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SHORT COMMUNICATION

# PALEOECOLOGICAL IMPLICATIONS OF NEW MEGAFAUNAL $^{14}$C AGES FROM THE MCKITTRICK TAR SEEPS, CALIFORNIA

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The McKittrick tar seeps, located along the eastern foothills of the Temblor Range in the southern San Joaquin Valley of California (Kern County), are part of a vast complex of oil, gas, and tar seeps that occur throughout the heavily faulted zone that constitutes the western part of California (Hodgson, 1987) and includes the better known Rancho La Brea tar pits approximately 180 km southeast. The McKittrick seeps have yielded a diverse late Pleistocene biota that includes exceptionally well-preserved insects (Pierce, 1947; Miller and Peck, 1979; Miller, 1982, 1983; Stankiewicz et al., 1997), plant tissues (Mason, 1944), reptiles (Miller, 1942; Brattstrom, 1953), birds (Miller, 1924, 1925, 1927, 1935; DeMay, 1941), and mammals (Merriam and Stock, 1921; Schultz, 1938). Even from early descriptions, notable differences between the McKittrick and Rancho La Brea assemblages have been observed, e.g., fewer felids and dire wolves at McKittrick (Schultz, 1938), and distinct differences among and between localities in the relative abundance of aquatic birds (Miller, 1935). Schultz (1938) cogently argued that these differences likely reflected the same ecological differences we see today between the inland San Joaquin Valley and the southern coastal areas of California. The coastal and inland areas of southern California are typically recognized as distinct biozones or ecozones under multiple schema (e.g., Bailey, 1976, 1983; Welsh, 1994). The area surrounding McKittrick has most recently been recognized as a distinctive desert biozone, the San Joaquin Desert, with many endemic and endangered species that merit significant conservation efforts (Germano et al., 2011).

McKittrick fossils have generally been considered late Pleistocene (Wisconsinan) in age based on faunal comparisons (Schultz, 1938; FAUNMAP Working Group, 1994) and to belong to the Rancholabrean North American Land Mammal Age based on the presence of *Bison* (Lundelius et al., 1984; but see Bell et al., 2004, for problems with use of *Bison* for biostratigraphy), and it is usually considered contemporaneous with the other tar seep fossil deposits in the region: Rancho La Brea, Carpinteria, and Maricopa (Fig. 1). Rancho La Brea is among the best dated late Pleistocene sites (including 209 dated megafaunal specimens; O'Keefe et al., 2009). By contrast, the age of the McKittrick fossils has been constrained by only one direct faunal date from the LACM collection (France, 2008; *Hemiauchenia*, 26,850 ± 590 $^{14}$C ybp).

McKittrick provides an important inland corollary to the coastal Rancho La Brea tar pits; the two sites are separated by 180 km, but likely reflect quite different environmental settings in the Pleistocene as they do today and can also provide important information on the evolution of this distinctive ecological area, the San Joaquin Desert. Before we can meaningfully use McKittrick fossils for paleoecological or paleobiological analysis, a more solid temporal context for the site is needed. Here we report AMS radiocarbon dates on bone collagen for three specimens from McKittrick (*Arctodus simus*, *Panthera atrox*, *Cervus elaphus*; Table 1). All three taxa also occur at Rancho La Brea, but only *Arctodus* has been directly dated there (age range 28,350–27,330 $^{14}$C ybp for three specimens; O'Keefe et al., 2009).

**Abbreviations—$^{14}$C ybp**, radiocarbon years before present; **AMS**, accelerated mass spectroscopy; **LACM**, Natural History Museum of Los Angeles County, Los Angeles, California; **LACMIP**, LACM Invertebrate Paleontology Division; **UCMP**, University of California Museum of Paleontology, Berkeley, California.

