasts, probably regularly redistributed by shallow ploughing (Plate 4).

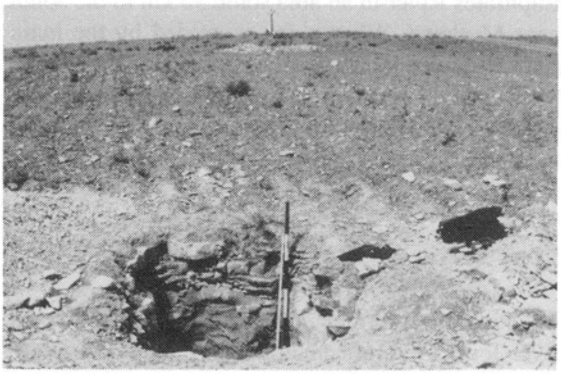

Plate 4 Shallow soil profile in pit dug in lower unit mudrock, on cultivated 5° slope 225 m from the west bank of the Euphrates River, looking west towards the plateau. Many small stones and large angular fragments in the ploughed soil, and salt efflorescence on rock faces in pit.

The typical soil is a silty loam to silty clay loam, sometimes with small angular blocky peds or crumb structure, porous and often apedal, with little or no horizon differentiation. A typical colour is 10YR 7/4 dull yellow orange to 10YR 5/4 dull yellowish brown when moist. The soil effervesces with dilute hydrochloric acid throughout the profile, with carbonate present mainly as a powder and rarely as small nodules at 20 cm depth. Gypsum commonly occurs at 60 cm depth in the deeper soils, and varies from an open crystalline framework to fine grains which helps give a porous and open texture to the soil.

Fine salt effloresces on joint faces below the soil level in pits and wadi walls, breaking up the rock to a fine powder. Soil may be found extending down joints in the rock; it is often of a pinker colour, and contains gypsum.

The plateau soils of the region have been classified by Van Liere (1964) as Calciorthids (solonized brown soil in the common Australian terminology) and Torriorthents. Wolfart (1967) showed Subarid Brown Soils with "limecrust" developed on limestones and marls in this area, and Lithosols and Regosols further upstream on similar rocks.

Away from the river onto the main tableland which extends towards Aleppo, there is less dissection, and the soil cover is apparently deeper, and noticeably redder in colour. The soil in the study area probably consists of minor remnants of an original red plateau soil left after erosion, with a younger layer of wind-deposited silty loam carried from the main plateau to the west in more recent arid conditions.

Dry-land farming for grain crops is practised on the slopes developed on the lower unit mudrock. Grazing of the stubble after harvesting probably increases wind erosion.

A thin soil is found on the rock of the upper unit calcarenite, but much of each mesa top is relatively bare rock, with the few plants surviving in deeper patches of soils along joints and other cracks. However, up to 1.5 m of stony soil has been noted in archaeological excavations (P. J. Connor, pers. comm.).

Soils on the terrace deposits, with the exception of those mentioned earlier along Wadi Abu Gal Gal, are young alluvial soils with little obvious profile development (Torrifluvents of Van Liere, 1964, and hydromorphic soils of Wolfart, 1967).

Hydrogeology

Major active springs occur at the town of Abu Gal Gal, and maintain a regular flow throughout summer in Wadi Abu Gal Gal. Other minor springs occur along wadis e.g. at Jebel Haloula on Wadi Abu Gal Gal, and on lower slopes, but few are active in summer.

Wells are used as a minor source of water in the villages, tapping the lower unit mudrock, but most water used is carried up from the river using donkeys. A well in gravels at the downstream end of Wadi Abu Gal Gal is pumped for irrigation water.

Several old aqueducts, now no longer used, are found along Wadi Abu Gal Gal. Van Loon (1967, p.5) referred to major irrigation works built in Byzantine times along the Euphrates.

Ancient cisterns have been dug in the upper unit calcarenite on the tops of the fortified mesas e.g. a Hellenistic cistern over 7 m deep on the acropolis of Jebel Khalid. These cisterns must have been filled by rainwater, or by carting water from the river; there appears to be no groundwater inflow and they are now dry and partly filled with rubble.

Discussion

Following the main uplift of the region and regression of the sea in the late Pliocene, the area has been dissected by wadis and rivers over at least the last two million years.

