Analytical Approaches to the Manufacture and Use of Bone Artifacts in Prehistory

by

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ABSTRACT

Mesolithic and Neolithic bone artifacts were analyzed with the aim of contributing knowledge regarding technological achievements, food procurement and processing, personal adornment and other aspects of social behavior.

Part I presents the methodology involving the integration of data obtained through experimental replication, surface traces, metric analysis, ethnographic analogy, and archaeological context. Replicative experiments were performed to reconstruct manufacturing techniquesand test functional hypotheses. Surficial topography was examined using a scanning electron microscope for the identification of manufacturing and use traces. Five key measurements were devised for evaluating gross morphology and working surfaces of artifacts. Where applicable, ethnographic analogy was employed as a source for hypotheses about artifact function. Archaeological context was studied to reveal distributional and associational patterns that might contribute evidence pertaining to the use of bone artifacts and their temporal development. Emphasis was placed on comparing data derived from the various methods to determine whether they supported or refuted one another. Interpretations were formulated on the basis of documented patterns rather than isolated events and, whenever possible, from multiple analytical techniques.

Part II demonstrates the general applicability of these methodological approaches through three case studiesselected to maximize diversity of cultural affilia-

tion, environmental conditions, temporal duration, preservational factors, and sample size. The first case study is a large, well-preserved collection from the Mogollon-Pueblo village of Point of Pines in the American Southwest. The assemblage is derived from a settlement of brief duration situated in a prairie environment. The second is a medium-sized collection from Tell Abu Hureyra in northern Syria with a long sequence from the Mesolithic through Ceramic Neolithic. The third case study consists of two small samples from Ulu Leang and Leang Burung, rock shelters in Indonesia which offer an interesting contrast in settlement type and environment from the two open air sites.

Dedicated to the memory
of my grandparents,
Hazel and Wyatt Adams

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Chapter 1

Introduction

Artifacts made of bone, antlers, ivory, and teeth are not generally found in vast quantities within a single archaeological site, especially when compared to pottery and lithic artifacts. Still, their numbers are usually greater than more perishable products such as horn, leather, wood, or textiles. Being neither abundant nor rare may perhaps explain why the field of bone artifact analysis has remained the domain of a relatively small group of specialists and why until recently it has been slow in developing a rigorous methodology.

Stimulated by the rapid expansion of knowledge in related fields such as taphonomy and the growth of methods in experimental replication and microwear analysis, the study of bone artifacts has progressed significantly in the past decade. Answering a need for more exacting techniques of analysis and greater objectivity in interpretation, specialists have adopted ideas and equipment from external disciplines such as material science and engineering. The results of the increased effort to understand the various roles of bone implements and ornaments in ancient cultures have been far-reaching and have produced information important to a diverse range of topics.

Of greater interest than the current status of methodology and interpretation is the potential development of the field in the near future. As more data accumulate concerning the physical properties of bone, surficial traces, and efficiency in manufacturing and use through experimental replication, the reliability and scope of interpretation of bone artifacts should continue to increase. Within material science in the areas of fracture analysis and tribology exists the necessary technology to solve many of the problems that face archaeologists and thwart our efforts to understand the economic role of bone artifacts.

The Development of Bone Artifact Analysis

With a few illuminating exceptions, descriptions of archaeological bone artifacts in writings of the first half of this century consisted of brief catalogue listings of types, frequencies, and basic measurements, accompanied by drawings or photographs. Few hypotheses were offered for possible functions, although functional names were frequently assigned to types. It is equally unusual to find mention of contextual association between bone implements and other materials, despite the fact that excavations were conducted on a much grander scale than is typical today. These early brief reports retain their value of presenting raw data and illustrations, but it is among the exceptional works that we can witness the emergence of the theoretical framework employed today.

Bone artifact typologies have not been exposed to rigorous reexamination and reorganization as has been the case with many lithic typologies. Instead, there is a tendency for each researcher to develop his or her own criteria for classification of bone artifacts without necessarily expressing them in detail. An early exception was the American archaeologist A. V. Kidder (1932), who devised a typology for bone artifacts found in the Anasazi site of Pecos, New Mexico which has continued to be widely applicable to material from the various Southwestern cultures. Kidder's typology is both functional and stylistic. At the larger, more general level of classification he attempted to assign functions on the basis of gross morphology, tip morphology, and visible wear patterns. For the most part these functional classifications have remained valid today. At a more specific level he classified subtypes based on method of manufacture, retention of the articular condyle, and the element upon which the tool was made. The direct historical approach, which is so readily applicable to the prehistoric and early historic Pueblo Indians because of strong continuity of traditions, was used to identify functions of objects such as musical instruments and ceremonial paraphernalia. Manufacturing debris, unfinished pieces, resharpened and recyled artifacts were recognized for the valuable information they provided concerning manufacturing stages and utilization of materials. Lastly, close attention was given to the temporal and spatial distribution of items. Archaeological context was an aspect that Kidder took great care in recording and which has, in turn, yielded considerable information. There is no doubt that he was aided by the fact that preservation was excellent and that the Pecos collection is one of the largest assemblages of bone artifacts known from a single site, totaling 5,368 objects (Kidder 1932: 203), but the quantity of material makes it that much more important that it was analyzed so thoroughly. Kidder's ability in establishing a meaningful typology for pottery is well acknowledged, but his bone artifact typology is also an important contribution to Southwestern archaeology.

Taphonomy has been very significant in the interpretation of bone artifacts by providing identifications of natural surface modifications which can be distinguished from those derived from cultural processes. The field of taphonomy predates Efremov's original work of 1940 in which he defined it as the subdiscipline of palaeontology devoted to "the transition (in all its details) of animal remains from the biosphere into the lithosphere" (Efremov 1940: 85). As early as 1938, Pei described the natural processes that had modified bone from the Chinese Middle Palaeolithic site of Zhoukoudian, including carnivore and rodent gnawing, root etching, water and chemical action. Kidder (1932) had already briefly mentioned and illustrated an example of root etched bone from Pecos.

It is difficult to highlight a single example of how taphonomy has aided in the interpretation of bone accumulations thought to be associated with hominids, but certainly one of the most familiar is the work of Brain in the Transvaal. Through the observation of taphonomic processes Brain demonstrated that bone fragments identified as representing the "Osteodontokeratic Culture" (Dart 1957, 1959a, b) could be produced by carnivores such as leopards and hyaenas (Brain 1970), and by soil abrasion and trampling by cattle (Brain 1967). The results of many of the taphonomic studies have led to greater caution in assigning bone accumulations to the agency of hominids and have helped bone artifact specialists sort out various traces on obvious tools.

Few would dispute that one of the most historically significant works for either lithic or bone artifact studies is Semenov's Prehistoric Technology (1964). First published in Russian in 1957, M. W. Thompson's English translation a few years later made it accessible to a wider range of researchers and inspired innumerable projects in both experimental replication and microwear analysis. Semenov recognized the benefit of integrating these two fields and ethnographic analogy in any methodology concerned with the interpretation of manufacture and use of bone or stone artifacts. Although today techniques have been improved, particularly with better optical equipment and scanning electron microscopy, many of his ideas about bone artifacts remain as a firm foundation for research that has followed.

In addition to his identification of a variety of microwear traces and his use of experiment to confirm the plausibility of hypothesized functions, Semenov employed several other important principles. One is that the distribution and directionality of microwear patterns may be studied to determine the orientation of the tool in regard to how it was positioned in the hand and how it moved in relation to the material it contacted. Thus, Semenov applied the field of kinematics to archaeological objects. Unlike many researchers continuing into the present, Semenov was attentive to the taxa, elements, and portions of bones selected for particular tasks. Keenly aware of the close association between natural morphology and adaptation of bones to certain uses, he demonstrated repeatedly the forethought and ingenuity with which early man applied his knowledge of his prey's anatomy to practical purposes. The variations in mechanical properties of bone, antler, and ivory were observed and noted by Semenov during his experiments, although physical tests such as those conducted by Amprino (1958), Bonfield and Li (1965, 1966), or Evans (1973) were not performed. The most crucial aspect of Semenov's work, which has in some senses been superseded and certainly expanded, is that it stimulated so many others and illustrated how much information is preserved within prehistoric objects if we study them in sufficient detail.

Current Research

The past two decades have witnessed a rapid increase in the quantity of research devoted to the interpretation of natural and cultural processes affecting bone and substantial progress in techniques of analysis. A thorough coverage of the abundant literature is not feasible here, but brief accounts may serve to illustrate the state of bone artifact analysis today.

Great strides have been made in the area of taphonomy with studies of gnawing by rodents (Shipman and Rose 1983a: 81-85), carnivores (Sutcliffe 1970; Haynes 1980; Binford 1981), and artiodactyls (Sutcliffe 1973; Brothwell 1976), digestion of bone in owl pellets (Mayhew 1977; Dodson and Wexlar 1979) and mammalian carnivores' feces (Mellett 1974), weathering (Behrensmeyer 1978; Miller 1975; Gifford 1977), and breakage patterns (Hill 1976; Haynes 1983). Work on large accumulations of bone such as Morlan's examination of the material from the Old Crow area (Morlan 1980) have clarified problematic cases. For a thorough summary of research in taphonomy see Gifford (1981).

Butcher marks have been analyzed and replicated with the objective of distinguishing among those made with stone and metal (Walker and Long 1977) and separating them from natural traces (Bunn 1981; Potts and Shipman 1981). Since cut marks are inflicted on bone artifacts in the process of manufacture and use, progress in the area of butcher marks is relevant to the study of bone artifacts.

Use of scanning electron microscopy has made publication of high quality micrographs of traces possible and has greatly increased the potential for locating and identifying embedded matter, residues, and fine microwear by expanding the range of magnification available.

Techniques of manufacturing bone artifacts have been studied through a combination of experimental replication and analysis of surface traces with significant results. To cite a few examples, the stages and processes of manufacture have been identified for combs (Galloway and Newcomer 1981; Ambrosiani 1981), harpoons (Julien 1982), needles (Stordeur 1977; Stordeur-Yedid 1978; Bouchud 1977), and projectile points (Newcomer 1974 and 1977). Through the good fortune that manufacturing traces are often highly visible and easy to interpret and the fact that discarded debitage and unfinished pieces may be recovered, the reconstruction of manufacturing techniques has been very successful.

The analysis of use traces has been more restricted by the difficulty of distinguishing between surface alterations created by different materials, particularly those made by plant and animal products. Despite this limitation, experimental replication has been conducted in order to demonstrate the applicability of certain artifacts to particular tasks and their relative efficiency. By comparing microscopic surficial traces on the working surface or edge of experimental tools with those on their archaeological counterparts it is sometimes possible to support or refute hypotheses about function. An interesting example is the case of European bone skates, which show extensive signs of wear on the lower surface in archaeological examples. Semenov (1964: 191-193) argued that the wear patterns were not like those on modern skates and that the design was wrong for the type of skating we know today. MacGregor (1975) demonstrated that by propelling oneself with a stick and not raising the skates off the ice the wear traces could be replicated quite accurately.

J. D. Clark (1977) conducted several experiments with large, essentially unmodified splinters of bone in order to produce wear patterns. Among the tasks performed were digging, stripping bark, shredding fibers for cordage, and removal of periosteum and muscle from butchered animals, all of which demonstrate the effectiveness of opportunistic flake tools. Other experiments designed to test the usefulness of archaeological bone tools include the preparation of yucca fibers (Osborne 1965), defleshing hides (Steinbring 1966), shooting bone points (Guthrie 1983), and using arrow shaft-straighteners (Campana 1979).

One area which has recently begun to demonstrate its great potential is the testing of mechanical properties of bone, antler, ivory, and horn in order to understand ancient preferences for certain types of material for particular tasks. Albrecht (1977) examined the compression strength and bending strength of each of these raw materials as a means of explaining the relative abundance of antler points compared to those of bone or ivory in Upper Palaeolithic industries. In a similar study MacGregor and Currey (1983) were able to show that antler was superior to bone in comb-making because the teeth were less likely to break. The same article illustrates that archaeological tools reflect an awareness on the part of the maker to the anisotropic nature of the material by orienting the grain of the bone or antler in such a manner as to provide the most durable object.

Typological considerations have received minimal attention until the French scholar Camps-Fabrer began organizing colloquia on bone artifact research. Major meetings held periodically have brought together workers for the purpose of presenting and discussing current investigation. As a result several edited volumes have been produced (Camps-Fabrer 1974, 1977, 1979, 1982) which cover a wide range of approaches. The regional variation in bone artifacts limits the success of general classification schemes, but Camps-Fabrer (1968) and others have made substantial progress in standardizing terminology and defining types. Much more work remains to be done in this area, however.

In summary, the proliferation of new approaches and the increase in the quantity and quality of research in recent years indicate a very promising future for the analysis of bone implements and ornaments. There is no reason to doubt that adoption of techniques from material science, improved optical microscopy, expansion of the application of SEM, and more controlled and varied experimental replication will produce significant results in the years to come.

Research Design

The selection and organization of data to be analyzed in this research are oriented toward developing a productive suite of methods and techniques for studying bone artifacts. The purpose for choosing the three case studies from widely divergent geographic regions and cultural affiliation is to examine the general applicability of the methodology. Examples were drawn from Mesolithic and Neolithic cultures in both arid and humid environments, from large open air settlements and smaller cave occupations in both Old and New World localities. The sample sizes ranged from 160 to 1268 and the number of recognizable types from two to 25.

Part I of the thesis sets forth the methodology and discusses general aspects of bone and bone artifacts which may apply to collections from any region. The second chapter covers the physical and chemical properties of bone, antler, dentine, and enamel in order to provide a basis for hypotheses regarding the selection of raw material, the efficiency of osseous material for certain tasks, and the mechanical causes of wear.

Chapter 3 outlines the methodological approaches employed on the three case studies and how they may be interrelated, complement one another, or serve as cross-checks for each other. The five major approaches combined in the following study are: analysis of surface traces, experimental replication, ethnographic analogy, examination of the archaeological context, and metric analysis of tool morphology. It seems inappropriate to rank these equally valid techniques in order of significance, but because of the recent and potential expansion of the fields of microscopic surface analysis and experimental replication a considerable portion of Part I is devoted to these two areas of research. New quantitative parameters for bone artifacts are introduced through the use of a set of measurements designed to distinguish between types of pointed and spatulate implements. Traditionalapplications of ethnographic analogy and contextual analysis are incorporated with more recent developments in the other methods.

The fourth chapter attempts to describe a wide range of both natural and cultural traces, particularly those that relate to the case studies. While a complete description of known surface modifications could fill an entire volume, it is hoped that the most frequently encountered traces found on bone from Stone Age sites are included. A host of other traces appear with the introduction of metal which are not covered in this research, but are discussed by other researchers (Semenov 1964; Stordeur 1980a).

Chapter 5 describes experimental replication specifically related to the analysis of material from the case studies, but the research is general enough to be applied to similar artifacts from other regions.

Part II is devoted to the application of these methods to the three case studies. The first and largest collection (1268 objects) is from the Mogollon-Pueblo site of Point of Pines ruin in east-central Arizona. A Neolithic settlement of more than 600 rooms, Point of Pines was occupied between AD 1200 and 1450. The semi-arid climate of the region contributed to the excellent preservation of bone and the exposure of 150 room floors and hundreds of burials provided important contextual information.

The second case study consists of a collection of 418 bone artifacts from Tell Abu Hureyra, a large mound on the bank of the Euphrates in northern Syria. Occupied during the Mesolithic, Aceramic Neolithic, and Ceramic Neolithic, Abu Hureyra's long sequence allows for comparisons with many sites of shorter duration in the Levant and provides evidence for the progression of types and manufacturing techniques through the millennia. Preservation of the bone surfaces is extraordinarily good, but the age and dry condition of the material have rendered it quite fragile.

The artifacts from the third case study are derived from two caves on the island of Sulawesi, Indonesia. The material is Mesolithic and Neolithic and dates to between 6000 and 850 BC. In contrast to the other two open air sites, Ulu Leang and Leang Burung are small occupations in natural shelters in a humid environment. The collections are limited to two basic tool types: awls and projectile points, but variation is considerable nonetheless. A thin deposit of calcium carbonate over the entire surfaces of the artifacts from Ulu Leang presented a challenge in terms of preparation, but served as a protective seal under which surface traces were well preserved. The Indonesian material was chosen to demonstrate the value of smaller collections which at first sight may appear to be poorly preserved and for comparison with the very different assemblages from Point of Pines and Abu Hureyra.

The choice of methods and techniques is not meant to indicate that these are necessarily the best or only means of maximizing information derived from modified bone. Application of these or other techniques is, in some respects, dependent on the size of the collection, number of types, methods of excavation and provenience recording used, preservation of surface traces, relevance of the direct historical approach or ethnographic analogy, and other factors. Among the three case studies, in fact, great variation in the yield of certain techniques may be noted, so that it is prudent to examine an individual collection initially to evaluate the advantages of using particular methods. If the scope of an analysis is focused on a more restricted topic, such as manufacturing processes for one type of tool, then it is possible to employ more detailed experimental replication, record more measurements and microscopic traces, or run more elaborate mechanical tests on replicas. Rather than presenting a comprehensive, universal guideline for the analysis of bone artifacts of any period or geographic region, the research design of this thesis is directed toward demonstrating how complementary and interdependent the various analytical approaches are and how fruitful a combination of techniques can be.

The primary aims of this research are to demonstrate the benefits of using a wide range of analytical techniques, to expand our understanding of the role of bone artifacts in prehistory, and to use information gleaned from the study of worked bone to further illuminate other aspects of past societies.

Chapter 2

Bone as a Material Resource

Bone consists of approximately one third organic and two thirds inorganic material. The organic portion is primarily composed of collagen, a tough structural protein common to the connective tissue of most multi-celled animals. In growing bone collagen is constantly undergoing resorption and replacement so that the size and shape of the bone is always appropriate for the size of the animal (Brown 1975: 18). Collagen contributes to the elasticity and tensile strength of bone and when removed the remaining inorganic structure becomes extremely brittle. How much collagen is retained in bone artifacts through their use life depends on many factors such as whether the bone is collected from the ground surface or a midden deposit or prepared from a fresh kill. How the bone was cleaned of soft tissue is also important, since boiling converts collagen into gelatin, effectively removing much of it from the bone.

The remaining organic tissue is a ground substance consisting mainly of mucopolysaccharides, or a protein-carbohydrate complex (Hancox 1972:41). The function of this amorphous ground matrix is poorly understood, but may relate to mineralization, hydration, or structural support of collagen fibers (Hancox 1972: 43-44). In addition to collagen and the protein-carbohydrate complex, the organic component of cancellous bone includes a minute portion of lipids, about .12% of the full weight of the bone (Hancox 1972: 44).

The inorganic portion of vertebrate bone contains the minerals calcium, phosphate, carbonate, magnesium, chloride, fluoride, and citrate (Brown 1975: 332). Calcium phosphate constitutes about 85% of the mineral contents, especially in the form of crystalline hydroxyapatite, $Ca_{10}(PO_4)_6(OH)_2$. The needle-like apatite crystals are less than 50 Å in diameter and range from 400 to 2000 Å in length (Hancox 1972: 46). This necessitates a high magnification of, for example, 40,000X, with an electron microscope in order to observe the overall shape of a crystal.

In addition to the apatite phase, bone mineral includes a significant portion of a noncrystalline, or amorphous, calcium phosphate (Posner 1971: 2), which appears in transmitting electron micrographs as dense ovals lying in no particular plane. It has been found that the amount of noncrystalline mineral is highest in immature bone and decreases with age in mammals as it is replaced by crystalline apatite (Waterman 1971: 183). This amorphous salt occurs, albeit in small amounts, in mature bone and dentine, but not in mature enamel.

The inorganic constitutents of bone provide rigidity and resistance to compression, as well as serving as the body's storehouse for minerals. The mechanical durability of bone is due to the fact that small apatite crystals are imbedded in a matrix of collagen. Some of the brittle crystals may crack, but the stress is then diffused into the surrounding collagen. Unless great stress is applied, breakage of all of the crystals along the line of fracture will not occur (Brown 1975: 336).

The specific gravity of bone is about 1.9; its compressive strength is approximately 20,000 pounds per square inch; and its tensile strength is around 15,000 pounds per square inch (Sisson and Grossman 1953: 24).

Structurally, there are two kinds of bone, woven and lamellar. Woven bone consists of an array of course collagen fiber bundles interwoven in all directions, like felt, in a matrix (Hancox 1972: 19-20). The osteocytes (bone-forming cells) are likewise distributed randomly without orientation. Around the woven bone are relatively large vascular spaces. New bone, whether it is deposited in the embryo, in fracture healing, or in osteosarcomas, is made up of woven bone. Only as bone is resorbed is it replaced with the second kind, lamellar bone. Lamellar bone consists of fine bundles of collagen fibers laid down parallel to others in the same sheet, or lamella. Lamellar bone gradually replaces the irregularly structured woven bone with orderly sheets of bone oriented in three ways: in concentric rings around Haversian canals which convey blood vessels, in the interstices between Haversian systems, or lying flat in stacks (Hancox 1972: 26). Eventually, all woven bone is replaced by lamellar bone, but this is in turn resorbed and replaced by new lamellar bone.

The architecture of bones consists of two basic forms: compact and cancellous bone. Compact bone is the hard, dense, outer structure which is constructed of lamellae of bone with only a very few small lacunae. In contrast, the inner cancellous, or spongy, bone is made up of thin, interwoven trabeculae of bone surrounding large vascular spaces containing blood vessels, fat, and myeloid tissue. The scaffolding of the trabeculae is arranged in response to load-bearing and mechanical stresses invoked through movement of the body. Within the long bone diaphysis is the medullary, or marrow, cavity where haemopoiesis occurs.

Immature mammalian bone differs from adult bone in that it is predominantly woven rather than lamellar bone, there is a higher amorphous mineral salt content, the medullary cavity and adult trabecular structures have not fully formed, and the epiphyses are not fused with the diaphysis yet.

Fracture Mechanics of Bone

Chert and obsidian are basically isotropic materials, that is their internal structure is random so that mechanical properties are similar regardless of the direction in which force is applied. In contrast, bone and ivory are orthotropic or anisotropic in nature. The internal structure is aligned in a nonrandom way such that variation in the direction of loading produces different stress-strain responses. More energy is required to fracture bone across the grain of the collagen fibers than along it. Collagen fibers in long bones generally run longitudinally. Transverse breaks are rough and sawtooth in appearance in fresh bone, unless it has been heated to temperatures above 200° C (Bonfield and Li 1966: 871). Above 200° C fractures across the grain are more continuous and smooth, suggesting pyrolysis of the collagen fibers. Fractures parallel to the length of the collagen fibers require less loading and are smooth in appearance irrespective of the temperature to which they have been exposed (Bonfield and Li 1966: 872). At temperatures above 200 °C the energy absorbed in either kind of fracture diminishes to zero due to deterioration of the material.

The modulus of elasticity, i.e. the ratio of stress to strain when a material undergoes simple stress (Davis, Troxell, and Hauck 1982: 19) is a measure of the stiffness of a material. Stiffer substances require more stress to produce a given amount of strain. It is difficult to measure the modulus of elasticity in a two phase tissue such as bone because the organic matrix has a low modulus and less strength while the hydroxyapatite crystals have a high modulus and more strength (Herrmann and Liebowitz 1972: 829-30). The apatite must bear the bulk of the stress and it must be bonded tightly with the organic matrix.

The type of fracture produced under a given load depends significantly on the condition of bone. From the time a bone is cleaned of meat it begins dehydrating. Certain factors may also lead to denaturation of the collagen fibers. While fresh bone may break in spiral fractures which run obliquely around the diaphysis, bone that has undergone considerable dehydration, as through weathering and age, tends to break parallel to or along split-line cracks produced experimentally by decalcifying bone (Tappen and Peske 1970). Postdepositional and post-excavational breakage patterns often include clean transverse fractures perpendicular to the original alignment of collagen fibers and apatite crystals, suggesting that denaturation has succeeded to the point of greatly weakening the fibers, if not destroying them.

Spiral fractures have frequently been attributed to human devices (Sadek-Kooros 1972; Bonnichsen 1979), but it has also been demonstrated that carnivore chewing (Sutcliffe 1970), weathering (Hill 1976), and trampling by man and other animals (Myers, Voorhies, and Corner 1980) can result in spirally fractured bone, especially in elements that frequently undergo torsional stress in life. It seems evident given the growing data on breakage patterns that, as an anisotropic, two phase material, bone fractures in certain ways because of its condition and loading, rather than due to the specific agent causing the damage. Amount of load required to break a bone probably depends on several factors including the thickness of the compact bone and the overall condition. The compressive strength of trabecular bone is the same as that for compact bone if the variation in density is taken into consideration. In other words, all bone mechanically behaves the same in terms of compressive strength (Carter and Hayes 1976), given a known state of preservation.

Denaturation and Dehydration of Bone

Collagen, the structural protein contained in bone, at the molecular level forms a triple helix stabilized by interhelical hydrogen-bonding. Denaturation, a physical or chemical change in a protein's structure at the secondary or higher level through the disruption of hydrogen bonds and disulphide links, can be caused by several agents, including ultraviolet radiation from the sun, acidic soils, salts, and heating. Although the higher levels of the collagen structure are disrupted in denaturation, the primary structure, i.e. the amino acid sequence of the polypeptide chain, may be retained in bone almost indefinitely in the right circumstances.

Proteins, because they are polar, interact strongly with water; but usually their large molecular size impedes their solubility. The effect of water on collagen is to disrupt some of the hydrogen-bonding, causing gelatinization of the protein. Heating also converts collagen to gelatin through pyrolysis.

The agents causing dehydration and denaturation of bone should play an important role in how easily dry bone is worked and in how well buried osseous material is preserved in the archaeological record. The position that prehistoric tool-makers preferred "green" bone to work rather than dry bone is contingent on the processes undertaken in the preparation and treatment of bone prior to artifact manufacture. If the bone is taken from meat that has been cooked, either by roasting or boiling, instead of being used immediately after the animal is killed, then some denaturation of the collagen has already occurred.

An important study conducted by Amprino (1958) on the physical properties of bone demonstrated that the condition of the bone greatly alters its hardness. Amprino defined hardness of a solid material as "its resistance to the penetration of another solid body" (Amprino

1958: 161). His findings are briefly summarized below. Firstly, the values of hardness were higher when collagen fibers were cross-sectioned than when sections running parallel to the long axis of the fibers were tested. Secondly, variation in hardness was caused by both the degree of mineralization and the orientation of collagen fibers. Mineralization is dependent on age and diet. Thirdly, hardness significantly increased as moisture content of the bone declined, but soaking samples in saline solution from 4 to 48 hours returned it to about the same hardness as that of fresh bone. Fourthly, bone hardness increased as it was heated in an oven up to 200° C, but from 200° to around 500° there was a decline in hardness. At temperatures slightly above 500° Amprino found that hardness again increased and continued to do so up through 800°, at which point the testing was discontinued.

The implication from this research is that the ideal time to work bone is when it is fresh and uncooked. If it has been air-dried or cooked at low temperatures much of its original softness may be restored by soaking for prolonged periods. Once the artifact has been manufactured it can be dried by heating to temperatures under 200° C to harden it. Heating to very high temperatures, e.g. above 500°, may increase hardness, but also risks shrinkage cracks and increases brittleness. Examples of excessive heat damage can be seen in artifacts and human bone in cremations where warping and cracking are extremely severe.

Shrinkage occurs as bone dehydrates, forming cracks which may be undesirable in artifacts. Experimentation on fresh fallow deer metapodials shows that within two hours after the periosteum has been removed from the bone's surface fine cracks begin to form, making a snapping sound. If a bone is split by the craftsperson when moist and shaped into smaller pieces that are under less stress dehydration shrinkage may be less likely to lead to faults in the material. An alternative to working the bone immediately is to store it under damp conditions, such as wrapped in wet leaves or hides or soaking it in a container of water until manufacturing begins. Soaking has the advantage of macerating any soft tissue that is still adhering to the bone so that the bone is eventually clean; but it may break down collagen fibers and affect elasticity.

Antler, Dentine, Enamel, and Ivory

Antler is true bone that grows very rapidly and is normally shed annually. Antlers are a pair of bony projections on the frontal bones of cervids that, with the exception of reindeer, caribou, and a few aberrant females of other species, occur only in males. Growing antlers are supplied with blood through vessels both within and outside the bony tissue. Grooves on the outer surface of dead antlers reflect the paths of blood vessels when the velvet was intact.

The gross structure of antler differs from other adult bone in that the cancellous bone lacks clear trabecular patterns or marrow cavity and the outer layer is not as dense as normal compact bone (Modell 1969: 120).

Despite the fact that antler is richly supplied with blood, it does not produce red blood cells. Only a small amount of fatty marrow is present in antler (Modell 1969: 119). Although it is microscopically most similar to the tissue of a malignant bone sarcoma, which also grows at a phenomenal rate, antler conforms to a rigid structural pattern in accordance with its species.

The unique design of antlers, being external and shed annually, has certain implications involving their use as a raw material. Chiefly, the animal need not be killed, or even seen, in order to utilize this by-product. Shed antlers were regularly collected where available, as is reflected by the appearance of the pedicle in archaeological specimens. If it has been broken away from the frontal, but still retains a part of the cranial surface, then the deer was killed, but if a rounded, finely pitted surface is present on the pedicle, then the antler was shed.

The form of antlers varies between species, within populations, and through the life of an individual. Such variation could have been exploited in the selection of antler as a raw material depending on the artifacts to be made. The proportion of cortical bone to cancellous bone is an important feature that affected the production of artifacts. Certain species, such as reindeer and caribou, generally produce antlers with thick compact bone and very little spongy tissue. This may lead to a conscious selection on the part of the craftsperson for those species which regularly yield antler with a high proportion of cortical bone.

Dentine forms most of the tooth and lies below the enamel. It is very similar in chemical composition to bone. Calcium phosphate is the predominant inorganic constituent, mainly in the form of apatite crystals. Collagen fibriles form the matrix surrounding them. Unlike bone, however, dentine contains no living cell bodies. The odontoblasts lie on the outer surface of the pulp cavity within the tooth and communicate with the dentine through tubules (Romer 1962: 303).

Enamel differs from bone, antler, and dentine in that it is extremely dense, hard, and relatively lacking in organic matter. In young enamel as much as 20% of its constituents may be proteins, but these decline to a very low level in mature enamel (Eastoe and Camillar 1971). The inorganic component is chiefly large prismatic crystals of hydroxyapatite. No amorphous calcium phosphate salts occur in adult enamel. The apatite crystals stand up on the dentine's surface and extend outward to the outer surface of the tooth. Each prism is separated from others by a thin layer of organic matter. No living cells are present in enamel, which is produced by the enamel organ in the epidermis above the tooth (Brown 1975: 322).

Elephant ivory is derived from the dentine of the tusks, or upper incisors, and is characterized by a unique cross-hatched grain of curving lines. It is denser than the dentine of other animals, but is remarkably elastic and flexible. The only enamel on an elephant tusk occurs at the tip while the animal is young.

Through its life the tip enamel is worn off. True ivory is superior to other so-called ivories for artifact fabrication not only because it has a fine grain, but also because it comes in large pieces and the pulp cavity of the tusk is relatively small. Walrus tusks have been used instead of ivory where available, but the dentine is less dense than that of elephant ivory and the pulp cavity extends far into the tusk, limiting the size of objects made from it. Whale teeth may also be used as a kind of ivory, especially by scrimshaw artists. The forty to fifty cheek teeth of the sperm whale and the single large tusk of the male narwhal are the most commonly utilized (Wills 1968: 18).

The Availability, Morphological Variability and Workability of Bone

The availability of bone as a suitable raw material for the manufacture of implements and ornaments is dependent on three factors: the variety of animal species within a reasonable distance from home base, the relative abundance of bone in comparison to other resources, e.g. stone, shells, or wood, and the recognition by the people of the animal products as resources. The extent to which cultures exploit bone is greatly modified by environmental factors. For example, the Inuit, inhabiting the polar regions, have traditionally relied heavily on bone and ivory in the absence of adequate supplies of hardwood; whereas tropical forest peoples often depend more on hardwoods or bamboo as raw material for analogous implements.

The wide range of morphological variation inherent in bone, antlers, and teeth enables artisans or toolmakers to be very selective in their choice of material. That human choice plays an active role in the manufacture of bone artifacts is readily apparent in the recurrent patterns in most assemblages. Selection occurs at three major levels: taxon, element, and portion of element. Between taxon and element there may also be selection based on sex, age, or size of the individual. For example, the decision to use antlers, horn cores, tusks, or the baculum (except for species in which the females have either of the first three elements listed) usually automatically involves the choice of male animals. For some artifacts it may be less desirable to use the bones of younger individuals because of the size and durability required for a specific task. The lack of epiphyseal fusion in immature individuals may make their bones less suitable where the morphology of the articular condyle is significant to the function or desired appearance of an artifact. Alternatively, the lack of fusion of an epiphysis may facilitate the manufacture of an artifact in which the removal of one articular condyle is necessary in order to form a working tip.

Selection of taxa to be utilized in bone artifact production begins with the hunter. Those species which are successfully hunted or trapped largely provide the raw material; but within the total sum of osseous material collected only a small portion is eventually used for artifact manufacture. Some may be eliminated because of ritual treatment of the remains of animals of a certain species. In other cases no use may have been found for bones of a particular type of animal, especially if it is rarely caught or slain. Although it is very difficult to substantiate archaeologically, it is known that preindustrial people often associate certain powers to animals and their byproducts, such as strength, cunning, agility, or aggresiveness. Particularly where teeth or claws of some carnivores are worn as ornaments the qualities attributed to the living animal may be just as or more important than the morphology of the element.

Decisions about which elements of a given animal would be used depended upon the intended use of the artifact and the morphology of the bones. Long bones were extensively used because of their length, durability, or their cylindrical diaphysis. Most awls were made from long bones because the shape is conducive to making a slender tool with an elongated shaft. Femora are round in cross-section and have a large marrow cavity, so they are well designed for making rings and beads. Flat bones, especially scapulae, are suitable for the manufacture of pendants. Mammal vertebrae are too irregular in shape to have been used very frequently in artifact manufacture. The four straight metapodials in artiodactyls were widely utilized for artifact manufacture because of their morphology and size. Elements like ulnae, fibulae, or metapodial splints that taper naturally at one end are well suited to the manufacture of pointed implements with little input of labor required.

Portions of elements were also selected according to shape and size. The articular condyle chosen to act as the handle of an implement was often the easiest to hold with minimal modification. If a piece was ornamental, such as a hairpin, a condyle which could be modified so as to resemble an animal or in a decorative manner might be retained. Sometimes the diaphysis alone may have been utilized with both articular ends removed.

Choices at all of these levels were made with concepts of durability, efficiency in manufacture and use, and aesthetic appearances in mind. This is not to suggest that decisions were made at every level for every tool. Most tool types were made on more than one kind of bone; but usually the bones selected for a tool category have features in common, such as shaft length, diameter, or straightness. Patterns of preference are generally visible, with certain taxa, elements, and portions showing a higher frequency than others for a particular tool type.

Bone, antlers, teeth, and ivory vary somewhat in their potential to be worked because of their thickness and relative density. The taxonomic group from which a bone is derived also influences whether the bone is thin-walled as in birds or leporids (rabbits and hares) or thick-walled as in large ungulates. The choice of element is important, since some bones have a very thin covering of compact bone overlying cancellous tissue, while others have a thick, durable compact layer surrounding a marrow cavity.

Beyond these factors, however, bone, antler, teeth, and ivory are comparable in their potential to be altered through certain manufacturing techniques. Like lithic implements (Deetz 1967: 48) bone artifacts are made by the removal of material. Unlike pottery, metal, and textiles, which involve additive processes, once material has been removed from a bone artifact during manufacture it cannot be replaced. Therefore, bone artifact manufacture is generally a reduction or subtractive process. There are some exceptions in which two or more component parts have been joined to make a complex tool (Balikci 1970: 18). Because bone working is normally subtractive, broken implements may be rejuvenated by making them into smaller tools. Recycling (i.e. converting used tools into different kinds of tools) and modification such as resharpening are important factors which must be considered, both in terms of the final appearance of an artifact and in estimating the use life of the object.

The efficiency of bone tools as opposed to implements made from other materials such as chipped stone or wood in performing a given task is an important aspect which is best investigated through experimental replication. Some tasks like sewing and basket-weaving require long, smooth, pointed implements, for which bone is the most suitable natural material; but if a keen cutting edge is required then bone is less desirable than chipped stone.

It may be demonstrated through prehistoric patterns of usage, ethnographic examples, and experimental replication that the decisions involved in selecting a particular bone to make a tool for a certain task are numerous and occur at several levels.

Chapter 3

Methodology

The methodology employed in this research involves the integration of analysis of microscopic traces, experimental replication, ethnographic analogy, contextual analysis, and quantitative methods. The analysis of artifacts has progressed significantly in the last decade beyond the simple recording of basic morphology, measurements, and location of discovery. Recent developments in artifact research involve close attention to minute detail, while numerous analytical approaches combine to recreate a relatively accurate account of the processes leading to the final product.

Attribute Recording

For each artifact in the study collections, an index card was filled out with archaeological, zoological, and artifact-related data. Figure 1 shows the format for recording data used in this analysis. Every artifact was examined with either a hand lens or a stereo microscope at magnifications of between 16 and 40 diameters to discover alterations in surface topography.

Provenance information was employed in the contextual analysis, though this was supplemented with field descriptions of associations between various kinds of artifacts and features when possible.

Zoological data such as taxon, element, pathologies, age, and sex criteria were carefully recorded for two reasons. Firstly, the recording of all information normally noted for unmodified bone by the zooarchaeologist provides the researcher analyzing the faunal material

Figure 1

Bone Artifact Recording Form

Site Name or Number   Artifact Catalogue Number

Provenience   Date of Excavation

Artifact Type

Taxonomic Identification of Bone

Element   Side

Portion of Element

Other Zoological Data (epiphyseal fusion or other age criteria, sex criteria, pathologies, anomalies, etc.)

Natural Surface Modification (animal gnawing, root etching, weathering, water rounding, etc.)

Breakage (old or fresh, spiral, transverse, longitudinal, impact, etc.)

Burning

Manufacturing Traces

Use Traces

Postexcavation Treatment (cleaning, coating with preservative, removal of calcium carbonate, etc.)

Measurements

    Length

    Maximum Width

    Distance from Tip to Location of Maximum Width

    Tip Width (5 mm from end)

    Tip Thickness (5 mm from end)

Other Remarks

Drawing in plan and cross-section on reverse.

with additional clues as to the utilization of animal products. It may also yield new taxa not identified among the bulk bone fragments. These data derived from the bone artifacts should then be incorporated with data for the entire faunal assemblage. Secondly, patterns of selection of raw material for bone artifacts based on taxa, age groups, elements, portion of elements, etc. will only become apparent if the zoological attributes are recorded whenever possible.

Considerable emphasis is placed on alterations in surface topography and condition in this study. This encompasses natural modifications such as rodent and carnivore gnawing, root etching, weathering, and water rounding, as well as cultural modifications such as manufacturing and use traces. All of these features provide important clues in reconstructing the history of the artifact from the craftsmanship of making the implement, through its use, to its depositional environment.

Postexcavation treatment simply refers to whether the bone was cleaned to remove calcium carbonate or coated with varnish or polyvinyl coating to preserve the surface. Most of the material from Ulu Leang I and Leang Burung I required some cleaning to lift off the layer of calcium carbonate that obscured surface topography and microwear. This was accomplished by gently prying the carbonate off with the edge of a sharp scalpel blade. Use of a dilute acid solution was rejected since this can damage the bone surface or erase microwear and is difficult to control. It was decided that the few marks left by the scalpel were easily recognized and were limited enough that no information about microwear was lost through this method. The excavators on a few occasions found it necessary to coat a small number of bone artifacts that were in a very friable state in order to prevent exfoliation of the surface. This coating usually disguises polish and all but the most pronounced traces of manufacture and wear, so it is advantageous to note such treatment.

The quantitative data that were recorded for many of the artifact types consisted only of length, maximum width, and thickness. For all long, slender, pointed or spatulate tools, however, a combination of five measurements was taken where possible. The goal of this metric analysis is to sort out some of the tool types by function based upon their morphology, proportions, and size.

Terminology

Standard anatomical terms were used for natural features of the bones (Fig. 2), maintaining orientation words such as medial, lateral, proximal, and distal as references to position of the element in the articulated skeleton. Diaphysis is the term applied to the main body of the element, excluding the articular ends, or epiphyses. The term "shaft" is reserved for the portion of the artifact between the base and tip or working end. Illustrations of artifacts are generally oriented with the working part at the top of the page and the base at the bottom (Fig. 3). An exception would be a sounding rasp, innominate beamer, or other implement having its working edge located parallel to the longitudinal axis of

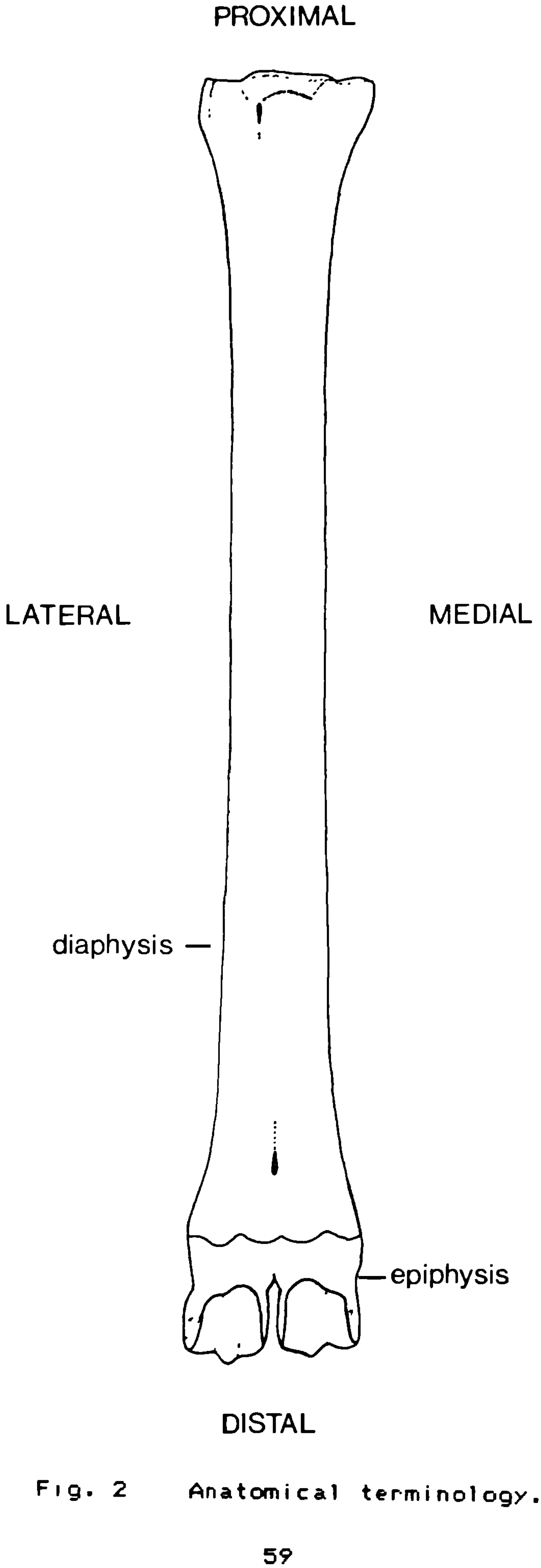


Fig. 2 Anatomical terminology.

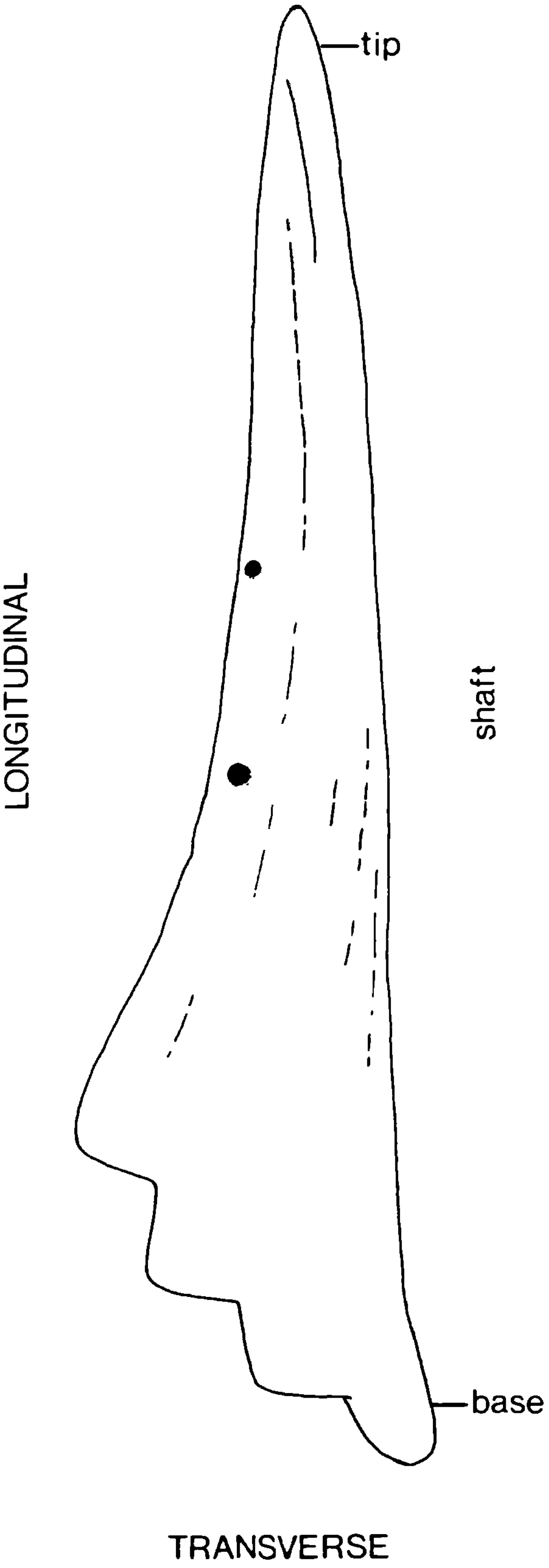


Fig. 3 Artifact terminology.

the bone. In these cases the artifacts will be oriented with the proximal end of the bone at the top of the page. Ornaments are illustrated in the position in which they were presumably worn.

Quantitative Methods

The predominance of long, narrow, pointed objects within most bone artifact collections necessitates quantitative, as well as qualitative, means of distinguishing different types. For example, in examining hundreds of awls and hairpins from Point of Pines, Arizona, and other Mogollon culture sites it became apparent that hairpins had stout tips that were either oval or concavo-convex in cross-section. Awls were usually sharper, thinner, and rounder in cross-section. The projectile points from Tell Abu Hureyra, Syria, and Ulu Leang I and Leang Burung I, Sulawesi, were round in cross-section like most awls, but were larger in diameter near the tip (measured 5 mm from the end of the tip) and the maximum width of the shaft was located about the mid-point. Awls tended to flare out toward the base.

Many factors make it difficult to establish a method for categorizing tip and shaft morphology with a concise set of measurements. Tips may range in cross-section from triangular to round, ovate, lenticular, concavo-convex, rectangular, and irregular in shape. The cross-section changes as one progresses from the tip towards the base, so that where the measurements are taken determines what the cross-section will appear to be. Asymmetry occurs when the angle of taper toward the tip is different on either side or the point of inflection occurs higher on one side than on the other. Sometimes the inflection is so gradual that no distinction can be made between the tapering of the shaft and the convergence of the tip. Resharpening and use alter the morphology of a tool through its use life. The thickness and diameter of the bone selected to be made into a tool are contributing factors in the fineness of the point and the shape of the cross-section. The tip of a tool made on a thin-walled long bone of a bird or small mammal can be shaped and resharpened into a fine point more easily than one made from a thick-walled bone. The diameter of the long bone diaphysis and its curvature can affect the cross-section of the tip if minimal modification has taken place, such as in the case of utilized splinters or if the tip is very broad, as in spatulae.

A combination of factors, such as the bone selected as raw material, the method and amount of manufacturing employed, the tool function, and the amount of use and resharpening, may contribute to the final morphology in a manner that renders every implement unique. For this reason only five measurements have been chosen in order to highlight the most important features of these artifacts and attempt to demonstrate trends for separating tool types. The frequency of breakage among archaeological bone artifacts, occurring either during use or post-depositionally, hinders quantitative studies because measurements require that the complete dimensions be present. For certain artifact types the sample sizes were originally quite small, but the elimination of artifacts too incomplete to be measured has further decreased their frequencies. Interpretations based on small sample sizes must be approached with caution since the graphs might exhibit different trends if the collections were much greater in size.

Five basic measurements were taken with the realization that many more would be required to fully describe each artifact's unique morphology. The measurements selected in the end were those which seemed most meaningful in distinguishing types and which were most feasible given the fragmented state of many of the artifacts. Below are brief descriptions of the measurements taken on long tools with the working surface at the end.

A. Total length: on objects retaining their original longitudinal dimension, this is the maximum distance from base to tip.

B. Maximum width: on complete objects, or those in which it is clear that the maximum width is still preserved, it is the greatest dimension measured perpendicular to the length. The term "width" is not used here in the same way as it is in anatomical studies in which it must always refer to measurements taken medio-laterally. In this case it is independent of the orientation of the bone in the animal's body.

C. Location of maximum width on shaft: the distance from the tip to the position on the shaft where the maximum width is taken. This measurement is taken on objects retaining their tip intact.

D. Maximum width 5 mm from the end of the tip. This measurement requires that the t p be intact.

E. Maximum thickness 5 mm from the end of the tip: the measurement taken perpendicular to D. This measurement requires that the tip is complete.

Metal sliding calipers were used to measure the artifacts. Measurements D and E were taken by placing the artifact on a measuring board to locate the line 5 mm up from the tip on graph paper on the board. The calipers were placed at the 5 mm line to measure the width, then the artifact was rotated 90° so that the thickness could be measured.

Figure 4 presents a schematic view of an artifact displaying the five basic measurements and Figure 5 shows the three kinds of scatter diagrams used to plot the measurements. Scatter diagram 1 displays the relationship between maximum width and total length. It is a very general way of expressing overall morphology. Unlike a simple ratio B/A, the two-dimensional graph has the advantage of providing absolute size differences. In addition to showing the relative slenderness of a tool, it also exhibits the range of lengths and widths for each tool type, based on complete specimens. Needles and pins have a low ratio because they are long and slender, whereas utilized splinters and splinter awls have considerable variation in the width/length ratio. Projectile points tend to be rather uniform in absolute width and length.

Scatter diagram 2 represents the location of the widest part of the tool on the shaft. The location of the maximum width may be expressed as a ratio of C/A. On

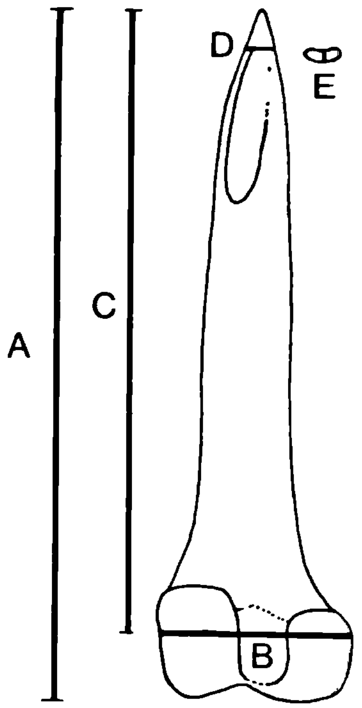
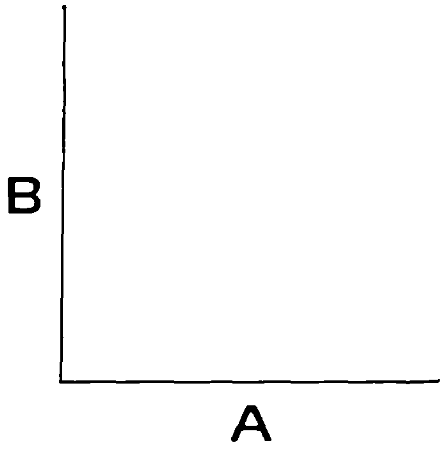
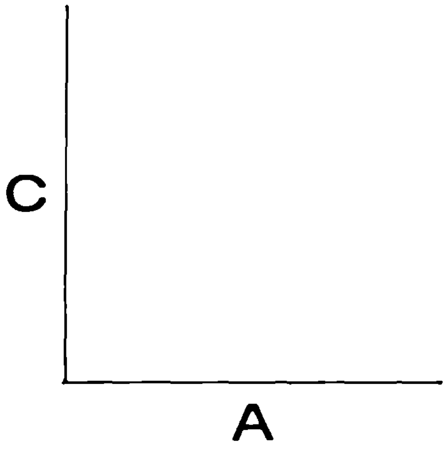


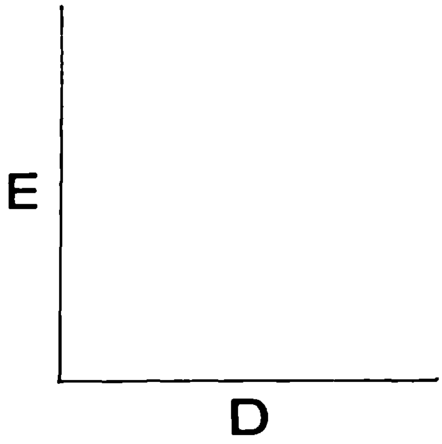
Fig. 4 Five measurements employed in metric analysis of pointed or spatulate implements.



1. Gross dimensions



2. Location of maximum width on shaft



3. Tip dimensions

Fig. 5 Three scatter diagrams used for plotting the five key measurements.

the scatter diagram this is shown by plotting the total length along the X axis and the distance from the tip to the widest part of the tool on the Y axis. Implements that flare gradually from the tip to the base will be represented by dots just below or nearly on a line bisecting the graph at a 45^{o} angle. None of the dots will appear above that line since it is impossible for C to be greater than A. Great variation occurs in some tool types, such as splinter awls and utilized splinters. Needles and pins display a tendency for the maximum width to be very near the base. Awls with an articular condyle retained as the base show a definite trend toward having the widest part of the implement at the base. The exception is the case of ulna awls due to the fact that the wide articular surface is somewhat closer to the middle of the shaft and the narrower olecranon process is at the base.

Scatter diagram 3 expresses tip morphology based on the width and thickness as measured 5 mm from the end. Round, triangular, and square tips may all have about equal width and thickness and hence will be represented by dots on or just below a line bisecting the right angle formed by the intersection of the X and Y axes. The tips of awls show great consistency in size regardless of their overall morphology or location of the widest part of the tool. This may be due to the fact that the tip is the functional part of the tool and is hence more restricted by factors relating to the efficiency and effectiveness of the piercing implement. For awls the tip tends to be round in cross-section or at least has a thickness nearly equivalent to the width. The diameter of most awls at this point is between 1 and 3 mm. Needles and pins are usually under 2 mm. Utilized splinters demonstrate a wide variation in tip dimensions because by their definition they have had no modification such as scraping or abrading performed at the tip. It is possible that fortuitous splinters with narrow tips were used as awls, while those with broad tips were adopted as spatulae, but the microwear patterns on the utilized splinters from Tell Abu Hureyra do not lend support to this hypothesis. Instead, the wear traces on utilized splinters appear distinct from those on other artifacts.

Metric analysis conducted on the specimens in these collections shows general trends among the tool types, but does not delineate groups based solely on proportions or absolute size. While size, cross-section, and general morphology are basic criteria for distinguishing tool types, no single group of measurements can be shown to set up nonoverlapping classes of objects. Microwear traces often assist in assigning a function to a particular artifact, but there is still a limited number of objects that are marginal and difficult to place under a single typological heading.

Scanning Electron Microscopy

The surface topography of bone records and preserves its history, including such features as the nutrition, health, and age of the animal, butchering techniques, the types of tools used in butchering, traces of manufacturing and use on bone artifacts, and natural modification formed just prior to or subsequent to deposition in the archaeological record. Interpretation of surface topography is therefore an important aspect of both zooarchaeology and the analysis of bone artifacts.

The study of microtopographic alterations in bone has made significant contributions to our understanding of bone artifact technology (Semenov 1964). In most cases monocular or stereo optical microscopes have been utilized at low magnifications. The scanning electron microscope, however, has proved to be extremely valuable in paleontology in the identification of dental wear patterns in extinct species (Wyckoff 1973; Walker 1980) and taphonomic processes affecting bone (Shipman 1981; Shipman and Rose 1983a). In archaeology the SEM has been applied to the examination of drilling in human teeth (Gwinnett and Gorelick 1979), engraving in Near Eastern seals (Gorelick and Gwinnett 1979), and in lithic microwear analysis (Unger-Hamilton 1984).

One of the purposes of this research is to determine the optimal techniques and methods for the investigation of microscopic traces on bone artifacts with the SEM. Many of the difficulties encountered are specifically related to the nature of osteological material, i.e. its size, structure, and porosity; whereas other problems pertain to the conservation measures associated with the care and handling of fragile prehistoric objects.

The application of scanning electron microscopy is not strictly a substitute for optical microscopy. Because both instruments have strengths and shortcomings, any thorough analysis of microtopography, whether of bone, lithics, or other material, should incorporate both forms of microscopy in a complementary program.

Preliminary analysis of the microtopography of the bone artifacts involved examination with a hand lens and a stereo microscope at magnifications ranging from 16 to 40 diameters. Because of the excellent state of preservation of most of the artifacts, this method proved quite informative for general observation. The SEM was used on representative samples of the various natural and cultural surface modifications. The major factor limiting the number of samples examined with the SEM was time. Most of the other difficulties encountered were overcome with several techniques described below.

Scanning electron microscopy employing the secondary electron emission, or "normal", mode, is designed primarily for revealing the three-dimensional outer structure of thick, opaque objects, so it is well suited for the analysis of microtopography on bone. Electron microscopes were developed to enhance resolution at high magnifications. The effective limit with optical microscopes is around 1500X, with a resolving power of .25μ at best. Resolution in a scanning electron microscope, alternatively, can approach 100 Å. Improved resolution is an important feature of the SEM when residues, embedded particles, or very fine wear patterns are examined, but because microscopic surface analysis of bone largely utilizes magnifications below 200X a fine quality optical microscope normally has adequate resolution.

Perhaps more critical to the archaeologist is the increased depth of field provided by the SEM. This feature represents a marked improvement over optical microscopes, since it is over 300 times greater with an electron microscope (Ruckman, Larner, and Smith 1976: 264). Optical microscopes limit the area in focus at one given moment to a very shallow plane, requiring the operator to adjust the focus knob gradually to greater distances. The object's surface, unless very flat, is never sharply focused throughout with an optical microscope. This factor has proven a major disadvantage where photomicrographs are published in papers about microwear since interpretation of traces is difficult when most of the image is out of focus. The only negative aspect of the expanded depth of field in the SEM is that depth perception may decrease, causing the surface topography to appear somewhat flattened. Tilting the stage improves depth perception, but the optimal solution is to produce stereo pairs of electron micrographs.

The third major advantage of the SEM is the broad, and more or less continuous, range of magnification from as low as 10X at times to as high as 100,000X or more. Generally, optical microscopes have only three or four magnifications to select from and the range is much more restricted.

In contrast, the major disadvantages of the SEM are: specimen size limitations, availability and/or cost of operation, and the lack of color and polish visibility in the image. Preliminary observation in this research utilizing an optical microscope was directed toward locating microscopic surface traces, studying variation in surface polish, and noting changes of coloration due to charring, soil staining, or the presence of pigments. Later stages of the analysis employed the SEM to further discern wear patterns, search for embedded particles, and photographically record microtopography.

Most critical to the application of the SEM to the study of bone artifacts is the fact that the electron beam is transmitted through an evacuated column. Electrons have no penetrating power through normal air, but can travel reasonable distances through a vacuum (Hawkes 1972: 6). This requires the specimen to be placed in a vacuum chamber. The chamber is the limiting factor for specimen size. The dimensions of the chamber and the amount of movement the stage has within it are quite variable and depend on the age of the SEM and the purpose for which it was originally designed. Recent models designed to accommodate large biological, geological, or industrial specimens are best suited to the analysis of bone artifacts. Those with large chambers generally have stronger vacuum pumps as well, enabling rapid evacuation of the chamber in spite of the porosity of most archaeological bone. Despite improved vacuum pumps, all but the smallest and densest samples of archaeological bone require preliminary desiccation.

The desiccating procedure involves placing the bone objects to be examined into a glass desiccator under a vacuum with silica packets for 24 to 48 hours prior to viewing. The outgassing of the bone draws out most of the moisture, which is then absorbed by the silica packets. By placing specimens in a desiccator prior to examination, it is possible to expedite evacuation of the SEM vacuum chamber when the specimen is in place, thus greatly reducing operating time. Specimens should be kept in the desiccator until shortly before being placed in the SEM chamber, so that they do not become rehydrated during the interim.

After drying, the object may require coating to improve its conductivity. A thin carbon or metal coating (about 50 to 200 Å in thickness), if properly applied in a vacuum evaporator or with a sputter coater, accurately retains the surface topography while inhibiting static charging. Charging occurs when a specimen is not sufficiently conductive (Heurle et al. 1972: 76-77) and is caused by an accumulation of electrons on the surface of the object (Muir and Grant 1973: 328). When these electrons sporadically discharge the result is a white halo around the edges of the object, a bright flare in spots, or static on the cathode ray tube (CRT) display. The problem is especially acute with friable bone or experimental pieces which may have considerable amounts of loose particles on the surface. In the image unattached soil particles or wear debris may be surrounded by a dark area as a result of charging. The edge bright-up effect which is often quite pronounced may interfere with the viewing of microwear.

Metal coatings also dissipate heat at the specimen's surface created by the electron beam knocking off secondary electrons. The build-up of heat may lead to beam damage and result in an eruption or erosion of the bone surface in the scanned area when the object is viewed for an extended period of time using a high accelerating voltage or a rapid scanning speed (Fig. 6).

Although coating decreases static charge and inhibits heat damage, it is generally not desirable to coat archaeological specimens for several reasons. Museum conservators recommend avoidance of any unnecessary chemical applications to specimens, especially to those of great antiquity, scientific importance, or rarity. The maintenance of the integrity of the piece allows the object to be observed by other researchers or as an exhibit in a state most similar to its original condition. In addition, many additives or coatings have deleterious effects in the long term and may interfere with or negate future chemical testing. If X-ray microanalysis or some other surface analysis is to be conducted on pigments or residues, then metal coating is not a viable procedure. Alternatively, it can be argued that the sacrifice of a few fragmentary specimens from a large sample may yield enough important information to outweigh the negative aspects. This decision is best left to the combined discretion of the conservator and the researcher, but reproduction through moulding and casting is one possible way of avoiding coating.

It has been suggested that aluminum coatings may be subsequently removed with sodium hydroxide solution (Sylvester-Bradley 1969) or sodium hypochloride. A plasma asher may be used to oxidize carbon coatings, while gold

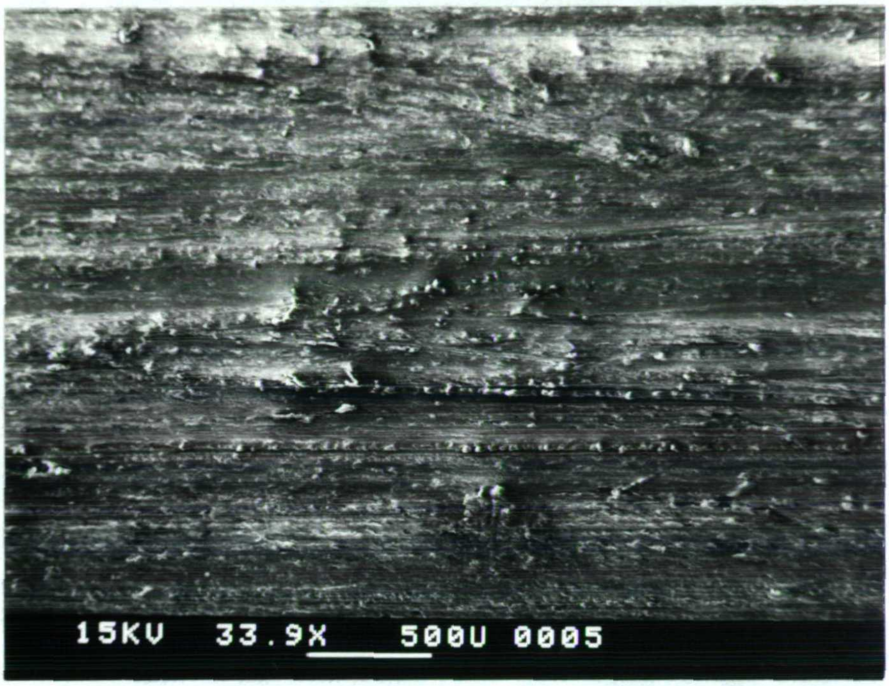


Fig. 6 Beam damage and charging on experimentally scraped bone caused by using a rapid scanning speed for an extended period. Note the small, bright prominences surrounded by dark areas in the photograph (33.9X).

or gold-palladium may be eliminated with potassium cyanide. The results can sometimes be destructive to the bone, however, as has been noted for sodium hydroxide solution (Muir and Grant 1973: 328). Sodium hypochloride continues to destroy bone by causing the surface to become brittle and chalky even after long periods of washing in plain water. Potassium cyanide is extremely dangerous to use because of its lethal nature and can be less than satisfactory for removing coatings on some specimens. The best policy is to carefully evaluate the need to coat and the type of coating most appropriate for the analysis and to treat the coating as more or less permanent.

An intermediate solution to charging is the use of a transparent anti-static spray that is soluble in water. Anti-static sprays decrease charging without visually altering the specimen. Although specimens coated with anti-static spray may be rendered less valuable for some future types of chemical analysis, they are unimpaired for photographic or exhibition purposes. There is no evidence at present that anti-static coatings have any long term deleterious properties when in contact with bone, but those that are water soluble may be largely removed by soaking. The reduction in charging after the application of an anti-static coating is effective for a brief period of perhaps about one half hour so it must be applied shortly before placing the specimen in the SEM chamber.

The nature of the archaeological bone material used in this research permitted observation with the SEM without coating in most cases. When charging became a serious problem other specimens were substituted, the object was coated with anti-static spray, or a silicone rubber mould was made. Modern experimental bone artifacts, made to replicate manufacturing and use traces, may be coated with gold-palladium since they are of no intrinsic archaeological value. To achieve the highest resolution with minimal charging a thin coating of gold-palladium alloy was applied with a sputter coater so that the coating was uniform.

Lowering the electron beam's accelerating potential to minimum voltage (10 Kv or less) and increasing the working distance by lowering the stage reduces charging and enables uncoated archaeological specimens to be viewed at low magnifications (generally under 500X). The greater the time the specimen is exposed to electron bombardment, the more charging and beam damage may occur, so duration of exposure is also an important factor. Reducing scanning speed is another means of minimizing the charging effect and beam damage. Although good quality micrographs were often obtained without coating archaeological specimens, it should be noted that the problem of charging is highly variable depending on the individual object and its preservational condition. Difficulties increase as higher magnifications are needed.

Because most electron microscopes are designed primarily to accommodate small specimens, the stubs upon which objects are mounted are usually only 1cm in diameter. In order to secure larger artifacts in the vacuum chamber so that they could be tilted and rotated a larger specimen mount was necessary. A specially designed brass plate with a diameter of 10 cm and four notches spaced around the circular margin allowed large objects to be secured with brass wire stretched over the upper surface or wrapped around the artifact. Smaller artifacts were held by a piece of double-sided tape, but since this can increase charging by insulating the specimen, a very small piece was used. A wire running over the surface of the bone helps drain the accumulation of electrons on the surface. The silver dag and other adhesives normally used on scientific specimens are not advisable for archaeological bone for conservation reasons. Adhesives may pull pieces of the surface off when removed, cover or destroy wear traces, or have other deleterious effects years after application. The irregular surfaces and heavy weight of many bone artifacts also complicate the use of adhesives, so complete avoidance is recommended for archaeological specimens. The experimental pieces, in addition to coating, may be attached to the mount with silver dag or sectioned into pieces small enough to be accomodated on a standard stub.

Molding

There are situations in which, because of prudence or necessity, the original artifacts cannot be studied directly with the SEM. The solution to this problem often can be found in the application of molding techniques. A few reasons for making molds of surface topography of bone artifacts are given below (see Pameijer 1978, 1979).

1. The object is too valuable scientifically to be viewed with the SEM directly because of risk in handling or possible beam damage.

2. The object is only available with limited access, e.g. it is in another country or cannot be removed from the museum or institution in which it is housed and no SEM is present on location.

3. The object is too large or too porous to be accommodated by the SEM vacuum chamber and have the chamber properly evacuated.

4. The object cannot be coated for viewing, but is insufficiently conductive without coating.

5. With experimental replications of artifacts, longitudinal studies concerned with topographic changes over time through overlapping of different manufacturing patterns or progressive use wear may be desirable.

6. When a nondestructive means of obtaining a cross-section of the surface is needed the mold may be sectioned with a fine scalpel.

When compared with other molding materials silicone rubber has numerous advantages in producing negative replicas of archaeological objects. Silicone rubber has an extremely accurate reproductive quality (Pameijer 1978; Larsen 1979). It is resistant to deterioration caused by light, air, or ozone, stable in a wide range of temperatures (-100^{o} C to 260^{o} C), adhesion repellent, and physically inactive when hardened (Larsen 1979: 15). The linear shrinkage of silicone rubber is less than 0.6% when prepared correctly (Larsen 1979: 16). Although it should not be applied to very friable bone, it normally releases readily from solid bone without the aid of a releasing agent. This is important because releasing agents reduce the amount of fine detail that can be reproduced in the negative replica.

For this research Dow Corning Silastic 9161, available in Britain, and Silastic 3110, available in the United States, were used because they have several advantages over other types of silicone rubber. Silastic has the consistency of thick cream, so that it flows into very fine striations and pits on the bone surface. The reproductive quality is thus sufficient for microscopic analysis at high magnifications. Vulcanization occurs at room temperature, thereby easing preparation. The tensile strength is about 120%, which is much lower than that of other brands. The lower tensile strength means that if the mold should resist separation from the artifact the mold would tear rather than causing breakage of the fragile specimen. Finally, compared to other brands of silicone rubber, Silastic is relatively inexpensive. It is important when viewing a silicone mold in the SEM to maintain an accelerating voltage of 15 Kv or less to prevent damage to the mold. In this study the Silastic 3110 was particularly susceptible to beam damage even when coated with gold-palladium.

To prepare the bone surface for molding it is important that it be free of dust, dirt, and mineral deposit. Gentle washing with water removes loose dirt, but occasionally calcium carbonate must be lifted off delicately with a scalpel blade. Care must be taken to prevent damage to the surface with the scalpel, but if fresh cut marks occur they should not be included in the area to be molded. It is important not to apply the molding material over varnish or polyvinyl coatings, since these alter the surface topography. The silicone rubber should not be allowed to flow over provenance information or catalogue numbers written on the surface in ink because the rubber may remove the ink from the artifact. It is also prudent to avoid molding over a surface that is exfoliating or has deep cracks into which the rubber may flow. Silicone rubber may make bone unsuitable for radiocarbon dating, so the choice of artifacts to be molded should not include material needed for dating (Larsen 1979: 38).

The production of silicone rubber molds of small areas of bone artifacts is relatively easy and requires little time. The only equipment that is needed consists of: waxed paper cups, a wooden spatula, a pipette (preferably disposable), a scale, and capped vials for storing the finished molds.

The silicone rubber is first stirred thoroughly for a few minutes to mix fillers that tend to settle out. The amount to be used is poured or spooned into a waxed paper cup and weighed. The proper amount of catalyst s determined by weight according to the manufacturer's instructions and desired setting time. Because the catalyst deteriorates through time, it is wise to experiment with a small sample of rubber on something unimportant to insure that enough catalyst has been added to initiate hardening. The catalyst is a peroxide and as such should be handled with great care to avoid contact with the skin or eyes. After carefully adding the catalyst to the rubber with a pipette, the two components are thoroughly blended with the wooden spatula. A longer setting time is preferable in order to allow air bubbles to escape for two or three minutes before applying the rubber to the bone surface. Larsen (1979) recommends applying the rubber in two stages to minimize air bubbles on the surface in contact with the object. Firstly, a thin layer is applied with the spatula so that it flows across the surface, allowing it to harden for approximately one hour. Following that, more rubber is applied to build up the mold's thickness so that it can be removed and handled without tearing. The mold should be kept in place for 24 hours and will be completely dry in about 72 hours. Because silicone rubber is easily contaminated by dust and fingerprints, the replica surface should not be handled. To maintain pristine molds they should be immediately placed in clean vials with caps. In preparing the molds for viewing with the SEM it is best to coat them with about 150 Å of gold-palladium alloy in an evaporator. Sputter coaters may cause deformation of the mold (Pameijer 1979: 572).

The negative replica in this case was used directly in the SEM without the production of a positive cast. The reasons for employing a reversed replica of the surface microtopography are threefold: the elimination of the difficult process of making epoxy casts, the greater accuracy of detail found in the initial mold, and the fact that observing striations and pits converted into ridges and prominences is sometimes more informative than looking at the original recessed features.

If a positive replica is to made, then the mold should not be coated with gold-palladium. Epoxy resins have been found to be very successful (Walker and Long 1977; Shipman 1983), but even with them considerable loss of accuracy in detail may occur (Pameijer 1978).

One of the most useful applications of silicone rubber molds is in discovering the morphology of profiles of surficial traces. To learn what the profile of a pit or striation in bone is characterized by molds of surface topography were sectioned with a sharp scalpel and cut into narrow strips. Each strip was then mounted on edge on a stub with an adhesive so that the profile could be viewed in the SEM. The profile of the mold is the reverse of the actual specimen's profile, which is sometimes difficult for the reader to interpret readily. To present these profiles visually the SEM micrographs were blown up to 8" by 10" photographs and the outline of the profile was drawn over with a pen. The photograph was then bleached so that only the ink outline of the profile remained. These profiles are presented in a reduced form and in the proper position so that the bone's surface is at the bottom of the illustration. Since measurements were not taken from these profiles and the magnification was increased beyond that needed to delineate the salient features, the accuracy of this method appears to be quite adequate for differentiating many types of marks. Traces derived from natural and cultural processes were examined in this way. The strips were long enough so that numerous examples of the marks could be examined from one specimen. Molds of each type of mark were made from several specimens in order to confirm shared characteristics. With the information from the cross-sections added to that obtained from SEM micrographs of the surface it is possible to improve the confidence level of identifications of surface alterations.

Photomicrography

The greatest advantage of scanning electron microscopy in artifact analysis is the ability of producing photomicrographs of three-dimensional objects with high resolution and a great depth of field with minimum effort. The size format of the negative depends on the camera attachments available for the SEM which is being used. One of the best combinations available today is the Polaroid Land 4" X 5" Type 55/Positive-Negative film. This provides an instant positive print and a 4" X 5" negative that requires only fixing in sodium sulfite and rinsing. The print immediately informs the researcher if the contrast and brightness are properly adjusted, if the image conveys the desired information, and if charging is interfering with resolution. The large negative size allows considerable enlargement without the graininess of 35 mm film.

The instant prints have less contrast than prints processed in the normal way from the negative using medium contrast paper or filters. This should be considered when adjusting contrast on the SEM after examining the Polaroid prints. In addition, the instant prints are often not of the same archival quality as those developed in the traditional manner. If they are not uniformly coated with the protective coating included in the film box within five minutes of developing, then fading can occur over a period of a few months. Because of the better contrast and greater longevity it is recommended that the instant prints be supplemented with contact prints or enlargements processed to archival standards.

The advantages of using the larger format film are the improved resolution and the handiness of making large contact prints. There have been criticisms leveled at users of 35 mm film with scanning electron microscopes, since the benefits gained by using an expensive SEM as opposed to an optical microscope are partially negated by the poor resolution in enlargements made from 35 mm film (Muir and Grant 1973: 317-18). There are other alternatives, such as normal 4" X 5" film and 70 mm roll film which are less expensive than the instant positive-negative film. The extra cost of using the positive-negative film should be weighed against the delays and costs of using large quantities of regular film, processing in a dark room, and returning to retake failures. Since SEM operating time is costly and usually limited, the extra expenditure on film may be compensated by other factors. In this study both 4" by 5" instant print film and 70 mm roll film were employed.

Stereo-pairs of scanning electron micrographs reveal information about the width-depth proportions of surface features and the relationships between different structures on the bone surface that cannot be clearly discerned in a single image (Fig. 7). The Polaroid-Land film, if used, allows the researcher to see a stereo image while the specimen is still in the chamber (Boyde 1971: 4). The specimen is photographed once, tilted 7 to 10°, refocused, and photographed again in the new position.

The angle of the tilt that gives the most realistic stereo view depends on the subject. If the vertical measurements seem extreme, then the angle is too great. If, on the other hand, the surface appears too flattened, then the angle needs to be increased (Muir and Grant 1973: 319). Taking stereo micrographs is greatly facilitated if the tilt angle can be accurately controlled. Most recent electron microscopes are equipped with knobs that show the angle of the tilt with reasonable precision. It is important that the tilt axis of the stage should correspond with the line axis of the image on the cathode ray tube (Boyde 1970: 108). If the images are photographed at 5° on either side of normal incidence, then there should be no noticeable change in magnification from one edge of the image to the other (Boyde 1970: 111). After tilting the stage the specimen requires refocusing. This should be done by raising or lowering the stage with the Z control rather than with the focusing knob, which rotates the image slightly as the final condenser lens is focused (Boyde 1970: 108-109).

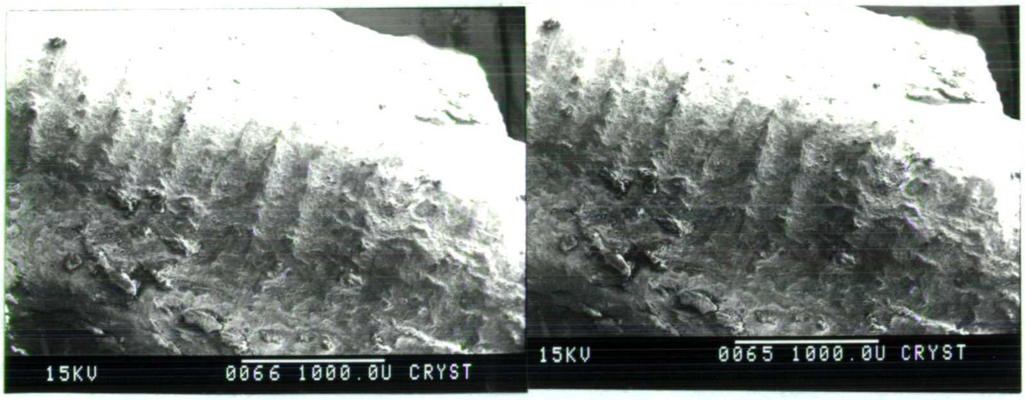


Fig. 7 Stereo pair of rodent gnawed archaeological bone (36X).

Experimental Replication

The importance of experimental replication is that it tests hypotheses about past human behavior by simulating the conditions that formed the archaeological evidence. Because most scholars studying prehistoric cultures are far removed from societies possessing primitive technology, hypotheses about how an archaeological object was made or used involve substantial guesswork. Experimentation, adhering as closely as possible to ancient conditions, may demonstrate the practicality and efficiency of the hypothesized manufacturing technique or use, as well as indicating how a tool was probably held and operated. Experimental replication is not restricted to answering questions about artifacts, since features, architecture, and even entire sites may also be the subject of experimentation (Ingersoll, Yellen, and MacDonald 1977). Since the emphasis in this study is on one specific kind of artifact, i.e. those made from bone, the discussion of experimental replication will be limited in scope to techniques which elucidate the manufacture and use of artifacts.

The archaeologist is not normally in a situation in which there are no clues for the function of an object, although he often faces the problem of eliminating some of the suggested uses. Lim tations that restrict the possibilities are the narrow range of materials, products, activities, and occupations available to, for example, Neolithic societies. Ideas for the use of an implement are frequently derived from knowledge of the material culture of extant preindustrial societies or, more rarely, from items in our own past or present inventory of goods. Despite the multitude of known tools from ethnological examples, there is always the possibility that the method of manufacture or the function of an implement has been abandoned prior to historic times or is not described in available literature. In this case the archaeologist has no analogy to apply to the prehistoric object. Experimentation on a variety of materials available to the past culture coupled with microwear analysis may shed light on the possible function of the implement.

The complexity of a tool's morphology may furnish clues about its function. Simple artifacts such as bone points are sometimes difficult to assign specific functions since objects of the same morphology may be used in many ways. For example, a small point could be hafted to an arrow shaft, mounted on fishing equipment, or in some cases used as an awl. More complex or specialized tools, such as combs may be easier to relate to a limited function.

The analysis of traces is important in supporting or refuting the experimenter's proposed method of use. Since striations and polish can provide information about how the tool was held, the directionality of movement when used, the location of the working edge or surface, and the material upon which it was used, microwear analysis is a valuable aid for the experimenter working with bone.

Coles (1979: 38) outlines three levels of experiments. The lowest is copying the original morphology of an artifact without adhering strictly to the same types of materials or manufacturing techniques employed in the original or testing its use or function. The second level involves making a replica using the technology and materials available to the ancient craftsperson in order to duplicate the original as closely as possible. The third level goes beyond manufacture and attempts to replicate function, including how the tool was manipulated and in what environmental circumstances it was used.

Individual strength and ability, as well as familiarity with the materials, are important factors in experimental replication. In the case of bone certain preparatory steps, such as using the bone immediately after butchering the animal or soaking it for several days to restore moisture, ease the manufacturing process. The initial attempts to make or use a replica may not be adequate tests of the feasibility or efficiency of the method. Greater confidence in the results may arise from repeated trials. Timing a manufacturing process or a simulated task may be of little practical use and may actually mislead the archaeologist if adequate proficiency is not first achieved. Microscopic surface patterns created by the novice experimenter may vary considerably from those formed by an ancient master craftsperson and this can be a guide in determining proficiency.

Chapter 5 describes details of the experimental replication performed in this research. Limited simulation of natural processes which alter bone, such as weathering and carnivore gnawing, were conducted, but the primary emphasis was on attempts to replicate manufacturing and use for the various artifact types in the collections. During experiments efforts were made to utilize manufacturing tools that have been documented as present or were known to have been developed in the region at the time of the site's occupation. When available the bone debitage and partially finished artifacts were analyzed in order to reconstruct the stages of manufacture. Microscopic traces created through manufacture served as the major guide as to how tools were made.

Experimental replication simulating artifact function relied partially on the direct historical approach (in the Point of Pines case study) or ethnographic analogy and partially on microwear analysis for clues to several possible alternative uses. In most cases the morphology of the tool greatly restricted the range of probable functions. In a few instances experimental replication and subsequent microwear analysis of the replicas demonstrated negative results, i.e. that the implement, in all probability, was not used in a manner that was suggested through ethnographic analogy.

Ethnographic Analogy and the Direct Historical Approach

Information on the ethnographic and historic use of bone artifacts was applied to these case studies in two ways: ethnographic analogy and the direct historical approach (also known as the folk-culture approach). The latter is most relevant in the case study involving the Mogollon artifacts from Point of Pines, Arizona. Although the direct historical approach had been used previously, Strong (1935) formalized this method and demonstrated its applicability in the North American Plains. In the first half of this century the direct historical approach was shown to be very valuable in the northeastern, central plains, and southwestern areas of the United States. Advocates supported it because it worked from the known to the unknown (Strong 1935: 296; Steward 1942: 337).

Traditionally, the direct historical involves the study of extant or recently living groups of people, tracing the changing or stable features of their culture backward through time by looking at progressively older archaeological material. The great continuity of cultures in the American Southwest has enabled archaeologists to use the direct historical approach with considerable confidence (Kidder 1932; Parsons 1940; Judd 1954). It was originally developed as a formal approach in order to produce temporal sequences at a time when chronometric techniques were inadequate and to discover the relationships between prehistoric cultures.

The present research utilizes the direct historical approach with a more restricted orientation, that of discovering the specific use of bone artifacts and their roles in society. It can be very useful in identifying the function of problematical artifacts, e.g. religious paraphernalia, musical instruments, and some kinds of ornaments. In turn, by understanding what these objects represent we can establish the time depth of certain traditions. The plethora of ethnographic and historic accounts of Indians of the Southwest, particularly the Zuni and Hopi who exhibit many similarities to the ancient Mogollon culture, was referred to for identifying the functions of many implements and ornaments.

It is evident that this approach must be used judiciously since some items of the material culture shift meaning or even function through time. For this reason, the direct historical approach is used not in isolation, but to complement other evidence derived from analysis of microscopic traces, experimental replication, and archaeological context. The fact that the direct historical approach is one of the older methods for interpreting cultures does not diminish its value. As Clark and Kurashina (1981: 304) state, "Probably the most reliable reconstructions are those where a direct relationship can be established between the ethnographic present and the archaeological contexts through the historical record."

Ethnographic analogy that does not rely on any geneological connection may also be useful in interpreting prehistoric material culture. Ascher (1961) outlined several important guidelines for what he termed the "new analogy" which provided restraint in drawing analogies from ethnographic cases. Wherever possible priority should be given to analogies drawn from cultures at similar levels of technological development and subsistence strategy, under similar ecological conditions, and with greater regional proximity. As he succinctly states, "Seek analogies in cultures which manipulate similar environments in similar ways" (Ascher 1961: 319).

An example of ethnographic analogy used in the case study from Ulu Leang 1 and Leang Burung 1, Indonesia, is the comparison of the hafting and use of modern bone bipoints from Australia with those in the prehistoric Indonesian collections. Ethnographic analogy may be employed to reconstruct manufacturing techniques in some cases, but with the exception of the Inuit and other circumpolar peoples there are relatively few extant cultures who have maintained traditional methods of working bone with stone tools.

Numerous cautionary tales have demonstrated the failings of ethnographic analogy. Especially relevant are the studies that contrast how extant cultures classify their tools compared to the formal typologies archaeologists construct (Heider 1967; White and Thomas 1972). Two points that emerge are that a. archaeologists need to use ethnographic analogy and often do so quite unconsciously, but b. they should be aware of the shortcomings of this interpretive tool. Similar cultures existing in neighboring communities in the same ecozone may utilize similar objects for different purposes (Heider 1967). One group may regard an item with reverence and consider it highly valuable, while another group may regard it only in terms of its mundane function.

