Early Pleistocene Presence of Acheulian Hominins in South India

Shanti Pappu, *et al.*

Science **331**, 1596 (2011);
DOI: 10.1126/science.1200183

Early Pleistocene Presence of Acheulian Hominins in South India

Shanti Pappu,[1]* Yanni Gunnell,[2] Kumar Akhilesh,[1] Régis Braucher,[3] Maurice Taieb,[3] François Demory,[3] Nicolas Thouveny[3]

South Asia is rich in Lower Paleolithic Acheulian sites. These have been attributed to the Middle Pleistocene on the basis of a small number of dates, with a few older but disputed age estimates. Here, we report new ages from the excavated site of Attirampakkam, where paleomagnetic measurements and direct $^{26}Al/^{10}Be$ burial dating of stone artifacts now position the earliest Acheulian levels as no younger than 1.07 million years ago (Ma), with a pooled average age of 1.51 ± 0.07 Ma. These results reveal that, during the Early Pleistocene, India was already occupied by hominins fully conversant with an Acheulian technology including handaxes and cleavers among other artifacts. This implies that a spread of bifacial technologies across Asia occurred earlier than previously accepted.

The Acheulian is a phase of the Lower Paleolithic typified by assemblages of large cutting tools primarily composed of bifaces. So far, evidence from Africa suggests that it emerged around 1.6 million years ago (Ma). Determining when hominin populations routinely crafting these Acheulian stone tools inhabited India is critical for understanding the dispersal of this distinctive technology across Eurasia. Limited evidence has suggested that Acheulian hominins appeared in India substantially later than in Africa or southwest Asia (*1*–*5*).

Here, we present age estimates obtained from excavations at Attirampakkam (13°13′50″N, 79°53′20″E, 38.35 meters above sea level), an open-air Paleolithic site situated near a meandering tributary stream of the river Kortallaiyar, northwest of Chennai, in southeast India (Fig. 1) (*6*–*9*). Attirampakkam was discovered in 1863 by Robert Bruce Foote and is one among a cluster of sites constituting the southernmost extension of the South Asian Acheulian (*10*). Extensive excavations since 1999 have exposed a sequence of stratified deposits reaching a maximum thickness of ~9 m (fig. S1). In all of the trenches, Acheulian assemblages were encountered continuously within deposits (layers 6 to 8, Fig. 1) derived from eroding Cretaceous shale and sandstone outcrops in the catchment. These floodplain sediments aggraded during occupation, leading to

[1]Sharma Centre for Heritage Education, 28, I Main Road, C.I.T. Colony, Mylapore, Chennai 600004, Tamil Nadu, India. [2]Department of Geography, Université Lumière-Lyon 2, CNRS-UMR 5600, 5 Avenue. P. Mendès-France, 69676 Bron cedex, France. [3]Centre Européen de Recherche et d'Enseignement en Géosciences de l'Environnement (CEREGE), Europôle de l'Arbois, BP 80, 13545 Aix-en-Provence Cedex 04, France.

