Interdisciplinary approaches to reconciling legacy paleontological collections to advance discovery and improve resource management

Lauren E. Parry, *Tule Springs Fossil Beds National Monument*
Erin E. Eichenberg, *Tule Springs Fossil Beds National Monument*

ABSTRACT

Like many National Park Service sites, Tule Springs Fossil Beds National Monument in Nevada has associated off-site legacy paleontological collections in museum repositories across North America. These legacy paleontological collections, which were created during past expeditions, are at risk of becoming forgotten or inaccessible, yet they hold the potential to revisit old questions and old sites utilizing new techniques, methods, and ideas. The authors present a case study that outlines a suggested framework to reconcile problematic or underutilized legacy paleontological collections based on the 2020–2023 inventory of the Southwest Museum Expedition Tule Springs Collection curated at the Autry Museum of the American West. The authors also explore the effectiveness of an interdisciplinary approach to paleontological resource management. Digitization of associated historic archives and photographs can help assign updated geologic context to unprovenienced fossils, as well as locate historic paleontological sites for conservation and study. Legacy paleontological collections are also artifacts of the time of collection; the cultural context of fossil collections can be just as important as their geologic context. Although new data collection is beneficial for scientific inquiry and science-based natural resource management strategies, the importance of well-understood and accessible legacy paleontological collections for these efforts cannot be overstated. Revisiting these collections can facilitate scientific discovery by providing more accurate and comprehensive data to park staff and researchers. Paleontological and museum management programs and the scientific community will benefit from bridging the past and the present through an interdisciplinary approach.

INTRODUCTION

Since the early 1900s, the fossiliferous deposits of the Tule Springs area in southern Nevada, USA, have been intermittently studied by interdisciplinary teams of scientists (Figure 1). Current research supports that these deposits, now formally described as the Las Vegas Formation, were formed by dynamic desert wetland environments from approximately 573,000–8,500 years before present (Haynes 1967; Springer et al. 2015, 2018). These paleo-environments supported the Tule Springs local fauna, a diverse Rancholabrean assemblage of megafaunal mammals (including carnivores and rodents), birds, reptiles, amphibians, and fish (Scott et al. 2017). Tule Springs Fossil Beds National Monument (TUSK) was established as the 405th unit of the National Park System in December 2014, primarily to conserve, protect, and interpret these nationally important Pleistocene fossils and their geologic context (Public Law 112-272) (Figure 1B). As TUSK is a relatively new park, many representative fossils of this fauna and associated archives are curated off-site in legacy paleontological collections managed by other agencies and institutions. Legacy paleontological collections are museum collections originating from previous expeditions. Since legacy paleontological collections were often not documented and curated according

CORRESPONDING AUTHOR
Lauren E. Parry
Tule Springs Fossil Beds National Monument, National Park Service
601 Nevada Way
Boulder City, NV 89005
lauren_parry@nps.gov

