Paleoamericans, Pleistocene terraces and Petroglyphs: the case for Ice Age mammoth depictions at Upper Sand Island, Utah, USA

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INTRODUCTION

The San Juan River valley near Bluff, southeastern Utah, is underlain by near-horizontal sandstone formations of Mesozoic age interbedded with mudstone, shale and limestone. Erosion of these sedimentary rocks has produced the characteristic mesa topography of the region. The stepped terrace topography is a product of intermittent river aggradation and downcutting, combined with uplift: sandstone bedrock is exposed as cliffs ranging from a few meters to 20 m high in many places, and over this bedrock are preserved the gravels and sandy sediments of relict floodplains, now isolated from the river that formed them.

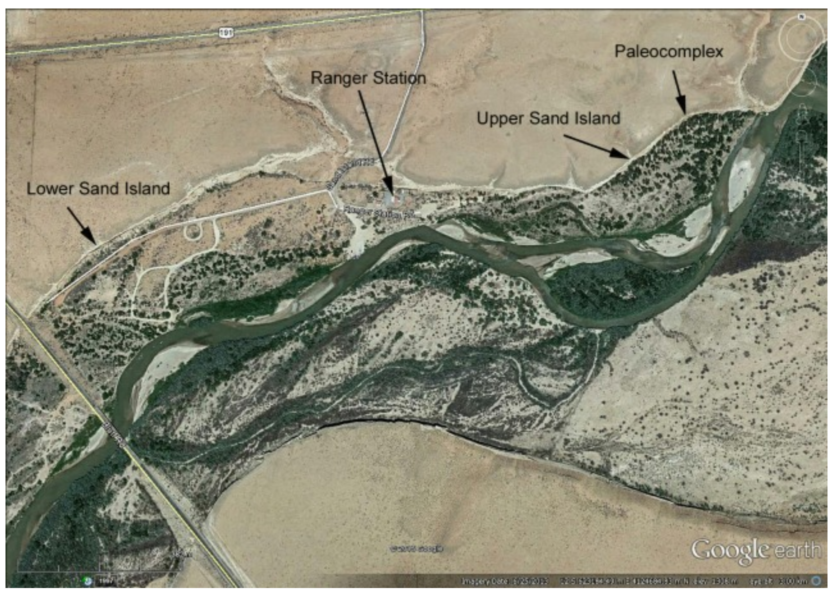

Figure 1. Sand Island Recreation Area, San Juan River. Note approximate location of paleocomplex along the 1.3 km-long Upper Sand Island rock art gallery. Basemap image by Google Earth .

Between the towns of Bluff and Mexican Hat, the cliffs and terraces paralleling the San Juan River represent an “archaeological frontier” par excellence. The area contains a multitude of archaeological remains including notable features such as a Clovis-era campsite, Basketmaker pithouses, and Puebloan cliff-dwellings. Evidence that the region had great appeal to a succession of peoples, whether seasonal occupants or longer-term inhabitants, is apparent in the thousands of petroglyphs on the cliffs along both sides of the river. Near the Sand Island Recreation Area, downstream from the town of Bluff, the engravings adorn the Navajo sandstone in two massive rock art galleries. Known as Lower and Upper Sand Island (Fig. 1), they demonstrate that the area bordering the floodplain of the San Juan River has attracted people for thousands of years, from nomadic Paleoamericans at the end of the Last Glacial to the arrival of Mormon settlers in the nineteenth century and tourists today.

There are many petroglyphs at this site, and notably two at Upper Sand Island which have been interpreted as representing mammoths (Malotki and Wallace 2011; Malotki 2012; Malotki et al. 2014). The petroglyphs in question are incised into sandstone cliffs at the margins of Quaternary terraces on the north (right) bank of the San Juan River. For convenience this site is referred to here as the "mammoth recess." Various methods, detailed in the comprehensive report by Wakeley and Gillam (2014) and an earlier report (Gillam and Wakeley 2013), have been used in an attempt to date the petroglyphs. These include dating of the rock face by exposure (cosmogenic) methods, radiocarbon studies, degree of desert varnish development, the "microerosion"[1] technique and an analysis of terrace chronology, cliff geomorphology and river erosion.

It appeared to the present authors that not all of the conclusions reached by Gillam and Wakeley (2013) and Wakeley and Gillam (2014) were justified by the information provided in these papers. Accordingly, following a brief description of the petroglyphs that have generated most controversy, and their archaeological and paleoenvironmental setting, this paper highlights some of the perceived weaknesses in the interpretations of Gillam and Wakeley (2013), Wakeley and Gillam (2014) and Gillam (2015). A full literature review of all issues relating to the San Juan River mammoth petroglyphs, however, is not attempted in this paper.

THE PETROGLYPHS AT LOWER AND UPPER SAND ISLAND

Figure 2. Location of paleocomplex with Mammoth 1 (M1) and Mammoth 2 (M2) on the 20 m-high Navajo sandstone cliff. Photo © Ekkehart Malotki.