*To whom correspondence should be addressed. E-mail: pappu.shanti@gmail.com

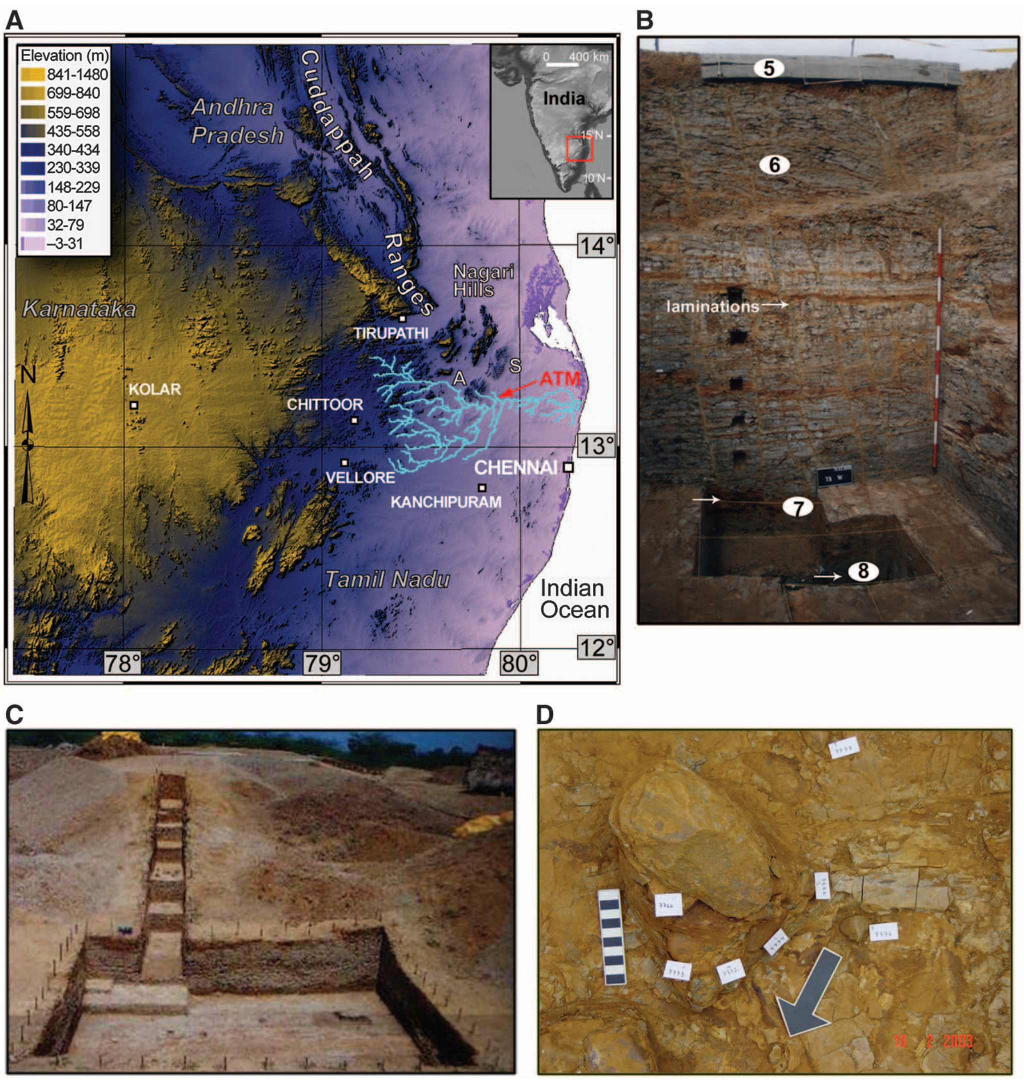

Fig. 1. Location of the Paleolithic site of Attirampakkam (ATM), Tamil Nadu, India. (**A**) Regional topographic setting, showing the extent of the Kortallaiyar river catchment and major cities. The Allikulli (A) and Satyavedu (S) Hills consist of massive deposits of quartzite cobble beds (i.e., source materials of crucial importance to hominins). Relief in the Precambrian Nagari Hills is formed by resistant quartzite ridges, which themselves supplied the Allikulli and Satyavedu conglomerate beds during the Cretaceous. Map projection: Transverse Mercator. (**B**) View of the west wall of trench T8 (sampled for paleomagnetic measurements) showing numbered layers 5 to 8, as mentioned in the text. (**C**) View of step trench GT-01 and trench T8 in the process of excavation. (**D**) Close-up view of layer 7 in trench T8, showing an in situ biface (bar scale gradations in units of 1 cm). The arrow indicates the magnetic north.

repeated burial of artifacts discarded at the site. Alternating sand and silty clay beds lacking paleosols suggest periodic cycles of sediment deposition without lengthy interruptions (*6*). The suspended silt particles settled out under conditions of low-velocity laminar overbank streamflow, burying the stone tools without displacing them. A disconformable upward sequence of coarse lateritic gravels, clay-rich silts, and finer lateritic gravels (Fig. 1) overlies layer 6 and contains later Acheulian–to–late Middle Paleolithic assemblages. Such a complete stratified sequence emphasizes the long-term attractiveness of this site (*6*–*9*).

