REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEMS

Tony J. Wilkinson

Today remote sensing and Geographical Information Systems (GIS) appear quite regularly in the media. Geographical Information Systems are credited with almost magical qualities, whereas "cutting edge" satellite imagery is reputed to be able to do remarkable things such as, for example, reading from space the license plate of a military vehicle. It does not take much imagination to envision how these technologies can be applied to archaeology, and at the Oriental Institute over the last few years we have slowly been developing a modest capability in these areas of research. The current note is to update readers of the *Annual Report* on some of the useful ways these technologies can be employed in the archaeology of the ancient Near East.

Here I discuss first how GIS can be employed for large-scale regional analysis of archaeological landscapes. I then focus on progressively smaller areas, in which ground control (i.e., field investigations) becomes vital to the interpretation of remotely-sensed data. Most of our work is done in the Annette Klein Archaeology Laboratory, a research laboratory in the basement of the Oriental Institute, where we conduct research in part funded by a collaborative program of the Argonne National Laboratory and the University of Chicago. Jason Ur and Carrie Hritz have been working in the laboratory on a range of satellite imagery from northern and southern Iraq and northern Syria, as well as parts of southern Turkey. The hard work of Carrie and Jason during the first year or so of the laboratory is much appreciated, as is the stalwart contribution of John Sanders who advised during the establishment of the laboratory and helped install the software.

Geographical Information Systems provide a way of organizing mapped data in the form of layers or overlays so that it is possible to see how different properties of the landscape relate to each other. For example, if one has a map of soils of an area, a second map of archaeological sites, and a third map with mean annual rainfall, then superimposing one map over the other shows how, for example, sites relate to the distribution of soils and rainfall, or conversely how soils themselves relate to the pattern of rainfall. Of course these methodologies have been in use for decades, but it is now possible to pursue such investigations using more and more layers of mapped information, and also to analyze them quantitatively using a wide range of analytic tools. In addition to their analytical capabilities, GIS also enable us to visualize, for example, two dimensional landscapes in three dimensions. Even some rather simple capabilities provide useful results, as the following example should make clear.

In the last two years a small group of Oriental Institute researchers including myself, McGuire Gibson, John Sanders, and Steven Cole have been trying to recreate an ancient "cyber community" based on a Bronze Age Upper Mesopotamian city state, and then to determine how such a community could have thrived, or suffered, over long periods of varying climate. In order to build such a model, not only do we need to know much about the systems of cultivation that existed some 4,000 years ago, but also roughly how much land might have been devoted to cultivated crops, and how much to animal husbandry, specifically for flocks of sheep and goats. Unfortunately for one of the main areas of interest, the Khabur Basin in northern Syria, there was insufficient information from the ground to make such deductions. However, by combining some basic principles of landscape archaeology with GIS analysis, we have been able to make a preliminary estimate in the following way.

First it was necessary to determine the cultivated areas around a specific tell, then if all the Bronze Age sites in the Khabur Basin could be recognized, we would then be able to estimate roughly the cultivated areas around each site. Finally by default, and by analogy with modern village cultivation systems, we could infer that the land beyond the areas of defined cultivation were available for pasture. Fortunately GIS and remote sensing technologies aid us in most of these problems.

For example, in many parts of northern Syria and Iraq, radial systems of linear valleys radiate from the larger Bronze Age sites and then fade out some 2–5 km (1.3–3.0 miles) distant. These "linear hollows" (as they are described in earlier *Annual Reports*) appear to have been etched into the terrain as a result of the sustained passage of humans and their animals, which wear down and compress the ground surface and encourage erosion of the tracks. The fade-out point of the tracks must then represent a zone at or near the limit of cultivation where traffic along village tracks dwindled to a minimum as more traffic was generated to gain access to the nearer fields than to those near the borders of cultivation. This process of fade-out is illustrated from the map of the modern small town of Qara Qosh to the southeast of Mosul where the radial tracks exhibit branches and then fade out beyond, apparently in the vicinity of the limits of the lands of Qara Qosh and before the lands of the neighboring smaller villages are reached (fig. 1).

