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EARLY PLEISTOCENE (LATE BLANCAN) VERTEBRATES FROM SIMON CANYON, SOCORRO COUNTY, CENTRAL NEW MEXICO

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Abstract—A recently discovered assemblage of vertebrate fossils 53 km south-southwest of Socorro, here named the Simon Canyon Local Fauna (LF), is one of the most precisely dated early Pleistocene (late Blancan North American Land Mammal Age—NALMA) faunas in New Mexico. The site is located near the lower (eastern) end of Simon Canyon in the central San Marcial Basin, Socorro County, in central New Mexico. The fossils were collected primarily from two axial-fluvial sand tongues of the Palomas Formation. The lower 4 m of the 12 m thick, upper sand tongue yielded most of the fossils and also contained pebbles of obsidian. Trace-element analysis of three obsidian clasts, using X-ray Fluorescence (XRF) methods, indicate a close match with the 2.23±0.15 Ma El Rechuelos Rhyolite. A 0.8 m thick, coarsening-upward, pebble-boulder pumice bed is present 4 m above the top of the upper sand tongue. Its geochemistry supports a correlation with the Otowi Member of the Bandelier Tuff (OMBT), assuming this bed is the same as the Fort Craig pumice. We interpret that this pumice was transported here via a dam-burst flood within thousands of years after the associated Toledo caldera eruption in northern New Mexico at 1.63 Ma. Thus, the age of the upper axial-fluvial sand tongue is bracketed between 2.4 Ma and 1.6 Ma. The Simon Canyon LF consists of 15 species of vertebrates, including seven mammals known from Blancan NALMA vertebrate faunas in New Mexico and elsewhere in the southwestern U.S.: *Glyptotherium texanum* (glyptodont), *Canis* cf. *edwardii* (wolf), *Equus scotti* (large horse), and four camels, *Camelops* sp., *Gigantocamelus spatulus*, *Hemiauchenia* cf. *blancoensis*, and *Hemiauchenia gracilis*. Except for *Equus scotti* and *Camelops* sp., these Blancan vertebrates were collected in the lower third of the upper axial-fluvial sand tongue or within 1 m below it. The most age-diagnostic of these species are *Glyptotherium texanum*, a mammal of South American origin and a participant in the Great American Biotic Interchange that first arrived in New Mexico at the beginning of the late Blancan (~2.7 Ma) and became extinct at the end of the early Irvingtonian NALMA (~1.0 Ma), and *Hemiauchenia gracilis*, a small camel known only from the late Blancan (~1.6–2.5 Ma). Conspicuously absent are Blancan mammals that became extinct at ~2.2 Ma (e.g., *Borophagus*, *Nannippus*) as well as *Mammuthus*, a Eurasian immigrant whose first appearance in North America defines the beginning of the early Irvingtonian at ~1.6 Ma. Thus, the mammalian biochronology of the Simon Canyon LF indicates a latest Blancan age (~1.6–2.2 Ma) for the fauna collected in the upper axial-fluvial sand. This biochronologic age is remarkably consistent with the independent 1.6–2.4 Ma age provided by the overlying OMBT pumice bed and the El Rechuelos Rhyolite obsidian clasts found in the lower part of the upper axial-fluvial sand tongue.

INTRODUCTION

Vertebrate faunas of the Blancan North American Land Mammal Age (NALMA—Pliocene through early Pleistocene) are widely distributed in the Rio Grande rift of New Mexico, from the Albuquerque Basin in north-central New Mexico south to the Mesilla Basin bordering Texas and the state of Chihuahua, Mexico (Tedford, 1981; Morgan and Lucas, 2003; Morgan and Harris, 2015). This paper describes a moderately diverse local fauna with geochemical age constraints that was recently discovered in the east-central San Marcial Basin 53 km southwest of Socorro, New Mexico (Fig. 1). Simon Canyon is a small, southeast-flowing drainage located 4 km southwest of the larger Milligan Gulch (Fig. 1), both of which flow into the Rio Grande in the eastern part of the basin.

We collected a sample of vertebrate fossils consisting of about 50 identifiable specimens from 18 individual sites, here designated the Simon Canyon Local Fauna (LF; new name), from Simon Canyon and a small, unnamed north-south oriented tributary of Simon Canyon. The sites are located on the Paraje Well 7.5-minute quadrangle, west of the Rio Grande in southern Socorro County (Figs. 1, 2). The approximate coordinates of the Simon Canyon LF are 33°36'N, 107°05'W, and the fossil sites range in elevation from about 1370–1395 m (~4500–4580 ft).

These fossils were initially discovered by geologists from the NM Bureau of Geology and Mineral Resources, including D. Love in December 2019 and D. Love, K. Hobbs, and Kristin Pearthree in May 2020. Except for M.S. Shackley, all authors of this paper participated in two fossil-collecting trips to the Simon Canyon area in November and December 2021. The fossils consist of isolated surface finds recovered mostly as float, although a few fossils were excavated in place. We found no concentrations of fossils that could be quarried, no associated or articulated elements, and no accumulations of small vertebrates suitable for screenwashing.

Two other sites containing Blancan vertebrates from the Palomas Formation in the San Marcial Basin have been reported previously: Tiffany Canyon, at the northern end of the basin, with the extinct horse *Equus scotti*, and Silver Canyon, at the southern end of the basin, containing *Equus* sp., a gomphothere, and the rodent *Neotoma* (Morgan and Lucas, 2003; Morgan et al., 2009; Morgan and Harris, 2015). Several other recently discovered Blancan localities in the San Marcial Basin include a gomphothere from near the mouth of Silver Canyon

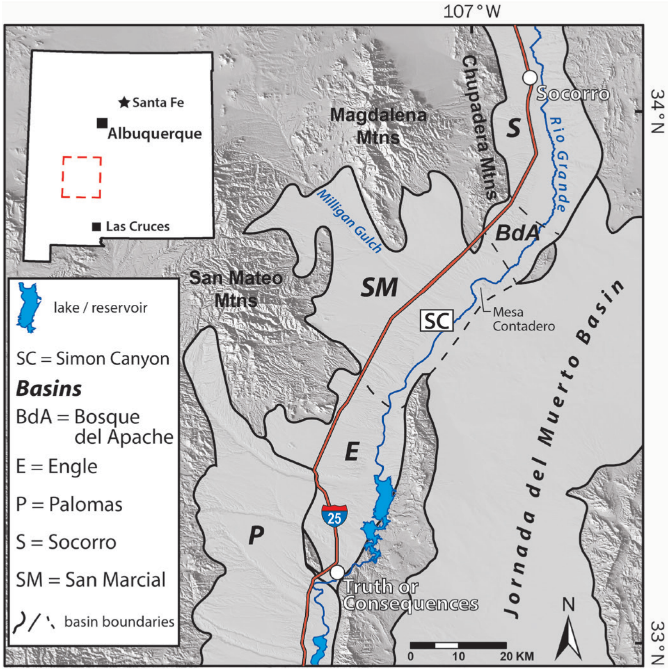

FIGURE 1. Location of the Simon Canyon Local Fauna (SC) within the San Marcial Basin (SM). Simon Canyon is a small southeast-flowing drainage located 4 km southwest of the larger Milligan Gulch, both of which flow into the Rio Grande.

and the glyptodont *Glyptotherium* from a site south of Crawford Hollow. The fossils from these two new sites, together with the faunas from Silver Canyon and Tiffany Canyon, will be discussed in detail in a paper currently under preparation by the authors of the present report.

The age and correlation of North American Cenozoic mammalian faunas have been well-documented over the past 80 years, beginning with Wood et al. (1941) who established the North American Land Mammal Ages (abbreviated as NALMA). The individual Cenozoic NALMA are discrete intervals of time, generally several million years in duration, characterized by an assemblage of genera and/or species of mammals. This paper deals with fauna from the Blancan NALMA, which has been subdivided based on assemblages of arvicoline or microtine rodents (Bell et al., 2004). Because arvicoline rodents are uncommon to absent in most New Mexican Blancan faunas, Morgan and Harris (2015) proposed an informal biochronology for Blancan mammalian faunas from the American Southwest that was based primarily on large mammals. In the biochronology of Morgan and Harris (2015), the Blancan NALMA in New Mexico is divided into early (~4.9–2.7 Ma) and late (~2.7–1.6 Ma) intervals. With the Plio-Pleistocene boundary placed at 2.6 Ma (*per* Gibbard et al., 2010), almost the entire late Blancan, except for a brief interval between 2.7 Ma and 2.6 Ma, is now considered to be early Pleistocene.

