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The Functional Riddle of 'Glossy' Canaanean Blades and the Near Eastern Threshing Sledge

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Abstract

This paper examines aspects of the agricultural activities and network supported by 'Canaanean' blade segments from Ninevite V sites located principally in Syria and Iraq. Technological and functional analyses of an extensive sample of these tools, alongside experimental and ethnoarchaeological reference data, points to their use as instruments for working cereals, but not a harvesting tool (sickle) as is usually assumed. Our analyses indicate that these blades were standardised inserts used in a special raft-like threshing sledge as described in contemporary cuneiform texts. The functional study was enlarged to include an extensive experimental program that studied harvesting and other manual tools. In particular, we analysed all effects of the functioning of reconstructed threshing rafts, armed with reproductions of Canaanean blade segments. Microscopic silica phytolith 'sheets', extracted from soil samples taken from structures in various sites, indicated that straw chopped with the instrument was used in large quantities as mudbrick temper, fuel and animal fodder. Experimental studies carried out on blades to examine indicators of the knapping method revealed traces of a special manufacturing technique—pressure debitage with a lever and a copper-tipped point, which was identified on standardised Canaanean blades in the northern Mesopotamian sites studied. Our findings suggest that these Canaanean blade segments were produced in northern Mesopotamian workshops and then distributed over the region to equip threshing sledges. This lends support to hypotheses that local centres controlled extensive networks of village sites in the Ninevite V period, and were devoted to the large-scale production, storage and redistribution of agricultural products, possibly in exchange for items such as the specially produced threshing sledge blades.

Introduction and Objectives

Following the apparent collapse of the Uruk culture in the fourth millennium BC, a new type of village life emerged at Amuq in southern Anatolia in present-day Turkey and northwest Iraq during the third millennium BC, in the

Ninevite V period (named after the northern Iraqi site Nineveh). These villages were for the most part constructed on virgin soil. An exception is Tell Leilan in the Khabur valley, which has Uruk levels underlying the Ninevite V. Various suggestions have been made concerning the origin of the settlers in the Uruk levels,

the nature of the Uruk expansion (Butterlin 1998), as well as the identity of the 'founders' of the Ninevite V village sites. However, because scholars have used very different sampling strategies, by surveying or excavating the sites, and in studying the material culture, it is difficult at present to compare them on a pan-regional or even an interregional scale (Butterlin 1998; 2003).

The Middle Khabur valley was a bounded and uniform ecological zone during the third millennium BC, with a large concentration of these small, closely spaced village sites that appear fairly similar in size, in diversity of cultural remains, in ceramic types, tool assemblages and diminutive architecture, and in faunal and botanical remains (i.e. Schwartz 1998; Chabot 2002). Storage structures and macrobotanical (i.e. seed) remains found in many of the sites indicate they served principally for grain storage and treatment, while calculi, numeric tablets and seals in some of the sites suggest that this activity was under exterior administrative control (Fortin 1997; McCorriston 1998). Did these sites produce and control agricultural products as staple finance, exporting primary agricultural products throughout the region, as suggested for Jordanian sites (Philip 2001)? Were the sites dedicated to storage of grain and fodder for pastoral nomads (Hole 1991)? Or did they practice only a short-term or intermediate storage? Fortin (1998: 237) points out that because granaries at Tells 'Atij and Gudedda in the Khabur Valley are above-ground and not well-sealed, they would have been emptied just months after they had been filled.

Might the villages, given the nature of their architecture, even represent non-domestic habitations, serving as a network of relay-sites for an agricultural production ultimately controlled by city-states (such as Mari, Tell Brak, and Tell Leilan), as described in Mari texts (Fortin 1998: 238)? Could such city-states have controlled other villages, which in turn supplied sites in the region with products such

as specialised chipped stone tools? One part of the chipped stone material found in most Early Bronze Age, Ninevite V sites is an 'ad hoc' flint flake industry, made locally, because all stages of manufacture are found at the site and the raw material is found nearby (e.g. Chabot 2002; Van Gijn 2003). The other, an industry of Canaanean blades, which represent a technical apogee of sorts by their almost 'industrial' standardisation, are not locally made. In the case of the Ninevite V sites we have studied, these special blades are imported from other 'workshop' sites still unlocated. Their nature and the implications for their production and use forms the principal focus of this article, exploring aspects of the socioeconomic basis of the northern Mesopotamian sites.

Canaanean blades were first defined by Neuville (1930a: 205-206), by their trapezoidal section, at the Et-Taouamin cave in Palestine. Amongst many other subsequent studies on these blades, we note only J. Cauvin's work (1962) at Tell Byblos in Lebanon, and Crowfoot-Payne's (1960) at Amuq in present-day northeast Syria. Although this type of blade already existed during the preceding Uruk period, it was prevalent mainly in the southern Levant, and known in the northern Levant in just a few sites such as Jebel Aruda and Tell Leilan. During the third millennium BC, Canaanean blades, in the form of truncated segments, were systematically in use in numerous sites in both the northern and southern Levant. The amplitude of the phenomenon and its geographic coverage increased in the Ninevite V period. As Rosen (1997) has pointed out, the appearance of metallurgy, far from instigating the demise of the chipped stone industry in the Middle East, coincided with the appearance of new manufacturing techniques of flint tools in the Uruk, of which the Canaanean blade technology is a prime example. These specially truncated blades occurred in abundance from Syria to Iraq and Palestine and even Egypt (e.g. Anderson and Inizan 1994; Butterlin 2003;

Rosen 1997) during the Uruk and the Ninevite V periods (Figure 1). Recent excavations in the northern Levant and particularly in the Khabur valley have significantly increased the database of blades from the latter period. The blades rapidly decrease after the Early Bronze Age, and disappear entirely shortly thereafter.

Intrigued by the standardisation and wide regional distribution of the Canaanean blades in the protohistoric period, we sought to ascertain whether they were produced using specific knapping techniques that differed from those used for other blade industries. Another objective was to consider whether these blades were produced in order to serve a specific function at the Ninevite V sites, assumed to be agricul-

turally based. Finally we wished to see whether determining their mode of manufacture and use could shed light on technology, economy and social organisation in this region during the third millennium BC.

The Archaeological Sample Studied

The originality of this study lies in the methods used to study the blades individually, both for marks of knapping technique and for analysing microscopic use-traces, and in the extensive experimental and ethnographic databases on which our interpretations are based. In the course of this research, our observations have led us constantly to update the database, using replicas of Canaanean blades in harvesting



Figure 1. Purposively fragmented Canaanean blades from four tell sites, in the Khabur Valley (a, b, c) and from Eski Mossul (d), with gloss and microscopic wear traces showing the characteristics of use as threshing sledge inserts. Some show remains of bitumen used to attach them to the instrument (a, b, c). (Photos: P.C. Anderson, A. van Gijn, J.D. Strich, B. Bireaud.)
a. Kashkashok (Syria); b. Leilan (Syria); c. 'Atij (Syria); d. Kutan (Iraq).

and threshing experiments, aided by relevant information in cuneiform texts (Anderson and Inizan 1994). In addition, phytolith analysis (Anderson 2003) has been carried out on structural remains in a few of the sites, in order to find remains of plants that may have been processed using an instrument armed with Canaanian blades.

The sample of Canaanite blades we identified and studied, selected from blades with and without gloss from sites in northern Mesopotamia, includes approximately 800 Ninevite V implements from sites located in present-day northern Syria and Iraq and southern Turkey (Figure 2): 249 tools from Tell ‘Atij and 53 from Tell Gudea (Anderson and Chabot

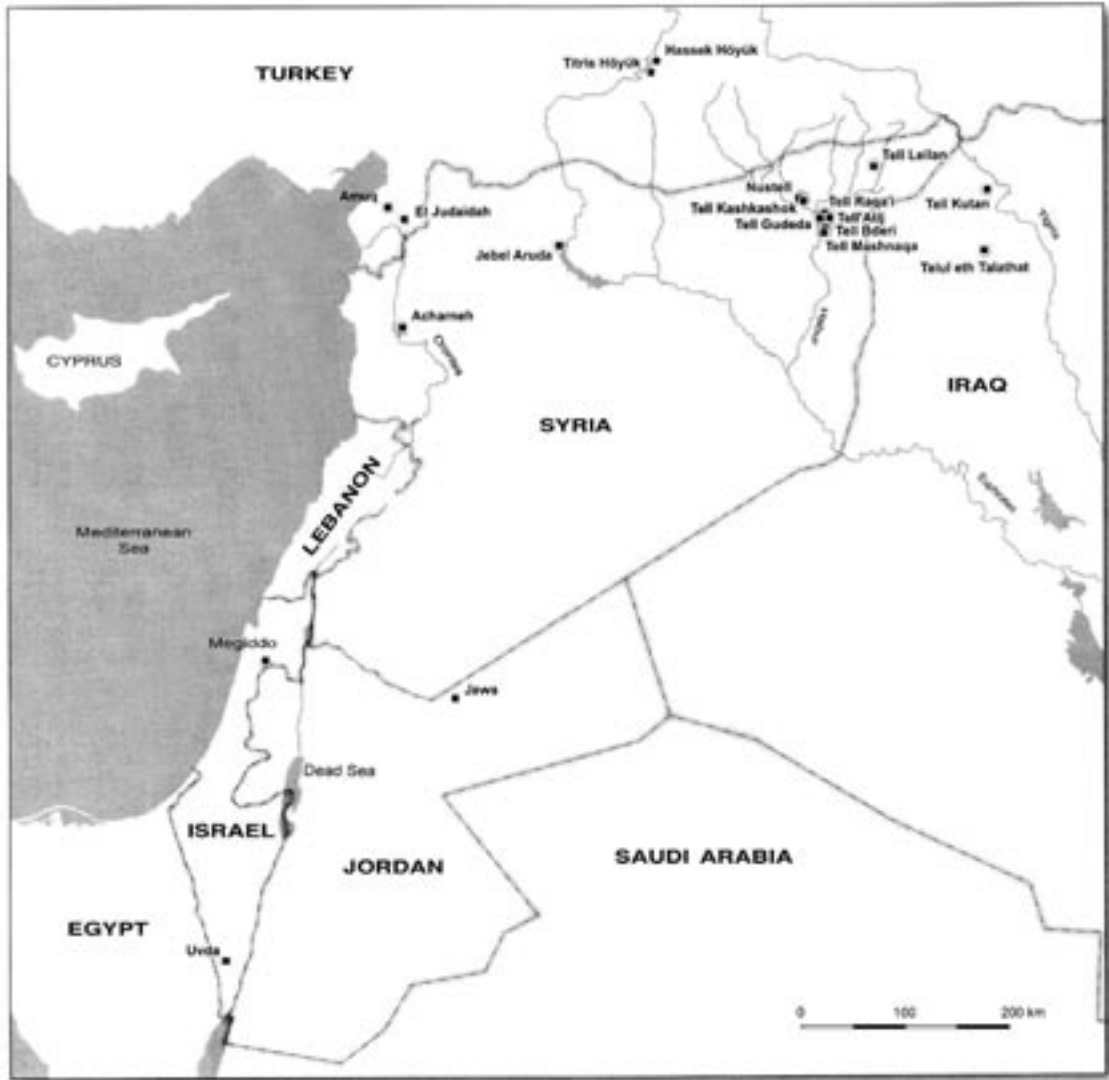


Figure 2. Location of sites mentioned in the text. Squares: sites from which the authors studied material. Stars: other sites.

2001; Chabot 2002); 284 from Raqai (Chabot n.d.); 13 from Tell Leilan III, operation 1 (Van Gijn 2003); 59 from Nusstell (Chabot n.d.), 10 from Telul eth Talathat V; 26 from Tell Kashkashok (Anderson 1994a; Anderson and Chabot 2001); 17 from Tell Bderi (sample studied by Chabot 1998); and 12 blades from settlements on the north and south sides of the Jebel 'Abd al-'Aziz in the Western Khabur basin (Anderson 2003; Hole and Kouchoukos 1995). Forty-five blades from Judaidah-Amuq levels F and G (Anderson 1994a; Crowfoot Payne 1960) in southern Anatolia were studied, as well as 20 from Kutani, in the Eski Mosul area of northwest Iraq (Anderson 1994a; Anderson and Inizan 1994; Anderson 2000). A new study of several blades from Tell Acharnah in the Orontes Valley shows the presence of Canaanean blades in an 'intermediate' region, thus far little explored.

Canaanean blades from rare Uruk settlements in the north were also studied: 25 Canaanean blades from the Uruk site of Jebel Aruda in Syria (Hanbury-Tenison 1983; Van Driel and Van Driel-Murray 1983); and 18 tools from the Early and Late Uruk levels of Tell Leilan, operation 1 (Van Gijn 2003). Finally, 20 glossed blades, of which 8 were Canaanean, from Leilan period II, Lower Town, are currently being studied (Van Gijn).

The scope of our research to date, using an array of methods to identify Canaanean-blade knapping techniques and microscopic traces of use in the north, rather than on a pan-regional basis, unfortunately is inadequate to allow detailed comparison with the rich southern Levantine data published on Canaanean blades, not least because the latter have not been studied with the same methodology or the reference data used in the present research. Study of southern Levantine material using this methodology is still in its infancy (e.g. Chabot and Eid 2003), despite the large volume of data examined in the past (Rosen 1997). Material we have studied

from the south, such as a sample of 82 tools from the extensive tomb deposits at Megiddo in Palestine (Anderson and Inizan 1994), principally date from the Middle Bronze Age, with a few from the Late Bronze Age and Iron Age (Guy 1938). Such blades are clearly intrusive, as this type had gone out of use by the beginning of the second millennium BC. Essentially we studied the Megiddo blades for use-wear traces, not technological markers of the indirect percussion versus pressure with a lever and point, which at the time had not had not yet been published (Pélegrin 2002). We have examined glossed tools of a different nature from Chalcolithic-Early Bronze Age sites in 'outlying' areas, one blade and 30 macro-lunates from Uvda Valley in the Negev (Avner *et al.* 2003) and three blades from Jawa in Palestine (Betts 1991; Chabot, analysis in progress).

General Observations on Canaanean Blades

In the Ninevite V sites we have studied, Canaanean blades tend to be long and regular in size and shape, particularly in width and thickness, and have a trapezoidal (or, more rarely, a triangular) section, a straight-edged profile, and parallel edges and dorsal ridges (arises) (Figure 1). The flint used to produce Canaanean blades has not been found locally in the area of the sites (Chabot 2002). Furthermore, production debitage is completely absent from the sites examined in our sample, and the technology underlying blade production, as well as truncation, with or without retouch, of the blades into blanks, appears to use methods otherwise unattested in these sites. Thus these blades and blanks must have been produced elsewhere, because neither cores nor waste material from the production or truncation of the blades, are found in the sites where the tools were used.

