Stone tool production and utilization by bonobo-chimpanzees (*Pan paniscus*)

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Using direct percussion, language-competent bonobo-chimpanzees Kanzi and Pan-Banisha produced a significantly wider variety of flint tool types than hitherto reported, and used them task-specifically to break wooden logs or to dig underground for food retrieval. For log breaking, small flakes were rotated drill-like or used as scrapers, whereas thick cortical flakes were used as axes or wedges, leaving consistent wear patterns along the glued slits, the weakest areas of the log. For digging underground, a variety of modified stone tools, as well as unmodified flint nodules, were used as shovels. Such tool production and utilization competencies reported here in *Pan* indicate that present-day *Pan* exhibits *Homo*-like technological competencies.

hominin | bonobo targeted tool use | stone tool wear pattern | food acquisition | bonobo survival strategy

The ability to produce stone tools and use them successfully across habitats and climates was a major innovation and driving force in early *Homo* adaptability, advancement, and species dispersal (1). *Pan* [bonobo-chimpanzees (*Pan paniscus*) and chimpanzees (*Pan troglodytes*)], which are sister species to the *Homo* genus (2), also use tools (3), for example, hunting with spears (4), digging tubers with sticks (5, 6), and breaking nuts with a stone hammer and anvil (7–9). Here we describe the ability of two language-competent bonobos (10), Kanzi (KZ; male, age 30 y) and Pan-Banisha (PB; female, age 28 y), to produce novel stone tools and effectively use them, supporting the hypothesis that present-day *Pan* exhibit technological competencies formerly assigned only to the *Homo* genus.

In the 1990s, KZ and PB were taught by Toth et al. (11, 12) to knap flint flakes and use their sharp edges to cut rope or leather. Our current work with KZ and PB more than a decade later expands and complements those studies with respect to tool forms manufactured and their specific uses.

Results

All of the stone tools made by KZ and PB were created solely by direct percussion, with the core held in the left hand and the hammer stone in the right hand (Fig. 1*J*). In previous experiments, the bonobos used various knapping methods (11). Both KZ and PB preferred to work with flint products (Fig. 2); some of their tools are shown in 3D in Figs. 3–5. KZ produced two types of artifacts: thick cortical flakes removed from the core's edge (Figs. 1 *A*, *G*, and *K* and 3) and small flakes with sharp edges (Figs. 1*D* and 4). PB made flakes of various sizes, but not core-edge thick flakes (Fig. 5). Our present findings indicate that the stone tools manufactured by the bonobos were subsequently targeted to achieve the experimental missions. Each time KZ or PB picked up a tool for use, it was recorded as one observation.

Log-Breaking Experiments and Quantification. In 24 log-breaking sessions, KZ used the following stepwise strategy: (*i*) hammering the log with large cobble stones; (*ii*) throwing the log on the cement floor, or aiming rocks at it; (*iii*) inserting sticks into the glued slits; (*iv*) making stone tools and using them in drilling, wedging, chopping, scraping, and cutting actions; and (*v*) using body weight and limbs to force the log open. Fig. 1*I* shows an open log after food extraction.

KZ processed a total of 24 logs. The 156 tool uses observed during this processing included 13 stick tool insertions, 3 antler strikes, 4 log-on-log strikes, 76 unmodified-stone log hammering (50 hammering log with rocks, 22 stone throwing on log, and 4 throwing log on rock, with precision), and 60 observations of modified stone tool uses (18 uses of chopper-like tools, 22 uses of drill-like tools, 2 uses of scraper-like tools, 10 uses of small flake insertions, and 8 observations of cutting logs). KZ made a total of 23 stone tools, including 5 thick cortical flakes struck from a core's edge (Fig. 3) and 18 smaller flakes with sharp edges (Fig. 4).

In contrast, PB managed to break only two logs, by throwing them on the floor. The 10 observations of PB's tool use in log processing included 1 stick insertion, 8 rock hammering, and 1 use of KZ's drill tool, along with 2 small flint tools that she made but did not use after the first try.

