

Human (Clovis)–gomphothere (*Cuvieronius* sp.) association ~13,390 calibrated yBP in Sonora, Mexico

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The earliest known foragers to populate most of North America south of the glaciers [$\sim 11,500$ to $\geq \sim 10,800$ ^{14}C yBP; $\sim 13,300$ to $\sim 12,800$ calibrated (Cal) years] made distinctive “Clovis” artifacts. They are stereotypically characterized as hunters of Pleistocene megamammals (mostly mammoth) who entered the continent via Beringia and an ice-free corridor in Canada. The origins of Clovis technology are unclear, however, with no obvious evidence of a predecessor to the north. Here we present evidence for Clovis hunting and habitation $\sim 11,550$ yBP ($\sim 13,390$ Cal years) at “El Fin del Mundo,” an archaeological site in Sonora, northwestern Mexico. The site also includes the first evidence to our knowledge for gomphothere (*Cuvieronius* sp.) as Clovis prey, otherwise unknown in the North American archaeological record and terminal Pleistocene paleontological record. These data (i) broaden the age and geographic range for Clovis, establishing El Fin del Mundo as one of the oldest and southernmost in situ Clovis sites, supporting the hypothesis that Clovis had its origins well south of the gateways into the continent, and (ii) expand the make-up of the North American megafauna community just before extinction.

Paleoindian | proboscidean

Clovis is the oldest well-established archaeological technocomplex in North America and is documented across much of the continent. The fundamental characteristics of this earliest well-defined foraging group to occupy North America south of the glaciers remain unclear, however. The timing of their appearance, the geographical origins of their distinctive Clovis projectile points, and their subsistence base, are the subject of continued debate (1–5). Archaeological excavations at El Fin del Mundo in northwestern Mexico (Fig. 1) provide new data and insights for all of these issues.

In situ Clovis sites are known primarily from the Great Plains and southeastern Arizona (3). The latter represents the densest concentration of in situ Clovis sites, with four Clovis–mammoth sites along a 20-km reach of the upper San Pedro River and two other Clovis sites in the same area with probable mammoth associations (Fig. 1) (6). In 2007, following reports from a local rancher, we discovered Clovis artifacts and Proboscidean remains eroding from an arroyo wall at El Fin del Mundo. Excavations and surveys during 2007–2012 documented Clovis artifacts in association with the remains of two gomphotheres, a Clovis camp on the surface of the surrounding uplands, and nearby sources of raw material for manufacture of stone tools. This paper focuses on the Clovis–gomphothere bone bed, to our knowledge the first in situ Clovis finds reported south of the international border.

El Fin del Mundo is located in an intermontane basin within a chain of volcanic hills in the Sonoran Desert ~ 100 km northwest of Hermosillo, in the Mexican state of Sonora (Fig. 1). The site is exposed by an arroyo system along the distal edge of a large bajada composed of Pleistocene and older basin fill. The drainage is part of the Rio Bacoachi. Dissection left the local basin fill

exposed in head cuts and in a series of erosional islands (Fig. 1). The bone bed, artifacts, and their containing strata are associated with only one of these islands (locality 1) (Fig. 1 and *SI Appendix, Site Stratigraphy and Formation Processes* and Fig. S1). Locality 1 is isolated from and stratigraphically different from all other exposures in the area. Geomorphic and stratigraphic relations, therefore, cannot be fully reconstructed across the site.

Results

In locality 1, three strata (2–4, bottom to top) were identified (described in *SI Appendix, Site Stratigraphy and Formation Processes* and Tables S1 and S2), resting on the local bedrock (Fig. 2 and *SI Appendix, Site Stratigraphy and Formation Processes* and Fig. S2). Strata 3 and 4 filled a channel of unknown width (but < 100 m; *SI Appendix, Site Stratigraphy and Formation Processes*) and length cut into stratum 2. Stratum 2 is up to 3 m thick and is composed of pebbly sandy clay fining upward into a sandy clay with well-expressed (Bt-Bk soil horizonation) soil in the upper ~ 1.0 m (“Big Red” in Fig. 2, *SI Appendix, Site Stratigraphy and Formation Processes* and Table S2). Where not incised, exposures of stratum 2 are locally buried by late Pleistocene and Holocene seep or spring carbonates (Fig. 2 and *SI Appendix, Site Stratigraphy and Formation Processes*, Fig. S4, and Table S2).