Long slopes have developed on the lower unit mudrock, running towards the river, with a series of main wadis at right angles to the Euphrates, and smaller tributary wadis showing structural control. A plateau survives away from the river, and nearer the river isolated mesas capped by the hard upper unit calcarenite are found, the river's course being partly controlled by a major synclinal structure with associated north-south faults.

A series of terraces has developed, the main high level terrace in the area being along Wadi Abu Gal Gal. A Middle or Upper Palaeolithic artefact suggesting an age of about 100,000 BP was found in the upper terrace unit (the Gal Gal unit). Along the main river and most wadis only a single low level terrace is found.

Soil development has occurred in several stages, rare older soils having well-developed calcrete horizons, and sometimes structured clay sub-soils, (e.g. Wadi Abu Gal Gal lower terraces) and sometimes a high degree of induration of the parent terrace gravels. The younger and modern soils have fine carbonate distributed throughout a simple unstructured silty loam profile, and gypsum and other salts at shallow depth, correlating with the modern semi-arid climate.

Human occupation has included grazing and general removal of vegetation, and has accentuated the effects of wind and water erosion under a semi-arid climate.

Slope deposits have formed thin stony mantles during the last few thousand years, and continue to develop today.

Relationship of Geology to Archaeology and Prehistory

The aim of the field project was to provide information for the archaeologists working in the area. The relationship between the archaeological features of the area and its rocks and landforms is discussed first, and then a palaeoclimatic history is considered, and related to the history of human occupation.

The River Crossing

A major feature of the study area is the river crossing – the only ferry between Jerablus to the north and Meskene to the south is a barge which operates just south of el-Quitar, where the river is narrow, and low terraces occur on each side, with gentle approaches down wadis from the plateaus to east and west (Fig. 1). Such a crossing would have been an equally important site in the past.

Siting of Settlements and Defences

These depended on the the narrowness and steepness of the river margins, combined with the suitability for a defensible crossing point. The Bronze Age fortress of el-Qitar is one of a string of fortresses extending from Carchemish in the north to Tell Faq'ous in the south, possibly under Hittite control, to protect the region against Assyrians across the Euphrates to the east. It dates from 3,500 to 3,000 BP, to judge from a tablet found in the excavation and dated at 3,300 to 3,200 BP (Late Bronze Age), and from dates obtained by radiocarbon. It was "destroyed at the end of the Late Bronze Age, never to be occupied again" (McClellan, 1986, p.438.) It forms a twin fortress with Jebel Ahmar across the river, which here is only 100 m wide, and so capable of being covered by bow and arrow range.

Jebel Khalid, a Classical (Hellenistic) fortress, dating from the beginning of the 3rd Century BC, i.e. 2,300 BP, performed a similar function at a later period, perhaps in conjunction with the mesa of Jebel es-Soda on the eastern bank, although this feature is apparently unfortified. On the Euphrates 30 km to the north a later Islamic fortress called Qalat Najim is also recorded.

Modern villages occupy sheltered positions along the river below the windy plateau and mesas, with better access to water and irrigation land. Today Syrian and Russian geologists are studying the area as a future dam site, which will probably be between el-Qitar and Jebel Ahmar.

Use of Stone for Building

The main stone construction so far studied is the 4 km long defensive wall which runs around the top of Jebel Khalid (Plate 5). The wall averages 2.8 m wide, and originally was probably more than 6 m high, with 28 towers of various sizes. The wall was constructed of regular-sized blocks in a strict *emplekton* or "interwoven" technique (P.J. Connor, pers. comm.).

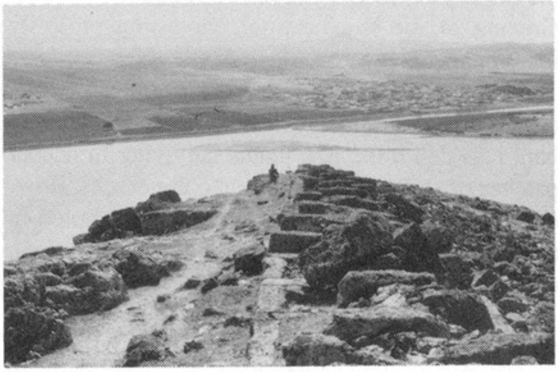

Plate 5 Hellenistic defensive wall on Jebel Khalid, looking east across the Euphrates and river terraces to the village of Ramale and beyond to the plateaus of Mesopotamia.

