# The efficiency of stone and bone tools for opening termite mounds: implications for hominid tool use at Swartkrans

**J. Lesnik[a*] and J.F. Thackeray[b]**

**STONE AND BONE TOOL ARTEFACTS HAVE been recovered from Swartkrans cave deposits in the Cradle of Humankind World Heritage Site, dated to the early and middle Pleistocene. It has been suggested that bone tools were used for digging up tubers of edible plants, excavating termite mounds, or as multi-purpose tools. Here we present results of experiments on the efficiency of both bone and stone tools for the excavation of modern termite mounds. Efficiency of penetrating a termite mound crust is defined by the total excavated mass of the mound, when controlling for the number of strokes used. We demonstrate that stones of considerable mass are most effective in opening up termite mounds, whereas bone tools are relatively more efficient than stone tools when controlling for mass. The light weight, efficiency, and the nature of polish and wear on some Swartkrans artefacts makes it probable that selected bone tools were being carried by hominids and used for more than one purpose.**

## Introduction

Swartkrans cave, situated one kilometre west of Sterkfontein in Gauteng province, South Africa, has yielded fossilized remains of *Paranthropus robustus* and *Homo ergaster*, together with stone artefacts, bone and horn tools, as well as evidence for the controlled use of fire in Pleistocene contexts.[1] The function of the bone tools has been studied by Brain and Shipman,[1] Backwell and d'Errico[2–4] and van Ryneveld.[5] Termite foraging has recently been emphasized. Here we reconsider these interpretations in light of experiments undertaken using both bone and stone tools to excavate termite mounds. These insects may have been an important source of protein for Pleistocene hominids.

## Materials and methods

We examined the following question: to what effect, if at all, are bone tools more efficient than stone tools for breaking through the hard crust of termite mounds associated with the genus *Trinervitermes*, which has a widespread distribution in southern African savanna habitats?[6] To do so, we first measured length, width and mass of large stone artefacts from Swartkrans (Members 1, 2 and 3). The raw materials of the artefacts were also recorded. Based on these criteria, 10 experimental stones of various sizes were chosen from naturally available raw materials exposed at the nearby site of Kromdraai, and used by us as digging tools. We did not modify the experimental stones, although mostly altered stones were measured from the Swartkrans sample. Our stones were chosen for their suitability for grasping and for having a naturally tapered edge for striking.

Backwell and d'Errico's (2001) analysis of Swartkrans bone tools suggests that they were manufactured from weathered long bones. Here, bone tools were made from both weathered and fresh bone. The weathered bone tools were made from the remains of modern *Equus asinus*. The spine of a scapula as well as a partial rib made sturdy tools. Two more tools were made from an *Equus* mandible, simulating possible use of a *Hipparion lybicum* mandible from Swartkrans (Member 3) that displays wear and polish.[1] One of our tools included both the mandibular and ascending rami, using the anterior end for digging. The second mandibular tool more closely simulated the Swartkrans specimen in the sense that the ascending ramus was broken off and the posterior portion of the horizontal ramus was used for digging. Both portions of mandible contained all premolars and molars, which added considerably to the mass of the experimental tool.

Horn core artefacts are also found in the Swartkrans sample.[1] A weathered horn of a modern wildebeest (*Connochaetes*) was used as a tool in our experiments. In addition, fresh *Bos* femora were obtained from a local butcher. A large, 3.5-kg quartzite stone from this study was used first to break the shafts of each femur and then employed further to strike off bone flakes. In total, four bone tools were created from shaft fragments, one with the distal end of the bone still intact.

Our experiments were conducted outside the Cradle of Humankind, near Krugersdorp, on land recently disturbed by fire. The first author used each tool to strike an intact area of termite mound crust 25 times, after which the freshly loosened material of the termite mound was collected and weighed.

## Results

There is a linear relationship between the length and mass of both stone and bone tools (Fig. 1). The two materials show different trajectories (slope of graph), however, due to their different densities. Bone manifested slightly more variation than stone. The difference is not of major concern, however, given the small sample size, the variation in the cortical and trabecular structure within each bone, and the inclusion of both weathered and fresh bone in the figure. The length and mass of the bone tools from Swartkrans are not included here because of their fragmentary nature and the use of plaster in some of their reconstructions.

