# Low Impact, High Resolution: Unraveling and Learning from 13,000 years of Indigenous Use of Eagle Cave

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**Low Impact, High Resolution: Unraveling and Learning from 13,000 years of Indigenous Use of Eagle Cave**

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Eagle Cave is one of the largest and most significant rockshelters in the Lower Pecos Canyonlands (LPC). The history of the site's archaeological investigations is in many ways a history of Lower Pecos archaeology with extensive excavation and rock art documentation from the 1930s through the 2014-2018 ASWT investigations (Black and Kilby 2024; Lindsay et al. 2024). Consequently, Eagle Cave provides one of the most informative archaeological datasets in the LPC for learning about hunter-gatherer lifeways. Importantly, the Skiles Family have remained stewards and caretakers of Eagle Cave since the inception of archaeological work. This paper summarizes the archaeological investigations of Eagle Cave—from rock art documentation to dirt excavations—and we explore the implications of nearly a century of archaeological work in terms of what we have learned, what we are learning, and what questions we have yet to ask. Although this paper focuses on archaeological work, it is also a reflection of the Skiles' stewardship, compassion, and perseverance for learning about Eagle Cave.

## Eagle Cave: The Archaeological Site Within an Indigenous Landscape

**Commented [AMC1]:** Primary

Eagle Cave is the most imposing rockshelter within Eagle Nest Canyon (ENC), a short box canyon emptying into the Rio Grande near Langtry, Texas. The site is located near the midpoint of ENC between Bonfire Shelter and the Rio Grande (Figure 1), and inside the shelter an observer is dwarfed by the ca. 950 $m^2$ of floor space and a ceiling 20 meters overhead. Scattered across the surface are thousands—perhaps millions—of fire-cracked rock (FCR) fragments, the durable remains of earth ovens constructed by Indigenous foragers over several hundred generations. Looking outward the viewer is confronted with a nearly sheer cliff face opposite Eagle Cave, and Guy Skiles' windmill visible overlooking the canyon. Dense vegetation grows in the bottom of ENC towards the Rio Grande, but the hills and cliffs of Mexico are visible above the cottonwoods, willows, and salt cedar.

Figure 1 here

Looking back into the rockshelter, beneath the scattered FCR are deeply stratified deposits containing all matter of perishable artifacts preserved by the dry, arid environment. On a bedrock ledge on the upstream end of the site are nearly two dozen ground stone bedrock features, and on the opposite end of the site is what remains of a Pecos River Style pictograph panel (Figure 2). Although Eagle Cave is primarily known for the artifacts and features preserved *inside* the rockshelter, dozens of bedrock features and a small rock art panel occur *outside* of Eagle Cave proper (see Castañeda 2024).

Figure 2 here

When looking at Eagle Cave, and the impressive density of archaeological material within and around the site, it is no wonder why archaeologists have spent so much time here over the past century. As we summarize in this paper, there is an incredible record of forager behavior preserved within the site that we can analyze using scientific methods to learn more about past Indigenous lifeways. However, it remains equally important to consider Eagle Cave as a culturally significant, "persistent place" for Indigenous peoples that was the scene of feasting and aggregation for millennia (Schlanger 1992). The concept of persistent places has been applied to sites in the LPC (Knapp 2015:139), but this concept is generally considered from a subsistence/ecological view (Black and Thoms 2014:209; Howard 2016:167). Certainly, foodways play a central role in the persistency of human behavior, but this ecological view can exclude culturally salient aspects of sites and landscapes (Zawadzka 2019). Therefore, it is important to acknowledge that Eagle Cave is one of the largest rockshelters in the LPC and undoubtedly had a "life history of place" (Ashmore 2002:1178) imbued with cultural significance spanning 13,000 years. Symbolic expression as reflected by the Pecos River style pictographs and the numerous painted pebbles are clear reflections of this cultural significance (Boyd 2016; Castañeda et al. 2019; Mock 2013; Roberts 2014:81). However, we cannot overlook cultural significance symbolized and expressed by economic features like earth ovens (Hayden and Adams 2004; Hayden and Cousins 2004; Miller 2019).

## Eagle Cave Archaeologists: 1930-2010

Commented [AMC2]: Primary

Archaeologists were drawn to the Lower Pecos in the 1930s because of the preservation of artifacts and pictographs within the region's many rockshelters (Black 2013). Eagle Cave became a focus of several archaeological expeditions because of its large size, deep deposits, pictograph panel (Figure 3), and proximity to a major road (Route 90). As described in an unpublished manuscript:

> "During the busy interval [~1930-1940] when [the] Witte went in for archeology, almost every expedition took time out to have a go at Eagle Nest Cave [Eagle Cave]. This covered a period lasting ten years. Had there been a guest book in the cave, it would have contained the names of more than a hundred amateur and professional archaeologists from throughout the nation." [Woolford and Quillen nd.:4]

