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Cover Image

View looking northwest at Tonuco Mountain (a.k.a. San Diego Mountain), located along the eastern Rio Grande Valley between Las Cruces and Hatch in Doña Ana County, NM. Early Spanish settlers and explorers traveling between Chihuahua, Mexico and Santa Fe, New Mexico followed the Camino Real, which ran between the river and Tonuco Mountain in this area. The Tonuco Mountain horst is part of a structurally complex uplift with evidence for Neogene as well as older Laramide deformation (see Seager et. al, 1971, NM Bureau of Mines and Mineral Resources, Bulletin 97). The steep western side of the mountain includes interbedded volcanic, volcaniclastic and alluvial deposits of the Lower Santa Fe Group (including the Neogene Rincon Valley and Hayner Ranch formations), which are downfaulted against Proterozoic basement and overlying Paleozoic sedimentary rocks to the east. Fluorite and barite mineralization, largely in veins in Proterozoic rocks, were exploited to a limited degree at Tonuco Mountain during the early twentieth century. Pale-colored bluffs and cuestas eroded into the lower part of the Santa Fe Group are visible in the middle and foreground. The photo was taken during fieldwork in an area where exposures of the Upper Santa Fe Group (Plio-Pleistocene; Camp Rice Formation) have yielded an assemblage of late Pliocene vertebrate fossils (Tonuco Mountain Local Fauna), including a recently discovered early Blancan tapir, discussed by Morgan and others in this issue. *Photo and caption by Jeffrey Amato, NMSU.*

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The tapir *Tapirus* (Mammalia: Perissodactyla) from the late Pliocene (early Blancan) Tonuco Mountain Local Fauna, Camp Rice Formation, Doña Ana County, southern New Mexico

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Abstract

A mandible of a tapir (*Tapirus* sp.) from the late Pliocene (early Blancan North American land mammal age–NALMA), Tonuco Mountain Local Fauna (LF), Doña Ana County, southern New Mexico, is a significant addition to the small sample of fossil tapirs known from the late Cenozoic of New Mexico. The Tonuco Mountain tapir mandible is not identified to the species level because the diagnostic characters in the genus *Tapirus* are primarily found in the skull. It is most similar in size and morphological features to the mandible of the late Blancan species *Tapirus lundeliusi* from Florida. The Tonuco Mountain LF consists of 17 species of vertebrates, including a mud turtle, two tortoises, a duck, and 13 species of mammals. Among mammals in this fauna, the camel *Camelops*, the peccary *Platygonus*, and the horse *Equus scotti* first appeared in North American early Blancan faunas at about 3.6 Ma, whereas the horses *Nannippus peninsulatus* and *Equus simplicidens* became extinct in New Mexico in the late Blancan at about 2.6 Ma. The association of these mammals, together with the absence of mammals of South American origin that first appeared in the American Southwest at about 2.7 Ma, restricts the age of the Tonuco Mountain LF to the late early Blancan, between 2.7 and 3.6 Ma. The fossils from the Tonuco Mountain LF are derived from sediments of the axial-fluvial lithofacies of the ancestral Rio Grande, referred to the Camp Rice Formation. The sediments in the lower 30 m of the Camp Rice Formation section containing the Tonuco Mountain LF, including the *Tapirus* mandible, are normally magnetized and correspond to the lowermost portion of the Gauss Chron (C2An.3n), above the Gilbert/Gauss boundary (younger than 3.58 Ma) and below the base of the Mammoth Subchron (C2An.2r; older than 3.33 Ma). The mammalian biochronology and magnetostratigraphy restrict the age of the Tonuco Mountain LF to between 3.3 and 3.6 Ma (early late Pliocene, late early Blancan). The tapir mandible from the Tonuco Mountain LF is the first record of *Tapirus* from the early Blancan (2.7–4.9 Ma) of North America. *Tapirus* had a restricted geographic distribution in the late Pliocene and earliest Pleistocene (late early and late Blancan; ~1.6–3.6 Ma) of temperate North America, occurring primarily in the southern United States from Florida to California, including New Mexico.

Introduction

Exposures of the Camp Rice Formation near Tonuco Mountain, also known as San Diego Mountain, Doña Ana County, southern New Mexico, have produced a fairly diverse late Pliocene (early Blancan NALMA) vertebrate fossil assemblage called the Tonuco Mountain Local Fauna (Morgan et al., 1998). Field work in this area in the 1990s by Jerry MacDonald and paleontologists and geologists from the New Mexico Museum of Natural History (NMMNH) and New Mexico State University (NMSU) recovered fossils of 16 species of vertebrates: a turtle, two tortoises, a bird, and 12 species of mammals. While conducting geologic field work in the spring of 2008, co-author Eric Gottlieb collected the lower jaw of a tapir (genus *Tapirus*) from the Camp Rice Formation in the same general area where the remainder of the Tonuco Mountain Local Fauna (LF) was recovered. No fossils of *Tapirus* were collected in the earlier work on the Tonuco Mountain LF, and tapirs are rare in the Pliocene and Pleistocene vertebrate record of New Mexico (Morgan and Harris, 2015; Harris, 2016). We describe and illustrate this tapir mandible, compare it with other Pliocene and Pleistocene species of *Tapirus* from North America, use biochronology and magnetostratigraphy to establish its age, and discuss the occurrence of tapirs in the Pliocene and Pleistocene of New Mexico.

Materials and Methods

Fossil tapirs from New Mexico are reported from three museums: New Mexico Museum of Natural History (NMMNH), University of Texas at El Paso (UTEP), and the Frick Collection at the American Museum of Natural History (AMNH-FM). Other abbreviations used are: BLM (U. S. Bureau of Land Management), FAD (First Appearance Datum), GABI (Great American Biotic Interchange), GPTS (Geomagnetic Polarity Time Scale), LF (Local Fauna), NALMA (North American land mammal age), and NMSU (New Mexico State University). Measurements and dental descriptions of tapir teeth follow Hulbert et al. (2009). Abbreviations for tooth positions are standard for mammals, with upper case letters designating upper teeth and lower case letters for lower teeth. For example, an upper fourth premolar is designated as P4, while a first lower molar is m1. Only premolars (P/p) and molars (M/m) are represented in the fossil record of tapirs from New Mexico. All measurements are in mm.

The Miocene/Pliocene and Pliocene/Pleistocene boundaries and subdivisions of the Pliocene and Pleistocene epochs follow Gibbard et al. (2010) and Gradstein et al. (2012). The names and boundaries of the geomagnetic chrons and subchrons of the Geomagnetic Polarity Time Scale follow Berggren et al. (1995) and Gradstein et al. (2012). The definitions, boundaries, and subdivisions of the Blancan, Irvingtonian, and Rancholabrean North American land mammal ages follow Bell et al. (2004), with several minor changes in the boundaries between the subdivisions of the Blancan, specifically pertaining to the New Mexico record, from Morgan and Harris (2015).

Locality and associated vertebrate fauna

The Tonuco Mountain Local Fauna (LF) was named for a series of about 12 individual fossil localities of late Pliocene (early Blancan) age, located about 5 km southeast of Tonuco Mountain and 10 km northwest of Radium Springs, between Interstate Highway 25 and the Rio Grande, in northwestern Doña Ana County, southern New Mexico (Morgan et al., 1998; Fig. 1). Tonuco Mountain is also known as San Diego Mountain; the latter name was used in a previous geologic report on this area (Seager et al., 1971). The general vicinity where the Tonuco Mountain LF was collected is called Cedar Hill on the USGS Selden Canyon 7.5 minute topographic map (1982). The specific locality where the tapir jaw was collected is designated NMMNH locality L-8679 (Fig. 1). The approximate coordinates of the tapir locality are: 32°34' North latitude, 106°57' West longitude, and the elevation is 1,329 m (4,361 ft). The exact GPS coordinates and other field data for the tapir

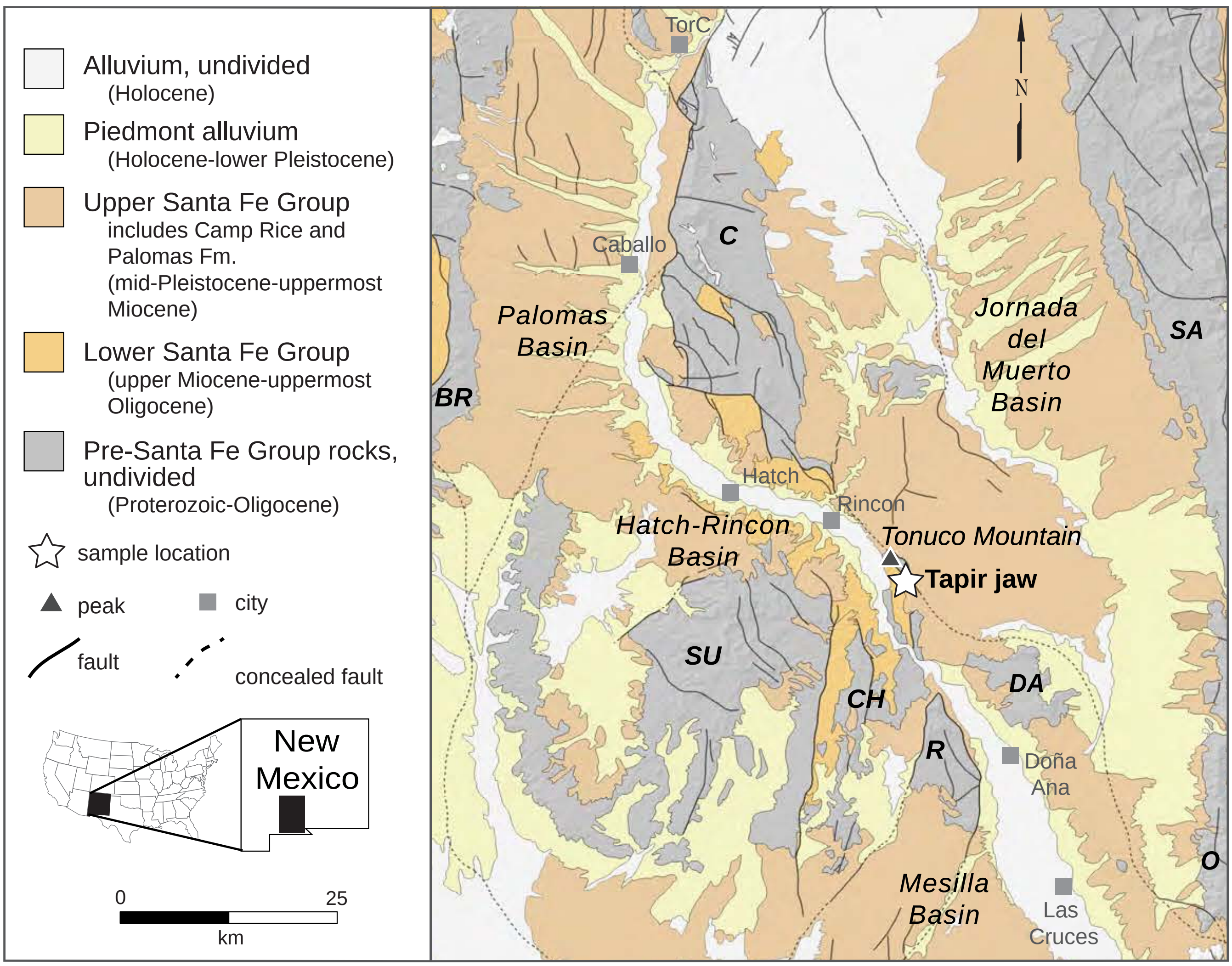

Figure 1. Small inset map on the bottom left shows the general location of the study area in south-central New Mexico. The enlarged map on the right shows the location of the fossil site where a tapir (*Tapirus*) mandible was collected, designated by a star, as well as nearby cities and towns, a geologic map, mountain ranges, and structural basins mentioned in the text (e.g., Jornada del Muerto basin). The tapir jaw is from the Tonuco Mountain Local Fauna (NMMNH locality L-8679) of Pliocene (Blancan) age, derived from the Camp Rice Formation, Cedar Hill area, Doña Ana County. Abbreviations for the basement ranges are as follows: BR = Black Range; C= Caballo Mountains; CH = Cedar Hills; DA = Doña Ana Mountains; O = Organ Mountains; R = Robledo Mountains; SA = San Andres Mountains; SU = Sierra de las Uvas.

locality and the other sites where the Tonuco Mountain LF are found are archived in the NMMNH Paleontology Collection. The fossil localities where Tonuco Mountain LF are found are on land under the jurisdiction of the U. S. Bureau of Land Management (BLM) and the New Mexico State University (NMSU) Animal Science Ranch.