Stratum 3 is composed of unbedded, poorly sorted pebbly sandy clay up to 1 m thick (3A) overlain by a poorly sorted sandy

Significance

Archaeological evidence from Sonora, Mexico, indicates that the earliest widespread and recognizable group of hunter-gatherers (“Clovis”) were in place $\sim 13,390$ y ago in southwestern North America. This is the earliest well-documented population on the continent and suggests that the unique Clovis artifact style originated in the southwest or south central part of the continent, well south of the Arctic gateways into the continent. These hunters targeted gomphotheres, an elephant common in south and central North America, but unknown in association with humans or at this late age in North America.

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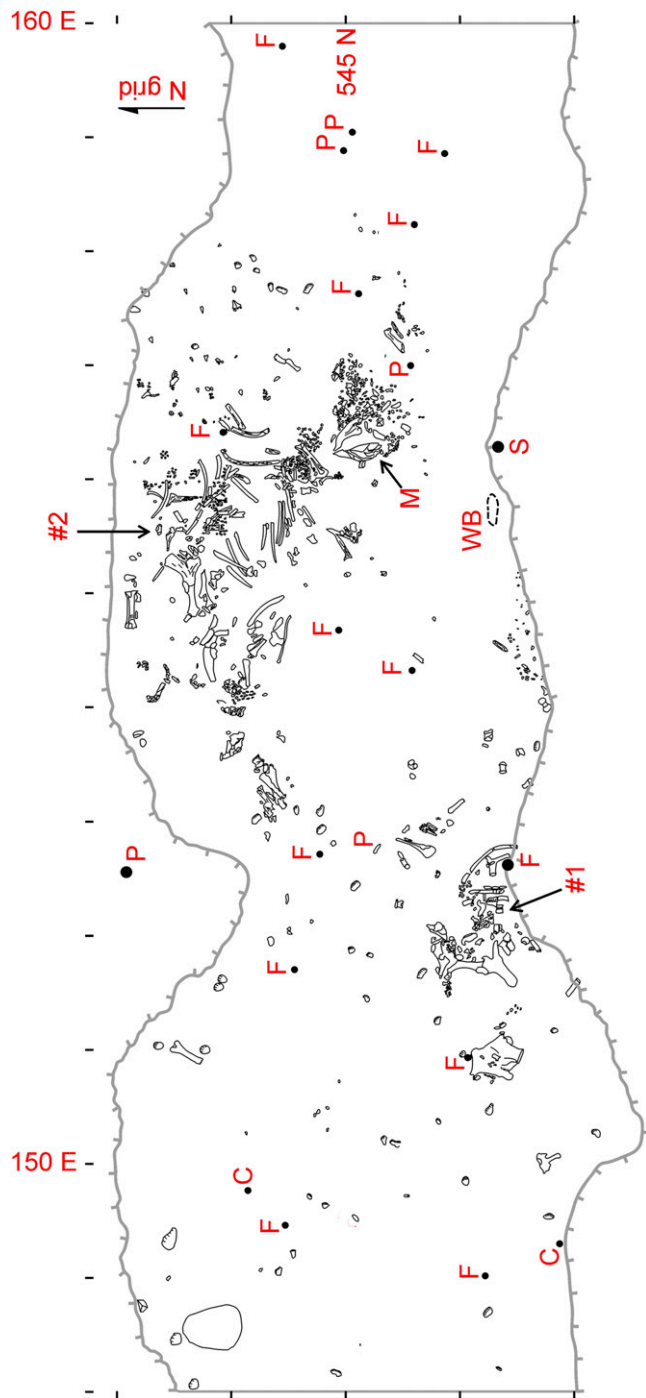


Fig. 3. The upper bone bed in locality 1, showing bone concentrations 1 (#1) and 2 (#2), and highlighting the mandible (M). Also shown are key archaeological finds recovered in situ: C, charcoal; F, flake; P, projectile point; WB, worked bone with incised V.