Figure 3 here

The earliest documented archaeological work in Eagle Cave focused on rock art recording (see Figure 3, Table 1). In 1931, Emma Gutzeit and Virginia Carson produced a watercolor of the largest and most iconic anthropomorph at Eagle Cave: a large figure painted predominantly in black and yellow, with a rabbit-ear headdress, and a long line of dots representing speech or breath emanating from the figure's mouth (Figure 4a; Carson 1931). The pictograph panel at one time spanned a large portion of the shelter's back wall, but today the rock art is only preserved on the downstream end of the site. Some figures are over six feet in height, and many anthropomorphs (human-like figures) display the iconic "rabbit ear headdress" (Castañeda et al. 2024; Macrae 2018; Steelman, Boyd, and Allen 2021). Subsequent rock art recording was conducted by A.T. Jackson (1938:196-198) and Forrest Kirkland (Kirkland and Newcomb 1967:39; Figures 4b and 4c).

Figure 4 here

Table 1 here

The first professional archaeological excavations followed quickly on the heels of the rock art recording. E.B. Sayles and J. Charles Kelley visited Eagle Cave in 1932 as part of Sayles' survey of Texas archaeology (Sayles 1935). Although we lack a complete record of Sayles and Kelley's work (Sayles [1935] only describes the artifacts), from Kelley's unpublished 1932 field notes we know they excavated at least one modest trench in the center of the site (Figure 5a), and focused efforts on the recovery of fiber artifacts. During their excavations, they also encountered a "metate" that Kelley describes as: "containing numerous small mortar holes around larger bowl which had been bored completely through." This massive artifact is still on the surface of the site today (Figure 6).

Figures 5 and 6 here

The first major excavations at Eagle were conducted by the Witte Museum between 1935 and 1936 (Davenport 1938). Most of the Witte's efforts focused on the excavation of a long trench through the center of the site and a T-trench along the shelter wall (see Figure 5b). The impetus of the work was to collect specimens for museum display. Based on the field notes, the artifacts excavators were most interested in finding were painted pebbles, an artifact class frequently encountered within Eagle Cave (see Castañeda et al. 2019). Even though the Witte's excavation methods were very coarse by today's standards, archaeologists identified five stratigraphic "zones" within Eagle, and they attempted to excavate by these identified layers[i]. The lowest zone—Layer E—was considered sterile (Figure 7).

Figure 7 here

The primary published account of the Witte Museum's efforts in Eagle Cave is Davenport (1938). However, there were additional Witte Museum-related excavations in Eagle post-1936. There are three photo albums that depict artifacts recovered in 1939 and 1940 (Martin and Dorchester 1941a, 1941b, 1941c), including one alleged Folsom point that has not been relocated in the Witte collections (Koenig, Kilby et al. 2022:379). Nevertheless, the Witte Museum collected thousands of artifacts—from flakes and animal bones to painted pebbles and perishable artifacts—and the Eagle Cave collection constitutes the Witte's largest archaeological collection from a single site.

*University of Texas Excavations – 1963*

**Commented [AMC3]:** Secondary

In 1963 the University of Texas (UT) began work in Eagle Cave as part of the Amistad Salvage project. In the preceding decades the Witte trench had slumped, so UT archaeologists and local laborers re-excavated and expanded the Witte trench to conduct stratigraphic excavations (Figure 8). Once intact deposits were exposed along the trench, Richard Ross and Mark Parsons spent three days profiling the north wall (Figure 9). They identified 6 broad "zones" (Stratums I-VI), with several dozen smaller, interspersed lenses. After Ross and Parsons profiled the main trench, they turned their attention to a deep looter's pit on the north side of the site (Figure 10). In his 1963 field notes, Parsons refers to this unit as Test Excavation II, but will herein be referred to as UT North (Nielsen 2017, 2024). The slumped pit was cleaned out, the walls were straightened, and the stratigraphy visible in the east, west, and south walls was recorded. Ross noted that while most of the major zones from the main trench seemed to be present in UT North, the stratigraphy did not correlate exactly between the two areas. Aside from these vague comments and a few collected samples, no discussion or interpretations of the UT North investigations were included in the field notes or the resulting report (Ross 1965). Instead, most of the UT effort and documentation focused on the expanded Witte trench excavations.

Figures 8, 9, 10 here

From October to early December 1963, eight 5-x-5 foot units were excavated on the north side of the main trench (see Figure 5c). The stated objective was to collect a sample of projectile points to aid in constructing a Lower Pecos cultural chronology (Ross 1965). The UT crew excavated these units until they hit the "sterile yellow cave dust" of Stratum 6 and stopped (Ross 1963 field notes, on file at TARL). The only additional unit they excavated was a deep test to bedrock (Figure 11). Subsequent conventional radiocarbon assays showed occupation in Eagle Cave above Zone 6 spanned from 8700 – 2000 RCYBP. After UT excavations were completed, they only backfilled the deep test, once again leaving the main trench open. The UT Eagle Cave collection is substantial, but aside from the projectile points and painted pebbles, the results of the 1963 excavations have never been fully reported (see Ross 1965, and review by Hurt 1966).