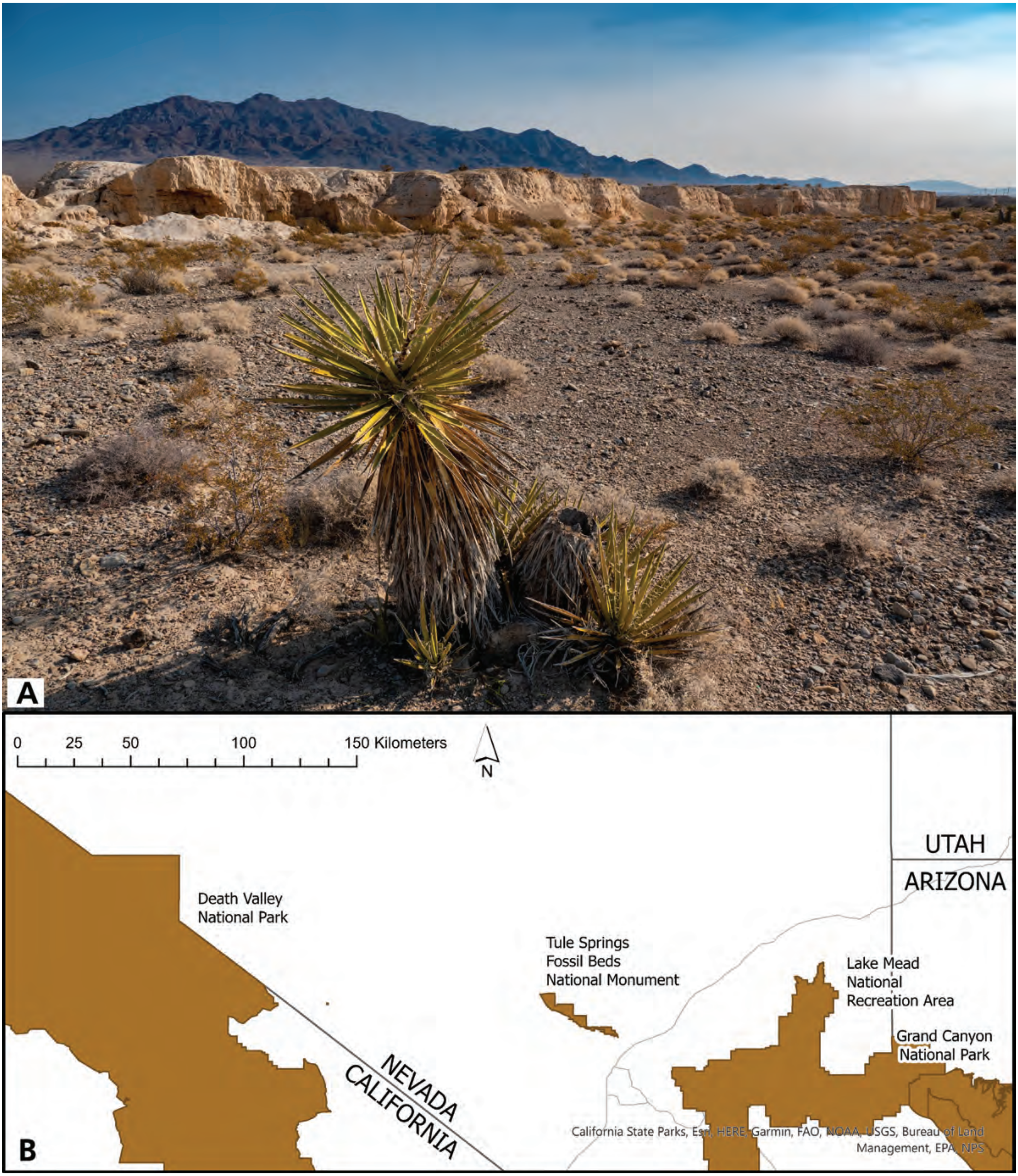


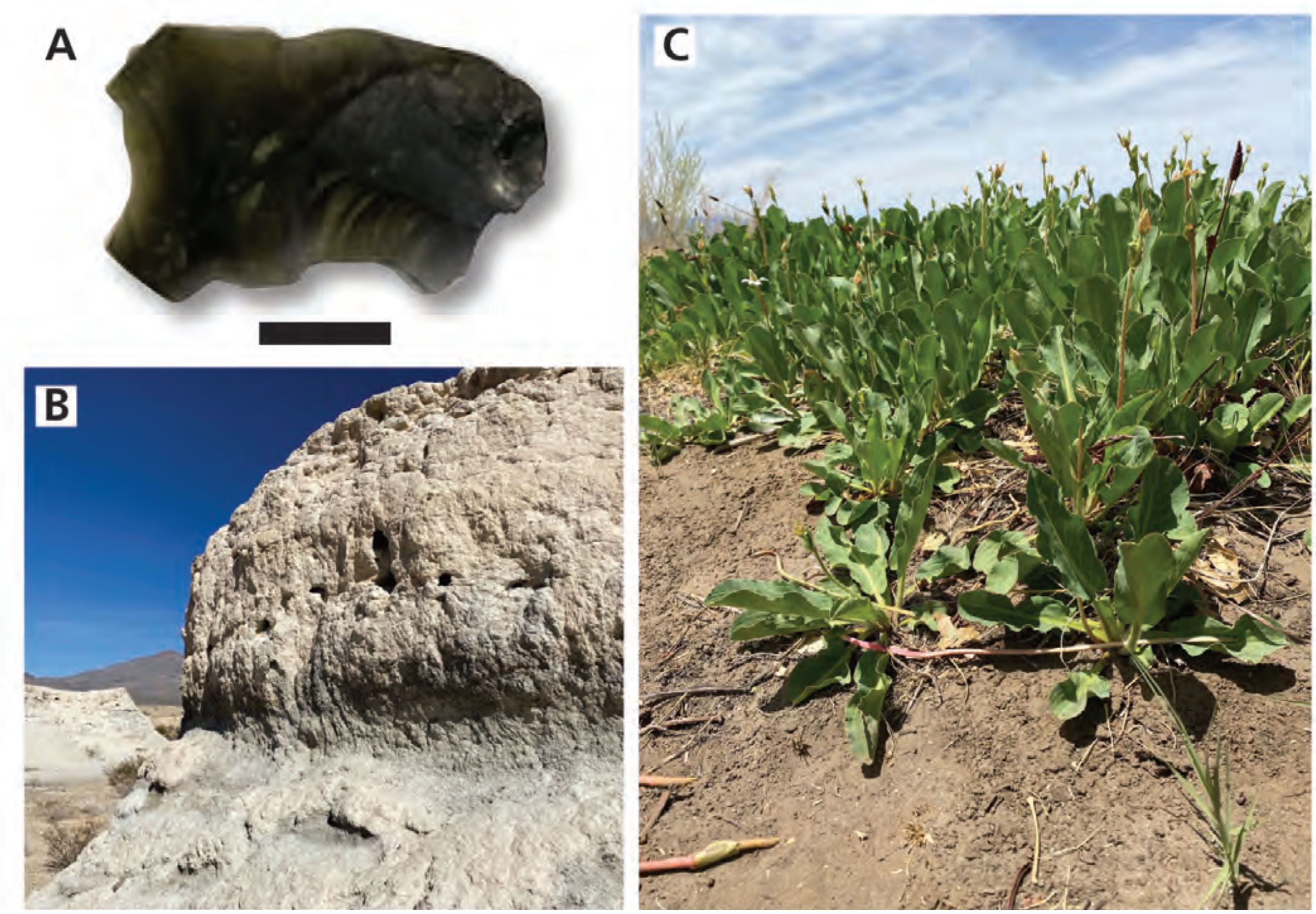
FIGURE 1. (A) Exposures of the fossiliferous Las Vegas Formation are preserved within Tule Springs Fossil Beds National Monument (TUSK) in southern Nevada, USA. NATIONAL PARK SERVICE / A. CATTOIR (B) The National Park Service (NPS) administrative boundaries across the Mojave Desert region (highlighted in brown). TUSK encompasses 22,650 acres within the upper Las Vegas Wash, approximately 90 km (56 mi) east of Death Valley National Park and 34 km (22 mi) northwest of Lake Mead National Recreation Area.