Together, the two galleries at Lower and Upper Sand Island display nearly the full suite of rupestrian styles the American Southwest has to offer. In addition to elements or clusters of Western Archaic Tradition, Glen Canyon Linear, Basketmaker II and III, Pueblo II and III, as well as (proto)historic Ute and Navajo iconography, the Upper Sand Island site houses a remarkable paleocomplex (Fig. 2) featuring two engravings that have been credibly identified by both paleontologists and Ice Age art specialists (Fig. 3) as Columbian mammoths (Malotki and Wallace 2011: 148; Clottes 2013: 9; Dick "Sir Mammoth" Mol, pers. comm. 2014).

[1] The microerosion technique (Bednarik 1992) is not accepted as scientifically valid (Zilhão 1995; Field and McIntosh 2009, 2010; Malotki et al. 2014). After cataloging and discussing five fundamental flaws in the technique, Field and McIntosh (2009: 18) remarked that both the theory and the practical application of the 'micro-wane' method were unproven and that "it should not be promoted as a method for dating petroglyphs."

As is common practice world-wide in the portrayal of most animals, the megabeasts, including the bison overlying the dorsal ridge of Mammoth 1 (Fig. 4), are rendered in side view. Also known as “canonical view,” this profile pose provides a maximum of information and makes anatomically relevant details easily recognizable. Among the prominent traits observable on the proboscidean depictions are their paired tusks, trunks, and domed heads, which in the case of Mammoth 2 (Fig. 5) is better described as a pronounced topknot, a signature feature of *Mammuthus columbi.* Perhaps the most critical diagnostic detail that might easily escape modern observers is the distinctive inverted V-shaped bifurcation at the tip of the trunk. Mammalogists refer to this as “fingers.” As appendages of prehension, they aid proboscideans in grasping food during foraging activities. Modern African elephants have two prehensile digits, while Asian elephants have only one finger-like projection on the tip of their trunk. The fingers shown on woolly mammoth paintings at Old World Paleolithic cave sites such as Rouffignac, La Baume-Latrone and Chauvet (Fig. 6) all feature one long and one short projection, with the latter usually referred to as a thumb. The same is observable on the trunk of Yuka, a young mummified woolly mammoth carcass that was discovered in the Siberian permafrost in 2010 (Fig. 7).

The fingers depicted in both the Upper Sand Island petroglyphs are of equal length. Whether this is simply the result of artistic license or whether it reflects actual anatomical accuracy for Columbian mammoth may never be known unless a carcass of this species is found in North America. One can say, however, that the depiction of this small anatomical detail unequivocally speaks to the paleoartist’s intimate knowledge of the living animal’s characteristics. It furthermore supports the authenticity of the depiction, for no modern hoaxer would be likely to have been familiar with it. Additionally, it is inconceivable that “collective memory” based on oral transmission could be responsible for retaining precise anatomical features of extinct fauna over a span of thousands of years and hundreds of generations.

Figure 3. Jean Clottes and the senior author eye-level with Mammoth 1 on scaffold at Upper Sand Island, May 2013. Photo © Ilona Anderson.

While there is a general consensus among all those who have closely studied the proboscidean engravings at Upper Sand Island that they are authentic (that is, not the product of some modern hoaxer who might have used metal tools), ascertaining their approximate age remains a challenge. There are currently no absolute chronometric methods that can be applied to petroglyphs.

In the absence of direct scientific dating evidence, one has to rely on other clues relating to style and context. The accurate anatomical renderings (see above) support the “self-dating” concept offered by Züchner (2001): “Rock art is self-dated when it shows a certain object, a certain symbol, or an extinct animal species whose age is known.” Numerous other scholars concur: Solomon (2014: 131) states that “images of animals