Fig. S7C). Its proximal margin exhibits a snap break of the type commonly seen in impact fractures. It retains no basal margins, including any of the ground portions that would have been within the haft. The fourth in situ Clovis point (no. 63008) is complete (Fig. 4F and *SI Appendix, Fig. S7D*). One margin displays some evidence of slight reworking in the form of random invasive pressure flaking along both margins.

Three complete Clovis points and three stone tools were recovered from disturbed contexts (Fig. 4A–C and *SI Appendix, Fig.*

S8 and Table S3). A clear quartz point (no. 58342) (Fig. 4C and *SI Appendix, Fig. S8A*) was found ~1.0 m from gomphothere no. 2 at the same elevation (*SI Appendix, Table S6*). At the east end of locality 1, in an area heavily mixed by mammal burrowing, a point (no. 59569) (Fig. 4B and *SI Appendix, Fig. S8B*) was recovered from a krotovina. Another Clovis point was found on the surface ~8.0 m southeast of locality 1 (no. 46023) (Fig. 4A and *SI Appendix, Fig. S8C*). The scraper (no. 45980) that fell out of the bone bed just before site discovery (*SI Appendix, Fig. S11*) shows unifacial retouch scars on both margins (*SI Appendix, Fig. S9 A and E*). Found nearby was the distal fragment of a biface (no. 46021) (*SI Appendix, Fig. S9 B and D*) and a midsection made of quartz with epidote inclusions (no. 46022) (*SI Appendix, Fig. S9C*).

Twenty-one flakes (12 flakes in situ and 9 in screening) and some modified bone were recovered from the feature. The flakes are both fine retouch flakes and bifacial thinning flakes that were probably obtained in the process of resharpening butchering tools. The flakes range in size from 32.4 to 4.0 mm. Most were found in the same level as and directly associated with the bone concentrations and adjacent areas, and among charcoal concentrations (Fig. 3 and *SI Appendix, Table S6 and Figs. S14 and S15*). The raw material of the flakes is the same type of stone used for points and tools found at locality 1 and the upland campsite. Flake no. 63448 was made of rhyolite identical to Clovis point no. 63177 and within 30 cm of dated charcoal (*SI Appendix, Fig. S15*). Two flakes of clear quartz were also recovered. Modified bone includes a burned bone and two bone ornaments, all recovered in an area between the two bone concentrations (Fig. 3).



Fig. 4. Artifacts from locality 1: out-of-context points A (46023), B (59569), C (59342); points found in the bone bed: D (63177), E (63008), and F (62943); and rounded and incised bone G (59892).



Fig. 5. Reverse sides (A'–F') of points in A–F from Fig. 4.

Both ornaments are rounded and polished. One (no. 59892) has two incisions in a V shape (Fig. 4G).

Most of the raw material for stone tools is probably local. Chert is common in channel gravels in the area. Clear quartz crops out in a hill ~5 km west of the site. Rhyolite is exposed in locality 22 on the site uplands (Fig. 1) and is also common in the volcanic hills surrounding the basin.

The upper bone bed includes remains identifiable as proboscidean (Gomphotheridae). The bone was found in two concentrations, both partly removed by the erosion that formed the locality 1 “island.” The two concentrations represent two individuals. Concentration no. 1 is a subadult (13–24 y, *sensu* ref. 13) with astragali, phalanges, and metapodials showing fused epiphyses. Other bones from no. 1 include vertebrae, long bones, a complete pelvis with both ilia present, and intact ischia and acetabulums, and foot bones. The remains in concentration no. 2 are from a younger (0–12 y old) individual, based on molar eruption, and also on bones that do not have fused epiphyses and diaphyses on the vertebrae centrum. Concentration no. 2 includes a mandible and a few molar fragments, pelvis, ribs, vertebra, scapula, and cranial fragments. Presence of two premolars and first molar (m1) in the mandible and their stage of wear indicate that this animal could be around 11 y old. The molars show the bunodont pattern

characteristic of gomphotheres (Fig. 6). The m1 is identifiable as a brevirostrine taxon, *Cuvieronius* sp. The mandible has both rami damaged on the coronoid processes. Individual no. 1 is an unidentified proboscidean roughly the same size and age as individual no. 2. Those characteristics and the proximity of the two bone concentrations suggest that no. 1 is likely another gomphothere.

