Title
Evidence for the Extinction of Mammoths by an Extraterrestrial Impact Event

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EVIDENCE FOR THE EXTINCTION OF MAMMOTHS BY AN EXTRATERRESTRIAL IMPACT EVENT

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At Paleo-Indian kill sites throughout North America abundant fossil evidence exists for Mammoths, dated to ≈11,000 rcy BP (13,000 cal yr BP), often fully articulated and partly butchered, whose remains could not have been exposed to the elements for more than a short time. They appear to be the victims of a sudden, catastrophic event. At several sites a black mat lies in direct contact with the bones. No evidence for Mammoths, or the Paleo-Indians who hunted them, is found in later sediments. We have investigated Paleo-Indian sites at Gainey, MI, Murray Springs, AZ, and Blackwater Draw, NM where we discovered a layer of abundant, rounded, ferromagnetic particles in direct contact with the Mammoth fossils. These particles can readily be extracted from the sediment with a strong permanent magnet. Many of the particles from the Gainey, MI site appear to be meteoritic and shocked, as shown in Figure 1.

FIGURE 1. Magnetic particles from the Gainey MI site. Shown are a black, highly magnetic particle, a translucent perfectly spherical particle, and a thin slice with a rhombohedral cleavage pattern that is consistent with an explosive shock.

The magnetic particles at Murray Springs and Blackwater Draw appear more weathered than those at Gainey. Figure 2 shows the distribution of particles in the sediment at Murray Springs. Magnetic particles are not usually found in sediments, and the large abundance, >0.1% by weight, below the black mat is remarkable.

We have performed elemental analyses of particles and sediments from all three sites at Becquerel Laboratories using Neutron Activation Analysis. The results, shown in Figure 3, indicate that the Fe/Co, Fe/Cr, Fe/Sc, and Fe/Zn ratios in the particles are similar at all three sites, suggesting a common origin, different from the associated sediments and the earth's crustal or solar abundances. Modern magnetite particles recovered at the surface of the Murray Springs site have very different ratios suggesting the magnetic particles there could not have come from the same local source.

High densities of ion tracks, pits, and embedded micrometeorites are observed, preferentially on one side, in cherts at Clovis sites (see Firestone and Topping, 2001). Figure 4 shows an example of micrometeorites seen at two sites. Table 1 shows the density distribution of these impacts, which peaks near the Great Lakes, suggesting that an impact event may have occurred near there. This is consistent with the location of the impact site suggested for the Carolina Bays (see Eyton and Parkhurst, 1975).