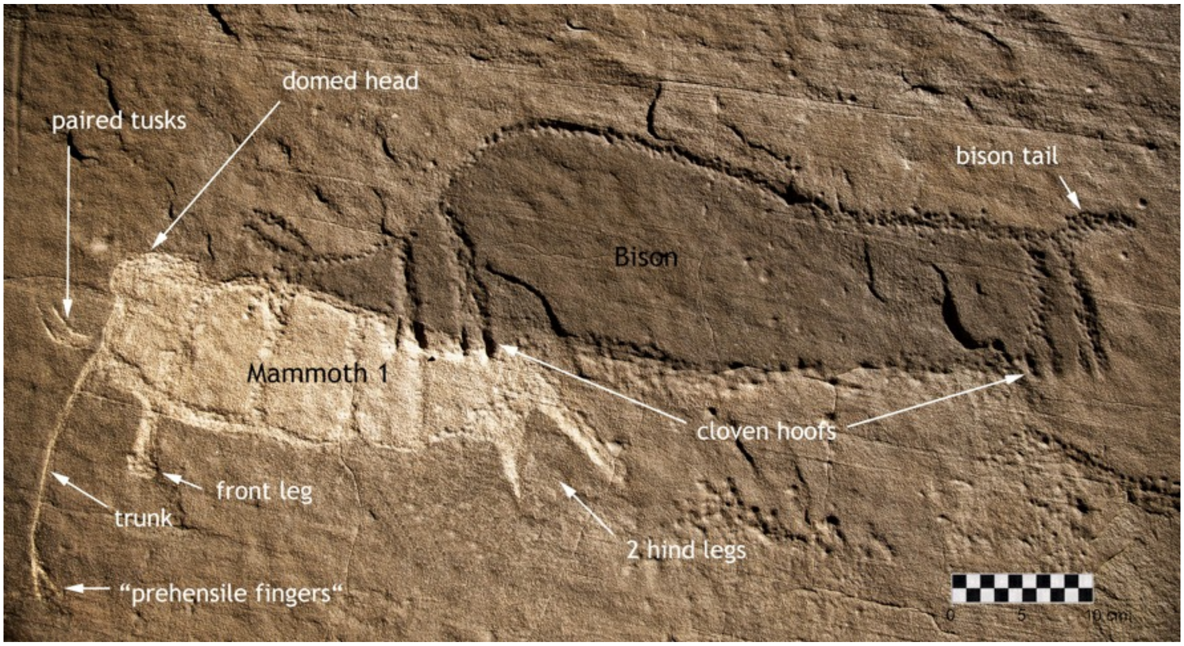

Figure 4. Mammoth 1 with superimposed bison. Artwork © Julia Andratschke.

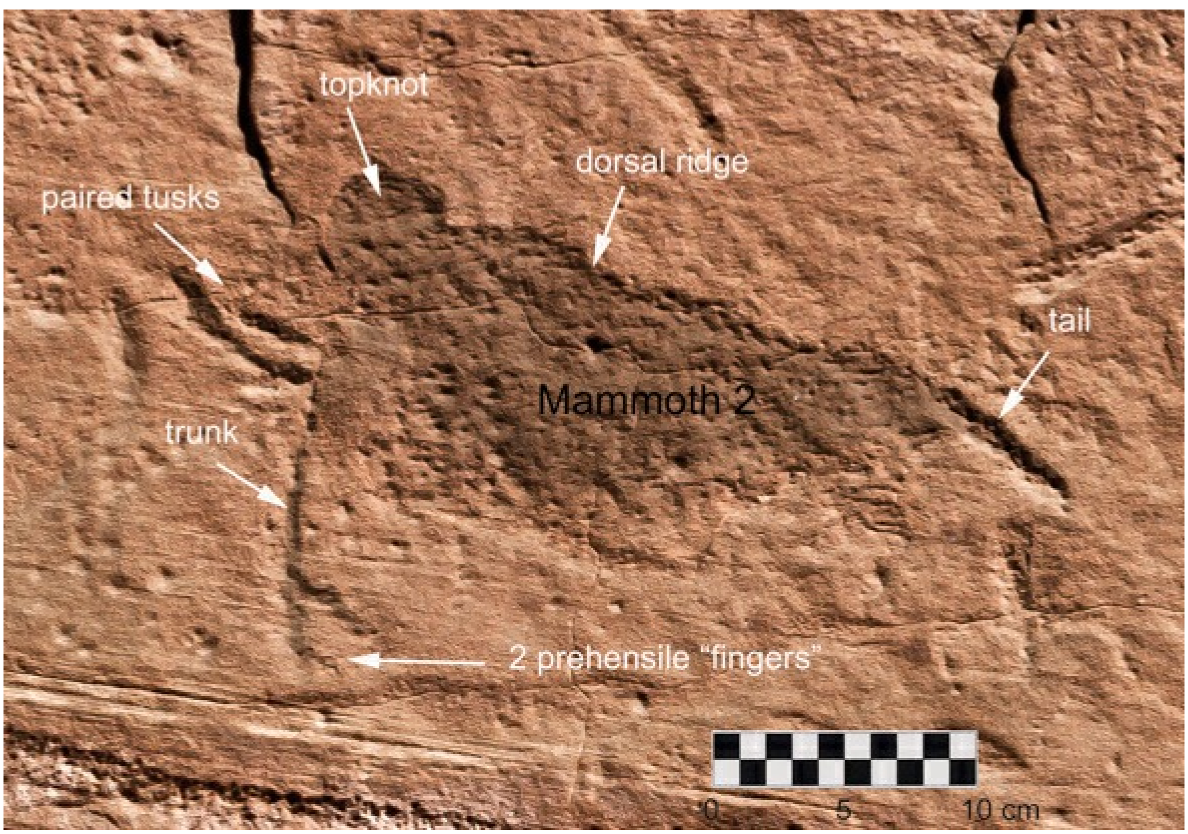

Figure 5. Mammoth 2 with pronounced topknot, signature feature of Mammuthus columbi. *Artwork © Julia Andratschke*.

Figure 6. Upper Paleolithic paintings of woolly mammoth, clearly depicting one "finger" and one "thumb" at the tips of their trunks. From left to right: Grotte de Rouffignac (Photo © Frédéric Plassard), Grotte Chauvet (Photo © Jean Clottes), and Grotte de La Baume-Latrone (Photo © Jean Clottes).

