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ANCESTRAL LIFEWAYS: THE FAUNAL RECORD

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Science is the set of tactics and strategies that we use to study the reliability of what is considered to be knowledge or understanding. Scientists, like all people, begin with ideas about the world they seek to understand. They also begin with some knowledge or belief about that world. They study the accuracy and reliability of their knowledge and seek experiences that are designed to expose limitations in the body of ideas and beliefs with which they begin their quest.

Archeology is the science that seeks to examine the accuracy and reliability of our alleged understanding about the past. It seeks to know what the ancient past was like, and how, if at all, this past might affect the present.

Paleoanthropology is the study of ancient people. It is the field that addresses the hard to know domain of our evolutionary ancestors. These ancestors are not like Granddad or Uncle Wilbur; they were animals that are recognized as being so different from us that they are judged to belong to species quite distinct from ourselves. They are, nevertheless, ancestors, since they are thought to represent historically linked phases of our biological history. They represent ancient breeding populations out of

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PRESIDENT'S MESSAGE

To our fellows, members, and friends:

The Leakey Foundation recently received a generous anonymous grant for a four year period of hunter-gatherer study: $10,000 in 1985 and another $10,000 in each of the years 1986, 1987 and 1988, provided the amounts pledged for the last three years are matched two to one. The Foundation is grateful for this timely pledge. The living hunter-gatherer communities are fast disappearing due to encroachment by farming and the timber, mining, petroleum, fishing and tourist industries.

There is immense value in the study of these people. Until about 10,000 years ago, hunting-gathering was the way of life of all our ancestors for millions of years. These early humans learned about the seasons from their observations of the clouds, the sun, the moon, the stars and even the planets long before the advent of farming. Some of their primitive medicines have survived the test of time, becoming a part of our modern culture. Art and music, too, originated earlier than farming, together with an elaboration of culture and probably a sophistication of language. Throughout this time, the human brain became larger and more complex in response to challenges which we know little about.

We receive many worthy grant requests for hunter-gatherer studies, as well as for paleoanthropology and primatology. Unfortunately we are able to fund only a fraction of those approved by our Science and Grants Committee.

We need more four year pledges. Such monies can fund those studies which are considered of the highest priority by our Science and Grants Committee. It is most important to encourage talented scientists in doctoral and post doctoral studies for long term projects, to help young scientists with their early research. This was the direction indicated to us by Louis Leakey many years ago. It has paid off with many discoveries, new concepts and a number of now seasoned research and teaching scientists who have had their start with Leakey Foundation grants.

The study of evolution, primate and human nature and survival is what the Leakey Foundation is all about. Excitement and a fine sense of relevancy are rewards for those who contribute in any way to the quest for such knowledge.

EDWIN S. MUNGER ELECTED TO THE ROYAL SOCIETY OF SOUTH AFRICA

Ned Munger, president of the Leakey Foundation for nearly 15 years, has been elected a Foreign Associate of the Royal Society of South Africa. The distinction was conferred on him at the Taung Jubilee in Johannesburg in January.

Dr. Munger has held the position of professor of political geography at Caltech since 1961. His global outlook and professional studies have led him to visit 151 countries around the world. In particular, he has traveled to Africa 61 times, spending a grand total of 14 years in one part or another of the continent. The place of the Afrikaner in today's world has been one of his special interests, reflected in several of his books. The Munger Africana Library at Caltech numbers some 30,000 items and is one of the most important research facilities of its kind.

While he was president of the Leakey Foundation, Ned Munger was responsible for the deployment of many grants to train young African students in archeology and anthropology. Today he is still aiding the Foundation in this work which contributes to the scientific skills and knowledge of Africans in Africa.

THE L.S.B. LEAKEY FOUNDATION

The L.S.B. Leakey Foundation was established in 1968 by a group of eminent scientists and informed lay people who recognized a critical need to strengthen financial support for new multi-disciplined research into human origins, our evolving nature and environmental future. It was named in honor of the man who had become known as "the Darwin of pre-history," Dr. Louis S.B. Leakey.

The Foundation sponsors:

International research programs related to the biological and cultural development of humankind.

Long-term primate research projects which may help us to understand how we evolved as a species.

The training and education of students in these fields.

Conferences, publications of scientific papers, and educational programs designed to disseminate knowledge relevant to our changing view of humanity's place in nature.

The L.S.B. Leakey Foundation is a public foundation. All contributions are tax-deductible as provided by law.

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FAUNAL ANALYSIS

The following reports are from some of the many scientists engaged in this important field whose work is supported by your contributions to the Leakey Foundation.

MANY STRATEGIES MANY GOALS

Diane Gifford-Gonzalez
University of California
Santa Cruz

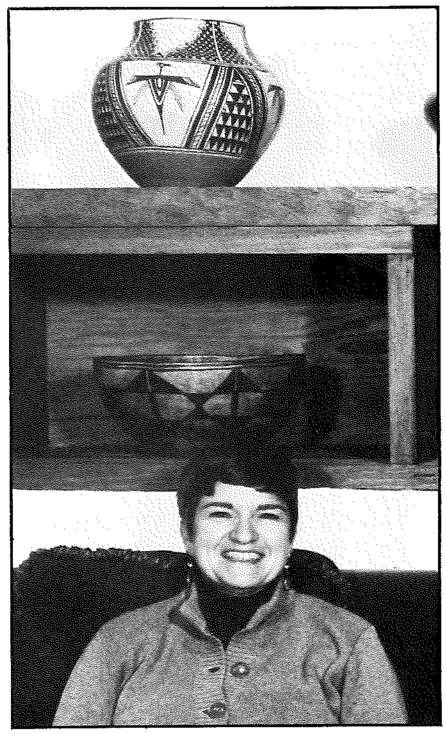
People interested in the remote human past have studied ancient animals' bones, shells, and other preserved remains since the very beginnings of research on prehistory. In fact, the first hints that humans existed on the earth in ages more ancient than those described in Biblical narratives were the bones of extinct creatures associated with undeniably human artifacts. Dr. Mary Leakey's great-great-grandfather, John Frere, a Suffolk gentleman interested in antiquities, was one of a number of early investigators who were provoked to speculate on humanity's antiquity by such evidence. In 1797, Frere reported on a find of what we now know to be Acheulian handaxes at Hoxne, associated with "extraordinary bones," including a jaw bone "of enormous size," in deposits some 12 feet below the surface. In his letter reporting these finds, Frere said that the "situation in which these weapons were found may tempt us to refer them to a very remote period indeed; even beyond that of the present world."

The way to such 18th century speculations as Frere's had been paved by over a century of development of paleontology, which studied the fossilized remains of animals using the methods of comparative anatomy. Anatomical analyses of fossils led to widespread acceptance by educated men of the possibility that some animals, though perhaps not humans, had lived in times beyond the reach of Biblical records. Likewise, after stone-using "savages" had been discovered by Europeans exploring the Americas and other continents, antiquaries had come to recognize in shaped stones retrieved from the European earth the handiwork of human beings who, in Frere's words, "had not the use of metals." The juxtaposition of such artifacts with ancient creatures' bones inevitably led to theorizing, such as John Frere's, that humans might indeed have existed in very remote times.

Between 1800 and 1860 other discoveries and systematic excavations in Britain, France, Belgium, and Germany vindicated earlier tentative claims of great human antiquity. Repeatedly, the clinching evidence was remains of extinct, often Ice Age animals, stratigraphically associated with human artifacts or human skeletal remains.

For many educated people a great antiquity of humankind was established by the 1860s, reinforced by publication of Darwin's theory of evolution of species. In the wake of this major reorganization of Western thought, prehistoric archeology and the study of fossil hominids emerged as distinct intellectual pursuits. Faunal analysis was from the outset an important part of prehistoric archeology, as well as a valuable adjunct to the study of fossil hominids. It remains a major component of research into prehistoric human evolution and behavior to this day.

The specific ways animal remains can be employed to tell us about the prehistoric past vary tremendously, both in the research strategies used and the goals pursued. Fundamental identification of bones and shells and the species from which they come relies on methods drawn from comparative anatomy and taxonomy. Faunal analysts share these approaches with paleontologists and physical anthropologists who study human and primate anatomy. New methods of analyzing faunal materials are constantly being developed. Some of these include analysis of stable isotopes in bone to reconstruct animals' and humans' diets and use of the scanning electron microscope to study bone modification. The Leakey Foundation has funded some such innovative approaches. In addition to these types of direct examination of prehistoric faunal remains, faunal analysis also includes studies of modern bones and the processes that affect them. The goal of research on contemporary bones is isolating cases that are analogous to prehistoric ones, in which the actual processes affecting materials can be observed and evaluated. These investigations, usually called ethnoarcheology and taphonomy, have enhanced the study of fossil faunal assemblages tremendously.



Diane Gifford-Gonzalez.

Despite this ever growing diversity in faunal analyses, most share one or more of three objectives, each aimed at obtaining a specific type of information about the prehistoric past. These aims are: (1) establishing the age of studied deposits, which includes learning relevant information about the evolution of animal species, (2) establishing the environmental context of the deposits, and (3) reconstructing human diet and behavior.

Establishing Age

Dating is the longest standing use to which faunal remains are put. The early European paleontologists defined successive ages based on the stratigraphic relations of deposits containing distinctively different marine or land dwelling animal species. Later, faunas typical of various spans of evolutionary time were more closely described and placed in chronological order. Over the years, such biostratigraphic units have been defined for most parts of the continents and for many marine environments, providing useful keys to dating new locales.

Faunal dating relies upon the fact that, through processes of natural selection and evolution, some animal species become extinct over time, while others appear. Certain zoological families or orders are especially useful for dating because they changed form relatively swiftly over time. For the Pliocene and Pleistocene epochs, elephants, pigs, and a number of carnivore lineages are very good time indicators.

Before the development of isotopic dating methods, most archeological and fossil hominid sites of great age were dated through the use of fauna. For example, Louis Leakey and his predecessor Hans Reck, a German paleontologist, recognized the potential of Olduvai Gorge to testify to early phases of African prehistory because fossil species typical of the Early Pleistocene epoch were discovered in initial explorations of the gorge. Even today, faunal dating is a major tool in establishing chronological relations in areas lacking materials datable by isotopic means, such as the australopithecine caves of the Transvaal in southern Africa.

Faunal dating is somewhat imprecise, but it is the first step in assigning sites and the evidence they contain to some definable block of time. It has even been used to cross-check isotopic dating. Although biostratigraphic research has been going on continuously for centuries, it is by no means complete. As new fossil localities and fossil-rich regions are explored, they must be tied into well-dated faunal sequences from other regions. The Foundation has funded basic research in biostratigraphy several times.

The key to faunal dating is thorough knowledge of the evolution of specific lineages. Scholars doing basic research on evolution of various groups of animals have also been supported by the Leakey Foundation. Dr. Vera Eisenmann, an expert in the evolution of horses, was supported in a project that aimed to standardize measurements and study techniques for equid fossils, as well as a month-long study of horse fossils at the Page Museum. Dr. Eisenmann noted that her study was relevant not only to understanding the evolutionary history of the horses but also to contributing usefully to biostratigraphy.

Establishing Environmental Context

Because every animal species requires a particular range of food and water, and lives in specific climatic conditions, their remains can testify to the environmental context of an archeological or fossil hominid site. Species with closely related modern descendants provide the most accurate information, since wildlife ecologists have documented the finer points of their requirements. However, even species without living descendants can often supply valuable information on the habitat and climatic context of earlier humans.

Faunal remains, specifically of fossil bovids, contribute some of the best evidence for a major change in climate in eastern and southern Africa a little over two million years ago that may have had an impact on the course of hominid evolution. Dr. Elisabeth Vrba of the Transvaal Museum, whose research has been supported by the Leakey Foundation, undertook an extensive study of the evolution of the bovids, an abundant zoological family that includes all antelopes, buffalos, sheep, goats and cattle. Although many species of fossil antelopes from two to three million years ago are now extinct, they nearly all have close modern relatives whose food habits and environmental requirements are known. An expert like Dr. Vrba can infer from their teeth whether certain species were browsers, eating mainly leaves of shrubby vegetation, or grazers, living primarily on grasses.

Dr. Vrba notes that while both browsers and grazers coexisted in deposits from all periods, up until around 2.5 million years ago browsers were extremely common; thereafter, grazing forms, including ancestors of the wildebeest and various gazelles, became dominant, and browsing antelopes declined in abundance. The implication is that bushy habitats, which depend on moderate rainfall, were reduced in abundance, while dry-adapted grassy habitats spread.

The scantier pollen evidence from the same time span reflects just such a vegetation shift, from Ethiopia to southern Africa. Another line of evidence, ocean temperature data retrieved from deep-sea bottom drillings, indicates a contemporaneous cooling trend in the earth's climate. This is thought by many to reflect the onset of glaciation in the higher latitudes, which also involved a pronounced shift toward somewhat cooler and substantially drier conditions over much of Africa. Thus, the faunal remains are only one of several independent lines of evidence for this climatic shift, but they are the most abundant and widespread traces available on the African continent.

Dr. Vrba suggests that this shift, which enlarged the grasslands at the expense of bush and forest and reorganized the faunal communities associated with them, had a major impact on the direction of hominid evolution. Other scholars as well as Vrba have noted that the period between 2.5 and 2.0 million has yielded the first traces of stone tools, and saw the onset of increasingly swift speciation among the hominids. Between 2.0 and 1.5 million years ago both robust australopithecines and the *Homo* lineage underwent swift morphological and, as suggested by the early archeological materials, behavioral changes.

Larger animals such as the antelopes studied by Vrba can provide information on gross features of the environment. But such animals are very mobile and most can actually live in quite a variety of vegetation communities. Smaller animals, however, are often more tightly tied to a very specific set of habitats. Their remains, when recovered from a fossil or archeological locality, can add specific detail to the rough outline provided by the remains of larger animals. The Foundation has recently supported a number of valuable studies of microfauna from major East African fossil localities.

Faunal remains have been used to determine the season in which sites were occupied, as well as their overall environmental setting. Traditionally, zooarcheologists have used migratory birds, dental eruption patterns in mammals with seasonally restricted birth seasons, and antler growth phases in deer to assess the season or seasons over which archeological remains accumulated. Recently, microscopic studies of other kinds of animal remains have expanded the possibilities of assessing the season of site use. Certain fish bones, fish scales (often preserved in the soils of relatively recent sites), and the dentine and cement of mammal teeth all grow in an incremental process, somewhat as does a tree. Like trees in temperate climates, animals living in variable environments add more to their bodies in the season of plenty than in the lean part of the year. This results in growth bands in the tissue that differ in thickness, color, and texture according to the season they were laid down. Under high magnification (either high-power light microscope or SEM) these bands can be counted like tree rings to assess the number of seasons an animal had lived and, in some cases, the season it died. This technique often requires special sectioning and staining of specimens. It works well with the remains of many temperate latitude fish and with the teeth of some mammals in hot-cold and wet-dry seasonal climates. However, it isn't possible to use it with all species even in variable environments. Nonetheless, incremental line studies have opened a new avenue for research on seasonal use of the landscape and its resources by humans.