In the aforementioned step iv, KZ used the thick cortical flakes as an axe and wedge (Figs. 1 *A*, *B*, *G*, and *H* and 3) and used the small flakes as drills or scrapers (Fig. 4, tools 1–5). Fig. 1 *E* and *F* shows the drilling motion and its resulting wear patterns. Of note, KZ's accuracy in specific tool use in log processing is clearly demonstrated by the wear patterns left repeatedly along the glued slit, the weakest area of the log (Fig. 1 *C* and *F* and Movie S1). The various wear patterns left on the logs processed by KZ are shown in Fig. 2 and discussed below.

Digging Experiments and Quantification. The digging experiments further exemplify task-specific tool use. We repeatedly observed that both KZ and PB dug according to soil conditions. Digging in soft sand was done with the hands, digging in muddy soil was done with branches, and digging in hard soil was done with stone tools and antlers. Of note, both KZ and PB used unmodified flint nodules for digging; however, KZ also dug with a thick oval flake that he made (Figs. 1 *K* and *L* and 3, tool *4*), whereas PB used most of the stone tools that she made for this task (Fig. 5 and Movie S1).

KZ was observed using the following tool types for digging (a total of 13 occasions): one antler, seven branch tools, and five stone tools (two modified and three unmodified). PB used the following tool types for digging (a total of 89 occasions): 6 antler tools, 73 branch tools, and 10 stone tools (1 unmodified) (Fig. 5).

Discussion

Stone tool uses have evolved separately across taxa; for example, *Neophron* vultures use pebbles to break eggs, *Cariama* seriema birds kill prey by striking them on rocks, and *Cebus* capuchin monkeys use stones as hammers to break nuts on flat rock anvils

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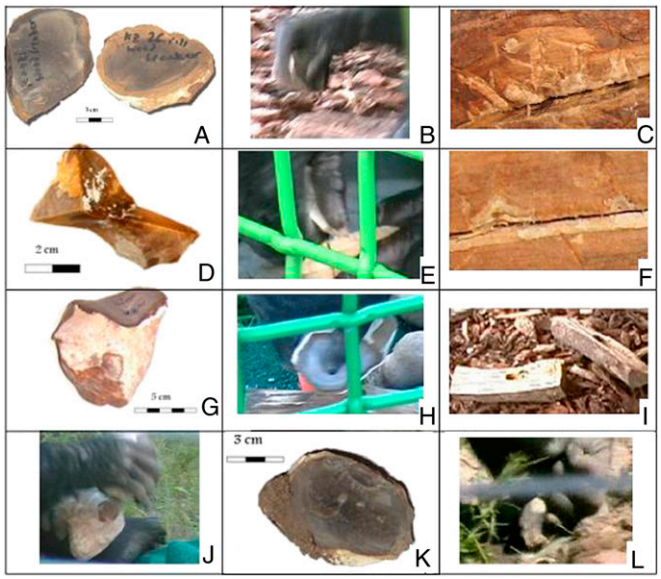

Fig. 1. Stone tools made by KZ and their use. (*A* and *B*) Thick cortical flakes (*A*) used as choppers to break the log by hitting along the log's slit (*B*). (*C*) Close-up view of the slit with chopping wear-patterns. (*D*–*F*) A small flake with sharp edges (*D*), used in drilling motions on the log's slit (*E*), resulting in two drilling wear patterns (*F*). (*G*–*I*) Thick cortical flake (*G*) used as a wedge (*H*) to open the log (*I*). (*J*–*L*) KZ knapping (*J*) a thick cortical flake (*K*); its edge soiled by digging (*L*); see Movie S1.

(9). However, in terms of tool variety and complexity, *Pan*'s and *Homo*'s multifunction tool types (6–8) and multistage tool uses (6) overshadow those of other taxa (5, 6).

In previous studies, KZ and PB produced flint flakes and used them only to cut rope to open a box or to cut leather to open a drum for food (11, 12). In the present study, however, these bonobos were faced with challenges of food retrieval similar to those occurring in natural conditions. Our observations of log breaking and digging in the ground under stones with specifically produced and used stone tools demonstrate *Pan*'s high mental competency and ingenuity. To accomplish these activities, they produced and used a wider variety of tool types than hitherto reported, with more complex uses, which formed wear patterns very similar to those produced by early *Homo* (13–15). The earliest record of tool-assisted wear patterns on bovine bones is 2.5 mya at Bouri Formation, Ethiopia (14), representing early *Homo* efforts to break them for marrow or to cut flesh. The glued logs encapsulating food serve as a substitute for the marrow in long bones (16).