There is an approximately linear relationship between the amount of termite mound removed with 25 strikes of a

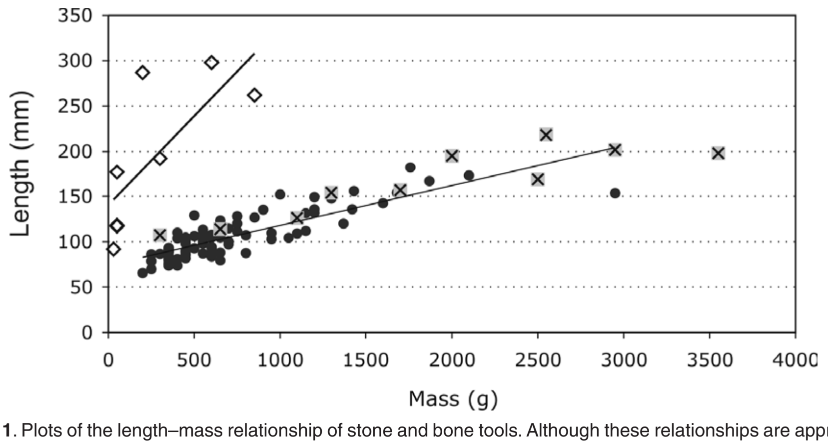


**Fig. 1**. Plots of the length–mass relationship of stone and bone tools. Although these relationships are approximately linear for both materials, the regression lines have different slopes, reflecting differences in portability of the tools. Key: ●, Swartkrans stone artefacts; ×, experimental stones; ◇, experimental bones.

[a]Department of Anthropology, University of Michigan, Ann Arbor, MI 48109, USA.
[b]Transvaal Museum, P.O. Box 413, Pretoria 0001, South Africa.
*Author for correspondence. E-mail: lesnikju@umich.edu

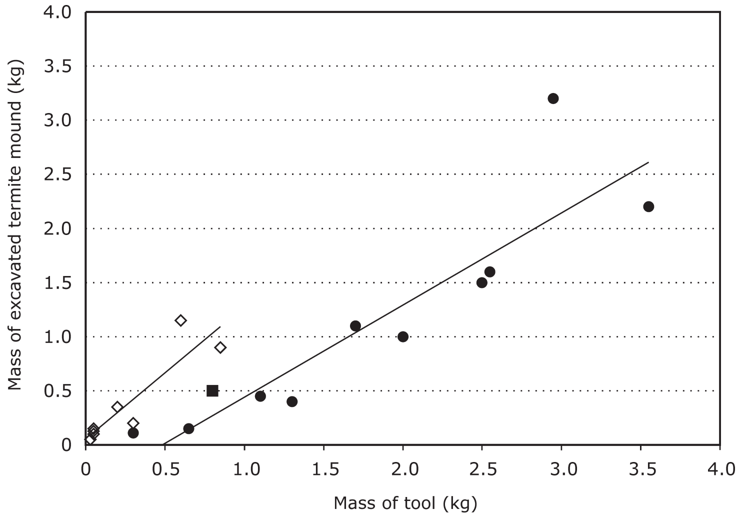


**Fig. 2**. Relative efficiency of experimental stone and bone tools, corresponding to the amount of termite mound excavated with 25 strokes of each tool. Large stones remove the greatest amount of the outer crust of a termite mound for the same effort. Bone tools are more efficient than stone tools per unit mass. Key: ◇, bone tools; ●, stone tools; ■, wildebeest horn tool.

modern experimental tool and its mass (Fig. 2). Using this relationship to define efficiency, bone and stone tools can again be distinguished, as expressed by differences in slope of the corresponding regression lines.

## Discussion

Backwell and d'Errico[2] aver that stone tools from Swartkrans have too large a surface area for penetrating the hard outer crust of termite mounds. This may be true for stones with a mass under 1 kg, which corresponds to the majority of the sample of modified stone from the site. Our results suggest, however, that unmodified stones that weigh over 2 kg are much more effective for the excavation of termite mounds than bone tools. Using a large local stone for such a purpose would not leave a signature of hominid use and therefore would not be collected as an artefact. However, both manuports and modified stones of this approximate size have been found in deposits excavated at Swartkrans, implying that hominids valued large stones for some purpose.[7]

Bone tools are more efficient than stones of the same mass, and remove approximately twice as much termite mound per unit mass for the same effort. As with the Swartkrans bone tools, they may have been used to excavate termites, but they would not have been the most effective means available for the removal of the outer crust. Once the outer crust is broken, the mass of the tool no longer relates to its efficiency in removing the soft interior. The surface area of a tool, among other attributes, may then play a preferred role for excavating the easily removed inside of the mound.