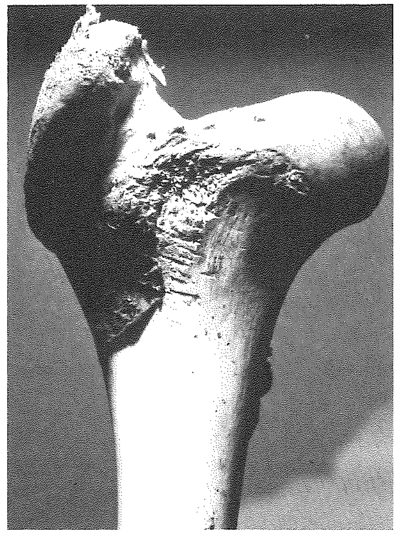
Studying Human Diet and Behavior

Perhaps the most exciting uses to which faunal remains can be put are projects unraveling what hominids ate and how they went about getting their food. Animal bones, shells, and other kinds of preserved remains have been used to reconstruct ancient diet and, by extension, ancient foraging practices, for well over a century. Yet today the field is as exciting as it has ever been, combining remarkable new advances in the technology of analysis with unresolved and hotly argued controversies over the nature of early hominids' diet and way of life.

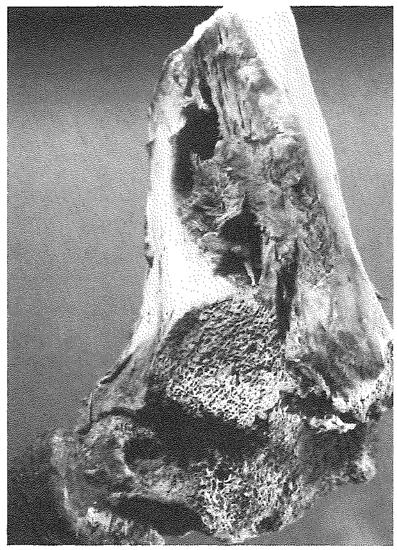
In the past 25 years, faunal analysis has undergone a major shift in methods and orientation. This shift has had many different facets, but its essence is a much more skeptical and resourcefully critical examination of alleged evidence for human diet and behavior. This has been especially true of studies of very old sites and faunal materials. Researchers trained in physical anthropology, archeology, and paleontology have focused a remarkable amount of attention on distinguishing the action of hominids in accumulating and modifying bones from that of nonhuman agents such as carnivores, flood events and the like, that also concentrate and modify bones.

Research that draws distinctions between the effects of human versus nonhuman modification of bone falls into a category called *taphonomy*, a word now familiar to many who follow research on early hominids. Derived from the Greek words for burial and law, the term taphonomy covers all those studies aimed at better understanding the ways in which animals' remains come to be preserved as fossils. The ultimate intention of such work is to produce a better grasp of what information can and can't be obtained from fossils. Most people doing taphonomy are looking for unequivocal clues to the operation of different kinds of agents and forces on animal remains. For example, is a set of scratches on a bone the result of butchering with stone tools by some hominid or of gnawing by a carnivore? While many taphonomic projects have nothing to do with hominids, paleoanthropology has seen a real upsurge in this research in the 1970s and 1980s. The first effect of such detailed investigations has often been to cast doubt on the human origins of faunal assemblages formerly widely accepted as hominid food remains. This has been what much of the current controversy is about. But the ultimate effect of close critical reviews of faunal materials is to propel faunal research to a new level of efficiency in exploiting the fossil record. Taphonomic research involves the study of modern cases in which the actual processes that produce an enduring trace can be pinpointed, and then evaluation of prehistoric materials informed by understandings drawn from the modern studies.

Taphonomic research has been supported by the Foundation, including my own ten-year study of animal carcasses at Lake Turkana, monitoring damage, disarticulation, weathering, and other natural modification of their bones from the time of death.



Proximal cow femur with heavy cutmarks on proximal shaft, plus mid-shaft break. (modern Dassanetch site)



Distal cow femur showing heavy carnivore (probably hyena) gnawing on distal end. Typical carnivore "attack strategy" of gnawing spongy bone at articular ends. (Dassanetch)

Proximal cow radial ulna, with human-caused mid-shaft break, burning traces on break and articular area, and reduction of olecranon process by carnivore gnawing. (Dassanetch)

Recently, quite a lot of taphonomic research in paleoanthropology has focused on re-evaluating early hominid archeological sites and faunal assemblages from East Africa. This has gone on in an atmosphere of considerable controversy over how to interpret the sites. Dr. Lewis Binford, of the University of New Mexico, challenged a number of widely accepted interpretations of Early and Middle Pleistocene sites, including those at Olduvai Gorge, in his book, *Bones: Ancient Men and Modern Myths*. He argued that no one had published compelling evidence that the bones on such sites were there because of hominid actions, and that numerous other possibilities existed to account for their presence. He contended that it was logically unacceptable to assume a behavioral association of bones and stones simply because of their spatial proximity, in a landscape where hundreds of large animals died yearly and where nonhuman carnivores and scavengers accumulated and modified bone. Further, he argued that until clear evidence of human processing of these bones was documented, inferences of hunting and even of meat-eating by hominids were not warranted, being more "modern myths" than scientifically supported inferences.

These were controversial claims, bound to stir up debate among investigators of such ancient archeological sites. In fact, at the time that Binford wrote, several researchers were carrying on specialized research on the faunal remains from Olduvai and Lake Turkana that established *some* level of hominid involvement but at the same time called into question some of the earlier inferences Binford challenged. In 1981, the same year as *Bones* was published, Henry Bunn, Richard Potts, and Pat Shipman published articles in *Nature* magazine, reporting that two independent studies indicated that the cutmarks made by stone flakes existed on some bones from archeological sites at East Lake Turkana and Olduvai. An independent check on hominid involvement with animal remains came in a study of use-wear on the edges of stone tools, carried out by Drs. Lawrence Keeley and Nicholas Toth and also published in *Nature* in 1981. They found some stone tools from Lake Turkana displayed polishes on their edges typical of meat-cutting and contact with bone.

At the same time that evidence for hominid modification of bones was documented, the overall picture of how these assemblages formed became much more complex. In addition to cutmarks on the bones, Bunn, Potts, and Shipman all discerned marks of carnivores' teeth. Dr. Pat Shipman, who has pioneered the use of the scanning electron microscope (SEM) to study bone modification, noted cases in which both cuts and gnaw marks were present on the same bone. Interestingly, in one case, the cut was made *after* the bone was gnawed by a carnivore. These findings indicated a much more complex history, and one in which hominids do not figure so dominantly, for these assemblages.

All these researchers have dealt with the question of whether early hominids hunted and agree that the evidence is not compelling. Other ideas about early hominid meat eating have been advanced. Based on some early published data on element representation and breakage patterns in the Olduvai assemblages, Binford contended in *Bones* that hominids seem to have been focusing more on meat-poor, marrow-rich bones of larger hoofed animals. He suggested that this reflects an inability to gain access to meat-rich parts of the body, and hence a rather low place in the carnivore hierarchy, more typical of a scavenger than a predator.

Pat Shipman's study of the Olduvai bones reported in the Spring, 1984, *AnthroQuest* supports this direction of inference; most of the cutmarks on the Olduvai bones are on meat-poor marrow bones. She also noted that few of the cutmarks reflect primary disarticulation of a fleshy carcass, typical of the strategy of modern human hunter-gatherers. Shipman has gone on to elaborate her idea that early hominids were primarily scavengers, rather than hunters, who ate meat and marrow when they could get it, as part of a diet more traditionally ape-like than earlier reconstructions allowed. It's of considerable interest to note that Robert Blumenschine, whom the Foundation has supported in his study of scavenging on the Serengeti (*Anthroquest*, Spring, 1984), found that marrow bones and the brain in the cranium were the only edible items regularly available after lions were through with their kills.

More detailed faunal analyses, relying on a knowledge of distinctive traces obtained through experiments and observations of modern situations in nature, have thus led to a major reorientation in the way we view early Pleistocene archeological remains and the hominid lifeways they reflect. Critical review will doubtless continue, resulting in either revisions of earlier ideas or support of them in greater precision and detail.

What are some of the more promising directions of contemporary faunal analysis? One line of research is high magnification examination of bone modification. Shipman's earlier SEM research on cuts, gnawmarks, and other modification is now being adopted by other researchers and applied to archeological problems in both the Old and New Worlds. This work continues to yield further insights. It's now clear that a few "cutmarks" aren't enough to testify to hominid involvement since several researchers have found cut-like scratches on bones predating the emergence of hominids. These are thought to have been produced by sharp particles rubbing against the bones. What's needed is thorough documentation of numerous and anatomically *patterned* marks on a good number of bones, as well as careful analysis of the sediment substrate, to assess the potential for cut-mimicking marks. In short, the task of drawing distinctions between human and nonhuman agencies becomes more stringent and precise.

Another very exciting approach to analysis of faunal assemblages is assessing the mechanics and logistics of butchery. There are proverbially a number of ways to skin a cat, and likewise a number of ways to break up the carcass of any animal. Most animals' basic anatomy has changed very little over the time hominids have evolved, and the contemporary world is full of instructive instances of what is possible in butchery strategies. Ethnographic observations of hunters have shown that the same group of people may take the same kind of animals apart quite differently on different occasions, according to considerations about nutritional yield of the animals, transport distances to a home base, and the need to store food for the future. Thus, it is at least theoretically possible to study archeological faunal assemblages to gain insights into specific hunting and butchery strategies of prehistoric hominids.

The strongest statement of these possibilities was made by Lewis Binford, first in *Nunamiut Ethnoarchaeology*, which reported his observations of Eskimo butchery strategies, later in *Bones*, and most recently in *The Fauna from Klasies River Mouth*. It's long been known from ethnographic accounts that hunters killing larger game at a distance from their home camps discard less useful parts of the carcass at the kill site and select other segments to transport home. Based on his experience with modern Eskimos' treatment of caribou carcasses, Binford outlined several general butchery strategies, ranging from cases in which hunters were motivated to get every last bit of food value out of a kill to those in which they had enough food to "afford" taking only the cuts that provide the highest nutritional return for the energy expended in butchery and transport. As a starting point in figuring out prehistoric butchery and utilization strategies, Binford proposed a rating scale that related bones of an animal's skeleton to the food value of the carcass segments in which each lies, including meat, fat, and marrow. This "utility index" could, he proposed, be used to evaluate the pattern of bone representation in archeological faunal assemblages and to infer patterns of animal butchery, transport and use.

One of the most interesting applications of this approach is Dr. John Speth's *Bison Kills and Bone Counts*, published in 1983. Working with the late prehistoric bison kill site of Garnsey, in eastern New Mexico, Speth noticed that while male bisons' limbs, the most nutritively valuable parts of any bison carcass, were removed from the kill site, those of females were not. Speth asked why male and female carcasses would be treated so differently by the ancient hunters. Dental evidence indicated the animals were killed in a series of ambushes, all in the spring of the year. Researching modern bison ecology and physiology, Speth found that in the spring reproducing females are in much poorer condition than males, because of the combined stresses of poor winter forage, pregnancy over the winter months, and lactation after the calves' birth in the spring. At this time, their bodies would be especially depleted in fat reserves, both in the soft tissues and in marrow and bone fat.

Speth saw a connection between this fat impoverishment and the neglect of female bisons' limb bones by the ancient hunters. Turning to ethnographic and historical reports of hunting life on the American plains, Speth found that human hunters also suffered a cycle of fat depletion over the winter months and made extraordinary efforts to get animal fat. In these regions, the natural winter diet was likely to be high in lean animal protein and low in carbohydrates. This regimen, when also poor in fat, results in a physiological inability to assimilate nourishment from food eaten, digestive upsets, and a wasting starvation. The well-known "Scarsdale Diet" is based on a mild and controlled form of the same physiological syndrome. Based on this knowledge, Speth reasoned that what the Garnsey bison hunters were mainly after was fat-rich meat and fatty bone marrow, and that males rather than females were their best choice. Thus, an understanding of the utility of different carcass segments, combined with a knowledge of physiological cycles in humans and animals, produced a thought-provoking explanation of the patterns in a faunal assemblage. As usual, we archeologists can't "prove" this is what really motivated the actions of the Garnsey hunters, but it is a plausible scenario and one with interesting implications for understanding other archeological assemblages.

Binford has recently used his utility index approach to make the case that hunting as we know it among modern humans did not emerge until the appearance of modern *Homo sapiens sapiens*. His book on the fauna from the site of Klasies River mouth, in the Republic of South Africa, reports on a study of fauna from layers containing Middle Stone Age stone tools, thought to be associated with the *Homo sapiens* forms preceding modern humans, and Later Stone Age layers, associated with modern hominids. The evidence there suggests to Binford that MSA hominids were scavenging rather than hunting larger animals, contenting themselves with the leavings of carnivore kills and natural deaths. Moreover, Binford contends that the butchery patterns evident on the MSA bones did not resemble those typical of the intensive division and sharing-out that so uniformly characterize modern hunter-gatherer meat processing. In conclusions bound to generate controversy in paleoanthropology, Binford states the Middle Stone Age hominids (roughly contemporaneous to the Neanderthals of Europe) were not hunters of the same competence as modern humans, and may not have regularly shared food among themselves.

Binford's conclusions about early *Homo sapiens* diet and behavior may ultimately be supported or falsified by other investigations. However, this is less important than the fact that the research demonstrates the potential of new approaches to fauna to gain insights into the dynamics of ancient human behavior.

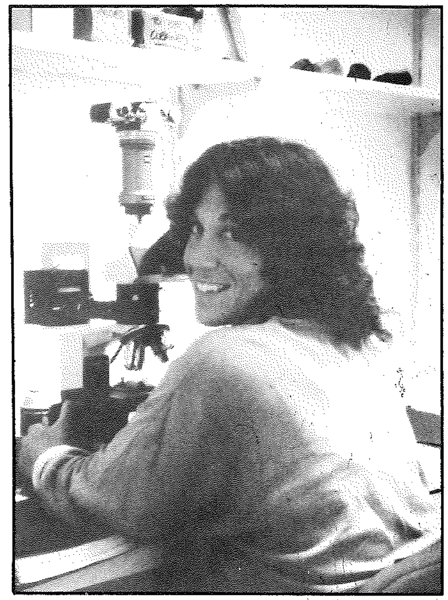
Another recent approach to studying the way humans interacted with animals in the remote past has been proposed by Dr. Richard Klein. He has developed a method for estimating the age at death of grazing and browsing species by measuring the degree of wear on the crowns of their teeth. Reasoning that teeth in these species begin to wear at the time of eruption and that such animals usually die when they run out of usable teeth, Klein has sought to develop a formula for calculating the age of an animal from the height of its teeth. He has used the resulting age determinations to construct mortality curves for different species recovered in archeological sites from Africa and Europe, in an attempt to diagnose the nature of hominid use of prey species.

I used this method to reconstruct the slaughtering practices of early pastoralists in Kenya (research partially funded by the Foundation). In the course of this research, I have found that the formula given by Klein needs further refinement to give the best results with cattle teeth. Nonetheless, I believe the basic approach has considerable potential for shedding light on details of how humans used wild and domestic mammal species for food.

Although faunal remains have been part of prehistoric investigations from the very beginning, their potential for revealing information about the past continues to unfold. Gains come both from new techniques and from more rigorous, critical ways of thinking about what the materials mean. Whatever direction paleoanthropology takes in the future, faunal remains will continue to play a major role. Like bones in the vertebrate body, they provide an unvarying structure and support, allowing continued movement into new and rewarding areas. □

MICROWEAR ANALYSIS OF EXPERIMENTAL QUARTZ TOOLS

Carole Sussman
Department of Anthropology
Harvard University



Carole Sussman.

