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THE OLDOWAN:
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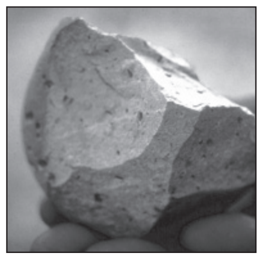
Edited by Nicholas Toth and Kathy Schick



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Photographs of the Stone Age Institute. Aerial photograph courtesy of Bill Oliver.

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CHAPTER 1

An Overview of the Oldowan Industrial Complex: The Sites and the Nature of Their Evidence

Kathy Schick and Nicholas Toth

This chapter will present an overview of the Oldowan Industrial Complex (hereafter referred to as the Oldowan), discussing its definition, its chronological and geographic context, the nature of the Oldowan archaeological record, contemporaneous hominins, key issues, and recent trends in research over the past few decades. This introduction will provide a context and foundation for the subsequent chapters which present case studies into aspects of the Oldowan. We also hope that this chapter will serve as a reference for scholars interested in the Early Stone Age of Africa.

Defining the Oldowan

The Oldowan is a term used for the earliest archaeological traces in Africa. The term is also sometimes used for the earliest stone age sites in Eurasia. The Oldowan is characterized by simple flaked and battered artifact forms that clearly show patterned conchoidal fracture, produced by high-impact percussion, that is unlike any found in the natural (non-hominin) world. These artifacts include battered hammerstones and simple core forms, often made on water-worn cobbles but sometimes on more angular chunks of rock. These materials herald a new chapter in the human evolutionary record and mark a significant departure from the rest of the primate world: the onset of a technology-based adaptation in which synthetic tools supplemented the biological repertoire of these creatures. In the genus *Homo*, profound changes in size of jaws and teeth, brains, body size and proportions, and geographical range began after this adaptation commenced.

Classification of Oldowan Industries

The term "Oldowan" was first used by Louis Leakey in 1936 to describe materials at Olduvai Gorge (formerly known as "Oldoway Gorge") predating Acheulean handaxe and cleaver industries (Leakey, 1936). Previous to this, Leakey had used the term: "pre-Chellean" to refer to these artifact assemblages. Leakey had also suggested using the term "Developed Kafuan" (the Kafuan now widely believed to be naturally broken pebbles or geofacts), but the prehistorian E.J. Wayland convinced him that the early Olduvai materials were distinct from the Kafuan and warranted a new name. Leakey thought the term Oldowan would probably be dropped over time (Gowlett, 1990), but in fact for the past 70 years it has usually stood as the generic term for pre-Acheulean lithic industries in Africa as well as for simple stone artifact assemblages contemporary with the Acheulean and lacking the handaxe and cleaver elements.

Mary Leakey's seminal work was published as *Olduvai Gorge Volume 3: Excavations in Beds I and II, 1960-1963* (Leakey, 1971). In Beds I and II (ca. 1.9-1.3 mya) Mary Leakey divided the prehistoric archaeological sites at Olduvai into several different industries:

1. Oldowan: beginning near the base of Bed I, ca. 1.85 mya), are assemblages characterized by "choppers, polyhedrons, discoids, scrapers, occasional subspheroids and burins, together with hammerstones, utilized cobbles and light-duty utilized flakes" (Leakey, 1971, p. 1).

2. Developed Oldowan A: Beginning in at the base of Middle Bed II (ca. 1.65 mya) "Oldowan tool forms persist, but there is a marked increase in spheroids and subspheroids and in the number and variety of light-duty tools" (Leakey, 1971, p.2). No bifaces (picks, handaxes and cleavers) were associated with these assemblages. Quartz/quartzite comes into increasing use throughout Bed II times, and lavas become proportionally less prevalent in most artifact assemblages. Chert was also available in the Olduvai basin during this time

3. Developed Oldowan B: This industry, found in Middle and Upper Bed II, is similar to Developed Oldowan A, but with more light-duty tools and some bifaces (usually small and poorly-made).

   [Beginning in Upper Bed IV, ca. 1.1 mya and outside the scope of this survey, Mary Leakey described a Developed Oldowan C, consisting of even higher percentages of light-duty scrapers, as well as higher numbers of *outils écaillés*, laterally trimmed flakes, pitted anvils and punches. There are also very low numbers of choppers as well as some small, crude handaxes, but no cleavers].

4. Early Acheulean: Beginning in upper Middle Bed II (ca. 1.5 mya), bifaces (handaxes, cleavers, picks) become prevalent at some sites in Olduvai Gorge, and these are designated as Acheulean. This tradition continued in Bed III, Bed IV, and the Masek Beds to around 0.4 mya.

During the 1960's and 1970's, other Plio-Pleistocene sites in East and South Africa were discovered (e.g. Gona, Melka Kunture, Omo, East Turkana or Koobi Fora, Chesowanja, Sterkfontein, Swartkrans) that did not have handaxe/cleaver/pick elements in their lithic assemblages. These assemblages were often assigned to the Oldowan or Developed Oldowan, although sometimes investigators have, at least for a time, applied more regional names to similar industries (e.g., "Shungura Facies" for the early Omo sites, Chavaillon, 1976). Although the cultural-historical pattern of lithic industries at Olduvai are not necessarily repeated at other depositional sequences in Africa, the Olduvai data was important in showing the emergence of new technological elements through time within a long stratigraphic sequence.

Although we now know that the Oldowan first appears in the prehistoric record around 2.6 mya, it is more difficult to define when it ends, as even some Holocene sites around the world (e.g. Tasmania) associated with anatomically modern humans exhibit very simple Oldowan-like stone technologies. Mary Leakey believed the Developed Oldowan persisted at Olduvai into Upper Bed IV (ca. 1.1 mya), and the term is not commonly also used for sites under one million years old. With the emergence of the Acheulean between 1.7 and 1.5 mya, contemporaneous non-handaxe/cleaver/pick industries are sometimes viewed as a possibly functional variant of the Acheulean and have sometimes been assigned to a separate "African Tayacian" or "Hope Fountain" industry (Isaac, 1977).

Glynn Isaac (1976) suggested grouping these early Oldowan and Developed Oldowan sites found in Africa together under the rubric "Oldowan Industrial Complex." The term Oldowan has also been used for early sites in Eurasia, such as at Ubeidiya in Israel and at Dmanisi in the Republic of Georgia. Some researchers have preferred to use prehistorian Grahame Clark's (1961) term "Mode I industries: chopper-tools and flakes" to describe these simple technologies.

Oldowan Technology

The Oldowan Industrial Complex is characterized by simple core forms, usually made on cobbles or chunks, the resultant debitage (flakes, broken flakes, and other fragments) struck from these cores, and the battered percussors (hammerstones or spheroids) used to produce the flaking blows. Another element at many Oldowan sites is the category of retouched pieces, normally flakes or flake fragments that have been subsequently chipped along one or more edges. It has been argued (Toth, 1982, 1985; Isaac, 1997) that much of Oldowan technology can be viewed as a least-effort system for the production of sharp cutting and chopping edges by the hominin tool-makers, and that much of the observed variability between sites is a function of the quality, flaking properties, size, and shape of the raw materials that were available in a given locale.

Experiments have shown that the entire range of Oldowan forms can be produced by hard-hammer percussion, flaking against a stationary anvil, bipolar technique (placing a core on an anvil and striking it with a hammer), and, occasionally, throwing one rock against another. The typological categories commonly applied to Oldowan cores (Mary Leakey's "heavy-duty tools," outlined below) can be viewed as a continuum of lithic reduction with the intent of producing sharp-edge cutting and chopping tools (Toth, 1985; Schick & Toth 1993). In this view, many of the cores and so-called 'core tools' found in Oldowan assemblages may not have been deliberately shaped into a certain form in order to be used for some purpose; rather their shapes may have emerged as a byproduct of producing sharp cutting flakes (discussed further below in the section on "Recent Trends in Oldowan Research").

Classification of Oldowan Artifacts

Early systems for classifying "pebble tool" industries include Movius (1949), Van Riet Lowe (1952), and Ramendo (1963). Below we have outlined some examples of classification systems applied more recently to Oldowan or Mode 1 industries by some researchers in the field, to illustrate various approaches to classifying early stone artifact assemblages.

Classification System: Pierre Biberson

Pierre Biberson (1967) presented a typological system for classifying pebble tools (*galets aménagés*) from the Maghreb and the Sahara of North Africa. This system was as follows:

Unifacial forms:

I.1 Unifacial: Single scar: on end of cobble

I.2 Unifacial: Single or multiple concave scars: on any part of cobble

I.3 Unifacial: Two or more scars: on end of cobble

I.4 Unifacial: Two or more scars: on side of cobble

I.5 Unifacial: Two or more scars: on end of chopper; stepped flaking

I.6 Unifacial: Pick-like pointed form on cobble: less invasive flaking; point has a trihedral cross-section section

I.7 Unifacial: Pick-like pointed form on cobble: more invasive flaking, with intersecting scars creating a third edge; point has trihedral cross-section

I.8 Unifacial: Multiple scars: on most of side of cobble; flaked edge is curved

Bifacial forms:

II.1 Bifacial: Single scar on each face: intersecting on same end of cobble

II.2 Bifacial: At least two scars from each face: one face is struck from end of cobble; other face is struck from side of cobble, producing an edge along the side of cobble

II.3 Bifacial: Single scar on each face, oblique to each other, on end of cobble; partially intersecting scars

II.4 Bifacial: Single scar first struck from one face; multiple scars then removed from the other face (using the initial scar as striking platform) to create narrowly-developed cutting edge

II.5 Bifacial: Multiple scars first struck from one face; intersected by large single removal from other face

II.6 Bifacial: Single large scar from one face; multiple scars then removed from the other face to create well-developed cutting edge

II.7 Bifacial: Sinuous edge on short amount of the cobble circumference; a series of flakes is first removed from one face; these scars then used as striking platforms to remove a series from the other face

II.8 Bifacial: Single large scar removed from one face; multiple scars then removed from opposite face, using original scar as striking platform; original face then re-flaked

II.9 Bifacial: Pick-like pointed form made on end of cobble by intersection of two bifacial edges

II.10 Bifacial: Sinuous cutting edge produced by alternate flaking: first removing a flake from one face, then using that scar as a striking platform to remove flake from other face, etc. the cobble being turned over after each removal

II.11 Bifacial: Sinuous cutting edge along side of oblong cobble; multiple scars on each face

II.12 Bifacial: Regular flaking around much of circumference to produced fan-shaped form

II.13 Bifacial: Flaking around much of circumference, with the intersection of two edges (not forming a distinct point); with a cortical unflaked edge as well

II.14 Bifacial: Pebble or large flake flaked around entire circumference to produce a thick, biconvex discoidal core

II.15 Bifacial: Made on large cortical flake; flaked around part of circumference, with striking platform intact

II.16 Bifacial: Wedge flaked flake ("orange quarter") struck from core; dorsal face shows previous flake removals and cortex along one side of flake; cortical striking platform

Polyfacial forms:

III.1 Polyhedral: Appreciable cortex on core; unordered flaking; subspherical shape

III.2 Polyhedral: Less cortex on core; multidirectional flaking over core with one sinuous, bidirectional cutting edge

III.3 Polyhedral: multidirectional flaking over entire surface of cobble, polyhedric and subspherical ("faceted stone ball")

III.4 Polyhedral: Multidirectional flaking, pyramidal shape, flaked to a point; pick-like form on cobble

III.5 Polyhedral: One bifacially flaked sinuous edge; flakes then removed at right angle from one end of that edge (in a third direction)

III.6 Polyhedral: Unifacial or bifacial main cutting edge, with flakes removed from each end of the main edge perpendicular to the main axis of that edge

Although this system is not much used today, it is interesting that Biberson did look closely at the patterning and sequencing of flakes that were detached from cores. Aspects of this approach have been revived recently in some Oldowan analyses, with detailed drawings of artifacts indicating the direction and/or sequence of flake removals on Mode 1 cores (e.g. de la Torre *et al.*, 2003; de Lumley *et al.* 2005; de Lumley & Beyene, 2004).

Classification System: Mary Leakey

The first typological system widely used for the Oldowan, and still the one most commonly used today, was developed by Mary Leakey (1971) in her work at Olduvai Gorge. She made it clear that some of her types, e.g. choppers and scrapers, were not necessarily functional classes, but morphological ones. On the other hand, it seems clear that she felt that many of the core forms were tools in their own right and exhibited damage that she interpreted as utilization.

Leakey classified the Early Stone Age, non-Acheulean, materials in Beds I and II at Olduvai Gorge as follows:

1. Heavy-duty tools (greater than 5 cm or ~2 in maximum dimension).
   a. Choppers: cores, usually made on water-worn cobbles with a flaked edge around part of their circumference. Leakey subdivided this group into five types: side, end, two-edged, pointed, and chisel-edged.
   b. Discoids: cores, usually made on flat cobbles or thick flakes, with a flaked edge around most or all of their circumference.
   c. Polyhedrons: heavily reduced cores comprised of three or more edges.
   d. Heavy-duty scrapers: thick cores with one flat surface intersecting steep-angled flake scars.
   e. Spheroids and subspheroids: more or less spherical stones showing signs of flaking and/or battering.
   f. Proto-bifaces: artifacts intermediate in morphology between a chopper and an Acheulean biface (handaxe).
2. Light-duty tools (less than 5 cm in maximum dimension, usually retouched forms made on flakes or flake fragments).
   a. Scrapers: pieces that have been retouched along a side or end. Leakey subdivided these into six types: end, side, discoidal, perimetal, nosed, and hollow.
   b. Awls: pieces that have been retouched to form a point.
   c. Outils écaillés ("scaled tools"): pieces with flakes detached from opposite ends. Some of these are almost certainly bipolar cores for flake production.
   d. Laterally trimmed flakes: flakes with more casual and uneven retouch.
   e. Burins: rare forms with a flake detached along the thickness of the edge. In later time periods, these are known to be engraving tools.
3. Utilized artifacts
   a. Anvils: stones with pits in them that suggest their use as an anvil in stone tool manufacture.
   b. Hammerstones: stones (often cobbles) that have battered areas that suggest they have been used as a percussor or hammer in stone tool manufacture.
   c. Utilized cobblestones, nodules and blocks: pieces of stone with some damage to edges (chipping or rounding) that suggests their use as a tool.
   d. Heavy-duty flakes and light-duty flakes: flakes with some chipping or rounding of their edge
4. Debitage: flakes, broken flakes, and other fragments produced through stone knapping but which show no further modification (neither retouch nor utilization damage).
5. Manuports: Unmodified stones that appear to be found outside their natural, geological context and are assumed to have been carried to the site by hominins.

Classification System: Glynn Isaac

Another approach to classifying Oldowan sites, essentially a simplified version of Leakey's typology, was proposed by Isaac (1997) based on the study of the Koobi Fora materials. He divided the archaeological materials as follows:

1. Flaked pieces (cores and "tools") (FPs):
   a. Choppers
   b. Discoids
      i. regular
      ii. partial
      iii. elongate
   c. Polyhedrons
   d. Core scrapers
      i. Notched
      iii. Denticulate
      iii. Side (lateral)
      iv. Short (equidimensional)
      v. End (terminal)
      vi. Arcuate
      vii. Double-sided
      viii. Nosed
      ix. Pointed
      x. Perimetal
   e. Flake scrapers
      i. Notched
      ii. Denticulate
      iii. Side
      iv. Short
      v. End
      vi. Arcuate

vii. Double-sided
viii. Nosed
ix. Pointed
x. Perimetal

2. Detached pieces or debitage (DPs)
   a. Whole flakes
   b. Flake fragments (snaps, splits)
   c. Angular fragments
   d. Core fragments
3. Pounded pieces (PPs)
   a. Hammerstones
   b. Battered cobbles
   c. Anvils
4. Unmodified pieces (UNs)

Classification System: Henry de Lumley

De Lumley's approach to Oldowan industries in Africa and Eurasia (e.g. de Lumley & Beyene, 2004; de Lumley et al., 2005) makes a clear typological distinction between "pebble tools" (*galets aménagé*) and cores, the latter constituting part of his "debitage" category, along with flakes, fragments and other flaking debris.

1. Whole pebbles (unmodified)
2. Fractured pebbles
3. Blocks (unmodified)
4. Percussors
5. Pebble tools (*galets aménagé*)
   a. With a single concave flake scar
   b. Chopper (unifacial)
   c. Double chopper
   d. Rostro-carinate ("beak-like")
   e. Chopper associated with a rostro-carinate
   f. Chopping-tool (bifacial)
   g. Chopping-tool associated with a chopper
   h. Chopping-tool associated with a rostro-carinate
6. Debitage
   a. Cores (nucléus)
      i. Unifacial cores
         (a). Unidirectional
         (b). Bidirectional
         (c). Multidirectional
      ii. Bifacial cores
         (a). Unidirectional
         (b). Bidirectional
         (c). Multidirectional
      iii. Multifacial globular cores
      iv. Prismatic cores
      v. Atypical cores
      vi. Casual cores (ébauchés)
      vii. Core fragments
   b. Flakes
      i. Type 1: Flakes with total cortical surface
      ii. Type 2: Flakes with mostly cortical surface
      iii. Type 3: Flakes with residual cortex
      iv. Type 4: Flakes with no cortex
      Note - Flakes are further subdivided by eight types of platforms: cortical, smooth (lissé), dihedral or faceted, linear or punctiform, removed (ôté), nul, absent, and indeterminate.
   c. Small flakes
   d. Debris

In this system of classification, retouched pieces are not considered as a separate category, but rather are noted within each lithic class (e.g. fractured pebbles, pebble tools, cores, debris, or flakes). Retouch is classified into categories such as shallow, steep, flat, invasive, burin-like, etc. Also note that cores that do not fit into his "pebble tool" categories are classified with debitage, effectively sorting cores that produced flakes into two separate classes, either as tools or as waste or byproducts.