The Bronze Age equivalent of such a system is illustrated in figure 2, which illustrates a CORONA satellite image taken in December 1967 of the area of Tell Cholma Foqani in the western Khabur Basin in northern Syria. The Bronze Age tell is in the center of the image whereas the distinctive lines that radiate out from the site, linear hollows, represent the fossils of ancient tracks. This site therefore supplies the basic model for the large or moderate size central tell (i.e., a Bronze Age village or small town) surrounded by its territory of fields extending for some 2–5 km away.

Next, to compute the number of Bronze Age sites in the Khabur Basin we can use a relationship developed in earlier ground surveys in the region. This work demonstrated that Early Bronze Age settlement mainly occurred in the form of tells, that is sites that were rather higher (usually greater than 5 m) in comparison to their area (see Tell Beydar survey in the 1997/98 *Annual Report*, p. 24, fig. 6). Thus most tells are likely to have been occupied during the third and perhaps the second and the fourth millennium BC. Although only an approximation, this technique enables us to make an estimate of the number and distribution of Bronze Age sites in those areas that had not been surveyed by archaeologists. Then we could complete the picture by

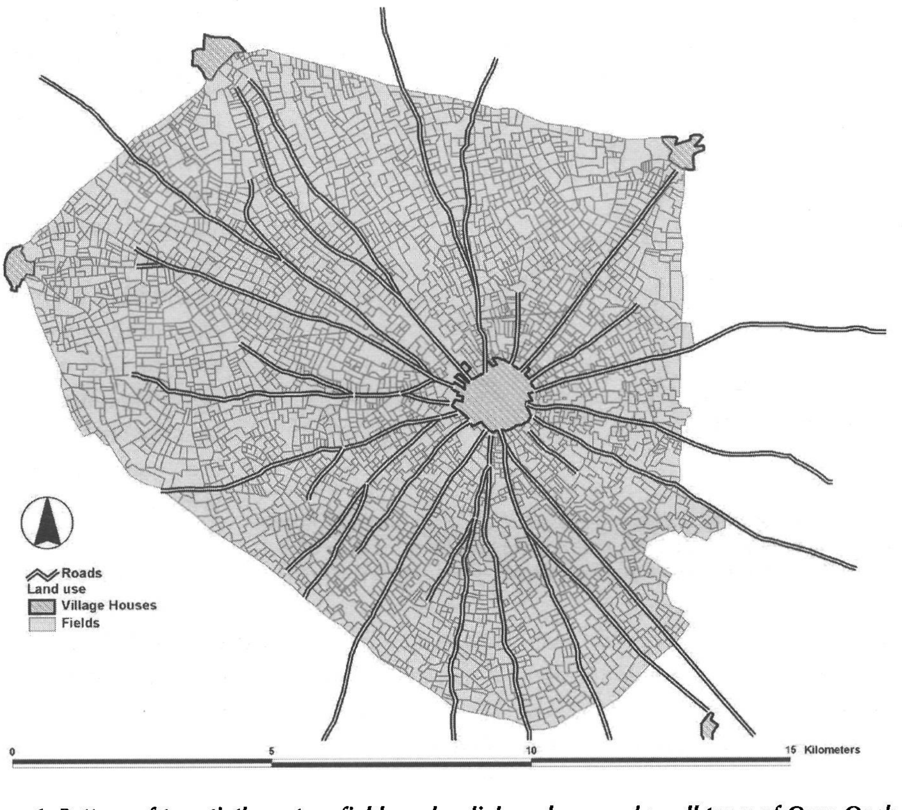

Figure 1. *Pattern of twentieth-century fields and radial roads around small town of Qara Qosh in northern Iraq, which is similar to that existing in Bronze Age. Image by Jason Ur*