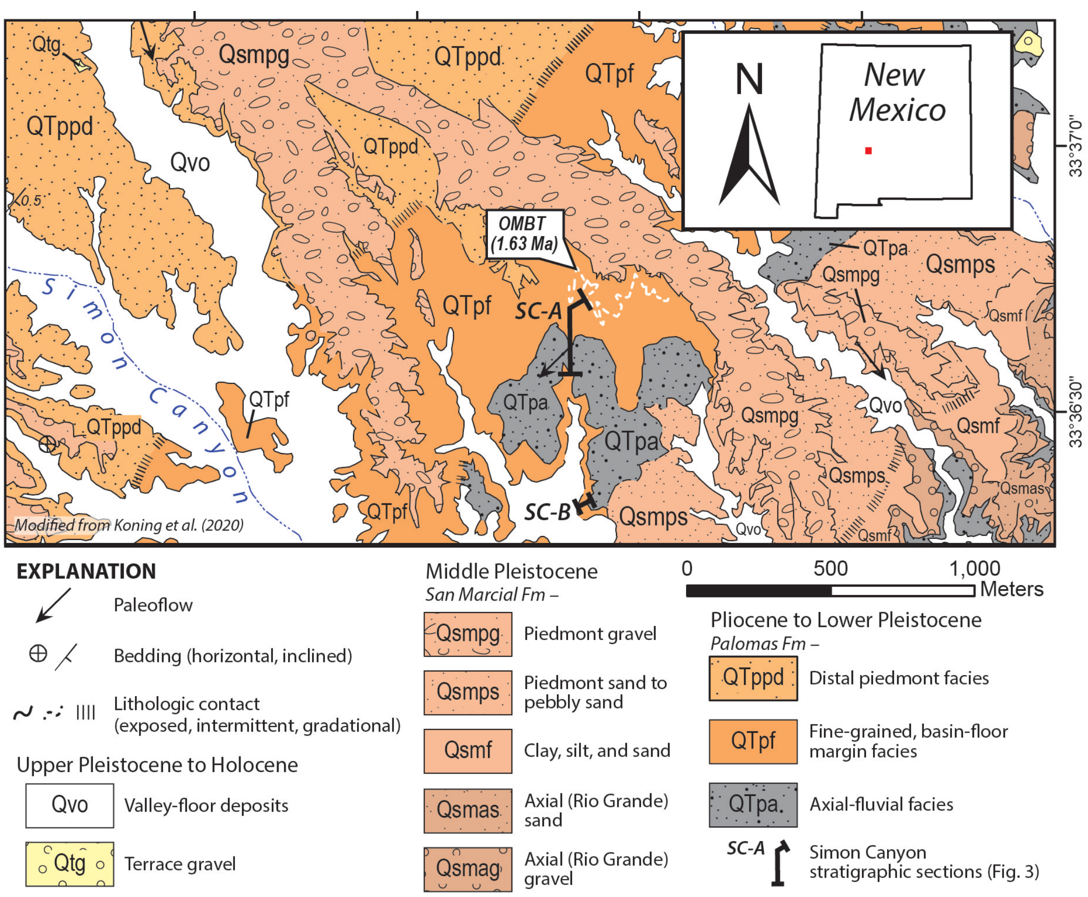

FIGURE 2. Geologic map showing stratigraphic units of the Palomas Formation near the Simon Canyon Local Fauna, which corresponds to the near-vicinity (i.e., within a few hundred meters) of stratigraphic sections SC-A and SC-B in Figure 3. Geology is from Koning et al. (2020). The white, dashed line represents the bed of Otowi Member of the Bandelier Tuff (OMBT) pumice (1.63 Ma) present at the top of stratigraphic section SC-A.

TABLE 1. Trace element concentrations for the three obsidian clasts collected in the lower 1/3 of the upper axial-fluvial tongue (SC1, SC2, SC3), and USGS RGM-1 rhyolite standard. All measurements in parts per million (ppm).

Sample	Ti	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Ce	Pb	Th	Source
SC1	913	427	7539	55	170	12	25	72	48	0	15	24	23	ERR[2]
SC2	780	389	7501	41	142	13	20	71	46	13	57	24	23	ERR[2]
SC3	827	335	7311	44	142	11	23	72	42	46	55	19	19	ERR[2]
RGM1-S4[1]	1536	317	13263	46	152	108	24	223	6	818	46	23	12	STND[3]
RGM-1 recommended	1619	279	13010	32	150	110	25	220	8.9	810	47	24	15	

[1] Major and minor oxide values for RGM-1 in this laboratory available in Shackley et al. 2016, 2018.
[2] ERR = El Rechuelos Rhyolite
[3] STND = Standard

PURPOSE

After presenting the stratigraphic framework of the Simon Canyon LF, we briefly describe the vertebrate fossils found there. We end by discussing the mammalian biochronology of the Simon Canyon LF and how it compares with independent age constraints from an overlying rafted-pumice deposit and obsidian correlated to a specific volcanic center. Further age control (detrital sanidine ages) is pending, but we are cautiously optimistic that the Simon Canyon LF may prove to be one of the best-dated Blancan vertebrate faunas from New Mexico.

METHODS AND MATERIALS

Fossils

The fossils collected from the Simon Canyon LF are housed in the vertebrate paleontology collection of the New Mexico Museum of Natural History (NMMNH) in Albuquerque. The fossils have been assigned NMMNH catalog numbers, and the sites from which the fossils were recovered have been assigned NMMNH locality numbers. The fossils are from land under the jurisdiction of the U.S. Bureau of Land Management (BLM) and were collected under Paleontological Resources Use Permit number NM 14-09S, issued to the NMMNH.

The fossils were collected by surface prospecting and are documented by detailed stratigraphic and locality data, including UTM coordinates in the NAD 83 datum. In the interest of maintaining site confidentiality, UTM coordinates for individual fossil sites are not provided here but are archived by the NMMNH and the BLM state office in Santa Fe and are available to qualified researchers. Fossils were identified by: (1) comparisons with similar vertebrate fossils of Blancan age from New Mexico housed in the NMMNH vertebrate paleontology collection, and (2) comparisons with descriptions and illustrations of Blancan fossils from the literature.

X-ray Fluorescence Spectrometry (XRF) of Obsidian Clasts

Publications by Church (2000) and Shackley (2021) have demonstrated that obsidian in Quaternary ancestral Rio Grande deposits can be "chemically fingerprinted" to distinctive source areas in the Jemez Lineament (particularly the Mount Taylor, Jemez Mountains, and Taos Plateau volcanic fields). The presence of such obsidian clasts in a clastic deposit provides a maximum age constraint for that deposit. To determine the chemical composition of obsidian found in our study area, with the goal of matching this composition to that found in potential upstream source areas, we used trace element analysis. The analyses were performed at the Geoarchaeological XRF Laboratory, Albuquerque, New Mexico, using a Thermo-Scientific Quant'X energy-dispersive EDXRF laboratory spectrometer. The instrumental methods and settings are available in Shackley (2005), Shackley et al. (2016), and http://swxrflab.net/anlysis.htm. Assignment to source is from the source standards library in the laboratory (see also Shackley et al., 2018).

LITHOSTRATIGRAPHY

Palomas Formation

The Simon Canyon LF vertebrates are from clastic deposits of the Palomas Formation (upper Santa Fe Group). In the central San Marcial Basin, there are three main lithofacies of the Palomas Formation (Jochems and Koning, 2019; Koning et al., 2020, 2021; Fig. 2). Mapped near the modern-day Rio Grande, the axial-fluvial facies (QTpa of Koning et al., 2020) is composed primarily of light-brownish-gray to white, well-laminated, quartz-rich sand with <25% pebble beds containing variable proportions of exotic (extra-basinal) chert and quartzite. About 0.6 km to the west of the San Simon Canyon LF are distal piedmont lithofacies (QTppd of Koning et al., 2020) composed of 1–15% gravelly bodies of volcanic composition interbedded with orange to tan, very fine to fine sand and clayey to silty fine sand. Between these two lithofacies lies a fine-grained, transitional unit composed mainly of floodplain deposits, containing ≤1% volcanic pebbles that are interbedded with minor tongues of axial-fluvial sand. Its paleogeographic position is inferred to have been the western margin of a relatively wide basin floor.