Classification System: Nicholas Toth

An alternative system of describing the predominant technological patterns at Oldowan sites was suggested by Toth (1982, 1985) based upon his study and experimental replication of Oldowan sites at Koobi Fora, East Turkana, Kenya. This classification system allows the researcher to classify and describe Oldowan artifacts based upon major aspects of the technological operations involved in making them.

It first divides the artifact population into major categories (cores, retouched pieces, flakes, flake fragments, chunks, and percussors). It then classifies cores and retouched pieces according to dominant technological operations involved in their manufacture:

1. the blank form used (a cobble, a flake or flake fragment, or other indeterminate form)
2. the mode of flaking (unifacial, bifacial, polyfacial, or some combination thereof)
3. the extent of flaking (partial circumference, total circumference). In practice, the amount of circumference flaked is also estimated to the nearest 10%.

For instance, cores are divided first based upon the original form of the material flaked. Cores made on cobbles are then classified according to the mode of flaking, and then with regard to how extensively the form was flaked. For cores on flakes, a similar classification is made according to the mode of flaking (and also with regard to whether unifacial flaking was on the dorsal or ventral surface of the flake), and then again according to how extensively it is flaked. Retouched pieces are also classified according to mode and extensiveness of flaking.

Whole flakes are classified into one of seven flake types, according to the technological information they hold on their platforms and dorsal surfaces with regard to prior flaking of the core. This system of flake classification is similar to that of Villa (1983), a simplified system based on Tavoso (1972), in turn modified after the system of de Lumley (1969).

Flake fragments are classified according to the portion of the flake represented (split, snap, or indeterminate). Angular fragments (probable fragments of flakes whose portion of the entire flake cannot be identified with certainty) and more massive chunks represent final categories of miscellaneous debris resulting from conchoidal fracture of stone.

This technological classification system is as follows:

1. Cores and retouched pieces
   a. Cores
      i. Made on cobbles
         1. Unifacially flaked
            a. Partial circumference
            b. Total circumference
         2. Bifacially flaked
            a. Partial circumference
            b. Total circumference
         3. Unifacially and bifacially flaked
            a. Partial circumference
            b. Total circumference
         4. Polyfacially flaked
            a. Partial circumference
            b. Total circumference
      ii. Made on large flakes/flake fragments
         1. Unifacially flaked on dorsal surface
            a. Partial circumference
            b. Total circumference
         2. Unifacially flaked on ventral surface
            a. Partial circumference
            b. Total circumference
         3. Bifacially flaked
            a. Partial circumference
            b. Total circumference
         4. Unifacially and bifacially flaked
            a. Partial circumference
            b. Total circumference
      iii. Made on indeterminate blanks
         1. Bifacially flaked
            a. Partial circumference
            b. Total circumference
         2. Polyfacially flaked
   b. Retouched pieces (retouched pieces are defined as retaining flake scars that are normally less than 2 cm long, suggesting edge modification rather than flake production)
      i. Unifacially flaked on dorsal surface
         1. Partial circumference
         2. Total circumference
      ii. Unifacially flaked on ventral surface
         1. Partial circumference
         2. Total circumference
      iii. Unifacially flaked on dorsal and ventral surface
         1. Partial circumference
         2. Total circumference
      iv. Bifacially flaked
         1. Partial circumference
         2. Total circumference
2. Flakes and fragments (debitage)
   a. Whole flakes, classified into flake types
      i. Flake type I: Cortical platform, cortical dorsal surface
      ii. Flake type II: Cortical platform, partially cortical dorsal surface
      iii. Flake type III: Cortical platform, noncortical dorsal surface
      iv. Flake type IV: Noncortical platform, cortical dorsal surface
      v. Flake type V: Noncortical platform, partially cortical dorsal surface
      vi. Flake type VI: Noncortical platform, noncortical dorsal surface
      vii. Flake type VII: Indeterminate whole flake

   Flakes are further subdivided on the basis of other attributes; for example, for flakes with partially cortical dorsal surfaces, it is noted whether the cortex is on the side or bottom of a flake (or some other pattern).

   b. Flake fragments
      i. Split flakes
         1. Left split
         2. Right split
      ii. Snapped flakes
         1. Proximal
         2. Mid-section
         3. Distal
      iii. Angular fragments (indeterminate part of a flake)
   c. Chunks (miscellaneous fracture from flaking, usually more massive than angular fragments)
3. Percussors
   a. Battered hammerstones
   b. Battered subspheroids/spheroids

This classification system takes a *technological* view of stone fracture at archaeological sites and makes no assumptions about end products or 'mental templates' in the mind of the prehistoric tool-maker or of the archaeologist (e.g., whether a core is a deliberate 'core tool' produced for or used in some task). This system effectively classifies assemblage components into pieces that have been flaked, the resulting flaking debris or debitage, and percussors used to flake cores. Thus, this classification system focuses on the technological operations evident in a lithic assemblage without dwelling on elaborate subclasses based on details of artifact morphology. It can thus reveal useful information regarding the actual patterns of technological operations involved in the manufacture of the artifact assemblage at hand.

Conclusion

In sum, as of yet there is no standardized system of classifying Oldowan lithic assemblages. We would argue that a system that describes the general patterns of lithic reduction (e.g. Isaac and Toth) allows for less subjective categorization of stone artifacts. However, as use of Leakey's typology is so widespread (sometimes with modification), it may be useful to classify an assemblage according to this system in addition to any other classification system employed. Leakey did not make a distinction between "heavy-duty tools" and "cores," so presumably most cores are put in the tool category in her system. Very casual and minimally flaked cores would probably be assigned to her "utilized cobblestone, nodules and blocks" category.

A major meeting of minds at the Stone Age Institute in the fall of 2005, focusing on new approaches to the Oldowan, was organized in order to address many of these issues regarding Oldowan technology and typology. One of the aims of this conference, involving many of the major researchers is this field, was improving standardization of the ways that we classify and analyze early stone artifact assemblages so that we might make more realistic comparisons and contrasts between different Oldowan occurrences.

Major Oldowan Sites And Their Context

Overview

The earliest identified stone artifacts presently date back to approximately 2.6 mya at Gona in Ethiopia. Although this date could very possibly be pushed back with future field work, this 2.6 mya date currently establishes the beginning of the known archaeological record. It is more difficult to say when the Oldowan ends, however, since many stone industries from around the world retained a similar simple, unstandardized technology, even into Holocene times. In this chapter, we are primarily considering the time period of approximately 2.6 to 1.4 mya, after which time Acheulean sites become more common on the African continent.

The time period between 3.0 and 2.0 mya was a very interesting one: it marked a phase of global climatic cooling and drying, witnessing the spread of grasslands on the African continent, major turnovers in fauna (extinctions and new speciation events), the emergence of both the robust australopithecines and the genus *Homo*, and as noted, the first clear evidence of protohumans making and using stone tools and modifying animal bones. Moreover, these stone artifacts and animals bone were being deposited in densities sufficiently large to be identified during survey and to merit excavation and detailed analysis.

Most Oldowan sites are located along stream courses (fine-grained floodplains and coarser-grained channel), deltas, or lake margins. The sites in finer-grained floodplain, deltaic and lake-margin deposits normally exhibit less geological disturbances and are better candidates for examining behavioral and spatial patterning. In South Africa, the Oldowan sites are found in limestone caves infillings. The archaeological materials may have washed into these deposits from the surrounding landscape, or they may have been carried to or flaked at the site by the hominins themselves. There is evidence that some of the early hominin skeletal remains deposited in these caves had been killed and eaten by large carnivores as well.

The Oldowan sites in Africa document the earliest archaeological traces yet known, and show the development of stone technologies from their earliest occurrences in East Africa (by 2.5 to 2.6 mya) and their subsequent appearance in southern Africa by about 2 mya and in northern Africa by at least 1.8 mya. Although some studies have suggested a stage of early lithic industries technologically more 'primitive' than the Oldowan (often referred to as a "pre-Oldowan" industry, discussed further below), the earliest stone artifact assemblages from Gona, Ethiopia, establish a very well-documented lithic technology that shows that these toolmakers had mastered the basic skills to flake lava cobbles efficiently. It is true, however, that assemblages with appreciable frequencies of retouched flakes become common only after 2.0 mya.

The key technological elements of the Oldowan include battered percussors (hammerstones and spheroids/subspheroids); a range of core forms made on cobbles, chunks, and larger pieces of debitage; a range of debitage (whole flakes, split and snapped flakes, and angular fragments); and sometimes simple retouched pieces. The raw materials used generally reflect what is available and suitable for flaking in a given region: volcanic rocks such as lavas and ignimbrites are common, and in many areas basement quartzes and quartzites were also common. In North Africa, as at Ain Hanech, fine-grained limestones were also a major source of raw material. At some sites, cherts/flints were also locally available in larger quantities (e.g. some Bed II sites at Olduvai and at Ain Hanech), but generally their frequency is rather low. Different site assemblages often show major differences in their composition in terms of proportion of cores to debitage, proportion of retouched pieces, types of raw materials used, types and range of core forms produced, and the overall size distribution of cores and debitage. This could be due in part to hominin behavior, but it could also be strongly influenced by geological site formation processes, such as water action separating out different classes and sizes of artifacts.

Much of the variation among Oldowan assemblages at different sites is likely the result of use of different raw materials with different initial shapes, sizes, flaking qualities and characteristics, proximity to raw material sources, proximity to water, duration of occupation and/or reoccupation, and functional needs or constraints. Some differences among assemblages may also be attributed to technological norms that may have developed within groups of tool-makers (e.g. a preponderance of unifacial flaking of cobbles, or the Karari core scrapers made by the removal of flakes from the dorsal surface of thick cortical flakes).

When preservation is favorable, mammalian (and sometimes reptilian and avian) fauna is preserved at Oldowan sites. The mammalian remains usually have a wide representation of bovids, equids, and suids. Sometimes large mammals, such as elephant and hippopotamus are also found. These remains are often fragmentary and at some sites (e.g. FLK Zinj at Olduvai, FxJj 50 at East Turkana, and Sterkfontein Member 5), there is clear evidence of hammerstone fracture of limb bones and cut-marks from sharp-edged stone artifacts. These patterns will be discussed in more detail below.

The hominins associated near or at Oldowan sites (discussed in greater detail below) include the robust australopithecines (*A. aethiopicus*, *A. boisei*, and *A. robustus*), other australopithecines such as *A. garhi*, and larger-brained, often more gracile and smaller-toothed forms attributed to early *Homo*. At present, it cannot be established with certainty which of these species were the principal Oldowan tool-makers and tool-users. It is possible that multiple taxa could have had flaked stone technologies. It is arguable, however, that the evolving *Homo* lineage exhibits reduction of strong biological adaptations in term of the size and masticatory power of its jaws and teeth, along with a relatively rapid overall increase in brain size, which likely points to a shift toward an adaptation based more and more upon technological means and less and less upon strictly biological means. As stone technologies continue after the demise of the australopithecines, with *Homo* continuing to evolve and spread afterwards, it is certain that the *Homo* lineage had firmly incorporated stone technologies within its behavioral and adaptive repertoire.

In East Africa, the majority of Oldowan sites are found in fluviatile and sometimes lake margin environments (common places of sedimentation as well as sources of raw materials for the stone artifacts). The Eastern Rift Valley of Africa, in particular, provides an exceptionally favorable environment for the preservation of early hominin activity areas. Numerous depositional basins accumulated here during the Plio-Pleistocene, with subsequent tectonic uplift and erosion exposing these ancient deposits. Volcanic ash deposits and lavas have yielded precise radiometric dates, and some of these ashes also have been chemically correlated from one site to another over substantial distances in the region, providing additional means to place sites within a regional chronology. The alkaline chemistry of many of these volcanic eruptions played a major role in the preservation and mineralization of the fossil fauna as well.

In South Africa, the Plio-Pleistocene Oldowan sites are all found in karstic limestone cave infillings, and as such may represent an amalgam of slope wash processes in the surrounds of the cave, carnivore transport of bone, and hominin behavior at the site. It has been suggested by Brain (1981) that these caves may have also been sleeping quarters for hominins and baboons, which might explain the extraordinarily high numbers of these taxa in the deposits.

Here we will outline the types of evidence found at the major Oldowan localities that have yielded sites which have been excavated, analyzed, and published. We will first consider the East African evidence, all sites located in the Great Rift Valley, then examine the evidence from Southern Africa found in the infillings of karstic limestone caves, and finally consider the North African evidence.

East African Localities

Gona, Ethiopia

Age: 2.6-2.5 mya; also sites at 2.2-2.1 mya

Geographic/geological setting: The Gona sites are located in overbank floodplain deposits of the ancestral Awash River.

Key sites: EG10, EG12, OGS 6, OGS 7, DAN 1, DAS 7 (2.6-2.5); DAN 2 (2.2-2.1 mya)

Raw materials: Lavas, especially trachytes; ignimbrites; some volcanic cherts (vitreous volcanic rock)

Nature of industries: Simple cores (unifacial and bifacial choppers, etc. with very few retouched flakes)

Other associated remains: Some surface cut-marked bone

Key publications: Roche & Tiercelin, 1980; Harris, 1983; Semaw, et al., 1997, 2003; Semaw, 2000; Stout et al., 2005

Hadar, Ethiopia

Age: 2.3 mya

Geographic/geological setting: Fine-grained river floodplain deposits

Key sites: AL-666; AL 894

Raw materials: Basalt and chert

Nature of industries: Simple cores and debitage; little retouch on flakes

Other associated remains: An early *Homo* maxilla (A.L. 666) was found near the *in situ* artifacts; fossil mammalian remains included *Theropithecus* (baboon) teeth, a bovid (*Raphicerus*) horn core, and murid mandible fragments

Key publications: Hovers, 2003; Hovers et al., 2002; Kimbel et al., 1996

Middle Awash, Ethiopia

Age: 2.5 mya; 1.5-1.3 mya

Geographic/geological setting: fluviatile sands and interbedded volcanic ashes

Key sites: Bouri (Hata Beds); Bodo (Bod A5 and A6)

Raw materials: Lava and chert at Bodo

Nature of industries: The Bouri peninsula (Hata Beds) has cut-marked and broken mammalian bones suggesting stone tool-using hominins at 2.5 mya (essentially contemporaneous with the Gona artifacts); at Bodo (A5 and A6) surface Oldowan artifacts have been found at 1.5-1.3 mya

Other associated remains: At Bouri (Hata Beds), the cranium and holotype of *Australopithecus garhi* was found at 2.5 mya

Key publications: Asfaw et al., 1999; De Heinzelin et al., 1999; de Heinzelin et al., 2000

Konso Gardula, Ethiopia

Age: 1.7- less than 1 mya

Geographic/geological setting: Riverine sand and silt deposits in a palaeoenvironment reconstructed as dry grassland

Key sites: KGA 3, 5 and 7-12

Raw materials: Basalt, quartz, quartzite, and silicic volcanic rock

Nature of industries: The earliest Acheulean (characterized by crude bifaces and trihedral picks made on a range of blanks (cobbles, blocks, and large flakes) and possibly contemporaneous Oldowan industries at ca. 1.7 mya

Other associated remains: A cranium and mandible (KGA 10-525) of *A. boisei* and a mandible of *Homo erectus* at ca. 1.4 mya

Key publications: Asfaw et al., 1992; Suwa et al., 1997

Melka Kunture, Ethiopia

Age: 1.7-1 mya

Geographic/geological setting: Primarily fluviatile deposits

Key sites: Garba, Gomboré, Karre

Raw materials: Lava and quartz

Nature of industries: Oldowan; later Acheulean and Developed Oldowan

Other associated remains: From the Oldowan levels, an early *Homo* child mandible at Garba IV and a partial hominin humerus from Gomboré 1B

Key publications: Chavaillon et al., 1979

Fejej, Ethiopia

Age: 1.96 mya

Geographic/geological setting: Fluviatile sediments

Key sites: FJ-1, in level C1

Raw materials: Mostly quartz and basalt

Nature of industries: Simple cores and debitage

Other associated remains: Hominin premolar and two molars, attributed to early *Homo*; distal humerus fragment, attributed to *A. boisei*

Key publications: Asfaw et al., 1991; de Lumley & Beyene, 2004

Omo Valley, Ethiopia (Shungura Formation)

Age: 2.3-2.4 mya

Geographic/geological setting: River floodplain deposits

Key sites: Omo 71, Omo 84 Omo 57, Omo 123, FtJi1, FtJi2, FtJi5

Raw materials: Primarily quartz

Nature of industries: Simple cores and debitage, bipolar technique evident

Other associated remains: *A. boisei* and early *Homo* from deposits (not at site locales)

Key publications: Chavaillon, 1970; Chavaillon & Chavaillon, 1976; Howell et al., 1987; Merrick, 1976

East Turkana (Koobi Fora), Kenya

Age: 1.9 to 1.3 mya

Geographic/geological setting: River floodplain, river channel, and deltaic deposits

Key sites: In the KBS Member, FxJj 1 (Oldowan); FxJj 3 (Oldowan); FxJj 10 (Oldowan); FxJj 11 (Oldowan); FxJj 38 (Oldowan); in the Okote Member, FxJj 17 (Oldowan); FxJj 50 (Oldowan); FxJj 16 (Karari); FxJj 18 complex (Karari). FxJj 20 complex (Karari); FwJj 1 (Karari).