The light weight and relative efficiency of bone tools makes them portable yet highly useful for a variety of tasks. Brain and Shipman[1] suggest tuber digging, based on scanning electron microscope images of bone tools. Backwell and d'Errico[2–4] propose the excavation of termite mounds, whereas van Ryneveld[5] concludes that bone was used for both tasks along with others such as bark removal and hide processing. Van Ryneveld's conclusion is closest to our own, based on the minimally overlapping samples used in the two earlier studies (samples obtained from Brain and Shipman, 2004; Backwell and d'Errico, pers. comm.). Although the tools studied by Backwell and d'Errico manifest a characteristic wear pattern that strongly suggests use on termite mounds, we do not consider that it refutes the analysis conducted by Brain and Shipman on a 75% different sample. Until both samples are analysed together, there is no need to consider the two tasks mutually exclusive. Other support for the multiple-use hypothesis comes from the amount of wear and polish at the ends of tools in the Swartkrans sample. Backwell and d'Errico report that the pattern of wear is present after excavating one termite mound for about 15–30 minutes. Our observations suggest that although the striations are present after breaking into one mound, the amount of wear and polish does not reflect what is seen in the Swartkrans sample. We are confident that the tools were used on multiple occasions in order to accrue this level of wear, but whether it would take 4–8 hours of use, as Brain and Shipman proposed applied to their sample, is uncertain. The amount of wear and polish does not say anything about *different* tasks, but it does suggest that tools were used several times, and were probably saved and carried to more than one locality.

The most efficient bone tools were shaft fragments with an articular surface still intact. Our results show that this efficiency was a result of the extra mass provided by the articular surface, but can also be related to being easier to grip, as noted by van Ryneveld.[5] The availability of such bones from scavenged remains, however, was probably limited because carnivores such as hyaenas and large cats often gnaw epiphyses.[8, 9] Size selection is also seen in the Swartkrans bone tools. Backwell and d'Errico[2] aver that the bone fragments used for tools were 13–16 cm in length. Larger tools are more efficient than smaller ones due to their greater mass, but too much bulk limits portability. This narrow size range seen in the Swartkrans sample might reflect the optimal size for tools that would have been both portable and effective for breaking into the crusts of termite mounds.

Only one horn tool was analysed in our experiment, and its efficiency was intermediate between that of bone and stone tools of the same mass. Its greater efficiency than bone was likely due to the sharply tapered edge of a tool with mass at the upper limit of values obtained for bone. The greater mass came from using the entire horn, however, making it unwieldy.

Termites contribute to the diet of all the great apes. Gorillas,[10] orangutans[11] and chimpanzees are known to break open mounds with their hands, and different groups of chimpanzees have developed a variety of techniques of using tools to extract termities.[12,13] Some people (including the Venda in South Africa) consume termites, and the high protein resource may have also contributed to the palaeodiet of australopithecines. Scott *et al.*[14] have presented results on dental microwear in hominids, including *Australopithecus africanus* and *A. robustus* from Sterkfontein and Swartkrans, respectively. They observe 'some differences' between microwear in the two species and aver that *A. robustus* may have had a diet that included 'hard and brittle foods', whereas *A. africanus* consumed 'tough' foods. Stable carbon isotope analyses of hominid tooth hydroxyapatite imply the consumption of insects, including termites.[15,16] Scott *et al.*[14] state that hard, brittle or tough foods account for patterns of microwear in australopithecine teeth, but it is possible that the grit associated with termite mounds and the silica contained in the hard termite bodies could have contributed to the observed dental patterning.

## Conclusion

We postulate that termites supplemented hominid diets at Swartkrans, and grit associated with these insects contributed to the 'hard and tough' signals apparent from dental microwear studies. Some of the bone tools from this site show evidence of termite foraging, but we have observed that bone would have been of limited efficiency for breaking open the outer crusts of termite mounds. Although only a tool's wear pattern can provide direct evidence of the tasks it performed, understanding the tool's efficiency can provide insight into why it was chosen for use. Stones with a mass of over 2 kg are more efficient than bone tools for penetrating the crust of a termite mound; however, bone tools are more efficient than stones of equal mass for excavating the exposed mound interior. Bone tools may have been selected by the Swartkrans hominids because of their lightness and efficiency, making them easily portable for a range of tasks.

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