SHORT REPORTS

Earliest Evidence for Ground-Edge Axes: 35,400±410 cal BP from Jawoyn Country, Arnhem Land

Jean-Michel Geneste[1], Bruno David[2], Hugues Plisson[3], Chris Clarkson[4], Jean-Jacques Delannoy[5], Fiona Petchey[6] and Ray Whear[7]

Abstract

Evidence for the world's earliest stone tools dates to 3.4 million years ago and pre-dates the earliest known *Homo* species in eastern Africa. However ground-edged tools did not appear until the dispersal of cognitively fully modern *Homo sapiens sapiens* out of Africa. We report on the discovery of the earliest securely dated ground-edge implement in the world at Nawarla Gabarnmang (northern Australia). The fragment of ground-edge axe is sandwiched between four statistically indistinguishable AMS radiocarbon dates of 35,400±410 cal BP, indicating technological innovations by fully modern *Homo sapiens sapiens* at the eastern end of the Out-of-Africa 2 Southern Arc dispersal route.

Introduction

While evidence for stone tool-use among our archaic hominin ancestors dates to 3.4 million years ago (McPherron *et al.* 2010; Semaw *et al.* 1997), the first use of grinding to shape stone tool edges such as axes is clearly associated with *Homo sapiens sapiens*. While grinding as a technology is much older than the colonisation of Australia (such as for the preparation of ochre; e.g. Henshillwood and d'Errico 2005; Soressi and d'Errico 2007), ground-edged tools do not see their earliest appearance in Africa like so many other important technologies (Henshilwood *et al.* 2002), but in Australia – at the eastern end of the Out-of-Africa 2 dispersal of modern humans sometime after 80,000 years ago. The late appearance of edge-grinding to make cutting or chopping tools – long after complex projectile and composite tools first appeared elsewhere – supports a mosaic-like origin of cultural complexity within our species, with complex new technologies appearing gradually, sometimes with multiple independent origins. New evidence for the earliest securely dated ground-edge implement in the world indicates that Australia was in this way an important locale of technological innovation 35,000 years ago.

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Nawarla Gabarnmang

Archaeological excavations undertaken in May 2010 at Nawarla Gabarnmang in northern Australia, 43km and 105km respectively from Australia's two earliest known Aboriginal sites Nauwalabila 1 (Roberts *et al.* 1993) and Malakunanja II (Roberts *et al.* 1998), reveal two AMS radiocarbon determinations of 30,615±309 BP (Wk-28616) and 31,316±618 BP (Wk-28130) above a fragment of ground-edge axe and two determinations of 30,761±314 BP (Wk-28621) and 31,063±595 BP (Wk-28131) immediately below it (Table 1). The four charcoal samples were taken from the lower excavation units (XUs), namely XUs 28-31 in Stratigraphic Unit 5 (SU5), surrounding the fragment of ground-edge axe located in XU30. The AMS radiocarbon samples were prepared at the Waikato Radiocarbon Dating Laboratory in New Zealand using a standard acid-base-acid treatment (Olsson 1986). Graphite targets were prepared by the reduction of cryogenically purified CO_2 to graphite, using hydrogen over pre-cleaned iron powder at 550°C. The radiocarbon results were calibrated using IntCal09 (Reimer *et al.* 2009) in OxCal v4.1.7 (Bronk Ramsey 2009) and produced a combined statistically indistinguishable age of 36,230–35,880 and 35,580–34,850 cal BP, equivalent to a mean age of 35,400±410 cal BP for the four SU5 samples (95.4% prob.; $\chi^2_{3:0.05}=1.232 < 7.815$). This represents the earliest known ground-edge axe in the world, with the previous securely dated oldest examples dated to 22,000–30,000 BP from Japan and northern Australia (O'Connor 1999; O'Connor and Veth 2006; Oda and Keally 1992; Schrire 1982; Zhao *et al.* 2004; see also Morwood and Trezise 1989 for a report of a purportedly similarly-aged, lost axe excavated by amateur researchers in Cape York Peninsula in the 1960s).

Nawarla Gabarnmang is a large rockshelter in Jawoyn Aboriginal country in southwestern Arnhem Land. Located on top of the escarpment in the Kombolgie Formation, it consists of stable and hard orthoquartzite and softer and less stable quartz sandstone bedrock subject to *in situ* weathering through hydration and solution processes along bedding planes and fissure lines. The double-ended rockshelter has a subhorizontal ceiling ranging from 1.75m to 2.45m above floor level. The area under the well-protected overhang is 19m long by 19m wide and provides shelter for rich cultural sediments entirely protected from rainfall. Charcoal is abundant throughout the excavated deposit.

Square A at Nawarla Gabarnmang consists of a 50cm x 60cm sounding excavated in mean 1.8cm-thick XUs following the observed stratigraphy. Cultural items ≥2.0cm long and individual fragments of charcoal observed *in situ* were plotted in three dimensions. Bedrock was reached at 66.2cm below surface. All other excavated sediments were sieved in 2.1mm mesh sieves and residual materials were bagged for laboratory analysis.