Despite the attempt to integrate data gathered by several methods, ethnographic analogy being only one example, the examination of the bone artifact collections from widely different cultures has shown that there are many aspects of these objects that cannot be deciphered from the archaeological record. Ethnographic analogy is at best a way of making an educated guess as to how the material culture functioned in a once living society. Other methods, such as analysis of surface alterations and experimental replication may serve to support or refute hypotheses obtained from ethnographic examples, but it is difficult for the researcher to ever state unequivocally that he or she has "proof" of how an artifact was employed. The importance of ethnographic analogy is in providing clues to the archaeologist whose own industrialized society has blinded him or her to a vast array of technologies, such as the manufacture and use of objects of stone, bone, pottery or wood.

Archaeological Context

In the 1960's and 1970's many American archaeologists attempted to reconstruct major aspects of social organization through the interpretation of intrasite distribution of material culture (Hill 1970; Longacre 1970). Binford (1964: 425) referred to the archaeological record as a "fossil record of the actual operation of an extinct society." Recently archaeologists have become more aware of natural processes that contribute to the formation of the archaeological record through soil science (Wood and Johnson 1978) and taphonomy (Gifford 1981). Schiffer (1976) has delineated many of the problems related to noncultural and cultural formation processes which limit our capabilities for reconstructing systemic behavior from archaeological context. Natural and cultural processes which interject distortion in the archaeological record must be recognized and where possible understood before inferences can be made about past cultural activities.

Schiffer's (1976: 30) useful distinction between primary refuse (that which is discarded at the location of its use) and secondary refuse (that which is discarded away from its location of use) illustrates the hazards of attempting to associate artifacts with rooms, features, or other artifacts occurring in close proximity. Primary refuse would maintain some locational context related to the activity in which the material participated, however secondary refuse may share no close relationship with surrounding artifacts or features.

Certain sites, because of their temporary nature or limited scope, may contain recognizable primary refuse. A kill and butchery site would be an example in which there is a high potential for discarding materials at the activity locus. Alternatively, a sedentary village which is occupied for many years by a relatively dense population might be expected to have developed a system of refuse disposal in areas not then in use. Settlements occupied by Neolithic agriculturalists, such as those used as case studies in this report, have a high potential for disposal of secondary refuse.

A major problem that is also associated with long-term occupation of a settlement is the disturbance and mixture of previous deposits by the inhabitants. Activities like the intrusion of burials into trash middens or storage pits through earlier floors serve to complicate the interpretation of context.

Wood and Johnson (1978) have thoroughly described the various processes of pedoturbation (homogenization of soil through biological, chemical, or physical mixing) that can confuse the archaeological record and create false associations of artifacts and natural materials. Burrowing animals, roots, freezing and thawing, subsidence, wind, water, and other factors may inflict significant changes, moving cultural materials horizontally or vertically or dispersing, concentrating, or rearranging them.

Taphonomic processes are important in interpreting the context of modified bone in archaeological sites. Bone artifacts are particularly susceptible to redistribution by carnivores or rodents because of their nutritive value. Fortunately, many of the taphonomic processes that affect bone leave diagnostic traces on its surfaces, e.g. root etching, water transport, and animal gnawing. Evidence of weathering informs the archaeologist that the bone has lain on the surface for a period of months or years and may, therefore, have been moved by natural or cultural agents from its original position. The combination of taphonomic analysis of the osseous material by a zooarchaeologist and the site's soil configuration by a soil scientist can provide detailed information about the reliability of associations of bone artifacts with other archaeological material.

The salient problem with interpreting archaeological context lies in understanding the cultural formation processes, such as refuse disposal, and natural processes, such as pedoturbation and taphonomy, that intervene between human behavior and the subsequent discovery of the archaeological record.

A combination of methods has been applied to the analysis of the bone artifacts in the three case studies in order to maximize the amount of information obtained and to use one method to act as an independent means of confirming or refuting interpretations based on another method. It is clear that by narrowing the focus of the analysis to a small range of artifact types more specific problems could be attacked; but since it is often the case that whole assemblages must be analyzed and related to other materials from a site this has been the approach adopted here.

Chapter 4

Traces in Microtopography

Alterations in the surface topography of bone created after the death of the animal may be divided into two major categories: natural and cultural modifications. Natural modifications include such processes as animal gnawing (chiefly rodents, carnivores, and artiodactyls), dissolution from digestive juices of predators, root etching, water rounding, soil abrasion, and weathering. Cultural modifications encompass alterations caused by burning, butchering, and the manufacture and use of bone artifacts.

It is important that the archaeologist examining bone artifacts is familiar with the intrinsic microtopographic variations in the numerous bones of different species in order to recognize when external forces have actually altered the surface. Modern comparative osteological collections are of value in identifying rugosities, foramina, and grooves formed in the living animal. In addition to normal surficial structures there are anomalies and pathologies caused by factors such as malnutrition, disease, or injury, which can mar the natural topography of bone (Steinbock 1976; Baker and Brothwell 1980). These are too numerous and complex to be outlined here, but should be considered during examination of osteological material.

In conjunction with a thorough knowledge of anatomical features of bone, researchers in recent years have attempted to document changes in osseous material as a result of natural taphonomic conditions such as desiccation, exposure to ultraviolet radiation, freezing and thawing, trampling, soil abrasion, animal gnawing, and so forth (Miller 1969, 1975). With the growing fund of knowledge about both natural and cultural processes that work on bone, interpretation of traces today can be relatively precise. Two aspects of surficial traces contribute to clarification of the processes involved in the alteration of bone. Firstly, several distinct kinds of traces have been identified by their unique morphological characteristics through experimentation and observation. Secondly, the patterning of traces on bone is very important in separating natural from cultural modification. The physical characteristics and distribution over the surface of each of the major kinds of modification will be discussed below.

Rodent Gnawing

Rodent gnawing is very commonly found on archaeological bone, perhaps because middens provide suitable habitats for many species. Gnaw marks are inflicted by the paired incisors. Rodent incisors are continuously growing and therefore must be frequently resharpened and worn down. The incisors are designed with enamel only on the labial surface which forms a chisel-edge when the dentine posterior to it wears away more readily (Wood 1952: 28). The result is a tooth that maintains a sharp cutting edge at all times. Failure to wear down the growing incisors can cause the teeth to curl around, becoming useless or even penetrating the skull. Of nutritional benefit, minerals needed for tooth growth and maintenance of the skeleton can be derived by injesting bone.

The traces left by rodents are extremely diagnostic in appearance. Occurring primarily on crests, processes, borders, and articular ends (Pei 1938: 4), rodent gnawing consists of paired parallel grooves with flat or U-shaped bottoms (Figs. 7, 8, 9). The length of the grooves is dependent on the contours of the bone and the bite of the rodent. The width of an individual groove is indicative of the size of the rodent, e.g. mouse, rat, muskrat or squirrel, porcupine, or beaver (Wood 1952: 27). It is often difficult to observe the pairing of grooves when gnaw marks are plentiful and are overlapping or immediately adjacent to one another. The proliferation of rodent gnawing sometimes forms a scalloped profile. Where the rodent does occasionally work on the diaphysis of a long bone the marks usually run transversely. If the rodent succeeds in penetrating the marrow cavity, round "windows" may be produced.

Porcupines, particularly in the Old World (Family Hystricidae), are notable in the amount of damage which they may inflict on bone (Pei 1938: 4) and the misinterpretation of their work for that of early hominids (Dart 1958). They and other rodents with pronounced lobes on their incisors form grooves in the bone that are lined with fine parallel striae, whereas the gnaw marks of most rodents do not possess these details.

Carnivore Gnawing

Carnivores, especially canids, felids, and hyaenids, are noted for their habits of destroying and

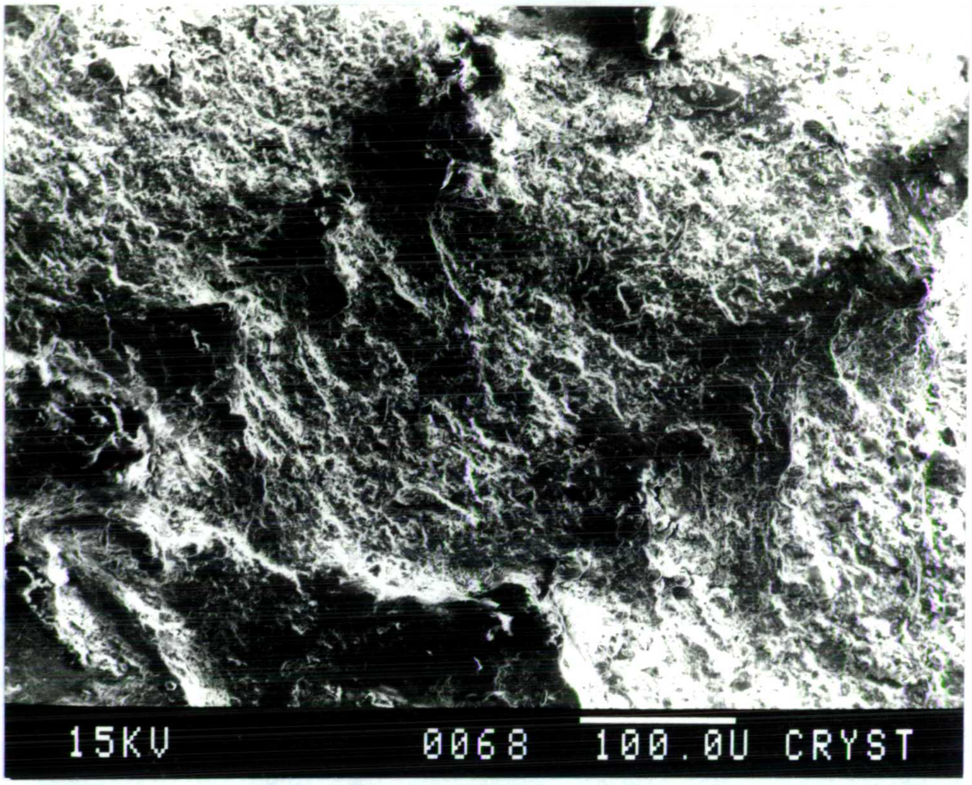


Fig. 8 Rodent gnawed archaeological bone (200X).

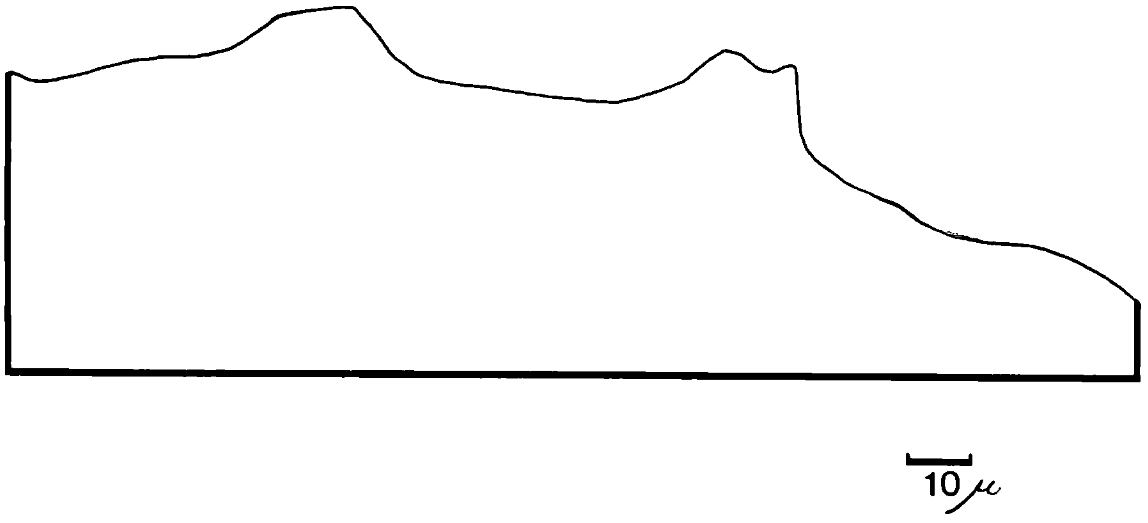


Fig. 9 Profile of grooves in rodent gnawed bone.

partially devouring bone. The surficial traces and breakage patterns created by the shearing and crushing actions of carnivore dentition have been thoroughly examined by paleontologists and archaeologists (Pei 1938, Miller 1969, 1975; Sutcliffe 1970; Brain 1970; Shipman and Phillips 1976, 1977; Haynes 1980; Binford 1981; Bunn 1981; Shipman 1981a).

There are four diagnostic surface alterations that, along with characteristic breakage patterns, identify carnivore activity. The first and most distinctive is the appearance of rosettes, or round perforations, where the cusp of a tooth has punctured the thin compact bone. This usually occurs on ribs, scapulae, vertebrae, innominates, or the epicondylar regions of long bones where the compact bone is sufficiently reduced in thickness to allow the teeth to puncture it. The round punctures are depressed fractures, so the edges are crushed inward (Potts and Shipman 1981: 578). These tooth marks may in some cases have been inflicted by the canines, as seems to be likely with the Australopithecine skull from Swartkrans (Brain 1970), but generally carnivores use their carnassials and back molars for crushing bone (Mech 1970: 169; Kruuk 1972: 107; Fox 1978: 116). The conical cusps on premolars and molars are capable of producing round perforations and much greater force can be applied by the cheek teeth because of their proximity to the axis upon which the jaw rotates. The action of chewing involves both the upper and lower teeth like a hammer and anvil, so there are usually tooth marks on both sides of the bone. Puncture marks have sometimes been mistaken for drilled perforations, as for example when gnawed proximal phalanges of artiodactyls are misidentified as whistles (Binford 1981: 44).

The second diagnostic trace produced by carnivores is a general pitting of the surface (Fig. 10). The shallow indentations rupture only a thin outer layer of bone, often roughening a large area on both sides or all around a bone. This pattern is typically found on thick compact bone, such as that in the diaphysis of the limb bones of large mammals, which cannot be punctured easily. Pitting is formed when the carnivore is biting down on a thick bone with the premolars and molars for prolonged periods. Formed in the same way as puncturing, pitting often surrounds or is opposite to a perforation. The profiles of these pits are generally broadly V-shaped or rounded (Fig. 11).

The third major form of surficial modification caused by carnivores consists of scoring, which produces shallow, round-bottomed grooves (Bunn 1981: 575). Unlike rodent gnawing these grooves are not found in parallel, closely set pairs, but are separate individual marks that usually occur perpendicular to the longitudinal axis of the bone (Binford 1981: 47). As Shipman has noted (1981a: 108), the groove's surface is unmarred by fine striae. It may change direction abruptly or angle off as the tooth slips over the bone, particularly if the bone shifts position, but the scoring otherwise follows the contours of the bone. The hard compact bone of the diaphyses of long bones, such as femora and humeri whose

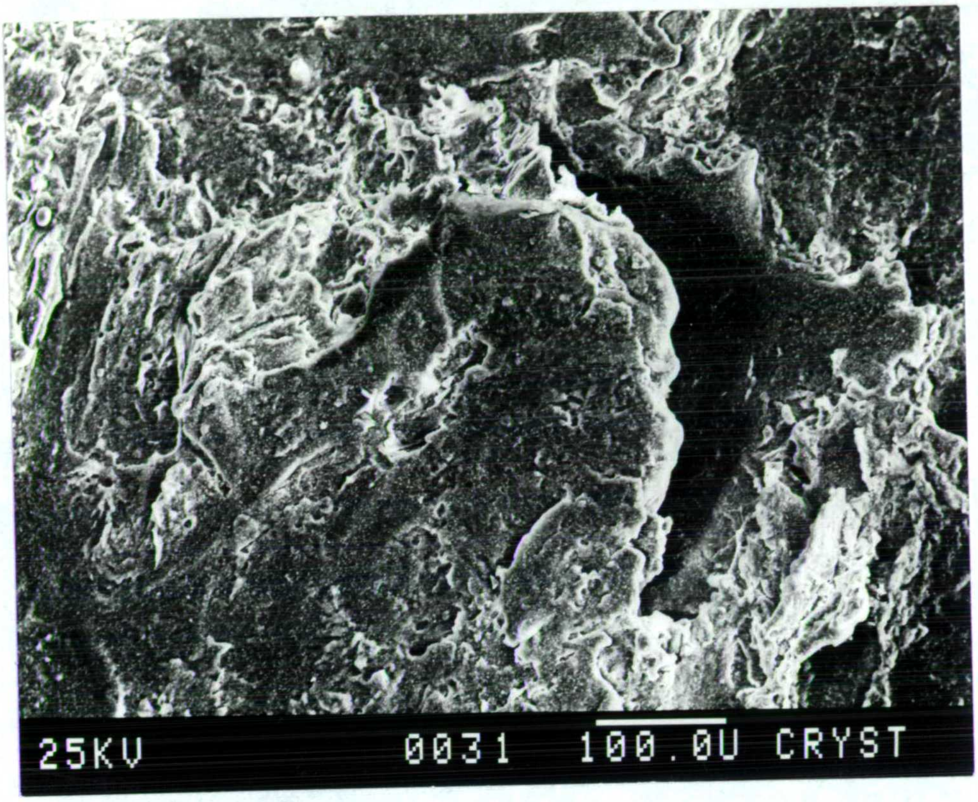


Fig. 10 Negative replica (silicone mold) of modern bone gnawed by dog showing outline of round pit caused by tooth cusp crushing outer surface (160X).

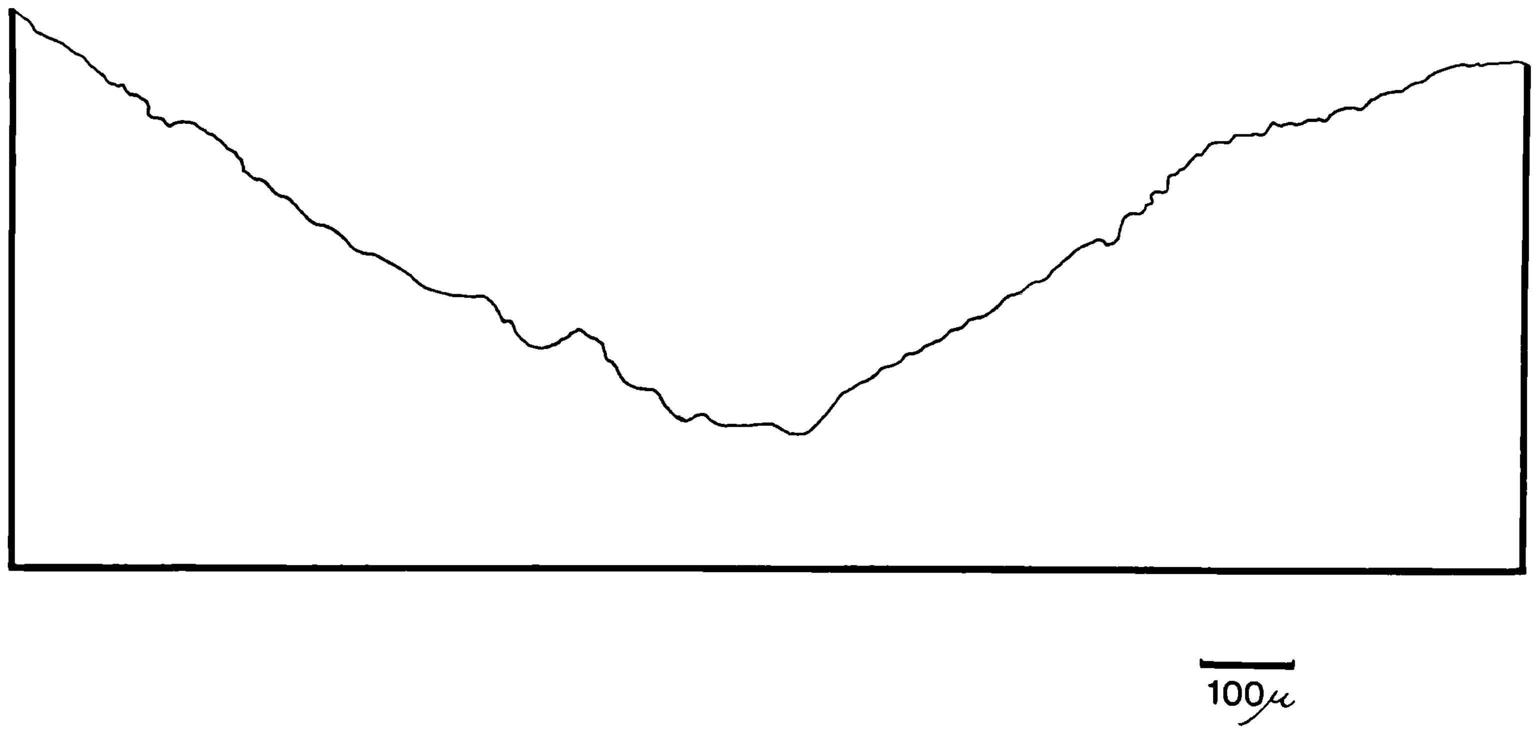


Fig. 11 Profile of pitting in modern bone created by dog gnawing.

cylindrical shape make it difficult for the carnivore to firmly clamp down and crack through them, are the most frequent recipients of these traces.

The fourth alteration consists of denticulate flaking along the thin edges of articular condyles, spines and processes, or margins of broken bones. This may be mistaken for percussion flaking by hominids, but is usually accompanied by other traces of gnawing and breakage typical of carnivores.

Observations were made when a large domestic dog was given a fresh cow vertebra with some meat still attached. The dog is a mixed breed, half Malamute and half German Shepherd, weighing 27 kg. Within 30 minutes the neural spine was completely devoured and after one hour the stout vertebra was reduced to half its original volume. The incisors were used to nip off muscle and other soft tissue (Fig. 12). It is possible that some of these bites may have inflicted shallow grooves on the bone, although very little force was applied. The vertebra was shifted to the carnassials and even further back in the mouth to the last molars in order to crush and grind up the bone (Fig. 13). Considerable force was applied when crushing bone with the cheek teeth. The bone was secured either between the front paws and the ground or by turning the head sideways and bracing the bone between the teeth and the ground surface. The bone was per odically shifted from one side of the mouth to the other, stopping occasionally to pull off soft tissue with the incisors. The only times the canines were

Fig. 12 Domestic dog using incisors to nip soft tissue from cow vertebra.

Fig. 13 Dog crushing vertebra with its molars.

employed were when the bone had slipped away and needed to be retrieved or the dog chose to rearrange the bone's position in the mouth or on the ground (Fig. 14). In short, the canines were used as tongs to clasp the bone and orient it in the proper position, but not for crushing. The function of canine teeth in wild predators is for threatening, seizing, killing, grasping, dragging and ripping open prey rather than chewing. Probably most of the traces on bone left by carnivores are produced by premolars and molars.

Artiodactyl Gnawing

Sutcliffe (1973) gives a thorough description of osteophagia in artiodactyls. Artiodactyls develop the habit of chewing bone and antler in regions where phosphorus is deficient in the soil or where calcium, iron, or aluminum are so excessive that phosphorus intake by plants is inhibited (Sutcliffe 1973).

In Britain the calcic soils lead to phosphorus deficiency in deer which in turn results in high frequencies of deer-gnawed antler in paleontological and archaeological collections. Bone or antler chewed by deer may exhibit alternate furrows on either surface producing a zigzagged outline as the opposing cusps in the upper and lower dentition try to occlude. Antlers are sometimes chewed down the middle, leaving two prongs of hard tissue on either side. Shed antlers are sought after by deer as a source of nutrition and may become scarce in a short time if the need is great. Several other kinds of artiodactyls, including sheep (Brothwell 1976) and giraffes, have also been observed chewing bones.

Fig. 14   Dog using canines to reposition vertebra.

Alterations from Digestion

The consumption of bone and subsequent transport through the digestive system of predators alters bone in a characteristic manner. A naturally produced polish or surface erosion may develop on the bones of small vertebrates eaten by certain kinds of birds. Herons (Hibbert-Ware 1940), owls, hawks, falcons, eagles, crows, ravens, gulls, cormorants, and some other kinds of carnivorous birds regurgitate indigestible parts of their prey such as fur, claws, chitinous material, bone and teeth (Grimm and Whitehouse 1963). The pellets are highly resistant to weathering for years (Brooks 1929: 222) and may be deposited nearly anywhere, since some species eject them in flight. Sites located in entrances of caves or abutted against cliff faces may contain faunal remains from pellets that could be confused with intentionally polished artifacts. The degree of alteration of the bone depends on many factors such as the species of bird ingesting the prey, the bird's age, the maturity of the prey, and the quantity of indigestible matter consumed. Gallinaceous birds and most other seed-eating species do not produce pellets.

Compared to other raptorial birds the pH of the mature owl's ventriculus is more neutral or even alkaline (Reed and Reed 1928; Duke *et al.* 1975), so bones are well preserved in owl pellets. This condition causes bone in owl pellets to appear polished to the unaided eye, but pitted when magnified (Fig. 15). Formation of a pellet in the ventriculus of a great horned owl (*Bubo virgini-*

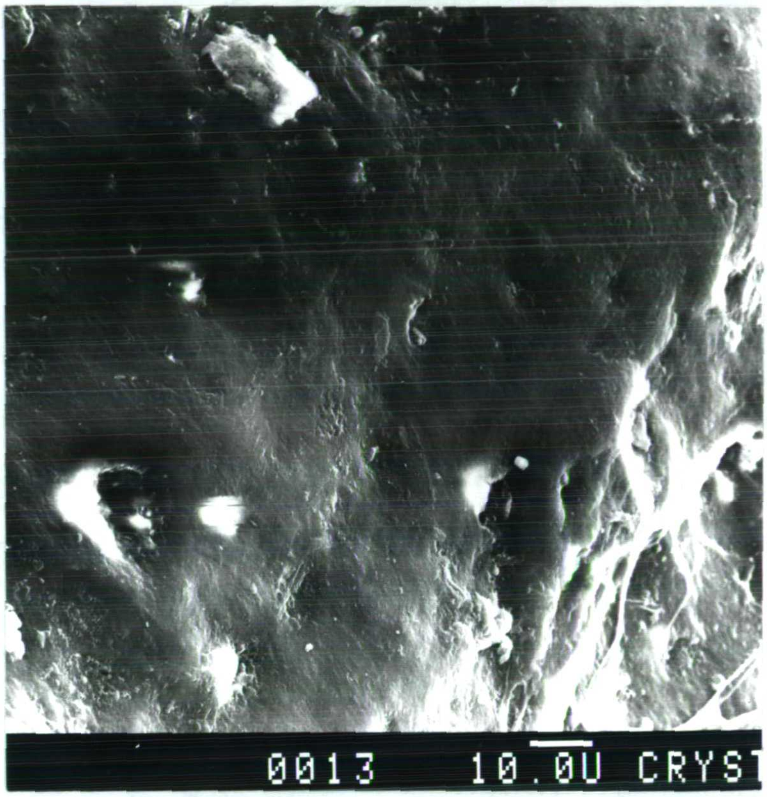


Fig. 15 Bone derived from modern owl pellet exhibiting surface pitting due to etching by digestive fluids (780X).

agus) takes between 8 and 10 hours, but may be retained several more hours before ejecting (Grimm and Whitehouse 1963). Owlets may delay ejection of the pellet so long that the bone is completely digested, but as the owl matures the quantity and preservation of bone improves (Errington 1930: 292). The digestive fluids of owls consist primarily of water with lesser proportions of HCl, pepsin, salts, and mucin.

The marsh hawk (*Circus cyaneus*) produces pellets that contain bone in a more eroded state than that found in owl pellets and much of the osseous material is completely digested. Pellets of red-tailed hawk, red-shouldered hawk and other species of the genus *Buteo* generally contain no bone because their digestive acid completely destroys it (Errington 1930: 293). Falcons (*Falco* spp.) produce pellets devoid of bones or teeth unless an adult has had unusually large quantities of skeletal material (Bond 1936: 75). Heron pellets exhibit a wide range of destruction to bone, from surface etching of to reducing bone to a powdery dust. This is more pronounced destruction than occurs in gulls (Hibbert-Ware 1940: 440).

The alteration of bone in the ventriculus of certain pellet-producing species is represented in a continuum as follows: 1. glossy polish over the surface of the bone as in owl pellets, 2. perforation of the surface with tiny pits and erosion of the articular ends and tooth enamel, 3. softening, thinning and brown staining, and 4. reduction of bone into powder.

Keys to recognizing polished or eroded bone as the result of pellet formation in raptorial birds are the small size of the elements, their possible occurrence in tight clusters, lack of standard manufacturing traces, and overall coverage of the surface modification. Areas where faunal remains from avian pellets are most likely to accumulate are sites in caves or along cliff faces.

Preservation of bone in the scats of carnivorous mammals varies among the different taxa. Hyaenas digest bones completely, leaving only the inorganic constituents (Kruuk 1972: 66-67; Brain 1981: 64), but other carnivores' digestive systems are less destructive to osseous material. Accumulations of bones of small animals that exhibit spiral fracturing of long bones, erosion of the edges of fractures and natural prominences, and severe comminution of the less dense elements may be remnants of carnivore scats. Bones from the scats of most carnivorous mammals other than hyaenas are not as highly polished or eroded from gastric fluids as those regurgitated by birds. The gastric acids in owls are approximately three times stronger than those of canids (Brain 1981: 118), for example. The alteration to the surfaces of bones digested by carnivores, if any is notable, consists of a light polish that at high magnification appears to have eroded away the surface features of the bone and rounded any roughly broken edges. The physical traces resemble those on water-worn bone (Mellet 1974: 349). Classic gnaw marks are often not present on the smaller fragments (Binford 1981: 60).

Scats from coyotes (Canis latrans) were collected in southern Arizona in order to observe the modifications to bones of prey after passing through the entire digestive system of a carnivore. The bulk of the skeletal material obtained by soaking and screening the feces appears to have been derived from black-tailed jackrabbit (*Lepus californicus*). The elements had been severely destroyed through breakage so that only teeth, articular condyles, and dense bones of the feet were still identifiable. Spiral fractures were common and numerous sharp splinters were recovered. The fragments resembled those found in wolf feces by Binford (1981: 201), i.e. chips, splinters, and lumps of cancellous bone. The surfaces of many of the bones were lightly polished and the edges of fractures were rounded from erosion (Fig. 16).

Water Rounding and Soil Abrasion

As bone is transported or deposited in an aqueous medium such as a stream, waterborne particles of sediments impact its surface and cause a diagnostic wear pattern. Similar wear may develop on bones trampled by large animals around watering holes (Brain 1967). Unlike wear created intentionally by man, which is concentrated in specific areas and shows definite distribution patterns, water rounding and natural abrasion are often uniformly distributed over the bone's surface. The resultant alteration is a smoothing and rounding of all crevices, rugosities, and broken edges. The surface of a completely water-rounded bone magnified 60 times shows that the outer lamellae have been differentially eroded in areas (Fig. 17). This wear may be replicated by

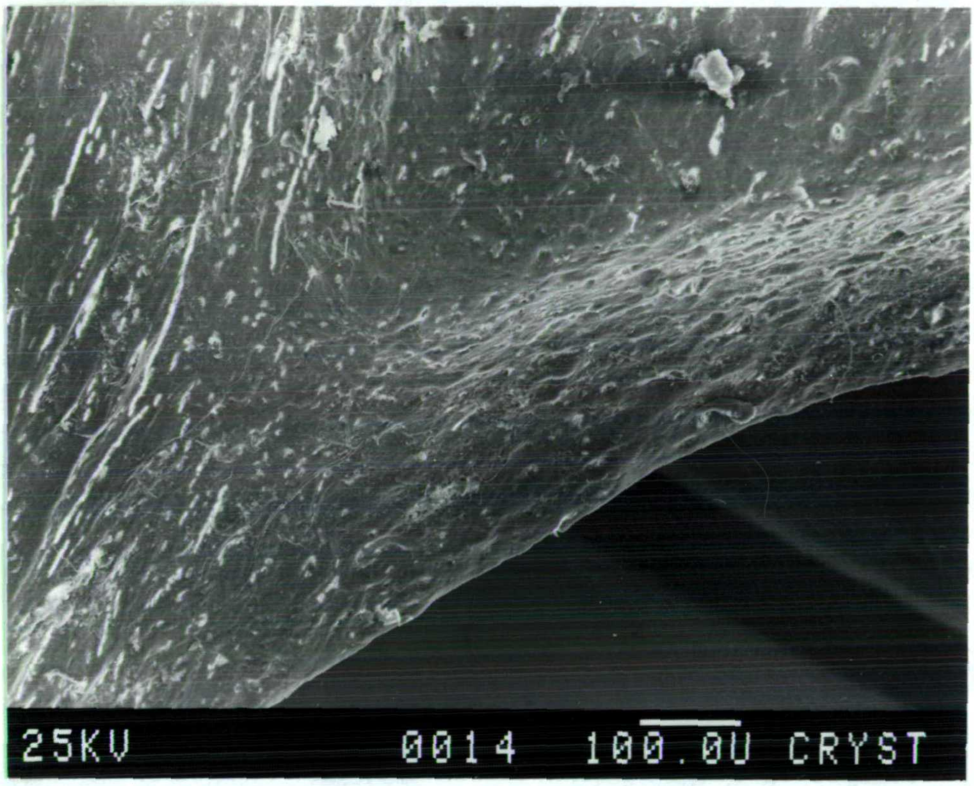


Fig. 16 Fragment of partially digested jackrabbit bone recovered from coyote feces. Note surface pitting and rounding of fracture margin.

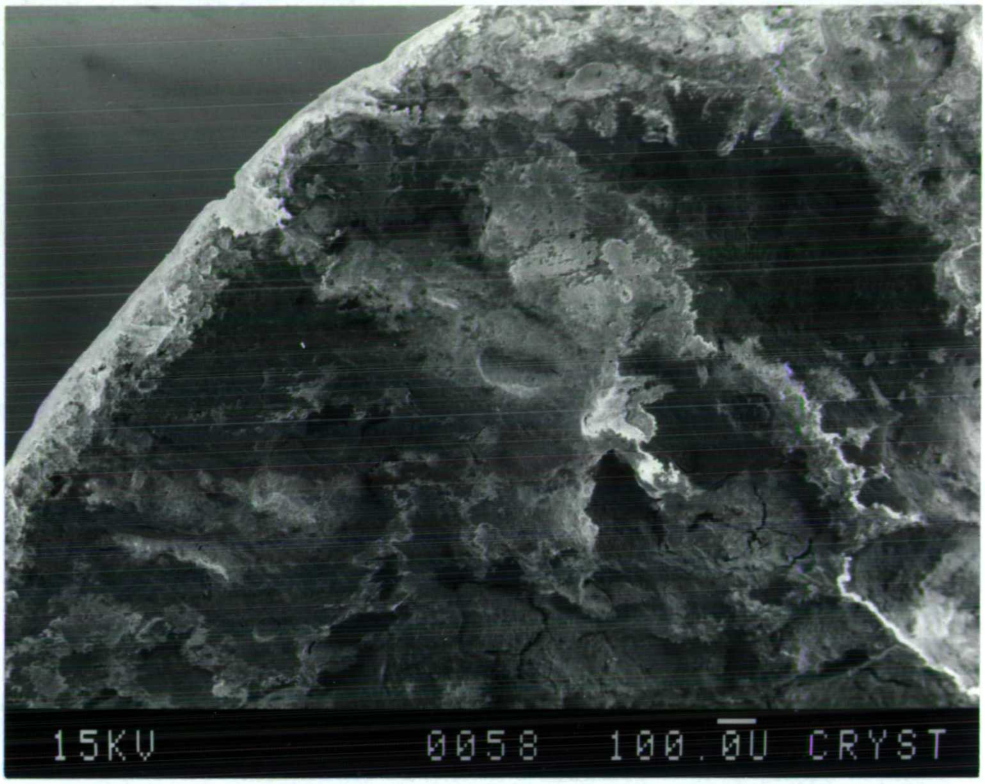


Fig. 17 Bone fragment from Ulu Leang 1 with rounding of the fracture surface and peeling of the outer lamellae due to erosion from waterborne particles (60X).

placing bone fragments in a geologic tumbler with water and sand (Shipman and Rose 1983: 77, 79-80).

Aeolian Abrasion

Bombardment from airborne sediments in deserts causes an etched or melted appearance on bone surfaces rather than a polish (Brain 1967: 99). The upper surface of a bone lying on the desert floor will be gradually planed down so that the cancellous tissue is exposed in areas that project above the surrounding sands (Fig. 18). The direction of the prevailing winds can be determined by noting the orientation of the bone in situ and examination of the low undulating ridges that form parallel to the wind direction. These bone "ventifacts" are faceted on the windward side by the impact of saltating sand grains (see Bagnold 1941: 11).

Weathering of Bone

Weathering is a complex process involving an interplay between climatic factors such as sunlight, temperature, precipitation, and wind. Exposure of bone on the ground surface for prolonged intervals of months or years results in severe destruction (Fig. 19). Ultraviolet radiation denatures collagen and causes the bone to turn from a creamy yellowish white to a greyish white. The surface eventually becomes chalky and friable (Miller 1975: 215). Air drying and heat desiccate the organic constituents. Shrinkage of osseous material due to loss of organic components and moisture varies considerably since the water content of the bones of young animals may be as high as 73% by volume (Evans 1973: 43), but averages between 10 and 30% in adults. Reduction caused

Fig. 18 Aeolian abrasion on addax metatarsal from northern Sudan. Note in profile how the surface of the distal condyle has been planed down to one level.

Fig. 19 Surface of whale vertebra exposed to weathering in southern Arizona for ten years.

by loss of moisture results in the formation of cracks that in the early stages of weathering follow the patterns of collagen fibers (Tappen and Peske 1970). In most cases long bone collagen fibers are aligned longitudinally so that split-line cracks formed in the laboratory and weathering cracks are parallel to the long axis of the bone. In limb bones that endure great tortional stress through life, such as the humerus and and tibia, the collagen fibers are oriented more diagonally around the diaphysis so that spiral fractures can occur through weathering (Hill 1976).

After the breakdown of collagen fibers transverse weathering cracks may form. Exfoliation of the outer lamellae of cortical bone may also appear after extended exposure. Other factors such as the expansion of minerals that have filled the interstices or freezing and expansion of ice crystals in cracks may accelerate deterioration.

The two major indicators that bone has been exposed to weathering damage are a bleached, chalky or greyish white color and extensive cracking or exfoliation. Attempts have been made to estimate the length of time that weathering has taken place (Miller 1975; Shipman 1977; Behrensmeyer 1978), but Gifford (1977) has demonstrated how differential weathering can occur on a single skeleton because of variations in microenvironments of individual bones.

Root Etching

Under the right conditions buried bone may acquire traces caused by contact with plant rootlets (Pei 1938: 12). These vermiculations and pits (Fig. 20) may be etched into the bone through dissolution of the surface by the excretion of amino acids by the root tips or, as has been suggested, by products of microorganisms associated with the roots (Bokhari *et al.* 1979; Morlan 1980: 36). Their dendritic pattern is extremely diagnostic and once recognized it is difficult to mistake it for any other type of surface alteration, whether natural or cultural. The grooves made by the rootlets are very broad and shallow in profile (Fig. 21). Whereas the unaltered cortical bone may be shiny, the etched surface will be rough and will often display fine micropitting. If the process of root etching has occurred long after the initial deposition of the bone, the vermiculations may be strikingly lighter in color compared to the unmodified surface.

Natural Damage on Deer Antlers

Deer antler tines were frequently used to perform pressure flaking on chipped stone artifacts without any modification to the tines necessary except breaking them from the main beam. The primary evidence that tines were actually utilized by man is the microwear created during pressure flaking. Supportive evidence includes association with stone debitage, modifications made to the base such as drilling or smoothing, or resharpening of the tip. The mere presence of antler in a site does not in itself prove that it was used as a tool since much of the

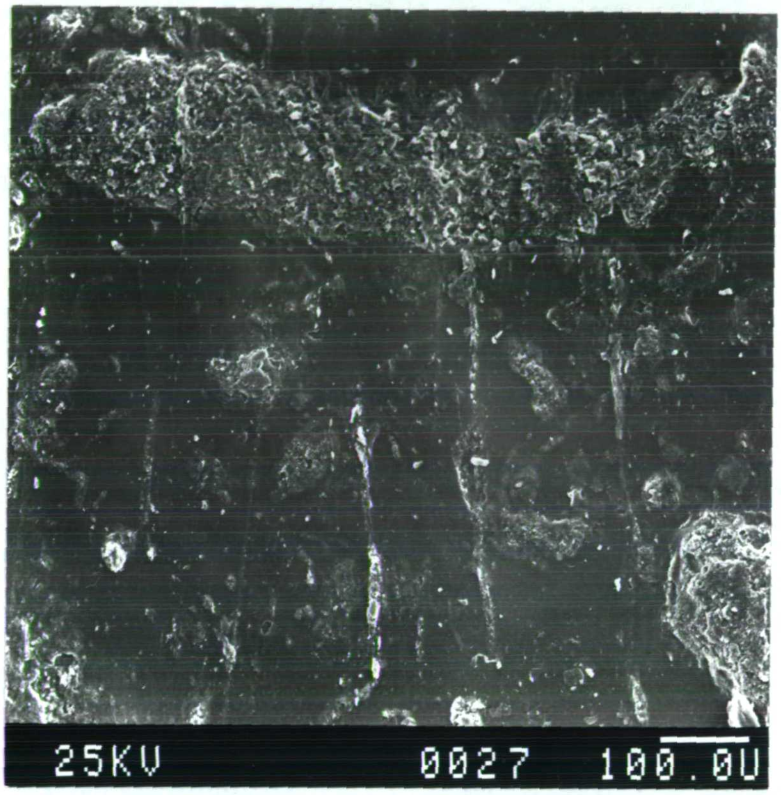


Fig. 20 Root etching on an archaeological bone artifact (silicone mold). Note large grooves at the top and lower right corner and pitting of the surface (110X).

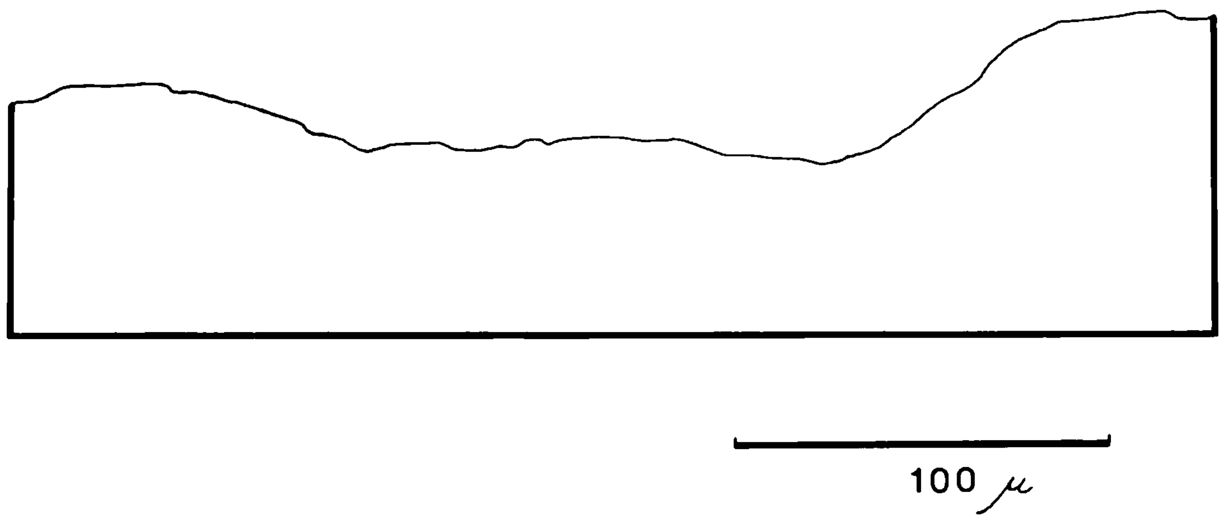


Fig. 21 Profile of shallow groove made by root etching on archaeological bone.

bone discarded in middens remains substantially unaltered.

Interpretation of microwear is complicated by the fact that natural damage is inflicted on antler during the animal's life. When the velvet is in the process of shedding deer expedite the removal of dead tissue by rubbing their antlers against trees or the ground. The relatively fresh antler is softer than completely dry shed antlers and is susceptible to damage. Other behavior, such as using the antlers to battle other males or to uproot plants may also cause damage to the tines.

The surfaces of 110 pairs of unshed antlers on the skulls of several species of deer were examined for evidence of damage inflicted during the life of the individual (Fig. 22). Shed antlers were not selected as examples since gnawing by rodents and deer, soil abrasion, or other taphonomic processes might complicate or obliterate wear acquired during the period that the antlers were attached to the living animal.

Several patterns emerged suggesting that there are diagnostic characteristics for natural damage that differ from use wear on prehistoric antler tools. The major types of surface alterations inflicted by the deer are: abrasion and polishing of tines and parts of the beam, impact fractures at the tips of tines, and marring of the beam and tines with straight, shallow cuts. The most prevalent natural wear across a wide range of species dispersed throughout the world is polishing of the tines. Impact fractures at the tips were also widespread, but localized polish or abrasion on the beams and cuts on the

Figure 22

Types of natural damage observed on deer antlers

TAXON	NO. #	POLISHED TINE	TERMINAL IMPACT	POLISHED BEAM	MARRING ON BEAM
Cervus elaphus	20	X	X	X	X
C. unicolor	16	X	X	X	-
C. duvauceli	3	X	X	X	-
C. timorensis	2	X	X	-	-
Odocoileus virginianus	26	X	X	X	X
O. hemionus	10	X	X	X	X
Dama dama	12	X	x	x	-
Capreolus capreolus	18	X	X	X	-
Hippocamelus antisiensis	1	X	X	-	-
H. bisulcus	1	X	X	-	-
Blastocerus dichotomus	1	X	X	-	-
TOTAL	110				

beams and tines were more taxonomically specific. The morphology of the antler appears to have a major effect on the areas of the beam which frequently make contact with resistant objects in the environment. The age of the individual is also important. Young males with spikes may exhibit polishing of the tips, but rarely have significant marring near the base of their antlers.

During the period of months in which the deer actively uses its antlers for scraping the earth, thrashing, and fraying (Chapman and Chapman 1975: 121-122; Strandgaard 1972: 93-99), the tines may develop a polish that extends from the tip to several centimeters down toward the main beam. In modern specimens this is vividly demarcated by the lighter color of the polished area where the dark natural staining has been worn off. This is usually less evident in archaeological specimens, although the polish may remain intact. The action of rubbing the tines of the antlers against the ground surface or vegetation often rounds the tips of the most predominantly used tines (Fig. 23). Extensive attrition from abrasion may occur on the tines and occasionally parts of the beams, leading to the formation of actual wear facets.

Terminal impact fractures are defined as the removal of longitudinal flakes initiated at the tips of tines when they strike a resistant obstacle with great force. The resistant obstacle may be the ground surface, large trees, or the antlers of another deer. It is common to find that after a tine has suffered an impact fracture the broken surface has been thoroughly polished or

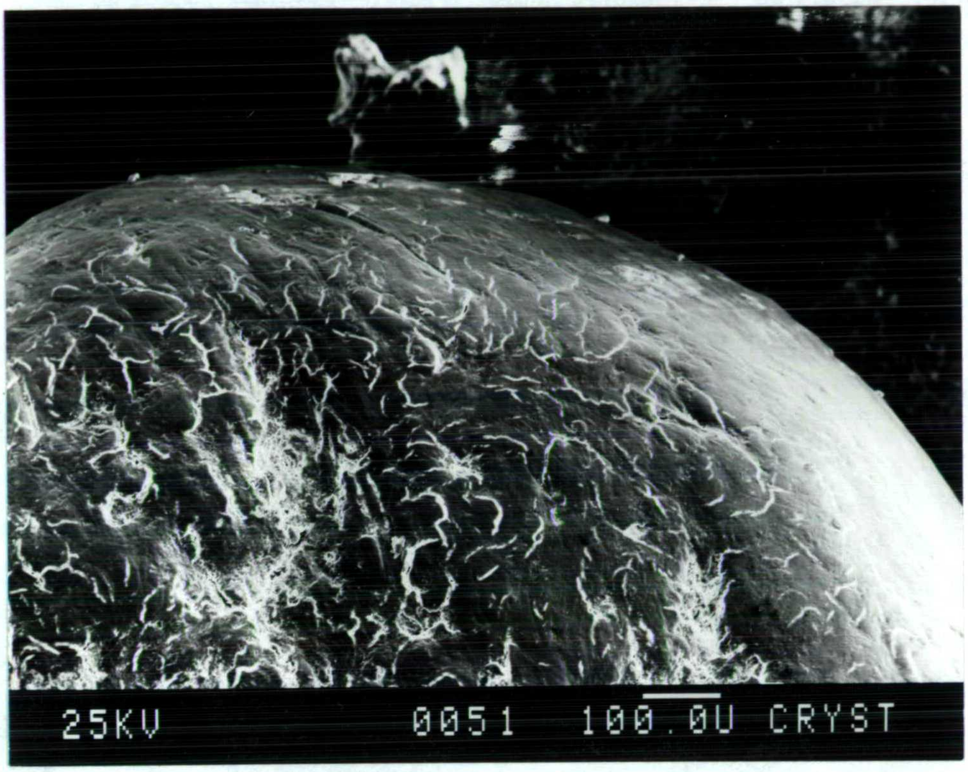


Fig. 23 Polish and abrasion striations at the tip of a red deer antler tine caused by the deer rubbing it against the ground or vegetation (100X).

abraded (Fig. 24). The combination of these natural traces may mimic certain types of use on archaeological tools, such as burnishers.

Marring consists of randomly oriented shallow cuts widely dispersed over the tines and occasionally on the main beams (Fig. 25). Lacking patterned directionality, these fairly straight cuts are probably caused by glancing blows against rough surfaces, such as the bark of large trees.

In addition to these three basic forms of wear, antlers may exhibit malformation caused by disease or injury and partial loss due to accidental breakage. The first of these is rarely mistaken for human alteration and the second often cannot be distinguished from damage that occurs after the antler is shed or utilized by man.

It is important to note that natural damage on antlers can be quite marked and may initially resemble use traces on prehistoric tools. It is easy to mistakenly identify natural polish and rounding of the tines as the result of using them as polishers. Terminal impact fractures occur on the tips of awls and projectile points. Marring superficially resembles cut marks made by a stone tool, although the contrast in directional patterning and the microscopic detail of the cut marks are useful criteria for differentiating these traces.

These descriptions of natural traces on bone do not exhaust the total range of modifications caused by taphonomic or behavioral processes but hopefully serve to

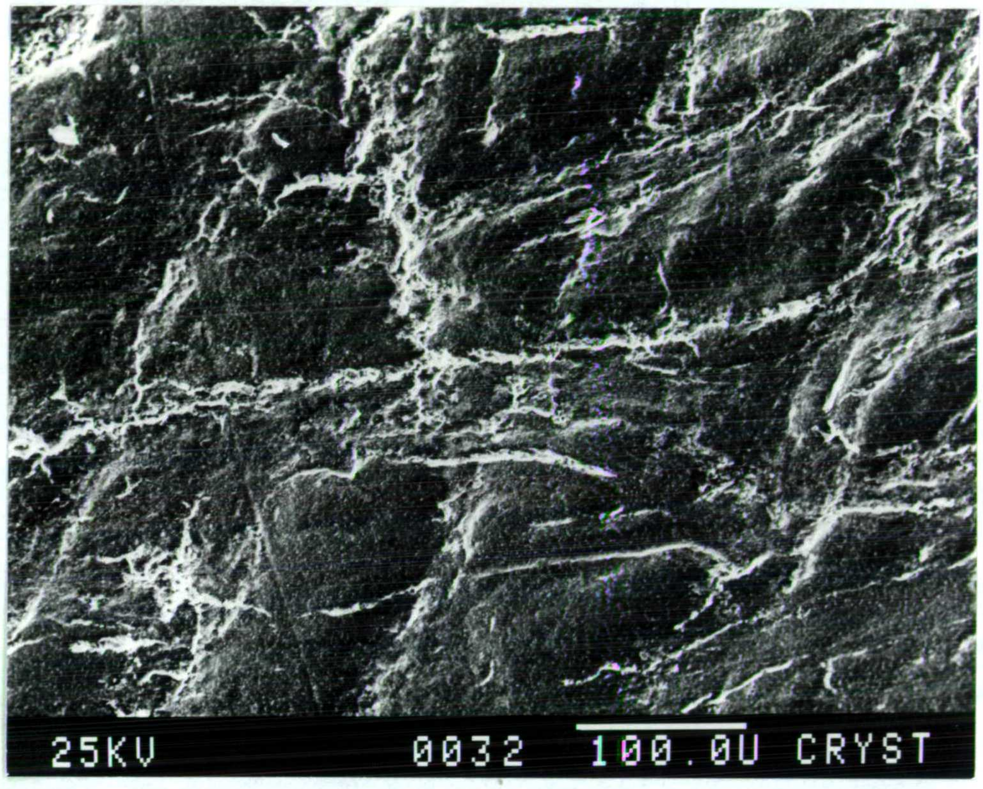


Fig. 25 Marring of the surface of a red deer antler tine caused by rubbing the antler against trees or the ground. Note that the grooves are multidirectional and do not contain fine parallel striae along their floors or walls like those on flakers or hammers (200X).

provide the reader with illustrations of the more common occurrences.

Cultural Modifications

Surface alterations on archaeological bone that are inflicted by man may be divided into two major categories: manufacturing traces and use wear. Of the two groups of traces, those left by manufacturing processes are more easily deciphered and are better understood in terms of their formation. At present a wide range of manufacturing traces have been defined. The major types relevant to the case studies are outlined below.

Scraping Bone with a Stone Tool

One of the earliest methods of altering the shape of bone splinters to make them more suitable for particular tasks is scraping of the surface. A wide range of stone tools may be employed for scraping bone including flakes, blades, scrapers, notches, and burins. Scraping with the durable edge of a burin may be bidirectional, but in the case of most flakes or scrapers it is difficult to reverse directions in a reciprocal motion. The sharp edge of the stone tool held at a relatively high angle of attack causes microcutting of the bone's surface. Asperities in the edge of the stone tool create striations that are diagnostic of this manufacturing process. When experimental replication of scraping is conducted, debris formed by microcutting of the bone consists of long, thin, smooth shavings that often curl into helical shapes.

Manufacturing traces created by scraping appear as sets of parallel striations that may overlap if repeated strokes are taken. There can be considerable variation in the depth of individual striae and it is common for a larger groove to be composed of many finer striations in its floor and along its sides. Unlike sandstone abrasion, the striae from scraping have a tendency to be wavy (Figs. 26 and 27). The transverse profile of a scraped surface has a low relief including very narrow indentations with angular and irregular cross-sections (Fig. 28).

When great force is applied to the stone tool or it is held at a very high attack angle (i.e. nearly perpendicular to the bone surface), the tool may bounce over the surface and create "chattermarks" (Newcomer 1974: 149). Chattermarks are low ripples that run transversely to the microcutting striae like undulations in a rough dirt road. These ripples are most easily seen with the eye or an optical microscope by placing a light source at a low angle to the surface so that shadows are cast by each chattermark (Fig. 29). Because of the reduced depth perception with a SEM, it is very difficult to observe chattermarks directly without using stereo pairs or viewing them in profile.

Sandstone Abrasion

Abrasive wear is the displacement of material through plowing, microcutting, or spalling caused by the relative motion of two surfaces against each other. The loss may occur on one or both surfaces depending on their respective hardness and whether it is caused by asperities or embedded particles on one of the surfaces or a

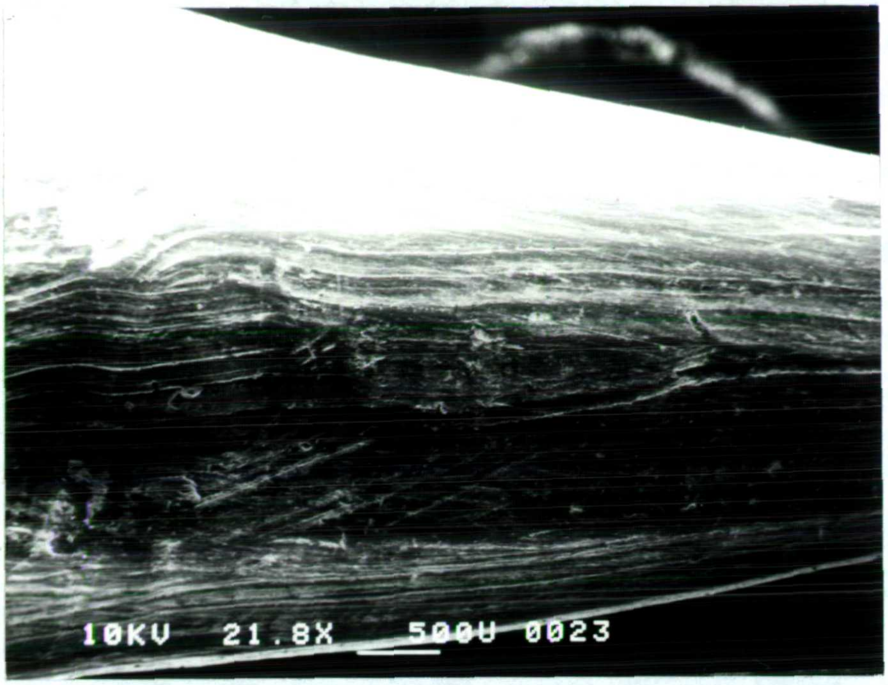


Fig. 26 Awl shaft from Abu Hureyra showing wavy striae created by scraping with a stone tool during manufacture (21.8X).

Fig. 27 Modern bone scraped experimentally with a flint flake (14.5X).

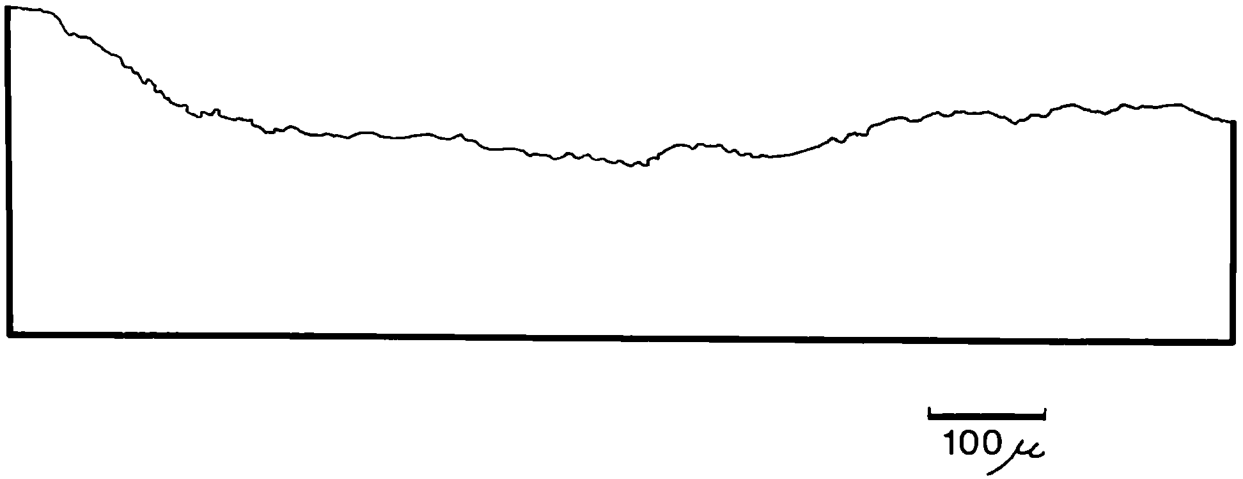


Fig. 28 Profile of experimentally scraped bone.

grinding medium placed between the two surfaces. Abrasion may occur in either a dry state or in a wet medium. Wear analysis of sand on metal has shown that dry sand produces more striae and hence greater wear than does wet sand (Zum Gahr 1981). In contrast to polishing, abrasion employs an abrasive agent that is much harder than the substance to be worked and leads chiefly to mechanical attrition of the stressed surface rather than changes at the molecular level (Adamson 1960: 232, 233).

If sandstone is used as an abrasive on bone the sand grains slide across the surface of the bone causing attrition by plowing and microcutting. Wear debris from plowing, which is the most common mechanism of wear in this case, consists of short, irregular, flat chips (Zum Gahr 1981: 386, 387) produced when bone is deformed, displaced to the edges of the groove, and detached by subsequent abrasive contact. After one set of grooves is formed by the leading edge of the abrader, the grains that immediately follow form their own grooves and tear loose the plowed-up ridges formed by preceding grains. The resulting surface traces are closely packed, overlapping, parallel striations of fairly uniform depth, width, and distribution (Fig. 30). The profiles of abrasion striae may vary in size and form, but the presence of spherical grains in sandstone often creates round-bottomed grooves (Fig. 31). Overall, the abraded bone surface has a profile with a low relief consisting of few asperities and numerous closely placed valleys. Because the abrader is usually rubbed over the bone's surface in

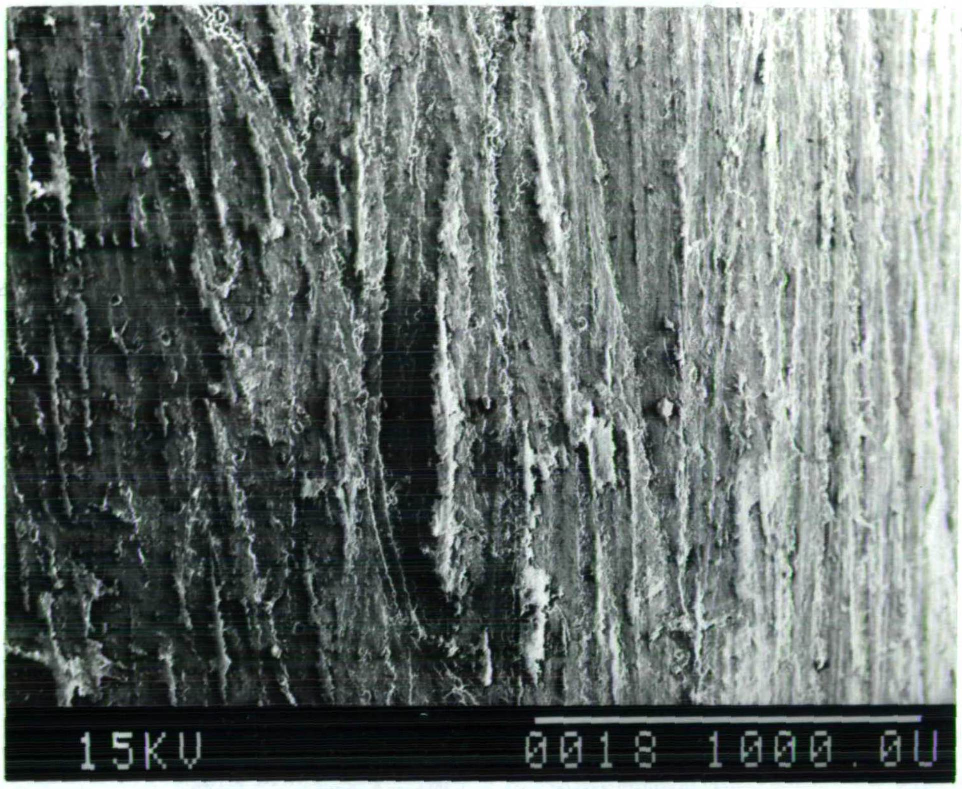


Fig. 30 Shaft of experimentally manufactured awl showing striations from sandstone abrasion (39X).

Fig. 31 Profile of experimentally abraded bone.

at least two directions and there is no restriction on the directionality, sets of striae may cross over, intersect, and form zig-zagged patterns (Fig. 32). When an area of bone is rubbed repetitively in one plane by a flat piece of sandstone a visible facet is formed, the edges of which can be eliminated by shifting the plane of contact. This description is presented in a manner that implies that the active piece is the abrader and the stationary piece is the bone. The reverse may often be true, especially if bedrock or a sandstone block in a wall is used, but the formation of wear is identical.

Manufacture Polish

Applying a polish to a bone surface is a simple process that requires only a few minutes labor. At present there is great difficulty in categorizing polish on bone according to the material that created it. Manufacturing polish can in most cases, however, be distinguished from use polish because of its uniformity and even distribution. Use polish is restricted to the working surface or edge that is in frequent contact with another material and handling polish occurs on the asperities of the base or handle in the small areas that are held. Alternatively, manufacturing polish is widespread on the shaft or body of the artifact, but often does not extend to the articular or medullary surfaces.

An intentionally manufactured polish usually bears traces of faint, muted striations indicative of the directionality with which the process was conducted (Fig. 33). Most of these scratches are formed by the abrasive

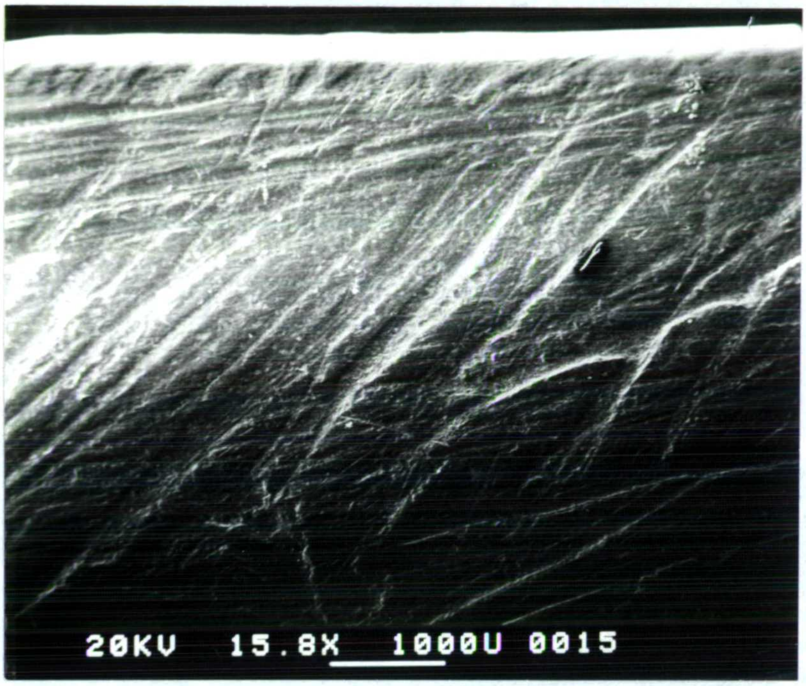


Fig. 32 Archaeological awl from Grasshopper Pueblo, Arizona, showing sandstone abrasion (15.8X).

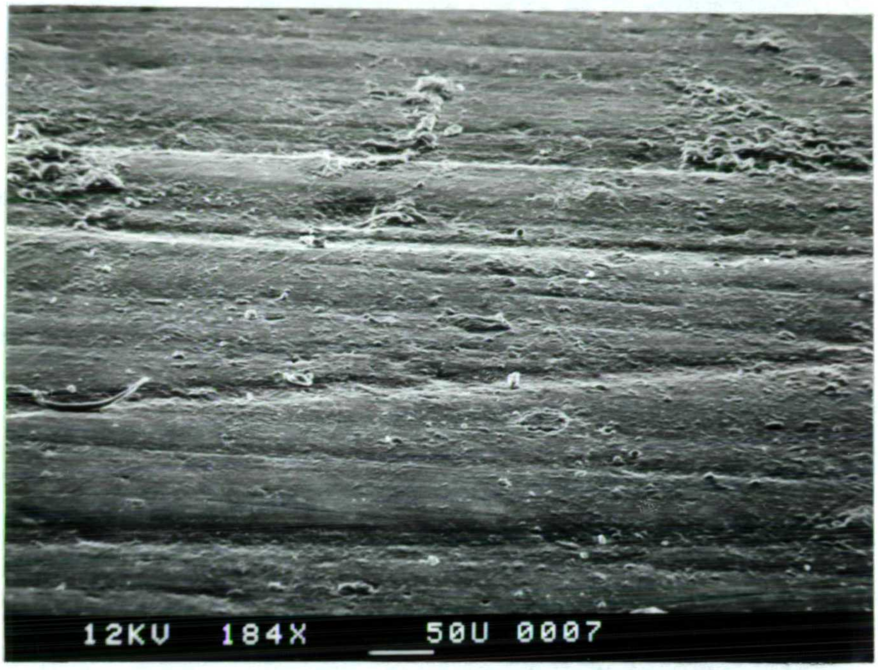


Fig. 33 Surface of bone polished experimentally by alternating abrading with sandstone and rubbing with wet leather (184X).

or bort employed in the initial stage of the polishing process, although some striae may be remnants of previous manufacturing steps such as scraping. Scanning electron microscopy is useful in interpreting manufacturing polishes since the elimination of reflected light in the image allows the striations to be seen more easily. The striae appear much shallower than those on an unpolished surface and their edges are less distinct and more rounded from the polishing.

The process by which bone surfaces are polished, either during manufacture or use is uncertain. In contrast to fine abrasion which works merely through mechanically removing asperities, a true polish actually alters the crystallinity of the surface. The alteration in the molecular structure of an object's surface is probably due to high local temperatures raised through friction of the surfaces of the two materials sliding over each other. The polished layer, known in material science as the Beilby Layer, may then be the result of a softening or actual melting of the object's surface (Adamson 1960: 234). Its exact formation is not completely understood, but it is either amorphous in structure or microcrystalline (Adamson 1960: 233). In either case it appears microscopically as a viscous film that has flowed over the surface and into minute pits and scratches. The type of plastic deformation that occurs with melting of the surface from friction is difficult to detect on materials that are microcrystalline initially, like chert and bone. Although it may be questionable that sufficient heat from friction is generated by hand polishing to melt the apatite crystals in bone, remodeling of the surface by altering the collagen and other organic constituents is certainly possible. Because bone is a two-phase material containing both organic and inorganic components, interpretation of the surface modifications due to polishing is very complex.

Grooving and Snapping

An extremely important technique for cutting out bone artifact blanks is known variously as groove and snap, groove and splinter (Clark 1953), and longitudinal debitage (Newcomer 1977). Superior to earlier techniques because it allows exact shapes with parallel sides to be made with minimal effort and waste, this method first appeared with frequency in the Upper Paleolithic. The groove and snap technique can be used to form any shape in bone or antler, but is most often used to make longitudinal, transverse, or annular cuts. Curves and circles are more difficult to cut than straight grooves because the tool must cut diagonally across the collagen-apatite bundles, but if care is taken in the initial formation of the groove quite satisfactory results may be obtained.

The traces remaining behind on artifacts and manufacturing debris are extremely diagnostic. The groove is begun by making a scratch along the surface which is gradually deepened and widened by repeated strokes back and forth. Because of the hardness and curvature of bone, some slippage frequently occurs during this first stage. Indications of slippage generally appear as individual wayward scratches that begin parallel to or inside the groove and angle off across the surface of the bone. Sometimes the shoulder of the stone tool scrapes the bone surface on either side of the groove, but these striations are separable from slippage by their adherence to a path parallel to the groove. Within the groove the walls are marred by fine parallel striations created by irregularities in the stone tool's cutting edges. This microcutting, present on both bone and antler that have been grooved, runs along the sides of the groove from top to bottom (Fig. 34). The actual groove is roughly V-shaped in profile before it is snapped (Fig. 35). At a high magnification (e.g. 600 X), the walls of the groove viewed in profile exhibit delicate indentations and a slight waviness representing the microcutting of the fine striae viewed on end (Fig. 36).

After the groove has reached sufficient depth in the cortical tissue of the bone or antler to insure that the blank can be snapped free along the designated outline, force is applied and a crack initiated (see Chapter 5). The broken portion of the bone underlying the groove is rough and irregular in comparison to the finely striated groove wall (Fig. 34). A finished artifact frequently has all of the snapped zone and most of the grooved zone smoothed by longitudinal scraping, abrading, or polished. The amount of visible traces of grooving and snapping varies widely from one piece to another. Traces of this technique on discarded unfinished pieces and debitage are generally much more clearly preserved.

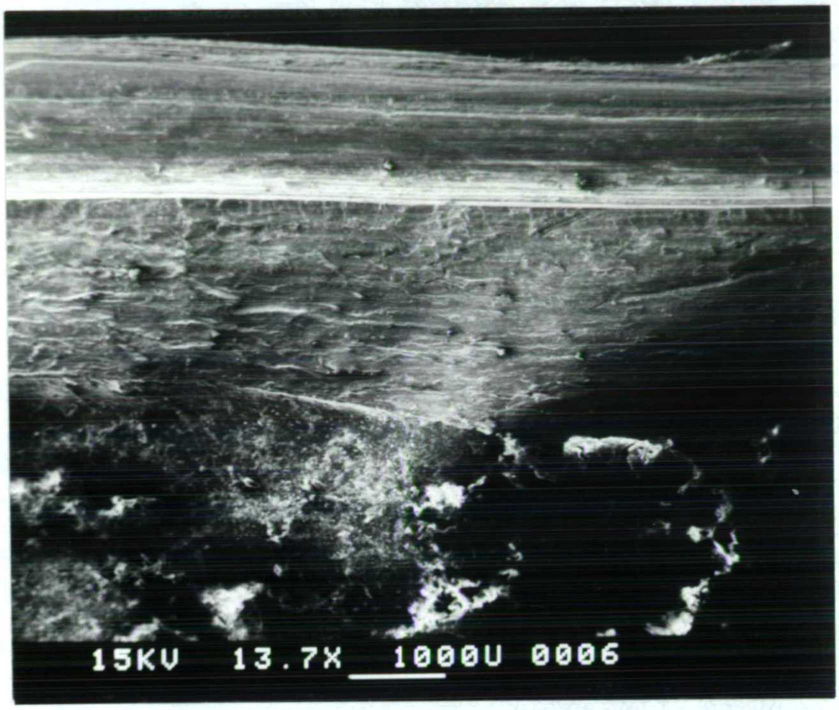


Fig. 34 Experimentally grooved and snapped bone showing longitudinal striae along top and ragged broken surface immediately below (13.7X).

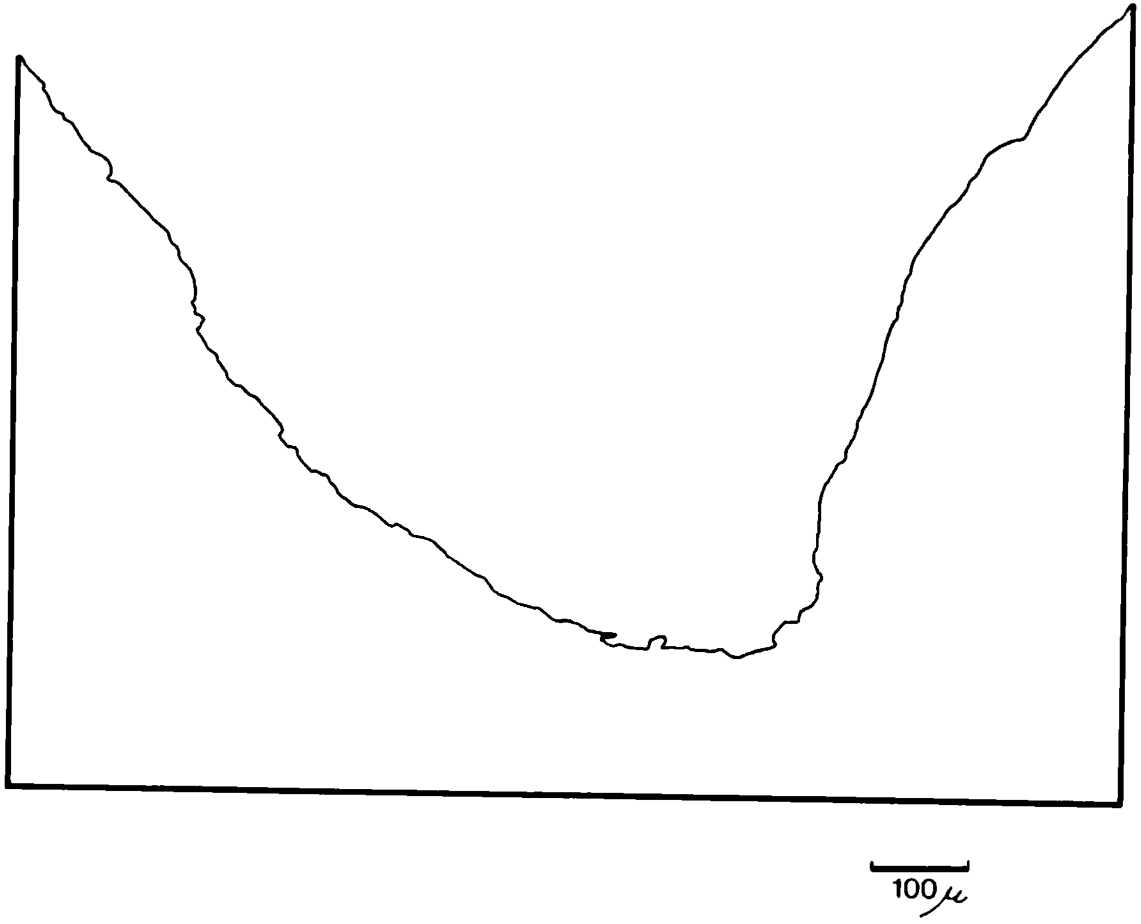


Fig. 35 Profile of archaeological grooved bone from Point of Pines.

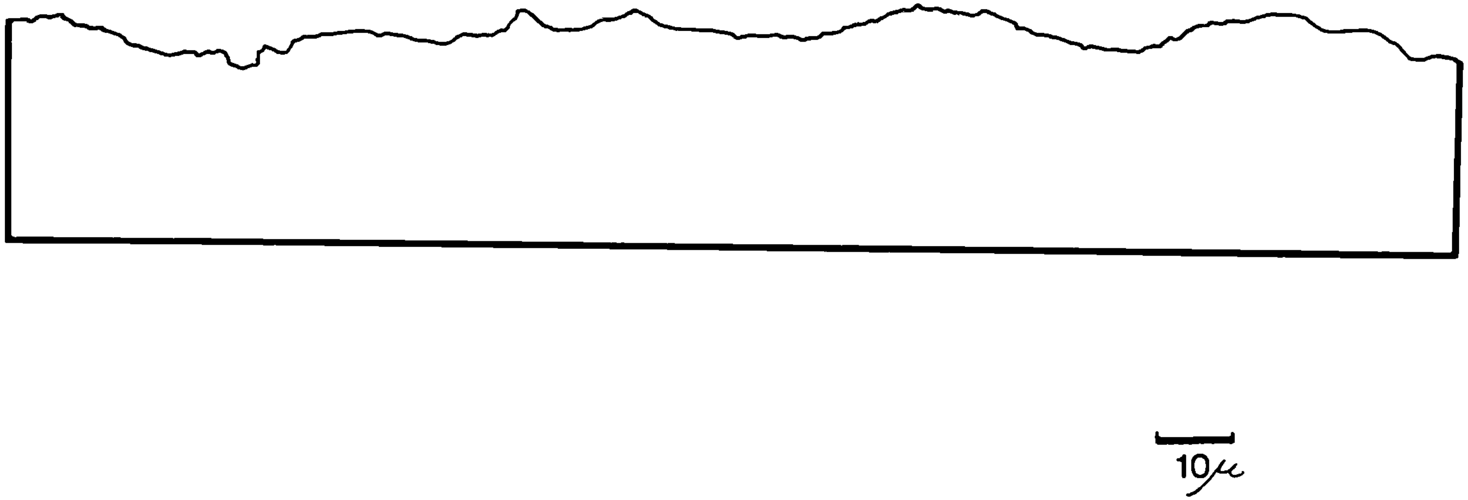


Fig. 36 Profile of archaeological grooved bone from Point of Pines showing close-up of one side and indentations in wall representing fine striations.

Incising

The incising of decorative motifs in the surface of bone or antler is a difficult procedure if great precision is required or elaborate curvilinear designs are desired. Because of the anisotropic nature of bone, it is easier to cut straight longitudinal lines than transverse or diagonal lines. Curvilinear lines are yet more difficult since slippage of the cutting tool is a problem. For this reason, most decoration on bone tends to consist of fairly straight transverse and longitudinal lines combined with occasional drilled dimples or perforations.

Traces on bone incised with a stone tool resemble those in grooves made for grooving and snapping. The technique is exactly the same except that the incised lines are narrower and shallower. The walls and floor of the incisions are marred by fine parallel striations and the profiles range from very narrow V-shaped cuts to more open grooves. If two or more incisions intersect and overlap, it is sometimes possible to determine which line was made first by the presence of debris from the second cut lying across the first. Abrading or polishing is occasionally performed in the areas around incised lines in order to remove evidence of slippage and soften the edges of the incisions.

Chopping of Antler and Bone

Chopping through antler with a large flake or biface produces marks that resemble those on the ends of chopped wood. A broad V-shaped channel is first cut all around the circumference of the antler beam or tine, unless it is thin enough to be severed from one side. The traces on the chopped antler end consist of a series of short transverse cuts that slice, compress, and fracture the material through which they pass. The numerous strokes required are witnessed by the terracing or stepping of the severed area as blows toward the middle penetrate progressively deeper. If the antler is rotated, then the center is the last to break through. Because the chopping near the outer surface extends back further than that in the center, the severed end is usually somewhat conical (Fig. 37). If the small part remaining in the center that is still attached to both sides is simply snapped in two, then a short cylindrical prominence may protrude from the end. The natural external surface of the antler on either side of the chopped area may exhibit shallow transverse cuts where a few blows made contact outside the primary chopping zone.

Chopping through bone is different from severing antler because the outer compact tissue of bone is very dense and may overlie only the fine trabeculae of cancellous bone or merely a medullary cavity. Because of this condition, a few powerful strokes are superior to multiple weak blows. Occasionally it is possible to see straight, shallow cuts near the chopped edge of a bone where blows have been too weak to break through. The edge of a chopped bone is characterized by an irregular, nibbled outline. Depressed fractures with the broken pieces displaced slightly are sometimes visible. The upper surface of the chopped edge is often deformed downward and the break may be slightly beveled so that the lower surface extends beyond the upper (Fig. 38).

Drilling

Drilling with a chipped stone bit forms characteristic traces on the inner wall of the perforation that can be identified if use wear does not obliterate them. Because long bone cortical tissue is harder than antler, the traces are usually more clearly defined and crisper in the former. The rotation of the cutting surface of the drill creates very fine parallel striations running around the inside of the wall. These striae, representing microcutting by minute asperities on the edge of the stone drill, are similar in appearance to the traces found on the inner walls of grooves made with chert tools.

A chipped stone reamer may be used to enlarge the center of a drilled perforation, but this does not significantly alter the microwear traces since the direction of movement and the material used are basically the same as that for drilling.

Biconical drilling can usually be identified by the fact that both rims will be larger than the center of the perforation. The extent to which this feature is developed may vary considerably and some holes made with long, straight-sided drill bits and a pump or bow drill may have nearly straight sides. A perforation drilled from one side only is distinguished by the discrepancy between the size of the openings on the upper and lower surfaces. The upper rim will always be slightly larger than the

Fig. 37 Experimentally chopped reindeer antler.

Fig. 38 Experimentally chopped cow scapula.

lower one, unless a reamer has been used to expand the perforation from below.

Butchering Marks

During the process of skinning, eviscerating, sectioning, and stripping the meat from the carcass of an animal, cuts are sometimes made in the bone surfaces. It is often possible, by ethnographic examples and knowledge of the distribution of tissues of the anatomy, to understand the purposes for particular cut marks (Guilday, Parmalee, and Tanner 1962). For example, fine cuts on the anterior surface of the mandible near the symphysis are usually associated with skinning, whereas transverse chops through the ribs represent sectioning of the carcass into usable pieces of meat. Interpretation of the distribution patterns of butcher marks will not be outlined herein, but the physical appearance of butcher marks is pertinent to the analysis of surface alterations.

Chipped stone butchering tools produce V-shaped cuts of various dimensions depending on the shape of the tool and the kind of stroke used. Many are only short superficial slices made while skinning or removing meat, when little force is necessary. Slicing marks are typically narrow and possess fine parallel striae along their walls like those in incised grooves. Chop marks, commonly inflicted when severing ligaments and tendons at articular joints, can sometimes be distinguished from slicing marks by the downward deformation of the lateral edges of the mark, but longitudinal striae may also be present if the tool slides during chopping or as it is removed (Fig. 39). Chopping marks tend to be wider at the top than slicing marks, but are also V-shaped in profile (Fig. 40). The simplest way of examining the interior of butcher marks for evidence of directionality and the type of tool used is to make a silicone rubber mold of the mark and examine the negative replica for striations. A cross-section through the mold reveals the profile of the mark with considerable accuracy. Walker and Long (1977) have illustrated the differences in profile between cutmarks made with various kinds of stone tools as opposed to metal knives and axes. The incisions made by a flint bifacial cutting tool are wider at the top and more irregularly shaped than those made with a metal knife. It is not possible to correctly identify the kind of tool employed in each case, however.

Use Wear on Flakers

From the Upper Paleolithic onward antler tines were frequently utilized in pressure flaking stone tools. Since no modification other than breaking the tine from the main beam was necessary to convert a tine into a pressure flaking tool, manufacturing traces are usually not available to distinguish between utilized and unutilized tines. The presence of the antler in an archaeological context does not alone constitute sufficient evidence that it was used as a tool, since much antler on sites was collected as raw material that was never actually employed. The most significant evidence of use of an antler tine as a flaker is use wear at the tip.

