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Pre-Columbian monkey tools

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Stone tools reveal worldwide innovations in human behaviour over the past three million years [1]. However, the only archaeological report of pre-modern non-human animal tool use comes from three Western chimpanzee (*Pan troglodytes verus*) sites in Côte d'Ivoire, aged between 4.3 and 1.3 thousand years ago (kya) [2]. This anthropocentrism limits our comparative insight into the emergence and development of technology, weakening our evolutionary models [3]. Here, we apply archaeological techniques to a distinctive stone tool assemblage created by a non-human animal in the New World, the Brazilian bearded capuchin monkey (*Sapajus libidinosus*). Wild capuchins at Serra da Capivara National Park (SCNP) use stones to pound open defended food, including locally indigenous cashew nuts [4], and we demonstrate that this activity dates back at least 600 to 700 years. Capuchin stone hammers and anvils are therefore the oldest non-human tools known outside of Africa, opening up to scientific scrutiny questions on the origins and spread of tool use in New World monkeys, and the mechanisms — social, ecological and cognitive — that support primate technological evolution.

Over the past decade, wild Brazilian *S. libidinosus* have been seen habitually using a variety of stone and stick tools for foraging and social display [4,5]. Genetic data demonstrate a complex biogeography for this genus, including a likely Middle-to-Late Pleistocene age for the emergence of *S. libidinosus* and its colonization of the Brazilian interior [6]. However, the capuchin fossil record is patchy, and the circumstances leading to tool use in this genus are unknown.

At two long-term *S. libidinosus* research sites in semi-arid Northeast Brazil — Fazenda Boa Vista (FBV) and SCNP — capuchins use stone tools to process indigenous cashew nuts (*Anacardium* spp.) [4,7]. Cashew nut mesocarp contains a caustic, resinous material [7], a defensive mechanism that capuchins at the two sites avoid through different behavioural adaptations. FBV monkeys rub fresh cashew nuts on a rough surface to abrade a hole and access the kernel, and also occasionally use stone tools to crack older, drier nuts [7]. In contrast, SCNP capuchins use stones much more frequently for cashew processing, with portable stone anvils and hammers used to process all stages of the nut [4]. Human consumption of cashews dates