Stone has been used by humans for the past two million years as a means of efficiently exploiting resources for food, shelter, tools to make tools, etc. Remains of these stone tools and the waste products of their manufacture are often preserved in the archeological record.

Studies of tool damage caused by use has long been considered a promising line of investigation. By using low magnification to look at striations left on the tool and analyze the types of chips and breakages along the edges, information is provided on relative hardness of the material worked but not specifically on what material the stone tool was used upon.

Larry Keeley (1974) first recognized and described microwear on artifacts made of flint. He found, when he examined flint at high magnification, that polishes could be detected along the tool edges after use and are distinctive and identifiable as to material worked and activity performed. This method is now being extensively applied to flints and cherts.

In many areas and many time ranges, artifacts are made of materials other than flints and cherts. Quartz is one very important material that comprises a major component of many Old and New World stone tool assemblages in many time periods. I chose to investigate the residues and abrasion left on quartz tools after purposeful use on various materials in the hopes that Keeley's method could be expanded to include other raw materials.

All material is cleaned before examination and is examined using a metallurgical microscope. The results are reported here.

Over 200 experiments simulating those activities known or thought to have been performed in prehistory have definitely established that use wear is distinctly visible, microscopically, on the surface of quartz tools. Experimental activities were carried out, whenever possible, in natural settings and were goal oriented. Variables in the experiments include duration of use, material worked, and actions performed. The term "polish" is used here to describe an alteration in the texture of the surface of the quartz; usually, but not necessarily, it appears as a smoothing and "bright" quality which is somehow different from the surrounding quartz surface.

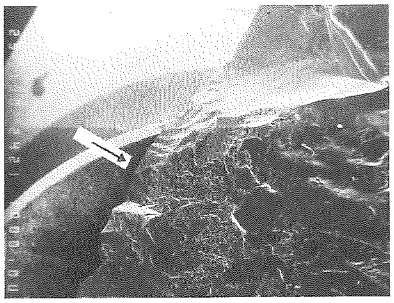
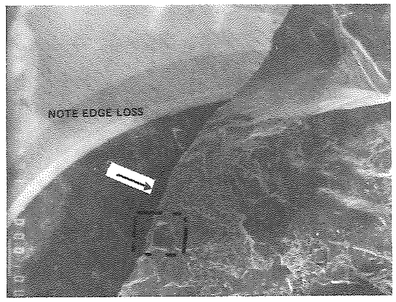
Cutting soft plants produced scalar and half moon scars along the worked edge of the tool. Pitting, striae, and rounding of the edge are all features associated with this activity. The intensity of all of them seems to vary with the amount of silica present in the plant itself and its brittleness. It was interesting to note that the striations did not necessarily run parallel to the direction of use.

Sun-dried hide stretched over a log quickly produced polish on the quartz when scraped. Distinguishing features are severe edge damage on the side not in direct contact with the hide, slight rounding of the worked edge, and a roughened, "corroded" aspect on the edge in contact with the hide. Pitting tends to follow the direction of use, running perpendicular to the edge. No striae were noted.

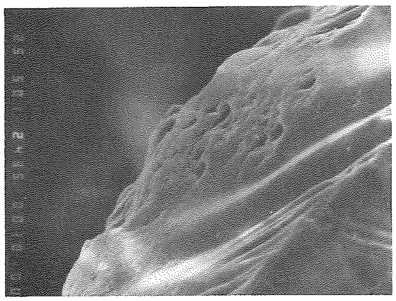
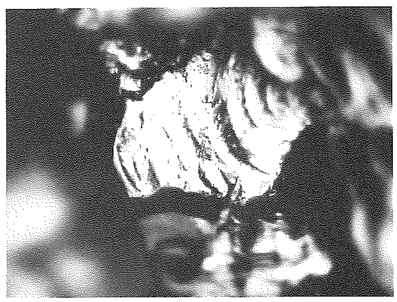
Sawing several types of wood produced edge damage in the form of half

The following is a series of photographs depicting use-wear polish on experimental tools made of quartz (vein and crystal). All photographs are labeled and each "set" depicts the same area of a tool photographed using a light microscope (Olympus BHM) and a scanning electron microscope (Jeol-35), unless otherwise stated.

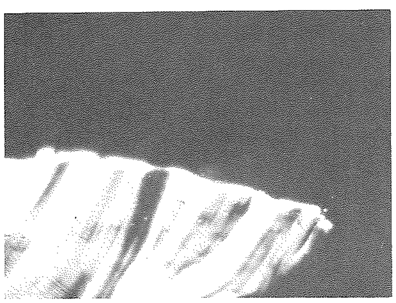
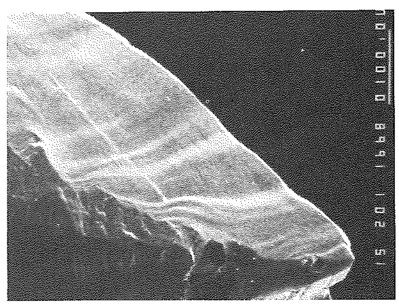
It is interesting to note how different the images are using the two different types of microscopes. Wear patterns on the tool used to cut grass show up readily at 200X under the Olympus whereas the SEM required a higher magnification to distinguish use-wear on the same piece at the very same place.

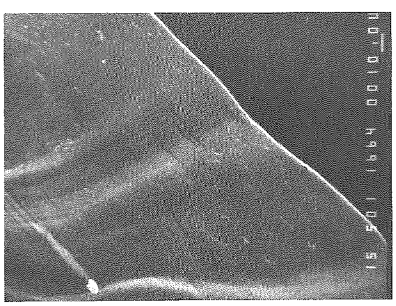
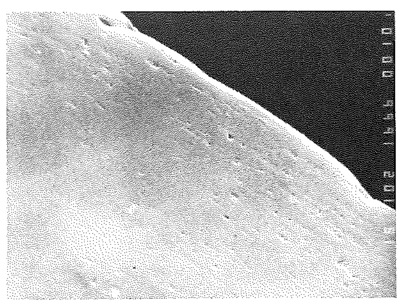
Before use | Bone Scraping 60 min. SEM-10 x | After use

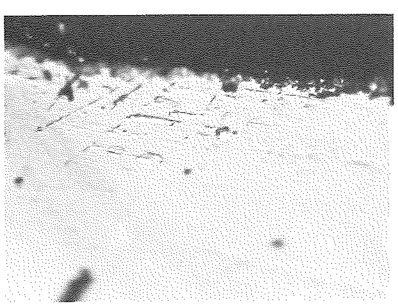
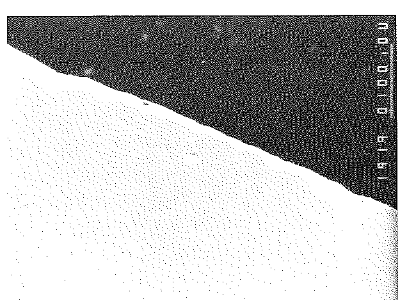
SEM-200 x | Enlargement of Bone Scraping | Light Microscope 200 x

Light Microscope | Cutting Grass 60 min.-200 x | SEM Photo

500 x | Cutting Grass 60 min.-SEM Photos | 1000 x

Light Microscope | Sawing Antler 60 min.-200 x | SEM Photo

moon and scalar scars, roughened areas near the edge, pitting and striae. The hardness of the wood determined the amount of edge damage, with harder wood such as oak producing more scarring. Pitting developed more quickly on the hardwood with a bright polish arising more slowly. Softer wood such as pine causes rapid polish development, with striae running parallel to the cutting edge.

Sawing dry antler produced abrasion on the quartz, with rough areas, pitting and narrow striae. Step and scalar scarring were present on the edge. Graving soaked antler caused broad, shallow striae running parallel to the direction of use, with pitting and rough areas present intermittently down the edge. Fresh bone graving produced long, narrow striae, with rounding of the worked edge and what appears to be comet-tailed pits in the rough, low lying areas. Sawing fresh bone left scalar scars and striae running parallel to the edge. Polish develops slowly but becomes concentrated after long periods of use.

To summarize briefly, it has been demonstrated that use wear polishes are detectable on the surfaces of experimental quartz tools after purposeful use. Polish is best detected on tools used on such materials as dry hide, antler, bone, soft wood and various soft plants. For some of these materials (soaked antler, for example) evidence of use was visible after one minute. What now remains is to determine if textural differences can be distinguished among the materials which produce clear evidence of use wear on quartz. The fine-tuning of this technique should lead to the identification of specific activities in the archeological record.

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MIOCENE PRIMATES FROM PASALAR

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When I was still a graduate student at Cambridge in 1969-70, I remember first hearing about a small hill in Turkey that was full of primates. No one seemed to know much about it, but rumors abounded about its richness and about the identity of the fossil hominoids. The site of the small hill was known as Pasalar, and the hominoids consisted mainly of isolated teeth collected by Heinz Tobien of the Johannes-Gutenberg-Universitat in Mainz, but other than this, little else was known. It came to take on a kind of fabulous quality in my mind over the years, so that when I had the opportunity to try to initiate a program of field work in Turkey in 1975, my first thought was for Pasalar. However, it is easy to have thoughts but more difficult to put them into practice.

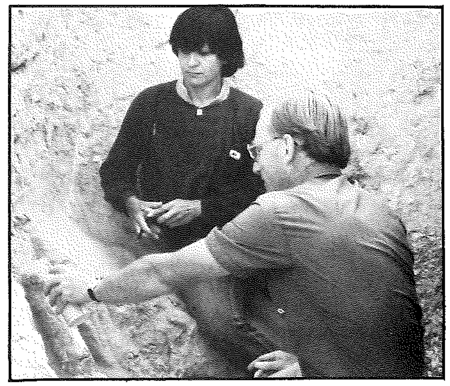
On that first visit to Turkey in May, 1975, I visited the Maden Tetkik ve Arama Instituso (MTA) with Theya Molleson. Everyone was very friendly and helpful, and we quickly established a basis for future cooperation on a long term program of research in the Turkish Miocene. In the end we arranged for our first field season to concentrate on the Middle Miocene sites at Yeni Eskihisar and nearby Sari Cay, although neither site was particularly rich nor had produced primates from earlier excavations. In 1976, Theya and I were joined by Chris Stringer and Peter Whybrow from the Natural History Museum in London, together with Chris' wife, Rosie, and my wife, Libby. Our work was only a qualified success, for although we found a lot of fossils and did some useful work on the stratigraphy of these sites, we did not find any hominoids.

Partly because of this lack of hominoids, at the end of our first field season Libby and I drove up north to try and find the "fabled" site of Pasalar. We did this surprisingly easily, although neither of us spoke a word of Turkish, and the site certainly fulfilled all my expectations, so much so that I was resolved to try and work there the following year. This was not to be, however, for the MTA were very insistent that we attempt to excavate at Sali-Pasalar (a Late Miocene site not to be confused with Middle Miocene Pasalar) and so did not apply for the right sort of permit for Pasalar. As a result, our relations with the MTA suffered an irreversible collapse just before we were due out there again in 1977, and instead I combined with Heinz Tobien in Mainz to write up the site, with Heinz describing the stratigraphy and myself the primates, which I assigned to two species of *Sivapithecus* and *Ramapithecus*.

Several years were to pass before I could begin to think again about working at Pasalar. In 1980-81, Dr. Berna Alpagut from the anthropology department of the University of Ankara visited the Natural History Museum in London for a year, and during that time we discussed the possibilities of collaborating on field work in Turkey. I persuaded her that Pasalar would be a good place to work, and on her return to Turkey she set about persuading the authorities to grant a permit. This was not easy, for the MTA still had an option on the site, but eventually she succeeded, and we had our first field season in September, 1983. I was joined by Dr. Lawrence Martin, who had done much of his thesis work on the Pasalar hominoids, and Berna was joined by Dr. Erksin Gulec, also from the University of Ankara.

Our main aim in 1983 was to examine the stratigraphy at Pasalar to find out where the fossils were located and how they came to be there in the first place. We dug a large trench through the deposits and quickly established, as the Germans had before us, that the fossils were concentrated in a greenish-gray sand. This bed can best be described as an outwash deposit which was probably accumulated very rapidly under high energy conditions (fast water flow). The site is at the foot of an extensive range of hills within a few meters of the bedrock itself, and the sediments must represent the sweepings, as it were, of the adjacent hillsides scored by a Miocene flood. They were deposited rapidly where depositional conditions changed abruptly at the break of the slope as the hills pass into the bottom flats of the sedimentary basin. Technically, the sediments could be described either as a well-sorted debris flow or a poorly-sorted alluvial fan, and probably conditions were intermediate between these.

These depositional conditions suggest that the fossils had probably not been carried far before being deposited in their present resting place. They probably represent animals that were living and died on the hillsides adjacent to the site and their bones were washed down with the sediments a distance of no more than a few kilometers. This is important, for it means that a major taphonomic bias is eliminated so that we can say quite a lot about the paleoecology of those Miocene hillsides based on the animal communities that were living there. One of the extraordinary things about the Pasalar fauna is that all groups of mammals appear to be well represented, with very small mammals like rodents and insectivores being found side by side with medium sized animals like pigs and bovids and with large mammal-like rhinos and proboscideans. Even the carnivores, so often poorly represented in fossil faunas, are relatively abundant at Pasalar. In fact there appears to be very little taxonomic or size bias in the Pasalar fauna, so that it may approximate closely the actual mammalian community living there in the Miocene. Careful examination of the structure of this community suggests that Pasalar in the Middle Miocene would have been wetter and warmer than at present, probably with a subtropical climate supporting frost-free evergreen woodlands. The monsoon forests of India might be a good example of the sort of vegetation type — seasonal subtropical woodlands supporting a diverse mammalian fauna.



Peter Andrews and Berna Alpagut excavating a proboscidean tusk from the main trench at Pasalar.

Perhaps the most remarkable feature of the Pasalar fauna is the abundance of hominoids. After the bovids and pigs they are the most abundant kind of animal. Their identity is not as clear cut as it appeared to me when I described them in 1977. The teeth are certainly thick enameled and are extremely similar to the teeth from the Siwalik deposits of India and Pakistan assigned to *Sivapithecus* and what used to be called *Ramapithecus*; this genus is now grouped with *Sivapithecus* and is not considered any longer to have any special affinities with man but to be related to the orangutan instead. Part of the reason for this change is the demonstration by Lawrence Martin that thick enamel is a primitive character retained by these hominoids, and so this character alone is not enough to identify them. There are two other characters that link the Pasalar teeth with *Sivapithecus*, and these are the flattened enamel dentine junction of the molars and the extremely small size of the lateral incisors compared with the centrals. In the absence of characters shared with any other group, it is reasonable at this stage to group the Pasalar hominoids in *Sivapithecus*, but it is clearly important to add to the sample to check this slightly tenuous identification. Many more hominoid specimens remain to be found there and it may yet be possible to recover more complete specimens.

The linking of the Pasalar *Sivapithecus* with other species of that genus and with the orangutan is of particular importance because of the age of the Pasalar deposits. They are located very early in the Middle Miocene, and although there is no absolute age for the Pasalar fauna, it appears to be most similar to that from the French site Sansan, which is generally considered to be about 14 million years old. This could indicate, therefore, an origin for the orangutan lineage at least 14 million years ago, and this in turn affects the possible branching time of the human line from either or both of the African apes. The confirmation of the age of the Pasalar deposits and of the orang affinities of the hominoids are two of the important issues that remain to be established by further field work.