Strong weathering of the gomphothere remains is illustrated by the heavily pitted, checkered, and fibrous surfaces, along with desiccation cracks and exfoliation. Some bones show carnivore tooth punctures, furrowing, and trampling marks. Weathering of the bone has so far precluded recognition or identification of cut marks or other human modification beyond the two small bone ornaments.

Discussion

Artifacts found in association with the bones and at the same level in adjacent areas provide strong evidence that human hunters likely created the feature. The random (nonanatomical) position of the bone in two distinct piles suggests human action. Clovis projectile points are hunting weapons and were likely used as such at El Fin del Mundo. Three of the four points are complete, but the fourth is missing its base due to an impact-related snap. This contrasts to the basal point fragments common in the upland camp (SI Appendix, Fig. S12). This pattern of the distribution of complete points and basal fragments is similar to that reported from other Paleoindian kills and camps (6, 14–16).

The base of the bone in the two concentrations is ~10–15 cm below the top of stratum 3B and the depth range of most artifacts and bone is within ~15 cm of the top (SI Appendix, Fig. S5 and Tables S5 and S6), suggesting that the bone bed was created as upper 3B was aggrading. The vertical distribution of the artifacts and bone and teeth fragments suggests some mixing. The butchering activity and bone piles could have started on top of 3B under muddy conditions and become mixed by gravity



Fig. 6. The mandible from bone concentration 2, showing the molars characteristic of *Cuvieronius* sp. The molars have rounded cusps and are trilophodont with internal lophids simpler than external ones.

settling, humans, or perhaps other animals walking through the mud, cracking, or some combination of all of these processes.

Numerical age control for the upper bone bed and encasing deposits was established using radiocarbon dating (Fig. 2 and *SI Appendix, Radiocarbon Dating and Table S8*). Charcoal flecks found among and at the same level as the stone flakes (*SI Appendix, Figs. S14 and S15*) and the burned bone fragment at the west end of the feature (Fig. 3) provided radiocarbon dates of $11,550 \pm 60$ ^{14}C yBP on one piece of clean charcoal and $11,880 \pm 200$ ^{14}C yBP on humates extracted from another piece (*SI Appendix, Radiocarbon Dating and Table S8*). The charcoal date of $\sim 11,550$ is probably the best approximation of the age of the feature, or $13,390 +105/-119$ Cal yBP, because humates can include contaminants (*SI Appendix, Radiocarbon Dating*).

Stratum 3 and the exposed bone must have been buried relatively quickly under the diatomite of stratum 4 to preserve some of the bone. The age range of the diatomite is unknown, but the oldest charcoal date among flecks scattered across an erosion contact at the top is $\sim 9,715$ ^{14}C yBP ($11,136 +109/-344$) (Fig. 2 and *SI Appendix, Fig. S2 and Table S8*). The rest of stratum 4 accumulated relatively rapidly; shell at the top of the sequence was dated to $\sim 8,870$ ^{14}C yBP ($9,993 +191/-255$ Cal yBP) (Fig. 2 and *SI Appendix, Radiocarbon Dating and Table S6*).

El Fin del Mundo provides strong evidence for the association of Clovis hunters with gomphotheres (*Cuvieronius* sp.). Evidence for prolonged or repeated use of the area or both is indicated by the extensive camp (the subject of continuing research), found in an arc 500–1,000 m around locus 1 on the stable uplands to the southeast, south, and southwest, where 13 Clovis points (two heavily reworked; most of the rest point bases) (*SI Appendix, Artifacts from the Surface of the Upland Camp, Table S4, and Fig. S12*), 25 point preforms, 38 end scrapers, 39 large blades, and 7 blade cores and core tablets were recovered from among an extensive surface lithic scatter (*SI Appendix, Fig. S13*). The only comparable Clovis site with both a megafauna kill and adjacent upland occupation is Murray Springs, AZ, ~ 250 km to the northeast (Fig. 1) (3).