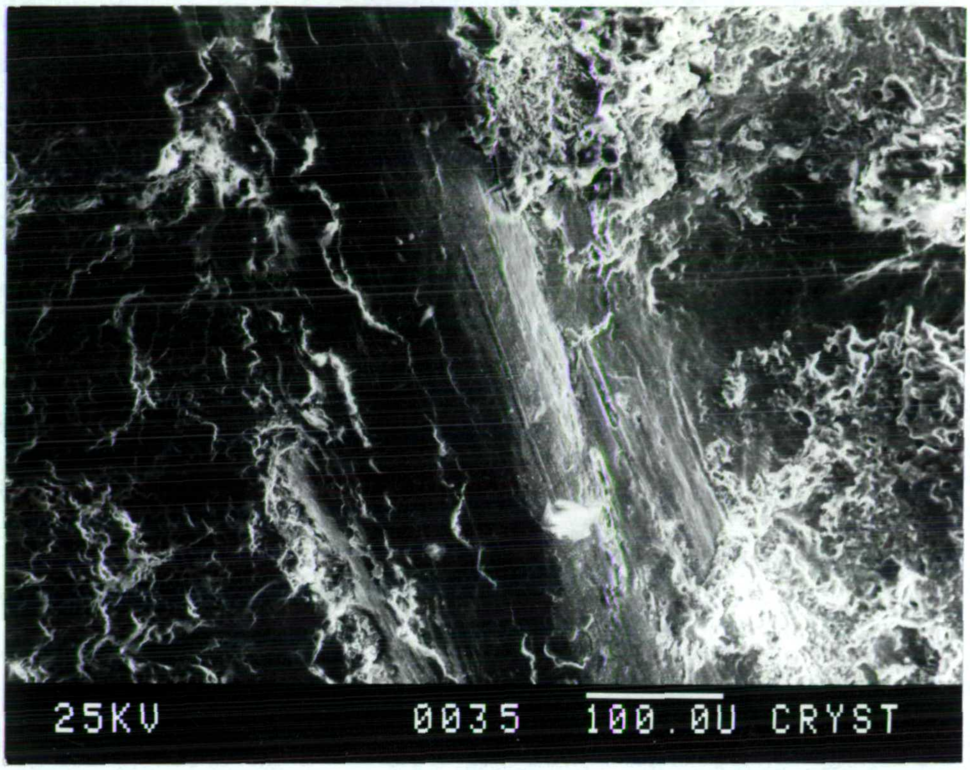


Fig. 39 Chop mark on experimentally chopped cow scapula (silicone rubber mold). Note that it is broad, has a scalloped layer of depressed material along the edge, and contains longitudinal striae like those found in slice marks (180X).

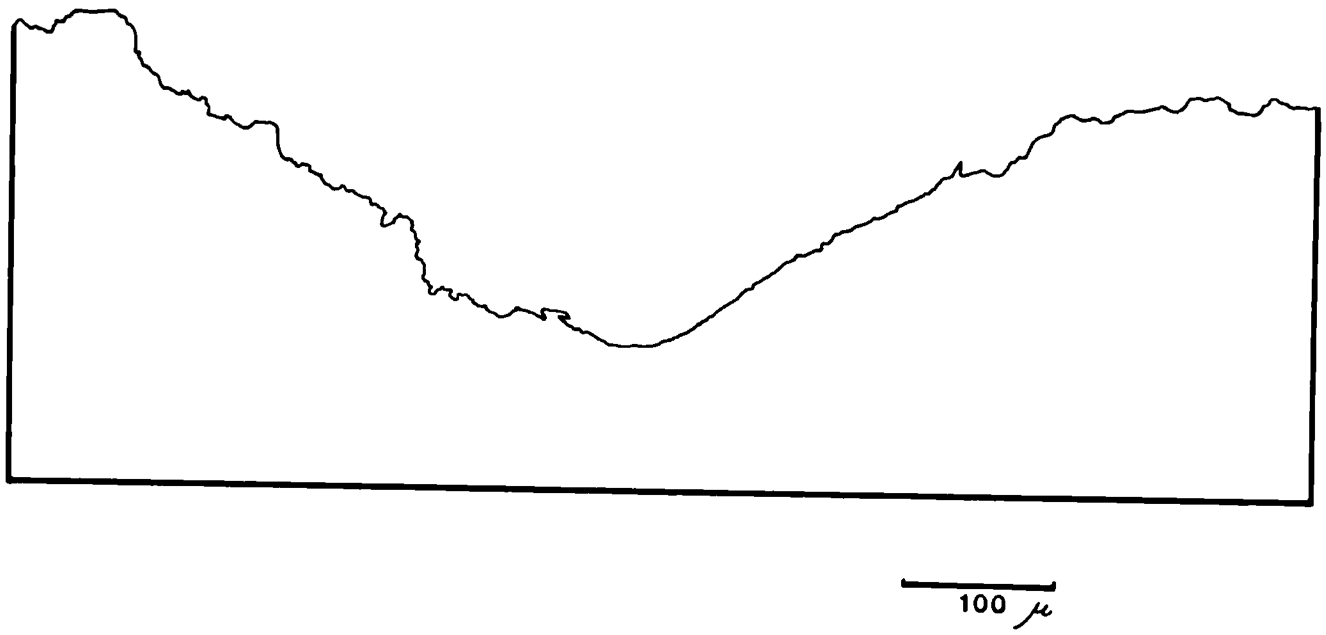


Fig. 40 Profile of chop mark.

There are three reliable characteristics that can be used to identify antler tine pressure flaking tools. Firstly, the tips of flakers are usually blunted from use. This differs from the polished rounding seen on unmodified tines in that the tips of flakers are heavily pitted (Fig. 41). This pitting is due to crushing of the antler's surface when it is pressed against the chert. Secondly, leading away from the pitting and down the shaft for a short distance are longitudinal scratches (Fig. 42). These marks are not usually parallel to each other and often run slightly diagonally or angle off near their termination. Each scratch is composed of many fine, parallel striations caused by the eminences in the stone's surface microcutting the antler as the two materials slide against one another. The presence of microscopic striae on the bottom and walls of the scratches set them apart from the smoother cuts produced in natural marring. Many of the scratches terminate in the third diagnostic feature of flaker use wear, what appears initially to be a transverse V-shaped notch. In reality, the cause of the terminus is the fact that the stone's edge has gradually cut deeper into the antler until it has pushed up so much material in front of it that the asperity on the chert can penetrate no further and is snapped off. The striation thus disappears under the amassed debris from the cutting, part of which is still attached to the antler (Fig. 43). The combination of these three major use wear traces on the tips of antler tines recovered from archaeological sites may be used to

Fig. 41 Tip of antler tine flaker from Grasshopper Pueblo, Arizona showing pitting damage (13.5X).

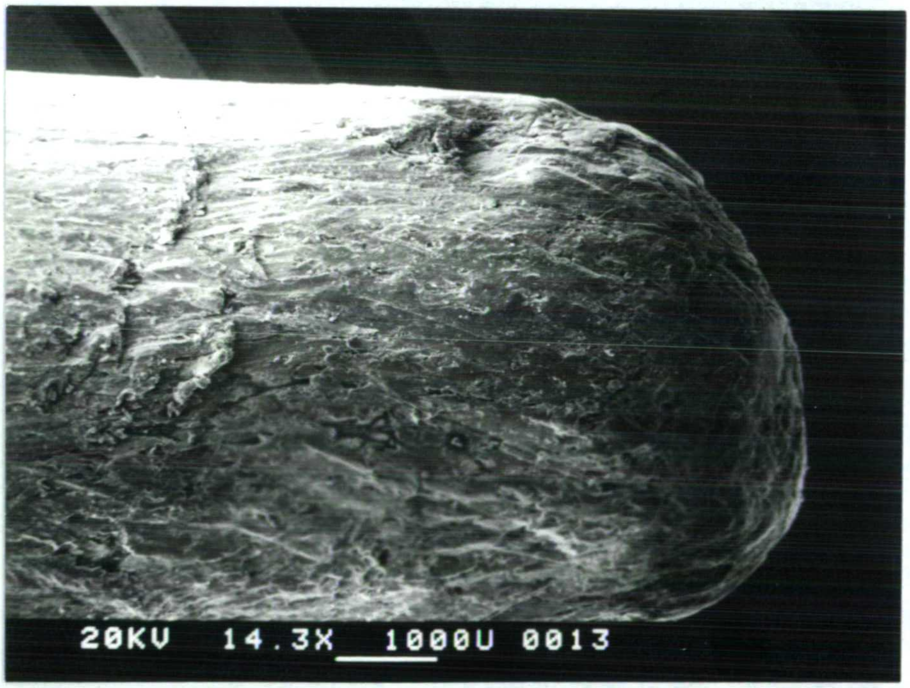


Fig. 42 Same flaker with longitudinal striae running down from the tip (14.3X).

substantiate classification of these objects as pressure flakers.

Use Wear on Antler Hammers

Antler beams and large tines have been employed by many cultures as hammers in working stone by the soft hammer percussion flaking technique. Both shed and unshed antlers were used as the raw material for hammers. The wear created by hammering chert with an antler hammer is characterized by severe attrition in the impact area. Use wear on hammers can range from a very localized patch of damage to quite extensive wear over much of the surface of the tool. Generally, however, the tool fits more comfortably in the hand in a particular position or one end is more effective so that wear is likely to be concentrated. If the proximal end of an antler beam is used to strike the lithic material, then part or all of the burr may be worn away.

Wear patterns on an antler hammer consist of heavy pitting, sets of fine parallel striae, and slanting V-shaped cuts compactly distributed over the impact area (Fig. 44). As the chert and antler make contact some slippage inevitably occurs, causing scraping of the antler's surface. As in the case of pressure flakers, the microcutting of the antler by asperities on the lithic surface or edge creates sets of fine parallel striations on the antler's surface. If penetration of the flint is deep, then slanting, V-shaped notches are formed. Pitting is produced in the areas where direct compression of the antler occurs. The profile of a well-used antler ham-

Fig. 43 Same flaker showing amassed debris at terminus of one of the striations (77X).

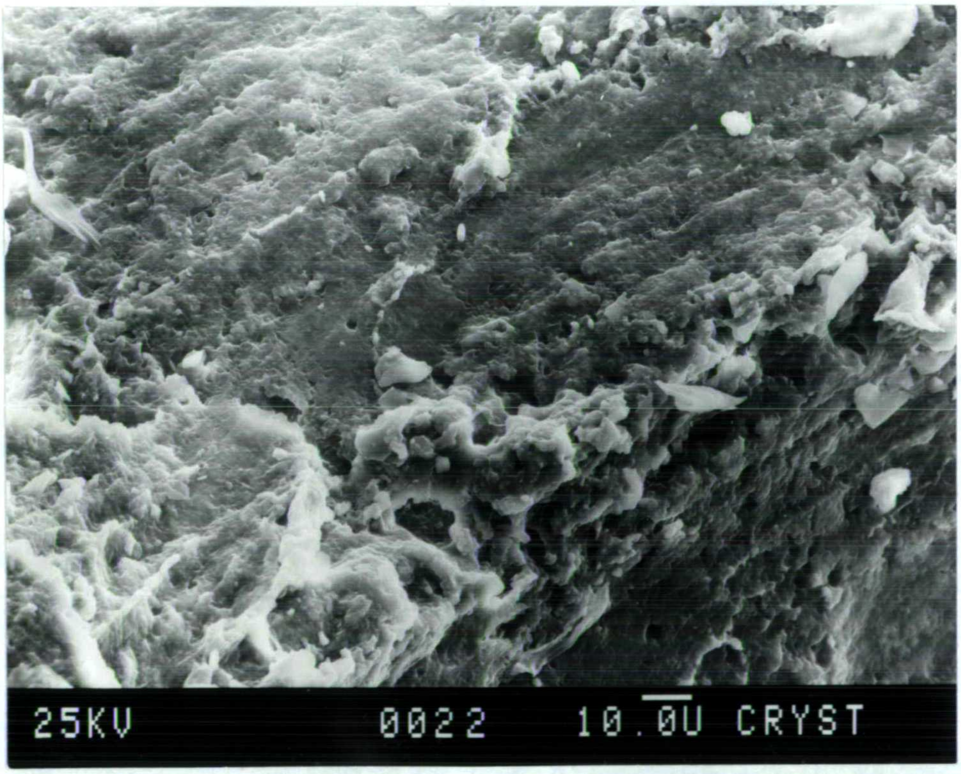


Fig. 44 Wear on antler hammer from Point of Pines (silicone rubber mold) (660X).

mer's surface is characterized by deep, broad, irregular indentations, flat, tilted surfaces, and sloping V-shaped notches (Figs. 45 and 46). If use of one portion of the antler is prolonged, then heavy surface attrition may create a wear facet in that area.

Impact Fractures

A general category of use damage that has been observed on a wide range of tools, as well as unutilized deer antler, has been classified as impact fracturing. This breakage pattern involves the removal of one or more longitudinal flakes emanating from the end. It occurs with frequency on the tips of projectile points (Fig. 47) and through natural damage of antler tines (Fig. 24). Terminal impact damage has also been observed less commonly on the tips of awls (Fig. 48). The removal of scalar flakes from the working edge of a gouge is comparable to the narrow flakes driven from slender, pointed implements, except that the contact surface is broader so that the width of the flake is generally greater in proportion to its length. Terminal impact fractures occur when the tip of a tool or weapon strikes a resistant obstacle such as the ground, a stone, a tree, or the bone of an animal, with great force. This type of breakage may be distinguished from many kinds of post-depositional damage which are frequently characterized by relatively straight longitudinal or transverse fractures through the thickness of the bone. The latter breakage pattern often exhibits a fracture surface that is perpendicular to the the bone's surface.

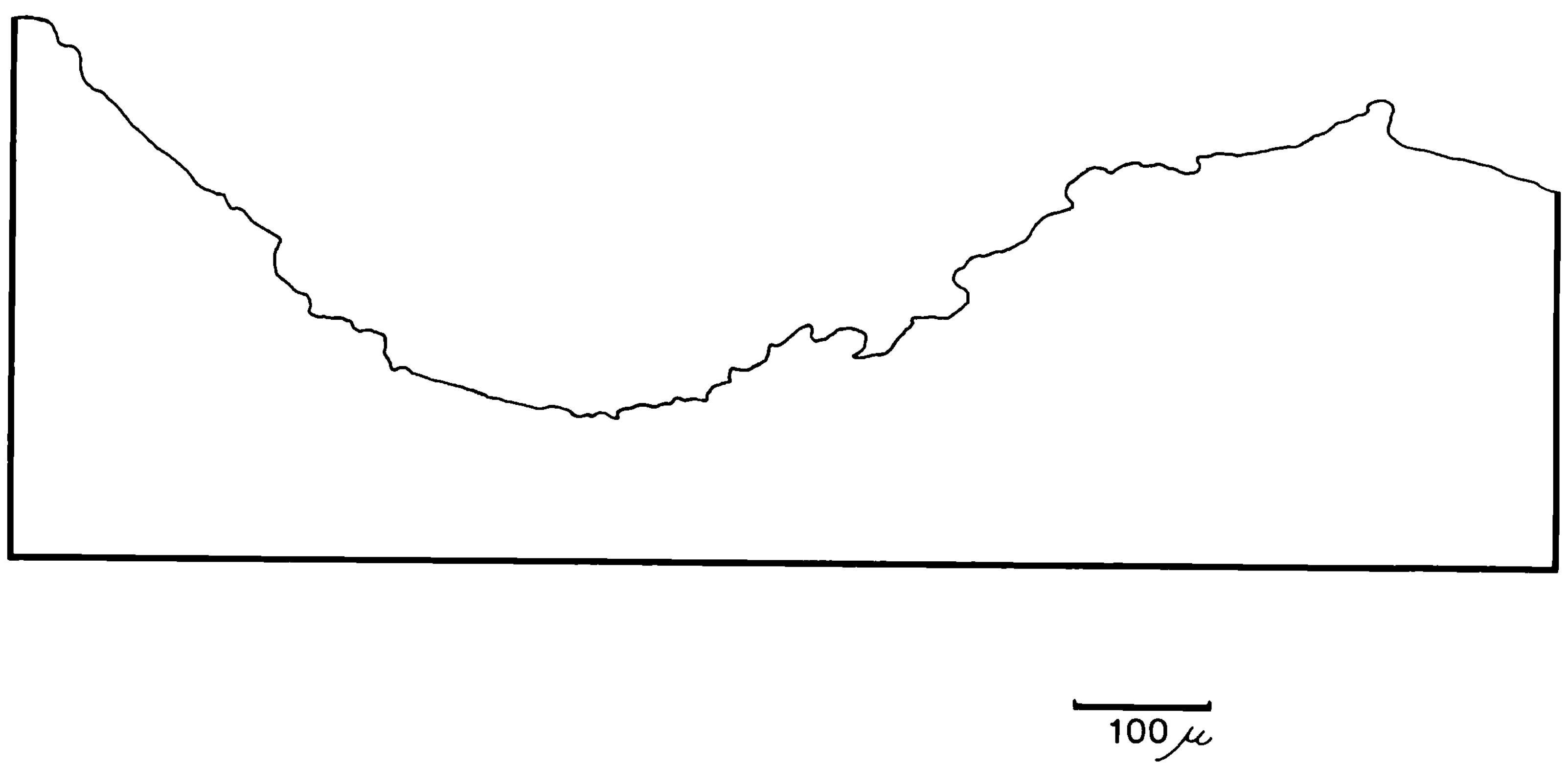


Fig. 45 Profile of antler hammer use wear with deep irregular pitting.

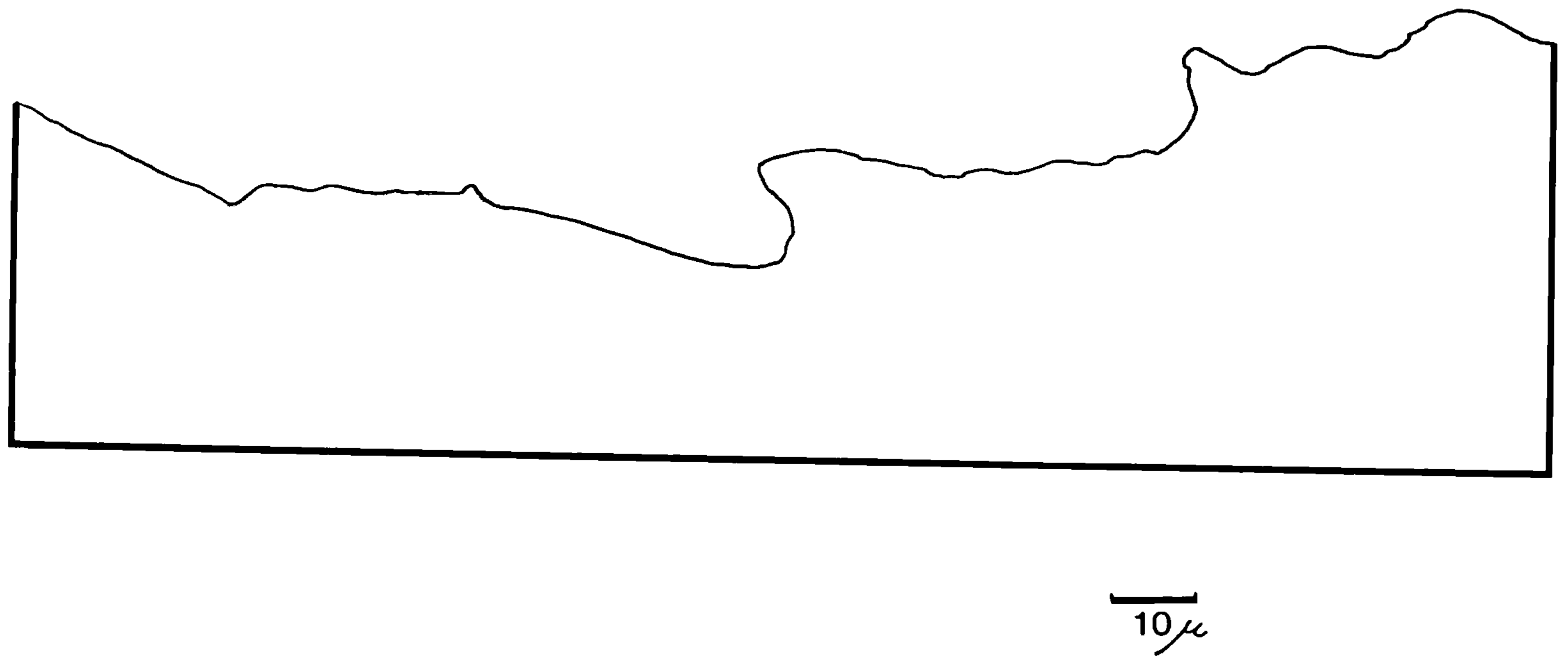


Fig. 46 Profile of antler hammer use wear with slanting V-shaped cuts.

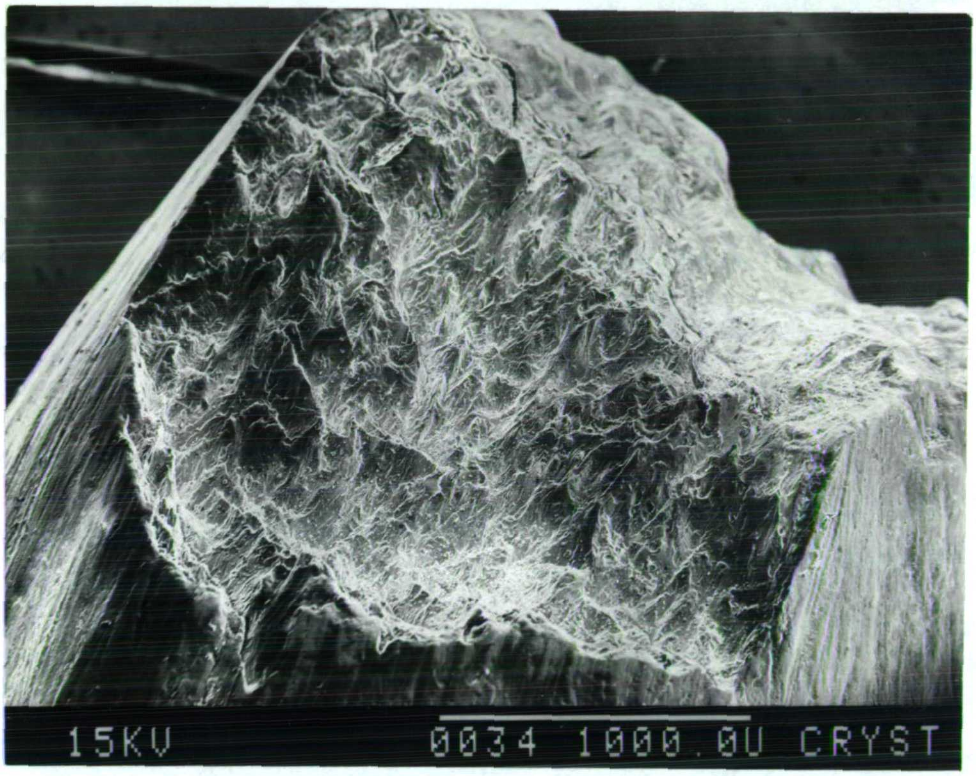


Fig. 47 Terminal impact fracture on experimental bone projectile point (36X).

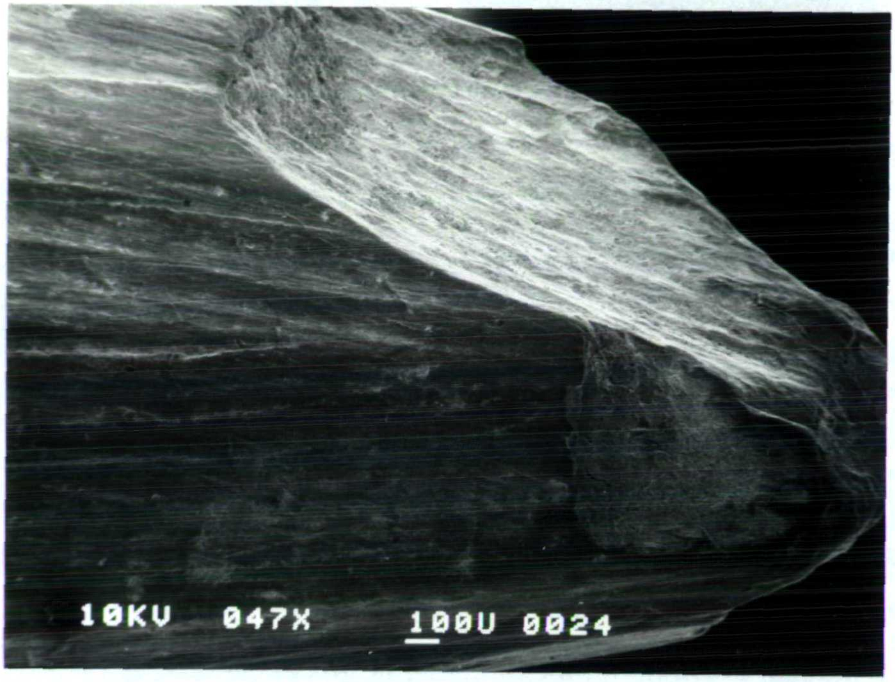


Fig. 48 Terminal impact fracture on awl tip from Abu Hureyra (47X).

Handling Polish

Bone artifacts that have been used for prolonged periods of time develop a polish on surfaces that are handled most frequently. The polish forms very gradually by rubbing the fingers or the palm repeatedly in certain areas. The oils in the skin, coupled with fine particles of grit gently smooth the surface eminences, leaving recessed areas unpolished. This selected distribution of polish differs from intentional manufacturing polish which is uniformly spread over most of the shaft's surface. With a few exceptions, such as the tips of hairpins or the teeth of combs, handling polish occurs on the shaft or base of an implement rather than the working edge or tip. Ornaments like rings, beads, and pendants frequently possess polish on the edges and most prominent areas. Because the formation of handling polish is so similar to that caused by hide scraping, these polishes can only be distinguished by their distribution and the morphology of the tool on which they occur. The location of handling polish not only sets it apart from other use wear, but can also provide important information regarding how a tool was held. In association with directionality of the use wear at the tip, therefore, handling polish can be very useful in determining the kinematics of a tool's operation. There is also a potential for handling polish to yield information on handedness.

Polish on Hide Processing Tools

Use wear on implements used for removing hair or subcutaneous fat from hides consists of a very glossy polish that is concentrated predominantly on the working edge of the tool. Very little of the polish spills over onto adjacent flat surfaces for a distance of more than 1 or 2 mm. unless the tool has endured extremely prolonged use. The repeated action of drawing the implement over hides that have a light coverage of fine dust or grit on their surfaces creates microscopic striations that sweep over the edge of the tool (Figs. 49 and 50). These minute scratches, clearly visible only at magnifications of about 100 times or more, are aligned along the direction of movement and are useful in determining how the tool operated. The polish formed from friction of bone against hide may be qualitatively described as very glossy or even greasy in appearance. In time it obliterates surficial features so that when viewed at extremely high magnifications (2000X) the surface still appears smooth.

Although hide polishes seem to be more glossy than polishes caused by waterborne particles, digestion, or plant silica, this is very subjective. Through the use life of any tool the wear traces are cumulative, so that classification of polishes must rely more on the tool's morphology, other types of wear which indicate the motions involved, ethnographic analogy, and possibly archaeological context. Hide polish may occur not only on scrapers, but on awls, thong smoothers, leather burnishers, and tools or ornaments which have had a thong strung through them.

Wear on Shaft-Straighteners and Thong-Smoothers

Perforated bone and antler tools have been used to

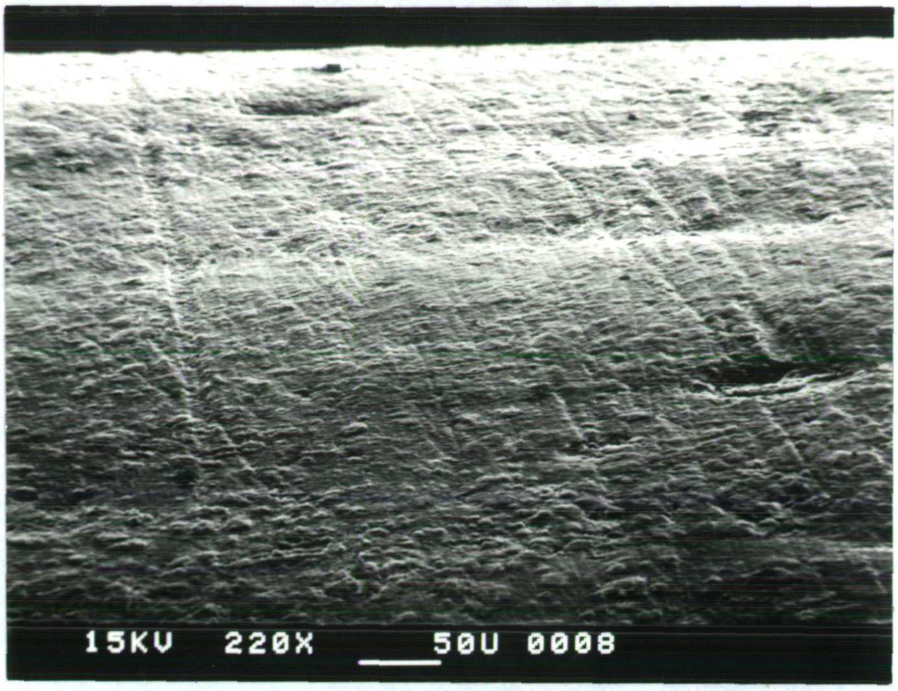


Fig. 49 Experimental hide scraper made on a horse rib. Note the fine transverse striations sweeping transversely over the edge (220X).

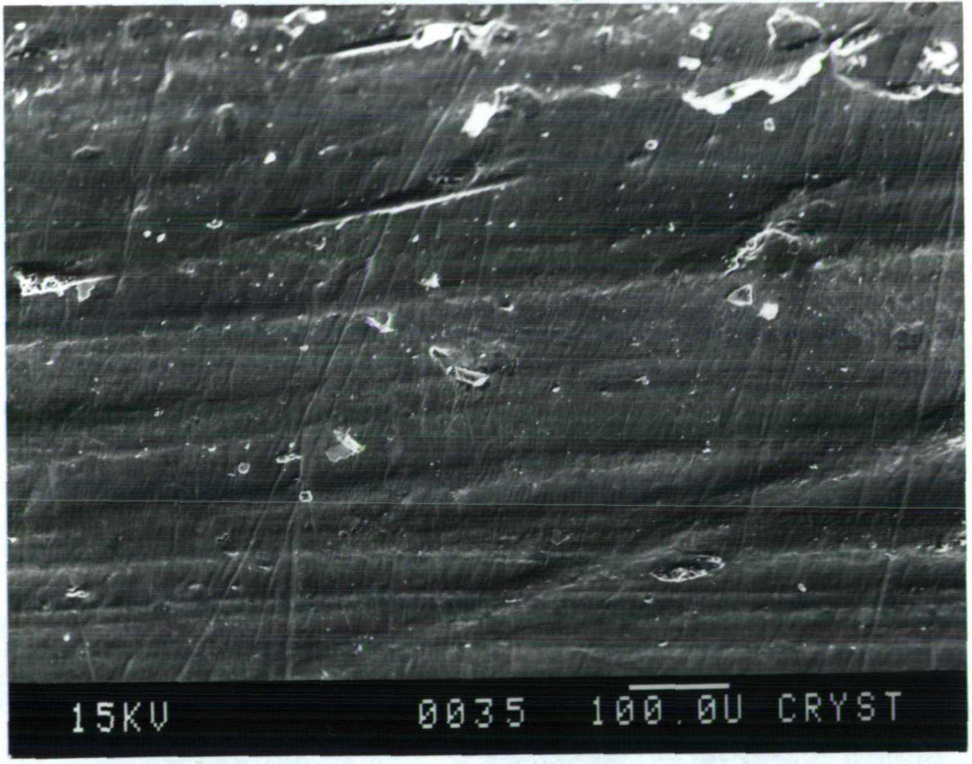


Fig. 50 Archaeological hide scraper, or beamer, made on a deer innominate from Point of Pines. The horizontal grooves are manufacturing traces formed by scraping and thinning the edge of the bone and have been muted by wear polish. The fine vertical striae represent use wear and resemble those seen on the experimental hide scraper.

straighten arrow shafts and to smooth leather thongs (Jenness 1937; Campana 1979). Although the morphology of these tools is similar in both cases, the use wear traces are distinct enough to allow identification of their function. The wear patterns on both of these implements is of particular interest in light of the numerous perforated antlers from Mogollon collections in the American Southwest. Thorough examination of the specimens from Point of Pines and other sites in the area has failed to reveal any use wear in or around their perforations. For this reason traces on experimental and ethnographic examples of shaft-straighteners and thong-smoothers were analyzed.

Traces on arrow shaft-straighteners that have endured a reasonable amount of use appear as polish and grooving across the rim of the hole on the upper surface and extending diagonally to the opposite side of the rim on the lower surface. Friction created by drawing the arrow shaft through the perforation diagonally leads to attrition that bevels the hole (Fig. 51). Generally, the diagonal beveling runs longitudinally in relation to the bone or antler shaft, but some pieces show up to four locations around the hole where attrition has occurred (Campana 1979). The sizes of the cylindrica grooves worn in the sides of the perforation are indicative of the diameter of the arrow shafts which were inserted for straightening. Although the surface margins of the hole are enlarged by wear, the inner portion of its walls remain nearly the same diameter as when it was drilled.

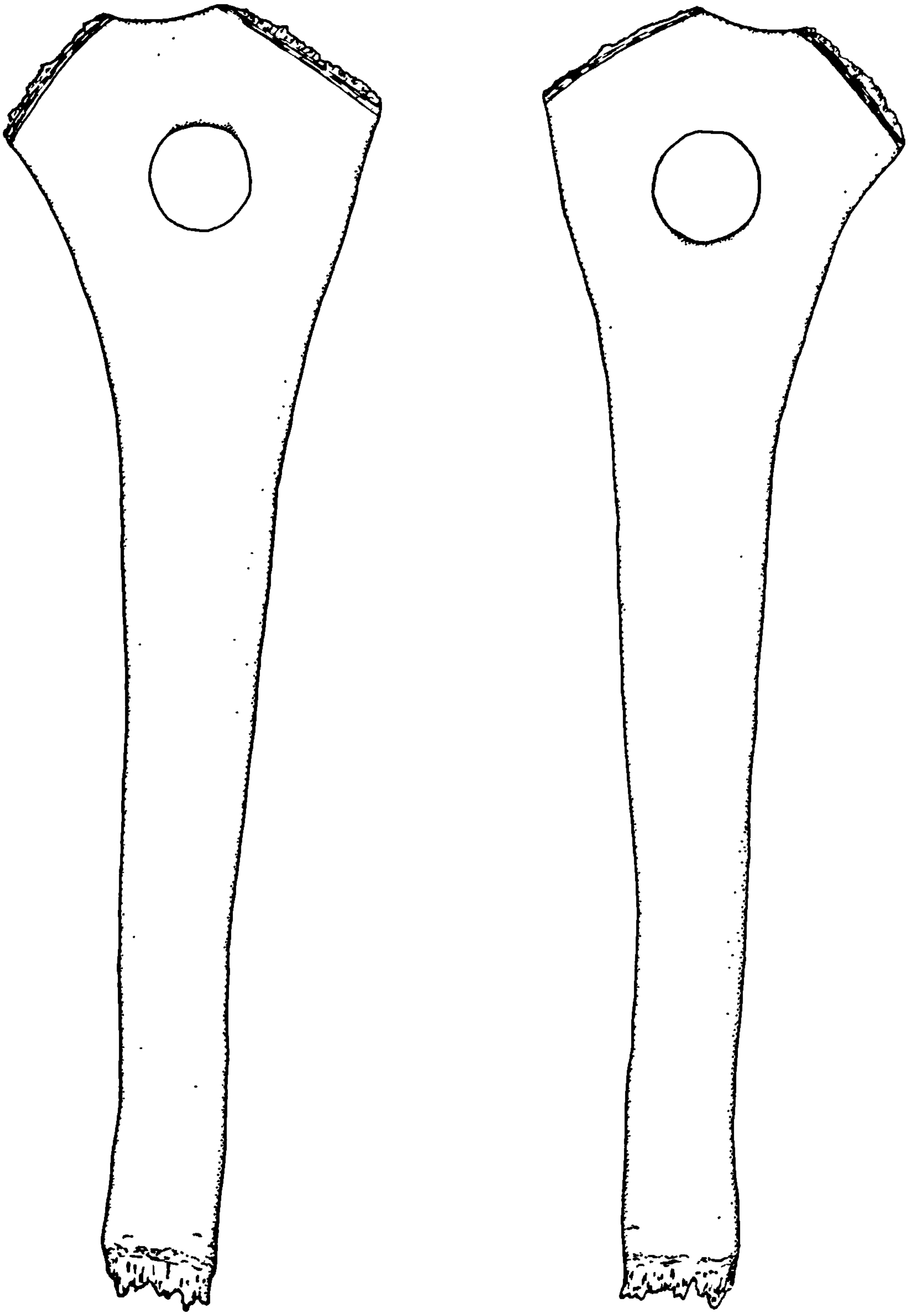


Fig. 51 Location and form of use wear on shaft-straighteners. Attrition through use wears away the rim of the perforation on the upper and lower surfaces on opposite sides creating a diagonal groove.

To prevent denting of the shafts of arrows by the crisp edge of the perforation when the tool was new, there is ethnographic evidence that the Eskimo manufactured a groove on either side of the perforation (Jenness 1937). In some of the examples observed in museum collections the manufacturing traces still visible in the grooves substantiated this account.

An experimental shaft-straightener made on a mule deer antler that was not grooved during manufacture developed wear that beveled the rim after only 20 willow shafts were worked. A polish was well-developed on this specimen, but wear was much less pronounced on a shaft-straightener made from red deer antler used by another experimenter on very soft shafts made of snowberry. Development of wear is probably dependent on the thickness of the cortical tissue of the antler, the type of wood from which the shaft is fabricated, and the amount of force used by the operator.

Production of the polish on the inner surface of the groove may be attributed to the siliceous content of the wood and is therefore closely allied with the polish formed by phytoliths in the grasses used for basket-making.

Thong-smoothers are similar in morphology to shaft-straighteners, but the wear around the perforation is quite distinct. Although the wear traces consist of polish, fine striations, and attrition of the perforation's margins, no cylindrical groove is formed on opposite sides of the upper and lower surfaces. Instead, the rims are worn and rounded in the same spot on the two surfaces. Whereas a pristine biconically drilled hole in bone or antler generally has a rather crisply defined rim, the area where a thong has been repeatedly rubbed back and forth through the hole will be gently rounded. The annular striations created by the drill around the walls of the perforation are replaced by a glossy polish and sometimes fine transverse striae in the used portion (Fig. 52).

As explained in Chapter 6, perforated antlers from Point of Pines differed from ethnographic and archaeological examples of shaft-straighteners and thong-smoothers in that striae from drilling were not obliterated by use polish and attrition. The rims of the perforations were crisply defined, with the exception of the small hole in the handles of a few examples, which was probably used for stringing a thong for carrying the tool.

Wear on Awl Tips

The use of awls in basket-making is well-documented in ethnographic literature (Mason 1904). Of the three basic types of basketry, i.e. coiled, twined, and plaited, only the first requires an awl in its manufacture. Coiled baskets are constructed from two types of elements, the passive, horizontal foundation and the active, vertical stitches (Adovasio 1977: 53). When coiled baskets are made, an awl is used to separate the elements of the foundation to allow penetration of a stitch through the previously formed coil. The repeated penetration of the awl tip through the coils eventually polishes the awl tip. The polish, which becomes visible

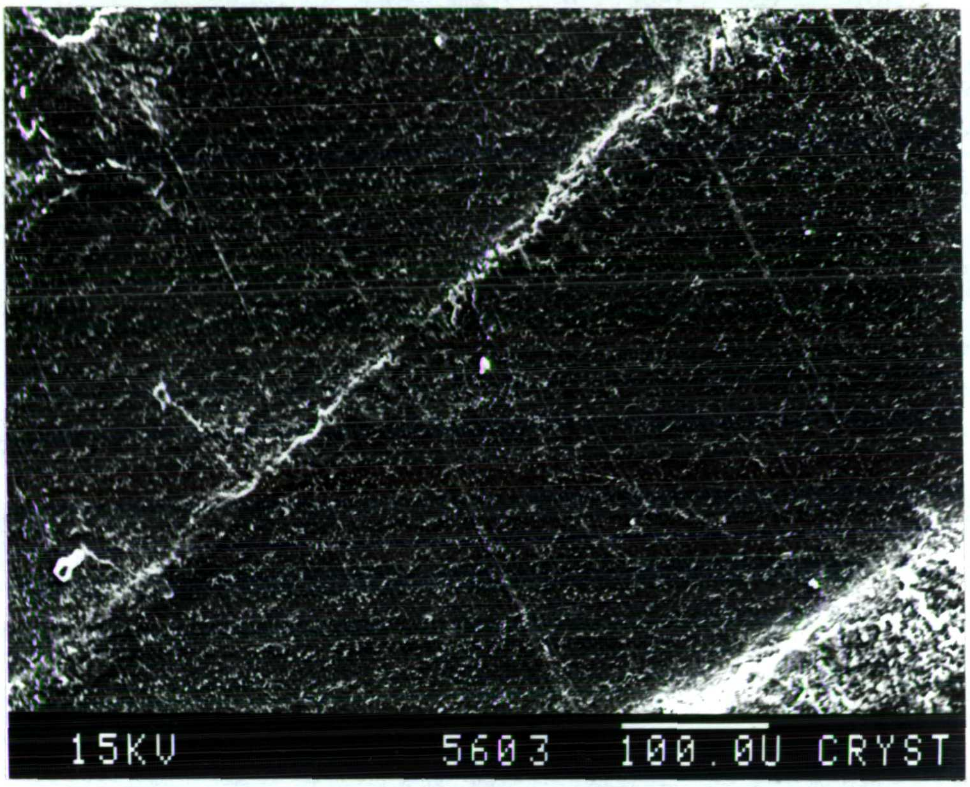


Fig. 52 Inner surface of experimental thong-smoother (silicone rubber mold) showing heavy drilling stria (lower left to upper right) and light use wear striae running perpendicular to manufacturing traces (180X).

after several coils have been completed on a single basket, is a uniform gloss from the end of the tip to a few millimeters up the shaft. The height to which the polish extends up the shaft is determined by the extent of penetration, which in turn depends on the thickness of the foundation and the diameter and taper of the awl tip. Narrow-shafted awls with fine points may penetrate deeply through the foundation so that the tip extends well beyond the back surface of the coil. Clearly, the tip of an awl that has a broad shaft and steep taper cannot penetrate as deeply as a narrow one. To be most efficient the awl should be able to separate the foundation elements easily and be inserted completely through to the other side. Thicker foundations require deeper penetration, which leads to polish further up the shaft.

Unfortunately, polish that occurs on basketry awls is not distinguishable from polish created by piercing hides. It is highly probable that one implement could have frequently served both functions. It is useful, however, to hypothesize how the polish is formed during basket-weaving.

The grasses often used in the manufacture of coiled baskets contain silica, which acts as a very fine abrasive. Three kinds of silica deposits occur in grasses and are known as membrane, intercellular, and intracellular silification (Parry and Smithson 1964: 171-172). The third and most significant form occurs when the lumen of "silica cells" in the epidermis of the leaf and culm contains silica bodies, or opaline phytoliths (Palmer and

Tucker 1981, Gould and Shaw 1983: 382). While deposition of silica may take place in a wide range of plants and in many parts of a plant, phytoliths are most abundant in the leaves of monocotyledonous plants, such as Gramineae (Rovner 1971: 344-345). Identical in composition to opals, phytoliths are extremely durable. The tiny particles range from 20 to 1000μ in length, with most being between 20 and 200μ (Rovner 1971: 346).

The outcome of repetitive friction between the bone awl and the fine abrasive silica bodies in the grass fibers of the basket foundation is a high polish all around the awl's tip (Fig. 53). An extremely worn awl may exhibit a shouldering at the line of maximum penetration due to a gradual attrition of the sides of the tip. Not all shouldering is caused by use, since a thick shafted awl may be reduced sharply at the tip during manufacture or resharpening to improve its efficiency. The shouldering caused by use is usually less pronounced in its appearance than that made by manufacturing. The tips of awls and needles used for sewing leather also exhibit highly polished surfaces. No striations derived from use are generally visible on awl tips and the manufacturing or resharpening striae become muted or vanish entirely with use (Fig. 54). Evidence of recurrent resharpening of the tips and short shaft lengths of some archaeological specimens suggests that extended use may dull the tips. Breakage may also necessitate modification. Impact fractures that are sometimes observed on the tips of awls probably occur when the implement is accidentally dropped, too much force is applied when

Fig. 53 Experimental awl tip with polish overlying faint sandstone abrasion striations (39X).

Fig. 54 Awl shaft from Abu Hureyra with scraping striations muted by use polish (202X).

piercing a substance, or the awl is pushed through a soft material and hits a hard surface behind.

Use Wear on Gouges

Large implements found at Point of Pines ruin and other Mogollon sites in the region have been classified as gouges. These tools demonstrate a clear selection for the largest, strongest bone available as the raw material for their manufacture. Bear femora were preferred, but the long bones of deer were also occasionally utilized. The purpose for choosing elements with thick cortical tissue and a long diaphysis is evident when the damage due to use is observed.

During manufacture the working end is beveled and abraded to form a stout, but fairly sharp chisel-like edge. Four types of use wear are visible on the working end of the gouges found in the Point of Pines collection (Fig. 55). A high polish is present on the external surface of the working edge to a height of 3 to 5 mm up the shaft. This use polish caused by contact with the substance on which the tool was used is usually associated with a rounding of the edge from attrition. Longitudinal striae originating from the edge travel up the shaft a few centimeters before disappearing. The edge is often heavily damaged by the removal of scalar flakes and smaller chips, predominantly from the external surface. The medullary surface usually lacks wear traces although in some cases breakage of the edge is so severe that both sides are affected. Handling polish is very clear on the shafts of these gouges, but notably absent from the

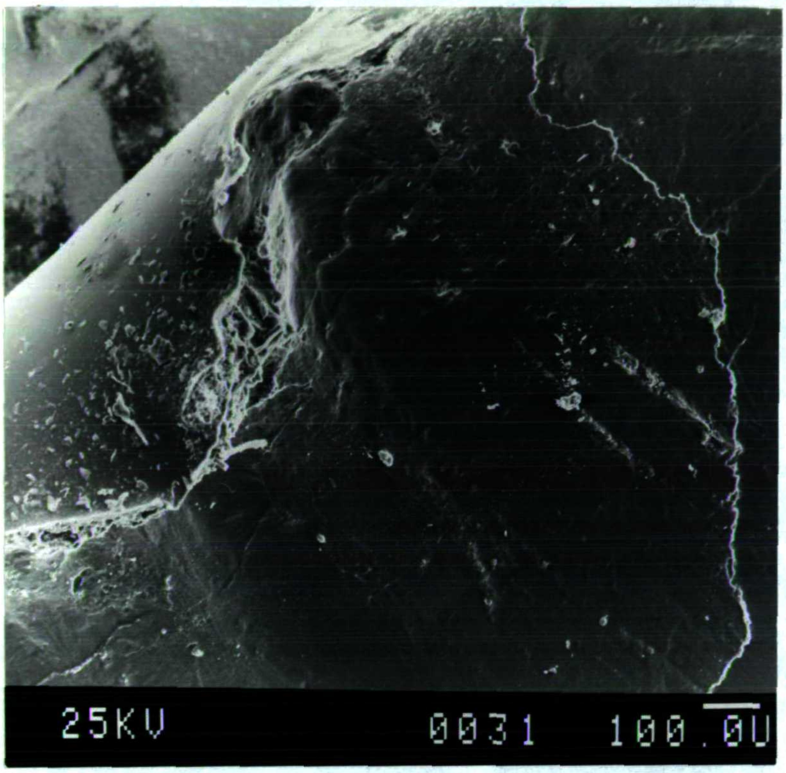


Fig. 55 Tip of bone gouge from Point of Pines (silicone rubber mold) showing chipping, polishing, and rounding of the end and longitudinal striae running from the working edge up the shaft (360X).

bases.

The combination of use wear at the working end and handling polish around the shaft enabled reconstruction of the mode of operation of these tools. The handling polish indicates that the gouges were gripped about the middle, rather than at the end. Attrition and deep striae on the external surface of the edge suggest that the tool struck a resistant material at an angle of approximately 30° to 45° and continued its forward progression for several centimeters after initial contact.

Experiments using a gouge made from a cow femur to remove shavings on a beam of soaked cottonwood (see Chapter 5) were successful in recreating the use wear at the edge. Polish, rounding, and longitudinal striae occurred after about one hour of use, but after two hours only a few small chips were removed from the external surface of the edge (Fig. 56). The experimental tool was thicker than the prehistoric artifacts because of the robusticity of cattle bone. This may have made the tool somewhat stronger. In addition, the cow femur was shorter than that of a bear, so less powerful strokes could be used and care had to be exercised to avoid scraping the knuckles of the operator. Wear on the archaeological specimens indicates that they withstood extensive use.

Conclusions

The above descriptions of natural and cultural traces include some of the most frequently observed surficial alterations on prehistoric bone artifacts. An attempt was made to define the major forms of manufactur-

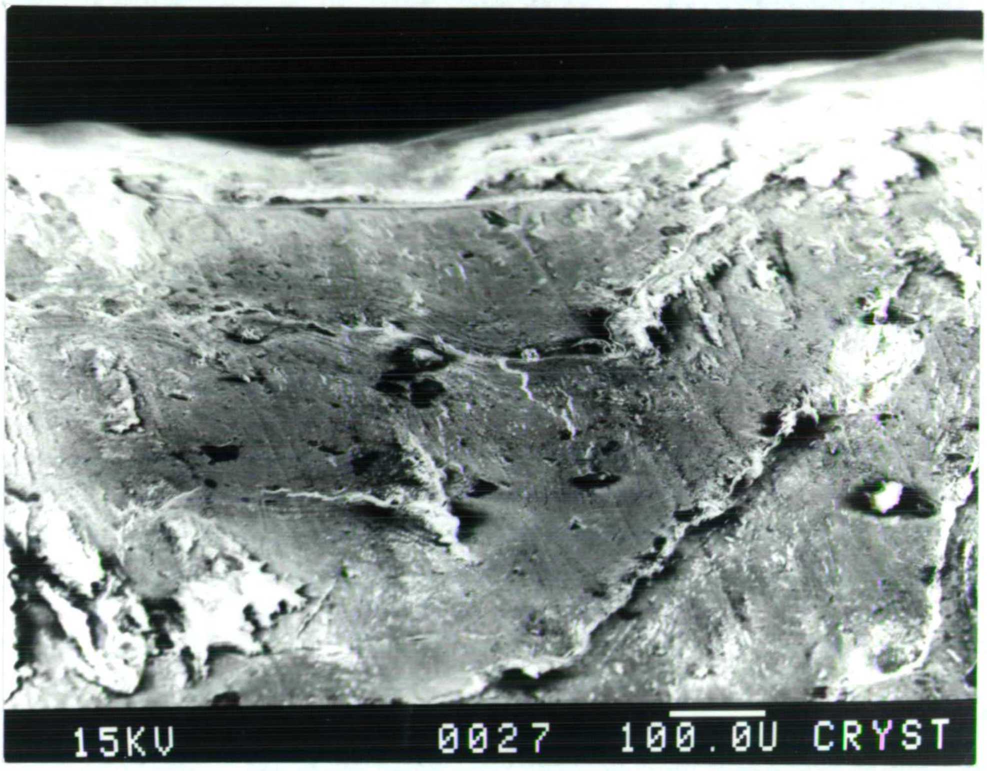


Fig. 56 Tip of experimental gouge showing chipping, polishing, and rounding of the end and longitudinal striae running from the working edge up the shaft (120X).

ing and use traces visible on the artifacts from the three case studies which follow, but many more kinds of surface modifications exist in other collections. It is hoped that these observations will assist others in their interpretation of traces, but it is clear that there are a myriad of ways in which bone may be altered by natural processes, through manufacture, and during use.

Chapter 5

Experimental Replication

A variety of manufacturing techniques and uses for bone artifacts were explored through experimental replication in order to gain an understanding of how bone and antler respond physically to different kinds of treatment.

Preliminary Preparation of Bone

After an animal is killed and butchered for food preparation, the bones may be either cooked with the meat and recovered after the meal or segregated from the meat as a final stage of butchering. The first method may have been the simpler procedure for preparing raw material for bone artifact manufacture since cooked meat is easily detached from the bone, but the second method would have retained the fresh state of the bone and reduced some of the risks of cracking.

During experimentation fresh bone with meat still attached was treated in several ways to prepare it for production of artifacts. The lower portions of two fallow deer limbs were skinned and butchered in order to remove the metapodials for artifact manufacture. After the muscles and ligaments were removed with a sharp chert blade, the periosteum was scraped and peeled off with the same tool. As the metatarsal and metacarpal were being prepared they began to show signs of desiccation. The surfaces which had had the periosteum removed changed from semi-translucent to opaque white in places and within two hours fine cracks began to form. The experiment was conducted indoors, away from wind or sunlight, in a relatively humid room. The formation of splits in the fresh bones was signaled by the actual crackling sounds emitted as the bones dried out. Indications from this experiment and previous experiences with butchering animals in skeletal preparation are that some technique may have been employed to prevent immediate desiccation of bone. This presents no major problem, since the cleaned elements may have been wrapped in wet skins or submerged in a container of water. Alternatively, the initial manufacturing of the rough tool blank could have been conducted prior to removal of the periosteum. Longitudinal sectioning of the bone shortly after the meat was removed apparently allowed shrinkage to occur with a reduction in the formation of undesirable splitting. After scraping off the periosteum, the fresh metapodials were grooved and snapped into rectangular blanks for making bipoints.

Sheep limb bones with meat still attached were roasted over an open fire until the meat was cooked thoroughly (approximately 30 minutes). The meat was then cut off and the bone allowed to cool. Because the diaphyses were well insulated from the flames by the meat, their appearance was unchanged. The condyles exhibited some shrinkage and browning of the hyaline cartilage, but the actual bone was not significantly altered. Grooving and snapping was performed without any detectable difference in the properties of the bone.

The most destructive process of cleaning bone was by boiling. When the meat and bones of birds and leporids were boiled, warping of the flat bones and cracking of long bones occurred. This damage was less severe for larger mammals such as sheep, however.

It was observed that bone from cooked meat could be used for making artifacts providing that the meat insulated it completely, but that boiling of small avian or mammal bones caused damage. More important to the manufacturing process is whether the bone was allowed to become desiccated after cleaning. A radius of a mule deer that had been prepared by macerating and had been thoroughly dried for a year was successfully grooved and snapped after it was soaked in plain water for two weeks. Attempts at working dry bone by grooving and snapping or scraping were more time-consuming and less effective in removal of material than for fresh or rehydrated bone. Antler, which does not require the cleaning process of internal bones, may be allowed to dry completely and then rehydrated within a few hours to restore its softness.

It is important to stress that the amount of cleaning considered adequate by the prehistoric people probably differed greatly from standards we might set today. The level of preparation would have varied depending on the intended use of the object and the amount of surface preparation required. Some ethnographic examples of hide scrapers made on metapodials, for example, retain the ligaments and carpals or tarsals as a part of their base (Steinbring 1966). Archaeological examples also occasionally occur in which small bones are still associated with one end in their proper anatomical position suggesting that connective tissue was allowed to simply dry in place. Artifacts that were to be polished or incised, on the other hand, would have been cleaned more thoroughly.

Grooving and Snapping

Before the advent of metal tools, the groove and snap technique was the most efficient means available for shaping bone artifacts. Used primarily to cut out a blank of proper proportion and dimensions, grooving and snapping created minimal wastage and allowed accurate control over the outline of the artifact.

In the process of manufacturing experimental artifacts the groove and snap technique was used on both antler and bone. Longitudinal, transverse, annular, and converging diagonal grooves were cut, depending on the desired shape of the artifact. In keeping with the fact that bone is anisotropic (Evans 1973), it was observed that longitudinal grooving required significantly less input of time and energy than did annular or transverse grooving which cut across the collagen-apatite bundles. Grooving that crossed the grain diagonally was the most difficult to initiate due to the curvature of the bone which caused slippage of the stone cutting tool. Diagonal grooving encountered about as much res stance as transverse cutting since it was also crossing the longitudinal alignment of fibers and crystals.

Several stone tools including flakes, blades, scrapers, burins, and piercers were employed to determine the most effective method of cutting through bone. Unretouched flakes or blades with a straight edge worked well if a very light amount of pressure was applied and the stone was held firmly so that no transverse wobbling occurred. Too much downward force or lateral vibration caused dulling of the tool's fine edge. Although thin flakes removed less material to reach a given depth, they quickly lost their keen edge and because so little force could be used progress was slow. Scrapers were generally too thick and irregular to produce a narrow groove. The tip of a burin was also too thick to cut a groove with minimal effort. The most effective tool for grooving was a piercer (Fig. 57). The narrow, sturdy tip worked well for cutting the groove and could be used bidirectionally without sustaining significant damage. The groove produced with a piercer was wider than that made with a flake or blade, but because the tool's tip was stronger more downward pressure could be used with each stroke. As a result the time required to produce a groove along the surface of a metatarsal was about 15 minutes with a piercer, compared to 25 minutes with a set of several flakes.

One problem with using a piercer is initiating a long, straight groove. The first few strokes that determined the exact position of the groove were difficult to incise properly with a piercer due to slippage of the tool's tip. If a straight-edged flake or blade was first employed to score a line in the proper position and of the necessary length, then the piercer tracked the line without slippage. Less slippage occured with the long cutting edge of a flake because as the leading part cut

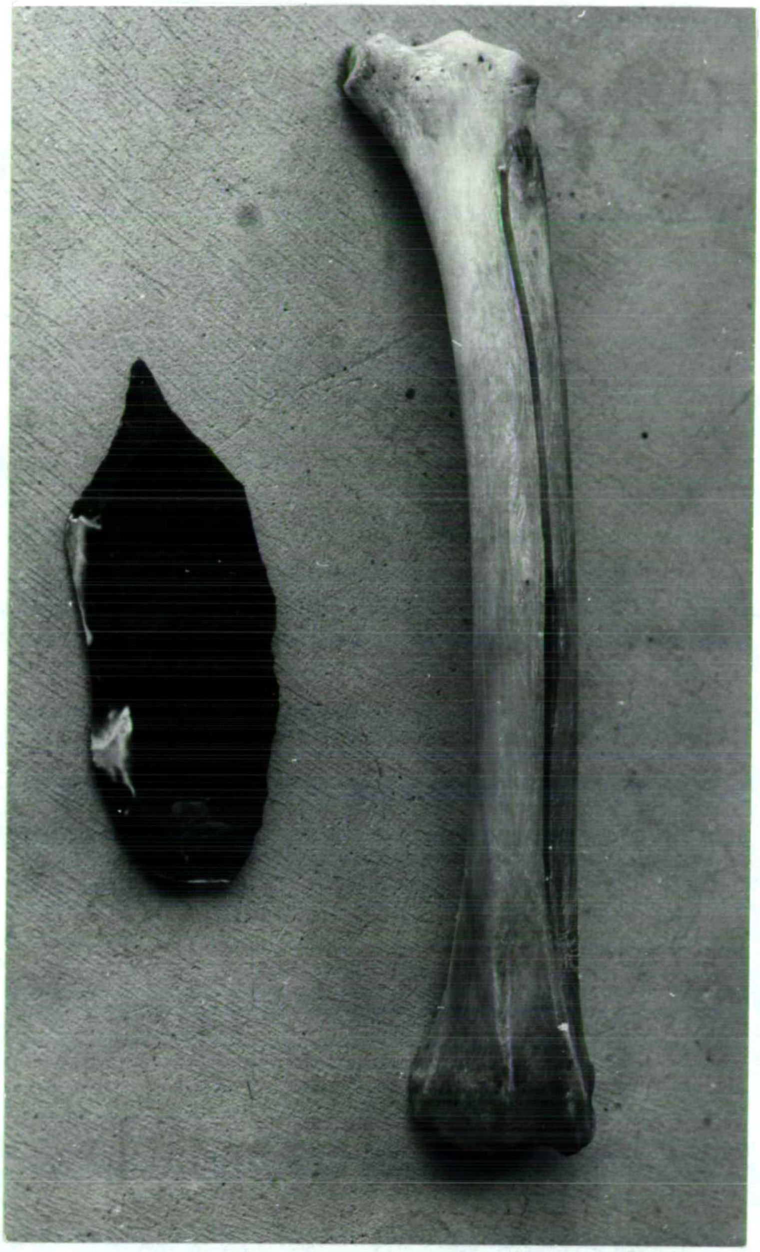


Fig. 57 Flint piercer and mule deer radius with groove made by piercer.

an incision, the trailing part glided through the groove and prevented lateral movement. Only a few strokes of the flake were usually necessary to establish a track for the piercer to follow. Grooving had to be slow and firmly controlled in the beginning, but after about three minutes the groove was deep enough that slippage no longer impeded work.

Rapid reciprocal movement of the piercer through the groove continued from 10 to 30 minutes depending on the length of the groove and the thickness of the cortical bone. Fresh or rehydrated bone was significantly easier to groove than desiccated bone.

As the grooving process continued it was necessary to clean the groove by removing the accumulated manufacturing debris. The bone dust was blown away or shaken off if the bone was worked in a dry state, but rehydrated bone was cleaned by immersing it in a container of water. This latter method proved very successful, since even bone that has been rehydrated for two weeks can desiccate quickly through evaporation. The repeated immersion minimized moisture loss and kept the surface soft and easy to work.

The depth to which a groove was cut determined the ease with which it could be snapped and the likelihood that the crack would follow the groove. If the groove was too shallow there was a risk that the crack would angle off across the bone's surface and possibly ruin the artifact blank. The disadvantage of grooving completely through the bone was the extra input of time and labor. Some unfinished archaeological specimens demonstrate that grooving occasionally extended into the marrow cavity in places, but in no observed cases was it continued until the entire external dimensions of a blank were cut out.

The ways in which the bone was snapped along the groove depended on the thickness of the cortical bone and the depth of the groove. The long bones of birds or small mammals that were grooved annularly were easily snapped in two by holding the element across the worker's shin and pulling both ends toward the body in the same way that twigs may be broken. Longitudinal grooves on thick bone were successfully snapped by breaking through a thin spot in the groove with a stone tool and using it like a wedge or lever to extend a crack along the groove. Large bones of deer were broken by striking the element near the crack with a hammerstone, but this often caused improper breakage in some areas. A deer radius that had been rehydrated before working was allowed to dry thoroughly in the sun after grooving. As shrinkage due to drying occurred, the bone split along the bottom of the groove which could then be wedged apart. Soaked antler that has been sectioned longitudinally by grooving can be snapped by bending against its natural contour (Chech 1974: 77; Newcomer 1980: 21-22). The difficulty of snapping a bone along a groove depends on the depth of the groove, the thickness of the bone, the complexity of the incised outline, the technique used to initiate the crack, and the worker's own strength.

Scraping the Bone's Surface

Scraping was an important technique for removing periosteum, smoothing and tapering the sides of artifacts, eliminating unwanted ridges or processes, sharpening the tip or working edge, and numerous other tasks in the preparation or rejuvenation of a bone artifact. In making experimental artifacts it was performed with a stone tool which was pushed or drawn over the bone surface with the application of steady pressure. The microcutting inflicted by the stone tool's edge produced minute helical shavings. The gradual loss of this material from the artifact's surface was the means by which irregularities and excess bone were removed through scraping. The process was extremely slow since the amount of material removed with each stroke is very small. It is, therefore, beneficial if a blank of approximately the desired size and form is made by grooving and snapping so that the amount of material that must be extracted by scraping is minimal.

Several types of stone tools were used in this experiment, following procedures similar to those described by Newcomer (1977: 148-151). Initially, an unretouched chert flake was pushed unidirectionally along the surface of a fresh metatarsal of a deer at an attack angle of about 60^{o}. Although striations formed on the surface of the bone, very little tissue was removed. The fragile edge of the flake shattered if enough force was applied to cut into the bone's surface. The flake's edge also quickly became chipped and damaged, rendering it too dull for use within a few minutes. Large numbers of flakes would have been needed to scrape the surface of a single bone artifact. The microwear created by the use of an unretouched flake differed slightly from that visible on archaeological specimens. The long facets with widths up to 1 mm on prehistoric scraped artifacts demonstrated that substantially more material was removed in one stroke than could be done with the delicate edge of an unretouched flake. Also, it was difficult to apply enough force to cause chattermarks, a feature commonly observed on prehistoric artifacts.

A chert scraper was then tested, holding it at about the same angle of attack. Because of the better design of the edge, much more force could be applied. It was more effective in removing material than the unretouched flake and could be made to produce chattermarks, but was difficult to use bidirectionally.

Lastly, a burin was used so that the edge that forms the angle between the burin facet and the ventral surface was in contact with the bone (see Bordes 1965). This implement proved to be the most efficient because the edge was straight and the angle at which the ventral surface and burin facet intersected approached 90°. This wide angle made the edge extremely durable so that sufficient force could be applied to remove relatively large amounts of bone in a single stroke when compared with the other stone tools. The shavings taken off with the burin facet's edge were very fine and curled into helical shapes. Surface traces on the experimental piece were virtually identical to those seen on archaeological specimens from Abu Hureyra, where burins are fairly common. An additional advantage of the burin was that it could be used bidirectionally without damaging the edge, thus greatly increasing the amount of work performed in a brief period of time. The burin maintained its crisp, sharp edge even after scraping bone for one hour. Because it was held at a low angle to the bone's surface (approximately 10 to 20°) with reasonable force and because the burin's edge was straight, little slippage occurred.

Scraping Out Cancellous Tissue in Antlers

When thin, light-weight implements were manufactured from antler it was often desirable to remove part or all of the soft inner tissue. The manner in which this was performed is unclear since distinct manufacturing traces were usually eliminated by the final finishing process and because traces were difficult to interpret on the rough, porous inner structure of antler. One method that was successfully attempted by experiment was simply cutting into the exposed cancellous tissue of soaked antler with a fine chert flake. A sawing motion was used to cut deeply into the inner structure, stopping as the compact outer layer was struck from the inside or when the flake failed to penetrate to further depths. Longitudinal cuts were made, varying the tilt of the flake so that the cuts intersected one another. This released long, thin strips of cancellous tissue that could easily be pulled off the antler. When the bulk of the material had been removed by this method, the remainder was cleaned out by scraping the inner surface longitudinally with the edge of the flake. The perforated antlers from Point of Pines, discussed in Chapter 6, appear to have been thinned in a similar manner.

Abrading with Sandstone

As a complementary or alternative method to scraping, abrading was frequently used to finish bone artifacts. The use of abrading depended on the availability of suitable granular stone. There may also be a correlation between the absence of burins and the greater reliance on abrading rather than scraping. In the New World, where true burins were very rare, abrading was the chief finishing technique, but elsewhere, such as Europe and the Near East, scraping was common from the Upper Paleolithic through the Neolithic.

Experimental replication of abrasion striae was very simple. A small slab of tabular sandstone measuring 8 by 6 by 2 cm, was selected as a portable abrader, while a large block fixed in the ground was used as a stationary abrader. Conclusions derived from experimentation were that both types had certain advantages. With the small hand-held abrader in one hand and the bone artifact in the other it was easy to restrict the area that was abraded and the angle the abrader struck the bone's surface. By turning the abrader and using its narrow edges and corners small depressions and crevices could be ground on intricately shaped artifacts. Very small pieces of sandstone were used for sanding the inside of rings and other areas of limited access. One of the most obvious assets of a hand-held abrader is its portability.

Stationary abraders are generally fortuitous surfaces of stone that were available at the moment the craftsperson needed to grind an implement. In the American Southwest sandstone boulders near sites or building blocks in walls occasionally bear grooves formed by the repeated sharpening of bone awls and other artifacts. Because the grinding material was not initially designed to be an abrader, its contours may not be perfect for some tasks. Stationary abraders are generally not effective for detailed work because they have a broad surface and they cannot be manipulated. Experimentation, however, demonstrates that when the abrader is immovable both hands are free to hold the artifact and more force can be applied. As a result, the amount of time required to shape or sharpen a bone implement is greatly reduced. Stationary abraders, it was observed, are more efficient for removing large quantities of osseous material from flat or convex surfaces, but not as useful as portable abraders for concave or detailed surfaces.

Grinding with sandstone was most successful when the bone surface was dry. Sanding a wet surface increased slippage, reduced the amount of material removed, and caused the bone debris to adhere to the abrader. The accumulation of bone powder on the working surface of the abrader clogged it and reduced its grinding efficiency. When both the bone and the sandstone were dry most of the debris could be blown away or rubbed off with the hand or a piece of cloth.

The action of abrading a small area of bone with a reciprocal motion for a few minutes with a flat abrader formed a facet on the bone surface. To prevent or remove faceting the abrader was shifted frequently to cover another adjacent area in a slightly different plane. Grooved abraders eliminated the problem of developing facets on convex bone surfaces. Although grooved abraders were common in the American Southwest, the amount of faceting on some awl tips showed that they were not always employed.

Abraders are useful in removing muscle ridges and other rugosities, changing the contours of bone, smoothing cut or broken edges, grinding down articular condyles, eliminating other manufacturing traces, sharpening the working tip or edge, and other tasks in the manufacture or rejuvenation of bone artifacts. Unless followed by considerable polishing or wear, the use of an abrader on bone is clearly indicated by the diagnostic zigzagged parallel striae inflicted by the grains of sand on its surface.

Chopping Antler and Bone

An expedient, but imprecise method of removing large quantities of bone or antler involved the use of a sturdy stone flake, chopper, or biface. Chopping was used for such tasks as severing antlers or horn cores from skulls and breaking off unwanted portions of flat bones. At Point of Pines the articular ends of ruminant femora were removed in preparation for ring manufacture by chopping, but the application of this technique on thick cortical bone was not widespread. Chopping through antler often requires a long series of strokes because the shaft is solid, but soaked antler was relatively soft so that the amount of force needed with each blow was not excessive.

Breaking through the thin cortical bone of scapulae, ribs, and innominates required fewer strokes, but greater force since normal bone is harder than antler.

One of the disadvantages of chopping is that the exact position of the break is difficult to control. In addition, the edges of cut bone are extremely rough and require great labor to render smooth through grinding or scraping. This may explain why the technique was applied either at the earliest stages of manufacture for initial reduction of burdensome material or on parts of implements that did not require highly finished edges. The advantage of chopping is that, in terms of the amount of time invested, it is a very efficient means of reducing bone and antler.

Experimental replication of this manufacturing method was conducted on the beam of an antler and a fresh cow scapula. The stone implement utilized in each case was a large chert flake. The antler was softened by soaking in water for six hours in advance of the experiment. The action of severing an antler in this manner was essentially the same as for chopping wood with an axe. A V-shaped cut was made by directing a blow slightly less than perpendicular to the antler and changing the angle of attack with the succeeding stroke so that small wedges of material were eventually removed. The antler beam was of sufficient diameter to require that it be turned and chopped all around the circumference. Debris consisted of short chips that were thick at one end and thin at their terminus. The evidence of chopping was very extensive on the severed ends of the two pieces. A hafted axe would have accomplished the task in less time and probably with fewer strokes, but it was possible to achieve the same results with a hand tool.

Thick shavings were removed from the cut edge of a longitudinally bisected red deer antler with a stone flake using chopping strokes. After the antler was soaked it was held upright with one end on the ground and the other braced with one hand. Instead of striking the antler perpendicularly, the chert flake contacted the antler at an angle of about 30 to 40°. The debris thus formed consisted of shavings of antler that were thick at the top and frayed and tightly curled at their terminus (Fig. 58). If straightened out, these shavings would have measured between 1.5 and 2 cm in length and were up to 2 mm in thickness. This technique would have been useful for reducing the width or thickness of a piece of antler in a brief period of time.

In order to recreate the damage inflicted on normal bone by chopping, the vertebral border of a fresh cow scapula was severed with a large stone flake. The scapula retained a thin layer of muscle and fascia and all of the intact periosteum overlying the area that was to be chopped. Resting the blade of the scapula on a wooden block, several harsh blows were struck before the bone broke. Deep, straight gashes were visible in the soft tissue above, but this was only reflected in the bone's surface by very shallow cut marks on either side of the broken area. The blows that succeeded in chopping through the blade formed a nibbled edge with semi-

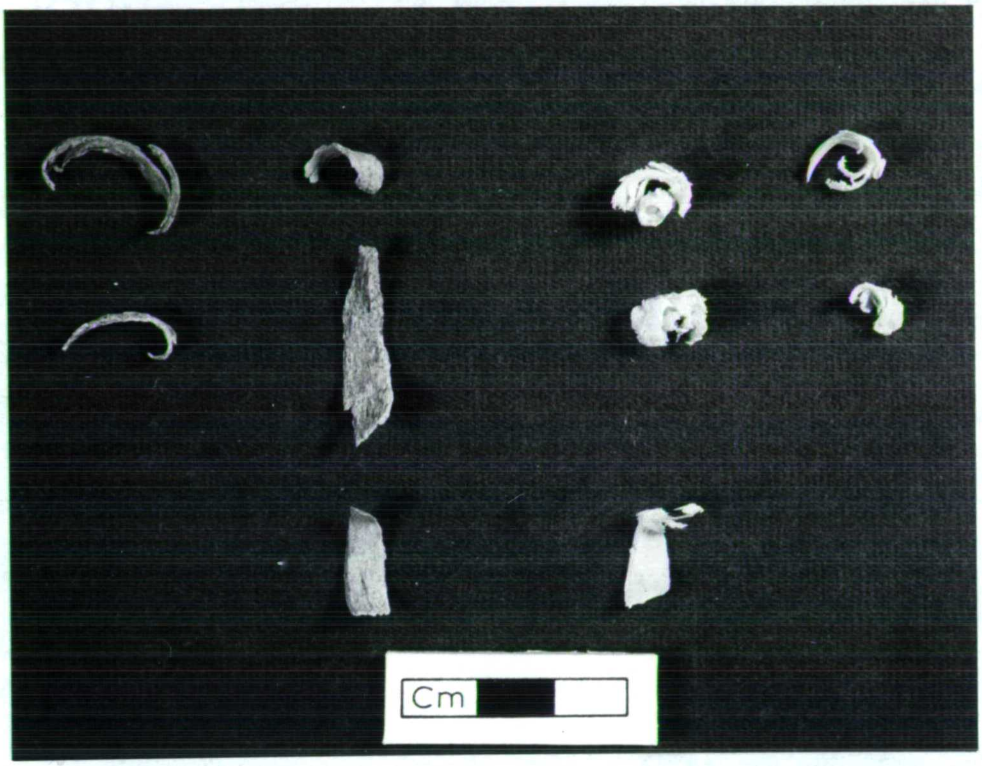


Fig. 58 Antler shavings from Grasshopper Pueblo, Arizona (left) and shavings from antler experimentally chopped with a low angle of attack (right).

circular notches, a crimped margin, and depressed fractures on the upper surface (Fig. 38).

Drilling and Perforating

Drilling experiments were performed using a bow drill and a pump drill on bone and antler. In one case the distal trochlea of a sagittally split mule deer metatarsal was drilled with a pump drill. The perforation was initiated in the small dimple on the lateral surface of the trochlea and was completed by turning the metatarsal over and drilling through the natural indentation on the inner surface. The ease with which the perforation was made was due in part to the fact that the two anatomical depressions are centered on the condyle so that the holes from either side are aligned properly and meet in the middle. The biconically drilled perforation was slightly constricted in the center, but this was corrected by hand turning a small reamer in the hole to cut back the central portion of the wall. Miscellaneous pieces of antler were drilled in the same manner. The extent to which the cross-section of the perforation had an hour-glass or straight-sided outline depended on the shape of the drill and the skill of the craftsperson. A long drill bit with straight sides held consistently perpendicular as it turned produced a perforation with relatively straight sides. The use of a reamer removed much of the central constriction on hour-glass shaped holes, however, and left behind similar manufacturing traces.

Needles from the site of Tell Abu Hureyra were perforated primarily by gouging out a hole with a narrow-tipped piercer or similar fine tool. This was replicated by incising back and forth in short longitudinal strokes on the upper shaft of a modern needle blank. When a narrow trough had been incised on one side, the needle was turned over and the process repeated on the opposite side until a hole was pushed through in the center (see Stordeur 1977). The advantage of making a perforation in a needle by this method is that the thread could lie in the trough when sewing, reducing the size of the hole made in the fabric or hide and the friction when pulling the needle through.

Manufacturing Polish

An important method of finishing ornaments and other skillfully crafted bone artifacts was by polishing the surface. Polishing not only created a surface that was highly reflective and smooth to the touch, but it also removed most of the natural surface features and manufacturing traces. It is not known precisely in what manner polishes were produced prehistorically, but the following method was successfully employed during experimentation.

The first step involved abrading the surface of an awl made on a sagitally split mule deer metatarsal with a fine grained sandstone abrader. Longitudinal strokes were used to remove the rough edges made by grooving and snapping and to smooth the bone's natural surface texture. On a bone like a metatarsal or metacarpal which had a fairly smooth diaphysis naturally, very little abrading was required, but if muscle ridges or crests were present much more work was necessary. Although this method smoothed the surface, fine striations made by the sandstone created a "matte" finish. Following the abrading, wet leather was rubbed over the surface with a circular motion. The abrader and damp leather were used alternately until a polish began to form. As a result of using the leather after the sandstone, some of the fine particles of sand adhered to the leather and acted as a bort in the polishing process. The leather was then used exclusively for a few minutes at the end to soften the striations made by abrading. The entire polishing of the convex surface of the metapodial awl consumed only 20 minutes and yielded a very reflective surface similar in appearance to that found on hairpins at the Point of Pines site. When viewed microscopically this piece exhibited longitudinal striae that were muted by the rounding of their edges with the leather polishing material (Fig. 33).

Use of a Hide Scraper

Bone implements with various morphologies have been used by preindustrial societies to prepare hides (Cushing 1920: 431; Steinbring 1966; Mason 1971: 567-568). Tools from Point of Pines have attributes which suggest that they were used as beamers to deflesh hides or remove the hair. Mason (1971: 567) described how a beamer was used to remove hair after a hide had been wetted and allowed to decompose for a period of time to loosen the hairs. A suitable bone was selected and modified by sharpening a long border to a thin edge. The hide was stretched over a wooden beam so that the external surface faced up and the hair was lying toward the worker. The bone blade was held with one end in each hand and pushed over the skin against the lay of the hair (Fig. 59). When the hair was eliminated in one area, the hide was shifted on the beam and a new area was worked until the whole hide was bare. The tool was also reported to have been used to squeeze out excess water in the skin.

Another purpose for beamers is the removal of subcutaneous fatty tissue from the internal surface of the skin. In an experiment the skins of a raccoon and a badger were defleshed with a beamer made from a horse rib using the same movements as those employed for removing hair. The horse rib was chosen because the margin is thin enough that no scraping was necessary to improve its efficiency. By not inflicting manufacturing traces on the rib analysis of the use traces was simplified.

Work over a two hour period led to the formation of a glossy polish along the edge of the rib (Fig. 49). The rib was soaked for three days in a solution of enzyme detergent and water to remove any oily residue from the skin that had accumulated along the edge of the tool. The wear pattern, discussed in Chapter 4, was very similar to that found on innominate beamers from Point of Pines. The action of pushing the blade across the surface of the hide caused wear to form transversely rather than parallel to the edge as on knives or saws. The fine striae that swept over the edge of the prehistoric beamers provided an important clue as to the direction of movement involved.

Fig. 59 Illustration of hypothesized method of operating deer innominate hide scraper, or beamer.

Use of Basketry Awls

In order to understand the kinematics of using an awl in manufacturing a coiled basket, the author was trained by an expert basket-maker to make a simple flat basket. The basket was made according to a style used by modern Papago Indian women in southern Arizona. It is an open-coil style using a split-stitch. The foundation consisted of bear grass (*Nolina microcarpa*) collected locally in southern Arizona, split into eighths, and inserted in bundles of eight to ten strips. The stitches were made from new white leaves taken from the heart of the yucca plant (*Yucca elata*). These were prepared by stripping the hairs, peeling off one edge to allow moisture to escape, sun-drying them for one day, soaking them for an hour, and scraping them with a knife until they were thin and pliable. The awl was used to begin two baskets and to complete one that was approximately 20 cm in diameter. The total time in which the awl was used was about eight hours.

The experimental awl was manufactured by grooving and snapping a deer metatarsal sagitally, tapering the tip with two converging grooves, and finishing it with a sandstone abrader. The awl measured 11 cm in length and the tip was 2.5 mm in width and 2 mm in thickness (measured 5 mm from the end). In conferring with basket-weavers and through actual use it was learned that a narrower tip with a more gradually tapered shaft would have been more efficient. At times, it was difficult to penetrate completely through the foundation and make an opening that remained large enough on the back side of the basket to put the stitch through after the awl was removed.

During weaving the awl is held between the index finger and third digit with the tip pointing away from the hand and the base resting in the palm. This frees the fingers for manipulating the materials without setting the awl down when not in use. The round distal condyle of metapodials provides a convenient base that prevents the awl from slipping through the fingers. When piercing the foundation to spread the elements the base of the awl is supported by the thumb. The awl may be pushed directly into the foundation, but sometimes it is necessary to pivot the awl sideways slightly to spread the elements apart enough to penetrate the back side of the coil. The awl is then pulled back out so that the pointed tip of a yucca leaf can be drawn through the hole to make a stitch.

The wear polish at the tip of a basketry awl occurs because friction is created by the repeated penetration and withdrawal of the awl into and out of the foundation (Figs. 60, 61). Since the foundation consists of plant fibers, the silica particles in the elements finely abrade the tip of the awl. A similar polish forms at the tip of needles, pins, and awls used for piercing leather, so until plant polish and animal polish can be confidently distinguished it is difficult to determine whether an awl has been used for basket-weaving.

Bone Gouges and Woodworking

Large implements from the Point of Pines collection

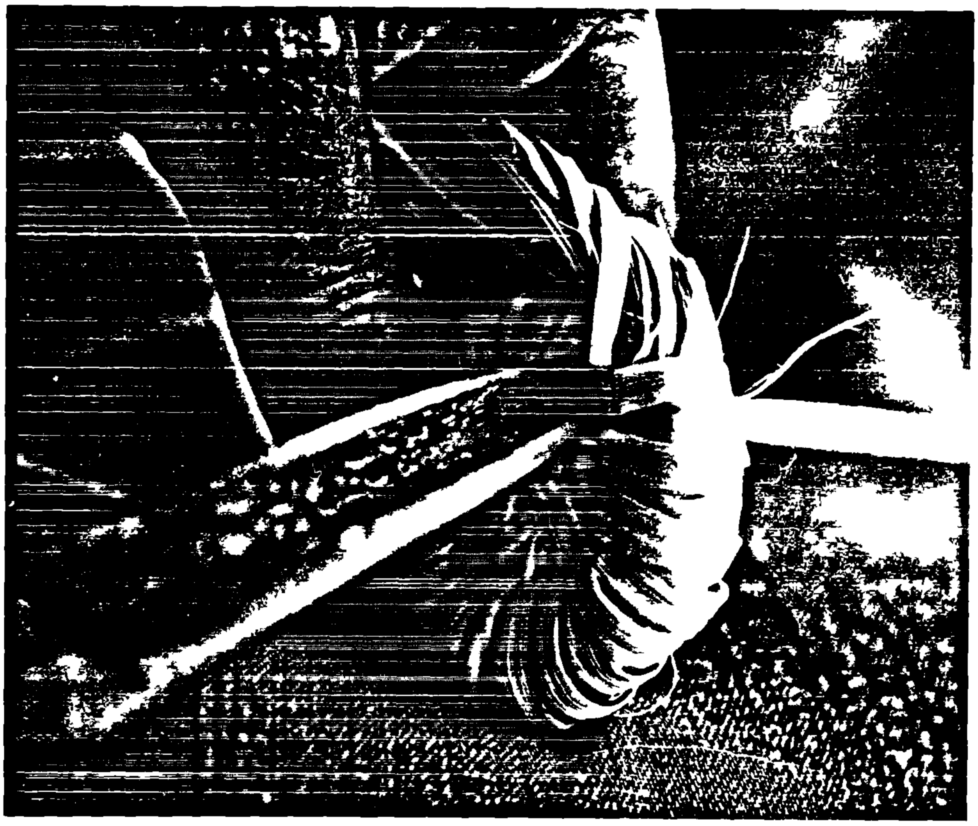


Fig. 60 Bone awl being used to spread the foundation for insertion of stitches when making a coiled basket.

Fig. 61 Tip of awl protruding out the back of the basket showing depth of penetration needed to open the foundation.

made from the elements of deer and bears exhibited extensive use wear indicative of tasks involving great velocity or force. The beveled working edges of these tools, though stoutly made, had received severe damage in the form of attrition, polish, longitudinal striations, and scalar flaking. In light of this use wear, particularly the chipping and flaking of the edge, it seemed unlikely that these implements were used for scraping hides or processing plant fibers (see Steinbring 1966 and Osborne 1965).

Analysis of the design of the tool, the microwear and damage along the working edge, and the distribution of the handling polish on the shaft aided in formulating the following hypothesized use for bone "gouges".

If an element with especially thick cortical tissue is chosen and a stoutly beveled working edge is shaped at one end by removing the condyle and abrading the diaphysis, a strong tool for chopping through res stant materials can be produced. On the prehistoric examples, the direction of the striations, leading up the shaft away from the tip, and the rounding of the external surface of the edge suggest that the tool struck another material at a low angle so that the momentum of the swing carried the bone gouge some distance after initial impact.

An experimental replica of a gouge was made on a cow femur because its cortical bone is of a thickness that is comparable, though slightly greater, than that of a grizzly bear's femur, the element frequently selected at Point of Pines. The proximal condyle was removed, one surface of the diaphysis was cut back, and the working edge was shaped with an abrader. The distal condyle was unfused and became disarticulated in the process of macerating the bone to remove all of the soft tissue.

