Contesting early archaeology in California

ARISING FROM S. R. Holen *et al. Nature* **544,** 479–483 (2017); doi:10.1038/nature22065

The peopling of the Americas is a topic of ongoing scientific interest and rigorous debate[1,2]. Holen *et al.*[3] add to these discussions with their recent report of a 130,000-year-old archaeological site in southern California, USA: the Cerutti Mastodon (CM) site, which includes the fragmentary remains of a single mastodon (*Mammut americanum*), spatially associated stone cobbles, and associated lithic debris that they claim indicates prehistoric hominin activity. In sharp contrast, we contend that the CM record is more parsimoniously explained as the result of common geological and taphonomic processes, and does not indicate prehistoric hominin involvement. Whereas further investigations may yet identify unambiguous evidence of hominins in California around 130,000 years ago, we urge caution in interpreting the current record. There is a Reply to this Comment by Holen, S. R. *et al. Nature* **554,** http://dx.doi.org/10.1038/nature25166 (2018).

Holen *et al.*[3] claim prehistoric hominin involvement at the CM site based primarily on four lines of evidence: a reliable radiometric age; the presence of stone artefacts; clear evidence of tool-imparted percussion damage to the remains of the mastodon; and an undisturbed geological context. We take no issue with the published age for the site, but we believe that the latter three claims warrant further examination.

The CM site stone artefacts are an assortment of cobbles and fractured cobble fragments excavated from a sandy silt matrix. There is no evidence of formal stone tool forms or diagnostic lithic micro- or macro-debitage. Instead, the CM site artefacts are identified by their proximity to the remains of the mastodon and their large size relative to the enveloping sediment. Additionally, surface features such as the presence of pitting and scratching on cobble surfaces, the presence of several cobble fragments with fracture morphologies reminiscent of hammerstone and/or anvil usage, and the presence of several refitting cobble fragments are interpreted as evidence of hominin percussive activities on-site. The lack of discarded formal tools and diagnostic lithic debitage is noteworthy, and is unusual relative to most archaeological assemblages that purport hominin processing of proboscidean remains (although see Haynes[4]). We also note that upslope of the site there are numerous alluvial fans, with clastic material a common occurrence. The cobbles and pebbles at the CM site can be derived from modest alluvial fan input with fines subsequently winnowed with lower energy fluvial erosion. Crucially, none of the criteria that Holen *et al.*[3] use to define stone artefacts either requires prehistoric hominin involvement or meets the accepted criteria for falsifying natural 'geofacts'[5]. The range of possible geological interpretations for the lithic assemblage highlights the critical issue of equifinality, in which an end product such as a shattered cobble may be generated via many and potentially unrelated means. It is a principle that applies to the bone record as well.

We contend that Holen *et al.*[3] presented equivocal evidence in support of tool-imparted percussion damage to the remains of the mastodon. The critical observations are of spiral fractures, cone flakes, impact flakes, bulbs of percussion, impact notches, negative flake scars, anvil-polished specimens, percussion-fractured specimens, and refitting specimens. These bone damage features are inferred to implicate sole agency by prehistoric hominins. As with the stone artefact record, issues of equifinality must first be addressed, including the question of whether other processes could produce such bone damage.

Haynes[6] presents compelling evidence of non-cultural and/or non-prehistoric processes producing comparable damage at the 24,000-year-old Inglewood Mammoth Site (IMS), Maryland, USA. As at the CM site, the IMS contains the remains of a single juvenile proboscidean recovered *in situ* from a sealed deposit of sandy clays with pebbles and cobbles[6]. Haynes[6] provides descriptions and images of curvilinear and spiral 'green-bone' fractures on cranial, axial and appendicular specimens. Some of these fractures are recent in origin, probably related to heavy earthmoving equipment working on-site[6]. Other damage may reflect perimortem injuries sustained by the mammoth. No evidence of prehistoric hominin activities are noted or suspected for the site. Post-burial bone notches, impact points and impact scratches occurred on a number of specimens.

We report a similar record of fractured proboscidean bones at the Waco Mammoth National Monument (WMNM), Waco, Texas, USA. The site contains the remains of at least 26 mammoths buried in fluvial sands, silts and clays, and dates from 66,800 to 51,300 years ago[7]. The WMNM was initially investigated as a potential archaeological site, although no evidence of prehistoric human activities was discovered. Figure 1 shows post-burial damage to WMNM mammoth long bones morphologically consistent with observations from the IMS and CM sites. This includes damage that resembles spiral fractures with associated sedimentary abrasion, hammerstone pseudo-notches[8], negative flake scars, partially detached flakes and incipient notches, and bulbs of percussion. Such damage, including spiral fractures, is well known in the fossil record from as early as the Triassic period[9] and can occur post-burial[6]. They neither require nor solely indicate prehistoric human agency[4,6,8].