TABLE 1. Vertebrate faunal list from the late Pliocene (early Blancan NALMA) Tonuco Mountain Local Fauna, Camp Rice Formation, Doña Ana County, New Mexico.

Reptilia			
	Testudines		
		Kinosternidae	
			Kinosternon sp.
		Testudinidae	
			Gopherus sp.
			Hesperotestudo sp.
Aves			
	Anseriformes		
		Anatidae	
			genus and species undetermined
Mammalia			
	Lagomorpha		
		Leporidae	
			genus and species indeterminate
	Carnivora		
		Mustelidae	
			Taxidea sp.
		Canidae	
			Borophagus sp.
			Canis lepophagus
	Perissodactyla		
		Tapiridae	
			Tapirus sp.
		Equidae	
			Equus scotti
			Equus simplicidens
			Nannippus peninsulatus
	Artiodactyla		
		Tayassuidae	
			Platygonus cf. *P. bicalcaratus*
		Camelidae	
			Camelops large undescribed sp.
			Hemiauchenia blancoensis
			Hemiauchenia small sp.
	Proboscidea		
		Gomphotheriidae	
			cf. *Rhynchotherium* sp.

Seager et al. (1971, p. 18) first mentioned vertebrate fossils from the Cedar Hill/San Diego Mountain/Tonuco Mountain area in their study of the geology of San Diego Mountain. They stated that "…horse teeth, fragments of mastodont teeth, and miscellaneous bone fragments of medium-to-large size vertebrates have been recovered..." and "...are currently being studied by W.S. Strain, University of Texas at El Paso." Strain, now deceased, never described these specimens, and Morgan et al. (1998) were unable to determine their whereabouts. In the 1990s, Jerry MacDonald from Las Cruces, New Mexico, field crews from the NMMNH, and co-author Greg Mack and his students from NMSU collected additional vertebrate fossils from the Tonuco Mountain/Cedar Hill area. Morgan et al. (1998) described these fossils as the Tonuco Mountain LF, composed of 16 species, including the mud turtle *Kinosternon*, the land tortoises *Gopherus* and *Hesperotestudo*, a duck (Anatidae), and 12 species of mammals (faunal list in Table 1). In the spring of 2008, Eric Gottlieb, then a geology graduate student at NMSU, discovered a lower jaw of the tapir *Tapirus* in an in-place sandstone bed of the Camp Rice Formation in the Cedar Hill area (Fig. 3). *Tapirus* is a new addition to the Tonuco Mountain LF, as no tapirs were identified in the original sample of this fauna (Morgan et al., 1998).

The Tonuco Mountain LF is mostly composed of large vertebrates, including numerous shell fragments of large tortoises and isolated teeth and postcranial elements of horses, camels, and proboscideans, as well as a few specimens of carnivores (Morgan et al., 1998). Fossils are not particularly common in this area, consisting primarily of isolated elements recovered through surface prospecting. Two proboscidean fossils, a partial lower jaw and a partial femur, were excavated from in-place deposits and preserved in plaster jackets. The most common mammals in the Tonuco Mountain LF are: two species of the horse *Equus*, *E. scotti* and *E. simplicidens*; one species each in the camel genera *Camelops* and *Hemiauchenia*; and a gomphotheriid proboscidean probably referable to the genus *Rhynchotherium*. The gomphothere was previously referred to the genus *Cuvieronius* (Morgan et al., 1998). However, subsequent work has demonstrated that *Cuvieronius* is restricted to Pleistocene faunas (Irvingtonian and Rancholabrean NALMAs), and the similar *Rhynchotherium* occurs in North American faunas from the Hemphillian and Blancan NALMAs (Morgan et al., 2016). Giant land tortoises of the genus *Hesperotestudo* are also common members of the fauna. Two postcranial elements of rabbits (Leporidae) and two partial limb bones of ducks (Anatidae) are the only small vertebrate remains recovered from the Tonuco Mountain LF. Despite a concerted effort by NMMNH field crews to find small vertebrate fossils, no concentrations of smaller vertebrates were located in the predominantly coarse-grained sediments of the Camp Rice Formation in the Tonuco Mountain/Cedar Hill area.

Geology

The fossils in the Tonuco Mountain LF, including the tapir mandible described here, were derived from sediments of the Camp Rice Formation southeast of Tonuco Mountain near Cedar Hill, in the western portion of the Jornada basin (Morgan et al., 1998). The Camp Rice Formation in southern New Mexico is primarily composed of sediments of the axial-fluvial lithofacies of the ancestral Rio Grande (Mack et al., 1993, 1998). The Camp Rice Formation was originally named by Strain (1966) for strata in the Hueco bolson or basin in the Rio Grande valley of Trans-Pecos Texas south of El Paso, about 180 km southeast of the Tonuco Mountain/Cedar Hill area. A late Blancan vertebrate fauna named for the type area of the Camp Rice Formation, the Hudspeth LF (Strain, 1966), is somewhat younger than the Tonuco Mountain LF (Morgan et al., 1998). The Camp Rice Formation has subsequently been used as a map unit in the Mesilla, Jornada, and Hatch-Rincon basins in southern New Mexico (Seager et al., 1971; Seager and Clemons, 1975; Vanderhill, 1986; Mack et al., 1993, 1998; Morgan et al., 1998). North of the Hatch–Rincon basin, in the Palomas and Engle basins in Sierra County, similar sediments forming the axial-fluvial lithofacies of the ancestral Rio Grande are referred to the Palomas Formation (Lozinsky and Hawley, 1986a, b; Mack et al., 1993, 1998); these strata contain both early and late Blancan vertebrate faunas (Morgan et al., 2011).

There are two published stratigraphic sections of the Camp Rice Formation in the Tonuco Mountain/Cedar Hill area (Mack et al., 1993; Morgan et al., 1998). Even though these sections were measured at different times, by different geologists, and in slightly different locations, they are remarkably similar in overall thickness and lithologic descriptions of the individual units. The stratigraphic section of Mack et al. (1993) included

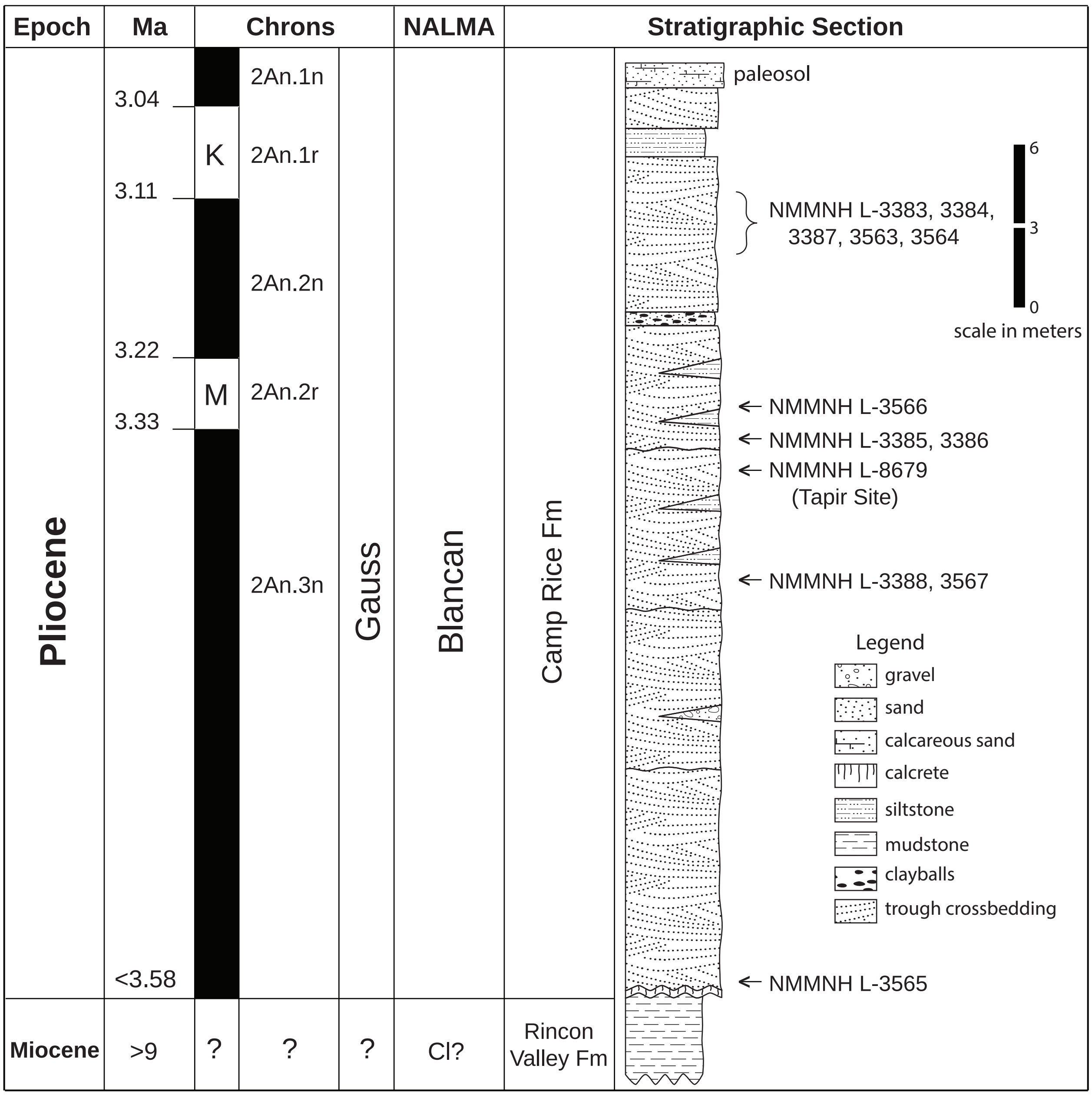

Figure 2. Stratigraphic section of the Camp Rice Formation from the Cedar Hill/Tonuco Mountain area, Doña Ana County, New Mexico, showing the lithology, stratigraphic position of key vertebrate fossils, including the tapir (*Tapirus*) mandible (NMMNH locality L-8679), and magnetostratigraphy (section modified from Mack et al., 1993; Morgan et al., 1998). The entire magnetostratigraphic section is within the Gauss Chron. K is the Kaena subchron and M is the Mammoth subchron. Other subchrons are designated by letters and numbers (e.g., 2An.3n), corresponding to the Geomagnetic Polarity Time Scale (Gradstein et al, 2012). NALMA is the abbreviation for North American land mammal age. Cl is the abbreviation for the Clarendonian NALMA.