The sample of hominoids found so far at Pasalar amounts to 232 specimens. In 1983, with the emphasis of our work so much on the geology and taphonomy of Pasalar, we only found 26 hominoid specimens. In the following year, however, when we started to excavate, we found a further 118 specimens, and in our 1985 season we can reasonably expect to double this number. All parts of dentition are now well represented except for the lower lateral incisors. The previous collection of 88 teeth collected by Heinz Tobien lacked many of the anterior teeth, but we have been fortunate in recovering many new incisors and canines which demonstrate the existence of two hominoid species at Pasalar. This I had suspected and published before, but it has never really been certain that two species were represented in the collection, but the presence of male and female canine morphotypes for both the large and the small parts of the population makes it reasonably certain that two species are represented. These we now assign to two species of *Sivapithecus* – *S. darwini* as I had already described, and *S. alpani* which takes its name from the Candir mandible described by Dr. Ibrahim Tekkaya of the MTA in Ankara.

It is important to emphasize the significance of the concentration of fossil hominoids from Pasalar. With our two seasons' collections added to the earlier German collection, there are now 232 specimens from two species known from Pasalar, and all but three of these come from a single sedimentary horizon. By comparison, the rich Miocene deposits from East Africa have larger numbers of specimens but they are scattered over several or often many different sedimentary levels. For instance, Songhor in Kenya has produced 352 hominoid specimens from several different areas in many different horizons, and even the richest of these has probably produced less than 100 specimens. In the course of my excavations there in 1971-72, the greatest number of hominoids from any one place and any one horizon was only 17. Similarly, the even greater number of hominoids recovered from Rusinga Island, now approaching 500, comes from a multitude of different sites and levels probably spanning several million years. In fact there is only one other site that I know of that exceeds Pasalar in terms of hominoid productivity, and that is Lufeng in China. There, likewise, the specimens are mainly isolated teeth, although they also have some remarkably complete specimens as well, but there also there are several different sedimentary horizons yielding hominoids, and it is not clear from the literature what sort of concentration is present in any one of these. With another couple of field seasons at Pasalar the hominoid sample should exceed 500, and we will have the opportunity then of assessing variability in these fossil species from a single time horizon.

I have laid a lot of stress here on the importance of getting good samples of Pasalar hominoids from a single time horizon. This is because all of the fossil hominoid species known at present from reasonably good samples come from a number of different levels, sites, geological formations or countries; in other words they come from different times as well as different places, and they differ from present day species in having this added time dimension. When we look at a species living today, we are looking at a single slice of time in the course of that species' evolutionary history, and whereas it might be expected to vary in the course of its history, a variation that can be picked up in the fossil history of the species, its reduced variation from the single time period of the present day is not immediately comparable with anything in the fossil record except under exceptional conditions. It is these conditions, and the opportunity to study them, that is available to us at Pasalar, together with the unique sample of animal species which enables us to determine something of the conditions under which the hominoids lived. □

CHASED OR FOUND: HOW DID OUR ANCESTORS ACQUIRE ANIMAL FOODS?

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The relative importance of hunting and scavenging to the acquisition of animal foods by prehistoric hominids has been actively debated by paleoanthropologists for 25 years. The issue has more than academic importance. Hunting, on the one hand, implies that meat comprised a substantial portion of the diet of even the earliest meat-eating hominids and that, in general, many of the subsistence-related social patterns that distinguish modern hunter-gatherers from nonhuman primates had arisen early in human evolution. Scavenging, on the other hand, may evoke images of much less group coordination in meat acquisition, pursued less frequently and more opportunistically than hunting. Viewed in this way, scavenging distances our perception of early hominid adaptation from that of modern hunting groups.

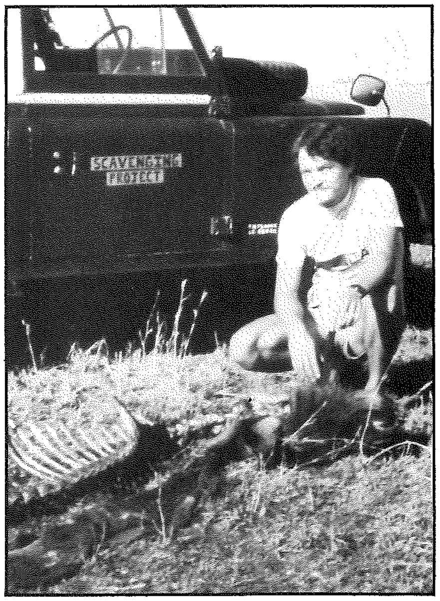
Until recently support for each position has taken the form of appeals to intuition or gross analogy to the habits of predatory nonhuman primates. Chimpanzees and baboons acquire meat almost exclusively by hunting small prey; if viewed as an elementary version of modern human hunting, this evidence supports the notion that early hominids hunted rather than scavenged. Supporting the scavenging stand is the frequent occurrence at even the earliest archeological sites of large animals, the very size of which would seem to prohibit hunting by technically ill-equiped early hominids. This line of reasoning contributed to the advancement of the idea of a distinct scavenging phase in human evolution, devoid of and preliminary to hunting, and had proponents including Louis Leakey.

Given such disparate views, there is a clear need to devise definitive tests of the hunting and scavenging positions, using the most direct evidence we will ever have: bone remains at archeological sites. Elizabeth Vrba was the first to propose such a test. Citing studies of modern predation and scavenging, Vrba suggested that assemblages accumulated through scavenging should contain few young individuals and a relatively large size range of species, whereas those accumulated by hunting should preserve relatively more young and species of a restricted size range. Richard Klein more recently suggested a similar age criterion for distinguishing hunted from scavenged bone accumulations.

Within the last two years, several other direct tests of scavenging versus hunting have been proposed. Unlike the age and size criteria, these tests attempt to determine the timing of hominid access to carcasses on the reasonable premise that evidence for early access would support the hunting stand, and late access the scavenging one. Pat Shipman's method is perhaps the clearest application of this premise. On bones that bear overlapping carnivore tooth marks and stone tool cut marks, Shipman has shown that ultramicroscopic examination can reveal which mark was inflicted first. Two other methods for determining the timing of hominid access to carcasses rely instead on a comparison of skeletal part profiles in an assemblage with those parts potentially procurable from a complete carcass. Rick Potts uses Andrew Hill's carcass disarticulation sequence to predict which parts should be available to a hunter (i.e., all parts) versus a scavenger (i.e., parts that disarticulate late in the sequence). Louis Binford uses similar reasoning, but predicts skeletal part composition of hunted and scavenged assemblages on the basis of the consumption sequence of carcasses by predators and scavengers.

I have recently completed a year of field research in Tanzania's Serengeti National Park and Ngorongoro Crater on the scale and characteristics of scavenging opportunity in contemporary settings. The research, funded in substantial part by the Leakey Foundation, was aimed at understanding factors that affect and characterize the availability of scavengable food. Scavenging opportunity was measured in terms of both the distribution of edible tissues remaining at various stages of carcass consumption, and the corresponding types and conditions of bones that bore or contained the scavengable food. The latter measure provides an interpretive link between the process of scavenging as observed in modern settings, and the archeological residues of animal food acquisition by hominids. Preliminary analysis of these data enable an evaluation of the ways by which archeological bone assemblages can be interpreted in order to come to grips with the issue of hominid hunting and scavenging.

My observations point to skeletal part profiles interpreted via the sequence of carcass consumption as the most accurate method of distinguishing scavenged from hunted components of archeological assemblages. Carnivores tend to consume carcass parts in a very regular sequence. This indicates that scavengers will have access to a limited and predictable set of edible (and corresponding skeletal) parts, specifically those which predators consume late in the sequence, if at all. Thus, and in agreement with Binford, archeological assemblages accumulated through scavenging should contain a series of body parts distinct from those accumulated through hunting; minimally, the scavengable parts include the cranium (for the brain) and defleshed limb bones (for their marrow). The sequence of carcass disarticulation, however, appears to be a less useful predictor of the edible parts available to scavengers. One reason is that disarticulation of fresh carcasses varies in important ways with the type and number of consumers, both in terms of the sequence of disarticulation,



Robert Blumenschine.

and the amount and type of food remaining on the disjointed parts.

As with all interpretive devices, there are potential sources of error associated with the use of body part data and the consumption sequence. One difficulty I can foresee results from the frequently observed partial use of a bone's edible tissues by predators. For example, lions commonly deflesh upper hindlimbs (femora) early in the consumption sequence, making fully fleshed femora unavailable to scavengers and therefore diagnostic of hunted assemblages. Lions, however, are unable to expose marrow within femora of adult wildebeest-sized animals: *defleshed* femora with marrow are therefore frequently available to scavengers and should be common components of scavenged archeological assemblages.

There must be a way to detect partial use of edible tissues on archeological bone. A seemingly effective way of doing so relies on examination of carnivore gnaw marks and stone tool cut marks. Overlapping tooth and cut marks can provide the most unambiguous clue; for example, a cut mark that overlies a tooth mark would indicate scavenging by hominids. Unfortunately, overlapping sets of marks occur very rarely relative to the incidence of non-overlapping marks, and are therefore of limited usefulness. Tooth and cut marks may be useful for detecting partial use on a much larger sample of fossil bones in the following way: Many carnivores tend to inflict characteristic damage to bones while defleshing them; if defleshing by carnivores is complete, one would expect to find carnivore gnaw marks to the exclusion of stone tool cut marks if the bone was scavenged by hominids for its marrow only. By examining the presence or absence of carnivore and hominid inflicted marks, partial use of skeletal parts otherwise diagnostic of a hunted assemblage should be evident in assemblages actually accumulated through scavenging.

A second potential source of misinterpretation of body part data from the consumption sequence arises from the effect of carcass size on the completeness of carcass consumption by predators. I have observed a relationship between increasing carcass size and a progressively earlier stage in the consumption sequence at which initial feeding by predators stops. In other words, scavenging from large animals will provide parts more indicative of those a hunter might procure from smaller carcasses. This problem, however, should arise only with the largest animals (e.g. buffalo and especially elephant). In fact, the relationship upon which this problem is based provides an additional key rather than a hindrance to distinguishing hunting from scavenging. Small carcasses, such as Thompson's gazelle, and young individuals of larger species are in many cases completely or nearly completely consumed by predators, providing little or no opportunity for scavengers. Scavenged assemblages, therefore, should be conspicuous in a preponderance of bones of medium sized (e.g. wildebeest) to large species, and in a small number of young individuals except of the largest species. The latter criterion is, of course, similar to that proposed by Vrba and Klein.

Paleoanthropologists are rapidly closing in on a solution to the puzzle of how our ancestors obtained meat and other animal foods. Binford has recently presented a strong case for the hunting of small animals and scavenging of large ones by hominids at a Late Pleistocene site in South Africa. Although the debate continues with perhaps more vigor than ever, new insights appear imminent, especially if interpretations of the archeological evidence are based on a detailed understanding of modern scavenging and hunting. Our knowledge of human origins will be fuller if we can determine how the first meat-eating hominids acquired their food, and when hunting became a dietarily and socially important activity. □

TOOTH ENAMEL THICKNESS AND HOMINOID EVOLUTION

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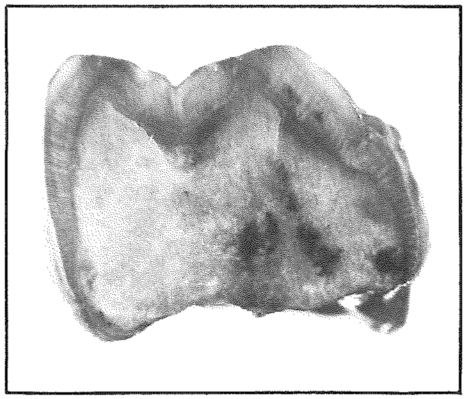
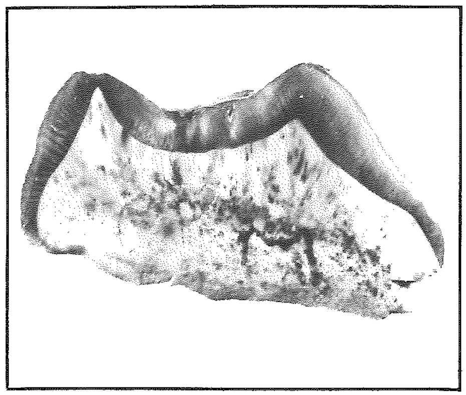
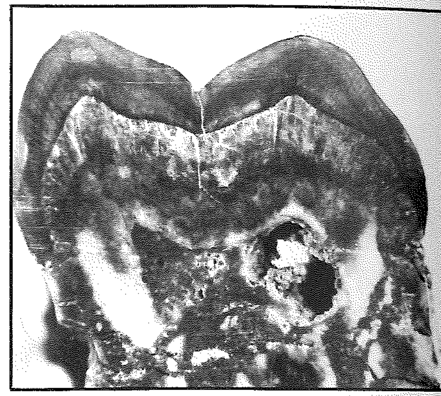


Sivapithecus alpani.

Sivapithecus darwini.



Sivapithecus sivalensis.



Sivapithecus punjabicus.

Four categories of tooth enamel thickness are now defined. Thin fast formed enamel represents the ancestral condition for hominoids, and the thickness was increased for the great apes and humans. It is primitively retained in *Homo* and in the fossil hominoids *Sivapithecus* and *Ramapithecus*. Thick enamel, previously the most important character in arguments about the earliest hominid, does not identify a hominid.

Some authors have continued to support the position that thick enamel identifies the Miocene hominoids *Sivapithecus*, *Ramapithecus* and *Gigantopithecus* as early members of the human lineage. Others have interpreted it as indicating a close relationship between men and the orangutans. Still others have suggested that thick enamel is of little taxonomic value.

The alternative views in this debate share several features. They have been based on very limited samples or on estimates whose accuracy has been questioned. Consequently there is no agreement as to what the terms "thick enamel" and "thin enamel" mean or about which fossil taxa have thick enamel or thin enamel. My research is based on a quantitative study of enamel thickness in extant hominoids and in four species of later Miocene hominoids and on scanning electron microscope (SEM) analysis of enamel microstructure.

The ideal measurement of the amount of enamel on a tooth crown would be the volume of the tissue. To obtain these data requires serial sectioning of the crowns. This was considered too destructive for use on the present samples, and so this ideal measurement of enamel thickness was approximated by dividing the area of the enamel cap exposed in a single section by the length of the enamel-dentine junction over which it formed. This dimension will be referred to as average enamel thickness.

The sample studied included 24 unworn or very lightly worn molar teeth for each species of extant great ape and humans as well as a smaller number of molars of *Hylobates* and *Sivapithecus* including *Ramapithecus*. These were cut longitudinally to provide two cut surfaces on which enamel thickness measurement could be taken.

As the species included represented a considerable range of variation in body size, the problem of allometry arose in making comparisons between species. It has been shown that enamel thickness increases with large body and tooth size in anthropoid primates: Gorillas have absolutely thicker enamel than do chimpanzees related directly to body size; orangutans and humans have relatively thicker enamel even when scaled for body size. To resolve this issue it is clearly necessary to scale the average enamel thickness against body size, and as body weight data are not available for fossil species, various dental estimators of body size were tested to try to find one suitable for use on fossils. The best one was found to be the combined area of the dentine and the pulp in the same section on which enamel thickness was measured. Combined with average enamel thickness, this produces a dimensionless index referred to as relative enamel thickness.