Simon Canyon Fossil Sites

The fossil sites occur over a north-south distance of about 1.6 km (~1 mile) and through a stratigraphic interval of about 25 m (80 ft) in the Palomas Formation (Fig. 2; near stratigraphic sections SC-A and SC-B). The fossils are mostly, perhaps all, derived from unconsolidated tongues of axial-fluvial sand within the fine-grained transitional unit. Two stratigraphic

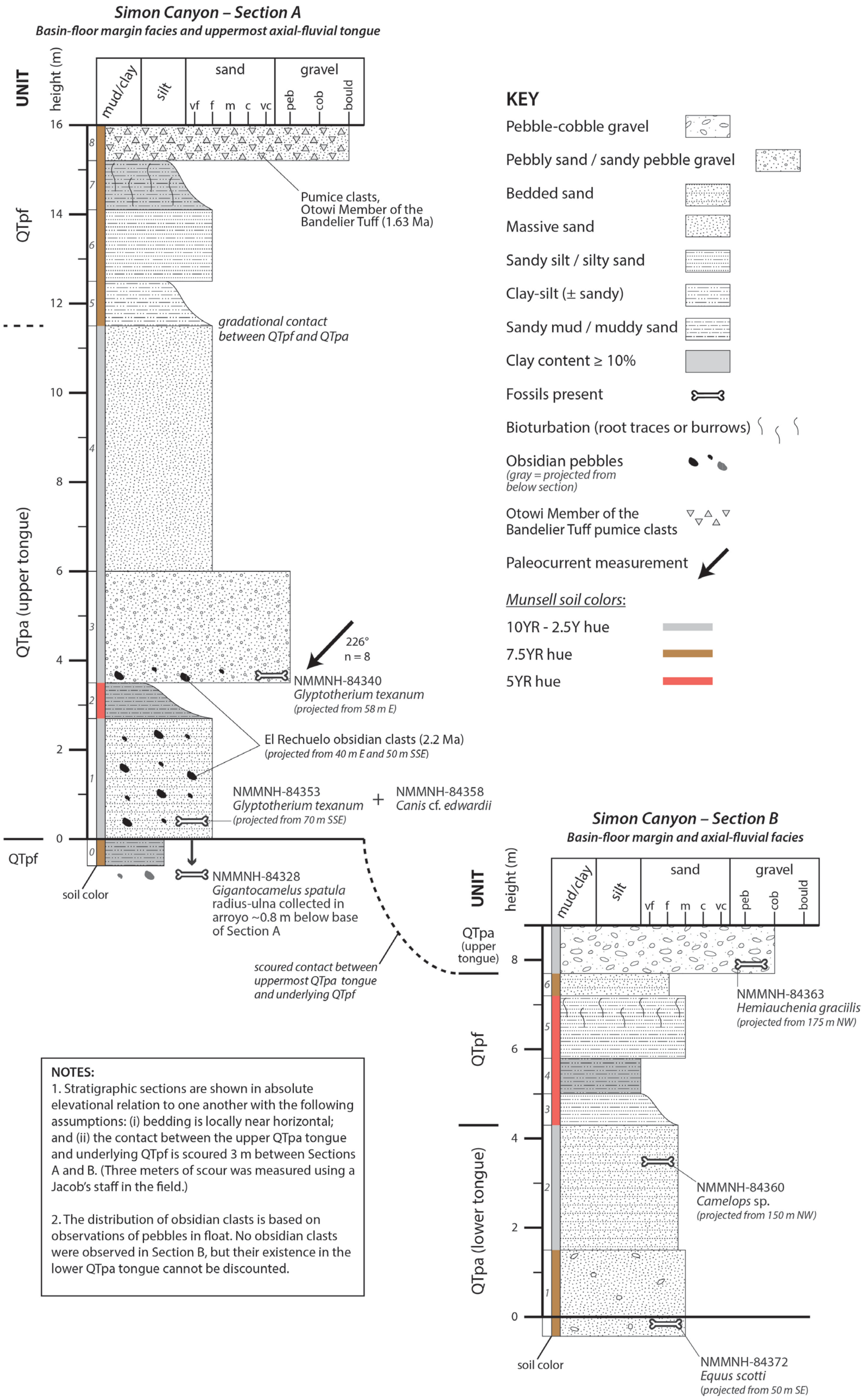

FIGURE 3. Simon Canyon stratigraphic sections A and B (SC-A and SC-B in Figure 2). Palomas Formation stratigraphic units are listed on the left: QTpf = fine-grained transitional unit; QTpa = axial-fluvial sand tongue. Note there is a lower (section SC-B) and an upper (section SC-A) axial-fluvial sand tongue, with the upper tongue yielding the most fossils. The age of the upper tongue is tightly constrained between 1.63 and 2.4 Ma because of the confirmed presence of El Rechuelos obsidian clasts (maximum age) and the Otowi Member of the Bandelier Tuff (OMBT) pumice bed (minimum age). The OMBT pumice bed is interpreted to have been deposited during a flood event from a dam burst in White Rock Canyon near Santa Fe (Reneau and Dethier, 1996). Similar 1.62 Ma pumiceous flood deposits are seen along the Rio Grande to the north (Cather and McIntosh, 2009) and south (Mack et al., 1996).

TABLE 2. Vertebrates from the Simon Canyon Local Fauna, early Pleistocene (late Blancan), Palomas Formation, Socorro County, New Mexico.

- Reptilia
  - Testudines
    - Testudinidae
      - *Gopherus* sp. (desert tortoise)
      - *Hesperotestudo* sp. (giant land tortoise)
- Aves
  - Galliformes
    - Phasianidae
      - *Meleagris* sp. (turkey)
- Mammalia
  - Cingulata
    - Glyptodontidae
      - *Glyptotherium texanum* (Texas glyptodont)
  - Proboscidea
    - Gomphotheriidae
      - Genus and species indeterminate (gomphothere)
  - Lagomorpha
    - Leporidae
      - Genus and species indeterminate (rabbit)
  - Carnivora
    - Felidae
      - Genus and species indeterminate (puma-sized cat)
    - Canidae
      - *Canis* cf. *edwardii* (Edward's wolf)
  - Perissodactyla
    - Equidae
      - *Equus scotti* (Scott's horse)
      - *Equus* sp. (small species of one-toed horse)
  - Artiodactyla
    - Camelidae
      - *Camelops* undescribed species (large camel)
      - *Gigantocamelus spatulus* (giant camel)
      - *Hemiauchenia* cf. *blancoensis* (Blanco camel)
      - *Hemiauchenia gracilis* (gracile llama)
    - Cervidae
      - *Odocoileus* sp. (deer)

sections depict the position of several key fossils from the Simon Canyon LF relative to various stratigraphic units (Fig. 3). The upper stratigraphic section (Section A) is 16 m thick and the lower (Section B) is 8.5 m thick. The two are tied by the base of the upper axial-fluvial sand; note that this scoured contact extends down-section ~3 m between the base of Section A and the top of Section B (Fig. 3).

The two axial-fluvial tongues (unit QTpa) in the stratigraphic sections are separated by 3–6 m of fine-grained sediment (silt, silty very fine– to medium-grained sand, and clay-silt) mapped as the transitional unit (QTpf, Figs. 2, 3). Many of the fossils are broken and waterworn, suggesting transport in a rather substantial river or stream, almost certainly the ancestral Rio Grande, prior to their final deposition. The upper axial-fluvial tongue is 11–12 m thick and mappable at 1:24,000 scale (Koning et al., 2020). The lower 6 m consists of bedded sand to pebbly sand with minor clayey sand (Fig. 3), whereas the upper 6 m is characterized by very fine– to fine-grained, massive sand. The lower axial-fluvial tongue is 4.5 m thick and fines upward from a slightly pebbly sand to a medium-grained, horizontal planar- to cross-laminated sand.

Gradationally overlying the upper axial-fluvial tongue is 3.5–3.8 m of the transitional unit (QTpf) overlain by a 0.8 m thick bed of pumice. The transitional unit here consists of sandy silt-clay and silty very fine– to fine-grained sand. The pumice bed coarsens upwards from pebbles to cobbles and small boulders (<30 cm, long clast axis).

Age Control from Gravel Clasts

Distinctive obsidian gravel clasts were discovered in float 0–4 m above the base of Section A (Fig. 3), in the lower third of the upper axial-fluvial tongue (QTpa). Some obsidian float was projected into the section 0–1 m below the base of Section A (Fig. 3), but it is undetermined whether these were weathering directly out of this particular stratigraphic interval or represent lag gravel from erosion of the overlying axial-fluvial sand. Three obsidian clasts were sampled (SC1, SC2, SC3) and their trace element concentrations analyzed using XRF methods. The results of these analyses are shown in Table 1. The trace element chemistry of these three samples was compared with known upstream obsidian source areas that predate 1.6 Ma. These source areas include the El Rechuelos Rhyolite (Jemez Mountains), Grants Ridge (Mt. Taylor area), and Horace/La Jara Mesa (Mt. Taylor area). Of these source areas, there was a close geochemical match with the El Rechuelos Rhyolite, as illustrated using Rb vs. Zr and Y vs. Nb (Fig. 4).

The El Rechuelos Rhyolite obsidian source is located 20 km SSW of the town of Abiquiu, on the northern slopes of the Jemez Mountains (map unit Ter2 of Kempter et al., 2004). There were five eruptive episodes here, but only the latest produced archaeological artifact–quality obsidian (Konkright, 2019). Collections in the Geoarchaeological XRF Laboratory were made at two to three small, coalesced domes near the head of Cañada de los Ojitos and as secondary deposits in Cañada de los Ojitos (collection localities S080999-1&2). The geochemistry of these source samples (data in http://swxrflab.net/jemez.htm#El%20Rechuelos) are compositionally similar to the data presented in Baugh and Nelson (1987), Glascock et al. (1999), and Konkright (2019). The rhyolite has recently been investigated and re-dated by the $^{40}Ar/^{39}Ar$ technique to 2.23±0.15 Ma (Konkright, 2019), in good agreement with an earlier $^{40}Ar/^{39}Ar$ age on obsidian of 2.10±0.02 Ma (WoldeGabriel et al., 2006; Kelley et al., 2013). Therefore, the presence of this obsidian in the lower third of the upper axial-fluvial sand tongue provides a maximum age constraint of 2.23±0.15 Ma for the fossils collected there.