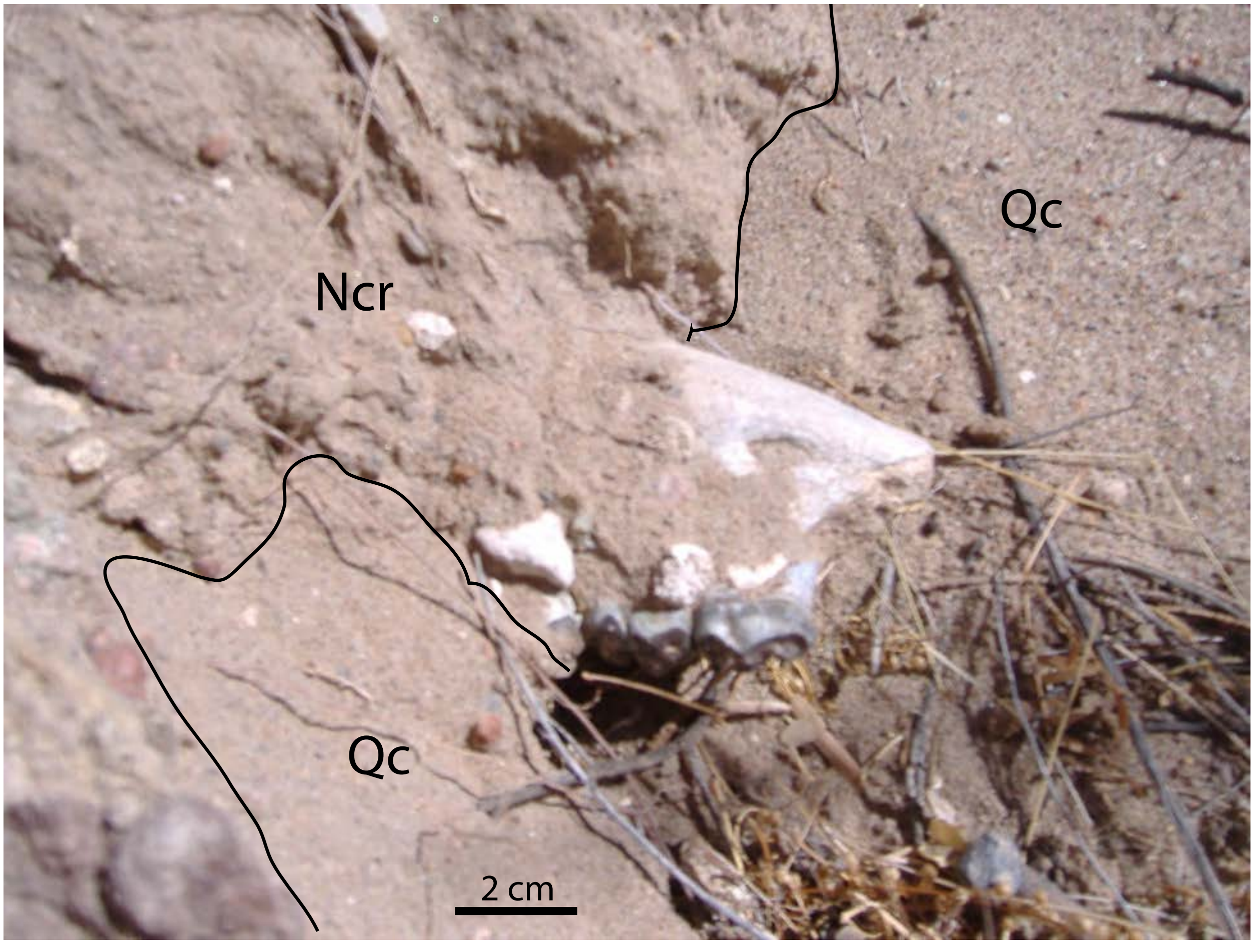

Figure 3. Anterior end of a tapir (*Tapirus*) mandible with two premolars (p2 and p3) exposed, preserved in place in a poorly exposed bed of the Camp Rice Formation, Cedar Hill area, Tonuco Mountain Local Fauna, Doña Ana County, New Mexico (NMMNH locality L-8679). Ncr, Pliocene (Blancan) Camp Rice Formation; Qc, colluvium. Collected by Eric Gottlieb in March 2008. The scale bar at the bottom of the photograph is 2 cm.

magnetic-polarity stratigraphy, which is discussed in more detail below. The stratigraphic section of Morgan et al. (1998) also indicated the position of key vertebrate fossils of the Tonuco Mountain LF.

The Camp Rice Formation is well exposed on the north- and northwest-facing escarpment of Cedar Hill, where it unconformably overlies red mudstones of the Miocene Rincon Valley Formation and is capped by a petrocalcic paleosol (Hawley et al., 1969; Seager et al., 1971). The two measured stratigraphic sections of the Camp Rice Formation at Cedar Hill are about 50 m in thickness, and consist primarily of sandstones (57%) and conglomerates (38%), with sandy mudstone (5%) as a minor component. Figure 2 is a composite of the two published stratigraphic sections for the Cedar Hill area, showing both the magnetostratigraphy (Mack et al., 1993) and placement of key vertebrate fossils (Morgan et al., 1998), including the stratigraphic position of the tapir mandible from site NMMNH L-8679. The jaw was collected ~20 cm above the modern wash base from a bed of poorly sorted and poorly consolidated, grayish-brown, conglomeratic sandstone of the Camp Rice Formation, and ~30 m above the projected contact with the underlying Rincon Valley Formation (Fig. 2). At the exposure, the alluvial stratum that contained the fossil is partly covered by finer-grained Quaternary colluvium eroded from the overlying outcrop, and is discernable from the latter by a greater abundance of predominantly matrix-supported gravel-to pebble-size clasts, a more consolidated (clumpy) appearance, and a slightly steeper profile at the exposure (Fig. 3).

Chronology

Biochronology

Most of the vertebrate faunas from the Camp Rice Formation in southern New Mexico and southwestern Texas are referred to the Blancan NALMA on the basis of mammalian biochronology. The Blancan NALMA in the American Southwest has been subdivided into the following four intervals, with approximate age ranges in parentheses (Bell et al., 2004; with modifications from Morgan and Harris, 2015): earliest Blancan (~3.6–4.9 Ma); late early Blancan (~2.7–3.6 Ma); early late Blancan (~2.2–2.7 Ma); latest Blancan (~1.6–2.2 Ma). The boundary between the early and late Blancan at 2.7 Ma is slightly older than the revised Pliocene/Pleistocene boundary at 2.58 Ma (Gibbard, 2010). Among the mammals identified from the Tonuco Mountain LF, the following are indicative of the Blancan: the dogs (Canidae) *Canis lepophagus* and *Borophagus* sp.; the horses (Equidae) *Nannippus peninsulatus* and *Equus simplicidens*; the peccary (Tayassuidae) *Platygonus bicalcaratus*; and two camels (Camelidae), *Hemiauchenia blancoensis* and a large species of *Camelops* previously referred to *C. traviswhitei* (Morgan and Harris, 2015). Baskin and Thomas (2016) recently synonymized *C. traviswhitei* with the Rancholabrean species *C. hesternus*, but also indicated the presence of a large species of *Camelops* in Blancan faunas of western North America. This large and evidently undescribed species of *Camelops* is present in the Tonuco Mountain LF and many other New Mexico Blancan faunas (Morgan et al., 1998; Morgan and Harris, 2015).

Several species restrict the age of the Tonuco Mountain LF within the Blancan. *Equus simplicidens* is absent from very early Blancan faunas, appearing about 4 Ma, and became extinct in New Mexico in the early late Blancan at about 2.6 Ma. *Nannippus peninsulatus* has a similar biochronologic range, disappearing from New Mexico at about 2.6 Ma (Morgan and Harris, 2015). There are no records of *E. simplicidens* or *N. peninsulatus* in New Mexico from sites younger than the Gauss/Matuyama boundary (2.58 Ma). Both of these species are known from the Blanco LF in the Panhandle of Texas (Dalquest, 1975), which occurs in the lowermost Matuyama Chron (C2r.2r; 2.15– 2.58 Ma; Lindsay et al., 1976), almost certainly in the older part of that time interval (~2.4–2.6 Ma). *Platygonus* and *Camelops* do not appear until the beginning of the late early Blancan (about 3.6 Ma; Lindsay et al., 1984). A second species of *Equus* from the Tonuco Mountain LF, *E. scotti*, is larger than *E. simplicidens* and has a different enamel pattern in the upper and lower cheek teeth. *E. scotti* is the typical large horse in southwestern early Irvingtonian faunas, including Tijeras Arroyo and Adobe Ranch from New Mexico, but is also fairly common in the Blancan (Morgan and Lucas, 2003; Morgan and Harris, 2015). *E. scotti* first appeared in New Mexico in late early Blancan faunas, including Tonuco Mountain from the Camp Rice Formation and Arroyo de la Parida, Cuchillo Negro Creek, and Elephant Butte Lake from the Palomas Formation (Morgan et al., 2008b; 2011).

The Tonuco Mountain LF lacks South American immigrant mammals that participated in the Pliocene phase of the Great American Biotic Interchange (GABI), and first arrived in the southwestern United States at the beginning of the late Blancan at about 2.7 Ma (Woodburne and Swisher, 1995; Woodburne, 2004, 2010; Morgan, 2008). The first appearance datum (FAD) of 2.7 Ma for South American immigrants in the American Southwest is based on the occurrence of xenarthrans (glyptodonts and mylodontid ground sloths) and/or caviomorph rodents (capybaras and porcupines) in one or more early late Blancan faunas in Arizona and New Mexico, in strata of the uppermost Gauss Chron just below the Gauss/Matuyama boundary at 2.58 Ma. Mammals of South American origin that first appeared in the American Southwest about 2.7 Ma include: the glyptodont *Glyptotherium texanum* (= *G. arizonae*; see Gillette et al., 2016) and the capybara *Neochoerus* (=*Phugatherium* of Vucetich et al., 2015) *dichroplax* from the 111 Ranch Fauna in Arizona (Ahearn and Lance, 1980; Galusha et al., 1984) and *Glyptotherium texanum* and the mylodontid ground sloth *Paramylodon garbanii* from the Pearson Mesa Fauna in New Mexico (Tomida, 1987; Morgan et al., 2008a). Biochronologic data restrict the age of the Tonuco Mountain LF to the late early Blancan, between 2.7 and 3.6 Ma, based on the first occurrence of *Equus scotti, Camelops* and *Platygonus* at about 3.6 Ma, the presence of *Nannippus peninsulatus* and *Equus simplicidens* which became extinct in New Mexico at about 2.6 Ma, and the absence of South American immigrants which first appeared about 2.7 Ma.

Magnetostratigraphy

A previous study of the magnetic-polarity stratigraphy of the Camp Rice Formation at Cedar Hill further refines the age of the Tonuco Mountain LF (Mack et al., 1993), and specifically the lower jaw of *Tapirus* reported here. Paleomagnetic samples confirm that the entire measured stratigraphic section (~50 m) of the Camp Rice Formation at Cedar Hill is within the Gauss Chron (C2An; 2.58–3.58 Ma; Mack et al., 1993; Fig. 2). The lower 30+ m of this section consists of a long interval of normal polarity that was correlated with the lower Gauss Chron (C2An.3n; between 3.33 and 3.58 Ma). The lowermost boundary of the Gauss Chron is not preserved in the Cedar Hill section because the Camp Rice Formation unconformably overlies the Miocene Rincon Valley Formation. The age of the base of the Cedar Hill section cannot be precisely dated but is younger than the boundary between the Gauss and Gilbert chrons at 3.58 Ma.

The stratigraphic positions of key vertebrate fossil specimens of the Tonuco Mountain LF, which were found at four different levels (Morgan et al., 1998), are plotted together with the magnetostratigraphy (Mack et al., 1993) on Figure 2. The fossiliferous interval containing the Tonuco Mountain LF is above the base of the Gauss Chron (younger than 3.58 Ma) and below the top of the Kaena Subchron (C2An.1r; 3.04 Ma), providing an age range of approximately 3.0–3.6 Ma (Morgan et al., 1998). The site where the tapir mandible was collected (NMMNH L-8679) occurs in the lower 30 m of the Cedar Hill section of Mack et al. (1993). These strata are normally magnetized and correspond to the lowermost portion of the Gauss Chron (C2An.3n), above the Gilbert/Gauss boundary (3.58 Ma) and below the base of the Mammoth Subchron (C2An.2r; 3.33 Ma). The combination of magnetostratigraphy (lowermost Gauss Chron) and mammalian biochronology (late early Blancan) restricts the age of the tapir jaw to between 3.3 and 3.6 Ma.

Systematic Paleontology

Class MAMMALIA Linnaeus, 1758
Order PERISSODACTYLA Owen, 1848
Family TAPIRIDAE Gray, 1821
Genus *TAPIRUS* Brisson, 1762
Tapirus sp.

Referred specimen—NMMNH 63863, partial left dentary with p2–m2 (measurements in Table 2).

Locality—NMMNH locality L-8679, Tonuco Mountain Local Fauna, Camp Rice Formation, Tonuco Mountain/Cedar Hill area, Doña Ana County, New Mexico (Fig. 1).