The modern gouge was used to work cottonwood, a soft wood indigenous to North America and used today by the Hopi Indians of northern Arizona to carve their Kachina dolls. A section of trunk about 12 cm in diameter and lacking bark was soaked for two days prior to working. The segment of wood was braced against a rock on which the experimenter was seated. Using the gouge to drive off thick shavings, a flat surface was produced on one side of the log (Fig. 62). The wear from roughing out a wooden surface for a total of two hours was very similar to that seen on the prehistoric artifacts, although it was less pronounced. The polishing and rounding of the external surface were obvious with the unaided eye. Longitudinal striae were faint, but visible when magnified. Chipping was less invasive, but nonetheless present. The difference in the amount of wear on the archaeological and experimental gouges (Figs. 55, 56) probably reflects the more extensive use that the prehistoric implements received. It is also very probable that the ancient woodworkers were able to use considerably more force with each stroke. Because the cortical bone of the cow femur was slightly thicker, the edge was difficult to sharpen sufficiently. In addition, the greater thickness may have made the edge more resistant to flaking. The femur of a cow is much shorter than that of a bear, so the upper end and base of the tool had to be held in order to prevent

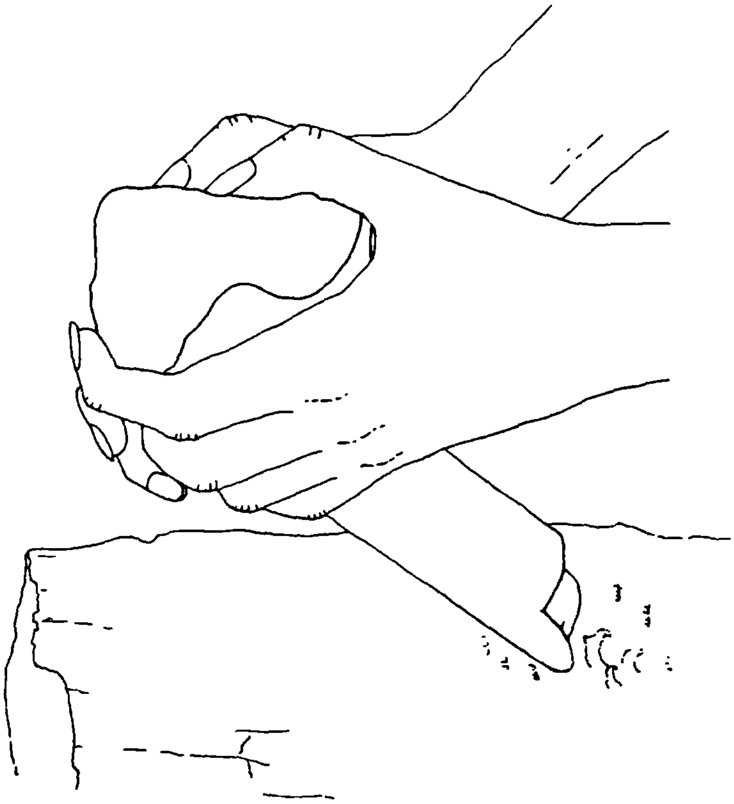


Fig. 62 Illustration of hypothesized method of operating bone gouge for woodworking.

scraping or injury to the hands with each blow. Handling polish on the archaeological specimens suggests that they were held nearer the middle of the shaft.

This hypothesis presents only one possible use for bone gouges from Point of Pines. The wear patterns strongly suggest how the tool was held and the heavy impact damage implies use involving considerable velocity or force against a resistant substance. Although it may be exceeding Asher's recommended restrictions in drawing analogies (1961), a similar tool has been reported to have been used by the KoKo Tai'yuri of North Queensland, Australia, which at least demonstrates that such an implement can be used effectively in woodworking (Thomson 1936: 73).

Bone and Antler Projectile Points

In order to replicate a range of breakage patterns created by the impact of projectile points against a solid, resistant object two sets of experiments were conducted by M. H. Newcomer and the author. The first involved the firing of eight antler and two bone points into a fresh whole sheep carcass from a distance of approximately five to six meters with a 49 lb. recurved bow. The blanks of the double-beveled antler points used in this experiment were manufactured with metal tools, but the entire surfaces of the points were finished by scraping with flint. The bone points were made by grooving and snapping blanks from a fallow deer metatarsal followed by scraping longitudinally with a burin to produce bipoints. Hafting of the points onto fletched arrow shafts was performed by cutting a V-shaped notch in the arrow shaft across the grain to accommodate the base of the point and applying an adhesive of pine resin and beeswax.

The results from this experiment were limited because of the difficulty of striking bone each time when a whole carcass was used as the target. Breakage was restricted to crushing of the tips of several of the points and removal of a flake from the tip in three cases. The method of attaching the points to the arrow shaft may also account for the minimal damage due to breakage. As the tip struck bone the base of the point was driven back into the arrow shaft, causing the wood to split. Each point could therefore only be fired once unless the shaft was replaced. Hafting with resin and beeswax appears to have created a condition in which the shock of impact was absorbed by the retraction of the point into the arrow shaft, minimizing breakage of the projectile point. None of the points penetrated bone, although one passed between two ribs and punctured the liver to considerable depth.

The second experiment involved the use of six antler, seven bone, and two ivory points which were hafted with sinew wrapping. In place of a carcass, a large lamb shoulder served as the target. The piece of meat incorporated the humerus and scapula of the sheep, but to increase the probability that bone was struck with each shot, three scapulae and a pelvis of Bos taurus were placed behind the meat. The same bow was used and as in the first experiment all of the arrows were fired by one archer (M. H. Newcomer). In this case breakage was noticeably greater than in the initial set. The number of points exhibiting breakage was increased because of the higher proportion that actually struck bone. Thus, the use of a large piece of meat backed by bone proved a more efficient way of achieving results. The severity and the variation of the breakage were more pronounced in the second set. It was observed that the sinew wrapping prevented the splitting of the arrow shaft and therefore reduced the shock absorption effect seen in the first set of arrows. Penetration was not restricted to soft tissue. In one instance the point passed through the meat, the scapula of the lamb, and two cow scapulae behind.

In addition to crushing and the removal of a flake at the tips of the points, there were beveled breaks further down the shaft (Fig. 63). In only one case was the base snapped off. Examination of one bone and two antler points with the SEM revealed that when the tip is broken at impact there is often a rounding of the broken surface or its margins (Fig. 64). This is thought to be caused by the compressive force by continuation of the arrow's forward momentum after the initial break. Similar rounding can be produced by gradually pressing a projectile point against bone in a vice.

The occurrence of crushing, the removal of a flake from the tip, and rounding of the fracture surface are the most common features seen on the prehistoric bone points from Abu Hureyra, Ulu Leang, and Leang Burung. Transverse breaks occurring at right angles to the surface in the mid-shaft region have been replicated during

Fig. 63 Experimental projectile points showing breakage due to impact with bone when shot through meat from a distance of 5 to 6 m: a. ivory, b-d. bone, e-h. antler.

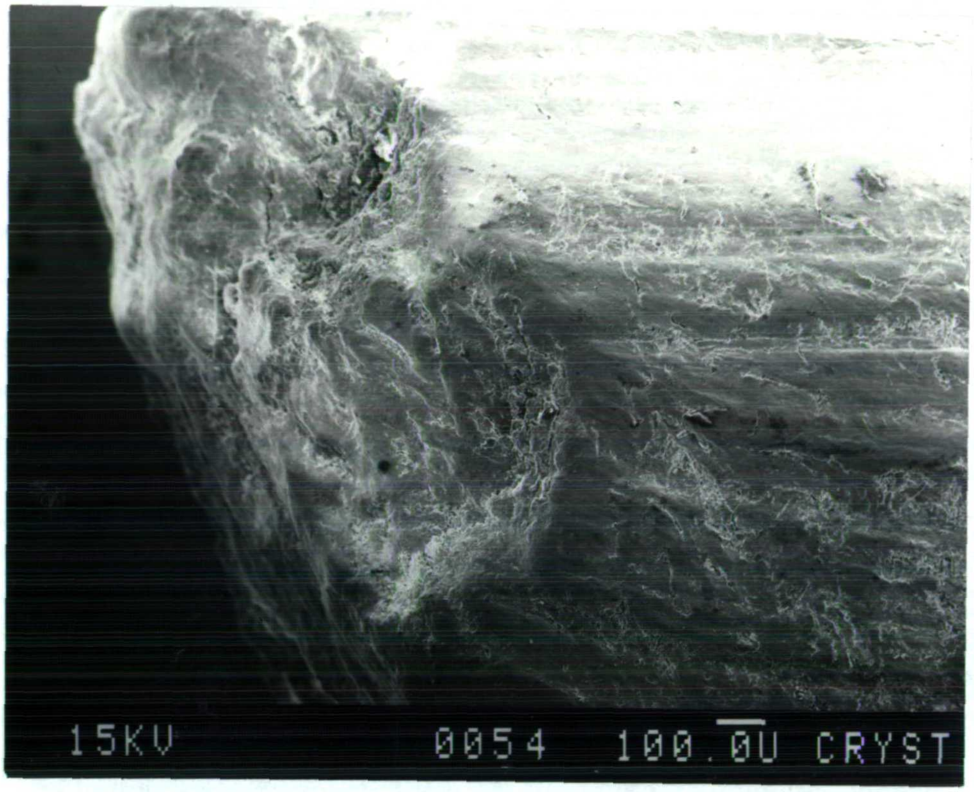


Fig. 64 Crushing and rounding of tip of antler projectile point shot experimentally (60X).

impact experiments, but are probably more often caused by postdepositional damage after the collagen fibers have been denatured. Beveled breaks, which were frequent in the second experimental set, may be caused by failure due to strain from compressive and possibly shearing forces when the point strikes a resistant surface such as the bones of the hunter's prey. The beveling of the fracture surface is best explained by the anisotropic arrangement of collagen fibers and apatite crystals in a longitudinal pattern which deflects a break that would be transverse in an isotropic material.

Breakage took place when the projectile point struck thick cortical bone directly. Thin cortical bone such as the central portion of the scapular blade or ribs was easily penetrated by bone or antler points, but the neck or caudal margin of scapulae or any part of large limb bones caused the point to break or be deflected. In the two experiments no breakage occurred when the points passed through meat alone.

Severity of breakage of projectile points is probably dependent on a wide range of variables. The material from which the point is made, e.g. antler, bone, or ivory, has been shown to affect its resistance to breakage (Albrecht 1977; Guthrie 1983). The condition of the bone would also be a factor since fresh bone is more resilient than dry bone (Evans 1973: 55). Tyzzer (1936) showed that once a point was damaged from impact severe breakage was likely to follow when the point was next shot. The shape and thickness of the point may affect breakage since a thin, flat point might be more likely to snap in two than a stout point with a round cross-section. The experiments described herein demonstrate that the kind of hafting technique employed is extremely important where breakage is concerned. Splitting of the arrow shaft is more common when mastic is used alone, but breakage of the point tends to increase when sinew wrapping is employed. The velocity of the projectile, and hence the pull of the bow and the distance the arrow must travel to reach its target, would determine the force with which impact occurs. In addition, the amount and the nature of the soft tissue through which the projectile passes before striking bone would play a role in slowing the forward progress on of the arrow. This is linked to the shape of the point and the design of the haft and arrow shaft, since the skin of the animal tends to close tightly around the arrow and a bulky haft or rough arrow shaft may rapidly decrease velocity. Finally, the contour of the bone which is struck and the angle of impact are important since several of the points were deflected when they struck the curved margin of the scapula or the rounded diaphysis of the humerus.

In summary, a variety of factors are important in determining the extent of breakage that takes place when a projectile point strikes an animal. Points which miss the intended target and strike the ground, a tree, or other obstacle are affected by these and other factors, as well. The kinds of breakage patterns that appear on projectile points have been observed on other types of tools such as awls and needles, but crushing, flaking, and rounding of the fractured surface at the tip are much more common on artifacts classified as projectile points. The types of breakage produced during the experiments are thought to be related primarily to compressive force at the tip of the point and the anisotropic structure of bone and antler.

Conclusions

The experimental replication performed in the course of this research was designed to attempt to answer key questions encountered in the three case studies, but is not intended to be exhaustive in its approach. It is hoped that these experiments can be continued and expanded into longitudinal studies involving larger sample sizes in forthcoming research.

Chapter 6

Point of Pines

Point of Pines ruin is located on the San Carlos Apache Indian Reservation, Graham County, east-central Arizona (Fig. 65). This region, known as the Basin and Range province, is the southeastern part of a more or less continuous range of mountains stretching from the San Francisco Peaks in north central Arizona southeasterly to the White Mountains and into west central New Mexico. The montane zone separates the Colorado Plateau to the north from the Sonoran Desert to the south.

The site is situated in an archaeologically rich intermontane basin called Circle Prairie which has an average elevation of 1828 m and consists of a nearly level, grassy meadow surrounded by stands of juniper, pinyon, and pine forests. Gently rolling hills rise up in all directions with mountains visible at some distance. To the south Nantack Ridge slopes upward to 2316 m above sea level, drained by numerous intermittent streams that have cut valleys into it. The ridge has an abrupt scarp on its southwestern side that presented an ideal setting for small cliff-dwellings.

Circle Prairie is well-drained by the Black River to the north, Turkey Creek and Point of Pines Creek through the center, and Willow Creek to the east (Fig. 66). Sites were distributed near the edges of the prairie to maximize proximity to both woodlands, which were abundant with wildlife, and arable land. From 2000 BC to perhaps AD 1 the area was sparsely occupied by transient groups of hunter-gatherers who depended on deer, pinyon nuts,

Figure 65

Map of Arizona and western New Mexico locating major sites referenced in the text.

1. Grasshopper
2. Bear Ruin
3. Kinishba
4. Broken K
5. Carter Ranch
6. Table Rock
7. Hawikuh
8. Zuni
9. Awatovi
10. Montezuma Castle
11. Tonto Ruin
12. Winona and Ridge Ruins
13. Turkey Hill Ruin
14. Los Muertos
15. Snaketown
16. Casa Grande
17. Ventana Cave
18. University Indian Ruin
19. San Cayetano
20. Babocomari
21. Cameron Creek
22. Higgins Flat
23. Starkweather
24. Turkey Foot Ridge
25. Tuzigoot
26. Foote Canyon

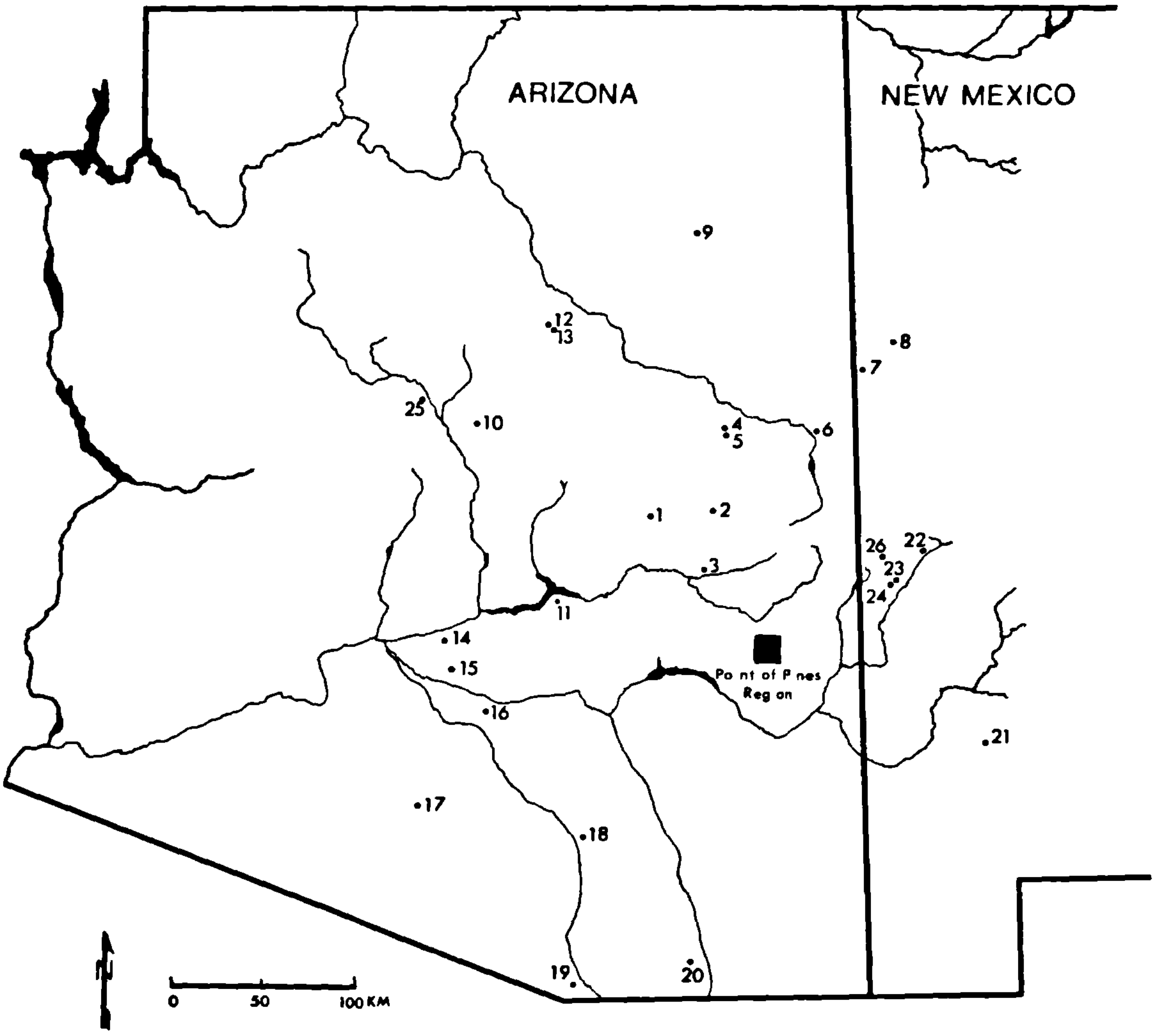

ARIZONA
NEW MEXICO
9
12
13
8
7
25
10
4
5
6
1
2
26
22
3
23
24
11
14
15
Point of Pines Region
16
21
17
18
19
20
N
0
50
100 KM

Fig. 65

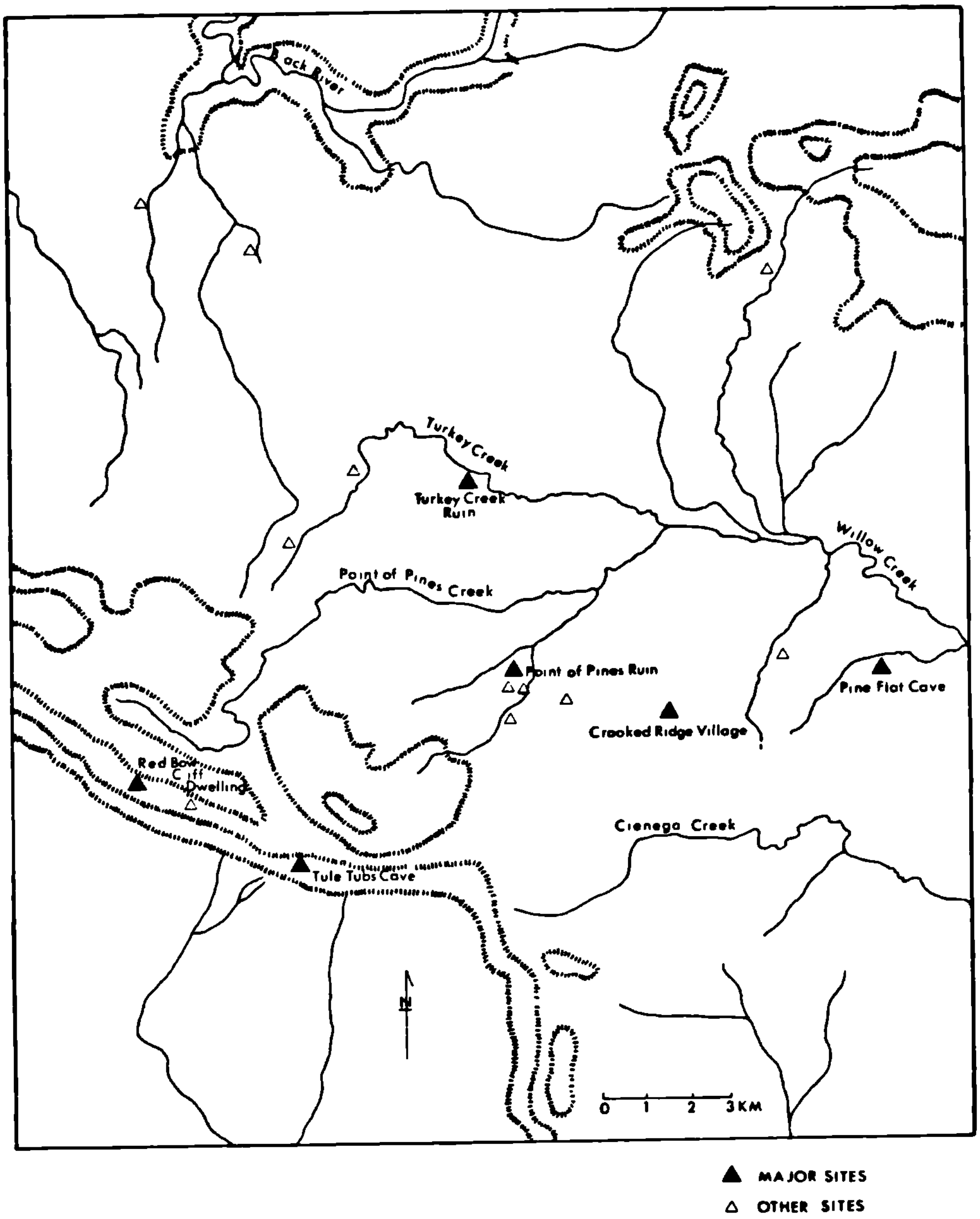


Fig. 66 Map of the Point of Pines region with major sites referenced in the text.

and other wild resources. The earliest known sedentary settlement is Crooked Ridge Village (Az W:10:15), dating from the fourth to the seventh centuries AD (Wheat 1954). Sedentism and population increase were an outgrowth of the arrival of plant domesticates such as maize (*Zea mays*), kidney beans (*Phaseolus vulgaris*), tepary beans (*P. acutifolius*), and squash (*Cucurbita mixta*), all of which were present in the later site of Point of Pines (Az W:10:50) (Woodbury 1961).

By AD 1000, larger masonry pueblos replaced pit-houses, marking a gradual increase in population that peaked in the 1300's. With its estimated 600 to 800 rooms, Point of Pines ruin was the largest settlement in the area; but other sites such as Turkey Creek ruin were also substantial. As in other regions of the Southwest, a rapid decline of population in the mid-fifteenth century is reflected in the abandonment of the large pueblos around Circle Prairie.

The Point of Pines area was inhabited by people belonging to the Mogollon culture, one of the three major prehistoric cultures of the American Southwest. Comprehensive descriptions exist elsewhere in the literature (Martin 1979; Martin and Plog 1973), so only a few of the salient characteristics will be highlighted here. The Mogollon culture differs from the Anasazi of the Colorado Plateau to the north and the Hohokam of the Sonoran Desert to the south by its adaptation to ecological zones formed by mountainous terrain (Martin 1979: 61). It developed apparently out of the Cochise culture, an indigenous Archaic group of hunter-gatherers. These people hunted deer, antelope, mountain sheep, bison, jackrabbit, cottontail, turkeys, and other available game. They fished when possible and collected a wide variety of plants including pinyon nuts, walnuts, and acorns. It is uncertain when domestic corn arrived in the Mogollon area from Mexico, but shortly afterward sedentary villages of pithouses appear, the earliest known of which date to 500 BC. Red on Brown pottery appears between 300 BC and AD 100 in various parts of the Mogollon area (Martin 1979: 63). Architecture evolved through several stages until by AD 900 to 1000 regular coursed masonry houses attached in cellular fashion to one another and forming large room blocks became common. Ceremonial structures known as kivas developed from round, oval, or D-shaped pithouses to large rectangular surface buildings. Population growth was apparently steady between AD 900 and 1250, but population decline and abandonment of some areas occurred in New Mexico by AD 1250 (Martin 1979: 73). The Point of Pines area and pueblos further north and west continued to grow until AD 1400-1450 when they also diminished in size or were abandoned.

One of the more significant aspects of the research conducted at Point of Pines and neighboring settlements is the information provided about the relationship between the Anasazi of the Colorado Plateau, the Mogollon of the Basin and Range province, and the Hohokam of the Sonoran Desert. Around AD 1000 the indigenous Mogollon culture received an influx of people from the north that led to a partial blending of the two cultures. The resulting amalgamation is referred to as the Mogollon-Pueblo culture (Gifford 1980). Contact with the Hohokam also affected the styles of many artifacts, including those of bone.

Point of Pines ruin is a large masonry pueblo consisting of over 600 rooms with a large wall enclosing all but a few small outlying room blocks (Fig. 67). Excavation of pithouses, plazas, middens, burials, kivas, and 150 rooms of the pueblo was conducted by the University of Arizona Archaeological Field School under the direction of E. W. Haury between 1946 and 1960 with the cooperation of the San Carlos Apache Tribal Council. As part of the long-term investigation of the region involving intensive survey and considerable sampling of neighboring sites, the excavation of Point of Pines ruin provided substantial insight into the Mogollon-Pueblo culture.

The site, dated largely by pottery seriation, was probably occupied from c. AD 1200 to 1450. The large number of tree-ring samples support these dates, but do not in themselves provide bracketing dates for the occupation (Bannister and Robinson 1971: 32-38). Most of the dendrochronological samples were recovered from a restricted portion of the pueblo that was apparently occupied from about AD 1270 to 1290 by a group of immigrants from the Kayenta area of northeast Arizona (Haury 1958). Eighteen of the 21 rooms inhabited by these outsiders were burned in a massive fire which terminated their stay at Point of Pines and left large quantities of primary refuse and perishables.

Bone Artifacts

The collection of 1268 bone implements and ornaments from Point of Pines ruin has a high potential for yielding information about the inhabitants. Preservation of the artifacts is extraordinarily good, so that microscopic surface traces are retained and the surfaces are not friable. The large quantity of complete specimens and vast array of tool types provide enormous variety both in terms of basic morphology and stylistic motifs. The unmodified faunal material has been analyzed (Stein 1963) and was available for further research in relation to taxa represented in the artifact collection. In addition to the material from the main site 441 artifacts from 17 other sites in the vicinity were examined. The author has also studied the 1942 bone artifacts from Grasshopper Pueblo (S. Olsen 1979) and 1436 from Kinishba (S. Olsen 1980), both of which are northwest of the Point of Pines region (Fig. 65). Ethnographic accounts for the use of similar bone objects by extant indigenous Southwestern Indians have supplied considerable documentation regarding the function of many of the prehistoric types.

Figure 68 displays the typology for bone artifacts found at Point of Pines and the numerical distribution by taxon for those in the present collection in the Arizona State Museum. At the time of excavation some bone artifacts were discarded after listing their numbers and types. Since these were not illustrated and no formal typology was applied in the field, only approximate estimates of the original proportion of each type can be

Fig. 68

BONE ARTIFACT TYPOLOGY FOR POINT OF PINES

TYPES TAXA	Flaker	Hammer	Beveled Antler Tool	Perforated Antler	Gouge	Beamer	Rib Scraper	Scapula Scraper	Spatulate Tools
Class Aves									
Branta canadensis									
Accipiter sp. indet.									
?*Cathartes aura*									
Cathartes aura									
?*Buteo* sp. indet.									
Aquila/Haliaeetus									
Meleagris gallopavo									
Grus canadensis									
Class Aves/Mammalia								3	
Class Mammalia	1								
Lepus californicus									
Sylvilagus sp. indet.									
Canis sp. indet.									
Vulpes fulva									
Ursus sp. indet.					1	1			
U. americanus									
U. cf. *horribilis*					5				
U. horribilis					4	1			
Felis concolor									
Lynx rufus									1
Suborder Ruminantia	1				2	1	36	27	7
Antilocapra americana					2	6		2	1
Bison bison						2			
?*Ovis canadensis*									
O. canadensis						1			1
Odocoileus sp. indet.	34	1	138	34	-	2		2	2
O. cf. *virginianus*									
O. virginianus						1		2	
O. cf. *hemionus*				2					
O. hemionus	1			2	1	35			
TOTALS	37	1	138	38	15	50	36	36	12

Fig. 68 (continued)

TYPES	Ulna Awl	Splinter Awl	Shaped Awl with Plain Base	Awl with Articular End as Base	Pin	Needle	Spindle Whorl	Sounding Rasp	Tubular Whistle
TAXA									
Class Aves		2							4
Branta canadensis									1
Accipiter sp. indet.									
?*Cathartes aura*									
Cathartes aura									
?*Buteo* sp. indet.									
Aquila/Haliaeetus				1					3
Meleagris gallopavo				1					1
Grus canadensis									
Class Aves/Mammalia		2	1						1
Class Mammalia		40	98		7	2		2	
Lepus californicus				1					
Sylvilagus sp. indet.				1					
Canis sp. indet.									
Vulpes fulva				5					
Ursus sp. indet.				1					
U. americanus									
U. cf. *horribilis*									
U. horribilis									
Felis concolor				1					
Lynx rufus				6					
Suborder Ruminantia	24	17	20	19			1	13	
Antilocapra americana	22			6				3	
Bison bison									
?*Ovis canadensis*	2								
O. canadensis									
Odocoileus sp. indet.	22		1	4					
O. cf. *virginianus*	2			1					
O. virginianus	3			4				1	
O. cf. *hemionus*	5	1		1					
O. hemionus	27	4		5				2	
TOTALS	107	66	120	57	7	2	1	21	10

Fig. 68 (continued)

TYPES	"Bitsitsi" Whistle	Painted Bone	Paint Container	Frog Effigy	Disc	Pendant or Ornament	Tube	Ring	Ring Debitage
TAXA									
Class Aves	6						19	1	
Branta canadensis							4		
Accipiter sp. indet.							1		
?*Cathartes aura*							1		
Cathartes aura							1		
?*Buteo* sp. indet.							1		
Aquila/Haliaeetus						1	7		
Meleagris gallopavo			1				15		
Grus canadensis							5		
Class Aves/Mammalia	1						3	1	
Class Mammalia	14			1	7	8		47	1
Lepus californicus									
Sylvilagus sp. indet.							1		
Canis sp. indet.							1	3	
Vulpes fulva									
Ursus sp. indet.						1			
U. americanus									
U. cf. *horribilis*									
U. horribilis									
Felis concolor									
Lynx rufus									
Suborder Ruminantia						1		32	27
Antilocapra americana		1							3
Bison bison									
?*Ovis canadensis*									
O. canadensis									
Odocoileus sp. indet.		5				1			21
O. cf. *virginianus*									
O. virginianus									3
O. cf. *hemionus*									2
O. hemionus									10
TOTALS	21	6	1	1	7	12	59	84	67

Fig. 68 (continued)

TYPES	Hairpin	Awl or Hairpin	Misc. Worked Pieces	TOTALS
TAXA				
Class Aves				32
Branta canadensis				5
Accipiter sp. indet.				1
?*Cathartes aura*				1
Cathartes aura				1
?*Buteo* sp. indet.				1
Aquila/Haliaeetus				12
Meleagris gallopavo				18
Grus canadensis				5
Class Aves/Mammalia				9
Class Mammalia	42	16	1	290
Lepus californicus				1
Sylvilagus sp. indet.				2
Canis sp. indet.				4
Vulpes fulva				5
Ursus sp. indet.				4
U. americanus			1	1
U. cf. *horribilis*				5
U. horribilis				5
Felis concolor				1
Lynx rufus				7
Suborder Ruminantia	95	13	8	344
Antilocapra americana	14		2	62
Bison bison				2
?*Ovis canadensis*	1			3
O. canadensis	1			3
Odocoileus sp. indet.	8		20	295
O. cf. *virginianus*	1			4
O. virginianus	5			19
O. cf. *hemionus*	3		1	15
O. hemionus	18	1	5	111
TOTALS	188	30	38	1268

reconstructed from the records.

Manufacturing Techniques

Owing to the excellent preservation of bone surfaces and the large quantity of manufacturing debris and unfinished pieces, a wide variety of manufacturing techniques could be recognized for the artifacts from Point of Pines.

One of the most pervasive manufacturing techniques among Mogollon-Pueblo bone artifact assemblages was grooving and snapping. Both annular and longitudinal grooving and snapping was performed in order to achieve the desired size and shape. Inferences about this technique made from observation of finished artifacts are confirmed by study of long bones on which the groove and snap process was begun but interrupted before completion. The widths of grooves on unfinished objects support the hypothesis that a stone piercer rather than a flake was used to form the groove. A flake or blade may have been used to commence cutting the groove, since piercers tend to slip laterally until an adequate track has been incised in the bone's surface. Incising, i.e. the cutting of fine, shallow grooves for ornamentation, was also performed with a stone tool.

An equally prevalent manufacturing technique at Point of Pines was abrading with a portable hand abrader or using the surface of a boulder or building stone to grind bone implements. Sandstone is a common raw material in the Southwest which served many functions prehistorically, including acting as a natural abrasive. In addition to finishing newly made bone implements, abraders were often used to resharpen broken or dull points on awls or rejuvenate other worn working edges on bone artifacts.

Somewhat less frequently employed but nonetheless a common manufacturing technique was scraping with a chipped stone scraper. The absence of burins in the Mogollon-Pueblo culture may account for the reduced emphasis on scraping, since a scraper with a thin edge is quickly blunted from use damage. Scraping was used, however, to shave off the periosteum adhering to green bone, to take off the rough edges made by grooving and snapping, to remove unwanted natural rugosities, to transform the shape of articular condyles, and to thin the edge of hide scrapers.

A method of roughly removing articular condyles or sectioning antlers involved chopping with a stone axe. This powerful, but imprecise technique expedited manufacture of large, thick bone implements, but lacked the uniformity and finished look achieved with grooving and snapping. It quite sensibly does not appear to have been utilized as a technique for making ornaments. Instead, hacking or chopping is generally found on either heavy-duty or bulky tools and not on surfaces where the operator must rest his hand.

The final major manufacturing technique used at Point of Pines is drilling. Excluding whistles, most of the drilled objects from the collection appear to have been biconically perforated with a stone drill. Judging from the variety of holes seen in needles, whistles, pendants, awls, and perforated antlers, a wide range of sizes of drills was employed.

Artifact Types:

Pressure Flakers

Antlers, rather than limb bones, were predominantly used in making tools for pressure flaking flint. These implements occurred in two forms: tine flakers (Fig. 69a) and shaped antler rods (Fig. 69b). The tine flakers often had no modifications performed except chopping or breaking them from the main beam. Evidence that these slightly modified tines were used as flakers consists of contextual data and microwear. There were traces of re-sharpening by abrading on only two of the tines. Two others had their bases cut down to form a peg on the end that may once have been inserted into a wooden handle.

The three shaped antler rods were more complex in their manufacture. Their form was cut out of an antler beam by incising two parallel grooves through the compact layer and undercutting through the cancellous tissue until the rod could be snapped free. The roughly broken cancellous tissue, the edges, and both ends were then abraded until smooth. One end was abraded to a narrower point than the other, but both appear to have been functional. With a rather abrupt inflection at the tips the three shaped antler rods were sturdy but capable of focusing the pressure on a small point. Their lengths were 11.5, 12.2, and 21.5 cm.

A ruminant metacarpal and a large mammal long bone with stout tips and heavy wear appear to have been used

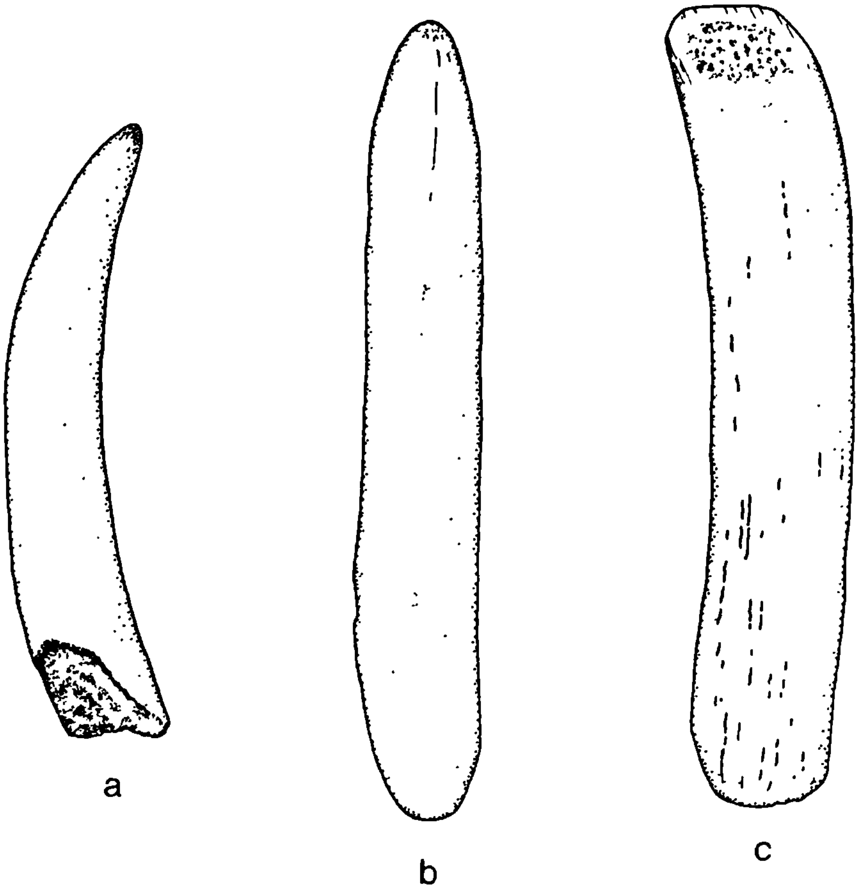


Fig. 69 a. antler tine flaker, b. cut antler flaker, c. beveled antler implement. Scale 1:1.

as flakers. The significant preference for antler over the dense compact tissue of long bones not only in the Southwestern United States, but elsewhere as well, suggests that the greater resilience of antler makes it more suitable for working flint.

Microwear on these implements closely resembled that observed on experimental tine flakers. The tips are blunt and pitted, while long scratches containing many fine parallel striae run from the tip to several millimeters down the shaft and end abruptly with an accumulation of microcutting debris shoved up at their terminus. The resharpened tines and the shaped antler rods exhibited traces of sandstone abrasion at their tips, as well.

The distribution of flakers is widespread spatially and temporally throughout the site. Rooms 8 and 62 of the main site and room 5 of W:10:50 B contained greater than the usual numbers of antler flakers. From the association of antler artifacts and stone debris it was possible to identify at least two flint knapping _loci_. Floor 1 of Room 8 produced five antler flakers _in situ_ with a large accumulation of flint chips and partial projectile points. Though the artifacts were unfortunately not saved, the floor of Room 75 yielded an array of materials that must have represented a workshop area. Among the remains were two cores of chert, one core of obsidian, chips and flakes of obsidian, three projectile points, a hammerstone, and three antler flakers. These work areas are similar to one found at Turkey Creek

Pueblo (Az W:10:78) (S. Olsen, in preparation), another major site in the Point of Pines area in which one square meter of a floor contained 17 antler tines and 60 chert chips and blades. Other large caches of flakers were also found in rooms and burials at Turkey Creek.

Antler tine flakers are common throughout the Southwest, but the shaped rods are generally restricted to the Mogollon-Pueblo region and to a somewhat lesser extent the eastern Pueblo area. Their occurrence has been noted at Grasshopper (S.Olsen 1979: 348-349)., Kinishba (S. Olsen 1980: 57), Sierra Ancha (Haury 1934: 126), Table Rock Pueblo (Martin and Rinaldo 1960: 276), Gran Quivira (Hayes, Young, and Warren 1981: 144), Hawikuh (Hodge 1920: Pl. XXII), Pecos (Kidder 1932: 282), and Awatovi (Wheeler 1978: 67).

Antler Hammer

Only one antler beam segment that had been used chiefly for soft hammer percussion flaking chert was present in the Point of Pines collection. This specimen, from Room 8, subfloor, was heavily pitted at the proximal end so that the burr was completely worn off. In morphology the hammer resembles those in abundance at Grasshopper (S. Olsen 1979: 346-348) and collected in smaller numbers elsewhere in the Mogollon-Pueblo area. The only manufacturing processes involved chopping through the beam at the proximal end if the antler was not shed and chopping off the brow tine and upper portion of the beam.

The infrequency of this artifact type at Point of Pines may in part be accounted for by the fact that large quantities of antler were discarded by the excavators, but in addition, there seems to be a very real shortage of antler hammers since they are not recorded n the field notes. One possible explanation is a preference for wooden hammers for percussion flaking. Another is that they were discarded elsewhere, such as at quarries (Holmes 1919:192-193). Antler hammers are very common at the site of Grasshopper (S. Olsen 1979: 346-348).

Beveled Antler Implements

A complex problem arises in the interpretation of the function of a large group of antler tools. Very simple in their manufacture, they are identical to antler tine and shaped rod flakers except that one end has been beveled (Fig. 69c). The unifacial or bifacial beveling appears to have been performed with a coarse abrader. Abrasion striations are predominantly transverse, but may include small areas of diagonal or longitudinal striae as well. Where two opposing facets are present they meet at the tip to form a straight chisel-like edge. The function of these implements is difficult to determine from either the morphology or the microwear. The straight edge on some suggests the possibility of their use as wedges or chisels, but none of the tips show evidence of heavy use. In addition, many of the unifacially faceted tools are too thick to have performed well in these functions. The sizes of the facets range from tiny areas of around 5 mm in width to quite broad surfaces about 30 mm across. In the absence of observable damage at the tips of these tools, it is possible that they were used as polishers for smoothing pottery or other materials.

Since the grit in ceramic clay could create wear patterns very similar to sandstone abrading, this function would explain the paucity of other wear patterns at the tip. There is light hammering damage on the shaft near the base of 28 of these implements, but this is not necessarily caused by percussion flaking chert. This wear consists of long gashes and crushed areas rather than shallow pits crowded together with series of short, fine striae typical of flaking hammers. The beveled tools exhibit no damage on the basal end as might be expected on wedges for splitting wood.

The archaeological context does not substantiate or refute any of the suggested functions. The tools were often found in groups in rooms, but not in clear association with other types of artifacts. Room 62, Level 3 produced five beveled antler tools, and when Room 68 burned, a cache of eight of these implements was left behind in a corner.

The distribution of beveled tools in burials does not provide any definitive information about the age or sex of the owners of the artifacts, since two were derived from the area around the head of an infant (Burial 69), one from a burial of a child aged 4 to 6 years (Burial 132), one from beside the knee of a female aged 20 to 25 years (Burial 72), and one from a cremation of indeterminate sex (Cremation 187).

Indeterminate Worked Antler

Because of their fragmentary condition or the small or obscure form of their facets, some implements could not be classified as either beveled tools or flakers. A few other pieces of antler appeared to be either unfinished antler artifacts or manufacturing debris with chopping marks indicating where the antler was sectioned.

Perforated Antlers

One set of artifacts from Point of Pines is extremely perplexing in that conflicting ideas about function emerge from ethnographic information and microwear analysis. Perforated antlers are distributed throughout the Mogollon-Pueblo area, but are generally absent from adjacent regions, such as the Colorado Plateau or Sonoran Desert. These artifacts have been categorized as shaft-straighteners or wrenches in most of the literature because of the similarity in gross morphology to some ethnographically known arrow shaft-straighteners. Although no other plausible explanation of their function can be offered here, the absence of use traces presents a problem if the original functional classification is to be upheld.

The manufacture of perforated antlers involved several steps. Since few unfinished pieces are available, the order in which the various tasks were performed must be inferred from manufacturing traces and the morphology of the finished specimens. Six of the artifacts retained the proximal end of the main beam. Of these, half were shed antlers and half had been severed from the skull at the pedicle. The first step in making perforated antlers from unshed antlers would have been chopping through the pedicle with an axe or chopping tool. If an antler was derived from a mature stag the tines and upper beam were also hacked off to produce a tool of manageable size. If a young male's antler was chosen and the tines were small, they were often left intact. The next step involved thinning the upper part of the Y-shaped implement (Fig. 70a-c) in preparation for drilling. Two alternative methods were employed. Antlers with large diameters were grooved and split and the cancellous tissue was scraped out with a stone tool. Smaller antlers were sometimes heavily abraded until the outer compact tissue was removed, but often the cancellous bone was left intact. In order to maintain a solid handle, the base of the beam was usually not grooved and snapped or abraded. Whether thinning the antler served any purpose related to the function is difficult to determine, since the function is unknown, but it greatly facilitated the subsequent manufacturing step, that of drilling the perforations.

Despite the thinning procedure, the holes were still biconically drilled. This is evidenced by the slight flaring of the walls of the perforations toward both rims and the constriction in the center, producing an hourglass cross-section. Variation in diameter among the perforations on any individual specimen is so minimal that it appears likely that a single drill was often used to carry out all of the drilling on a given antler. There is no convincing evidence that the holes were intentionally graduated in size. The handles are free of perforations except for one small hole sometimes made near the base. This isolated perforation may have had a piece of twine or a thong strung through it for carrying.

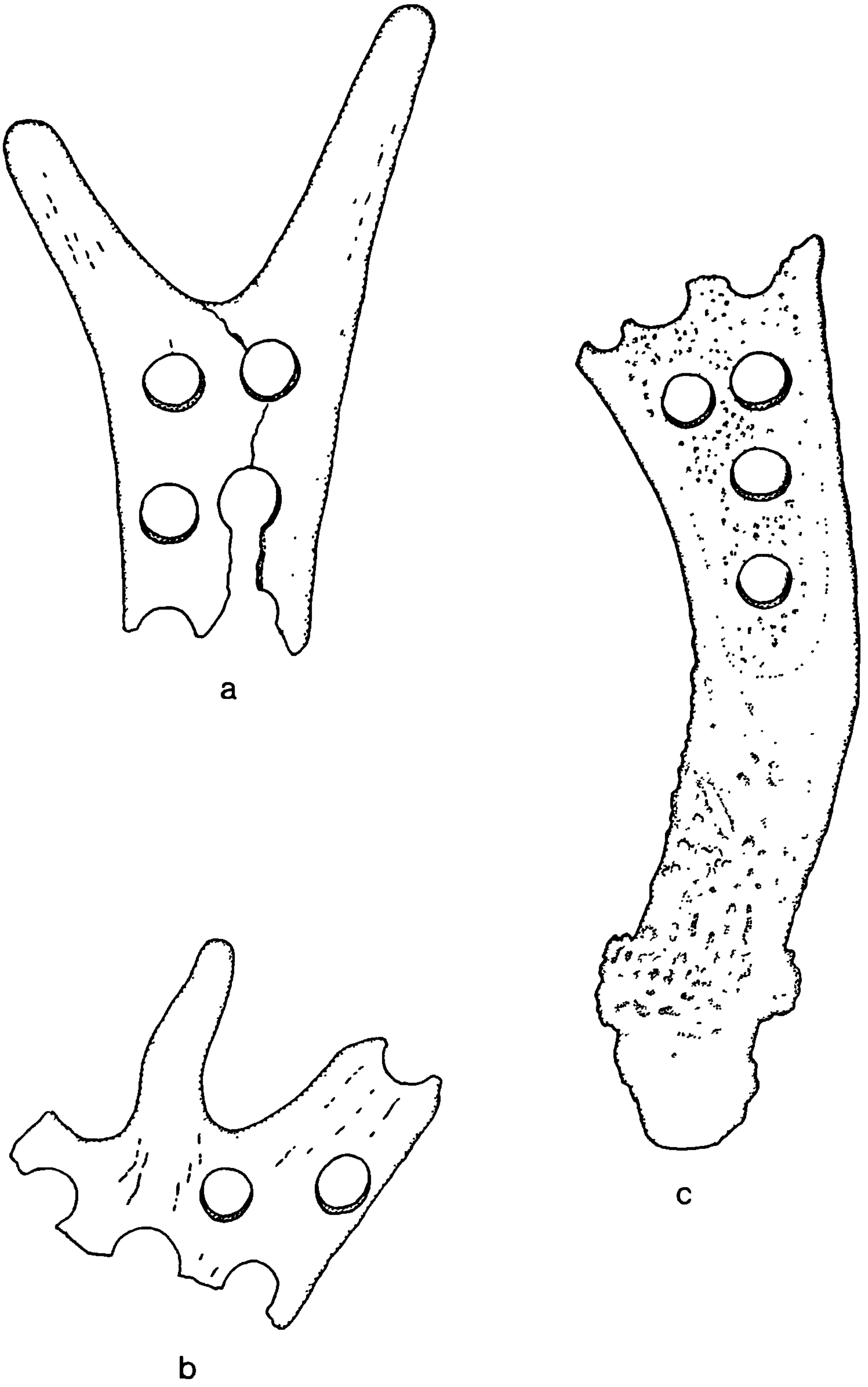


Fig. 70 Perforated antler implements. Scale 1:1.

Light polish on the inner basal surface of some of these holes suggests wear of this kind. The larger, grouped perforations are located further up the beam where it branches. Their placement is not in orderly rows; rather they are spaced as closely as possible to one another. The combination of thinning the antler and leaving only narrow walls between the crowded perforations substantially weakens the implement. For this reason, perforated antlers are virtually always fragmentary when recovered. The overall morphology has had to be reconstructed by looking at hundreds of fragments and partial specimens, but the Y-shaped outline appears to have been typical throughout the Mogollon area. In three cases multi-purpose tools were made by modifying or simply using one of the tines of the perforated antler for another function. Two implements had an abraded facet on one tine tip that resembled those on beveled tools. Another displayed clear use wear that indicated that the tine had been employed as a flaker.

Perforated antlers were plentiful in the pueblos of Grasshopper, Kinishba, Turkey Creek, and Point of Pines, but also occurred in many other sites. Among those yielding examples of perforated antlers were Canyon Creek ruin (Haury 1934: 126), Broken K (Martin, Longacre, and Hill 1967: 108), Higgins Flat Pueblo (Martin, et al. 1956: 117, 120), Carter Ranch (Martin, et al. 1964: 94, 102), and Az W:10:51, near Point of Pines ruin (Wendorf 1950: 83). The Classic Period Hohokam site of Los Muertos in the Salt River Valley (Haury 1945: 160-161) produced a fragment of a large mammal limb bone with at least two large perforations that may have served the same function as the Mogollon-Pueblo antler implements.

As mentioned above, ethnographic analogy has been used to classify these tools as arrow shaft-straighteners. Perforated sheep and goat horns were collected in 1879 and 1881 (Stevenson 1883, 1884) from Zuni Pueblo, New Mexico, and the Hopi village of Walpi, Arizona that were described as arrow shaft-straighteners. An example that is illustrated from Walpi has only four perforations without any evidence of heavy wear portrayed. Through the hole closest to the tip a leather thong has been strung with a rod tied to the other end. It is tempting to use this and other ethnographic accounts as confirmation of the function of prehistoric perforated antlers, but problems arise with their documentation. In addition to several other questionable explanations of artifacts, two different Zuni names are used for the perforated horns which were collected and the word given as the Hopi term for arrow shaft-straightener is not a Hopi word at all (Emory Sekaquaptewa, personal communication). Better documented examples of arrow shaftstraighteners are recorded from the Great Basin (Steward 1941: 290). The Great Basin Shoshoni shaft-straighteners normally had no more than three perforations that were clearly graduated in size. Wear on recent ethnographic examples is quite pronounced and diagnostic (see Chapter 4).

The need for a shaft-straightener can be questioned, since large quantities of arrow shafts made from "carrizo" cane (*Phragmites communis*) have been found in Mogollon occupied rock shelters. Red Bow Cliff Dwelling, near Point of Pines, produced no less than 433 arrow fragments (Gifford 1980: 94). This demonstrates that, while wooden foreshafts were used, the arrow shafts were made of cane which will not withstand straightening in this manner. A cache of cane cut to standard lengths and notched at both ends for arrow-making was also collected in the nearby Tule Tubs Cave (Gifford 1980: 133). Other possible uses for perforated tools include thong-smoothing (Campana 1979) and straightening pieces of antler (Bilikci 1970: 18; Guthrie 1983: 280). Both of these functions are unlikely on the basis of an absence of use wear. The second may be discounted by the fact that the perforations are smaller than the width of most antler tools and the thinning and drilling of many holes would have made the perforated implements very weak.

The distribution of perforated antlers at Point of Pines or other sites such as Kinishba, Grasshopper, or Turkey Creek Pueblo, does not provide many clues to the way in which the implements were utilized. At Point of Pines they are derived mostly from room fill with a small number actually lying on floors. Burial 3, that of a middle-aged male, Cremation 184, an adult of indeterminate sex, and Cremation 189, a teenager, each contained perforated antlers. Along with the antler tool in cremation 184 were numerous small flint chips. Whether they bore any relationship to the perforated antler is uncertain. Fragments of a perforated antler were found both inside and outside the jar containing the ashes of Cremation 187. It is interesting to note that associated with this cremation were antler flakers and flint chips. There may be some relationship between arrow-making and the perforated antlers other than that conventionally assumed. Evidence is very limited, but the diameters of the holes are appropriate for receiving cane arrow shafts. The approximate range of sizes of the perforations is 7 to 11 mm. Also, there are examples of their association with flakers and flint chips in cremations and a composite tool with a flaker at the end of a perforated antler.

Hide Scrapers or Beamers

Long implements possessing a thin blade edge along one side were very likely used to scrape hides. The blade was probably employed by pushing or pulling it across a hide stretched over a large beam with both ends of the tool held by the hands (Fig. 59). Innominates of ruminants were the most commonly selected elements for this task, although many of the long bones of large mammals were also converted into efficient beamers (Fig. 71a).

In the case of innominates, modification commenced with separating the left and right innominates where they join at the pubic symphysis and from the sacrum at the auricular surfaces of the ilia. The tuber sacrale, tuber ischii, the symphyseal branch of the ischium, and all of the pubis were removed either by chopping or more rarely by grooving and snapping. The latter technique, when used on the tuber sacrale of the ilium and across the

Fig. 71 a. beamer made on a deer innominate, b. gouge made on a bear femur. Scale 1:1.

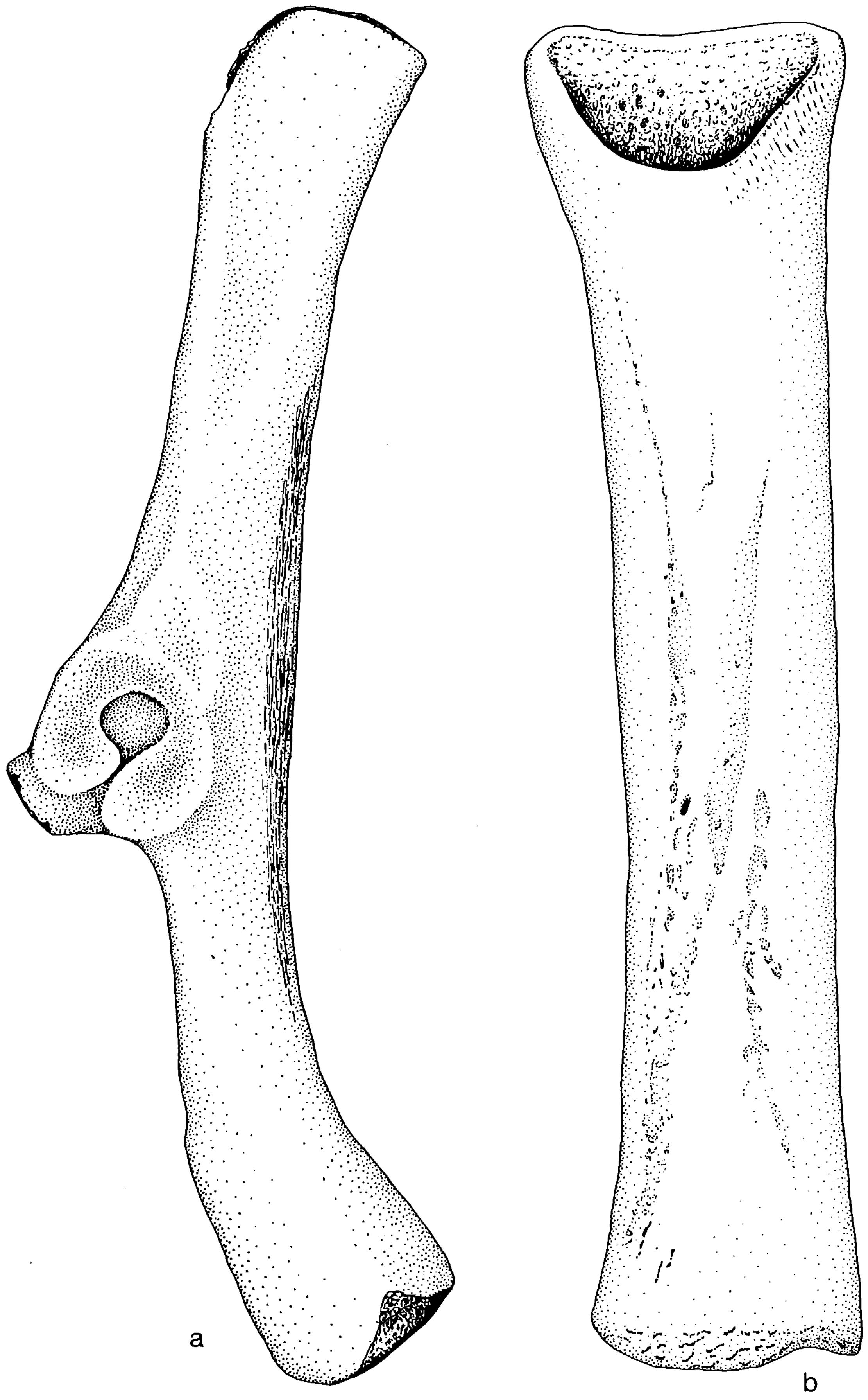


Fig. 71

symphyseal branch of the ilium formed a more comfortable grip than did chopping, but would have been a more time-consuming manufacturing technique. The purpose for removing so much material was to convert the innominate into an implement with a long blade edge that could be easily grasped at both ends. The ischiatic spine between the greater and lesser sciatic notches was thinned by scraping with a chert tool longitudinally down both surfaces near and along the edge. Little or no abrading was done along the chopped surfaces to improve the appearance of these implements.

Several other elements were also altered to form a blade along one or both edges, presumably for the same purpose. The medial margins of whole radii of an adult grizzly bear (*Ursus horribilis*) and a mule deer (*Odocoileus hemionus*) were shaved with a stone scraper to form a keen working edge. The elements were otherwise unmodified. Another mule deer radius and a femur of a bison (*Bison bison*) were grooved and snapped longitudinally and bisected. The two edges of the anterior half of the radius and the lateral half of the femur were then sharpened by longitudinal scraping. Beamers were also made on the fused radius and ulna of both pronghorn (*Antilocapra americana*) and bighorn (*Ovis canadensis*) by honing the naturally thin posterior margin of the ulna. Two other ulnae, one of a pronghorn and one of a mule deer, were prepared in the same manner. A bison scapula was grooved and snapped through the infrascapular fossa so that the caudal margin could be used as a beamer.

Finally, a tool having a beamer blade along one edge and either a gouge tip or a narrow hide scraper on the distal end was made from a bear femur.

Microwear along the blade of the beamers consisted of both manufacturing traces and use wear. Longitudinal scraping to thin the blade left striations up to 2 cm out from the edge and parallel to it. These have been largely obliterated from the actual edge in most cases by a glossy polish which rarely extended in from the edge more than 1 mm. Under magnification of 100 times or more very fine striations may be seen sweeping transversely over the edge (Fig. 50), indicating that the implements had been pushed or pulled perpendicularly to their long axis rather than drawn back and forth like a knife or saw. These wear patterns closely matched those created by experimental hide scraping to remove the fat adhering to the skin (Fig. 49). The polish was induced by rubbing against the hide, with the oils of the skin acting as a lubricant. The fine scratches were probably created by fine particles of dust from the fur of the animal or the ground.

Experimental work was conducted initially using a bone blade made on a horse rib as a cutting tool for harvesting grasses. The blade was ineffective as a knife, however, especially when compared to a stone tool. After four hours of work no polish was visible to the unaided eye, though continued use probably would have produced wear polish similar to that seen at the tip of an awl. It was after this experimental work that the fine transverse striae indicating the kinematics involved were discovered on the archaeological specimens.

The distribution of beamers at Point of Pines shows that there were several rooms containing three or more of these implements but with two exceptions the hide scrapers do not occur in clusters or form patterns suggesting activity areas. In Room 1 of W:10:50 B four beamers were recovered from Floor 2 fill, while in Room 52 of the main pueblo three were collected from the same level of secondary refuse. Beamers do not appear to be closely associated with any artifacts of bone or other material that is preserved archaeologically.

Mason (1971: 567-568) has described the use of bone beamers made of the radio-ulnae of caribou for removing the hair on hides by North American tribes, and Steinbring (1966) discussed defleshing tools used in the northern Plains. There is little information available on the bone hide scrapers in the Southwest, although Cushing (1920: 431) made a general statement about their use. The early introduction of iron implements by the Spaniards in the sixteenth century probably accounts for the decline or disappearance of many bone implements such as hide scrapers and awls in historic times.

Small Scrapers

A large quantity of artifacts that may be related to beamers in function has been subsumed under the classification of "small scrapers". These are mainly manufactured on ruminant ribs and scapulae, both of which possess qualities which allow them to be easily converted into blade-like implements. Rib scrapers were made by breaking or chopping the rib into segments of suitable size (Fig. 72a). The broken ends and the cranial and caudal borders were usually abraded smooth. The corners were rounded and the borders ranged from slightly convex through straight to slightly concave. In a few cases, both ends of the scraper were left unabraded, exhibiting the nibbled edges of the rough blank. The complete scrapers varied in length from 3.9 to 24.8 cm with a mean of 9.4 cm. In selecting the raw material the upper five or six ribs of ruminants were preferred because of their broad, flat morphology. The remaining ribs become progressively narrower and more rod-like in cross-section and were hence less useful as scrapers.

On most of the rib scrapers a light polish partially obliterated the abrading striations along the cranial and caudal margins, but did not impinge on the shorter edges. A few of the ribs bore evidence of pronounced wear polish that extended well onto both faces.

Rib scrapers were evenly distributed in various rooms throughout the pueblo with the highest frequency occuring in Room 1 of W:10:50 B where three were found scattered in different levels. It is interesting to note that four of the beamers were also retrieved from this room, although the lack of clustering does not suggest the presence of a specific work area within the room.

This type of scraper has been found in abundance at Grasshopper (S. Olsen 1979: 352) and Kinishba (S. Olsen 1980: 55) in the Mogollon-Pueblo area and Gran Quivira, New Mexico, east of the Rio Grande (Hayes, Young, and Warren 1981: 146). No ethnographic descriptions of the

Fig. 72 a. scraper made on a ruminant rib, b. scraper made on a ruminant scapula, c. spatula made on ruminant radius, d. short gouge made on a grizzly bear radius. Scale 1:1.

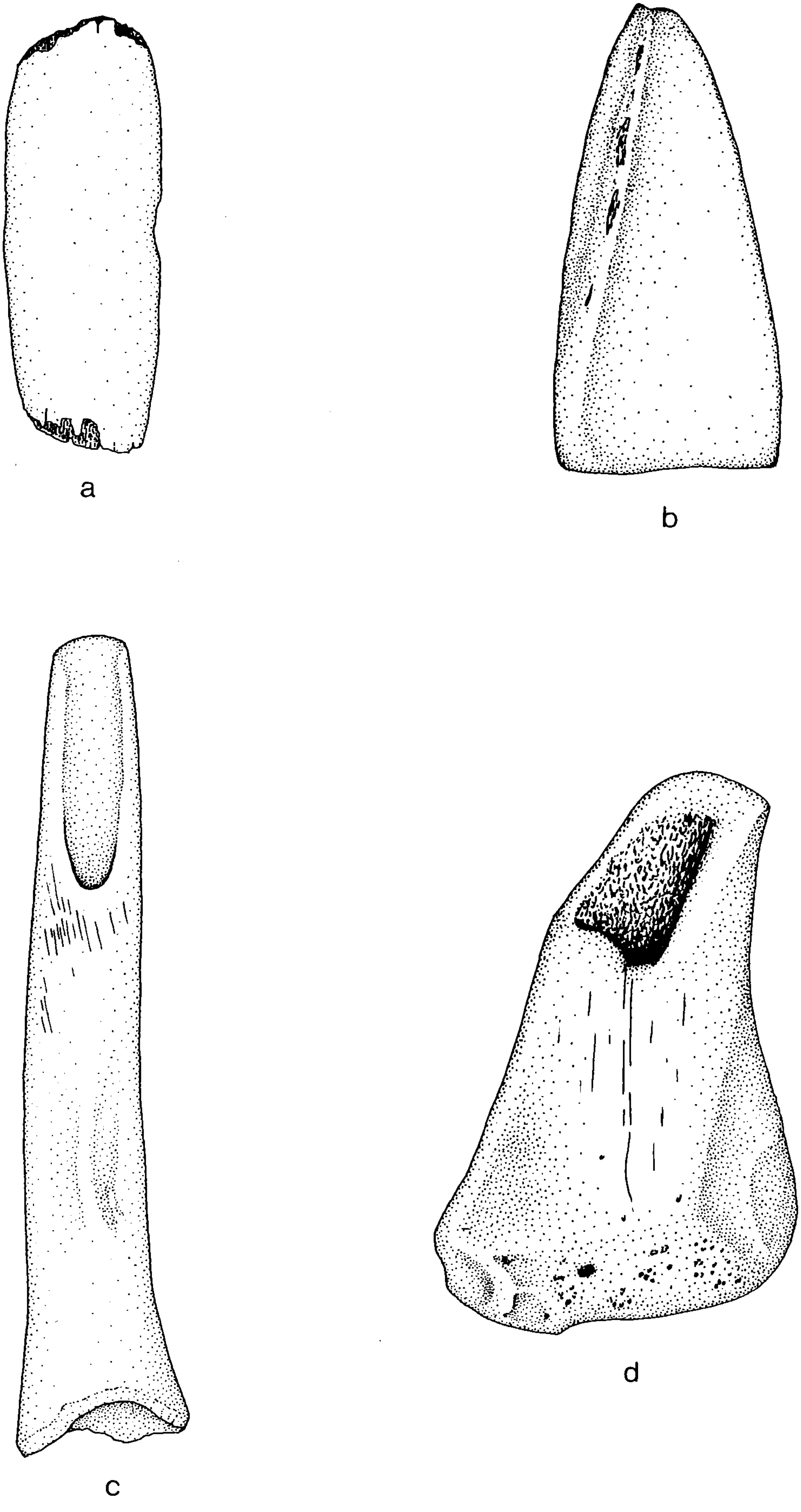


Fig. 72

use of short rib segments among Southwestern Indians were encountered, but they could have served many useful purposes. The wear along the long edges would support the hypothesis that this type of implement was used as a hide scraper or sweat scraper. In either case a polish would develop along the edge after prolonged use. Other possible applications could be in culinary tasks such as scooping up food or cutting soft substances like dough or squash (Hayes, Young, and Warren 1981: 147). This might be expected to lead to attrition due to abrasion from contact with pottery or stoneware, but is unlikely to have polished the edges.

The second tool that is subsumed under the heading of small scrapers is made by cutting or breaking out sections of the scapular blades of ruminants (Fig. 72b). There is considerable variety in the outline of these tools which includes ovals, rectangles, triangles, and irregular shapes. The manner of fabrication is difficult to discern in detail by observing the finished artifacts, but debitage suggests that they were removed from the remainder of the scapula by grooving and snapping in most cases. A few specimens with irregular borders appear to have been broken or chopped off the scapular blade. If the area of the blade used for the artifact contained the scapular spine this process was generally chipped away down to its base and finished by abrading. In some cases one or more of the natural borders of the scapula were retained, but this must have decreased the functional surface since the cranial and caudal borders are thicker than the rest of the blade and unsuited for use as a scraper. After the blank was cut out, the edges were smoothed and the corners rounded by abrading. The abrasion striae on both the rib and scapula scrapers are perpendicular to the plane of the blade, indicating that the abrader was applied to the edge with a transverse motion rather than a longitudinal one.

Use wear is very light and not visible on each piece, but where present it consists of a polish along the longest edges. There is some supportive evidence in their distribution that suggests the scapula and rib scrapers performed the same function. Seven rooms at Point of Pines contained both types. Room 1 of W:10:50 B yielded one scapula scraper along with four beamers and three rib scrapers. Scrapers made on scapulae are not common outside the Point of Pines area.

Gouges

A group of artifacts made on very durable bone and bearing extensive wear patterns have been herein classified as gouges. Aspects of their morphology suggest that these implements were used for heavy labor involving substantial force against a resistant surface (Fig. 71b). The elements selected as raw material, e.g. the radius, metacarpal, and femur of ruminants and the radius and femur of black and grizzly bears, are extremely sturdy due to the thickness of the cortical bone. Three of the femora and a radius were identified as grizzly bear, while another three were tentatively identified as grizzly. This species is very rare in the mountains of east-central Arizona in historic times and extrapolating from the faunal remains from archaeological sites in the Point of Pines region (Stein 1963) and from Grasshopper ruin (J. Olsen 1980) they were rarely hunted by the prehistoric people. The black bear (Ursus americanus) is more frequent, though not common, in the region today and in prehistoric faunal material. Despite a paucity of unaltered bear bones in this and other sites in the area, there appears to be a clear selection for their elements in making bone gouges. The same trend is apparent at the site of Kinishba (S. Olsen 1980: 61). The explanation presented here is that bear femora, particularly those of the grizzly bear, constituted the largest and heaviest elements available in the area with the exception of the extremely rare occurrence of bison bones. For heavy-duty tasks, then, the grizzly bear elements would have been very appropriate.

The manufacture of gouges would have been time-consuming and tedious because of the thickness of the cortical bone, but the manufacturing techniques were not particularly complex. Initially, in most cases, the articular condyles were removed from both ends. The method for removal is still evident at the base where the rough, nibbled edge of the diaphysis exhibits evidence of chopping. The working end was prepared by cutting or chopping through the shaft diagonally so that one surface was set back and the other retained a broad, shovel-like blade. Extensive abrading was performed on the inner bevelled surface of the working edge, while more moderate grinding was done on the external surface in order to thin the edge. The abrading striae on both sides indicate that the action was conducted perpendicular to the longitudinal axis of the bone.

The use wear, described in detail in Chapter 4, provided abundant information about how the tool was manipulated and properties of the surface to which it was applied. Experimental replication conducted on soft wood (see Chapter 5) and ethnographic analogy verified the feasibility of the hypothesized function of these implements. The general morphology narrowed the possible ways in which the tool could be held and operated, but did not reveal the material upon which it was used. The Plains Indians used similar implements as hide scrapers (Steinbring 1966), while Osborne (1965) has suggested that objects from Anasazi assemblages sharing many attributes in common with the gouges from Point of Pines were used as yucca fiber strippers. The use wear on the edge of the gouges did not substantiate either of these two uses, however. Use wear on experimental awls employed in making coiled baskets of bear grass and yucca leaves consisted of a smooth polish. Wear along the edge of a rib used in scraping hides was expressed predominantly as a very glossy polish with fine striations. It is unlikely that working with either delicate leaf fibers or hides would have led to the pronounced damage present on the edge of the archaeological gouges. Four distinct kinds of use traces were evident on the gouges from Point of Pines. The first was a rounding of the external surface above the edge caused by attrition. Associated with this was a high polish from the edge to several millimeters up the shaft. Fine striations running longitudinally from the working edge and through the polish indicate the direction of motion. The fourth, and most destructive form of use damage was the removal of scalar flakes along the edge predominantly on the external surface. In a few instances breakage actually took away a portion of the edge, which probably would have necessitated resharpening before work could continue. Handling polish was present on most of the specimens around the middle of the shaft demonstrating that the tool was held, probably with both hands, at this point rather than at the base. There was one exception, a very short gouge made on a grizzly bear radius, which retained the distal condyle at its base (Fig. 72d). This gouge has had the articular surface ground down probably to provide a smoother surface to rest the hand. In its present state the tool would have been difficult to manipulate with both hands around the shaft. It is difficult to determine, however, if the tool was originally designed with a short handle or whether it was reduced through resharpening.

The ethnographic example that seems the most appropriate analogy to explain the wear patterns on the Point of Pines gouges is geographically far removed. The Koko Tai'yuri near the Edward River in North Queensland, Australia, hollowed out troughs or vessels in soft wood with gouges made from the tibiae of kangaroos and the tibiotarsii of emu (Thomson 1936: 73). These gouges were made in about the same way as those from Point of Pines except that the distal condyle was retained at the base. They are described as having considerable wear. The KoKo Tai'yuri held the tool diagonally at the midshaft with the base tipped away and the working end tilted toward the worker (Thomson 1936: Plate X). The strokes were directed downward and toward the body as they struck the wood, removing shavings and chips.

Experimental use of a gouge made on the femur of a domestic cow (*Bos taurus*) and used to shave off the surface of a piece of soaked cottonwood for two hours produced all of the wear traces seen at the working end of the archaeological specimens. The only differences were that there was less attrition and the scalar flakes which were removed were smaller on the experimental piece, presumably because of the limited amount of use.

No distribution patterns suggesting associations of the gouges with structures, features, or other artifacts were discernible at Point of Pines. Most were strewn through secondary refuse in both rooms and open areas. Three gouges were found on floors, but no definite signs of woodworking areas were detectable.

Spatulate Tools

A small group of implements from Point of Pines are set apart by their diminutive spatulate tips. Their function is not readily assignable on the basis of archaeological context or microwear and ethnographic descriptions of their use in the Southwest are lacking.

There was relatively little standardization in the manufacture of these tools, except that they all had flat, squared-off working ends (Fig. 72c). The most frequently utilized elements were metapodials of ruminants, though a radius and two tibiae were also used. In one case a radius of a bobcat (Lynx rufus) was modified by removing the proximal articulation and abrading the end of the diaphysis. Splinters of indeterminate long bones of large mammals were abraded transversely at one end until a flat facet was formed on one or both surfaces. The majority of the spatulae exhibited no evidence of workmanship other than breaking off one articular end and shaping the tip with an abrader. Some of the spatulae made on ruminant metapodials were grooved and snapped sagittally to make a thin, straight shaft. One of these had a spatulate tip at both ends. Two multi-purpose tools possessed a spatulate tip at one end and an awl tip at the other. Two others were made on broken hairpins, providing evidence of recycling of material.

Microscopic surface traces appear to offer few hints as to the function of these implements. The only recurrent traces are those created by the transverse abrasion that forms the chisel-like working end. The abrading is predominantly bifacial. Polish, chipping, or longitudinal striations indicative of use wear were not apparent. One specimen displayed light hammering damage on the shaft near the base similar to that on many beveled antler tools. Since the tips of both the antler tools and the bone spatulae were made by transverse unifacial or bifacial abrading and use wear was difficult to detect on both, the appearance of hammering wear on one of the spatulae suggests that the two types may have served similar functions. There is the possibility that the transverse striae which contribute to the formation of the facets by attrition were related to use rather than fabrication or that they were formed both by manufacture and by use. If this is the case, then the spatulae may have been used to polish or burnish other materials as has been suggested for the beveled antler tools. The two tools are still maintained as separate types because the bone spatulae are generally quite narrow. Only a very few of the antler implements had facets approaching the small size of those on bone spatulae.

The contexts in which spatulae were discovered do not suggest any particular function. Most were recovered from room fill and were not consistently associated with any other type of material or artifact. In Room 68, however, eight beveled antler tools were found with one spatula made on the metatarsal of a ruminant, providing a small piece of supportive evidence for the hypothesis that the two types served the same or complementary functions. The difficulty in assigning a function is due to the simple morphology of the tools and the lack of diagnostic microwear, fruitful contextual information, and ethnographic accounts of their use in the Southwest.

Awls

The greatest category of bone artifacts from Point of Pines, either in terms of sample size or subtypes, is that of awls. With the exception of implements referred to in the literature as "ulna awls" which may have been used as shedding tools in textile weaving, awls were probably generally used in making coiled baskets and for piercing hides. Although there is a wide variation in the choice of elements employed, the manufacturing processes, and the overall dimensions of these tools, the awls have a relatively standardized tip morphology.

The awls from Point of Pines and other Mogollon-Pueblo sites could be classified in a myriad of subtypes depending on how characteristics are weighted. Kidder (1932) established a typology for awls from the Anasazi culture which will provide the basic guidelines for the classification used in this research. The way in which awls are subdivided is probably more of a convenient tool for archaeologists than a set of types recognized and set apart linguistically by the society who employed them. It is still useful, however, in demonstrating preferences in selection of raw material and for visualizing manufacturing patterns according to which certain elements were transformed into awls.

The following classification system has been adopted for the Mogollon-Pueblo bone awls.

a. Splinter awls: those made on fortuitous, long splinters with modification limited to scraping or abrading of the functional tip and occasionally up one, but not both sides.

b. Shaped awls with plain bases: those modified by grooving and snapping, scraping, abrading, or any combination of the above along both edges and at the tip and possessing a base without the articular condyle present.

c. Awls retaining an articular surface as the base. These may be made on either split or whole elements of birds and mammals.

Splinter Awls

Requiring a minimum of labor, splinter awls were made simply by shattering long bones, as in the process of marrow extraction, and sharpening one end of a long, slender splinter (Fig. 73c,d). At Point of Pines either a granular abrader, or more rarely a chert scraper, was used to sharpen the point.

The series of measurements taken on splinter awls from Point of Pines shows that, despite the lack of modification to the edges and base, variation in gross dimensions (Fig. 74) is not substantially different from that seen in other awls. The location of the maximum width on the shaft does exhibit greater variability than is graphed for awls with more uniform edges (Fig. 75). This variation is predictable given that breakage of unmodified bone is difficult to control and because no finishing techniques were used on the shaft or base. The tip morphology and dimensions are much more conservative, with the width and thickness basically in accordance with the measurements of other subtypes of awls (Fig. 76)

Most of the splinter awls from Point of Pines were fabricated from large mammal long bones. The absence of diagnostic features often defeats more accurate identification, but the thickness of the cortical bone and curvature of the diaphyses suggest that bones of ruminants were frequently selected. This is supported by the identifiable elements, which include most of the larger limb bones of ruminants. Other elements chosen for use as splinter awls include two long bones from birds and two

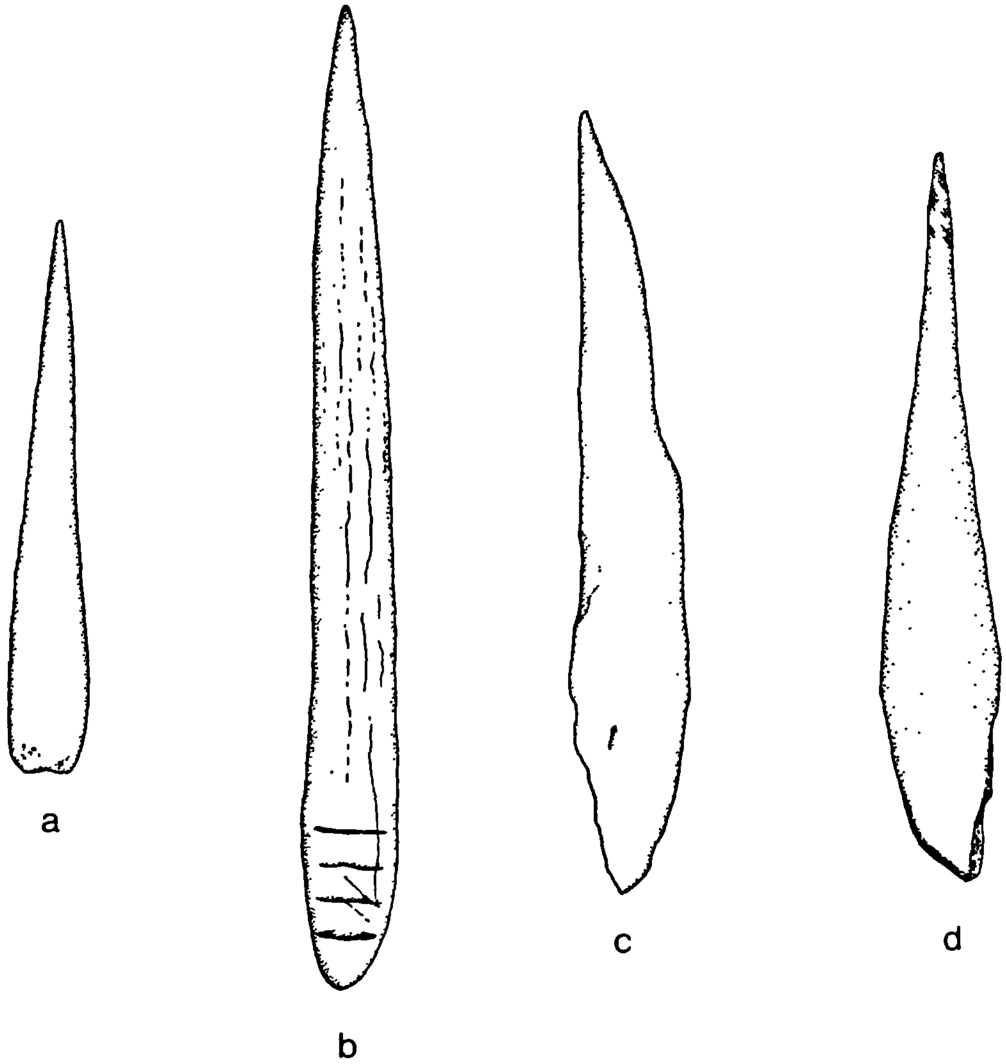


Fig. 73 a-b. shaped awls with plain bases, c. splinter awl made on a ruminant femur, d. splinter awl made on a long bone of a large mammal. Scale 1:1.

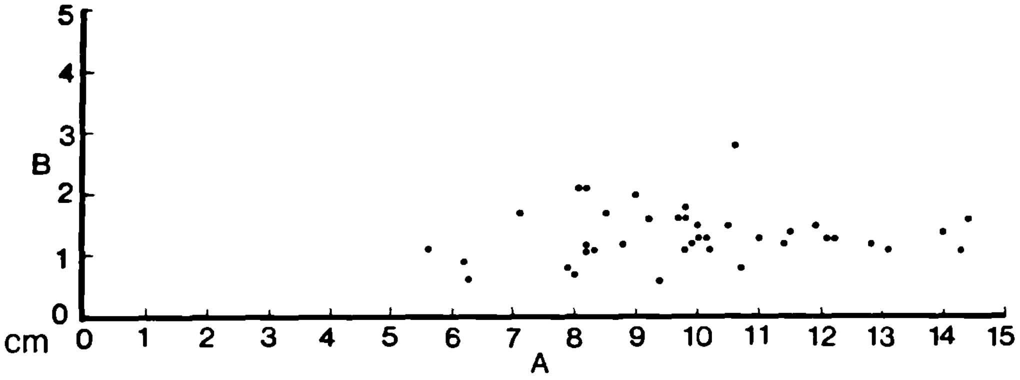


Fig. 74 Scatter diagram 1: gross dimensions for Point of Pines splinter awls.

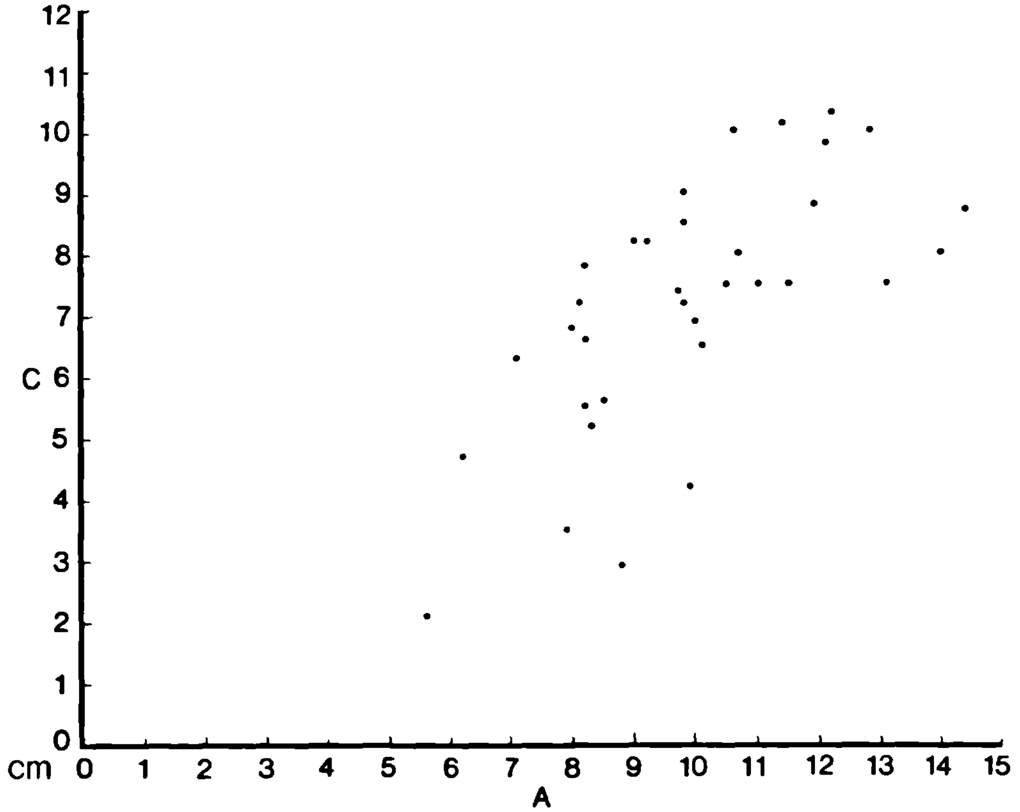


Fig. 75 Scatter diagram 2: location of maximum width on the shaft for Point of Pines splinter awls.

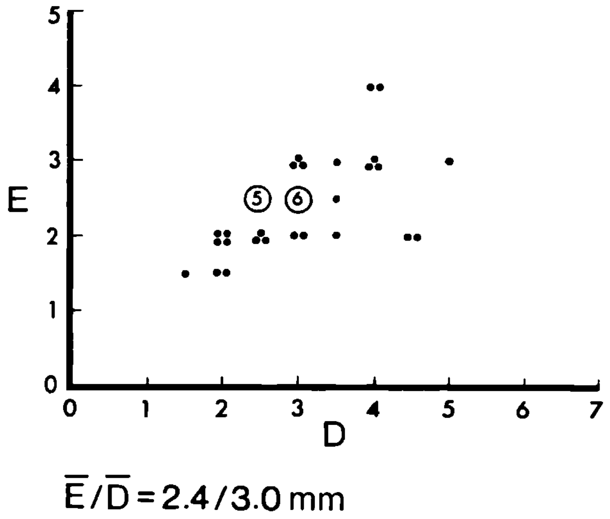


Fig. 76 Scatter diagram 3: tip dimensions for Point of Pines splinter awls.

from birds or small mammals.

The majority of the splinter awls were derived from secondary refuse and were distributed fairly evenly throughout the site. Some were intentionally discarded by the excavators after being noted, but because of the lack of modification of the shaft, many more broken splinter awls may have been missed. Use wear at the tips of the splinter awls was identical to that on other awls from the site and consisted of polish around the tip up to a distance of around 10 mm from the end.