The pumice bed capping Section A is probably correlative to the "Fort Craig pumice" that was geochemically correlated by Dunbar et al. (1996) to the Otowi Member of the Bandelier Tuff (OMBT), also known as the lower Bandelier Tuff. No location of the "Fort Craig pumice" was given in Dunbar et al. (1996), but it is described in that work as a coarse pumice, and the only coarse pumice identified within 7 km of Fort Craig is the pebble-boulder pumice seen here and a correlative bed mapped

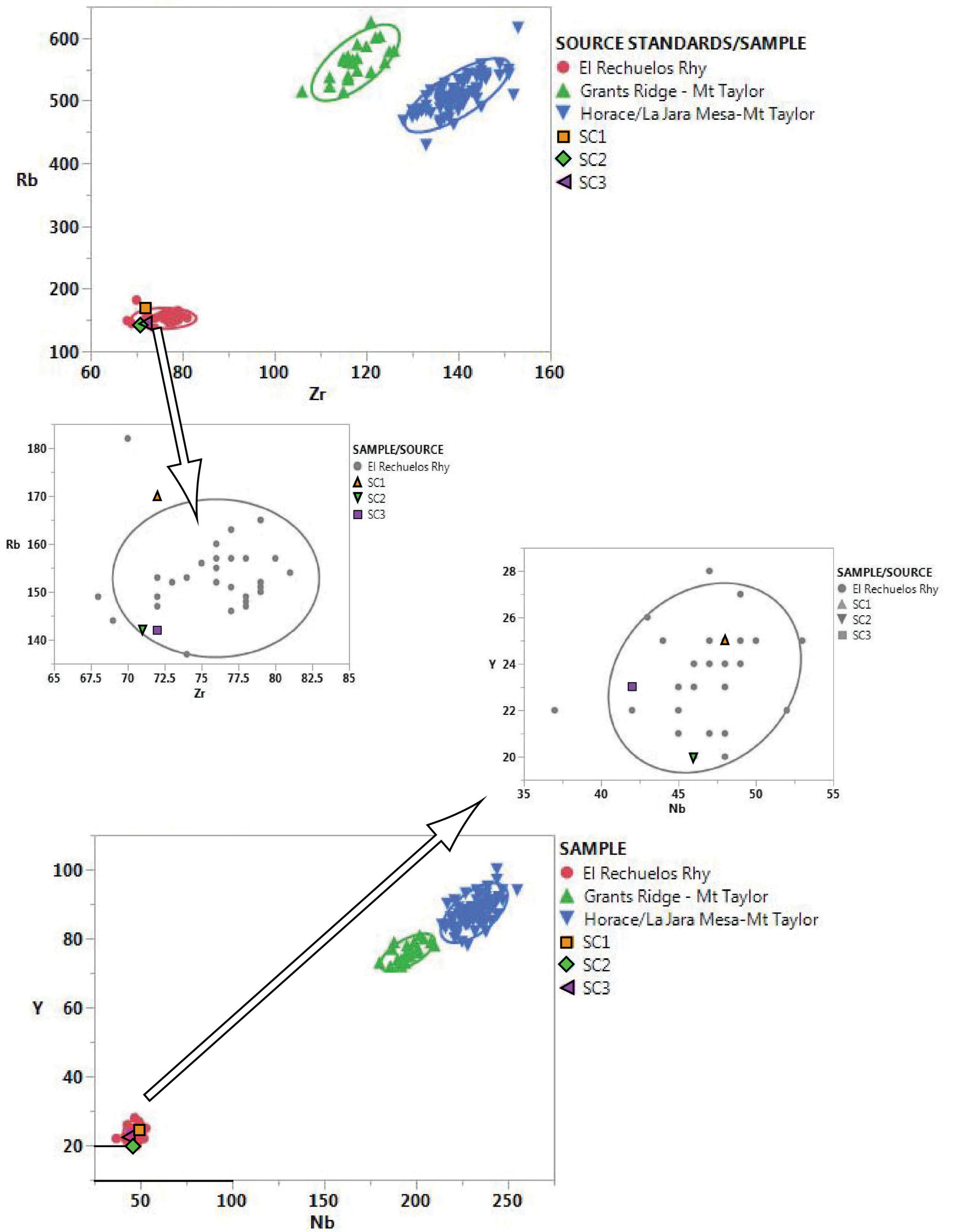

FIGURE 4. Zr/Rb (top) and NB/Y (bottom) bivariate plots of Mount Taylor and El Rechuelos Rhyolite source standards and the three obsidian clasts (SC1, SC2, SC3) collected at the Simon Canyon LF. The three most-likely upstream sources must predate 1.63 Ma and are the El Rechuelos Rhyolite, Grants Ridge (Mt. Taylor area), and Horace/La Jara Mesa (also in the Mount Taylor area). Note the close correspondence of the three Simon Canyon LF samples with the El Rechuelos Rhyolite. The two middle bivariate plots comparing the three Simon Canyon obsidian clasts and El Rechuelos Rhyolite obsidian standards provide increased clarity. All measurements are in ppm. Confidence ellipses at 90%.

0.5 km to the northeast of the Simon Canyon LF site (Koning et al., 2020). The correlation of the "Fort Craig pumice" to the one capping Section A is also consistent with verbal communication to D. Love by Steve Cather (co-author on the Dunbar et al. 1996 paper). Assuming the Fort Craig pumice is the one observed at the top of Section A, then there is a geochemical similarity between this pumice and the OMBT bed sourced in the Jemez Mountains (e.g., Dunbar et al., 1996, fig. 3.10), as interpreted from data using ion microprobe analyses (Dunbar et al., 1996). The weighted mean age of the OMBT tephra in the Jemez Mountains is 1.611±0.008 Ma (Spell et al., 1996; *nota bene* the use of an age of 27.9 Ma for the Fish Canyon Tuff sanidine standard in that publication). We recalculate the Spell et al. (1996) age relative to the Fish Canyon Tuff sanidine standard age of 28.201 Ma of Kuiper et al. (2008) using the formula

$$\textit{published age}\left(\frac{\textit{age of new standard}}{\textit{age of standard used for published age}}\right) \rightarrow 1.611\,Ma\left(\frac{28.201\,Ma}{27.9\,Ma}\right)$$

yielding an age of 1.628±0.008 Ma for the OMBT tephra. We use the age of 1.63 Ma hereafter for the OMBT. Another coarsening-upward pumice deposit in Rio Grande axial-fluvial facies, found east of San Antonio and compositionally correlative to the pumice at Simon Canyon (Dunbar et al., 1996), is ~1.61 Ma (Cather and McIntosh, 2009).

Like the obsidian age, the 1.63 Ma age of the pumice bed can be viewed as a maximum age. However, we argue that the pumice deposit represents a rafting event from a pumice-dam burst, a phenomenon which has been previously interpreted for the White Rock Gorge (Reneau and Dethier, 1996) and for various pumice beds in the southern Rio Grande rift (Mack et al., 1996; Cather and McIntosh, 2009). The relatively thick nature of the pumice bed (0.8 m) is consistent with a raft-flow deposit, as is the wholly pumice composition of the gravel. The cobble- to small boulder–size clasts cannot have been emplaced here by ash-fall processes, given that the site is 260 km south of the source of the pumice, the Toledo caldera in the Jemez Mountains (Spell et al., 1996). Furthermore, the pumice bed is not associated with axial-fluvial sand but is interbedded within floodplain deposits. This suggests a flood spilled out of the channel of the ancestral Rio Grande and swept across most of the floodplain, leaving behind a thick deposit of pumice. Given these observations, combined with previous study of these types of deposits, we interpret that this bed of OMBT-derived pumice originated from a dam-burst event near the Toledo caldera. A dam of nonwelded OMBT in the White Rock Gorge would not be expected to be very strong nor is there evidence of a long-lived lake in the Española Basin, so it is reasonable to infer that the dam-burst flood occurred within a few thousands to perhaps a few tens of thousands of years after the associated caldera eruption and that the 1.63 Ma age of the pumice is very close to the depositional age.

VERTEBRATE PALEONTOLOGY

The following is a brief review of the vertebrate paleontology of the Simon Canyon LF. A complete vertebrate faunal list for the Simon Canyon LF is presented in Table 2, but only the most diagnostic fossil specimens from this fauna are discussed in this section. We will present the comprehensive vertebrate paleontology of the Simon Canyon LF and several other Blancan faunas from the San Marcial Basin in a longer paper to be published later this year in the New Mexico Museum of Natural History and Science Bulletin. That paper will include a complete listing of specimens with detailed descriptions, measurements, illustrations, and comparisons of the vertebrate fossils from the San Marcial Basin.