We obtained 3528 Acheulian artifacts from trench T8, excavated specifically to investigate the deeper layers. The tools were crafted primarily on fine- to coarse-grained quartzite, a source material widely available as cobble and boulder deposits in the near hinterland. Artifacts include retouched and trimmed large cutting tools (>10 cm) including handaxes, cleavers, trihedrals, unifaces, and other retouched/trimmed large flakes, as well as smaller flake tools with only a few artifacts on cobbles (Fig. 2) (*9*). Large flakes were minimally retouched, generally retaining a small proportion of cortex. Among the bifaces, handaxes predominate and are mainly on end- or obliquely struck large flakes displaying variability in flaking techniques and shapes, with elongate and ovate shapes predominating. Cleavers (parallel-sided, divergent, and convergent) remain scarce, are on flakes, and range from minimally shaped "cleaver-flakes" to reduced cleavers. Cores for detachment of large flakes are absent, implying that Acheulian hominins were transporting to Attirampakkam (i) large flakes and (ii) partly to fully shaped tools from surficial quartzite cobble beds used as quarrying sites noted elsewhere in the region. Further shaping and reduction were carried out at Attirampakkam, as indicated by waste flakes that include biface thinning flakes [see supporting online material (SOM) text].

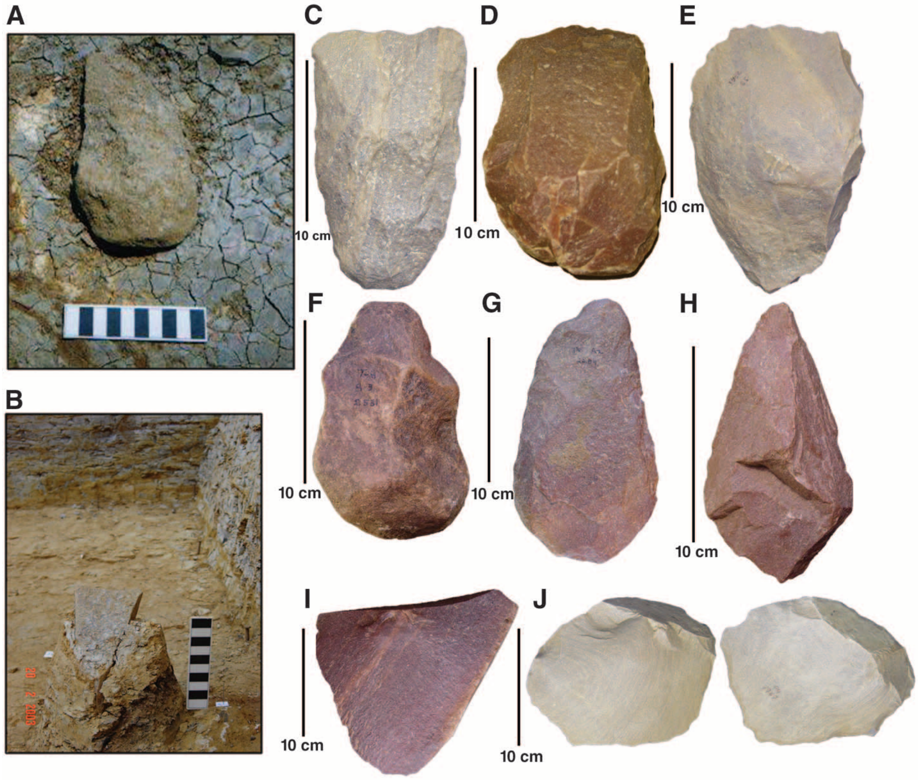

Fig. 2. Acheulian artifacts in trench T8. Close-ups of artifacts in layer 6 (**A**) and in layer 7 (**B**). Artifacts include cleavers (**C** and **D**), large flake tool with a cleaverlike working edge (**E**), handaxes (**F** and **G**), trihedral (**H**), large flake (**I**), and Kombewa flake (**J**). Bar scale gradations as in Fig. 1.

Table 1. Cosmogenic nuclide concentrations and Acheulian artifact burial ages.

Samples	Depth* (cm)	^{10}Be† (10^6 at·g^{-1})	^{26}Al† (10^6 at·g^{-1})	Minimum burial age‡ (Ma)	Denudation before burial§ (m·My^{-1})	Maximum burial age‡ (Ma)	Denudation before and after burial (m·My^{-1})
T8 6074	755	0.508 ± 0.03	1.131 ± 0.254	1.89 ± 0.44	1.44 ± 0.34	2.16 ± 0.5	1.39 ± 0.32
T8 8824	950	0.543 ± 0.017	1.29 ± 0.123	1.75 ± 0.18	1.45 ± 0.15	1.93 ± 0.19	1.43 ± 0.15
T7A 6877	487	0.436 ± 0.02	1.032 ± 0.103	1.81 ± 0.2	1.87 ± 0.21	2.22 ± 0.24	1.78 ± 0.2
T3 B1-14	532	0.514 ± 0.041	1.493 ± 0.072	1.38 ± 0.13	1.99 ± 0.19	1.57 ± 0.15	2.03 ± 0.2
T3 B1-197	642	0.76 ± 0.062	2.082 ± 0.098	1.39 ± 0.13	1.17 ± 0.11	1.52 ± 0.14	1.17 ± 0.11
T3 B1-337	855	0.429 ± 0.034	1.236 ± 0.051	1.43 ± 0.13	2.44 ± 0.23	1.59 ± 0.14	2.47 ± 0.23