Shaped Awls with Plain Bases

As the name implies, these awls were carefully made by longitudinal grooving and snapping the shaft and breaking off both articular ends. Most of the bases were rounded or squared off with evidence of grinding (Fig. 73a,b). Two were bluntly pointed at the base. Although the lengths of these awls varied widely, from 6.6 cm to 20.5 cm, their widths were fairly compactly distributed between 0.4 cm to 2.5 cm. (Fig. 77). There was a tendency for the maximum width to be located near or at the base, but this was somewhat variable (Fig. 78). Tip morphology was very consistent (Fig. 79), with most of the awls having fine tips with a round cross-section and high polish. Two of the awls were so thoroughly worn, probably from basket-weaving, that there was a pronounced shouldering below which the tip was very thin. There were some awls with intermediate or even blunt tips similar to the finest tips on hairpins. In these cases assignment to one type or the other was dependent on

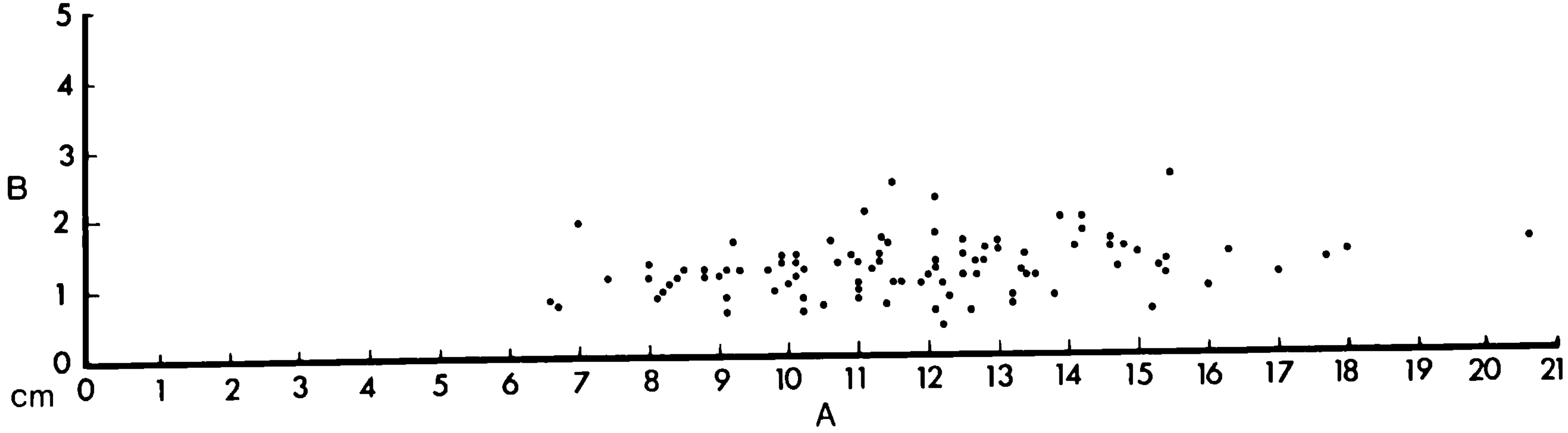


Fig. 77 Scatter diagram 1: gross dimensions for Point of Pines shaped awls with plain bases.

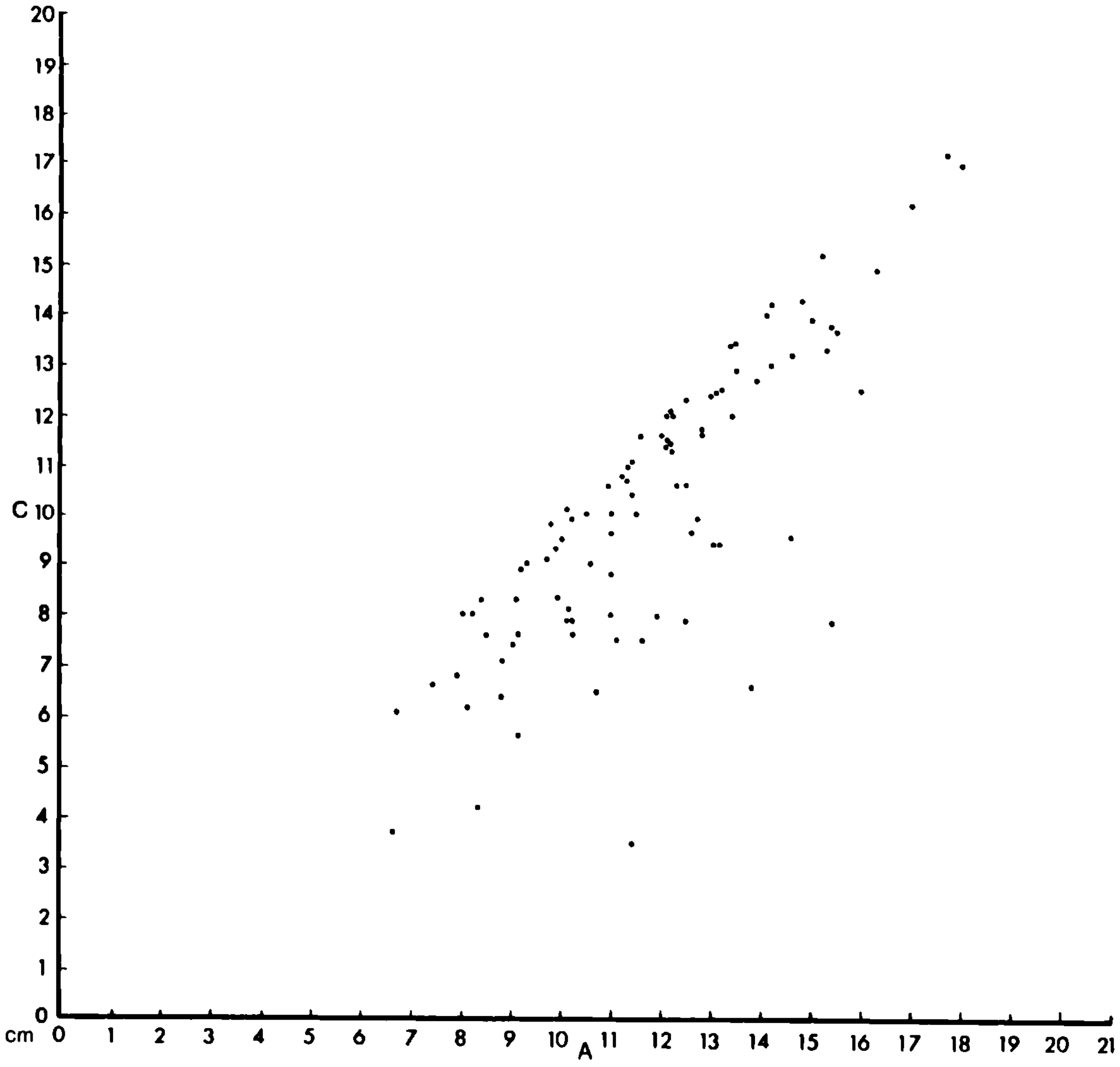


Fig. 78 Scatter diagram 2: location of maximum width on the shaft for Point of Pines shaped awls with plain bases.

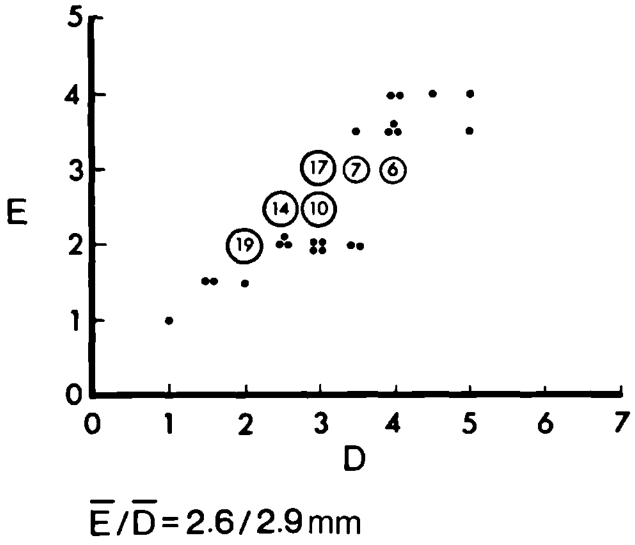


Fig. 79 Scatter diagram 3: tip dimensions for Point of Pines shaped awls with plain bases.

gross morphology and modifications such as the presence of overall polish on hairpins.

Because so many of the diagnostic characteristics were removed from awls with plain bases, identification as to taxon or element was severely hampered. For the majority of the specimens this was limited to the designation of large mammal long bone. Of those that could be further identified, all but one were ruminant bones. These included tibiae, metatarsals, metacarpals, and a radius in descending order of their frequency. A single long bone of a bird or small mammal was made into a plain awl.

Several of these awls were biconically drilled through the base. The purpose of this perforation is unclear. It may have converted the awls into large needles for making coarsely woven items such as nets, or alternatively the hole may have served merely as a way of running a thong or string through the base for carrying. There are indications among other artifacts like perforated antlers that this was a common practice.

It is important to emphasize that there are numerous partial pieces, consisting of basal, shaft, or tip fragments, that cannot be clearly assigned to either the category of awls or hairpins. The designation of a specimen as a hairpin as opposed to an awl relies heavily on multiple characteristics that occur on the base, shaft, and tip, so fragmentary artifacts are often ambiguous.

Awls Retaining an Articular End

The most frequently chosen elements for awls which use an articular end as the base are the metapodials of ruminants. Metapodial awls are extremely common in the Southwest, perhaps because of the prevalence of mule deer, white-tailed deer, pronghorn, and bighorn in the diet of the prehistoric people.

Manufacturing processes were extremely varied among metapodial awls. Metatarsals appear to have been chosen somewhat more often than metacarpals, a trend that is evident in other Mogollon-Pueblo collections in regards to both awls and hairpins. The distal condyle was retained as the base slightly more often than the proximal articular surface. There are three basic styles that were used: a metapodial that kept the whole distal condyle as the base and the entire circumference of the diaphysis for the handle, a metapodial that was split sagittally and retained only half of the distal condyle, and a metapodial that was split and maintained a portion of the proximal surface as the base.

The whole condyle style of awl was made by breaking off or otherwise eliminating the proximal articular surface and grinding the shaft to a point. Although the procedure was simple, the amount of grinding needed to remove either the posterior or anterior surface of the shaft so that a narrow point could be made on the remaining extension of bone was considerable. Examples of unfinished awls and hairpins show that the bulk of the excess material along the shaft near the tip was removed purely by grinding. To expedite this tedious task, it appears that a rough grained abrader was used. This is evidenced by the width and depth of the abrasion striae. The tip was then sharpened to a fine point with an abrader so that it was round to oval in cross-section and very sharp. Modifications of the base ranged from no treatment at all to grinding and carving of the condyles. Recycling of broken hairpins by converting their tips into functional awls is clear in at least three cases. These had elaborately modified bases and a high polish applied to the shaft. One of the awls possessed an indentation in the epicondylar region below the base in order to accentuate the condyle, a trait commonly found on hairpins. Two others were drilled medio-laterally through the condyle. In contrast to their smoothly polished shafts, the tips of these recycled hairpins were heavily abraded to form a fine point. Metapodial awls that were not made from broken hairpins rarely exhibit an overall polish on their shafts, although small areas of handling polish are occasionally observed.

Metapodial awls retaining half of the distal condyle were also popular at Point of Pines. Their manufacture involved the making of longitudinal grooves on the anterior and posterior surfaces of the metapodial in order to split the bone sagittally. Unfinished grooved metapodials show that the grooves did not taper and converge on one side, but rather continued and wrapped around the proximal articular surface so that two equal parts would have been formed when the bone was split. One half of the naturally bifurcated distal condyle formed the base of each of the two artifacts made from an individual metapodial. Many of the bases of these awls had had minor grinding performed around the articular condyle in order to lower the prominent natural ridge (Fig. 80c). The proximal end was removed, probably by breaking, and the shaft abraded to a point. Both edges were then usually abraded until smooth.

Awls made on metapodials that used the proximal end as the base were made in much the same way as those described above, except that the longitudinal grooves were not necessarily incised through the sagittal plane. The articular surface received little attention, but the edges of the shaft were usually ground smooth.

Those awls which retained one of the articular ends as their base but were not made on the metapodials of ruminants were less common at Point of Pines. The scapula of a ruminant was shaped into an awl in much the same way that hairpins and sounding rasps were made on this element. The caudal margin served as the shaft and the point was made near the vertebral end. The glenoid fossa, which formed the base, was drilled three times. One of the attempts at perforating was never completed, but two finished holes were presumably made so that the implement could be strung for carrying. A deer radius was converted into an awl by removing the distal articulation, narrowing the shaft with longitudinal grooving and snapping and sharpening the point and edges with an abrader. No modifications were made to the proximal end, which served as the base.

Fig. 80 a. jackrabbit ulna converted into an awl, b. awl made on a jackrabbit tibia, c. awl made on a ruminant metapodial retaining half of the distal condyle with ridge ground and epicondylar area indented, d-e. needles, f. pin with annular incision around base. Scale 1:1.

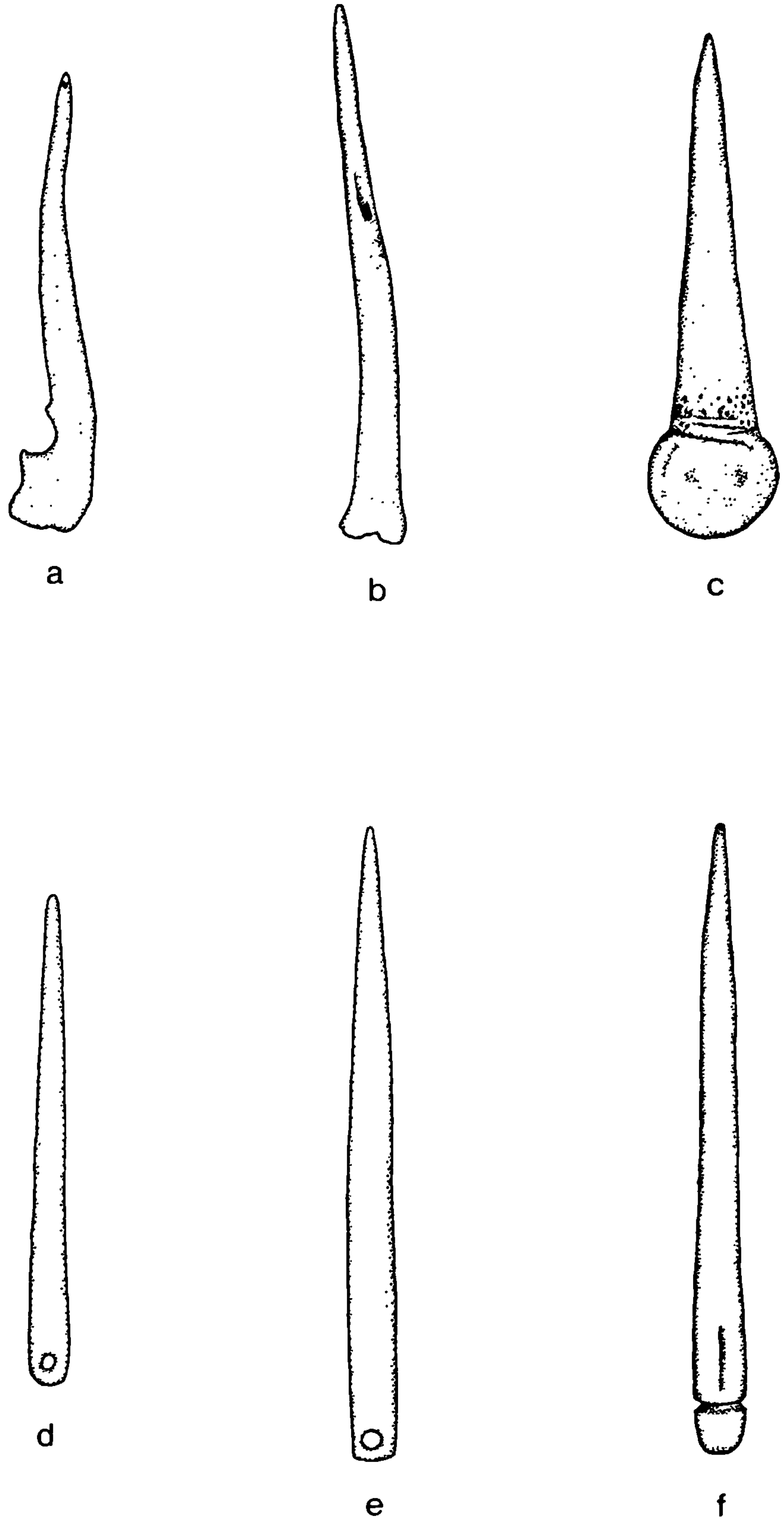


Fig. 80

Differing in their manufacture and overall size were the awls made from the bones of smaller mammals. These mplements not only retained one articular condyle, but with the exception of two, they also kept the diaphysis intact down to the tip. Manufacturing was facilitated by the naturally narrow diaphysis which required only that the end be broken and sharpened to a point. The exceptions are an ulna and a femur of the bobcat (*Lynx rufus*), which were split longitudinally by the groove and snap technique in order to reduce the shaft's width. Other ulnae and femora of bobcats used for awls were not thinned in this manner. A variety of limb bones of several taxa including cottontail, jackrabbit, fox, bobcat, puma, and bear were converted into this type of awl (Fig. 80a,b).

The radii of one turkey (*Meleagris gallopavo*) and two eagles (*Aquila chrysaetos* or *Haliaeetus leucocephalus*) were made into awls by removing the distal condyle and abrading the broken end into a point. The thin-walled, tubular diaphyses of the radii formed an unusual tip resembling a quill pen when sharpened. Their fragile concavo-convex tip morphology, probably would not have been very durable or efficient for basket-weaving or hide-piercing, which may explain their low frequency in the Mogollon-Pueblo collections.

Awls with an articular end at the base have a wide range of lengths (from 6 to 19.3 cm) and a greater range of maximum widths than splinter or plain-based awls (Fig. 81). There is a strong tendency for the maximum width to

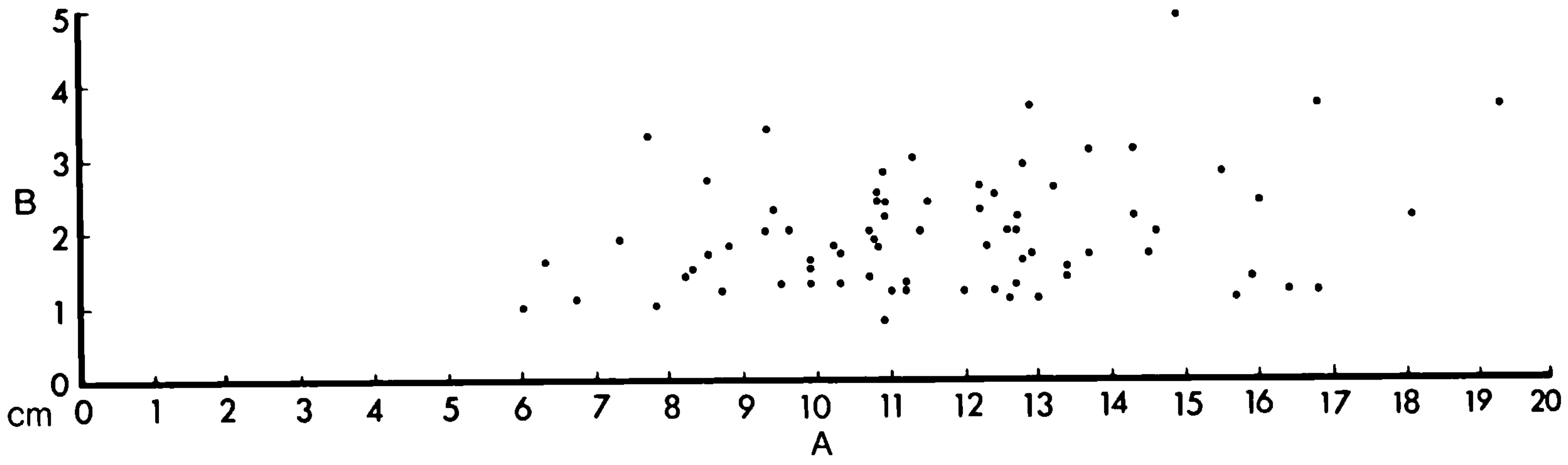


Fig. 81 Scatter diagram 1: gross dimensions for Point of Pines awls with an articular end as the base.

be located at or near the basal end because of the expansion of long bones at the condyles (Fig. 82). The tips of the awls retaining an articular end tend to be slightly larger on the average than those of the other two types, but are still well within the typical size range for awls (Fig. 83).

Pins and Needles

There is no clear demarcation between artifacts that might be designated as pins and awls because a fairly evenly distributed range of sizes exists for both. In general the pins are narrower than most awls, with a maximum width of less than 1 cm, and have a round cross-section throughout the shaft. There may have occasionally been an overlap in functions, with pins serving as awls and *vice versa*. Many of the pins are finely made and exhibit ornamental incising and carving. In the process of manufacture of a pin a high polish was applied to the whole shaft and the tip was sharpened to a very delicate point. Examples of decorations on the base and upper shaft of pins include diagonal or zigzagged incised lines on the upper surface of one, an animal effigy head on the base of another, and two cases in which an annular incision was cut just below the basal end (Fig. 80f). The tips of these objects were too fine to suggest that they were small hairpins.

Three of the smaller perforated awls approached the size of large needles. One maintained the broader, more flattened cross-section through the upper shaft that is typical of most awls, but the other two were round in cross-section throughout and were quite narrow (Fig.

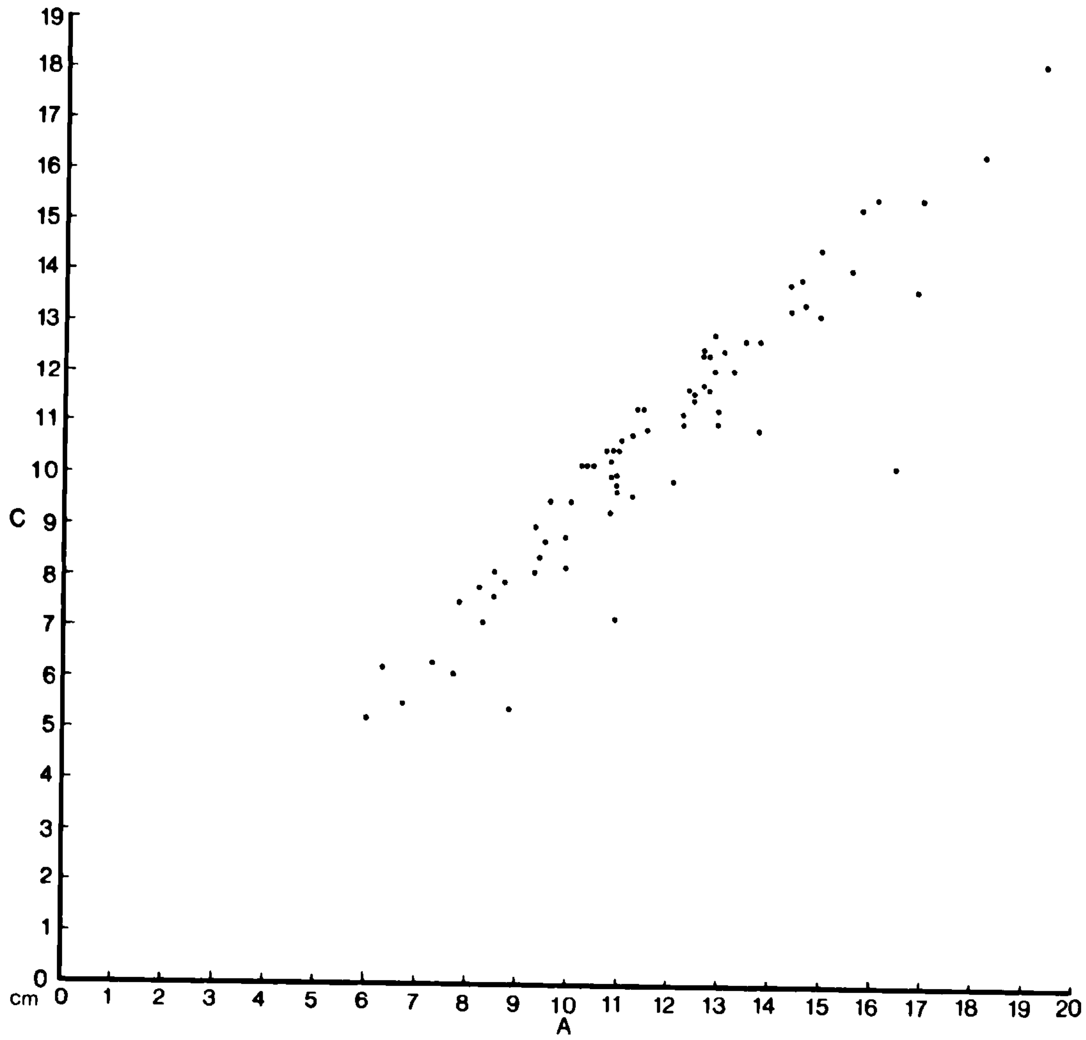


Fig. 82 Scatter diagram 2: location of maximum width on the shaft for Point of Pines awls with an articular end as the base.

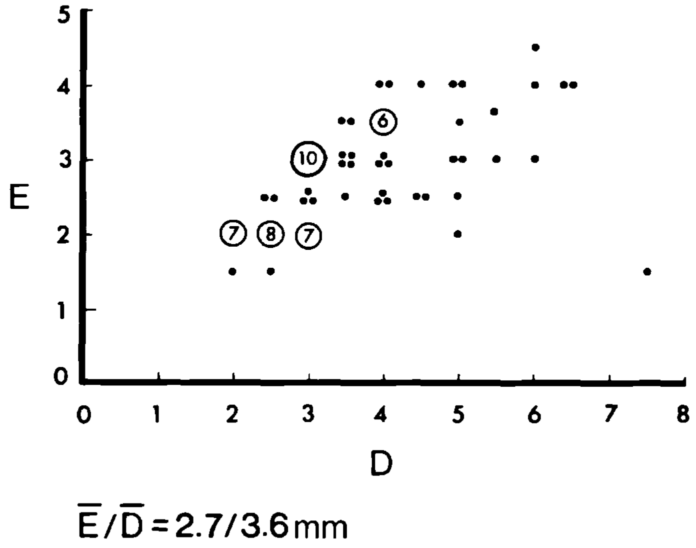


Fig. 83 Scatter diagram 3: tip dimensions for Point of Pines awls with an articular end as the base.

80d,e). It seems very likely, therefore, that these two specimens could have functioned as proper needles. The majority of the fine sewing needles at Point of Pines were manufactured from shell.

The scatter diagrams for needles and pins show that they are more slender through the base and shaft than most awls (Fig. 84), but are similar to them in the positioning of the maximum width (Fig. 85) and in their tip morphology (Fig. 86).

Ulna Awls or Weaving Tools

One group of pointed implements differed from other awls in tip morphology and use wear. For the most part these artifacts were fabricated on the ulnae of ruminants, which are endowed with a natural morphology that requires minimal alteration. Ulna awls were made by removing the styloid process and distal portion of the diaphysis with a single transverse break. The naturally attenuated shaft was tapered to a point with an abrader. The olecranon process, which served as the base and handle, was in many cases unfused. Where the epiphysis was missing it is difficult to determine whether it was removed prehistorically or became detached after the implement was discarded. Two specimens have had the end of the olecranon cut off and retain only the radial notch at the base (Fig. 87c). In several examples, the coronoid process, semi-lunar notch, and articular facets for the radius and humerus were reduced by scraping, grinding, or a combination of both. The majority of ulna awls from Point of Pines, however, were modified only at the

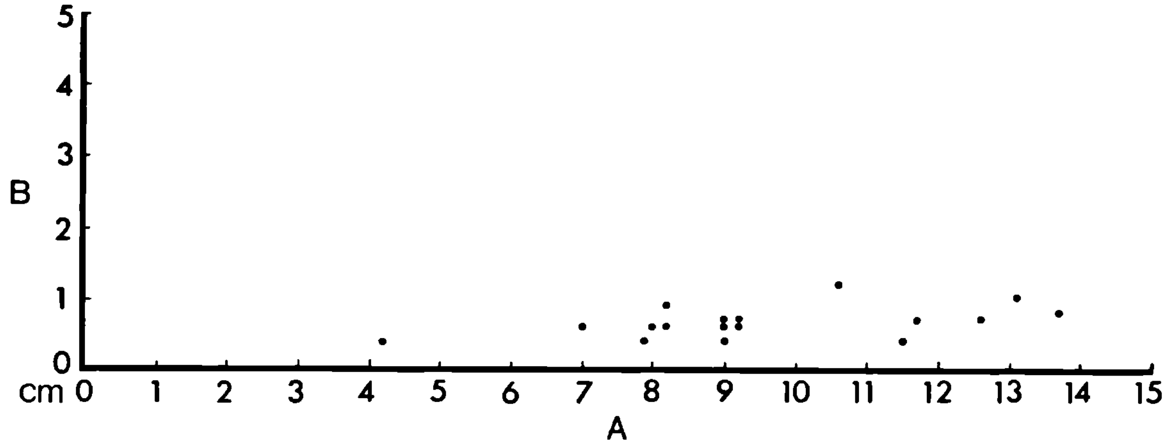


Fig. 84 Scatter diagram 1: gross dimensions for Point of Pines needles and pins.

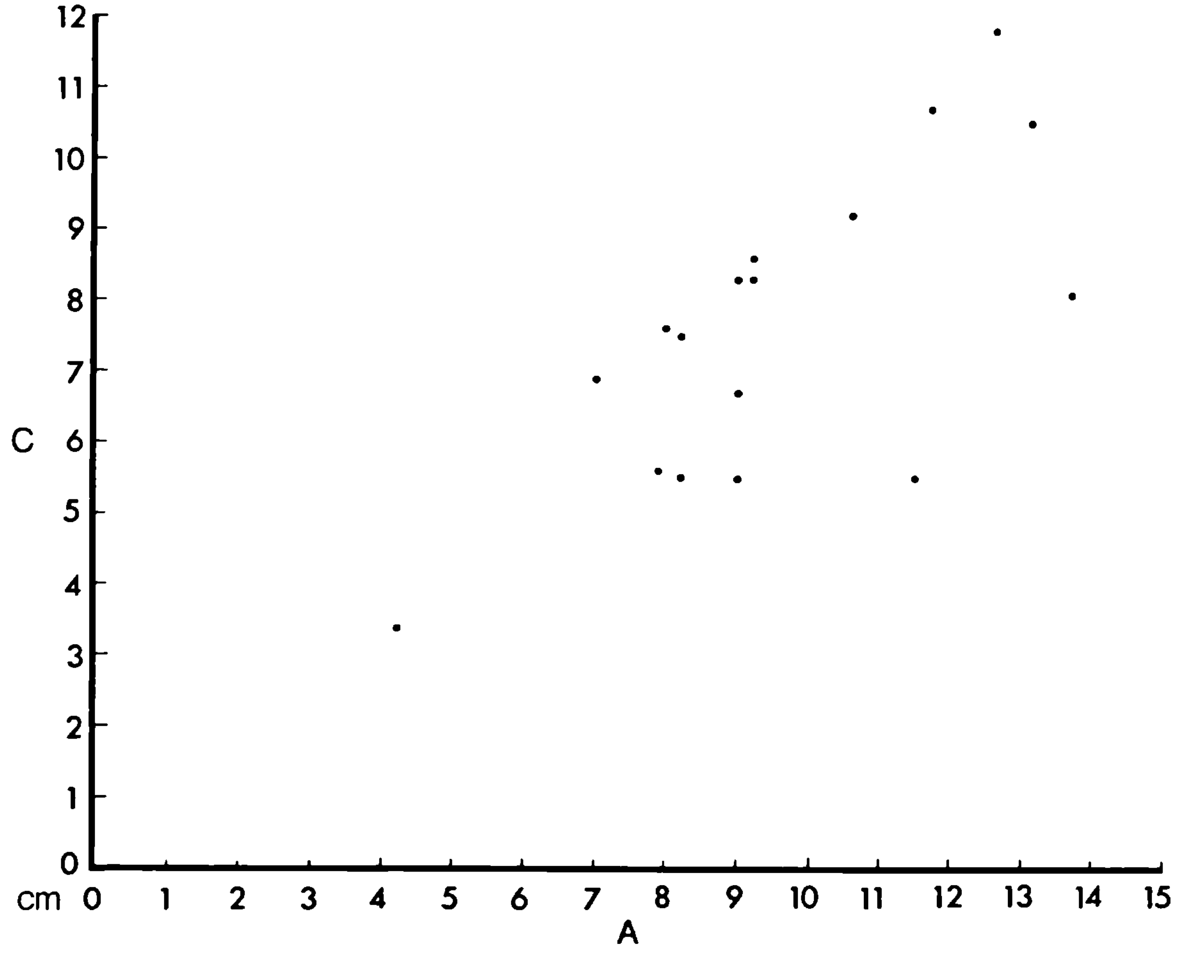


Fig. 85 Scatter diagram 2: location of maximum width on the shaft for Point of Pines needles and pins.

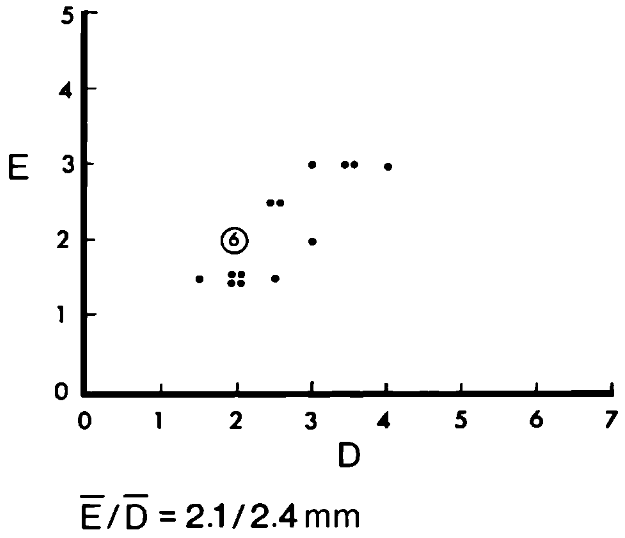


Fig. 86 Scatter diagram 3: tip dimensions for Point of Pines needles and pins.

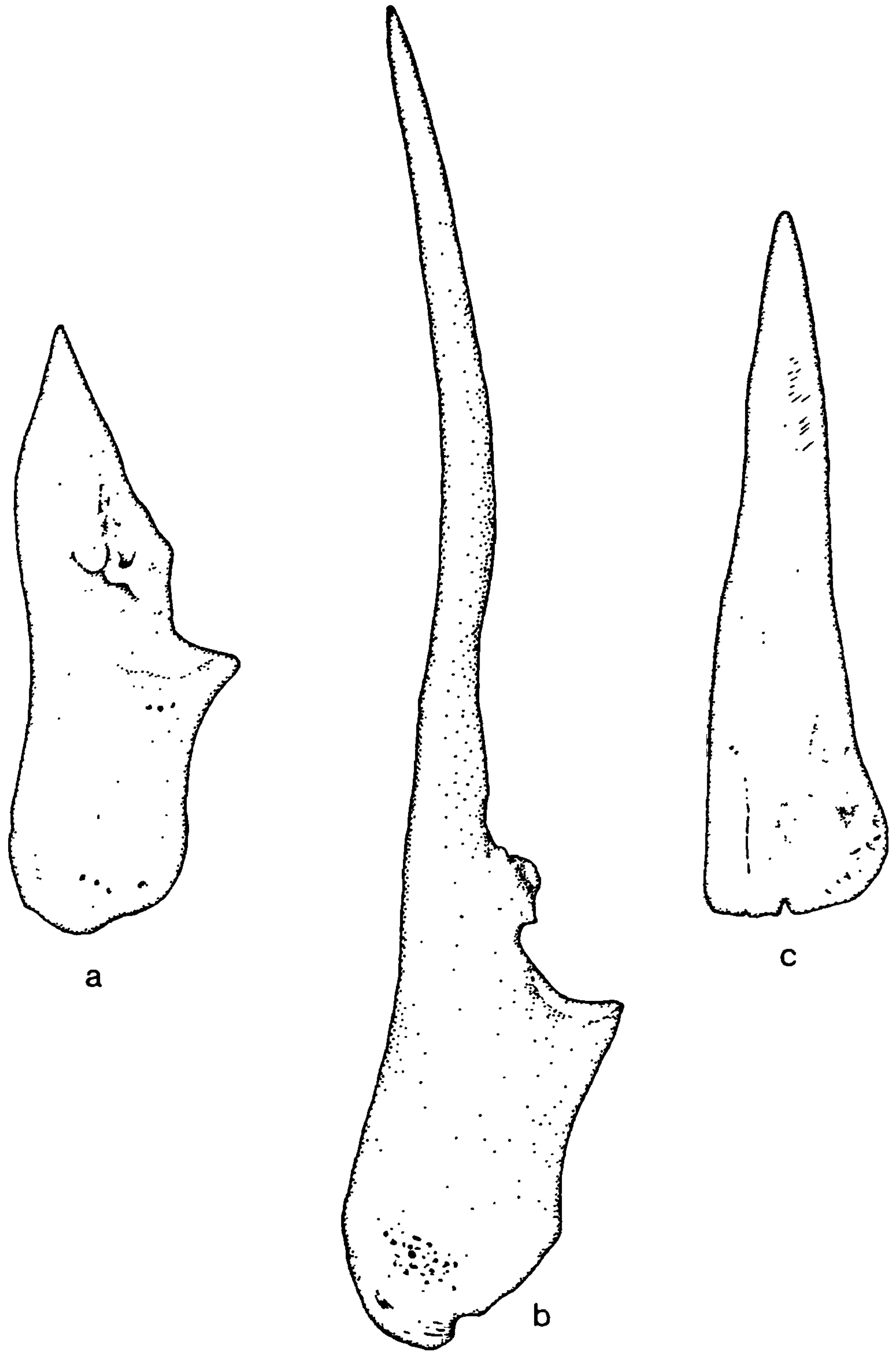


Fig. 87 a. ulna implement with typical awl tip and no modification to the base, b. ulna implement with long, flat blade and no modification to the base, c. ulna implement with long, flat blade, olecranon removed, and articular surface ground. Scale 1:1.

distal end (Fig. 87a,b). There is a wide range of variation in the total lengths of ulna awls, but the maximum width is very uniform because it conforms to the size of the proximal articulation (Fig 88). The location of the maximum width is generally well below the basal end (Fig. 89) because the articular surface is positioned inferior to the narrower olecranon process. The tips range from sizes typical of most awls with round, narrow cross-sections to broad, lenticular shapes (Fig. 90). Wear patterns and the shift from long blades with lenticular tips to short shafts and round tips suggest that some recycling may have been practiced. All of the specimens possess a polish along both edges of the shaft from the tip to the proximal articulation that appears to be caused by use. Very fine, microscopic striae running longitudinally near the edge demonstrate the direction of movement which formed the polish (Fig. 91). There is also handling polish on the olecranon process and in a concentrated area around the semi-lunar notch on both sides. This is apparently where the tool was gripped between the thumb and other fingers.

Those ulnae with flat, lenticular blades display little increase in polish at the tip, but those with a short shaft and a tip that is round in cross-section also have a well-developed polish all around the tip. Specimens with long shafts and lenticular tips and those with short shafts and round tips possess polish along both edges. It is hypothesized that the long implements initially served one function and as they were resharpened and mended they were recycled by converting them into

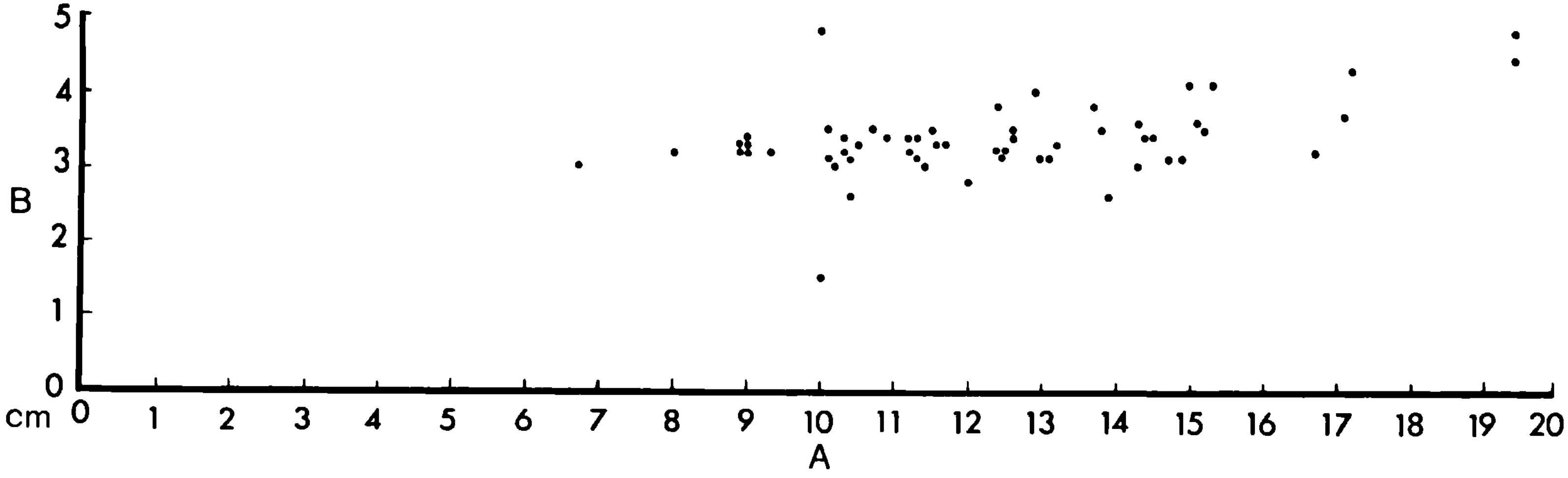


Fig. 88 Scatter diagram 1: gross dimensions for Point of Pines ulna implements.

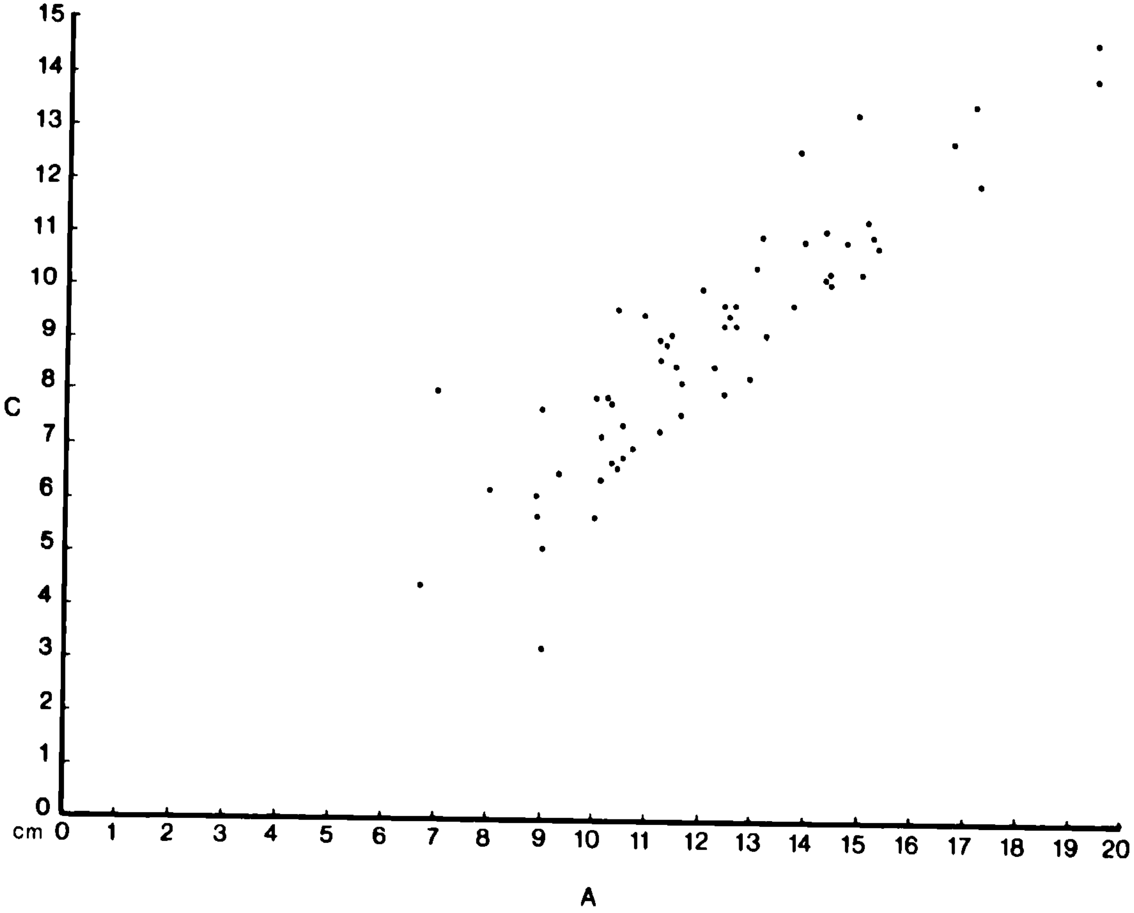


Fig. 89 Scatter diagram 2: location of maximum width on the shaft for Point of Pines ulna implements.

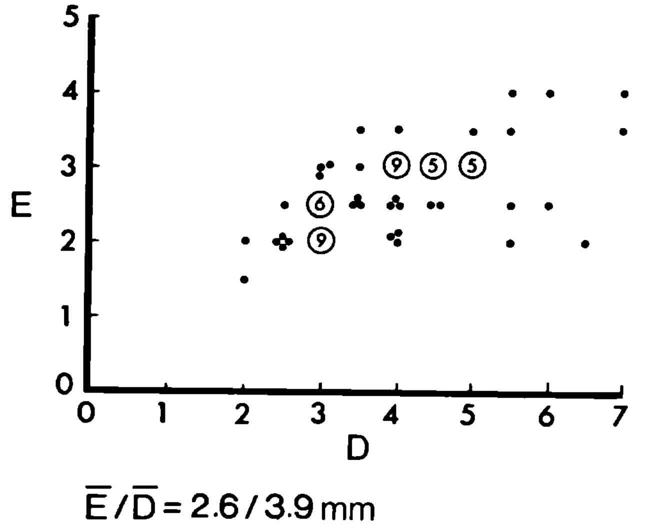


Fig. 90 Scatter diagram 3: tip dimensions for Point of Pines ulna implements.

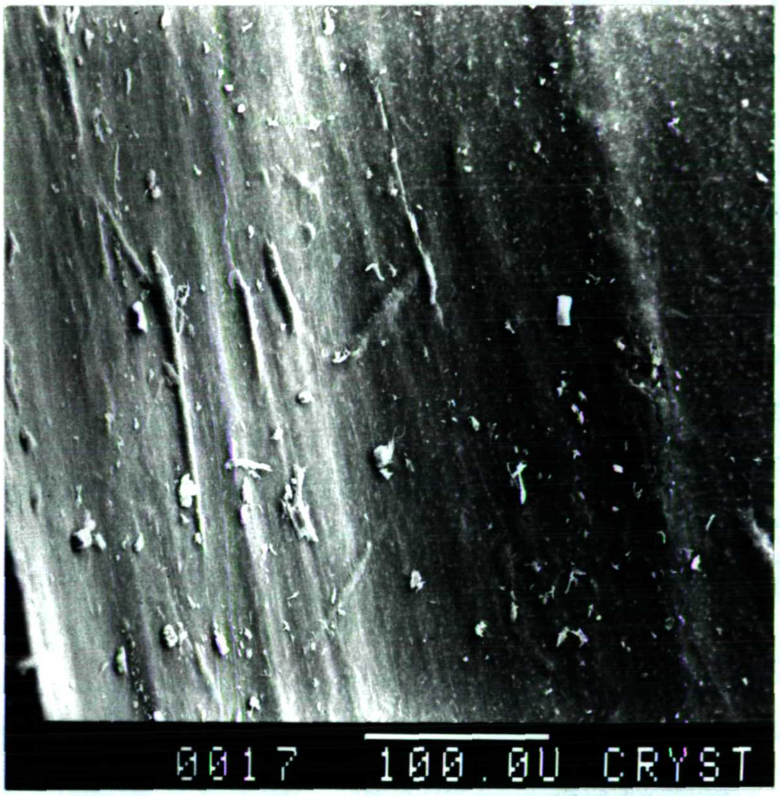


Fig. 91 Edge of the blade of an ulna implement showing probable use wear in the form of a polished surface and longitudinal striae (silicone rubber mold) (200X).

basketry or hide piercing awls. The function performed by long ulna tools cannot be ascertained with complete confidence, but it is clear from the distribution of polish and striae along both edges and the presence of broad, flat tips that they were not conventional piercing tools. One possible function suggested by the use wear is a specific kind of weaving tool. Weavers using a backstrap loom or a primitive type of loom without a heddle or shed rod have been known to use a pointed, flattened implement (Bird 1977: 121). This tool fulfilled three functions: picking up alternative wefts, opening a section of shed when turned on edge, and beating the weft in place. The combination of these strokes would explain the morphology of the archaeological specimens and friction between both edges of the tool and the warp threads as it slipped between them might create the appropriate use wear. If a backstrap loom was used, then the textile would be narrow enough for a bone to work as a shedding tool since the warp can be opened in successive sections for insertion of the weft (Bird 1977: 125). Sticks projecting from the floor of Red Bow Cliff Dwelling, just south of Point of Pines, have been interpreted as stakes for a loom (Gifford 1980: 18). The backstrap loom seems to have spread into the Southwest from Mexico, possibly with the diffusion of cotton, ca. AD 700, but the exact date of its arrival is not known since evidence is rarely preserved (King 1977: 129). In ethnographic examples it has been used chiefly for belt-weaving, but it could also be useful in making straps, loin cloths, or wider garments by sewing strips together.

This hypothesized function of ulna awls expresses only one possibility, and there may be other explanations for their use that are also in accordance with the polish along the edges of the tools. Polishes remain very difficult to interpret in terms of identifying the material upon which the bone implement was used. The distribution of the polish and the directionality of the fine striae are important, however, in recreating the movement of these tools.

Context is of no particular assistance in determining function of the ulna tools. They appeared in the fill of rooms, kivas, and open areas throughout the site. Only one was associated with a cremation. The ulna tool, found outside of the cremation vessel, was charred suggesting that it was related to the burial, rather than merely being incorporated with the fill around it. Some rooms, such as Rooms 25, 72, 82, 86, and Room 5 of W:10:50 B, contained four or more ulna tools, but there is no evidence for work areas or associations with other types of materials. Usually the rooms that yielded numerous ulna tools were equally rich in a variety of bone and other types of artifacts.

Ulna implements are among the most common types of bone artifacts in the Mogollon-Pueblo culture and distribution of wear polish is highly standardized on these tools. In the case of those from Point of Pines there is evidence to suggest that some were recycled into awls. Ulnae of ruminants have been selected by peoples throughout the Southwest and elsewhere as raw material for awls, weaving tools, flakers, or other pointed tools because manufacturing is facilitated by the natural morphology of the distal diaphysis.

Spindle Whorl

A single disc cut from a right scapula of a ruminant has been classified as a spindle whorl. The disc was probably made by incising a circular groove in the thin blade of a scapula and snapping it out. Perhaps because it is a difficult task to perform with accuracy, the whorl is not a perfect circle. Grinding was used to finish the outer margin, and a small perforation was drilled in the center.

The spindle whorl's morphology closely resembles ethnographic examples made of wood used in the Southwest and northern Mexico, such as those of the Tarahumara of Sonora. The function of a spindle whorl is to provide momentum to the spindle as the spinner dangles and twirls it to draw out the fibers he or she is spinning. The presence of a spindle whorl on the site implies that the occupants of Point of P nes were textile weavers. This is further substantiated by bits of cloth which have been preserved in some of the burned rooms. Raw cotton, bolls, seeds, and plant stems were abundant in the nearby Red Bow Cliff Dwelling (Gifford 1980: 202). Wooden spindle whorls and spindle shafts have also been found there (Gifford 1980: 90), and bone whorls are reported from Az W:10:51 (Wendorf 1950: 81), Canyon Creek ruin (Haury 1934: 88-89), Table Rock Pueblo (Martin and Rinaldo 1960: 277-278), and Hawikuh (Hodge 1920: 144).

Miscellaneous Bone Discs

A variety of flat, circular bone objects of uncertain function were produced from the excavations at Point of Pines. Three were made from long bones of large mammals and were thick in cross-section. Their diameters were 1.4, 1.8. and 1.8 cm and their edges were carefully smoothed and rounded with an abrader. One of the larger discs had a flat back with an "X" incised on its surface and a domed, highly polished front (Fig. 92a).

Four discs made from large mammal scapulae resembled the spindle whorl except for their smaller diameters and lack of a center perforation. One disc, measuring 4.1 cm across, was painted red on one surface. Other discs ranged from 1.4 to 5.3 cm in diameter.

Unperforated discs appear sporadically in Southwestern sites, but usually in very low numbers. They have been reported at Grasshopper (S. Olsen 1979: 364), Carter Ranch (Martin, et al. 1964: 101), and Hawikuh (Hodge 1920: 147-148). It is tempting to refer to them as pendant blanks, and there is no reason why this may not be appropriate for some of those made from scapulae. Others, however, are more difficult to assign a function to because they are rather large, are painted, polished, or incised on one side, or otherwise give the impression of being finished, functional artifacts. One possibility for some is that they were used as gaming pieces. The highly polished, domed disc from Point of Pines is the most likely candidate for a gaming piece. A concavo-convex disc made on a long bone and a flat scapular disc of equal diameter were collected from the floor of Kiva

Fig. 92 a. domed, polished disc with "X" incised on reverse, b. drilled pendant or clothing ornament made on a ruminant scapula, c. frog or toad fetish, d. pendant or clothing ornament made from a ruminant scapula, e. lizard pendant made on a ruminant scapula, f. silhouette of a bird with spread wings, g. antler pendant carved to resemble a large claw. Scale 1:1.

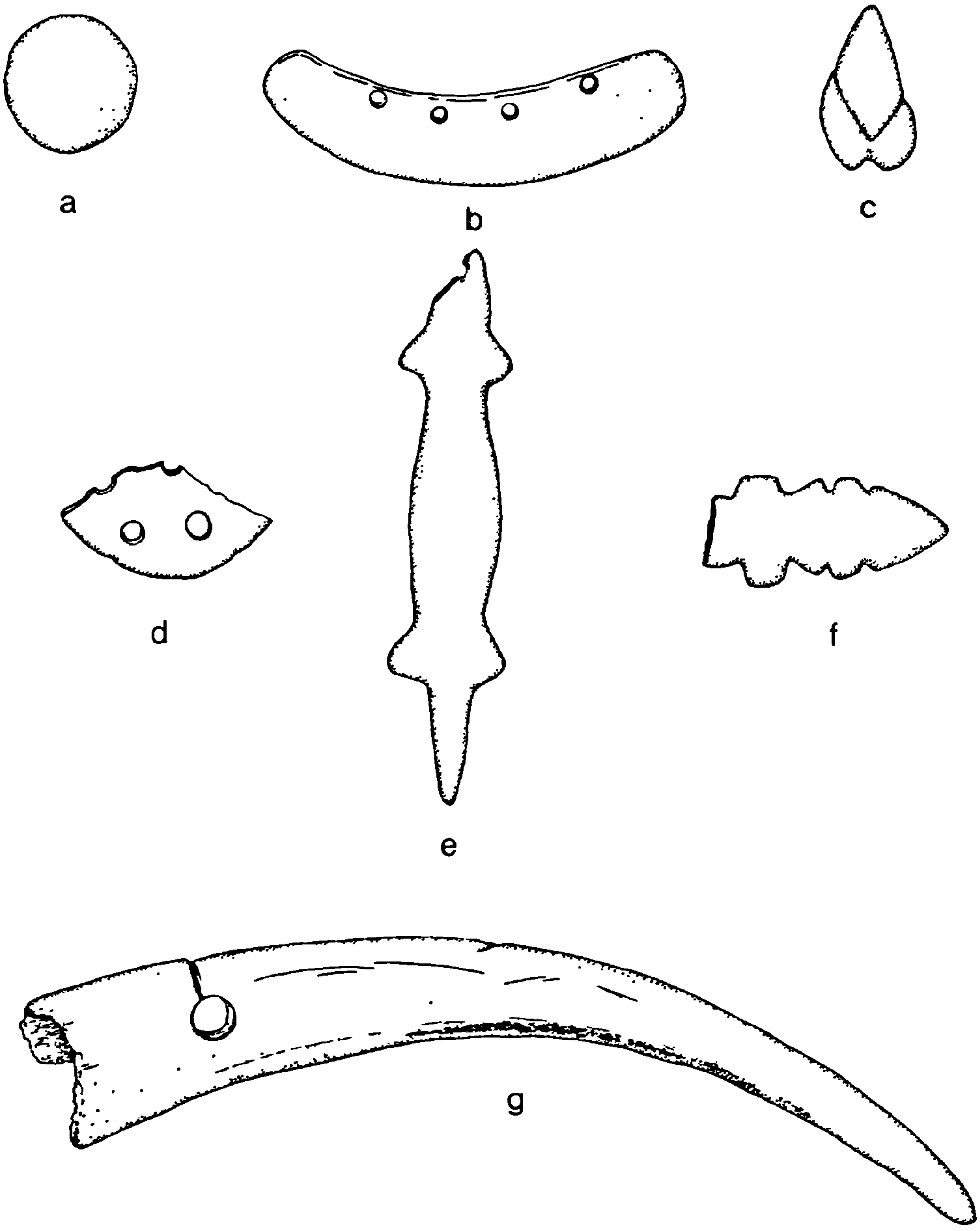


Fig. 92

2. The others were scattered about in secondary refuse.

Zoomorphic Fetish

There are several examples of zoomorphic motifs incorporated in hairpins and pendants from Point of Pines and other Mogollon-Pueblo sites, but the use of bone as a material for carving fetishes appears to be extremely unusual. At Kinishba a proximal phalanx of a ruminant was carved so that the proximal end resembled the head of a canid and the distal end that of a bighorn. The effigy from Point of Pines probably represents a frog or toad and measures just 2.3 cm in length (Fig. 92c). Animals carved in stone or molded in clay are plentiful in the Point of Pines area and elsewhere in the Mogollon-Pueblo region. The Zuni Indians still place great religious significance on animal fetishes as powerful symbols (Cushing 1974).

The tiny frog or toad was apparently made from an articular surface or some other part of a large mammal element where the cortical bone was substantially thickened. How it was originally roughed out is difficult to determine, but a triangle may have been removed from the whole bone by grooving and snapping. The surfaces were ground down to the proper form and a "V" was incised in the back to delineate between the torso and legs. Another V-shaped notch was cut from the point of the nose to the middle of the body to serve either as a gaping mouth or as the separation between the stomach and the feet.

The bone fetish was derived from Room 2 of W:10:50 B in secondary refuse that also contained another animal effigy (discarded by the excavators) and a human effigy.

Painted Bones

A small number of bones were decorated with paint. Pigments such as red and yellow ocher, hematite, turquoise, and other forms of cuprous ore were abundant in many locations in the site. Black paint was probably carbon-based, although manganese dioxide may have been used occasionally. The most common type of painted bones at Point of Pines were mandibles of ruminants. Two immature deer mandibles (Odocoileus sp. indet.), from different areas of the site were painted with vertical stripes of black, yellow, and red along their horizontal ramus. One area outside the rooms produced a cranium and matching mandibles from a young, male mule deer (Odocoileus hemionus), two other deer mandibles, and a right maxilla of a pronghorn (Antilocapra americana). The deer skull is represented by two antler beams, the right premaxilla, two fragments of the right maxilla, the left temporal, the left mandible, part of the right mandible, and several small fragments (Fig. 93). From the parts that are represented it appears that the whole skull was covered with red paint. Vertical black stripes were applied below the orbits on the maxillae and continued down to the inferior margin of the lateral surface of the mandibles. The medial surfaces of the mandibles were not painted in any of the examples. The accompanying two deer mandibles and pronghorn maxilla were dabbed with red paint. Other than the application of paint to the outer surfaces, all of these elements were unmodified. Their function was probably ceremonial rather than practical.

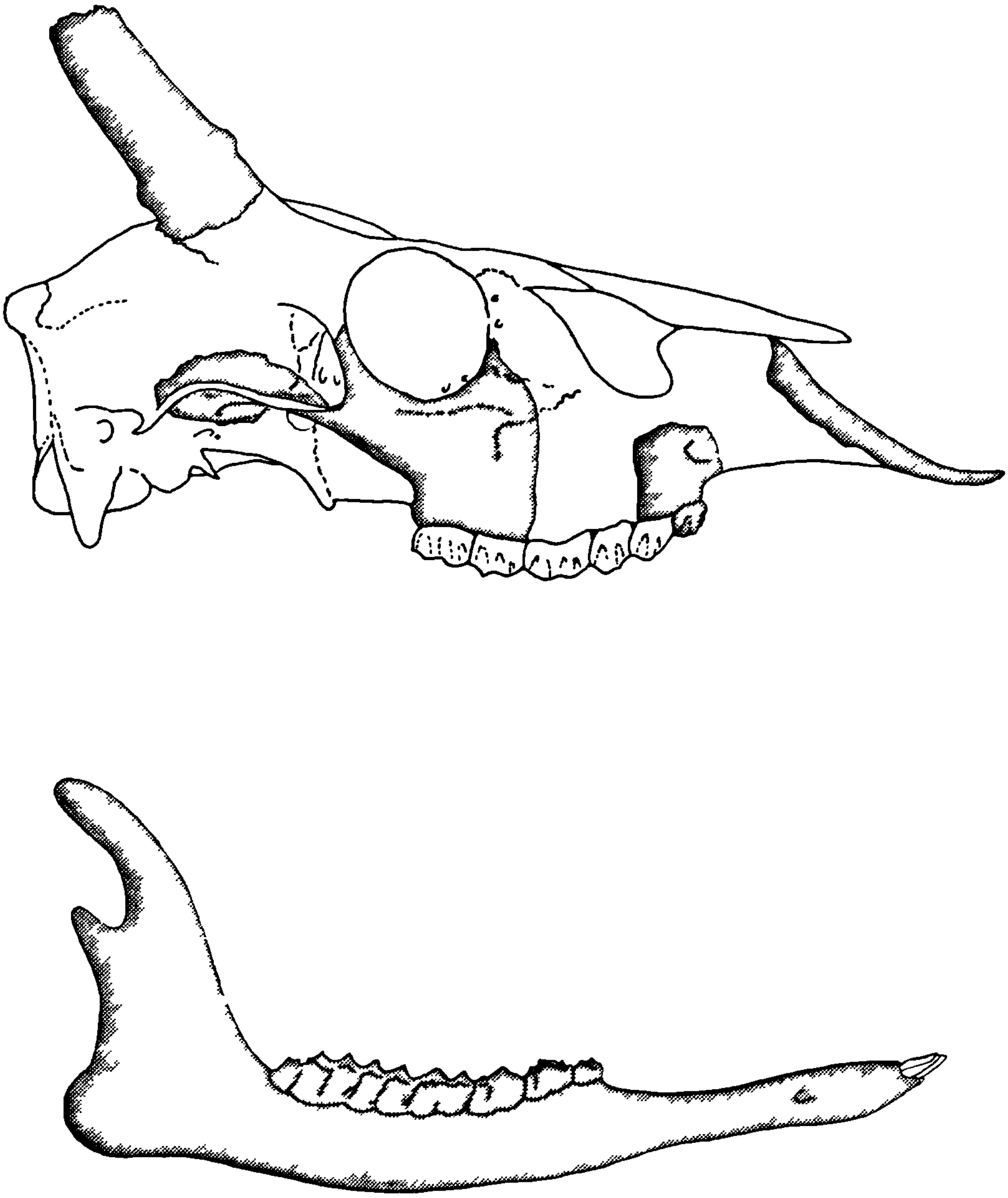


Fig. 93 Painted cranium and mandibles of young mule deer showing areas preserved. The whole skull was apparently painted with red ocher and vertical black stripes.

Limited experimentation was conducted to test the methods of mixing and applying paint to bone. Red and yellow ocher powders were made by rubbing solid pieces on a slab of sandstone. This action created abrading facets on the pieces of pigment like those seen on many samples collected at Point of Pines. Each pigment was then mixed with egg, which served as the binding medium. The paint was spread on a modern, clean bone surface with a frayed yucca leaf and allowed to dry in the sun. Within 15 minutes the paint had hardened so that it did not smear when touched. Egg was chosen to mix with the pigment because the presence of domestic turkeys in the pueblo would have given the people access to eggs and because eggs provide an excellent binding medium. When ground pigment was mixed with plain water and applied to bone the individual grains separated and spread thinly over the surface. Upon drying, the pigment lacking a binding medium brushed off at first touch. In order for the painted bones to have maintained their coloration and distinct polychrome designs for 600 to 800 years a binding medium must have been mixed with the pigment. Today the prehistoric paint is water soluble, but does not brush off with handling.

The practice of painting bones is widespread in the Southwest, but the number of individual specimens retrieved at any given site is usually quite low. A survey of literature shows that painted bones have been found in northern Arizona at Fitzmaurice ruin (Barnett 1973: 58) and Winona and Ridge ruins (McGregor 1941: 233). In the

Hohokam area of southern Arizona painted bones were collected from Ventana Cave (Haury 1975: 383) and Snaketown (Gladwin, *et al.* 1937: 155). Mogollon-Pueblo sites in Arizona yielding painted bones include Broken K (Martin, Longacre, and Hill 1967: 115), Grasshopper, Kinishba (Baldwin 1939: 322; S. Olsen 1980: 153-154), and the two small sites of Tule Tubs Cave and Pine Flat Cave in the Point of Pines area (Gifford 1980: 129-131, 176). The protohistoric to historic villages of Hawikuh (Hodge 1920: 141-142) and Gran Quivira (Hayes, Young, and Warren 1981: 156) in New Mexico also produced painted bone. Both within and among sites the taxa and elements varied considerably, but the most frequently selected were mandibles and scapulae of deer or other ruminants.

Traditions described by ethnographers for the Zuni and Hopi Indians may elucidate the ceremonial significance of painted bones in prehistoric times for the Mogollon-Pueblo people. The Hopi painted the bones of deer, pronghorns, and bighorns with red ocher, sprinkled them with corn meal, and arranged them in a shrine (Beaglehole 1936: 8). The skull was decorated along the jaws, rostrum, and eye sockets, while long bones were streaked longitudinally. This description of a shrine is remarkably similar to the cluster of cranial and mandibular fragments found at Point of Pines. The Zuni Indians of New Mexico displayed respect for the first kill of an adolescent hunter by painting one of its bones with red and/or black paint (Hodge 1920: 141). Either or both of these customs may have descended from the prehistoric tradition.

Paint Container

A unique artifact identified as a paint container was found in Room 91 fill. The element from which it was manufactured, a synsacrum of a turkey, was rarely utilized in artifact production. Two similarly modified turkey synsacra were found at Mound 7 of Gran Quivira, New Mexico (Hayes, Young, and Warren 1981: 156). In making the container the transverse processes and neural arch were removed from the centra of the fused lumbar and sacral vertebrae (Fig. 94). Some abrading was then done to smooth the edges of the artifact. The natural morphology of the neural canal which was then exposed formed an elongated basin. This depression was filled with a cake of ground hematite, presumably made solid by some form of binding medium. Because the cake had been molded by the shape of the bone and had shrunk away from the sides of the container, it is likely that the paint was in a paste or liquid form when it was placed in the container.

Pendants

Twelve pendants were collected at Point of Pines. Eight were cut from large mammal scapulae, one from a long bone, one from an indeterminate flat bone, one from an antler tine, and two from ungual phalanges. Of those made from scapulae one was rectangular with a small hole drilled at one on the narrow ends. Another was crescentic with rounded corners and was drilled four times along the concave edge (Fig. 92b). A fragmentary round disc cut from a scapula was drilled at least four times and

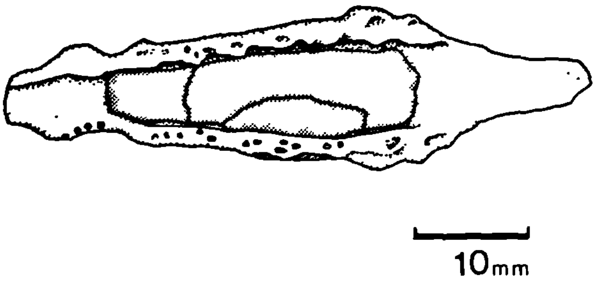


Fig. 94 Paint container made from the synsacrum of a turkey with cake of ground hematite in place.

possibly more (Fig. 92d). This resembles a bone "patch" from the nearby site of Tule Tubs Cave (Gifford 1980: 130-131) and may have been attached to clothing for decoration. A pendant with a stylized representation of the silhouette of a lizard was drilled for suspension through the head (Fig. 92e). Pendants of similar morphology of stone, shell, and bone have been found at Tonto ruin, Tuzigoot, Carter Ranch, Ridge ruin, Winona, Montezuma's Castle, Starkweather ruin, Cameron Creek, and other sites (Jernigan 1978). A Haliotis shell pendant from Point of Pines is also shaped like a lizard. Other pendants made on scapulae included an elongated, tapered one, a cross and a drilled scapular spine. A broken pendant made on a flat bone of a large mammal probably represents the silhouette of a bird with spread wings (Fig. 92f).

The manner in which these pendants were manufactured is difficult to determine with certainty because there are no unfinished pieces or debitage. Those made on scapulae were probably first outlined in the bone by incising and then snapped out. The final product was finished around the edges with an abrader. Drilling was unidirectional since the bone was very thin.

The ungual phalanges of a bear and an eagle were each drilled near the proximal end for suspension. The bear claw was collected from Cremation 186, but was unburned. An interesting pendant which could be classified as a "pseudomorph" was made from an antler tine carved to resemble an enormous claw (Fig. 92g). The artisan took advantage of the naturally curved tine and carved a shoulder near the base to resemble the bony sheath at the proximal end of an ungual phalanx of a carnivore. The base was then drilled biconically for suspension.

Rings

Rings are quite plentiful at Point of Pines ruin. In this case debitage is available which clearly delineates the stages of manufacture. In the sites in the Point of Pines region a pattern for fabricating bone rings differs from the method prominently used in other Mogollon-Pueblo areas. The initial step in preparing a long bone (nearly always a femur) in the Point of Pines area usually involved chopping off both articular ends. This step is not necessary to make rings and is only occasionally found in collections from New Mexico or the Mogollon Rim area to the north. At such sites as Grasshopper, Kinishba, Foote Canyon Pueblo, and Broken K Pueblo in Arizona and Hawikuh in New Mexico most of the ring stock retained the condyles. Not only does the removal of the condyles require extra labor, it also risks cracking the diaphysis. If there is a need for maximizing the nutritional yield of a carcass, then labor intensive tasks such as marrow extraction and production of bone grease may be implemented. By removing both ends, the marrow can be neatly cleaned out of the medullary cavity with a stick while fresh. The cancellous tissue of the condyles can then be utilized for bone grease. This preparatory step also allows the craftsperson to defer ring-making to a later time, since the cleaned out tubes can be stored without spoilage of the marrow. At Point of Pines, in fact, there is a large quantity of tubes produced by hacking off both condyles. Some exhibit light scratches made when just beginning annular grooving in the manufacture of rings. For some reason the work was never completed on these specimens and the tubes were probably stored away for future production. The chopping inflicts irregular compression fractures and chipping that cause the raw edge to look "nibbled". These ends never display any further modification such as grinding that would indicate the tubes were finished artifacts.

The manufacturing debris provides very complete information about the stages of manufacture that followed. After the ends were removed, the femoral diaphysis was often scraped longitudinally. This may have been done primarily to remove the periosteum, since the middle portion of the diaphysis is relatively smooth with the exception of the *linea aspera* on the posterior surface. Annular scoring was then done in one or more places along the shaft. Sometimes the artisan carefully scratched out the ring segments, marking where each groove was to be placed. There is a range of variation in the number of ring segments on each femur from as few as one to as many as five (Fig. 95a). No shortage of raw material was apparent, since ring stock was rarely exploited to its full potential. Rings from the central third of the diaphysis are more round in cross-section and less affected by the muscle ridges and the distal epicondylar fossae. For this reason, rings from the central part of

Fig. 95 a. ring stock made on a ruminant femur, b. ring made on a femur with no grinding or finishing, c. ring which has been ground until smooth and polished, d-f. tubes made from avian long bones, g. tubular container made from turkey tibiotarsus. Scale 1:1.

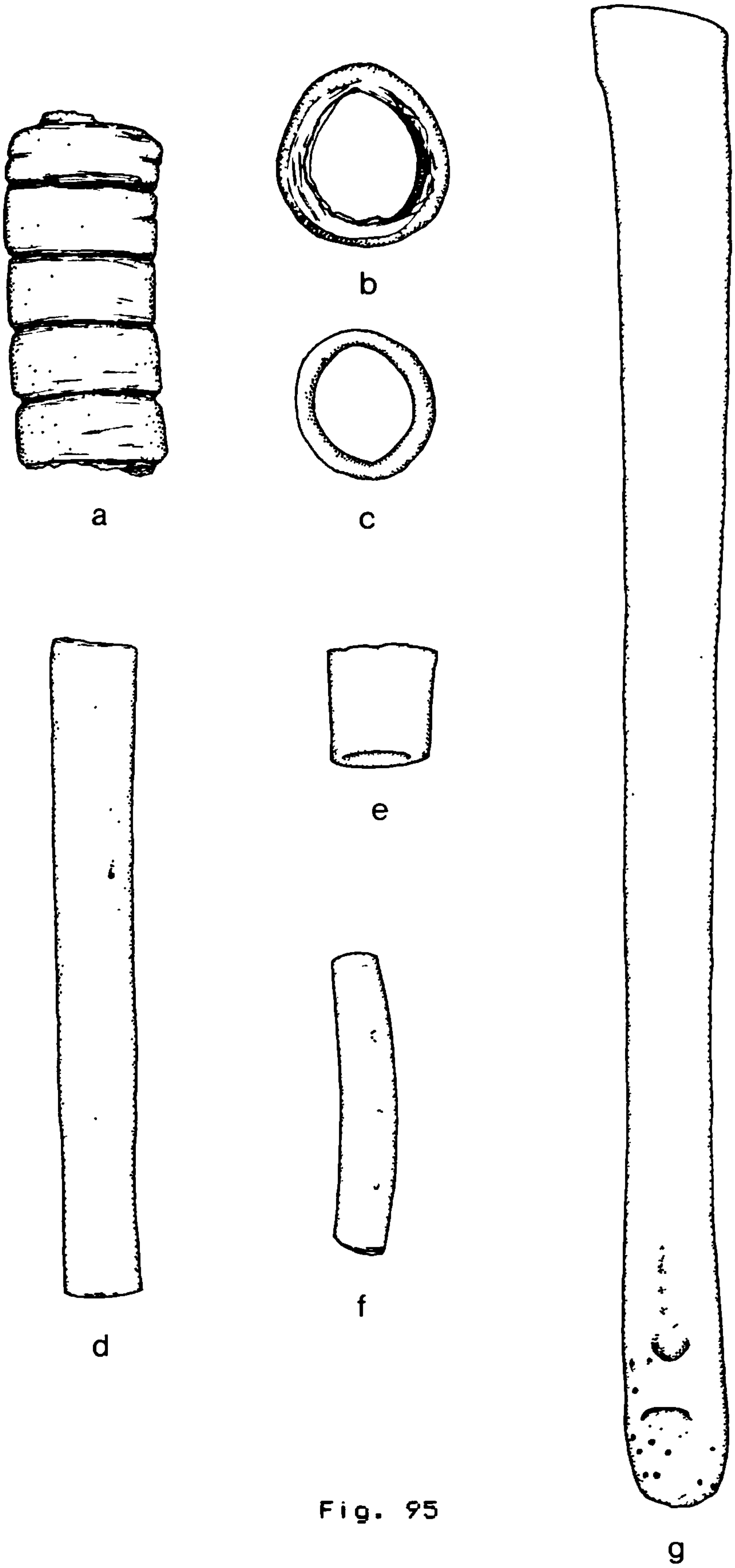


Fig. 95

the femur were better designed for wearing on the fingers.

After one groove was snapped the rough edge was ground smooth on an abrader. A second groove, placed about 1 cm down from the first was then snapped. The newly produced rough edges of the ring and the ring stock were then also ground smooth, and so on. Rings were often smoothed on the inner and outer surfaces as well as the ends. An abrader sufficed for grinding down the ridge of the linea aspera on the posterior surface of the femur, but smoothing and sizing of the inner surface was more complex. The best produced rings were probably finished by rubbing with loose grit on a flexible backing such as leather. Microwear evidence of this technique consists of very fine striations going around the inside of the ring. Another less refined method involved abrading vertically on the inner surface of the ring. Because the abrader was rigid and not usually rounded, flat facets were worn around the inner surface of the ring. This made the ring uneven in thickness. Abrasion striations formed by the sandstone run transversely and are zigzagged from the reciprocal motion of the abrader. The third and least common method for thinning and smoothing the walls of a ring involves reaming it with a chert tool. Microwear indicating the application of this technique consists of scraping striae running around the inner surface. The amount of smoothing on the external surface varied from no modification (Fig. 95b), through abrading of the muscle ridges, to polishing the whole surface (Fig. 95c). Well-worn rings are polished inside and out, but this is often difficult to distinguish from intentional polish.

The silhouette of the ring viewed from the end is often a clue as to the element utilized. Femora, the traditionally exploited elements, have a tear-drop outline with the linea aspera forming a narrow protuberance at the top.

Only a very small number of rings were decorated in any way. One ring fragment was drilled, either so that it could be mended or to be worn as a pendant. A triangular pattern was incised on one delicate ring and another had a line incised around it. Ornamentation was apparently done after the ring had been ground smooth, but before the final polish was applied.

Polish from wearing is visible on the inner surface and along the edges of rings. If a ring was worn for many years, all of the surfaces became polished and in some cases it wore very thin in places. In the early stages handling polish can be distinguished from intentional manufacturing polish by its distribution, which is unevenly dispersed over the external surface.

Some of the rooms at Point of Pines exhibited unusually high proportions of ring stock, debitage, and rings. In most cases the ring manufacturing debris was not concentrated in one area or in situ on a floor suggesting primary deposition. It may be only accidental that the trash filling these rooms contained more ring-making materials than appeared in secondary refuse of other rooms, however, it might also imply that the activity *loci* for fabrication of rings were located in close proximity to the abandoned rooms into which the debitage was discarded. Rooms 62, 93, 99, and 110 were especially prolific in evidence of ring-making. Room 62 contained fourteen pieces of ring stock and five completed rings distributed within Levels I-III and Floor I (Level IV). Room 110 was exceptional in producing 23 examples of manufacturing debitage and two rings from Levels I and II.

It is from the burials that the most complete and accurate information about the wearing of ornaments is derived. This is especially true of rings, which may be worn on the fingers or strung as beads on necklaces and bracelets (S. Olsen 1979: 359-360). Few rings from Point of Pines were recorded to be in place on skeletons. Those that were *in situ* were all worn on fingers. Burial 69, that of a small infant, contained three bone rings made from the same dog or coyote femur. Two were still on the second and third digits of the left hand, while the third was found under the right hand. Another infant, Burial 80, was wearing a ring on the right hand. Two adult males (Burials 63 and 261) were apparently wearing rings on their hands, as well. Several cremations produced charred rings that were probably worn by the deceased at the time. Unlike the situation at Grasshopper ruin (S. Olsen 1979: 360), there is no indication that rings were strung on bracelets or that only children and females wore them. There also seems to be no preference for wearing them on the left or right hand or particular digits.

Bone Tubes

Tubular beads are quite plentiful in Mogollon-Pueblo bone artifact assemblages, and in this regard Point of Pines is no exception (95d,e,f). The stages of manufacture are identical to those for tubular whistles, except that the beads are rarely drilled. Manufacturing began with the removal of the articular condyles by annular grooving and snapping. If more than one bead was to be made from a single element, then further annular sectioning was done. The surfaces were scraped longitudinally and occasionally polished. The rough ends were also generally abraded to remove most of the traces of the groove-and-snap technique. If avian ulnae were selected, then the feather papillae were ground down with an abrader (Fig. 95f).

Derived from Pithouse 14 fill, and therefore probably older than the others, was a bead with longitudinal grooves along the shaft on one side. The smallest bead (1.2 cm in length), which came from Room 12 of W:10:50 B, was highly polished and incised. The design on this specimen consisted of three segments set off with annular scoring subdivided by short longitudinal lines. Jernigan (1978: 187) has noted that incising is less common on Mogollon tubular beads than on those from Hohokam sites.

Two tubes have a fine perforation drilled at one end on one surface only. The function of the hole is uncertain, but the tubes may have either been suspended from one end as components of rattles or sewn onto clothing.

The most frequently chosen elements for making bone tubes were the ulnae of large birds, such as eagles, turkeys, Canada geese, turkey vultures, and sandhill cranes. Radii, femora, tibiotarsii, and a tarsometatarsus were also utilized. One cottontail humerus and one dog or coyote femur were converted into tubular beads. Diameters varied depending on the taxon and element selected. Lengths ranged from 1.2 to 18.3 cm, with a mean length of 6.8 cm.

An important source of information, particularly regarding the taxa and elements chosen for making tubular whistles and beads, is the debitage remaining after the artifacts are made. Tube debitage consists of the articular condyles of either end of the hollow long bones used for tubes. They are recognizable by the annular grooving and snapping traces where the diaphysis has been severed. These were unfortunately absent from the Point of Pines collection, either because they were discarded in the field or because they were not sorted from the bulk faunal remains.

The only interesting occurrence of a bead in the archaeological context is a charred one from Cremation 209, which must have been worn at the time the body was cremated.

The identification of the function of bone tubes is not verifiable for every specimen. The smaller ones were most likely beads that were strung as necklaces or bracelets, but the larger ones may have one of many functions. Some of the tubes from the Zuni site of Hawikuh, New Mexico, were found arranged in rows about the wrists of male skeletons indicating that they were components of wristguards (Hodge 1920: 125-126). Other tubes in Hawikuh burials were positioned as necklace beads (Hodge 1920: 134). It has also been suggested that some of these objects served as drinking tubes in hide water bags or medicinal sucking tubes.

Cummings (1940: 63) noted the use of bone tubes as pigment containers at the site of Kinishba, Arizona. Three artifacts from Point of Pines may have functioned in this manner. A turkey ulna and a Canada goose radius found together in Room 94 fill each had one end removed and the edges of the opening ground smooth. The condyle at the other end remained intact, but in the case of the radius was ground down somewhat. A turkey tibiotarsus from Room 5 also had one end grooved and snapped off while the other articular condyle was ground smooth (Fig. 95g). Hollow long bones of large birds would have made excellent containers for powdered material, especially if only one end was open. Wooden or resin stoppers could have been used to seal the containers. No evidence of pigment or other contents was visible in any of the tubes, however. There is a possibility that these were merely unfinished tubular beads, but since two of the tubes have grinding done on the articular condyle it appears that there was no intention of removing that end. All three are quite long (12.5, 15.8, and 20.5 cm) and the grooved and snapped end has been ground in two cases.

Hairpins

Mogollon-Pueblo hairpins constitute some of the finest examples of stylistic expression and craftsmanship seen in prehistoric bonework in North America. The coordination of natural morphological features of the bone with a variety of design motifs, as well as the highly polished surfaces and finely incised ornamentation, demonstrate the ability of the makers of these artifacts.

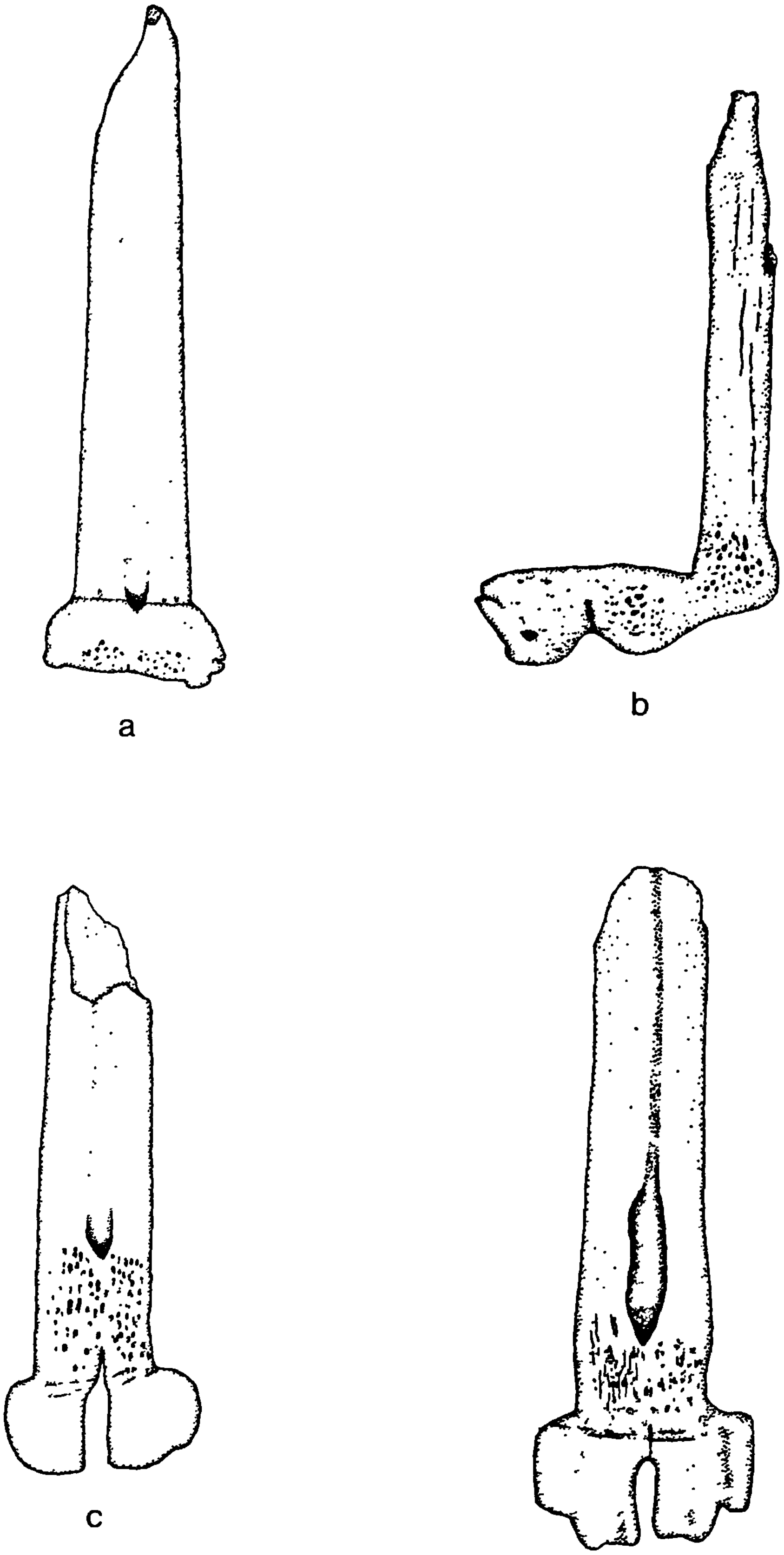
In the Mogollon area hairpins are of interest because of their association with adult males of some status and the fact that this trait is shared with the more southerly Hohokam culture. In the analysis of these artifacts in Southwestern sites their context in burials has provided significant evidence for their classification as hairpins and the sector of the population who wore them.

