



Quaternary Age Of The Gatuña Formation at Livingston Ridge

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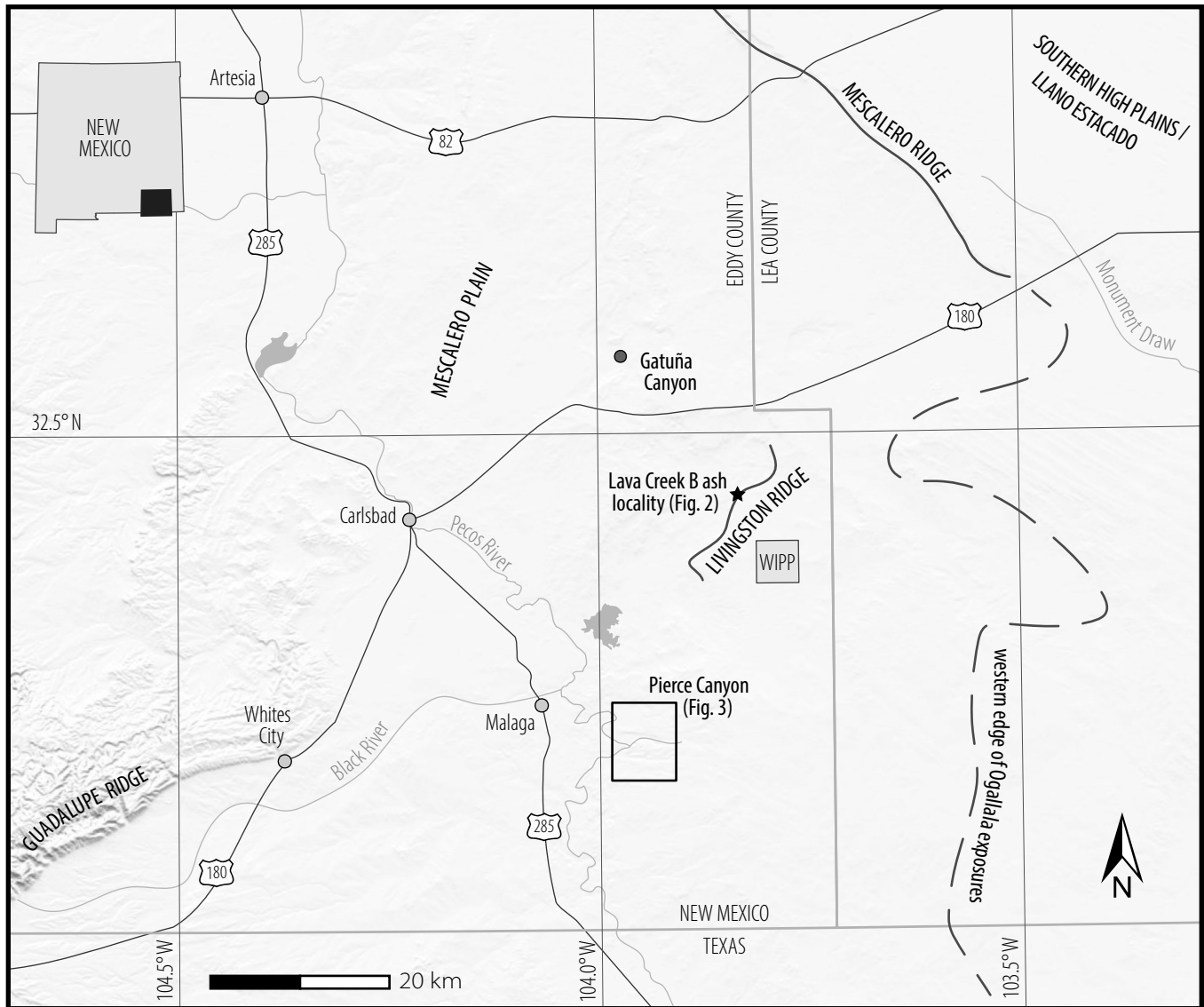


FIGURE 1. Key localities within the Lower Pecos Valley, with map extent in southeastern New Mexico shown at top left. WIPP – Waste Isolation Pilot Plant site.