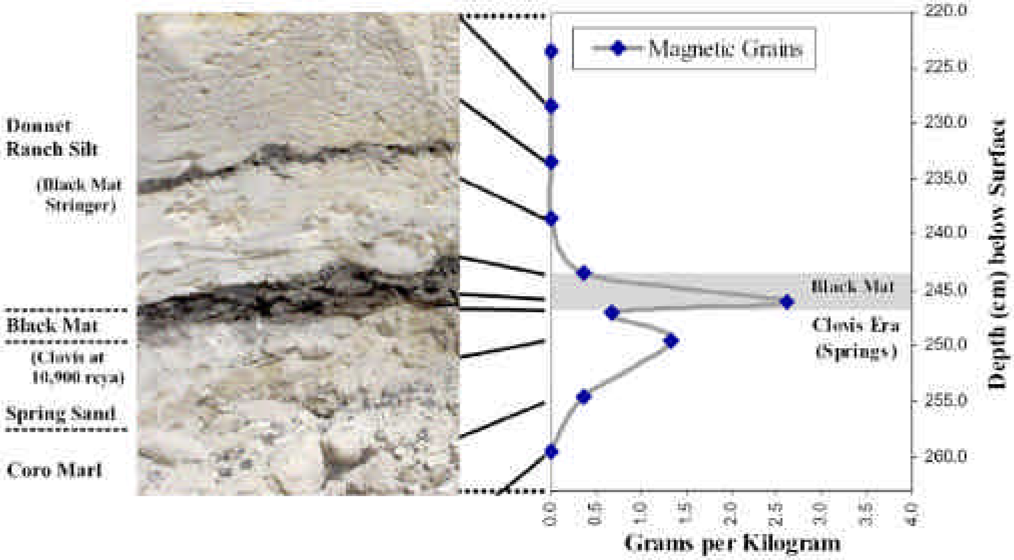
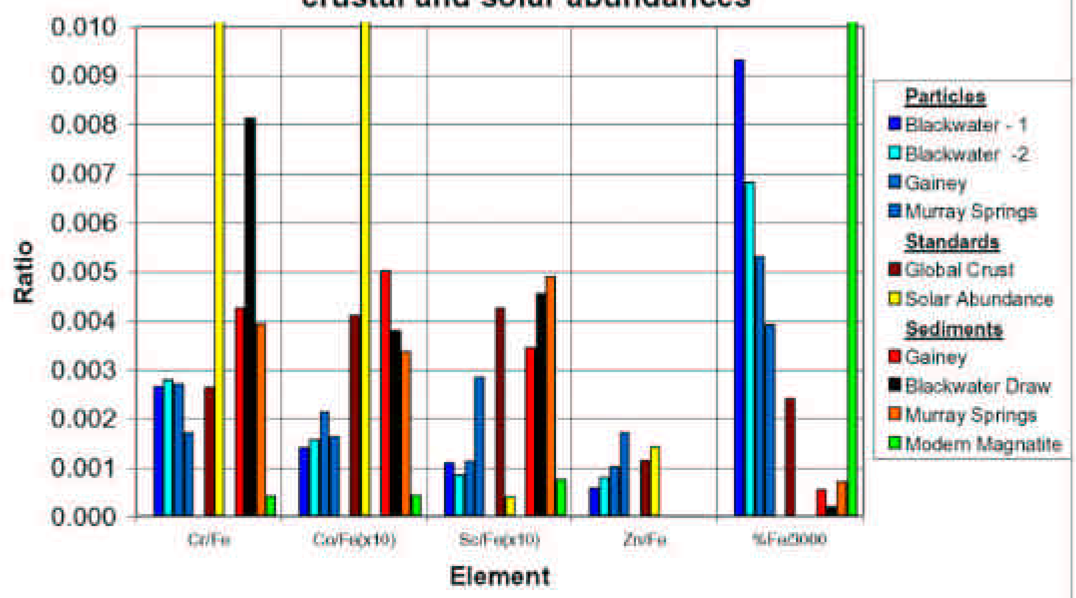


FIGURE 2. Distribution of magnetic particles in the sediment at Murray Springs. The particle density is strongly peaked near the bottom of the black mat, although some particles appear to have mixed into older sediments.

FIGURE 3. Comparison of elemental abundances in magnetic particles and associated sediments with crustal and solar abundances



In addition to the impact evidence in chert artifacts at Gainey, Murray Springs and Blackwater Draw, we have discovered a Mammoth tusk containing at least six micrometeorites embedded in the bark. The largest one, shown in Figure 5, is 4 mm in diameter surrounded by a carbonized ring. Each of the embedded micrometeorites strongly attracts a magnet indicating significant iron content.

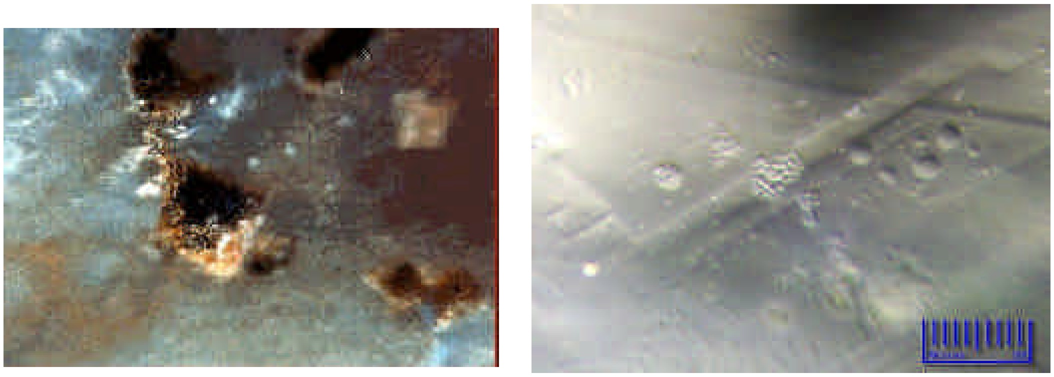


Figure 4. Left: embedded micrometeorites in chert from Gainey. Right: spalling and pitting in a quartz Clovis point from the Lehner Ranch site near Murray Springs.

Table 1. Embedded particle and track densities in chert artifacts from Clovis sites.