Hairpins appear with relatively high frequency at Point of Pines, since they number at least 188 and constitute nearly 15% of the total assemblage. Another 30 fragmentary specimens were categorized as either hairpins or awls. It is often difficult to distinguish between hairpins and awls, and this problem is especially acute when interpretation of field notes or even published descriptions is essential. No attempts were made by the author to segregate the two types for discarded material from Point of Pines since criteria such as tip measurements and microwear were not available. No single characteristic can be completely relied upon in defining hairpins or awls, partly because there is evidence to suggest that broken hairpins were recycled as awls. The absolute size and morphology of the tip appear to be the most reliable criteria, but even these traits may not be divided into two mutually exclusive groups.

A wide range of styles were manifest in the Point of Pines hairpins with certain motifs being associated with particular skeletal elements. Ruminant metapodials were the most commonly selected elements for hairpins. These were altered in three basic ways in making hairpins, just as the metapodial awls were.

When the whole distal condyle of a metapodial hairpin was retained, it was modified in a variety of artistic ways. Frequently the ridges and sides of the trochlea were ground down to smooth the surface of the base (Fig. 96c). In many cases the epicondylar region was ground or incised, exposing cancellous tissue and forming a constriction between the base and the shaft of the hairpin (Fig. 96c,d). The trochlear ridges were sometimes accentuated by incising grooves along their margins. Other means of altering the whole condyle included biconical drilling through it medio-laterally, undercutting the trochlear surface to form stylized mountain sheep horns, or cutting off the articular end completely. One unique specimen has had the distal condyle ground down to form a rounded cylindrical body of an animal with four tiny protuberances representing feet facing up and a pointed nose at one end (Fig. 96a). Metapodials from immature individuals in which the distal condyle was unfused were modified by grinding the metaphyseal region smooth or incising it in some manner after the epiphysis was removed. In some cases the epiphysis was left in place and was found loosely associated with the shaft. Each piece differs in minute detail and it would be difficult to

Fig. 96 a. hairpin made on a mule deer metatarsal with the distal condyle carved to resemble an animal, b. hairpin made on a ruminant radius with the proximal end carved to resemble an animal, c-d. hairpins made on mule deer metatarsals with the whole condyle retained and modified by grinding and scraping. Scale 1:1.



a

b

c

d

Fig. 96

describe the vast array of designs employing the whole distal condyle.

The second type of metapodial hairpin was made by grooving and snapping through the bone sagittally so that one half of the distal condyle remained attached to half of the diaphysis and the other half condyle was attached to the other part of the diaphysis (Fig. 97a). The benefit of this manufacturing technique is obvious: two hairpins can be produced from each metapodial. With four metapodials in each ruminant, a total of eight hairpins or awls could be made from one animal. Another advantage could be the reduction in weight, which might have been important for keeping the hairpins in place. The "half-condyle" hairpins were styled in ways similar to those used for the "whole-condyle" hairpins, i.e. grinding, incising, and drilling. One unusual example was grooved and snapped medio-laterally rather than sagittally and was modified so that the distal condyle was cut out to form two sweeping arcs resembling mountain sheep horns (Fig. 97b).

The third and least common type of metapodial hairpin was split sagittally, but retained part of the flat proximal articular surface as the base. These were simple in form with an abraded, squared-off base, sometimes perforated through the epicondylar region.

The tibiae of ruminants were frequently chosen for hairpin manufacture and were modified in a number of manners. The proximal end usually served as the base. A stepped motif utilizing the flaring, slightly convex, medial surface of the anterior crest was extremely common

Fig. 97 a. hairpin made on a ruminant metapodial retaining half of the distal condyle as the base, b. hairpin made on a ruminant metapodial with the distal condyle carved to resemble mountain sheep horns, c. plain-based hairpin with two perforations in the base. Scale 1:1.

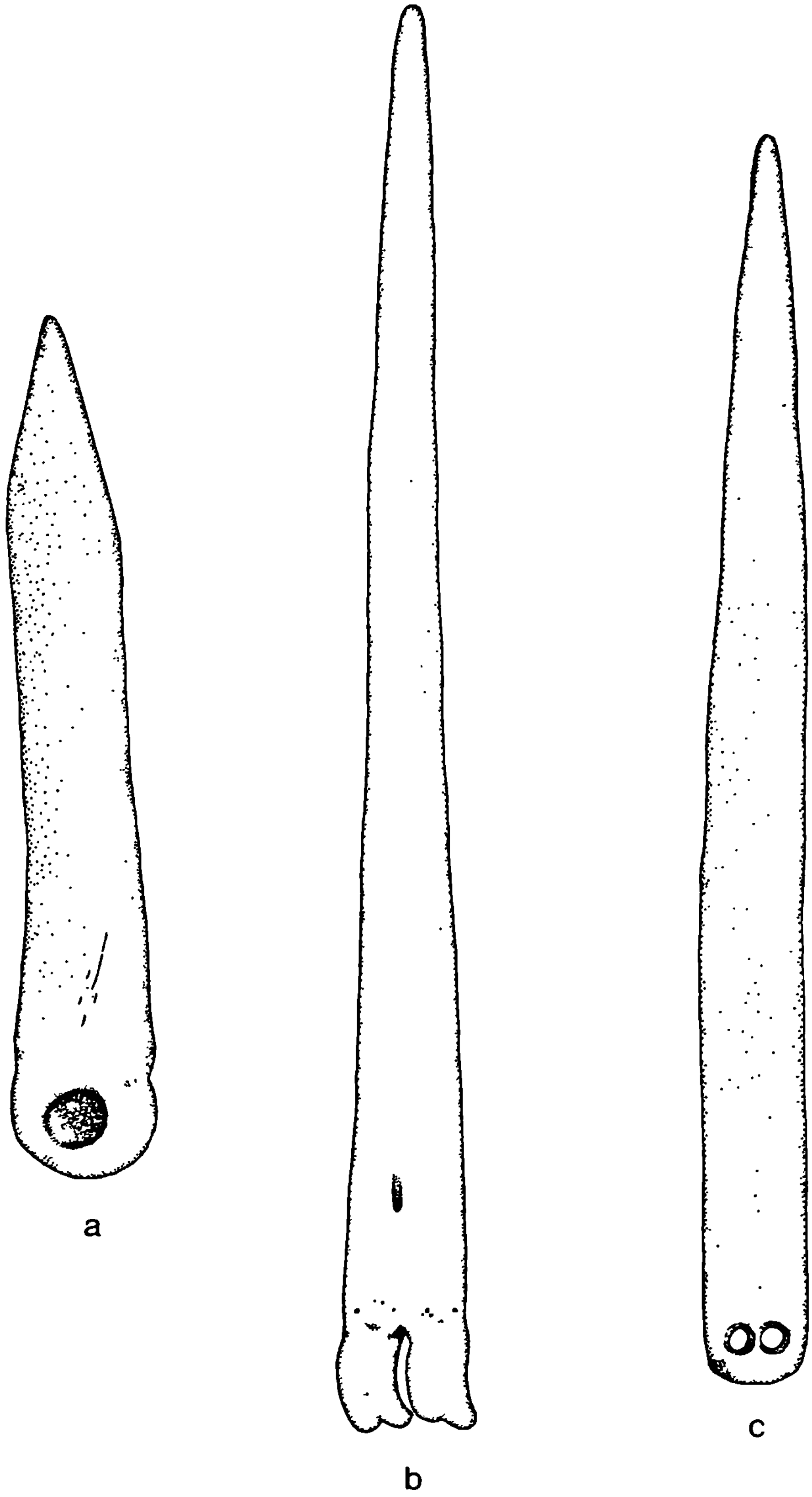


Fig. 97

in the Point of Pines region (Fig. 98c). The broad base, coupled with a very long diaphysis provided the artisan with raw material for a dramatic ornament.

An example of an unfinished tibia hairpin yielded information about how these artifacts were made. The partially completed piece was bisected longitudinally and the proximal and distal articular ends were removed by the groove and snap technique. Following this, as another specimen shows, the step motif was scratched out on the external surface of the anterior crest. The transverse and longitudinal edges of the stepped margin were made by grooving, but the inner corners, which are difficult to cut without overlapping the intersecting grooves into the hairpin's surface, were made by drilling. The placement of a perforation in the corners prevented the extension of a crack beyond the termination of the grooves. After the rough blank was cut out all of the margins were smoothed and the tip was tapered with an abrader. The finishing touch consisted of polishing the entire hairpin until most manufacturing traces were obliterated. Not all of the tibiae were cut according to this stepped motif. Some had a right angle cut in either side of the base, leaving a square projection in the center. Others had a plain, rounded or sloping base, lacking indentations. One style maintained the posterior surface of the diaphysis as the shaft and the curving epicondylar region and a small portion of the proximal articular surface as the base. In three examples of this style the articular end was carved to represent an ani-

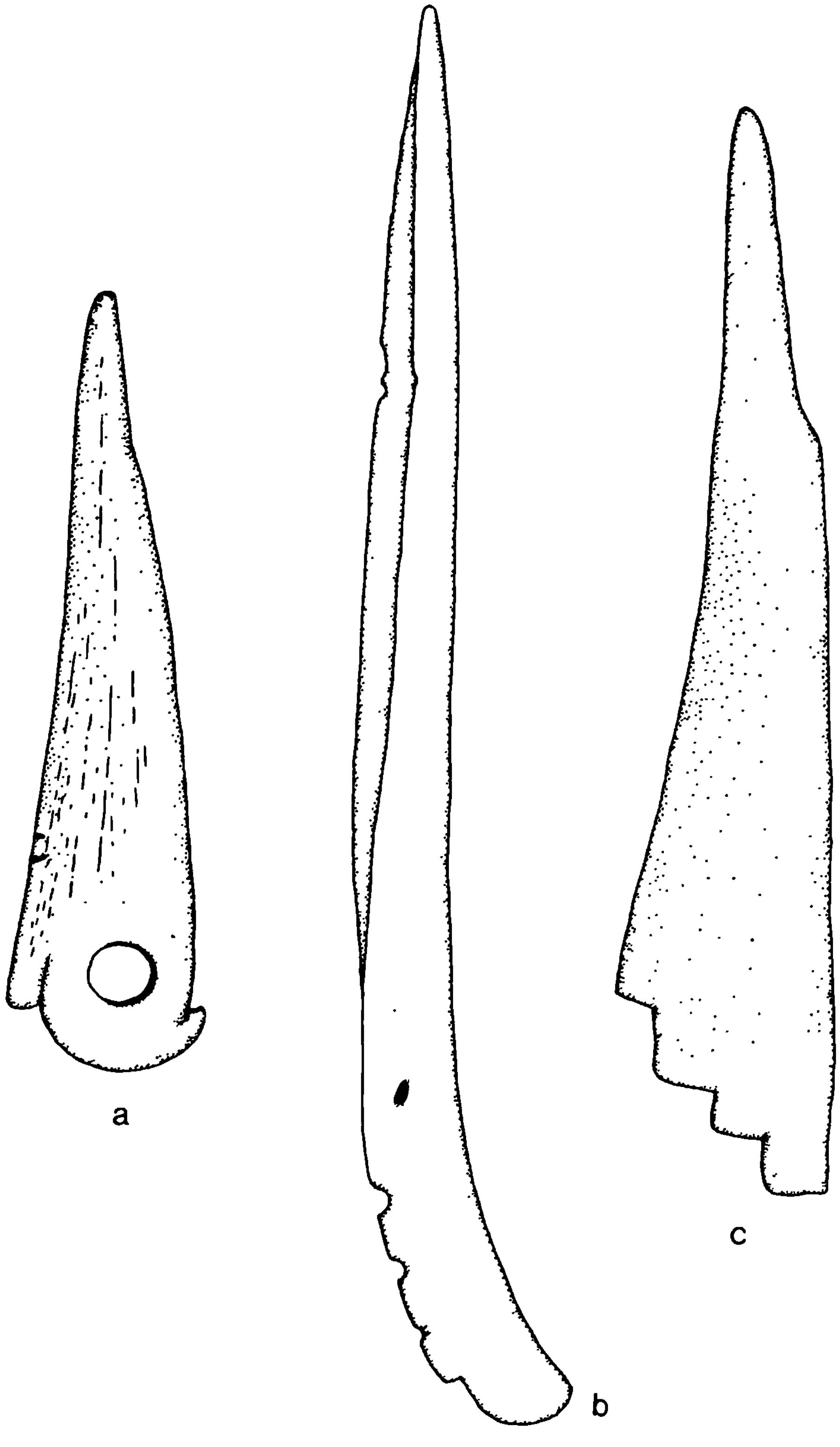


Fig. 98 a. hairpin made on a ruminant tibia with an unusually designed base, b. tibia hairpin with rounded notches and a perforation in the shaft, c. tibia hairpin with the common stepped motif. Scale 1:1.

mal's head with a long nose and two pointed ears. A variety of other modifications include transverse incised lines across the base, small rounded notches along one margin (Fig. 98b), and a large circular hole drilled in the surface of the base. Some of the hairpins made on tibiae possessed one or two small perforations near the midpoint of the shaft along one edge. It is possible that these were for suspension of the artifact in some manner, but the holes are not centered properly . For carrying, the perforations would be more conveniently located at the base. One possible explanation is that a string running through the two openings attached the bone ornament to a headband. There are ethnographic accounts of Southwestern Indians wearing headbands with hairpins (Corbusier 1971). At times larger perforations were incorporated in the design of the base (Fig. 98a).

Ruminant scapulae were selected for hairpins with less frequency than metapodials or tibiae. The dished glenoid fossa functioned as the base, while the shaft was made from the thick caudal border. In manufacturing scapula hairpins a long groove was incised parallel to the caudal margin in the thinner interior of the blade. The groove gradually crossed the neck of the scapula diagonally so that all but the glenoid, neck, and caudal margin was removed when the groove was snapped. An abrader was used to smooth the rough edge, sharpen the tip, and remove the coracoid process. One of the hairpins was drilled down through the center of the glenoid, while another was drilled through the neck and had incised lines notching the lip of the glenoid.

Occasionally, hairpins were manufactured on the radii of ruminants. Two finished and two unfinished specimens retained the proximal articulation and one roughly made piece had the distal end as the base. With the exception of one hairpin which had zoomorphic features carved into the base (Fig. 96b), the radius hairpins were lacking the finely finished aspect of most hairpins. The surfaces were not polished and the grooved and snapped edges were not ground smooth.

One other kind of hairpin is typical in the Point of Pines collection. This is simply a plain, long-shafted hairpin made on a long bone of a large mammal without an articular condyle as its base. The removal of the articular surfaces and other diagnostic features on the shafts of these plain hairpins complicates identification of the taxon or element utilized, but on those where identification was possible ruminant limb bones predominated. The bases are generally ground or cut off so that they are rounded or square and the shafts are highly polished. Sometimes the bases have one or two small perforations just above the end (Fig. 97c).

Hairpins resemble awls in their gross morphology in often retaining an articular condyle at the base, having a shaft formed by longitudinal grooving and snapping, and tapering to a point at one end. Much of the literature describing artifactual assemblages from Southwestern sites inadequately distinguishes between awls and hairpins because of their common morphological attributes. Although there is a small intermediate group of objects that, mainly because they are fragmentary, unfinished, or poorly executed, fail to fall into one category or the other, assignment to type is usually possible. Characteristics that tend to be associated with hairpins are: total lengths that approach the maximum for the element selected (Fig. 99), high overall polish obliterating manufacturing traces, stylistic modification of the base, symmetry of the shaft and tip, gradually tapering shaft, a stout tip, and the absence of use wear at the tip. When, as is often the case, all of these traits occur in one specimen, it can be classified with confidence as a hairpin.

Awls are less restricted in their overall appearance, but their tip morphology is extremely important. Most awls are shorter and narrower than hairpins so that they conveniently fit in the hand. Resharpening also reduces their total length, creating a wide range of sizes including some that are very short. Overall polish, symmetry, and a gradually tapering shaft are featured on some awls, but are not crucial to their performance. Articular surfaces, when present at the bases of awls, are rarely modified in an artistic fashion.

Most critical to the distinction between hairpins and awls is the tip morphology and size. Hairpin tips tend to have a broad, lenticular or oval cross-section with absolute measurements that are greater than most awls (Fig. 101). Awls, on the other hand, tend to have round tips of smaller diameter. These characteristics seem to be related to the function of the objects. Sharp hairpins could inflict injury to the scalp of the wearer,

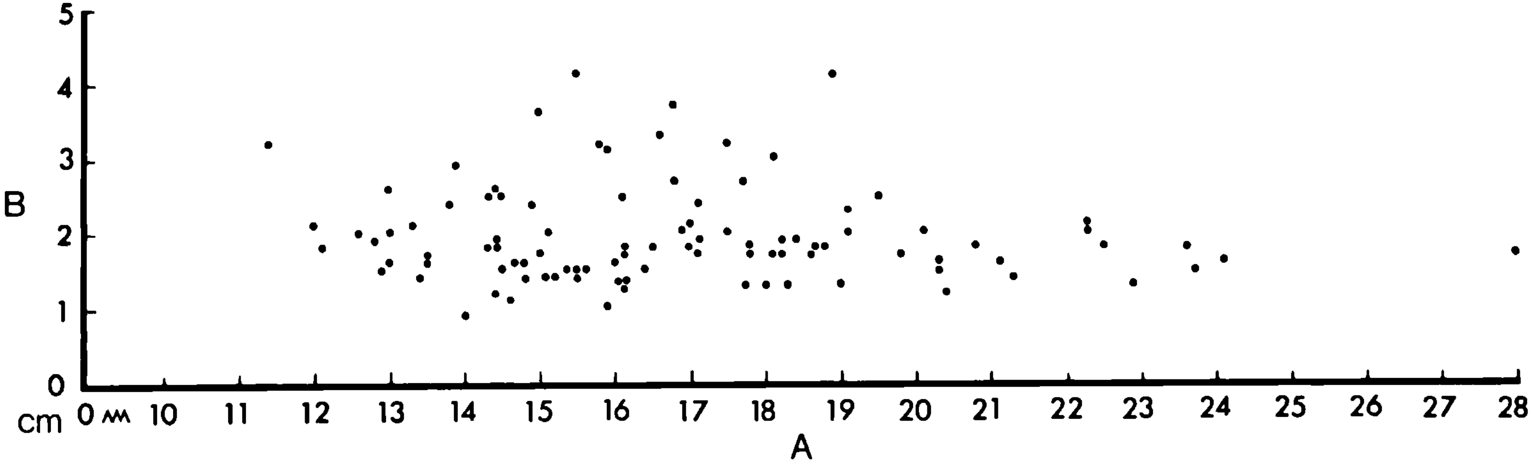


Fig. 99 Scatter diagram 1: gross dimensions for Point of Pines hairpins.

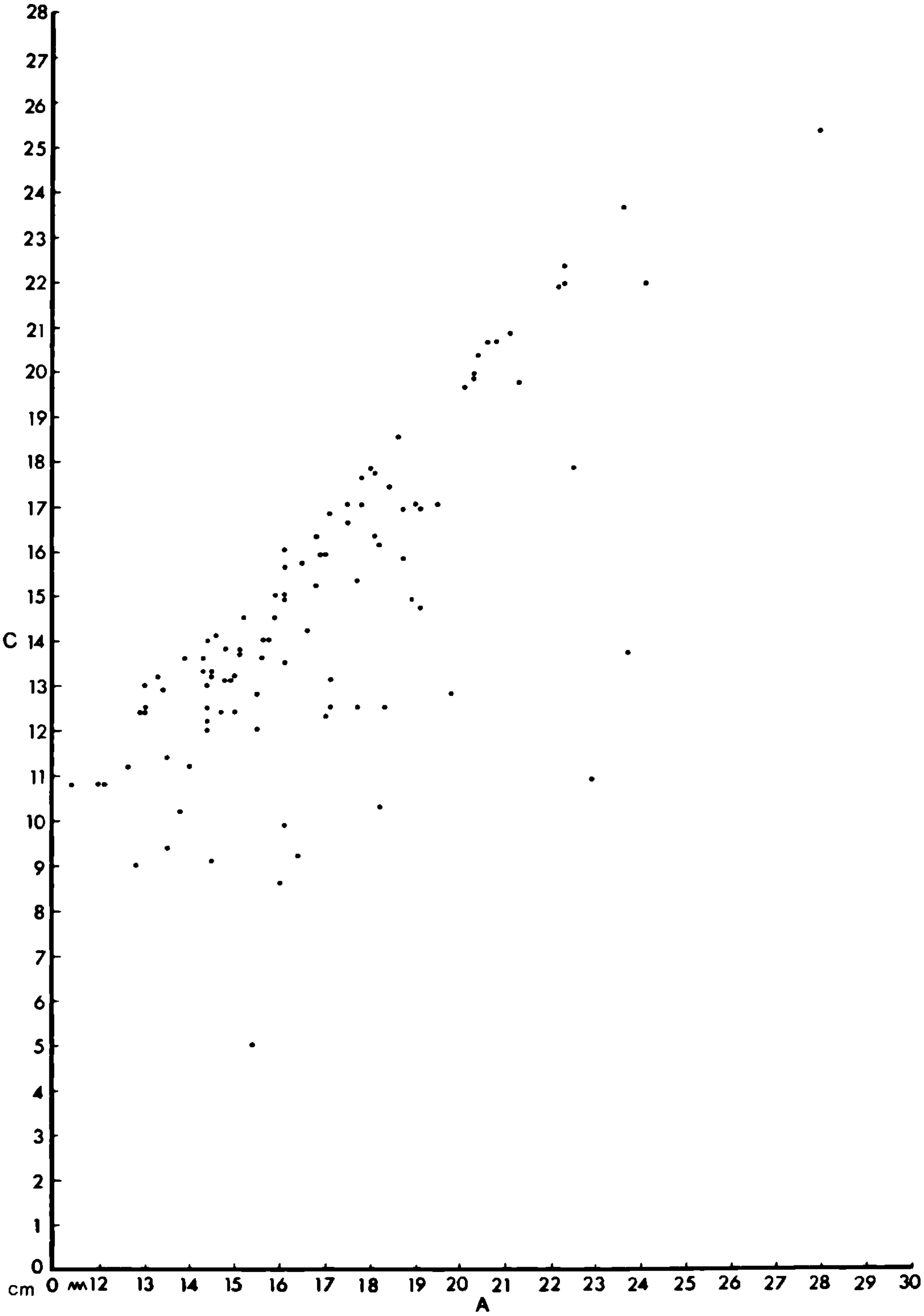
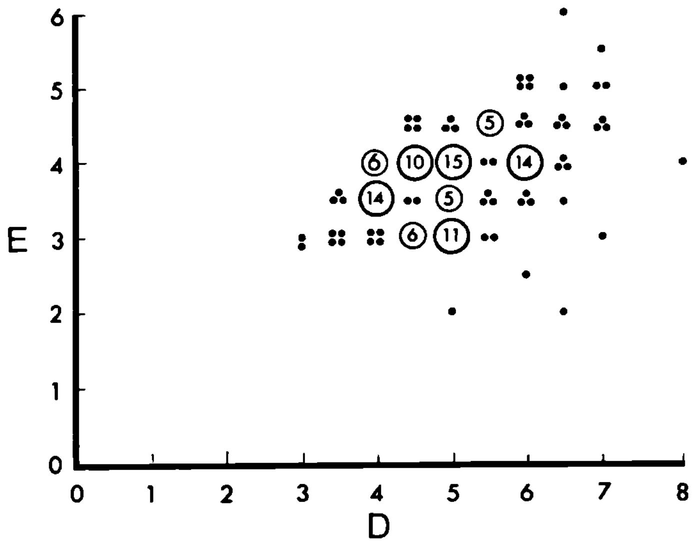


Fig. 100 Scatter diagram 2: location of maximum width on the shaft for Point of Pines hairpins.



$\overline{E}/\overline{D} = 3.8/5.1$mm

Fig. 101 Scatter diagram 3: tip dimensions for Point of Pines hairpins.

while large, blunt awls would be ineffective for basket-making or piercing hides.

Another important guide to the type of artifact is the distribution of polish over the surface. Whereas hairpins have an evenly applied polish over nearly the entire surface, exclusive of the articular end, awls usually display a concentration of polish at the tip. Hairpins rarely exhibit traces of damage or resharpening of the tip unless they have been converted into awls. In cases that suggest recycling, the base and shaft retain the features of a hairpin, including a polish that is interrupted only by harsh abrasion where a fine tip has been shaped. An otherwise broad, gradually tapering shaft will often be sharply inflected in order to reduce the tip to the proper diameter for piercing without attention to the symmetry of the tool. No attempts are made to erase abrading striations at the tip of recycled hairpins and the polish and attrition that occurs there resembles that formed on awls.

Archaeological context is extremely significant for identifying the large, ornate artifacts as hairpins. In sites of the Mogollon-Pueblo and Hohokam cultures these ornaments have consistently been found around or beneath the skulls of adult males. Only a few were discovered in the hand or at the side of the individual. Hohokam sites producing burials and cremations containing hairpins include: Ventana Cave (Haury 1975), Snaketown (Haury 1976), Las Acequias, Ruin II (Haury 1945), Casa Grande (Fewkes 1912), and San Cayetano (Di Peso 1956). Hairpins found in Mogollon-Pueblo burials occur at Grasshopper (S.

Olsen 1979), Kinishba (Cummings 1940), Carter Ranch (Martin *et al.* 1964), and in the Point of Pines region, Az W:10:52 and Turkey Creek ruin. Their distribution extends as far north as Turkey Hill Pueblo, near Flagstaff, and into the Tonto Basin in Arizona, and in Hawikuh and the Mimbres area of New Mexico.

A few examples of descriptions of their occurrence in burials may serve to demonstrate not only their function, but perhaps some hint of their association with members of high status in the society. At Grasshopper, the burial of a male of 40 to 50 years was equipped with a vast array of grave goods, among which were no fewer than nine hairpins placed around the skull. These were of the finest craftsmanship and included a metapodial hairpin with 101 square pieces of turquoise arranged in a mosaic around the base and an elaborately incised bear femur wand (S. Olsen 1979). Grasshopper yielded 30 hairpins in burials, 18 of which were positioned near skulls. All but one of 14 the burials, a child aged 4 to 6 years, were adult males ranging from 25 to 50 years of age. At Carter Ranch, a Mogollon-Pueblo site in eastern Arizona, four male burials were lavishly accompanied by pottery, shell, turquoise beads, and large bone hairpins (Martin *et al.* 1964: 62). A cremation at Snaketown, identified as an adult male, contained seven hairpins (Haury 1976: 303). The most convincing evidence that these large ornaments functioned predominantly as hairpins was the discovey at Ventana Cave of a mature man interred with a human hair wig with four hairpins inserted in it (Haury

1975: 440-442). These are only a small sample of the cases in which adult males were interred with large amounts of grave goods that included hairpins. There seems to be a correlation between age, sex, number of other grave goods, and the quantity of hairpins found in burials. Given the accumulation of data, it is tempting to suggest the possibility that the grander, more elaborately made hairpins served as symbols of wealth or status.

It should be noted that in addition to the large number of cases in which the hairpins were found about the skull there are also examples in which these objects were found clasped in the hand or lying at the side of the individual. At Hawikuh, for example, a male was holding four large hairpins in his left hand. While three hairpins were found around the heads in Upper Pima burials at San Cayetano, one was situated near the left hand of a male (Di Peso 1956: 76-77). Some of the hairpins at Grasshopper were found at the sides or near the hands of the deceased. Although there are other examples, the numbers of hairpins found _in situ_ in locations other than near the head are relatively low in contrast to those distributed about the skulls.

Despite a lack of ethnographic descriptions for the wearing of hairpins for the descendants of the Mogollon-Pueblo people, there are records for their use by other cultures of the Southwest. Corbusier (1971: 32-33), in his descriptions of giving medical aid to Apaches said that men wore their hair long and tied up with a garter or strip of cloth, "in which they carried a slender stick or bone about eight inches long, which serves as a comb." The hairpin was used to scratch the scalp when lice were particularly troublesome. The Papago, who do appear to be the direct descendants of the Hohokam, wore their hair wound in a "war knot" around a short club covered with deer hide. The nearby Pima were known to have worn hairpins while participating in races or kick ball games (Di Peso 1956: 76).

At Point of Pines the predominance of hairpins in adult male burials is discernible. Inhumations and cremations of six adult males, one teenage female, one infant, and twelve adults of indeterminate sex contained hairpins. The position of the hairpins in relation to the body was rarely recorded, but in one case a hairpin was situated beside the arm and in another it was near the head. Four cremations contained two hairpins each and one cremation yielded three hairpins.

Although the hairpins associated with burials supply important information, many more were found in rooms within the pueblo. Several were collected from floors, but the majority were mixed with other refuse in the fill deposits of abandoned rooms.

Sounding Rasps

Made by simply incising transverse notches along the edge of a bone with a stone tool, sounding rasps required a minimum of preparation in most cases. By far the most common elements selected for notching were ribs of ruminants (Fig. 102f). The incisions were made on either the cranial or caudal margin, or even on the concave internal

Fig. 102 a-b. "Bitsitsi" whistles, c-d. tubular whistles made on a turkey tibiotarsus and an avian long bone, e. sounding rasp made on a deer scapula, f. sounding rasp made on a ruminant rib. Scale 1:1.

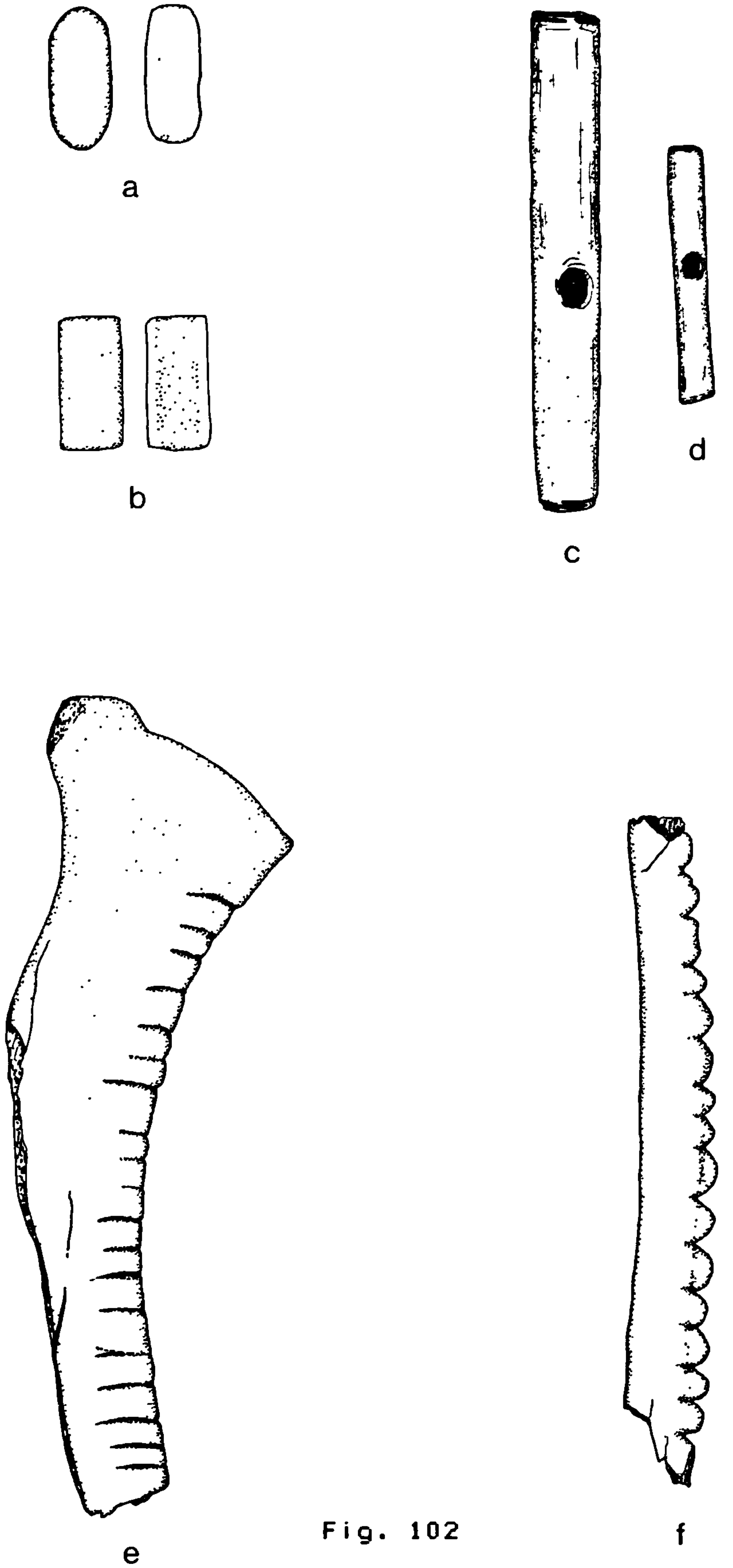


Fig. 102

surface. All of those from Point of Pines are incomplete mid-sections so it is impossible to determine if the vertebral or sternal ends had been worked.

The second most frequently chosen elements for fabrication of sounding rasps were the scapulae of ruminants. These were often prepared by breaking or cutting away most of the blade, maintaining the glenoid and neck as the handle and the caudal border as the rasping surface (Fig. 102e). Alternatively, the whole scapula was sometimes kept intact with the serrations being the only form of alteration present.

A few other elements were also modified by notching. The posterior margin of a mule deer ulna, the lateral edge of the innominate of a pronghorn, and the posterior surface of a ruminant metapodial were used as sounding rasps. The transverse indentations were made on the sounding rasps with varying degrees of regularity, spaced on the average from 3 to 5 mm apart.

These objects are difficult to identify as musical instruments from their archaeological context. Many have been classified as tallies or scrapers (Hodge 1920: 140). Their function is not self-evident, but can be traced through the direct historical approach from modern rasps used by many Southwestern Indian tribes.

Archaeomusicologists refer to sounding rasps as "scraped idiophones", an idiophone being a musical instrument in which "the substance of the instrument itself yields the sound" (Lund 1981: 249). Sounding rasps are played by setting one end on top of a resonator, such as an inverted basket, gourd, or pot, holding the other end up in one hand, and stroking the serrated margin with a stick or bone. Today in the Southwest rasps are often made of wood and are stroked with a sheep scapula or other bone. Wooden rasps are rarely preserved in the archaeological record, so the frequency of use of sounding rasps in prehistoric times may be underestimated. A rasp set was found at Pecos Pueblo, New Mexico, which consisted of a ruminant radio-ulna and metapodial and a notched wooden rasp (Kidder 1932: 255).

Although use wear is quite readily detectable on the notched edges of well-used bone rasps, the pattern is not distinct enough to be separable from wear that might occur from other tasks involving a similar motion. The edge is polished and the corners of the notches are rounded by attrition due to repeated friction. Very fine longitudinal striae are sometimes also visible in the polished area. In extreme cases the edge between the notches has been worn or broken down to expose the cancellous bone within.

Sounding rasps are used today by many Southwestern tribes including: the Hopi (Tanner 1976: 195), the Zuni, Pueblo, Ute, Yaqui, Papago (Densmore 1957: 3), Apache, and Navajo (Queen 1978: 13). The choice of wood or bone for the rasp and scraper, the spacing of the notches, the ornamentation, and even the way in which the rasp is stroked vary depending on the tribe and the circumstances of their use (Queen 1978: 13). The distribution of sounding rasps in prehistory encompasses most of the Southwest, with their presence frequent in Hohokam, Mogollon, and Anasazi sites (Tanner 1976: 194).

Tubular Whistles

A group of artifacts made from thin-walled tubular long bones of birds or small mammals were probably used as whistles (Fig. 102c,d). Fabrication began by removing both articular condyles by annular grooving and snapping. The surface of the shaft was smoothed all around by longitudinal scraping with a chert tool. This removed prominences such as the papillae on bird ulnae or muscle ridges on other limb bones. The ends of the tubes, still rough from snapping off the condyles, were ground smooth with an abrader. One window was gouged, drilled, or cut into the diaphysis of the bone either at the midpoint or about one third of the way from the end. Sometimes the edges of the perforation were smoothed by gentle abrading, especially if the hole was gouged rather than drilled. Large bird ulnae were the most frequently selected elements for whistles, but a radius and two tibiotarsii were also used.

These "aerophones" may have been played in a number of ways. If they were used as "block-and-duct" flutes, then a drop of resin, lac, beeswax, or similar substance would have been set inside opposite the window in order to form a block (Lund 1981: 259). The blow hole would then have been at one end. Another possibility is that the whistles were blown from one end without a block. Experimentation with intact whistles in the Point of Pines collection demonstrated that they would emit a loud tone if blown without a block if the lips were pursed around the blow hole. Further experiments with a fresh bone whistle were also conducted because fine cracks in prehistoric whistles can alter or diminish the sounds produced. A beeswax block was put in the experimental whistle, but this seemed to reduce the sound emitted rather than increase it. Another possibilty is that they were played like a bottle with the air crossing over the hole at one end, but this was less successful in producing an audible sound. Simple ductless aerophones without windows may have been played in this manner (Lund 1981: 257), but these would be indistingu shable from the other large tubular artifacts. The last possibility is that the player held the whistle horizontally and blew across the window. This did not, however, produce a sound that was loud enough to be effective. Given the limited set of experiments conducted here and the absence of any evidence of blocks, even in whistles found in dry caves where other perishables are well-preserved, it seems likely that the Mogollon-Pueblo people blew directly into one end of blockless whistles. Ethnographic data support the lack of blocks in bone whistles, although cane flutes retained the inner septum as a block (Queen 1978: 18-19). The only sign of wear is light traces of handling polish distributed over the external surfaces.

Whistles constitute part of a long tradition in the American Southwest that continues today. They are used as bird calls while hunting and for ceremonial purposes by many tribes. Mogollon-Pueblo bone artifact assemblages generally include several tubular whistles with one window each, but the bone flutes or flageolets with several stops known from Anasazi and Hohokam sites are absent.

"Bitsitsi" Whistles

The small reed whistles found in Mogollon-Pueblo sites are an example of artifacts that would be extremely difficult to identify through microwear analysis, archaeological context, or any means other than the direct historical approach. When intact they consist of two small rectangular or oval sections of long bone with a thin leaf slipped between as a reed. A binding of cordage or sinew holds the three pieces together. The Zuni Indians of New Mexico call these whistles "rabbit tongues" because the sound emitted is similar to the scream of an injured rabbit. They are played while concealed in the mouth of the "Bitsitsi" who performs in one of the Shalako rites (Hodge 1920: 130-131). The Hopi use similar whistles to imitate hawk cries (Hayes, Young, and Warren 1981: 151).

Manufacturing probably began with annular grooving and snapping to make a short bone tube. The tube would then have been bisected longitudinally, producing two equal-sized curved rectangles (Fig. 102a,b). The edges were ground so that less than half of the circumference was retained, but some of the curvature still remained visible. The sharp corners were often rounded and the grooved and snapped ends abraded until smooth. On three occasions the ends were abraded enough to form bevels. When fitted together the two pieces of bone produced a tube about 2 cm in length and 1 cm wide with a lenticular cross-section. Because the reed and binding materials are perishable and the two bone pieces are frequently separated in the archaeological record, these objects are often mistaken for pendant blanks, dice, or gaming pieces.

At Point of Pines, at least 21 rectangular bone pieces of the kind used for Bitsitsi whistles were recovered. Seven were individual parts scattered through room fill, but 14 were found in pairs. One cremation contained 10 pieces that could be arranged into five pairs based on size. The five whistles were apparently added to the ashes in the cremation vessel, as they were uncharred.

Exploitation of Taxonomic Groups for Raw Material

Within the description of individual artifact types brief mention was made of the taxa and elements selected for the manufacture of each product, but the overall significance of certain animals in artifact production should also be assessed. Figure 68 provides the range of taxa represented and their distribution among the artifact types.

Several genera of large birds were represented, including Canada geese (*Branta canadensis*), at least four kinds of birds from the Order Falconiformes (hawks and eagles), turkeys (*Meleagris gallopavo*), and sandhill cranes (*Grus canadensis*). The thin-walled long bones were chiefly used for tubular whistles, Bitsitsi whistles, and tubular beads. At least four awls and two possible tubular containers were also made from large bird limb bones. The adaptation of the turkey synsacrum as a paint container was most unusual, especially since the vertebrae and pelvis of birds are rarely employed as implements or ornaments. The use of bird bones was significant for certain artifacts, but in terms of the total worked bone assemblage they constituted only 5.8%.

Nearly 23% of the artifacts could only be identified to Class Mammalia because diagnostic characteristics had been removed during manufacture or were missing as a result of breakage. These represent a wide variety of types of both utilitarian and ornamental function. Many of the smaller mammalian bones, such as those of leporids, could not always be distinguished from avian bone and were therefore combined in a special category as bird or small mammal. Only a few of the indeterminate mammalian bones were in the medium size range and the rest could safely be classified as large mammal bones. Large mammals in the region include grizzly and black bear, the puma (*Felis concolor*), and several species of ruminants.

Despite the fact that the people of Point of Pines exploited black-tailed jackrabbits (*Lepus californicus*) and cottontails (*Sylvilagus* spp.), only three leporid elements were identified among the artifacts. The osseous remains of rodents were utilized to an even lesser extent as raw material, as witnessed by their absence among the identifiable elements in the worked bone assemblage.

On the other hand, the bones of carnivores were more frequently modified than their low numbers in the faunal collection would predict. The explanation for their use as raw material for artifacts may involve several factors. Although occasional kills may have been made to rid the area of a menacing predator or for religious or social reasons, it is unlikely that carnivores, excepting dogs, were an important source of protein for the village. One conjecture is that elements of carnivores were less intensively comminuted due to marrow processing than the major species contributing to the aboriginal diet, enabling the whole elements to be modified into artifacts.

Small awls retaining an articular end at the base were made on the bones of red fox (*Vulpes fulva*), bobcat, and puma. A spatula was also made from a bobcat element. The only identifiable examples of the use of *Canis* bone were a tubular bead and three rings.

Bear long bones were well suited to the manufacture of heavy duty tools such as beamers and gouges because of their large size and thick cortical bone. The number of grizzly bear bones among the artifacts in comparison to their paucity in the faunal material shows a definite effort was made to conserve this scarce resource. This trend was also noted at Grasshopper (S. Olsen 1979) and Kinishba (S. Olsen 1980), despite in the former case a complete absence of grizzly bear bones in the faunal material (J. Olsen 1980). The ungual phalanx of a bear was perforated to be worn as a pendant. When fresh its appearance may have been quite different if the keratinous claw was left in place.

The majority of both unmodified and modified osteological remains from Point of Pines was derived from ruminants. All of the species whose ranges encompass Circle Prairie today were represented in the artifact collection, with the addition of two bison bones. Although bison were not documented in historic times in east-central or southern Arizona, their sparce remains have been identified at Snaketown (Gladwin *et al.* 1937: 156), Bear ruin (Haury 1940: 15), Babocomari Village (Di Peso 1951: 3-4) and University Indian ruin. At Point of Pines the manufacture of two beamers in the Mogollon-Pueblo style on the limbs of these large bovids reduces the possibility that the bone could have been derived from intrusive large domestic cattle.

The representation of medium-sized ruminants among the bone artifacts reflects the relative abundance of the species in the faunal remains from Point of Pines (Stein 1963). The prevalence of mule deer (*Odocoileus hemionus*), followed by pronghorn (*Antilocapra americana*), white-tailed deer (*Odocoileus virginianus*), and finally bighorn (*Ovis canadensis*) is typical in prehistoric faunal assemblages in Arizona. The frequencies of white-tailed deer and pronghorns may fluctuate, but mule deer are usually present in larger numbers and bighorns are always scarce.

An important source for implement production was deer antler. Among the Mogollon-Pueblo collections there is great consistency in the use of antler as opposed to long bones for certain tool types. From the few specimens retaining the proximal end of the main beam it appears that both shed and unshed antlers were utilized in fairly equal numbers.

If all ruminants are considered together, there are very few artifact types that were not made from their elements. Only the tubular whistles and beads seem to have been unsuited to the use of the heavy, thick-walled elements of these large mammals.

Conclusions

Point of Pines ruin, in east-central Arizona, provides a valuable example of how fruitful the analysis of bone artifact assemblages can be. The 1268 artifacts examined herein are unquestionably in a better state of preservation and more varied than are most bone artifact assemblages. Combining these assets with the well-documented Southwestern prehistory and the cultural continuity of the region, the Point of Pines collection is optimal for the application of a multidimensional methodological approach. It is with these factors in mind that Point of Pines was selected as one of the three case studies in this research. The Mogollon-Pueblo culture, in general, has produced notably large collections of bone artifacts and because of the aridity of the climate and favorable soil conditions, these survived in a very pristine state.

Chapter 7

Tell Abu Hureyra

Tell Abu Hureyra is a very large mound some eight meters high covering approximately 11.5 hectares, near the south bank of the Euphrates in northern Syria. Situated in the archaeologically productive Levant, the site was scheduled to be flooded as the dam at Tabqa became operational in 1974. A rescue project involving two field seasons of excavation in 1972 and 1973 was conducted by A. M. T. Moore under the auspices of the Pitt-Rivers Museum of the University of Oxford with the support of the Oriental Institute of the University of Chicago, among other institutions, and the authorization of the Syrian government (Moore 1975a: 52).

The site is located 15 m above the Euphrates flood plain near the modern village of Abu Hureyra, 130 km east of Aleppo (Fig. 103). Although today the Euphrates flows no nearer than 1 km north of the tell, a secondary channel active in recent times passes along the western edge of the mound indicating frequent fluctuations in the river's course. From north to south the tell is about 480 m in length and has a width of 290 m from east to west.

Excavations involved seven separate soundings distributed over the surface of the mound (Fig. 104). The deepest of these, Trench E, uncovered stratified layers of occupation from Late Mesolithic (c. 9,500 BC) to early Ceramic Neolithic (c. 5,500 BC). Weathered deposits suggest a hiatus between the Mesolithic and the early Aceramic Neolithic (c. 8,500 to 7,500 BC) (Moore 1975b:

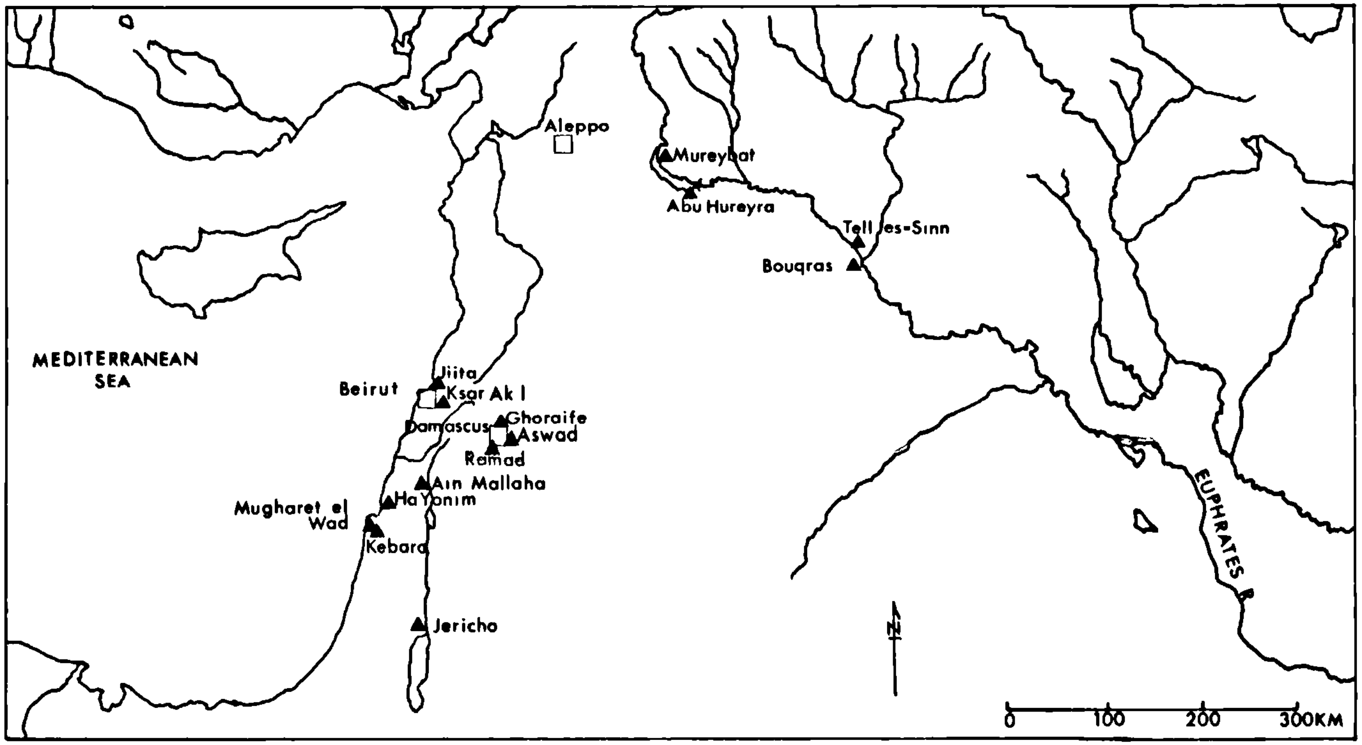


Fig. 103 Map of the Levant with major sites referenced in the text.

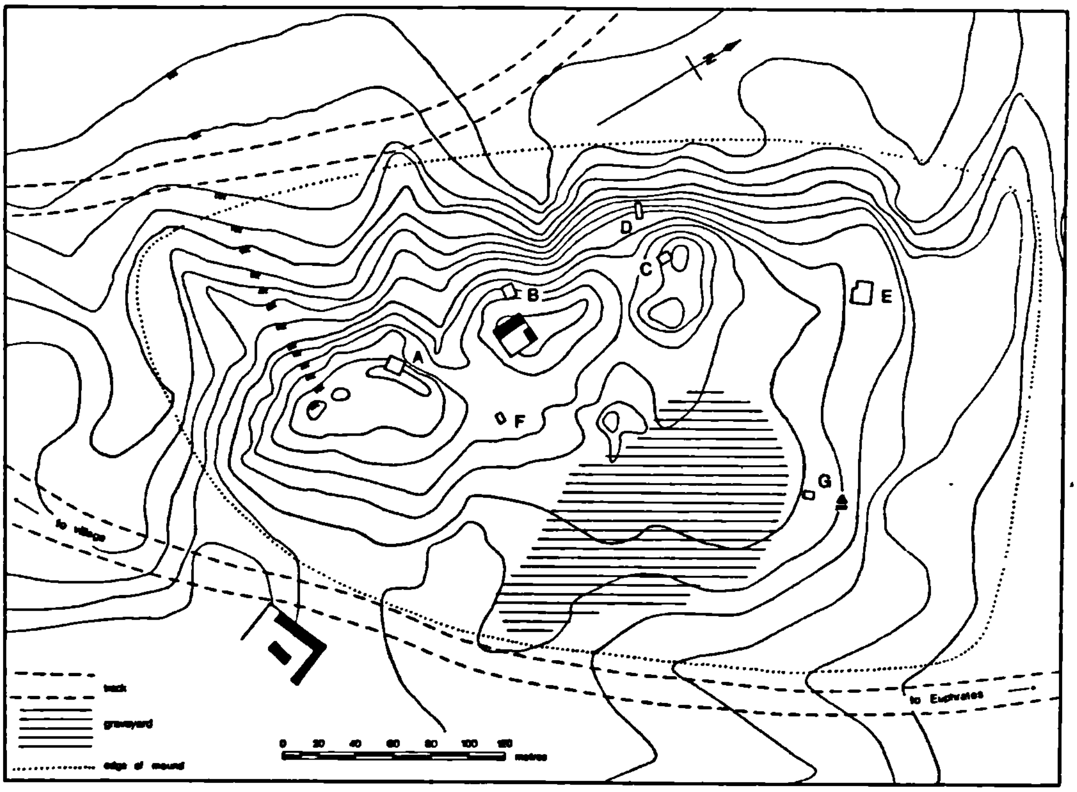


Fig. 104 Site plan of Abu Hureyra showing locations of excavation trenches (from Moore 1975a:54).

116; Moore 1979: 68).

The bone artifact collection from Tell Abu Hureyra consists of 418 implements and ornaments (Fig. 105). The most common artifacts are awls, followed by utilized splinters, needles and projectile points. Also included in the assemblage are some fine examples of unusual types, such as fishhooks, a large ringed hook, two drilled phalanges, a notched rib, and several tubular beads.

Preservation of the artifacts' surfaces is remarkable considering their age and is due largely to the aridity of the region in recent millennia. Taphonomic processes such as root etching, animal gnawing, and weathering were minimal impairments to the interpretation of microwear. Despite excellent surface preservation, the bone artifacts are very fragile so that postdepositional breakage hampered quantitative analysis and classification in many cases.

Manufacturing Techniques

The most basic manufacturing technique employed at Abu Hureyra consisted of simply shattering bone and collecting long, narrow splinters for use without further modification. Utilized splinters are recognizable as artifacts because of the wear at one end, rather than by any evidence of manufacture.

At a more sophisticated level, both annular and longitudinal grooving and snapping were conducted. Artifacts manifesting traces of this technique include tubular beads, awls, and the flat implements. Manufacturing

Fig. 105

BONE ARTIFACT TYPOLOGY FOR TELL ABU HUREYRA

TYPES	Antler Hammer	Flaker or Pestle	Projectile Point	Fishhook	Hook and Ring	Utilized Splinter	Spatula	Flat Implement	Splinter Awl
TAXA									
Class Aves/Mammalia									1
Class Aves									1
Class Mammalia			16	2		12	1	8	24
Vulpes vulpes							1		
Family Felidae							2		
Suborder Ruminantia						12			9
Dama sp. indet.	1								
Gazella sp. indet.						3			
Ovis/Capra						1			1
Bos sp. indet.								10	
Equus sp. indet.									
Bos/Equus		1			1			1	1
TOTALS	1	1	16	2	1	28	4	19	37

Fig. 105 (continued)

TYPES	Shaped Awl on Splinter	Shaped Awl Made by Groove and Snap	Awl with Articular End as Base	Awl Fragments	Needle	Pin	Needle or Pin
TAXA							
Class Aves/Mammalia							
Class Aves							
Class Mammalia	6	7		106	16	2	24
Vulpes vulpes							
Family Felidae			1				
Suborder Ruminantia	2		42	6			
Dama sp. indet.							
Gazella sp. indet.			14				
Ovis/Capra			27				
Bos sp. indet.							
Equus sp. indet.			5				
Bos/Equus				2	2		5
TOTALS	8	7	89	114	18	2	29

Fig. 105 (continued)

TYPES	Tubular Bead	Drilled Tooth	Drilled Phalanx	Notched Rib	Misc. Worked Fragments	Manufacturing Debris	TOTALS
TAXA							
Class Aves/Mammalia						1	2
Class Aves	2						3
Class Mammalia	2	1			12	1	240
Vulpes vulpes							1
Family Felidae							3
Suborder Ruminantia	2			1	1	1	76
Dama sp. indet.						4	5
Gazella sp. indet.			2			4	23
Ovis/Capra						6	35
Bos sp. indet.						2	12
Equus sp. indet.							5
Bos/Equus							13
TOTALS	6	1	2	1	13	19	418

debris discarded after grooving and snapping bone and antler and unfinished grooved pieces was also recovered. Although further modification has possibly eliminated evidence of the groove and snap technique, it is likely that blanks for needles and projectile points were fabricated in this manner, as well.

The most salient manufacturing traces on finished pieces were those created by scraping with a stone implement (Fig. 26). Over half of the tool types and the majority of actual artifacts displayed some traces of scraping. The edges and tips of awls and the entire surfaces of the flaker, needles, projectile points, and the fishhooks were scraped. Scraping may be performed with flint flakes or scrapers, but is most effective in planing down a surface when the edge of a burin is used. Supportive data substantiating the hypothesis that burins were used in scraping bone at Abu Hureyra come from microwear analysis performed on the burins themselves (Moss 1983).

Drilling constitutes the fourth major manufacturing technique and was conducted on needles, the tooth pendant fragment, the perforated phalanges, and two of the hooks. It is clear from the range of sizes of perforations that a variety of drills was used. The extremely small perforation made in one needle is so straight-sided that it may have been made by a thorn or wood splinter and abrasive powder rather than a flint drill. On the other hand, the ring on the ringed hook was perforated with a very large drill bit.

Rather than drilling, the majority of the needle eyes were made by carefully gouging a longitudinal trough on both flat surfaces of the base until the centers of the gouge marks met to form a small perforation. There may be many reasons why this technique seems to have been preferred over drilling. To drill a very small perforation biconically on a narrow surface requires skill and patience. As is visible on one unfinished example from Abu Hureyra, the hole may be initiated too close to one edge so that as it is deepened it expands to incorporate the lateral surface and breaks out one of its walls (Fig. 131h). With gouging, which is a slow, gradual process, it is easier to control the centering of the perforation. The most obvious advantage of gouging a perforation is that, as with modern needles, the thread lays in the trough rather than making a sharp bend which drags through the material it is sewing and breaks the thread's fibers.

Incising was used in only a minor way on awl handles either as a simple form of decoration or to improve the user's grip. It was probably performed in the same manner as grooving except that the incised lines are narrower and shallower than grooves that were to be snapped in the manufacture of a tool.

A few examples displayed traces of grinding, or abrading, applied during manufacture. Although abrading appears to have been of minor significance in this collection, specimens bearing the characteristic striations associated with it include the fishhooks, the tooth pendant, tubular beads, some of the flat implements, and a utilized splinter derived from an ulna of a small ruminant.

Further details of the combinations and sequences of manufacturing techniques for each tool type are discussed under their individual headings.

Descriptions of Artifacts:

Bone Flaker or Pestle

A long rod made from dense cortical bone of a large mammal shows heavy wear suggestive of use as a pressure flaker. The artifact, which is 8.7 cm long and has a maximum width of 1.9 cm, is rounded at both ends and oval in cross-section (Fig. 106e). The parallel sides suggest that the tool was manufactured by longitudinal grooving and snapping, but no traces are evident along the edges. Scraping has smoothed away all earlier traces of manufacture and trimmed down any irregularities in the surface. The implement is derived from a Neolithic layer in Trench E.

At both ends are multiple wear facets created by attrition of the surface. The tips are pitted and long striae run out in several directions away from both ends and up the shaft a short distance. Like the striations on experimental flakers (see chapters 4 and 5) they are individual furrows that are not always straight and, on close inspection, are lined with finer parallel scratches. Each stria ends abruptly where contact with the flint ceased or the minute asperities that were cutting into the bone snapped off.

Tools of similar size and shape made of antler have been found at Tell Aswad and Ramad (Stordeur 1982: 15,

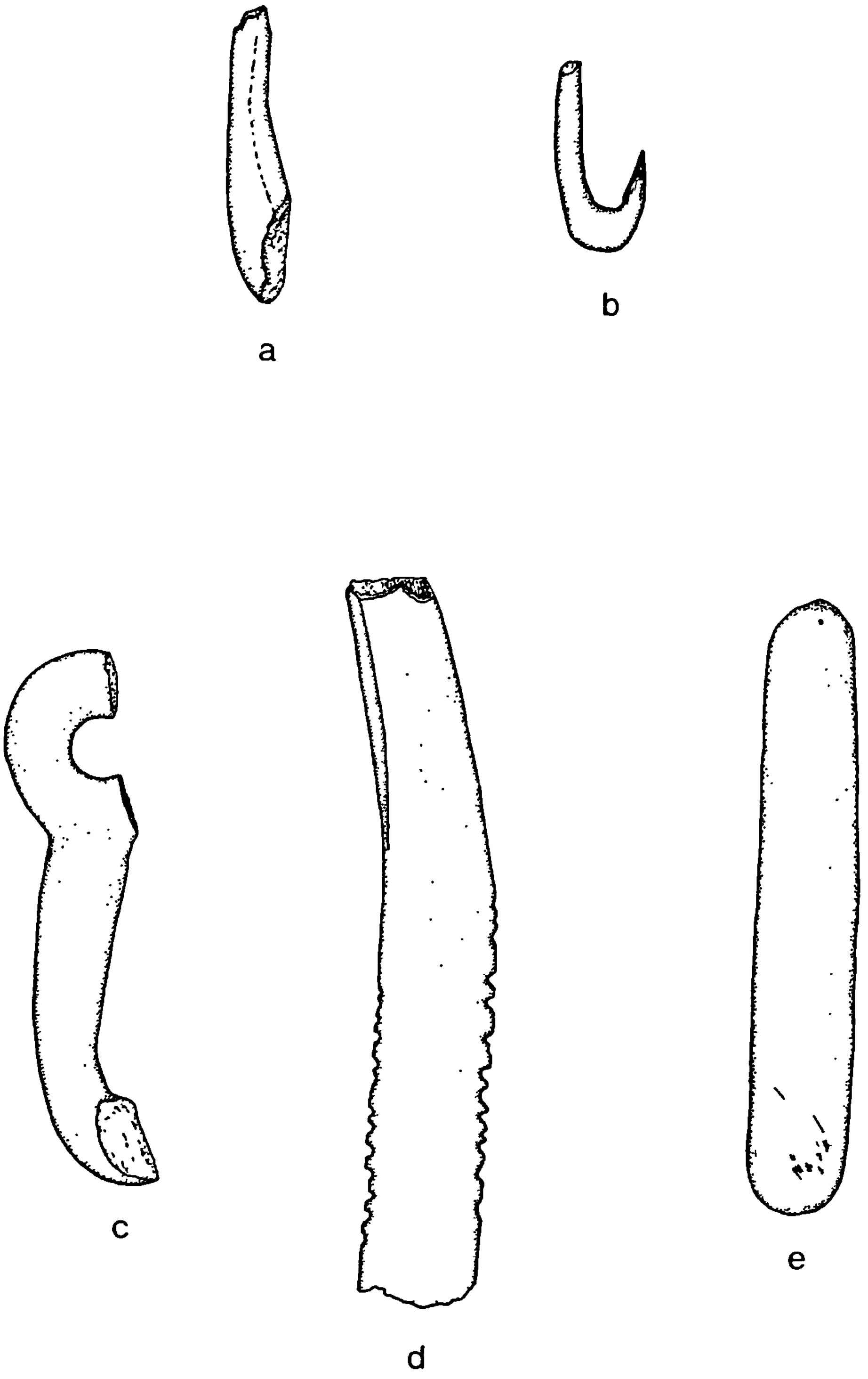


Fig. 106 a-b. fishhooks, c. ringed hook, d. notched rib of a ruminant, e. bone flaker or pestle. Scale 1:1.

18). The tips vary in morphology from flat to rounded or conical and the wear is described as consisting of crushing and circular striae caused by rotating against a grainy surface. It is possible that a blunt point was made on these implements by abrading, which could explain the presence of circular striations. Stordeur (1982) has classified them as pestles because of their resemblance to stone and terracotta pestles in the area and because of the appearance of the microwear at the tips.

Antler Hammers

A segment of the main beam of a fallow deer antler has extensive use wear resembling that on experimental hammers used in flint knapping (see chapters 4 and 5). Both ends of the piece are broken off, but the shaft has two large areas of pitting and V-shaped nicks with some smaller spots of damage about the surface. Its present length is 7 cm, but the original artifact may have been much larger. No manufacturing traces of any kind are visible on this fragment derived from an Aceramic Neolithic level in Trench E.

A second specimen which has been grooved and snapped longitudinally and charred also bears traces of use in soft-hammer percussion flaking of flint. This piece was derived from a Neolithic level in Trench E, Extension 2.

Projectile Points

The projectile points from Abu Hureyra demonstrate a great continuity with the Upper Paleolithic, as witnessed in the fine array of bone and antler points from Ksar

Akil, Lebanon (Newcomer 1974). Whether or not it has wider implications, at Abu Hureyra there appears to be a move away from the use of antler in favor of the exclusive use of bone points (Fig. 107a-i). Like those made on bone at Ksar Akil, the projectile points at this site are round in cross-section rather than lenticular or flattened. Unfortunately, breakage of one or both ends has made measuring and determination of morphology very difficult, but it seems that most of the artifacts were either bipoints or at least had a tapered base. Some are so finely pointed at both ends that it is difficult to distinguish between the base and tip, but on three of the specimens the tapered base has a small truncation formed by the failure to completely sharpen it during manufacture. The largest and one of the best preserved examples still bears traces of annular grooving and snapping at the base.

Only four of the points were complete enough to allow all of the measurements to be taken. They are similar in gross morphology with lengths ranging from 3.7 to 5.7 cm and maximum widths of .5 or .6 cm (Fig. 108). The location of the maximum width on the shaft tends to be near the midpoint, since both ends are tapered (Fig. 109). The tips of the projectile points are round in cross-section and are very uniform in dimensions, measuring between 3 and 3.5 mm in diameter (Fig. 110).

All of the points exhibit striations and often chattermarks typical of tools shaped by longitudinal scraping over their entire surface. How their blanks were formed

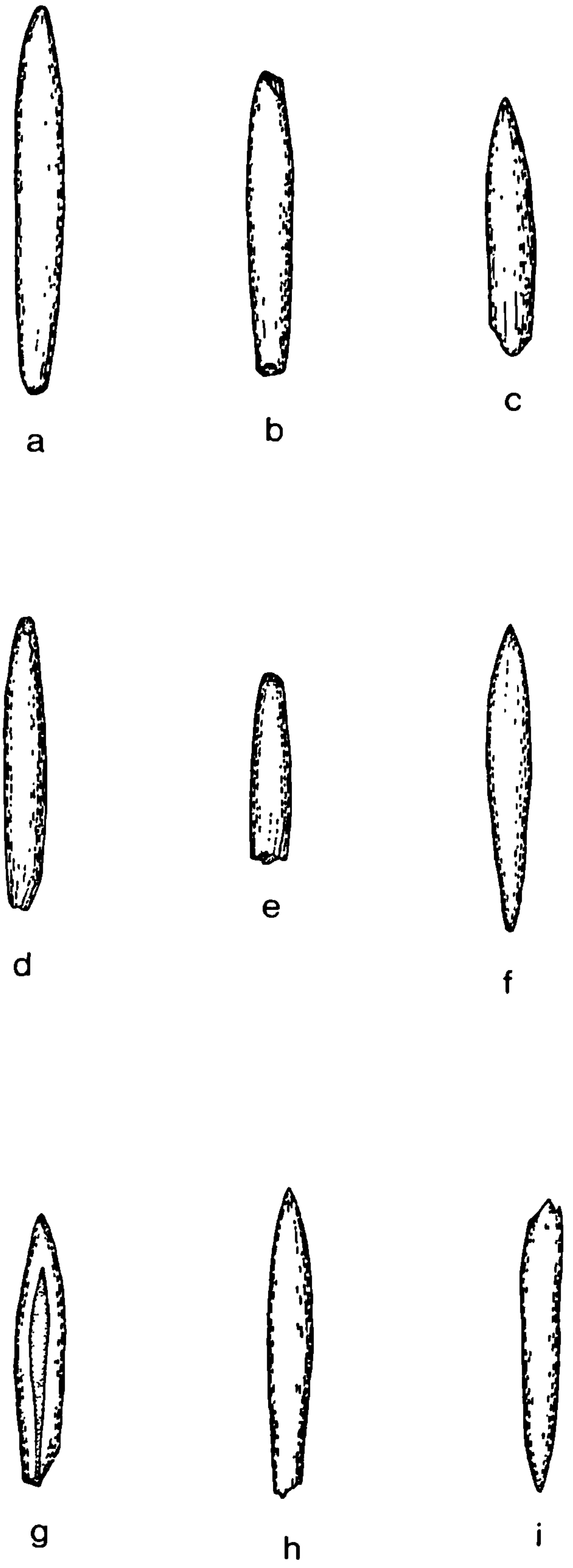


Fig. 107 a-i. bone projectile points. Scale 1:1.

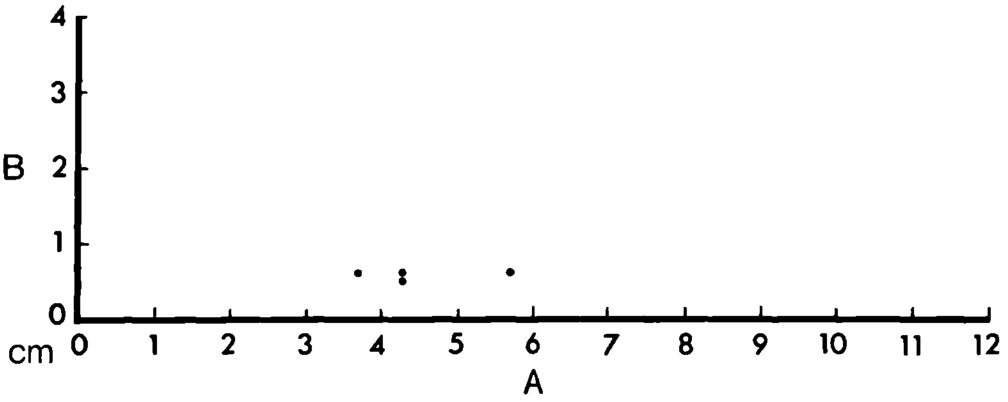


Fig. 108 Scatter diagram 1: gross dimensions for Abu Hureyra projectile points.

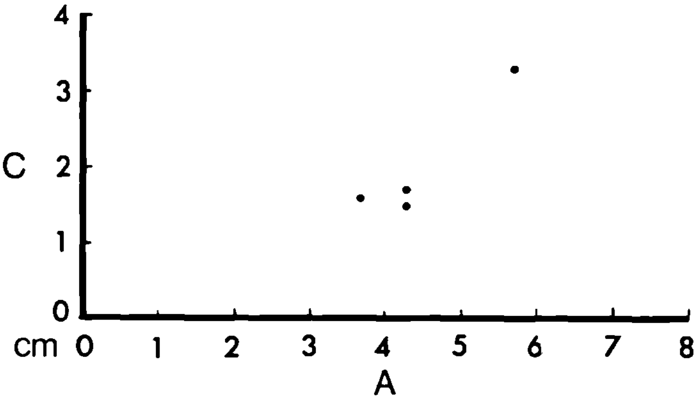


Fig. 109 Scatter diagram 2: location of maximum width on the shaft for Abu Hureyra projectile points.

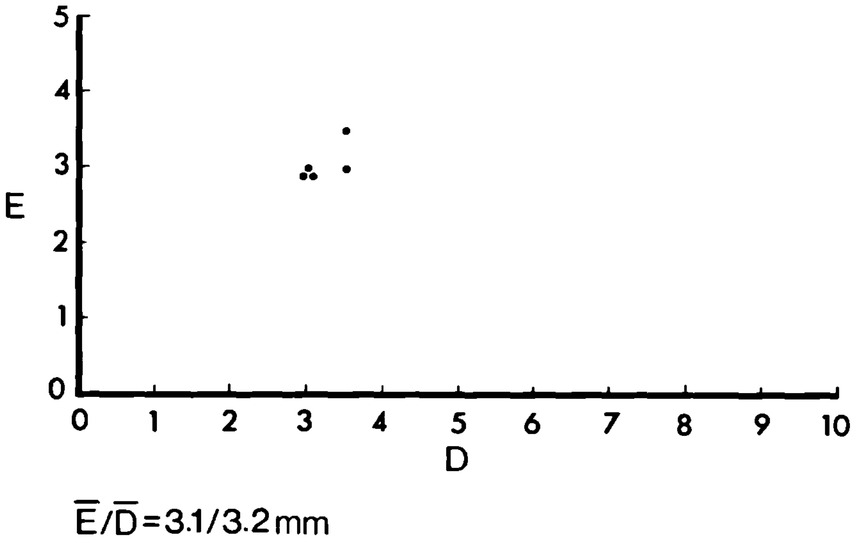


Fig. 110 Scatter diagram 3: tip dimensions for Abu Hureyra projectile points.

is not clear because of the lack of unfinished pieces and other manufacturing traces on completed specimens. The maximum diameter is large enough to indicate that the thick cortical walls of the diaphyses of long bones from cattle, equids, or equally large mammals were used.

The abandonment of the use of antler points at Abu Hureyra may be quite significant when combined with other data. Antler, especially when presoaked, is easier to work than dense bone. Experiments have shown that antler is more resilient and therefore less likely to break (Albrecht 1977; MacGregor and Currey 1983). The fact that there are relatively few pieces of worked antler in the site and that the single flaker and all of the projectile points are made of bone is probably related to availability. Unworked deer bone and antler are not common at Abu Hureyra and it appears that populations of gazelles, sheep, goats, cattle, and small equids were much more plentiful than any of the cervids during the Mesolithic and Neolithic in the vicinity of the site (Legge 1975: 75). All of the bone projectile points in this collection were derived from Mesolithic levels, which coincides well with data from other sites in the Levant.

Seven of the points possess damage at their tips that may have been caused by use. This consists in one case of slight inward crushing of the tip and in the remaining six of the removal of a narrow flake from the tip to between 2 and 5 mm. down the shaft. Breakage of this kind may occur during impact with a resistant surface. Although there is no proof that the ancient breakage happened when the projectile impacted with its intended target or the surrounding environment, the high incidence of this pattern in the small collection from Abu Hureyra is interesting.

Bipoints are well documented at numerous sites during the Natufian, including Kebara and El Wad on Mount Carmel, Erq el Ahmar in Judea, ha-Yonim and Mallaha in Galilee, and Mureybat on the Euphrates (Stordeur 1979).

Hooks

A unique specimen derived from Trench E Neolithic deposits consists of a large hook that was designed to be attached to something else by twine strung through the ring at the base (Fig. 106c). The ringed hook was made from thick cortical bone of a robust mammal such as Bos sp. indet. or an equid. It is difficult to determine how the blank was formed initially, but an elongated rectangle may have been removed from a long bone diaphysis and drilled near both ends to form the ring and inner curve of the hook. The corners may then have been rounded and the opening for the hook cut out. The piece was finished with longitudinal scraping over its whole surface, smoothing all the edges and constricting the area between the ring and the hook. The surface of the hook has been burned and has light root etching, but these do not interfere with the evidence of use.

The length (7.6 cm) and overall robusticity imply that the hook was designed for heavy-duty tasks. The ring, which has an inner diameter of 9 mm, is highly polished around the end and particularly along the perforation's wall on the side away from the hook. In addition, the hook bears a highly polished surface which is most prominent on the inner curve, but is also present on the bottom. The concentration of polish in these locations on the ring and the hook suggest that, whatever its function, the artifact was linked between two ropes or pieces of twine that gradually rubbed the bone surfaces smooth. Due to breakage it is impossible to reconstruct the morphology of the terminal end of the hook.

A very fine example of a fishhook recovered from Neolithic deposits in Trench D is missing only a small part of its base (Fig. 106b). It was manufactured on a long bone of a medium to large mammal and was smoothed and rounded by longitudinal scraping. The inner curve of the hook was formed by drilling a hole approximately 5 mm in diameter. The tip was sharpened to a fine point by scraping and the bottom was rounded by abrading. Minus the broken base, the present length is 2.7 cm and the maximum diameter of the shaft is 5 mm.

A third hook of a size intermediate to the others was found in Trench E, Extension 4. Like the small fishhook, it was shaped largely by longitudinal scraping with abrading on the bottom. Both the base and the upturned part of the hook are missing, so little can be added about its morphology (Fig. 106a). The bottom of the hook has a great height and there is no indication that the inner curve was formed by drilling. Given its fragmentary state it is difficult to determine whether this object was used as a fishhook or perhaps served some other function.

The faunal remains from Abu Hureyra do not suggest that fishing was a major source of dietary protein there, but the proximity to the Euphrates and the presence of small proportions of fish bones (Legge 1975: 75) do imply that fishing was a minor activity undertaken by the inhabitants. This is substantiated by the occurrence of two possible fishhooks. The restricted sampling undertaken at Abu Hureyra may have failed to reveal activity areas where fish remains and hooks would have been more plentiful.

Hooks of any style are very rare in the Levantine Mesolithic and Neolithic. Fishhooks were reported from the Natufian deposits of Kebara (Stordeur 1979). All three hooks from Abu Hureyra were collected from Neolithic levels.

Flat Implements

Several fragmentary implements were found at Abu Hureyra whose functions cannot be readily assessed. Their complete morphology can only be reconstructed based on common features of the fragments and on the two nearly whole specimens. The broken pieces share enough characteristics to imply that they represent a particular type of artifact. Many of the examples were fabricated from ribs of large ungulates, either cattle or equids (Fig. 111a-d). The ribs were split from margin to margin longitudinally by grooving along the outer compact bone and breaking through the delicate trabeculae of the inner, cancellous tissue. The bases were made by segment-

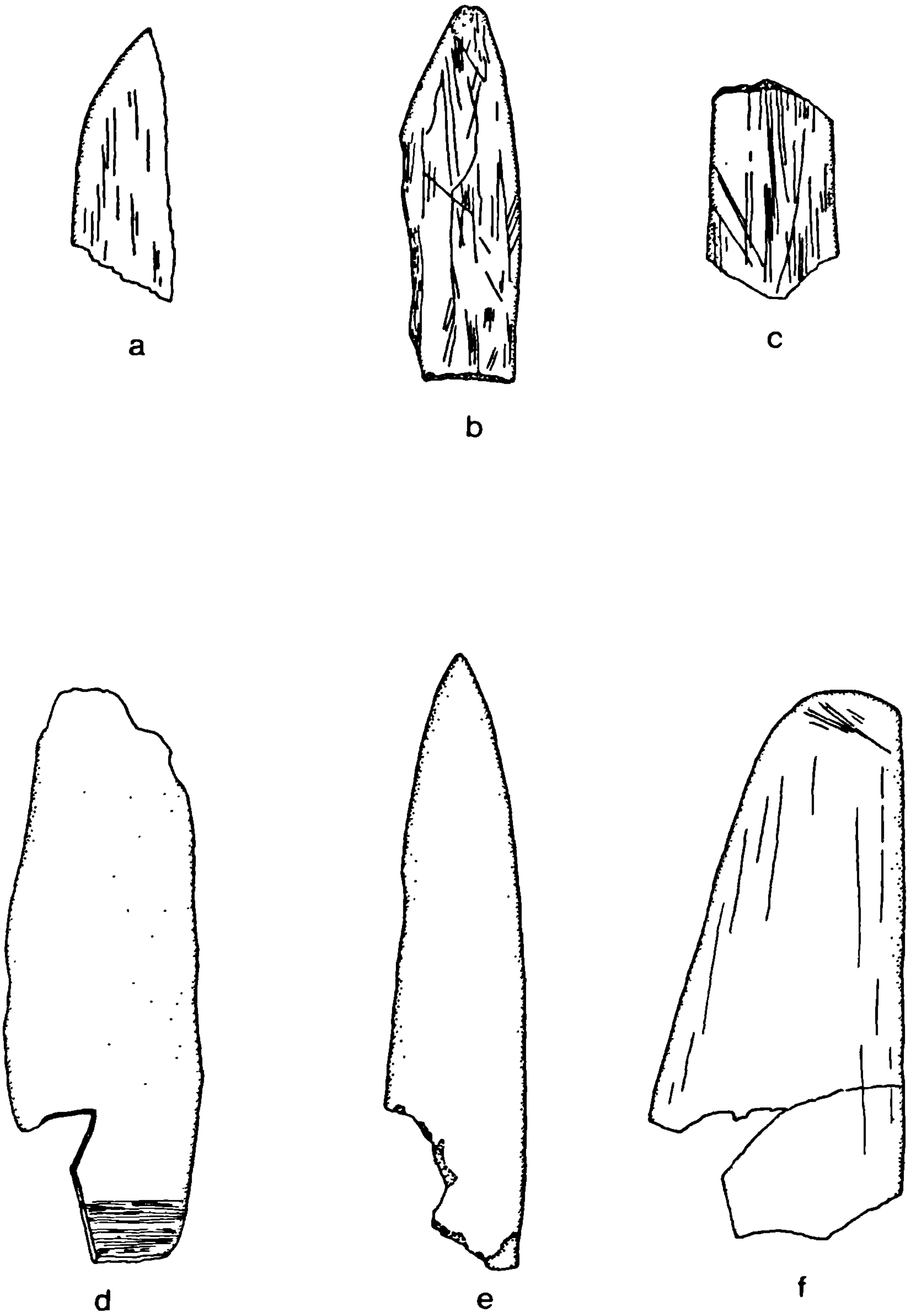


Fig. 111 a,b,f. flat implements made on large mammal bones, c,d,e. flat implements made on cattle ribs. Scale 1:1.

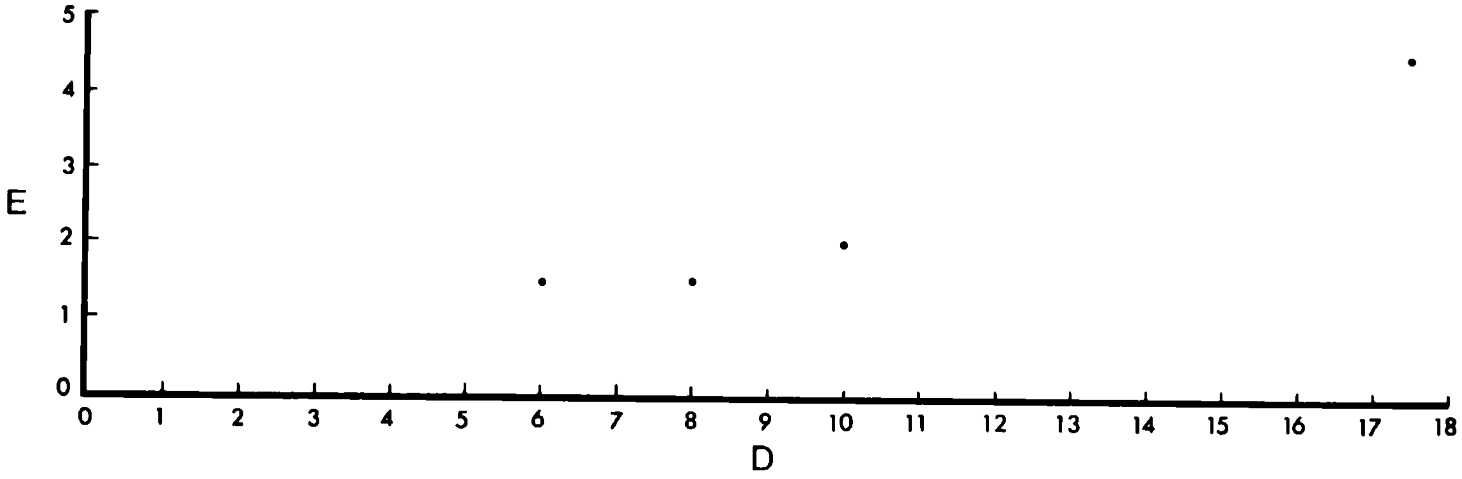
ing the rib with transverse grooving and snapping or by breaking and lightly grinding one end. The splitting of the rib must have been aimed at forming a thinner blade, although the margins were never sharpened. Splitting does produce twice as many tool blanks, but since these artifacts have a very low frequency at the site and unworked cattle and equid ribs are relatively common in the faunal remains, this does not seem to be a significant factor. The ribs of small ruminants, such as sheep, goats, and gazelle, are delicate enough without splitting to form tools with thin margins, but even the upper five ribs are much narrower than the flat implements. It appears that, while keen edges were not necessary to the tool's morphology, the blade was designed to be thin and relatively broad.

Other examples of flat implements were made from large mammal long bone splinters which were somewhat smoothed around the edges by light transverse abrading or longitudinal scraping (Fig. 111e, f). The majority of the flat implements also exhibited deep striae from longitudinal scraping on the external surface of the cortical bone. All have broad, flat cross-sections and parallel edges along the shaft. Where present the tips have large angles of convergence and the outlines of the tips are convex or asymmetric with one straight and one curved side. The bases are roughly squared off. Lengths of the two nearly complete specimens is not great (5.2 and 6.9 cm), but an extremely robust example made on a femur of Bos sp. indet. is 15.8 cm long and other fragments are between 8 and 9 cm in length. Scatter Diagram 3 (Fig.

112) shows the range of tip dimensions on four specimens which were sufficiently complete for measuring.

Use wear on these artifacts consists primarily of a polish along and confined to the rounded edges from the tip to as much as 4 to 5 cm up the shaft, except for the largest specimen which has polish around the end and far up along one edge. Ten out of 18 of the flat implements from Abu Hureyra were blackened from burning, a much higher proportion than exists for other bone artifacts in this collection. The function of this tool is problematical. While the general form is similar to a knife, the edges are not sharpened to make a keen blade for cutting. The polish is similar to that found on hide scrapers, but a pointed tip would not be necessary or desirable for removing hair or flesh from animal skins and the edge should be honed if it were to be used as a scraper. It is possible that the implements were employed in weaving, which would explain the broad, flat shaft, the wide but pointed tip and the polish along the edge. Some of the very long examples of flat implements, such as one from Ghoraife which is 28 cm in length (Stordeur 1982:16) would have worked very well as shedding tools for weaving with a simple loom. Used in this way, the shorter examples from Abu Hureyra would not have been very practical.