Raw materials: Primarily basalts, also ignimbrite, chert, quartz

Nature of industries: Two variants of the Oldowan Industrial Complex identified, the Oldowan Industry - simple cores and debitage with a rarity of retouched forms - in both the KBS Member and the overlying Okote Member; and the Karari Industry - numerous core scrapers and more prevalent retouched pieces – in the Okote Member.

Other associated remains: Fauna present at a number of sites; overall fauna primarily larger mammals from grassland, bush, and riverine forest habitats; fauna showing cut-marks and hammerstone fracture at FxJj 50; cut-marked bones at GaJi 5, c. 1.6 my, a deltaic locality with no stone artifacts; a large number of hominin fossils stratigraphically associated with the Oldowan KBS Member and the Okote Member have been attributed to a number of taxa, including *A. boisei*, *Homo* sp., *Homo rudolfensis*, *Homo habilis*, and *Homo erectus/ergaster*.

Key publications: Isaac, 1997; Wood, 1991

West Turkana (Nachukui Formation), Kenya

Age: 2.34 mya (Lokalalei); also later sites to 1.6 mya

Geographic/geological setting: Palaeosols in a river floodplain

Key sites: Lokalalei 1 and Lokalalei 2c

Raw materials: lavas

Nature of industries: Lokalalei 1 contains simple cores and debitage, while the slightly younger Lokalalei 2c shows heavier reduction of cores and considerable refitting of stone artifacts; the authors argue that site 2c, with finer-grained lavas, shows a level of technological skill and complexity in the Oldowan that is unknown elsewhere at this time

Other associated remains: A right lower molar of a juvenile hominin attributed to early *Homo* was found at the same stratigraphic level and close to the archaeological site Lokalalei 1; cranium of *A. boisei* (KNM WT 17400) at 1.7 mya

Key publications: Kibunjia et al., 1992; Roche & Kibunjia 1994; Roche et al., 1999; Brown & Gathogo, 2002; Delagnes & Roche, 2005

Chesowanja (Chemoigut and Chesowanja Formations), Kenya

Age: Approximately 1.42 mya (dated basalt separating Chemoigut and Chesowanja Formations

Geographic/geological setting: Fluviatile deposits on a saline lake margin

Key sites: GnJi 1/6E in earlier Chemoigut Formation; GnJi 10/5 in overlying Chesowanja Formation

Raw materials: Mostly lavas

Nature of industries: Oldowan forms such as scrapers, choppers, polyhedrons, flakes and fragments

Other associated remains: Partial cranium of *Australopithecus boisei* (KNM-CH 1); also additional cranial fragments of *A. boisei* (KNM-CH 304) in the Chemoigut Formation; bovids, equids, hippotamus, and crocodile; burnt clay at GnJi 1/6E

Key publications: Harris & Gowlett, 1980; Gowlett et al., 1981

Kanjera, Kenya

Age: 2.2 mya

Geographic/geological setting: Open, grassy habitat in fluvial, swamp and lake flat deposits in a lake margin environment

Key sites: (Kanjera South) Excavation 1 (in Beds KS-1 and KS-2), Excavation 2 (in Bed KS-3)

Raw materials: Mostly fine-grained lava, also other igneous rock, quartzite, quartz, and chert; some raw materials non-local

Nature of industries: Oldowan cores (choppers, polyhedrons) and debitage, some retouch

Other associated remains: Diverse vertebrate fauna with a large proportion of equids, as well as *Metridiochoerus* and *Dinotherium*; partial hippopotamus axial skeleton and artifacts in Excavation 2

Key publications: Ditchfield et al., 1999; Plummer et al., 1999

Olduvai Gorge, Tanzania

Age: 1.85-1.35 mya (Beds I and II)

Geographic/geological setting: Lake margin, channel, and floodplain deposits in grassland/woodland environments

Key sites: Bed I: DK (Oldowan); FLK NN Level 4 (Indeterminate); FLK NN Levels 1-3 (Oldowan); FLK "Zinjanthropus" Level (Oldowan); FLK Upper Levels (Indeterminate); FLK North Levels 1-6 (Oldowan); Bed II: HWK East Levels 1 and 2 (Indeterminate); FLK North, clay with root casts (Indeterminate); FLK North Deinotherium Level (Indeterminate); HWK East: Sandy Conglomerate (Developed Oldowan A); FLK North, Sandy Conglomerate (Developed Oldowan A); MNK Skull Site (Oldowan); EF-HR (Early Acheulean); MNK Main (Developed Oldowan B*); FC West (Developed Oldowan B*); SHK (Developed Oldowan B*); TK (Developed Oldowan B*); BK (Developed Oldowan B*)

(*sites with bifaces; these sites would now probably be assigned to the early Acheulean)

Raw materials: Quartz/quartzite, lava, chert

Nature of industries: Oldowan and Developed Oldowan; through time, quartz/quartzite replaces lava as the predominant raw material and frequencies of artifact classes such as spheroids/subspheroids, light-duty tools (e.g. flake scrapers)

Other associated remains: Well-preserved fauna at a number of sites, including DK and FLK *Zinjanthropus*; numerous hominin remains in Beds I and II of *Australopithecus boisei*, *Homo habilis*, and *Homo erectus*; direct association with Oldowan at FLK *Zinjanthropus* (OH 5: *Australopithecus boisei* and OH 6: *Homo habilis*) and FLK NN Level 3 (OH 7 and 8: *Homo habilis*)

Key publications: Leakey, 1971, 1975; Bunn & Kroll, 1986; Peters & Blumenschine, 1995; Blumenschine & Peters, 1998

Peninj, Tanzania

Age: 1.6-1.4 mya

Geographic/geological setting: Channels in a deltaic environment on the edge of the proto-Lake Natron

Key sites: ST Site Complex (cluster of 11 sites in same palaeosol)

Raw materials: Basalt, nephelinite, quartz

Nature of industries: Simple cores, retouched flakes, debitage,

Other associated remains: Well-preserved fauna with numerous cut-marks and percussion fractures; mandible of *A. boisei* from contemporaneous deposits; Oldowan occurrences contemporaneous with nearby early Acheulean sites

Key publications: Dominguez-Rodrigo et al., 2002; de la Torre et al., 2003; de la Torre & Mora, 2004.

Nyabusosi, Uganda (Western Rift)

Age: 1.5 mya

Geographic/geological setting: Lacustrine sands

Key sites: NY 18

Raw materials: Mostly quartz, some chert

Nature of industries: Choppers, minimally-worked cobbles, retouched pieces (notches and denticulates, etc.), and debitage (many flakes without cortex)

Other associated remains: Remains of *Elephas*, *Hippopotamus*, *Kolpochoerus* and *Phacochoerus* (pigs), *Kobus, Redunca*, and *Pelorovis* (buffalo) are found in the same formation

Key publications: Texier, 1993, 1995

South African Localities

Sterkfontein, South Africa

Age: Approximately 2 to 1.4 mya

Geographic/geological setting: Karst cave breccias

Key sites: Member 5

Raw materials: Quartz and quartzite

Nature of industries: In Sterkfontein East, simple Oldowan cores, flakes and fragments, a few retouched pieces; also Acheulean in Sterkfontein West deposits between 1.7 and 1.4 mya

Other associated remains: Hominin ulna, 3 teeth of *A. robustus*; early *Homo* (STW 53) with cut marks on zygomatic

Key publications: Field, 1999; Kuman, 1994, 2005; Pickering et al. 2000

Swartkrans, South Africa

Age: 1.8-1.0 mya

Geographic/geological setting: Karst cave breccias

Key sites: Member 1 (ca. 1.8-1.5 mya), Member 2 (ca. 1.5-1.0 mya), and Member 3 (ca. 1.5-1.0 mya)

Raw materials: quartz, quartzite, chert

Nature of industries: simple core forms, debitage, and some retouched pieces

Other associated remains: A wide range of fossil mammals are found in these breccias, including a wide range of artiodactyls, also hominins, baboons, carnivores (*Panthera, Euryboas, Crocuta, Canis, Hyaena,* etc.), hyrax, horse, and porcupine; hominins include *Australopithecus* (*Paranthropus*) *robustus*: SK 46 (cranium); SK 48 (cranium); SK 79 (cranium); SK 876 (mandible); SK 23 (mandible); SK 6 (mandible); SK 12 (mandible); SK 80 (pelvis); SK 3155 (pelvis); SK 97 (proximal femur); SK 82 (proximal femur); *Homo ergaster*: SK 847 (cranium); SK 15 (mandible)

Key publications: Brain, 1981; Clark 1991; Field, 1999; Kuman *et al*., 2005.

Kromdraai, South Africa

Age: 2.0- 1.0 mya

Geographic/geological setting: Cave breccias in a grassland/woodland karstic environment

Key sites: Member A (some artifacts also in Member B).

Raw materials: Primarily quartz, also quartzite and some chert

Nature of industries: A small assemblage of 99 artifacts at Kromdraai A, mostly simple cores and flakes, with one relatively large flake (more than 10 cm long) and two subspheroids; two artifacts at Kromdraai B

Other associated remains: Remains of *A. robustus* have been found in Member B, which also contains a more closed, humid-adapted fauna than that of Kromdraai B, which is typical of a drier, more open habitat

Key publications: Kuman et al. 1997, 2005; Field, 1999

North African Localities

Ain Hanech and El-Kherba, Algeria

Age: ca. 1.8 mya

Geographic/geological setting: The archaeological occurrences are in sandy floodplain silts overlying a cobble conglomerate

Key sites: Ain Hanech and El-Kherba

Raw materials: Fine-grained limestone cobbles and flint pebbles.

Nature of industries: Limestone cores including choppers, discoids, polyhedrons, and spheroids ("faceted balls") and associated debitage; also, in flint, small cores made on pebbles, retouched flakes (scrapers, denticulates, notches), and debitage,

Other associated remains: Mammalian remains including gazelle, caprids, *Equus* (horse), and *Pelorovis* (buffalo), and *Kolpochoerus* (pig)

Key publications: Sahnouni et al. 1996, 1997, 2002; Sahnouni & de Heinzelin 1998; Sahnouni, 2005

Casablanca Sequence, Morocco

Although there have been claims that prehistoric sites in this region are over 1.5 million years old, it now appears that the earliest of these archaeological sites are no older than 1.0 million years old. As such, these occurrences are outside the scope of this chapter, but for further information the reader might consult Raynal et al., 2002.

Contemporary Hominin Taxa

Overview

A number of early hominin taxa appear to be contemporary with the earliest stone tools of Africa during the time span of the Oldowan between 2.6 and 1.4 mya. Paleoanthropologists continue to debate just how many species are represented during this time, with "lumpers" favoring fewer species and "splitters" advocating more species.

Hominins contemporary with the earliest stone tools are generally placed in one of two genera, either *Australopithecus* or *Homo* (though some researchers place the later australopithecines in the genus *Paranthropus*). The earliest well-represented bipedal hominins tend to be the smaller-brained australopithecines, *A. afarensis* in East Africa and *A. africanus* in South Africa. Neither of these taxa is presently associated with flaked stone artifacts: *A. afarensis* precedes the first appearance of stone tools in East Africa, and *A. africanus*, though overlapping in time with stone tool sites in East Africa, is not yet found in association with archaeological materials in South Africa.

There are at least two taxa contemporary with the very earliest stone tool sites in East Africa: *A. garhi* and *A. aethiopicus*, both relatively small-brained, the latter more robust in features such as sagittal cresting and size of the cheek teeth. The presence of such relatively robust features in the cranium and teeth is observed in later australopithecines in *A. boisei* in East Africa and *A. robustus* in South Africa, until the demise of these lineages by approximately 1.2 to 1.0 mya.

Coexisting with these australopithecines, starting by at least 2.3 mya, are taxa attributed to the genus *Homo*. Finds attributed to early members of this genus (generally to Homo sp. between 2.4 and 2.0 mya), show features, particularly in their reduced dentition and somewhat larger cranial capacity (and probably a higher brain/body encephalization quotient or EQ), that distinguish them from contemporary australopithecines, linking them evolutionarily with later developments in the *Homo* lineage but not presenting features in fossil finds sufficient to produce an individual species diagnosis. Species designations among the *Homo* taxa include the earlier forms, *H. habilis* in East and South Africa and *H. rudolfensis* in East and Central Africa, and subsequently *H. ergaster/erectus*.

Phylogenetically, it is possible that the major evolutionary lineage that led to modern humans could have been *A. afarensis* to *A. garhi*, to *H. habilis*, to *H. ergaster/erectus*, and ultimately to modern humans. The lineages that led to the robust australopithecines could have been *A. afarensis* to *A. aethiopicus* to *A. boisei* in East Africa, and *A. afarensis* to *A. africanus* to *A. robustus* in South Africa.

Catalog of Hominin Fossil Taxa

The following inventory of Plio-Pleistocene hominin taxa presents the forms present during the time range of the earliest archaeological occurrences (ca. 2.6-1.4 mya). This catalog includes each taxon's known time range, key sites and fossils, major anatomical characteristics, associated archaeology, and other considerations such as possible phylogenetic status. Useful reviews of these hominin forms in their evolutionary context include Aiello & Dean, 1990; Boaz & Almquist, 1999; Bilsborough, 1992; Boyd & Silk, 1997; Campbell & Loy, 1996; Day 1986; Delson et al., 2000; Johanson & Edgar, 1996; Klein, 1999; Lewin & Foley, 2004; and Wolpoff, 1999.

Australopithecus garhi

Time range: ca. 2.5 mya

Key sites: Bouri (Middle Awash), Ethiopia

Key fossils: Bouri: BOU-VP-12/130 (partial cranium with upper dentition); BOU-VP-12/87 (crested cranial vault); BOU-VP-17/1 (mandible); BOU-VP-12/1 (partial humerus); BOU-VP-35/1 (partial humerus); BOU-VP-11/1 (proximal ulna); BOU-VP-12/1A-G (partial femur and forearm elements)

Anatomical characteristics: Small braincase; prognathic lower face; large anterior and posterior dentition; postcrania suggest a humanlike humerus/femur ratio and an apelike humerus/ulna ratio

Cranial capacity: ca. 450cc (one specimen)

Associated archaeology: Cut-marked and percussion fractured bones at Bouri; roughly contemporaneous with the earliest Stone Age sites at Gona

Other: Asfaw *et al*. (1999) have suggested that this taxon, contemporaneous with *Australopithecus* (*Paranthropus*) *aethiopicus* in East Africa and *Australopithecus africanus* in South Africa, may be ancestral to the genus *Homo*. Contemporaneous isolated non-robust dentition from the Omo may be from this taxon as well. This taxon could well be responsible for the stone tools at Gona at 2.6 mya.

Australopithecus africanus

Time range: 3.0-2.2 mya

Key sites: Taung, Sterkfontein, and Makapansgat, South Africa

Key fossils: Taung: Taung child (juvenile cranium, mandible); Sterkfontein: STS 5 (cranium); STW 505 (cranium); STS 71 (cranium, mandible); STS 36 (mandible); STS 52 (partial cranium, mandible); STS 14 (partial skeleton); STS 7 (partial scapula, humerus); Makapansgat: MLD 37/38 (cranium); STS 14 (vertebral column, rib fragments, pelvis; partial femur)

Anatomical characteristics: Small braincase; prognathic lower face; no sagittal cresting; large incisors, premolars, and molars; more ape-like limb proportions

Cranial capacity: ca. 440cc (range 430-520cc)

Associated archaeology: Unknown from South African cave deposits in which this taxon is found, but *A. africanus* is contemporaneous with the earliest stone tools in East Africa

Other: Bone tools attributed to *A. africanus* by Dart (1957) are now believed to represent animal bones modified by non-hominin agents. Some palaeoanthropologists argue that this taxon is ancestral to the genus *Homo*; others argue that it is ancestral to the South African robust australopithecine *A. robustus.*

Australopithecus (Paranthropus) aethiopicus

Time range: ca. 2.5 mya

Key sites: West Turkana, Kenya; Omo Shungura Member C, Ethiopia

Key fossils: West Turkana: KNM-WT 17000 (cranium without dentition); Omo 18 (mandible)

Anatomical characteristics: Small braincase; sagittal cresting in males; very prognathic lower face; large cheek teeth with thick enamel

Cranial capacity: 410cc (one specimen)

Associated archaeology: Unknown, but contemporaneous with the earliest stone tools at Gona in Ethiopia

Other: Some palaeoanthropologists argue that this taxon may be ancestral to both the later East and South African robust australopithecines; others argue that it is ancestral only to the East African variant *A. boisei*.