to current professional standards and practices, important data can become lost if these collections remain uninventoried. This paper will identify major areas where data loss can occur in legacy paleontological collections and explore solutions to reconcile and consolidate this information to support scientific discovery and place-based heritage conservation.

EARLY PALEONTOLOGY AT TULE SPRINGS

Pleistocene vertebrate fossils at Tule Springs were first documented in the scientific literature in 1903 by Josiah Edward Spurr and Robert B. Rowe (Spurr 1903) and first curated in a museum collection in 1919 by Chester Stock and Richard J. Russell of the University of California, Berkeley, Museum of Paleontology. Without adequate absolute dating methods, paleontologists in the early 20th century had only a general idea of the relative age of Pleistocene fossils. It was in this context that the 1927 publication of research on the Folsom site, New Mexico (26CX1), fundamentally changed the understanding of North American archaeology and paleontology with the discovery of prehistoric spear points directly associated with Pleistocene fossils from extinct bison (Figgens 1927). This finding inspired several North American archaeologists to pursue evidence of additional "Early Man" sites, as they were referred to at the time. It was with this major goal in mind that archaeologist Fenley Hunter of the American Museum of Natural History (AMNH) and paleontologist Albert C. Silberling led the first major effort to explore the archaeological significance of the Tule Springs area in 1932–1933. During fieldwork, they discovered an obsidian flake embedded within carbon-rich matrix they originally thought had direct context with Pleistocene fossils (AMNH Locality 96) (Simpson 1933) (Figure 2A). This artifact prompted AMNH to invite archaeologist Mark R. Harrington to the site to investigate further. Following this invitation, the Southwest Museum Expeditions, led by Harrington and

FIGURE 2. (A) The obsidian flake (AMNH 20.2/810) collected by Fenley Hunter and Albert Silberling in 1933 from AMNH Locality 96. Scale bar measures 1 cm. (B) Modern photograph of a "black mat" within the Las Vegas Formation. Originally interpreted as cooking hearths, these localized beds or deposits of carbon-rich sediment formed surrounding vegetated Pleistocene-age wetlands. (C) This process can be seen today in the Tule Springs area in the organic-rich soil that forms within vegetated spring mound alignments at Corn Creek, Nevada, spanning the boundary between Desert National Wildlife Refuge (US Fish and Wildlife Service) and TUSK.



Ruth DeEtte Simpson of the Southwest Museum of the American Indian, studied Tule Springs in 1933, 1955, and 1956, resulting in artifact and fossil finds they believed to be contemporaneous with each other. Museum collections from these expeditions included an assemblage of artifacts, fossils, sediment, and charcoal samples. These collections were curated at the Southwest Museum of the American Indian in Los Angeles, California (now part of the Autry Museum), and, at the time of collection, were administered by the General Land Office and the Bureau of Land Management (BLM). During that time (1933–1956), all fossils and sediment samples in this collection were curated as archaeological materials because of the perceived relationship between early peoples and Pleistocene megafaunal mammals at Tule Springs.

KNOWN PROBLEMS WITH LEGACY PALEONTOLOGICAL COLLECTIONS

Legacy paleontological collections are at risk of becoming orphaned. The Society for the Preservation of Natural History Collections defines "orphaned collections" as groups of objects and/or associated records with unclear ownership that have been abandoned. This can happen due to funding cuts, an institution's change in research focus, staffing changes, or collections transfers. For example, administrative jurisdiction for the greater Tule Springs area has changed since these legacy paleontological collections were made, resulting in the collections being split between various state and federal land management agencies. Split collections can also mean that different fragments of the same fossil specimen could be stored at different institutions, or that new field collections could be disconnected from earlier fossil specimens from the same locality. All these factors inhibit further scientific understanding of the Tule Springs local fauna and important shared geological heritage.