*All depths obtained from individual trench datums were standardized by reference to a common stratigraphic datum coinciding with the highest point at the site. Density of materials is 2.2 g·cm^{-3}. †Measurement uncertainties are restricted here to analytical uncertainties within 1 SD. ‡Minimum and maximum ages are calculated following (*11*). The minimum burial age calculations are based on the stratigraphic and geomorphic evidence that the samples were deeply buried in the past but were recently brought nearer the surface by erosion of the topsoil. Maximum burial ages account for postburial production of ^{10}Be and ^{26}Al by muons. In the latter case, denudation is considered constant before and after burial. Burial-age uncertainties (±1σ) include systematic errors in half-lives. Spallation productions are 2.88 and 19.03 at·g^{-1}·year^{-1} for ^{10}Be and ^{26}Al, respectively. Likewise, slow and fast muon contributions are 0.07 (^{10}Be) and 0.46 (^{26}Al) at·g^{-1}·year^{-1} and 0.03 (^{10}Be) and 0.20 (^{26}Al) at·g^{-1}·year^{-1}, respectively. §Calculated background denudation rates are maximum rates. The low values obtained are consistent with the low-elevation, low-relief topographic setting close to oceanic base level. Further, the fact that ^{10}Be concentrations among artifacts are statistically similar (see SOM text) suggests that the clasts share similar preburial exposure histories, implying that hominins exploited surface scatters of raw material clasts.

Because they are quartzite, the artifacts were amenable to cosmic-ray exposure dating. This technique is based on the accumulation in quartz exposed at Earth's surface of rare nuclides produced by neutrons and muons through nuclear reactions induced by high-energy cosmic radiation. Sediment depositional histories can be revealed by using pairs of radioactive cosmogenic nuclides and exploiting their respective half-lives (*11*). Here, we use ^{10}Be [$T_{1/2}$ = 1.387 ± 0.012 million years (My)] and ^{26}Al ($T_{1/2}$ = 0.717 ± 0.017 My) to date the burial of six quartzite artifacts from layers 6 and 8 (fig. S1). During exposure at the surface, ^{26}Al/^{10}Be ratios vary between ~3.5 and ~7.1, depending on exposure time and local denudation. Given that, before artifact production and burial at the site, hominins initially collected source materials with similar preburial surface exposure histories from the surrounding landscape, the measurement of ^{26}Al/^{10}Be concentration ratios within artifacts will determine their burial age. This approach can be applied to artifacts from Pleistocene archeological sites that were rapidly buried to depths exceeding 5 to 10 m (*12*) or to older samples in cave sites where production is instantaneously halted by complete shielding from cosmic radiation (*13*). At Attirampakkam, however, comparatively shallow burial (Table 1) may have failed to interrupt production entirely. The measured nuclide concentrations, therefore, are the sum of the inherited nuclides at the time of deposition, corrected for radioactive decay, and of the concentration produced at a constant depth since burial (*11*). Depending on the model used for depth-dependent nuclide production by muons, results provide age brackets ranging from a minimum burial-age estimate with a weighted sample mean of 1.51 ± 0.07 Ma (see SOM text) to a maximum burial-age estimate with a weighted mean of 1.68 ± 0.07 Ma

(Fig. 3 and Table 1). Given that physical knowledge of the muonic contribution to in situ nuclide production is currently debated (table S1)—and also that Acheulian sites in Africa, southwest Asia, and Pakistan are around or younger than 1.6 Ma (*1*, *12*, *14*–*17*)—we consider the more conservative minimum burial ages (Fig. 3) to be more likely.