Figure 11 here

### *Eagle Cave 1963-2010*

Commented [AMC4]: Secondary

After the University of Texas excavations in Eagle Cave, the archaeological prominence of the site subsided, but the site was not forgotten. Michael Collins (1991) published a rockshelter formation hypothesis arguing that if Eagle Cave contained any Paleoindian deposits, they might be deeply buried towards the mouth of the site instead of near the shelter wall. In 1995 the Texas Archeological Society Rock Art Task Force visited the site and produced grid-drawings of the pictograph panel (site records on file at TARL). John Russ and colleagues (2000) included samples from Eagle Cave in study using calcium oxalate coatings on shelter walls to create a regional paleoclimatic reconstruction[ii]. Later, Katherine Turner-Pearson (2007) attempted to recover human hair from sediment samples collected from intact stratigraphy still exposed along the main trench, but this effort proved unsuccessful.

## ASWT and Shumla Investigations at Eagle Cave

Commented [AMC5]: Primary

New research by ASWT and Shumla at Eagle Cave began in 2010 when Steve Black organized a total data station mapping of the site, and Tiffany Osburn of the THC carried out a ground penetrating radar (GPR) survey. The GPR data showed intriguing anomalies that required ground-truthing excavations to interpret. With the encouragement of Jack Skiles, Black aspired to undertake new excavations at Eagle Cave, but lacked funding. This circumstance changed several years later when advocational and professional archaeologist E. Thomas Miller of Kerrville passed away at the age of 96. Miller, who first excavated with Black in 1979 at the

Panther Springs Creek site, left a generous bequest to Texas State University in support of ASWT research. This gift allowed ASWT to undertake a major investigation program in Eagle Nest Canyon.

This research began with Texas State University's 2013 ENC Archaeological Field School, which combined dirt archaeology under Black and rock art archaeology under Carolyn Boyd. Boyd, Castañeda, and Koenig directed students recording rock art at Eagle Cave. During the field school the pictographs were intensively documented following Shumla methods using photography, illustrations, digital microscopy, and portable X-ray fluorescence (pXRF) spectroscopy (Koenig et al. 2014), as well as collecting paint samples for radiocarbon dating. Radiocarbon dates on the pictographs were recently published (Steelman, Boyd, and Allen 2021), and are currently the earliest published dates on Pecos River style in the region (ca. 3450 cal BP; Steelman, Boyd, and Bates 2021). Shumla continued work at Eagle Cave during the Alexandria Project (Lindsay et al. 2024), linking iconographic patterns to other regional pictograph sites (Castañeda et al. 2024).

### *2014 Eagle Nest Canyon Expedition*

**Commented [AMC6]:** Secondary

The first major ASWT field season at Eagle Cave was in 2014. During this six-month session we began removing slump and fill from disturbed areas of the site until intact layering was reached (see Figure 2). These stratigraphic exposures were designated Profile Sections (PS), and a total of five were defined in 2014. Profile Section 1 exposed intact stratigraphy around a large animal burrow (Figure 12a), PS2 exposed a deep profile along the rear wall (Figure 12b), PS3 and PS4 were excavated in the UT North area (Nielsen 2017, 2024), and PS5 was excavated on the south wall of the Witte/UT trench (Figure 12c). In each instance, we carefully removed disturbed deposits to expose intact stratigraphy, and then excavated small excavation units by natural layers to document and sample intact profiles. Structure from Motion (SfM) photogrammetry was intensively used to document each unit and profile (Koenig et al. 2017; Willis et al. 2016) and orthographic photos were printed and subsequently annotated in the field. With these annotations we collected samples directly from the profile and excavated small sampling units following the defined stratigraphy. To keep the profiles stable and ensure we had secure horizontal areas to stand/sit to work from, we stepped the excavation units. Special samples such as radiocarbon samples, spot samples, archaeoentomology samples (discussed below), and residue samples were recorded and collected separately, and burned rock was tabulated and weighed in the field and then discarded following ASWT "Rock Sort" methodology (see Heisinger 2019, 2024; Jamieson 2024; Koenig et al. 2023). In addition to strat (stratigraphic layer) recording and sampling, a robust geoarchaeological sampling strategy that included the collection of cube column samples, bulk matrix samples, and micromorphological (micromorph) samples was employed (Nielsen 2017, 2024). The ASWT Eagle Cave motto "Low Impact, High Resolution" encapsulates our methodological strategy: we sought to obtain precisely targeted scientific samples from finely documented stratigraphic exposures while minimizing additional excavation damage to the site.