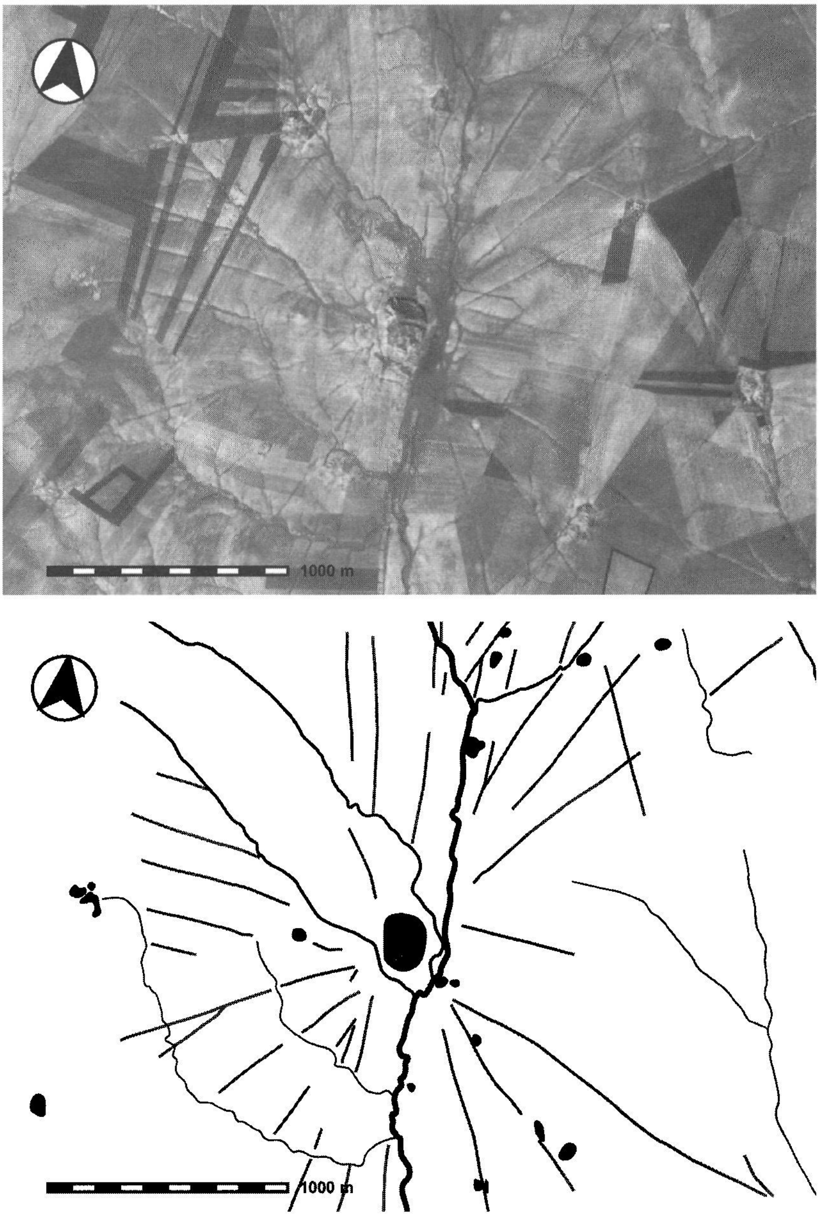

Figure 2. (top) Photograph taken by satellite (11 December 1967) of Tell Cholma Foqani, northwest of Chagar Bazar in northeastern Syria. (bottom) System of radial linear hollow roads extrapolated from photograph. Image by Jason Ur

combining this distribution of tells with the record provided by patchy archaeological surveys in the area. Tells, being conspicuous landmarks, can be recognized on maps of the region because they are usually referred to by name, and in addition they are recognizable on satellite images either from their distinctive pattern of erosional gullies or from the shadow they cast, especially during periods of low angle sun.

These principles have enabled Jason Ur and Carrie Hritz to produce a first approximation of the Bronze Age settlement pattern of the upper Khabur Basin (fig. 3), which shows tells (small open circles), surrounded by the estimated cultivated land within 3 km (gray encircling areas, "buffers" in GIS terminology). This map is useful first because it shows the very distinctive alignments of Bronze Age sites and cultivated land along the wadis, and by default, areas of non-cultivation beyond (white areas). Interestingly, these white areas of land left vacant form elongated patches often paralleling the wadis usually along the watersheds. The patches appear to form interconnected corridors of land that would have potentially provided grazing as well as passage for pastoral nomads through the area. Nevertheless, despite these large areas of potential pasture, it is quite clear that the Khabur Basin must have been rather densely settled in antiquity. Furthermore, during times of maximum population, probably in the third quarter of the third millennium BC, there must have been a considerable pressure on most of the pastureland.