KZ produced Leakey's two main Oldowan tool categories (17, 18): heavy-duty and light-duty stone tools [i.e., chopper-like and wedge-like tools (Fig. 3); and scraper-like and drill-like tools (Fig. 4), respectively]. Thus, KZ's tools exhibit a basic level of functional typology. The heavy-duty tools, unmodified hammer stones and thick cortical flakes, leave percussion and chopping marks, respectively. The hammer strikes are indicated by points of impact, fractures, and blunt strikes with ridges (Fig. 2 *A*, *B*, and *E*), whereas the chopping actions are indicated by angles of strikes, indentation dimensions, and prominent sharp and deep impacts (Fig. 2 *D*, *G*, *H*, and *J*). Light-duty tools demonstrate more finely patterned cut and scrape marks (Fig. 2 *C*, *F*, and *I*). Thus, wear patterns indicate the various functional uses of the different tools.

Wear patterns on fossilized bones have become a key factor in interpreting tool use and function in the paleontological record (13–16, 18). Hitherto, only early *Homo* was thought to produce such tool use markings. Here we report that present-day *Pan* also has such competencies, thus indicating the potential for stone tool use in even earlier hominin taxa than *Homo* (19). Given that *Pan* has curved finger phalanges similar to those of australopithecines/*Homo habilis* (20) and wrist bones and cranial capacity similar to those of *Homo floresiensis* (1, 21, 22), makers of Oldowan stone tools (21), the similarity between the wear patterns observed on KZ's logs and those seen in early *Homo* artifacts from 2.5 mya (13–16, 18, 19) is significant. Our experiments thus suggest that the wear patterns resulting from the various tool uses by *Pan* can be used to help decipher the earliest wear patterns preserved on bones (19). Therefore, our results reinforce the evidence for early *Homo* traits in *Pan* (23), and suggest that the potential for the development of the observed tool use existed in the last common ancestor of *Pan* and *Homo* (24).

Materials and Methods

Background. The experimental field setting described here was the Great Ape Trust/Bonobo Hope Sanctuary in Des Moines, Iowa, a semicaptive culturally rich environment. The experiments were conducted over a 3-mo period between June and August 2011. The half-siblings KZ and PB had been reared in a *Pan*/*Homo* bicultural family (bonobos and humans) by two of the authors (S.S.-R. and E.R.-P.). The bonobos' language acquisition was enabled by exposing them from infancy to meaningful symbol vocabulary communicated via a computer-controlled lexigram keyboard that included 480 word symbols. Objects around the bonobos were associated with these abstract symbols, and the chimpanzees eventually attained a working vocabulary of 480 symbols and understood up to 2,000