Other proboscidean assemblages share a similar taphonomic signature with the WMNM, IMS and CM sites. Holen and others report various combinations of spiral fractures, impact points, bulbs of percussion and bone flakes at numerous other late Pleistocene mammoth death sites in the Americas[10,11]. As with the CM site, these latter assemblages uniformly lack unambiguous stone tools, cut marks, or any other unquestionable evidence of hominin activities, and most predate well-vetted geochronological and palaeogenomic evidence of the initial peopling of the Americas around 15.5 thousand years ago[1,2,12–14].

Moreover, it is not just what is present at the CM site, but also what is missing. Specifically, hammerstone striae and/or pits (HSSP)[15] are noticeably absent despite reasonable cortical bone preservation, several hundred bone fragments, purported hammerstones, and purported anvil abrasions on both the bones and the cobbles. Experimental studies show that hammerstone-percussed proboscidean limb bone fragments should bear HSSP on greater than 30% of specimens created when using a hafted hammerstone and anvil[12]. The absence of HSSP at the CM site—a proposed percussed bone assemblage—cannot be explained using current experimental models and contradicts the assumption of hammerstone-wielding hominin involvement in bone breakage.

Lastly, we question the assertion of an "undisturbed geologic context" at the CM site. Although the distance between some refitted finds necessarily suggests pre-burial breakage and scattering of some items (for example the molar fragments), other features of the record plausibly reflect subsequent forces modifying the assemblage over the last 130,000 years. As fluvial deposits slowly covered the remains, the bones of the mastodon would have remained semi-pliable for years[6]. Proboscideans or other large mammals subsequently using the muddy watercourse could potentially trample, displace, fracture, abrade and reorient (for example the semi-vertical tusk) the interred materials[4,6]. Later sediment compaction by metres of overburden and then eventual

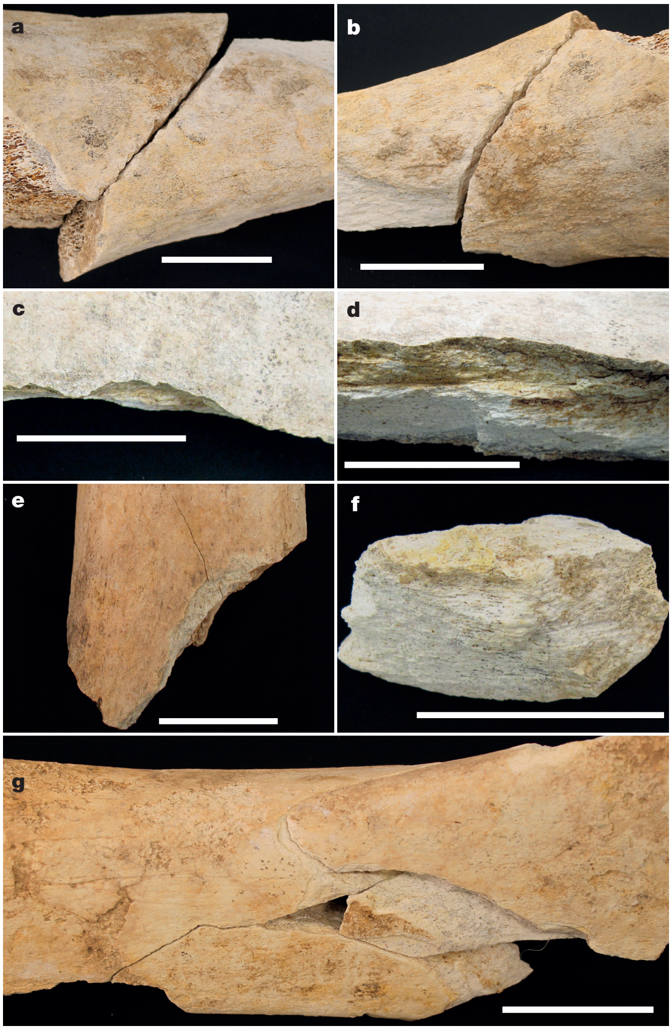

Figure 1 | Fractured proboscidean bones from WMNM. a, Curvilinear fracture between refitted fragments BU-MMC-641a and BU-MMC-641b. **b**, The opposite side of the refitted fragments depicted in **a**. **c**, Hammerstone-like 'micro'-notch[8] on the cortical surface without diagnostic percussion pit, fragment BU-MMC-1011a. **d**, Negative flake scar on the same bone as that depicted in **c**. **e**, Post-burial curvilinear fracture on fragment BU-MMC-210a. **f**, Bone flake with bulb of percussion, fragment BU-MMC-642b. **g**, Comminuted fracture with refitted flakes and associated sedimentary abrasion on fragment BU-MMC-716a. Scale bars, 5 cm.

disturbance by heavy construction equipment (see supplementary information 6 of ref. 3) would confound the taphonomic history of the site further, as it has at both IMS and WMNM[6].