In the present work, sequential cuts made into the enamel provided information about enamel prism cross sections. These were examined at a series of depths into the enamel while sectioning teeth for enamel thickness measurements. When sectioning was completed, the cut surfaces were examined by back-scattered scanning electron microscopy to obtain additional information.

All the hominoid species examined had two very thin layers of slowly formed enamel, one at the tooth surface and the other immediately adjacent to the enamel-dentine junction. In *Homo*, *Hylobates* and *Sivapithecus*, all the rest of the enamel was fast formed (pattern 3) decussating enamel, accounting for the great proportion of the enamel.

Gibbons have thin enamel because it forms for a relatively shorter period (in relation to size) than does the enamel in species belonging to the great apes and humans. All the members of the great ape and human group have an extended developmental period of tooth enamel relative to size. If all the enamel was fast formed it would be thick, as indeed it is in man. The thin enameled and intermediate thick enameled great apes form enamel over the same relative time period as the thick enameled species, but their enamel is thinner. In *Pongo*, the fast formed decussating enamel is overlain by a moderately thick outer layer of slowly formed non-decussating enamel. In *Pan* and *Gorilla*, the fast formed decussating enamel was overlain by a thicker layer of slowly formed non-decussating enamel than in *Pongo*. There are therefore differences in the slowing down process between the

African apes and the orangutan, resulting in differing proportions of enamel types which in turn produce differences in thickness.

The results of the study have the following consequences with regard to the possible homology of enamel thickness categories: *Pan* and *Gorilla* have the same enamel thickness and the same distribution of enamel microstructure. Their shared possession of thin enamel may therefore be considered a homology. Gorillas and chimpanzees have the same relative enamel thickness as gibbons but different prism packing patterns and different rates of formation. The thin enamel of gibbons and that of gorillas and chimpanzees is therefore not homologous. The slowing down process of enamel secretion differs between African apes and orangutans in nature and extent. This means that the two great ape branches are not homologous in either enamel thickness or enamel microstructure. Conversely, gibbons and humans have similar prism packing patterns and therefore rates of formation, but very different enamel thicknesses. The only groupings of hominoids which have the same enamel thickness and microstructure are chimpanzees with gorillas, and *Homo* with *Sivapithecus*.

The recently proposed close relationships between man and the orangutan depend very largely on the interpretation of thickened enamel as a shared derived character between these genera, but as this has been shown not to be the case, and as it is the determination of ancestral conditions that is the main aim of this research, this view is not accepted here.

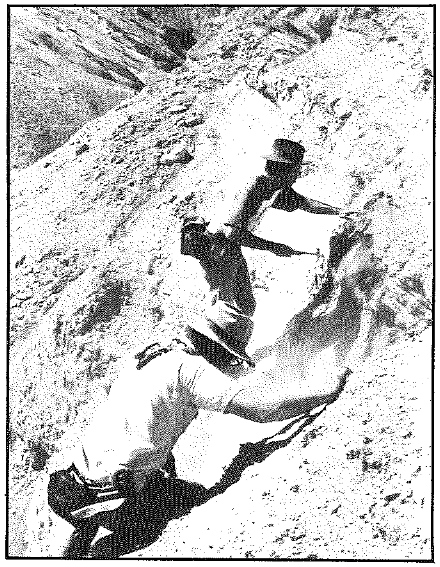
Thick enameled, human-like teeth have previously been used to support the hominine status of *Ramapithecus* and more recently *Sivapithecus* and even *Pongo*, but these features have been shown by the data to be a primitive state with the great apes and humans. Moreover, the common ancestor of the great apes and man, and of the African apes and man, would have had teeth which resembled those of hominids. This fact should be borne in mind by those attempting to establish the earliest record of hominids from deposits of Later Miocene to Early Pliocene ages. Of the living members of the great ape and human group, only *Homo sapiens* retains the condition of enamel thickness and development from the common ancestor of that group and may, therefore, be regarded as the most dentally primitive.

Editor's note:

Homology refers to similarities of organisms based on common evolutionary descent.

Analogy refers to similarities between organisms based on common function not due to evolutionary relationship. ☐

Perched high above the gully floor, Drs. Nick Toth (foreground) and Tim White expose the fossil-bearing horizon away from the quarry for a distance of over 100 meters.



PALEONTOLOGY, ARCHEOLOGICAL STYLE

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As archeologists studying the behavioral and adaptive patterns of our early hominid ancestors during the last three million years in East Africa and Western Europe, it may seem strange that we have spent a summer digging a Miocene site (15 million years old) in Southern California, since there is absolutely no chance that any human ancestors existed in the Americas at that time. (The earliest definite evidence indicates they were here only in the last 30,000 years.) In fact, the absence of hominids is exactly *why* we had chosen the site.

Since many of the behavioral interpretations of early hominid lifestyles, such as hunting or scavenging, meat eating, home bases, and food sharing, have been based on the nature of fossilized bones found in association with stone tools at early prehistoric sites such as Olduvai Gorge in Tanzania and Koobi Fora in Kenya, it is absolutely essential that we be able to separate patterns of bone collection and modification that have been caused by hominids from those produced by non-hominid agencies.

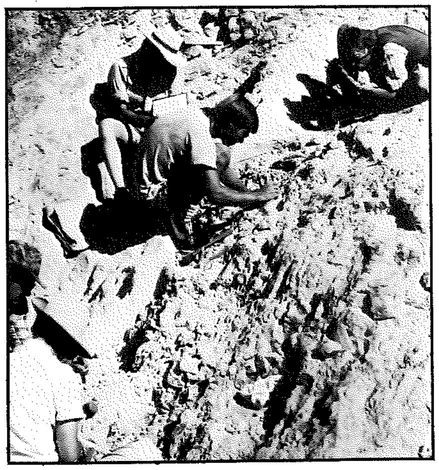
To make these distinctions, several lines of evidence have been used. These include: 1) studies of bone modification and collection by modern hunter-gatherers; 2) studies of bone modification and collection by modern non-hominid animals (e.g. carnivores, rodents, etc.); and 3) studies of other modern natural forces that modify bones (e.g. root acids, abrasion, chemical weathering, etc.).

In all of the above types of study, the bones under scrutiny are modern and have not gone through the transformational processes that make them mineralized fossils. Another valuable approach to bettering our understanding of the natural history of bones is to excavate, with archeological precision, fossil bone-bearing sites in contexts that have *nothing* to do with hominids, with the express purpose of examining how similar or different their bone contents are from those found at Early Stone Age sites. Pioneers of detailed paleontological excavations have included F. Clark Howell's team at the Omo, Ethiopia, A. Kay Behrensmeyer in East Africa and Pakistan, and Michael Voorhies in North America. This is the approach we have followed in our recent study in Southern California, a study specifically designed as a test case to look critically at our ability to make accurate interpretations of the bones we find at Early Stone Age sites.

The Robbins site is a paleontological quarry that was tested in the 1970s by Dr. Robert Reynolds, curator of earth sciences at the San Bernardino County Museum. We were searching for an ancient site in North America with well-preserved bone, a range of animal types, a prehistoric grasslands environment and fine-grained geological context. The Robbins site met our criteria, and at the invitation of Dr. Reynolds we decided to conduct excavations here.

The site is situated in the Mud Hills of the high Mojave Desert about ten miles north of Barstow. The modern-day landscape is dominated by eerie Joshua trees, scrub and cactus, with the principal animals being jackrabbit, kangaroo rat, coyote, tortoise and the rare but highly impressive Mojave green rattlesnake. The fossil-bearing units are found in eroded wash gulleys in a typical badlands topography that strongly resembles prehistoric fossil localities in the East African Rift Valley.

Fifteen million years ago, however, the setting was very different. Grassland plains stretched out over the terrain, bordered on one side by active volcanoes. A lake with streams flowing into it was located in a depression in the grasslands, bordered by more lush vegetation. Large herds of the diminutive, deer-sized horse *Merychippus* grazed near the water's edge. Also present were smaller herds of extinct camel and



Robbins quarry excavations in progress. The ancient beds have been tilted to nearly 40 degrees from their original horizontal position. Clockwise from bottom: Carole Travis, Tom Gehling, Kathy Schick, Ted Daeschler, and National Geographic photographer David Brill.

pronghorn antelope, as well as coyote-like carnivores, small hornless rhinos, giant "dog bears," and the mammoth-like gomphotheres. At our site and at other nearby localities we have discovered bones of all of these creatures.

The Robbins site is sandwiched between two volcanic layers that have been dated by the potassium-argon technique, establishing that the fossils uncovered are approximately 15 million years old. This time period is called the Miocene worldwide and the Barstovian (earlier Miocene) in North America, named after nearby Barstow.

The excavations were directed by us and supervised by U.C., Berkeley, paleontologist Ted Daeschler. The crew consisted of Alemseged Abbay (Ethiopia; U.C., Berkeley), Tom Gehling (U.C.B), Christa Sadler (U.C.B.), Mike Siskin (U.C.B. and Basin Research) and Carole Travis (Jackson, Wyoming). Visitors included Dr. and Mrs. J. Desmond Clark (U.C.B.), Dr. Tim White (U.C.B.), Berhane Asfaw (Ethiopia; U.C.B.), Gen Suwa (Japan; U.C.B.), and photographer David Brill of the National Geographic Society.

We were able to camp about a quarter of a mile from the site. Situated on top of the escarpment overlooking the sedimentary outcrops, the camp consisted of our vehicles, a large laboratory/mess tent with supplies, a cooking area, individual tents, and a 50 gallon water drum. Conditions were comfortably Spartan.

During the first week of the field season we were hit by 60 mph winds that knocked down the mess tent, destroyed our personal tent, and sent another untethered tent sailing over the escarpment and down to the valley floor, undamaged. The nights were bitter cold, so that on the following weekend most of the crew went to the Barstow K-Mart to buy sweatshirts. Once the winds died down, we were able to build nightly campfires; I was impressed at how much a fire improved morale in the camp, and thought of how important the invention of fire must have been as a focus of social interaction for our ancestors. As the field season progressed, the Mojave got a little hotter each day until, toward the end, temperatures reached 120°F.

Cooking was an egalitarian affair, with teams alternating chores daily. *Haute cuisine* included American, Scandinavian, Hungarian and Ethiopian versions of barbecued chicken, hamburgers, chili, curried chicken, spaghetti, and "tuna surprise."

Daily entertainment was provided by the United States Air Force out of Edwards Base, who seemed to have selected our excavation and campsite as a simulated target. One especially vivid memory, seen from our cots on the edge of the escarpment late one night, was of a supersonic fighter banking over the twinkling lights of Barstow some ten miles distant and in a matter of seconds roaring directly over us at very low altitude.

The fossils were found in a hardened layer of volcanic ash, which covered a clay deposited in a prehistoric lake. The lake also contained the bones that subsequently became fossilized.

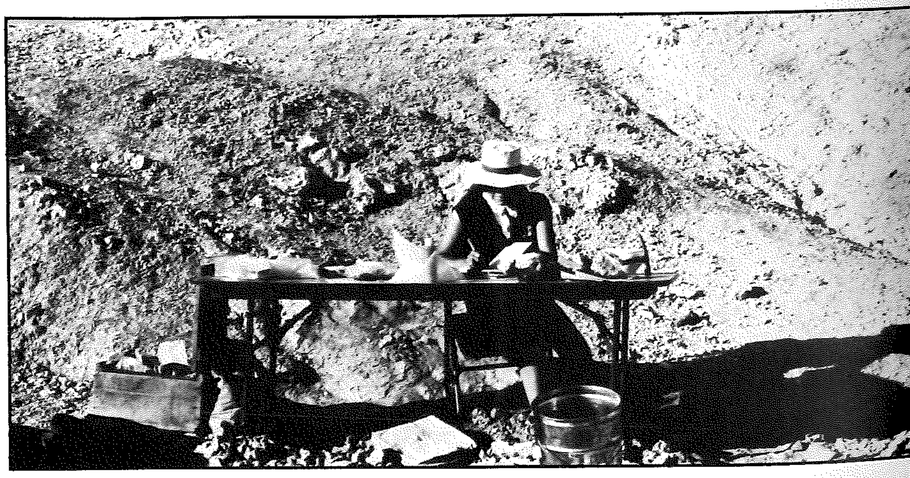
There was considerable overburden to dig through before we reached the fossil level; some of these overlying levels were harder than concrete. The general excavation procedure was as follows: 1) We removed the overburden using jackhammers and shovels; 2) proceeded to excavate using wood chisels and rubber mallets once the fossil horizon was reached; 3) carefully used awls, dental picks, and brushes when fossils were located to extract them from the deposits; and 4) screened all excavated sediment for small bones or fragments.

We also stripped the overburden above the fossil-bearing horizon for more than one hundred meters along the winding outcrops to quarries that were blasted out by Childs Frick of the American Museum of Natural History in the 1930s. All the bones that were exposed in this "two dimensional" excavation were plotted and recovered so that a better understanding of the local paleogeography and prehistoric conditions of burial and fossilization would be possible.

Major questions we asked in this research were: 1) How did the fossil bones arrive at their place of burial? 2) What agencies were responsible for the selection of certain body parts over others? And 3) do the patterns of bone modification resemble those induced by hominids? The provisional working hypothesis that we are employing is that many of the fossils found at the site represent animals that perished in a minor catastrophic ash-fall (such as the Mt. St. Helens event) and were exposed on the surface for a short duration, during which time the carcasses were ravaged by carnivores. Ribs, crania, and marrow-bearing bones were preferentially destroyed by gnawing. Then moderate water action redeposited the surviving bones some distance downstream, especially jaws and lower limb elements, the later probably still articulated with dried skin and ligaments.

We are taking a very close look at a number of aspects of the fossils from our site, including the range of taxa represented, the individual body parts present, the spatial density of bones, the sizes of bone fragments, and patterns of breakage, striations, and punctures found on the bones. The scanning electron microscope is an important tool for obtaining high-quality magnifications of bone surfaces and their modifications.

We hope that more archeologists and paleontologists will conduct similar investigations of well-preserved fossil localities so that the sample size of such evidence will be increased, and a fuller appreciation of the range of variation in natural bone modification will become possible. □



"Another day at the office." Dr. Kathy Schick at work identifying, recording, and plotting each fossil discovery from the excavations.

continued from page 1

Lewis Binford.

which the genetic raw material of our own kind arose.

What were our ancestors like? How much of what we consider to be "human nature" would be discernible if we magically traveled back in time and observed the behavior of our biological ancestors?

Almost from the beginning of our recognition that humankind had a vast and complicated history there were two generalizable views of the past. One view was recently summarized as follows:

> Many modern scientists . . . would have us believe that primeval man has been "a coarse and filthy savage, repulsive in feature, gross in habits . . . sheltering himself in damp and smoky caves with no eye heavenward."

In contrast, there are those who view ancient humans as if they were essentially like ourselves. Their nature was thought to have been given at creation, and if any change occurred it was in general a falling off, a deterioration, leading to what some have judged to be the "degraded stations now occupied by so many."

This push-pull of bias, this competitive advocacy for differing views of human history, is not exclusive to the nineteenth century. It is a continuing fact of the modern field of paleoanthropology. Most of the arguments regarding "new ideas" currently being debated are conformable with either the bloodthirsty or the noble savage models of man's past.

