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Pan the Tool-Maker: Investigations into the Stone Tool-Making and Tool-Using Capabilities of a Bonobo (*Pan paniscus*)

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Beginning in May 1990, a long-term collaborative investigation between palaeolithic archaeologists and cognitive psychologists has focused upon the stone tool-making and tool-using abilities of a captive bonobo (*Pan paniscus*). To date, this bonobo (named Kanzi) has acquired the basic skills required to produce usable flakes and fragments by hard-hammer percussion (as well as by his own innovation of throwing), although his skills in flaking stone are not yet as well developed as those exhibited by the earliest known tool-making hominids of the Oldowan industry. This research strategy allows direct comparisons and contrasts to be made between the products of modern human stone tool-makers, prehistoric proto-human tool-makers and non-human primates that have not evolved a flaked stone technology in the wild. This enables us to investigate what possible cognitive and biomechanical conditions of pre-adaptation for lithic technology may be present in extant apes. The bonobo's stone tool-making abilities are compared to those evident among early hominids in order to understand the complexities of this derived behaviour pattern in the earliest stone tool-makers. The possible evolutionary implications of this study are discussed.

Keywords: BONOBO, CHIMPANZEE, EXPERIMENTAL ARCHAEOLOGY, OLDOWAN, PRIMATE TECHNOLOGY, STONE TOOLS, TECHNOLOGY.

Introduction

Beginning in May 1990, a collaborative project involving palaeolithic archaeologists and developmental psychologists was initiated to investigate the stone tool-making and tool-using abilities of Kanzi, a 9-year-old male bonobo (*Pan paniscus*), well known for his proficiency in acquisition and communicative use of symbols (Savage-Rumbaugh *et al.*, 1990). (Kanzi has been raised in captivity at the Language Research Center, where he has become quite proficient in the use of lexigrams to communicate as well as adept at verbal

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comprehension.) After the first 18 months of the project, Kanzi has been able to master the basic skills required to remove simple flakes from stone cores using freehand, hard-hammer direct percussion and then subsequently to use these flakes for cutting activities. His tool-making has also involved his own innovation of throwing stones against a hard surface or other stones in order to initiate fracture. The stone artefacts produced by Kanzi can be directly compared to those of the Early Stone Age in order to compare and contrast their features and assess the relative capabilities of the bonobo species and early proto-human tool-makers. Such comparisons may yield important clues regarding the evolution of the hominid (and ape) brain.

The adoption of flaked stone technology has been one important feature distinguishing the proto-human and human species in a behavioural sense in the natural world: no other animal yet observed in nature has demonstrated even a casual involvement in deliberate stone flaking, i.e. the intentional fracture of rocks in order to produce potentially useful stone implements. Modern humans still make and use flaked stone tools on a regular basis in a few parts of the world, and prehistoric hominids flaked stone over a 2·4 million year time span, but extant non-human primates, including the great apes, as yet have not been reported to flake stone intentionally in the wild for any purpose.

This behavioural development in the prehistoric hominid lineage was accompanied by a variety of anatomical changes which ultimately included alterations in the size and structure of the brain and their cognitive and perceptual effects. In human evolutionary studies, one important question concerns assessing the levels of cognitive sophistication of the first tool-making hominids known in the prehistoric record: the makers of artefacts of the "Oldowan" or "Mode I" technological stage, dating from 2·4 million years ago to less than 1·5 million years ago in Africa (Toth, 1985; Toth & Schick, 1986; Schick, 1987; Wynn 1988; Isaac, 1989). One very useful way to investigate the cognitive and motor capabilities of these earliest known tool-makers would be to compare their material culture with that which non-human primates as well as modern humans are capable of producing.

The study described here attempts to estimate the point in our evolutionary past at which hominids demonstrate cognitive and motor skills in their tool-making that are substantially greater than those of which modern apes are capable. The specific question posed has been this: are the stone artefact products observed in the earliest archaeological record significantly different than those which a modern ape is capable of manufacturing, given the wherewithal and motivation to fracture stone for some purpose? In essence, we are asking whether the earliest stone tool-makers may basically have been "bipedal chimpanzees" (as suggested by Wynn & McGrew, 1989), i.e. evolutionarily derived from the ape–human ancestor in terms of locomotor abilities and functions but still retaining essentially primitive cognitive and manipulative abilities, or whether we can identify in the stone tool assemblages certain characteristics which are significantly beyond the capabilities of our closest living relatives, the members of the genus *Pan* (bonobos and chimpanzees).