Australopithecus (Paranthropus) boisei

Time range: 2.3-1.2 mya

Key sites: Olduvai Gorge and Peninj (Natron), Tanzania; East Turkana and West Turkana, Kenya; Omo and Konso Gardula, Ethiopia; Malema, Malawi

Key fossils: Olduvai: OH 5 (cranium); East Turkana: KNM-ER 406 (cranium); KNM-ER 732 (cranium); KNM-ER 729, 1477, and 3230 (mandibles); West Turkana: KNM-WT 17400 (cranium); Chesowanja: KNM-CH 1 (partial cranium); Konso Gardula: KGA 10-525 (cranium and mandible); Peninj (mandible); Omo L.a-125 (mandible)

Anatomical characteristics: relatively small braincase; males with pronounced sagittal cresting; hyper-robust posterior dentition with reduced anterior dentition; broad and dished face with large, flaring zygomatic arches

Cranial capacity: c. 520cc; range 500-530cc

Associated archaeology: Contemporaneous with Oldowan and/or early Acheulean sites at East Turkana, West Turkana, Olduvai, Peninj, Konso Gardula, and Chesowanja. In direct association with Oldowan artifacts at FLK Zinj site, Olduvai

Other: Both *A. boisei* and early *Homo* are contemporaneous

Australopithecus (Paranthropus) robustus

Time range: 2.0-1.0 mya

Key sites: Swartkrans, Kromdraai, and Drimolen, South Africa

Key fossils: Kromdraai: TM 1517 (cranium, mandible); Swartkrans: SK 48 (cranium); SK 46 (cranium); SK 79 (cranium); SK 876 (mandible); SK 23 (mandible); SK 6 (mandible); SK 12 (mandible); SK 80 (pelvis); SK 3155 (pelvis); SK 97 (proximal femur); SK 82 (proximal femur); Drimolen: DNH 7 (cranium and mandible); DNH 8 (mandible)

Anatomical characteristics: Relatively small braincase; large molars and premolars with thick enamel; sagittal crest in males; broad and dished face

Cranial capacity: ca. 530cc; range 450-550cc

Associated archaeology: Associated with Oldowan artifacts in the cave breccias at Swartkrans and Kromdraai

Other: *A. robustus* is contemporaneous with early *Homo* at Swartkrans and Drimolen, which makes it difficult to ascribe the Oldowan artifacts at these sites to a specific hominin

Early Homo sp.

Time range: 2.4-2.0 mya

Key sites: Baringo (Chemeron), Kenya; Hadar, Ethiopia

Key fossils: Baringo (Chemeron): KNM-BC 1 (temporal fragment); Hadar: AL-666-1 (maxilla); also possibly isolated teeth from the Omo Valley, Ethiopia

Anatomical characteristics: non-robust teeth relative to *A. boisei*

Cranial capacity: Unknown

Associated archaeology: Associated with Oldowan artifacts at Hadar; contemporaneous with Oldowan sites at Omo, West Turkana, etc.

Other: These fossils are primarily fragmentary jaws and isolated cranial fragments; there are no crania complete enough to estimate cranial capacity

Homo habilis

Time range: 2.0-1.6 mya

Key sites: Olduvai Gorge, Tanzania; East Turkana, Kenya; Sterkfontein, South Africa

Key fossils: Olduvai: OH 7 (partial cranium and mandible); OH 24 (cranium); OH 13 (partial cranium, maxilla, mandible); OH 8 (foot); OH 62 (partial skeleton); East Turkana: KNM-ER 1813 (cranium); KNM-ER 1805 (cranium); possibly Sterkfontein: STW 53 (cranium)

Anatomical characteristics: somewhat larger braincase than australopithecines; moderate brow ridge and moderately prognathic face; no sagittal cresting; reduced dentition relative to australopithecines; longer arms and shorter legs relative to modern humans

Cranial capacity: ca. 630cc; range 510-650cc

Associated archaeology: Associated with Oldowan artifacts at Olduvai and East Turkana; directly associated with Oldowan artifacts at FLK Zinj (OH 6: isolated teeth) and FLK NN Level 3 (OH 7: fragmentary cranium, mandible; and OH 8: clavicle, hand and foot bones)

Other: Many palaeoanthropologists believe that *H. habilis* is the best candidate for the ancestor of later *Homo* taxa.

Homo rudolfensis

Time range: 2.4 -1.7 mya

Key sites: East Turkana, Kenya; Uraha (Chiwondo), Malawi

Key fossils: East Turkana: KNM-ER 1470, 1590, and 3732 (crania); KNM-ER 992 and 1802 (mandibles); Olduvai: possibly OH 65 (maxilla); Uraha: UR 501 (mandible)

Anatomical characteristics: Braincase significantly larger than australopithecines; large maxilla; large premolars and molars; flat face; no brow ridge; no sagittal cresting

Cranial capacity: ca. 725; range 625-800cc

Associated archaeology: Contemporaneous with Oldowan sites in East Africa (e.g., KBS Member at East Turkana)

Other: Some palaeoanthropologists prefer to group these fossils with *Homo habilis*; others feel that the facial architecture, larger braincase, and larger dentition of this group warrant its own taxon.

Early Homo ergaster/erectus (considering fossils older than ca. 1.4 mya)

Time range: 1.8-less than 1.0 mya (in Africa)

Key sites: East Turkana and West Turkana, Kenya; Olduvai Gorge, Kenya; Swartkrans, South Africa; Dmanisi, Republic of Georgia

Key fossils: East Turkana: KNM-ER 3733 (cranium); KNM-ER 3883 (cranium); West Turkana: KNM-WT 15000 (skeleton with skull); KNM 730, 820, 992 (mandibles); Olduvai Gorge: OH 9 (cranium); Swartkrans: SK 15 (mandible), SK 847 (cranium); Dmanisi: D2280, D2282, D2700, D3444 (crania)

Anatomical characteristics: larger braincase that australopithecines and habilines; more modern human limb proportions

Cranial capacity: ca. 875cc; range 650- 1067cc

Associated archaeology: Contemporaneous with Oldowan and/or early Acheulean sites at East Turkana and West Turkana

Other: Some palaeoanthropologists view *Homo ergaster* (e.g., KNM-ER 3733, 3883, KNM-WT 15000) as a separate taxon (and a better candidate for modern human ancestry) from *Homo erectus* (e.g., OH 9). The lower end of the cranial capacity range here is based on the Dmanisi specimens. The date of the earlier Javanese *Homo erectus* materials is controversial; some favor a date of around 1.7 mya, while others argue for a date of less than 1.0 mya

Current Issues of Contention

A number of subjects in the archaeology of human origins have generated interesting and vigorous debates over the past few decades. Here we will review key areas of contention between researchers and refer the reader to key literature on these issues.

Existence of a "Pre-Oldowan"?

Some archaeologists, notably Roche (1989), Piperno (1993), and de Lumley (de Lumley & Beyene, 2004; de Lumley *et al*., 2005) have suggested in the past that lithic industries prior to 2.0 mya (Gona, West Turkana, Omo) exhibit less skill in knapping than those younger than 2.0 mya, such as those in the Okote Member at East Turkana and in Beds I and II at Olduvai Gorge. However, excavations in recent years at Gona in Ethiopia (Semaw, 1997, 2000; Semaw *et al*., 1997) have shown that at the oldest archaeological sites yet known, dated to between 2.6 and 2.5 mya, flaked lava cobbles exhibit a surprising level of skill and control of flaking, suggesting that the moniker "Pre-Oldowan" might be dropped.

Since then, Roche et al. (1999) have found well-made Oldowan artifacts from West Turkana dated to 2.3 mya. They suggest that, in view of this West Turkana evidence from 2.3 mya, that sites between 2.6 and 2.0 mya are variable, with artifacts in some assemblages appearing more "sophisticated" and those in others appearing more "crude." However, it is very likely that much of this variation may be due to differences in the quality and flakability of the raw materials used in different assemblages (e.g., the trachytic lava cobbles at Gona flake much more easily flaked than many East African basalts, making it easier to remove numbers of large flakes from cores), rather than profound differences in the skill, control or cognitive abilities of the knappers.

Experimental archaeological work with modern African apes (this volume) shows that bonobos (pygmy chimpanzees) with substantial training still produce Oldowan-like artifacts, but their assemblages of artifactual products can be shown to exhibit less skill (seen in numerous attributes of the cores and flakes) than is found at early Oldowan sites (see the chapter in this volume). If such artifactual assemblages were to be found in the prehistoric record prior to 2.5 mya, and this appeared to be a consistent pattern, there may then be some justification to separate these assemblages from the classic Oldowan.

It does seem true that Oldowan sites older than 2.0 mya tend to have few or no retouched flakes in their lithic assemblages. This pattern begins to change after 2.0 mya, with retouched forms (light-duty scrapers, awls, etc.) becoming more prevalent at sites at Olduvai Gorge and also, over time, at East Turkana.

Who Were the Oldowan Tool-makers?

As noted above, there were probably at least nine hominin taxa present in Africa during the major time period of the Oldowan, between 2.6 and 1.4 mya. These included *Australopithecus garhi, A. africanus, A. aethiopicus, A. boisei, A. robustus, Homo habilis, H. rudolfensis, and H. ergaster/erectus*. At our present state of knowledge, all of these taxa, with the exception of *A. africanus*, were contemporaneous with nearby Oldowan sites.

At a number of localities, hominin fossils are found in geological strata contemporaneous with archaeological materials in that region. These localities include Hadar (early *Homo*), Middle Awash (*A. garhi*), Konso Gardula (*A. boisei, Homo ergaster/erectus*), Melka Kunture (early *Homo*), Fejej (early *Homo, A. boisei*), Omo (*A. boisei*, early *Homo*), East Turkana (*A. boisei, H. habilis, H. rudolfensis, H. ergaster/erectus*), West Turkana (early *Homo*), Chesowanja (*A. boisei*), Olduvai Gorge (*A. boisei, H. habilis, H. erectus*), Peninj (*A. boisei*), Sterkfontein (*A. robustus*, early *Homo*), Swartkrans (*A. robustus, H. ergaster*), and Kromdraai (*A. robustus*). At a few sites, notably Olduvai FLK Zinj, the fossil remains of *A. boisei* and *H. habilis* were found in direct association with a discrete Oldowan archaeological horizon. In view of the fact that diverse mammalian fauna are often in association with these Oldowan occurrences, it cannot be demonstrated clearly, based on these associations, that hominins found at or near archaeological horizons are necessarily the tool-makers. If hominin remains are indeed functionally associated with artifacts at a given locality, it must be considered that they could represent *either* the dinner or the diner. The only known Oldowan-age hominin fossil exhibiting identifiable cut-marks is the STW 53 cranium, attributed to early *Homo* (Pickering et al., 2000).

Mary Leakey (1971) argued that *H. habilis* was the principal Oldowan tool-maker, relegating *A. boisei* to a minimal role in early lithic technology (perhaps a tool-user responsible for minor modification to artifacts). Many paleoanthropologists still favor the scenario of the genus *Homo* being responsible for many or most of the Oldowan archaeological occurrences, since this genus exhibits marked brain expansion and tooth reduction over time after the onset of stone tools, while the robust australopithecines exhibit less encephalization and little if any reduction (and possible increase) in size of cheek teeth and chewing musculature over time, until their extinction by 1.0 mya.

A different scenario has been presented by Susman (e.g., Susman, 1991; Grine & Susman 1991), who proposed that the robust australopithecines may have been the first makers of stone tools and may have relied heavily upon technology in their adaptation, especially in the processing of plant resources. He argued that hand bones attributed to *A.* (Paranthropus) *robustus* from South Africa exhibit human-like morphology for precision grasping.

It is possible that all of the hominin taxa contemporary with the Oldowan had capacity for and some involvement in use of stone technology. It is also possible that there may have been marked variability between different taxa, and possibly substantial variability among populations of a single taxon, with regard to involvement in stone tool-making or tool-using. What is clear, however, is that by 1.0 mya, only representatives of the genus *Homo* survived (*H. erectus* or *H. ergaster*), all of the australopithecines had gone extinct, and stone tool-making continued not only in Africa but also in areas of Eurasia into which *Homo* populations had spread. This implies that the *Homo* lineage had significant involvement in stone tool manufacture and that over time this behavior maintained a relatively consistent role in its adaptation.

What Were Oldowan Tools Used For?

The function of palaeolithic stone artifacts and the overall adaptive significance of human technology are questions that have perplexed prehistorians for over a century and a half. Although the use of ethnographic analogy to associate recurrent stone artifact forms with known functions in recent times can yield possible clues to the prehistoric uses of early stone artifacts, it does not clearly identify which Oldowan artifacts were actually utilized as tools, or what they were used for.

Experimental functional studies can, at the very least, identify the functional capabilities of different artifact classes (based on such criteria as shape, edge sharpness, weight, raw material, etc.) for a range of different tasks that might have been carried out in Early Stone Age times (Jones, 1981; Toth, 1982, 1985; Tactikos, 2005). Such tasks might include stone tool manufacture, animal butchery (hide slitting, gutting, dismembering, defleshing, marrow/brain processing), nut-cracking, simple wood-working, digging, hide-working, and manufacture of simple containers. Efficiency experiments performing such tasks with a range of Oldowan artifact forms yield valuable information as to the relative efficiency of each tool for a given task.

Experiments in using the range of Oldowan artifacts for various tasks have highlighted the possible importance of an artifact type within Oldowan assemblages whose usefulness may have been underestimated in archaeology, namely, the flake. A comprehensive experimental study of Oldowan artifact function indicates that sharp flakes and flake fragments are enormously useful in cutting operations, particularly in various aspects of animal butchery (skinning, defleshing, dismembering, etc.). Thus, flakes may not simply represent debitage or "waste," but might rather represent a central component of the Oldowan toolkit (Toth, 1982, 1985, 1987b).

Such experiments can also show the relationships between *processes* (e.g., skinning, dismembering and defleshing) and resultant *products* that may have visibility in the prehistoric record (e.g., striations identified as cut-marks on bones or distinctive use-wear polishes on stone tool edges). Thus, we can identify key signatures or "smoking barrels" that can give corroborative evidence of the prehistoric functions of artifacts.

The class of battered cobbles or other pieces of stone (hammerstones, battered subspheroids or spheroids) strongly suggests that these objects were primary tools used as hammers to flake cores, and as such indicates that Oldowan hominins by 2.6 mya were using tools to make other tools, a pattern that is rare if not absent in the technological repertoires observed among modern apes in the wild. Such functional experiments can then associate a range of possible tasks which would be efficiently performed with a given artifact type.

A very valuable functional signature has been found in cut-marks on animal bones at Oldowan archaeological sites, which indicate that early hominins were skinning, disarticulating, and defleshing carcasses of small, medium, and large mammals (Blumenschine, 1986; Bunn ,1981; Dominguez-Rodrigo, 2002; Egeland et al., 2004; Monahan, 1996; Monahan & Dominguez-Rodrigo, 1999; Oliver, 1994; Pickering, 2001; Pickering and Domínguez-Rodrigo, this volume; Potts & Shipman, 1981). Experiments as well as actualistic studies of carnivore damage to bones have helped differentiate between cut-marks made with stone tools and tooth-marks made by carnivores (Bunn, 1981; Potts & Shipman, 1981). The majority of Oldowan cut-marks tend to be sets of parallel striae, suggesting that sharp-edged flakes, as opposed to unifacially or bifacially retouched edges, were primary artifacts used as butchery knives (see Toth, 1985:112).

Many of these studies have also shown that mammal long bones sometimes exhibit hammerstone percussion marks (e.g., see Blumenschine & Selvaggio, 1988), fracture patterns showing spiral fracture with discrete points of percussion (from contact with stone hammers or anvils), flake scars on bones, and occasional bone flakes. These patterns are consistent with the use of simple stone hammers, and possibly anvils, as percussors for marrow processing.

Another 'smoking barrel' so to speak, or positive evidence for stone tool function, is provided by microwear studies, or analysis of microscopic modification that can develop on stone tool edges during their use (Keeley, 1980). Microwear, or wear-patterns in the form of striations, polishes, and edge damage and modification (chipping, rounding, etc.) has been shown experimentally to develop on the edges of stone tools (primarily in fresh, fine-grained siliceous raw materials) in the process of their use for different functions. Although most raw materials used in the manufacture of early stone tools (lavas, quartz, quartzite, etc.) have not proven to be very amenable to such analysis, a study of a limited sample of more rare siliceous artifacts (mostly in chert, also ignimbrite) from sites in the Okote Member at East Turkana have revealed a fairly diverse set of prehistoric activities dating to approximately 1.5 mya (Keeley & Toth, 1981; Keeley in Isaac, 1997:396-401).

Examination of a sample of 56 artifacts (mostly flakes and flake fragments, including a few with retouch, along with one pebble core "bifacial chopper") from 9 Okote and KBS Member sites found unequivocal and interpretable microwear traces on nine artifacts from five of the Okote Member sites. This sample of 56 artifacts represents the majority of suitable-looking specimens from Koobi Fora assemblages excavated at that time. Subsequent examination of an additional sample of 39 specimens, including a small chert core and an ignimbrite 'scraper' form did not show definite microwear traces.

These nine artifacts show a fairly diverse range of activities for the size of the sample and, interestingly, the working of both plant and animal materials: "four meat or butchering knives, two soft-plant knives, two woodscrapers (one of which had traces of use as a saw on another edge), and one wood saw" (Keeley in Isaac, 1997:399). As plant processing in Oldowan times is a nearly invisible activity due to the general lack of preservation of macroscopic plant remains, this microwear evidence provides an invaluable window into this aspect of early hominin adaptation. The plant-cutting knives show classic 'sickle gloss,' indicating the gathering or processing of soft plants, whether for food, bedding, or other purposes. (Experimentation by Toth has demonstrated that this gloss forms much more quickly on African savanna grasses than on temperate European ones).

The wood scraping and sawing would appear to indicate the shaping of wood, presumably to make other tools such as spears, digging sticks, etc. Microwear evidence for cutting meat found on four of the nine artifacts (from two sites, FxJj 50 and FxJj 20) corroborates indications from cut-marked bone, and, interestingly, two of the artifacts showing meat-cutting polish at FxJj 50 were found less than a meter away from a cut-marked bone (Keeley in Isaac, 1997:401).

Archaeologists studying Oldowan occurrences (and Palaeolithic archaeologists in general) are aware that a great deal of prehistoric tool use is, at present, invisible in the archaeological record, and what we are sampling is the 'tip of the iceberg,' but hopefully a representative sample of common tool-using activities. It is likely that future techniques will be developed to gain a much better understanding of the functions of ancient tools (for example, higher-resolution organic residue studies, even possibly DNA residues of great antiquity).