After production, many of the blades were intentionally fragmented in order to create a 90° angle, which is not a simple feat techno-

logically. Our observations allow us to estimate that the blades were broken into two or three (Amuq, Kashkashok, Megiddo) or even four to five segments (Kutan, 'Atij, Gudedu, Raqa'i, Nusstell), with the medial part used to produce two, three or, rarely, four fragments per blade, which are straight and without curvature. Most undoubtedly travelled to the sites in this form, because the technique of fragmentation requires a great deal of technical skill, and is not used for other stone tools on the sites. It is also important to note that contiguous segments from the same blades are absent from any given site. Moreover, distal fragments are almost always missing from these sites. It is uncertain whether blade truncation into elements occurred at workshop sites near the flint resources, or in locations other than the locus of final consumption, although caches of complete blades have been found at several sites. Seven complete blades, for example, were found in a jar from an Uruk level at Jebel Aruda (Hanbury-Tenison 1983).

The blade fragments can be divided into three kinds of blanks: blades with two potential cutting edges, blades with natural backs and blades with abrupt backing retouch. Since all three have similar widths, it would appear that the objective of the backing retouch was to standardise the width where needed. This width was apparently related to hafting or insertion standardisation, because nearly all blade segments had more or less abundant traces of bitumen residue on the backed or the non-active cutting edge, used as adhesive to fix the blades into an instrument. The bitumen from Khabur sites is of non-local origin (Fortin 1998). Macroscopic and microscopic observation of the active, glossed edges of the archaeological tools show they were used without retouch. In fact, most archaeological blade fragments were never intentionally retouched on their cutting edge, with light edge scarring occurring only in the course of use. Only a

few of the most worn tools were intentionally retouched on the glossed (active) edge, but this consisted of re-sharpening in the course of use. This observation lends further support to the suggestion (above) that these tools were imported and used in these sites in the form of intentionally fragmented blanks. Other raw material such as bitumen may also have been imported for making instruments on site, or blanks and bitumen may have arrived already inserted into an instrument.

Functional Hypotheses on Canaanite Blades

Canaanite blade segments traditionally are assumed to have functioned in an agricultural activity and are typically referred to as 'sickles' in the literature (i.e. Anderson 1980; Rosen 1996; 1997) because most display a faint to marked gloss on their lateral edges, visible to the naked eye (Figure 1a). At the Ninevite V sites, these blade segments frequently show traces of hafting in the form of remnants of the bitumen used to glue them into an instrument.

Paradigms established early in analysis of chipped stone implements consider tools with gloss found in settlements as indicative of use in harvesting cereals. Woolley (1956: 14), however, suggested another function, engaging ethnographic parallels from the region: he thought that a concentration of Canaanite blades from Ur 'was not used in the harvest-field, but on the threshing-floor and that they were set in the wooden *tribulum* (the flat wooden sledge with flints set in its under-surface) which is certainly a prehistoric invention and is still used in Mesopotamia and Syria'.

That the instrument filled with Canaanite blades was related to some agricultural process is not an unreasonable working hypothesis, given the presence of numerous silos and granaries with carbonised seed remains in Ninevite V sites (McCorriston 1998; Fortin 1997; Schwartz 1987; Weiss *et al.* 1990). The numerous experimental tool-use studies (followed by

examination at low and high magnifications of the experimentally used tools) over the course of the past 25 years have confirmed that gloss (or sickle sheen, as it is sometimes called), which appears the same to the naked eye, can in fact be produced by a variety of uses, particularly cutting of silica-rich plants (cereals and reeds) and treatment of these (chopping, threshing), but also by the working of wood, soft stone, the scraping of clay and certain skin-working procedures (Anderson 1994b; Juel Jensen 1994; Van Gijn 1994; 1999). However, once the experimental tools are examined using reflected light microscopes at magnifications of 100-200x, the surface of the gloss can be 'read', and microscopic attributes of its appearance on the flint surface (e.g. polish, morphology of abrasion, striae, pits, etc.) allow for distinction among those different functions producing macroscopic gloss (Anderson 1994b; Juel Jensen 1994; Van Gijn 1994; 1999). Experiments precisely geared to match archaeological contexts have in fact produced microscopic wear patterns that are identical to traces found on archaeological tools. One goal of our study was to ascertain the attributes of the microscopic use-traces on Canaanite blades, and to reenact through experimentation with instruments and materials ancient processes directly attested both in settlements and in cuneiform texts from this period.

In fact, recalling Woolley's predictions, on a microscopic level (100-200x) the features of gloss on Canaanite blades did not resemble flints having been used in experimental sickles to harvest plants, but rather showed a remarkable similarity to tools known to us from our analyses of approximately one hundred ethnoarchaeological flint tools from different regions: threshing sledge or *tribulum* flints. Indeed, numerous studies describe microwear traces within the gloss found on ethnographically documented threshing sledge inserts from various countries that until recently have

used this tool. Bordaz (1965) and Whallon (1978), examining threshing sledge flints from Turkey, describe the characteristic heavy edge rounding visible on the most highly glossed blades. Whallon illustrates striations on a very worn blade, seen under low magnification (30x) of the stereoscope. Following this, studies examining attributes using high magnification were carried out along with morphometric analysis of sledge flints from Turkey (Ataman 1999), Cyprus (Kardulias and Yerkes 1996; Yerkes and Kardulias 1994) and Bulgaria (Gurova 2000). As Whallon (1978) and Ataman (1999) observed, although macroscopic traces on very worn ethnographic sledge flints can be characteristic, the traces visible under the binocular microscope at magnifications of 10-40x alone are not adequate for distinguishing attributes diagnostic of use in a threshing sledge. Ataman (1999) also showed that the traces need to be viewed at higher magnifications in order to be differentiated from other uses such as harvesting, an observation which our experiments confirmed, as well as our observations of microscopic traces using high and low magnifications to study threshing sledge flints from Turkey, Crete, Spain, Cyprus and Greece (Anderson and Inizan 1994; Anderson 1994a; 2003). Furthermore, it was found that use of high magnification allowed detection of characteristic use-traces on blades without any macroscopically visible gloss traces formed. We initially used this ethnographic database of traces as a means of comparison with traces seen on glossed blades from Late Neolithic, Chalcolithic and Bronze Age sites in the Middle East (Anderson 1994a; 1994b; 2003). Similarly, Skakun (1994; 1999) used high-magnification microscopy in her recent analyses of microscopic use-traces on ethnographic sledge flints, and of comparable traces on blades from the Chalcolithic and the Bronze Age in Bulgaria and the Ukraine.

Methods of Manufacture of Canaanean Blades: Results of Technological Analysis

Our definition of Canaanean blades (i.e. Anderson and Inizan 1994) is based upon technological (knapping) attributes. Detailed technological study by Chabot and Pélegrin has shown that there are actually two types of large blades, traditionally termed Canaanean, but with each kind produced using a different knapping technique. Pélegrin (2002) has shown that two techniques are the only means of obtaining large, regularly shaped blades of Canaanean type: either use of indirect percussion or pressure debitage with a lever, the latter producing Canaanean blades that are distinct-

tive in relation to other blade technologies (Anderson and Chabot 2001; Pélegrin 2002). These Canaanean blades, pressure flaked using a lever and a point of copper or antler, are remarkable for their standardisation and are here referred to as type A (Figure 3a). They are more regular than their counterparts made using indirect percussion (Chabot 1998; 1999; 2002), which are here referred to as 'type B' (Figure 3b). These types coexist in Ninevite V sites, and experiments in core reduction sequences and subsequent study of fine morphological attributes on blades have shown that type B was made in the initial stage of the production process that culminated in type A blades, from the same core (Pélegrin 2002; and in Anderson 2000). Identifying these

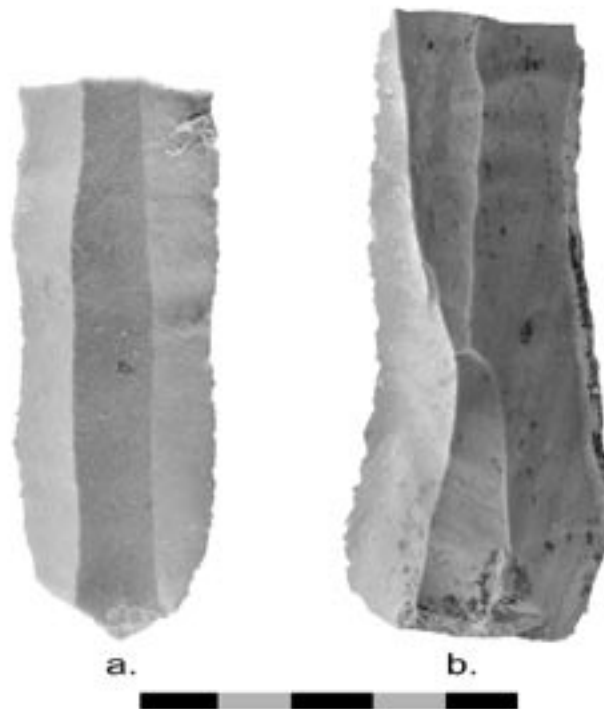


Figure 3. Two large, regularly shaped Canaanean blade segments from Tell 'Atij.

- a. A Canaanean blade with fine attributes showing it was knapped using pressure debitage with a lever and a copper-tipped point (referred to here as 'type A').
- b. A blade made by indirect percussion ('type B'), which could have been produced in the early stages of knapping a Canaanean-type core that produced type A Canaanean blades. (Photos: P. Laliberté.)

Canaanian type A blades in the archaeological record is of interest because they are characteristic enough to serve as a marker of this very specialised knapping process and can help trace the diffusion of these blades.

The distinguishing characteristics of the application of the technique, found after numerous experimental trials (Pélegrin 2002), can be observed on the proximal (butt) end of the blades. The study of archaeological material from the Near East and eastern Europe indicates that two kinds of point can be used to apply pressure: a copper point or an antler point (Pélegrin 2002). Study of blades from northern Mesopotamia has shown that the use of antler points is rare: for example, at Tell 'Atij, of the 36 proximal (butt) ends of blades well-preserved enough for analysis, only one was made with an antler point, whereas the others were produced using a copper-tipped tool. Even though most Canaanian blade segments are medial, which do not carry diagnostic marks of the knapping technique, clearly most workshops furnishing northern Mesopotamian sites with blades employed copper-tipped points for pressure debitage with a lever. In eastern Europe, antler points were by far the most commonly used in the workshops. It is important to note that one kind of point does not represent a more advanced stage, technologically speaking, than the other; experiments showed that each method produces blades of excellent quality.

Pressure knapping with a lever and a point of copper, because of the relative hardness of copper, produces a circular crack on the butt (platform). This technique produces a clean detachment, whereas its use with an antler point works by tearing away, thus producing a lip, without a crack, on the butt. The butt is usually of smaller size than one made for knapping with a copper point (see Pélegrin 2002 for minimum dimensions). Pressure with a lever produces wrinkles on the bulb of percussion. This technique, using either kind of

point, produces what we refer to as type A Canaanian blades. This method is particularly remarkable in that it involves immobilisation of the core and the use of a long lever. The set-up and preparation of the cores may demand skill and experience, but once the installation is ready, the actual knapping of blades does not require use of great force, as the pressure is multiplied by the lever, equivalent to a shock of 300 kilos, on the core platform, which becomes the butt or the striking platform of the blade (Pélegrin 2002).

The use of this very specific technique might point to the blade production of particular workshops or networks of workshops. Indeed, although three Canaanian blade workshops have been identified and studied, two from the Uruk period at Hassek Hoyuk (Behm-Blanke 1992; Otte *et al.* 1990) and Hacinebi (Edens 1999) and one from third millennium BC Titris Hoyuk (Hartenberger *et al.* 1999), which indicate the likely origins of this special technique as it was applied in the north. Given the raw material on which pressure-knapped blades are made using a lever (for example, a grayish-pink fine-grained flint), it would seem that the workshops furnishing the Ninevite V sites may be sought in the Bingol area of Turkey, near Hassek Höyük. No raw material sources are known from northern Syria or northern Iraq that would produce the large flint nodules needed to produce Canaanian blades. For example, the Canaanian blade production sequences from the third millennium BC workshop in Har Haruvim in Palestine (Shimelmitz *et al.* 2000) appear to be of a different nature than those in northern sites, in that the *chaîne opératoire* is one of indirect percussion debitage. In this study, therefore, in addition to morphometric, typological and technological observations, we applied Pélegrin's criteria for separating type A and type B blades. Both types of blade were subjected to a functional analysis.

Wear Traces on Canaanian Blades

Methodology

Between 1960 and 1990 it was demonstrated that a combination of experimentation and the microscopic study of use-wear traces can produce interpretations of prehistoric tool function (Juel Jensen 1988; Keeley 1980; Semenov 1964). This stands in contrast to more speculative criteria that served in the past to ascribe functional names in typological studies (i.e. 'scraper', 'adze', 'sickle blade'), based upon a simple similarity in form to ethnographic tools, or the presence of gloss (see above). Not surprisingly, recent experiments, combined with microscopic analysis of tools, have shown that hypotheses of function made on the basis of morphology are often incorrect (e.g. Van Gijn 1988; 1999; Anderson 1994b). On the other hand, experimentation and the deduction of function may also be aided by using an ethnoarchaeological approach, both to study microscopic use-wear traces on ethnographic tools that may have had a use similar to ancient ones, and to observe procedure and techniques in activities, the material remains of which indicate that they were carried out in settlement sites.

The entire surface of the Canaanian blades, as well as the area with gloss, was studied at various levels of magnification. On a macroscopic level, the position of the gloss and other traces such as edge rounding and edge chipping, as well as adhesive (bitumen) traces, helped to deduce the mode of insertion of each object in an instrument. It is only at high magnification (100-300×) that one can detect attributes indicating the tool's mode of use, that is, the motion, direction and the particular contact material held stationary or in motion. This requires use of a reflected-light (metallographic) microscope, the method primarily used in this study, sometimes supplemented by a stereoscope (5-50× magnification), and only rarely by the SEM, as it was

found to highlight fewer diagnostic attributes of sickles and sledge blades than the optical (metallographic) microscope (Anderson 1994b).