## MATERIALS AND METHODS

### Historical and Curatorial Context

Excavations at McKittrick primarily took place between 1921 and 1927, along with small collections made in the mid-1940s, with the last significant excavation in 1949 (Merriam and Stock, 1921; Miller, 1924; Pierce, 1947; Church, 1968; Sternberg, 1985). Although fossils were known from asphalt deposits in the McKittrick area in the early 1900s, construction of the Taft-McKittrick highway exposed the first significant fossil deposits. Collections made in the area by a Mr. Owen of the Southern Pacific Railroad Co. were first accessioned into the University of California under the locality number UCMP 1370, a locality designation that was then used subsequently for other fossils found generally in the McKittrick area and/or which lacked specific pit information. Under the direction of Chester Stock, the UCMP conducted the first excavations in 1921, with further small collections made in 1922–1924 (UCMP loc. 4096). In 1925, Charles Sternberg began excavating at McKittrick, first in the old UCMP quarry, and then at a new locality, which became UCMP loc. 7139 (Sternberg Pit; Anderson, 1908; Merriam and Stock, 1921; Schultz, 1938; Church, 1968; Miller, 1983). Following Stock's departure from the UCMP in 1926 to assume a position at the California Institute of Technology (CIT), collections made by Sternberg in 1926–1927 went with Stock and locality CIT VP loc. 138 (= UCMP loc. 7139) was established. The CIT collections were later acquired by the LACM. In 1945, Dwight Pierce made collections of insects from the McKittrick tar seeps (LACMIP loc. 260). Additional collections were made by the LACM in the same area in 1947 (Pierce, 1947; Miller, 1983). In 1949, the LACM, along with the Kern County Museum and CIT, reworked the old UCMP site, recovering additional specimens (Church, 1968). Specimens recovered from the McKittrick tar seeps by University of California students on class trips to the area in the 1960s are cataloged under locality V3401 (for a site west of McKittrick), or under UCMP loc. V78042 (for McKittrick and Asphalto general collections). Historical data and detailed locality information (when available) is on file at UCMP and LACM.

### Geologic and Taphonomic Context

Stratigraphic relationships within and between excavation pits are not well documented. The LACM collections by Pierce in the 1940s appear to be younger than the UCMP localities, are

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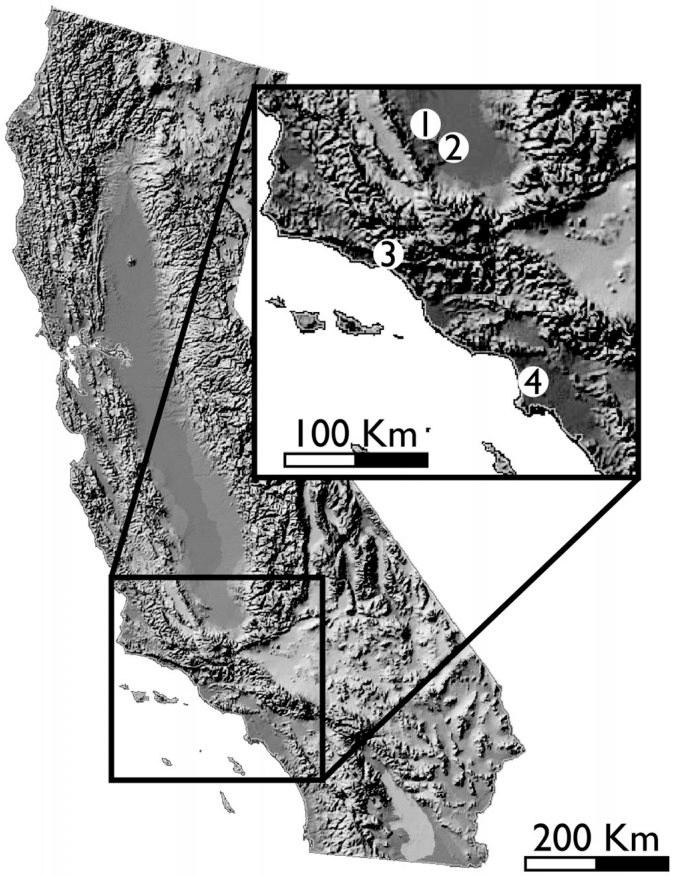