The extraordinary claim by Holen *et al.*[3] of prehistoric hominin involvement at the CM site should not be contingent on evidence that is open to multiple, contrasting interpretations. Until unambiguous evidence of hominin activities can be presented, such as formal stone tools or an abundance of percussion pits, caution requires us to set aside the claims of Holen *et al.*[3] of prehistoric hominin activities at the CM site.

Methods

The Baylor University Mayborn Museum Complex (BU-MMC), Waco, Texas, is the official repository for around 70% of the recovered WMNM remains, with the remainder left *in situ* for display at the WMNM site. Approximately 1,100 trays of curated fossils are available for study, with most trays containing multiple specimens. Individual specimens are labelled here based on tray number (BU-MMC), followed by a letter designation (for example 642a, 642b). Specimens were selected based on gross bone damage morphologies, with the aim of recording damage similar to that reported from the CM site. Images were obtained using a Cannon EOS Rebel XS digital camera.

Data availability. All data are available from the corresponding author upon reasonable request.

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Holen *et al.* reply

REPLYING TO J. V. Ferraro *et al. Nature* **554,** http://dx.doi.org/10.1038/nature25165 (2018)

Contrary to our hypothesis[1] that the Cerutti Mastodon (CM) site represents a 130,000-year-old archaeological site, in the accompanying Comment[2] Ferraro *et al.* argue that the site formed through 'common' geological and taphonomic processes. As a source for the cobbles that we interpreted as hammerstones and anvils, they postulate a previously unrecognized alluvial fan, later removed by fluvial winnowing that somehow left our five cobbles, refitting flakes, and fragments of stone, mastodon bone and teeth in place. There is no sedimentological or geomorphic evidence of an alluvial fan, and their scenario leaves unexplained a number of taphonomic features, including the two discrete concentrations in which were found cobbles, refit stones and bones, impact-fractured bones, side-by-side femoral heads and a tusk oriented vertically.

Ferraro *et al.*[2] also speculate that the stone and bone fractures that we analysed can be explained by post-burial processes such as sediment compaction or interaction with excavation equipment, whereas we contend that these features are part of the CM biostratinomic (pre-burial) record. Support for our view is provided by the fact that most CM bones and stones were enclosed within crusts of pedogenic carbonate that establish a 'chain of evidence' showing that breakage and positioning of objects occurred many thousands of years ago, and, as we contend, before burial[3]. The only pre-burial cause of bone breakage Ferraro *et al.*[2] consider is trampling, which we have argued is incompatible with other site data[1].

Ferraro *et al.*[2] draw comparisons to the Inglewood Mammoth Site (IMS)[4,5] and the Waco Mammoth National Monument (WMNM)[6]. For the IMS, they cite an observationally based study[4] that proposes that excavating equipment caused the spiral fractures on many of the bones. However, this claim is compellingly refuted by an experimentally based study[5] that shows that the IMS spiral fractures are ancient after all, and probably occurred before burial.

WMNM bones illustrated by Ferraro *et al.* (figure 1 of ref. 2) lack clear evidence of true spiral fractures or normal impact notches[7], instead representing classic examples of dry bone fracture, with rough texture on fracture surfaces and contrasting coloration of broken versus cortical surfaces (figure 1b, d, g of ref. 2). The closest approach to a notch (shown in figure 1c, d of Ferraro *et al.*[2]) is a shallow, irregularly arcuate break—described as a pseudo-notch or micro-notch—that does not extend to the medullary portion of the bone, unlike the 'normal notch'[7,8] we illustrated[1], which was defined by two clear inflection points, a negative flake scar, an attached cone flake and smoothly curved fracture surfaces that extend completely through the cortical portion of the bone. Only 'normal notches' are used to determine human agency[7,8].

By overlooking the most important bone evidence, which includes impact features such as cone flakes, bulbs of percussion and a large impact notch with associated negative flake scar, as well as bone distribution patterns, bone refits and missing femoral diaphysis pieces, Ferraro *et al.*[2] did not consider precisely those features that are individually and collectively most likely to have been caused by cultural processes. They have not offered a cogent alternative site formation hypothesis that accounts for all evidence presented.

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