The Microscope Study of Gloss on Canaanian Blades

The strongly pronounced microscopic traces of wear observed on Canaanian blades (Figure 4a, 4b; Figure 8c, 8d) fall within the range of such traces that result from contact with silica-rich plants: a flattish, white-appearing polish distributed in a wide band due to the extensive coverage of the blade surface by the cereals. Linear use-wear traces show the direction of movement is roughly parallel to the blade edge, and that the blade was used moving in a single direction, as if to cut. Our knowledge of wear traces on tools used in experiments and in ethnographic contexts enabled us to narrow down the potential uses to just three. The first, corresponding with most archaeological assumptions, is that these traces result from harvesting cereals. The second and third hypotheses pertain to processing of cereals after harvest. One is cutting stems by hand on the ground (or on a stone or wooden billet); the other is inserting the blades in a threshing sledge, which was pulled on a threshing floor over thick layers of sheaves of cereals.

The wear traces we have observed on about 800 Canaanian type A and B blades from the Bronze Age do not match traces obtained experimentally from cereal harvesting (Figure 4c), nor do they correspond to traces from cutting cereal stems by hand, well-known and abundantly described from about 50 of our own experiments (200 blades) (Anderson 1994b; 1998; 1999; 2000; Anderson *et al.* 2001; Van Gijn 1988; 1990; 1999) and from another 50 or so blades used and illustrated by other researchers (e.g. Juel Jensen 1994; Skakun 1999). Harvesting invariably produces traces (100-200× magnification) with a smooth texture, fine linear striations (Figure 4c), no

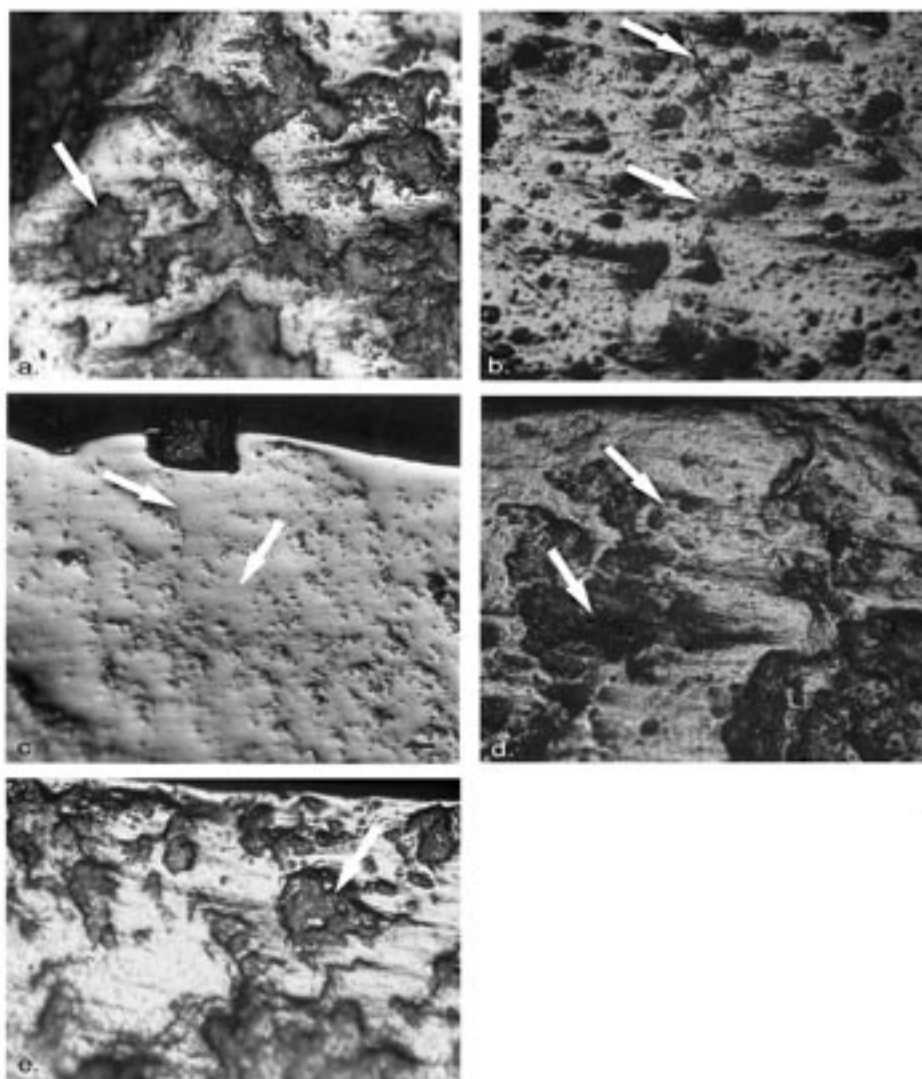


Figure 4. Variability in glossy surfaces on flint tools, as seen by high magnification reflected light microscopy, using a metallographic microscope.

a. Features characteristic of use in a threshing sledge (arrow: irregular depressions formed) on a Canaanian blade from Tell Leilan (original magnification: 100×). (Photo: A. van Gijn.)

b. Gloss on a Canaanian blade from Tell 'Atij, showing irregularly oriented scratches (upper arrow) and numerous comet-shaped depressions (e.g. lower arrow) (original magnification: 50×). (Photo: J. Chabot.)

c. Features on an experimental blade used in a sickle to harvest barley for 4 hours (original magnification: 100×). Arrow: fine striations barely visible in the smooth, bright texture, although the photo was taken at the same magnification as for tools with threshing sledge traces in a, d, and e. (Photo: A. van Gijn.)

d. Features seen on an ethnographic threshing sledge insert from northern Spain (original magnification: 100×). Arrows: large, comet-shaped depressions and pitting formed during use. (Photo: A. van Gijn.)

e. Features on an ethnographic threshing sledge blade from Cyprus. Arrow: comet-shaped depressions (original magnification: 100×). (Photo: P. C. Anderson.)

craters or other topographical features, and a rather flat surface (Table 1). Rather, the traces we observed on the Canaanean blades lacked the above features, and on the contrary showed wide linear traces, a duller and more abraded surface, and randomly oriented scratches (see arrows, Figures 4a, 4b; 8c, 8d; Table 1). These linear traces represent the same microscopic use features that we and others have observed on threshing sledge inserts removed from ethnographic sledges (Figure 4d, 4e).

Traces on threshing sledge blades are distinctive from other kinds of use in that they show the result of a continuous motion. They are inserted in and weighted down by the sledge frame (to which stones or a person often serve as additional ballast), which was dragged along using traction through thick layers of plant material placed on a prepared surface, the threshing floor (Figure 5). This peculiar contact mode with plant material takes place in the presence of abrasive elements from the soil adhering to the plants.

It is the combination of the above-mentioned factors which accounts for the simultaneous presence of a number of very distinctive features of the glossed micro-surface: smooth, bright areas interrupted by zones with rough, abraded and pitted topography; characteristic linear features such as long troughs drawn from large irregular pits in the surface (like very large comet features) (see arrows, Figure 4a, b, d, e). These features are all found on the Canaanean blades, as well as on the ethnographic threshing sledge inserts, stretching over much greater areas on the surface than occurs for other uses, undoubtedly due to the mode of traction. Finally, randomly oriented fine scratches and longitudinal features are found on both ethnographic and experimentally used threshing sledge flints and the Canaanean blades.

We explain these features by the fact there is a continuous motion of the blade when used in a threshing sledge, as it penetrates into the layer of plant material on the threshing floor,

Table 1. Comparison of microwear traces on the used edge of sickles vs threshing sledge inserts, when viewed at 100-200× using a reflected-light microscope.

	Sickle inserts	Threshing sledge inserts
Microwear	Appears smooth and brilliant, flowing where most developed. Most intense on very cutting edge, gradually fading out on flat surfaces back from the edge, and stopping where a haft or adhesive covered the surface. Small, circular natural depressions in the flint, not affected by polish development, appear dark (Figure 4c).	Of irregular texture, with rough, mat and bright areas interspersed (Figure 4a, c, e; 8a-d; 10c). Flatter topography for the bright areas. Usually developed fairly equally on the very edge and on flat surfaces back from the edge, stopping where surface is covered by sledge frame or adhesive (Figure 1b). Large, irregular depressions, which are probably due to plucking out of the raw material of the tool as a result of use (Arrows, Figures 4a, b, d, e; 8a, c, d).
Polish		
Striations	Very thin striations, often with a dotted bottom, of fairly regular width and orientation, parallel to one another (arrows, Figure 4c).	Wide, irregular and superficial grooves (Figures 4d, 8c, 10 c, arrow). Large, irregular comet-shaped depressions (Arrows, Figures 4b, d, e; 8a, c; 10a, c). Striations are irregular in width and not all parallel to one another. Complex patterns.
Abrasion	None	Heavy abrasion, long, linear traces, irregularly-oriented scratches (Figure 4b, upper arrow).

bringing its entire working surface into contact with the plant materials (Figure 5). These materials strike the blades at various angles as the instrument is pulled forward, with the stems

flowing often parallel to the blades, bringing the sledge blades into constant contact with the silica-rich cereal epidermis covering the stem. In fact an essential difference between the



Figure 5. a. Use of a wooden plank-type threshing sledge today in southern Syria, 2001, near the final stages of reducing the straw to fine pieces. The farmer is working on different small threshing floors alternately, installed directly on the dry cut grass (e.g. see right, middle of photo).
b. Experiments in southern France with the reconstructed Mesopotamian raft-like sledge, in the early stages of the work, on a beaten clay threshing floor constructed in a grassy area (see Figure 7). (Photos: P.C. Anderson.)

motion of the threshing sledge and harvesting is that in order to cut the plants in harvesting, the blades contact cereal stems at near right-angles, as the stems are held rigid by the harvester. Two microscopic features characteristic of gloss on threshing sledge flints—the rougher, non-linked polish, and the characteristic very long, drawn wide linear features—are absent from both experimental sickles and from tools used to cut harvested straw by hand, on the ground or any other surface; these observations were made from independently conducted experiments (Anderson *et al.* 1998; Clemente and Gibaja 1998; Skakun, pers. comm. 1996). Sickles exhibit areas of smooth, bright polish, most pronounced at the very edge, fading away gradually further from the edge, and fine, fairly short striae (see arrows, Figure 4c). Microwear traces produced on blades used to cut straw on the ground by hand, although also showing some abrasion features and a certain roughness due to soil contact, lack critical attributes of wear traces that are found on the archaeological blades and on ethnographic threshing sledge inserts. The difference is notable in the distribution and frequency of linear features, such as the very long, continuous grooves and striae, which, for threshing sledge blades as well as Canaanian blades, occur deep into the tool edge surface, and are not restricted to the very edge, as for the other uses. For harvesting and cutting of straw, the distribution of the traces reflects the fact that the very edge works under far greater pressure than the sides of the blade; the pressure on sledge blades surface appears similar at the very edge and on the surfaces adjacent to it.

Therefore, the third option, use in a threshing sledge, was the only functional option that corresponded to the peculiar traces seen on hundreds of Canaanian blades. This deduction, however, was based upon ethnographic sledge inserts that were generally smaller than and very different in morphology from the Canaanian blades (Figure 6b). Moreover, the ethnographic sledges used slots in planks to

insert the blades (Figure 6a, b), a system that would have been unstable for holding the wide Canaanian blades in place during use. References to the threshing sledge in cuneiform clay tablets allowed us to overcome this concern, because they described a raft-like instrument for the time, with ‘teeth’ inserted between lashed wooden staves and fixed with bitumen. This instrument was distinct from another tool, the harrow, also made with a raft-like frame but with wooden points inserted, not stone. To see whether the archaeological blades could have been used to arm a harrow, we studied blades from an ethnographic threshing sledge used to work clay, which revealed traces that differed recognisably from those on inserts used to thresh cereals and pulses (Anderson and Inizan 1994). We then needed to test the threshing sledge in experiments. Several sledges were built (as described below), using replicas of Canaanian blades. They were used to treat different kinds of wheat and barley on threshing floors with surfaces of clay, of paving stones, and of short grass, in order to test efficiency and variability under different conditions.

Reconstruction of a Bronze Age Threshing Sledge

Ethnographic Evidence Concerning Threshing Sledge Planks

Ethnographically documented threshing sledges were traditionally used all over the Mediterranean, Balkan and Black Sea areas (e.g. Luquet and Rivet 1933), and have a structure made of joined planks of varying width. The inserts, either blades of flint or obsidian or, more recently, metal blades, are set in grooves cut in the underside of the plank. Alternatively, regions without flint resources today sometimes use stone materials such as pieces of basalt (or pieces of various types of stone), which are inserted in cup-like hollows made in the plank (Anderson 2003; Skakun 2003). All such forms of inserts are

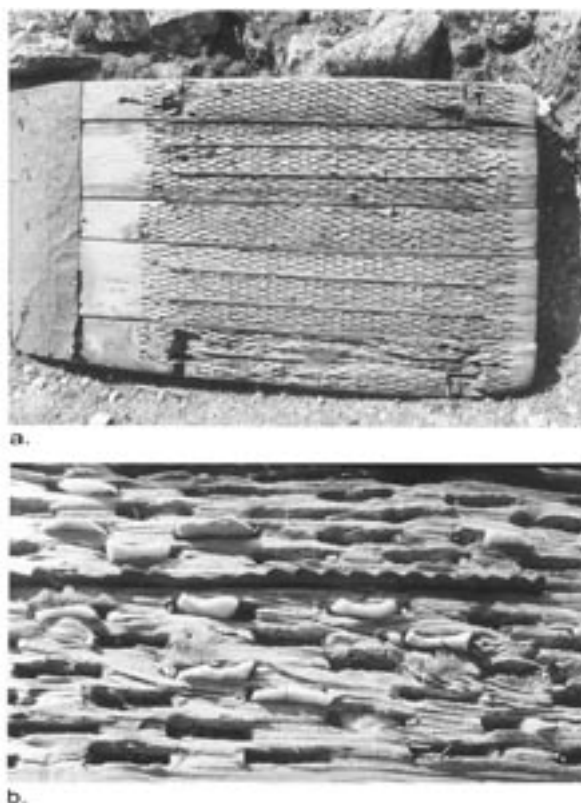


Figure 6. The underside of the working surface of a threshing sledge from northern Spain.

a. General view

b. Detail of the insertion pattern in slots of the flint pieces and of a metal saw-blade, set higher than the blades. (Photos: P. van der Velde, Leiden University.)

hammered into specially cut grooves or hollows on the underside of the sledge, without use of adhesive material, and the hammering creates edge damage on the blades' active edges (Ataman 1999; Whallon 1978; Yerkes and Kardulias 1994: 286).