Description—NMMNH 63863 consists of a partial mandible of a medium-sized tapir with the p2–m2, lacking the lower incisors, canine, and third molar (m3), as well as the mandibular symphysis, ascending ramus, masseteric fossa, and mandibular angle (Fig. 4). The open alveolus behind the m2 and lack of wear on the posterior cingulum of the m2 indicates that the m3 had

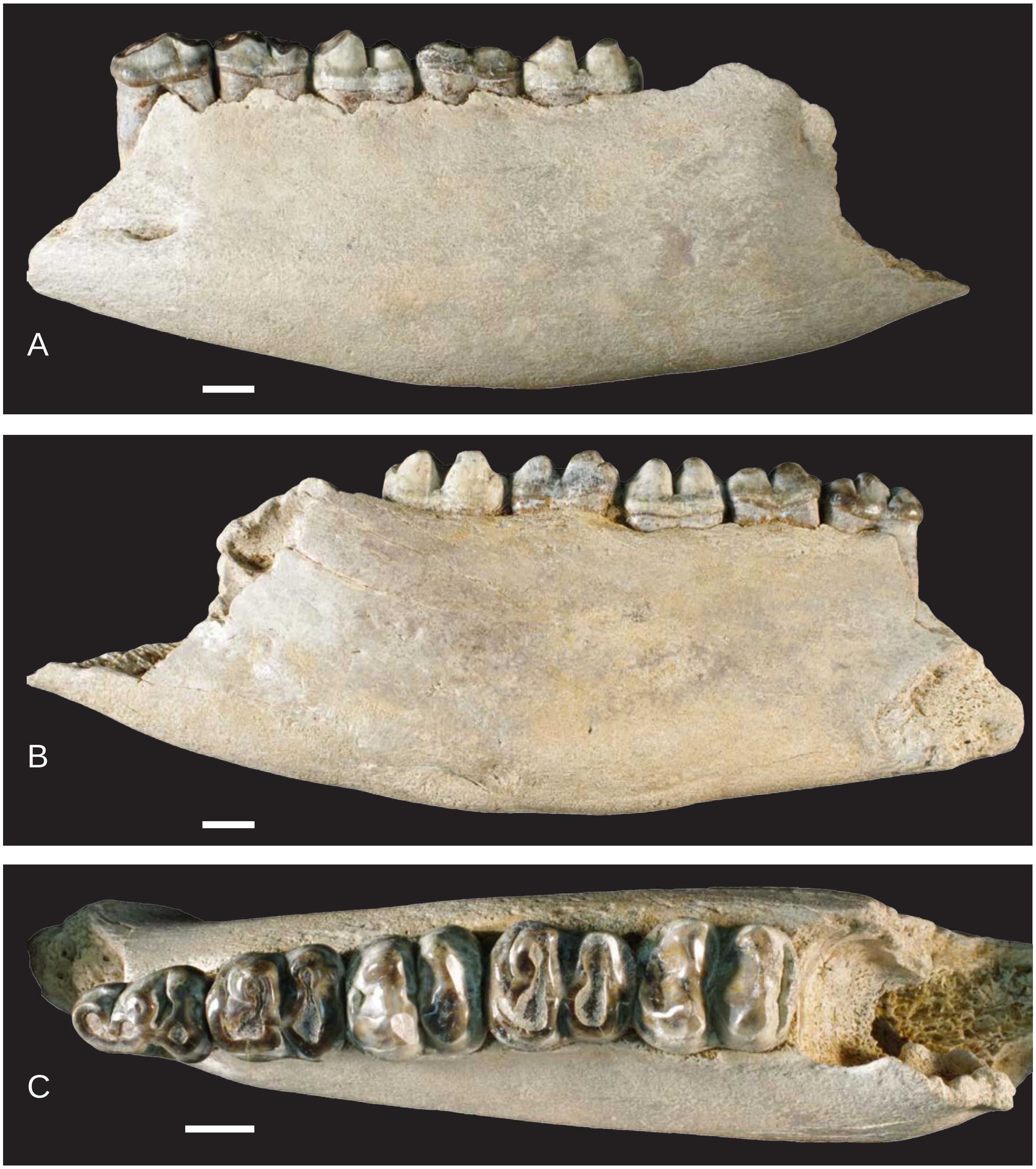

Figure 4. Tapir (*Tapirus* sp.), partial left dentary with p2-m2, where p refers to premolar and m to molar (NMMNH 63863) from the early Blancan Tonuco Mountain Local Fauna, Doña Ana County, New Mexico in labial A), lingual B), and occlusal C) views. All scale bars are 1 cm.

not erupted, but it had mineralized and was beginning to erupt. The p4 is fully erupted and in wear. This places it in the young adult stage of Hulbert et al. (2009). The remaining portion of bone preserves these features: 1) mental foramen and termination of the mandibular symphysis are located ventral to p2; 2) ventral border of the ramus below the cheektooth series is strongly concave; 3) the dentary is deep and thick relative to tooth size; and 4) depth of the mandible is much greater below the molars than below the anterior premolars. The thickness of the jaw ventral to the p4–m3 is partially due to what appears to be a pathologic excess of bone deposited on the lower lingual surface of the dentary. This pathologic bone deposit also makes the ventral border of the ramus look more curved than it would be otherwise.

The teeth, especially the p2–p3 and m1, are far more worn than is usually observed in *Tapirus* at the young adult stage of dental eruption and wear (Fig. 4c). The transverse crests of the p4 and m2 are rounded and polished. This could have been caused by either a diet comprising more abrasive fodder than normal (or one contaminated long-term by grit or volcanic ash), or that the individual had pathologically soft tooth enamel. An alternate hypothesis for the unusual tooth wear is that eruption of the m3 began much later than normal. Whatever the cause for the unusually heavy wear, it was a long-term event, based on its uneven expression on the teeth: greatest in those teeth that erupted first (m1, p2, and p3), but still acting on the m2 and p4 that would have erupted a year or more after the p2 and p3. The underlying morphology of

TABLE 2. Measurements of the lower dentition and dentary of *Tapirus* sp. from the early Blancan Tonuco Mountain LF, Doña Ana County, New Mexico. Abbreviations: l (length), w (width). Measurements of the depth of dentary were taken on the lingual (medial) surface. All measurements are in mm.

Species, locality and catalog number	length of p2–p4	p2		p3		p4		m1		m2		depth of dentary below	
		l	w	l	w	l	w	l	w	l	w	p2	m2
Tapirus sp.													
Tonuco Mountain, NM													
NMMNH 63863	61.9	20.8	14.4	19.5	17.2	19.9	18.3	21.7	19.2	23.7	20.3	50.5	58.3

the lower cheekteeth is that found on late Miocene and younger members of the genus *Tapirus*. The one possibly phylogenetically significant feature is a relatively strong posterior cingulum on the molars.

Comparisons—Based on tooth size (Table 2), NMMNH 63863 belongs to a medium-sized species of *Tapirus*, similar in size to the extant species *Tapirus terrestris* and *T. bairdii*, and the extinct species *T. lundeliusi* and *T. veroensis* (Hulbert, 2010). The premolar length (p2–p4) of 61.9 mm is within the observed range of these four species, together with the middle Miocene *Tapirus johnsoni*. The premolar length is about 20% greater than the largest individual of the small-sized late Miocene and earliest Pliocene (Hemphillian NALMA) species *T. polkensis*, but below the observed range of large-bodied species such as the extant *T. indicus*, the late Miocene *T. webbi*, and the Pliocene and Pleistocene *T. haysii* and *T. merriami* (Jefferson, 1989; Hulbert, 1995, 2010; Hulbert et al., 2009). In addition to size, *T. webbi* differs from NMMNH 63863 by its relatively narrow cheekteeth and shallow ramus (Hulbert, 2005). *T. johnsoni* differs from NMMNH 63863 by having the mental foramen located more anteriorly and less of a difference in jaw depth below the premolars and molars. Among North American *Tapirus*, NMMNH 63863 is most similar to *Tapirus lundeliusi* (late Blancan of Florida) in its combination of moderate size and morphologic features of the dentary, most notably its relative great depth ventral to the molars.

Discussion

A brief review of *Tapirus* from New Mexico and the American Southwest

Fossils of tapirs (*Tapirus*) are rare in the Pliocene and Pleistocene of New Mexico. In addition to the mandible from the Tonuco Mountain LF described here, only seven other fossil tapir specimens have been reported from the state (Vanderhill, 1986; Harris, 1993, 2016; Morgan and Harris, 2015). The most complete tapir fossils from New Mexico are two specimens referred to the large species *T. merriami* from the latest Blancan La Union Fauna (= Mesilla Basin faunule B of Vanderhill, 1986), from the Camp Rice Formation in the Mesilla basin in southern Doña Ana County. A partial articulated skeleton lacking the skull and jaws from the La Union Fauna (AMNH-FM 37301) is mostly unprepared and still preserved in a plaster jacket. Only the left humerus, radius, ulna, and metacarpals 2–4 of this specimen have been removed from the jacket and prepared. This skeleton is tentatively referred to *T. merriami* based on its large size, but the diagnostic dental features of this species cannot be evaluated because the skull was not preserved. A palate with right and left P1–M2 from the La Union Fauna (UTEP 33–42) is the only tapir fossil known from New Mexico that can be confidently identified to the species level. Dental features of this specimen indicate referral to *T. merriami* based on characters proposed by Jefferson (1989), in particular, large size and a submolariform P2 with a weakly developed protoloph. A third specimen of large *Tapirus* from the La Union Fauna consists of a dentary fragment with the roots of two teeth (UTEP 33-90). With the exception of the palate, the two other tapir fossils from the late Blancan La Union Fauna do not preserve the diagnostic dental characters of *T. merriami*, and are only tentatively referred to that species based on their large size and occurrence in the western United States.

Tapirs are unknown from faunas dating to the Irvingtonian NALMA (early to medial Pleistocene) in New Mexico, and the record of *Tapirus* from the Rancholabrean NALMA (late Pleistocene) in the state is sparse. Three Rancholabrean specimens from New Mexico are tentatively referred to the large species *T. merriami*: a fragment of a left dentary with the roots of m2 and m3 from the Albuquerque Gravel Pits in northern New Mexico (NMMNH 61715; Morgan and Harris, 2015) and two specimens from Eddy County in southeastern New Mexico, a third metatarsal from the Lost Valley site in Dry Cave (UTEP 1-827) and an upper incisor (I2) from Dark Canyon Cave (Harris, 1993, 2016). There is also a record of *Tapirus* from a cave in the Cornudas Mountains in Otero County in southern New Mexico, presumably of late Pleistocene age, although the nature of the fossil material is not known and the locality is questionable (Harris, 1993, 2016). Their large size and occurrence in the American Southwest suggest that Rancholabrean tapir fossils from New Mexico are probably referable to *T. merriami*.

Jefferson (1989) reviewed the fossil history of *Tapirus* from the region west of the Rocky Mountains, including California, southern Oregon, Arizona, and northern Mexico, but he did not examine any Pliocene or Pleistocene tapirs from New Mexico. Jefferson (1989) referred specimens of large tapirs from late Blancan and early Irvingtonian faunas in southern California (e.g., Anza-Borrego, Bautista Creek) to *T. merriami*, whereas smaller tapirs from the early Irvingtonian El Golfo Fauna in Sonora, northwestern Mexico were identified as *T. californicus*. Exclusive of California and New Mexico, fossils of a large *Tapirus*, probably referable to *T. merriami*, are known from four other southwestern Blancan faunas, all late Blancan: Hudspeth in southwestern Texas (Strain, 1966); 111 Ranch and San Simon in southeastern Arizona (Morgan and White, 2005); and Donnelly Ranch in southeastern Colorado (Hager, 1974).

Large tapirs of late Blancan and early Irvingtonian age from the eastern United States, particularly Florida, have been referred to *Tapirus haysii* (Ray and Sanders, 1984; Hulbert, 1995, 2010). Hulbert (2010) described the medium-sized species *T. lundeliusi* from the late Blancan of Florida. Among the three recognized species of North American Blancan tapirs, *T. haysii, T. lundeliusi*, and *T. merriami*, the early Blancan *Tapirus* mandible from the Tonuco Mountain LF is most similar in size and morphological characters to *T. lundeliusi*. However, a referral to that species cannot be confirmed because the key morphological features distinguishing *T. lundeliusi* are in the skull, whereas only a lower jaw is known of the Tonuco Mountain tapir.

The tapir fossil from the late early Blancan (~3.3–3.6 Ma) Tonuco Mountain LF represents the oldest *Tapirus* known from New Mexico. A tapir reported from the Elephant Butte Lake Fauna from the Palomas Formation in Sierra County (Tedford, 1981) would also be late early Blancan in age based on the mammalian biochronology of that fauna (Morgan et al., 2011), but we have not been able to verify this record. *Tapirus* is unknown from the numerous Miocene faunas from the Albuquerque and Española basins in northern New Mexico (Morgan, 2015). After the Tonuco Mountain mandible, the next oldest tapirs from New Mexico are the three specimens of *T. merriami* from the latest Blancan La Union Fauna (~2.0–2.2 Ma).