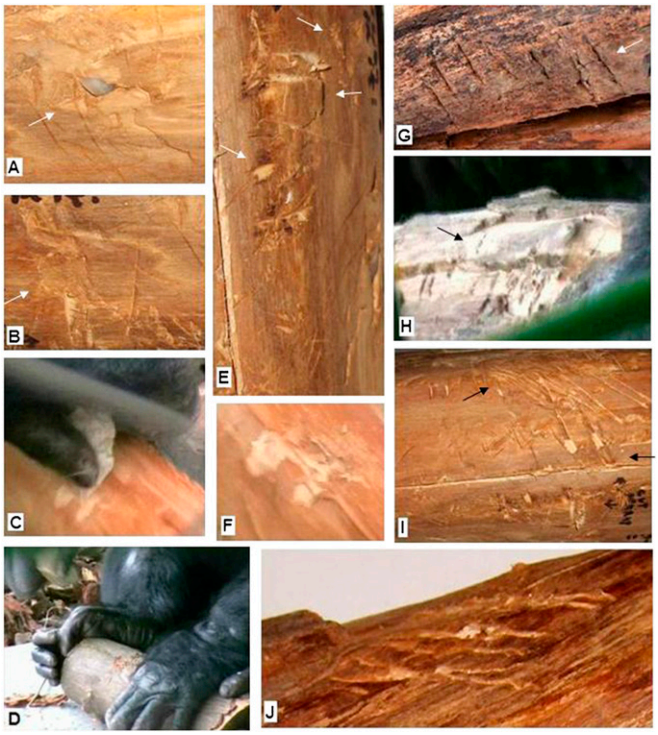

Fig. 2. Wear patterns on the logs processed by KZ. (*A*) Flint flake embedded in a log after sharp-edged hammer-stone percussion (arrow). The ridge forms the opposite strike direction. (*B*) Depressions from blunt hammer strikes (arrow). (*C*) KZ using small sharp-edged flake to scrape the log's surface along the glued slit; note the coloration difference between outer and inner layers (*F*). (*D*) KZ making chopping wear-patterns along the log's slit with a thick cortical flake. (*E*) Depression (upper arrow), fracture (middle arrow), ridges, and deep conical marks (lower arrow) from hammer striking. (*G* and *H*) Deep parallel chopping marks perpendicular to the log's slit (arrows). (*I*) Chopping marks (lower arrow) and oblique elongated sharp cutting marks (upper arrow). (*J*) Chopping marks along the slit with impact signs. Compare with early *Homo* bone processing wear patterns (13–15).

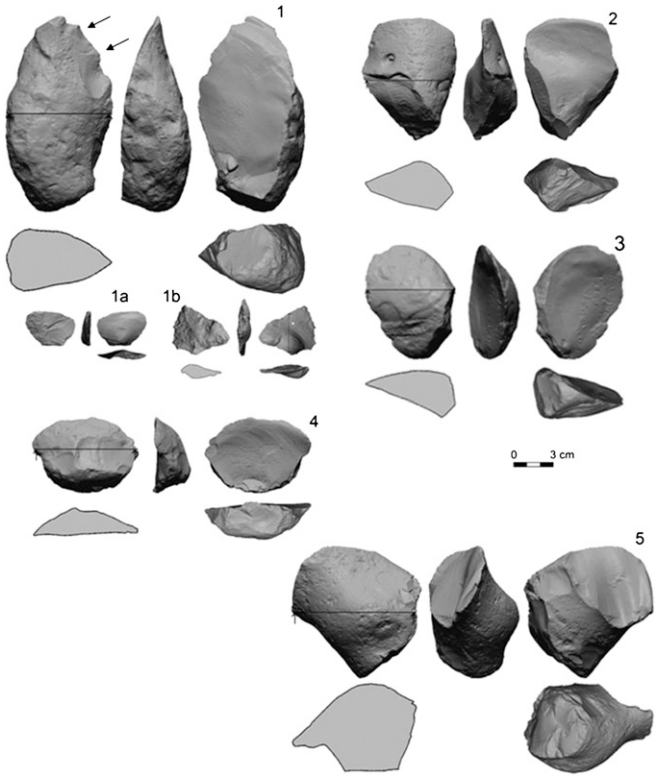

Fig. 3. (*1–5*) Thick cortical flakes struck by KZ from core edges (see *2* in Fig.1*A Left*; see *3* in Fig. 1*A*, *Right*; see *4* in Fig. 1*K*; and see *5* in Fig. 1*G*). The thick proximal half of *1* was used to forcefully hammer a log; then the log was repeatedly and perpendicularly hit with the right distal sharp edge as an axe. Flakes *1a* and *1b* were detached in the process (lower and upper arrows, respectively), leaving a denticulate edge.These tools are shown in Movie S1 as follows: *1*, *2*, and *3* were used as axes (min 1:08–1:23, 0:16–0:57, 0:58–1:07, respectively). *4* was used as a digging tool (min 3:14–3:45); and *5* was used as a wedge (min 2:28–2:46).

English words, making them language-competent for communication (10). In addition to KZ and PB, five other bonobos living with them were presented