QUATERNARY AGE OF THE GATUÑA FORMATION AT LIVINGSTON RIDGE

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ABSTRACT—The age, internal stratigraphy, and regional context of the late Cenozoic Gatuña Formation in southeastern New Mexico remain uncertain. Previous workers have extended the original Gatuña stratigraphic concept to include essentially any late Cenozoic deposits along the Pecos Valley in eastern New Mexico and down into western Texas. The only absolute age constraint for strata unquestionably assigned to the Gatuña Formation comes from an outcrop along Livingston Ridge in Nash Draw (Eddy County, NM), where an interbedded volcanic ash has been correlated with the ca. 0.63 Ma Lava Creek B eruption of the Yellowstone caldera. Previous workers proposed a diachronous Gatuña Formation with a Miocene to Pliocene lower section, supported by interpretation of a pedogenic carbonate horizon farther south at Pierce Canyon as an intraformational equivalent to the Neogene Ogallala caprock of the High Plains. Field relations documented during recent geologic mapping in the Pierce Canyon area are inconsistent with the existence of such an intraformational caliche. New detrital sanidine ⁴⁰Ar/³⁹Ar age analyses from Gatuña Formation sediments underlying the Lava Creek B ash at Livingston Ridge yield numerous Quaternary ages, with ~1.3–1.6 Ma youngest detrital grain ages providing a ca. 1.3 Ma (n = 3) maximum depositional age. The Gatuña Formation at this site is thus entirely Quaternary. No existing evidence requires a pre-Quaternary depositional age for the Gatuña Formation in southeastern New Mexico, but neither does any existing data preclude possible Miocene-Pliocene ages for at least some Pecos Valley deposits.

INTRODUCTION

The Gatuña Formation was named by Lang (in Robinson and Lang, 1938) for terrestrial deposits exposed in Gatuña Canyon, approximately 35 km northeast of Carlsbad, New Mexico (Fig. 1). Lang indicated that the formation is of Quaternary age, accumulating in “post High Plains” time following deposition of the Ogallala Formation. The Gatuña Formation is in part characterized by a caliche caprock (pedogenic calcic horizon) informally referred to as the “Mescalero caliche,” named for the Mescalero plain or geomorphic surface that extends along the eastern side of the Lower Pecos River Valley of New Mexico. The Gatuña Formation and the Mescalero caliche lie at lower elevations and to the west of the Mescalero Ridge escarpment of the Neogene Ogallala Formation and the Llano Estacado (Fig. 1; Bachman, 1976). Deposits along the Pecos River extending northward to Guadalupe County, New Mexico, and southward into Texas, including Neogene strata, have since been assigned to the Gatuña Formation (e.g., Kelley, 1971; Reeves, 1972; Eifler, 1975; Powers and Holt, 1993). The defining characteristics of the Gatuña Formation have thus been significantly expanded from the original concept of Quaternary terrestrial strata underlying the Mescalero caliche that occupy a discrete area east of the Pecos River below the High Plains escarpment.

Recent geologic mapping of the Pierce Canyon 7.5-minute quadrangle, Eddy County, New Mexico (Attia and Allen, 2022), which lies just east of the Pecos River near Malaga, raised several questions about the internal stratigraphy, age, and regional significance of the Gatuña Formation. The Gatuña Formation is comparatively thick (generally 10s of meters) and well exposed in the Pierce Canyon area, with ample evidence of solution subsidence before, during, and after deposition. Widespread dissolution of Permian evaporite deposits and associated land subsidence have down-dropped, fragmented,

and rotated stratigraphic sequences, creating local controls on erosion and deposition that complicate stratigraphic and geomorphic interpretations of late Cenozoic landscape deposits in this area. Here, we present detrital sanidine ⁴⁰Ar/³⁹Ar geochronology from a Gatuña Formation sample collected from key exposures along Livingston Ridge in the Nash Draw area to the north of Pierce Canyon (Fig. 1). Combined with existing tephrochronology at the sample site, these new data constrain the entire section at Livingston Ridge to be of Quaternary age.

EXISTING AGE CONSTRAINTS

Age constraints on deposition of the Gatuña Formation, ranging from older than ca. 13 Ma for some deposits to as young as ca. 0.1 Ma for the capping Mescalero caliche, are summarized below (Hawley, 1993; Powers and Holt, 1993; Hall and Goble, 2012). The only direct age constraint on the Gatuña Formation is provided by an interbedded ash along Livingston Ridge (Figs. 1, 2) that is correlated with the ca. 0.63 Ma Lava Creek B eruption of the Yellowstone caldera (Bachman, 1980; Izett and Wilcox, 1982; Matthews et al., 2015; Jicha et al., 2016). The Gatuña Formation is relatively thin at this locality and lies above Permian strata of the Dewey Lake Formation (Fig. 2).