The mandible of *Tapirus* from the Tonuco Mountain LF fills a long gap in the North American tapir record, between the small species *T. polkensis* from the late Miocene and earliest Pliocene (late Hemphillian; ~5–7 Ma) of Florida and Tennessee and *T. haysii, T. lundeliusi*, and *T. merriami* from the early Pleistocene (late Blancan; ~1.6–2.6 Ma; Jefferson, 1989; Hulbert et al., 2009; Hulbert, 2010). Based on the published fossil record of *Tapirus* from North America (Ray and Sanders, 1984; Jefferson, 1989; Cassiliano, 1999; Graham, 2003; Hulbert, 2010), the Tonuco Mountain tapir appears to represent the only known early Blancan specimen. In a biochronologic analysis of the mammalian fauna from the Fish Creek-Vallecito Creek section in the Anza-Borrego Desert, Cassiliano (1999) recorded at least five specimens of *Tapirus*, with the earliest record from the lower Matuyama Chron corresponding to the latest Blancan (~2.2 Ma). Blancan tapirs are more common in Florida than anywhere else in North America, but all of these records are late Blancan in age (Hulbert, 2010). Hulbert (2010) described the species *Tapirus lundeliusi* from several latest Blancan faunas in Florida, including Haile 7C, Haile 7G, and Inglis 1A. These three faunas are broadly correlative with the latest Blancan La Union Fauna in southern New Mexico (Morgan 2008), which has produced the large tapir, *T. merriami*. Early Blancan faunas appear to be absent in Florida, as this was a time period of warm temperatures and high sea levels that mostly inundated the Florida peninsula (Morgan, 1993).

Paleoecology and biogeography

The Tonuco Mountain fauna is predominantly composed of large species of ungulates, in particular, horses and camels, that preferred a grassland or savanna habitat, as well as numerous specimens of the giant land tortoise *Hesperotestudo*. Based on their abundance in other New Mexico Blancan faunas that sampled a savanna environment, it appears that land tortoises also favored grassland habitats. There is a minor component of freshwater species in the Tonuco Mountain LF, including the small mud turtle *Kinosternon* and ducks, and possibly the tapir. The occurrence of the Tonuco Mountain LF in sediments of the axial-fluvial lithofacies of the ancestral Rio Grande provides evidence for riparian conditions along a perennial river. Several species of living tapirs are found in the tropics of Central America and South America, where they prefer forested habitats along rivers, and are known to be semiaquatic (Hershkovitz, 1954).

The presence of giant land tortoises in the Tonuco Mountain LF indicates a warmer climate than present. Living giant tortoises do not dig burrows and cannot survive prolonged exposure to freezing temperatures, and are now found primarily in subtropical and tropical regions. Hibbard (1960) and many others since have used the presence of giant land tortoises of the genus *Hesperotestudo* (= *Geochelone*) in North American Pliocene and Pleistocene faunas to indicate the absence of freezing winter temperatures. Cassiliano (1997) reviewed the physiology, ecology, and distribution of the living species of giant land tortoises. His detailed analysis of the temperature-controlled geographic distribution of living giant land tortoises supported Hibbard's (1960) original hypothesis that the presence of *Hesperotestudo* (= *Geochelone*) in a fossil site indicates the lack of prolonged freezing temperatures. In the early Irvingtonian (about 1 Ma), large species of land tortoises in the genera *Hesperotestudo* and *Gopherus* disappeared from the American Southwest, including New Mexico, probably indicating the onset of Ice Age climatic conditions with cooler winter temperatures (Morgan and Harris, 2015). Blancan vertebrate faunas from New Mexico, Arizona, and southwestern Texas, together with pollen and other paleobotanical data, indicate that the Pliocene climate in the American Southwest was considerably warmer and wetter than the Pleistocene and modern climate in this region (Thompson, 1991).

Graham (2003) proposed that temperature was not an important limiting factor in the Pliocene and Pleistocene distribution of tapirs in temperate North America. Instead, he suggested tapirs were very selective browsers, so-called "gap specialists," and that they disappeared from the temperate portion of their New World range owing to the disappearance of their preferred habitat following the end of the Pleistocene about 11 ka. Graham's (2003) hypothesis was based primarily on the geographic distribution of several species of *Tapirus* during the Irvingtonian and Rancholabrean, when tapirs were found as far north as New York, Pennsylvania, Indiana, Illinois, Nebraska, and Oregon. Perhaps tapirs became adapted to cooler climates and feeding in temperate forests during the Ice Age climatic conditions of the medial and late Pleistocene, as *Tapirus* had a more southerly distribution in North America during the late Pliocene and early Pleistocene (Blancan).

With the exception of a few records, the occurrence of *Tapirus* in North American Blancan faunas is limited to the southern United States, including Florida, Texas, New Mexico, Arizona, and southern California. Moreover, most of these records are from the southernmost regions of those states, south of 35° N latitude. The largest number of Blancan faunas containing tapirs are from peninsular

Florida, where Hulbert (2010) recorded *Tapirus* from 25 sites, all of which are south of 30° N. The second largest concentration of Blancan *Tapirus* records is from southern California, mostly from the Anza-Borrego Desert succession between 33° and 34° N (Jefferson, 1989; Cassiliano, 1999). There are only two well-documented Blancan tapir records north of the southernmost states: Donnelly Ranch in southeastern Colorado just north of the New Mexico border, between 37° and 38° N (Hager, 1974), and Big Springs in Nebraska at about 42° N, by far the northernmost Blancan tapir record (Voorhies, 1987). The Big Springs vertebrate fauna is unusual in containing several species with southern affinities, including the large extinct armadillo *Dasypus bellus*, ringtail *Bassariscus*, cotton rat *Sigmodon*, and giant land tortoise *Hesperotestudo*, as well as *Tapirus* (Voorhies, 1987). The type locality of *Tapirus haysii*, on the Neuse River near New Bern, North Carolina, at about 35° N, is also located farther north than most other Blancan sites with *Tapirus*. Although the Neuse River Fauna has been considered Blancan (Graham, 2003), the age of this fauna is not well established and could be Irvingtonian (Ray and Sanders, 1984).

Most of the classic Blancan faunas from western North America lack tapirs, including: Blanco and Cita Canyon from the panhandle of northwestern Texas (Dalquest, 1975; Schultz, 1977); the numerous Blancan faunas from the Meade basin in southwestern Kansas (Martin et al., 2000), Blancan faunas from Nebraska, with the lone exception of Big Springs (Schultz et al., 1975; Voorhies, 1987); and Hagerman in Idaho (Ruez, 2009). Except for Florida, which has more Blancan sites with *Tapirus* than the remainder of the United States combined, Blancan tapirs are rare in the southern states where they do occur. There are 40 Blancan faunas in New Mexico, only two contain *Tapirus* (Morgan and Harris, 2015), two tapir records in Arizona among 15 Blancan faunas (Morgan and White, 2005), and a single Blancan tapir locality in Texas (Strain, 1966). Surprisingly, there are no published Blancan records of *Tapirus* from Mexico (Lindsay, 1984; Miller and Carranza-Castañeda, 1984; Carranza-Castañeda, 2006), and no Blancan faunas are known from Central America.

Conclusions

A mandible with p2-m2 of a medium-sized species of tapir (*Tapirus* sp.) is reported from the late Pliocene (early Blancan NALMA), Tonuco Mountain LF, Doña Ana County, southern New Mexico. The mandible is similar in size and certain morphological features to the late Blancan species *Tapirus lundeliusi* from Florida (Hulbert, 2010), but is not referred to that species because the diagnostic species-level characters of the genus *Tapirus* are found in the skull which is not preserved in the New Mexico specimen.

Biochronology and magnetostratigraphy indicate an age of between 3.3 and 3.6 Ma (early late Pliocene; late early Blancan NALMA) for the Tonuco Mountain LF, including the *Tapirus* mandible. Mammalian biochronology suggests an age range of 2.7–3.6 Ma for the Tonuco Mountain LF, based on: 1) the presence of *Equus scotti, Camelops*, and *Platygonus*, all of which first appeared in the late early Blancan at about 3.6 Ma; 2) the presence of the horses *Equus simplicidens* and *Nannippus peninsulatus*, which became extinct in New Mexico at about 2.6 Ma; and 3) the absence of mammals of South American origin that participated in the GABI and first appeared about 2.7 Ma in the American Southwest (Morgan et al., 1998; Morgan and Harris, 2015). Paleomagnetic data for the lower 30 m of the stratigraphic section of the Camp Rice Formation containing the Tonuco Mountain LF (Mack et al., 1993), including the *Tapirus* mandible, further constrains the age of this fauna. These strata are normally magnetized and correspond to the lowermost portion of the Gauss Chron (C2An.3n), above the Gilbert/Gauss boundary (3.58 Ma) and below the base of the Mammoth Subchron (C2An.2r; 3.33 Ma). Thus, the magnetostratigraphy constrains the age of these strata to 3.33–3.58 Ma, consistent with the mammalian biochronology.

The tapir mandible from the Tonuco Mountain LF is the only record of an early Blancan (2.7–4.9 Ma) *Tapirus* known from North America. All other Blancan specimens of *Tapirus* are from the late Blancan (1.6–2.7 Ma).

The fossil record indicates that tapirs had a restricted geographic distribution in the late Pliocene and earliest Pleistocene (late early and late Blancan; ~1.6–3.6 Ma) of temperate North America, occurring primarily in the southernmost United States, south of 35° N, including Florida, Texas, New Mexico, Arizona, and southern California, with two more northerly records from Colorado and Nebraska.

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Gallery of Geology

The rare and unusual pseudofossil Astropolithon from the Lower Permian Abo Formation near Socorro, New Mexico

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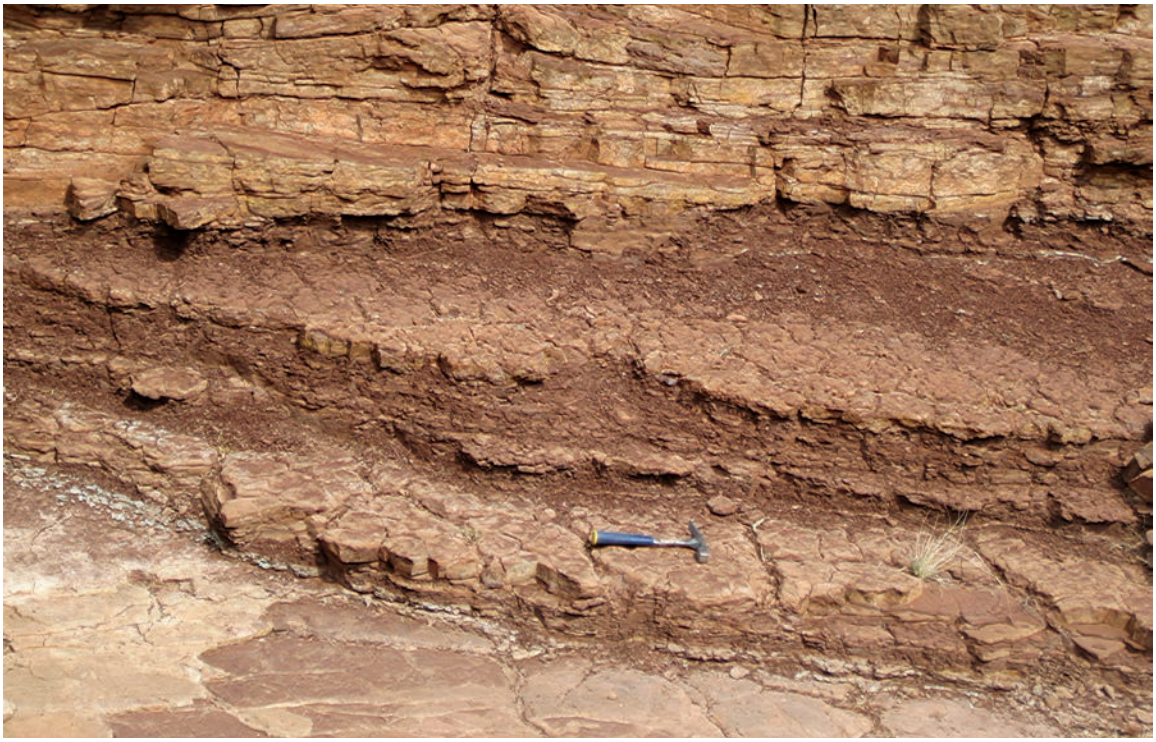

Figure 1. Overview of Astropolithon locality northeast of Socorro. The rock hammer is lying on the bed covered with Astropolithon.