What Was the Nature of Oldowan Sites?

Explaining *how* and *why* early hominins collected, and then concentrated at discrete focal points on the landscape, lithic raw material (sometimes brought in from multiple distant sources), and also, at some sites, presumably animal bones as well, are important issues in human origins studies. Thus, the nature of variability between sites (for instance, in terms of artifact and fossil densities, the nature of artifact assemblages, spatial patterning at the site, vertical dispersion of materials, geological context, associated fauna, and so on), and possible explanations for such variability have been topics of great interest and concern in early stone age studies.

Mary Leakey (1971) divided the sites at Olduvai Gorge into: a) Living floors (limited vertical dispersion); b) Butchering or kill sites (associated with the skeleton of a large animal or group of animals) c) Sites with diffused material (significant vertical dispersion); and d) River or stream channels (artifacts incorporated in gravel deposits). Leakey interpreted her "living floors" as ancient camps of Oldowan hominins.

Glynn Isaac (1971) developed a classification of sites according to their proportions of stone artifacts relative to bone remains. The major categories in this classification were: a) "Camp" or occupation sites (high density of both stone and bone); b) Quarry or workshop sites (high density of stone, low density of bone); c) Kill or butchery sites (high density of bone, low density of stone); and d) Transitory camps (low density of both bone and stone). Isaac (1978) went on to argue that the occupation sites were early examples of "home bases" where early hominins shared food resources. He also postulated more hunting and scavenging and a sexual division of labor among these hominin social groups. Isaac (1984) later replaced the term "home base" with the term "central place foraging" areas to denote sites where hominins were concentrating stones and bones without the necessary (but possible) corollaries of food-sharing and division of labor.

Lewis Binford (1981) first suggested that early Oldowan sites simply represented places where hominins were doing marginal scavenging at places where carnivores collected and consumed animal carcasses. Later, he revised this interpretation and argued that Oldowan hominins were marginal scavengers, but may have collected bones on the landscape and processed them for marrow and relict meat (Binford, 1987). He did not think that such attributes as food sharing or a sexual division of labor were necessary for these tool-making populations.

Richard Potts (1984, 1988) suggested that Oldowan sites were "stone caches" where hominins stored materials for later use. In this model, hominins were transporting stone and depositing it in concentrations away from the original sources, thus creating "caches" of raw materials on their landscapes; if a need for stone emerged, they would have then gone to the nearest source. Potts argued that this model was energetically efficient, giving these early hominins an adaptive edge over other groups that did not cache.

Robert Blumenschine (1986, 1988) argued that many Oldowan sites represent the scavenging behavior of early hominins. In this model, hominins were accessing parts of carcasses left behind by carnivores such as large cats or cached in trees by leopards. This model posits that scavenging opportunities, including marrow extraction of felid kills abandoned in riparian woodlands, would have been markedly greater during the dry season, and thus the Oldowan archaeological record may have a built in bias for representation of dry season activities with little representation of hominin behaviors during the rainy seasons (Blumenschine, 1986).

Kathy Schick (1986, 1987a, 1987b) suggested that many Oldowan sites, particularly those with high densities of artifacts and bones, represented favored places for early hominins, likely due to proximity to resources such as food and water as well as amenities such as trees that could provide shade or escape from predators, and possibly sleeping quarters. This model of site formation proposes that hominins were repeatedly or habitually carrying stone around the landscape, with disparity between stone brought in and that taken away resulting in a range of different sites, from dense concentrations to relatively thin scatters of artifacts. At especially favorably located places, a range of food processing and feeding behaviors probably occurred, some in conjunction with stone tool-making and tool-using.

Clearly at the larger sites, the amount of lithic material brought to the site exceeded the amount taken away, resulting in the accumulation of sometimes thousands of artifacts and hundreds of kilograms of material. Some of these sites could also have served as *de facto* depots of raw material for re-use, i.e., materials discarded and left behind by hominins, not deliberately stored or "cached" (Schick, 1986:167), but which could have been tapped into by the same hominins or other individuals or groups for use at some later time, if the lithic material were not buried or obscured by vegetation or sedimentation (Schick, 1986:163-169).

It seems advisable to keep in mind that many early stone age sites could differ greatly in terms of what they represent about early hominin behaviors: They may be 'capturing' different subsets of the overall behavioral repertoire of early hominins over time and space. Sites could vary from one another, for instance, in terms of any of the following variables, each of which could potentially impact the observable archaeological patterns left behind in their wake:

- the numbers of individuals active at the locale
- composition of the group by age or sex
- the kind and variety of on-site activities pursued, e.g.,
  - food consumption
  - meat or marrow processing
  - plant processing
  - stone tool-making
  - manufacture or use of tools in other substances such as wood

  - food-sharing
  - sleeping
- the amount and kinds of food resources available at or near the site or brought to the location
- proximity of the site to stone resources for tool-making
- duration of occupation and frequency of reoccupation of the site locale
- proximity of the site to amenities (such as water, shade, trees or other havens from predators)
- seasonal constraints and opportunities
- available environments and microhabitats
- arbitrary differences (or 'cultures' with a small "c") among different groups
- evolutionary change in hominin behaviors over time

Thus, search for a monolithic behavioral model for the formation of early sites is likely unrealistic, but we are becoming better armed to wrestle with the more particulate questions regarding behavioral processes evident at a particular site. The past few decades have witnessed a trend toward increasingly sophisticated and self-critical modeling of the dynamics of site formation, and preliminary models and observations are being constructed based on a wealth of valuable experimental and actualistic research.

Oldowan Hunters or Scavengers?

As recently as the 1950's through the 1970's, many paleoanthropologists as well as popular authors emphasized the role of hunting in early human evolution (see, for example, Ardrey, 1976; Dart, 1953; Lee & DeVore, 1968). Binford (1981) provided a direct challenge to the assumption that hunting constituted a major component of subsistence activities of early hominins, and argued for scavenging as a major means of acquiring meat resources among these hominins. At the same time, Brain's (1981) examination of the faunal remains from the Transvaal cave accumulations in South Africa concluded that the australopithecine bone breccias were not the result of hominin predation, but rather primarily the accumulation of carnivores such as leopards and hyenas.

With the identification of animal bones with stone tool cut-marks and hammerstone percussion damage and fracture at Olduvai Gorge sites such as FLK Zinj, BK, MNK Main, and HWK East Level 1-2; at the ST Site Complex at Peninj (Natron); at FxJj 50 at Koobi Fora; and subsequently also at Swartkrans Member 3 and Sterkfontein Member 5 in South Africa, the question as to how early hominins were procuring animal resources has come under very close, active scrutiny. In the past few decades a great deal of paleoanthropological research has centered on whether the faunal remains found at Oldowan archaeological sites show patterns indicating the relative involvement of hominins and various carnivores in accumulating, modifying, and accessing food resources from archaeological faunal remains.

At the present time, there are two major schools of thought regarding hominin-modified bones at such Oldowan sites:

1. That these faunal remains represent scavenging behavior on the part of Oldowan hominins, and that the major source of meat/marrow for these hominins was from carcasses largely consumed and left behind by predators such as large cats. This perspective has been forwarded by Blumenschine (1986, 1987, 1989); Selvaggio (1994), and Calpaldo (1995).

2. That these faunal remains represent predation or at least primary access (e.g., confrontational scavenging) to carcasses on the part of Oldowan hominins, with presumably a great deal more meat and other animal resources available to the tool-makers than in the scavenging scenario. This perspective has been forwarded especially by Bunn, Pickering, and Domínguez-Rodrigo (Bunn et. al., 1980; Bunn, 1982, 1983, 1994; Bunn & Kroll, 1986; Pickering, 1999, 2001; Domínguez-Rodrigo, 2002; Domínguez-rodrigo & Pickering, 2003). (See Pickering and Domínguez-Rodrigo, this volume, for further discussion and review of this issue).

Since Oldowan hominins were almost certainly opportunistic omnivores, and at any given time there may have been more than one species making and using stone tools, it would not be surprising if a wide range of behavioral and subsistence patterns are ultimately identified in the early archaeological record. Furthermore, these patterns could have varied seasonally, regionally, environmentally, temporally, and among different groups or populations. Hopefully fine-grained taphonomic analysis of greater numbers of Oldowan faunal assemblages in a variety of situations and environments will potentially exhibit patterning that might yield insight into such variability in hominin subsistence behaviors.

Causes for Encephalization in the Genus *Homo*?

The fossil evidence indicates that some taxa of hominins exhibited larger brains and probably higher brain to body ratios (EQ's or Encephalization Quotients) than earlier taxa (the earlier australopithecines) and contemporaneous taxa (the later robust australopithecines) by at least 2.0 mya and perhaps earlier. These larger-brained forms are conventionally put into the genus *Homo* (*H. habilis, H. rudolfensis, H. ergaster/erectus*). It is interesting and perhaps significant to note that, at the present time, we do not yet have fossil evidence of such encephalization, nor evidence of a profound reduction in the size of jaws and cheek teeth, in hominins contemporaneous with the very earliest Oldowan sites around 2.5-2.6 mya (*A. garhi, A. aethiopicus*, and *A. africanus*).

A great deal of recent debate has centered on the various causal factors that might be responsible for, or involved in, this encephalization in the genus *Homo*. Hypotheses have revolved around such factors as social intelligence, tool manufacture and use, and changes in hominin diet. Here we will review some of the major hypotheses regarding brain expansion in the human lineage.

The Social Brain Hypothesis

Primatologist Robin Dunbar (1992, 1993) has found that neocortex ratio (the ratio of neocortex size to overall brain size) in primates (and also carnivores) is correlated with group size. Group size is taken as a general index or proxy of social complexity, with primate species living in larger social groups typically having more complex social interactions than do those living in smaller groups. A larger neocortex ratio would presumably allow for a higher level of social intelligence necessary to negotiate the more complex networks of interactions and relationships in larger groups.

Dunbar suggests that the process of neocortical encephalization in the human lineage allowed for larger group sizes (for modern human foragers, the prediction would be about 150 individuals), the selective forces including clearer "theory of mind" (the cognitive ability to understand the beliefs and desires of others) as well as better communication skills that would ultimately lead to modern human language. As early hominins became more socially complex, larger neocortical areas would have evolved in tandem with larger social group sizes. Presumably, once set forth, neocortical encephalization could then also have been selected for due to other reasons as well, as it would have conveyed greater overall intelligence for use not only in social groups, but also in foraging behaviors, in planning or timing of various activities, or in tool manufacture and use. The theory of "*Machiavellian Intelligence*" (Humphrey, 1976; Byrne & Whiten, 1988) is a similar perspective that also emphasizes primate social interaction, politics, "theory of mind," deception, and intelligence.

The Symbolic Hypothesis

Neuroscientist and evolutionary anthropologist Terrence Deacon (1997) has suggested that the near-synchronous appearance of encephalization, stone tools, hunting and butchering, reduction in sexual dimorphism, and probable male provisioning, pair-bonding, and mating contracts, are interrelated features correlated with the rise of symbolic thought and communication starting in early *Homo*. In Deacon's framework, a symbol represents "… some social convention, tacit agreement, or explicit code which establishes the relationship that links one thing to another" (1997, p. 71). In his hypothesis, key results of this early enhancement in symbolic thought and communication (at first, use of simple gestures, vocalizations, activities and objects, possibly highly ritualized) would ultimately include improvements in sharing knowledge about the environment and in manipulating and negotiating with other individuals.

The Tool-Making Hypothesis

Since the time of Darwin, it has long been hypothesized that tools constitute a defining characteristic of what it is to be human. Tools have often been taken not only to represent a hallmark of the human lineage but also a major impetus for the brain encephalization in human evolution. Although in recent years we have increased our knowledge and appreciation of tool use and even occasional tool manufacture by other species, the profound technological adaptation accomplished by the human species still stands out as a remarkably significant departure from the rest of the animal world. Washburn (1960) proposed a "*biocultural feedback*" model for the coevolution of human genetic evolution and human cultural evolution (including tools). In this feedback loop, the evolution of culture and tools in our lineage would have led to selection for genetic and biological foundations for these behaviors (including intelligence), leading to more complex cultural adaptations, and so on. This idea is echoed in sociobiologists Charles Lumsden and Edward O. Wilson's (1983) "*gene-culture coevolution*" model.

A number of researchers have emphasized how the role of technology in our adaptive strategy may have contributed to the increased intelligence and encephalization in the human lineage. Kathleen Gibson (1986) has suggested an "*extracted foods*" hypothesis, arguing that primates that exploit foods which are difficult to extract and process tend to be more intelligent and encephalized. In primates neocortical size is correlated with "…the complexity and variety of the sensorimotor coordinations needed for the finding and processing of foods" (Gibson, 1986:100), and this pattern is even more exaggerated in human evolution, with tools and technology allowing for even more efficient extraction.

We have argued that, although there is nothing inherent in tool-making that would lead to encephalization, it is through tool-making and tool-use that early hominins were able to expand their diet breadth and increase the quality of their diets (Schick & Toth, 1993). By creating synthetic "organs" (a phenomenon we called "*techno-organic evolution*"), hominins were gradually able to enter the niches of other animals such as predatory and scavenging carnivores, suids, and insect-eating mammals, increasing their survivability and reproductive success. The combination of tool-making and tool-use, leading to expansion of diet breadth, increase in diet quality, increase in social complexity, and rise of more predatory behavior, and the cumulative impact of these adaptations on reproductive success, would have driven encephalization over time.

The Expensive Tissue Hypothesis

Anthropologist Leslie Aiello and Peter Wheeler (1995) have suggested that animal species tend to have as large a brain as their metabolism can support. In order to allow for evolutionary brain expansion, there must be a novel way to reallocate expenditures within their overall metabolic budget. In modern humans, the brain (a very 'expensive' tissue) comprises about 2% of body weight but consumes about 20% of the body's metabolic budget. Larger brain/body size proportions are normally associated with higher intelligence, which could increase evolutionary fitness through improving a species' adaptation by making them more efficient foragers and social animals.

In modern humans, the brain utilizes a significantly higher proportion of the metabolic budget than in other primate species, while the budget for the human gut (the gastro-intestinal tract) is significantly reduced relative to most other primates. In effect, comparing humans with other primates, the human brain has increased evolutionarily in terms of its size and its metabolic budget at the expense of the gut, which has undergone a corresponding decrease in its size and energy budget.

In early hominins, it is hypothesized that this shift towards encephalization would have been correlated with a reduction in the hominoid-like gut (a larger size necessary for digesting and detoxifying a high vegetable diet). The size of the gut is largely tied to the kinds of foods a species consumes, in terms of how digestible they are and how much quantity must be consumed to meet nutritional requirements. Species with "lower quality" diets, such as herbivores, tend to consume larger quantities of less digestible foods, requiring a larger gut. Conversely, species with "higher quality" diets, such as carnivores, tend to consume lesser quantities of more digestible foods, requiring a smaller gut (especially a smaller stomach but proportionally longer small intestine to absorb nutrients). The evident gut reduction in the human lineage could have been made possible then by increasing diet quality (especially the proportion of proteins and fats) through more omnivorous behavior (such as scavenging or hunting, or focusing on invertebrate foods such as insects). Over time, the use and reliance of tools and technology could greatly enhance acquisition and processing of a higher-quality (more easily digested) diet and thus allow further encephalization and further gut reduction.

Presence of Fire at Oldowan Sites?

At some point in human evolution, hominins likely learned to maintain natural fires (started by lightning strikes, volcanic eruptions, spontaneous combustion, etc.), and presumably much later in time learned to manufacture fire, probably through some friction technique such as a hand drill, bow drill, fire saw, etc., or by a percussion technique such as striking a flint against a pyrite. In general, the recurrent and presumably habitual use of fire at archaeological sites occurs only in the late Acheulean and Middle Palaeolithic/Middle Stone Age in the last 250,000 years. By that time, palaeolithic peoples almost certainly knew how to manufacture and maintain fires and hearths.

Intriguingly, there are a few Oldowan sites where evidence such as reddened and baked sediments or thermally altered stone or bone suggests the presence of fire. The major issue here is whether the fire was directly associated with hominin behavior, i.e., whether the hominins started or maintained the fire, or whether these are natural fires that swept through an area where hominins had left materials behind. There are no known hearth structures associated with Oldowan sites (pits, rings of stone, etc.), so establishing hominin control or manufacture of fire is even more challenging.

At Swartkrans Member 3, associated with Oldowan tools and the remains of *A. robustus*, several hundred pieces of fossil mammal bone (within a bone assemblage of nearly 60,000 pieces) have been interpreted to show signs of exposure to fire (i.e., to temperatures achieved in experimental campfires, or from approximately 650° C to a maximum of 860° C) (Brain & Sillen, 1988; Brain, 1993; Sillen & Hoering, 1993). The evidence for burning included fossil bone discoloration (buff, to dark brown or carbonized, to calcined), thin section analysis (showing cracks and other changes in structure) (Brain, 1993), and chemistry (carbon-containing char, altered fats, etc.) (Sillen & Hoering, 1993). Due to the distribution of these bones throughout much of the depth of deposit at Swartkrans (approximately six meters of deposit), it has been inferred that hominins may have tended fires repeatedly during the time of deposition.