The Gatuña Formation must be older than its pedogenic carbonate caprock, the Mescalero caliche (Bretz and Horberg, 1949; Maley and Huffington, 1953; Vine, 1963). “Uranium-trend” age estimates obtained during studies at the Waste Isolation Pilot Project site near Livingston Ridge (Fig. 1), using an empirically calibrated, open-system age model, suggested a ca. 0.57–0.42 Ma age for the Mescalero caliche, and a 0.33 Ma age for the overlying Berino paleosol developed in overlying eolian deposits (Rosholt and McKinney, 1980). Hall and Goble (2006, 2012, 2023) presented several optically stimulated luminescence ages from deposits above and one age

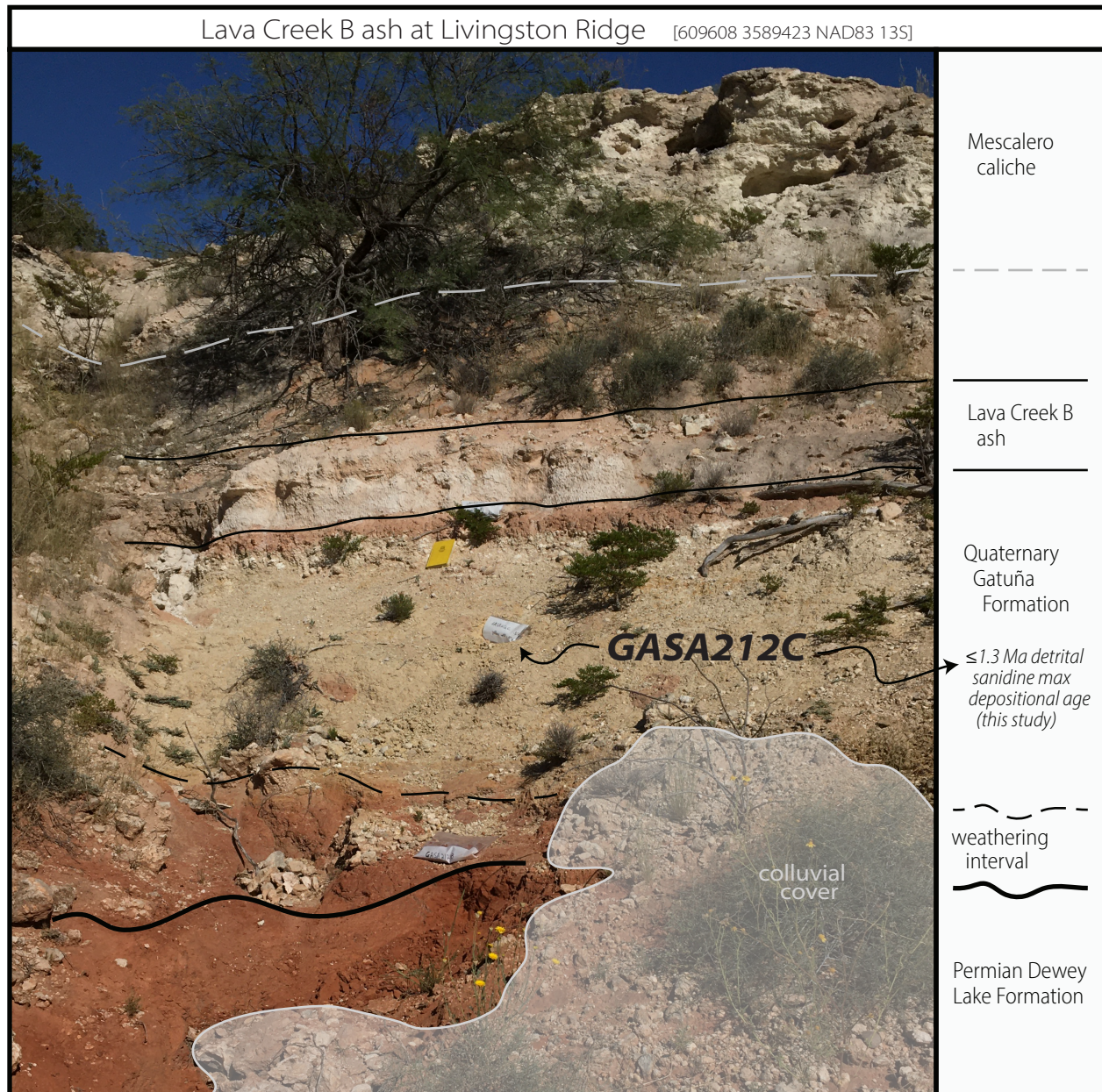


FIGURE 2. Livingston Ridge locality where sample GASA212C was collected.

below the Mescalero caliche, suggesting ages of 0.1–0.135 Ma for the Mescalero caliche.