FIGURE 1. Map of California showing the tar seep localities of (1) McKittrick, (2) Maricopa, (3) Carpinteria, and (4) Rancho La Brea.

separated by hundreds of meters, and appear to represent distinct asphalt deposits. Plant material and insect fragments from LACMIP loc. 260 (Pierce's site 4) returned reliable dates ranging from 5255 to 7975 $^{14}$C ybp (for three dates; Miller, 1983). The one date on wood from the UCMP collection (UCLA-728; 38,000 ± 2500 $^{14}$C ybp) (Berger and Libby, 1966) was considered questionable by Miller and Peck (1979). Currently, we know of no other direct $^{14}$C dates for specimens from the UCMP loc. 1370 collection. Finally, specific locality information was not provided for the dated LACM *Hemiauchenia* specimen (France, 2008).

The fossiliferous deposits at McKittrick are primarily composed of thin lenses of asphalt and silt (Miller, 1935; Schultz, 1938). VanderHoof (1934) reported 180 bands of alternating asphalt and alluvial deposits, and interpreted the bands to form from tar seeping up through fissures, becoming more fluid and spreading out during summers, with alluvium being deposited during winter rainy seasons. The asphalt deposits record both Pleistocene and Holocene remains. Upper layers, some containing Holocene fauna, appear to be better stratified than the Pleistocene deposits. Much of the McKittrick cervid material (*Odocoileus* and *Cervus*) came from upper stratigraphic levels and was regarded as either late Pleistocene or early Holocene (Schultz, 1938). In addition to apparent temporal differences within and between McKittrick localities, environmental differences are indicated between the UCMP sites. For example, although UCMP loc. 4096 and 7139 are only about 30 m apart, the avifaunas differ significantly between these two asphalt lenses. UCMP loc. 4096 is dominated by waterfowl and shorebirds, composing two-thirds of the bird species, whereas at UCMP loc. 7139, 17% of bird taxa are aquatic species, with the remainder being nonaquatic taxa, including raptors, more characteristic of the avian assemblage at Rancho La Brea (Miller, 1925, 1935, 1944) and desert tortoises (*Gopherus agassizi*) are relatively common (Miller, 1942; P. Holroyd, pers. observ.). There are also preservational differences between the two UCMP localities. Specimens from UCMP loc. 7139 are better preserved, whereas specimens from UCMP loc. 4096 tend to crumble, perhaps due to less thorough tar impregnation (Miller, 1935).

### Sample Preparation and $^{14}$C Analysis

Specimen information is provided in Table 1, and all sampled specimens are from UCMP loc. 1370 (general McKittrick collection). Small bone fragments were removed from each specimen with a Dremel microdrill. Bone collagen from the *Cervus* sample was prepared and analyzed by Beta Analytic Inc. *Arctodus* and *Panthera* samples were prepared following the protocol of Fox-Dobbs et al. (2006), and purified collagen was analyzed at the Center for Accelerator Mass Spectrometry, Lawrence Livermore National Laboratory.

## RESULTS AND DISCUSSION

The *Arctodus* specimen was dated to 11,040 $^{14}$C ybp, and the *Panthera* was dated to 15,290 $^{14}$C ybp. Both of these dates are the youngest reported occurrences of these two predators in California, and to the best of our knowledge, the Pacific coastal region of North America. The McKittrick *Arctodus* falls within the range of published radiocarbon ages (34,080–9630 $^{14}$C ybp) for this species from sites throughout North America (reviewed in Schubert, 2010) and is contemporaneous with other dated *Arctodus* from west of the continental divide (Huntington Dam, Utah; 10,976 ± 40 $^{14}$C ybp). The McKittrick *Panthera* contributes to a very small set of $^{14}$C dates for *Panthera* from sites south of the Laurentide ice sheet (summarized in Barnett et al., 2009). Although Holocene records of *Cervus* are abundant in North America, $^{14}$C-dated late Pleistocene occurrences of elk are rare, particularly south of the Laurentide ice sheet (FAUNMAP, 1994; O'Gara and Dundas, 2002). The McKittrick *Cervus* specimen, dated to 11,160 $^{14}$C ybp, provides an important numerical age record for elk in California. It is the only directly dated Pleistocene *Cervus elaphus* specimen in the state and establishes the occurrence of the species in the southern San Joaquin Valley by at least the late Pleistocene. Although two other