That our ideas of the human past are undergoing major changes is certainly true. That the change is in the direction of one of the opposing positions presented above is also true. The difference between the changes that occurred in our views during the nineteenth century and those that are occurring today is that the current pendulum swing is being conditioned by major shifts within the field of archeology, not by general shifts in our broader culture that make one view of humanity more acceptable than another.

One philosopher of science recently argued that growth in knowledge is not just an accretional consequence of scientific activities — that is, an increase in our acknowledged skills in looking at the world and describing it — but instead is prompted by major changes in how we think about what we have seen and in how we assign meaning to the observations we have made. Put another way, when a field is undergoing fundamental change the most common arguments will be about the ways in which we give meaning to observations. During periods of normal scientific growth, arguments generally concern the significance of meaningful observations with respect to questions of theoretical interest.

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That the field of paleoanthropology is undergoing a major paradigm shift is indicated by the fact that much, if not most, of the current debate in the field concerns how we verify the accuracy of meanings attributed by archeologists to properties of the archeological record.

Such a period can be most exciting, stimulating, and certainly confusing to casual observers. The general public may in fact be unwittingly used during periods of fundamental change. During such episodes the major points at issue concern the question, "How do we know?" Under such conditions, discussions of "what we know" can be very misleading.

Let me see if I can clarify this situation by briefly tracing some of the tactics we have used over the past 50 years to learn something about the past.

It should first be realized that the past is gone. We cannot observe the past directly; we can only examine the remnants of the past and make inferences as to what they imply. Early paleoanthropologists commonly looked at the archeological record with an assumed notion of how the past had proceeded. Modern man was used as the standard, and the ancient past was thought to have been a progression of situations that marked our transition from the bestial world of animal ancestors to our present condition. Archeologists in turn sought evidence in the archeological record for the origin of those characteristics that were judged to set us apart from the animal world. When did man first use fire? When did man begin to walk upright? When did man first evidence an aesthetic sense? When did morals appear? Much of early archeology was dedicated to answering these types of questions, and many archeologists still pursue them.

The first step in another approach was heralded by Raymond Dart's discovery in 1925 of the first example of what we today call *Australopithecus*, a fossil that documented a phase of our evolution that was earlier than anything previously known. The problem that Dart faced was different from those faced by other researchers. He argued that this newly discovered fossil was ancestral to humans. Not only was this fossil the earliest known, it was also different from modern humans in many important ways. Because no one knew what our ancestors should look like, the result was a storm of controversy regarding the particular anatomical features that could be cited to justify the argument that the fossil represented an ancestor.

In the 1940s Dart adopted a new strategy of argument. Since the anatomical features that mark a human ancestor were unknown, he realized that the arguments over opinions could go on indefinitely. To combat this Dart took a different approach. He asked himself what essential features of behavior mark us as distinct from other primates. He suggested that we are the only predatory primate, the only "killer-ape," as he called us. He further

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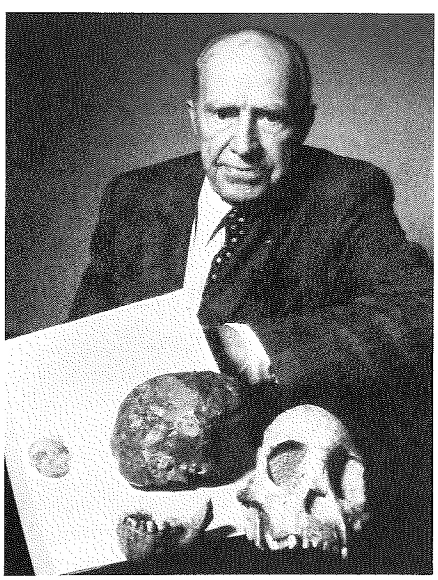
reasoned that we are the only primate to use tools and to control fire. If he could prove that his fossil antecedent practiced these behaviors, then he could certainly claim that he had found an ancient human ancestor. This line of reasoning hit the ball into the archeologist's court. It would be through understanding the archeological record that proof of human ancestry would be established.

The fossil that Dart had discovered was recovered during operations at a limestone quarry. Dart searched the other remains recovered in association with the fossil to reveal facts that could be cited in support of his claims for human ancestry. The most obvious and numerous remains recovered from the same deposits were the bones of other animals. Many different species were represented, and the bones were recovered in many forms that were different from bones as they occur in living animals. The bones were broken, some were marked with scratches and other inflicted scars, but more importantly for Dart, the frequencies of the bones in the deposits were very different from the known frequencies in living animals. Dart argued that the fossil hominids, the australopithecines, had been the agents responsible for the accumulation of the deposits in the limestone caverns. They had been cave living killer-apes. He also argued that the unusual frequencies of bones derived from the differential selection of anatomical parts that were brought to the cave homes for food and for use as tools. These modified and scarred bones were presumably the first tools, used before the manufacture of tools from more durable substances, such as stone, was learned. Dark stains in the deposits were cited as evidence for the use of fire. In short, Dart argued that the evidence from materials associated with the fossil australopithecines proved that they were human ancestors.



They were viewed as cave-living predators who made tools from animal bones and used fire.

Almost from the first appearance of Dart's construction of the past there was resistance to the "bloodthirsty killer" view of our ancestry. Some of this resistance was prompted by the popularization of Dart's ideas by the professional writer Robert Ardrey, who clearly suggested that we are, by nature, killers. Warfare and modern nationalism were thus viewed as inevitable consequences of basic human nature. Objections stemming from less contemporary concerns pointed out that the deposits yielding the fossils and the alleged bone tools could simply be the remains of ancient hyena lairs. Suggestions such as this led to an important posture within the field of archeology. We realized that we did not know what hyena lairs should look like when seen in ancient deposits. In short, we realized something of the nature of our ignorance, and we further realized the kind of knowledge needed for an accurate understanding of the past. Because of this, much work addressed to reducing our ignorance was initiated.

Of particular importance was the work of C. K. Brain, a South African archeologist and paleontologist. He realized that hyenas are not the only animals who accumulate bone in lairs and sleeping places. Brain studied leopards, hyenas, owls and African porcupines, and he studied modern groups to learn how people treat bones and how gnawing dogs might affect bone frequencies in deposits so that they no longer resembled those known in living animals. With this knowledge Brain could address the facts that Dart had previously noted, the biased frequency of bones and the association of animal bones with those of ancient hominids. Brain developed relevant new knowledge to the point where he could diagnose the ancient deposits that Dart had studied. Some of the fossil-yielding sites were natural traps — like sink holes — where bones from the surface washed down into existing limestone caverns, with the occasional addition of trapped animals who fell in or entered and could not get out. Other caves had openings to the surface, and the interiors were inhabited and used by animals.

One famous site, Swartkrans, yielded many fossils of what is today called *Australopithecus robustus*. With his knowledge of leopard behavior and of geology, Brain was able to demonstrate that, instead of the hominid being the killer-ape, he had in fact been part of leopards' meals.

Ironically, while most of the fossil-yielding South African sites have turned out to be complex deposits representing the material remains of interactions among natural processes and active animal agents and not the cave homes of killer-apes, as Dart imagined, the research that his ideas prompted has turned the field of paleoanthropology into a true science. Rather than passively digging sites in order to research

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the history of innovation and invention, we were actively engaged in researching the domains of our ignorance. The resultant knowledge makes it possible to construct a more accurate picture of the past. Archeologists were not the "Raiders of the Lost Ark" adventurers seeking treasures hidden in the record. They became scientists seeking knowledge from hyena lairs, modern people, laboratory experiments, and any place in the world of relevant causal process that could enlighten our ability to know the past.

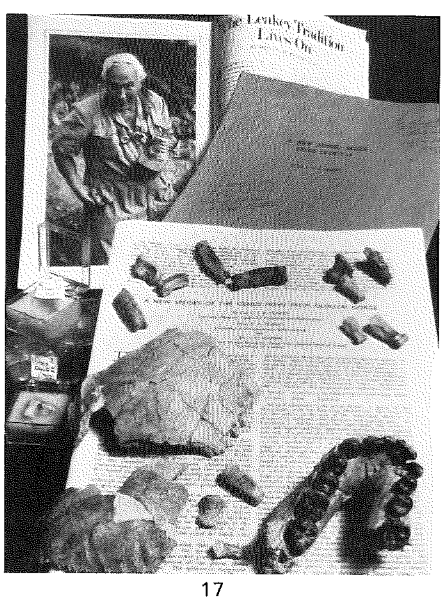
During the time of the Dart controversy another important figure in paleoanthropology was working with great dedication at the famous sites of Olduvai Gorge. Of course, I am referring to Louis Leakey. Leakey was well known for his belief that the characteristics of modern people had great antiquity. His response to Dart's arguments had been essentially to reject them by suggesting that our ancestors were not by nature killers. Rather, they had been small, peace-loving creatures who were eclectic feeders, occasionally consuming birds' eggs, small birds, and perhaps a baby antelope or pig encountered while foraging primarily for plant foods. Leakey did not discover a fossil hominid in Olduvai Gorge until 1959. Shortly after his discovery of the fossil we call *Zinjanthropus*, large excavations at the site by his wife, Mary, revealed some very important evidence. In the same deposit with the fossil hominid were unquestioned stone tools. Perhaps more disturbing to Leakey was a large array of animal bones. These were not the bones of baby birds, antelope or pigs. They were the bones of large Pleistocene animals. Everything seemed to point to the conclusion that these sites were ancient homes of our ancestors. In this type of setting the animal bones seemed to be self-evident testimony to the nature of the hominids' diet. Leakey's position quickly shifted, and in the able hands of Glynn Isaac, one of Leakey's students and collaborators, a new view of early hominid life was developed. While the data from Mary Leakey's excavations seemed to prove that early hominids were hunters, Isaac concluded that they were not bloodthirsty killers – they were home-loving and family-loving creatures, as we are. They hunted animals to be sure, but they did so with National Rifle Club standards, only to provide for their families.

The past was constructed anew. Early humans lived in family groups that were organized by a sexual division of labor in which men hunted and women gathered. Hunting was done to provision others, and the sharing of meat by male hunters was considered to be the behavioral context in which our language and communication skills might have developed. In short, the "human" way of life was painted as characteristic of our ancient ancestors as far back as 2,000,000 years ago.

If Robert Ardrey was the popularizer for Raymond Dart, then *National Geographic* and Time-Life books made the Leakey–Isaac view "truth" for most contemporary readers.

During the time of these developments I had been worrying with the interpretation of the archeological remains of much later fossil ancestors – the Neanderthals who lived in Europe between 100,000 and 40,000 years ago. In the 1960s I had come to the conclusion that the record from Neanderthal sites was qualitatively different from remains left by our own species – modern individuals of both ancient and contemporary forms. The Neanderthals had been traditionally viewed as a somewhat brutish and perhaps "slower" form of modern human who lived in caves and were primarily hunters. I concluded that the projection of our knowledge of modern humans back to the ancient past was perhaps obscuring our abilities to see history clearly. Much as Brain had done, I turned my attention to the study of the contemporary world for new and relevant knowledge. I studied the few cases of hunting peoples remaining in the modern world, the Nunamiut Eskimo of Alaska and the Alyawara-speaking peoples of Australia. My strategy was to understand in detail how hunting was manifest in the archeological record, how the organized tactics of food procurement, storage, and processing for consumption produced differing and diagnostic traces of ancient behavior. I too had to face the problem that Brain had faced, namely, what processes in nature might modify the remains of animal bones that an archeologist might recover. I studied wolves and the bones they introduced to their lairs, and like Brain, I studied the effects that gnawing animals had on the bones. My work on this subject was carried out among the Navajo of Arizona.

The more I learned about hunting and characteristic archeological signatures for typically human ways of life, the more I was convinced that ancient human beings – the Neanderthals – had been very different from us. If this was true, then the cozy picture of very early hominids painted by Leakey and Isaac for a much earlier time period appeared to be paradoxical. In 1977 I challenged the Leakey-Isaac view in a detailed review of a book by Isaac. In that review I brought to bear some of the knowledge I had gained from the study of hunters, as well as my skepticism regarding the accuracy of the past as constructed by Leakey and Isaac.



The response was most gratifying. Isaac, who was working at a site then thought to be one of the earliest documents of hominid tool use, took up the challenge and started his students working on the study of butchering marks, bone breakage and the details of the horizontal distribution of tools and bones. They also studied other details thought to be important to the demonstration of hunting and of the way of life of our ancestors more than 2,000,000 years ago.

I too saw the importance of this challenge and shifted my research attention to the dawn of human tool use. I wrote and, in 1981, published *Bones: Ancient Men and Modern Myths*. In this work I used all my accumulated knowledge of human hunting as well as my observations of animals, combined with the observations of other scholars, to address the study of the important sites excavated by the Leakeys at Olduvai Gorge. From this perspective, the bone content of the sites did not look like they were produced by hunters. In fact, the most common bias in the parts of animals represented were the lower legs of ungulates, which have essentially no meat on them. On the other hand, many of the characteristics seemed similar to what was then known of animal behavior, particularly of the hyena and perhaps the lion. Two things seemed clear. First, if the hominid occupants of those sites were responsible for all the bones within them, then they were certainly behaving very differently from any known modern hunters; in short, their behavior was quite different from ours. In fact, it was so different that it suggested to me that the hominids were scavenging very marginal foods from carcasses already consumed and ravaged by other predators/scavengers. Second, when considered against my knowledge of animal behavior, other facts seemed to indicate that agents, importantly the hyena, also contributed extensively to the content of the deposits.

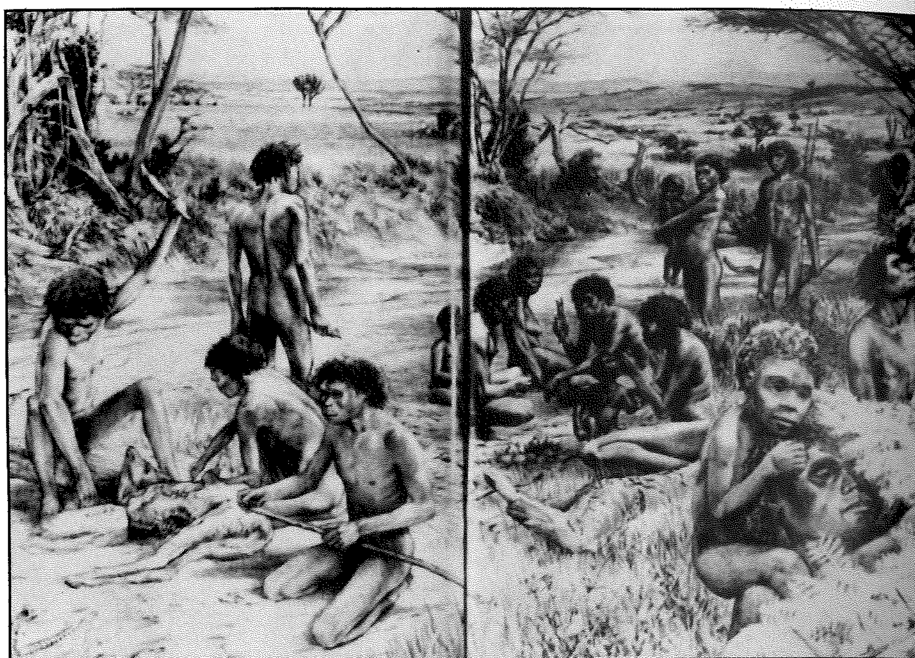
These conclusions forced many further thoughts. We had learned from the Dart experience that the simple association between hominid remains and bones did not unambiguously indicate that the hominids were the exclusive agents responsible for the accumulation of the deposit. In the case of Dart's data the challenge had been to learn the complex of interactions among natural processes and active animal agents that could produce a cave deposit, which might also include evidence of hominids. In contrast, the Olduvai sites are what we call "open sites." That is, they are buried deposits that had been formed on open land surfaces. Was it possible that a deposit that yielded unambiguous hominid evidence, such as stone tools, could also have a complex history of formation comparable to that of cave deposits? I suggested that this seemed likely because a land surface is available to all the active components of an ecosystem. Hominids may have been a part of that system, but many other agents could equally contribute to the debris accumulated and subsequently buried on such a land surface. Investigations by geologists had shown that the famous sites were concentrated along one small segment of what was an ancient lake at the time the sites were occupied. The concentration of sites

". . . the content of the sites was like a chemical compound — it looked like a single thing but was in fact made up of numerous elements."

was understandable in that they occurred where the water flowed into a lake that was landlocked and therefore salty. They were concentrated around the rare points where potable water was obtainable. This made complex formation processes even more likely, since most if not all animals must drink. Concentrations of remains from many other animals, both from natural deaths and from the actions of predators, might well be expected around rare water sources in an otherwise dry environment.