Initial insight into the potential stone tool-making abilities of apes was provided over a decade ago by Wright's (1972) study of an orangutan in the Bristol Zoo. In that study, the ape was taught to use a stone hammer to strike a pre-shaped flint core which had been secured to a wooden platform; it then used the resultant flake to cut a cord securing a box holding a food reward. The program terminated after the first successful trial by the orangutan. This experiment demonstrated that an ape's behaviour could be shaped to learn to produce and use a stone cutting tool, and led Wright to suggest that, therefore, australopithecines would also have had the ability to make and use stone artefacts.

Using Wright's study as a foundation for further research, we decided to investigate the tool-making and tool-using abilities of a bonobo as a long-term project. This research was designed to allow the ape's tool-making behaviour to develop over time in a context

of problem solving, and to permit more systematic and detailed comparisons between artefacts observed in the Early Stone Age record and the stone artefactual materials produced by an ape. The interim results of this investigation are presented here.

Methodology and Results to Date

This study has not concentrated on the ability of an ape to learn a particular series of actions to produce a desired result: the eminent learning and even tool-manipulation abilities of apes have been repeatedly demonstrated and reported in the wild and in captivity (e.g. Goodall, 1964, 1986; Rumbaugh and Gill, 1973; Beck, 1980; Boesch & Boesch, 1981; Jordan, 1982; Lethmate, 1982; Sumita *et al.*, 1985; Savage-Rumbaugh *et al.* 1986, 1990; McGrew, 1989), and Wright's (1972) experiment applied these directly to a simple instance of stone flaking with the orangutan. Our strategy has been to motivate Kanzi to want a sharp-edged cutting tool (to cut through a cord or membrane to get into a box containing the desired reward), to show him the basic principles of producing sharp stone flakes and then to allow him to work out his own ways of producing his tools from an assortment of rocks provided.

Using a device similar to that developed by Wright (1972), a metal box was designed and built with a hinged rear door and a transparent plastic (Lexan) top; the entire unit was fixed to a large wooden or metal platform or table for strength and stability. The door of the box was pulled shut by a cord or rope which stretched across the inside, exited through a hole in the opposite end, and was bolted down to the platform. By cutting with a sharp stone flake through the length of rope extending from the box, the rear door could be easily opened to obtain the desired reward placed within (fruit etc.), which was clearly visible to Kanzi through the transparent top. In subsequent experiments, a wooden drum with a transparent plastic head stretched over the top has also been employed, with the reward inside obtainable by slitting through the plastic drum head. This experiment was incorporated to be more analogous to hide-slitting during animal carcass processing, the most formidable task when butchering an animal with stone tools.

Raw materials used in this study have included quartzite, quartz, lava and chert. Due to Kanzi's preference for the finer-grained, more easily flaked and sharper chert (obtained as nodules eroded from limestones in the eastern U.S.), over time this has become the predominant type of rock used in these experiments.

The initial step was to get Kanzi interested in stone technology through learning how useful the flaked products could be. In the first phase of this experiment, Kanzi was shown how a stone could be fractured and how the flakes produced could be used to cut the cord and allow him to open the box and obtain a treat. Kanzi immediately learned the utility of a sharp flake for this activity, and after the first few demonstrations he was very interested in receiving a flake (produced by the experimenters in his presence) which he would then use to open the box.

Throughout this program of experiments, Kanzi was not required to perform or accomplish tool-making or tool-using; rather, he was provided with the opportunity for these activities by placing the baited box and rocks in his environment (either an outdoor enclosure, an inside room or a large wood in which he frequently takes walks, all of which are filled with a range of other materials with which he can interact or not, as he wishes). After the initial phases of this experiment, in which humans directed his attention to the box and rocks, showed him what could be done with them and gave some verbal encouragement when he made attempts at tool-making, an "experience" as described below entailed providing him with the baited box and with the rock material which could be fashioned into tools. His acquisition of the use and manufacture of stone tools initially involved observational learning from his human models, which was then followed by long periods of trial-and-error learning on his own.