The Simon Canyon LF consists of 15 vertebrate species: 12 mammals, 2 tortoises, and a bird (faunal list in Table 2) of early Pleistocene (late Blancan NALMA) age, derived from 18 individual fossil sites (NMMNH Localities L-12840–12857). Although most of the fossils consist of isolated postcranial elements, with only a few teeth represented, we were able to identify about half the specimens to genus or species. Three of the taxa in the mammal fauna are identifiable only to the family level, a gomphothere (Gomphotheriidae), a small rabbit (Leporidae), and a large cat (Felidae). Two species can be identified to genus, a small species of the one-toed horse *Equus* (Equidae) and the deer *Odocoileus* (Cervidae). The remaining seven mammals are identified to the species level, although several are only tentatively referred (cf.), all of which are known from faunas referred to the Blancan NALMA: the glyptodont *Glyptotherium texanum*, wolf-like canid *Canis* cf. *edwardii*, horse *Equus scotti*, and four camels, a large species of *Camelops*, giant camel *Gigantocamelus spatulus*, and two species of the extinct llama genus *Hemiauchenia*, *H.* cf. *blancoensis* and *H. gracilis*. The most common species in the Simon Canyon LF is a large species of one-toed horse, *Equus scotti*, represented by a tooth and about ten isolated postcranial elements.

Reptilia

Testudinidae: *Gopherus* and *Hesperotestudo* (tortoises)

Two genera of land tortoises are identified from the Simon Canyon LF, *Gopherus* sp. and *Hesperotestudo* sp. The most diagnostic tortoise fossil is the distal end of a femur (NMMNH 84362; Locality L-12854), referable to *Hesperotestudo* on the basis of its large size. Several shell fragments are also identified as *Hesperotestudo* by their large size and thick shell (NMMNH 84338; Locality L-12846). Two much smaller and thinner shell fragments (NMMNH 84342; L-12848) are tentatively identified as the desert tortoise genus *Gopherus*. *Gopherus* and *Hesperotestudo* are both common in New Mexico Blancan faunas but have not been identified to the species level (Morgan and Harris, 2015). *Hesperotestudo* is unknown in New Mexico after the early Irvingtonian (about 1 Ma), presumably corresponding to the onset of cooler Ice Age climatic conditions at that time.

Aves

Galliformes: Phasianidae: *Meleagris* sp. (turkey)

A partial right tarsometatarsus (NMMNH 84352, L-12853) is the only bird fossil in the Simon Canyon LF. Although this bone is incomplete, lacking both proximal and distal ends, it preserves the base of the large, bony spur core on the medial edge of the tarsometatarsus that is the most characteristic feature of turkeys of the genus *Meleagris*, specifically males (Steadman, 1980). The tarsometatarsus of *Meleagris* from Simon Canyon is not complete enough for identification to species, and as such is not age-diagnostic. There are two other Blancan records of *Meleagris* from New Mexico, from the early Blancan Buckhorn LF, Grant County, southwestern New Mexico (Steadman, 1980), and the late Blancan San Antonio Fauna in Socorro County (Needham, 1936; Rea, 1980; Morgan et al., 2009).

Mammalia

Cingulata: Glyptodontidae: *Glyptotherium texanum* (glyptodont)

Two carapacial osteoderms or scutes from the Simon Canyon LF are identified as the North American late Blancan and early Irvingtonian glyptodont, *Glyptotherium texanum* (NMMNH 84340, L-12848; NMMNH 84353, L-12853). These two localities are less than 200 m apart, and only 3 m separate the localities stratigraphically (Fig. 3). NMMNH 84340 is somewhat waterworn around the edges but preserves both the external and internal surfaces, whereas NMMNH 84353 is split in half, preserving only the external surface. Both osteoderms are pentagonal or hexagonal in shape and exhibit the strong pitting and distinctive pattern of grooves on the external surface that characterize osteoderms of the carapace of *Glyptotherium* (Figs. 5A, B). The external surface has a shallow, circular groove in the center of the osteoderm that defines the central figure and six or seven additional shallow grooves that radiate outward from this central figure, defining seven or eight smaller squarish to hexagonal peripheral figures. The circular groove outlining the central figure also has from two to six deep, rounded pits that would have possessed large hairs when the glyptodont was alive (Gillette and Ray, 1981).

In a recent taxonomic revision incorporating large samples of *Glyptotherium* carapacial osteoderms from early Blancan faunas in central Mexico and late Blancan faunas in New Mexico and Arizona, Gillette et al. (2016) demonstrated substantial variation in size and characters of osteoderms. They recommended combining all North American glyptodonts from the late Blancan and early Irvingtonian into a single species, *G. texanum*, the oldest available name for these glyptodonts and the name assigned here to the osteoderms from the Simon Canyon LF. As discussed in more detail below under “Mammalian Biochronology,” glyptodonts of the genus *Glyptotherium* were participants in the Pliocene and early Pleistocene phase of the Great American Biotic Interchange (GABI), first arriving in New Mexico, Arizona, and western Texas at about 2.7 Ma and then disappearing from the American Southwest in the early Irvingtonian at about 1.0 Ma (Morgan, 2008). Therefore, the presence of *Glyptotherium* in the Simon Canyon LF indicates age range for this fauna of ~1.0–2.7 Ma.

Proboscidea: Gomphotheriidae: genus and species indeterminate (gomphothere)

Two localities referred to the Simon Canyon LF have produced tooth and/or tusk fragments of proboscideans, including a sample of 10 tooth fragments associated with about 50 small tusk fragments (NMMNH 84343, L-12849) and two enamel fragments and a small fragment of the cranium from a second site 10 m lower in the section (NMMNH 84370, L-12840). Tusk fragments cannot be identified beyond Proboscidea, but the tooth fragments are diagnostic of the family Gomphotheriidae. The tooth fragments have very thick enamel with a rough surface texture, and several of the fragments have small accessory cuspids or conulids. The presence of a textured enamel surface and accessory cuspids is typical of gomphotheres, whereas the contemporary mastodon *Mammut* (Mammutidae) has smooth enamel and lacks accessory cuspids. The small enamel fragments from the Simon Canyon LF are not identifiable to the genus level. Among the two genera of gomphotheres identified from Blancan faunas in New Mexico (Morgan and Harris, 2015), *Rhynchotherium* occurs in both early and late Blancan faunas, becoming extinct at about 2.2 Ma, whereas *Stegomastodon* occurs from the early Blancan (~3.5 Ma) to the early Irvingtonian, becoming extinct at about 1.0 Ma.

Lagomorpha: Leporidae: genus and species indeterminate (rabbit)

The slightly waterworn distal end of a tibia, identified as a rabbit in the family Leporidae (NMMNH 84341, L-12848), is the only specimen of a small mammal recovered from the Simon Canyon LF (Table 2). The distal tibia is similar in morphology but somewhat larger than the same element in the living desert cottontail *Sylvilagus audubonii*. New Mexico late Blancan faunas record the presence of two extant genera of leporids, *Lepus* (jackrabbits) and *Sylvilagus* (cottontails), as well as the extinct genus *Aluralagus* (Morgan and Harris, 2015). An incomplete tibia is insufficient for a generic identification.

Carnivora: Felidae: genus and species indeterminate (large cat)

A partial calcaneum of a large cat in the family Felidae is identified from the Simon Canyon LF (NMMNH 84329, L-12845). Comparison with modern felids reveals that this fossil is most similar in size and morphology to the calcaneum of the mountain lion *Puma concolor*. Three large felids in this general size range are known from late Blancan faunas in western North America, *Puma lacustris*, the cheetah-like cat *Miracinonyx inexpectatus*, and the small sabercat *Smilodon gracilis*. Although probably representing one of these three species, the partial felid calcaneum from Simon Canyon is not complete enough for an identification to genus or species.