The number of inserts and their size can vary greatly from sledge to sledge (Figure 6; drawings and measurements in Ataman 1999: 216-17; Kardulias and Yerkes 1996: 662; Skakun 1999). A certain irregularity in shapes of inserts used in recent times can occur because they are knapped with metal hammers (Ataman 1999: 212-13; Whittaker 2001, 2003;

Yerkes and Kardulias 1994: 285). The system of slots and hollows made in the underside of the sledge facilitates the insertion of various forms of blades, without their irregularity jeopardising the work and stability of the instrument. The inserts are usually arranged in a checkerboard pattern, presumably to avoid splitting of the plank, which might occur if slots and blades were lined up in rows (Handley pers. comm. 1999). The large size of the archaeological blades discussed here, however, and the presence of abundant bitumen (tar) deposits adhering to them, exclude a plank-like construction with insertion in slots.

The Textual Evidence for the Structure of the Sumerian Threshing Sledge

Grégoire (in Anderson 2000; in Anderson and Inizan 1994) has pieced together the construction of the Bronze Age threshing sledge (which we also refer to as a *tribulum*) from brief, contemporary references to the instrument, principally in the ‘Farmer’s Almanac’ (in Anderson and Inizan 1994; Civil 1994; Littauer and Crouwel 1990) and various cuneiform administrative archives (e.g. Gelb 1955). These documents seem to describe a sledge frame made of wooden staves lashed together with leather straps, which appear to go around the blades (Figure 7). The blades were placed in the interstices between the staves and fixed to the structure using bitumen, presumably heated, then poured into the interstices comprising this ‘raft-like’ structure. In this manner a smooth, flat underside of the raft’s working surface was obtained without use

of a plank-type construction. The manufacturing of planks would not have been possible because, according to the texts, the only trees available—poplar and willow, either imported or grown locally—had too small a trunk diameter to make planks. In the cuneiform inventories (e.g. Gelb 1955: 271, 273 tablet 33 [FM 229201 lines 31 and 35]), from 50–80 ‘teeth’ were needed to fill the threshing sledges. It is not entirely clear, however, whether this refers to the total number of blades required to make an entire *tribulum*, or only to replace missing blades in a larger one.

Archaeological and Experimental Study of the Threshing Sledge Structure

These textual references related to the structure of a threshing sledge appear relevant to the Early Bronze Age blades found in the archaeological sites studied, and concur with the frequent presence of thick bitumen (tar)

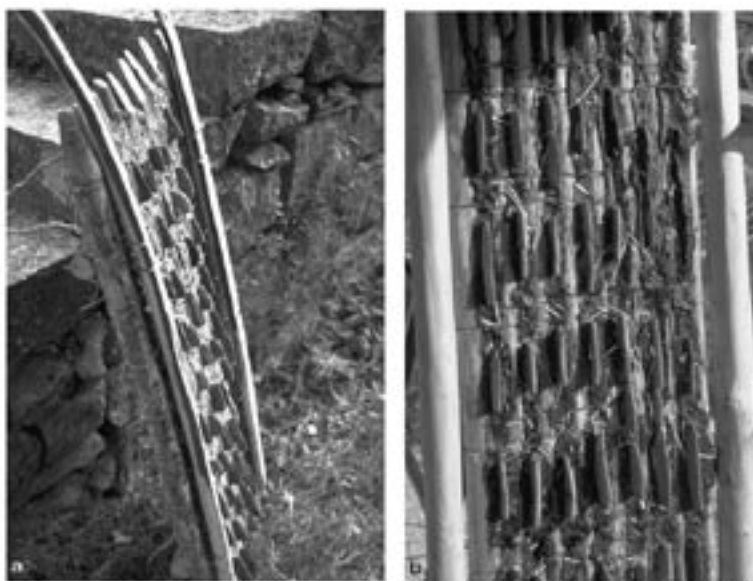


Figure 7. Experimental Sumerian raft-like threshing sledges, reconstructed on basis of data from cuneiform texts: staves lashed with leather straps, bitumen poured between staves in order to fix the blades.

a. The underside of the sledge, showing protrusion of blades according to the distribution of traces on archaeological Canaanite blade segments.

b. Photo with detail of insertion patterns (separately or in contact) of the experimental Canaanite blades. (Photos: P.C. Anderson.)

deposits adhering to the edge of Canaanite blades (Figure 1). In many cases, the bitumen carries the imprint of wood grain running parallel to the blade. A blade from 'Atij shows a thick bitumen deposit with imprints of hulled grain, probably from material on the threshing floor (Anderson and Chabot 2001: fig. 12b). A blade from Kashkashok with bitumen traces provides further hints as to the form of the instrument into which it was inserted (Figure 1a). The bitumen on this object has a concave imprint of the convex wooden surface against which it rested, recalling the staves lashed together to form the structure described in cuneiform texts.

Pélegrin produced the blades for our experiments; in terms of their dimensions and morphology, these blades correspond to those of the ancient Canaanite examples. They were fixed in a raft-like structure comprising 10 wooden staves of 3-5 cm in diameter, made from stakes sold for vineyards. Three sledges were made and two of them were used in the course of six seasons of experiments (1995-2002). We decided to use 50-80 blades, the minimum number deduced from the cuneiform textual descriptions (Gelb 1955), to arm the under surface of the sledges, in order to see whether they could function efficiently, even at minimal size (Figures 5b, 7a, b). Tar was melted and mixed with fine sand, to temper it, as preliminary trials showed tar used without temper would soften in the heat, and did not hold the blades rigidly. The tempered bitumen was spread between the staves as each blade was inserted. The blades were set to protrude according to the location of gloss and bitumen on the Bronze Age blades. It was observed that standardisation of blades allowed for construction of a solid instrument. We were able to appreciate this point fully when we witnessed the effect of inserting blades of different width, curvature and thickness between the staves in the first year of experiments. This produced a less solid

construction, causing the frame to move, and several blades twisted or fell out during use. In subsequent years, when Pélegrin's blades were available, we were able to build a stronger and more stable instrument. It did not need readjustment from one year to the next, owing to an assembly using blades that were flat and of standard width and thickness; these blades never fell out during use (and were indeed very difficult to remove for study, even when the tar was heated).

We have hafted blades using bitumen in sickle handles of various different forms, then removed blades after use with the adhesive and photographed them. The same procedure was used when we dehafter blades with their adhesive from the threshing raft. The results show that the appearance of the imprint on the Kutani blade (Figure 1a) is the same as the bitumen cast observed when blades were removed from the experimental sledges, and unlike the imprint resulting from insertion in a groove of a sickle haft or a groove in a plank like the traditional threshing sledge. The bitumen cast may have been preserved on the blade from Kutani because it remained fixed to the sledge until the wooden structure decayed. Unfortunately the bitumen adhesive is rarely preserved in this quantity, presumably because it remained on the sledge frame when blades fell or were removed. The bitumen is very fragile, and is rarely recovered in archaeological excavations. Other blades from Kutani were reported to have had abundant thick bitumen remains (Anderson and Inizan 1994), but unfortunately these had been removed for provenience analysis before we received them for study.

Blade Insertion Patterns and Use-Traces: Experimental Replication

Concerning the longitudinal insertion pattern of the blades, the archaeological material represents two kinds of situation: one where they are not touching one another, the other

where they are fitted against each other, end to end. At Kutun, it was noted that the wear extended around the intentionally fractured and truncated proximal and distal ends of blades, implying that they had been set in the sledge with gaps between them (Anderson and Inizan 1994). A different situation, however, was documented by an example from Tell 'Atij, found on a living floor: two blades, found adhering to one another in the excavation, were stored together although they had fallen apart during post-excavation handling (in Anderson and Chabot 2001: fig. 13). A microwear analysis of the traces shows that both were used in a threshing sledge. The striation and trace pattern, showing the direction in which the blades travelled, was continuous from one blade to the next, which allowed us to once again refit the blades together in their earlier functioning position. The excavator (Lisa Cooper, pers. comm.) later confirmed that our reconstruction corresponded to the way they had been found in the excavation, joined end to end. Both configurations were tried for the experimental sledges (Figure 7a, b), and appeared to function well. Blades were sometimes inserted somewhat obliquely, according to the use-wear trace distribution on the archaeological tools. The three reconstructed sledges measure 120-150 cm in length and 50 cm in width. They have five to seven rows of blades, producing a surface of approximately 100 cm by 20-30 cm for blade insertion, based upon the 'model' of 50-80 blades. Staves of 3-4 cm in diameter appeared to allow for the most efficient construction, given the dimensions of the blades. The sledges produced weigh approximately 25 kg.

After the first year of experiments, 'skis' were added to the sides of the sledge, protruding 15 cm from the front of the frame, which in practice helped the small instrument to glide over the thick plant layer, as well as raising the blades several millimetres off the ground. As they protrude farther from the sledge frame

than in most ethnographic examples, we wanted to prevent their coming into contact inadvertently with the hard surface of the threshing floor. The brief textual references to the sledge construction do not explicitly mention 'skis', but we added them because of our observations of wear trace distribution on the Canaanian blades. These traces were evenly distributed over the blade's working edges and adjacent surfaces, unlike ethnographic sledge flints, which can have a blunted or faceted area on the very edge contact area, polished like a water-worn pebble (Whallon 1978). In contrast, the experimental blades used in the first year touched the threshing floor, and the very edge had begun to wear down more than the other contact surfaces. This pattern did not replicate the pattern seen on the archaeological blades (Anderson 1994a; 1999). Observation of ethnographic sledges prompted this decision to add skis to our ancient threshing sledge design. In Turkey and elsewhere, wooden skis or runners are used under sledge-frames to slide over plants and soil during carriage of hay, etc. over fields. In Spain small wheels (or saw blades, see Figure 7b) are sometimes added to the threshing sledge's underside in order to lift the blades just off the ground surface, presumably to preserve them, as the blades are virtually unavailable today. The same phenomenon was observed in Cyprus, where metal runners are sometimes added to the sledge underside (Kardulias and Yerkes 1996). Although the sledge does function effectively without skis, we continued to use them because we saw that the addition of wooden skis or runners did not raise the sledge too much for it to continue cutting the plant material in the final stages. In fact our experiments and our observations of sledge use in Spain and Syria show that the work on the threshing floor is always complete before the layer of plant material becomes so thin as to bring the sledge in direct contact with the threshing floor. We observed that

the addition of skis even appeared to enhance the efficiency of these large-bladed 'Sumerian' sledges, by creating a slight gap for pulling in the stems at the front, and evacuating the chopped and threshed material at the rear (Figure 8).

Experimental Functioning of the Sledge and Threshing Floors

Over six years of experiments, the sledges were retooled with several new blades whenever experimental parameters changed, such as a different threshing floor surface or a different crop. The sledges functioned on different types of threshing floors: beaten and hardened clay threshing floors in southern France and in Spain, and on an ancient paved floor and on a surface of dry grass clipped short, in southern France. The working area of the threshing floors measured 8-9 m in diameter. Plant sheaves were first placed on the floor, forming a thickness of about 30 cm. The cereals had been harvested cutting close to the ground, leaving long stems. The weight of the sledges was sometimes increased to 40 kg by adding stones to their upper surface. The added weight was progressively decreased as the mattress of plant material diminished through the thresh-

ing and chopping action of the sledge. The sledge appeared to cut most efficiently after 20 minutes of work. Complete threshing of grain and chopping of straw was generally completed after two hours of sledge use. In Spain, sledge users said their sledges 'jammed' with the long straw at the beginning of the work, but then, as stems were progressively cut, the sledge functioned smoothly. We made the same observation for our sledge. It is possible that shorter stems were sometimes worked on the threshing floors in the Early Bronze Age, because one cuneiform text concerning harvesting practice indicates that sheaves were cut with metal sickles below the ear, not near ground level (Grégoire, pers. comm. 1994). Our experience indicated that our small sledge would operate efficiently with shorter stems and ears, avoiding the initial phase when the longer-stemmed sheaves underwent a first reduction in length on the threshing floor.

During the third millennium BC, cuneiform texts cite various traction animals, oxen or equids used to pull the sledges. We found that a horse or even one or two persons could pull the reconstructed sledge at an efficient, walking pace. In 1999, 78 kg of ripe einkorn wheat (sheaves cut near the ground) were threshed

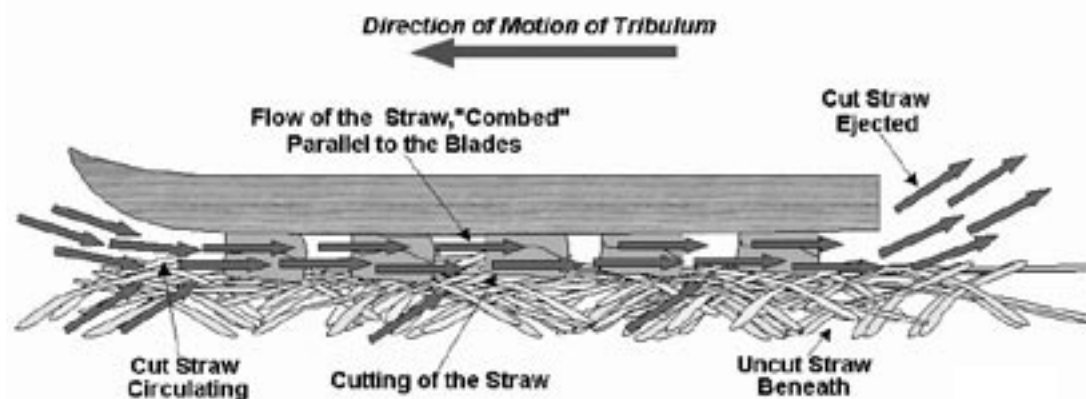


Figure 8. Mechanisms of cutting and flow of chopped straw on the threshing floor under the sledge. The diagram summarises findings from experimental measurement and recording of the motion of the *tribulum* (after Vargiolu *et al.* 2003: 451, fig. 17).

in four hours (over two days), taking 336 turns around a paved threshing floor 8 m in diameter; this totals over 8 km in distance. In 1996, it was noted that 30 hours of harvesting with stone-bladed sickles produced a quantity of bread wheat, which was thoroughly chopped and threshed in two hours with the experimental sledge, on a prepared earthen threshing floor of approximately 9 m in diameter. The ability of the sledge to produce massive quantities of chopped straw in such a short time is particularly remarkable. At the same time, the grain is threshed without damage or crushing. The sledge separated hulled grain (einkorn wheat, hulled barley) into spikelets. Such sledges are still used today on hulled wheat (e.g. einkorn) in Spain (Peña-Chocarro and Zapata 2003), and would have been used to process hulled barley, the crop best represented in macro-remains from many of the Ninevite V sites (McCorriston 1998). Free-threshing grain (bread wheat, durum wheat, etc.) was completely removed from its envelope without breaking any grains. Straw and chaff from grain envelopes (the latter only for free-threshing wheats) were neatly cut in our experiments. This occurred in the same way as we had observed the bread wheat being threshed by traditional sledges in Catalonia, and even when durum wheat was threshed with a basalt-studded sledge and a metal sledge in southern Syria (Anderson 1998; 1999; 2003). After the work of the sledges, grain and various chaff and straw fractions were separated by winnowing and sieving. Our results in weight of grain threshed in a given time were similar to those gained today, for example in southern Syria, although the non-bladed sledges used there took longer to obtain this result (Figure 5a; Anderson 2003).