The stone came from several quarries on the top of Jebel Khalid which can still be seen. The blocks were cut from the softer and more regularly-cemented rock found just below the mesa surface. Several partly-quarried blocks may still be seen in a number of places. Although originally easily cut, the blocks have hardened until they now appear similar to the exposed rock of the mesa top and scarp face; they are however very friable and are easily broken down to sand-size grains.

The stone used at el-Qitar and other sites has not been studied closely, but apparently again came from the upper unit calcarenite. The River Gate at el-Qitar is of roughly-dressed cyclopean rocks which have survived as a wall for 3,500 years.

Siting of other Archaeological Features

The fortresses on Jebel Khalid and el-Qitar were sited not only for their elevated positions commanding the river, but also for the suitable building stone in the vicinity. Bronze Age burial tumuli constructed on the ridge top above the river northeast of Joussef Pasha made use of the same rock, collected locally.

The lower unit mudrock provided suitable material for the excavation of tombs; to the west of Joussef Pasha (Plate 2), tombs possibly dating from 330 to 638 AD (Van Loon, 1967) are being regularly exposed by robbing. The original builders took advantage of the fine-grained, compact and soft rock to carve and inscribe the tomb walls. Descriptions have been published recently by Clarke & Connor (1987).

In the Hellenistic quarries on Jebel Khalid, extensive caves have been cut into the softer rock below the hard capping. These are generally squared-off inside, with an inner and outer compartment; one cave has a "barrel-vault" roof. These may have been used for such purposes as dwellings, food-storage and penning animals (Clarke & Connor, 1987) and some were probably occupied by Christian hermits ca. 300 to 600 AD.

Village House Construction, Ancient and Modern

Seeden (1982) and al-Radi and Seeden (1980) have reported on an area some 15 km south down the Euphrates which was studied before submergence when the Tabqa dam was being constructed. A site with Halafian (Neolithic) potsherds, flints and obsidian tools was excavated, and the dwellings discovered were compared with the modern buildings of the area. Many similarities were noted.

Seeden (1982) described the modern building techniques of the area. The lower walls, corners and door edges are constructed from large and regular limestone fragments gathered locally but without any further working. Smaller pieces are used as fillers, and to build the walls higher. The local soil, which includes sand and gravel, is excavated near the building, mixed with water, trodden, and straw and chaff added to give a material called *libn*. This is sometimes made into a type of mudbrick, but is generally used as a mud plaster, filling between the stones, and then plastering over to make a finishing coat. Mud brick may be used sometimes to build corners and upper walls, over and around the stones. A type of finishing whitewash called *trab abiad* (lit. "white soil") is made from a local marly rock which is crushed and dissolved in water.

Small buildings such as silos, ovens and courtyard walls may be constructed entirely of stone, with a mud plaster. In the villages of Joussef Pasha and Ramale, buildings are constructed of stone more or less completely to roof level, without the use of any mud brick, and then finished with mud plaster (Plate 6).

Plate 6 Stone and mud plaster houses and sleeping platforms of wood in the village of Joussef Pasha, with cliff of well-bedded upper unit calcarenite behind.

Roofs are constructed by laying poplar branches as rafters across the walls, and generally these are left projecting (Plate 6). Shorter poles and reeds are added, then quantities of the local thornbush, and finally a mud plaster (Seeden, 1982) The final flat roof has a continuous parapet and is generally drained using small projecting pipes. At Joussef Pasha and other villages, plastic matting is placed across the rafters before applying the mud cover, giving a clean and neat ceiling above the rafters. For smaller buildings such as silos wooden poles and sticks are placed in a radial or criss-cross fashion, and the mud roof however very friable and are easily broken down to sand-size grains.

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Low platforms of stone and mud are built beside the rooms as working and sleeping areas. Separate freestanding sleeping platforms of mixed stone and wood construction are also common at Joussef Pasha (Plate 6) and wood may be used as door frames. Elsewhere in Syria houses entirely constructed of mud brick are found, which may reflect both a lack of locally available wood and also the availability of suitable clay for mud brick construction.

Without regular repair or renewal, mud-dressed buildings will soon begin to decay (Seeden, 1982) and then collapse. The mud brick material found in the upper trench on the west side of el-Qitar (Fig. 3) indicates Bronze Age use of mud and mud brick in the study area, which decayed to form an archaeological layer with a maximum age of 3,500 BP.