Figure 7. Carcass of baby woolly mammoth Yuka in situ and close-up of her trunk tip, clearly showing one "finger" and one "thumb". Photos © Albert V. Protopopov and Valeri V. Plotnikov, Academy of Sciences of Yakutsk, Sakha Republic.

known to have become extinct by a certain period may provide broad dates;" Franklin (1993: 2) also holds that a minimum age can be assigned to the depiction of a faunal species, based on the time the species is believed to have become extinct; and Pettitt and Pike (2007: 41) speak of "indirect associative dating," a method which uses inherent chronometric information derived from the depiction of animals for which a broad extinction threshold is known.

Bona-fide mammoth portrayals such as those at Upper Sand Island cannot be younger than the generally accepted extinction time *(terminus ante quem)* for these megamammals. The established extinction threshold for *Mammuthus* in the American Southwest is c. 13,000 – 12,500 ka (Faith and Surovell 2009; Haynes 2013), so this temporal window, when combined with first evidence of presence of people in the area, is a "best-estimate" for the time of the creation of the engravings. In addition to stylistic details that mark the entire paleopanel as a "stylistic isolate," associated paleoenvironmental evidence indicates a Late Pleistocene age for the images. This evidence includes a Clovis-era campsite 12 km west-southwest of Upper Sand Island (Davis 1989). Numerous Clovis projectile points in the general vicinity of the Upper Sand Island region indicate Paleoamerican presence around 13,200 – 12,800 ka (Goebel et al. 2008). Evidence that the region was *Mammuthus* habitat is provided by several fossil finds (complete skeleton, dung, tusk fragment and femur) on the southeast Utah portion of the Colorado Plateau, all dated to between ca. 13,800 and 12,200 ka (Agenbroad and Mead 1989). This indirect archaeological and paleontological evidence from the adjacent area as well as the anatomical detail on the mammoth engravings discussed above support a Late Pleistocene age of the paleopanel.

As is to be expected, the proboscidean interpretation and the date of the engravings have been disputed. Schaafsma (2013), for example, sees the images as resulting from a Rorschach approach.[2] Sundstrom (2011, 2014), suggests that the two mammoth images, along with some unidentifiable adjacent glyphs, depict the transformational stages of the moth that pollinates the *Datura* plant. Gillam and Wakeley (2013), Wakeley and Gillam (2014) and Gillam (2015) argue that the Navajo sandstone cliff could not have served Paleoamericans as a canvas for their depictions because the cliff is the product of Holocene erosion. This claim and others are considered below.

USE OF TERRACE CHRONOLOGY AND GEOMORPHOLOGY AS AN INDIRECT DATING TOOL

Gillam and Wakeley (2013), Wakeley and Gillam (2014) and Gillam (2015) used terrace chronology, geomorphology and deduced erosion history of the San Juan River valley to indirectly date cliff faces and the petroglyphs engraved on them. Their observations and deductions are discussed below. The ages referred to in these comments are the revised ages provided by Wakeley and Gillam (2014).

[2] The Rorschach test, which relies on the perceptual reading of an inkblot, is a psychological instrument designed to shed light on a person's mental state. Obviously, such an "eyeballing" approach cannot be framed as a refutable proposition and therefore does not reflect rigorous scientific reasoning.

Terrace identification

Four terraces have been mapped around Upper Sand Island (Wakeley and Gillam 2014: Fig. 6), but this map is of insufficient range to predict the extent and heights of regional terrace aggradation events in the Bluff–Comb Wash reach of the San Juan River. A regional terrace map, produced from Google Earth information, is provided in Fig. 8. Terrace boundaries were defined from geomorphic steps in the landscape identifiable on the Google image.

Terrace heights on seven transects, approximately 1.3 km apart and at right angles to river flow, have been plotted (Fig. 9). Absolute heights were taken from the center of each terrace. It is recognized that erosion, dune accumulation, and runoff processes have probably all modified original terrace heights but Fig. 9 is the best representation that can be made as a first approximation. Terraces deduced to be degraded are generally paler in the Google image, and are shown as degraded terraces (deg) in Fig. 8 and as open squares in Fig. 9. Allowing for an east to west downslope gradient, terraces that probably formed during the same aggradation event have been identified by the same symbol (Fig. 9). Four terraces are identified: A, B, C and D. The youngest terrace (A) corresponds to the unnumbered terrace at the Gold Mine noted by Wakeley and Gillam (2014: Fig. H.5) and the oldest terrace (D) to the terrace T4 noted by Wakeley and Gillam (2014: Fig. 5) east of the airstrip, but terraces B and C are not regionally correlated with previously identified terraces noted by these authors. Terrace T0 (Wakeley and Gillam 2014) has not been identified from Google images. It is essentially the upper floodplain (“floodplain bench”) of the San Juan River and in Google images is indistinguishable from recent sediments.