At Koobi Fora (East Turkana), other evidence has been inferred to indicate presence of fire at an Oldowan occurrence. At the FxJj 20 Complex (at sites 20 Main and 20 East), some reddened, oxidized patches of sediment, two at 20 Main and three at 20 East, have been observed within the deposit at the approximate level of artifact horizons (Harris, 1978; Bellomo, 1993; Bellomo & Kean, 1997). These apparently burned patches are less than one meter in diameter and at least 5 cm in depth. Magnetic anomalies at FxJj 20 East roughly correlate with these reddened areas, presumably due to heating and localized alteration of the magnetic properties of the sediment (Bellomo & Kean, 1997). In addition, several chert artifacts show reddening and sometimes surface crazing and pot-lid fracturing that seem to suggest thermal alteration; one of the reddened pieces at FxJj 20 East refits to a set that does not show this color change. Burned clay has also been found at Chesowanja, Kenya, associated with Oldowan materials (Gowlett *et al*., 1981).

These curious occurrences may indicate hominin use of fire; however, it is not clear to us that natural processes can be completely ruled out at as a factor in the apparent burning in these instances. Glynn Isaac (pers. comm.) found that in his surface scatter study ("scatter between the patches") in the Okote Tuff complex (in which the FxJj 20 Complex is located), about one in every three surface samples yielded baked sediment fragments. This might well represent evidence of burning from bush fires in the region which also swept across the site areas at FxJj 20. For example, there is burned bone at the non-hominin site of Langebaanweg in South Africa from the Pliocene, dated to 5 mya (Hendey, 1982). Natural bush fires are relatively common occurrences in dry season conditions and can ignite bushes and trees which can burn for longer periods, and at very high temperatures, after grasses have been consumed. Until more Oldowan sites are excavated and show a clear, consistent pattern of burning, and one that is spatially discrete and stands out from 'background' burning, it is difficult to say with certainty how involved Oldowan hominins were with regard to the use of fire.

Do Chimpanzees in the Wild Produce Oldowan Sites?

Beginning in the 1960's, it became clear that modern chimpanzees in the wild made and used tools for a variety of tasks (see Goodall, 1986, for an overview of her observations of tool use among the Gombe chimpanzees). The cultural and technological patterns among different populations of chimpanzees are discussed in detail by McGrew (1992, 2004). Although the objects initially identified in chimpanzee tool-use were largely organic materials with little chance of preservation (such as twigs, grasses, leaves, etc.), later observations of chimpanzee use of stone hammers and anvils in nut-cracking activities in West Africa added materials with potential archaeological visibility to the tool-using repertoire of modern chimpanzees (Boesch & Boesch, 1983, 1984).

Beginning in the 1980's, researchers began also to look at the material culture and activities of chimpanzees from a more archaeological perspective, and to discuss the spatial distribution of materials used in different activities, density of such materials per unit area, possible ape 'mental maps' of resource locations (raw materials for hammers as well as nut resources), and optimization of transport of materials used for tools. This important research has focused on nut-cracking behavior (e.g., Boesch & Boesch, 1983, 1984, 1990, 1993; Boesch & Boesch-Achermann, 2000; Mercader *et al*., 2002), as well as the location of nests and feeding debris (Sept, 1992b).

This research has added an exciting dimension to studies of the Oldowan. First, it has enhanced and refined our appreciation of continuities between the behaviors of the extant apes and those of early tool-making hominins, essentially recognizing the potential of a "chimpanzee archaeology." In the primate world, tool-making, not to mention tool-using, is not an exclusively "human" or even an exclusively protohuman domain. The kinds of tool-making and tool-using behaviors we observe in modern apes gives us a valuable window into the possible range of tool use in our ancestors before percussion-fractured stone tools appear in our ancestry, as well the potential continued use of organic tools after the advent of stone tools. This research has also provided useful information for modeling the dynamics of site formation processes on the landscape, particularly concerning the interplay between tool-using behaviors and the build-up of potential archaeological residues.

If comparisons are made, however, between residues from chimpanzee activity areas and Oldowan lithic assemblages, it is imperative that the comparisons are valid and precisely evaluate comparable classes of material. For instance, it is not valid to make an "apples-to-oranges" comparison between, on the one hand, stone assemblages clearly showing conchoidal fracture through precise percussive blows, and, on the other hand, fragments or shards of crumbling or disintegrating stones or bedrock. The latter material is not characteristic of any Oldowan sites or Oldowan lithic assemblages yet known.

Mercader *et al*. (2002) carried out such a comparison in their study of stone debris excavated from an area reported to have been used over a number of years by chimpanzees for nut-processing (the "P100 site" in the Taï forest of Côte d'Ivoire). On the basis of this study, they argued:

> "Thus, chimpanzees engage in cultural activities that leave behind a stone record that mimics some Oldowan occurrences and invite us to speculate whether some of the technologically simplest Oldowan sites could be interpreted as nut-cracking sites or, more generally, if some subsets of Oldowan artifacts from the more sophisticated Oldowan assemblages could be interpreted as evidence of hard-object feeding by early hominins" (Mercader *et al*., 2002:1455).

We would strongly disagree with the notion that this stone debris, presumably (though not observably) produced as an incidental, unintentional by-product of nut-cracking, can be meaningfully compared to the stone assemblages found at early Oldowan sites. It does *not* mimic Oldowan occurrences. From our examination of a sample of Mercader *et al*.'s stone material (shown at the Paleoanthropology Society Meeting in Denver in 2002), it appeared to us that the great majority of the ostensible "stone assemblage" (most of which is classified by the authors as "microshatter") would not merit assignment to a conchoidally-fractured, or even clearly artifactual, class at excavated Oldowan sites.

The authors claim that these stone debris "fall within the size spectrum and morphological parameters observed in a subset of the earliest known hominin technological repertoires" (Mercader *et al*., 2002:1455). The argument that this material is like Oldowan materials because it falls within a similar size range is a *non sequitur*. In this issue, size does not matter: When stone is flaked, it fractures conchoidally producing many small, conchoidally-fractured pieces, but stone can also crumble and weather into small pieces that are not conchoidally-fractured.

This brings us to the second element in their stated criteria, i.e. that the Tai P100 stone debris falls within the "morphological parameters" of early stone technologies, which is not the case. The bulk of the Taï material does not show critical morphological parameters of flaking debitage, and thus the overall Taï 'assemblage' of stone material does not show salient characteristics of an Oldowan artifact assemblage. A basic flaw in this comparison is that, as de la Torre (2004:455) has noted, Mercader *et al*. "do not include a detailed and systematic analysis of the artifacts in question, and when this is done (see, e.g. Toth *et al*. 1993, Schick *et al*. 1999) the qualitative differences between the archaeological and ethological samples are always more important than their formal similarities."

In fact, for the most part, the P100 materials presented to us had the appearance of weathered or disintegrating rock. Whether disintegration happened "in place" due to weathering processes, or whether hammering activities were responsible or perhaps helped it along, is unclear. Largely missing are flakes with distinct bulbs of percussion, distinct platforms, and clear dorsal flake scars, as well as the cores with points of hammerstone impact, negative bulbs and scars, etc., clearly observable in Oldowan artifact assemblages. Whether this stone debris resulted directly from nut-processing activities is an interesting question that remains to be investigated and verified. However, forcing such debris into arbitrary "artifact classes" does not make them comparable to Oldowan artifacts.

At Oldowan archaeological sites, there is no question that the great majority of the stone flaking is intentional, controlled, and shows a basic sense of skill in lithic reduction. It is clearly organized in a manner to efficiently produce flakes from cores, creating sharp cutting and chopping edges (which are extremely difficult to find in nature) as well as a class of pounding/battering tools (e.g. hammerstones). Cut-marked animal bones and bone shafts showing hammerstone striae and fracture patterning, as well as the small sample of microwear polishes we have on Oldowan tools, make it clear that such sharp edges and percussors were used at times to process large animal carcasses. We would agree with de la Torre who, based on his analysis of Omo 57 and Omo 123, has asserted that the "small size of the Omo artifacts does not, as has been argued, make them similar to what chimpanzees could produce by crushing stones. On the contrary, it shows that the hominins had the technical knowledge and the manual precision required to produce flakes from minute fragments" (de la Torre, 2004:455-456).

In short, there has been no convincing evidence yet presented that chimpanzees in the wild have produced a lithic assemblage truly comparable to those identified, excavated and analyzed at Oldowan archaeological sites. The collection of stone debris reported from Tai bears no resemblance to an Oldowan assemblage in terms of the salient technological characteristics of early stone artifacts. This view is shared by a number of colleagues in our discipline, including Mohamed Sahnouni, Sileshi Semaw, and Tim White (all pers. comm., with permission). On the other hand, this research shows that chimpanzee nut-cracking behavior has the potential for "archaeological visibility" in the prehistoric record.

To identify potential "chimpanzee archaeology," it will be necessary and useful to have a critical, detailed description of materials altered by chimpanzee activities, and to verify the link between the materials and the activities. "Shatter" material such as that identified at the Taï P100 site should be analyzed and described accurately as to its salient characteristics, clearly noting differences from the conchoidally-fracture debitage produced in stone artifact manufacture. The raw materials of such shatter should be assessed as well, to see if these are consistent with the raw materials of the hammer and anvil components of the stone debris. If some materials can *truly* and *convincingly* be classified as cores or as conchoidally-fractured flakes and flake fragments, this (likely very small) sample should be identified and clearly presented in photographs or drawings and subjected to archaeological attribute analysis, not simply placed in "artifact-like" categories. Some materials might be able to be classified as cobble fragments, but classification as hammer or anvil fragments would require good evidence in terms of distinct battering marks.

In such an analysis, it would also be important to recognize and acknowledge any possible 'ringers.' For instance, it might be expected that an occasional flake might be found on the landscape that may represent low-density, archaeological background material from human activities on the landscape, and which may well stand out from the other debris, perhaps in terms of its weathering or an unusual or higher-quality raw material.

For primatologists in the field, some of whom have asked us what sorts of materials and conditions would be helpful to explore the issue of possible "chimpanzee archaeology," and how best to identify, distinguish and describe such residues, we suggest that it would be ideal to undertake the following procedures:

- To retrieve stone material from sites where chimpanzee nut-processing has been observed in real time, with observations of the types of materials used for hammers or anvils;

- To conduct controlled experiments in nut-processing with similar rocks from that region;
- To describe debris resulting in each situation with a neutral, critical eye in order to develop a better sense of real characteristics of the residues that result from the nut-cracking process;
- To be diligent in refraining from applying archaeological classification or artifact terminology (e.g. "platforms," "flakes," "flake fragments," etc.) unless absolutely justified by clear evidence of characteristics of conchoidal fracture;
- To be aware of the possible presence of some archaeological background "noise," or chance presence of some stone artifactual material from past human occupation in the area (very possibly in materials other than the local bedrock or the nut-cracking hammers and anvils);
- To compare and contrast nut-processing debris from the natural weathering and disintegration of the rocks available in the region, as rocks can disintegrate and crumble from weathering processes, affected also by internal bedding characteristics and flaws. It would be very useful to excavate samples of disintegrated stones or bedrock in the region away from nut-processing areas to see if many of the features found at the P100 Taï site or established chimpanzee nut-cracking sites are also be found in a non-ape context. In fact, we have recently analyzed a sample of naturally disintegrating Franciscan rock from the San Francisco region that exhibits size characteristics very similar to that of the excavated Taï P100 sample.

We and many of our paleoanthropological colleagues would welcome and value such critical investigations and analyses as important contributions to understanding stone residues that might be produced by chimpanzees. We look forward to such approaches in the future, and to the development of criteria to contrast and compare chimpanzee activity residues and the Plio-Pleistocene archaeological record.

Beyond Typology: Recent Trends in Oldowan Research

During the past few decades, a number of new approaches have been developed, many of them actualistic, that have been usefully applied to Oldowan studies. Here we will review some of the major approaches that have expanded our knowledge of the patterning, complexity, and context of Oldowan hominin behaviors.

Experimental Artifact Replication and Use

Experiments in making and using prehistoric stone artifacts, as well as have become an increasingly common approach to early stone age artifact assemblages. Such experimental approaches can address a number of important archaeological and paleoanthropological questions, including:

1. What *techniques of manufacture* were employed (e.g., direct freehand percussion, anvil technique, bipolar technique, throwing against an anvil, etc.)?
2. What *strategies or methods* were employed by Oldowan hominins? Can we diagram a clear reduction pattern (or *chaine operatoire*) from the unmodified raw material to the resultant archaeological flaked and battered artifacts?
3. What is the *relationship between artifact type and raw material type*? Do certain artifact forms tend to be made in certain raw materials? If so, might this result as a byproduct, with the nature of the raw material influencing patterns of fracture and modification, or is there good reason to invoke intentional selection of certain raw materials for the manufacture of certain artifact forms?
4. What are the *functional attributes for a certain artifact class in a given raw material*? For example, what Oldowan artifact classes are best for bone-breaking, animal disarticulation, or wood-working? How long can a given tool be used for a given function before it needs to be discarded or resharpened?

Casual experiments in making and/or using Oldowan types of tools were carried out in the 1960's by such prehistorians as J. Desmond Clark and Louis Leakey. A number of more detailed replication and use studies have since yielded insights into the manufacture and potential use of Oldowan artifacts (e.g., Jones, 1980, 1981, 1994; Toth, 1982, 1985, 1987b, 1991, 1997; Schick & Toth, 1993; Sahnouni *et al*., 1997; Ludwig, 1999; Tactikos, 2005; Braun *et al*., 2005a).

Some of the major observations that have emanated from these experimental studies have included that:

1. Direct, hard-hammer percussion was a major technique in the Oldowan, with bipolar technique also being used at some sites
2. Early tool-making hominins could be very dexterous and coordinated in reducing stone, sometimes reducing cores to a small size and directing blows of percussion in a skilled, controlled way
3. Many of the Oldowan "core tool" forms may simply be least-effort residual cores resulting from flake production, and that the final form of the core may be the product of the raw material type, size, and shape of the blank (cobble or chunk), and the extent of flaking (Toth, 1982, 1985, 1987b). Many of these Oldowan core forms grade into each other

(e.g, with continued flaking, choppers can transform into discoids or even polyhedrons).

4. There may be some indications of simple lithic "traditions" in the Oldowan that have a cultural (i.e. "learned") component. The predominance of unifacial flaking of cobbles at the Gona sites of EG 10 and EG 12, and at the Koobi Fora site of FxJj50 suggest such a component, as does the predominance of unifacially reduced thick flakes ("core scrapers" or "Karari scrapers") at a number of Koobi Fora sites along the Karari escarpment in the Okote Member (Toth, 1997; Ludwig, 1999).

5. There is a discrepancy between the cores/retouched pieces at many Oldowan sites and the experimentally-predicted debitage patterns. Often later stages of core reduction are preferentially represented at Oldowan sites, suggesting that tool-making hominins were testing cobbles and partially reducing cores "off-site", and transporting partially-flaked cores to sites for further reduction (Toth, 1982, 1985, 1997). This observation is also corroborated by refitting studies (see below).

One example of how experimentation can shed light on a palaeolithic problem can be seen in the class of battered artifacts called spheroids and subspheroids. For decades there has been considerable speculation as to what these enigmatic artifact types represent, with some ideas focused on their having been fashioned and shaped for some specific purpose or function. Various suggestions have included thrown missiles used in hunting or defense, hafted bolas stones, club heads, or some sort of plant processing tool (Willoughby, 1985). Experiments conducted in quartz/quartzite (Schick & Toth, 1994; Jones, 1994) however, demonstrate that these battered, rounded and spherical forms can be unintentionally produced after a few hours by using these stones as hammerstone percussors when flaking Oldowan cores.

These experimental observations were then tested against the archaeological sites in Beds I and II at Olduvai Gorge. Early in this Bed I to Bed II sequence, sites show relatively high percentages of lava in the "heavy-duty tool" categories and relatively little quartz, and these same sites contain low proportions of spheroids versus the numbers of hammerstones. Progressing upward through this Olduvai sequence, Oldowan and Developed Oldowan sites exhibit increasing greater percentages of quartz/quartzite (versus lava) in the "heavy-duty tool" categories, and these sites also exhibit increasing numbers of spheroids/subspheroids versus hammerstones in their assemblages. That is, as a greater emphasis develops on quartz rather than lava in producing cores or core tools, quartz spheroids and subspheroids become increasingly more common, and lava hammerstones less common. This pattern is predictable and readily understood in light of the experimental study of spheroid production: as quartz utilization increases over time for artifact manufacture at Olduvai, quartz is used correspondingly more often as hammerstones, resulting in battered quartz forms such as spheroids and subspheroids representing well-used quartz hammerstones (Schick & Toth, 1994).

Another example of how experimental research can lend insight into unusual or puzzling artifact forms can be seen in an investigation into another type of spheroid, the "faceted spheroid." These oddly-shaped artifacts, shaped into polyhedral, nearly spherical forms but with angular facets from flake scars around most of all of their surface, have presented provocative questions as to whether they are themselves tools or not, and, if so, why would they have been deliberately shaped in this way? Experiments have now shown that faceted spheroids may also represent an artifact type whose morphology results as a byproduct rather than through deliberate shaping per se.

Experiments in flaking limestone cores with a hammerstone have shown that, in their later stages of flaking, these cores can develop a faceted and nearly spherical form, like those artifacts often referred to as a faceted balls ("*boules à facettes*"), polyhedric balls ("*boules polyédriques*"), or faceted spheroids within Early Palaeolithic assemblages. Such faceted spheroids can develop when flaking cores in certain materials such as limestone that allow flaking to proceed until very obtuse angles are achieved on the core as it approaches exhaustion and further flaking becomes very difficult (Sahnouni *et al*., 1997). Thus, faceted spheroids may represent exhausted cores resulting as a byproduct from extensive flake production from certain raw materials such as limestone, rather than tools purposefully or deliberately "shaped" into this form.