Figure 12 here

During the 2014 field season, Jack visited Eagle (and the simultaneously excavated Skiles, Kelley, and Horse Trail) as frequently as possible. He often would drive down into the canyon, and the sound of his shutting truck door would signal Jack's imminent arrival. No matter how cold, windy, dusty, or dirty our work was that day, Jack was always interested in what we were doing, how we were doing, and what we were finding. On occasions when we recovered an interesting artifact or made a unique observation and Jack did not visit the site, the crew would excitedly visit Jack and Wilmuth at the house upon leaving the canyon. Whether it was a painted pebble or simply a fragment of FCR with interesting fossils, there was no better confirmation of the uniqueness of an artifact than to hear Jack proclaim, “Well I’ll be.”

### *2015-2017 Eagle Nest Canyon Expeditions*

Commented [AMC7]: Secondary

After developing and fine-tuning our methodology in 2014, in January 2015 we were ready to begin intensive excavation and sampling of the main trench. Over the next five months we began stepping back the south side of the trench and defined Profile Sections 7-16, primarily spanning the upper two meters of deposits (Figure 13a). Using the descriptions from Davenport (1938) and Ross (1965) we were able to correlate the ASWT strata designations to the earlier layer/stratum designations (Table 2). One of the aspects of the 2015 field season that made it so impactful was the transition from the small exposures of 2014, to linked profile sections spanning 10-15 meters across the trench. This stratigraphic cross section showed us major changes in stratigraphy and past behavior that were challenging to conceptualize within smaller exposures.

Figure 13 and Table 2 here

We returned to Eagle Cave in January 2016 to continue excavating the original UT/Witte profile. By mid-2016 we reached the bottom of the trench and encountered the “sterile yellow cave dust” where both the Witte Museum and UT had terminated controlled excavation. However, approximately 10-20 centimeters below the bottom of the Witte/UT trench, we exposed a layer of butchered *Bison antiquus* bones along with lithic debitage, tools, and decomposed wood centered around a surface hearth (Figure 14). We called this entire assemblage Feature 14, and based on several radiocarbon dates the assemblage dates to 12,680-

12,480 cal BP, which is during the Younger Dryas and contemporaneous with Folsom (Koenig, Kilby et al. 2022; Ringstaff et al. 2024). While we were excavating the bison bones, Jack Skiles came down to Eagle Cave as often as he could. He would walk around and through the trench, frequently leaning on his well-used cane, and watch quietly as the crew carefully exposed the hundreds of bone fragments. There is no doubt that Jack's mind was constantly in motion during these visits, likely thinking about the foragers who had left this scattering of bones and chert over 12,000 years ago. It is possible the butchered bison is associated with the Bone Bed 2 event(s) at Bonfire Shelter (see Kilby et al. this volume), but additional research and radiocarbon dating will be required to support this hypothesis. Scattered amongst the bison bones were numerous bighorn sheep (*Ovis canadensis*) dung pellets. The presence of bighorn sheep dung was a surprise considering no bighorn sheep specimens have been identified from archaeological or paleontological sites in the LPC (Mead et al. 2021). It was through the help of Raymond Skiles that we were able to collaborate with Jim Mead (Mammoth Site, South Dakota), who is a world expert in mammal dung.

Figure 14 here

Beneath the Feature 14 bison bones we encountered a semi-circular cluster of rocks (Feature 20), fragmented mammoth bones, poorly preserved bison bones, and approximately 100 pieces of lithic debitage (Figure 15). Radiocarbon dates bracketing this occupation range from 13,337 -12,704 cal BP, indicating this assemblage represents the Clovis-age use of Eagle Cave, and the first sample of excavated Clovis-age cultural material in the LPC (Koenig, Mackie et al. 2022; Munger 2022). By the end of the 2016 field season we had successfully exposed and sampled nearly 13,000 years of hunter-gatherer lifeways. We defined Profile Sections 17-39 (see Figure 13b), and were able to correlate nearly all of the UT and Witte stratigraphic zone definitions to our much more refined stratigraphic assignments. The final ASWT excavations in Eagle Cave occurred in November 2016, and January to February 2017, when we excavated several columns to collect archaeoentomology samples and prepared the site for stabilization and backfill (see Figure 13c; Black et al. 2024). It was during the backfilling efforts that we recognized dozens of bedrock features on the downstream end of the site. These features were fully documented in 2018 and are discussed by Castañeda (2024).

Figure 15 here

## Unraveling and Learning from the 13,000-year Record of Eagle Cave

Commented [AMC8]: Primary

The analysis of just the ASWT collection from Eagle Cave is a monumental task and will continue to unfold over decades. But an important first step in the ongoing analysis has been to establish a stratigraphic and chronological framework within which we can place all subsequent analyses. Because we have over 600 defined strata, to facilitate discussion we have defined 11 broad zones within the south wall of the main trench (Figure 16a). Table 2 provides a correlation between the ASWT Zones and previous stratigraphic designations, but basic descriptions follow:

Zone 1: Upper FCR zone, nearly continuous across profile.