Additionally, a very common hinderance to legacy paleontological collections research is limited or absent specimen provenience. This stratigraphic or site-specific context secures the critical "where" and "when" elements to the stories of our geologic past and are important variables for paleontological research to have broader implications. From our own experience, we have learned that provenience can be lost or prohibitively hard to locate if the collection becomes separated from associated archives, the author's penmanship is difficult to decipher, or the researchers were not exact in their initial documentation of the site. Fossils are non-renewable resources, and some extinct taxa are known only from rare specimens. Some taxa, like Columbian mammoth (*Mammuthus columbi*) and western camel (*Camelops hesternus*) are very common from Tule Springs, while others, like teratorn (*Teratornis merriami*) and American lion (*Panthera atrox*), are rare and currently known only from legacy paleontological collections. The way to ensure scientific repeatability is to record and maintain specimens thorough provenience documentation. If thorough documentation doesn't already exist, or isn't verified, it is still possible to secure it even decades later by utilizing associated archives.

FRAMEWORK FOR RECONCILING LEGACY PALEONTOLOGICAL COLLECTIONS

To support paleontological research and resource management, TUSK has developed and tested a framework for reconciling problematic or underutilized legacy paleontological collections. This framework can be applied by other sites or parks that manage historic fossil collections. The framework below was developed for the Southwest Museum Expeditions Tule Springs Collection Inventory Project and has proven to be a successful step-by-step model for creating a comprehensive inventory of a legacy paleontological collection and working collaboratively with other land management agencies and Indigenous Peoples. The framework consists of a seven-step approach, which includes: identifying legacy paleontological collections and their repositories, collaborating with other agencies to conduct a physical inventory of the collection, gathering provenience data, managing data, sharing data, consulting with affiliated Tribes, and consolidating collections.

Step 1: Identify legacy paleontological collections

- Identify and develop a list of legacy collections and their current repository locations
  - → Identify paleontological objects catalogued and documented within legacy cultural collections
- Identify the appropriate land management agency at the time of collection
- Prioritize inventories based first on risk and then by ease of access
- Collaborate with the managing agency by facilitating or funding the inventory

Step 2: Conduct an inventory of the legacy paleontological collection

- Conduct item-level inventory of the collection
  - → Analyze bulk collections by reviewing and identifying skeletal elements and taxa from diagnostic fragments
    - → Update catalogue records to identify diagnostic components of bulk collections
  - → Photograph objects
- Consolidate and update catalogue records and associated archives
- Create a comprehensive database to house the updated location and catalogue information

Step 3: Provenience data gathering

- Consolidate and organize historic field photographs and maps by locality (this can also include photographs from publications related to the collection)
- Create a photograph reference document with locality images and captions to use as a comparative guide in the field
- Locate historic fossil localities in the field using the photograph reference guide
  - → Use suspected locality area as a starting point to ground-truth photographed historic localities, paying attention to topographic and landscape features and weathering surface patterns
  - → Take a replicated photograph of the historic image, noting GPS location of photograph point and azimuth direction of the photograph
  - → Use GPS to map existing topographic features that were drawn on historic maps such as washes, ridges, or hills
  - → Once one locality is documented, use it as a reference datum for determining other nearby localities
- Cross-reference historic photos with unprovenienced fossils in legacy collection

Step 4: Data management

- Combine historic observations and modern geospatial data into current standard locality forms, maps, databases, and geodatabases
  - → Cross-reference cultural resource data for any localities that have archaeological or historical components (i.e. artifacts or historic excavations 50 years old or older)
  - → Update locality data with historic locality names
  - → List legacy paleontological collections, including catalogue numbers, in updated records
- Update catalogue records with new provenience data
- Identify whether any additional comparative studies or fossil preparation are needed

Step 5: Data sharing

- Create and publish a comprehensive finding aid[1] in the form of an itemized inventory list with the location of artifacts, specimens, and digitized and physical archives associated with the collection
- Make finding aid easily accessible to government agencies, researchers, and the general public
  - → Create list of interested state and federal land managers, academic partners, and organizations with which to share finding aid through cross-referenced web-hosted platforms

- → Determine a schedule to update the finding aid periodically as more legacy collections are recovered
- → Designate which agency or organization will oversee and ensure periodic updates to the collection finding aid

Step 6: Tribal consultations

- Initiate tribal consultation
- Share data with affiliated Tribes
  - → Share collection background, inventory lists, photographs, and reference documents
- Work with appropriate land management agencies and museum staff to facilitate access for tribal members to view the collection
- Determine if objects in the collection are subject to the Native American Graves Protection and Repatriation Act (NAGPRA)[2] of 1990 (Public Law 101-601)
  - → Facilitate respectful return of any collection objects subject to NAGPRA
- Consult with the Tribes on potential consolidation of collections and get input on the future management of the collection