By the end of the first day of experimentation, Kanzi had succeeded several times in using a human-produced flake to cut through the cord and had made casual but unsuccessful attempts to hit two stones together, following the human example to try to produce his own flakes. The next step was learning to discriminate different degrees of sharpness among a set of stones. In a series of 10 trials Kanzi was provided with his baited box and five quartz stones, only one of which was sharp and highly suitable for cutting. After some trial and error in the first five trials, in each of the last five in this series he immediately chose the sharpest, most efficient tool (although in each a new optimum tool was introduced and stone positions varied in each trial) and used it to cut the cord (taking from 30 s to just over 2 min). By the second day of working with Kanzi, then, he had not only developed an appreciation for a sharp stone tool but also a keen ability to discern one among a group of less useful stones.

Kanzi was now faced with a new problem: learning to produce the newly-desired, sharp-edged tools himself (when his baited box was provided to him). All sharp-edged stones were removed from his environment, and he was provided with cobbles and stone nodules to use to produce sharp flakes. The technique demonstrated to him was free-hand, hard-hammer percussion: holding a cobble in one hand and striking it with another rock (the hammerstone) held in the other hand. No attempt was made to "shape" his tool-making skills; teaching was primarily through example and, at the outset of the experiment, sometimes giving verbal praise when he attempted tool-making. The stages of Kanzi's tool-making abilities can be summarized as follows.

(1) Casual hitting of one rock with another using free-hand hard hammer percussion, as well as initiation by Kanzi of a somewhat more forceful anvil technique

For approximately 25 experiences (between 4 May and 15 June 1990), Kanzi observed a human hitting rocks together in order to produce sharp flakes, which Kanzi was then allowed to use to sever the string on the box. During these situations, Kanzi was encouraged (verbally and occasionally by placing rocks in his hands) to join in the activity and make the tools himself. He would often spontaneously join the human tool-maker and begin to strike one stone against another.

In these attempts, Kanzi would hold a rock in each hand and bring the one in his right hand either down on to, in a more or less vertical motion, or more horizontally (i.e. towards his body) against the other, relatively stationary, rock held in his left hand. He also experimented with bracing the "core" close to the ground with one or both feet as well as his left hand, and striking it with a rock held in his right hand. Alternatively, Kanzi sometimes held one rock in his right hand and struck it repeatedly against another stone on the ground (an "anvil" technique which had not been modelled for him). In these experiences, Kanzi's technique generally lacked force and precision, and entailed rather random, "half-hearted" tapping of one rock against any surface of the second, with no apparent choice of the angle or place of percussion and usually with little or no result. By the end of this series of experiences, however, Kanzi was finally successful in fracturing the rock himself: after detaching one large flake and proceeding to remove three smaller fragments, he picked up the first flake, carried it to the box and used it to sever its cord and gain access to its contents.

(2) Development of somewhat greater precision in hard-hammer percussion through concentrating hammer blows closer to the core edge

During the 75-day period following his initial flaking success, Kanzi was able to produce his own cutting tools on 15 more occasions when the box was produced, although in a few additional instances he either picked up a chunk of local granite found in his outdoor yard

or obtained a flake made by an experimenter which he used to access the box. During this period he became more successful at knocking small flakes or fragments from the edge of the core, but in general at this stage of the experiment he still was not hitting the core with enough force to knock off larger, more useful flakes (more than 2 cm long, or large enough to grip firmly and provide a long cutting edge).

(3) Development of a throwing technique to make stone tools

Several months after the inception of the experiment, but after only about 40 experiences overall, Kanzi developed his own technique to initiate stone fracture: throwing the rock against a hard tile floor (when the experiments were conducted indoors). This had never been modelled for him, and appears to demonstrate insight learning on his part based upon his cumulative tool-making experiences.

During this next 75-day period, in 26 experiences Kanzi produced his own tool to open the box 25 times by throwing and once by hard-hammer, free-hand percussion. Although prior to this he had shown little interest in throwing objects in his environment (such as balls or other toys), he quickly shifted to this technique as his principal mode of fracturing rock to produce suitable cutting edges. In this phase of his tool-making development, Kanzi learned the value of force in initiating fracture of the stone: he developed a very hard, rapid thrust in throwing the stone on the floor, which usually very reliably fractured the rock and produced useful flakes and fragments.