Since over half of the flat implements from Abu Hureyra are burned, this may have some relevance to their function. None of the pieces were calcined to the point of becoming grey, chalky white, cracked, or warped des-



$\overline{E}/\overline{D} = 2.4/10.4$ mm

Fig. 112 Scatter diagram 3: gross dimensions for Abu Hureyra flat implements.

pite the fact that experiments have shown that bone discarded on a fire or even hot coala can reach this state within 15 to 30 minutes if no soft tissue such as ligaments or periosteum is present to serve as an insulator. The burning does not, therefore, appear to be caused by disposal practices. Without forming a definite conclusion regarding the function of flat implements, the incidence of burning may suggest that the tools were used in some manner for cooking. This hypothesis requires further evidence such as experimental use of the tool in cooking or discovery of contextual information that may shed light on their use. If they were culinary utensils the flat implements made on cattle ribs may have been split in order to remove the red marrow in the cancellous tissue which would spoil over time. By scraping off all of the soft tissue including the periosteum on the cortical bone, splitting the rib, and removing the marrow through boiling, a sanitary cooking implement that would not contaminate food could be produced. This would provide one possible explanation for implementing the delicate and time-consuming task of grooving and splitting ribs when no keen edge was then shaped for cutting. It could also explain the deep longitudinal scraping striae on the cortical surface when the shape of the surface is basically unaltered and the bone is naturally very smooth. Light burning could have occurred frequently by setting the utensil on a stone or container too near the fire for brief intervals. Possible uses for the tools might include stirring large containers of food and turning over or removing fried bread from the stone surface upon which it is cooked.

All but one of the flat implements found at Abu Hureyra were recovered from Neolithic levels. The one discovered in the Mesolithic levels of Trench E was from an area designated as "complex fill", so it is possible that some mixing had occurred. Similar tools have been found at the sites of Mureybat (Stordeur 1978), Jericho (Marshall 1982), Aswad, Ghoraife, and Ramad (Stordeur 1982). Stordeur classifies these implements as "couteaux plats," or flat knives, but her classification is more inclusive than the one presented here, taking in narrow-shafted tools made on medium mammal long bones (Stordeur 1982: 16).

Spatulae

Four artifacts are tentatively labeled as spatulae, but their low frequencies make it uncertain whether they represent a distinct type. Two are similar in appearance, each consisting of a small mammal long bone which has had one end removed and part of the shaft broken away. The rough edges from the midshaft to the tip were then scraped longitudinally until smooth. In both cases the tip was unmodified during manufacture and was left as wide as the shaft. One was made on the radius of a felid (Fig. 113a), while the other was a tibia of a red fox (<u>Vulpes vulpes</u>). In both specimens, which were collected from Levels 9 and 11 of Trench Extension E2, the articular condyle at the base was unaltered and most of the length of the diaphysis was retained. The third example, derived from Trench B, Level 2, was a small splinter from

Fig. 113 a. spatula made on a felid radius, b. awl made on a ruminant metapodial with the proximal end as the base and incised cross-hatched design on the shaft, c. shaped awl with a plain base, d. splinter awl made on a ruminant radius, e. utilized splinter of a ruminant tibia, f. utilized splinter of a ruminant metapodial. Scale 1:1.

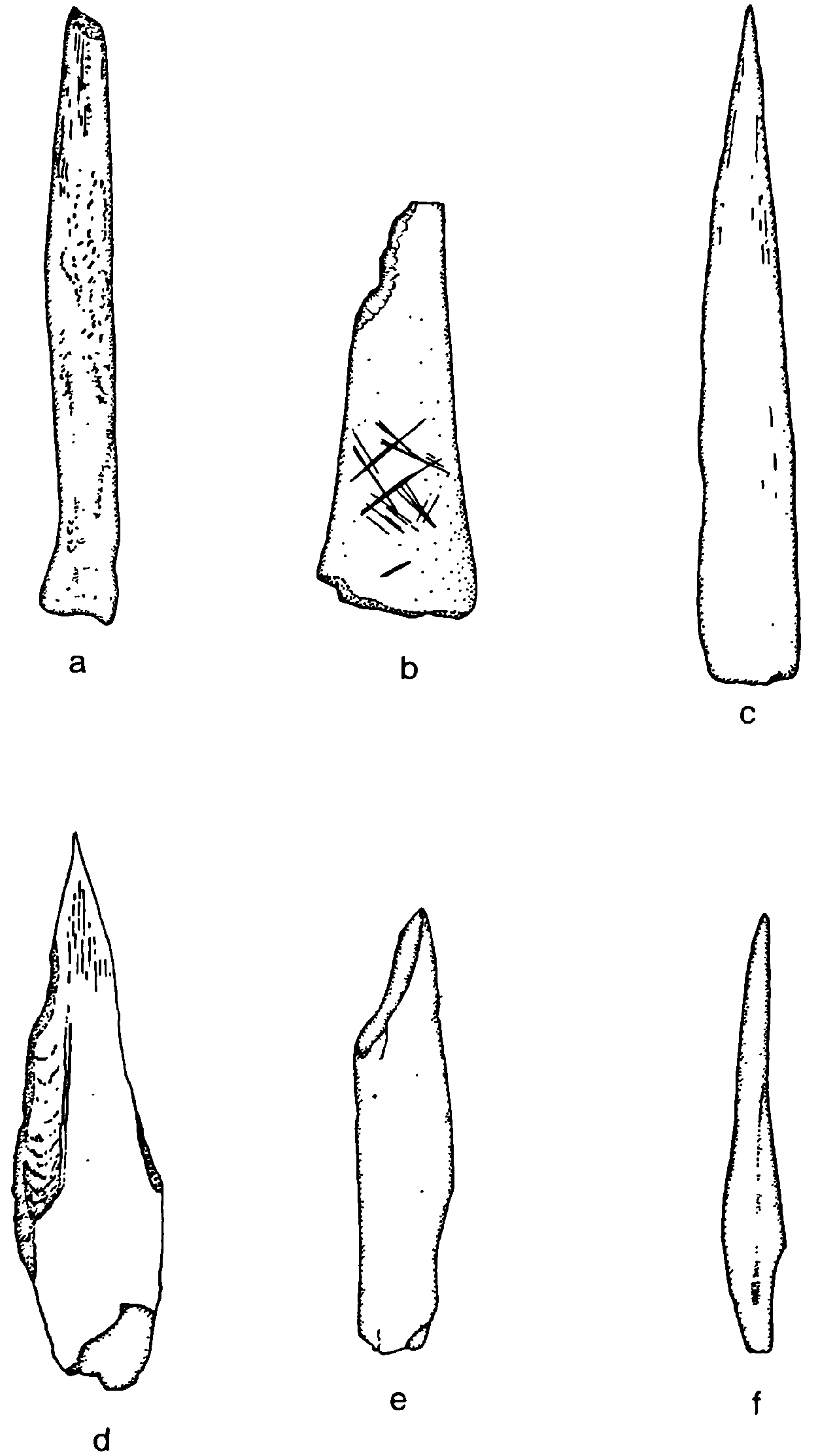


Fig. 113

a flat bone of a medium-sized mammal that was scraped along the shaft's surface and the tip without altering the edges. The fourth, from Trench D, consists of a broad tip fragment of a spatula made on a large mammal long bone.

The three spatulae which were complete enough to be measured demonstrated little conformity in gross morphology (Fig. 114), position of the maximum width on the shaft (Fig. 115), or tip dimensions (Fig. 116). All of the spatulae possess light use polish just along the working edge of the tip. No definitive evidence for a particular function presents itself. Determination of their use awaits additional occurrences at other sites which provide clues through their contextual association, or breakthroughs in the analysis of polishes. All four spatulae were derived from Neolithic levels.

Utilized Splinters

The existence of wear on fragments of long bones from medium to large mammals indicates they were used without any modification beyond breakage. Those splinters that possess diagnostic characteristics are limb elements such as the humerus, ulna, metacarpal, tibia, and metatarsal of small ruminants (Fig. 113e, f). No traces of grooving and snapping, scraping, grinding, or other manufacturing techniques are visible on these implements with the exception of one gazelle ulna which has had the ridge of the semilunar notch abraded off.

The splinters were in general quite irregular and variable in size and shape, as is expressed in the graphs of their measurements. Several interesting features may

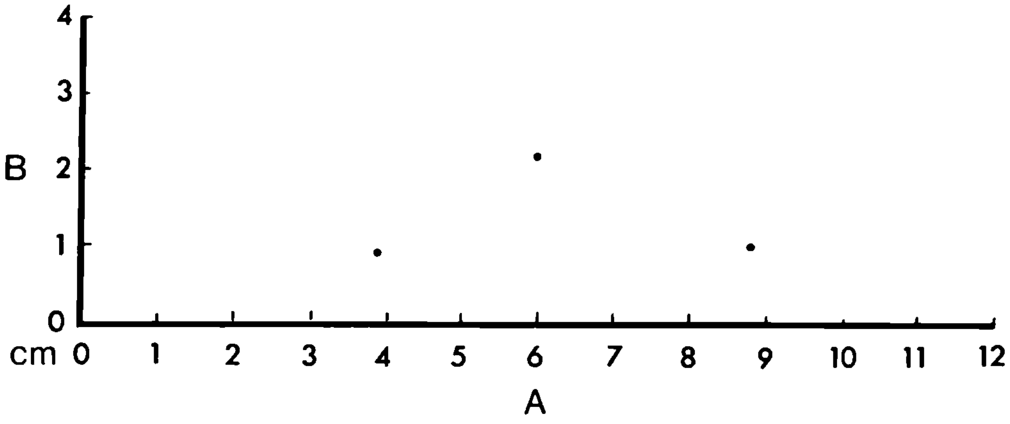


Fig. 114 Scatter diagram 1: gross dimensions for Abu Hureyra spatulae.

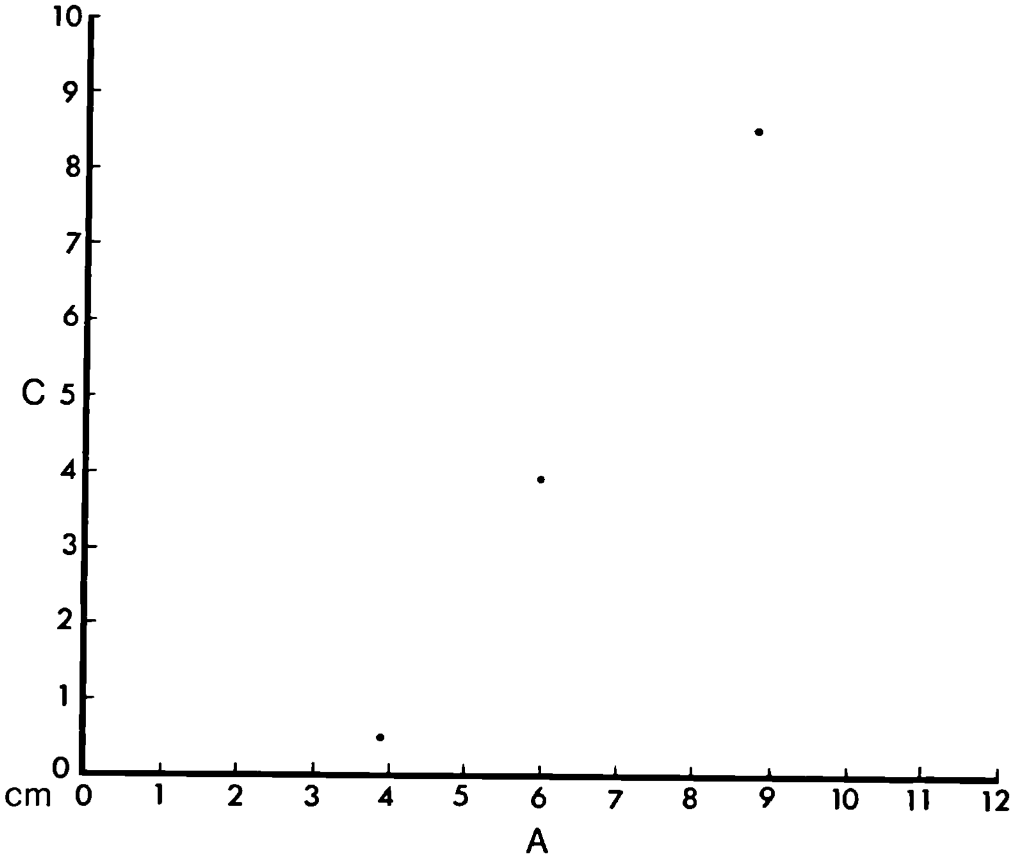
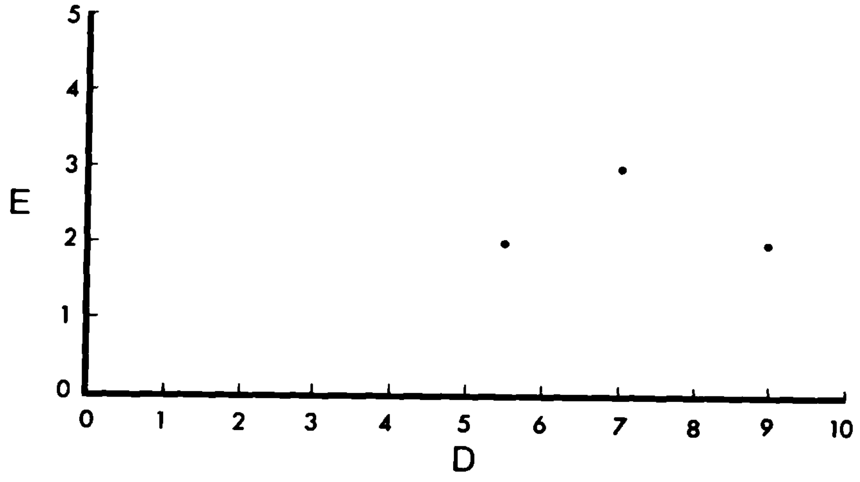


Fig. 115 Scatter diagram 2: location of maximum width on the shaft for Abu Hureyra spatulae.



$\bar{E}/\bar{D} = 2.3/7.2$ mm

Fig. 116 Scatter diagram 3: tip dimensions for Abu Hureyra spatulae.

be noted regarding their morphology. The first is that since no modification is performed their lengths vary greatly (from 3.7 to 9.8 cm) (Fig. 117). Widths are somewhat more uniform at under 2 cm, due to limiting factors built into the bone itself. Secondly, the location of the maximum width tends to be in the basal half of the shaft, but is still fairly variable (Fig. 118). Thirdly, the tips range from rather fine points to broad spatulate ends. The cross-sections are usually triangular or trapezoidal instead of round or lenticular since the converging broken edges are not shaved down during fabrication. Tip width and thickness measurements demonstrate extreme diversity with widths varying from 2 to 12 mm and thickness from 1 to 3.5 mm (Fig. 119).

Utilized splinters may have been opportunistic multipurpose utensils, but their wear patterns suggest that one function predominated. The only evidence that these irregular fragments were employed as tools is the consistent distribution of two types of wear patterns. The splinters, regardless of the breadth or shape of the tip, are polished at one end. This polish is distributed unevenly about the edges and medullary surface of the tip, but is more highly concentrated on its external, convex surface. The extent to which the polish spreads up the shaft is variable (from 1 to 40 mm from the tip), but it tends to be localized about the tip. On the external surface accompanying the polish are often found extremely fine transverse striations. These rarely overlap onto the broken edges or occur on the inner, concave

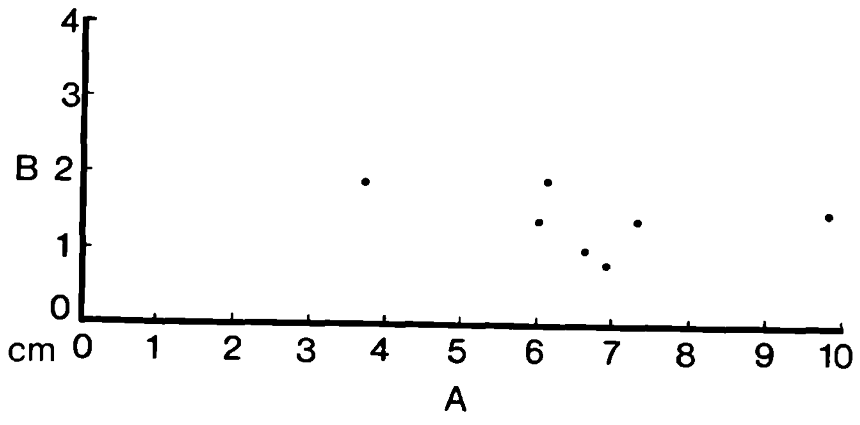


Fig. 117 Scatter diagram 1: gross dimensions for Abu Hureyra utilized splinters.

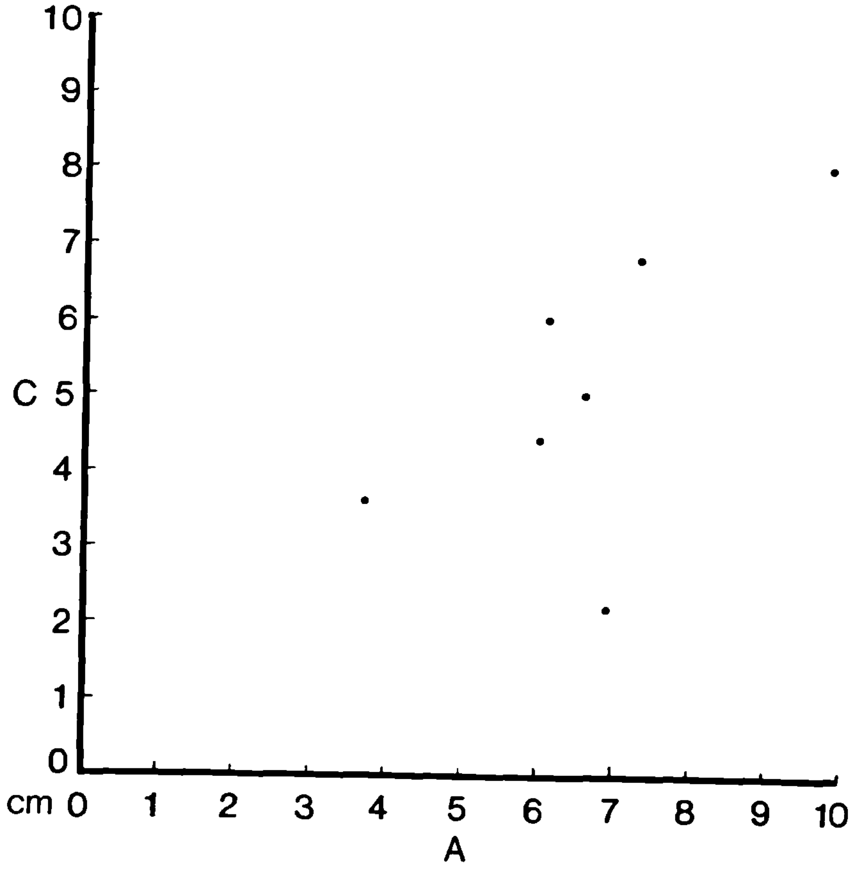
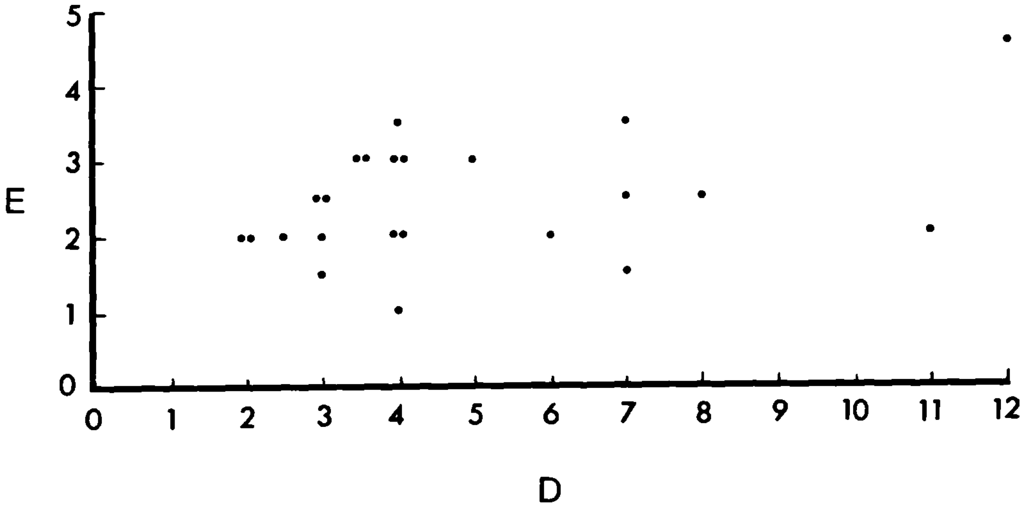


Fig. 118 Scatter diagram 2: location of maximum width on the shaft for Abu Hureyra utilized splinters.



$\overline{E}/\overline{D}=2.5/4.9$ mm

Fig. 119 Scatter diagram 3: tip dimensions for Abu Hureyra utilized splinters.

surface. The function which created these traces cannot be identified with certainty. Despite the mild abrasive action which caused the fine striae, no facets were worn in the surface of the bone. The directionality of movement must have been chiefly perpendicular to the long axis of the splinter. The task does not appear to have required a particular type of working end, since both delicate points and broad, spatulate tips exhibit identical traces. Occasional contact must have occurred between the unknown material and the splinter's inner surface, but with less frequency than with the external surface. It seems probable that the function of these fortuitous splinters might have been something akin to burnishing, smoothing, or flattening of soft substances such as animal hides or plant fibers. Those with fine tips may have occasionally substituted for awls, which could account for the presence of light polish on the asperities and ridges along the edges and inner surfaces, but polish also occurs on the inside of those with spatulate tips.

Utilized splinters have a long temporal span at Abu Hureyra. They are present in the lower Mesolithic levels of Trench E, as well as the Neolithic levels of Trenches B, C, and E. Recognition of these implements requires careful inspection of the faunal material, since they are difficult to identify before they are washed and examined under a strong light. Credit for retrieving many of these tools should be given to A. Legge and P. Rowly-Conwy who are analyzing the faunal remains from the site. If the use wear patterns, especially the directionality and location of the striations, had not been highly consistent the author might have attributed the surface modifications to natural processes. Bone fragments from Abu Hureyra did not show similar traces distributed randomly over the r surfaces to suggest that soil abrasion or other taphonomic processes were responsible. It would thus be difficult to account for the consistency of the concentration of polish and transverse striations at one end of splinters, primarily on the external surface, through natural processes.

Awls

There are three basic kinds of awls from Abu Hureyra, differentiated on the basis of their form and technique of manufacture rather than alternative functions. There is a range of sizes of tips within each of the three categories of awls but no significant difference between the groups. The predominant form of tip in each case is round in cross-section and measures between 1 and 3.5 mm in diameter. Although awls in general may have been used on a variety of materials, especially hides and baskets, there is no evidence to suggest that any of the three "styles" was chosen for a particular function. Instead, the most important difference seems to be the amount of time and effort allotted for their manufacture.

Since the tips of awls were sharpened by scraping, the most consistent traces at the functional end are comprised of longitudinal striations and chattermarks formed during manufacture. Frequently, the manufacturing marks are partially obliterated from the end of the tip to a distance of a few millimeters up the shaft by use polish. More rarely, excessive attrition causes a sharp reduction in the diameter of the tip, forming a shoulder between the shaft and the point. The length of the tip below the shoulder is thus likely to be highly indicative of the depth of penetration of the awl during use. Occasionally, a series of concentric striations appear around the tip that suggest the awl was rotated as it bore into a material. The microcutting of fine scratches in the tip's surface may have been caused by particles in the substance upon which the awl was used or simply by the presence of grit between the tool and the other material. The fourth kind of use damage is breakage of the tip. That breakage was not infrequent during use is evidenced by the fact that some of the awls from Abu Hureyra have considerable polish overlying fractured surfaces. Two kinds of fractures are represented with high frequency. The first, a clean transverse break occurring at right angles to the awl's upper and lower surfaces, is found on all types of artifacts and at various locations on their shafts. Associated with bone which has had much of its organic matrix denatured or dehydrated, straight transverse breaks are often postdepositional. These do not show evidence of reuse on their fracture surfaces. The second kind of breakage pattern is defined as "impact fracture" because it happens when the tip meets a resistant body with sufficient force to drive a flake off the end of the awl's point. Although this may include accidents such as dropping the awl with the point downward, it is less likely that impact fractures occur once the tool has been incorporated in archaeological deposits. It is on this type of fracture that the use polish is sometimes found.

As has been discussed earlier, awls may serve as piercing instruments in a variety of tasks. The most common ethnographic uses are for perforating hides and in weaving coiled baskets. Either of these functions produces polish and may eventually lead to shouldering of the lower shaft. Concentric striae could be formed if particles of grit were present on the hide or plant fibers. There is no direct evidence that hides were sewn at Abu Hureyra, though the faunal material implies they were readily available. Woven materials have been indirectly preserved through impressions (Moore 1979: 69), however none of these appear to have been made with the coiling technique. Plaited and twined baskets do not require the use of an awl during manufacture.

Splinter Awls

Splinter awls require the least amount of energy input during their fabrication. After breaking the bone, the second step in the manufacturing process consists of simply selecting a suitable splinter, i.e. one with sufficient length for holding, fairly regular sides, and a narrow end. Following this, the narrow end was scraped longitudinally until it was thin, relatively round in cross-section, and smooth (Fig. 113d). Occasionally the scraping extends further up on the external convex surface, but not completely up the edges of the shaft in this case. The entire manufacturing process would generally have taken less than 15 minutes to complete and the tool would have functioned just as efficiently as one made by more elaborate means. The only disadvantage for long term usage, aside from the aesthetic factor, might be a less comfortable grip than that provided by an awl with a straight-sided handle.

For the majority of the splinter awls there were insufficient diagnostic characteristics to identify the taxonomic group or element selected, except that they were made on long bones of medium or large mammals. One was definitely fabricated from a limb element of a large bird and another from a bird or small mammal bone. Among those that possessed identifiable traits were a radius, two tibiae, a metacarpal and a metatarsal of small ruminants.

Splinter awls, because of the lack of alteration above the tips, have a range of lengths and maximum widths similar to that for utilized splinters. In this case the total lengths span from 3.2 to 9.4 cm and the widths from .4 to 2.1 cm. (Fig. 120). Only one specimen has the location of the widest part of the shaft just below the midpoint. A few approach the midpoint but are still within the basal half (Fig. 121). There is a general trend for increased width with increased length.

The greatest contrast between utilized splinters and splinter awls appears when their tip morphologies are compared. The splinter awls have round or oval tip cross-sections and cluster in a small area of the graph (Fig. 122). Tip width ranges from just 1 to 3.5 mm and

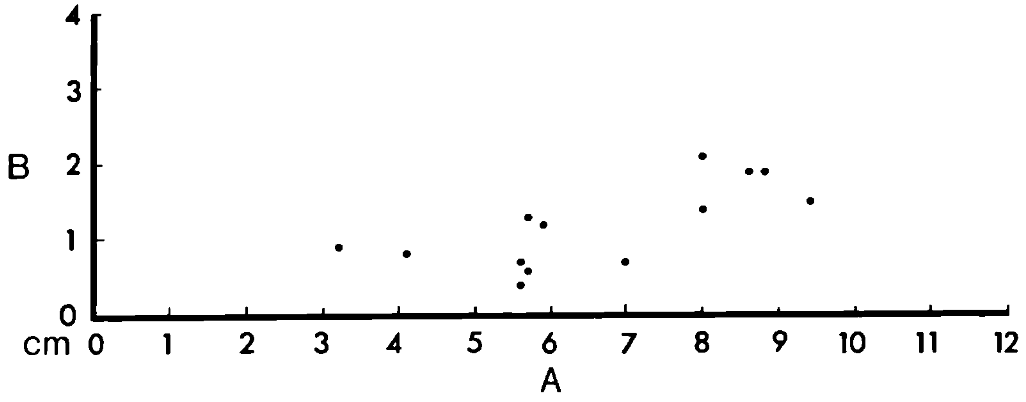


Fig. 120 Scatter diagram 1: gross dimensions for Abu Hureyra splinter awls.

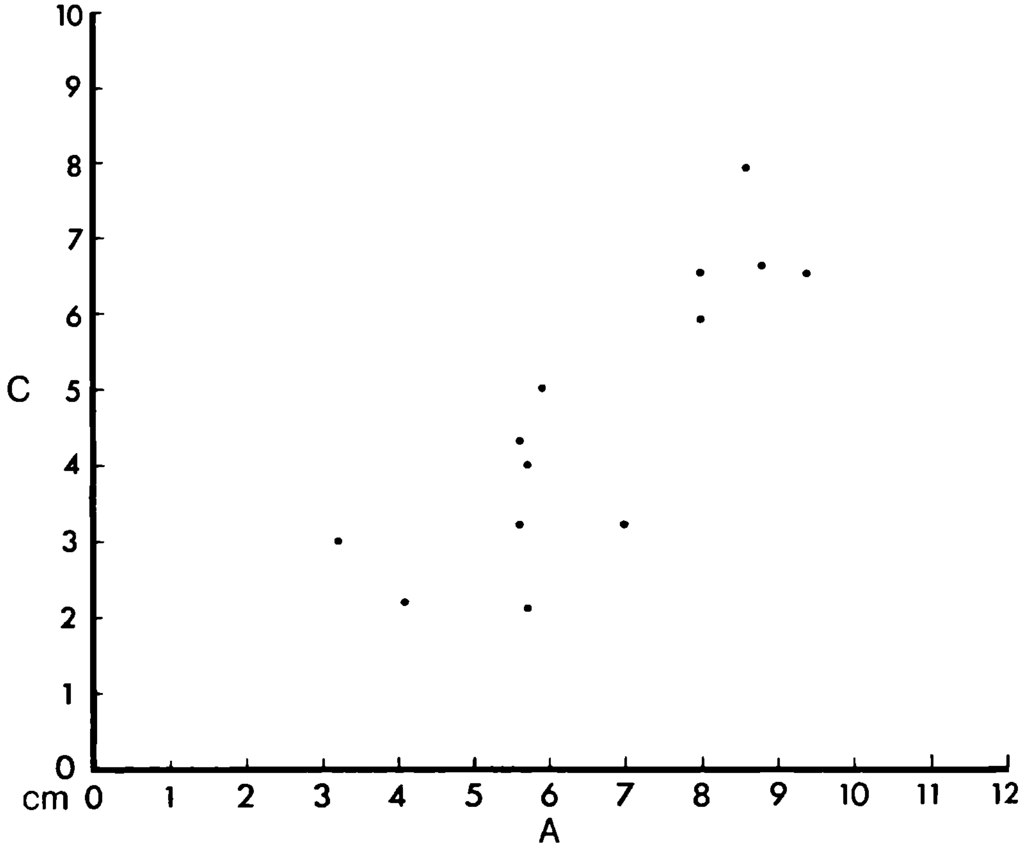


Fig. 121 Scatter diagram 2: location of maximum width on the shaft for Abu Hureyra splinter awls.

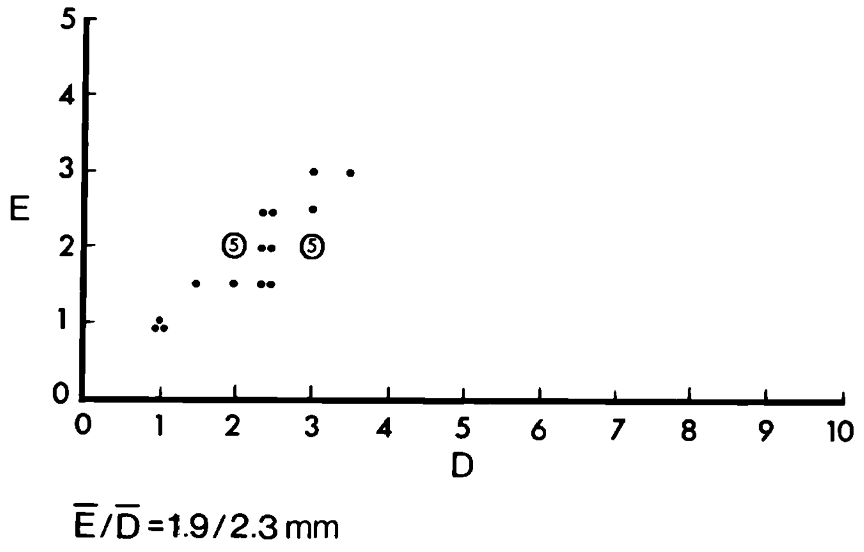


Fig. 122 Scatter diagram 3: tip dimensions for Abu Hureyra splinter awls.

thickness from 1 to 3 mm.

Use wear was nearly always expressed in the same way: a polish evenly distributed around the tip, spreading up just a few millimeters from the end. This lustrous polish obliterates the longitudinal striae created during manufacture nearest the tip, but as the polish fades further up the shaft the scraping traces become gradually more crisply defined. Three of the awls are burned at the tip.

Splinter awls have a long tradition in the Near East extending into the Upper Paleolithic at Ksar Akil (Newcomer 1974). As at Abu Hureyra, five of the awls from Ksar Akil have been exposed to fire at the tips (Newcomer 1974: 142). Splinter awls have also been reported at Mureybat (Stordeur 1978), Aswad, and Ghoraife (Stordeur 1982). At Abu Hureyra they occur in the Mesolithic and are plentiful in the Neolithic.

Shaped Awls with Plain Bases

The second style of awl found in this assemblage has had additional finishing work conducted during manufacture. The bases of the nine complete specimens are formed simply by breaking or by transverse grooving and snapping through the bone's diaphysis. No articular condyle is present. The fabrication of these awls usually consists merely of using a flint implement to smooth the irregular edges of a fortuitous splinter and sharpen one end (Fig. 113c). The convex external surface and base were also occasionally scraped. Awls of this kind may be distinguished from splinter awls by the presence of longitudinal striae and chattermarks along the edges.

The scraping of the edges of fortuitous splinters smooths and rounds their angles, but their outline still retains a wavy conformation.

There are very few whole examples in this category, but many of the indeterminate awl fragments of shafts and tips were very likely derived from shaped awls with plain bases. Although nine of the whole or nearly complete specimens were made by scraping down splinters, one was manufactured by longitudinal grooving and snapping. Grooved and snapped awls often retain traces of this manufacturing technique in areas where scraping has failed to completely obliterate them, but the clearest indication that the blank was predetermined n this manner is the uniform straightness of the sides.

Only four of these awls were complete enough to be recorded on the graph for overall morphology (Fig. 123), so little significance can be placed on their measurements. They demonstrated variability in length, but were all quite narrow. The maximum width was located at the base or just below it in the four cases measured (Fig. 124). Great conformity was visible in tip morphology with a range of 1.5 to 3.5 mm for tip width and 1 to 2 mm for tip thickness (Fig. 125).

Recognition of shaped awls with plain bases is difficult on fragmentary pieces since if the base is missing it is usually not possible to separate them from awls which might have had an articular condyle at the base. They have been identified at Mureybat (Stordeur 1978: 83-84, Fig. 37), at Aswad (Stordeur 1982: 13-14), and at

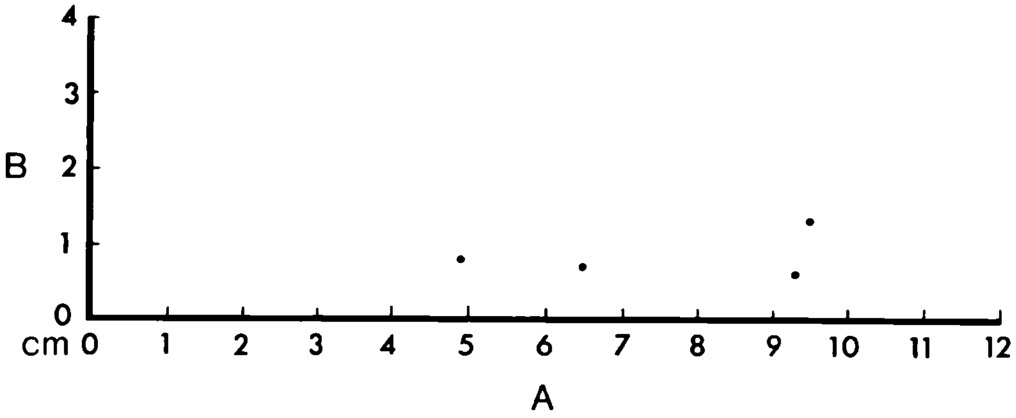


Fig. 123 Scatter diagram 1: gross dimensions for Abu Hureyra shaped awls with plain bases.

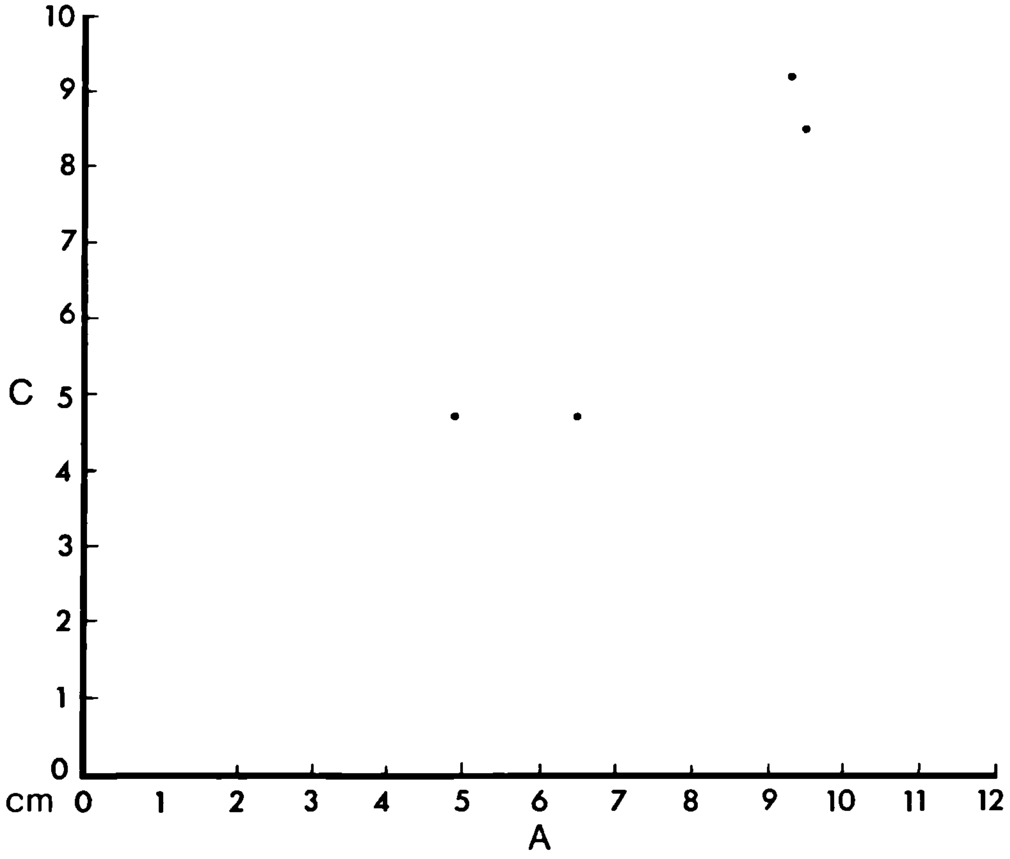
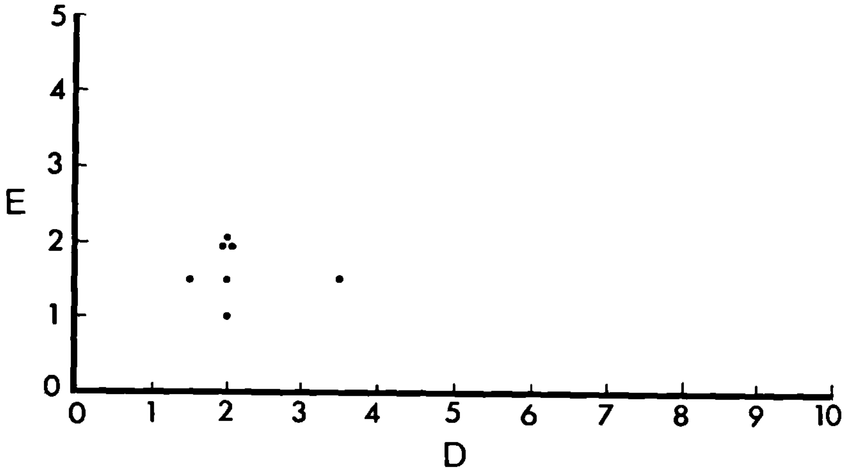


Fig. 124 Scatter diagram 2: location of maximum width on the shaft for Abu Hureyra shaped awls with plain bases.



$\overline{E}/\overline{D} = 1.7/2.1$ mm

Fig. 125 Scatter diagram 3: tip dimensions for Abu Hureyra shaped awls with plain bases.

Ramad (Stordeur 1982: 15). Three from Abu Hureyra were collected from Mesolithic levels of Trench E, while the others were found in Neolithic levels of Trenches A, B, C, D, E, and G.

Awls with Articular Ends as Bases

The third group of awls is a heterogeneous category in which the shared feature is the retention of one of the articular ends of a long bone at the base. In general the tips conform to the morphology of other awls, i.e. they are round or oval in cross-section and exhibit polish up from the end a few millimeters. Treatment of the shaft varies according to the element that was selected.

The gross morphology is expressed in the graph (Fig. 126) as a fairly close cluster with the exception of the two ulna awls and a very long metapodial awl. The location of the maximum width of the shaft is, with the exception of the two ulnae, very near the basal end (Fig. 127). Because of the morphology of the proximal ulna in which the apex of the coronoid process is wider than the olecranon process and is situated between 2 and 3 cm below the basal end, the maximum width is further down the shaft. The tips of some of these awls tend to be wider than any seen among the other two styles (Fig. 128), but this is often because the position in which the measurement is taken (5 mm from the end) is on a shoulder below which the tip diameter diminishes rapidly. The tip width ranges from 1.5 to 6 mm and the thickness from 1 to 3 mm.

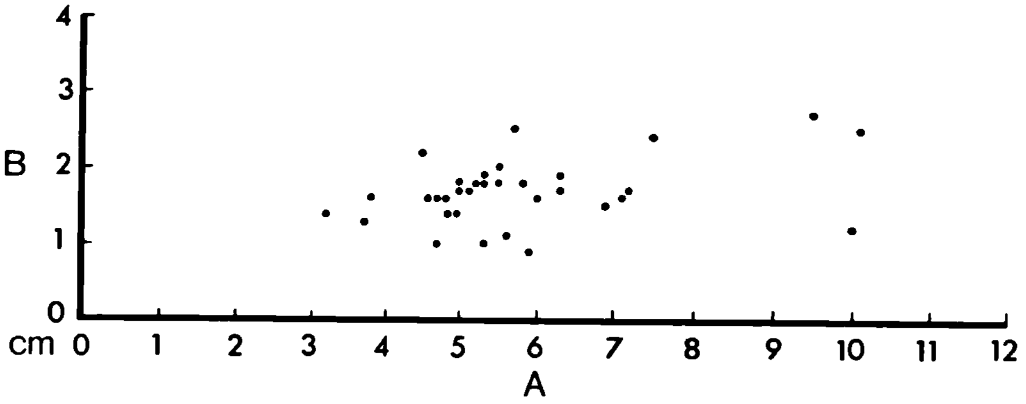


Fig. 126 Scatter diagram 1: gross dimensions for Abu Hureyra awls with an articular end as the base.

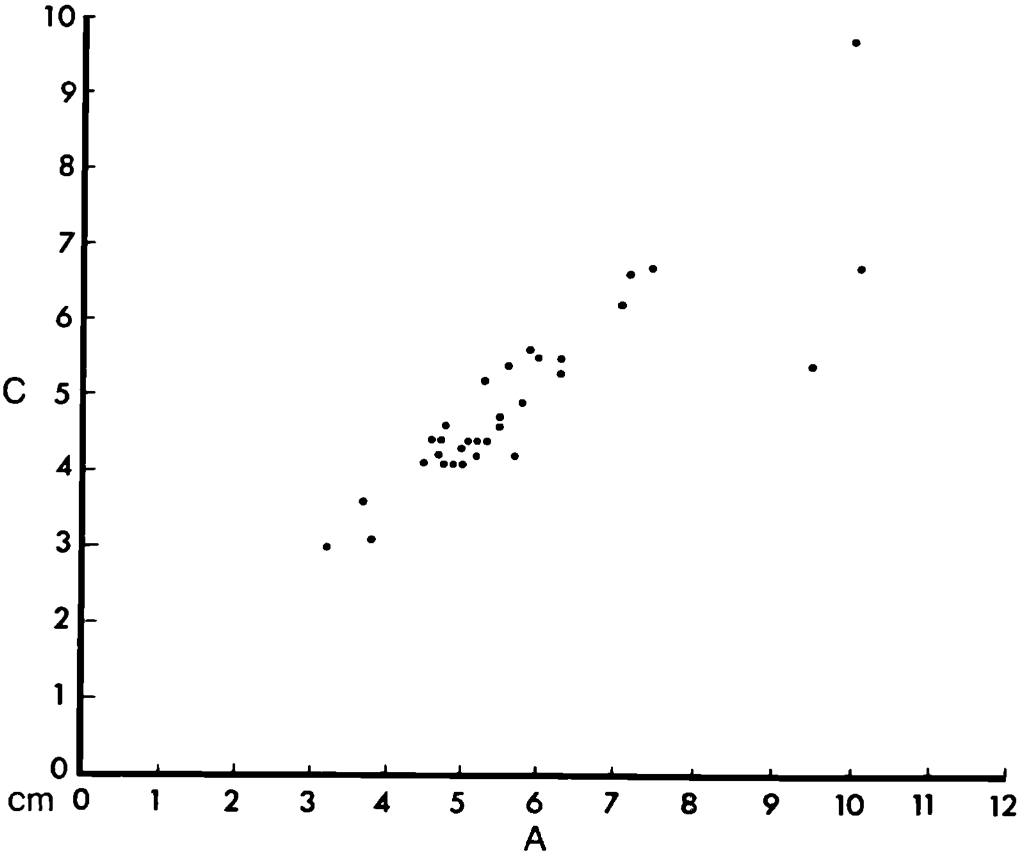
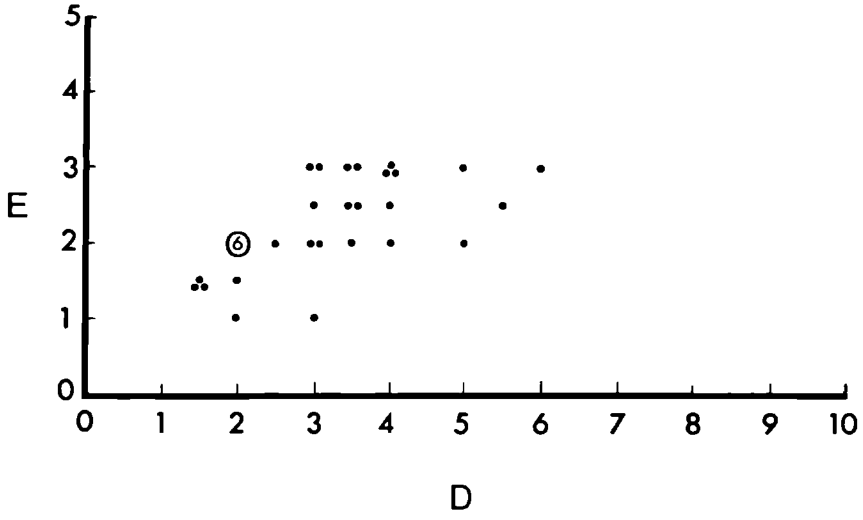


Fig. 127 Scatter diagram 2: location of maximum width on the shaft for Abu Hureyra awls with an articular end as the base.



$\overline{E}/\overline{D}$=2.2/3.1mm

Fig. 128 Scatter diagram 3: tip dimensions for Abu Hureyra awls with an articular end as the base.

The ulnae of small ruminants were probably chosen as raw material because of the ease with which they could be converted into awls. Without modifying the proximal end the tool becomes functional simply by breaking off the distal epiphysis and sharpening the broken diaphysis to a point (Fig 129d). To further smooth and taper them, the shafts of many were also longitudinally scraped.

Postdepositional breakage was frequent on these specimens, but the majority appear to have conventional tips. One ulna awl, derived from Trench Extension E4, Level 41, is exceptional, however, in having a broad, flattened tip that may have served a function other than piercing hides or working baskets. The tip and posterior margin of this implement are well-polished from wear which is reminiscent of that visible on the Point of Pines ulna tools. All of the ulna awls from Abu Hureyra appear to be Neolithic.

Also selected because its natural form facilitated manufacture is the fourth metatarsal of small equids (Fig. 129e, f). This vestigial element has a substantial proximal articular surface, but tapers to a point at the distal end which requires minimal sharpening to convert it into a useful piercing implement. All of the examples from Abu Hureyra were scraped along the shaft and tip to remove ridges and round the contours, but only small quantities of bone were actually removed. Polish at the tips muted the long striations and one fine example was noticeably shouldered from use (Fig. 129f). One of the awls made on *Equus* metatarsals is from a Mesolithic level in Trench E, but the other four are all derived from

Fig. 129 a. manufacturing debitage consisting of a proximal end of a sheep or goat metatarsal with extensive rodent gnawing, b. awl made on the distal end of a ruminant tibia, c. awl made on the distal end of a sheep or goat tibia, d. awl made on a sheep or goat ulna, e-f. awls made on fourth metatarsals of small equids. Note shouldering of the tip on f from use. Scale 1:1.

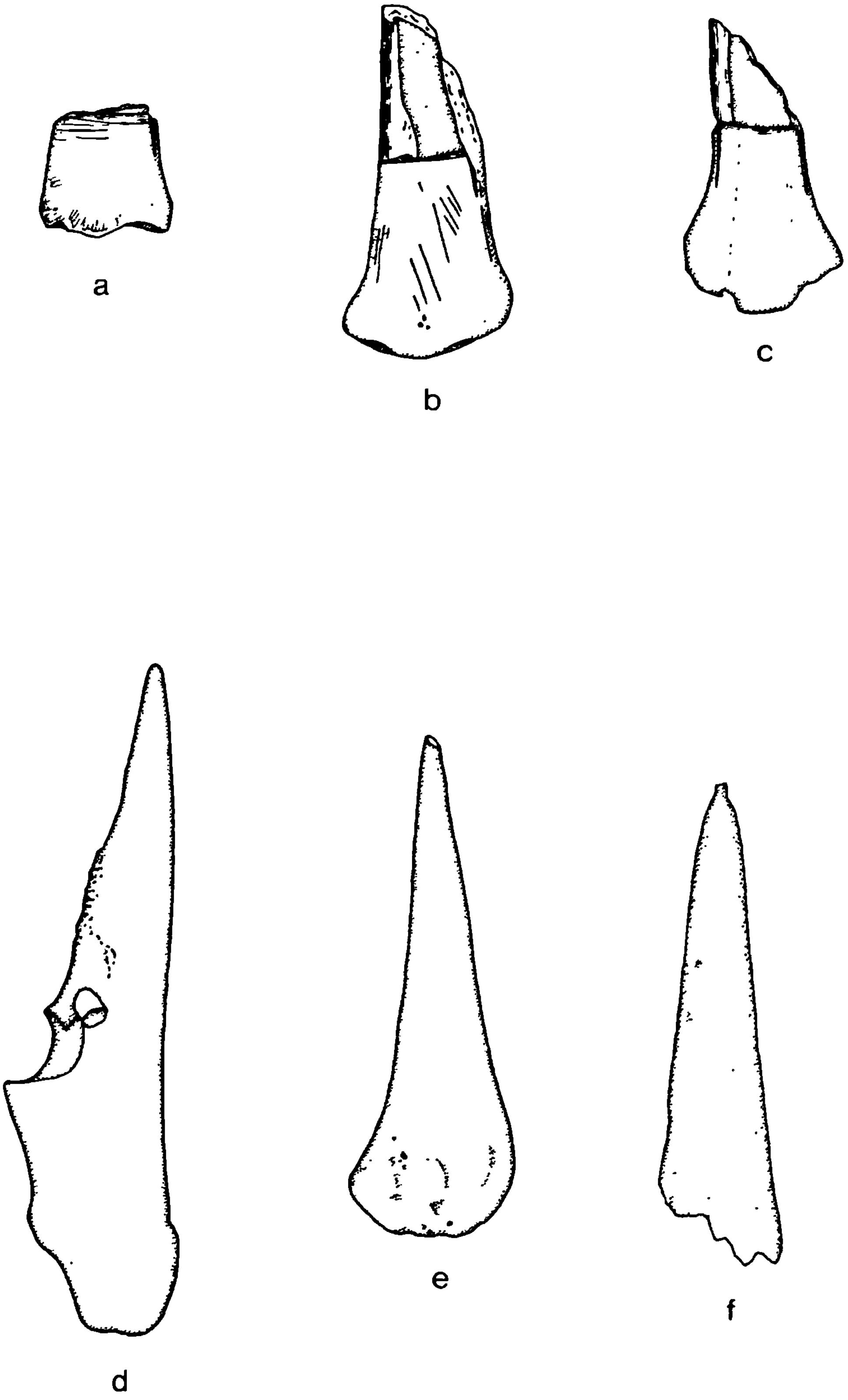


Fig. 129

Neolithic deposits in Trench C.

A unique specimen consisting of the proximal condyle and a portion of the diaphysis of a felid fibula was probably the base of an awl. Although the articular surface was unmodified, the shaft was scraped longitudinally and bore considerable handling polish. Given the narrow width of the shaft it seems very likely that the working end would have served as an awl rather than a more robust tool such as a spatula.

Combining the retention of an articular end and the groove and snap technique, awls made from tibiae and metapodials of small ruminants are especially well designed. The three made from tibiae retained the distal epiphysis, which was ground until most of the eminences were removed. Two long grooves were made down the medial and lateral surfaces of the bone, followed by an intersecting transverse groove below the base (Fig. 129b, c). When these grooves were snapped the handle consisted of the intact distal end of the diaphysis and the articular end, while the rest of the shaft and tip of the tool were made on only one surface of the diaphysis. Unfortunately, none of the tips of these awls was preserved.

The most frequent type of awl at Abu Hureyra was one made on a metacarpal or metatarsal of a small ruminant. The choice of these elements, which are popular in many bone artifact assemblages, seems to be based on their availability and the straightness of their diaphyses. In this collection the proximal and distal articular ends served as the base of awls in about equal proportions.

With the exception of awls that utilized the whole distal condyle (only four specimens) grooving and snapping was used to reduce the body to a thin, tapering shaft.

Metapodial awls which retained the proximal end were relatively standardized in form. Only one kept the whole articular surface intact, although the continuation of the longitudinal grooves up to the edge of the flat articular surface suggests that it was originally intended to be severed completely in half. Instead, a transverse groove was cut to take off one side below the base as in the case of awls made on tibiae. The others varied in the amount and part of the proximal articular surface and diaphysis retained, but were all made substantially according to one pattern (Fig. 130e). Tapering longitudinal grooves were cut from the proximal end to a location near the middle of the diaphysis where they converged. A sharp point with a round or oval cross-section was made by scraping with a flint tool. The edges and external surface were scraped, but the articular surface of only one specimen was abraded.

Three of these awls were incised on the shaft just below the base. On two a series of transverse lines were present. The third had a diagonal cross-hatched design roughly cut into its external surface (Fig. 113b). The high polish and rounding of the edges of the incisions imply considerable handling and it may be that the grooves improved the grip on these otherwise smooth shafts.

Awls made on the proximal portion of metapodials of small ruminants have been recovered at ha-Yonim (Bar-

Yosef and Tchernov 1970: Fig. 2.10), Jericho (Marshall 1982), Mureybat (Stordeur 1978: 84) and Ramad (Stordeur 1982: 17).

The four specimens that retained the whole distal condyle as the base showed no uniformity of manufacturing procedures. One had been grooved sagittally as far as the condyle, but when it was snapped prematurely the crack was apparently diverted to the side, leaving both halves of the "double pulley" condyle attached to the shaft. A point was made on the longest part of the diaphysis by scraping. A second awl was made simply by breaking the diaphysis and sharpening the distal half (Fig. 130d). The third and fourth had had the posterior surface of the diaphysis removed to reduce the shaft of the awl. This was accomplished by breaking it out and smoothing the edges by grinding.

Awls retaining the whole distal condyle have been collected at Mureybat (Stordeur 1978: 84), Aswad, Ramad, and Ghoraife (Stordeur 1982: 13-17).

The majority of the awls made on the distal part of the metapodial were grooved and snapped sagittally so that only one half of the condyle served as the base (Fig. 130a-c, f). When resharpening had reduced the shaft to a short, stocky extension of the base it was necessary to thin it by making a transverse groove into one or both sides removing part of the edge so that a narrow point could be formed by scraping (130a, c). Some of the awls made on metapodials of immature individuals had lost the unfused distal epiphysis either during use

Fig. 130 a. awl made on a ruminant metacarpal retaining half of the distal condyle with the shaft thinned by transverse grooving and snapping, b. awl made on a sheep or goat metapodial, c. awl made on a gazelle metapodial, d. awl made on a sheep or goat metatarsal retaining the whole distal condyle as the base and showing traces of carnivore gnawing, e. awl made on a sheep or goat metatarsal retaining the proximal end as the base, f. awl made on a ruminant metapodial with the unfused distal end as the base. Scale 1:1.

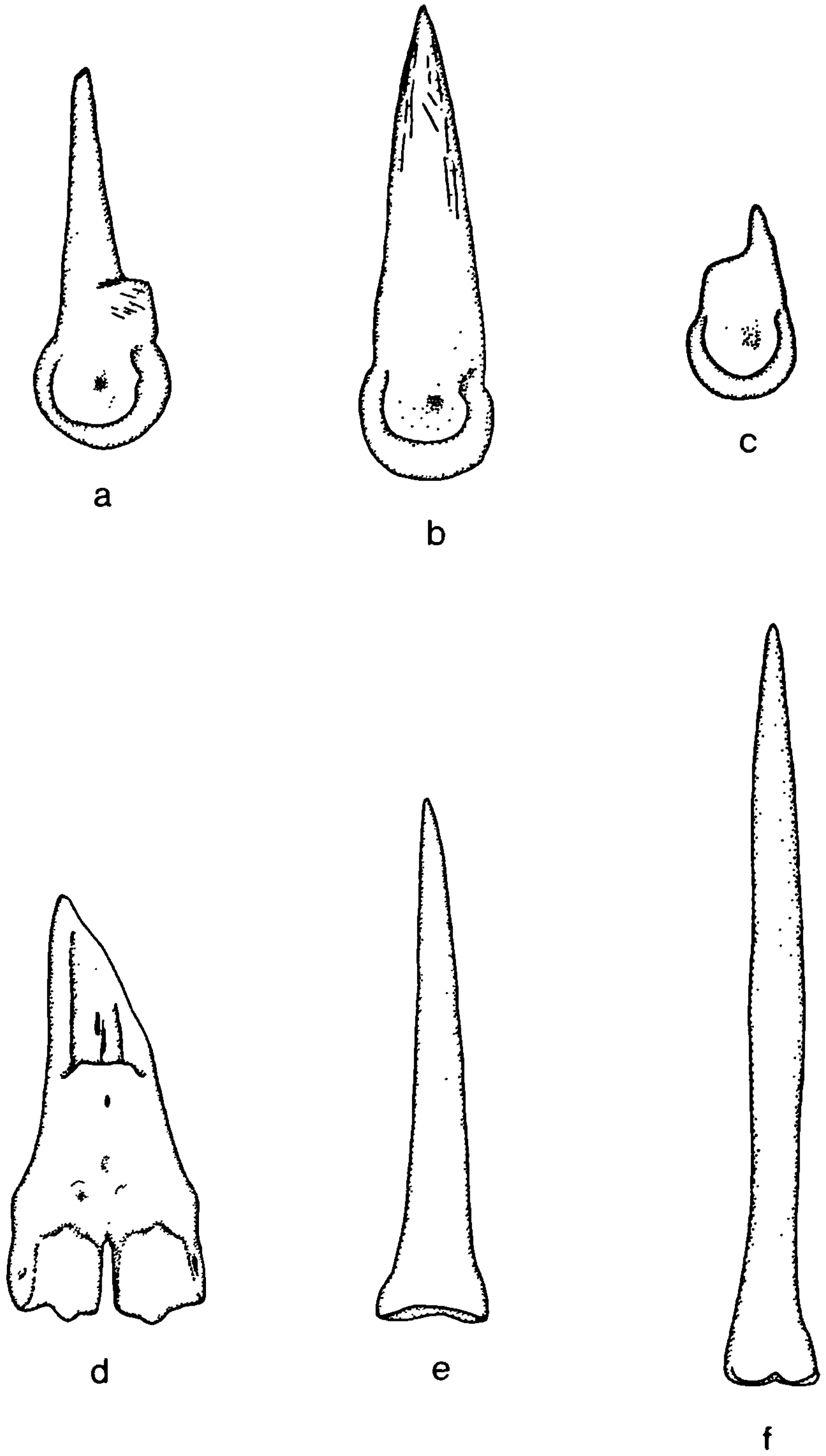


Fig. 130

or after being discarded (130f).

Awls made in this manner have been recovered at Mureybat (Stordeur 1978: 84), Jericho (Marshall 1982), Aswad, Ramad, and Ghoraife (Stordeur 1982: 11-15).

Metapodial awls are widely distributed at Abu Hureyra, with examples emerging from Mesolithic levels of Trench E and Neolithic deposits in Trenches A, B, D, E, and G.

Needles and Pins

The finest bone artifacts from Abu Hureyra in terms of their delicacy and precise manufacture are the needles. No manufacturing debris is known for these implements, but they were probably made by cutting two longitudinal grooves adjacent to one another in a long bone so that they eventually converged at one end and the resulting sliver of bone between them could be removed. The long striations and occasional chattermarks on the shafts of most of the needles indicate that the bone slivers were then smoothed by scraping with the edge of a flint tool. Though they display a wide range of sizes, all of the needles have delicate tips, gradually tapering sides, a round cross-section, and a drilled or gouged eye through the shaft near the base (Fig. 131a-e, g-j).

One very long needle (Fig. 131i) has a bulge or expansion near the base in order to accommodate a rather large eye (4.8 by 6.7 mm). The size of the eye suggests that it was designed for thick twine or yarn and may have been used on coarsely woven materials such as netting.

This and many of the other needles were perforated by gouging two grooves on opposite sides of the basal end

Fig. 131 a-e. needles, f. pin, g. large needle with eye made by gouging, h. needle blank in which the perforation was off-center and broke through, i. large needle with expanded basal end and enlarged eye, j. large needle. Scale 1:1.

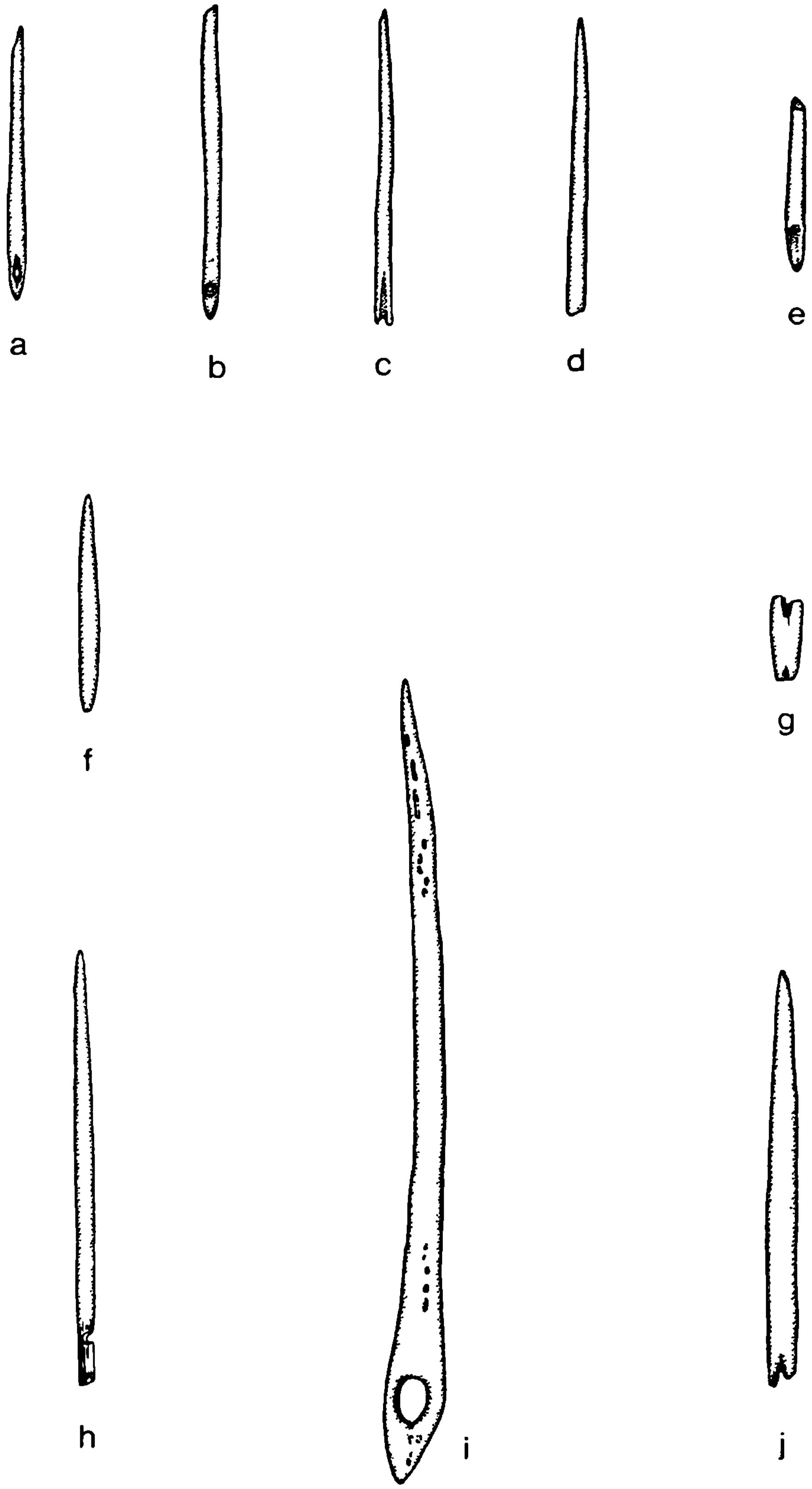


Fig. 131

of the shaft until their centers met and a hole could be broken through. The perforation thus made is often very irregular in outline.

On a few others the trough was cut in one or both sides to a shallower depth and the perforation was made by drilling biconically through its center or reaming it out with a borer. In these cases the concentric striae around the walls of the perforation and the uniformly round opening are indicative of drilling or reaming.

The opposing grooves made in the shaft may serve several functions. Firstly, they may actually play a role in forming the perforation if it is gouged out in the center. Secondly, if biconical drilling is preferred, then the groove helps to center and seat the drill properly so slippage or misalignment does not occur. Thirdly, during use the groove accommodates the thread so that it does not bend stiffly over a sharp edge as it is drawn through fabric, which may break some of its fibers.

One specimen is particularly enlightening because it bears traces that demonstrate the order of manufacturing stages for some of the needles. It is a whole needle that was never finished because an error in centering the drill caused the hole to break through one edge (Fig. 131h). The needle blank was probably made in the customary way with longitudinal scraping performed to smooth and shape it. A high polish was then applied to the shaft, but was partially destroyed by additional scraping near the base in preparation for drilling. In place of grooves, the basal third of the shaft was planed down on either side to flatten the convex surface and make a platform for the drill. A round indentation on one surface marks the location where the drilling began but was discontinued when it broke through one edge of the shaft. A second needle that was properly drilled (Fig. 131b) and a needle shaft fragment duplicate the appearance of longitudinal striae obliterating the overall polish seen on the above example. An important indication derived from these pieces is that polishes were sometimes applied during manufacture. Given the ambiguity of interpreting polish and the fact that wear would be expected to spread up the shaft from the tip it is very difficult to distinguish between manufacturing and use polish on needles, but in these cases the polish was clearly applied before the eye was made. Polishing would certainly be beneficial in reducing friction as the needle was drawn through hides or woven products. Precision scraping with an undamaged edge of a flint tool, such as a burin, can produce very smooth surfaces that mimic polish and would reduce friction. Some of the needles from Abu Hureyra exhibit this trait. Although they are glossy, faint traces in the form of faceting, chattermarks, and waviness of outline indicate that they were not polished with a fine abrasive.

A number of tip and shaft fragments lacking the eye and base were also found at Abu Hureyra. Because three unperforated "pins" have been recovered it is prudent to refer to the broken pieces only as needle or p n fragments.

The three pins are bipointed with a slight swelling of the shaft near one end (Fig. 131f). They are made by the same techniques used for the manufacture of needles, except that no eye is present. Two of the specimens are extremely fine, so that it is doubtful that perforations could have been made in their narrow shafts. The third is larger than the average size of needles.

Use wear is difficult to distinguish from manufacturing traces in some cases, but several of the needle or pin tips possess a greater concentration of polish than their shafts. It seems probable that this represents use polish. One of the pins has a series of concentric striations around the tip overlying the longitudinal scraping striae applied during manufacture. The annular scratches were made by turning the pin against an abrasive surface, but their exact cause is unknown.

Only one needle was found in the Mesolithic levels of Trench E, but they were widespread spatially and temporally in the Neolithic levels of most of the trenches. No change in size, shape, or manufacture is apparent through time. The graph of tip width and thickness reveals a consistency in both their absolute size and their roundness (Fig. 134). In accordance with the fact that they are all piercing implements, needles and pins overlap in tip diameter with the finer awls. The three needles and two pins that were whole enough to retain their total length and width are all less than 1 mm in width and have their maximum width located at or near the basal end (Figs. 132, 133). The maximum width is clearly under functional constraints for needles which are drawn completely through the material being sewn.

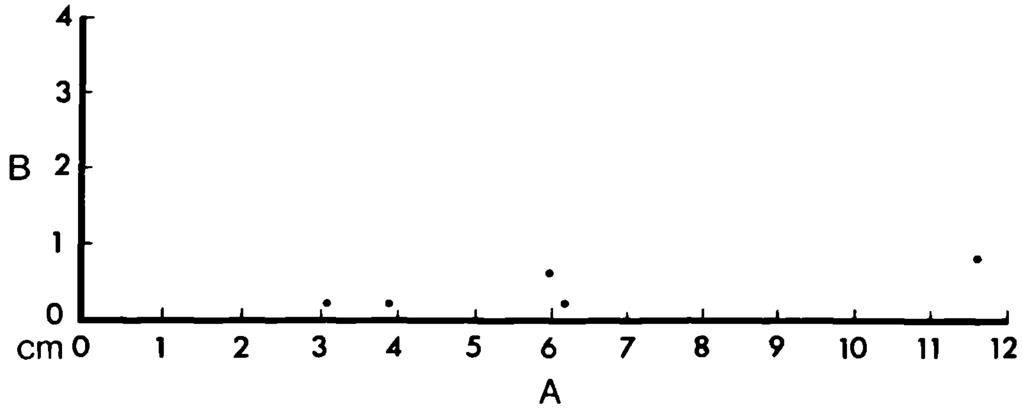


Fig. 132 Scatter diagram 1: gross dimensions for Abu Hureyra needles and pins.

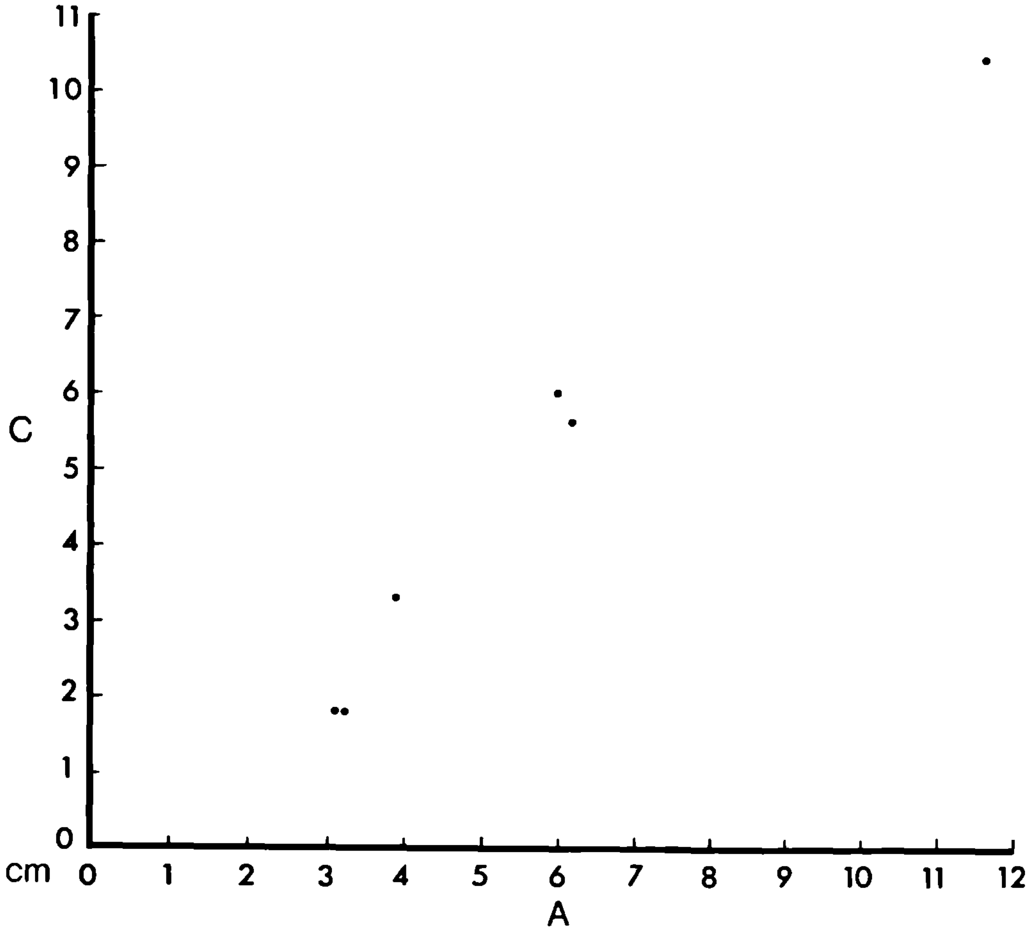
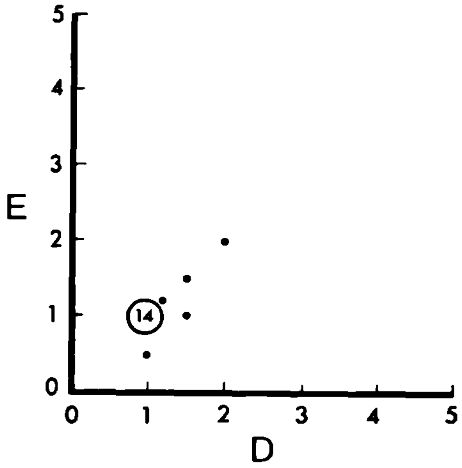


Fig. 133 Scatter diagram 2: location of the maximum width on the shaft for Abu Hureyra needles and pins.



$\bar{E}/\bar{D}=1.1/1.1$mm

Fig. 134 Scatter diagram 3: tip dimensions for Abu Hureyra needles and pins.

Observations show that for practical purposes the widest part of the shaft is usually where the eye is drilled.

Both small and long needles comparable to those found at Abu Hureyra have been found at Aswad (Stordeur 1982: 13) and Jericho (Marshall 1982), while twenty needle fragments were collected during Van Loon's excavations at Mureybat (Stordeur 1978: 85). Most of these were derived from a cache of 18 needle and awl fragments found in Structure I of Stratum VII (Van Loon 1968).

Notched Rib

The rib of a small ruminant collected from Trench A was modified by a line of notches on both margins for a distance of about 4 cm roughly opposite each other near the sternal end (Fig. 106d). Both ends are missing due to ancient breaks. Whether these fractures were part of the original manufacturing process or occurred accidentally is difficult to determine. The use of this artifact cannot be identified since no wear is visible. From the irregularly broken appearance of the notches it may be interpreted that a small piercer or similarly pointed tool was used to punch out the semi-circular notches. There is no indication that they were made by drilling or incising. This sole example of a notched rib from a Aceramic Neolithic level in Trench A at Abu Hureyra resembles an object from Phase III at Mureybat, ca. 8000 to 7600 BC which is scalloped along the edges and retains traces of four short teeth at one end of the rib (Stordeur-Yed d 1974: 438-9).

Perforated Phalanges

A proximal phalanx from a gazelle found in a Neolithic level of Trench D was perforated antero-posteriorly through the distal epicondylar region (Fig. 135b). Although there are concentric striae visible around the walls of the perforations, they are not continuous and the holes are not uniformly round. This suggests that a piercer was hand-turned to ream out the openings rather than using a hafted drill. An irregular opening on the posterior surface just below the proximal articulation appears to be due to accidental or post-depositional breakage. Based on the placement of the perforations, the phalanx may have been worn as a pendant. The scant polish visible on the artifact's surface may be caused by handling and there are no traces indicative of wear by a thread or thong through the hole. It is possible that the phalanx was meant to be a whistle, but the alignment of the two perforations is more suitable for stringing than for creating sound.

Another proximal phalanx of a gazelle, derived from Trench Extension E2 is perforated through the lateral surface of the distal diaphysis (Fig. 135c). The proximal half of the element has been recently broken off so it is difficult to determine if another hole might have been present. Light polish around the edge of the perforation and on the distal condyle is indicative of use.

Perforated phalanges of small ruminants were found at Kebara, El Wad, Erq el Ahmar, and Mallaha (Stordeur 1979: 38). These Natufian pendants differed from the ones recovered at Abu Hureyra in being severed in half below the perforation. Evidence for their use as orna-

Fig. 135 a. drilled tooth pendant, b-c. perforated proximal phalanges of gazelles, d. tubular bead made on an avian ulna, e. tubular bead made on a ruminant femur, f. tubular bead made on a small mammal long bone, g. tubular bead made on a large avian ulna, h. tubular bead made on a ruminant tibia, i. tubular bead made on a medium mammal long bone. Scale 1:1.

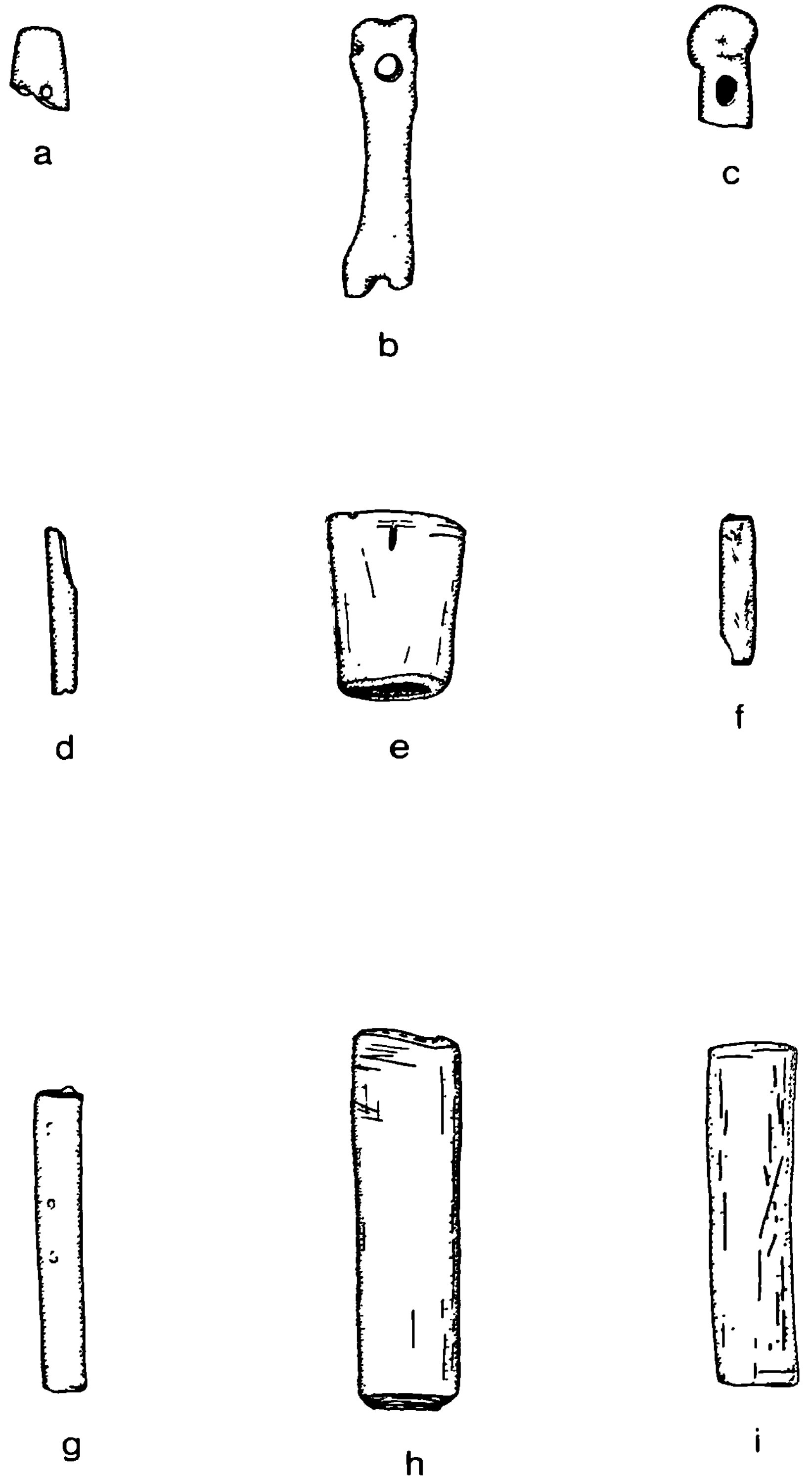


Fig. 135

ments attached to headdresses is derived from the well-preserved burials at El Wad (Garrod and Bate 1937: 40).

Tooth Pendant

A small fragment of the base of a pendant found in the Mesolithic portion of Trench E revealed the use of large teeth for ornamentation. Only the root survives, but its base was ground until smoothly rounded and a biconically drilled perforation was made 1 cm from the basal end (Fig. 135a). Immediately adjacent to the perforation on one side is a pit where drilling was abandoned before completion. The first attempt at drilling the tooth was apparently placed too near the margin so that work was interrupted and another perforation started closer to the center and sufficiently removed from the other edge to prevent it from breaking through. Visible on the upper edge of the perforation′s wall is a very light polish that suggests that the pendant had actually been strung and worn. The diameter of the hole is 1.5 mm.

During the Natufian at ha-Yonim canine teeth of fox and hyaenas were drilled through the root presumably for stringing (Bar-Yosef and Tchernov 1970: 145). Stordeur (1982: 15) records the presence of a drilled boar′s canine at Ramad. The specimen retains most of the body of the tooth, but the apical surface and the base of the root are missing. It is interesting to note that two completed biconical perforations are visible on it, but in this case the holes are aligned one below the other instead of side by side.

Tubular Beads

Several cylindrical objects made from avian and mammalian long bones were recovered at Abu Hureyra (Fig. 135d-i). Of these, five retain the manufacturing traces that demonstrate the use of annular grooving and snapping to remove the articular ends and produce a segment of the desired length. Following this step the external surface was smoothed of natural rugosities and ridges by longitudinal scraping. The smallest three have had their ends abraded to obliterate the annular striae and smooth the ragged edges.

Identification of the elements from which the tubular beads were fabricated is complicated by the removal of most of the diagnostic features of the bones. The femur of a small ruminant was identified in one case by the cross-section of the bead and the presence of a characteristic foramen (Fig. 135e). Another rather large bead was manufactured on the tibia of a small ruminant (Fig. 135h). The papillae for the attachment of the primary feathers were useful in identifying a large avian ulna converted into a bead (Fig. 135g). The cylindrical beads ranged from 1.9 to 5 cm in length and 0.3 to 1.8 cm in width.

A tubular bead collected in the Natufian levels of ha-Yonim (Bar-Yosef and Tchernov 1970: Fig. 4.5) was decorated with four annularly incised grooves at the end and three longitudinal lines along the central portion. At Aswad a small cylindrical bead was found (Stordeur 1982: 15). Beads from Mureybat made on avian and fox bones possess traces demonstrating that the ends were removed by means of the groove-and-snap technique (Stordeur 1979: 43) and are within the size range of those from Abu Hureyra. For the most part they are undecorated, but one specimen from the round house period was notched on the end by short incisions and bore irregular scratches on its body (Stordeur 1978: 88). At the Pre-pottery Neolithic sites of Bouqras and Tell es-Sinn large tubular beads made on the diaphyses of metapodials and tibiae of sheep or goats constituted the most frequently occurring bone artifact type (Clason 1979-1980: 39). All of the tubular beads from Abu Hureyra appear to be Neolithic in age.

Manufacturing Debris

Three pieces of antler identified as belonging to fallow deer (Dama sp. indet.) because of their small size and palmate morphology, were modified by longitudinal grooving and snapping (Fig. 136a-c). Broken into small segments, it is difficult to ascertain whether they were unfinished artifacts or discarded debitage from the fabrication of tools. In addition to the bisection of the beam, the outer surfaces were smoothed by scraping on two of the specimens. One of these also possessed a single transverse cut, suggesting that annular grooving and snapping would have been performed if the manufacturing process had continued. The third piece bore no signs of scraping, but showed traces of hammering damage from use. Since the only finished antler artifact found at Abu Hureyra was a hammer used in flint-knapping, it is unclear what form the finished product of the longitudinal

Fig. 136 a-c. grooved and snapped fallow deer antlers, d. metatarsal of Bos sp. indet. with traces of annular grooving, e. awl blank made by longitudinal grooving and snapping of a sheep or goat metatarsal. Scale 1:1.