On the other hand, in the area to the southwest around the upland of the Jebel Abd al-Aziz it is apparent that Bronze Age sites roughly encircle the foot of the Jebel, albeit with large areas of available pasture beyond. Fortunately we now know much more about this arid and remote southeastern area because of a recent survey conducted by Frank Hole (Yale University) and Nick Kouchoukos (formerly of Yale and now at the University of Chicago). Their work confirms that many of the Early Bronze Age sites in this climatically marginal area are large but may have been in part dependent upon the economy of pastoral production, as well as upon small areas of cultivated land around the sites. Such communities must therefore have received more of their livelihood from pastoral economies than those sites in the crowded area of the upper Khabur Basin itself (fig. 3).

GIS methodology also provides powerful software for the visualization of terrain. For instance in the area of the Tell Beydar survey (see 1997/98 *Annual Report,* figs. 2–3) it is possible to take data from contour maps and manipulate it to form three-dimensional images. In this case we can see one of the ancient pasture areas (fig. 4: dark plateau to the right), with a broad swathe of cultivated land through which a small line of tells is aligned along the wadi itself. Although we were aware of this landscape configuration from our fieldwork in the area, the powerful number crunching capabilities of the GIS software provide a novel way of illustrating this terrain.

It should be emphasized that there can be no substitute for ground survey for providing confirmatory evidence of features recognized on satellite images. It is therefore fortunate that in September 1999 I had the opportunity of undertaking some two weeks of geoarchaeological survey around Tell Brak in the Khabur Valley. During this fieldworkWalton Green (Cambridge University graduate student) and I were able to check the alluvial stratigraphy of the Brak area, and also to record sections through the linear hollows that radiate from that site. These features are shown in figure 5 (top) as faint broad lines in dark and light shades and (below) as radiating lines that lead away from the halo that surrounds the tell. Tell Brak is heavily eroded by gullies, hence it appears on the figure as a light area with alternating dark patches, the latter being slopes that were in shade when the picture was taken. The pale gray area that surrounds the tell, and from which the lines radiate, is an area that has accumulated sediments eroded from the main tell, as well as being an area of pits excavated perhaps to supply mudbrick for the buildings of the numerous superimposed settlements that form the tell. Although since the area was photographed from space in 1967 there has

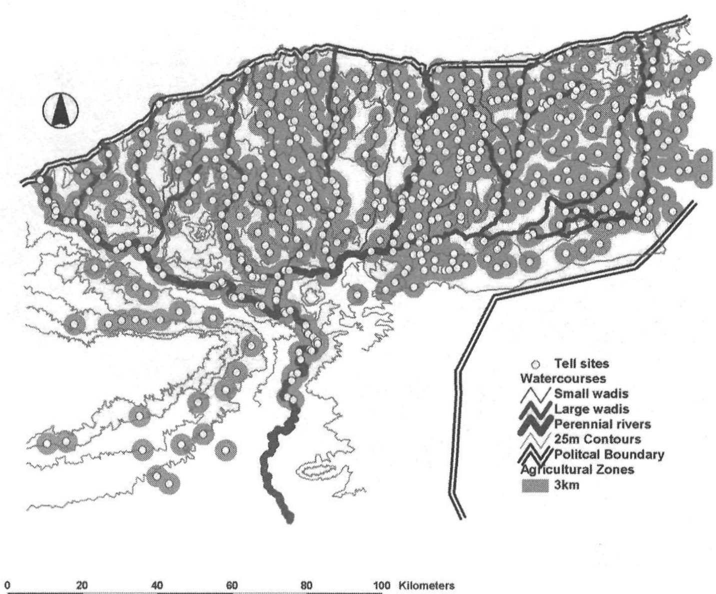

Figure 3. Pattern of Early Bronze Age settlement in Khabur Basin, inferred cultivation and potential pastoral areas. Image by Jason Ur and Carrie Hritz

been a vigorous growth of houses, shops, and various government buildings, it is still possible to recognize some linear hollows on the ground. Today these appear as broad hollows, some 50 to 100 m wide, but only about 1–3 m in depth.