Experiments in Oldowan stone artifact manufacture have also been conducted to examine physiological and biomechanical patterns that pertain to human evolutionary questions. These include studies of brain activity using positron emission tomography or PET (Stout et al., 2000 and this volume; Stout, this volume), kinesiological and biomechanical patterns (Dapena *et al*., this volume), and hand and arm muscle activity (Marzke *et al*., 1998),

Experiments in Site Formation Studies

Understanding both the behavioral and geoarchaeological processes of archaeological site formation can allow prehistorians to tease apart which patterns are the probable result of hominin behavior, other biological agents (carnivore or rodent modification of bones, bioturbation, etc.), geological processes (water action through stream flooding or wave action, sediment compaction, etc.). For example, before detailed spatial analysis is done to look for discrete behavioral patterns, it would be useful to know if geological processes have seriously reworked stone artifacts and animal bones to make such an analysis meaningless from a behavioral perspective. Isaac conducted pioneering exploratory experiments looking at geological site formation processes that can be involved in Oldowan sites (Isaac & Keller, 1967). A detailed study was conducted by Schick (1984, 1986, 1987a, 1987b, 1991, 1997) who set out a large number of facsimiles of Oldowan artifact and fossil concentrations, monitored their transformation by natural processes (particularly flood waters), and subsequently excavated and analyzed the remaining sites, and in addition conducted more controlled flume or laboratory channel studies.

Actualistic studies into site formation processes can yield important clues to evaluate the *degree* of disturbance of a site, rather than addressing disturbance in an unrealistic, binary, "either-or" scenario (Schick 1986, 1987a). Site formation experiments have made it very clear that we should discard the bimodal categories of "primary" context versus "secondary or disturbed" context. Rather, site disturbance occurs along a continuum and a detailed analysis of site patterns can yield valuable evidence as to how disturbed a site might be and clues as to the nature of that disturbance. This analytical procedure naturally makes an assessment of the sedimentary context of the archaeological deposit and the probable nature and energy level of depositional forces (channel flow, overbank floods, slope wash, etc.). Importantly, it also then analyzes characteristics of the artifact (and bone) assemblage contained within the sediment for clues as to the level and nature of disturbance during burial, as the sedimentary substrate can both overestimate and underestimate the energy of the depositional episode.

Criteria used as evidence of behavioral and geological site formation processes include:

1. Sediment particle size and sorting
2. Assemblage composition, including:
    i. Debitage size distribution
    ii. Relative proportion of debitage versus core forms
    iii. Proportion of micro-debitage (sampled at least, with very fine screen size and wet sieving)
    iv. 'Technological coherency,' or whether the debitage composition matches or is predictable from the cores present in terms of expected flake types and numbers, raw material, etc.
3. Refitting of stone and bone
4. Spatial patterns of assemblage components (cores, debitage size classes, conjoining sets) that might indicate on-site hominin behaviors (tool-making, tool-using) or rather disturbance by floods or other processes before or during the process of burial
5. Fabric of the artifact and bone deposit, such as imbrication, orientation, or dip, which might indicate disturbance by water
6. Artifact and bone condition, such as abrasion, physical or chemical weathering

Application of such criteria to archaeological site assemblages can help evaluate the probable degree of disturbance of sites during the process of burial within a unit of sediment. Ideally, such fine-grained assessment of the nature of site assemblages and their spatial distribution can help identify those sites with better 'behavioral integrity,' i.e., those that might bear more direct indications of on-site hominin behaviors (Schick, 1992, 1997).

Consideration of Raw Material Selection and Transport

Other aspects of lithic technology that have become areas of interest in their own right concern hominin selection of raw material for tool production and the transport of this raw material and manufactured stone artifacts to and from site localities where artifact manufacture and/or tool use took place. Such studies shed light on hominin tool-related behaviors in a larger framework, both spatially and chronologically, than merely what has occurred at a particular archaeological site. In effect, research into raw material selection and the transport of raw materials and artifacts bring into focus the larger environment in which the hominins were moving, living and adapting and allows us to appreciate aspects of hominin behaviors and the choices they made not just from "on-site" but also "off-site" archaeology.

Studies of the selection of raw materials for stone artifacts have obvious importance in view of:

- the impact that different raw material types can have on stone tool manufacture and its products
- if strong selectivity in use of raw materials can be demonstrated, possible implications with regard to hominin cognitive abilities and their familiarity and experience in tool-making activities
- potential insights into larger-scale hominin movements across the landscape from raw material sources to sites where artifacts were manufactured or discarded
- possible impact that a site's "distance-from-raw-materials" might have on lithic reduction patterns and the artifacts produced (for instance, whether local sources might yield larger, less heavily reduced cores than more heavily 'curated' materials from more distant sources, etc.)
- possible evidence for "opportunism" versus greater planning depth among hominins in their use of very local or more distant resources

Geologist Richard Hay carried out an assessment of the sources of raw materials at Olduvai Gorge in Beds I and II (Hay, 1971, pp. 17-18; Hay 1976:182-186) showing that tool-making hominins regularly transported rock to sites from sources a few kilometers away. He found that the "majority of artifacts at all excavated sites in Beds I and II are made of materials obtainable within a distance of 4 km, and at most sites are less than 2 km from possible sources" (Hay, 1976:183). Hay estimated that the transport distances of quartz/quartzite (from the basement outcrops at the Naibor Soit inselberg on the north side of the lake basin) and of lavas (from highlands to the south and east of the lake basin) would generally have been in the order of several kilometers. Notably, however, larger site assemblages normally also contain some materials obtained from more distant sources, at least 8 to 10 km away, and the proportion of such distant raw materials increases over time at sites in the Olduvai sequence to at least early Bed III times. Very few artifacts are made in 'exotic' materials from sources completely outside the basin (Hay, 1976:183).

Hay found that most of the lavas used in Bed I and lower Bed II probably came from the volcano Sadiman (in the volcanic highlands to the southeast of the Olduvai basin) in the form of rounded cobbles found in streams on the north side of the volcano. He argued that abundant use of the Sadiman-type lava versus other available lavas at Oldowan and Developed Oldowan A sites may have been due to preference for its "dense, homogenous nature" (Hay, 1976:183), but also noted that use of Sadiman lava dropped by Developed Oldowan B times, a trend which continue upward in the sequence. Use of a phonolite from Engelosin, a volcano to the north of the basin, is found first in Bed II sites situated from 9 to 11 km away from this source (Hay, 1971), and use of a gneiss of Kelogi type (outcropping in inselbergs near the west edge of the Side Gorge) is found in Bed I and Bed II sites at least 8 to 10 km from the nearest outcrops (Hay, 1976:184). Chert was available at the lake margin in Bed II times, but even this local material appears often to have been transported to other locales where it was worked and/or utilized (Stiles *et al*., 1974), and artifacts made in local basin cherts "are abundant only within 1 km of probable source areas" (Hay, 1976:185).

The chert-bearing exposures that were available to hominins at site MNK "Chert Factory Site" differ in oxygen isotope composition and in size to the chert artifacts found at that site, suggesting that hominins were transporting larger lithic materials there from some other chert source(s) (the cherts flaked at the site having formed in lower-salinity water than the local chert, possibly further south in the lake basin). Furthermore, at site HWK some 1.3 km northeast of MNK, it appears that many of the chert flakes found at HWK were brought in from such a quarry site already flaked, as they seem to represent a selected size without much small debitage (although this could also represent fluvial winnowing of the smaller size fraction from the site.)

Beginning in Bed II of Olduvai (the "Developed Oldowan"), tool-making hominins began to concentrate on working quartz and quartzite rather than lava at many sites (Leakey, 1971). Whether this represents intentional selection of these materials because of their hardness and sharpness, or whether this reflects difference ranging patterns or some other factor, remains unclear. In any case, this de facto 'preference' for quartz in fact increases over time throughout Bed II times, as quartz often represents the vast majority of the "heavy-duty tools," "light-duty tools," and debitage (Schick & Toth, 1994).

At Koobi Fora, Oldowan hominins usually selected raw materials in proportions that were generally available in the nearby gravel deposits (Toth, 1997), although they clearly avoided clasts that were highly vesicular or badly weathered. The occasional chert artifacts with a very diagnostic and distinctive color also suggest that some high-quality flakes may have been transported as individual artifacts some distance. The low proportion of early stages of reduction at many sites can partially be explained by testing raw materials out at gravel sources before transporting them for further reduction.

Analysis of the artifact assemblages at Kanjera in Kenya indicate that most of the artifacts were manufactured from fine-grained igneous rocks that were locally available. Nevertheless, approximately 15% of the artifacts were manufactured from raw materials that were not immediately local to the site (quartzite, chert, vein quartz and quartz porphyry) that were apparently brought in from more remote sources (Plummer et al., 1999). Recent research by Braun et al. (2005b) has been investigating the relationship between the mechanical properties of raw material and how it relates to artifact form and function.

More recently, research at Gona has indicated that at some very early Oldowan sites, dating to between 2.6 and 2.2 mya have rock types in higher than expected frequencies compared to frequencies in contemporaneous cobble gravels there (Stout et al., 2005). High-quality, fine-grained trachytes cobbles appear to have been preferentially selected as raw materials at sites EG13, DAS7, DAN1, OGS6, and DAN2d. In addition, most Gona sites (OGS7, DAS7, DAN1, OGS6, and DAN2d) had higher than expected frequencies of aphanitic volcanic rock (so fine-grained that individual crystals cannot be seen with the naked eye), and vitreous volcanic rock ("volcanic chert") in higher than expected frequencies. This suggests that the earliest known hominin toolmakers in the world already showed some discrimination in selecting higher-quality raw materials. Interestingly, similar selectivity is also known among certain birds in their choice of gizzard stones, presumably using visual clues such as polish, luster, and color to identify harder, finer-grained stones of chert.

Refitting Studies and Spatial Analysis

The ability to refit flaked lithic materials (and sometimes fractured bone) back together can yield very valuable information about early hominin behavior, technology, and site context. Refitting of stone artifacts can be used to:

1. Give a "blow-by-blow" account of core reduction/flake production at an archaeological site; this may give important information regarding the decision-making and possible technological patterns or strategies of Oldowan tool-makers.
2. Identify what stages of flaking are represented:
   - Do the refits form a complete cobble or chunk (complete reduction)?
   - Were cores brought in partially flaked?
   - Were cores (or select debitage) apparently carried away from the excavated areas?
3. Show whether the refitting sets have any special patterning, e.g., was the flaking done in a discrete place, or was the core moved around the site as reduction progressed?
4. Show what type of core/retouched piece may have been produced at a site and then taken away from the flaking area (or away from the site altogether) ("phantom" artifact), by making a mold of the empty space produced by refitted flakes/fragments.
5. Help assess the geoarchaeological context of the site, for instance, whether the spatial patterns are due to hominin behavior or have been altered appreciably by depositional forces such as stream or wave action, and also whether significant vertical dispersion of artifacts (as well as bones) has occurred after deposition (e.g. through bioturbation by roots, rodents, etc.).
6. Assess whether there is more than one temporal bout of hominin activity at a given site (e.g. are refitted sets found at different horizons offset vertically or microstratigraphically, suggesting separate flaking episodes spaced through time?).

To date, refitting has been successfully and systematically employed at a number of Oldowan localities in the greater Turkana basin. These include sites at Koobi Fora at East Turkana, where refitting at a minimum of eight different localities has revealed technological patterns of refitting stones, some of which show minimal disturbance by depositional forces as well as spatial configurations of both stone artifacts and broken bones that have been refitted (Bunn *et al*., 1980; Toth, 1982, 1985; Kroll & Isaac, 1984; Schick, 1984, 1986; Kroll, 1997). Some Koobi Fora sites, such as FxJj 3, FwJj 1, FxJj 20E, FxJj 50, and FxJj 64, exhibit refitting patterns that indicate discrete knapping areas, suggesting minimal geological reworking of lithic materials after hominin discard. At two of these sites, FxJj 50 and FxJj 64, there are also spatial concentrations of refitted animal bones exhibiting cut-marks and hammerstone fracture, suggesting that these were areas of meat and marrow consumption (Kroll, 1997).

Refitting has also been accomplished with great success in a lithic assemblage from Lokalalei 2C (LA 2C) at West Turkana, showing technological patterns at the site and spatial configurations of on-site flaking episodes dating to approximately 2.34 mya (Roche *et al*., 1999). At the Lokalalei site, approximately 10% of an assemblage of 2583 surface and excavated artifacts has been refitted (and 20% of the excavated assemblage of 2067 artifacts) to at least one other artifact. The refitting sets show knapping of over 60 cobbles at the site, most of these showing a few flakes struck from a core, sometimes with the core included. A few refitting sets, however, show a fairly large series of between 10 and 20 flakes removed from the core. The authors suggest that the technological patterns exhibited by the refitting at Lokalalei 2C demonstrate greater cognitive abilities and motor skills than they had previously attributed to Pliocene tool-makers, and conclude that, therefore, early Oldowan sites exhibit diversity in their technological patterns that likely represent differences among hominin groups in cognitive and motor skills (Roche *et al*., 1999).

However, the core forms at Lokalalei 2C do not necessarily exhibit more 'skilled' flake removal than at many other Pliocene localities, even at occurrences at Gona dating to 2.6 mya. The Gona sites, for instance, show a great deal of control, precision and coordination in consistent unifacial flaking and bifacial flaking of cores (Semaw et al., 1997, 2003, and Semaw, this volume). Clearly, however, the cores at Lokalalei 2C show on average more extensive core reduction than most Oldowan sites predating 2 mya. It may be that the Lokalalei 2C site differs more in degree than in kind: most of the cores are fairly extensively flaked, and, moreover, the refitting evidence provides more detailed information about flake removals and core manipulation than is normally available at early Oldowan sites. Of course, extent of core reduction might be expected to vary for any of a number of reasons, including, for instance, access to raw materials, competition within the hominin group for easily flaked cores (e.g. due to cobble shape), size and quality of the cobble blank, reoccupation and reuse of the site and its materials, demand or need for tools, etc., and it may not necessarily reflect tool-making skill.

The notion that hominin flaking at the Lokalalei 2C site is more 'elaborate' or 'sophisticated' than at other Pliocene localities, and that this reflects some profound difference in hominin abilities between sites, has not yet been demonstrated to the satisfaction of many Palaeolithic archaeologists. Much of Oldowan lithic technological variability may be due to differences in flaking qualities of the raw materials used and extent of core reduction at different sites for any of the reasons mentioned above, rather than firm differences in hominin technical abilities in their stone flaking. Such differences in abilities may certainly exist (especially considering the fact that multiple hominin taxa appear to have coexisted), but more work needs to be done to demonstrate real differences in technological 'skill' per se.

Taphonomic Studies

As previously noted in the section above on "Oldowan Hunters or Scavengers?," palaeoanthropologists have become increasingly critical in their approach to faunal materials found at archaeological sites. Over the past few decades, great strides have been made in developing criteria to identify diverse site formation processes involved in the concentration, modification, and preservation of animal remains. A range of diverse actualistic and experimental studies have greatly enlarged our understanding of the potential role of diverse agencies (hominins, different carnivores, rodents, etc.) in building faunal concentrations and provided valuable criteria to help infer the relative impacts of these different agencies. Application of such studies to Oldowan faunal assemblages is exemplified in the chapter by Pickering and Domínguez-Rodrigo in this volume, Pickering (2002), Brain (1981), and Bunn & Kroll (1986), .

The diverse range of criteria of interest to taphonomists now include, in addition to more traditional zooarchaeological analyses (such as identification of taxon, element, age, sex, left/right siding), a range of other features of bone assemblages that can potentially give information regarding the agent(s) of its accumulation and modification. These criteria include aspects of bone fragmentation (completeness/degree of fragmentation, element portion, shaft circumference, fracture patterning, etc.), more discrete evidence of hominin-induced modification (cut-marks, hammerstone striae, bone flakes and flake scars), evidence of other biological agents of modification (carnivore gnawing, rodent gnawing, root marks, trampling), other types of chemical or mechanical modification (acid etching, sediment abrasion, weathering), and signs of modification by heating or burning.

In addition, certain types of modification (e.g. polishing, patterned flaking or shaping) may suggest that bone was modified during manufacture and/or use as a tool. The increased use of optical and electron microscopy in examining striae, pits, depressed fractures has become a standard approach among zooarchaeologists and taphonomists. Image analysis systems are beginning to be being employed to help image, quantify, and analyze patterns of modification on bone surfaces.

Dietary Studies

Besides the information from faunal remains, several other lines of evidence can help yield clues pertaining to the diets of early hominins, what food items may have been part of this diet, and how early technology might have enhanced the acquisition and processing of such food items. Using modern primates and hunter-gatherers as models, most paleoanthropologists believe the bulk of the diet of early hominin populations consisted of plant resources such as berries, fruits, nuts, leaves, pith, flowers, shoots, seeds, and gum, as well as underground resources such as roots, tubers, corms and rhizomes. This plant component would have likely been supplemented by animal resources such as insects, eggs, small reptiles (e.g., lizards, tortoises, and snakes), amphibians, mollusks, and fish, as well as larger animals.

Systematic survey of modern environments thought to be similar to those of Oldowan sites (e.g. grassland, woodland mosaics with riverine forest and/or lake margin habitats) can enable researchers, based on hunter-gatherer and primate analogs, to assess the distribution and density of different edible resources and to model different hominin foraging patterns. Such studies have been done by Peters & O'Brien (1981), Sept (1984, 1992a), Vincent (1984), and Copeland (2004). Recently, the importance of underground storage organs (USO's) such as roots, tubers, rhizomes, and corms has been stressed by Laden & Wrangham (2005), showing that many of the Plio-Pleistocene sites yielding early hominin remains also contain cane rat fossils, animals that specialize in the feeding of such underground food resources.