Across much of New Mexico, the lower Permian (Wolfcampian-Leonardian) Abo Formation contains a significant record of continental plant fossils (DiMichele et al., 2013), vertebrate body fossils (Berman et al., 2015), and red-bed (*Scoyenia* ichnofacies) trace fossils representing both vertebrate and invertebrate producers (Hunt and Lucas, 2015).

Most unusual is recent discovery in the Abo Formation of Astropolithon, an inorganic sedimentary structure (pseudofossil) considered to have been formed within a cohesive microbial matground. This very rare and highly localized occurrence was discovered in 2012 by William DiMichele of the U. S. National Museum at a location near Mesa del Yeso, northeast of Socorro. The Astropolithon specimens are preserved in concave epirelief in the uppermost Abo Formation on top of a 15-cm-thick bed of massive, very fine grained sandstone about 7 m below the base of the overlying Arroyo de Alamillo Formation of the Yeso Group. Below the Astropolithon bed is a 0.3-m-thick bed of ripple-laminated sandstone with walchian conifer remains, and above is a 1.3-m-thick bed of ripple laminated sandstone with tetrapod footprints (*Batrachichnus, Dromopus*) near its base. These sandstone beds are intercalated with red mudrock, and, stratigraphically higher, the base of the overlying Yeso Group is marked by two thin dolomite beds.

The Abo deposits at the Astropolithon locality are characteristic Abo overbank mudrock and unchannelized sheetflow deposits of sand that produced thin, tabular sandstone beds with ripple lamination. However, this floodplain was beginning to feel the effects of a marine transgression advancing from the south at about the beginning of Yeso time. This marine transgression likely affected the climate and the salinity of the landscape, and these effects may account, at least in part, for the occurrence of Astropolithon.

The Astropolithon consist of a central area that is partially domed in appearance and surrounded by two or three concentric rings that show multiple radial lineations. The central area displays a wrinkled surface texture on the domed portion. The concentric rings outwardly rise in a stepwise fashion towards the uppermost bedding plane. These rings variably show outwardly directed, and sometimes branched, radial lineation. The bedding surface beyond the periphery of the outer ring shows in places relatively large reticulate "elephant skin" texture, as well as wrinkles. We confidently identify these unusual structures as Astropolithon, which is an inorganic sedimentary structure (pseudofossil).

Astropolithon hindii was first described by the prominent nineteenth century Canadian geologist and pioneering ichnologist Sir John William Dawson (1820–1899). He initially considered these structures, which he found

Figure 2. Closer view of the Astrolpolithon bed from above. Note: numerous, circular Astropolithon above the rock hammer. Rock hammer is 28 cm long.

in the Cambrian-Ordovician of Nova Scotia, Canada, to be organic, plant-like "fucoids" with radiating fronds (Dawson, 1878). He later reinterpreted Astropolithon as the mouths of large burrows with outwardly radiating trails, although he also thought that it might represent an organism (Dawson, 1890). In either interpretation, Dawson regarded Astropolithon as a fossil, so the Latin name he gave it was italicized.

Pickerill and Harris (1979) and Pickerill (1984) restudied the original material and determined that Astropolithon hindii is not a biogenically produced trace fossil, but instead is a sedimentary pseudofossil (sand volcano) produced on bedding planes by fluidization processes. Thus, Astropolithon is either a sediment volcano formed by the expulsion of water from sediment through different agencies such as slumping, rapid sedimentation or agitation (Reineck and Singh, 1980; Gerdes, 2007) or it is a ruptured gas dome that resulted from microbial mat decay (Pflüger, 1999; Ericksson et al., 2007). As an inorganic structure, Astropolithon is now regarded as a pseudofossil, so the name is no longer italicized.

We cut transverse sections through several of the Abo Formation specimens to determine that penetrative vertical shafts are not present. This demonstrates that the Abo specimens were not persistent sand volcanoes, but were more likely short-lived structures produced by fluidization or degassing processes (Hagadorn and Miller, 2011). The stepwise concentric ring structures seen in some of the Abo specimens may have resulted from the sequential expulsion ("multiple burps") of sediment outward from the central area. However, the concentric ring structures seen on most specimens might also have been formed by the sequential retraction of highly cohesive, expelled sediment that fell back towards the depressed central area.

Astropolithon is thought to form only within cohesive host sediments such as microbially bound sand (Seilacher and Goldring, 1996; Gerdes, 2007).

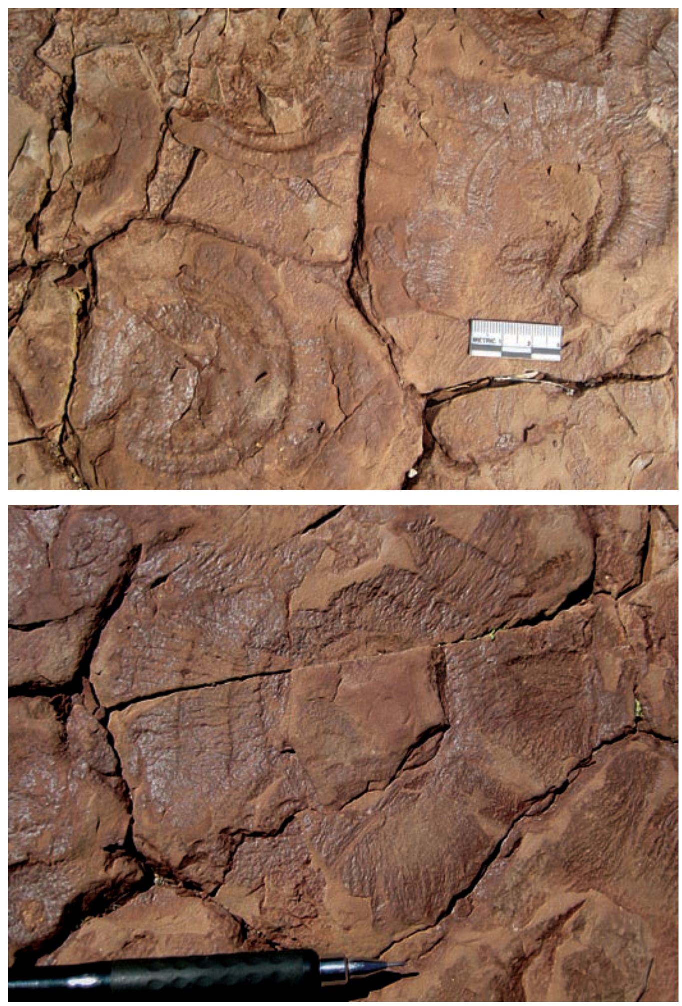

Figure 3. Views of selected Astropolithon in the Abo Formation. Note: structure of concentric rings with radial lineation and wrinkled clay drape.

Indeed, there are indications on the Abo slab surfaces that a microbial matground was present when the Abo Formation specimens were formed. These indications include examples of “elephant skin” texture, which is considered to reflect the growth structures of microbial mats (Porada and Bouougri, 2007).

Matground structures were notably common prior to the Cambrian agronomic revolution (Seilacher and Pflüger, 1994) but were limited thereafter to generally inhospitable habitats (Pflüger, 1999). Characteristic sedimentary structures appear in modern biomat habitats, but their preservation potential is very low (Pflüger, 1999). Interestingly, many of the Astropolithon from the Abo Formation show a clay drape, which may have quickly covered the already cohesive matground surfaces in which they formed. This clay drape might have helped stabilize and preserve the unusual multi-tiered morphology seen in the Astropolithon.

The Astropolithon documented here are readily interpreted as sedimentary structures mediated by a matground. They are microbially induced sedimentary structures (MISS) sensu Noffke et al. (2001), but can also be called pseudofossils or synsedimentary structures (Seilacher, 2007). The matground structures from the Abo Formation show elephant skin texture and “Kinneyia”-like wrinkles. Like Astropolithon, Kinneyia was a Latin name long ago applied to structures thought to be fossil. However, also like Astropolithon, Kinneyia has more recently been regarded as inorganic wrinkles in sediment, so the name is no longer italicized. However, both Astropolithon and Kinneyia are sedimentary structures that have been influenced (or controlled to some extent) by microbial films (MISS—microbially induced sedimentary structures). Therefore, Stimson et al. (2017) have very recently argued that such structures should be considered trace fossils and thus have italicized Latin names. Because this bold, recent proposal remains to be discussed at length, we simply follow the consensus view here that Astropolithon and Kinneyia are informal names applied to different kinds of MISS.

The mechanism of formation of the Abo Formation Astropolithon is reasonably that posited by Seilacher (2007) and Seilacher et al. (2002): (1) the microbial mat formed a seal above underlying siltstone/very fine-grained sandstone; (2) when fluid or gas escaped from the underlying layer, the mat was domed upward; and (3) it then radially cracked and collapsed. This happened without a central tube for liquid/gas release (as in a true “sand volcano”) or any deformation of the siltstone/very fine-grained sandstone layer. It took place in a floodplain setting, so the conditions to allow the matground to form must have been present and localized, possibly influenced by the beginning of a marine transgression that signaled the onset of Yeso Group deposition.

Astropolithon is an exceedingly rare structure in the geological record (Pflüger, 1999), and this is particularly true for post-Cambrian occurrences. Given the rarity of Astropolithon in the Phanerozoic record, the conditions under which the Abo Formation specimens were created must have been extremely unusual.

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New Mexico Geological Society spring meeting program

The following is the program for the New Mexico Geological Society annual spring meeting, which was held on April 7, 2017 at the Macy Center, New Mexico Tech campus, Socorro. For a PDF file of the program and the abstracts: nmgs.nmt.edu/meeting/

KEYNOTE

URANIUM INDUSTRY: OVERVIEW, Bonifas, B., bbonifas@energy-fuels.com, Energy Fuels Nichols Ranch ISR Uranium Mines, Linch, WY

ENERGY IN NEW MEXICO SESSION

THE UPPER MANCOS SHALE IN THE SAN JUAN BASIN: THREE OIL AND GAS PLAYS, CONVENTIONAL AND UNCONVENTIONAL, Broadhead, R.F., ron.broadhead@nmt.edu, New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801

GEOTHERMAL POTENTIAL OF THE SOUTHERN SAN LUIS BASIN, TAOS COUNTY, NEW MEXICO, Kelley, S., shari.kelley@nmt.edu, New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801; and Pepin J.D., Hydrology Department, New Mexico Tech, Socorro, NM,87801

URANIUM RESOURCES IN NEW MEXICO IN 2017, McLemore, V.T., virginia.mclemore@nmt.edu, New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801

THE EVOLUTION OF URANIUM MINERALIZATION IN NEW MEXICO, Lueth, V.W., virgil.lueth@nmt.edu, and McNamara, K., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, New Mexico, 87801

WATERSHEDS AND HYDROLOGYSESSION

TURNING TOYS INTO TOOLS: UNMANNED AIRCRAFTS FOR THE 21ST CENTURY GEOSCIENTIST, Zimmerer, M.J., matthew.zimmerer@nmt.edu, and Ross, J.I., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801

RELATIONSHIP BETWEEN TREE CANOPY COVER AND DISCHARGE OF UPPER GALLINAS WATERSHED, NEW MEXICO, 1939 – 2015, Yekkeh, B., b.yekkeh@gmail.com, New Mexico Highlands University, Las Vegas, NM, 87701

WHAT LIES BENEATH THE DUNES? GRAVITY MEASUREMENTS TO CHARACTERIZE SUB-SURFACE DENSITY STRUCTURE AND UNDERSTAND CONTROLS ON DUNE MIGRATION IN WHITE SANDS NATIONAL MONUMENT, NEW MEXICO, Dunagin, R., rdunagin@unm.edu, and Roy, M., University of New Mexico, 2112 Gold St, Albuquerque, NM, 87106; Kelley, S., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801; Worthington, L., and Butts, J., University of New Mexico, Albuquerque, NM, 87106