A volcanic ash interbedded in Pecos Valley deposits near Orla, Texas, has been dated to ca. 13 Ma on the basis of unpublished K-Ar age analyses and volcanic glass geochemical correlations (Powers and Holt, 1993; Cepeda and Perkins, 2006). These deposits were first mapped as Gatuña Formation by Eifler (1975), presumably as an extension of work published in Eifler and Reeves (1976). Assignment of Pecos Valley deposits of uncertain age to the Gatuña Formation in eastern New Mexico and south into Texas led to a proposed diachronous division into an upper part equivalent to a post-Ogallala unit and a lower, Miocene-Pliocene part equivalent in age to deposits of the Ogallala Formation (Hawley, 1993). Hawley (1993) proposed that caliche exposed atop the southern wall of Pierce Canyon

in fact represents a block of Ogallala-age caprock. Despite this, Hawley (1993) also suggested that the “Gatuña” term could potentially be restricted to only post-Ogallala deposits (*sensu* Bachman, 1980), assigning older valley and depression fills of the Pecos Valley to the Ogallala Formation or a new correlative unit.

PIERCE CANYON AREA FIELD RELATIONSHIPS

In Pierce Canyon and Cedar Canyon to the south (Fig. 3), the Gatuña Formation can be divided into three general facies (*c.f.*, Bachman, 1980). The formation is reportedly up to 300 ft thick in this area (Powers and Holt, 1993), although it is considerably thinner in the few places where underlying Permian strata are exposed (Vine, 1963). The “main facies” is dominantly