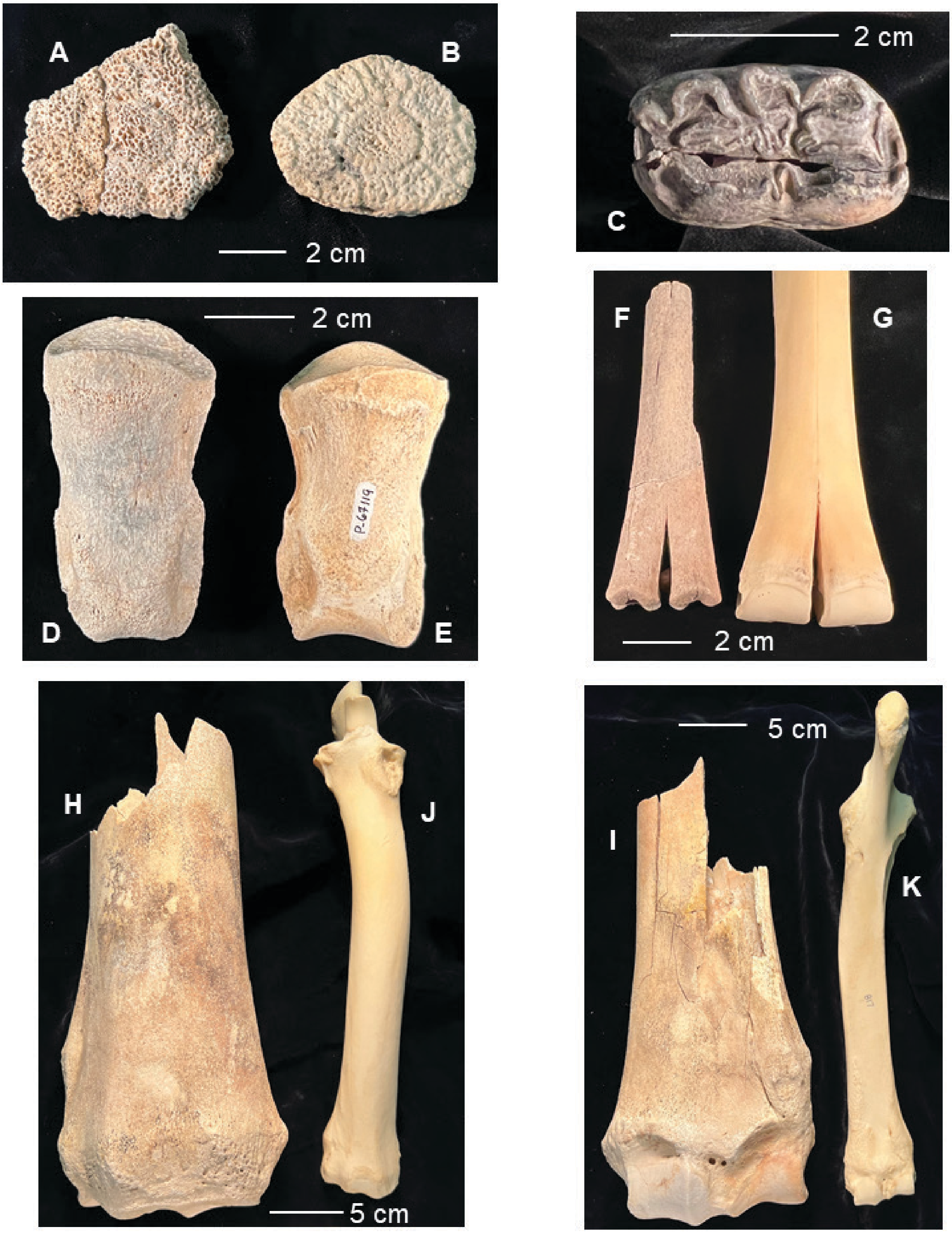

FIGURE 5. Early Pleistocene (late Blancan) vertebrate fossils from the Simon Canyon Local Fauna. **A, B.** *Glyptotherium texanum*, carapacial osteoderms, external view, A. NMMNH 84353, B. NMMNH 84340. **C.** *Equus scotti*, right third or fourth lower premolar, occlusal view, NMMNH 84372. **D, E.** Two species of *Camelops*, medial phalanx, anterior view, D. *Camelops* large species, Simon Canyon, NMMNH 84360, E. *Camelops hesternus*, late Pleistocene Canovas Creek LF, Catron County, New Mexico, NMMNH 67119. **F.** *Hemiauchenia gracilis*, juvenile distal metapodial, anterior view, Simon Canyon, NMMNH 84363. **G.** *Lama glama*, distal metacarpal, anterior view, modern. **H, I.** Distal right radius-ulna of *Gigantocamelus spatulus*, Simon Canyon, NMMNH 84328, H. Anterior view, I. Posterior view. **J, K.** Right radius-ulna of *Lama glama,* modern, J. Anterior view, K. Posterior view.

Carnivora: Canidae: *Canis* cf. *edwardii* (extinct wolf)

A nearly complete cervical vertebra from the Simon Canyon LF (NMMNH 84358, L-12853) is tentatively identified as the early Pleistocene wolf *Canis edwardii*. We compared this fossil to cervical vertebrae of living carnivorans in the same size range, and it is very similar in size and morphology to the 3rd or 4th cervical vertebra of the gray wolf or Mexican wolf (lobo) *Canis lupus*. The Simon Canyon fossil is similar to but much larger than comparable cervical vertebrae of the coyote *C. latrans*. The only wolf-like canid in North American late Blancan faunas is *C. edwardii*, and we tentatively refer the Simon Canyon vertebra to this species. The chronologic range of *C. edwardii* is late Blancan through early Irvingtonian (~1.0–2.5 Ma), with the type locality of the species from the latest Blancan Curtis Ranch Fauna in southeastern Arizona (Gazin, 1942; Tedford et al., 2009).

Perissodactyla: Equidae: *Equus scotti* (Scott's Horse)

A one-toed horse of the genus *Equus* is the most common species in the Simon Canyon LF, with more than 10 identifiable specimens representing several individuals. However, the only specimen from this fauna we feel confident in identifying to species is a well-preserved right third or fourth lower premolar (NMMNH 84372, L-12856), here referred to *Equus scotti* (Fig. 5C). Most of the postcranial fossils of *Equus* from Simon Canyon represent a large horse and are probably *E. scotti* as well, although they lack definitive characters of that species and are listed below under *Equus* sp. NMMNH 84372 is large, with an anteroposterior length of 31.7 mm, and high-crowned, with a crown height at the metaconid of 94.1 mm. The large size, hypsodonty (high-crowned), and rather complicated enamel pattern of the lower tooth from Simon Canyon are typical of *Equus scotti*. This species first appears in the New Mexico fossil record in the late early Blancan (~3.0–3.5 Ma), occurs throughout the remainder of the Blancan and into the early Irvingtonian, and disappears at about 1 Ma (Morgan and Harris, 2015). *E. scotti* is the most common horse in latest Blancan and early Irvingtonian faunas (~1.0–2.2 Ma) in New Mexico (Morgan and Harris, 2015). Although the presence of *E. scotti* is characteristic of late Blancan faunas in New Mexico, the presence of this species of large horse in the Simon Canyon LF only restricts the age range to ~1.0–3.5 Ma.

Perissodactyla: Equidae: *Equus* sp. (one-toed horse)

Most of the horse (Equidae) fossils in the Simon Canyon fauna consist of isolated postcranial elements and several cranial fragments that are identifiable only as *Equus* sp. Several of the most diagnostic postcranial elements include: partial cervical vertebra (NMMNH 84373, L-12857); unfused distal epiphysis of radius-ulna, juvenile (NMMNH 84348, L-12852); partial right calcaneum (NMMNH 84345, L-12851); partial metacarpal (NMMNH 84331, L-12846); and proximal phalanx (NMMNH 84344, L-12850). Most of these elements probably pertain to *E. scotti*, with the exception of a cervical vertebra (NMMNH 84373) that represents a much smaller species, listed in Table 2 as "*Equus* sp. (small species)." This vertebra is quite similar in morphology but much smaller than cervical vertebrae of the large late Pleistocene horse *Equus occidentalis* from two Rancholabrean faunas in New Mexico, Jemez Springs in Sandoval County and Lake San Agustin in Socorro County. Because *E. occidentalis* and *E. scotti* are both large horses, it appears NMMNH 84373 represents a smaller species of *Equus* that is not represented in the Simon Canyon LF by teeth.

Artiodactyla: Camelidae: *Camelops* large undescribed species (large camel)

A medial phalanx (= second phalanx) from Simon Canyon represents a large camel referred to the genus *Camelops* (NMMNH 84360, L-12854). Compared to medial phalanges of the other two genera of camels identified from Simon Canyon, this toe is much smaller than those of the giant camel *Gigantocamelus* and larger and more robust than middle toes of the two species of the lamine camelid genus *Hemiauchenia*. Medial phalanges of *Camelops hesternus* are present in several late Pleistocene (Rancholabrean NALMA) faunas in New Mexico, including Canovas Creek in Catron County and White Mesa Mine in Sandoval County (Morgan and Rinehart, 2007; Morgan and Harris, 2015). The medial phalanx from Simon Canyon is quite similar in morphology to second phalanges of *C. hesternus* from the late Pleistocene sites but is larger (Figs. 5D, E). The larger size of the medial phalanx agrees with other Blancan material of *Camelops* from New Mexico, in which Blancan specimens are larger than comparable elements of *C. hesternus* from Rancholabrean faunas (Morgan and Harris, 2015). A large species of *Camelops*, previously referred to *C. traviswhitei*, is fairly widespread in Blancan faunas in the American Southwest, including New Mexico and Arizona (Morgan and White, 2005; Morgan and Harris, 2015). However, Baskin and Thomas (2016) considered *C. traviswhitei* to be a synonym of *C. hesternus*, and consequently the large Blancan *Camelops* appears to be an undescribed species.