Clovis is classically associated with late Pleistocene megafauna, especially the proboscideans mammoth and mastodon, but also bison and horse. The research results presented here add another species of proboscidean to the menu of animals hunted and consumed by Clovis foragers. Evidence for hunting of *Cuvieronius* (as opposed to scavenging) is based on the presence of projectiles (Clovis points) among the bone, including one that likely snapped while hafted (no. 62942) (*SI Appendix, Fig. S7C*). Further, the likelihood of two juvenile gomphotheres dying together and then scavenged by Clovis foragers whose tools end up near the base of the bone bed seems quite remote.

The age of the bone bed at $\sim 11,550$ ^{14}C BP is at the oldest end of the known age range for Clovis in North America. The date is not unique, however. The Aubrey Clovis site in north Texas yielded two similar dates: $11,540 \pm 110$ and $11,590 \pm 90$ ^{14}C yBP, averaging $\sim 11,565$ ^{14}C yBP (17). The Gault–Friedkin complex in central Texas may also be about the same age but the dating there has less precision (4, 18, 19).

Jennings and Waters (4) based on their work at Gault–Friedkin, suggest that Clovis may have its origins in the southern part of the continent, rather than in proximity to the “Ice Free Corridor” from Beringia, south through modern Canada, and

into the midcontinent. Hamilton and Buchanan (20), based on a statistical analysis of Clovis radiocarbon dates propose that Clovis originated in the northern Great Plains, near the mouth of the Ice Free Corridor and rapidly spread across North America, quantifying decades of speculation. However, their data come from Waters and Stafford (1) who rejected Aubrey as a dated Clovis site. Many archaeologists took exception to their interpretation of Aubrey (2). By including Aubrey and now El Fin del Mundo in the corpus of dated Clovis sites raises the possibility that Clovis originated in the south. If it did not, then Clovis is even older than $\sim 11,550$ ^{14}C yBP.

The dating also provides the youngest numerical age control for gomphotheres in general and *Cuvieronius* in particular in North America, indicating that they too were part of the Rancholabrean Land Mammal assemblage and the late Pleistocene fauna that became extinct in North America at or just before the beginning of the Younger Dryas Chronozone.

Cuvieronius is known from the southern United States, central and southern México, and across Central and South America (21–25). Besides El Fin del Mundo, numerical age control for this genus in North America is available only from a site in northeast Sonora ($\sim 43,000$ – $40,000$ yBP) (26, 27). In western Mexico a gomphothere *Stegomastodon* is dated to $\sim 27,000$ yBP (28). An association of stone tools with gomphotheres is reported from Valsequillo (Puebla, Mexico), but the association is not confirmed (29). In South America, however, gomphotheres in archaeological contexts are well documented (30) although only a few are *Cuvieronius* (31).

El Fin del Mundo is the only human–gomphothere association in North America. It is also one of the oldest Clovis sites and youngest gomphothere sites on the continent and a rare example of *Cuvieronius* in the post-Last Glacial Maximum late Pleistocene. The kill represents a short-term event, but an extensive and varied stone tool inventory on adjacent uplands is indicative of longer-term occupation. The raw materials for the stone artifacts indicate relatively local procurement, typical of other Clovis sites in the region (32, 33) but atypical of Clovis sites in other parts of North America (34, 35). These data expand our understanding of the age range for Clovis, Clovis diet, raw material preference, and the late Pleistocene megafaunal assemblage of North America, and provide evidence for a southern origin of the Clovis technocomplex.

Materials and Methods

Archaeological field methods are discussed in *SI Appendix, Excavation Procedures*. Excavations were based on a standard metric grid and some water screening of excavated matrix. Geologic investigations included mapping outcrops, stratigraphic description and mapping, and collecting and analyzing thin section samples under a petrographic microscope. Radiocarbon ages from El Fin del Mundo were determined on charcoal, shell, and organic matter in sediment at the Arizona Accelerator Mass Spectrometry Laboratory (*SI Appendix, Radiocarbon Dating*). Calibrated radiocarbon ages (Cal BP) are given as the 2σ range and median probability of possible calendar year ages, following Calib 7.0 available at <http://calib.qub.ac.uk/calib/>.

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