(4) Improvement of his hard-hammer percussion technique through the application of more forceful, more precisely aimed blows (Figure 1)

Moving again to the outdoors, where he found throwing an ineffective flaking technique against the soft substrate, Kanzi returned to flaking by hard-hammer percussion but with more finesse and force than he had exhibited previously. During a 75-day period (in which he had relatively few tool-making opportunities), he used his throwing technique in four experiences indoors but shifted back to free-hand, hard-hammer percussion in an equivalent number of instances outdoors in a bark-covered area. After his experiences with throwing, however, his percussion technique had greatly improved: his blows were more forceful than in his previous hard-hammer attempts, and he was soon developing greater precision as well in this technique.

During the following 90-day period, Kanzi used free-hand hard-hammer percussion in 53 out of 58 experiences to produce a useful cutting tool which he then used to open the box (Figure 2). He was able now to direct the blows from the hammerstone more consistently towards the edge of the stone core rather than the centre. Once he successfully detached a flake from an edge of the core, he tended to concentrate his blows in that same general area in attempts to produce more flakes. He sometimes was very persistent in this: dozens or even hundreds of subsequent blows might be directed towards one general area of a core. The resultant cores tended either to be very simple, with only one or two flakes removed, or to have multiple, non-invasive flake scars and steep, battered edges, some even resembling the natural "eoliths" found in Europe (Oakley, 1980) (see Figure 3). Kanzi was thus able to produce a number of small but useful flakes through this method which he subsequently used for cutting activities.

(5) Development of a directed-throwing technique

More recently, Kanzi has discovered on his own that he can throw a well-aimed cobble against another on the ground to produce flakes and fragments, detached either from the