Step 7: Consolidation of legacy paleontological collections

- After tribal consultations, determine if collections should be consolidated and moved to a centralized curatorial storage repository where stakeholders and researchers will have better access
- If consolidation is recommended:
  - → Contact lead agency (i.e., landowner at the time of collection or its successor) to negotiate the move of the legacy collection
  - → Maintain comprehensive documentation to ensure an accurate dataset is available to researchers and government entities

SOUTHWEST MUSEUM EXPEDITIONS COLLECTION INVENTORY PROJECT

During Step 1 of the framework, the National Park Service (NPS) identified and located the Southwest Museum Expeditions Tule Springs Collection. The collection was transferred to the Autry Museum of the American West when the Southwest Museum merged with the Autry in 2003. Volunteers from the Ice Age Park Foundation (IAPF), a local advocacy group for Tule Springs, had conducted a preliminary inventory of the collection prior to the 2003 transfer; however, it was incomplete and resulted in only a few photographs of collections objects and select catalogue records. To initiate Step 2 of the framework, TUSK staff requested a physical inventory of the Southwest Museum Expeditions Tule Springs Collection from the Autry (accession number 10.F) in 2020. This step can be facilitated by either agency personnel or museum repository staff. To adapt to COVID-19 pandemic restrictions in 2020–2021, TUSK staff divided the inventory project into three phases, all funded by NPS. During Phase I of the project, Autry Museum staff remotely quality-checked and updated their catalogue records and databases to provide NPS with a preliminary list of accessioned artifacts, paleontological specimens, and archives. The completion of Phase I of the inventory revealed a significantly larger collection volume than was known from the preliminary IAPF inventory, with the number of known collection database line-items increasing from 91 to 587 in a new, more comprehensive and organized database. The Autry Museum staff conducted Phase II of the inventory to physically locate all items in the collection, including any unaccessioned objects. During Phase II, museum objects were also photographed, and archives were digitized. At the completion of Phase II, the known collection database line items increased from 587 to 625.

Phase III of the inventory was conducted by NPS in December 2022 and March 2023 and included further container- and item-level physical inventory of the collection object components. Paleontological and geological specimens were also analyzed by TUSK staff, geologist Kathleen

Springer (US Geological Survey), and paleontologist Eric Scott (Cogstone Resource Management, Inc.). Although the inventory list from Phases I and II seemed comprehensive, Phase III further refined details about bulk fossil specimens, such as more defined quantities of fragmented fossils and diagnostic skeletal elements hidden within large bags of bulk bone fragments. Analyzing bulk collections helps to make catalogue records more specific and accurate. Some bulk collections can have many components, such as, in this instance, Catalog No. 10.F.54B, consisting of a bag of more than 50 large mammal bone fragments. Twenty-four of these fragments are diagnostic to skeletal element and/or taxon. TUSK staff separated the diagnostic fragments into individual bags but kept the components together to maintain continuity. At the completion of Phase III, the known collection database line items increased from 625 to 629 (699 objects including bulk collection components). After the completion of the inventory project, NPS collaborated with BLM to share updated inventory data. Once all collection objects are accounted for, associated archives can lend critical historic and geologic context to legacy fossil collections.

REVERSE-ENGINEERING MISSING PROVENIENCE

Following Step 3 of the framework, historic photographs associated with legacy paleontological collections can help reconcile missing locality data and geologic context for unprovenienced fossil specimens. Reverse-engineering missing provenience first involves locating historic fossil sites in the field, followed by verifying the provenience of individual fossil specimens. With the help of a volunteer Friends Group (Protectors of Tule Springs), TUSK has been able to redocument historic fossil localities up to par with modern professional protocols and standards. Two of these volunteers, Sandy Croteau and Dev Basudev, explored areas of Tule Springs that were suspected to be the general locations of historic fossil sites and successfully matched the current landscape to historic photographs. A similar method was used by Harrington and Simpson in 1955 to rediscover the famous obsidian flake site (AMNH Locality 96) by comparing topographic features with photographs from 22 years prior. AMNH Locality 96, also known as Southwest Museum Area 3 Site A, was located by comparing historic photos, which showed the eroded excavation platform and darker-colored gravel deposits draped over lighter-colored badland features, to the modern landscape (Figure 3A–C). Using this locality as a datum, along with a historic map and historic photos gathered from the recent Southwest Museum Expeditions Tule Springs Collection inventory, TUSK staff were able to locate other sites more precisely, such as Southwest Museum Area 3 Site B, (Figure 3D-E). Following Step 4 of the framework, TUSK staff then performed site condition assessments, completed paleontology locality site forms, and collected more specific geospatial data for park cultural and paleontology geodatabases. These historic localities are managed as both cultural and paleontological sites and resource data are cross-referenced between disciplines and park staff divisions to maintain continuity. Using an interdisciplinary approach to manage these sites is an effective way to preserve the history of interdisciplinary science at NPS places with fossil resources.