Microscopic Use Traces on the Experimental Blades

Once the sledges were constructed, blades were easily added and removed merely by heating

the tar (bitumen); they were thus transferred to different sledge structures or studied with the microscope between seasons of use. Some blades have travelled approximately 100 km over the course of six years of experiments. Study of the flint blades under the microscope showed that the resulting wear attributes corresponded to those seen on the Canaanian blades: a matt, metallic-appearing surface with white smooth areas (Figure 9a, lower arrow), with large comet-shaped removals and drawn linear features extending well into the blade surface (Figure 9a, upper arrow). The same distinctive pattern had been noted on ethnographic sledge blades (Figure 4d, e) as well as on Canaanian blades (Figures 4a, b, and 9c, d): a background of either a matt or a flat bright surface, cut into by large shallow removals (depressions) tending to comet-shape, troughs running approximately parallel to the blade edge, and randomly oriented, long scratches. The degree of wear on many archaeological objects, like those on many of the ethnographic inserts, suggest that many were used for an extended period of time, probably over at least one generation (Anderson and Chabot 2001). This situation corresponds to the duration of use of blades in sledges described by farmers in northern and southern Syria, that is, 20 years (Anderson 2003). However, it is important to note that the traces seen at 100× on the experimental threshing sledge blades, even in early stages of development of the characteristic wear pattern, did not resemble traces from harvesting cereals in experiments (Figure 4c) during one, three, four, six, eleven or thirteen hours, nor do they resemble other archaeological tools having exactly the same traces obtained in harvesting experiments. Harvesting traces retain their general appearance, even if some of the archaeological tools were used for a longer period than the experimental ones. It should also be kept in mind that harvesting tools have a shorter potential use-life than threshing sledge blades, as their edges must be

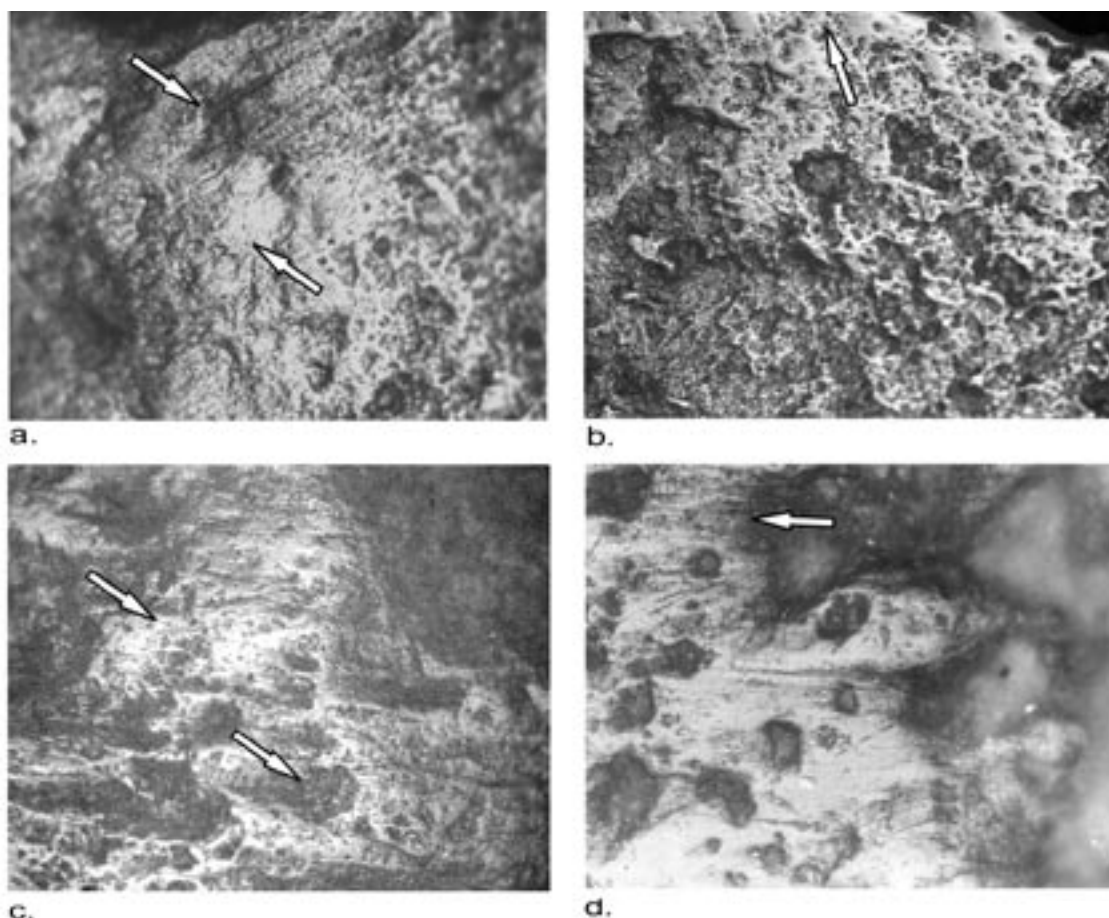


Figure 9. Use-wear traces seen using a high power reflected light (metallographic) microscope, original magnification 100×, on flint inserts used in experimental threshing sledges or on Canaanean blades interpreted as due to use in a *tribulum*.

a. Microwear traces on a replicated Canaanean blade used as an experimental threshing sledge insert for 10 hours to thresh wheat and barley, on beaten clay and on cut-grass floors. Some areas have a matt-appearing polish; there are comet-shaped removals (upper arrow) and other areas showing whiter, flattish polish deposits (lower arrow).

b. Double-use microwear traces on a replicated Canaanean blade, used for four hours in a sickle to harvest *Triticum monococcum* and *Triticum aestivum*, then inserted in a *tribulum* to thresh and cut *Triticum monococcum* on a paved threshing floor for four hours. Upper arrow: bright polish characteristic of harvesting. Lower part of image, below arrow: large, irregular depressions characteristic of the subsequent use in a threshing sledge. (Photo P.C. Anderson.)

c. Microwear traces on a Canaanean blade segment from the Ninevite V, Tell Hnaizir, in the Khabur Basin. Upper arrow: zone of whitish polish (compare with Figure 8a). Bottom arrow: one of the large, comet-shaped depressions, characteristic of use in a threshing sledge. (Photo P.C. Anderson.)

d. Traces on a blade from Jebel Aruda, Uruk. Arrow: a large, comet-shaped depression, removal characteristic of threshing sledge blades. (Photo A. van Gijn.)

capable of cutting plant stems in a tool guided by the hand. The experimental and ethnographic sledge blades, on the other hand, used from several hours to many years, when studied at 100-200× magnification, never develop the characteristic harvesting traces: fine linear features (Figure 4c), the smooth, linked microwear polish at the tool edge that gradually spreads onto the tool edge surface as use continues for longer periods (see Table 1).

Certain Canaanean blades have a brighter background than others, although displaying characteristic abrasion and linear features. Is this a variant of threshing wear due to differences in kind or humidity of plants at the time of threshing, or of threshing floor surface? Or rather, could the Canaanean blades have been used first to harvest, then to arm the threshing sledge? In order to test the possibility of double use of the Canaanean blades, first for harvesting then for threshing and cutting in the sledge (proposed in Anderson and Inizan 1994), experimental blades that had been used to harvest were put into a *tribulum*. We used replicas of Canaanean blades to harvest the cereals, cutting near the base of the stems, just before threshing. These blades showed the characteristic features of sickle use (see Table 1). Some blades were then removed from the sickles and inserted in a threshing sledge. In one double-use experiment, a blade was used to harvest for 13 hours, then employed in the threshing sledge for three hours. In a second trial, a tool was used to harvest in a sickle for four hours, then removed, inserted and used in a *tribulum* for four hours. The result of both these trials is that the dominant wear features seen on the blade were those from harvesting (Figure 9b, arrow), but wear features from the secondary use in the sledge were also visible to the trained observer. In particular, the threshing wear was even less visible on the tool used to harvest for only four hours before use in the sledge, perhaps because there was not a smooth, extensive sickle polish against which

to distinguish the abrasive features of the brief use in the threshing sledge. The threshing use, however, added abrasion features in the form of large pits and removals of irregular shape (Figure 9b, lower half of image) to the sickle features of smooth, flowing polish at the edge of the tool (Figure 9b, arrow). Although more double-use experiments over longer duration will help find criteria to identify more accurately whether there was double use (sickle/threshing sledge) of individual blades, current experiments indicate that threshing use is far more likely to be overlooked on archaeological material than harvesting use. For blades with double use, our experiments show that, in fact, the threshing use does not obliterate the harvesting use, contrary to what might be expected.

Why have other microwear researchers considered Canaanean blades to be sickles? Analysts are unaware of the various experiments producing gloss, particularly those from a threshing sledge; indeed the assumption that gloss is only related to sickle use is still widespread. In this way, Collin (Behm-Blancke 1992; Otte *et al.* 1990), in his analysis of Canaanean blades at Hassek Höyük did not consider possible uses for this tool type other than as sickle-blades, which he thought were used alone in sickles; he mentioned, however, that some blades had a very abraded wear which he could not explain. It appears likely that if the blades could be examined with a full reference database, they might prove to have wear matching that from sledge blades. Similarly, three blades from Chalcolithic/Early Bronze Age Jawa in Palestine (c. 2800 BC) were first interpreted as sickles, without a data base that included threshing sledge flints, but again with an observation by the analyst of heavy abrasion (Unger-Hamilton 1991). In light of work done today on cereal processing, not just harvesting, a restudy of the same three blades from Jawa by one of us (Chabot, analysis in progress) showed wear patterns characteristic of threshing sledge

inserts. Tools from Tell Leilan (glossed Canaanite blade fragments) thus were also initially interpreted as having been used in sickles, although the problem of the abrasive wear, which had not been obtained in harvesting experiments, was discussed; reanalysis of these tools showed they had wear traces characteristic of use in the threshing sledge (Van Gijn 2003). As this article explains, analysis of wear traces takes place by formal analogy with experimentally induced traces. The use-wear analyses mentioned above were conducted in the 1980s, using valid observation methods but limited paradigms, because much experimental work had yet to be completed. At the time, the abrasion some analysts were seeing on glossed blades was seen as the result of harvesting near the soil or of cutting weeds with cereals. These hypotheses may be discounted in the case of the Canaanite blades because these particular harvesting experiments (we have conducted approximately 50, involving about 200 blades) indicated that the abrasion produced in the wear traces was of an entirely different nature (i.e. fine striations—see Figure 4c), quite unlike that observed on ethnographic and experimental sledge flints, and also unlike traces on the Canaanite blades. We can now compare archaeological traces to all the experimental work conducted over the past 15 years on cereals, and draw upon a reference library of images exchanged among researchers. When the Canaanite blades from Kutan were first seen by one of us (Anderson and Inizan 1994), we knew sickle-harvesting did not produce such traces. Nonetheless we tried to conduct as many experiments as possible, for example, harvesting in the presence of abrasive factors, close to the ground, over acid and alkaline, rocky and fine soils, but in the end the traces like those seen on Canaanite blades never appeared (Anderson *et al.* 1998).

Early descriptions of traces on ethnographic sledge flints (e.g. Whallon 1978) used low magnification. Later it became apparent that

although the striations observed were not characteristic when viewed with a stereoscope, when the same features were seen at high magnification using a reflected-light microscope (allowing good depth of field), they were seen to be wide troughs, or large comet-like depressions which are indeed characteristic of sledge flints (note the overall pattern of these features in Figure 4b, then twice the magnification of the same features in Figures 4a, d, e). The picture became clearer when we were able to work directly with Natalia Skakun, in the late 1980s and early 1990s, and to observe these traces at higher magnification on ethnographic and archaeological tools from Bulgaria. Ataman (1999; originally published in 1992) carried out the first high-power microscopy study of flint and obsidian ethnographic threshing sledge flints. It became evident that in fact the only way to discover those features diagnostic of use in the threshing sledge was by using the reflected-light microscope, essentially at 100–200× magnification. Other features seen at low magnification, or with the naked eye, on ethnographic threshing sledge flints tend to be absent from the Canaanite blades, for example edge damage produced by the pounding from mallets during insertion into sledges and the extreme wear on the very edge, like a water-worn pebble (Whallon 1978).

Undoubtedly this is because, first, the archaeological blades were not inserted using force but rather glued into the threshing raft, as the texts describe. Secondly, recent contexts of use, knapping know-how and networks of distribution of blades may differ from those of the past: Although knapping of blades was a specialised craft activity, both in the protohistoric as well as in the recent past (Kardulias and Yerkes 1996; Whittaker 1999; 2003), the skills necessary for knapping long, regular blades had been lost (Figure 6). The Canaanite blades tend to be less worn than threshing sledge flints in ethnographic sledges, but in the case of the latter, the lack of available inserts in recent

times may have lead to a strategy of using them far beyond the optimum efficiency of the cutting edges. In short, analysis of finer traces at high magnification with a reflected-light microscope to look at the flint surface according to methods outlined by Keeley (1980) is the only means of seeing diagnostic traces that will be sufficient for distinguishing harvesting from use in the threshing sledge, cutting straw on the ground, etc. Indeed, not just the very edge, but the sides back from the edge have a different mode of contact with the plant stems in each case.

Measurements and Recording: Functions of the Bronze Age Sledge

The critical difference between the way the threshing sledge works versus other cutting methods is that when this instrument is used, the plant material remains mobile, rotating against the blades, with chopped straw forcibly ejected from the rear of the sledge as it moves along the threshing floor (Figure 8). This notion of the straw rotating is reinforced by observation of incisions on straw from the threshing floor (Figure 10a, see arrows), which show smooth, complex, often concave or step-like cuts. Engineers working at the École Centrale, Lyons, France, participated in our experiments and were able to carry out measurements that shed light upon the complex nature of the action of the Bronze Age Mediterranean threshing sledge (Vargiolu *et al.* 2003: 448-51). The objective of their study was to explore the relationship between the morphology of the use-traces, the mechanisms of use-trace formation and the working of the tool.