Is Terrace T2 actually a terrace?

This “terrace” and terrace T1 mapped south of it at the Ranger Station (Gillam and Wakeley 2013; Wakeley and Gillam 2014) are considered to be two parts of an alluvial fan of Buck Creek and other ephemeral drainage systems, which traverse the T2 landform and are visible on Google Earth images. The T2 landform slopes southwards, as would be expected for an alluvial fan, and the dip of the sedimentary layering within the T2 deposits is approximately 20^{o} (Wakeley and Gillam 2014: Fig. H.1) as would be expected in fan deposits. The fact that “terrace” T2 is not found elsewhere in the San Juan River valley supports the conclusion that T2 is a local feature and not a terrace of the San Juan River. Terrace T2 has been trimmed at some time by the San Juan River, leaving a low cliff (Wakeley and Gillam 2014, photo 34), and “terrace” T1, at the lower level, is interpreted to be the distal fan of Buck Creek, which has continued to disgorge sediment onto the San Juan River floodplain after the trimming event.

Wakeley and Gillam (2014: 54) obtained a radiocarbon age of c. 35 cal ka for shells found in deposits of the T2 landform and an OSL age of c. 29 ka for T2 sediments. (Fig. H.1 in this publication gives the uncorrected 20 ka age.) Both the 35 cal ka and 29 ka ages may be valid, with the difference being explained by fan development processes: a stream

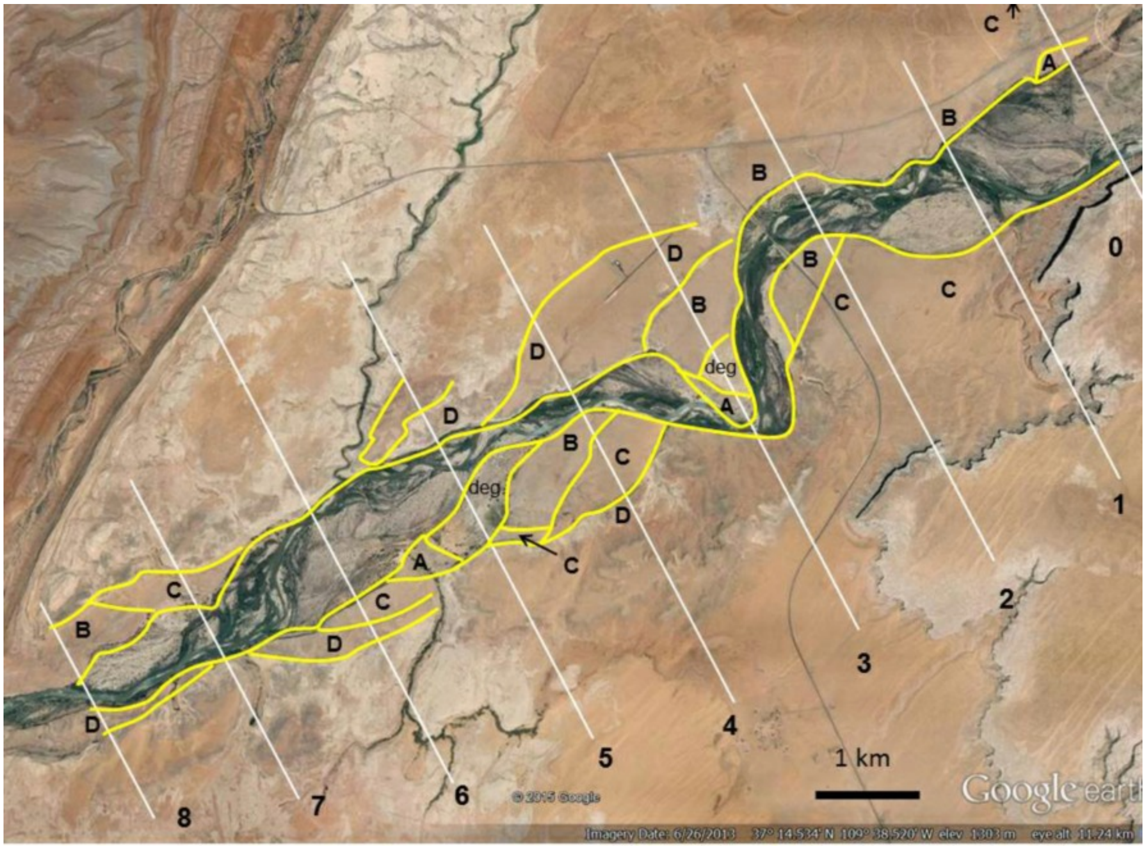

Figure 8. Late Pleistocene terraces (T1-T4) identified along the San Juan River from Bluff to Comb Wash. The abbreviation deg *indicates a probably degraded terrace. Numbered transects are approximately 1.3 km apart. Basemap image by Google Earth*.