Once the sites were properly located and redocumented, within-site provenience was assigned to legacy fossil specimens that lacked this information in their catalogue records. During Phase III of the legacy collection inventory, TUSK staff were able to verify the provenience of fossil specimens that lacked locality data by comparing them to field photographs in the collection's associated archives (Step 3 of the framework) (Figure 4). Although it is not possible to identify heavily fragmented fossil bone fragments, diagnostic fossils can be matched to photographs based on morphology, fractures, or surface stains (Figure 4A–D). Sometimes, fragmented elements need to be pieced together or prepared before a reliable match can be made (Figure 4C). TUSK staff evaluated the collection, following Step 4 of the framework, to identify needs for additional fossil preparation. At the request of NPS, BLM facilitated a loan of three unprepared, unlabeled plaster field jackets from the Southwest Museum Expeditions Tule Springs Collection at the Autry Museum, which had not been opened or prepared since their collection. Lab preparation (completed by Cogstone Resource Management, Inc.) has revealed that the unknown specimens

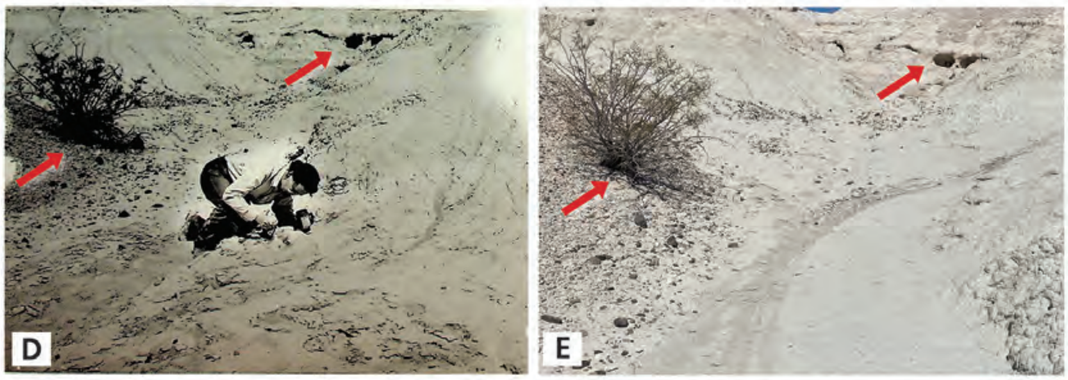


FIGURE 3. Landscape features were used to validate the locations of historic fossil localities at TUSK. (A) AMNH Locality 96; Southwest Museum Area 3, Site A photographed in 1933. This photograph was scanned from the Tule Springs Collection at the Autry Museum of the American West but is also printed in Harrington and Simpson (1961) and credited as "Courtesy Mr. Fenley Hunter, American Museum of Natural History". (B) Figure 44 from Harrington and Simpson (1961), captioned "The Fenley Hunter Site (Area 3, Site A) … 1959 [Photo by John Kettl]". (C) The same locality photographed in 2023. (A–C) The remnants of the excavation platform and dark gray gravel deposits (circled) were used to locate the site from historic photographs. (D) Photograph by Stuart Peck from the Southwest Museum Tule Springs Expeditions archives (MS.3.CUR.25.3), captioned "Simpson excavating Hunter Site." (E) Area 3, Site B, photographed in 2023. (D–E) The creosote bush (left arrows) and two hole-shaped depressions in the badlands (right arrows) were used to locate the site from historic photographs.

FIGURE 4. Identifying fossil specimens without in-site provenience from historic photos from the Southwest Museum Tule Springs Expeditions Collection. The scale bar is 15 cm (6 in) long, and the shaded portion is 10 cm (4 in) long. (A) Columbian mammoth (*Mammuthus columbi*) femoral head coated with shellack (10.F.163). (B) Photograph by Stuart Peck from Southwest Museum Expedition archives (MS.3.CUR.25.3), captioned "Miss Simpson follows up washed-out bone fragments. Tule Springs Site." This photograph was taken within Southwest Museum Area 3, Site B. 10.F.163 can be seen on the ground surface below Simpson's right hand. (C) Three fragments from western camel (*Camelops hesternus*) partial ilium (10.F.175) positioned together. (D) The same specimen photographed in Figure 44 from Harrington and Simpson (1961), captioned "Site C, Area 2: fragment of camel pelvis with associated charcoal; bone partially burned; length 20.5cm."

were a partial mandible from a Columbian mammoth (*M. columbi*) with well-preserved molars, and partial limb bones. After preparation, TUSK staff were able to match the previously unprovenienced field jackets to Southwest Museum Area 1 Site D using archived historic field photographs. When interdisciplinary methods are used together to reverse-engineer fossil provenience, researchers can confidently study legacy fossil collections using contemporary methods. These methods can reverse the data loss that can often occur with legacy fossil collections.