Zone 2: FCR/Fiber & coprolite zone; located closer to dripline.

Zone 3: Central “Oven-pit;” likely associated with Zone 2 FCR/Fiber deposit.

Zone 4: Well-stratified Archaic deposits located towards rear wall; truncated by Zone 3.

Zone 5: Middle FCR zone, only found in center of profile.

Zone 6: Brown sediments, nearly continuous across profile.

Zone 7: Lowest FCR zone, nearly continuous across profile

Zone 8: Mixed limestone attrition zone, nearly continuous across profile.

Zone 9: Thin, dense organic late Pleistocene/early Holocene.

Zone 10: Stratified limestone attrition zone with PaleoIndigenous archaeology.

Zone 11: Late Glacial deposits of large, angular limestone spalls.

Figure 16 here

The stratigraphic record of the main trench is currently supplemented by 53 AMS radiocarbon dates (see Figure 16b, Table 3). When the radiocarbon dates from the south trench are combined with those from UT North (*n*=18; McCuistion 2024), Eagle Cave represents one of the best-dated archaeological sites in Texas with occupation spanning from ca. 13,000 – 500 cal BP. Aside from the chrono-stratigraphic framework, we have thus far focused our efforts on four aspects of the archaeological record: 1) late Pleistocene archaeology; 2) paleoethnobotany; 3) site formation and geoarchaeology; 4) archaeoentomology; and 5) the record of early Holocene earth ovens. Because a portion of the late Pleistocene archaeology is published elsewhere (Koenig, Kilby et al. 2022; Koenig, Mackie, et al. 2022; Mead et al. 2021; Munger 2022; Ringstaff et al. 2024) and Hanselka and colleagues (2024) describe the ongoing paleoethnobotany work, we focus the following discussion on the latter three topics.

Table 3 here

*Site Formation and Geoarchaeology*

**Commented [AMC9]:** Secondary

As with all ASWT work at ENC sites, the excavation and sampling of Eagle Cave occurred with a strong geoarchaeological component (Frederick and Lawrence 2024). Nielsen (2024) explains many of the geoarchaeological goals, but there are some notable differences between the UT North sampling strategy and that which occurred along the main trench. At the start of this work, the only detailed analyses of rockshelter sediments in the LPC were those of

David Robinson at Bonfire Shelter (Robinson 1997) and Thomas Byrd at Seminole Sink (Byrd 1988). Robinson (1997) noted a prominent shift in the sediments from the end of the last glaciation when frost shattered limestone prevailed, to the Holocene when finer sediments began to accumulate. We were eager to see how well the Eagle Cave sediment record compared to Bonfire, but as excavation within the main trench progressed, it became clear that the majority of encountered deposits are, for the most part, anthropogenic (of human origin). Learning how to tease apart the sediments created by people from those that occurred naturally is one of main challenges facing the geoarchaeological team. Between the large amount of charcoal and well-preserved uncarbonized material, the extensive amounts of wood ash, and the ubiquitous gypsum of geological origin, these deposits present a myriad of unusual problems in the lab. Work on this front continues (Koenig 2023).

Mineralogical analysis of the sediments in Eagle Cave so far clearly shows that the deposits contain a significant amount of minerals (such as feldspars and quartz) that do not occur in the Devils River limestone within which the shelter formed. These externally derived sediments may have arrived by a number of processes (water, wind, and/or people), and figuring out which is the most likely is another key question. Based on flood records, we have determined that, surprisingly, it is possible that Rio Grande floods may have inundated Eagle Cave multiple times during the Holocene. This would have required a staggering 30-meter-deep water column at the mouth of the canyon. However, we have no concrete stratigraphic evidence that this has happened. In other words, we have not observed any distinct flood drapes like those that are present in Skiles Shelter, Kelley Cave or Horse Trail Shelter. It is possible that the amount of human use of Eagle Cave obliterated all stratigraphic traces of flooding. But one of the key analyses we will look towards for assessing the possibility of a flood water source for the external sediments is the amount of externally derived sediment (at the most basic level defined as the part of the sediment that does not dissolve in hydrochloric acid) and the particle size distribution of those deposits, as compared with known slack water sediments of the Rio Grande.

As noted, we have collected many micromorphological samples (impregnated matrix) for thin section analysis with a petrographic microscope. Although it has been possible to collect some samples in a “normal” manner (cutting out a sediment block with trowel and knife and then wrapping with toilet tissue and masking tape), most of the Eagle Cave sediments were so unconsolidated that this method of collection is impossible; a point we have tragically or comically (your choice) demonstrated repeatedly. To adapt to this problem, we poured polyester resin directly into small wells cut into (just above) the sediments we wanted to sample. The impregnated sample areas were then left *in situ* to cure over a month or more. This works wonderfully (albeit resulting in large, anthropogenic burrows into the pristine profiles), and will empower us to examine these deposits in a very different way. Preliminary work with the micromorphology samples underscored just how different a view of the deposits this method provides. Figure 17 shows the same sample as seen in the field and after slabbing on a rock saw. An immediate observation is that the dusty nature of the dry sediments obscures visibility of many attributes (especially charcoal content and the coarse [rocky] fraction). After these sediments have been embedded in plastic and cut with a rock saw, the resulting slab clearly reveals finer details.