These minimum ages are corroborated by results from a continuous paleomagnetic profile involving 49 samples collected down the 9-m stratigraphic section of trench T8. Stereographic projections (fig. S2) of the natural remanent magnetization and its stepwise alternating field and thermal demagnetization reveal two components: (i) a relatively stable upward vertical component (negative inclinations), suggesting that the primary magnetization was acquired in a reverse polarity field, but also (ii) highly unstable horizontal components starting from the northern quadrant, thus compatible with a normal polarity declination, then turning during treatments to the western quadrant. This results in a very coherent and systematic distribution of magnetizations along great circles ending in the southern quadrant. This north-south shift observed for most of the measured samples is interpreted to result from an overprint of the reverse polarity primary magnetization, itself of depositional origin, by a secondary magnetization that was acquired in a normal polarity field. This overprint is likely to be a chemical remanent magnetization, its chemical origin being supported by sample resistance to both alternating field and thermal treatments as well as by the deeply weathered state of the sediment. Such an interpretation suggests that the sediment sequence was deposited before the normal Brunhes chron; that is, before 0.78 Ma (*18*). Given the cosmogenic burial ages and the nature of the Acheulian assemblage (fig. S3 and S4 and table S2), we correlate the reverse polarity with the Matuyama chron and place it between the base of the Jaramillo (1.07 Ma) and top of the Olduvai (1.77 Ma) normal subchrons, neither of which are detected (Fig. 3). Considered together, the cosmogenic and paleomagnetic results indicate that Acheulian hominins were present in south India before 1.07 Ma.

These ages are contemporary with some other Lower Pleistocene Acheulian sites in Africa and southwest Asia. The earliest known dates for the Acheulian (~1.6 to 1.4 Ma) are from East Africa (*14*, *15*). Early Acheulian sites in South Africa have also yielded an age of ~1.6 Ma (*12*), suggesting rapid and widespread dispersal of this technology across Africa. Closer to India, the age of the Acheulian at ´Ubeidiya (Israel) is estimated at ~1.4 Ma (*16*), and the sequence at Gesher Benot Ya'aqov was formed between 0.7 and 0.8 Ma (*17*). In the Bose basin, China, Acheulian-like bifaces date back to ~0.8 Ma (*19*). In South Asia, there is at present little unequivocal evidence for a pre-Acheulian Early Pleistocene occupation, barring ages of ~2 Ma attributed to artifacts from Riwat (*20*) and of 2.2 to 0.9 Ma from the Pabbi Hills, Pakistan (*21*). Estimated ages for the Acheulian near Potwar, Pakistan, are 0.4 to 0.7 Ma (*22*). Sparse radiometric ages from sites in India have situated the Acheulian within the Middle Pleistocene, with a few dates suggesting an early Middle to Early Pleistocene age. However, these ages often exceed the limits of confidence of the methods used (*2*). They include an electron spin resonance (ESR) mean age of 1.27 ± 0.17 Ma, assuming linear U uptake, on two herbivore teeth from Isampur (*23*); an ESR age of ~0.8 Ma (lacking uncertainty envelopes) on calcrete from the Amarpura formation, Rajasthan (*24*), which has been correlated with the Acheulian site of Singi Talav (*4*); dates ranging from ~1.4 to 0.67 Ma for the tephra at Bori (Kukdi river) (*25*); and paleomagnetic measurements with evidence of reversals at the sites of Bori, Morgaon, Gandhigram, Andora, and Nevasa (*26*). However, the reliability of these ages has, in each case, been questioned on various grounds (*5*, *27*, *28*). Likewise, the age and stratigraphic position of artifacts and faunal remains from the Early Pleistocene Dhansi formation along the river Narmada are yet to be firmly established (*29*). Based on data from controlled excavations and two independent dating methods, our ages from Attirampakkam show that the Acheulian in India is older than previously thought. Evidence from other sites in South Asia should be reconsidered and redated.