The picture that emerged from my work was that the content of the sites was like a chemical compound — it looked like a single thing but was in fact made up of numerous elements. Unlike a compound, however, sites are an aggregate of many elements that were present by virtue of independent chains of causal activity juxtapositioned on a restricted land surface. Before we could know what the hominids were doing we had to be sufficiently knowledgeable to abstract from this aggregate the remains referable to the actions of non-hominid agents. In short, the total content of these sites could not be reliably taken as evidence regarding the character of hominid behavior. This was what Isaac and Leakey had ignored when developing their picture of ancient times.

Needless to say, my book caused immediate reactions. It was criticized on almost every conceivable basis in attempts to refute its message. Nevertheless, almost at the same time, the Africanists published results of studies on the Olduvai bones. Very high frequencies of hyena gnawing, evidenced by tooth impressions, were reported. This supported my claims that other animals were involved in creating the accumulations of bone on these sites. In addition, it was reported that tool-inflicted marks were concentrated on the lower limbs of ungulates. This new fact was also consistent with my observations that there was at the sites a bias in favor of lower limb bones, which yield essentially no meat. The high frequency of tool-inflicted marks seemingly supported my



earlier suggestion that the hominids were primarily scavenging marginal foods, such as bone marrow.

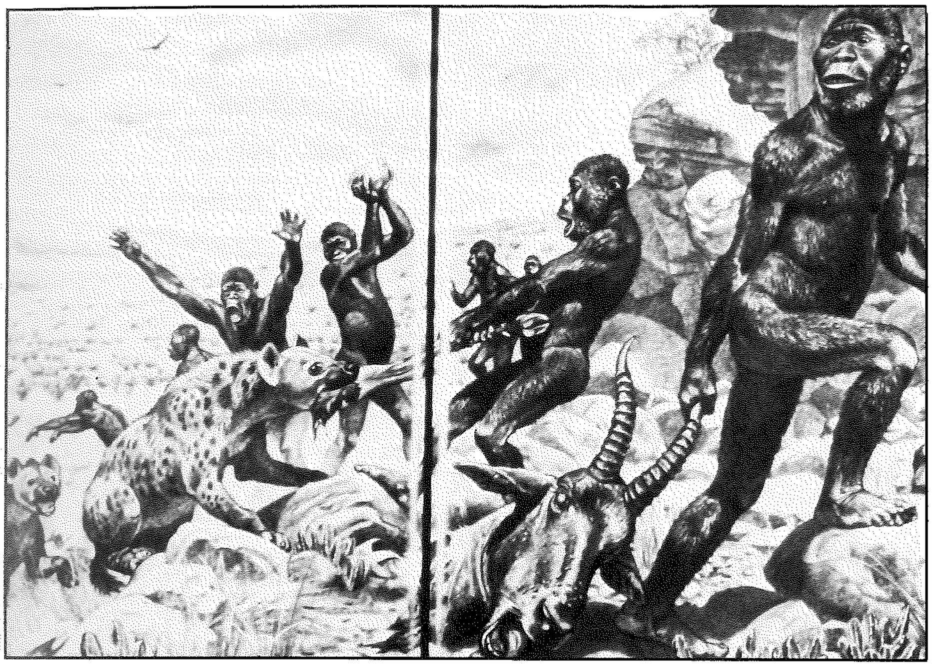
This was a very different view of the past from the picture of a hominid family camped on the edge of a lake, with the women gathering plant foods and the men going out hunting. Instead, we have a picture of a place frequented commonly by awesome predators, such as hyena and probably lion, possibly a regular drinking spot for both predators and prey, and the occasional presence of our ancestors processing scavenged animal parts for such marginal foods as bone marrow.

Not only did the serious researchers try to find flaws in my arguments, they went to work. Enough ambiguous observations had been demonstrated to indicate to the astute researcher that we needed more knowledge. In addition, we knew something of the types of knowledge that were needed.

It will be recalled that one of the reasons I questioned the reconstructions of ancient life in the first place was that my work with European Neanderthal remains had led me to suspect that even these relatively late ancestors were very different from us. Now I wanted to know in what ways similar African hominids may have differed in their behavior from their more recent European cousins. To investigate this area of interest I analyzed the faunal remains from an important South African site — the Klasies River mouth. I was surprised to realize that even during this late period, between 85,000 and 30,000 years ago, scavenging was still the dominant strategy for food recovery from medium to large animals. Only on the very young of large species and on the very small species did the telltale patterns of the hunting of live animals appear in the archeological record. The subsistence pattern seemed little changed some 1,700,000 years after the Olduvai sites were occupied. To be sure there were differences: fire was regularly used, caves were regularly occupied, and a different and more "designed" strategy of marrow-bone breakage was demonstrable. Nevertheless, the models of homebase-living hominids organized like modern human hunters were not easily accommodated to even this very recent material. Most of the animal parts introduced to the site had been scavenged. Hunting was certainly practiced, but only very small and relatively defenseless animals were being taken. This was a very different picture from the mighty hunter that commonly parades across the pages of Time-Life books and is supposedly representative of our past.

Our ancestors had not been killer-apes hunting the large and ferocious animals of their time. Instead they regularly scavenged the carcasses of animals killed by other predators and only relatively recently turned to hunting as a way of life. That early man was very different in his organized ways of life seemed established, but how and when did we begin to hunt? What role did such a change play in the behavioral transformation that led to the characteristics of our own species?

It had long ago seemed reasonable to imagine that early hominids radiated into the temperate zones where there was marked seasonality in the availability of plant foods, and that the hominids therefore increasingly turned to hunting. However, research had not been conducted on the faunal remains from early sites in order to document the radiation from the subtropics and the early periods of temperate zone occupation.



Last year I spent a considerable period of time in European museums and laboratories of prehistory studying the remains from a number of early sites. Three of these, Hoxne, Swanscombe, and Clacton, yielded evidence that they, like the Olduwan sites, were aggregates or the accumulations of numbers of independent processes. Certainly Hoxne and Swanscombe have considerable faunal remains that are characteristic of what might be called background fauna — the normal accumulation of skeletal parts on an exposed land surface being laid down independent of any actions by man. What is interesting about these sites is that the evidence for the presence of non-hominid bone-modifying predators/scavengers is minimal. Some animal gnawing is present but it is much less frequent than on the ancient African sites. Nevertheless, the processing of ungulate lower limbs for bone marrow was being practiced, as on the African sites. This establishes that the distinctive marrow scavenging tactics of early hominids were also characteristic of temperate zone hominids living in the open as recently as 300,000 years ago.

In addition to the open sites I studied a deeply stratified cave from France — the Abri Vaufrey. This site spans the important time period between 250,000 and 60,000 years ago. There too the very recognizable pattern of scavenging rather than active hunting persisted through layer upon layer of deposits up until around 80,000 years ago. As in the South African situation, the Europeans were turning to hunting at roughly the same time.

I began this journey through the science of paleoanthropology with the statement that science is a set of tactics. These tactics are used to study the reliability of what is considered to be the knowledge or understanding of the time. We have continually been forced to modify our views of the past. This is science at its best. It is a field dedicated to a very particular type of learning — self-teaching. It is also a set of strategies designed to do what on the face of things seems nearly impossible — to transform ignorance into knowledge.

Has science been successful? Do we now understand the past accurately? The answer to the first question must be yes. The answer to the second is almost certainly no. Let me illustrate.

During my recent investigations of the cave of Abri Vaufrey I recognized some patterning not previously noted, just as Dart had done years before. From a faunal perspective there were two distinct types of assemblage interleaved among the layers of ancient deposit. One type of assemblage consistently comes from levels lacking fire hearths and yielding a stone tool assemblage made from raw materials that came from a variety of locations in the surrounding area. Introduced animal parts tend to be biased in favor ot meaty elements, the thigh or shoulder of animals. This pattern is almost certainly the result of transport from the sources of procurement to this cave for consumption by hominids. Ironically, however, there are no inflicted cut marks on these bones that could be referable to stone tools! In addition, the tooth imprints on many of the bones are quite different from the marks I have come to associate with the non-hominid predators/scavengers known to have inhabited the area at the time. Are

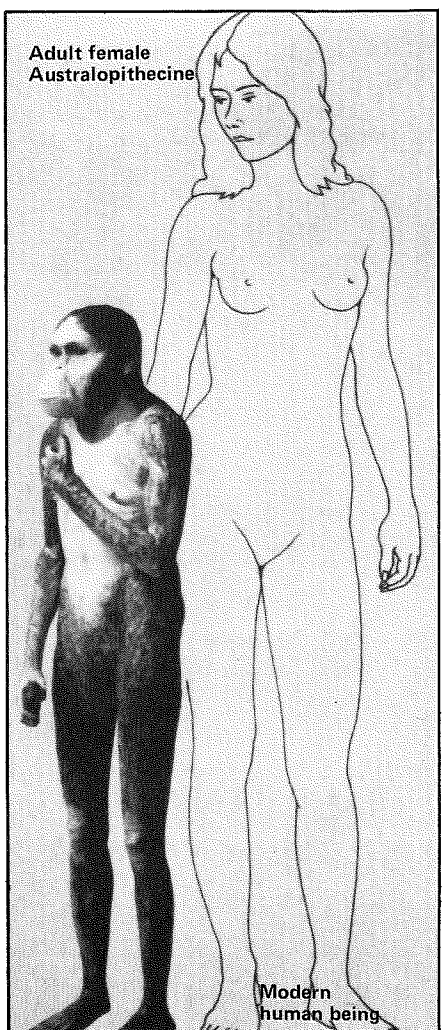
"Our ancestors had not been killer-apes hunting the large and ferocious animals of their time. Instead they regularly scavenged the carcasses of animals killed by other predators and only recently turned to hunting as a way of life."

these hominid tooth marks? If so, why are there no tool marks? I am currently exploring ways of developing recognition criteria to reduce the ambiguity in hominid tooth mark identification. Even if we are successful in this one area of research, how are we to understand the patterning in such layers? This question becomes even more interesting in the context of the other pattern recognized at Vaufrey.

In other levels at this cave there may be substantial evidence of fire associated with tool assemblages manufactured from raw materials immediately available around the site. In such a context the fauna contrasts strongly with that seen in the fireless levels. In the fire-yielding levels the hominid-associated fauna is the same as that known from African sites, ungulate lower limbs broken open for marrow. Meat-yielding bones are all but absent. As in so many other cases of lower limb bone assemblages there is a high frequency of tool-inflicted marks on the bone, while there are none of the "strange" tooth impressions being considered as possible evidence for hominid bone gnawing. These contrasts appear even more baffling when it is realized that there is no difference in the relative frequencies of tool types found in the tool assemblages from these two levels.

What does such variability mean? How do we design research to guide us toward understanding? It should be clear that the cycle will begin again. Many of us will disagree about what these patterns imply as far as the lifeways of our ancient ancestors are concerned. In the contexts of our differing views we will proceed along divergent research paths. New types of knowledge and understanding of our world will accumulate, rendering some ideas unlikely, as in the case of Dart's killer-ape view of the past, while other ideas may grow in their plausibility as more and more knowledge of how the archeological record was formed is amassed. Successful archeological science is perhaps best measured by the rate at which our views of the past change. From a scientific point of view the past 20 years have been most successful; they have been exciting and productive. Perhaps we are somewhat closer to a realistic view of the human past, but this will be changed and elaborated if the scientific process continues at the pace of the last few years.

With this in mind it is possible to summarize the picture of our ancient past that is emerging from our efforts. Our earliest tool-using ancestors were small creatures weighing barely ninety pounds. They walked erect, as we do, and from the neck down they looked very much like us. They made and used tools and seem to have been almost compulsive carriers of things. They appear to have foraged widely in the forested margins of the great subtropical savannas of Africa. Tooth wear suggests that they had a diet biased in favor of fruits. During their foraging for food they occasionally encountered the carcasses of animals who died naturally or as a result of predation. They sometimes picked up the very marginal parts that remained, which commonly consisted of the lower legs of ungulates. These parts were sometimes transported to locations near water sources where they were processed for marrow. Since marrow is a very high protein food but occurs in very small quantities, this activity must have contributed only marginally to their diet. It is not difficult to imagine this as a female activity related to the feeding of offspring at weaning time. Active hunting does not seem to have been practiced.



"Against [a] gradual background of change. . . an abrupt series of changes appears in the archeological record. . . many of us speculate this was the result of language. . . such ideas will feed the process of science for a long time."

Sometime between 1,000,000 and 700,000 years ago these ancestral populations began to radiate into the temperate zone. Their behavior appears to have been little different from that of their African ancestors. To be sure, fire seems to have been added to the list of "tools" and, judging from the context of its occurrence, seems to have been primarily used to secure sleeping places from intrusion by other denning animals. In the temperate zone the archeological remains are increasingly associated with the evidence of behavior by carnivores who sought the same protected sleeping places as the hominids. We know little of their diet, but hominid tooth wear studies suggest a much more rough set of meals. Cooking of food is not clearly indicated. We currently do not know how their societies were organized during this extensive period. It does seem clear, however, that they were not yet "human" in this regard.

This picture seems to remain largely unchanged in spite of demonstrable changes in brain size and other important anatomical characteristics over vast periods of time. This characteristic alone documents the gulf between our ancient ancestors and ourselves. Modern cultural human beings live in a world of symbols and abstracts through which they exhibit very responsive and rapid changes in their behavior. Ancient hominids seem to have changed as slowly as other animal species through the workings of biological evolutionary processes. Early humans were not a dull version of ourselves or a bestial savage; they were animals possessed of great intelligence, regular tool-using animals like no others known. They were not romantic ancestors, in the modern sense; but eclectic feeders commonly scavenging the carcasses of dead ungulates for minor food morsels.