Figure 17 here

So far, the most detailed work we have done with the deposits exposed by the main trench excavation at Eagle Cave is with the recently revealed Late Glacial age deposits near the bottom of the profile. These sediments are natural deposits comprised primarily of frost shattered limestone or *eboulis sec* (dry talus). The large amount of angular limestone debris is consistent with Robinson's (1997) observations from Bonfire Shelter, but somewhat to our surprise some of the rock fragments are quite rounded (or blunted, as Laville and colleagues [1980] describe for this type of deposit; Figure 18). The rounding of clasts such as these that have not travelled very far can only occur by a few processes, most notably cryoturbation (mixing promoted by freezing and thawing of the deposit) or dissolution of the limestone by exposure to water. The presence of micropitting on some of the rounded clasts would seem to favor the latter process. Which further implies that the deposits of Eagle Cave in the Late Pleistocene were not dry, but rather periodically wet, which is a prominent contrast with the Holocene sediments. Further supporting this impression is the presence of beds of decomposed organic matter, which are reddish-brown in color, and stand in marked contrast with the white, frost-shattered limestone debris (Figure 19).

Figure 18 and 19 here

We have dissected one of these "red beds," Strat S586, in order to better understand what they represent and the results are quite interesting. First, S586 has two bulk organic matter radiocarbon ages:13,175 to 13,005 cal BP (BETA 445876; d$^{13}$C value of -23.7 [akin to wood]) and 13,337 to 13,112 (DAMS 38282; $\delta^{13}$C value unreported). Today it contains about 18.6% organic matter (as determined by loss-on-ignition) and about 2.6% gypsum (measured by thermogravimetry). X-ray diffraction of this deposit revealed that the minerals present are dominated by calcite (51.5%), followed by quartz (22.6%), plagioclase feldspar (10.5%), clay minerals (5.9%), halite (4.4%), potassium feldspar (2.9%), gypsum (1.1%) and hematite (1.1%). The calcite, clay minerals, gypsum, and presumably the halite may be derived from the limestone and/or precipitated on the shelter walls from evaporation of the groundwater. But the quartz and feldspars are clearly externally derived sediment. Particle size analysis of the calcium carbonate and organic matter free portion of this deposit is a loam with a single mode at 3.77 phi (very fine sand). Examination of a thin section of this deposit (see Figure 19b) reveals that it has a strong horizontal fabric defined by the organic material, and fine sand and silt-sized minerals just scattered throughout. From this we conclude that the externally derived minerals are most likely eolian in origin (i.e., windblown). Examination of the thin section also revealed the presence of numerous fragments of woody tissue consistent with the carbon isotopic value obtained from the radiocarbon dating. The overall decomposed nature of the organic material, especially when compared with Holocene age organic-rich deposits, suggests that this sediment has been exposed to conditions somewhat conducive to organic matter degradation, most likely periodically wetness by seepage of water from the shelter walls. This organic bed deposit appears to have formed on the floor of Eagle Cave towards the end of the period of warm climate that immediately followed deglaciation (the Bolling-Allerod) and immediately proceeded the return of glacial conditions during the Younger Dryas.

The Late Glacial age deposits appear to be dominated by frost-shattered limestone with a background of wind-blown dust, the mineralogical composition of which suggests it most likely derived from the Rio Grande. Therefore, the Late Glacial paleoenvironmental conditions appear to contrast strongly with the warm, dry, desertic Holocene climate that represents most of the Holocene at Eagle Cave. At times the floor of the shelter was covered with organic detritus, and although we cannot yet be certain of the origin of the S586 "red bed," there are three potential explanations: 1) natural deposit of windblown organic debris; 2) cultural deposit of wood and processed fiber; or 3) disaggregated and compacted dung (mammoth or bison?). Strat 586 is directly beneath the Clovis-age assemblage described above (see Figure 15). We have liters of unscreened matrix from S586 to still be processed, but thus far we have not recovered any cultural material that unequivocally originated from S586. Although not known from Texas, thick zones of compacted megafauna dung are present within large rockshelters in Utah (e.g., Agenbroad and Mead 1987; Mead and Agenbroad 1992; Spaulding and Petersen 1980). We are currently collaborating with Drs. Jim Mead (Mammoth Site, South Dakota), Karl Rinehard (University of Nebraska), and Joeri Kaal (Pyrolyscience, Madrid) to determine whether S586 represents compacted dung. We have a lot of detailed work yet to do on these deposits, but it should be an interesting puzzle to solve.