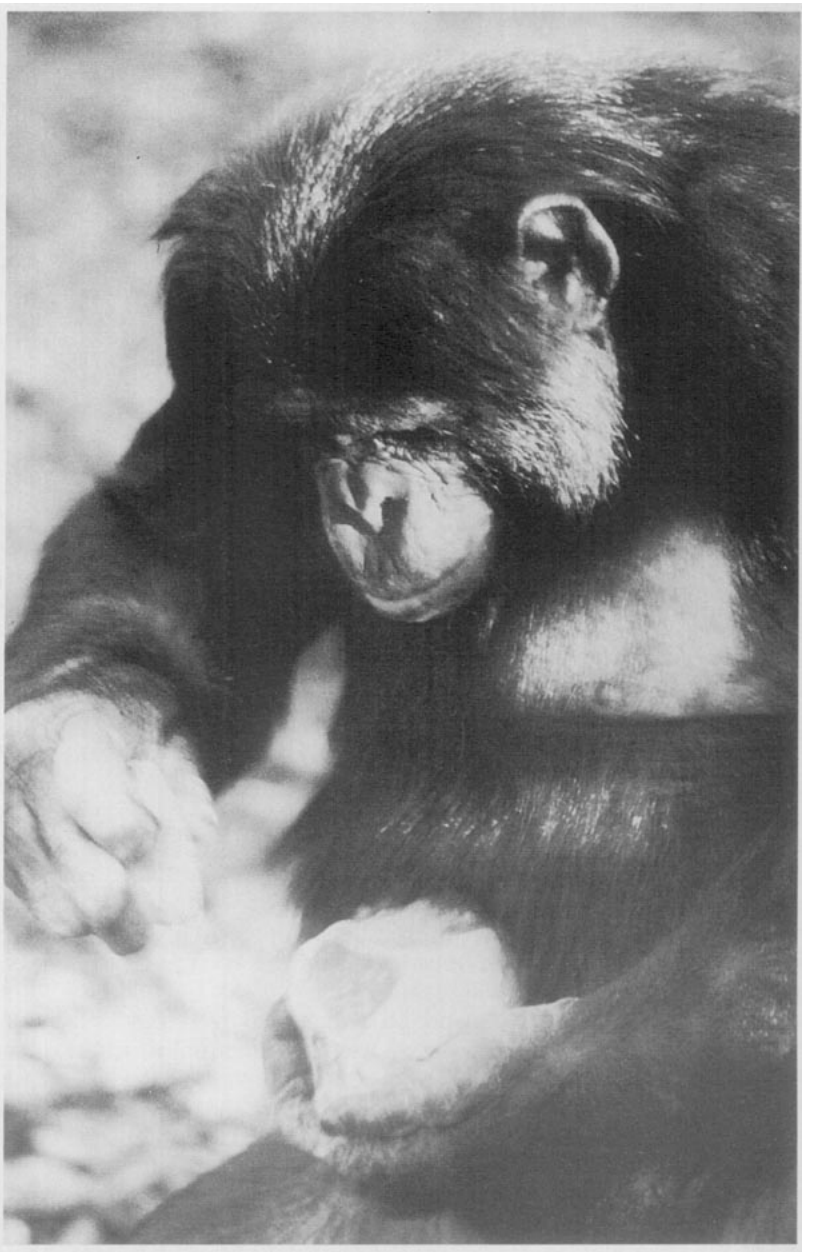

Figure 1. Kanzi flaking a chert core with quartzite hammerstone. (Photograph by R. Sevcik.)

thrown rock or from the stationary anvil. This would appear to be another example of insight learning combining his successful experiences in throwing indoors with his previous attempts (relatively unsuccessful) at holding a rock in his hand and hammering at a stationary stone lying on the ground. Through this throwing technique, he is able to impart a much greater impact force between the stones than by hand-held percussion.

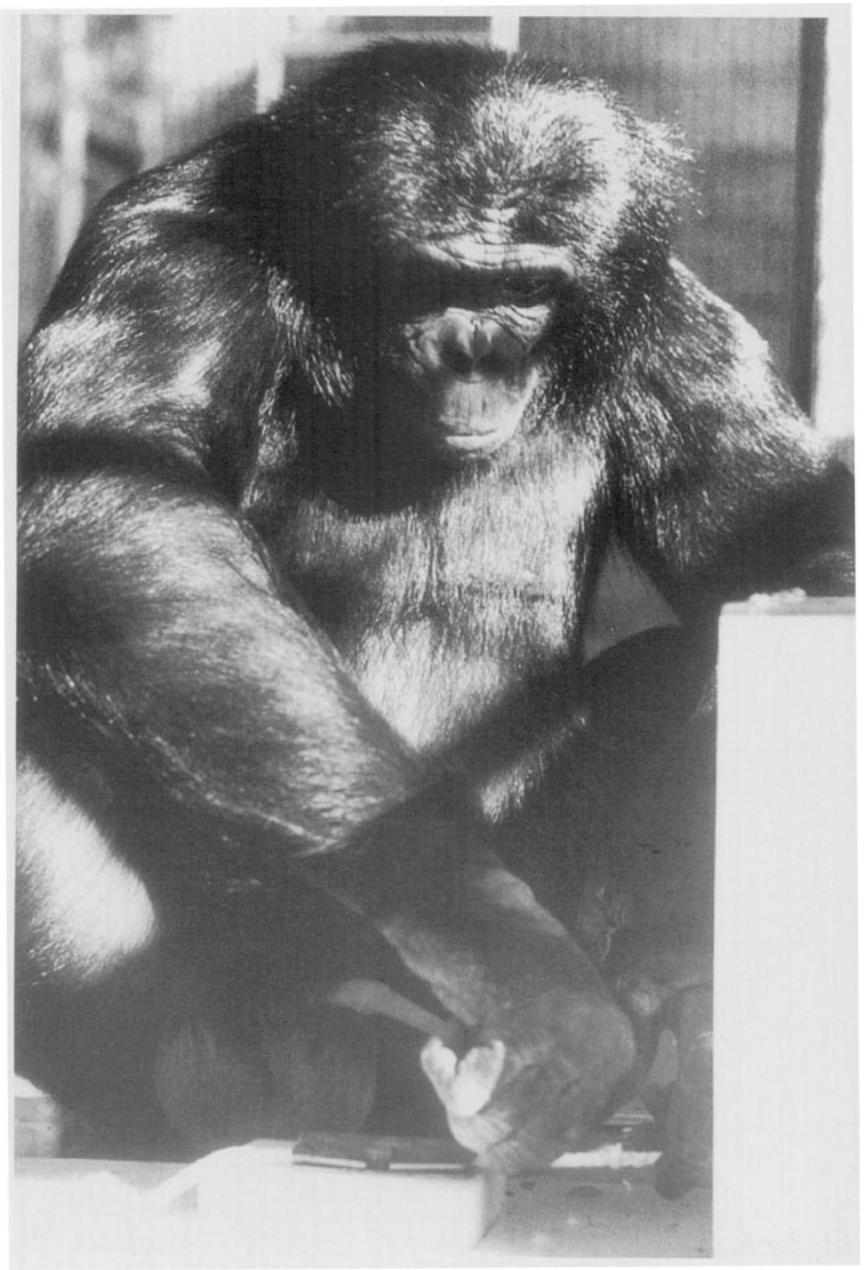

Figure 2. Kanzi using a sharp chert flake detached from a core to cut through a string to open a box to obtain a reward. The box has a clear plastic top so that the reward is easily visible. (Photograph by R. Sevcik.)