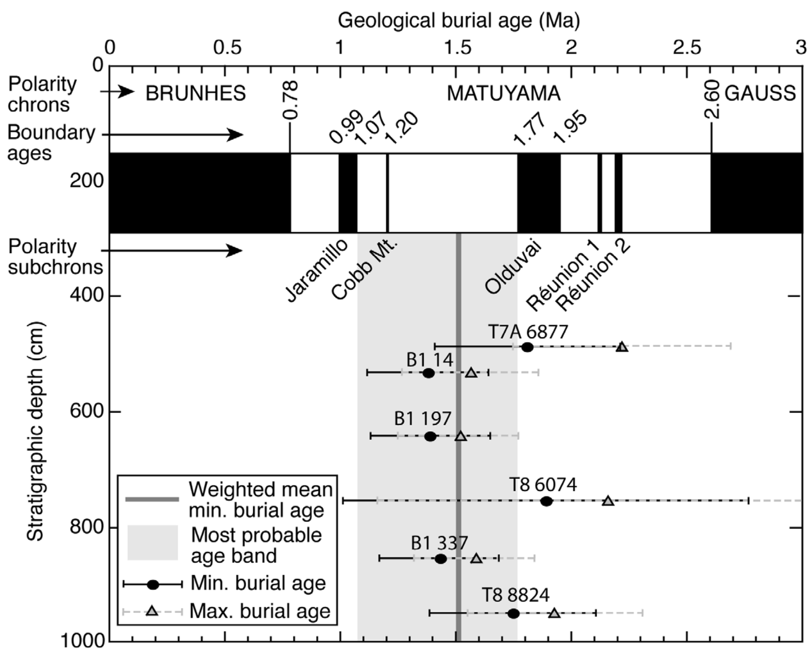

Fig. 3. Age constraints on artifact burial stratigraphy at Attirampakkam. Samples are from three separate trenches (T3, T8, and T7A) with a common reference datum representing the top of the sedimentary sequence, which is preserved near the site but was partly eroded at the site because of land-use practices and other factors (Fig. 1; see SOM). Error bars are ±2 SD; that is, there is only a 5% chance that the true age falls outside that range. Note that the Cobb Mt. subchron would have been undetectable at the sampling resolution applied.

References and Notes

1. R. Dennell, *The Palaeolithic Settlement of Asia* (Cambridge Univ. Press, Cambridge, 2009).
2. S. Mishra, *Curr. Anthropol.* **33**, 325 (1992).
3. M. D. Petraglia, B. Allchin, in *The Evolution and History of Human Populations in South Asia*, M. D. Petraglia, B. Allchin, Eds. (Springer, New York, 2007), pp. 1–20.
4. C. Gaillard, S. Mishra, M. Singh, S. Deo, R. Abbas, *Quat. Int.* **223–224**, 234 (2010).
5. P. R. Chauhan, *Quat. Int.* **223–224**, 248 (2010).
6. Y. Gunnell, C. Rajshekhar, S. Pappu, M. Taieb, A. Kumar, *Curr. Sci.* **91**, 114 (2006).
7. S. Pappu, Y. Gunnell, M. Taieb, J.-P. Brugal, Y. Touchard, *Curr. Anthropol.* **44**, 591 (2003).
8. S. Pappu, Y. Gunnell, M. Taieb, A. Kumar, *Man and Environment* **29**, 1 (2004); www.sharmaheritage.com.
9. S. Pappu, A. Kumar, in *Axe age. Acheulian Tool-Making from Quarry to Discard*, N. Goren-Inbar, G. Sharon, Eds. (Equinox, London, 2006), pp. 155–180.
10. S. Pappu, *A Re-Examination of the Palaeolithic Archaeological Record of Northern Tamil Nadu, South India* [British Archaeological Reports (BAR) International Series 1003, John and Erica Hedges, Oxford, 2001].
11. D. E. Granger, P. F. Muzikar, *Earth Planet. Sci. Lett.* **188**, 269 (2001).
12. R. J. Gibbon, D. E. Granger, K. Kuman, T. C. Partridge, *J. Hum. Evol.* **56**, 152 (2009).
13. G. Shen, X. Gao, B. Gao, D. E. Granger, *Nature* **458**, 198 (2009).
14. B. Asfaw *et al.*, *Nature* **360**, 732 (1992).
15. I. de la Torre, R. Mora, J. Martínez-Moreno, *J. Anthropol. Archaeol.* **27**, 244 (2008).
16. O. Bar-Yosef, N. Goren-Inbar, *The Lithic Assemblages of 'Ubeidiya: A Lower Palaeolithic Site in the Jordan Valley* (Hebrew Univ. of Jerusalem, Jerusalem, 1993).
17. N. Goren-Inbar *et al.*, *Science* **289**, 944 (2000).
18. S. C. Cande, D. V. Kent, *J. Geophys. Res.* **100**, 6093 (1995).
19. H. Yamei *et al.*, *Science* **287**, 1622 (2000).
20. R. W. Dennell, H. M. Rendell, E. Hailwood, *Curr. Anthropol.* **29**, 495 (1988).
21. R. W. Dennell, *Early Hominin Landscapes in Northern Pakistan: Investigations in the Pabbi Hills* (BAR International Series 1265, Archaeopress, Oxford, 2004).
22. H. Rendell, R. W. Dennell, *Curr. Anthropol.* **26**, 393 (1985).
23. K. Paddayya *et al.*, *Curr. Sci.* **83**, 641 (2002).