Artiodactyla: Camelidae: *Gigantocamelus spatulus* (giant camel)

The distal end of a right radius-ulna is identified as the giant Blancan camel *Gigantocamelus spatulus* (NMMNH 84328, L-12845). The distal articular surface of this specimen is well preserved, and the morphology is typical of the radius-ulna in other members of the family Camelidae, but it is of enormous size (Figs. 5H, I). NMMNH 84328 compares closely in size and characters to a radius-ulna of *Gigantocamelus* from the latest Blancan La Union Fauna in southern New Mexico (Vanderhill, 1986), and is considerably larger than that element in the other three genera of camels known from the Blancan of New Mexico, *Blancocamelus*, *Camelops*, and *Hemiauchenia*. We refer the Simon Canyon specimen to *G. spatulus*, because that is the only currently recognized species in the genus *Gigantocamelus* (Harrison, 1985). The distal radius-ulna of

G. spatulus from Simon Canyon is compared to a radius-ulna of a modern llama *Lama glama* in Figures 5H–K.

Simon Canyon is the third record of *Gigantocamelus spatulus* from the Blancan of New Mexico. The other two records are from the early Blancan Elephant Butte Lake Fauna in Sierra County and the latest Blancan La Union Fauna in Doña Ana County (Tedford, 1981; Vanderhill, 1986; Morgan et al., 2011). In her review of North American giant camels, Harrison (1985) listed ten Blancan localities for *Gigantocamelus* in western North America, with most records from the Great Plains—South Dakota and Nebraska south to the Texas Panhandle—including the type locality of the species *G. spatulus*, the late Blancan Blanco LF in the Panhandle of Texas. The only records she listed from outside the Great Plains province were from Idaho and southwestern Texas. More recent discoveries have expanded the record of *Gigantocamelus* in Blancan faunas from the southwestern U.S., including the three faunas from New Mexico mentioned above, as well as San Simon, Arizona (Morgan and White, 2005), and the Anza-Borrego Desert in southern California (Webb et al., 2006). *Gigantocamelus* is known only from the Blancan, with records ranging in age from about 2.0–3.5 Ma (Harrison, 1985). The latest Blancan (~2.0–2.2 Ma) records of *Gigantocamelus* from Simon Canyon and La Union appear to be among the youngest known records of this giant camel.

Artiodactyla: Camelidae: *Hemiauchenia* cf. *blancoensis* (Blanco camel)

A lumbar vertebra of a medium-sized camel (NMMNH 84368, L-12842) from the Simon Canyon LF is tentatively identified as the large llama *Hemiauchenia blancoensis*. The centrum is complete and well preserved, as are the basal and anterior portions of the neural arch. The neural spine and transverse processes are broken off and missing. The characters of this vertebra are very similar to those of other members of the family Camelidae. It is intermediate in size between the smaller lumbar vertebrae in a modern adult skeleton of the llama *Lama glama* and the larger vertebrae in the late Pleistocene camel *Camelops hesternus*. Among the five species of camels found in New Mexico Blancan faunas, only *Hemiauchenia blancoensis* fits into this general size range. *H. blancoensis* is one of the most common and widespread camels in southwestern Blancan faunas, including at least 10 records from New Mexico (Morgan and Harris, 2015). *H. blancoensis* has a similar chronologic range in New Mexico to that of *Gigantocamelus spatulus* and the large *Camelops*, all of which occur in late early Blancan through latest Blancan faunas, first appearing about 3.5 Ma and becoming extinct about 2.0 Ma.

Artiodactyla: Camelidae: *Hemiauchenia gracilis* (gracile llama)

Three specimens from the Simon Canyon LF are referred to the gracile or dwarf llama *Hemiauchenia gracilis*: distal end of a calcaneum (NMMNH 84349, L-12852); proximal fragment of a metapodial (NMMNH 84350, L-12852); and partial distal metapodial missing the distal epiphyses of a juvenile individual (NMMNH 84363, L-12854). Among these three specimens, only the distal metapodial (NMMNH 84363) is complete enough for a species identification. This fossil consists of the distal third of a metapodial, including the more proximal portion where the metapodials are fused and the more distal portion where the 3rd and 4th metapodials become separated (Fig. 5F). This fossil is very small and slender compared to the metapodials of most other camels known from the Blancan of New Mexico, including those of *H. blancoensis*. We also compared NMMNH 84350 to the metapodials in a modern skeleton of an adult *Lama glama*. The Simon Canyon specimen is smaller, with the shaft and distal metapodials slenderer (Figs. 5F, G). The Simon Canyon fossil is similar in size to metapodials of the very small lamine camel, *H. gracilis*, first described from several late Blancan faunas in Florida (Meachen, 2005). We refer NMMNH 84350 to *H. gracilis* because this species is the only Blancan camel in this small size range, as well as the similarity of the Simon Canyon specimen to metapodials of *H. gracilis* from faunas of similar age in Florida.

Hemiauchenia gracilis is an uncommon species of small lamine camel that has a limited chronologic range in the late Blancan from about 1.6 to 2.5 Ma and is known only from Florida and several states in the American Southwest. Two other records of *H. gracilis* from New Mexico are latest Blancan in age, La Union in Doña Ana County and Virden in Hidalgo County (Morgan et al., 2008; Morgan and Harris, 2015). There are also two records of *H. gracilis* from late Blancan faunas in southeastern Arizona, San Simon and Dyack (Morgan and White, 2005; Czaplewski, 2020), and a Blancan record from the Anza-Borrego Desert in southern California (Webb et al., 2006). *H. gracilis* from Florida, New Mexico, and Arizona is known only from the late Blancan, and is particularly diagnostic of latest Blancan faunas (~1.6–2.2 Ma).

Artiodactyla: Cervidae: *Odocoileus* sp. (deer)

Three specimens from Simon Canyon are identified as the genus *Odocoileus* in the deer family Cervidae: midshaft fragment of right antler (NMMNH 84333, L-12846); lateral half of proximal end of left radius (NMMNH 84364, L-12854); and distal epiphysis of left tibia (NMMNH 84367, L-12855). The most diagnostic specimen is a partial antler preserving the base of the brow tine and about 40 mm of the midshaft distal to the brow tine (NMMNH 84333). This specimen is identified as a cervid antler by the overall shape, surface ornamentation, and the thick layer of cortical bone with a small core of cancellous bone. The antler fragment compares well in size and overall morphology with antlers of the living male mule deer, *Odocoileus hemionus*. We refer the San Simon fossil to the genus *Odocoileus*, but it is not complete enough for a species identification. The only other genus of cervid reported from New Mexico Blancan faunas, *Navahoceros*, has much larger antlers (Morgan and Harris, 2015). Antlers from five other Blancan faunas in New Mexico have been referred to *Odocoileus*, but none are complete enough for a species identification (Morgan and Harris, 2015). *Odocoileus* first appears in the early

Blancan (~5 Ma) and is present throughout the remainder of the Pliocene and Pleistocene, and two species of this genus are still extant in North America (Kurtén and Anderson, 1980).

DISCUSSION

Mammalian Biochronology and Faunal Correlation

Although the Simon Canyon Local Fauna has a fairly diverse assemblage of vertebrates consisting of at least 15 species, including 12 species of mammals (Table 2), many of the fossils are incomplete, consisting of tooth fragments, partial limb elements, and toe bones, as well as several nearly complete vertebrae. However, because numerous late Pliocene and early Pleistocene (Blancan NALMA) vertebrate faunas are known from New Mexico that have larger and more diverse samples of fossils (Morgan and Harris, 2015), we were able to identify many of the fragmentary fossils from the Simon Canyon LF to genus and/or species, allowing us to provide an accurate estimate of the age of the fauna based on mammalian biochronology.

Seven species of mammals identified from the Simon Canyon LF are found in Blancan faunas elsewhere in New Mexico and/or southeastern Arizona (Morgan and White, 2005; Morgan and Harris, 2015), including: the glyptodont *Glyptotherium texanum*; the wolf *Canis edwardii*; the horse *Equus scotti*; and four camels, a large undescribed species of *Camelops*, *Gigantocamelus spatulus*, *Hemiauchenia blancoensis*, and *H. gracilis*. The age ranges of these seven mammals are indicated on Figure 6. *G. texanum*, *C. edwardii*, and *E. scotti* also occur in early Irvingtonian faunas, whereas the four species of camels are restricted to the Blancan. The presence of *Glyptotherium texanum* in the Simon Canyon LF is significant because glyptodonts are South American in origin and were participants in the Great American Biotic Interchange (GABI). The beginning of the late Blancan in the American Southwest at about 2.7 Ma is defined by the first appearance of *Glyptotherium* and several other genera of GABI or Interchange mammals that were immigrants from South America (Morgan, 2008). *Glyptotherium* disappeared from the southwestern U.S., including New Mexico, in the early Irvingtonian NALMA (~1.0 Ma), although this genus survived until the end of the Pleistocene (Rancholabrean NALMA) in the southeastern U.S., Mexico, and Central America (Gillette and Ray, 1981; Morgan, 2008). The presence of *G. texanum* in the Simon Canyon LF restricts the age of this fauna to ~1.0–2.7 Ma. The wolf-like canid *Canis edwardii* is widely distributed in late Blancan and early Irvingtonian faunas from Florida to California (Tedford et al., 2009), with an age range similar to that of *G. texanum*. *Equus scotti* is one of the most common mammals in Blancan and Irvingtonian faunas in New Mexico (Morgan and Harris, 2015), first appearing in the early Blancan at about 3.5 Ma and disappearing in the early Irvingtonian (~1.0 Ma), at about the same time *G. texanum* and *C. edwardii* also became extinct.