THE DEMISE OF THE CUATROCIÉNEGAS GYPSUM DUNE FIELD, AND WHAT IT MEANS FOR THE WHITE SANDS NATIONAL MONUMENT, Mamer, E.A., ethan.mamer@nmt.edu, and Newton, B.T., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801

PALEONTOLOGY IN NEW MEXICO SESSION

THE PALEOZOIC SECTION AT BELL HILL, SOCORRO COUNTY, NEW MEXICO, Lucas, S.G., spencer.lucas@state.nm.us, New Mexico Museum of Natural History, 1801 Mountain Road N.W., Albuquerque, NM, 87104; Allen, B.D., New Mexico Bureau of Geology and Mineral Resources, Socorro, NM, 87801; Krainer. K., Institute of Geology, University of Innsbruck, Innsbruck, A-6020, Austria; and Barrick, J.E., Texas Tech University, Lubbock, TX, 41053

PHYLOGENY OF THE ENIGMATIC EOCENE TESTUDINOID TURTLE *ECHMATEMYS* AND THE ORIGIN OF THE TESTUDINIDAE, Lichtig, A.J., ajlichtig@gmail.com, and Lucas, S.G., New Mexico Museum of Natural History, 1801 Mountain Road N.W., Albuquerque, NM, 87104

NEW EVIDENCE FOR CANNIBALISM IN TYRANNOSAURID DINOSAURS FROM THE LATE CRETACEOUS OF NEW MEXICO, Dalman, S.G., sebastiandalman@yahoo.com, and Lucas, S.G., New Mexico Museum of Natural History, 1801 Mountain Road N.W., Albuquerque, NM, 87104

X-RAY AND NEUTRON COMPUTED TOMOGRAPHY OF VERTEBRATE FOSSILS AT THE LOS ALAMOS NEUTRON SCIENCE CENTER, LOS ALAMOS NATIONAL LABORATORY, NEW MEXICO, Williamson, T.E, thomas.williamson@state.nm.us, New Mexico Museum of Natural History and Science, 1801 Mountain Road, NW, Albuquerque, NM, 87121; Brusatte, S.L, School of GeoSciences, University of Edinburgh, Grant Institute, James Hutton Road, Edinburgh, EH9 3FE, United Kingdom; Espy, M.A., Gautier, C., Hunter, J., Losko, A.S., and Nelson, R.O., Los Alamos National Laboratory, Los Alamos, NM, 87545; Schroeder, K., Department of Biology, University of New Mexico, Albuquerque, NM, 87104; and Vogel, S., Los Alamos National Laboratory, Los Alamos, NM, 87545

FUNCTIONAL CHANGE IN MOLLUSCAN DIVERSITY DYNAMICS OBSERVED ACROSS OAE2, Freymueller, N., nick-freymueller@unm.edu, and Myers, C., University of New Mexico, Albuquerque, NM, 87131

URANIUM IN NEW MEXICO SESSION

WHY I REMAIN A URANIUM BULL, Fulp, M.S., mickey@mercenary-geologist.com, MercenaryGeologist.com, LLC, Albuquerque, NM, 87105

GEOCHEMICAL PROCESSES CONTROLLING TRANSPORT AND DEPOSITION OF URANIUM, ESPAÑOLA BASIN, NEW MEXICO, Longmire, P., patrick.longmire@state.nm.us, New Mexico Environment Department, Ground Water Quality Bureau, 1190 St. Frances Drive, Santa Fe, NM, 87502; McLemore, V.T., New Mexico Bureau of Geology and Mineral Resources; New Mexico Tech, Socorro, NM, 87801; McQuillan, D., New Mexico Environment Department, Office of the Secretary, 1190 St. Frances Drive, Santa Fe, NM, 87502; Yanicak, S., New Mexico Environment Department, DOE Oversight Bureau, 1183 Diamond Drive, Suite B, Los Alamos, NM, 87544; and Vaniman, D., Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA, 91011

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REACTIVATION OF THE MT. TAYLOR MINE – OBSTACLES AND OPPORTUNITIES, Kuhn, A.K., akkuhn41@gmail.com, Alan Kuhn Associates LLC, 13212 Manitoba Dr. NE, Albuquerque, NM, 87111

ECONOMIC AND ENVIRONMENTAL GEOLOGY SESSION

URANIUM CONCENTRATIONS IN DUST FLUX ACROSS THE JACKPILE MINE SUPERFUND SITE, Brown, R.D., and Cadol, D., New Mexico Institute of Mining and Technology, Earth and Environmental Sciences, Socorro, NM, 87801; and Frey, B., New Mexico Bureau of Geology and Mineral Resources; New Mexico Tech, Socorro, NM, 87801

PHYLLIC ALTERATION IN THE COPPER FLAT PORPHYRY COPPER DEPOSIT, SIERRA COUNTY, NEW MEXICO, Maher, K., kierran.maher@nmt.edu, and Wallace, C., New Mexico Institute of Mining and Technology, Socorro, NM, 87801

PARAGENESIS OF URANIUM MINERALS IN THE GRANTS MINERAL BELT, NEW MEXICO: APPLIED GEOCHEMISTRY AND THE DEVELOPMENT OF OXIDIZED URANIUM MINERALIZATION, Caldwell, S., samantha.caldwell@student.nmt.edu, and Chavez, W.X., Jr., New Mexico Institute of Mining and Technology, Socorro, NM, 87801

GEOCHRONOLOGY AND GEOCHEMISTRY OF THE METASOMATIC PROCESSES RELATED TO EPISYENITES IN CENTRAL NEW MEXICO AND COLORADO, Smith, A.E., adam.smith@student.nmt.edu, New Mexico Institute of Mining and Technology, Socorro, NM, 87801; Heizler, M.T., and McLemore, V.T., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801; Maher, K.C., New Mexico Institute of Mining and Technology, Socorro, NM, 87801; and Ramos, F.C., New Mexico State University, Las Cruces, NM, 88003

40AR/39AR GEOCHRONOLOGY OF MAGMATISM AND ALTERATION IN THE GALLINAS MOUNTAINS WITH IMPLICATIONS FOR RARE EARTH MINERALIZATION, Robison, A., alanna.robison@student.nmt.edu, Dept. of Earth and Environmental Sciences, New Mexico Tech, Socorro, NM, 87801; McIntosh, W., and Lueth, V., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801

FORSTERITE AND PYRRHOTITE DISSOLUTION RATES FROM KINETIC TESTING USING MINE TAILINGS: RESULTS FROM GEOCHEMICAL MODELLING, Embile, R.F., Jr., RodrigoJr.Embile@student.nmt.edu, and Walder, I., New Mexico Institute of Mining and Technology, Socorro, NM, 87801

VOLCANOLOGY AND STRATIGRAPHY IN NEW MEXICO SESSION

DETRITAL SANIDINE 40AR/39AR DATING: TRANSFORMING SEDIMENTARY ROCK GEOCHRONOLOGY, Heizler, M.T., matt.heizler@nmt.edu, New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801; Karlstrom, K., University of New Mexico, Albuquerque, NM, 87131; Zimmerer, M., and Ross, J., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801; Crossey, L., University of New Mexico, Albuquerque, NM, 87131; and McIntosh, W., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801

40AR/ 39AR DETRITAL SANIDINE DATING OF THE OGALLALA FORMATION IN SOUTHEASTERN NEW MEXICO AND WEST TEXAS, Henry, K., kevin.henry@student.nmt.edu, New Mexico Tech, Socorro, New Mexico, 87801; Heizler, M.T., and Cather, S.T., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801

IMPLICATIONS OF PAST EXTENTS OF RIO SALADO AND RIO PUERCO DEPOSITS IN THE SOUTHWESTERN CORNER OF THE ALBUQUERQUE BASIN, NEW MEXICO, Love, D.W., david.love@nmt.edu, Rinehart, A., and Chamberlin, R., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801; Celep, E., Department of Earth and Environmental Science, New Mexico Tech, Socorro, NM, 87801; and Koning, D., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801

LITHOFACIES ANALYSIS OF THE SIERRA LADRONES FORMATION NEAR THE SEVILLETA NATIONAL WILDLIFE REFUGE HEADQUARTERS (SOUTHERN ALBUQUERQUE BASIN, NEW MEXICO): IMPLICATIONS FOR CLIFF FAULT MOVEMENT DURING THE EARLY PLEISTOCENE, Celep, E., Department of Earth and Environmental Science, New Mexico Tech, Socorro, NM, 87801, eda.celep@student.nmt.edu; Koning, D.J., and Love, D.W., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801

THE ONSET OF RHYOLITE VOLCANISM AND SUBSEQUENT COLLAPSE IN THE SCHOOLHOUSE MOUNTAIN CALDERA, MOGOLLON-DATIL VOLCANIC FIELD, SOUTHWEST NEW MEXICO, Swenton, V.M., vswenton@nmsu.edu, and Amato, J.M., New Mexico State University, Las Cruces, NM, 88003; Jonell, T., Louisiana State University, Baton Rouge, LA, 70803; and McIntosh, W.C., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801

THE “BOX CANYON TUFF” AND ITS RELATIONSHIP TO THE SCHOOLHOUSE MOUNTAIN CALDERA, MOGOLLON-DATIL VOLCANIC FIELD, SOUTHWEST NEW MEXICO, Amato, J.M., amato@nmsu.edu, and Swenton, V.M., Department of Geological Sciences, New Mexico State University, Las Cruces, NM, 88003; McIntosh, W., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801; and Jonell, T.N., Department of Geology and Geophysics, Louisiana State University, Baton Rouge, LA, 70803

THE LATE MIOCENE-EARLY PLIOCENE UNCONFORMITY IN THE RIO GRANDE RIFT, van Wijk, J., jolante.vanwijk@nmt.edu, and Axen, G., New Mexico Tech, 801 Leroy Place, Socorro, NM, 87801; Koning, D., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801; and Coblentz, D., Los Alamos National Laboratory, Los Alamos, NM, 87544

SEDIMENTOLOGY, STRATIGRAPHY, AND GEOCHRONOLOGY FROM EARLY(?)–MIDDLE EOCENE, POST-LARAMIDE VOLCANIC AND VOLCANICLASTIC STRATA OF THE PALM PARK FORMATION IN SOUTH-CENTRAL NEW MEXICO, Creitz, R.H., rcreitz@nmsu.edu, Hampton, B.A., Mack, G.H., and Amato, J.M., New Mexico State University, Department of Geological Sciences, Las Cruces, NM, 88003

CORRELATION OF ASH FLOW TUFFS FROM THE MOGOLLON-DATIL VOLCANIC FIELD IN SOUTHWESTERN NEW MEXICO USING LASER¬INDUCED BREAKDOWN SPECTROSCOPY (LIBS): AN ANALYSIS OF SANIDINE PHENOCRYSTS, Haskell, T.L., and McMillan, N.J., New Mexico State University, Department of Geological Sciences, Las Cruces, NM, 88003

URANIUM IN NEW MEXICO POSTERS

ASSESSING URANIUM CONCENTRATION IN STREAM SEDIMENT ON THE LAGUNA AND ISLETA PUEBLOS,Willis, B., brianne.willis@enmu.edu, Eastern New Mexico University, Portales, NM, 88130

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ENVIRONMENTAL AQUEOUS GEOCHEMISTRY OF URANIUM IN AQUIFER SYSTEMS, PAJARITO PLATEAU, NEW MEXICO, Longmire, P., patrick.longmire@state.nm.us, New Mexico Environment Department; Ground Water Quality Bureau, 1190 St. Frances Drive, Santa Fe, NM, 87502; Granzow, K., Yanicak, S., and Fellenz, D., New Mexico Environment Department; DOE Oversight Bureau, 1183 Diamond Drive, Suite B, Los Alamos, NM, 87544; Dale, M., Hazardous Waste Bureau, 1183 Diamond Drive, Suite B, Los Alamos, NM, 87544; Green, M., and Trujillo, A., New Mexico Environment Department; DOE Oversight Bureau, 1183 Diamond Drive, Suite B, Los Alamos, NM, 87544

SEQUENTIAL CHEMICAL EXTRACTION AS A METHOD TO DETERMINE URANIUM MINERAL LEACHABILITY AND SPECIATION, Pearce, A.R., alexandra.pearce@student.nmt.edu, and Walder, I.F., New Mexico Institute of Mining and Technology, EES Department, Socorro, NM, 87801; Frey, B., and Lueth, V.W., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801