Discussion

Kanzi has made significant and rather startling progress in his stone tool-making, rapidly acquiring many of the basic skills required to produce sharp-edged cutting tools from

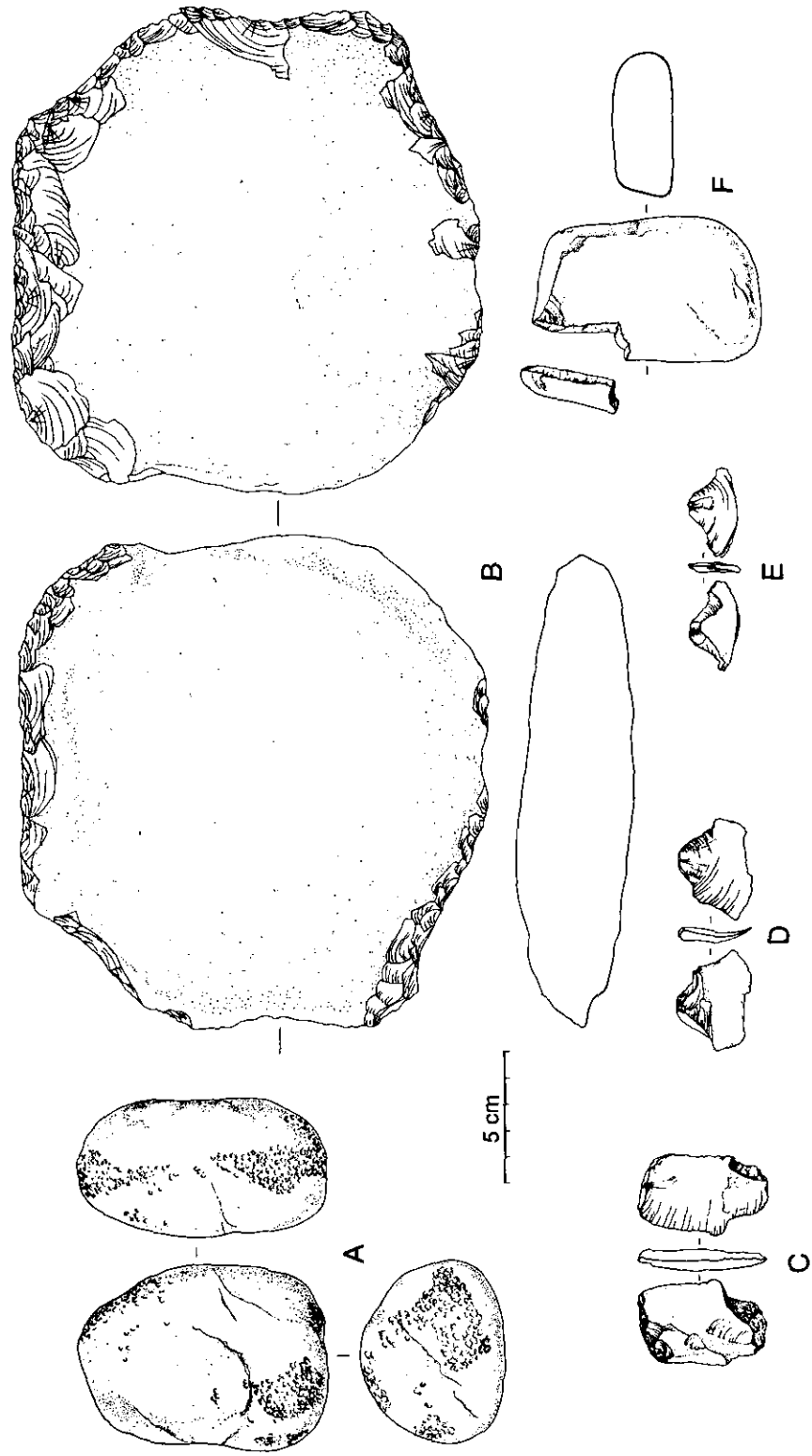

Figure 3. A typical range of artefacts produced by Kanzi during the experimental program: (A) quartzite *hammerstone*; (B) *chert core* (both faces and lateral outline); (C, D and E) chert flakes; (F) quartz core and flake. (Drawn by Judith Ogden and James Hull.)