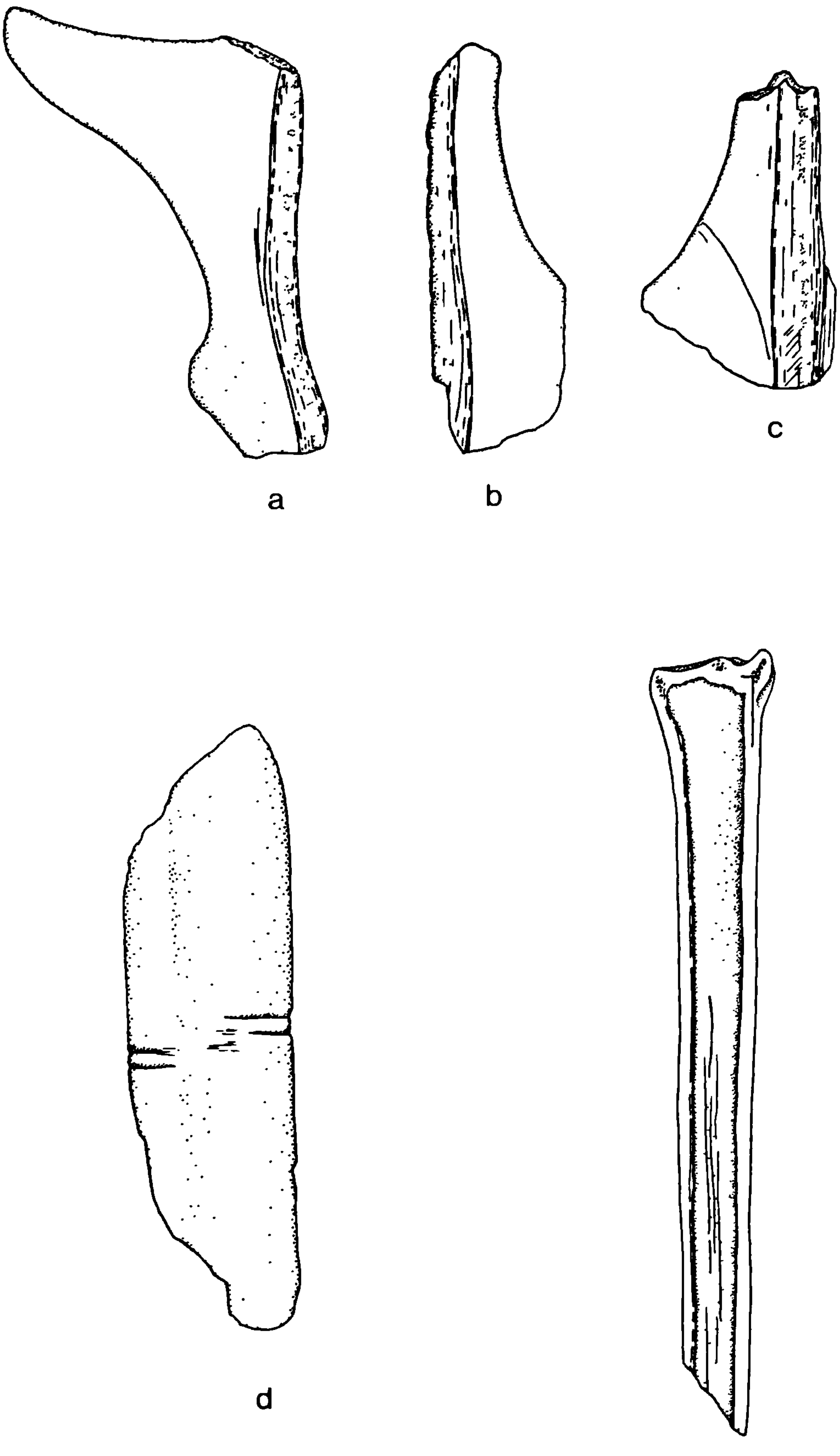


Fig. 136

splitting would have taken. These pieces indicate that antler was utilized more than is evident from the whole artifacts in the collection and that at least one type of implement is not represented in the excavated material. Two of the fragments were found together in Trench Extension E2, Level 7, Spit 2. The third came from the same area but from Level 21. All are of Neolithic derivation. The site of Bouqras produced a piece of manufacturing debris and a tube made on antler of fallow deer (Clason 1979-1980: 39).

Eleven pieces of manufacturing debris from the fabrication of awls were collected from the various levels of Trench E and its extensions. These may be categorized as two major forms: blanks that have been made by splitting long bones longitudinally with the groove-and-snap technique (Fig. 136e) and articular ends severed from the diaphysis by annular grooving and snapping. The bulk of these were made on the metacarpals and metatarsals of small ruminants. Two of the ends removed in order to put a point on an awl were distal condyles of metatarsals and exhibited traces of longitudinal grooving as well. Another was the complete proximal articulation of a metatarsal.

Diaphysis fragments of metapodials of gazelle and cattle possessed light annular scoring near the midshaft region which was never completed (Fig. 136d), while a metacarpal of *Bos* sp. indet. was grooved and snapped through the diaphysis. The intended purpose of dividing these bones into two equal parts is unknown since no artifacts retain evidence of this process.

Finally, a tibia of Bos sp. indet.was hacked through the mid-diaphysis with an axe or chopping tool. There is no indication as to whether this particular piece was intended for further modification or whether it was simply broken open to extract marrow. It is important to note the use of a large chopping implement, however, since fortuitous splinters of medium and large mammal bones were frequently retrieved and employed with or without further modification.

Taxa Selected for Raw Material

In accordance with the frequencies of gazelle, sheep and goat, cattle, and small equids in the faunal remains from Abu Hureyra, these were the primary animals from which elements were chosen in the manufacture of bone artifacts (Fig. 105). Availability must have been the major consideration in selection of raw material, but the size and morphology of the ungulate elements were also important.

Minimal use was made of avifauna, with only two tubular beads identified as the ulnae of medium to large birds. Bones of small mammals were employed to a slightly greater extent, but were usually not identifiable because of considerable alteration. Three examples of carnivore bone were found in the Abu Hureyra collection. The tibia of a fox or fennec and the radius of a felid were made into spatulae. The proximal end of a fibula of a felid appears to have served as the base of a narrow-shafted awl.

The bones of small ruminants were used in a wide variety of cases including utilized splinters, awls of every type, tubular beads, and the notched rib. Many more artifacts made on medium mammal long bones may have also been derived from ruminants, but identifying characteristics have not been retained.

Cervids are represented in low numbers in the fauna from Abu Hureyra, a scarcity that is reflected in the worked bone. A segment of an antler beam exhibited traces of use as a flint-knapping hammer and four pieces of manufacturing debris consisted of grooved and snapped sections of antler from fallow deer (Dama sp. indet.). None of the artifacts made on bone other than antler were positively identified as deer.

A total of 21 artifacts could be confidently assigned to the genus Gazella, although some of those allocated to the more general category of small ruminants may have also been made from gazelle bones. One of the more interesting examples is the drilled proximal phalanx which may have been suspended as part of either a headdress or a necklace. Utilized splinters made from ulnae and metatarsals and awls manufactured on metacarpals and metatarsals of gazelles were relatively common.

Of the artifacts made from bones of identifiable ruminants, those employing sheep or goat elements were the most numerous. Thirty-five objects including a utilized splinter, a splinter awl, various awls with articular ends as their bases, and debris from manufacturing metapodial awls were derived from either sheep or goats.

Of the 13 pieces of modified bone identified as Bos sp. indet., ten were classified as "flat implements". Nine of the ten were made from split ribs, while the tenth was derived from a femur. The remaining three cattle bones were worked by chopping or grooving and snapping, but were not actual implements.

The only bones of small equids definitely identified as tool material were the fourth metatarsal splints used as awls. Either or both *Equus hemionus* or *E. asinus* may have been represented among the five awls.

In light of the taxonomic data accumulated from the worked bone from Abu Hureyra, small ruminants such as sheep/goats and gazelles appear to have been the major sources of raw materials for artifacts. Metacarpals and metatarsals of these artiodactyls were the most frequently chosen elements, but ulnae and tibiae were occasionally selected. Regardless of taxon, with the exception of ribs, antler, and one tooth, the majority of the artifacts were made on long bones. The frequencies of identifiable taxa among the bone artifacts are extremely consistent with their availability and selection as food or other resources as reflected in the faunal material from Abu Hureyra (Legge 1975).

Conclusions

The collection of bone artifacts from Abu Hureyra is important because, with the exception of one brief hiatus, the site possesses a relatively long occupation during which many significant cultural developments such as the invention of agriculture occurred. The contemporaneity with parts of the Mesolithic and Prepottery Neolithic of Mureybat and the Prepottery Neolithic of

Bouqras and Tell es-Sinn in the Euphrates valley and Aswad II, Ghoraife, and Ramad to the southwest allow comparisons to be made among the assemblages. While it is surpassed in size by the collection from Jericho which consists of over 500 pieces (Marshall 1982: 570), the worked bone from Abu Hureyra represents one of the largest and most varied aggregates of its kind in the Levant. Conclusions regarding the comparative material must remain somewhat tentative at present since the data from the nearby sites of Bouqras, Tell es-Sinn, and other Levantine sites are currently undergoing analysis. Because the material from Mureybat, Aswad, Ghoraife, and Ramad has been documented by Stordeur (1978, 1982), the weight of the comparative study has emphasized these sites. Where reports of particular tool types have appeared in the literature these have been noted in the individual discussions of types from Abu Hureyra in this chapter.

Some general remarks about the temporal development of bone artifacts in the Levant may be presented, although definitive conclusions would be premature at this stage of our knowledge. During the Paleolithic variation in bone and antler artifacts was basically limited to two major types: points and awls. These were well made and even occasionally exhibited ornamentation in the form of incising, but it was during the Mesolithic that a great expansion of types and styles of bone artifacts took place. Craftsmanship and artistic expression also climax at this time. The Neolithic brought no drastic alterations in methods of manufacture or variety, although some individual types disappeared as others arose.

A long bone possibly derived from Mousterian levels at Mugharet el Kebara and a scapula from a small ruminant from the Terminal Aurignacian at ha-Yonim (Davis 1974) had deep, transverse cuts spaced along one margin. Whether these were used as tallies, musical instruments, or some kind of implement is not known. The Middle Aurignacian Layer E of El Wad produced seven awls, of which some were manufactured on gazelle metapodials which retained one articular end as their base (Garrod and Bate 1937: 49). An Aurignacian layer at Kebara produced two awls, one made on a tibia and retaining the proximal articular surface as the base and the other with a series of annular lines up the shaft (Garrod 1954: 177).

One of the larger Upper Paleolithic collections of bone tools was collected at Ksar Akil in Lebanon. Projectile points and awls made on splinters constituted the major types at Ksar Akil (Newcomer 1974). Antler, which in later times declined in quantity in the Levant, was used in the manufacture of large, symmetrical points with lenticular cross-sections. The bone bipoints with round cross-section from Ksar Akil differed little except in their greater dimensions from those found in Mesolithic levels at Abu Hureyra. Splinter awls, worked mainly at the tip by longitudinal scraping, closely resembled those from later Mesolithic or Neolithic sites, including Abu Hureyra. Two awls were marked with groups of transverse incisions. The most elaborately incised specimen was an awl made on a metatarsal of a small ruminant which retains the proximal end as its base and has straight sides (Tixier 1974). It was marked with five rows of more than thirty lines each.

There was little change in the Kebaran, with plain and incised awls continuing to be found, such as those from Jiita, near Ksar Akil (Copeland and Hours 1977).

By the Natufian a variety of bone implements and ornaments were being used at ha-Yonim Cave (Bar-Yosef and Tchernov 1970), including drilled canine and globular bone pendants, tubular beads made on bird bones, bipoints and gorgets, plain based awls, awls retaining whole or half articular condyles, heavy-duty choppers, spatulae, sickle hafts, and numerous pieces exhibiting punctated or incised designs. Natufian levels at Mugharet El Wad also produced a wide range of highly developed artifact types, such as barbed points, "lissoirs", sickle hafts, beads and pendants of various designs, and the usual awls with articular ends as bases. One of the most valuable aspects of the bone ornaments from El Wad is their context in burials. Headdresses consisting of _Dentalium_ shells and gazelle phalanx or bird tibiotarsus pendants and necklaces of paired globular bone pendants still _in situ_ demonstrate how the various types of ornaments were worn (Garrod and Bate 1937). One quite remarkable object thought to be Natufian was a finely sculpted fawn carved on the end of a bone which may have served as a sickle haft (Garrod and Bate 1937: Plate XIII, Fig. 3). Unfortunately, this unique artifact was found in the 1920's by previous investigators and may not have been derived from an undisturbed Natufian level. Also from the Natufian deposits of El Wad came a shaft-straightener made by perforating the neck of a fallow deer scapula. This piece which bears clear wear patterns has been thoroughly described by Campana (1979). Mugharet el Kebara produced several fine examples of sculptured bone sickle hafts, as well as fishhooks, barbed points, and awls. Three of the sickle hafts possessed a carved animal head at one end.

It is thus during the Mesolithic that a proliferation of bone artifact types occurs. At this time drilling, carving, and other design elaborations appear and flourish. The use of abrasives and polishing begins to appear with frequency on certain artifacts such as beads and pendants. Regional variation may be expressed in ornaments, but awls, in particular, remain consistent through time and space after the Paleolithic in the Levant.

Although some of the rarer artifacts may be present in individual sites occupied at different intervals, no highly visible trends develop in the Neolithic. At Mureybat examples of an unusual type of object, probably used as a weaving comb to push the weft down, were distributed through the levels beginning with the Epinatufian (c. 8400 BC) and continuing until PPNB times (c. 7600 BC) (Stordeur-Yedid 1974). The only ones found in Natufian deposits were found at Kebara. Combs that were more likely meant for the hair rather than weaving occur in the PPNA of Jericho (Marshall 1982: 18).

Bone sickle hafts, present in the Natufian, apparently fade out of fashion in the Neolithic. On the other hand, fishhooks continue through the Neolithic at Abu Hureyra, so that economic developments are scarcely reflected in the worked bone assemblages of the Levant. Needles appear with frequency in the Neolithic at Mureybat (Stordeur 1978), Abu Hureyra, Jericho (Marshall 1982), and Aswad (Stordeur 1982), suggesting greater emphasis on tailoring. Barbed points, which were never abundant in the Natufian are not represented in the Neolithic and the common b points of the Mesolithic disappear in the Neolithic.

Though never found with great frequency in the Mesolithic, incised, punctated, and sculpted designs in bone or antler fade out or become less skillfully executed with the arrival of the Neolithic. The fine craftsmanship of the young gazelle body from El Wad and the heads from Kebara, both carved on sickle hafts, is not equalled in the Neolithic. At Ramad I a possible zoomorphic pendant was found (Stordeur 1982: Fig. 7.6), but it is so stylized that it is difficult to identify the subject it represents. It may be the head of an equid. The intricate punctate designs decorating several pieces from ha-Yonim Cave are not continued in later times. Globular, or "twin" pendants become less common, although the simple cylindrical beads are still made in the Neolithic. Polishing and grinding increases during Prepottery Neolithic times as a means of improving the overall appearance of ornaments and for smoothing needles and awls.

It is during the Neolithic that flat implements, many of which are made of split cattle ribs, begin to make an appearance. Broad-tipped heavy-duty spatulae made from large mammal bones increase in frequency and are particularly numerous at Jericho throughout the PPNA and PPNB (Marshall 1982). Bone and antler "batonnets", possibly used for pressure-flaking flint or as pestles are found in low frequencies in the Neolithic. Awls do not change their basic morphology after the Mesolithic and it is interesting that despite advanced manufacturing techniques such as grooving and snapping, abrading, and polishing, the splinter awls of the Upper Paleolithic still occur in great numbers.

It appears that the general trend from the Upper Paleolithic through the Kebaran and Natufian of the Levant is towards a proliferation of bone artifact types and a more elaborate expression of artistic style. The Neolithic sees moderate advances in manufacturing technology while retaining the most utilitarian implements of the Natufian. There is, however, a reduction in the artistic quality and a decline in the number of ornaments made of bone, antler, and tooth.

Chapter 8

Ulu Leang 1 and Leang Burung 1

The third case study consists of two small collections of bone implements from southwestern Sulawesi in Indonesia. The choice of this material, which may be contrasted with the previous two case studies in terms of sample size, range of types, and conditions of preservation, was made to demonstrate the adaptability of the methodology. It became apparent during the analysis of the assemblages from these Indonesian sites that, while collection size and variability may affect the overall product of the analysis, there is still sufficient information contained within the material to justify the application of various techniques in order to maximize its contribution to cultural interpretations.

Cultural Affinities and Environmental Setting

The sites of Ulu Leang 1 and Leang Burung 1, from which the bone implements in this case study are derived, are situated in cliff-foot caves in the tower Karst topography east of Maros 'n Sulawesi Selatan (Fig. 137). The area has a long history of archaeological exploration which has been described at length elsewhere (Van Heekeren 1972; Mulvaney and Soejono 1970a and b). It was during their expedition to Sulawesi in 1902 and 1903 that Fritz and Paul Sarasin encountered archaeological deposits that they named "Toalean" after the extant Toale people in the region who they believed to be the descendants of this culture (Van Heekeren 1972: 107-109). Much research has been conducted since that time, with nume-

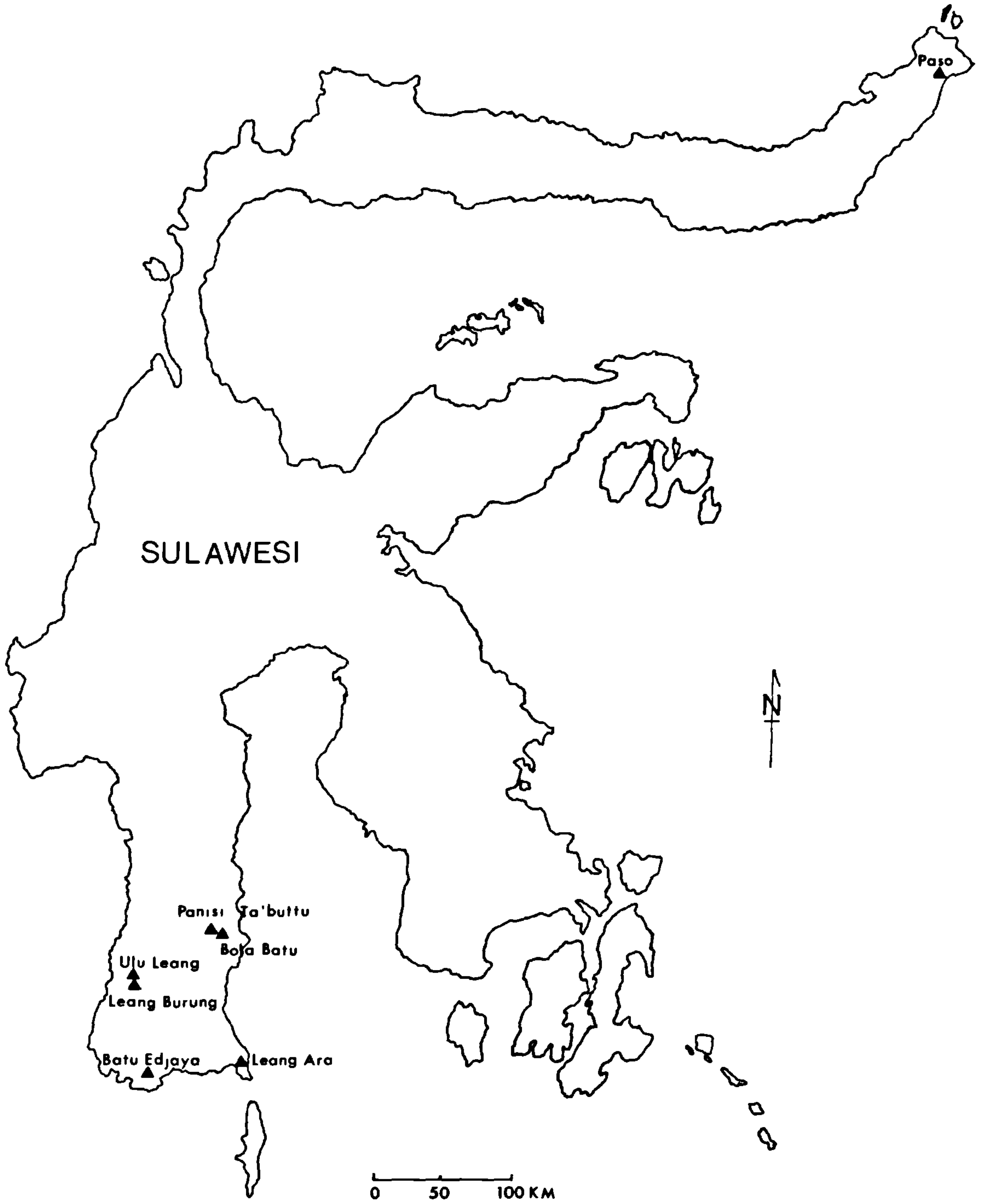


Fig. 137 Map of Sulawesi showing major sites referenced in the text.

rous caves producing Toalean artifacts. The Toalean of Sulawesi Selatan is a Mesolithic culture represented archaeologically by geometric microliths, backed blades and bladelets, hollow-based denticulate points (Maros points), shell scrapers, bone bipoints and awls, and rock art. Pottery appears in the uppermost levels at Ulu Leang 1 and throughout the deposits at Leang Burung 1. Severe disturbance by clandestine excavations and quarrying of limestone and soil for fertilizer has complicated the interpretation of the cultural sequences of most of the caves. Because of this it cannot be certain how valid are classification schemes such as Stein Callenfels' "Proto-Toalean", "Toalean", and "Upper Toalean" or Van Heekeren's "Lower, Middle, and Upper Toalean" (Van Heekeren 1972: 113-114). Exploration of the Maros caves in 1969 by the joint Indonesian-Australian expedition under the leadership of R.P. Soejono and D.J. Mulvaney (Glover 1976: 114) was undertaken with the goals of examining sites of the Toalean culture, collecting samples for radiocarbon dating, and investigating prehistoric contacts between Sulawesi and Australia. This work was continued by Glover in 1973 and 1975 at Ulu Leang 1 and Leang Burung 2.

Although some surface sites have been located, the Toalean is mostly known from cave occupations. By Late Neolithic and Iron Age times people had moved out of rock shelters and were using them for burial instead. There is abundant evidence for the exploitation of local fauna preserved in the archaeological record of these sites. Key sources of protein appear to have been pigs, anoa, macaques, phalangers, and large fruit bats. Shells of freshwater gastropods, particularly *Brotia* which is an edible genus enjoyed today by local inhabitants (E. Glover 1981), were especially plentiful in the archaeological deposits. Despite the easy access to nearby streams and the use of invertebrates, fish appear to have furnished a very small proportion of the diet. A variety of plant remains including *Panicum*, *Ficus*, and *Oryza* were collected at Ulu Leang. The rice, identified by T.T. Chang, was *Oryza sativa* and some of the grains have characteristics of domestic varieties, but Glover is cautious about interpreting Ulu Leang 1 as a site where cultivation was undertaken (Glover 1978: 95). An important aspect of the differential preservation in the archaeological record is the absence of tools and containers made from bamboo or wood. As in other lush tropical environments, the dependence on these materials may result in a paucity of archaeological material that makes the culture appear somewhat impoverished. The minimal use of bone implements may in part reflect a dependence on wood and bamboo.

Ulu Leang 1

Ulu Leang 1 is a cliff-foot cave located approximately 40 km northeast of Ujung Pandang at the base of a tower block of limestone in the Lealleang Valley. The cave is 15 m wide and 20 m deep with a ceiling 5 to 8 m above the gradually sloping modern floor (Glover 1976: 116) (Fig. 138). Analysis of the geology of the cave has revealed that dissolution of organic deposits by ground

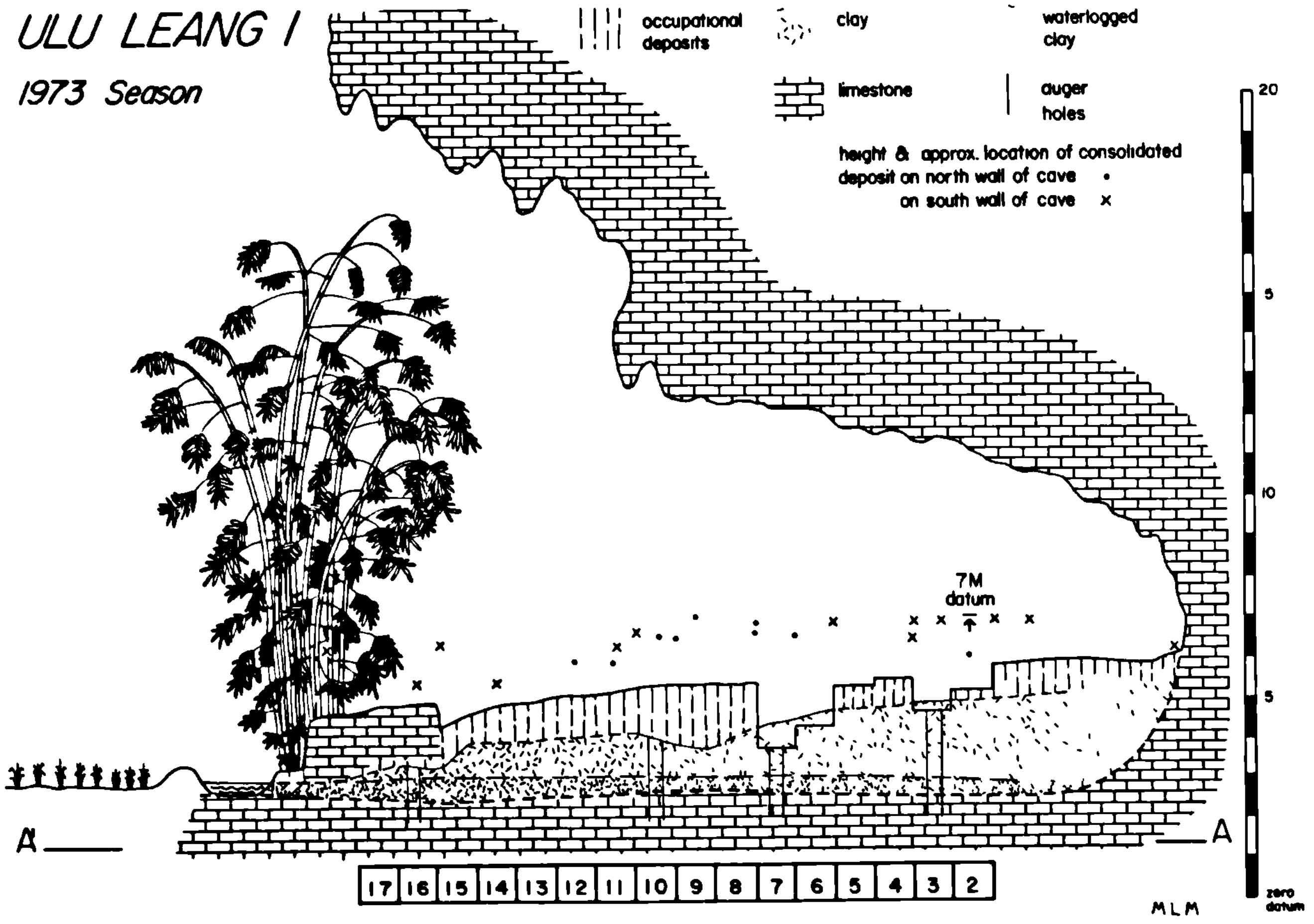


Fig. 138 Profile of Ulu Leang 1, 1973 season.

water and the resulting subsidence have caused differential lowering of loose sediments while cemented deposits have remained affixed to the cave walls (Glover 1977). Despite this situation it was possible to relate the layers in most of the sampled areas in the main part of the cave to each other. Stone artifacts in deposits in the entrance (Trenches K and L) suggest a rather earlier occupation than those from the interior and their layers do not correlate with those in the remainder of the sampled areas (Fig 139). Twenty meters above Ulu Leang 1 is another cave, Ulu Leang 2, which was used as a burial place in later times and contains glass beads, one copper bead, fragments of iron and a variety of pottery suggesting a period roughly within the range of 500 BC to AD 1000 (Glover 1976: 147). The bone artifacts described in this case study are derived from the lower cave only.

Ulu Leang 1 was excavated in 1969, 1973, and 1975 by I.C. Glover. The removal of more than 30 cubic meters of deposits led to the discovery of a wide array of stone tools and flakes, faunal material (both invertebrate and vertebrate), bone artifacts, plant remains, and hearths (Glover 1976: 120, 1979: 302). Radiocarbon dates from Ulu Leang 1 are important in assigning a temporal range for the Toalean since excavations prior to 1969 had not produced dates. The oldest levels just outside the dripline of the cave could not be dated because of the lack of shell and charcoal, but a series of dates from inside the chamber is given in Figure 140.

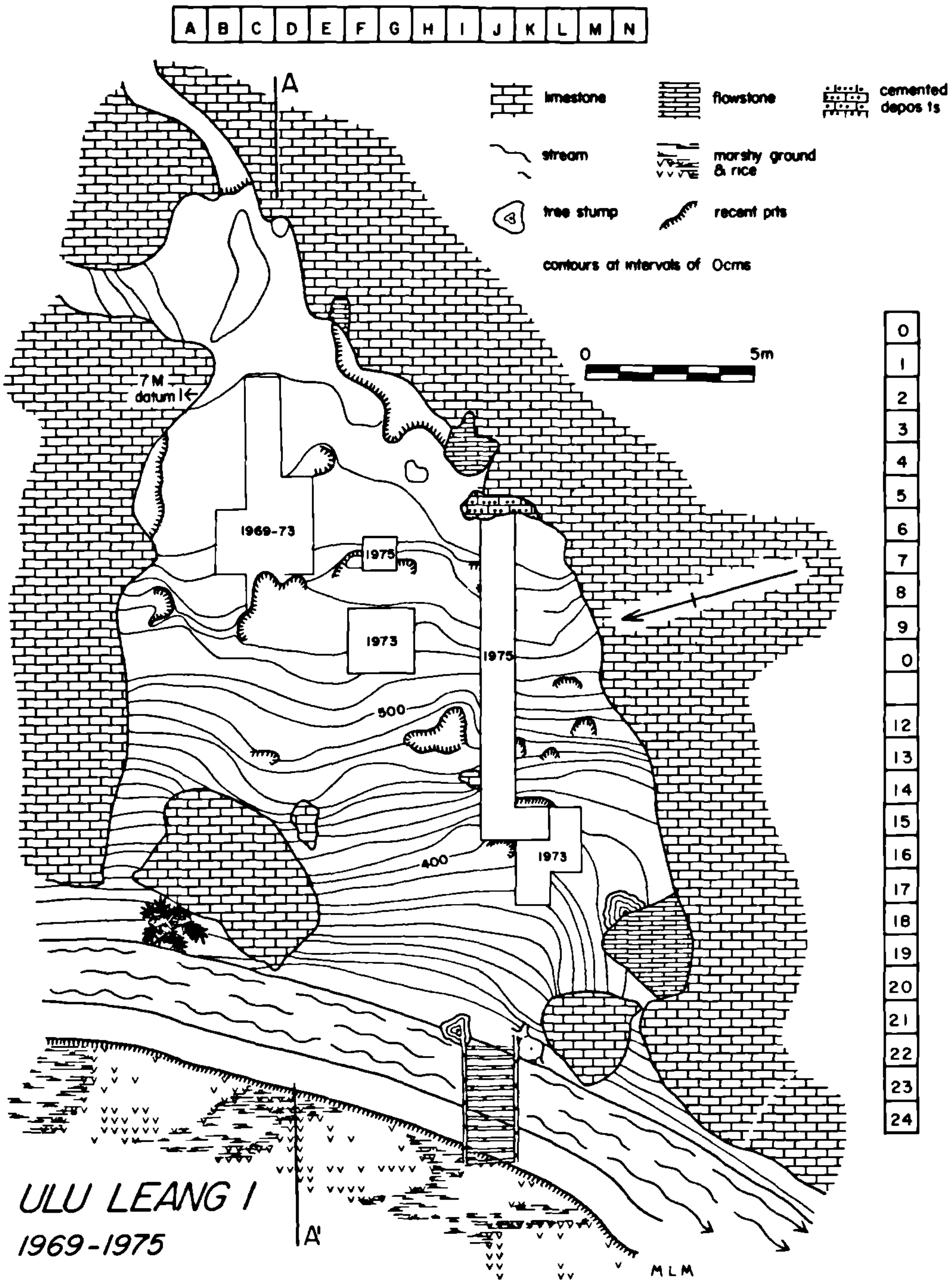


Fig. 139 Plan of Ulu Leang 1 showing excavations from 1969 to 1975.

Fig. 140 Radiocarbon dates for Ulu Leang 1.

SAMPLE #	TYPE	PROVENIENCE	LAYER, CM BELOW SURFACE	YEARS B.P.
GRN-8648	shell	FG7, south	II	10,740± 50
GRN-8290	shell	C7	II	10,560± 50
GRN-8647	shell	FG7, south	VII	8,895± 50*
GRN-8291	shell	J6, south	IV-V, 80-90cm	8,785± 45
ANU-606	charcoal	C6,7 (13-14)	I-II, 110 cm	7,170± 650
ANU-394	charcoal	C2 (5)	VII, 50 cm	5,740± 230
PRL-231	charcoal	C2 (3)	VII-2, 20-30 cm	4,390± 110
HAR-1734	charcoal	cemented breccia	in wall	4,050± 90
PRL-230	charcoal	C2 (2)	VII-2, 10-20 cm	3,550± 130
SUA-1080	charcoal	J9 (7-8)	hearth	1,490± 210**

*Anomalously old for this layer.

**Sample may be contaminated by more recent carbon.

Leang Burung 1

Leang Burung 1 is a similar cave located just 2 km south of Ulu Leang (Fig. 137). The cliff-base cave extends as far as 15 m into the limestone and has a steeply sloping floor. The site was partially excavated in 1969 by the joint Indonesian-Australian expedition under the direction of D.J. Mulvaney and R.P. Soejono. Although subsidence was minor at Leang Burung 1, slope erosion, roof fall, quarrying, and clandestine excavation have led to considerable destruction of the site. At least two vertical meters of deposits had been removed inside the cave, complicating archaeological interpretations. Three trenches were excavated with the hope of uncovering undisturbed deposits. Trench A was located inside the cave and revealed occupation levels below a largely disturbed zone of 50 cm depth. Trench B was positioned outside the cave and down slope from Trench A (Fig. 141). Beneath the mixed layer _in situ_ archaeological deposits yielded shells, vertebrate faunal material, pottery, stone tools, bone artifacts, and charcoal. Trench C connected Trenches A and B, but did not produce unmixed prehistoric cultural layers.

On a typological basis it appears that Trench B is older than all but the basal part of Trench A. Supporting this hypothesis are two radiocarbon dates: a sample derived from charcoal in Trench B, 150 cm below the present surface was dated to 1430± 600 BC, while one from Trench A, 270 cm below surface, was dated to 850± 400 BC (Mulvaney and Soejono 1970a: 31). The large

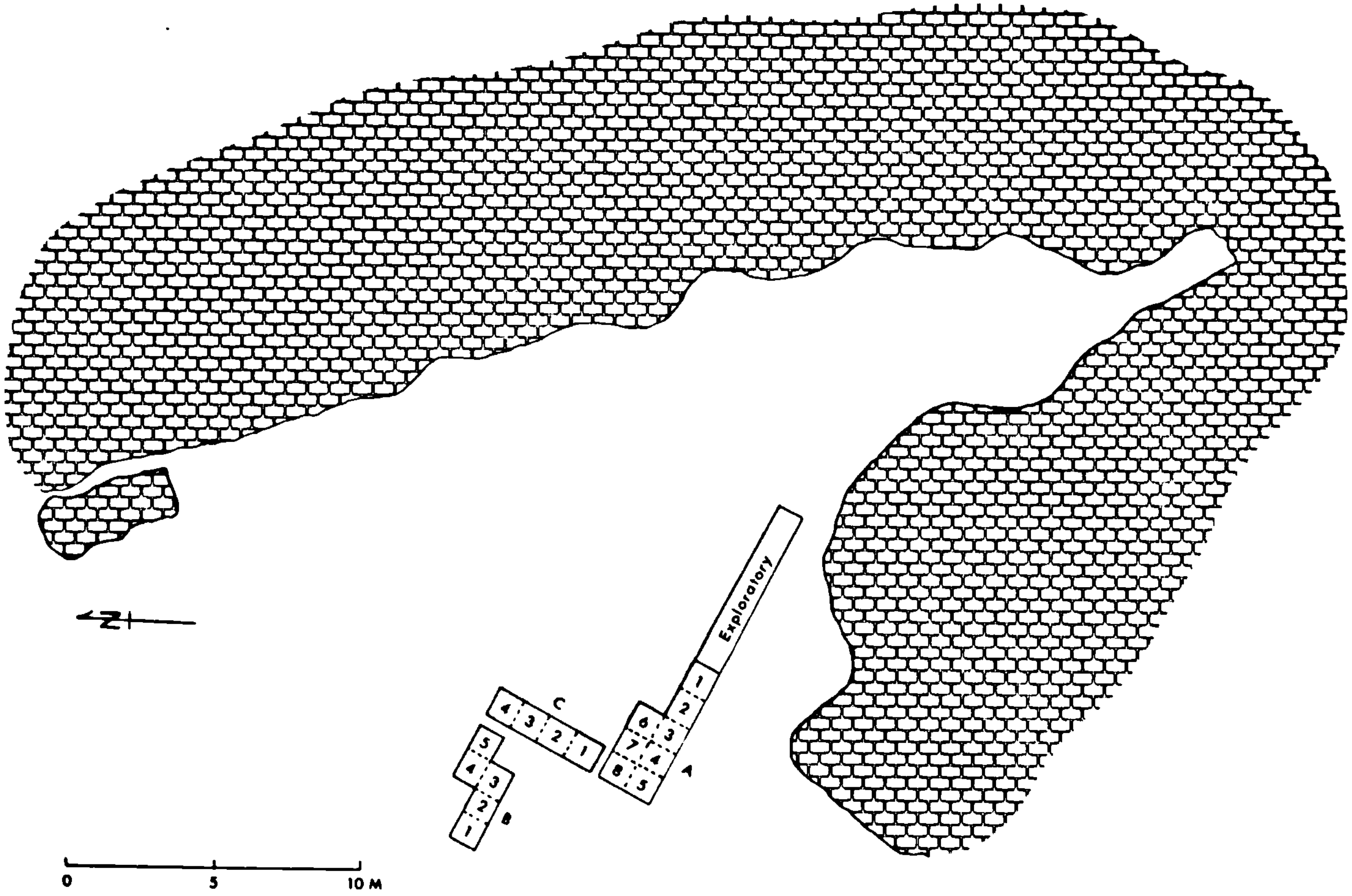


Fig. 141 Plan of Leang Burung 1.

standard error on these dates should be considered when interpreting the chronology of the site, but the radiocarbon dates coupled with the presence of pottery throughout the sequence at Leang Burung 1 indicate that it postdates all but the uppermost layers of Ulu Leang 1.

Located approximately 150 m south of Leang Burung 1 is the older site of Leang Burung 2, excavated in 1975 (Glover 1981). Radiocarbon dates derived from shell suggest a chronology for the site of between 19,000 and 30,000 BP (Glover 1981: 12). Typical Toalean artifacts such as backed blades, geometrics, pottery, and bone points were completely lacking, although flake tools, lithic debitage, faunal remains, and some plant remains were recovered. The absence of bone points and other Toalean artifacts at this early date may be important in establishing the temporal limits of the culture in Sulawesi Selatan and possibly the earliest use of bone as a raw material there.

The Toalean Bone Industry

The bone implements from Ulu Leang 1 and Leang Burung 1 are typical of those found in the Toalean at other sites in Sulawesi. The paucity of worked bone in an otherwise rich faunal assemblage suggests that there was little dependence on bone as a raw material and that the people relied more on wood and bamboo. Only two basic types of bone artifacts, points and awls, are generally found in Toalean sites. This may be contrasted with the richer Sampung bone industry of easterns Java (Van Heekeren 1972) or that from Niah Great Cave in Sarawak (Harrison and Medway 1962). The Toalean stone and bone assemblages suggest contact with Australia where geometric microliths and "Muduk" bone bipoints abound.

Very few examples of other bone artifact types have emerged from Toalean sites. A spatulate tool made on an ulna was found at Leang Ara (Van Heekeren 1972: 110). Spatulae were also reported at Panisi Ta'buttu, Batu Edjaya, and Bola Batu (Fig. 137) (van Heekeren 1972: 112-114).

Natural Traces

In the case of Ulu Leang 1 special attention should be paid to the taphonomic processes acting on bone in the various areas of the cave. Artifacts from the trenches located well within the cave were usually heavily encrusted with calcium carbonate. In most cases the carbonate layer was sufficiently thick to allow it to be gently pried up and lifted off with a scalpel blade. The considerable preparation required to remove the carbonate layer was repaid by the fact that the crust had encapsulated the artifacts and protected their surfaces from postdepositional damage, thus preserving manufacturing and microwear traces. The formation of the calcium carbonate deposits on bone is probably closely related to the process that caused cementing of the layers at the back of the cave in Square J6, namely percolation of water through the limestone (Glover 1979: 308-309).

Bone from the cave entrance, particularly in Trenches K and L, was less encrusted with carbonate, but was instead altered by another process. Both nonartifactual and worked bone fragments from this area frequently exhibited eroded and polished surfaces (Fig. 142). The traces resemble those seen on bone that has been transported long distances by fluvial action. Gradual attrition due to tumbling and bombardment by small particles in an aqueous medium results in a rounding of broken surfaces and a uniform polish that obliterates much of the natural or cultural surface features. It may be distinguished from polishes created during manufacture or use by its even distribution extending to the concave surface of the marrow cavity, depressions in the bone, and undercut broken edges. The lack of striations with definite patterns of distribution and orientation is also a clue that the polish is naturally formed. Examination of the eroded surfaces with a SEM shows that the polish is very different from that caused by manufacture or use. Instead of a smooth, uniform surface, portions of the underlying lamellae have been exposed leaving islands of the original outer layer (Fig. 17). There are two processes that may have been responsible for the eroding of bone in this part of the site. The stream that flows along the base of the limestone massif and contributed to the formation of the cave may have deposited bone fragments from further upstream. The bottom layer (I) is sterile yellow-red clay set down by the stream, but the archaeological layers above contain sediments deposited more likely by "dry, mass-movement processes" (Glover 1979: 99, 313). It is unlikely that the stream would have caused the accumulation of eroded bone points as well as other faunal material and heavily patinated stone tools. The other possible explanation is that the de-

Fig. 142 Water worn bone fragments from Ulu Leang 1.

posits have been exposed to harsh, periodic erosion from cascades of rainwater from the cliff face during annual wet seasons. Erosional polish, which obliterates all manufacturing traces, is fortunately much rarer on pieces from the cave's interior.

A collection of heavily eroded bone fragments from Trenches K and L and the basal levels of F and G were identified as spatulae (Glover 1976: 141). Confirmation of the presence of this tool type is complicated, however, by the combination of taphonomic processes and the simplicity of tool manufacture in the Toalean. The fragments are small and evenly rounded with no noticeable increase of polish or wear at either end which would indicate cultural modification (Fig. 142). Awaiting further evidence such as the appearance of manufacturing traces or microwear on uneroded pieces, the designation of these pieces as spatulae should be postponed.

The artifacts from Leang Burung 1 were well preserved, lacking both the erosional polish and the calcium carbonate encrustation. Root etching was noted on a few of the artifacts from both sites, but no indication of rodent or carnivore gnawing was visible on the worked bone.

Manufacturing Techniques

It is clear that the implements from Ulu Leang 1 and Leang Burung 1 were manufactured on fortuitous splinters rather than preformed blanks. There is no evidence of the use of the groove and snap technique either on the actual tools or on manufacturing debris. Recognition of manufacturing debris would in this case be extremely difficult, since bone is splintered in the process of marrow extraction and presumably useful pieces were simply selected from the shattered fragments. One of the attributes of a bone artifact assemblage based on splinters is a lack of uniformity of style and dimensions in the artifacts. In the same way that splinter awls from other regions are quite variable compared to awls made by grooving and snapping, points and awls from the Toalean tend to be highly irregular in outline.

The splinters were modified by longitudinal scraping with a stone tool in order to sharpen a point on one or both ends and smooth the rough edges. On the pieces that were not severely eroded long striations and occasional chattermarks bear witness to the use of this technique.

Two other types of traces may be distinguished on bipoints. Several specimens possess light diagonal or transverse abrasion striae in limited areas. This is so faint in some cases as to suggest natural soil abrasion, but on a few points and awls it is evident that grinding was used to shape the surface. Only in one case was it particularly extensive.

The second modification found on bipoints consists of the incising of fine cuts perhaps with the sharp edge of a chert flake held about perpendicular to the artifact's surface. Whether this was purely ornamental or also served some function is unclear in most cases, but one extraordinary piece is covered with rows of short incised lines (Fig. 148a).

Bone Awls

The two major types of bone artifacts that have been recognized in the Toalean by previous researchers are unipoints and bipoints. Although use wear is sparse and evidence for hafting is lacking, the morphologies of the two types suggest that bipoints were well-suited to be projectile points or barbs for fishing equipment and that unipoints were more likely to have been used as awls. Breakage is a severe problem in devising morphological and metric criteria for the two types and tip fragments often cannot be classified into either group with certainty. The absence of highly standardized or controlled forms due to the use of splinters for blanks has led to a wide variation in all of the dimensions of these tools.

As a result of this situation, only seven pointed objects from Ulu Leang 1 and four from Leang Burung 1 could be confidently classified as awls (Figs. 143, 153). These took a variety of forms and utilized several different elements (Figs. 144a-e, 154a-c). The only visible modification was longitudinal scraping of the edges and tip. According to the classification of awls used in the previous case studies, these would be termed "shaped awls" made on splinters of long bones from small, medium, or large mammals. The outlines are often wavy since scraping usually fails to remove large irregularities without great effort. Only two of the awls from Ulu Leang 1 were complete enough to be accurately measured (Figs. 145, 146). The tips of the awls are fine and round in cross-section (Figs. 147, 155), but breakage prevented a metric analysis in most cases. Use polish

Fig. 143

BONE ARTIFACT TYPOLOGY FOR ULU LEANG 1

TYPES	Awls	Projectile Points	Pointed Implements	TOTALS
TAXA				
Class Aves			1	1
Class Aves/Mammalia	1		1	2
Class Mammalia	4	72	52	128
Order Artiodactyla		1		1
Sus/Babyroussa	2			2
TOTALS	7	73	54	134

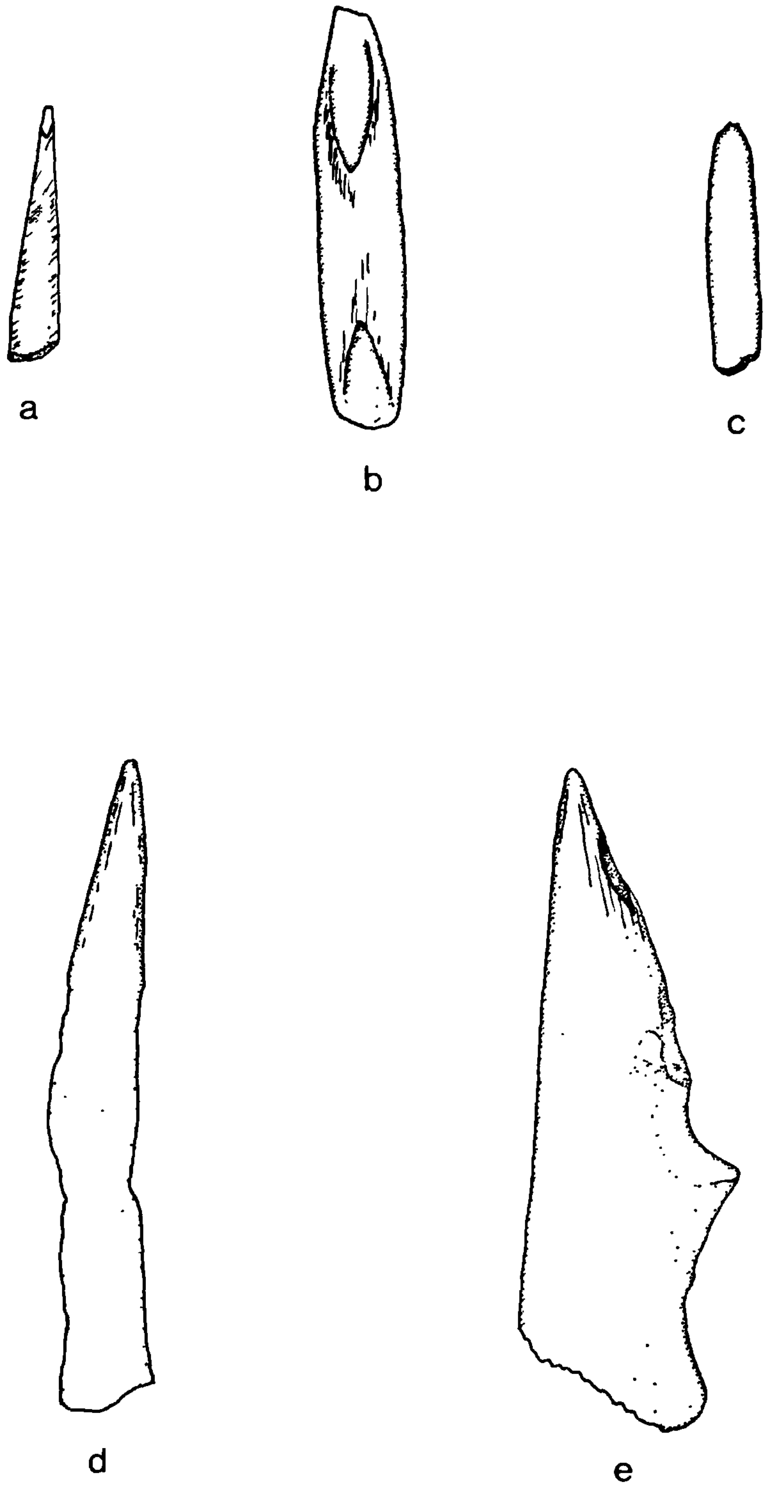


Fig. 144 Ulu Leang 1 awls: a. awl tip fragment showing traces of abrading, b. awl made on a femur of *Sus/Babyroussa*, c. awl with shouldering of the tip from use, d. splinter awl, e. awl made on an ulna of an immature *Sus/Babyroussa*. Scale 1:1.

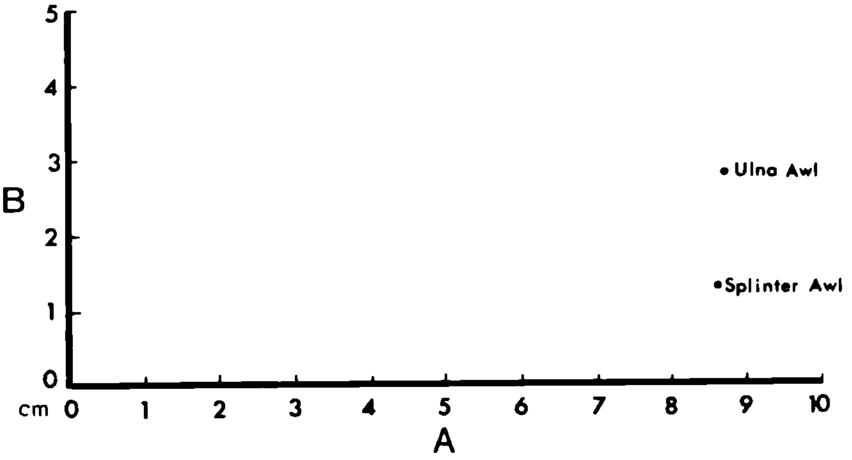


Fig. 145 Scatter diagram 1: gross dimensions for Ulu Leang 1 awls.

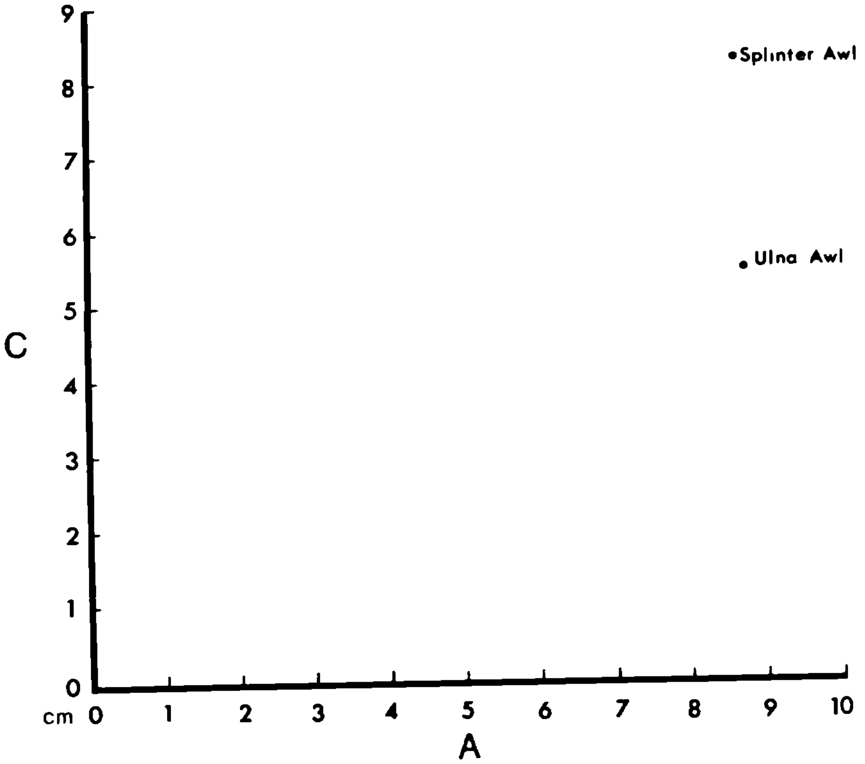
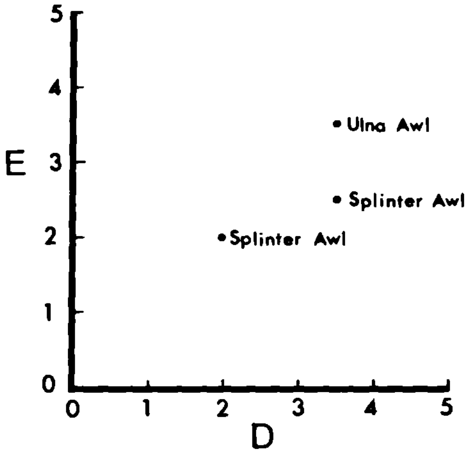


Fig. 146 Scatter diagram 2: location of maximum width on the shaft for Ulu Leang awls.



$\overline{E}/\overline{D} = 2.7/3.0$ mm

Fig. 147 Scatter diagram 3: tip dimensions for Ulu Leang 1 awls.

was not well developed in general, but one awl from each of the two sites has a shouldered tip indicative of piercing implements (Figs. 144c, 154a).

Very few of the awls retained sufficient natural characteristics to allow identification of the taxon or element from which they were derived. One awl from Leang Burung 1 (Fig. 154b) compares most closely with the posterior surface of the mid-diaphysis of a left metatarsal of the rusa deer *Cervus timorensis*. This species occurs on Sulawesi today (Whitehead 1972: 104-105), but has not been identified among the faunal remains analyzed by Clason (1980) at Ulu Leang 1 or Paso, an open-air site in north Sulawesi (Fig. 137) or at any other Toalean site. Because no articular surface or condyle is preserved and only a small percentage of the diaphysis is present, this identification must remain tentative. There is the remote possibility that the fragment was derived from a metapodial of an anoa.

Perhaps the best preserved awl in these collections is one from Ulu Leang 1, made on the ulna of a pig or babirusa (Fig. 144e). The unfused proximal epiphysis indicates that the animal was immature when killed. Modification consisted of removing the distal third of the diaphysis and scraping down the broken end until it tapered to a point with an oval cross-section.

Another awl from Ulu Leang 1 was made by scraping down the two ends of a femoral diaphysis of a pig or babirusa. Breakage inhibits reconstruction of its original morphology, but the tool may have been pointed at both ends. It is unusual in retaining the complete circumference of the diaphysis in the center (Fig. 144b). From the thin cortical walls and curvature of some of the awls it is evident that the long bones of small mammals were used in their manufacture. Possible sources for these elements include macaques and phalangers.

Projectile Points

Like the stone "Maros point", one of the key artifacts of the Toalean is the bone bipoint (Figs. 148a-i, 149a-i, 154d-j). These were originally referred to as "Muduk" points after those found in Australia (Mulvaney 1975: 102). Those from Ulu Leang 1 and Leang Burung 1 were simply made by scraping down a fortuitous splinter of a long bone or occasionally a rib until both ends were pointed. The scraping was not restricted to the tips, however, but extended to both faces and both edges. Overall size varied from a length of only 2.5 cm for the shortest to 6.7 cm for the longest complete specimen (Fig. 150). Maximum widths varied much less, ranging from 2 to 7 mm (Fig. 150). The location of the maximum width tended to be near the midpoint and in most cases was in the basal half rather than in the half nearest the tip (Fig. 151). The edges of the bipoints were nearly always convex, but a few had a long, narrow diamond-shaped outline. The tips of the points ranged from a width of 2 to 4 mm and a thickness of 1 to 4 mm (Figs. 152, 156), but were most often around 2 by 2 mm and round in cross-section.

Tyzzer (1936: 264) distinguished between "inherent" asymmetry in projectile points which is dependent on the natural characteristics of the element selected and "technical" asymmetry which is produced through manufacture. Both are significant in the points from the Toalean but only a few examples appear to have been _intentionally_ manufactured so as to be asymmetric. To the extent that splintering bone with a hammerstone may be considered a manufacturing technique, it was the major cause of irregularities in form due to bilateral asymmetry. The natural curves of certain bones are often responsible for bifacial asymmetry as when, for example, the marrow cavity, creates a concavo-convex cross-section or when the gradual bowing of a femur or radius is evident in a longitudinal profile. Symmetry of medium to large bipoints such as those from Abu Hureyra, Syria, is dependent on the availability of large mammal bones with thick walls and the ability to produce a blank of uniform dimensions. Lacking the groove and snap technique and bones of sufficient size to be able to eliminate the curvature of the marrow cavity it would have been difficult for the people of the Toalean culture to make symmetrical bipoints with a uniformly round cross-section like those from Abu Hureyra. The largest animals available at the time were the pig, the babirusa, the anoa, and possibly the rusa deer, all of whose bones may have been commonly selected; but these were not as suitable as those of cattle or equids. Identification of the elements upon which the points were made was extremely difficult because of the great extent of the surface alteration by scraping. One point from Ulu Leang 1 was made on the rib of an artiodactyl, perhaps a pig or

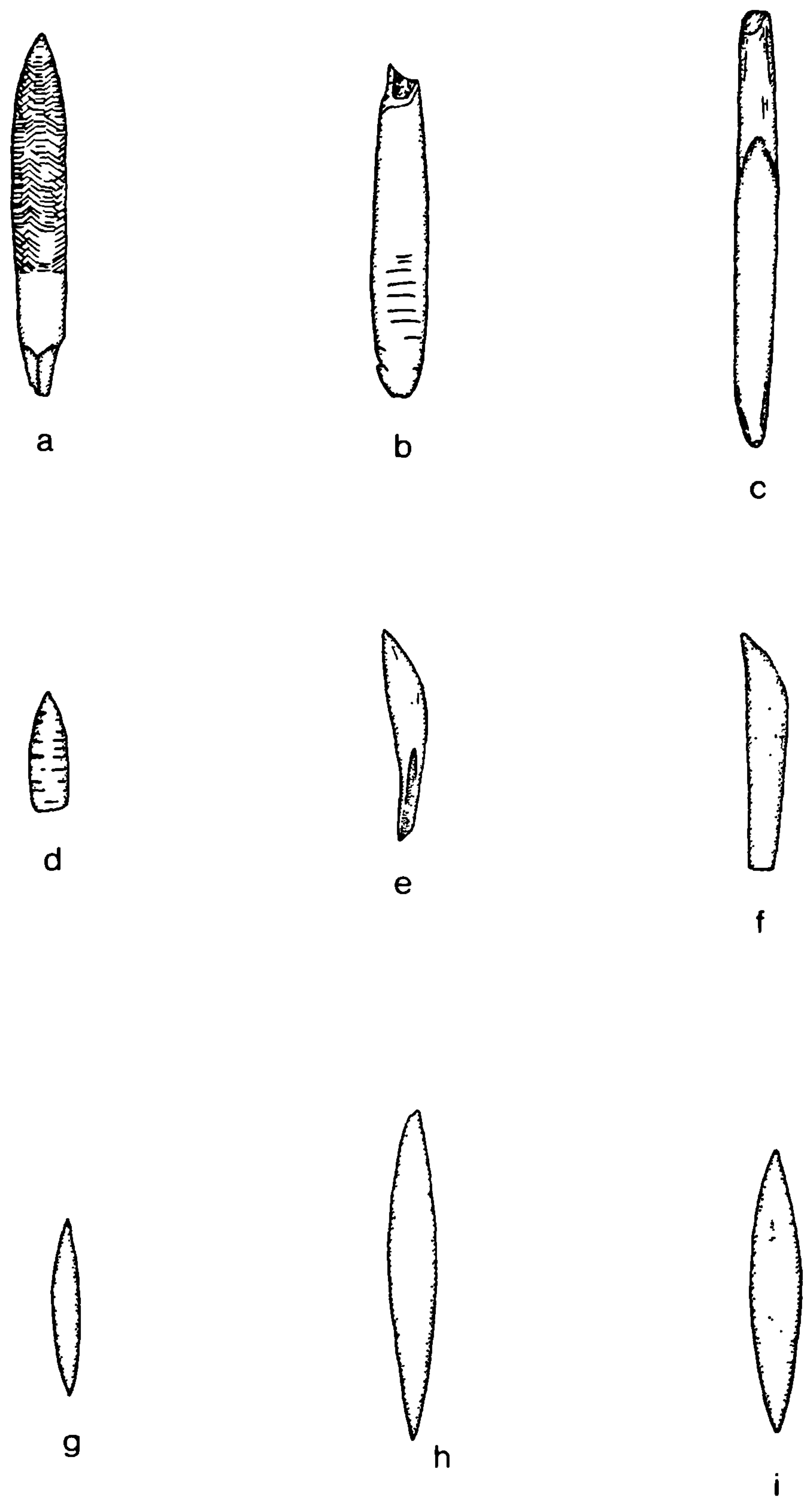


Fig. 148 Ulu Leang 1 projectile points: a. elaborately incised point, b. point made on a rib of *Sus/Babyroussa* and exhibiting transverse incising, c. long bipoint with damaged tip, d. point with annular incising, e-f. bilaterally asymmetric points, g-i. symmetric bipoints. Scale 1:1.

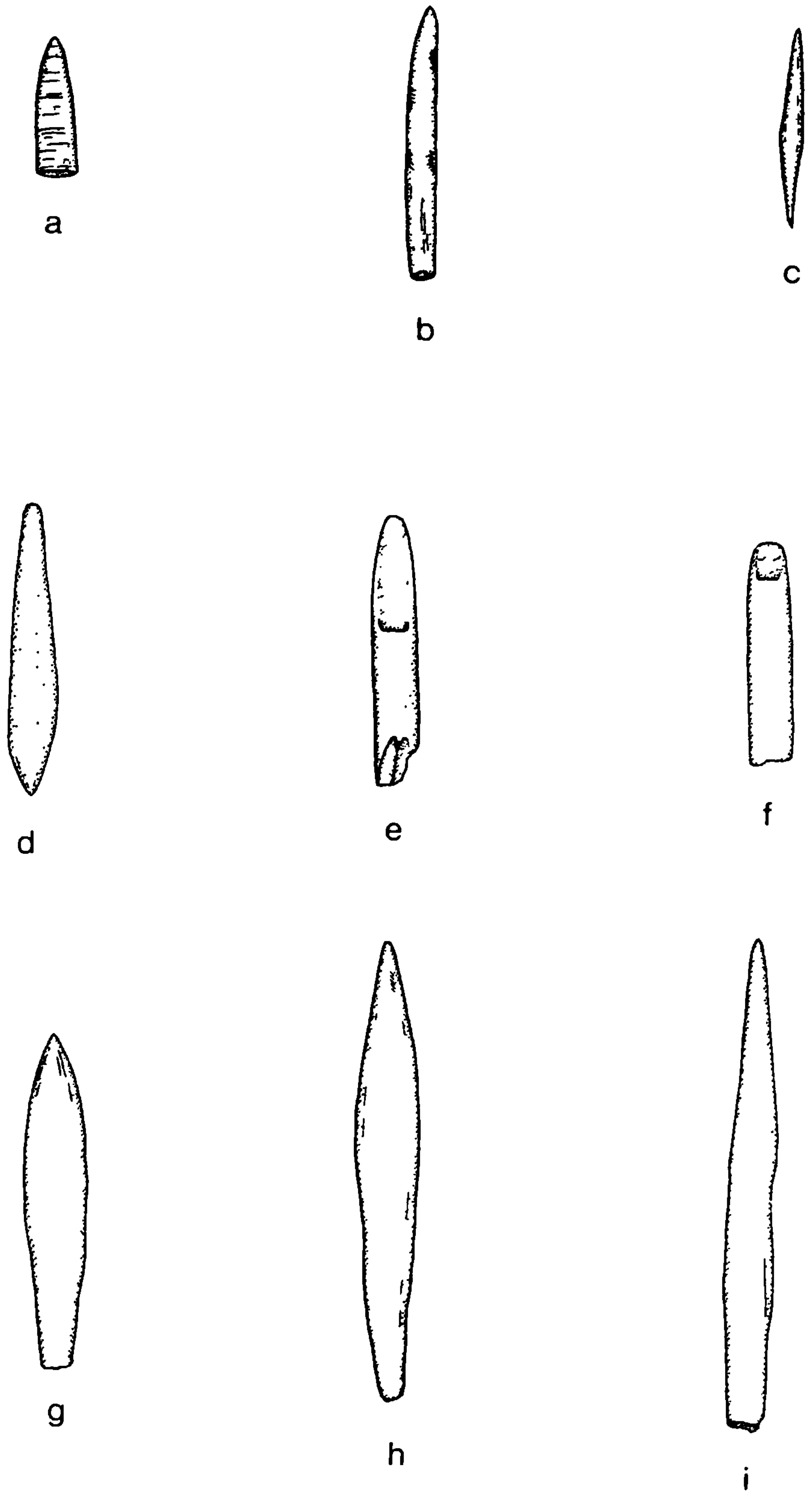


Fig. 149 Ulu Leang 1 projectile points. Note that a. has transverse incising and e. and f. have possible impact damage. Scale 1:1.

babirusa (Fig. 148b). Another, also from Ulu Leang, possesses a foramen that suggests that it was manufactured on the posterior surface of a tibia of a medium to large mammal. Many of the bipoints were made on small mammal long bones with thin walls and small diameters.

Five of the projectile points from Ulu Leang 1 have been scraped down at the tip so that one face is flat and the other is highly domed with a steep inflection (Fig. 148f). The morphology of these points is such that the tips appear to be off-center.

At least six of the projectile points from Ulu Leang 1 bore incised lines on their surfaces. The rib mentioned above possessed a series of transverse cuts on one surface and a few diagonal ones on the opposite side. A second point had transverse cuts on one surface (Fig. 149a). The third was broken above the tip, but maintained several parallel annular incisions spaced 1 to 2 mm apart around the tip (Fig. 148d). One possible explanation for the placing of incised lines on the surfaces of projectile points is to provide crevices for arrow poison to adhere. Examples of bone points grooved so that poison could be inserted are known in various parts of the world (Clark, Phillips, and Staley 1974) and two kinds of arrow poisons, Antiaris toxicaria and Strychnos are known to have been used in recent times in Sulawesi (Burkill 1966: 175-185).

One artifact is extremely unusual in the quantity and quality of its incised ornamentation. A stout bipoint with a round cross-section, this specimen is covered from one end up along the shaft to within about 1.8

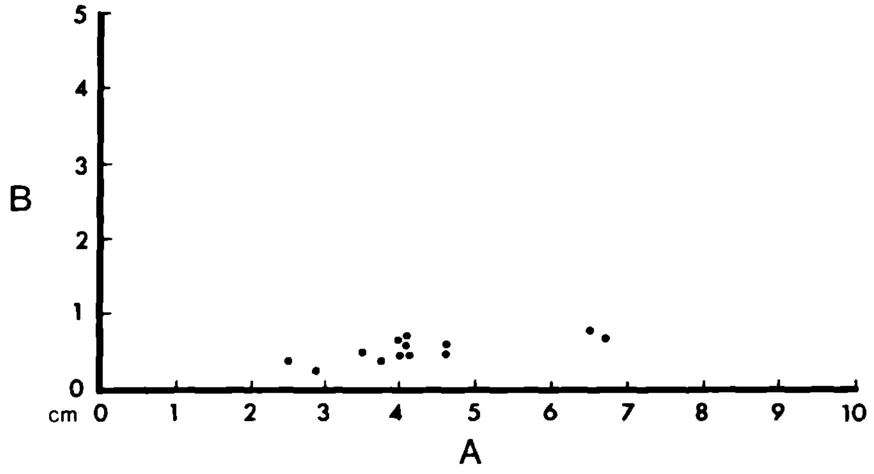


Fig. 150 Scatter diagram 1: gross dimensions for Ulu Leang 1 projectile points.

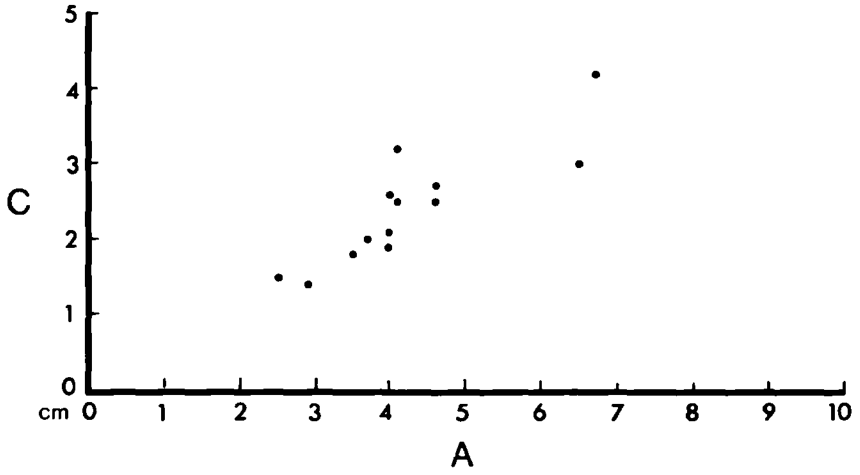
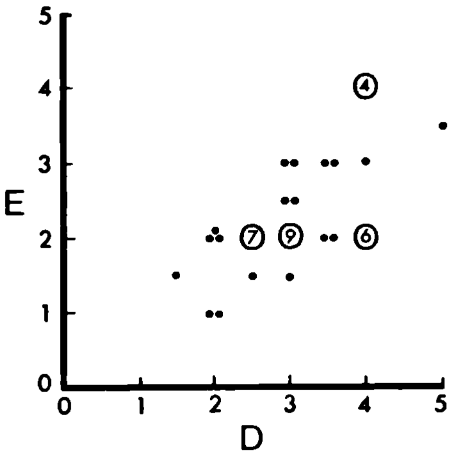


Fig. 151 Scatter diagram 2: location of maximum width on the shaft for Ulu Leang 1 projectile points.



$\overline{E}/\overline{D}$= 2.3/3.1mm

Fig. 152 Scatter diagram 3: tip dimensions for Ulu Leang 1 projectile points.

Fig. 153

BONE ARTIFACT TYPOLOGY FOR LEANG BURUNG 1

TYPES	Awls	Projectile Points	Pointed Implements	TOTALS
TAXA				
Class Mammalia	4	13	8	25
?*Cervus timorensis*	1			1
TOTALS	5	13	8	26

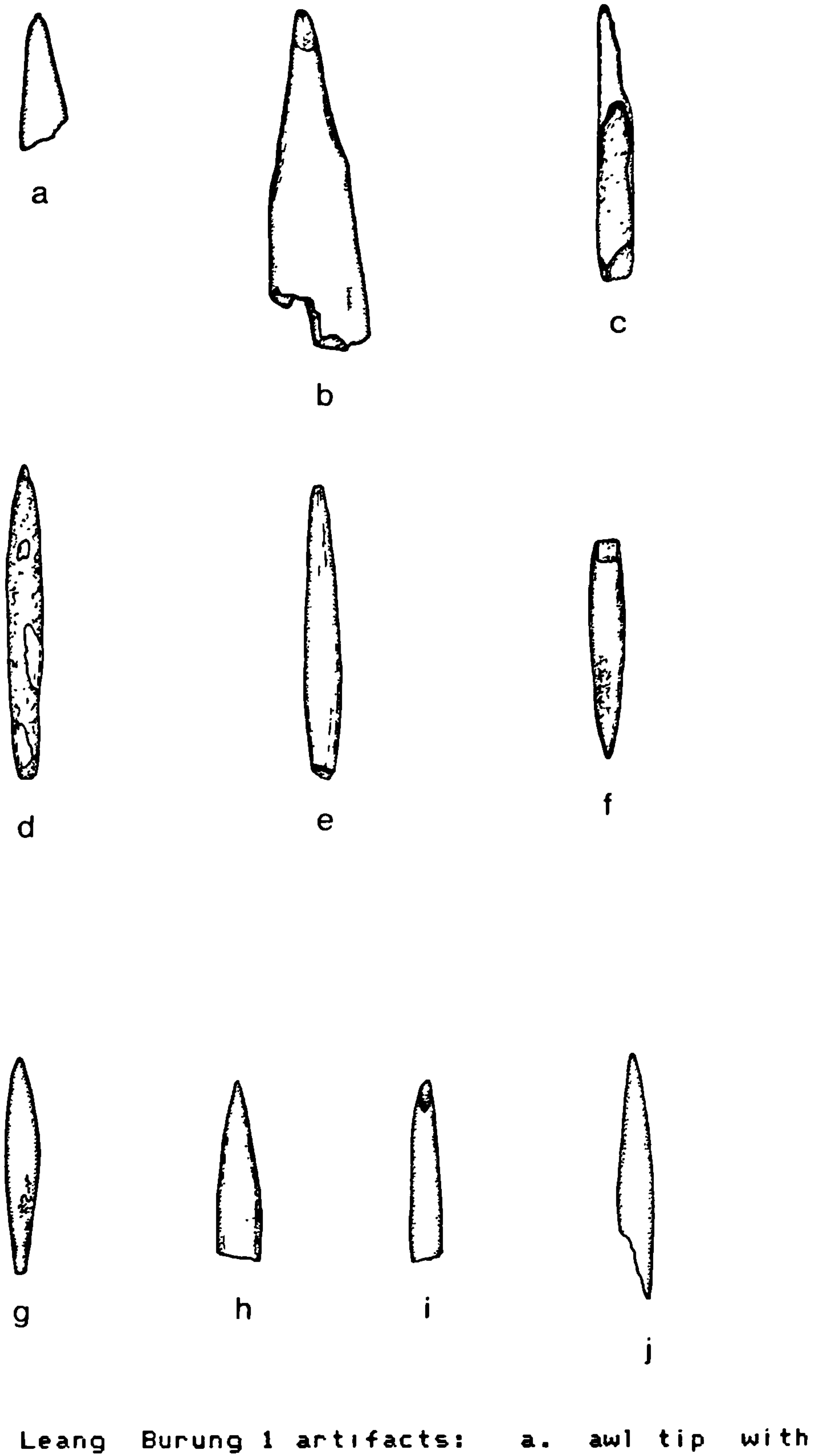


Fig. 154 Leang Burung 1 artifacts: a. awl tip with shouldering from use, b. awl made on a metatarsal of ?*Cervus timorensis*, c. splinter awl, d-j. projectile points. Scale 1:1.

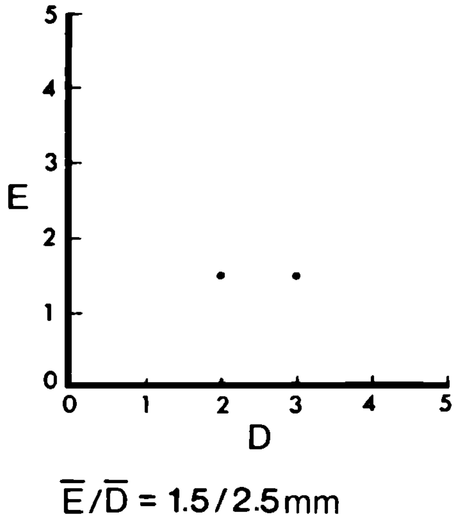


Fig. 155 Scatter diagram 3: tip dimensions for Leang Burung 1 splinter awls.

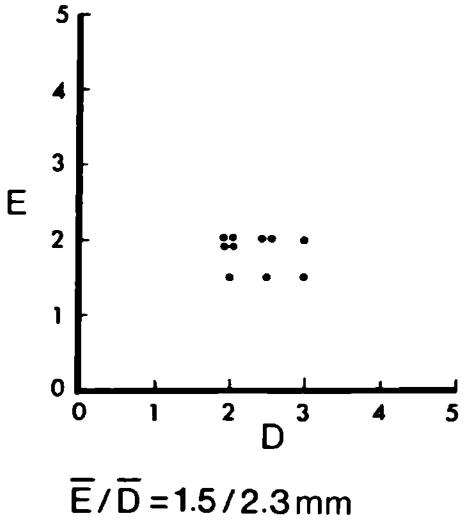


Fig. 156 Scatter diagram 3: tip dimensions for Leang Burung 1 projectile points.

cm from the other end with rows of short, fine, parallel incised lines. Some of the rows of lines run diagonally, tilted at different angles so that the intersection of two rows forms a chevron pattern (Fig. 148a). The high quality of craftsmanship expressed in this piece and the amount of care and time involved in its manufacture are quite exceptional among Toalean bone artifacts. It is possible that this bipoint had a special purpose, such as being worn as a nose ornament. One end is lightly polished as if by wear, but the other has several long flake scars suggestive of terminal impact like the damage seen on many projectile points.

Hafting of the projectile points from Ulu Leang 1 and Leang Burung 1 may have been accomplished in several ways. It is not possible to determine whether any individual point was mounted singly on an arrow shaft or composite fishhook or with others in a multi-pronged fishing spear. Bipoints have many known uses, including being worn as nose ornaments. Bipoints from a quadruple-pronged fish spear from Oenpelli, Australia (Mulvaney 1975: 102, 105) were inserted into split wooden prongs and held in place with resin, a method that could have been used by the Toalean. The most common way of securing a bone bipoint to an arrow shaft is by putting one end down inside a hollowed arrow shaft or foreshaft and attaching it by means of an adhesive and sinew. Either of these methods may be used for symmetric bipoints. There is some evidence to suggest that another hafting method may have been used occasionally: the five asymmetrically shaped points from Ulu Leang 1 may have been "spliced" onto an arrow shaft by beveling the shaft and attaching the point to the beveled surface. This would have brought the tip into proper alignment with the longitudinal axis of the arrow. Similar points were found along the coast of Maine and Tyzzer (1936) demonstrated that this unusual type of haft was not only plausible, but also effective. In the absence of evidence for hafting, it is important to note that any of the points may have been attached in a variety of ways to composite fishing weapons (see Stewart 1977 for examples) in addition to arrows.

Possible use wear was noted on many of the points from Ulu Leang 1 and Leang Burung 1. Two breakage patterns are thought to be associated with impact: crushing of the tip and longitudinal flake scars emanating from the end of the point. Crushing is somewhat difficult to distinguish from postdepositional breakage at times, but thirteen points from Ulu Leang 1 and five from Leang Burung 1 exhibit flake scars indicative of terminal impact.

A large proportion of the bone implements from Ulu Leang 1 and Leang Burung 1 were too fragmentary to be classified as either awls or points. These differed in no significant way from the complete tools except that they lacked enough of the shaft to determine whether they were bipointed or flared to a wide base, as in many of the awls.

No clear distributional pattern of bone artifacts occurred at either of these sites. Bone bipoints were found throughout the interior of Ulu Leang 1 and in smaller quantities in the earlier deposits in the entrance of the cave. The points and awls were derived from various levels at both sites and changes through time in manufacturing patterns or overall size were not evident.

Conclusions and Summary

The bone artifacts from Ulu Leang 1 and Leang Burung 1 are important in our understanding of the Toalean culture's technology and possible connection with Australia. These two sites are especially significant in providing dates for the Toalean of Sulawesi, so it is beneficial to use them as a basis for comparison of bone artifacts from other sites in the region. Awls made on splinters and bipoints resembling those from southwestern Sulawesi have been found at the site of Paso, a shell mound in the northernmost tip of Sulawesi (Bellwood 1976), so the full geographic distribution of these types and their relationship to other material aspects of the cultures of the region is difficult to ascertain at present. The simplicity of the Toalean assemblages sets them apart from the bone industries of the Sampung culture in eastern Java and of Niah Great Cave in Sarawak. The ornately incised bipoint from Ulu Leang 1 is unique in the Toalean to date, but may indicate that at least some artisans from this culture were willing to invest great time and skill in bone working.

Chapter 9

Summary and Conclusions

The three case studies described in this thesis were chosen to demonstrate the general applicability of a methodology that combines analysis of surface microtopography, experimental replication, ethnographic analogy, archaeological context, metric analysis, and general observations of the morphology of artifacts. Since the collections were Mesolithic and Neolithic n age and derived from temperate and tropical climates they do not represent the full range of utilization of osseous material, but enough variation is present to indicate the benefits of this kind of holistic approach.

During this research it was observed that each of the methods varied in its productivity and reliability in different conditions. The examination of surface microtopography is limited by the environmental setting of the site and other factors affecting bone preservation. While certain kinds of traces are extremely diagnostic, such as those formed by rodent gnawing, root etching, or scraping with a stone tool, other surface alterations, such as polishes, are more ambiguous. In general taphonomic and manufacturing processes are easier to identify and interpret than use wear.

The risks of using ethnographic analogy have been illustrated on many occasions by archaeologists. In the cases of perforated antlers and gouges from Point of Pines, ethnographic analogy may be less reliable than other methods of determining function, such as microwear analysis.

Archaeological context is of limited applicability because deposition of artifacts as secondary refuse bears little relationship to use areas within the site. Recognition of situations in which items are deposited as primary refuse at the location of use is hampered by later accumulations and natural and cultural disturbances. The contents of burials, however, have been demonstrated to be extremely valuable in yielding information about how ornaments were worn and by which sex and age of individuals. Patterns of distribution of certain tools with either males or females may also allow inferences about the division of labor by sex. Although a few work areas were recognized at Point of Pines, it should be noted that the potential value of context depends on exposure of large horizontal surface areas and the observation of associations between features and artifacts in the field. Certain sites are less likely to produce clear cases of work loci and the materials upon which some artifacts, such as awls, needles, and hide scrapers, would be used are rarely preserved.

Experimental replication provided many clues about the efficacy of manufacturing processes and proposed tool functions. Two major aspects of experimental replication became evident in the course of working bone. Firstly, an understanding of the material, its physical properties, its condition at the time it is worked, and how it is most efficiently worked is crucial to performing realistic experiments. That a thorough knowledge of bone, antler, enamel, and dentine as raw materials was achieved by the prehistoric craftsmen is witnessed by their products, but acquiring their level of skill necessitates a considerable investment of time for the archaeologist. Secondly, in replicating microwear through use of experimental bone tools there may be some discrepancy between traces on experimental pieces used for a relatively brief period and archaeological pieces which may have endured extensive use. There is a need for future experimental replication to follow through with longitudinal studies of wear, since many prehistoric artifacts were discarded only after they were deemed "exhausted".

The metric analysis of pointed and spatulate tools proved useful in distinguishing between awls, hairpins, and weaving tools based on trends in tip dimensions. Although the patterns of distribution of tip sizes were different when large numbers of objects were plotted, there was sufficient overlap among the tools that this criterion could not be employed in the absence of other corroborative data in designating the type of a particular specimen. When accompanied by other characteristics such as distribution of polish and amount of decoration on the base, the tip morphology provides a strong case for identification of the function of an object. The similarity in tip dimensions and morphology between awls made according to various styles and from widely divergent areas of the world demonstrates the functional constraints of piercing tools. Given the variability in any hand-made tools it is unlikely that metric analysis by itself can be used for identifying tool types, but it is important in substantiating qualitative observations in large samples. Most typologies devised by archaeologists are heavily dependent on the general morphology of artifacts. Ethnographic analogy compares archaeological objects with those of similar form known from ethnographic accounts. Gross morphology is extremely important, but examples in the case studies have shown that objects of similar form such as thong smoothers, arrow shaft straighteners, and the perforated antlers from Point of Pines may have very different functions. Recycling of weaving tools or hairpins into awls leads to different uses for the same tool with only minor alterations in morphology. In addition, the wide range of variation among awls in the three collections demonstrates how tools with very different overall dimensions and form may serve the same function. The gross morphology of a finished tool or ornament is dependent in part on the selection of a particular element of a certain taxon and how it was altered. A wide range of variation of gross morphology is often possible without affecting the function of the tool. The size and form of the working tip, edge, or surface is likely to yield more precise information about the function of an artifact since its usefulness is determined by its design.

The purpose of illustrating these points is not to discourage the use of the methods employed in this research, but rather to draw attention to the need to incorporate as many useful methods as possible in a study of bone artifacts. Since none of the methods used today may be seen as completely reliable, it is important to employ a wide variety that complement, corroborate, or refute each other. By relying chiefly on one method such as microwear analysis or ethnographic analogy in assigning a probable function to an artifact type there is a greater risk of error than if a combination of techniques is used and several lines of evidence are allowed to emerge.

The rapidly accumulating literature on the subject reveals the fruitful nature of bone artifacts as a source of information regarding many aspects of prehistoric cultures. In general current research in this area has been reliable and largely replicable. It is therefore crucial that the focus of individual researchers not become too restricted. There are several ways in which the perspective of the field may become unjustifiably narrow. As mentioned above, dependence on a single method limits the kinds of data that can be obtained and increases the chance of error.

The examination of a single type of bone artifact is acceptable for answering specific research questions, since more detailed analysis is possible with a restricted topic. It is equally important, however, to examine the whole range of osseous artifacts utilized by a society in order to understand the role of bone, antler, and ivory in their material culture and where relevant to relate the artifacts to one another.

A problem that is very apparent in the literature is the tendency during interpretation to isolate osseous material from other types of artifacts and features in the site. In part this is a product of the specialization of archaeologists and the compartmentalization of analytical procedures. The coordination of data derived from the study of unmodified bone, bone artifacts, other materials, and site context is necessary if a realistic view of the role of bone products is to be achieved. Implementation of this practice involves setting up close associations between the specialists so that feedback and integration of data continue throughout the various stages of analysis and interpretation.

Comparative studies of whole assemblages on a regional basis should be developed more fully, particularly since museum collections are adequate for many areas. On a wider scale, cross-cultural comparisons of ubiquitous bone artifacts such as awls, projectile points, needles, flakers, and hammers, may yield information regarding the physical constraints on the morphology of the tool in terms of certain functions, the kinematics employed, and the range of allowable variation.

Only by building a strong foundation of evidence for the manufacture and use of bone artifacts through time and space can we hope to draw general conclusions about bone as a raw material, the patterned selection of particular taxa and elements for artifact manufacture, and the development of bone technology in relation to other cultural advances.

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