Tooth-wear on Plio-Pleistocene hominins from can also show patterns of wear that may be indicative of dietary patterns (Grine, 1986; Grine & Kay, 1988). Recently, the teeth of *A. africanus* and *A.* (*P.*) *robustus* were re-analyzed using dental microwear texture analysis (scale-sensitive fractal analysis) (Scott et al., 2005). The results suggested that the microwear textures of *robustus* were more complex, and more variable in complexity, than *africanus*, suggesting that the *robustus* diet included hard, brittle foods, analogous to the diet of capuchin monkeys, which includes hard, brittle seeds. The dental microwear of *africanus*, on the other hand, suggested tougher foods, analogous to the diet of howler monkeys that includes tough leaves. The authors conclude that "early hominin diet differences might relate more to microhabitat, seasonality or fall-back food choice than to oversimplified, dichotomous food preferences" (Scott et al., 2005, p. 694).

A number of studies have investigated the stable carbon isotope ratios ($^{13}C/^{12}C$) in tooth enamel of fossil and modern animals (including hominins, baboons, and other mammals) in order to discern relative proportions of C_3 to C_4 resources in their respective diets (Lee-Thorpe & van der Merwe, 1993; Lee-Thorpe et al., 1994; Sponheimer et al., 2005a). Initial studies found a dietary distinction between, on the one hand, robust australopithecines along with three fossil baboon species (two species of *Papio* and one species of *Parapapio*), and, on the other hand, the *Theropithecus dartii* baboon (Lee-Thorpe & van der Merwe, 1993; Lee-Thorpe et al., 1994). This isotopic evidence appeared to indicate that the robust australopithecines and the three baboons with similar signatures were consuming relatively high amounts of C_3 plants such as tubers, roots, corms, fruits and nuts, while the *Theropithecus* baboon's carbon isotope ratios indicated a diet involving large amounts of C_4 foods, presumably grasses. Another interesting difference in C_3 versus C_4 isotopes was observed between two different felids, with lions apparently preying largely on C_4-rich grazers, but with leopards preying more on animals with high C_3 concentrations, perhaps including the C_3-rich robust australopithecines and baboons (Lee-Thorpe & van der Merwe, 1993). This earlier research indicated that robust australopithecines, in addition to their consumption of C_3 foods, also took in an appreciable quantity of C_4 foods (25 to 30% of their diet), either in the form of grasses or, perhaps, grass-eating animals (Lee-Thorpe et al., 1994).

Recently Sponheimer et al. (2005a) reported that carbon isotope evidence in tooth enamel of South African australopithecines indicates that gracile forms (*Australopithecus africanus* from Sterkfontein) and robust forms (*Australopithecus* or *Paranthropus robustus* from Swartkrans and Kromdraai) both had a strong reliance on non-C_3 foods, with C_4 resources evidently comprising 35 to 40% of their diet. This strongly contrasts with modern chimpanzee data, which indicates that these modern apes, living in tropical forests, have an essentially pure C_3 diet. Sponheimer et al. (2005a) suggest that other C_4 foodstuffs, besides such foods as sedges and termites, were probably a part of the gracile and robust australopithecine diet. Important food items the authors suggest could have contributed to the C4-component of australopithecine diet include grass seeds and roots, succulents (e.g. euphorbias and aloes), and various animal foods (e.g., grasshoppers, bird eggs, rodents, lizards, and young mammals such as antelope).

Oxygen isotope data suggest that the later, robust australopithecines lived in a more arid environment than the earlier, gracile form (Sponheimer et al., 2005a). This pattern may reflect changing environments over time, from wetter woodlands to more arid grasslands between 2.5 and 1.8 mya. Alternatively, ecological differences between the taxa could also have contributed to the oxygen isotope differences. Sponheimer et al. (2005a) make the interesting observation, however, that the proportion of C4 dietary resources remains much the same between the two taxa despite the oxygen isotope evidence for marked environmental change over time.

Investigation of another isotopic ratio, that of strontium to calcium (Sr/Ca), has provided additional information regarding early hominin dietary components (e.g., Sillen, 1992; Sillen et al., 1995; Sponheimer et al., 2005b). As strontium levels have been observed to be generally higher in herbivores than faunivores, Sr/Ca levels have sometimes been used as an indication of the relative degree of herbivory vs. carnivory among different animals. A study of the Sr/Ca ratio in tooth enamel in fossil fauna from the Sterkfontein Valley, fossil South African hominins (*Australopithecus africanus* and *Australopithecus/Paranthropus robustus*), and modern African mammals in Kruger National Park shows relatively high Sr/Ca ratios in both hominin taxa, more within the range of most grazing animals). This study also showed a higher ratio as well as a greater range of Sr/Ca levels among samples in the gracile form (*A. africanus*) than in the robust form (*A./P. robustus*) (Sponheimer et al., 2005b).

This relatively high strontium level for both hominin taxa here (higher than carnivores and leaf-eating browsers in the modern Sterkfontein Valley, the latter showing the lowest Sr/Ca ratios) appears to contradict a lower value for *Paranthropus* found in a earlier study, which was taken to indicate a more omnivorous diet (including significant intake of some sort of animal foods) for this robust form (Sillen, 1992). Sponheimer et al. (2005b) reject insectivory as a likely cause of the relatively high Sr/Ca ratios in these australopithecine taxa, for while insectivores also have high Sr/Ca, another ratio, Ba/Ca, is high in insectivores but very low in the australopithecines here. The combination of high Sr/Ca and low Ba/Ca are noted to have been found in mole rats and warthogs, so that consumption of roots and rhizomes, an important component of the diet of these animals, is suggested as a possible cause of the isotope patterns observed (Sponheimer et al., 2005b).

Interestingly, early *Homo* at Swartkrans (e.g. SK 847) has elevated Sr/Ca ratios compared to *A. robustus* (Sillen et al., 1995). It was suggested in this study that early *Homo* may have been exploiting geophytes, such as bulbs of edible lilies of the genus *Hypoxis*, which are available locally in the Transvaal today; alternatively, they may have been consuming animals with an elevated Sr/Ca ratio such as hyraxes.

Isotopic research has shown considerable promise as a tool for deciphering aspects of the diet of prehistoric animals, including various forms of hominin taxa as well as other mammals. At the present stage of development of this field, however, it seems advisable to keep in mind that:

- a relatively small sample of fossil specimens has thus far been subjected to analysis
- there is likely more to learn regarding diagenetic processes impacting isotopic signatures (isotope content in living specimens is often different from that in similar fossil taxa)
- there may also be more to learn about the influence of diet earlier versus later in life, seasonal changes in diet, etc., on the isotopic signatures

contained in different structural elements

- our reference sample needs to be enlarged for modern analogue species with known diet
- we should expand our knowledge of the range of variation in the diet of modern species in different environments, with different sets of available foods, etc., and the effect of such differences on isotopic signatures
- similar isotopic signatures might be obtained from diets with quite different food profiles, so that we may need additional analytical procedures to tease these apart (as in the above case involving the Sr/Ca ratio, in which the Ba/Ca ratio might help distinguish between different diet compositions).

It appears that, at the present stage of development of this line of research, each study presents some new intriguing pattern, though an overall synthesis of results is not yet attainable. Researchers are becoming increasingly aware, however, of the complexities involved in paleoisotopic studies, and undoubtedly further research along these lines will help further elucidate aspects of the diets of fossil hominins and other animals.

Landscape Archaeology

Most conventional Oldowan archaeological fieldwork at open-air sites has consisted of locating high-density surface occurrences on an eroding stratigraphic outcrop and subsequently conducting excavations at these localities to recover dense and informative *in situ* materials. Another approach, called landscape archaeology (earlier called study of "scatters between the patches" and subsequently referred to as "scatters and patches analysis" (Isaac & Keller, 1967; Isaac, 1981, 1997:9; Isaac et al., 1981; Stern, 1991), attempts to understand distributions of archaeological materials (artifacts and fossil bones) on the paleolandscape by examining their presence, nature, and densities along erosional outcrops at a given stratigraphic horizon. These surface materials are thus regarded as a sign or proxy of the *in situ* materials buried within the sedimentary units in these areas and which might represent or give some indication of landscape use within a single "unit" of time (although this "unit" is . Such materials are then examined for lithic technological patterns (e.g. raw materials, artifact types, ratio of cores to debitage, flake types as an indication of earlier or later stages of flaking, etc.) as well as the nature of the fossil remains.

Some of the interesting patterns that have emerged from this work are:

1. There often tends to be a co-occurrence on the landscape of the peaks of higher densities of both fossil bone and stone artifacts. This suggests that either early tool-using hominins were focusing on areas of their landscapes where animals were congregating and/or dying, or the hominins were major agents of collection and concentration of animal remains in areas where they also discarded large numbers of artifacts. In addition, bone preservation tends to be favored in fluvial floodplain environments with rapid burial and deposition. (Isaac, pers. comm., Stern, 1991:343).
2. That the *majority* of surface artifacts in these surveys are found in very low-density occurrences, rather than the dense concentrations or "sites" that archaeologists tend to focus on and excavate (Isaac, pers. comm., Stern, 1991). This suggests that much of the manufacture and/or use and ultimate discard of lithic materials occurred away from the anomalous dense concentrations. The implications of this pattern are that archaeologists may be missing important aspects of the overall behavioral repertoire of early hominins if they concentrate exclusively on the larger-scale concentrations of artifacts and bones for excavation, and that they should also pay special attention to lower-density "mini-sites" or even "single bout of activity" areas (e.g. Marshall, 1997: 220-223; also see Isaac *et al*., 1981, "Small is informative…" and Isaac 1981, "Stone Age Visiting Cards").

More recently, landscape archaeology has been applied systematically to the lowermost Bed II at Olduvai Gorge where a single stratigraphic horizon may be traced laterally for some distance and thus provide a window into patterns of hominin activities over the larger landscape (Blumenschine & Masao, 1991; Peters & Blumenschine, 1995, 1996; Blumenschine & Peters, 1998). Applications of this approach have been made as well to the East Turkana (Koobi Fora) archaeology (Stern, 1991; Rogers, 1996, 1997).

Placement of sites on the landscape relative to paleoecological variables such as climate (wetter or dryer climate, seasonality, etc.) and paleoenvironments (lake margin, alluvial plain, alluvial fans, riparian corridors, etc.) has been a major concern in a number of these studies (Peters & Blumenschine, 1995, 1996; Rogers et al, 1994; Blumenschine & Peters, 1998). Such research has also incorporated actualistic studies of modern analog landscapes in order to compare and contrast potential distribution of resources (e.g., drinking water, raw materials for tools, plant foods such as fruits or underground storage organs, animal foods such as scavengeable carcasses, trees and shrubs for shade or refuge) in the paleolandscape relative to the locations of lower-density scatters and the excavated, higher-density localities (Peters & Blumenschine, 1995).

Such studies have not yet generated overarching conclusions regarding Oldowan hominin activity variation across Plio-Pleistocene paleolandscapes, and of course such activity variation may well be inextricably linked to the constraints and possibilities within a particular sedimentary basin. Stern (1991) has also cautioned that sedimentary layers used for landscape archaeological studies, such as the lower Okote Member at Koobi Fora, can represent palimpsests developed over tens of thousands of years, and thus can be viewed as 'contemporaneous' in only a very special, very broad sense.

Nevertheless, landscape archaeological research can help build predictive models as to the kinds of stone and bone assemblages might be found within different components of the environment, and these predictions can be tested in future research. Further application of the landscape archaeological approach to Oldowan occurrences in a variety of sedimentary basins and critical synthesis of the results of different such studies are likely to provide interesting and useful information regarding the larger picture of Oldowan hominin activities across their paleoenvironmental landscape.

Conclusion

Some seventy years after Louis Leakey first proposed the concept of an Oldowan, dozens of sites in East, Central, South, and North Africa have produced evidence of early hominin tool-makers between 2.6 and 1.4 mya. The earliest Oldowan sites are found shortly before the first evidence of the emergence of the genus *Homo*, a lineage characterized through time by reduced jaws and teeth and increased encephalization relative to the robust australopithecines. Although we cannot presently establish which Plio-Pleistocene hominins were the predominant tool-makers, it appears that by 1.0 mya the robust australopithecines had gone extinct, making *Homo* the only hominin genus to survive.

Oldowan lithic technology was simple, characterized by battered percussors, cores made on cobbles and chunks, flakes and fragments, and sometimes retouched flakes. Although this technology was simple, many sites show considerable skill in removing large, sharp flakes from cores. When preservation is ideal, Oldowan assemblages are associated with cut-marked and broken animal bones that indicate these early tool-makers were processing animal carcasses as part of their overall adaptive strategy. Sites become more numerous after 2.0 mya, and by c. 1.7-1.4 mya new technological elements begin to appear, such as the consistent production of large (> 15 cm) flakes and the manufacture of picks, cleavers, and handaxes that heralds the beginnings of the Acheulean Industrial complex.

Some of the major conclusions of Oldowan research over the past half century have included:

- The Oldowan Industrial Complex is characterized by simple stone technologies that include percussors (hammerstones and spheroids), cores (e.g., choppers, discoids, heavy-duty scrapers, polyhedrons), unmodified flakes, sometimes retouched flakes, and other debitage (snapped flakes, split flakes, angular fragments, chunks).
- The earliest Oldowan sites are known from Gona, Ethiopia at c. 2.6 mya. The Oldowan is contemporaneous with early Acheulean industries (starting at c. 1.7-1.4 mya), and Oldowan-like occurrences continue to be found in later phases of prehistory. The term is especially used in Africa, but has also been applied to sites in Eurasia. Defining the end of the Oldowan is somewhat arbitrary, but usually the term is not used for industries less than c. 1 mya.
- Oldowan sites are found at open air localities along streams and lake margins in East Africa (Gona, Hadar, Middle Awash, Konso Gardula, Melka Kunture, Fejej, Omo, East Turkana, West Turkana, Chesowanja, Kanjera, Olduvai Gorge, Peninj, and Nyabusosi), cave deposits in the Transvaal region of South Africa (Sterkfontein, Swartkrans, Kromdraai), and open air sites along streams in North Africa (Ain Hanech and El-Kherba).
- Hominin taxa contemporaneous with Oldowan sites between 2.6 and 1.4 million years ago include *Australopithecus garhi, Australopithecus africanus, Australopithecus* (*Paranthropus*) *aethiopicus, Australopithecus* (*Paranthropus*) *boisei, Australopithecus* (*Paranthropus*) *robustus*, early *Homo* sp., *Homo habilis*, *Homo rudolfensis*, and *Homo ergaster/erectus*.
- Although it is not clear which hominin taxa were responsible for the manufacture and use of Oldowan stone artifacts, many anthropologists believe the genus *Homo*, with a larger brain and reduced jaws and dentition over time, was a more likely dedicated tool-maker and tool-user. After about 1 mya, the robust australopithecines (and earlier forms of *Homo*) were extinct, with only *Homo ergaster/erectus* and their descendants that carry on the stone tool-making tradition.
- Although some prehistorians suggest that some early sites should be assigned to a "Pre-Oldowan," others feel that the ranges of technologies exhibited at early sites all fall within the Oldowan Industrial Complex, with some sites exhibiting more heavily reduced cores and more retouched flakes than other sites.
- Oldowan tools were clearly used in animal butchery (meat-cutting/bone fracture) based on bone modification and lithic microwear. Microwear has also suggested that hominins used stone tools for a range of other functions, including woodworking and cutting of soft plant material. Much of the evidence from cut marks and microwear suggest that sharp, unmodified flakes were a major part of the technological repertoire of Oldowan hominins, along with stone hammers used in knapping and to break bones.
- Theories of how Oldowan sites formed include camps or home bases, scavenging stations, stone

caches, or more generic favored places. It is likely that a range of explanations is required to explain Oldowan occurrences through time, space, and environmental settings, and that different sites may have served different functions.

- Current debate about hominin foraging strategies has divided archaeologists into two main camps: those that favor a scavenging model, and those that favor a hunting/primary access model. It is possible that aspects of both models characterize early hominin procurement of animal resources, again, at different times, places and environments. Further research should clarify this picture.

- Theories to explain encephalization in the genus *Homo* include social complexity, the rise of symbolic behavior, tool-making, and higher-quality diet. It is likely that this phenomenon of accelerated brain expansion in the human lineage was due to the ability of hominins to access higher-quality food resources through the use of technology, which allowed for a decreased gut size and increased brain size.

- Evidence for fire is found at several Oldowan sites, notably Swartkrans Member 3 in South Africa and the FxJj 20 Complex at Koobi Fora, Kenya. Although hominins may have maintained fire at these sites, the possibility of natural fires modifying bones and lithic artifacts cannot be ruled out.

- Although modern chimpanzees nut-cracking behavior may produce battered and pitted stones and occasional stone fracture or disintegration, these phenomena are not really comparable to Oldowan sites. Oldowan lithic technology shows clear, deliberate, and patterned flaking of stone.

- Recent trends in Oldowan research have included experimental artifact replication and use, site formation studies, studies of raw material selection and transport, refitting and spatial analysis, taphonomic studies, dietary studies including chemical analysis of isotopic signatures in fossil bone, and landscape archaeology.

It is likely that many new Oldowan occurrences will be discovered in this century and that a range of new theoretical and methodological approaches will be applied to the earliest Palaeolithic record. These new lines of evidence should give us a clearer understanding of the complexity of the Oldowan archaeological record and a greater appreciation of the range of adaptive behaviors in the emergent tool-making and tool-using hominins that ultimately led to the modern human condition.

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