Clarification was provided by a backhoe trench cut by the local municipality. This provided a section which demonstrated that originally the linear hollow was some 1.5 to 2.0 m deeper but had since become filled in by deep loams washed from the surrounding fields. Centrally within the hollow and along its base, was a 6 to 9 inch thick deposit of pea grit or fine gravel that had been washed along the feature, apparently when it was in use. This gravelly deposit was the result of the flow of water along the hollow during times of intense rains such as are common in northern Syria in the fall, winter, or spring. However, it is clear from the lack of features resulting from waterlogging, the absence of freshwater molluscs, as well as the local nature of the stones, that these sediments were not deposited from permanent flow from wadis or canals, but rather were the result of episodic flow of flashfloods from the nearby surrounding terrain. In other words, as along any track today, these ancient tracks and roads concentrated runoff along them so that during wet weather they varied between being elongate puddles to flowing torrents of water. Such flow must therefore have eroded the hollows during their long life, which, judging from the date of occupation of Tell Brak, was between at least the fifth millennium BC and the Middle Assyrian period of the late second millennium.

These features are therefore formed by a complex range of processes, both human and natural. Because of the operation of such processes, the linear features we see on the images do not simply reflect the position of the ancient tracks, but they also result from erosional processes along them. Consequently such patterns usually only represent that part of the ancient system that was preferentially etched by erosional processes. That this is the case around Brak is quite evident because to the southeast of the site no such features are visible. This is presumably not because tracks were originally absent from this area, but rather because this sector receives little runoff from upslope and therefore erosion was minimized. Thus it appears that the linear hollows upslope of Brak were funneling runoff from those areas upslope and to the north and flow was then concentrated into one or two features that flowed southwest of the site and into the Jaghjagh River to the south.

Nevertheless despite their invisibility on the images, it seems likely that roads were in fact originally located in this empty area because about one mile north of the junction of the Jaghjagh River and the Wadi Radd a stone causeway had been constructed across the Jaghjagh (fig. 6). This feature, first recorded by Joan and David Oates, was originally considered to have been

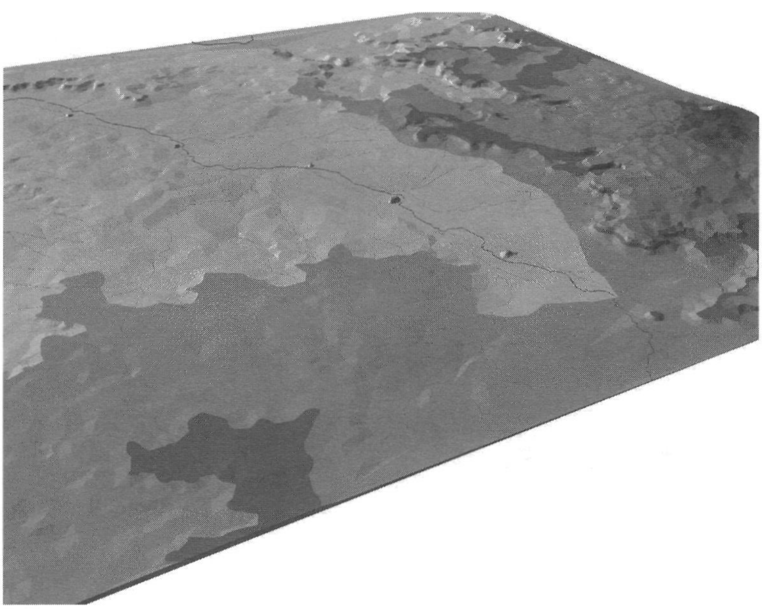

Figure 4. Three-dimensional reconstruction of area south of Tell Beydar in western Khabur River Basin with long-term pastoral zone on basalt plateau to right. Image by Jason Ur

in use during the Roman-Parthian period. However, when examined in detail in 1999, the alluvial deposits that overlaid the causeway, or were contemporaneous with it, proved to be associated with pottery of either fourth- or third-millennium BC date. Thus we potentially had a causeway of Chalcolithic or Bronze Age rather than Roman date. This was a valuable discovery, and it is therefore thanks to the generous support of the Brak expedition, David and Joan Oates, and Geoff Emberling, that funding was raised to enable Walton Green (pictured in fig. 6 during the initial recording in 1999) to excavate this feature in spring 2000. This work has now been completed, and preliminary examination of the pottery from the associated stratigraphy demonstrates that the feature dates from between the fourth and mid-second millennium BC and was probably mainly in use during the Early or Middle Bronze Age.