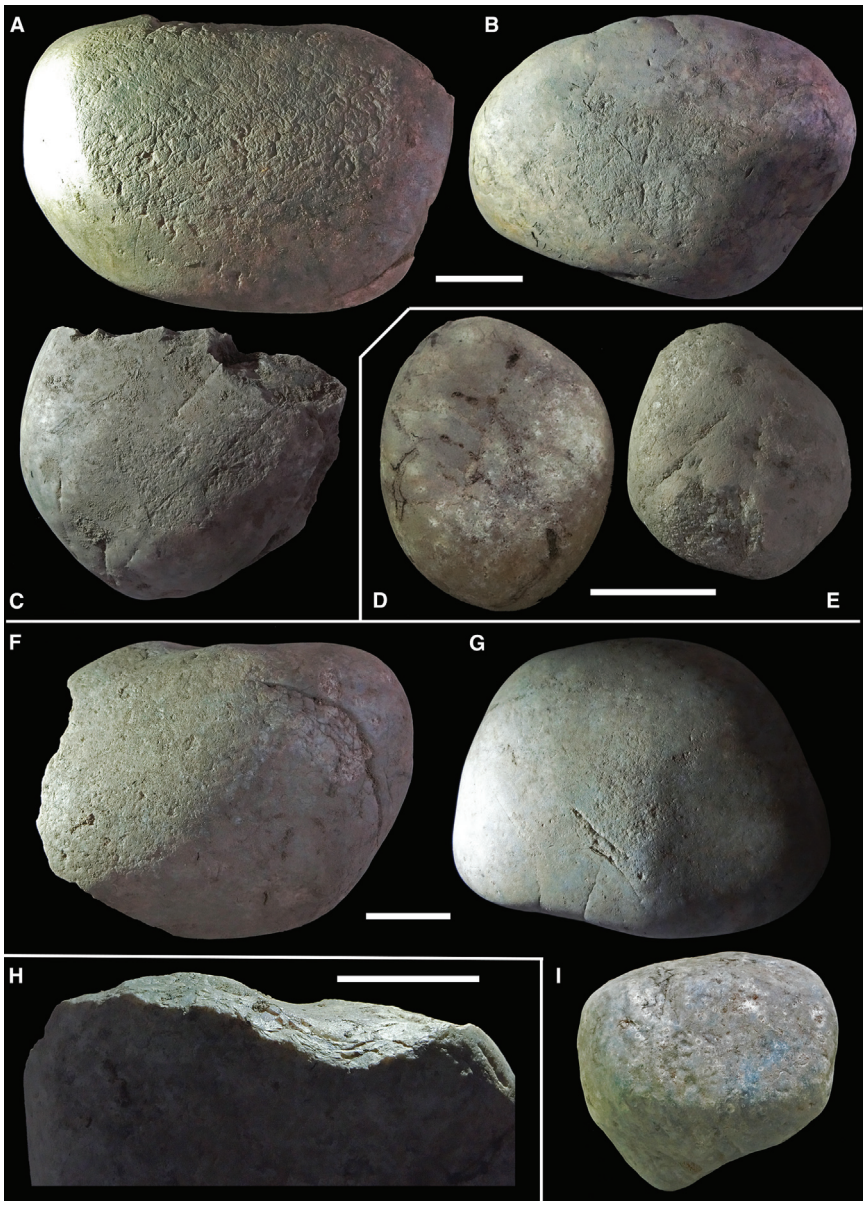

Figure 1. Selected capuchin tools excavated at Caju BPF2.
(A–E) Phase II; (F–I) Phase III; all were discovered in the western part of the site. (A–C) Quartzite anvils with impact marks and crushing damage on the central, flat use-surfaces; (C) also has a fractured margin, but because no conjoining pieces were recovered, this damage did not occur at the same place that the tool was found. (D,E) Quartzite pounding stones with impact marks, and removal of part of the surface of (E). (F,G) Quartzite anvils with damage localised to the central, flat use-surfaces. Another view of the fractured left edge of (F) is shown in (H); note the multiple step fractures indicative of repeated strikes. (I) Quartzite pounding stone with multiple impact marks; Figure S1 shows this tool *in situ* during excavation. All scale bars are 5 cm.

back at least 7000 years at SCNP [8], with people traditionally using roasting to detoxify the nuts rather than pounding tools.

Capuchins create recognizable cashew processing sites, by accumulating stone tools at specific points on the SCNP landscape. The monkeys bring tools to cashew trees, leaving them around the base and on tree branches following use. To help identify buried capuchin nut-cracking sites, we mapped modern surface tools and trees at four locations within SCNP (total 400 m^2). We identified these tools by the dark cashew residue on their surface, use-wear damage to the stone surfaces, their disproportionate size compared to the natural sediment, and their clustering.

We found that capuchin anvil stones were just over four times heavier than hammer stones, while hammers were in turn over four times heavier than natural stones in the same environment. Capuchins preferentially selected smooth quartzite hammers from available stones, and they strongly preferred using tabular sandstone for anvils (Supplemental information). The overall tool density at the surface sites was 0.45 m^{-2}, with a peak of 13 tools m^{-2}; at their upper level, these tool densities can approximate those seen at Early Pleistocene Oldowan hominin sites, such as West Gona, AL666 Hadar and Omo in Ethiopia, Koobi Fora in Kenya and Olduvai Gorge in Tanzania [9].

To establish the antiquity of capuchin cashew processing at SCNP, we excavated 35 m^2 to a maximum depth of 0.72 m below the ground surface, at a locality designated Caju Baixão da Pedra Furada 2 (Caju BPF2; S 08° 49.740' W 42° 33.292'). The closest stone source was a seasonally dry streambed about 25 m east of the site. At Caju BPF2 and other surface sites within SCNP, we used gas chromatography-mass spectrometry to chemically confirm that dark residues found on the tools derived from cashew processing (Supplemental information).

The excavation recovered 69 buried stone tools (Figure 1), identified on the basis of their large size relative to the site sediment, use-damage, and their spatial association with other tools. We obtained ten radiocarbon dates on charcoal from four discrete phases of sediment deposition: Phase I preserves modern material, Phase II provides a modelled age range of AD 1614–1958 (95.4% confidence interval), and Phase III dates to between AD 1266 and 1423. The base of the Caju BPF2 excavation, which did not reach bedrock, currently dates Phase IV to approximately 3 kya (Supplemental information).

Phase I contained 30 capuchin stone tools (1 conglomerate, 29 quartzite), while Phases II and III contained 39 pre-modern tools (Phase II: 24 quartzite, 1 sandstone; Phase III: 14 quartzite). Tools from all phases are not significantly different in weight or materials from those observed being used by modern monkeys. No evidence of human activity, such as hearths, flaked stone, ground stone, ceramics or occupation debris was found at the Caju BPF2 site, despite such features and artefacts being ubiquitous in all human-occupied sites in this region and period [10]. Capuchins are the only non-human animal that uses stone tools at SCNP.

We conclude that capuchin monkeys accumulated tools at Caju BPF2 over hundreds of years, before, during and after the European colonization of South America. The Phase III tools are therefore the oldest dated tools known for any animal outside of the human-chimpanzee clade. This technological tradition covers approximately 100 generations of behavioural transmission, and the similarity of ancient and modern behaviour — in materials, pounding function, tool size and density — demonstrates a strongly conservative element to capuchin stone tool technology. By analogy, the Brazilian capuchin record suggests that processing of both encased and potentially toxic foods may have played a role in the evolution of stone tool use in humans, within a larger framework of lithic and non-lithic tool proficiency.

SUPPLEMENTAL INFORMATION

Supplemental Information including experimental procedures, one figure and one table can be found with this article online at http://dx.doi.org/10.1016/j.cub.2016.05.046.

AUTHOR CONTRIBUTIONS

M.H., T.F. and L.V.L. designed the study, collected field data and wrote the paper; R.A.S. performed ^{14}C analysis and wrote the paper; F.B. performed GC-MS analysis and wrote the paper; E.B.O. designed the study and wrote the paper.

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