Between 100,000 and 40,000 years ago the faint glimmerings of a hunting way of life appear, there are changes in the way hominids used locations, and cooking seems to have been established. Against this gradual background of change a surprising and abrupt series of changes appears in the archeological record between 45,000 and 35,000 years ago. Hunting became dominant in many places, the design of tools changed to emphasize weapons, family life as we know it appeared, and importantly there was a burst of symbols, paintings, and carvings. In addition, the regular burial of the dead as well as many other distinctive human behaviors occurred. Our species had arrived – not as a result of gradual, progressive processes but explosively in a relatively short period of time. Many of us currently speculate that this was the result of the invention of language, our peculiar mode of symbolic communication that makes possible our mode of reasoning and in turn our behavioral flexibility. Such ideas will feed the process of science for a long time.

Acknowledgements

Photographs: **16–17**, by John Reader from his book, **Missing Links**, Little, Brown & Co.
Paintings: **18–19**, by Jay H. Matternes, courtesy Time-Life Books.
Chart: **20**, British Museum (Natural History), Cambridge University Press. ☐

CALENDAR

OF INTEREST

LECTURES

MARK AND DELIA OWENS
(Cry of the Kalahari: A Seven-Year Odyssey of Research & Adventure in the Kalahari Desert)

September 11, 1985
AAZPA Annual Conference
Columbus Zoo, Columbus, Ohio
Wednesday, 9:00 a.m.

September 13, 1985
The Dallas Zoological Society
Plaza of the Americas Hotel,
Dallas, Texas,
Friday, 6:30 p.m.

September 14, 1985
Chicago Academy of Sciences
Chicago, Illinois
Saturday, 8:00 p.m.

October 1, 1985
Zoological Society of Houston
Houston, Texas
Tuesday, 8:00 p.m.

October 8, 1985
The L.S.B. Leakey Foundation
Beckman Auditorium, Caltech
Pasadena, California
Tuesday, 8:00 p.m.

October 15, 1985
San Francisco Zoo
Morrison Auditorium,
California Academy of Sciences
San Francisco, California
Tuesday, 8:00 p.m.

October 29, 1985
Calgary Zoo
Jubilee Auditorium
Calgary, Alberta, Canada
Tuesday, 7:30 p.m.

November 1, 1985
Philadelphia Academy
of Natural Sciences
Philadelphia, Pennsylvania
Friday, 8:00 p.m.

GALA DINNER

HONORING MISS FLEUR COWLES
November 21, 1985
Beverly Wilshire Hotel
Beverly Hills, California
Thursday, 6:30 p.m.

KUDOS

for Gordon Getty and "Plump Jack"

"Plump Jack," a 12 minute piece for orchestra and vocal soloists by Gordon Getty, chairman of the board of the Leakey Foundation, was presented by the San Francisco Symphony to considerable acclaim in late March. The contata about Shakespeare's unforgettable Falstaff is the first part of a work-in-progress of four or five pieces inspired by the two plays about Henry IV, which are planned to take Falstaff to the end of his life. Getty's first essay in orchestration, the cantata was offerred in one of a series of four regular subscription concerts by Conductor Edo de Waart and the San Francisco Symphony.

San Francisco magazine, speaking of "Plump Jack," said, "All told, there is a genuine dramatic sensibility at work here . . . in clarity and economy Getty's music stands on its own." Byron Belt of WNBC-TV and the Newhouse Newspapers reported that "the music had the audience in chuckles at times, and clearly affected with sentiment at others . . . Gordon Peter Getty is clearly a welcome major force in the cultural life of America." "'Plump Jack' . . . makes it clear that he knows how to write for voice, that he understands pacing, that he has a good sense of humor, and that he can translate that humor into an orchestral score," said the *San Francisco Examiner*.

The Leakey Foundation is extremely proud of its talented and versatile chairman of the board.

OPPORTUNITY

Archeological Fun in the New Mexico Sun

The Organ Mountain Project sponsored by AFAR (Andover Foundation for Archeological Research), under the field direction of Dr. Richard S. MacNeish, plans to investigate the origins of agriculture in the Southwest at Las Cruces, New Mexico, from Feb. 1 to May 10, 1986. The team needs two groups to share the work in cave digs and lab using the most up to date interdisciplinary techniques.

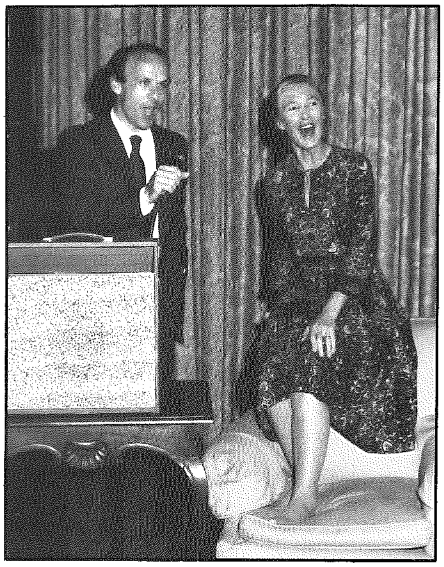
1. Young aspiring archeological students for 14 weeks who will make a donation of $2,000 to cover their room and board. Selection of this group of 12 will be made by Oct. 1, 1985.

2. Friends of AFAR may join for two weeks for a contribution of $1,000 or a month for $1,500.

To apply, write Dr. Richard S. MacNeish, AFAR, Box 83, Andover, MA 01810, or call him at (617) 470-0840.

NEW FELLOWS

The L.S.B. Leakey Foundation is pleased and honored to welcome as new Fellows: George G. Anderman, Denver, Colorado; Mrs. Arthur F. Crowe, San Marino, California; Ruth Schaffner, Santa Barbara, California; Marianne Bertino, San Gabriel, California; and Judy Smith, Los Angeles, California.



Drs. Jane Goodall and Richard Wrangham demonstrate chimpanzee calls at a reception following Dr. Goodall's delivery of the 1985 Allen O'Brien Memorial Lecture at Caltech in April.

July, 1985, marked the end of Dr. Goodall's first 25 years of research at Gombe – a quarter century of observations of a community of chimpanzees. She and her mother, Vanne, and their cook, Dominic, set foot on the Gombe shores in Tanzania on July 16, 1960. She is looking forward to the next 25 years. □

The grant program, the major purpose of the L.S.B. Leakey Foundation under the guidance of the distinguished Science and Grants Committee, depends upon public support for its success. Every penny of your contribution dollar directly supports the grant awards.

GRANT SPOTLIGHT

Sharon M. Swartz *$1,155 needed*

THE EVOLUTION OF STRUCTURE AND FUNCTION IN THE PRIMATE FORELIMB

The close functional relationship between limb form and function has long been known. The goal of this research is to determine the biomechanical criteria which distinguish the load-bearing differences in the skeletons of anthropoids that use their fore limbs primarily for suspension, rather than bearing body weight as in knuckle walking.

Zefe M. Kaufulu *$2,980 needed*

GEOLOGICAL INVESTIGATIONS IN MALAWI

This work will be carried on in the Plio-Pleistocene Chiwondo deposits of northern Malawi. The data will be synthesized with that from northern Malawi and East and South Africa. The research may provide clues to possible constraints which governed hominid adaptations and distribution during the Plio-Pleistocene.

George C. Frison *$2,500 needed*

CLOVIS TOOLS AND WEAPONRY EFFICIENCY

The applicant has been invited to participate in a Zimbabwe elephant culling operation. He will conduct experiments utilizing Clovis stone artifacts in killing, butchering and dismembering elephant carcasses. The information gained will aid further understanding of the human skills and technology necessary for successful big game hunting as well as of broader issues of the evolution of hunting.

Elwyn L. Simons *$2,525 needed*

CAPTIVE LEMUR BREEDING FACILITIES AT DUKE PRIMATE CENTER

These funds will match a grant from Duke University for modifying and expanding breeding facilities for rare and endangered species of prosimians.

Elliott H. Haimoff *$2,700 needed*

BEHAVIOR AND ECOLOGY OF THE CONCOLOR GIBBON IN CHINA

The concolor gibbon is the last ape species still to be studied in the wild. A three month pilot study of its behavior and ecology in Yunnan Province (P.R.C.) is proposed by Dr. Haimoff.

Patty L. Shipman *$4,150 needed*

FURTHER STUDIES OF MODIFIED BONES FROM OLDUVAI GORGE

The proposed research will examine the remains of large bovids at Olduvai to determine how early hominids used these animals and whether there is a noticeable change with the appearance of *Homo erectus*.

Lewis R. Binford and Chuan Kun Ho *$3,000 needed*

PALEOLITHIC RESEARCH IN CHINA

The funding is requested to conduct supplementary research in China for a taphonomic study of fauna at Zhoukoudian near Beijing. The scientists will also be able to visit newly discovered Paleolithic sites in Manchuria.

Michael D. Petraglia *$2,425 needed*

SITE FORMATION PROCESSES AND LITHIC REFITTING AT ABRI DUFAURE

Mr. Petraglia will conduct lithic refitting studies on archeological materials from Abri Dufaure to discover whether the observed patterning of the remains are the result of human activities or postoccupation disturbance.

Keith W. Adams *$1,355 needed*

BOTANICAL RESOURCES OF HUNTER-GATHERERS IN BOTSWANA

This research will provide botanical data for the evaluation of a model concerning the interaction of pastoral and foraging activities during the Late Stone Age and Early Iron Age in Botswana. Approximately 1500 years of plant exploitation will be evaluated.

Naama Goren-Inbar *$5,000 needed*

BIQUAT QUNEITRA, A MOUSTERIAN SITE IN THE GOLAN HEIGHTS

This single horizon, open air Mousterian occupation site has been exposed during two previous field seasons and found to be extremely rich with flint and basalt artifacts and paleontological remains. Additional exposure will further our understanding of the geology and spatial organization of the site.

Gregory T. Laden *$3,600 needed*

ANTIQUITY OF HUMAN OCCUPATION IN THE RAIN FOREST

This research will be conducted in the Ituri Forest of northeastern Zaire in conjunction with the Harvard-Ituri project, an ongoing multi-disciplinary research effort. It will focus on the history and development of the mutual relationship between the Efe Mbuti (Pygmy hunter-gatherers) and the Lese (village horticulturalists).

Lawrence G. Straus *$3,143 needed*

PALEOLITHIC RECONNAISSANCE AND ANALYSIS IN THE FRANCO-CANTABRIAN REGION

Dr. Straus requests funds for further analysis of material from the Magdalenian site of Abri Dufaure and for the preliminary survey of potential sites in the central Pyrenees. This is part of his ongoing study of Terminal Pleistocene hunter-gatherer adaptations in the area.

B. Arensburg,
O. Bar-Yosef, et al. *$10,000 needed*

ORIGINS OF MODERN HUMANS IN THE MEDITERRANEAN LEVANT

The objective of this extensive project is to amass new data on human origins through excavation of Middle Paleolithic deposits in Israel. Specific goals include: (1) The establishment of the era's chronology by radiometric methods; (2) the study of deeply stratified sites such as Kebara; (3) the study of the diet and culture of Middle Paleolithic humans from floral and faunal remains and lithic assemblages; and (4) the discovery of additional human remains.

Nicholas Toth and
Kathy Schick *$3,000 needed*

EXCAVATION AND ANALYSIS OF A STRIPED HYENA DEN IN JORDAN

These funds will support the excavation and analysis of the faunal assemblage at a hyena den, research relative to the processes of bone modification and accumulation by carnivores with den behavior. The scientists will also have the opportunity to identify Stone Age sites with potential for behavioral interpretations. Please see their article on page 13.

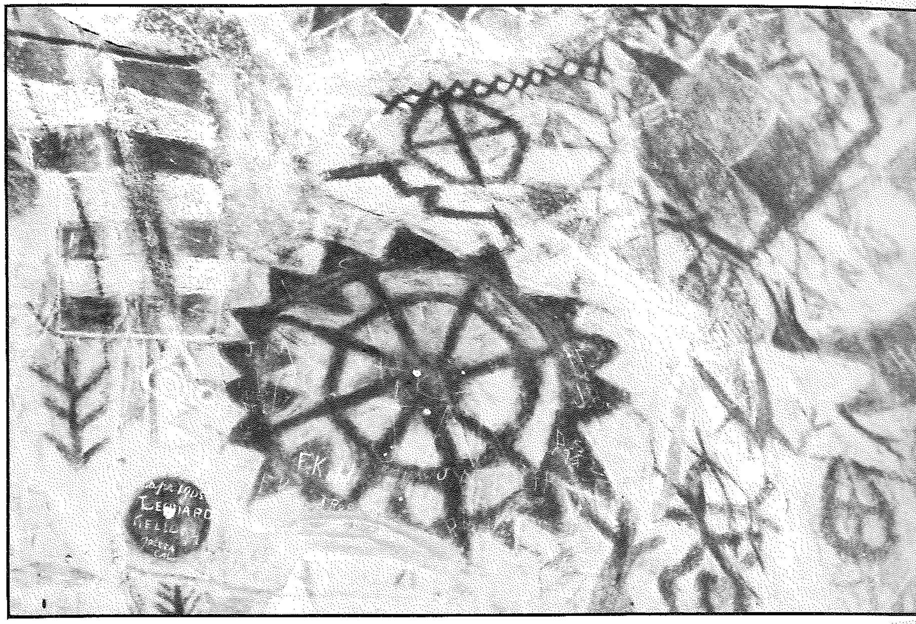
Carole E. Sussman *$3,944 needed*

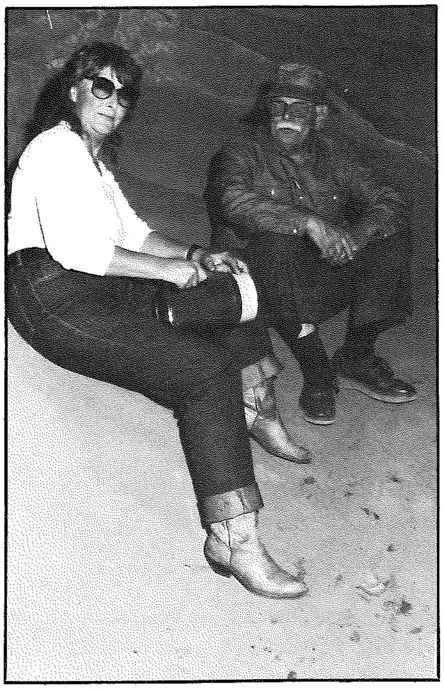
PRELIMINARY MICROWEAR STUDY OF SELECT TOOLS FROM OLDUVAI GORGE

This study has the potential to provide important information on specific stone tool function to increase our knowledge of early hominid adaptability and behavior. Sussman will use the new techniques of high power microscopy to identify the polishes on stone tools from Olduvai Gorge, Tanzania. Please see her article on page 7. □

ANNUAL MEETING

The Leakey Foundation annual meeting took place in Santa Barbara in May. A special treat for those attending was a visit to Painted Cave, a rock art relic of the hunter-gatherer Chumash Indians in the rugged slopes of the Santa Ynez Mountains.





Above, wall of Painted Cave. The paintings in red, black and white, were done as a cumulative composition with successive artists adding to or superimposing their work. The artists were very probably shamans and the symbols abstractions connected to the supernatural. The golden age of the Chumash extended from about 500 A.D. until shortly after 1800.

Left, Dr. Georgia Lee of Cal Poly, San Luis Obispo, and Fred Myers of Denver, a Foundation trustee, inside the sandstone cave chamber. Photos: George Jagels, Jr.

ANTHROQUEST
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