stone cores. He has not only shown fairly rapid improvement in the hard-hammer technique demonstrated to him, but he has displayed ingenuity and insight learning in his innovation of the throwing and directed-throwing techniques. Unlike Oldowan hominids, however, as yet he does not seem to have mastered the concept of searching for *acute angles* on cores from which to detach flakes efficiently, or intentionally using flake scars on one face of a core as striking platforms for removing flakes from another face. Thus, so far he does not tend to produce the acute-edged bifacial and polyfacial cores typical of many Oldowan assemblages.

Several criteria for assessing the degree of skill in flaking are being investigated and will be compared to Early Stone Age assemblages (Toth & Schick, in press). Realistically, such comparisons can only be made when comparing the experimental results with prehistoric archaeological assemblages in which similar types, sizes and shapes of raw material had been used. These criteria include:

(1) Flake angle: the angle formed between the striking platform of a flake and the dorsal surface of the flake (representing the edge angle of the core before the flake was detached).
(2) Degree of decortication of cores: if raw material was one with a cortical surface around its entire exterior (as with the rocks provided to Kanzi), the ratio of cortical to non-cortical surface on the core is a rough approximation of how efficiently the material has been reduced by flaking.
(3) The size of flakes removed: the ratio of the size of the largest flake scar to the maximum dimension of the core is a partial indication of how efficiently flakes are being detached from a block of stone.
(4) A number of more qualitative features, such as the number of hinge or step fractures on a core and the amount of battering on flaked edges, are also being considered in this study.

So far Kanzi has exhibited a relatively low degree of technological finesse in each of these aspects compared to that seen in the Early Stone Age record. The amount of force he uses in hard-hammer percussion is normally less than ideal for fracturing these rocks. His flake angles when using hard-hammer percussion tend to be steep (approaching 90°), while Oldowan flakes were generally detached from more acute-edged cores (flake angles typically 75–80°). As yet Kanzi's cores retain a very high proportion of their original cortex and are steep-edged and rather battered. The flakes he produces tend to be relatively small (generally less than 4 cm long) and often stepped or hinged, and his cores generally exhibit marginal (non-invasive) flake scars.

In sum, despite Kanzi's exceptional progress to date, his skill in flaking stone still contrasts sharply to that of Oldowan hominids as manifested in the archaeological record. To what degree the limitations in Kanzi's tool-making abilities at this point are due to his limited experience thus far (fewer than 200 experiences in total), to biomechanical constraints on core and hammer manipulation due to the musculoskeletal structure of his arms and hands, or to cognitive constraints in the bonobo, is not yet clear. These diverse possibilities will continue to be investigated as the experimental program proceeds.

Future Research

Besides our continuing studies of the development of Kanzi's stone tool-making and tool-using skills, other lines of research are being planned. One involves investigating whether other bonobos or chimpanzees at the Language Research Center will learn to make stone tools from Kanzi's example, potentially establishing a technological tradition learned and shared among the ape community there. Kanzi's younger half-sister,

Panbanisha, has recently begun to flake stone in a rudimentary way, apparently emulating her older sibling (this has not been modelled for her by humans).

Secondly, we have begun to put reward boxes/drums along the wooded outdoor paths of the 55-acre facility. As there are no suitable stones for flaking along the path, we will be examining whether or not Kanzi and other apes will begin to transport and/or cache stone in various activity areas, thereby creating "archaeological sites" away from the principal source of raw material at the laboratory facility or secondary sources we will make available in the woods.

Continued research along all these lines should provide important criteria for assessing the capabilities of modern apes versus early palaeolithic hominids with regard to stone tool-related activities. The results obtained thus far provide encouragement that direct, useful comparisons can be made between the products and processes of ancient hominids and modern apes in experimental situations with regard to stone tool manufacture, transport and use, and, potentially, the formation of archaeological residues or sites.

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