CULTURAL CONTEXT OF FOSSIL COLLECTIONS

Although science is a field that strives to be objective and data-driven, scientists cannot be separated from their human elements and attributes. Scientists are affected by sources of implicit bias such as their worldview, background, or academic interests. Legacy paleontological collections and associated archives are, in themselves, artifacts of the time of documentation and collection. These collections reflect what members of the scientific community were asking at that time, what they were interested in, what technology was available, and whose perspectives they were (or were not) including. The human element of paleontology can also drive important collecting biases, resulting in incomplete datasets and skewed interpretations. Pleistocene fossil collections historically were often excavated by archaeologists and curated as cultural resources. When fossils were primarily analyzed with an archaeological focus, the taphonomic interpretations were often biased toward butchering, hunting, and other human activities, even when not substantiated. All of this information can be consolidated into a finding aid to give historical context to legacy paleontological collections (Step 5 of the framework). For these reasons, it is important for natural resource and museum collections programs to preserve the cultural context attached to these collections.

As an example of an archaeological focus, consider the stated aim of the leaders of the 1956 Southwest Museum Expedition to Tule Springs:

> When considering the Pleistocene archeological record of North America, we are not concerned solely, nor primarily, with the artifacts as such. Our principal concern is with the understanding of Man, his life, his behavior, his problems… (Harrington and Simpson 1961: 40).

During the Southwest Museum Expeditions to Tule Springs, carbon-rich deposits, often containing carbonized wood, charcoal, and vertebrate and invertebrate fossils, were interpreted by archaeologists to be ash-filled hearths where "Early Man" cooked hunted game (Simpson 1933; Harrington and Simpson 1961). This conclusion led to hyperbolic taphonomic interpretations of these heavily weathered and fragmented Pleistocene fossils. In 1955, Harrington and Simpson interpreted this type of deposit as examples of animals being "dismembered" by humans, with their limbs "hacked off and thrown into the ash dump" (Harrington 1955: 553) close to "nearby cooking fire" (Harrington and Simpson 1961: Figure 20). This interpretation may owe something to the popular culture of the 1920s–1930s. At that time, depictions of prehistoric peoples were limited to the "caveman" stereotype, featured in books, short films, and the syndicated comic strip "Alley Oop," which premiered in 1932 and still runs to this day. Alley Oop, created by fossil enthusiast V.T. Hamilton, was a time-traveling cave man from the "Bone Age" who had a pet dinosaur. Seemingly inspired by their speculation of an "Early Man" site at Tule Springs and the popular comic strip character, "ALLEY OOP" was carved, presumably by someone on the Southwest Museum team, into an unidentified fossil bone fragment that was included in a bulk collection of bone fragments and partial bone elements (10.F.93A) (Figure 5A–B). It is unknown if this was carved into the bone in 1933, 1955, or 1956. Although not a paleontologically significant fossil specimen, the discovery of the "ALLEY OOP" bone fragment within a bulk collection represents the important historical context that can be exposed when comprehensive inventories of these legacy paleontological collections are done.

FIGURE 5. **(A–B) Southwest Museum Tule Springs Expeditions Collection specimen 10.F.93A. (A) One component of 10.F.93A is an unidentified long bone fragment etched with the phrase "ALLEY OOP." The scale bar measures 2 cm (0.8 in).** PHOTO COURTESY OF ERIC SCOTT **(B) 10.F.93A is a bulk collection consisting of one large bag containing more than 50 bone fragments, including at least seven diagnostic partial bone elements. The scale bar is 15 cm (6 in) long, and the shaded portion is 10 cm (4 in) long. (C) Photograph from the Tule Springs Expedition of 1962–1963 of a sign near their basecamp reading "ALLEY OOP 4 miles" with an arrow directing north.** COURTESY OF UNIVERSITY OF NEVADA–LAS VEGAS SPECIAL COLLECTIONS, CHARLES ROZAIRE COLLECTION ON TULE SPRINGS, NEVADA

Even though fossil- and artifact-bearing strata at Tule Springs were ultimately found to be non-contemporaneous during the Nevada State Museum Tule Springs Expedition of 1962–1963, an "Alley Oop" reference was still featured on a sign at the basecamp (Figure 5C). The recent advent of radiocarbon dating made testing the validity of "Early Man" sites more rigorous; however, media outlets were still itching for sensational content out of Tule Springs. C. Vance Haynes, geologist of the 1962–1963 Expedition, recalls a local Las Vegas news crew visiting the interdisciplinary team of scientists:

> Dick [Shutler] tried to explain that we were not trying to prove the presence of early humans there at an early age but to see if the evidence claimed for such was sound, which it was not up to that time. The reporter was not happy with our response and left the site in a huff" (C. Vance Haynes, personal communication, April 28, 2023).