One of the experimental sledges was equipped with instruments of measurement placed on one of the blades, and these recorded pressure on the blade in three directions, as well as any changes in temperature of the flint blade as it cut the straw. A hole was made in the sledge frame and covered with a transparent piece of plexi-glass, while a video camera mounted on

the plexi-glass filmed the movement of the plant material and of the sledge as it worked. Measurements over the first 45 minutes of work with the tool show that the friction is greatest during the first 15 minutes but then falls abruptly and stabilises. This conforms with our own field observations, and must be the result of a modification in the thickness of the bed of plant material. At first, the random orientation of the plants and the long stems forms a resistant layer. As work progresses, the straw is chopped and a new, more elastic layer of straw forms. The temperature varies only minimally, indicating that there is no thermal change of the flint surface during use. The video showing the straw being cut under the *tribulum* revealed that, after 15 minutes, the stems moved parallel to the sledge blades, whereas at the same time the straw was cut perpendicularly. The cutting mechanism is composed of a complex system with two layers of plant material (Figure 8): an upper one, made up of fragments of straw and seed heads already cut and being ejected from the back of the sledge; and a bottom layer, composed of plant material in the process of being cut. The action of the sledge serves as a comb, guiding the straw from the front to the back. The movement of this layer, which circulates like a fluid, causes the straw to be cut with great efficiency. This distinctive and complex movement on the threshing floor also explains the diversity in orientation of the distinctive traces that form on sledge blades. The video shows the progressive cutting of straw fragments: first the straw is scored many times as it moves against the sledge flints, making smooth, curved or straight patterns (Figure 10a, see arrows). It breaks apart progressively, following the pattern of the incisions; these patterns are reflected in the cut profiles of silica phytolith sheets, which encrust the epidermis. The effect of the silica-rich epidermis of cereal straw on flint surfaces was measured by a laboratory experiment (Vargiolu *et al.* 2003: 442-48), with the goal of understand-

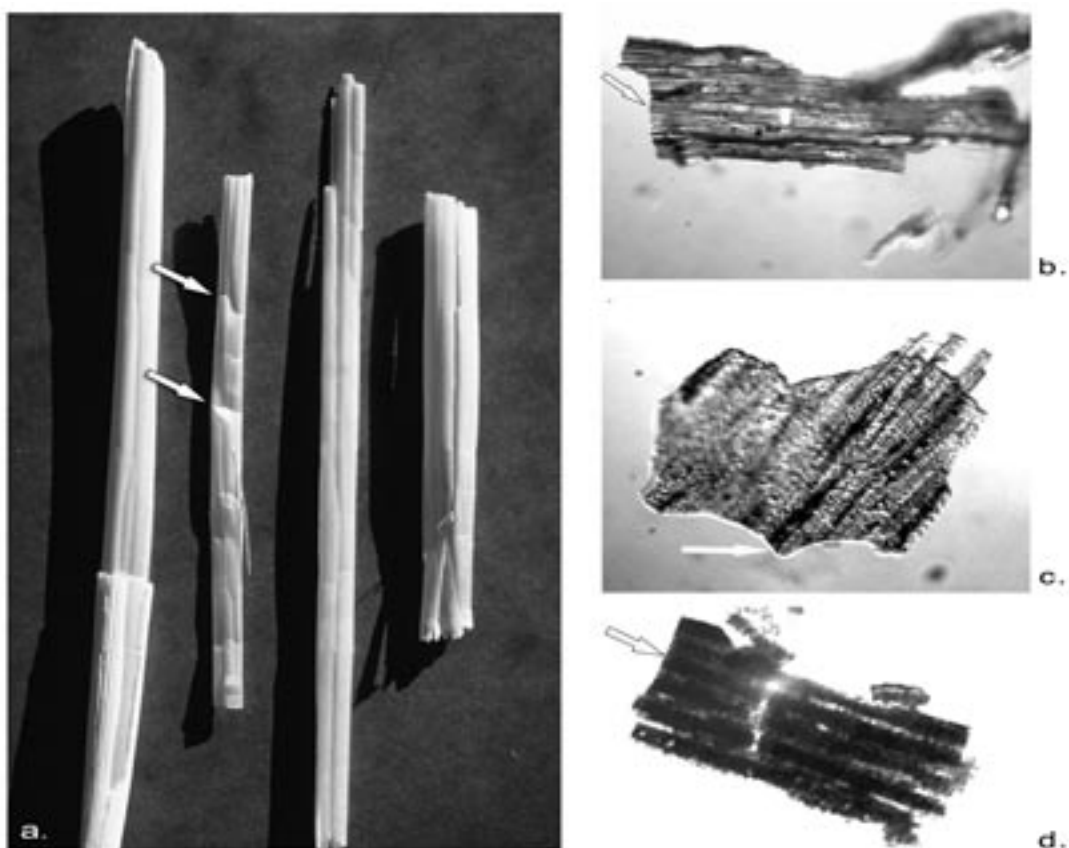


Figure 10. Effects of the threshing sledge on cereal stems and on the silica phytoliths contained in the stem epidermis.

a. Straw cut using the experimental Sumerian threshing sledge, showing smooth, concave or complex curved cut profiles (e.g. arrows), incised onto its surface by the blades before separation.

b. Phytolith with a smooth, complex cut profile (arrow), extracted by burning, derived from the wheat stems cut on a threshing floor in Catalonia, using an ethnographic *tribulum*. Note the similarity to the shape of the scoring on the straw in 9a (top arrow), both produced by a rolling action against the sledge blades.

c. Complex, double-concave cut phytolith (arrow), of a type produced only by the threshing sledge, which was extracted from straw cut on the threshing floor in experiments using the Sumerian threshing sledge.

d. Phytolith with smooth concave cut profile (arrow), characteristic of cutting by a *tribulum*, from chopped straw used as mudbrick temper at Tell 'Atij in Early Bronze Age Syria. The temper was probably derived from middens containing burnt threshing floor residue. (Photos P.C. Anderson.)

ing the distinctive nature of formation of the traces. Working with tribology (the study of surface wear), a device was used to fix an experimental Canaanean blade, and rub its surface against pieces of straw held immobile and fixed to the instrument stage, with the

blade moving in a direction parallel to the straw. Temperature and humidity as well as loading, speed and duration were held constant. Laser measurements of the flint surface were made in several areas before use, and after one, three and seven and a half hours. The

images obtained were qualitatively like wear traces on threshing sledge blades, with a surface roughness, large randomly shaped depressions, and flat areas which were smooth and bright. The topographic measurements showed there was an adhesive deposit composed of debris from the stems (i.e. silica). This layer adhered especially to micro-asperities of the flint surface, and was unstable in the low points. The deposit was detached in some low areas, creating new depressions. The layer deposited remained fairly constant in thickness, but the process of new deposits of material on areas of the micro-surface and new removals of material continues in a cyclical fashion, but with constant increase in the amount of depressions in the surface. The process is different from that of trace formation on sickles, where the wear is smooth and flat and abrasion forms fine striations, not the large areas of removals of material seen on the sledge blades.

In light of these observations, both harvesting with a sickle and using a blade to cut straw on the ground produces crushing and jagged cuts of the stem, presumably because directly applied pressure is used to sever the stems, and plant material is held stationary. This may help to explain why microwear traces on the blades used to cut straw on the ground lacked critical features of wear produced by use of blades in threshing sledges, particularly the characteristic 'drawn' features seen on the archaeological blades. These 'drawn' features result from the continuous motion of the sledge working in a curved motion around the floor, and also from the rubbing against the inserts of the silica-rich epidermis (outer crust of the stems), often running parallel to the blades, as opposed to the shorter and discontinuous motion associated with cutting by hand. Any hand cutting relies upon the tool edge being oriented perpendicular (not parallel) to the stems in order to achieve their separation, and the blade's friction against the silica-rich stem epidermis is different than for the sledge blades.

Laboratory simulation of contact between flint and cereal stems, and field trials with the *tribulum*, also offers some insights into how the traces were formed on the threshing sledge blades. These results suggest why, on the one hand, even dull sledge inserts can function, albeit extremely slowly compared with the experimental *tribulum*, and why, on the other hand, dull sledge inserts of basalt, highly rounded areas of sledge blades, and shaper blades all show the same basic microscopic use features when viewed with the reflected-light microscope at 100-200× magnification. In fact the 'wear' is not acting on the stone surface itself, but rather on a microscopic layer deposited on the working surface of the insert, which will be in similar contact with the straw (except for cutting), whatever its shape. According to our discussions with present-day sledge users in Spain and Syria (Anderson 2003), all sledges need to have inserts projecting at least a few centimetres from their bottom sides in order to function, but apparently whatever the nature of these projections, the sledge will work, and the distinctive flow of the plant material will occur on the threshing floor. We observed this for sledges with metal projections and basalt inserts in Syria. But when we asked the farmer using these if he were aware of bladed threshing sledges, he said he knew of them, and they were the very best, far more efficient than his, but he could not obtain blades with which to make one, and the bedrock in this volcanic region of Syria, the Jebel Hauran, does not yield stones which can be knapped into blades. When we showed him a photograph of the experimentally reconstructed sledge with large Canaanean-type segments, he greatly admired the fine blades, stating again that this sledge would work far more quickly and efficiently than any he knew of. Therefore, although there are many other solutions to threshing sledge construction that have been and are being used, the *tribulum* armed with large Canaanean blade segments

must have represented a kind of 'Rolls-Royce' of the threshing sledges, with aesthetics, efficiency and speed combined in accomplishing the task of threshing and chopping.

The Significance of the Threshing Sledge in Early Bronze Age Village Life

Identifying Uses of the Chopped Straw and Chaff

The threshing sledge not only very effectively threshed grains during the Early Bronze Age (its primary function), but also produced massive quantities of finely cut straw. Ethnographic observations show that traditional winnowing methods enable different size fractions of the chopped plant material to be separated, each fraction having particular uses: fuel, animal food, bedding material for humans and animals, temper for mudbrick and plaster, or for ceramic containers, such as granaries (Anderson 1998; 1999; 2000; 2003). Whittaker (1999: 13) describes how Cypriot villagers made numerous trips on donkeys to transfer bags of chopped chaff (and straw) from the threshing floor to storage structures used to feed the animals during winter; this was one reason given for the location of the threshing floor near the village and storage structures. In various areas of present-day Syria, we have seen that large quantities of chopped straw are needed not only as fodder, and hard stem bases of some cereals as fuel (Anderson 2003), but massive quantities are used as a tempering material in producing mudbrick and wattle and daub architecture, as well as in the plaster spread over the walls and surfaces of mudbrick structures annually.

Oates (1990) has underlined the great strength and insulation properties of straw-tempered (or chaff-tempered) mudbrick, dried in the sun. Ash was sometimes used as temper (as at Tell 'Atij, see below). The durability of mudbrick is ensured by frequent replastering, with chaff more likely to be used than chopped

straw, because it gives a smoother finish (Oates 1990: 389). Supplies of straw and chaff may not have been reliable when sites were located on the border of the rain-fed agriculture area, such as Tell Brak or Tell Rimah, and could have been imported from elsewhere. Based upon Oates' discussion with present-day brick-makers in northern Syria, 100 bricks require a minimum of one and a half sacks, or approximately 60 kilos of straw, which would be the product of roughly one-eighth of a hectare of barley (Oates 1990: 390).

Although other threshing methods such as flailing and trampling tended to be used in Cyprus for threshing pulses, the threshing sledge was used for cereals in order to obtain large quantities of chopped straw (Whittaker 1999: 13; 2003: 381). Palmer states that in Jordan, chaff (and chopped straw) from the threshing sledge is a valuable resource, and both harvesting techniques and storage facilities reflect this situation (Palmer 1998: 150, cited in Whittaker 1999). Can this be shown for the archaeological sites we have studied?

The effects of use of the *tribulum* in Early Bronze Age sites is shown, first, by the analysis of phytoliths, undertaken thus far for samples from Tell Leilan, Tell Atij, Tell Gudeda, and two outlying sites, Tell Acharneh and Uvda (see below). Phytoliths are microscopic plant silica that serve as a 'proxy' for the presence of the plants that decayed on the spot. Phytoliths survive in most environments in the soil or as a residue on tools; their shape or their imprint reflect characteristic forms of cells in the stems and chaff of cereals (and other plants) in which they form. Cut straw residue material was taken from ethnographic threshing floors in Catalonia and subjected to chemical digestion of its organic components, leaving the silica shell, a procedure meant to reduce them to archaeological-type remains of phytolith sheets of linked cell casts. They were then mounted on slides and studied at 200× and 400× magnification, using a transmitted-light microscope with

Nomarski (interferential) contrast. Some phytolith 'sheets' were broken in ways that can be seen in breakage patterns for any assemblage of decayed plants (Khedhaier *et al.* 2003), whereas other shapes reflected the action of the threshing sledge: the phytoliths, linked in sheets of cell imprints, were cut with peculiar smooth, 'razor-sharp' edges, and complex patterns (Figure 10), first observed by Juan Tresseras (1997) then by Anderson (1998; 1999; 2000; 2003) and others (Khedhaier *et al.* 2003; Cummings 2003). We were able to confirm this observation by analysing remains of cut cereals fragments gathered from threshing floors after our experimental sledge had been used (Figure 10a, b, c). Furthermore, we have found that such smooth-cut phytoliths cut in complex patterns were absent from stems cut other than with the threshing sledge, such as manually, harvesting with a sickle or using a blade against the ground or against a wooden or stone billet, as described above (Anderson 1999; 2000; Anderson *et al.* 1998).

Some cuneiform texts describe animal trampling as being used as one of the threshing methods. We examined phytoliths from cereal threshed and cut by animal trampling (mules and donkeys) in Morocco (Anderson 2003), a method efficient for threshing grain and one which, if pursued long enough, can cut the straw. This technique, common throughout the Mediterranean world, functions when one or several animals walk or run over the crop, with the percussion of their hooves cracking the straw as the grain is threshed (Llaty 2003). Of course this cracking or crushing of straw from trampling by draft animals pulling the sledge contributes to the cut phytolith assemblage found on threshing floors where sledges have worked. In ethnographic contexts where the animals are pulling the sledge (usually with a person sitting or standing on it), they proceed at a walking pace. We were able to study the effects on the straw in two cases, from Morocco, where animal trampling on

threshing floors was the only technique used. As above, we digested the cut straw taken from these threshing floors with a chemical treatment in order to destroy the organic components of the straw and extract the silica phytoliths. Our observation of the phytoliths at 200× and 400× magnification showed that trampling alone did produce cut phytoliths where the straw had been cracked or crushed, and these cut profiles may coincide with the less characteristic cut profiles found in assemblages of phytoliths produced by the threshing sledge pulled by animals.