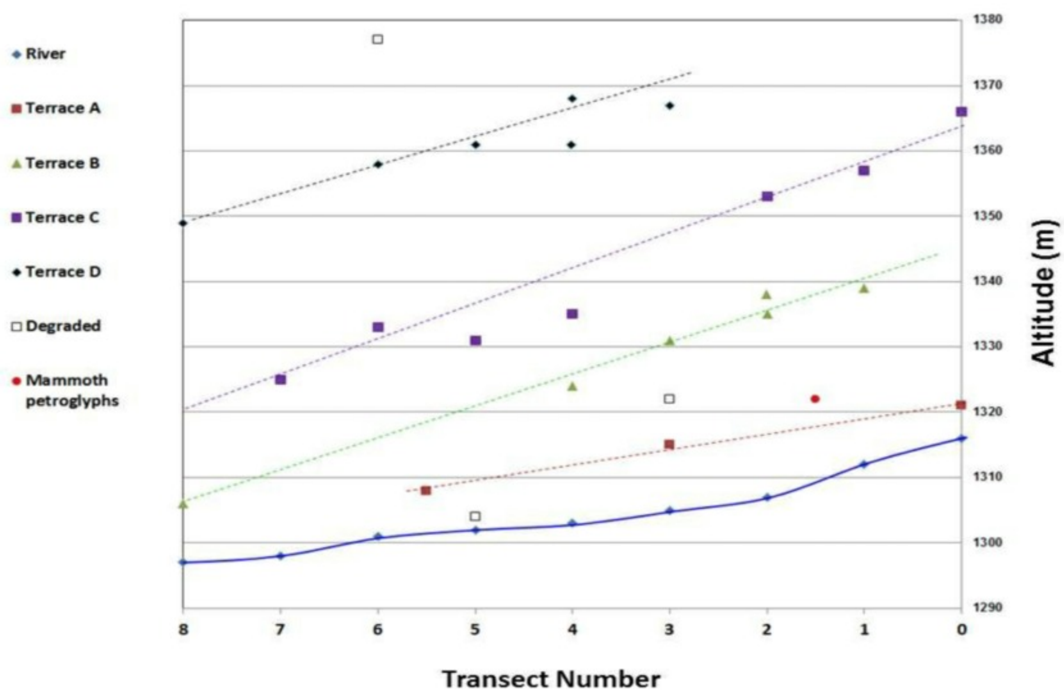

Figure 9. Gradients of late Pleistocene terraces and the San Juan river from Bluff to Comb Wash. Heights are derived from Google Earth imagery. Transect numbers are those shown on Figure 8. The approximate height of the mammoth petroglyphs located between Transects 1 and 2 is shown by the red dot.

depositing fan alluvium will sometimes deposit on one side of the fan, sometimes on the other; at times it will be aggrading its channel, at other times degrading. Consequently, in fan alluvium sediment age may vary widely, both horizontally and vertically.

The Buck Creek fan ("terrace" T2), being a local feature, does not help to date the cliff face at the mammoth recess.

The terrace sequence

Wakeley and Gillam (2014) note "three closely spaced terraces" in the Gold Mine area and obtained an age of c. 20 ka for a sample of alluvium from the terrace at 1315 m altitude. We noted four terraces in the Gold Mine area (Figs. 8 and 9, Transect 3): one at 1315 m, one at 1322 m (the pale area, probably degraded) on the promontory south of the Gold Mine, one at 1331 m, and one at 1367 m just south of the airstrip.

Terrace A

Wakeley and Gillam (2014) sampled the 1315 m terrace at the Gold Mine which we map as Terrace A (Fig. 8). The age they obtained (c. 20 ka) is consistent with this terrace being formed during the final stages of ice melt following the Last Glacial Maximum, i.e., this terrace is likely to be the last aggradation terrace to have accumulated in the Last Glacial. This conclusion is supported by the consistent location of this terrace next to the present river floodplain and the absence of lower (younger) terraces. (The floodplain bench T0 (Wakeley and Gillam 2014) is still subject to flooding and is not considered to be a terrace in this paper). It can be deduced that during the Holocene, sediment supply has decreased relative to supply in the Last Glacial, and the San Juan River has been downcutting and laterally reworking its channel (and incidentally destroying most traces of Terrace A) rather than aggrading.

Terrace A is mapped at three locations along the San Juan River (Fig. 8). The most westerly location of Terrace A, between Transects 5 and 6, could be interpreted as an alluvial fan of the adjacent stream and the deposits here require field checking. The degraded terrace at 1304 m altitude on Transect 5 may also represent the remains of Terrace A but this cannot be assumed.

Terrace B

Terrace B, mapped at six locations and south of Highway 191, was dated c. 42 ka by OSL methods (Wakeley and Gillam 2014: 54).

Terrace C

This terrace is mapped at seven locations. It is best preserved on the south bank of the San Juan River, in Transect 4, west of the Gold Mine. No age has been obtained for sediments in this terrace, but as it occurs between Terrace B (c. 42 ka) and Terrace D (c. 61 ka) it may be about 50 ka old.