Artefact Material

The main artefact materials used in the area are flint, used in Palaeolithic times, chert used mainly in Neolithic times, and vesicular basalt grinding stones, from at least the Bronze Age until the present day. The basalt is often vesicular, and in larger pieces than river pebbles would provide.

Many varieties of river pebbles including flint, quartz, and igneous and metamorphic rocks, but apparently not basalt, are found in the cemented terrace on the west bank of the Euphrates, northeast of Joussef Pasha, at about 16m above the river. Many rock types are also found in the terraces at lower levels, and similar river pebbles are found widely scattered across the landscape, and in the strata of the archaeological excavations, apparently carried and dropped by humans.

Flint occurs in the Tertiary limestones, including the lower unit mudrock, and also in Cretaceous rocks which outcrop on the east side of the river 50 km to the north. Basalt occurs 35 km to the north, and also downstream.

Sagona & Sagona (1988) have described Neolithic stone artefacts from Jebel Haloula, most being of flint or chert, but including obsidian; electron microprobe analyses of the obsidian suggest an eastern Anatolian origin.

At el-Qitar McClellan (1986) has recorded artefacts of obsidian, beads of shell and stone (carnelian, lapis lazuli), flint artefacts of Palaeolithic age, Neolithic flakes and implements of purple chert, and basalt grinding stones.

Seeden (1982) listed the following artefact materials at Tannira, some 15 km to the south of el-Qitar: pestles and hammerstones of basalt and chert, ground-edge implements in lava and greenstone, and artefacts and pebbles of chert, obsidian, greenstone, laminated chalcedony, banded ironstone, brown to red jasper, sandstone, shale, onyx, opal, quartz and gypsum.

A major human artefact is pottery, ranging from Bronze Age pots, including large storage jars, through Hellenistic pottery, distinctive red Roman pottery, and green-glazed Islamic pottery. The main types of pottery found in the area are summarized in Table 1.

Surface distribution of sherds has been the means of locating many sites, and in some cases has formed the basis for detailed collecting and analysis without excavation, e.g. the Jebel Haloula site of Halafian age on Wadi Abu Gal Gal.

Clay is not common in the river terraces, but the younger terraces along Wadi Abu Gal Gal have well-structured clay, and it may occur elsewhere along major wadis, and possibly on the Euphrates upstream and downstream of the study area. No sites used for pottery clay have yet been identified in the local area.

Food Production and Water Supply

Modern irrigation, use of aqueducts and wells, dry land ploughing, and the grazing of stubble have been discussed earlier; ancient practices were apparently very similar. The main water supply both past and present has been the Euphrates River, supplemented by springs and wells, with cisterns used extensively for storage in ancient times.

Relationship of Palaeoclimate to Archaeology and Prehistory

A first stage in understanding the human occupation of the study area is to make a comparison with better studied areas elsewhere in the Middle East and Mediterranean.

Studies of glacial conditions, lakes and pollen have been carried out to the north in Turkey. Pollen studies have been made in northwest Syria and to the northeast in Iran.

Along the coasts studies of deltas and marine terraces and shorelines have also provided evidence of past climate, but such areas are both distant from and at a much lower altitude than the study area, and cannot provide useful comparisons.

Sakaguchi (1986) has described the area around Palymra, some 200 km to the south (see Fig. 1) and made climatic deductions based on the presence of pluvial lakes in the past.

Pollen

Pollen evidence summarized by Bottema (1978) comes from two rather distant sites, in the Ghab valley in northwest Syria, and at Lake Zeribar in northwest Iran. At the Ghab valley site, which is today forested, the Upper Full Glacial from 27,000 to 14,000 BP had steppe vegetation, which continued through the Late Glacial from 14,000 to 11,000 BP after which a forest cover was present. At Lake Zeribar steppe gave way to savannah at about 10,000 BP.

The probable vegetation of the study area during the Last Glacial would be a grassland, followed in the Post-Glacial by forest vegetation to the south but not extending to the study area.

Alluvial Deposits

As Butzer (1978) pointed out, the main evidence in many areas is in the alluvial fills, now dissected. In the study area alluvial fills and terraces are found along the Euphrates and its tributary wadis. Further evidence may be found in the soils developed on and in the alluvium. Soils on the hillslopes, and the related thin slope deposits, may also provide some evidence. The youngest deposits and soils, and the most recent erosional features, may be the result of human activity.