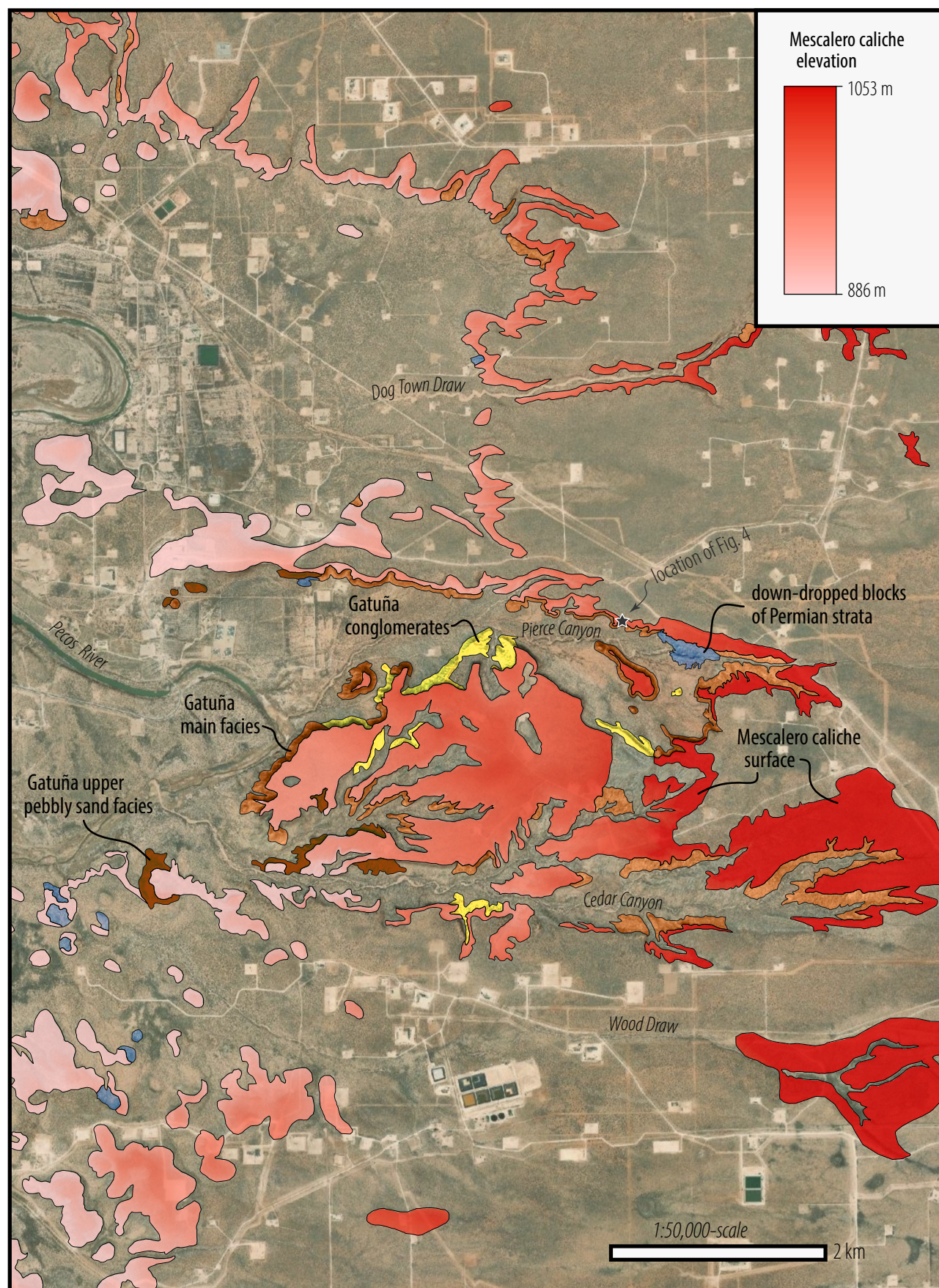


FIGURE 3. Elevation of the Mescalero caliche in the Pierce Canyon area draped over aerial imagery, with selected simplified geology from Attia and Allen (2022). Elevations derived from a digital elevation model (Intermap, 2008) that was clipped to the polygons mapped as Mescalero caliche.

composed of reddish mud, silt, and sand. The “conglomerate facies” is principally exposed along the southern part of Pierce Canyon and contains sedimentary (largely Permian carbonate), igneous (porphyry), and metamorphic pebble- to cobble-sized clasts. The conglomeratic facies locally overlies main facies deposits. The “upper pebbly sand facies” is composed of coarse sand to sandy conglomerate overlying main facies deposits throughout the area above a variably angular intraformational unconformity, though plan view footprints of such exposures are commonly too small to show on 1:24,000-scale maps (Fig. 4). Variable tilting of Gatuña strata is attributed to widespread and pervasive solution subsidence occurring throughout deposition. The protracted history of solution subsidence is recorded in variable dips of down-dropped blocks of Permian strata and overlying Gatuña Formation, as well as deformation and tilting of the overlying Mescalero caliche surface (Attia and Allen, 2022). Stratigraphic relations between the conglomeratic facies and upper pebbly sand facies have not yet been determined.

Previous workers proposed that petrocalcic horizons developed atop Gatuña Formation sediments in the Pierce Canyon area may be older than and distinct from the Mescalero caliche, potentially correlative with the Ogallala caprock. Cikosi (2019) interpreted an exposure just northwest of Pierce Canyon as an intraformational petrocalcic horizon, which he termed the “Pierce Canyon caliche.” Revisiting that outcrop, we did not observe a distinct, intraformational petrocalcic soil horizon within the Gatuña Formation. Instead, field relations indicate subsidence-related warping and displacement of the Gatuña Formation and its Mescalero caliche caprock, as is common throughout the area (Attia and Allen, 2022). Localized displacement down-dropped a block of the caliche, juxtaposing it against underlying Gatuña sediments.

Hawley (1993) proposed that the petrocalcic horizon capping Gatuña Formation deposits along the southern wall of Pierce Canyon is a remnant of an Ogallala-equivalent caliche, older than and distinct from the Mescalero caliche on the northern wall of the canyon, on the basis of more intense pedogenic development and higher elevations along the southern canyon rim. Our observations in and around Pierce Canyon provide no compelling evidence for this interpretation. First, the caliche capping the south wall only appears thicker and more intensely developed where it overlies conglomeratic facies deposits. Second, the caliche can be followed continuously around Pierce Canyon from its northern wall to its southern wall, as well as farther east and south (Fig. 3). The most significant difference in elevation of this surface is between the east and west ends of the canyon, not its southern and northern walls. The variation in elevation of the caliche surface extending from the south wall of Pierce Canyon across to Cedar Canyon is also comparable to variation in other areas. Differential solution subsidence has considerably locally deformed what was presumably once a relatively smooth surface. The overall west to east descent in elevation of the Mescalero caliche surface (Fig. 3) may reflect a primary gradient toward the course of the Pecos River or solution subsidence focused along the modern river.

DETRITAL SANIDINE GEOCHRONOLOGY

We revisited Bachman’s (1980) Lava Creek B ash locality along Livingston Ridge (Fig. 1). Sample GASA212C was collected from poorly bedded, weakly indurated silty sand, lying between Permian Dewey Lake Formation strata below and the Lava Creek B ash layer above (Fig. 2). Sediments overlying the ash layer grade upward into the Mescalero caliche. Detrital sanidine grains were separated from the sampled material and analyzed for $^{40}\text{Ar}/^{39}\text{Ar}$ ages following the methods of Heizler et al. (2021) at the New Mexico Geochronology Research Laboratory at the New Mexico Bureau of Geology and Mineral Resources. The 361 detrital sanidine grains analyzed over two separate runs yielded ages ranging from late Mesoproterozoic to Quaternary (complete data table is available as a supplementary file). Ages older than ca. 500 Ma are likely analyses of microcline and/or orthoclase that were inadvertently picked due to a similar appearance to sanidine. The sanidine distribution is dominated by 185 Quaternary dates that make up 51% of the total analyses. Although centered on a ca. 1.65–1.85 Ma peak,