Terrace D

This terrace is mapped at six locations. It is best preserved near the airstrip. It was OSL dated c. 61 ka from gravel pit sediments near the intersections of Highways 163 and 191 (Wakeley and Gillam 2014: 53).

Cosmogenic exposure dating of the cliff at the mammoth recess

F. Phillips (New Mexico Institute of Mining and Technology) dated a rock slab in the mammoth recess (Wakeley and Gillam 2014, Appendix J). The slab had fallen from the lower face of the recess. Exposure dating using ^{36}Cl gave an age of c. 33 ka. This age assumes no erosion of the rock face and does not take into account possible shielding of the rock by terrace deposits which may have abutted the cliff and have since been eroded. If shielding of a freshly eroded rock face has occurred, the measured age will *underestimate* the true age of the rock face, because less ^{36}Cl will have been generated at the rock face than would have been expected had the rock face been subject to continuous exposure. Erosion will also affect the ^{36}Cl age. If a large amount (e.g., meters) of erosion has occurred recently (as might be expected in rock falls), the ^{36}Cl data should indicate a Holocene age; this is not the case. If only a modest amount (e.g., millimeters) of erosion has occurred, the effect on the measured age is complicated by the fact that ^{36}Cl is produced by two processes involving low-energy neutrons and high-energy neutrons, and in the sandstone at Upper Sand Island the former process produces highest levels of ^{36}Cl at about 30 cm depth into the rock (F. Phillips, personal communication, April 23, 2015). Consequently, if modest erosion has occurred at the rock face the measured age will *overestimate* the true age of the eroded rock face, because these higher ^{36}Cl levels have been sampled. Calculations by F. Phillips demonstrate that if 10 mm/ka of erosion has occurred, the true age of the rock surface will be about 10 ka less than the measured age of 33 ka.

The scientific argument that inheritance of ^{36}Cl has influenced the 33 ka age obtained, to the extent that this age is erroneous (Wakeley and Gillam 2014, Appendix J), is not clearly presented and we consider the terms used by them (“totally unwarranted” and “almost certainly”) in the following statement (Wakeley and Gillam 2014, Appendix J: 183) to be too categorical and the conclusion incorrect: “At first glance, this age range seems to prove that the existing cliff face at Feature 43 has been stable since late Pleistocene time, and that petroglyphs of late Pleistocene age could be preserved there. However, such a conclusion would be totally unwarranted. A more complete study would almost certainly show that the face is younger, and it could even be as young as Holocene (less than approximately 12,000 years old).”

Ideally, ^{36}Cl ages would be obtained from surface rock at several locations in the mammoth recess. If significant surface erosion has occurred here results should be variable, as erosion rates are unlikely to have been uniform. On the other hand, several measurements giving approximately the same age would indicate surface stability. Pending further exposure dating of rocks closer to the mammoth petroglyphs in the cliff face of the mammoth recess or reliable independent assessments of erosion rates, the ^{36}Cl age of 33 ka is considered to be valid and to provide a useful estimate of the age of the cliff at this location. We are of the opinion that the exposure age of 33 ka should not have been dismissed and, with appropriate caveats regarding its reliability (as outlined above), deserved inclusion in the body of the Wakeley and Gillam (2014) and Gillam (2015) reports.

How old are the mammoth petroglyphs at the mammoth recess?

Direct dating

As discussed above, there seem to be no reasons to reject the ^{36}Cl exposure age (Wakeley and Gillam 2014, Appendix J). This age indicates that the cliff face at the mammoth recess, above the level of the notch visible in the cover photograph of the Grench (2014) report, is about 33 ka old, although if it can be shown that significant surface erosion has occurred, it could be younger.

Terrace chronology and cliff morphology

Gillam and Wakeley (2013) suggest that the mammoth petroglyph site was buried by "T2 alluvium." But the field evidence indicates T2 has the morphology of a fan, not a terrace. There is no field evidence to support the conclusion (Gillam and Wakeley 2013: 159): "When T2 was an active floodplain, it covered the entire valley floor at a level higher than those [sic] of T1 and T0 today."

The absolute heights of features shown in Fig. 6b of Gillam and Wakeley (2013) appear to be incorrect. The Google image shows the river at Upper Sand Island to be at an altitude of 1312 m, not 1306 m as shown in Fig. 6b. Assuming that the petroglyphs are about 10 m higher than the river (as shown in Fig. 6b), they must be at about 1322 m altitude. As the surface of Terrace A (dated c. 20 ka) would have been at about 1319 m altitude at this spot (Fig. 9), we can reach the important conclusion that *at the end of the Last Glacial, and for an unknown time after it, a terrace existed at the mammoth recess that would have provided ready access for local people, enabling them to engrave petroglyphs on a cliff face which is now almost inaccessible*.

In passing it should be mentioned that Terrace A at the mammoth recess would have been an ideal camping spot for hunters: it provided a well-drained site, close to water, facing the warm south, protected from northerly winds, a good view of the river, and a vantage point for locating game grazing on the floodplain.