THE CHARACTERIZATION OF URANIUM MOBILITY AT THE JETER MINE, LADRON MOUNTAIN MINE DISTRICT, SOCORRO COUNTY, NEW MEXICO, Winton, A., Ashlynne.Winton@student.nmt.edu, and Walder, I., New Mexico Institute of Mining and Technology, Socorro, NM, 87801; and Frey, B., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801

URANIUM RESOURCE POTENTIAL IN NEW MEXICO, McLemore, V.T., virginia.mclemore@nmt.edu, New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801; and Asafo-Akowuah, J., Mineral Engineering Department, New Mexico Tech, Socorro, NM, 87801

ECONOMIC AND ENVIRONMENTAL GEOLOGY POSTERS

THE RECENT ALPINE HIGH OIL AND GAS FIELD DISCOVERY, WEST TEXAS, Benson, A.L., benson1@newmex.com, University of New Mexico at Taos, PO Box 2848, Taos, NM, 87571

LEGACY MOLYBDENUM MINE TAILINGS IN THE CONTEXT OF THE QUESTA CALDERA: CHALLENGES IN DISTINGUISHING ANTHROPOGENIC FROM BACKGROUND WATER TYPES, Robinson, K.N., Kylian.Robinson@student.nmt.edu, New Mexico Tech, 1704 SE Columbia, Albuquerque, NM, 87196

ORIGIN AND MINERAL RESOURCE POTENTIAL OF THE ROSEDALE DISTRICT, SOCORRO COUNTY, NEW MEXICO, Zutah, W., william.zutah@student.nmt.edu, New Mexico Institute of Mining and Technology, Socorro, NM, New Mexico, 87801; and McLemore, V.T., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801

NICKEL LEACHING FROM DUNITIC MINE WASTE, Tinsley, M., margaret.tinsley@student.nmt.edu, Walder, I.F, Stopa, F., Donatelli, J., and Embile, R., New Mexico Institute of Mining and Technology, Socorro, NM, New Mexico, 87801

METAL LEACHING FROM THE VHMS SULITJELMA MINING DISTRICT, NORWAY, Stopa, F.K., franciszka.stopa@student.nmt.edu, and Walder, I., New Mexico Institute of Mining and Technology, Socorro, NM, 87801

DISTINGUISHING CALCITE WITH AND WITHOUT BIOMARKERS USING LASER-INDUCED BREAKDOWN SPECTROSCOPY (LIBS), GUADALUPE MOUNTAINS, NEW MEXICO, Jackson, B.A., brentj@nmsu.edu, and McMillan, N.J., New Mexico State University, Las Cruces, NM, 88003

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THE CRETACEOUS SECTION AT PLACITAS, SANDOVAL COUNTY, NEW MEXICO, Lucas, S.G., spencer.lucas@state.nm.us, New Mexico Museum of Natural History, 1801 Mountain Road N.W., Albuquerque, NM, 87104; and Rogers, J.B., Central New Mexico Community College, 525 Buena Vista SE, Albuquerque, NM, 87106

COMING SOON – GEOLOGIC MAP OF THE MOUNT TAYLOR VOLCANO AREA, NEW MEXICO: CENTERPIECE FOR THE 2020 FALL FIELD CONFERENCE, Goff, F., candf@swcp.com, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM, 87801; Kelley, S.A., and McCraw, D.J., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801; Goff, C.J., Independent Consultant, 5515 Quemazon, Los Alamos, NM, 87544; Frey, B.A., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801; Zeigler, K., Zeigler Geologic Consulting, 14500 Oakwood Place NE, Albuquerque, NM, 87123; and McLemore, V.T., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801

THE PALEOPROTEROZOIC MAZATZAL PROVINCE OF SOUTHERN NEW MEXICO: INSIGHT FROM DETAILED FIELD MAPPING AND ISOTOPE GEOCHEMISTRY, Howland, C., howlandc@nmsu.edu, and Amato, J.M., New Mexico State University, Las Cruces, NM, 88003

CHANGE IN PROVENANCE OF PROTEROZOIC METASEDIMENTARY ROCKS IN THE PICURIS MOUNTAINS BASED ON LASER-INDUCED BREAKDOWN SPECTROSCOPY (LIBS) OF DETRITAL TOURMALINE, Farnsworth-Pinkerton, S., shohauna@nmsu.edu, and McMillan, N.J., Geological Sciences, New Mexico State University, Las Cruces, NM, 88003; Dutrow, B.L., and Henry, D.J., Department of Geology & Geophysics, Louisiana State University, Baton Rouge, LA, 70803

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PRESCRIBED BURN IMPACTS ON SURFACE WATER QUALITY AND QUANTITY IN THE UPPER SANTA FE MUNICIPAL WATERSHED: BASELINE DATA AHEAD OF BURNS, Shephard, Z., zach.shephard@student.nmt.edu, and Cadol, D., New Mexico Tech, Earth and Environment Sciences Department (Hydrology), Soccoro, NM, 87801

A HYDROGEOCHEMICAL ANALYSIS AND RECHARGE EVALUATION OF CIENEGA SPRING LOCATED IN THE SANDIA MOUNTAINS, NEW MEXICO, Minitrez, A.J., alexmini@unm.edu, Crossey, L.J., and McGibbon, C., University of New Mexico, Albuquerque, NM, 87131

3D INVERSE MODELS OF MAGNETOTELLURIC DATA IN THE CENTRAL RIO GRANDE RIFT ILLUMINATE RIFT BASIN GEOMETRY AND POSSIBLE INTERACTIONS BETWEEN DEEP BRINES AND SURFACE WATERS, Folsom, M., mattfolsom99@gmail.com, and Pepin, J., New Mexico Institute of Mining and Technology, Socorro, NM, New Mexico, 87801; Peacock, J., United States Geological Survey; Person, M., New Mexico Institute of Mining and Technology, Socorro, NM, New Mexico, 87801; Kelley, S., and Love, D., New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, 87801

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PALEONTOLOGY POSTERS

STRATIGRAPHY AND AGE OF THE DINOSAUR¬DOMINATED FOSSIL ASSEMBLAGE OF THE UPPER CRETACEOUS HALL LAKE MEMBER OF THE MCRAE FORMATION, SIERRA COUNTY, NEW MEXICO, Lucas, S.G., spencer.lucas@state.nm.us, Dalman, S., and Lichtig, A.J., New Mexico Museum of Natural History, 1801 Mountain Road N.W., Albuquerque, NM, 87104; Elrick, S., and Nelson, W.J., Illinois State Geological Survey, 615 East Peabody Drive, Champaign, IL; and Krainer, K., Institute of Geology, Innsbruck University, Innsbruck, Austria

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A NEW CHASMOSAURINE CERATOPSID FROM THE HALL LAKE MEMBER OF THE MCRAE FORMATION (MAASTRICHTIAN), SOUTH-CENTRAL NEW MEXICO, Dalman, S.G., sebastiandalman@yahoo.com, and Lucas, S.G., New Mexico Museum of Natural History and Science, 1801 Mountain Road N.W., Albuquerque, NM, 87104

WATER-DEPTH-BASED DIFFERENCES IN AMMONOID ASSEMBLAGES FROM THE UPPER CRETACEOUS (TURONIAN) BLUE HILL MEMBER OF THE CARLILE SHALE, NORTH-CENTRAL NEW MEXICO, Foley, M.P., pfooley@gmail.com, and Lucas, S.G., New Mexico Museum of Natural History, 1801 Mountain Rd NW, Albuquerque, NM, 87104

A POSSIBLE NEW SPECIES OF *DIMETRODON* (EUPELYCOSAURIA: SPHENACODONTIDAE) FROM THE LOWER PERMIAN ABO FORMATION, SOCORRO COUNTY, NEW MEXICO, McKeighen, K.L., kentheartist1@msn.com, McKeighen, K.R., McKeighen, H.W., and Lucas, S.G., New Mexico Museum of Natural History and Science, 1801 Mountain Rd NW, Albuquerque, NM, 87104

LOWER CRETACEOUS (UPPER ALBIAN) NAUTILOIDS FROM CERRO DE CRISTO REY, DOÑA ANA COUNTY, NEW MEXICO, Sealey, P.L., ammonoidea@comcast.net, and Lucas, S.G., New Mexico Museum of Natural History, 1801 Mountain Road, NW, Albuquerque, NM, 87104; and Durney, K., 3701 Trailhead Court, Cedar Park, TX, 78613

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MAJOR ELEMENTS, TRACE ELEMENTS, AND SR, ND, AND PB ISOTOPES OF WHOLE ROCKS FROM THE DOÑA ANA MOUNTAINS: IDENTIFYING POTENTIAL CONNECTIONS BETWEEN CALDERA-RELATED IGNEOUS ROCKS IN SOUTH-CENTRAL NEW MEXICO, Askin, T.J., tyler537@nmsu.edu, Ramos, F.C., and Stevens, P.J., New Mexico State University, Las Cruces, NM, 88001

A MODEL FOR SOCORRO MAGMA BODY EMPLACEMENT, van Wijk, J., jolante.vanwijk@nmt.edu, Yao, S., and Axen, G., New Mexico Tech, 801 Leroy Place, Socorro, NM, 87801

USING A NEW TEMPORARY SEISMIC NETWORK TO DETECT EARTHQUAKES IN THE SOCORRO MAGMA BODY REGION, Vieceli, R.E., rhiannon.vieceli@student.nmt.edu, and Bilek, S.L., New Mexico Institute of Mining and Technology, Socorro, NM, 87801; Aster, R.C., Colorado State University, CO; Lowe-Worthington, L., and Schmandt, B., University of New Mexico, Albuquerque, NM, 87131

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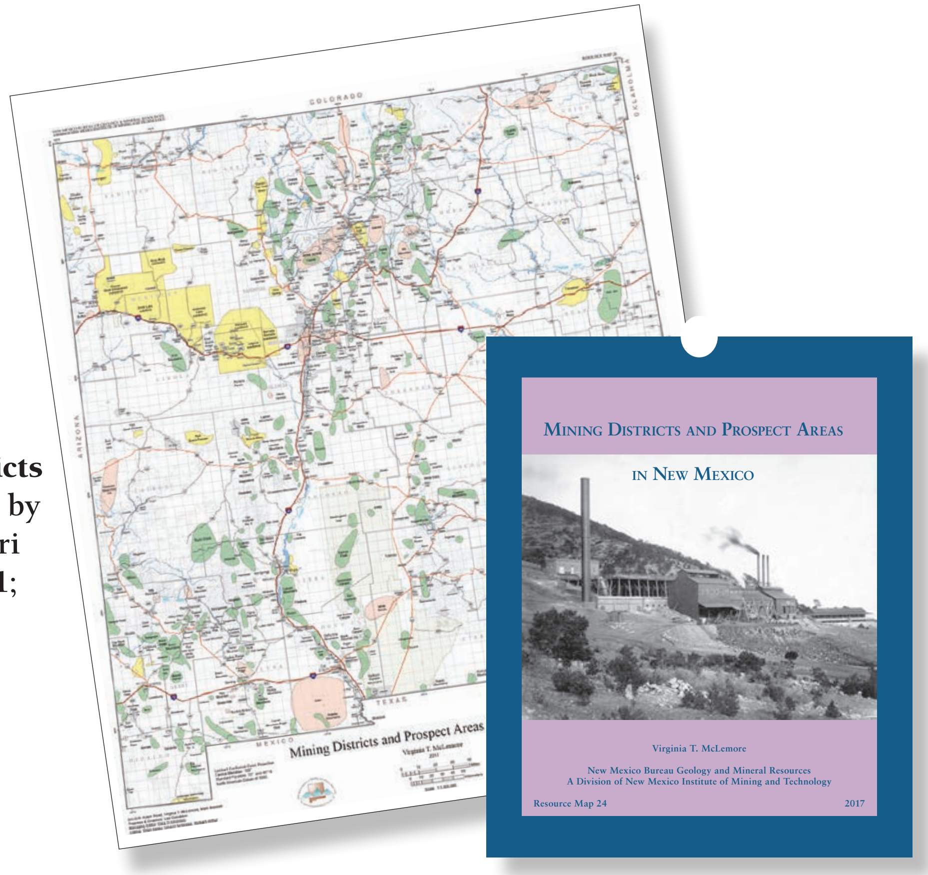

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