Other phytolith profiles produced by sledge threshing, however, show important differences from phytolith assemblages produced by trampling. For example, trampling did not produce long, smooth diagonal cuts, perfectly symmetrical and smooth long, straight cuts, or complex shapes such as double curves (Figure 10c) or straight-convex cuts (Figure 10b), as the sledge commonly did. This is probably because these particular cuts were produced by incisions from the rolling of the plant material against the sledge blades. Such long or complex shapes were not produced by simple pressure breaks from animal feet.

This finding was verified by examining material from our experimental threshing floor. When a horse once had refused to pull the experimental sledge, students and researchers pulled the sledge wearing soft shoes. We then extracted and examined the phytoliths and found that the distinctive phytolith cuts were present. This experiment provides some confirmation that these 'complex', smooth cuts—described above—are produced by the action of the sledge blades, and not by trampling from animal feet. It also confirmed that the sledge can produce less regular and smooth cuts as well, depending on how the straw meets the blades, but the former 'complex' types are the only ones that allow us to distinguish sledge threshing from threshing using animal trampling alone (Anderson 2003).

Remarkably enough, such smooth-cut, complex phytolith profiles, with curved or long, straight diagonal or perpendicular cuts, have been found in Bronze Age sites we studied, in levels which also had Canaanite blade segments showing traces of use as inserts in a threshing sledge, namely at Tell Leilan (Cummings 2003), Tell 'Atij (e.g. Figure 10d) and Tell Acharneh (Anderson 2003). It is interesting to note that the Tell Leilan samples came from ashy-appearing deposits in ovens, which were found to be of dung (coprolith) remains used to fuel the oven for firing ceramics. This finding provides some evidence for the use of chopped straw to feed domestic animals (Cummings 2003), and underlines the importance of dung fuel in this period (McCorrison 1998), as well as today throughout the Mediterranean region (Anderson 2003: 424-5; Anderson and Ertug-Yaras 1998).

The mudbrick architecture at Tell 'Atij was tempered with chopped straw, perhaps from the threshing floor there, as in the other Early Bronze Age sites. Just as large quantities of finely chopped straw are precious and indispensable in traditional contexts, the efficiency with which the threshing sledge produced it may help to explain the sledge's importance in early periods. In the Bronze Age the sledge was armed with blades that had sharp cutting edges to increase the speed of the work. Storage structures in some sites contained grain (McCorrison 1998). It is possible that chopped straw was stored in bags in clay granaries or in storerooms, as they are today in southern Syria (Anderson 2003). Research on phytolith remains from various areas in sites and further observation of remains on traditional and experimental threshing floors, will serve to explore these questions further.

We are in the process of extracting phytoliths from ashy accumulations, from walls of silos, and ashy-appearing chopped straw temper in mudbrick from Tell 'Atij. The analyses show that this temper is not wood ash, but

rather results from chopped threshing floor material, because of the presence of the special smooth, long concave (Figure 10d, see arrow) and double concave cut (e.g. Figure 10c, arrow) phytolith sheets, which in experiments were shown to be characteristic only of cutting with the bladed threshing sledge (Figure 10a, b, c). Therefore straw processed with the threshing sledge and in use at this time at Tell 'Atij was present in storage structures, and incorporated into mudbrick walls directly or as burnt material, probably from middens (McCorrison, pers. comm. 2001). Only phytoliths from chopped stems, not glumes, were found at 'Atij, which may reflect the harvesting of long stems. This would support the results from studying macro-remains, which indicate that plants were harvested by pulling and that the cereal was a hulled variety, such as hulled barley (McCorrison 1998). In addition this indicates that the temper was from the threshing floor, and not a residue of the dehusking process (Procopiou 2003). Interestingly, the particular level showing these phytolith data at Tel 'Atij is the same one in which nearly 250 Canaanite blade segments were found, all having traces indicating that they functioned over long periods of time while inserted in a threshing sledge (Anderson and Chabot 2001).

Threshing Sledge Use and variants of Canaanite Technology in the South

We have found five tools, with traces from use as threshing sledge inserts, in a small sample taken from Tell Acharneh, in the Orontes Valley in central Syria. The blades have marks showing production using pressure with a lever (Figure 11c, d) (Chabot, analysis in progress); the raw material of the blades, however, is different from that used for blades in the northern sites. This finding suggests that the site used blade segments produced by other workshops, possibly to the south. Most of the over 80 glossed blades and wide blade segments sampled from the Megiddo tombs

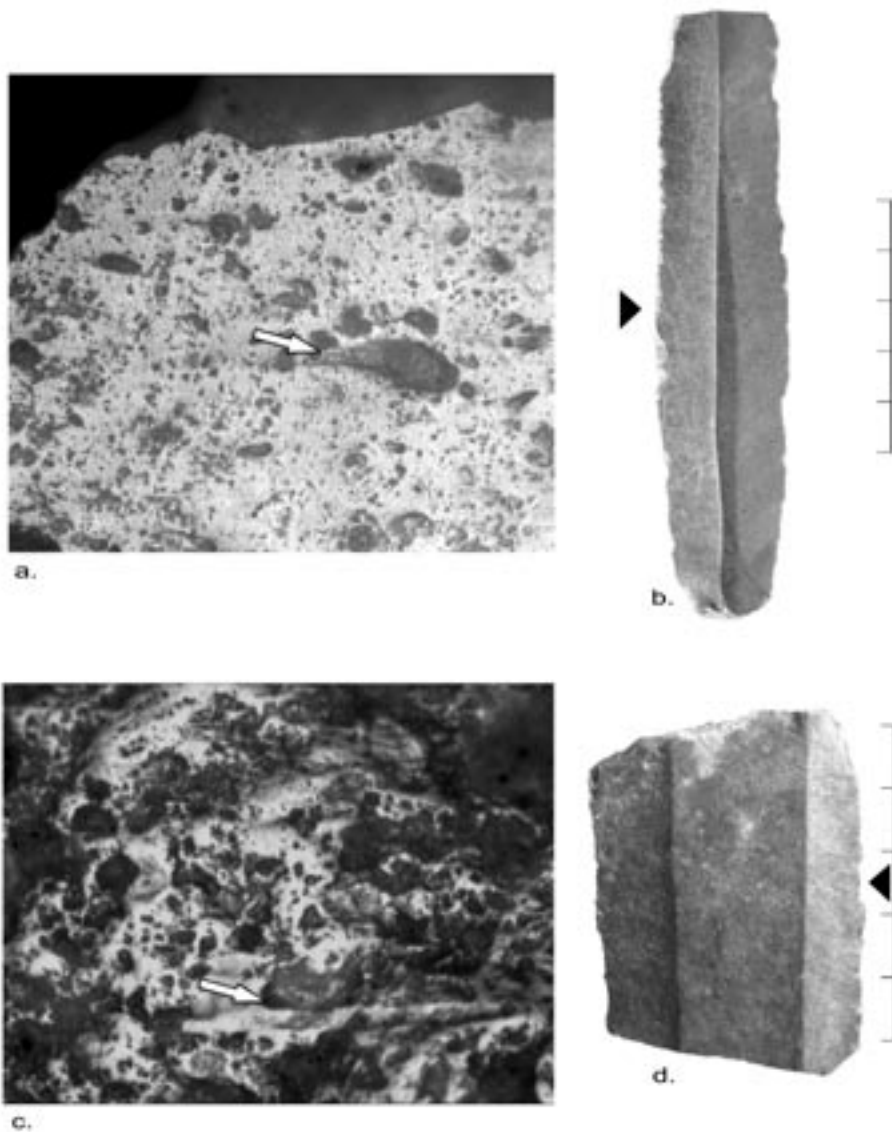


Figure 11. Tools made using Canaanian-blade technology, found in sites well to the south of those in northern Mesopotamia. These tools have gloss traces on both edges which, seen under 100x magnification, correspond to traces from use in a threshing sledge.

a. Traces of use-wear (arrow: comet-shaped depression) characteristic of threshing sledges (both edges) observed on:

b. a blade (arrow: area photographed in a) from the Uvda Valley, southern Negev, with fine characteristics showing it was pressure-knapped with a lever using a copper-tipped point.

c. Traces of use, characteristic of threshing sledge blades (arrow: grooves and comet-shaped depression) observed on:

d. a blade segment of a Canaanian blade from Tell Acharneh, Orontes Valley, central Syria. (Photos: J.D. Strich, P.C. Anderson, J. Chabot.)

showed traces from use in threshing sledges (Anderson and Inizan 1994). In fact, the single blade we were able to examine, from the Uvda Valley in the Negev, had traces like those from threshing sledge use (Figure 10a, b; Avner *et al.* 2003), although it is narrower than the blade segments we studied in sites from the north. This blade, however, has a well-preserved striking platform, which along with the bulb of percussion exhibits features and marks showing it was knapped using pressure debitage with a lever armed with a copper-tipped point, like the 'type A' Canaanite blades from northern Mesopotamia (Pélegrin 2002). It may have come from the north, as its raw material also suggests (Avner *et al.* 2003). Our research has shown that other tools from the Uvda Valley also have clear traces of use as inserts in a threshing sledge, but they represent morphological types absent from northern sites: they include a backed blade and a number of macro-lunates (Avner *et al.* 2003).

Nonetheless it seems clear that the process necessary to produce blades using pressure debitage with a lever armed with a copper-tipped point is so distinctive that sites containing such blades likely received them from workshops with which they were in direct contact. Such a system of production and consumption perhaps comprised a common network, or group of networks, with several sites being provided by (a) particular workshop(s). Our study, using Pélegrin's criteria to identify the use of a copper-tipped point and lever to pressure-knap the blades, shows that this method is by far the one most frequently attested in the Ninevite V sites, and equally for the Uruk material from northern Mesopotamia, indicating that this technique dates back to the Uruk period in this region. It seems premature to suggest an origin of particular blades or of the knapping technique using a lever with a copper-tipped point. Unfortunately these comparisons cannot be made with respect to

the blades illustrated and described in numerous studies of southern Levantine material because the same criteria of analysis have not been applied, and the drawings do not illustrate the parts of the blades critical for determining the knapping technique (Chabot and Eid 2003). Indeed Rosen (1983; 1997) has proposed that southern Levantine blades may have been pressure-knapped using a lever and a copper point, which can be confirmed only after comparing the southern Mesopotamian and Levantine material with our study through use of the same criteria.

Although these observations are promising both for tracing the development of the threshing sledge over a wider region and for exploring what may have been the nature and function of specialised blade production, the research is still too limited to allow extrapolation to the south of identifications made in this study of the northern Mesopotamian material. For example, analysis of microscopic use traces on blades from Abu Salabikh that have gloss, as well as thick bitumen deposits with a imprint different from those on some of the Canaanite blades (Crowfoot-Payne 1960), shows that these blades are of an altogether different nature, both technically and functionally, than the Canaanite blades analysed in our study (Anderson and Chabot, unpublished study 1999).

Data Concerning Threshing Floors

It is more difficult to identify threshing floors themselves in archaeological contexts, particularly those made from beaten clay, unless their location is suggested by the construction of a more permanent area using paving stones, stone borders, or dug into bedrock (Whittaker 2001; 2003). According to Grégoire (pers. comm., 2000), cuneiform texts indicate that each household had one or more threshing floors, which were permanent, constructed installations. Nearby structures housed workers, traction animals and tools and, like the

threshing floors themselves, were all located outside living areas. Once threshed, cereal grain was transported by waterways to silos located in small villages or in urban centres. It is therefore not surprising that excavations of tell sites, primarily dwelling areas, do not produce traces of ancient threshing floors. What do the Ninevite sites represent in this regard?

So far, nothing resembling a paved threshing floor has been found in the large number of Early Bronze Age sites excavated. Perhaps courtyard areas may have been used for threshing; our experiments show that the sledge could have worked in an area as small as 9×12 m in diameter. Most threshing floors are as likely to have been made of beaten clay, as they commonly are today, for example in Turkey (Anderson and Inizan 1994; Ataman 1999), some areas of Cyprus (Kardulias and Yerkes 1996), or Bulgaria and the Ukraine (Skakun 1999). They may even have been established on cut grass areas as they are in Syria today (Anderson 2003). Can microscopic use-traces indicate the kind of threshing floor surface? Using different types of threshing floors (beaten clay or paved) did not produce a demonstrable difference in traces on the sledge blades in experiments thus far. Ethnographic sledge flints from both cobbled and beaten earth threshing floors show features found on archaeological blades, and the floors may ultimately contribute to the variability in the traces. However, the present sample is inadequate to risk correlating certain features with particular kinds of floor surfaces.

In the Uvda Valley in the southern Sinai, however, Avner (1998) shows 20 threshing floors carved into hard limestone, and 12 others made of beaten clay. The floors, measuring 8–15 m in diameter, have been dated to the fifth–third millennia on the basis of cultural material and stratigraphic sequences (Avner *et al.* 2003: 456). We studied samples of phytolith and pollen from threshing floors as well as from granaries and silos. Preliminary results

show that phytolith remains from chopped straw are preserved in the soil from two threshing floors, dated to the fourth millennium BC, in the form of smooth-cut phytolith sheets of the complex type cut by a threshing sledge (Avner *et al.* 2003: 470, fig.15), which would concur with the presence of tools with traces interpreted in this study as stemming from use in a threshing sledge.

Discard Patterns and Ritual Indications for the Ancient Sledge

Quantifying the use of the threshing sledge in various sites will probably prove quite difficult. Many ancient threshing sledge blades appear to have been deposited in random, secondary archaeological contexts, apparently unrelated to use or storage of the sledge. This is particularly the case for north Syrian sites prior to the Bronze Age, for example in late Pre-Pottery Neolithic B (PPNB) sites (c. 7800 BP), where small numbers of blades made from local flint were found to have traces of use in a threshing sledge, with some seemingly used first to harvest (Anderson 2003). Blades with threshing sledge use-wear were reused as fill at the base of walls at El Kowm in the late PPNB in Syria (Anderson 1994a; 1994b; 1998). Ataman (1999) found, in studying discard patterns of sledges and their inserts in present day Turkish villages, that sledges were stored in structures outside village living areas. A few inserts that fell out on the threshing floor were inadvertently mixed in sacks of grain, and in that way brought into the living areas. Storage of agricultural instruments outside habitation structures, in special buildings near the threshing floors, is described in texts referring to the Mesopotamian Bronze Age (Grégoire 1999). It may be that finds of threshing sledge blades in the Bronze Age correspond to storage of the instruments, for example in non-habitation structures such as Fortin (1998) documents in most or all of the buildings at Tell 'Atij and Tell Gudeda. The fact that blades from all

these sites were used to varying degrees, but are still sharp, many with bitumen still adhering, suggests they may represent complete instruments that have decayed in storage buildings (rather than blades for retooling sledges, or for waste deposits of worn blades). Moreover, no by-products from truncating or backing retouch of the Canaanite blades were found in the course of careful excavation and mapping at Tell 'Atij (Chabot 2002). Today in Syria and Jordan, sledges sometimes double as doors for storage buildings during the non-threshing season. Could this have also occurred in Bronze Age Mediterranean countries, and explain the taphonomy of some of the Canaanite sledge blade finds? Other sites such as Jebel Aruda had a cache of Canaanite blades stored in a container (Hanbury-Tenison 1983). Does this represent material for retooling sledges, or rather a ritual context of deposition?