Terrace A is the youngest Last Glacial terrace, so erosion of Terrace A is unlikely to have occurred in the Last Glacial. There are no Holocene terraces (other than the floodplain bench) in this reach of the San Juan River valley, so the mammoth recess could not have been accessed from Holocene terraces – Terrace A must have been used as a platform for engraving the petroglyphs. From the field information and ages available it is not possible to determine how long Terrace A performed this function at the mammoth recess. The presence of talus below the mammoth recess shows that the cliff face here has not been eroded in the recent Holocene. A radiocarbon age on the talus deposits would provide a minimum age for the erosion event that eroded Terrace A. (An OSL age would be problematic, as some of the colluvium may have accumulated very rapidly without allowing sand grains to be fully exposed to solar energy.)

Apart from the 33 ka exposure age, the field evidence presented by Gillam and Wakeley (2013) argues against significant Holocene erosion at the mammoth recess: at locations where Holocene cliff erosion has occurred, talus has been eroded from bases of cliffs, the cliff has been undercut at a level close to the present river level, and the brown surface staining of old exposed faces has been removed by abrasion, exposing fresh pale sandstone (Gillam and Wakeley 2013: Fig. 7). None of these characteristics of Holocene erosion are present at the mammoth recess. Gillam and Wakeley (2013: 167) claim that "the 'mammoth' petroglyphs are on a unique section of cliff that is overhanging and therefore relatively young". We know of no geological studies where overhangs have been dated by reference to undercut layers below them. In summary, there is no evidence to suggest that Holocene processes have significantly eroded the cliff at the mammoth recess site, and the 33 ka exposure age is strong evidence to the contrary.

We deduce that while the San Juan River was aggrading Terrace A, it eroded back the lower part of an existing cliff (dating back about 33 ka from the present) to a modest extent, forming the notch visible in the photograph on the cover of the Grench (2014) report and the associated overhang. When Terrace A at this site was later eroded away in the Holocene, the notch was left "high and dry" (literally) and talus later accumulated, largely from the lower part of the recess (Wakeley and Gillam, Fig. J.1 and Grench 2014, cover photograph), but possibly also from the overhanging top of the cliff where pale loose rock is exposed (Grench 2014, cover photograph). This talus has not been removed by later river flow, demonstrating the limited erosion power of the present river at this site.

There is no evidence to support Wakeley and Gillam's generalization (2014: 72) that "all parts of the existing cliff surface are much younger than the time of initial incision below terrace T2."

Photographs show that the upper part of the mammoth recess is unaffected by rock falls (see Figs. 2 and 3). We suggest that this is because the sandstone here is more massive and less jointed, and the overhang itself probably protects the face from moisture and freeze-thaw effects.

Anatomically diagnostic details in the Mammuthus depictions: "The fingers have it"

Both mammoth petroglyphs (Malotki et al. 2014; see also Figs. 4 and 5 above) show curved tusks and a trunk with finger-like projections at their ends. The former features (tusks) might perhaps be remembered in stories long after mammoths became extinct, but it is not reasonable to assume that such a small anatomical detail as the prehensile fingers on the tip of the trunks could have been reproduced thousands of years later by someone who had never seen them. From the photographs in Malotki et al. (2014) there is no evidence that they, together with the trunks, were produced by water runoff—they are not vertical, and similar runoff channels are not characteristic of the sandstone here.

CONCLUSIONS

1. Four terraces of Last Glacial age have been mapped in the San Juan River valley, between Bluff and Comb Wash.
2. At c. 20 ka before present, the youngest of these terraces (Terrace A) previously abutted the mammoth recess at Upper Sand Island. This terrace would have provided ready access to the upper part of the recess (now almost inaccessible) for people to engrave petroglyphs.
3. Terrace A at the mammoth recess would have been an ideal camping spot for hunters: it provided a well-drained site, close to water, facing the warm south, protected from northerly winds, and had a good view of the river providing a vantage point for locating game grazing on the floodplain.
4. Terrace A was later eroded away at the mammoth recess site. Removal of Terrace A probably occurred sometime in the Holocene, as there is no evidence of younger Last Glacial terraces in this part of the San Juan River valley.
5. The field evidence, terrace chronology and exposure dating of the mammoth recess cliff indicate that the cliff at this point has been stable since the late Pleistocene. This stability may result from the massive and relatively unjointed sandstone formation in the upper zone of the mammoth recess.
6. The anatomical details of the mammoth petroglyphs suggest that the people who engraved the petroglyphs were familiar with living mammoths.

In conclusion we find that the field evidence (terrace morphology, terrace chronology and cliff morphology), OSL, radiocarbon and exposure ages, and petroglyph characteristics are all consistent with the petroglyphs having been engraved in the late terminal Pleistocene. The proboscidean images clearly testify pictorially to the co-existence of early Paleoamericans with now-extinct Pleistocene megafauna and establish the site as the only currently reported rock art location in the Western Hemisphere with figurative motifs datable to the Ice Age.

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