24. A. J. Kailath et al., *Radiat. Meas.* **32**, 371 (2000).
25. S. Mishra, T. R. Venkatesan, S. N. Rajaguru, B. L. K. Somayajulu, *Curr. Anthropol.* **36**, 847 (1995).
26. S. J. Sangode, S. Mishra, S. Naik, S. Deo, *Gondwana Geol. Mag. Spec. Vol.* **10** (2007), p. 111.
27. S. K. Acharyya, *Curr. Sci.* **84**, 127 (2003).
28. J. A. Westgate et al., *Quat. Res.* **50**, 107 (1998).
29. R. Patnaik et al., *J. Hum. Evol.* **56**, 114 (2009).
30. Excavations at Attirampakkam were funded by the Homi Bhabha Fellowships Council, the Leakey Foundation, the Earthwatch Institute, and the Sharma Centre for Heritage Education. Ongoing studies are being funded by the Indian Space Research Organisation, Regional Remote Sensing Centre, Bengaluru, (Geosphere Biosphere Program). We thank Uday Raj, S. Ravindranath, C. B. S. Dutt, P. G. Diwakar, and R. Ramesh. We also thank the Archaeological Survey of India, Delhi and Chennai Circle, and the Department of Archaeology, State Government of Tamil Nadu, for licenses to excavate and support; the Institut Universitaire de France for field and analytical costs; M. Arnold and G. Aumaître for assistance with ^{10}Be and ^{26}Al measurements; and the ASTER (Accélérateur pour les Sciences de la Terre, Environnement, Risques) national facility (CEREGE, Aix-en-Provence), which is supported by the Institut National des Sciences de l'Univers/CNRS, the French Ministry of Research, the Institut de Recherche pour le Développement, and the Commissariat à l'Énergie Atomique. All three reviewers contributed valuable comments.

Supporting Online Material
www.sciencemag.org/cgi/content/full/331/6024/1596/DC1
SOM Text
Figs. S1 to S4
Tables S1 and S2
References

8 November 2010; accepted 2 February 2011
10.1126/science.1200183

The Buttermilk Creek Complex and the Origins of Clovis at the Debra L. Friedkin Site, Texas

Michael R. Waters,[1]* Steven L. Forman,[2] Thomas A. Jennings,[3] Lee C. Nordt,[4] Steven G. Driese,[4] Joshua M. Feinberg,[5] Joshua L. Keene,[3] Jessi Halligan,[3] Anna Lindquist,[5] James Pierson,[2] Charles T. Hallmark,[6] Michael B. Collins,[7] James E. Wiederhold[3]

Compelling archaeological evidence of an occupation older than Clovis (~12.8 to 13.1 thousand years ago) in North America is present at only a few sites, and the stone tool assemblages from these sites are small and varied. The Debra L. Friedkin site, Texas, contains an assemblage of 15,528 artifacts that define the Buttermilk Creek Complex, which stratigraphically underlies a Clovis assemblage and dates between ~13.2 and 15.5 thousand years ago. The Buttermilk Creek Complex confirms the emerging view that people occupied the Americas before Clovis and provides a large artifact assemblage to explore Clovis origins.