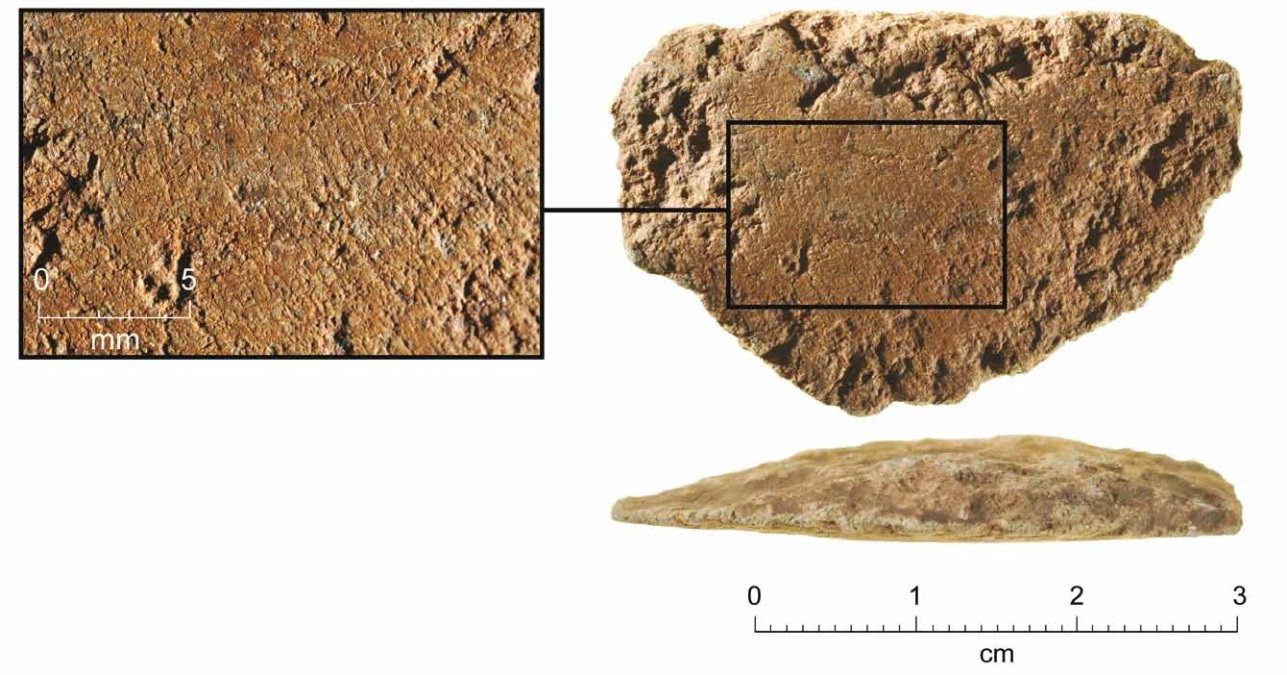

Figure 1 The Pleistocene ground-edge fragment from XU30 of Square A, Nawarla Gabarnmang. Grinding striations are clearly visible on the dorsal surface of the artefact (Photograph: Steve Morton).

The deepest and oldest layer above bedrock is SU5. The ground-edge axe fragment comes from XU30 in SU5 of Square A, at a depth between 47.7cm and 50.4cm below the present surface (Figure 1). Sediments in each of the five SUs consist of compact and well-consolidated loamy sands produced by chemical alteration of the surrounding sandstone bedrock and accumulated aeolian sediments. The terminal Pleistocene sediments of SU4, incorporating the Last Glacial Maximum into the Pleistocene-Holocene boundary, consist of a layer of exfoliated sandstone roof fall rocks infilled with compact loamy sands sealing the underlying SU5 (which contains the fragment of ground-edge axe reported here) from overlying sediments. It was explicitly noted during excavation that no evidence for sediment turbation was apparent, that no rootlets were evident, and that generally pieces of rock (including stone artefacts) were lying flat within SU5. Further support for the reliability of the chrono-stratigraphic sequence, and with this the age of the fragment of ground-edge axe, is found in the good chrono-stratigraphic order of the 18 radiocarbon determinations from Square A, each undertaken on a single piece of charcoal collected *in situ* and plotted in three-dimensions (full details of the Nawarla Gabarnmang excavations are in preparation). Together these characteristics of the sediments enveloping the ground artefact, and the artefact's highly weathered state consistent with the other stone artefacts from SU5 (noticeably different to the Holocene artefacts) mitigate against the possibility of its post-depositional vertical redeposition from higher levels.

Throughout the excavated sequence stone artefacts made of quartzite and chert number in the thousands, but preliminary analysis of the excavated artefacts indicate that the fragment of ground-edge axe reported here is the only volcanic artefact found. The stone raw material from which the ground-edge fragment is made is crystalline, of a basaltic type with reasonably fine crystals. The surface is chemically altered. The closest possible source of basalt is 37km to the southeast.