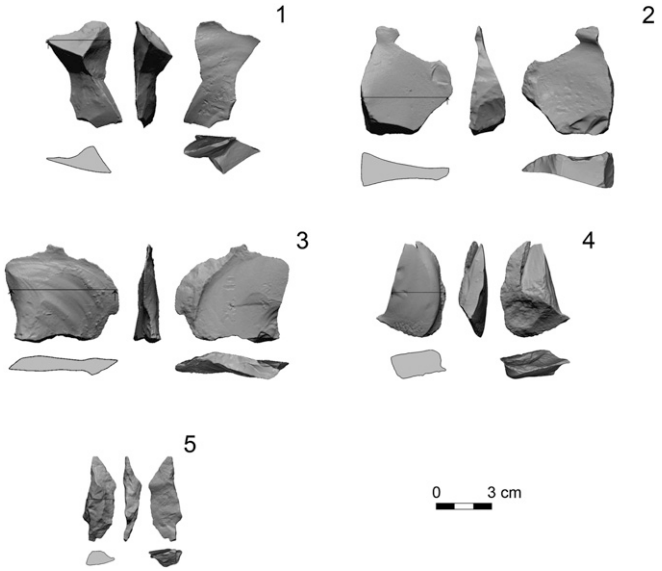

Fig. 4. (*1–5*) Small flakes with sharp edges made by KZ and used on the log slits (Fig.1 *D*); *1–4* were used in drill-like rotating motions (see *3* in Movie S1, min 1:24–1:45), and *5* was used to scrape (Movie S1, min 1:48–2:22).

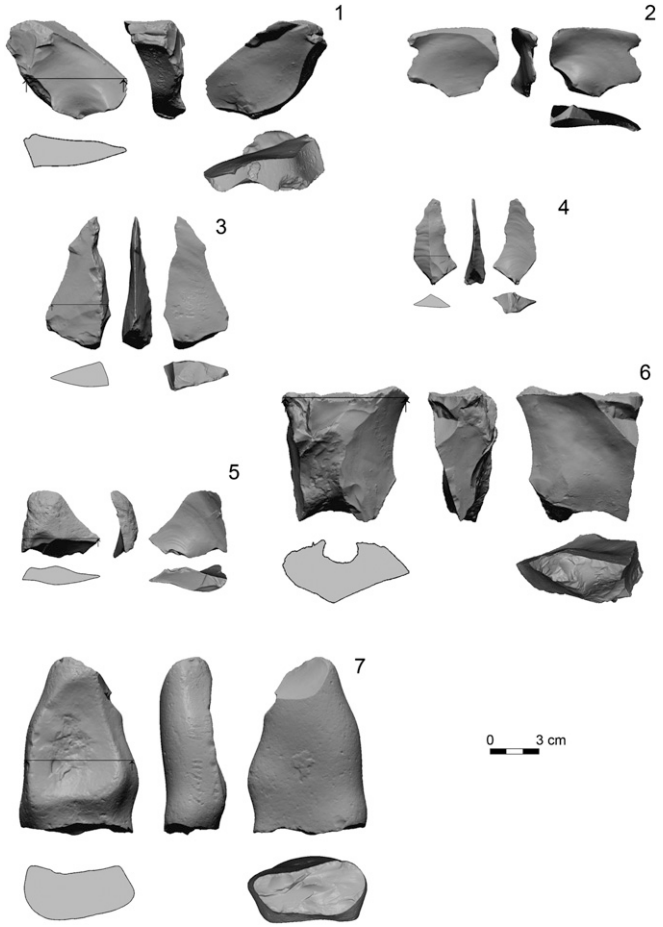

Fig. 5. Tools made by PB, all of which were used for digging. (*1* and *2*) Transversal flakes detached by consecutive well-aimed strikes at similar angles and distances from the core's edge, resulting in two cortical butts of similar thickness; *3* is a natural backed knife, and blade *4* has sharp edges; *6* is a thick block, one angle of which was used for digging, as was *7*, an unmodified flint nodule (Movie S1, min 4:00–4:13).

with the same experiments. The other bonobos, who had no previous experience with flint-knapping, were unable to produce stone tools; however, they processed/used wood, bone, and antler tools.

Tasks Given. KZ and PB were presented with two tasks involving resource acquisition: (*i*) breaking logs to obtain food hidden inside and (*ii*) digging for food hidden under rocks and condensed sand. For the first task, a wooden log (30 cm long and 10 cm diameter) was cut longitudinally into two halves; food was hidden in a central carved crevice, and the log was glued back together. For the second task, a pit was dug in the field and food was buried inside, under 60 cm of condensed sand covered with a 20-cm layer of stones of various sizes. To accomplish these tasks, the bonobos were provided with branches, antlers, and a variety of stones (granite cobbles, sandstones, and flint nodules). After being shown where the food was hidden, the bonobos' activities were observed without time constraints or demonstration. It should be emphasized that KZ and PB had never been requested to break logs or dig previously.

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