### *Archaeoentomology*

**Commented [AMC10]:** Secondary

The dry conditions in the shelters that favor botanical preservation also extend to insect remains, as was demonstrated by a feasibility archaeoentomological study (Panagiotakopulu et al. 2024). Palaeoentomological studies in the Chihuahuan Desert (primarily from packrat middens), have demonstrated the potential of fossil insects for understanding climate and environmental change during the Late Quaternary timeframe (Elias and van Devender 1990, 1992). However, there has been limited research on fossil insects recovered from human-affected environments such as rockshelters, and the only other results came from the Lateglacial and early Holocene Paisley in Oregon, with evidence for human lice *Pediculus humanus* L., bat bedbugs, *Cimex antennatus* Usinger & Ueshima, *Cimex latipennis* Usinger & Ueshima, and *Cimex pilosellus* (Horváth), and records of the spinose ear tick, *Otobius megnini* (Duges) (Adams and Jenkins 2017; Adams et al. 2020). Better understanding of the entomological record from rockshelters can provide innovative and high-resolution information, and can help refine our understanding of Holocene environmental and ecological conditions within the LPC (Figure 20).

Figure 20 here

The desiccating nature of the climate of Lower Pecos has led to excellent preservation of insect remains. Insects are an important, yet overlooked, aspect of the archaeological record, and because different insect taxa may have differing habitat and climatic requirements, they may provide information not available from other sources.  Insects often give an understanding of practices which tend to go unnoticed in the archaeological record, for example seasonal storage and processing of food materials (Panagiotakopulu and Buckland 2017), use of insecticides (Panagiotakopulu et al. 1995), fermentation of plants for alcoholic beverages (Buckland et al. 2009), seasonal occupation of the site and periods of abandonment (Panagiotakopulu et al. 2007). Studying the composition of the entomological assemblages can allow detailed reconstructions of human environments with information which ranges from the contemporary natural environment and climate to materials brought into the shelters for bedding, food provision, etc., as well as intimate details about living conditions (Panagiotakopulu et al. 2010) and evidence of disease vectors (Panagiotakopulu 2004; Reinhardt and Araújo 2015).

Examination of a suite of five samples collected from Eagle Cave demonstrate the potential of archaeoentomological research. The samples were processed using a methodology devised for retrieving desiccated desert assemblages, dry sieving over a 300 micron sieve (Panagiotakopulu et al. 2010). The insect assemblages are dominated by taxa which feed on mouldy materials, largely on decaying plant materials, primarily mycetophagids and latridiids. Part of the fauna indicated the presence of rotting cacti in the rock shelter. Among the species recovered are taxa which have become widespread pests of stored products, such as, for example *Ptinus* spp., which feeds on a variety of plant and animal substances, and *Cynaeus angustus* (LeConte), a minor pest of post-harvest grain. As the latter, introduced from America to Ireland in 1964 (Dunkel et al. 1982), has the potential to become cosmopolitan with trade, cave deposits offer the potential to plot its early progress across the New World. The primary habitat of *Cynaeus angustus* appears to be Agavoideae (e.g., *Agave* spp., *Yucca* spp.) and related plants, and this record indicates its occurrence as a pest in the Southwest well before farming. In addition, there is evidence for seed beetle (Bruchidae) infestation on mesquite beans, which may have been stored inside Eagle Cave. Such stores, although prone to insect attack, would have provided a buffering mechanism for the inhabitants of the shelter to survive harsh seasons.

The examined Eagle Cave insect material is particularly important as it provides evidence for the earliest synanthropic assemblages from North America, and the first records of stored products which precedes farming. Further research has the potential to uncover facets of everyday life and details about living conditions, from preparation of food to hygiene and to provide information about early human environments in North America.

### *10,000 Years of Earth Oven Cooking in Eagle Cave*

**Commented [AMC11]:** Secondary

Earth oven cooking is one of the most important Indigenous technological innovations in North American history. Alston Thoms (1989, 2008, 2009) argued that Indigenous peoples adapted to a changing post-Pleistocene landscape by intensifying their exploitation of geophytes and desert succulents through the adaptation of earth oven technology. This “carbohydrate revolution” (Thoms 2008) required the use of earth ovens to render complex carbohydrates such as inulin and starch edible, and the landscape signatures of this revolution are the massive piles of fire-cracked rock archaeologists refer to as burned rock middens, roasting pits, and earth oven facilities (Black and Thoms 2014).