Nearly 80 years ago, Clovis was identified as the oldest archaeological horizon in North America [~12.8 to 13.1 thousand years ago (ka)]. Decades of subsequent research have advanced our understanding of Clovis chronology, adaptations, and technological organization (*1*–*3*). Whereas genetic studies indicate that the first Americans hailed from northeast Asia (*1*), no fluted Clovis points or other diagnostic characteristics of Clovis have been identified there (*4*). Additionally, fluted points in Alaska are rare, are technologically different, and postdate Clovis (*5*, *6*). These lines of evidence suggest that, although the ultimate ancestors of Clovis originated from northeast Asia (*1*), important technological developments, including the invention

[1]Center for the Study of the First Americans, Departments of Anthropology and Geography, Texas A&M University, 4352 TAMU, College Station, TX 77843–4352, USA. [2]Luminescence Dating Research Laboratory, Department of Earth and Environmental Sciences, 845 West Taylor Street (m/c 186), University of Illinois, Chicago, IL 60607–7059, USA. [3]Center for the Study of the First Americans, Department of Anthropology, Texas A&M University, 4352 TAMU, College Station, TX 77843–4352, USA. [4]Department of Geology, Baylor University, One Bear Place no. 97354, Waco, TX 76798–7354, USA. [5]Department of Geology and Geophysics, Institute for Rock Magnetism, University of Minnesota, Minneapolis, MN 55455–0219, USA. [6]Department of Soil and Crop Science, 2474 TAMU, Texas A&M University, College Station, TX 77843–2474, USA. [7]Department of Anthropology, Texas State University, 232 Evans Liberal Arts, San Marcos, TX 78666, USA.

*To whom correspondence should be addressed. E-mail: mwaters@tamu.edu

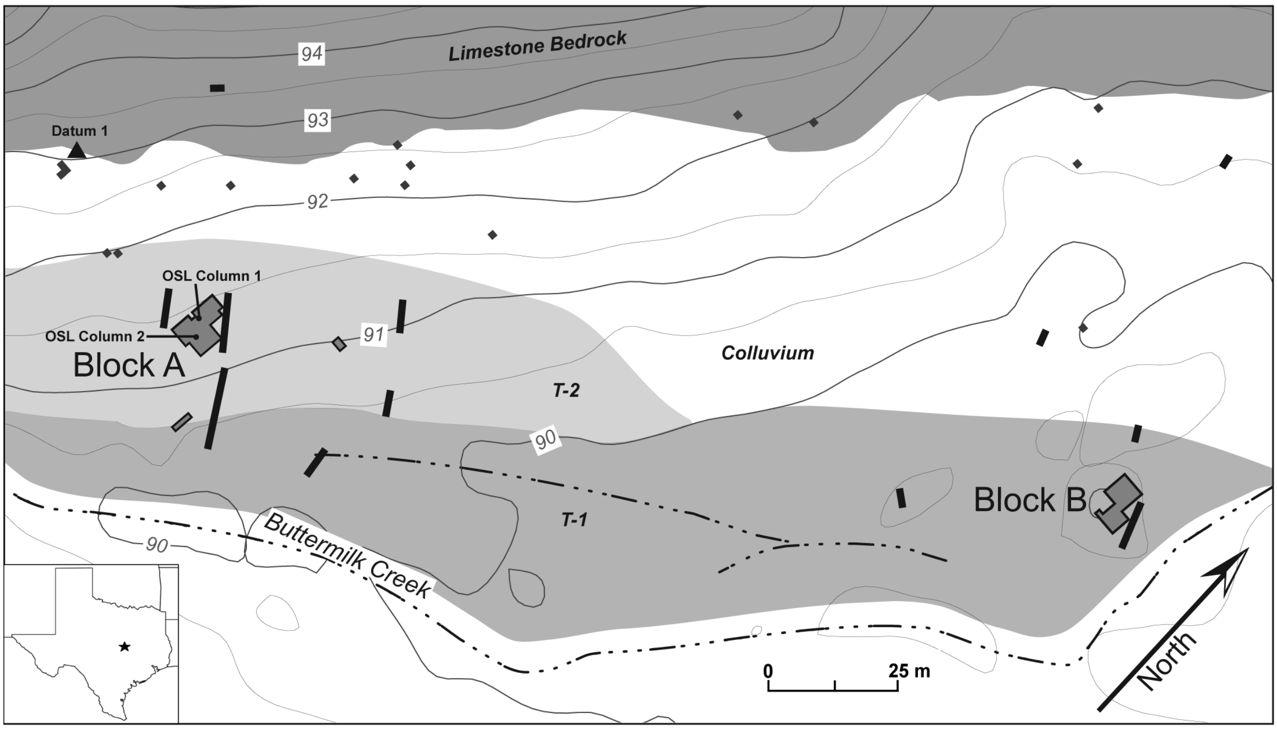

Fig. 1. Geomorphic surfaces and excavation areas and trenches (black rectangles and squares) at the Friedkin site.