Site	**Coordinates**	**Density/mm^2**	**Depth(mm)**	**Angle**
Baker, NM	34.5°N, 106.4°W	130±60	10	~90°
Alton, IN	38.7°N, 86.2°W	700±300	60	~90°
Taylor, IL	39.1°N, 88.2°W	~400	60	~90°
Shoop,PA	40.4°N, 76.5°W	130±60	5	~5°
Leavitt. MI	42.4°N, 84.3°W	400±90	120	~90°
Gainey. MI	42.6°N, 83.4°W	460±70	120	~90°
Zander, ON	43.4°N, 79.2°W	200±140	60	~85°

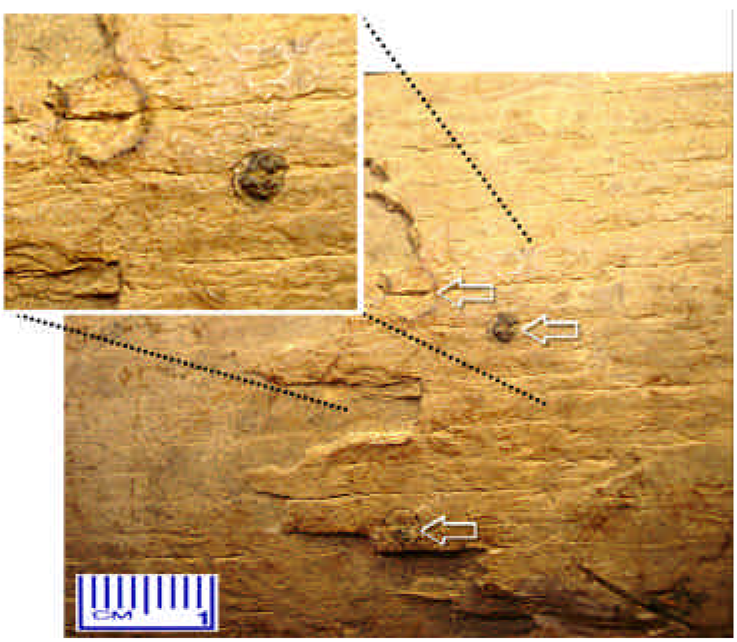


FIGURE 5. Embedded micrometeorites surrounded by carbonized rings in the bark of a Mammoth tusk. The inclusions all attract a magnet suspended nearby.

The condition of the tusk suggests that it dates to the late Pleistocene, and radiocarbon and palynological dating are planned. If our attribution of the tusk is correct, it provides prima facie evidence that Mammoths were directly impacted by high velocity micrometeorites and likely killed. Presumably this would have been a major, if not determining factor in the extinction of Mammoths and other megafauna.

If the source of magnetic particles is extraterrestrial, they could have been produced by the impact of a large meteor or comet over North America. Meteorites typically contain high nickel concentrations, which were not seen in our NAA measurements. Also, no crater can be associated with a meteor impact in this region. Comets are loosely aggregated and composed mostly of light elements, except perhaps in their nucleus, but a large comet exploding over North America could have blown terrestrial material into space, which would then redeposit over a large area, but this cannot explain the high velocity impact of magnetic material into the tusk or cherts. There was a significant increase in impact events during the Pleistocene as evidenced by $^{40}Ar/^{39}Ar$ dating of lunar glass spherules (see Culler, 2000), so it is reasonable to assume that an impact occurred..

Another possibility is that the particles arrived in the shockwave of a supernova. Our solar system exists in the middle of a local bubble (see Frisch, 1983) and there is evidence that about 20 near earth supernovas have occurred during the past 11 million years (see Benítez, 2001). Global radiocarbon doubled about 40,000 years ago and remained high until about 13,000 years ago when the excess ^{14}C began to steadily decline with very nearly the ^{14}C half-life (see Firestone, 2001). This is consistent with a γ-ray burst from the supernova, followed by increased cosmic ray irradiation of the atmosphere for many thousands of years and culminating with the shell of supernova ejecta impacting earth with a high velocity as it passed by. One signature of this impact would be the appearance of material with anomalous isotopic abundances for various elements. We have analyzed representative Paleo-Indian chert artifacts and controls from the Great Lakes region for ^{40}K by γ-ray counting and total potassium by Prompt Gamma-ray Activation Analysis. Enrichments of 20-90% in ^{40}K abundance were found only in the artifacts and associated sediments. This result supports the possibility that a nearby supernova played an important role in the creation of the magnetic particle layer, associated impact events, and the extinction of the Mammoths.

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