The Ground-Edge Axe Fragment

The ground artefact is a thin flake detached by percussion from a rectilinear edge. It measures 2.55cm x 3.93cm and is 0.61cm in thickness. The ventral surface clearly reveals the crystalline structure of the rock. The point of impact from which the flake was detached can be clearly distinguished. The flake exhibits

Table 1 Radiocarbon data from Nawarla Gabarnmang, Square A, Stratigraphic Unit 5.

XU	Depth (cm)	Lab No.	δ13C‰ (±0.2)	Conventional Radiocarbon Age (BP)	Calibrated Age BP
XU28	46.6	Wk-28616	23.7	30,615±309	36,120-36,020, 35,340-34,730 cal BP (68.3%) 36,260-35,820, 35,640-34,620 cal BP (95.4%)
XU29	46.5	Wk-28130	25.4	31,316±618	36,420-35,200 cal BP (68.3%) 37,110-34,690 cal BP (95.4%)
XU31	51.4	Wk-28621	24.2	30,761±314	36,170-35,960, 35,460-34,850 cal BP (68.3%) 36,290-35,760, 35,710-34,720 cal BP (95.4%)
XU31	52.7	Wk-28131	24.7	31,063±595	36,280-35,760, 35,740-35,070 cal BP (68.3%) 36,710-34,650 cal BP (95.4%)

no evidence of further modification following detachment. Its morphology shows that it was removed from the surface of the original tool.

The dorsal surface of the flake is smooth, slightly convex across its widest axis and slightly less convex in length. Under acute-angled light it exhibits extensive grinding striations along its entire length. The flake was ground smooth with a relatively fine-grained raw material, potentially sandstone of the local Kombolgie Formation.

The abraded surface contains a homogeneous central raised facet, ground smooth along its upper reaches; along its slope the relief becomes coarser with an increasing density of shallow surface depressions, vestiges of prior hammer dressing (pecking) or of the original surface of the rock. On the raised facet sets of superimposed and criss-crossing bands of striations notable for their short length (0.5cm on average) can be distinguished under binocular microscope (10X magnification).

The ends of the abraded striations along the edge of the flake are flush with the detachment edge, which eliminates the possibility that the artefact was ground after becoming detached from the axe. There is no evidence of subsequent modification in the form of retouch or subsequent grinding.

Although the flake does not intersect the cutting chord of the original tool, its attributes exclude the possibility that it could be a portion of grinding stone or percussion tool. The ground flake, wider than it is long, with a large straight butt and dorsal surface evenly ground to a slight convexity prior to its detachment, indicates with certainty that it is a lateral fragment of the cutting surface of a ground-edge axe. The percussion angle is close to 90° with the dorsal surface, and the precision of application of percussion force combined with the thinness of the removed flake indicates an intentional action. The removal of the flake was aimed at thinning a side of the axe, near its lateral margin and fairly close to the effective cutting edge so as to remove a small protuberance indicated by a concentration of short, multidirectional striations.

Discussion

The Nawarla Gabarnmang fragment of ground-edge axe represents the oldest confirmed ground-edged stone tool in the world. Stone artefacts and fragments of roof fall within the compact sediments of SU5 which contain the ground-edge fragment generally lie flat in the ground; are only associated with statistically indistinguishable radiocarbon determinations; were excavated in thin, mean 1.8cm XUs following the observed stratigraphy thereby avoiding as much as possible mixing sediments of different ages; are sealed by a terminal Pleistocene layer of roof fall which itself contains well consolidated loamy sands; are devoid of evidence of rootlet, insect or other animal disturbance; are well protected from rainfall and driplines; and are part of a long sequence of 18 AMS determinations on single pieces of charcoal which lie in good chrono-stratigraphic order. The sum of these factors indicates the reliability of chrono-stratigraphic results. Considered in the context of 22,000–30,000 BP ground-edge axes from Japan and other Australian sites (Morwood and Trezise 1989; O'Connor 1999; O'Connor and Veth 2006; Oda and Keally 1992; Schrire 1982; Zhao *et al.* 2004), it suggests that ground-edge axes were first invented along the Pacific rim by fully modern *Homo sapiens sapiens* towards the end of, or following, the Out-of-Africa 2 dispersal (Balme *et al.* 2009; Veth *et al.* in press). Reports of much older flaked and waisted (but not ground) axes from New Guinea (Anderson and Summerhayes 2008; Groube *et al.* 1986; Summerhayes *et al.* 2010) suggest that axe technology evolved into that of grinding for sharper, more symmetrical and maintainable edges (see Dickson 1981 for a classic text on Australian ground-edge axes). Hence Sahul was a centre for multiple innovations in axe technology. Axes fulfilled a unique position within the Aboriginal toolkit as long use-life chopping tools that were labour intensive to manufacture, highly valued and later exchanged over long distances (Brumm 2010; Hiscock 2005). The ground fragment from Nawarla Gabarnmang provides the most recent and secure *terminus ante quem* for the technological, social and symbolic transformations that must have accompanied the introduction of this distinctive new technology.

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