Traditionally terrace sequences have been used to erect a time scale for archaeological studies, with the depositional evidence used to make deductions also about past climate and related aspects such as vegetation, soils and erosion. In recent years it has become obvious that a simple interpretation of terrace altitudes, materials and soils is not possible.

The Euphrates River is largely fed from the high country across the border in Turkey, and today it is the snow-melt which produces high flow in April and May. In past colder conditions, such as during the Last Glacial, snow and ice melt would have given a higher and seasonally fluctuating discharge. As a result of glacial erosion upstream, and the action of frost, a heavily-loaded and aggrading river, probably a braided stream in part, would have occupied the Euphrates valley. A wide and deep floodplain deposit of coarse debris with seasonally interbedded finer deposits would have built up.

In a subsequent warmer period, the river would have established a lower flow with less fluctuations, a generally smaller and finer load, especially as vegetation was re-established in the highlands, and a single-channel meandering river, cutting down into the earlier floodplain, which would form a high terrace surface. This is similar to the situation today.

A series of cold and warm periods would thus produce a series of terraces, probably at successively lower levels, if overall the river was continuing to cut a deeper course. In some areas however, earlier terraces might be buried under later deposits.

In areas where the river was confined to a narrow gorge, such as between el-Qitar and Jebel Khalid, successive alluvial fills may have been more or less completely removed in subsequent erosional phases. Upstream from such a gorge, the river would meander and also remove much of the earlier fill. Downstream however such earlier deposits may remain. This is the situation today on the Euphrates, where the oldest and highest terraces are found downstream from the study area, but not found in the gorge, or the area immediately upstream.

However in a gorge evidence of past high level fills may be preserved as small cemented remnants, or benches cut into the slopes but without surviving river deposits. The cemented gravels just up-river from Joussef Pasha, discussed earlier, may be a remnant of an older high level terrace.

Another area where equivalent deposits may survive is in tributary valleys, where locally derived alluvial fill would be deposited, and graded to the alluvial fill of the main valley. When the main valley fill was removed, these tributary fills may survive as terraces, as with the high level terrace along Wadi Abu Gal Gal.

The terrace sequence in the study area has been discussed earlier, and related to sequences in adjacent areas. It provides a general framework for the palaeoclimate of the late Quaternary in the study area (Table 2).

Conclusion

The general picture for northern Syria was given by Butzer (1978). The Last Glacial was cool, and drier than present, with less forest or none at all, according to pollen data, and possibly some frost weathering according to cave evidence. Westerly winds shifted southwards to blow across Syria, but carried little moisture (Brice, 1975, p.351).

The early Post-Glacial (early Holocene) which followed was warmer and moister to the south, with forest colonization, but in the study area conditions may have been similar to present day. Sakaguchi (1986) recorded a warm-wet episode at the beginning of the Holocene, based on a pluvial lake near Palymra (Fig. 1) at that time. Butzer (1978, p.9) suggested that there has been "little alteration of climate of ecological significance in post-Pleistocene times north of perhaps 32° latitude". Brice (1975, p.354) suggested that the deepening of the Mediterranean cyclonic rain belt would have brought more rain to the Syrian plateau in the Holocene, and that there is no evidence of increasing dessication during this period.

The local sequence may now be considered. The earliest dated point in the study area is the Gal Gal terrace unit with its indurated capping and included artefact with an age of ca. 100,000 years. Younger units along the wadis, and the Euphrates itself, provide evidence of Holocene deposition and subsequent erosion. The thin deposits and soils on the hillslopes, and the presence of deeper and older soils on the plateau, and in alluvial deposits, suggest that the landscape has been under general erosion by water and wind, with some redeposition by wind, during most of the Holocene, the last 10,000 years. A summary of the terrace sequence for the study area is given in Table 2.

Palaeolithic occupation took place under generally colder conditions than today, with a grassed landscape, subject to winter snow and frost action, and cool summers, the gravel bed of the river flooding drastically in spring but with low flow in winter. A high watertable would maintain some flow from springs and along the main wadis. Dry westerly winds would erode and redeposit soil material, especially in winter.

The Holocene (Post-Glacial) has been a period not unlike the present day climatically, with cold winters and some rainfall, and hot and dry summers, the main river flowing regularly but peaking in spring following snow melt upstream. Changes in hillside erosion and related deposition along lower slopes, alluvial deposition and stream incision, and soil development on slope and stream deposits, have all most likely been due to the anthropogenic effects of grazing, agriculture and changing settlement patterns.

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