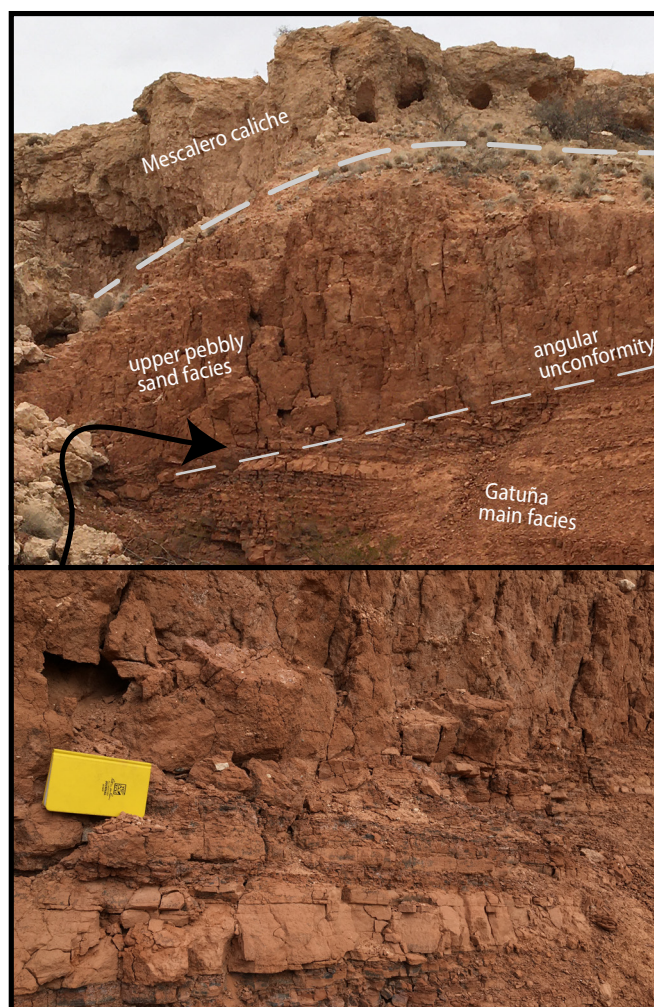


FIGURE 4. Field photographs of the Gatuña Formation just below the Mescalero caliche along the north wall of Pierce Canyon, highlighting the upper pebbly sand facies above an intraformational unconformity. UTM coordinates in NAD83 zone 13: 600415 E, 3562447 N.

the detrital age distribution shows younger populations (Fig. 5). The youngest coherent peak is composed of three analyses

with a weighted mean of ca. 1.32 ± 0.02 Ma, providing a ca. 1.3 Ma maximum depositional age. Thus, the entire section above