Outside northern Mesopotamia, many Canaanite blades are found in what may be ritual contexts, such as in tombs. For example the sample of blades from the Megiddo tombs (Guy 1938), particularly those that appear to be Canaanite blade segments, bore traces of use clearly characteristic of threshing sledge elements (Anderson 1994). In any case, this was a case of intentional deposition of the sledge blades. Other possible ritual deposits of the threshing sledge or its inserts have been found in archaeological contexts outside the region. In Bronze Age Durankulak in Bulgaria, Skakun found several extremely worn blades imbedded in an 'altar'; microscopic analysis showed them to be threshing sledge inserts (Skakun in Anderson and Inizan 1994). Skakun (1994; 2003) has also identified characteristic threshing wear on inserts from the burial of apparently whole sledges in Bronze Age and Iron Age tombs in Central Asia. These non-random, ritual contexts are still rare for prehistoric and proto-historic finds of threshing sledge flints, but closer attention to exact provenience of finds during excavation

may help to provide insight into the significance attributed to the sledge in different historic contexts.

Skakun (2003: 392) illustrates two cylinder seal imprints from fourth millennium BC proto-urban levels at Arslantepe and Uruk (Frangipane 1997; Littauer and Crouwel 1990). These seals depict the threshing sledge, pulled by animals, with one person driving the oxen and another sitting on what appears to be a throne or an elaborate chair on the sledges. The general scene gives another ritualistic impression. According to Skakun, ethnographic data from Syria also indicate that the ritual burial of persons on a 'bed' of a threshing sledge continued until the second half of the twentieth century AD. She describes a Syrian custom of using the threshing sledge in marriage ceremonies, where it was part of celebrations and games carried out on the threshing floor. Clearly, as remains of the threshing sledge are more widely sought and recognised in archaeological contexts, we are likely to find more evidence for its ritual or ceremonial significance. It would seem that the Canaanite blades used in the threshing sledge of the fourth and third millennia BC, far from composing a humble instrument dragged over plants on the ground, might also fulfil some symbolic function. The construction and use of the sledge is dictated to users by 'God the Farmer' in the 'Farmer's Instruction' (Civil 1994; Grégoire 2000), and is directly involved in giving life, food and perhaps even rebirth to the population.

Conclusion

Canaanite Blades: A Special Standardised Tool Production

This study had dealt with one of most remarkable stone tool types in Mediterranean and Near Eastern archaeology, the Canaanite blade. The advanced and highly specialised technology required to produce these standardised blades defies the general idea that

stone technology became insignificant with the advent of metal tools, or that metal tools merely replaced them (Rosen 1996). Remarkably enough, however, the sickles may represent an exception to this observation, as textual indications for the time do refer to metal sickles only; no references to stone sickles are apparent. Could this explain in part the lack of sickle blades in the northern Mesopotamian Ninevite V levels studied?

The Canaanean blades were distributed over a wide geographical area to enable a specialised agricultural activity, at least in northern Mesopotamia, and probably beyond: the threshing of cereal harvests using a sledge. Blade standardisation also ensured that this sledge could, according to the cuneiform description of the threshing instrument, be constructed using a raft-like frame, which our experiments showed required insertion of blades of a standard thickness and width to maintain stability. The wear traces observed on inserts in the experimental threshing sledge closely match those seen on the Canaanean blades, and the bitumen imprints on tools reflect the shape of the staves in the sledge frame. Virtually all Canaanean blades display characteristic microscopic features in their use-polish (see Table 1). The consistency of this observation for virtually all the approximately 800 Canaanean blade fragments of both A and B type that we have studied clearly suggests, at least for northern Mesopotamia, that this type of tool was produced specifically for threshing cultivated crops, not for the harvest.

This stands in sharp contrast with the other, 'ad hoc' flint objects in assemblages from sites dating to this period, objects that were produced from local raw materials without the specialised knapping techniques used in the blade technologies. It may be added that flint from the locally made flake industry does not display traces from use in any agricultural instrument. Instead these implements were used for brief periods held in the hand for

various small tasks such as the shaping of various objects (Chabot 2002; Van Gijn 2003).

Where Are the Sickles?

With virtually all of the type A and B blades from the Ninevite V levels in northern Mesopotamia having been used in a threshing sledge, the question remains as to how the crops were harvested. Prior to specific experiments, one of us suggested that blades first used in sickles could have been reused in a threshing sledge at Kután (Anderson and Inizan 1994), which would have explained the lack of flint sickles identified in Ninevite V sites. Experimental work later refuted this possibility and showed that the variability in traces on the blades in question were in fact representative of the range of traces characteristic of what threshing alone produces; results also revealed no residual traces from sickle-harvesting as a first use (Anderson 1999; 2000; Anderson and Chabot 2001). At Tell Leilan, however, a few tools seem to display characteristics of both uses, first in a sickle then in a threshing sledge (Van Gijn observation). At Tell Raqai the same has been observed (Chabot observation), but for several bladelets, not for the Canaanean blades. These are only incidental occurrences, however, and experimental work showed that traces of harvesting are not easily obliterated by a secondary use in the threshing sledge. Thus the predominant use of the Canaanean blades was as inserts for the *tribulum*. If this is so, where are the tools used to harvest in these Ninevite V sites?

One possibility is that the cereal crops were pulled up by hand, without using tools, as is done today in Syria with wheat and barley, particularly where the soil is friable (Anderson 2003). In support of this notion, McCorriston (2001; see also Chabot 2002) has found basal nodes from cereal culms in the archaeobotanical remains from Tell 'Atij, which would normally not be present if cereals were cut with sickles (as this part of the stem or culm is found

under the soil). Cuneiform texts indicate that only metal sickles of copper or bronze were used for harvesting, but because metal was rare and valuable, these were collected from the harvesters after use, weighed and ultimately melted down to make other objects and instruments (Anderson 2000). Therefore the metal sickles used were unlikely to have been stored or abandoned at the sites, or even preserved as such, and they thus escape modern detection.

Origins and Persistence of Canaanean Blades and their Function

In the northern Levant, Canaanean blades are usually associated with the Ninevite V period, but their presence in sites with underlying Uruk levels show that they occurred over a much longer time span. Studies we carried out of the material from Jebel Aruda (Hanbury-Tenison 1983; Van Driel and Van Driel-Murray 1983) and Tell Leilan (Weiss 1985; Weiss *et al.* 1990; Rova and Weiss 2003) indicate that the temporal dimension of Canaanean blades used to arm the threshing sledge needs to be extended back to the early Uruk. A large number were found in Tell Leilan Period V and IV, Early and Late Uruk respectively, displaying all the characteristics of typical Canaanean blades, most of which show traces of wear from use in a threshing sledge (Van Gijn 2003). Such traces were also observed on blades from the Uruk site of Jebel Aruda (Figure 8d). At the later end of the spectrum, a few Canaanean blades were also found in younger levels of period II at Tell Leilan, from the Lower Town, dated c. 2500–2100 BC (Weiss 1985). The number of typical Canaanean blades in this level was much smaller than in the earlier levels, and traces of use in a threshing sledge were encountered on the Canaanean blade fragments as well as on much smaller non-Canaanean-type blades and blade fragments.

Further south, regular blades having the appearance of Canaanean blades from Middle

and Late Bronze Age tombs at Meggido also showed traces of use in the sledge. Clear traces of use in sickles for harvesting of cereals, however, were found on smaller, narrower blades, not apparently made using the Canaanean technique, both at Tell Leilan period II levels and at Meggido. In any case, the threshing sledge remained in use far beyond the apogee of the Canaanean blade technology, with this function being transferred to blades produced using other techniques (Leilan, Meggido), in addition to the rare Canaanean blades. The two types may well have armed the same threshing sledges. Further study is needed to determine the form of the sledge frame in later periods, but blades may well have continued to be used in raft-like threshing sledges, particularly in areas where the wood supply or the diameter of trees was inadequate for making planks, and where the raft-like construction described in cuneiform texts would have been the best practical option.

Centralised, Regional Production or Production for Local Use?

It is clear that the Canaanean blades were highly valued and that an extensive distribution network existed to guarantee that villages were provided with the necessary tools. Ethnoarchaeological studies show fascinating variability in networks which existed for sledges and sledge flints. For example, with the sledge maker being both flintknapper and distributor, sledge makers sometimes travelled over long distances, providing sledges and blades to other members of the same ethnic or linguistic group (Bordaz 1965; Karimali 1994; Pearlman 1984; Whittaker 1999; 2003). The archaeological data do not yet show by whom and in what form the threshing sledge was distributed in Canaanean networks, nor if its production occurred in several stages and in different locations.

We do understand, however, why it was important to make tools of such a standardised

nature: they were used in an instrument whose structure required standardised inserts for its stability. This also explains why there is a great difference between their morphology, necessitating specialised craftsmanship unknown today outside of a few researchers who are expert both in flint knapping techniques and in the morphology of the inserts of present-day threshing sledges, knapped using metal hammers (Karimali 1994; Pearlman 1984; Whallon 1978; Whittaker 2003). Ethnographic sledges vary greatly in dimension, with some in Greece as small as our experimental sledge. They are made of planks with slots or holes cut into the underside, into which inserts of various morphologies can be installed together by force, pounding with a wooden hammer rather than lashing the frame and gluing the blades with an adhesive material.

The sledge not only effectively threshed large quantities of grain, it also produced straw. As we have seen, in the Bronze Age of northern Mesopotamia as well as in the recent past, specific size fractions of the straw chopped by the threshing sledge were used as fuel, fodder (subsequently discovered in dung used as fuel in an oven) or as temper material in mudbrick, other clay features, plaster and pottery. The chopped straw may also have been used for bedding. As such the sledge probably formed an integral part of the economic system of the villages. Estimates of the massive amounts of chopped straw needed for mudbrick architecture such as that in northern Mesopotamian sites, may explain the choice of the threshing sledge, as this instrument is used today where the need for chopped straw is extensive (Peña-Choccaro and Zapata 2003; Whittaker 2001). Oates (1990), for example, has estimated that the foundations alone of the outer wall of Naram-Sin's palace (c. 2254–2218 BC) at Tell Brak would have required for the approximately 810,000 bricks and their mortar, the straw from more than 13 sq km of cultivation; if the internal walls and superstructure are

added, this would require a formidable tract of land. Thus the Ninevite V sites in our study likely produced surplus grain, but also chopped straw or chaff, not only for themselves and other village sites but also for building as well as fodder. At the very least, the sites in marginal dry-farming areas may have created a demand for surplus production of straw as well as grain and a more or less complex distribution network.

As such, it may be that this demand for chopped straw was related to the fact that some or much of the crop harvesting during that time was done by pulling up the plant, or at least cracking off the stems at their very base (both techniques are used all over Syria today). These harvesting methods would ensure that a maximum of straw was obtained, and the fact that roots were also present would not be problematic if the straw were to be treated on the threshing floor. In areas where long straw is used for thatching or basketry, sickle cutting removes some of the straw length, but ensures that the roots, with contaminants such as soil and small stones, do not contaminate the thatch. In production sequences where chopped straw was a secondary product of high value as a commodity, however, harvesting by uprooting would be a viable option. Our experimental trials (Anderson 1999) showed that the pulling up of plants was done as rapidly as sickle-harvesting.

The Early Bronze Age of northern Mesopotamia (Ninevite V) is well known for the appearance of numerous villages built directly on virgin soil (this is quite different from earlier patterns where people built their villages one over another on the same site). This phenomenon is increasingly well-documented in the Middle Khabur valley (northeast Syria) where many 'new' sites—of a distinctive nature—have been recently identified and excavated ('Atij, Gudedda, Bderi, Nusstell, Raqa'i, Mulla Matar, Melebiya, Tuneinir). It has been suggested that their inhabitants produced sur-

plus grain (Fortin 1997), or 'staple finance' (Philip 2001: 167; Schwartz 1987), indicating that archaeological criteria by which staple finance might be recognised include data for intensified agricultural production, and the availability of storage and transport facilities (Schwartz and Klukas 1998). The use of a special, highly efficient threshing sledge in village sites throughout the region to produce large quantities of clean grain as well as finely chopped straw may well correspond to this concept. As such this may have comprised a kind of regional risk-abatement strategy. Philip (2001: 167; 2003) has also proposed a model of flexible, heterarchical corporate villages and middle-range societies rather than institutional power structures associated with city states, to describe Jordanian settlements during the Uruk period and the Early Bronze Age; he has also emphasised the importance of these sites' storage function. This model may also apply at least in part to the northern Mesopotamian sites considered in this study. In this sense villages could be seen as small homogeneous units ensuring the supply of primary products (i.e. grain, chopped straw, etc.), but dependent upon urban centres for specialised goods.

Such urban centres may have also controlled production of the specialised Canaanian blade segments. Although Uruk Canaanian blade workshops have been identified and studied in northern Mesopotamia, at this writing no workshops are known for the Ninevite V or Early Bronze Age. This is not surprising in that most excavations of this period over the past 15 years have been of sites located in northern Iraq and especially Syria. The majority of these excavations have produced large numbers of Canaanian blades, and study of their raw material strongly suggests that the workshop sites will be found in southeastern Turkey, in the same region where these blades were made in the Late Uruk period. Prospection and study of geological maps in Syria have

shown that the kind of raw material needed to produce these superblades is not found there, at least not in northern Syria (Chabot 2002; Laurent and Lease, pers. comm.). For knapping blades as long as 30 cm, large flint nodules are necessary, and the only area in which such nodules are presently known to occur is the Bingol region in Turkey. The old claim that Ninevite V sites were controlled from the south is changing (i.e. see Chesson and Philip 2003). In these cases the northern origin of raw materials and techniques used in northern Mesopotamian sites reinforces the idea of distinct networks of sites in that region. These sites appear to have retained the tradition of Canaanian blades and by the Late Uruk had developed a particular northern pattern of manufacture and distribution of Canaanian blades. Urban centres and groups of villages took part in a dynamic network involved in the production of agricultural products throughout northern Mesopotamia, and perhaps beyond. The large number of these sites and their distinctive agricultural activities offer an explanation for a specialised distribution network of high quality tools: the Canaanian blades.

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