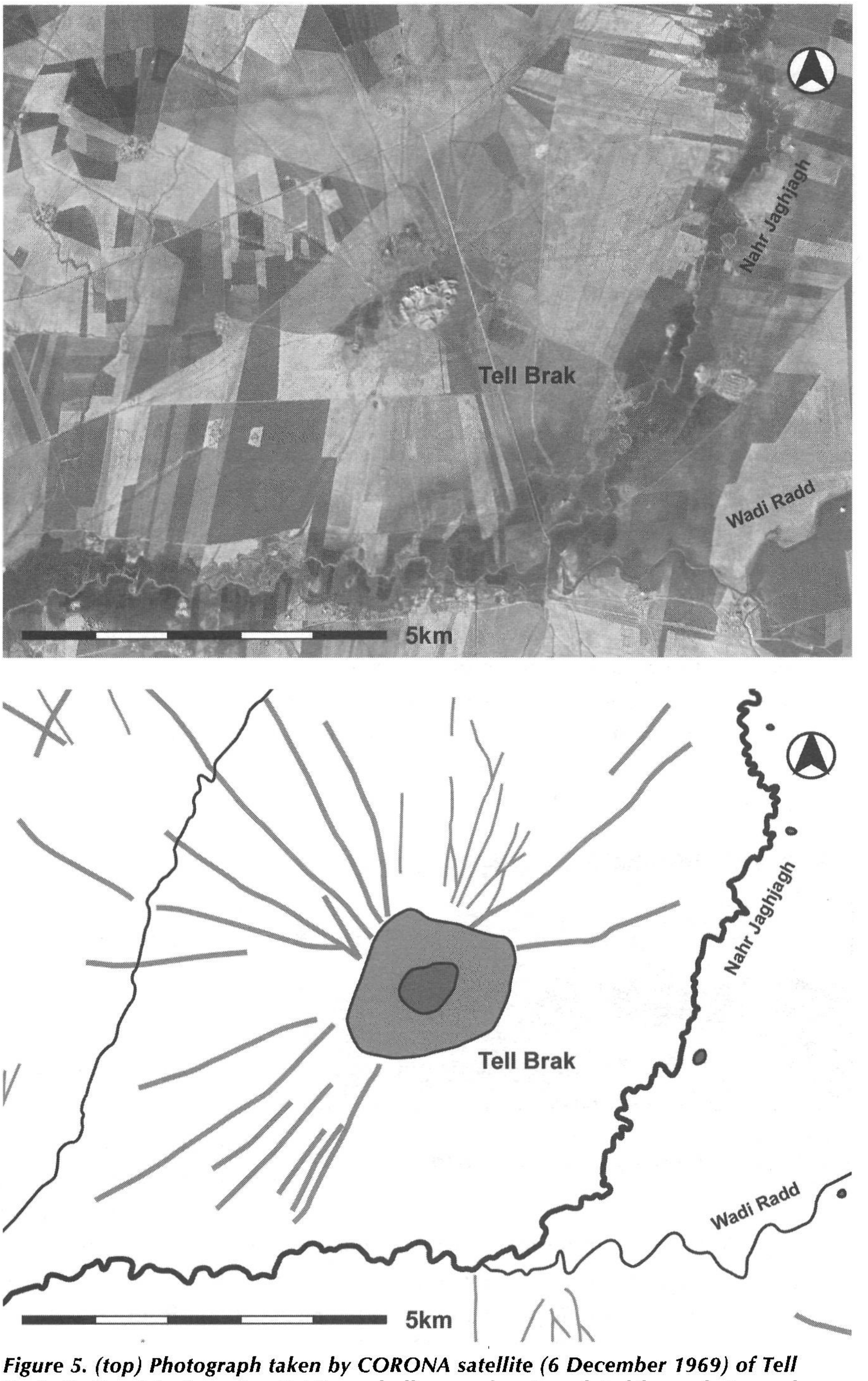

Figure 5. (top) Photograph taken by CORONA satellite (6 December 1969) of Tell Brak. (bottom) System of radial linear hollow roads extrapolated from photograph