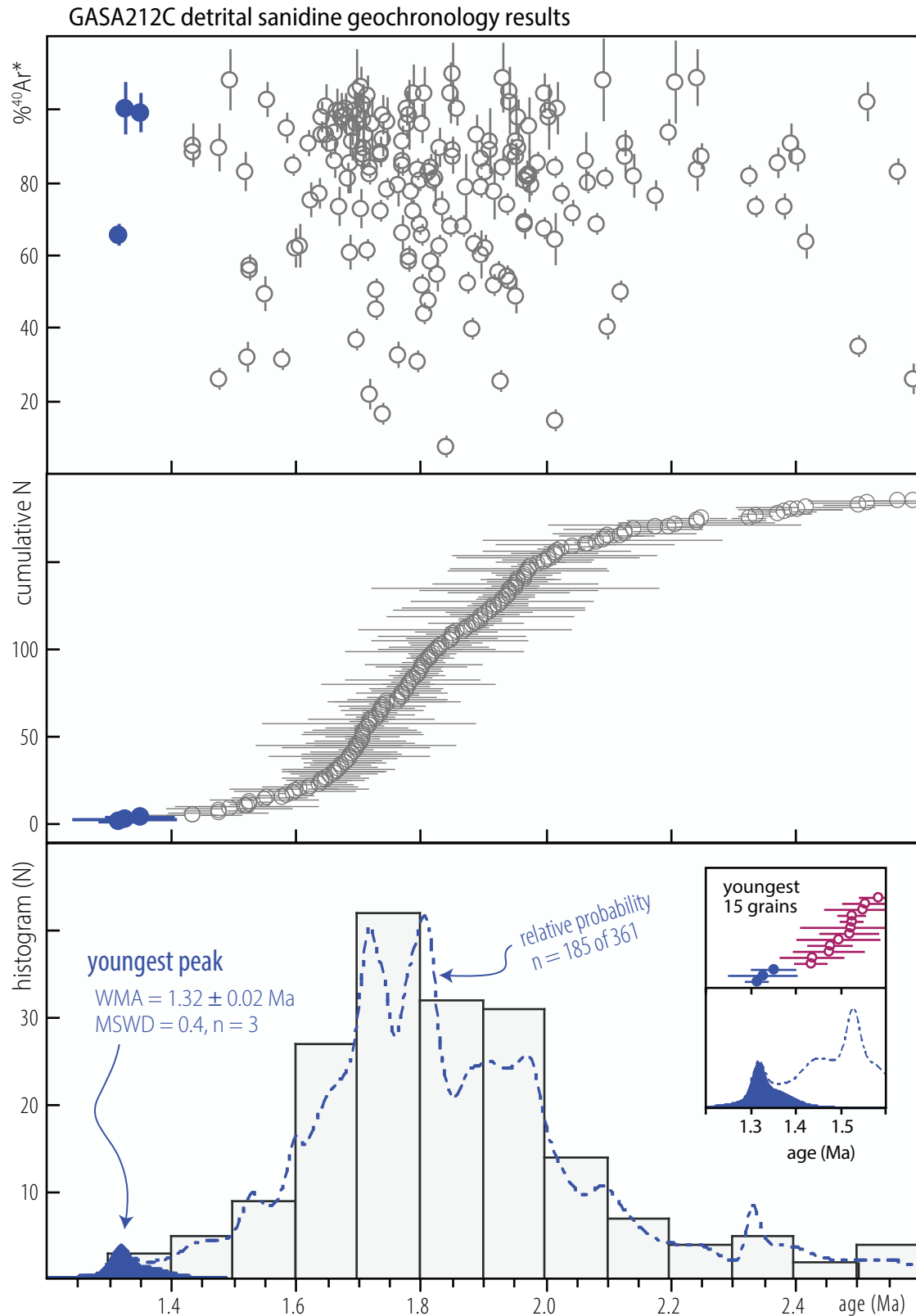


FIGURE 5. Summary of detrital sanidine $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology analyses from sample GASA212C, focusing on Quaternary ages and the weighted mean age (WMA) of the youngest peak given with 2-sigma uncertainty. Radiogenic yield of analyses shown in top panel, cumulatively ranked ages and uncertainties in middle panel, and histogram and probability density plot in bottom panel with inset highlighting youngest detrital ages. MSWD – mean standard weighted deviation.

the Dewey Lake Formation and below the Mescalero caliche at Livingston Ridge is Quaternary.

AGE AND CORRELATION OF THE GATUÑA FORMATION

Based on our examination of stratigraphic relations in the Pierce Canyon area and new absolute age constraints, we find no evidence requiring that the Gatuña Formation in southeastern New Mexico is diachronous or significantly older than the Quaternary deposits exposed along Livingston Ridge. Figure 6

shows a comparison of late Cenozoic stratigraphy between the Pecos River Valley and the Southern High Plains. We interpret the parts of the Gatuña Formation in southeastern New Mexico with robust age constraints as dominantly alluvial equivalents to Quaternary eolian and lacustrine deposits that postdate the Miocene-Pliocene Ogallala Formation on the Southern High Plains, such as the Blanco and Blackwater Draw formations (Fig. 6). It remains unclear how any older surficial or subsurface deposits of the Pecos Valley, if conclusively demonstrated to be of such age, would correlate to the Neogene stratigraphy of the Southern High Plains.