Many North American archaeologists consider earth ovens to be material indicators of Boserupian intensification and population growth (Freeman 2007; Freeman et al. 2023; Johnson and Hard 2008; Morgan 2015; Yu 2009). Intensification is an increase in time or labor spent in subsistence-related pursuits due to a decline in foraging efficiency caused by increasing local or regional population (Boserup 1965). In other words, as there are more mouths to feed people must work harder to acquire sufficient food. This conceptual relationship between population and food production is due largely to the energetic expense of earth oven construction and the relatively low caloric yields from processed plant foods (Dering 1999; Smith et al. 2001). In an alternative perspective, Brian Hayden (Hayden 2014; Hayden and Adams 2004) considers earth ovens as a means for producing surplus food to provision feasts and demonstrate/acquire prestige. Nevertheless, intensification is a useful concept for examining why and how people adapted subsistence strategies to cope with changing environmental or social conditions (Morgan 2015).

Eagle Cave provides a stratified and well-preserved record of earth oven cooking to examine earth oven intensification and evaluate whether regional population increase—inherently linked with climate change—and/or short-term episodes of population packing associated with social aggregations and feasting caused foragers to adopt a relatively expensive technology to meet subsistence requirements. The earliest earth oven deposits in Eagle Cave date to ca. 10,500 cal BP, with continued oven use until approximately 500 cal BP. Thus far, directed analysis of the Eagle Cave oven record has focused on the early Holocene deposits dating from ca. 10,500–5500 cal BP (Figure 21). Current analysis incorporates FCR, geoarchaeology, zooarchaeology, and lithic debitage data for evaluating diachronic changes in the archaeological record and their relationship with intensification pressures (Koenig 2023; Koenig et al. 2023).

Figure 21 here

Diachronic changes of artifact assemblages associated with the different early Holocene macro strata indicate LPC earth oven intensification was not a monolith (Figure 22). The presence of FCR throughout the sequence demonstrate that earth ovens were always in intermittent use, but only during three periods was there enough sustained oven construction to form stratigraphically discrete earth oven facilities (Koenig et al. 2023). The earliest two episodes of earth oven construction (ca. 10,500-10,200 [S594] and ca. 7500-7000 cal BP [S525]) both correspond to increasing regional population and contain evidence for a wide diet breadth and high residential mobility. The most recent stratum (ca. 6000-5000 cal BP [S385]) also appears to reflect a period of high residential mobility, but other aspects of the artifact assemblage are markedly different: there is a decline in regional population (McCuistion 2024), the stratum contains the highest proportion of deer-sized animals in the entire sample, and FCR are completely exhausted. These data suggest that the mid Holocene earth oven facility preserves a different intensification signature than the earlier episodes of oven construction, which instead of being related to regional population increase may be tied to aggregation and feasting. In this scenario it is likely both plants and animals were being cooked in earth ovens.

Figure 22 here

Future and ongoing studies of the macrobotanical, ground stone, and formal tool assemblages will continue to refine and improve this analysis (Fackler 2023; Hanselka et al. 2024). Integrating multiple datasets in this way allows us to evaluate intensification and changing foraging efficiency from multiple perspectives that are not possible from most open-air sites. Although the population-driven view of intensification is not without critique (Zeder 2012), these datasets provide valuable details on Indigenous subsistence and earth oven cookery that are not only directly applicable to the greater US Southwest US and Mexican Northwest, but provide useful comparative data for other dry rockshelter sites across arid North America (Goebel et al. 2007; McDonough et al. 2022). Eagle Cave can also provide an integral chronologic structure for evaluating how earth ovens fit into Indigenous lifeways in other areas of North America (Thoms 2009).

## Learning from Eagle Cave: Conclusion and Future Research

Commented [AMC12]: Primary

The archaeological record in Eagle Cave spans nearly 13,000 years, from the age of Clovis to near European contact. This is an unprecedented chronology of forager occupations in the LPC and provides important data for evaluating long-term changes over generations of Indigenous hunter-gatherers. As is obvious, the Eagle Cave research is very much a "work in progress" and we will continue to revisit and clarify our stratigraphic and archaeological signature definitions and interpretive models. Perhaps more than anything else, our work at Eagle Cave has taught us the importance of keeping an open mind. We have found ourselves continuously rethinking our initial (and previous) field interpretations as we consider different lines of evidence, different scales of inquiry, and different disciplinary perspectives.

As we continue to expand the Eagle Cave analyses, we want to continue to encourage multidisciplinary and collaborative research. We have thousands of samples awaiting analysis, and we anticipate the Eagle Cave collections being used not only by graduate students, but by research projects across the globe. This effort continues to be a direct reflection of the long-term stewardship of ENC by the Skiles Family.

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The Eagle Cave work is the result of thousands of field hours spent by crew members and volunteers from 2014-2017. Likewise, the ASWT core collaborators have volunteered their expertise and guidance to conduct different analyses. It is only through the contributions of crew members, volunteers, and core collaborators that Eagle Cave analyses are possible.

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[i] A charcoal sample collected from Zone B was one of the first radiocarbon dates from Texas (Schuetz 1957).
[ii] Steelman, DeYoung, and colleagues (2021) report new dates on calcium oxalate crystals from Eagle Cave.