All four species in the family Camelidae from Simon Canyon are known only from Blancan faunas. Three of these camels, a large species of *Camelops*, *Gigantocamelus spatulus*, and *Hemiauchenia blancoensis*, have similar chronologic ranges in Blancan faunas from New Mexico, first appearing in the early Blancan at about 3.5 Ma and becoming extinct in the latest Blancan by about 2.0 Ma (Morgan and Harris, 2015). Other species of *Camelops* and *Hemiauchenia* from Irvingtonian and Rancholabrean faunas did not become extinct until the end of the Pleistocene (Kurtén and Anderson, 1980). Records of the giant camel *Gigantocamelus* from western North America (Harrison, 1985) range in age from the early Blancan to late Blancan (~2.2–3.5 Ma). A radius-ulna of *Gigantocamelus* from the La Union Fauna in southern New Mexico is latest Blancan (~2.0–2.2 Ma), possibly the youngest known record of this genus (Vanderhill, 1986; Morgan and Lucas, 2003). The small llama *Hemiauchenia gracilis* occurs only in late Blancan faunas in Florida, New Mexico, Arizona, and California (Meachen, 2005; Morgan and White, 2005; Webb et al., 2006;

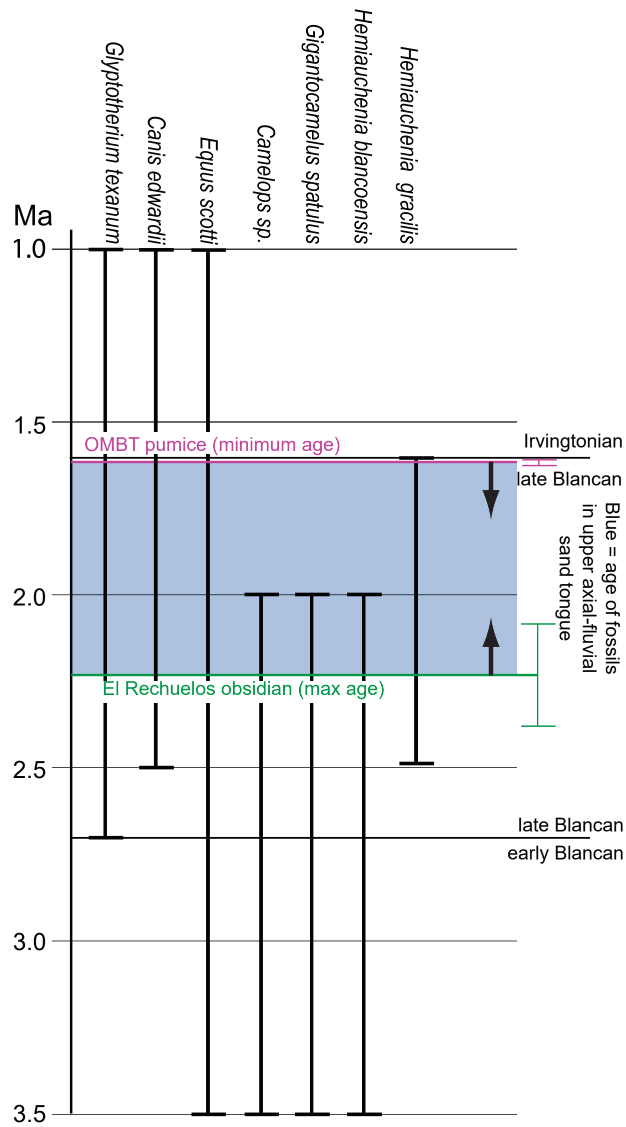

FIGURE 6. Illustration of the age ranges of seven age-diagnostic mammal species from the Simon Canyon Local Fauna. Also illustrated (in blue shade) is the age of the upper axial-fluvial tongue constrained by the overlying Otowi Member of the Bandelier Tuff (OMBT) pumice and the underlying El Rechuelos obsidian.

Morgan and Harris, 2015).

The age ranges of mammal species from Simon Canyon (Fig. 6) confirm that this fauna is no older than late Blancan, based on the presence of *Glyptotherium texanum* and *Hemiauchenia gracilis*, neither of which occurs in faunas from New Mexico that are older than 2.7 Ma. *G. texanum* first appears in New Mexico late Blancan faunas that are about 2.6–2.7 Ma in age, including Anapra, Hatch, and Pearson Mesa (Morgan and Harris, 2015; Morgan et al., 2018). *H. gracilis* is only known from latest Blancan faunas (~1.6–2.2 Ma) in New Mexico (Morgan and Harris, 2015), including La Union and Virden and now Simon Canyon, although this species does occur in several late Blancan faunas in Florida that may be as old as 2.5 Ma (Meachen, 2005). The younger end of the age range for the Simon Canyon LF is provided by *H. gracilis* at 1.6 Ma, as well as the large species of *Camelops*, *Gigantocamelus spatulus*, and *Hemiauchenia blancoensis*, all of which became extinct before the end of the Blancan. The Irvingtonian NALMA is defined by the first appearance of the mammoth *Mammuthus* in North America as an immigrant from Eurasia at about 1.6 Ma (Bell et al., 2004), including several records of early Irvingtonian (~1.3–1.6 Ma) mammoths from New Mexico (Lucas et al., 2017). *Mammuthus* is absent from the Simon Canyon LF, further supporting an age >1.6 Ma.

The mammalian biochronology of the Simon Canyon LF for fossils collected in Section A (especially the age-diagnostic fossils in the lower part of the upper axial-fluvial sand tongue, basal 4 m of the Section; Fig. 3) provides a fairly precise estimate of the age of this fauna, between 1.6 Ma and 2.2 Ma. Comparing this age range to the standard biochronology and subdivisions for the Blancan NALMA would place the Simon Canyon LF in the Blancan V (~1.7–2.5 Ma) of Bell et al. (2004), which is approximately equivalent to the late Blancan (~1.6–2.7 Ma) of Morgan and Harris (2015). The latter authors further subdivided the late Blancan into the early late Blancan (~2.2–2.7 Ma) and latest Blancan (~1.6–2.2 Ma), with the boundary between these two subdivisions at about 2.2 Ma, designated the "*Nannippus* extinction datum" by Lindsay et al. (1984), corresponding to the disappearance of several characteristic Blancan genera of mammals, including the borophagine canid *Borophagus*, the hipparionine horse *Nannippus*, and the gomphothere *Rhynchotherium*. Several species of mammals common in New Mexico Blancan faunas also became extinct at about 2.2 Ma, including the horses *Equus simplicidens* and *E. cumminsii* (Morgan and Harris, 2015). The absence in the Simon Canyon LF of *Borophagus*, *Nannippus*, and *Rhynchotherium*, as well as *E. simplicidens* and *E. cumminsii*, supports an age of <2.2 Ma for this fauna, whereas the absence of *Mammuthus* indicates an age >1.6 Ma. It should be noted that the presence of taxa is always preferable to the absence of taxa when analyzing biochronology.

The biochronologic age control agrees remarkably well with independent geochronologic data provided by the OMBT pumice and El Rechuelos obsidian. Simon Canyon LF fossils were found >11 m below the rafted pumice deposit and must therefore predate 1.63 Ma. The majority of fossils, particularly the age-diagnostic ones (*Glyptotherium texanum, Canis edwardii*, *Hemiauchenia gracilis*), were collected in the stratigraphic interval encompassing the lower 4 m of Section A (Fig. 3), located 11–15 m below the OMBT pumice bed. In this same fossiliferous zone, sparse El Rechuelos obsidian clasts were found on the surface of the lower part of the upper axial-fluvial tongue (Fig. 3). Thus, the age diagnostic fossils were found in the same stratigraphic interval as the 2.23±0.15 Ma El Rechuelos obsidian. Since the obsidian provides a maximum age constraint and the OMBT pumice bed a minimum age constraint, the fossils in the basal 4 m of the upper axial-fluvial tongue (Section A of Fig. 3) are between 1.63 Ma and 2.4 Ma, the latter being the maximum age of deposition based on the error of the $^{40}Ar/^{39}Ar$ dates of the El Rechuelos obsidian (Konkright, 2019). The fossils in the lower axial-fluvial tongue (i.e., Section B of Fig. 3), including *Equus scotti*, *Camelops* sp., and *Hemiauchenia* cf. *blancoensis*, have relatively wide age ranges (1.6 Ma to 3.5 Ma) that do not constrain the age of this tongue as precisely as fossils in the upper axial-fluvial tongue (Fig. 6).

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View to northeast down an unnamed tributary arroyo of the Rio Grande, near the abandoned town of San Marcial. On the left side of the arroyo, note the flat terrace surface underlain by light reddish-brown sediment (correlated to Matanza Formation), which disconformably overlies white axial-fluvial sediment of the Sierra Ladrones Formation. On the skyline (left to right) lie the Little San Pascual Mountains, Oscura Mountains, and Mesa del Contadero. The 818±10.6 ka basalt flow capping Mesa del Contadero overlies the Sierra Ladrones Formation and is not overlain by Santa Fe Group sediment. Thus it provides an important minimum age constraint for the Santa Fe Group and a maximum age constraint for river incision and the terraces flanking the Rio Grande (Sion et al., 2020). Photo by Daniel Koning.