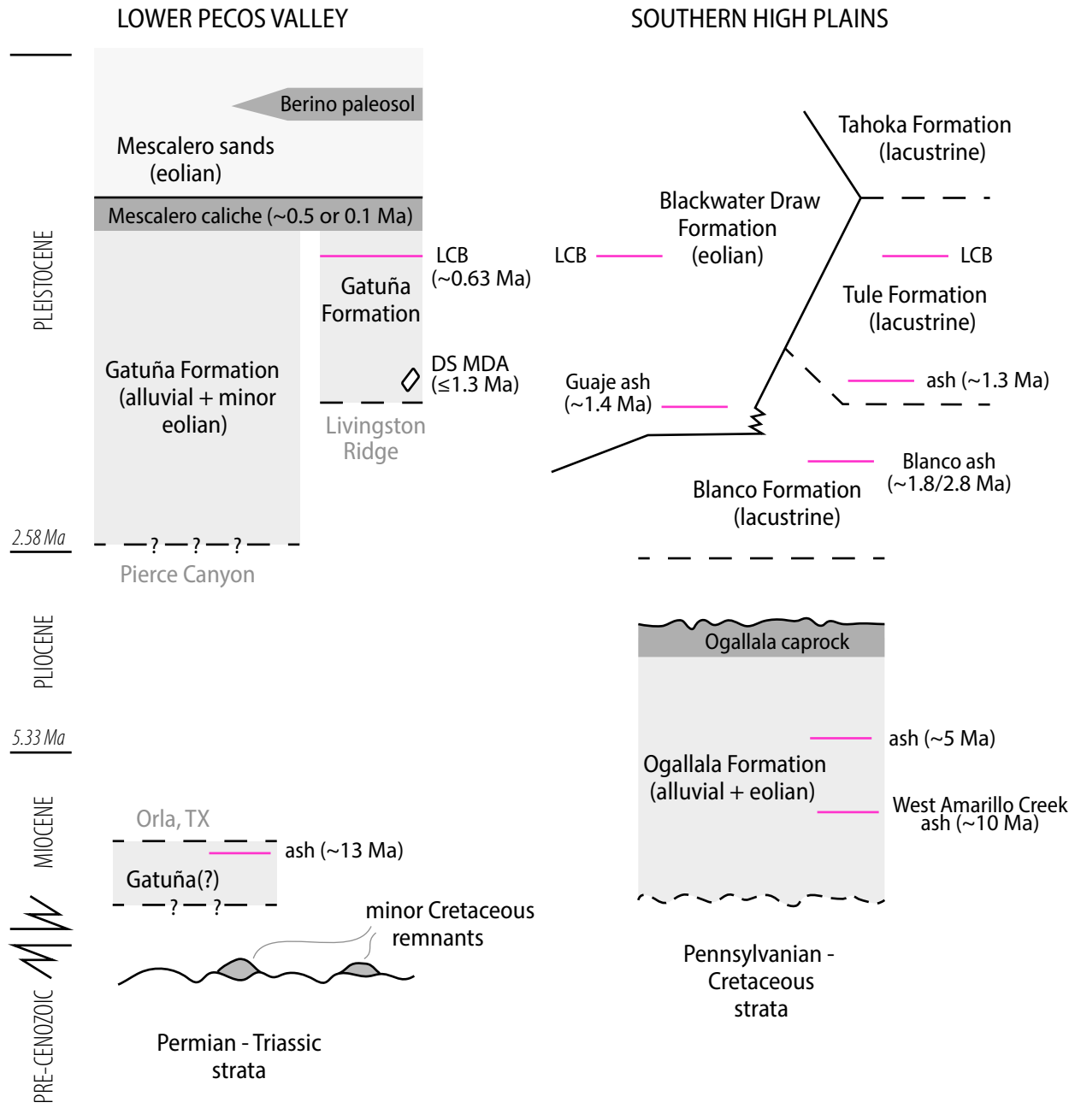


FIGURE 6. Comparison of the Neogene-Quaternary stratigraphy of the Pecos River Valley and Southern High Plains (Izett et al., 1972; Gustavson and Holliday, 1985; Schultz, 1986; Holliday, 1988, 1989; Hawley, 1993; Cepeda and Perkins, 2006). Pink lines are known ash bed occurrences. DS MDA – maximum depositional age of detrital sanidine geochronology sample, LCB – Lava Creek B ash.

The single, unpublished Miocene date of a volcanic ash in deposits assigned to the Gatuña Formation near Orla, Texas (Powers and Holt, 1993), is the only absolute age constraint indicating the existence of such older deposits. Cather and Heizler (this volume) report detrital sanidine ages for six samples of deposits mapped as Gatuña Formation. Five of the six samples yield early to late Miocene maximum depositional ages, with the other sample providing a late Pleistocene maximum depositional age. The pre-Quaternary maximum depositional ages of those sampled deposits do not preclude an older, Miocene age assignment, but neither can they conclusively refute an entirely Quaternary age for Gatuña strata. However, thick Pecos Valley fills in areas that have been subject to extensive solution subsidence are likely to contain Neogene deposits, as concluded by Maley and Huffington (1953), so we are left to decide what to call deposits of such ages. The Gatuña stratigraphic concept currently spans two distinct periods of deposition that occurred in distinct contexts (*sensu* Hawley, 1993), both the original Quaternary, post-Ogallala definition of Lang (Robinson and Lang, 1938) and later proposals of Ogallala-equivalent fills of an ancient Pecos Valley that was already maximally incised by the mid-Miocene (Reeves, 1972). More work to date and correlate the deposits of the Pecos River Valley is clearly needed and will ultimately lead to a better understanding of paleo-landscape development of the westernmost Great Plains in eastern New Mexico and western Texas.

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Appendices can be found at
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