TABLE 1. McKittrick specimen details and ages.

| UCMP no. | Species | Element | $^{14}$C age | Laboratory sample no. |
|---|---|---|---|---|
| 153241 | *Panthera atrox* | Mandible | 15, 290 ± 510 | CAMS-138656 |
| 153245 | *Arctodus simus* | Ulna | 11, 040 ± 310 | CAMS-138657 |
| 153257 | *Cervus elaphus* | Mandible | 11, 160 ± 60 | BETA-253903 |

**Abbreviations**: **BETA**, Beta Analytic Inc.; **CAMS**, Center for Accelerator Mass Spectrometry; **UCMP**, University of California Museum of Paleontology.

radiocarbon-dated late Pleistocene localities in California report *Cervus*, i.e., Rancho La Brea and Samwell Cave, the association of radiocarbon dates from these sites to the elk specimens is undetermined (Stock and Harris, 1992; Feranec et al., 2007; O'Keefe et al., 2009).

Direct evidence for temporal co-occurrence among *Cervus*, *Arctodus*, and *Panthera* during the late Pleistocene has not been well documented in most regions of North America. For example, although *Panthera* and *Arctodus* remains have been recovered from well-studied Rancholabrean localities (e.g., Natural Trap Cave and Rancho La Brea tarpits; Martin and Gilbert, 1978; Stock and Harris, 1992), we report the first $^{14}$C dates for both taxa from the same locality. In the case of McKittrick, the dates do not overlap, but further sampling is needed to explore patterns of co-occurrence between these predator taxa. In contrast, the new McKittrick $^{14}$C dates suggest possible co-occurrence of extinct *Arctodus* and extant *Cervus*. In eastern Beringia, the only North American region with a large number of dated *Cervus* and *Arctodus* specimens, there is no evidence for overlap in time. Specifically, *Cervus* appears in the fossil record ~13,000 $^{14}$C ybp, whereas *Arctodus* is absent after ~20,000 $^{14}$C ybp (Barnes et al., 2002; Guthrie, 2006). The McKittrick *Cervus* and *Arctodus* $^{14}$C dates highlight the potential for demonstrating the existence of faunal dynamics that lack modern analog, and may also lack other paleoanalogs. In fact, the carbon stable isotope values for the two taxa are similarly low in comparison with other analyzed megafauna at McKittrick, which may suggest a predator-prey interaction (Trayler, 2012).

Southern California was an ice age refugium (Johnson, 1977; Shaw and Quinn, 1986) due to its relatively mild climate during the last glacial maximum, and high vertebrate diversity (Stock and Harris, 1992). Nevertheless, the Pleistocene–Holocene megafaunal extinction event occurred as strongly and quickly in southern California as in other regions of North America (Koch and Barnosky, 2006). A detailed understanding of megafaunal extinction dynamics remains elusive, in part due to poor temporal context from most Rancholabrean fossil localities. Our results highlight the importance of future paleoecological work on the McKittrick biota. McKittrick radiocarbon dates span the Pleistocene–Holocene extinction event, and extend well into the Holocene (Miller, 1983; France, 2008; this study). This time period captures both the time period when both extinct and extant megafaunal taxa were present on the southern Californian landscape, and samples an area with a different ecological history than the better-known southern coastal regions.

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