Excavation by Walton Green suggested that the feature indeed was a causeway, but that during its use it did dam up the water sufficiently so that flow over it was quite vigorous. The alluvium that overlay or was contemporaneous with this causeway was a pale silty deposit that

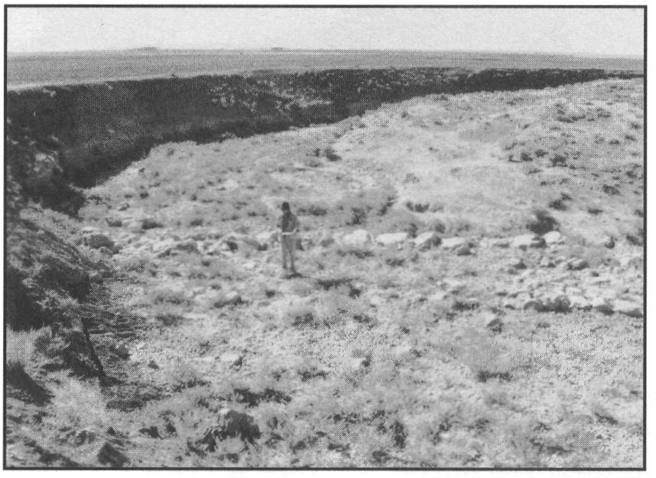

Figure 6. Walton Green recording probable causeway of Bronze Age date where road crossed Jaghjagh River near Tell Brak, Syria

contrasts quite markedly with the upper wadi fill of brown clay. This is evident in figure 6 in the wadi cut in the background that shows a dark (clay) upper fill over the lower pale-colored silty fill. Detailed examination of the alluvial sequence along much of the Jaghjagh and Radd within 5 km of Brak demonstrated that the lower pale fill was dated to the fourth and third millennium BC, but at one point about one and a half miles upstream of the crossing it was Late Bronze Age in date. This date was established by the presence of a large quantity of Late Bronze Age pottery and a single bronze arrowhead (fig. 7) contained within a deposit of the pale silts at the level of the wadi floor. These artifacts, which had presumably been dumped in the early Jaghjagh as domestic waste, have clearly not been moved any distance by the wadi. They therefore provide the latest date for the lower fill.

Overall, we can suggest that during the prehistoric period and through to the mid- to late second millennium BC, flow along the Jaghjagh had been vigorous and along a rather wide and shallow channel. Then after about 1300 or 1000 BC a distinct clay-rich upper fill accumulated, and the river developed a deeper and more meandering course. This later channel continued to conduct flow, but probably rather less vigorously than during the Bronze Age. Although this decline in flow may result from climatic drying during the first millennium BC or later, it may alternatively result from the siphoning off of the flow of the Jaghjagh by the development of large-scale irrigation systems upstream near the modern town of Qamishli. Although still a tentative suggestion, we know from Ottoman administrative records (*defterli*) that in the sixteenth and seventeenth centuries AD the region south of Qamishli was an area of rice cultivation. Furthermore, from the CORONA images it seems that a complex sequence of canals radiated out from the well-watered area around the twin towns of Nisibis (in modern Turkey) and Qamishli (in Syria). Such canals cannot yet be dated, but from the Ottoman records they can be seen to be at least 400 years old. To judge by their appearance on the images, however, these features were in use over several phases, and it will be one of our tasks in the future to try to map from the satellite images these possible irrigation systems.

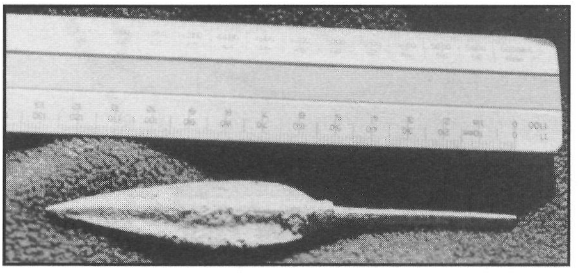

Figure 7. Late Bronze Age arrowhead recovered in situ in lower grayish silts of Jaghjagh River, northeast of Tell Brak, Syria