In a sign of how important the Tule Springs site was—and of the hunger for sensational "early Man" findings—before the Nevada State Museum Expedition had even reached its conclusions the publishers of *National Geographic* commissioned artwork for an upcoming issue depicting "Early Man" hunting a camel with spears and tree branches (Figure 6A). The magazine then had to omit the artwork once it became known that the evidence contradicted this depiction. There seemed to be a general sense of disappointment with this significant paradigm shift in research at Tule Springs, even though the results of the Expedition painted a compelling picture of the Pleistocene environments of the area (Wormington and Ellis 1967). Such course corrections call for engaging the public with new findings that build upon previous studies (Figure 6B). Updated interpretation can come from both the scientific process as well as incorporating Indigenous knowledges.

TUSK is situated on the traditional homelands of the Nuwu/Nuwuvi Nation (Southern Paiute). Cultural and natural resources at TUSK, and the landscapes upon which they are found, hold enduring cultural and spiritual

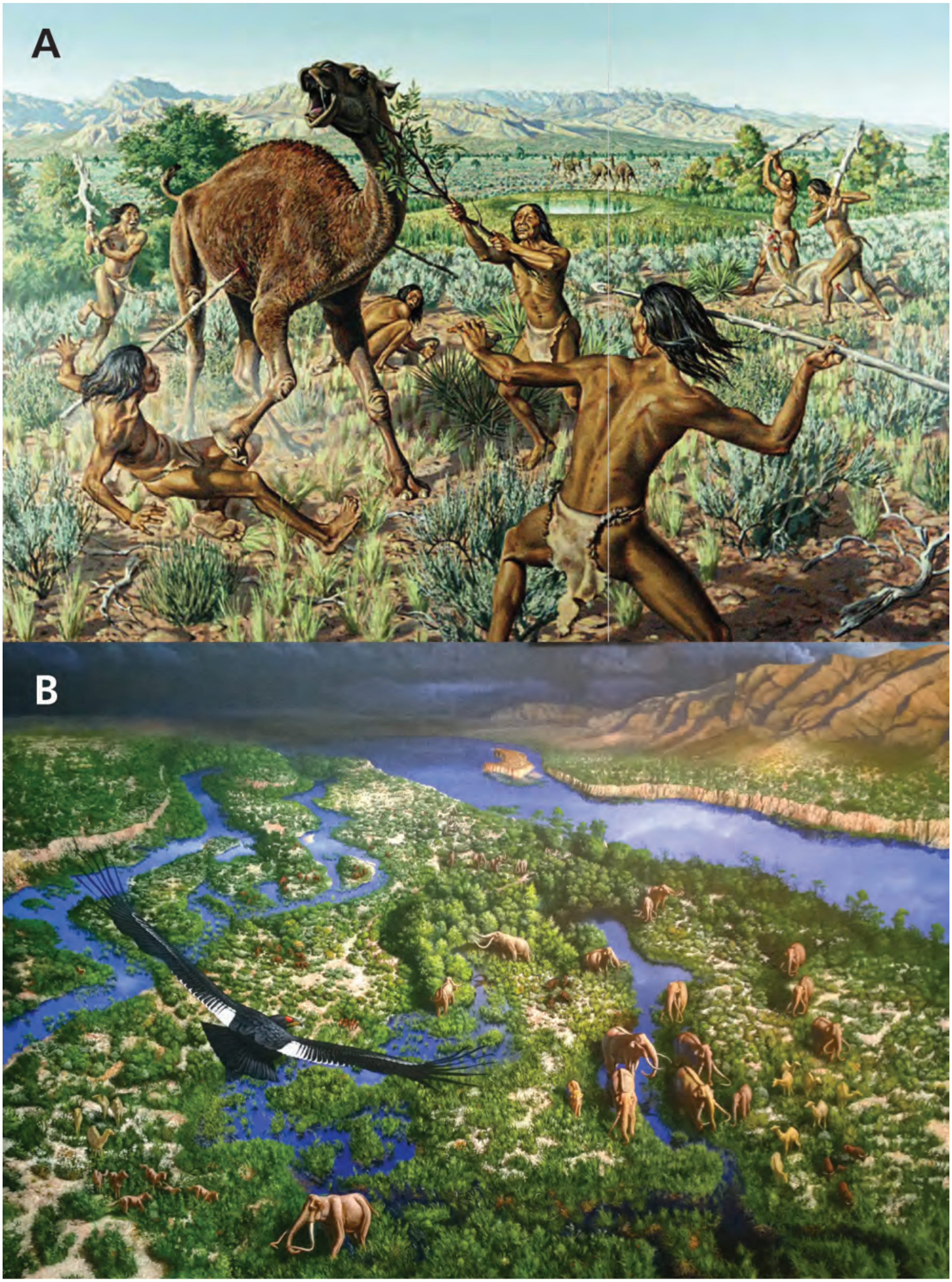


FIGURE 6. (A) Artwork by Jay Matternes, commissioned for the 1962–1963 Nevada State Museum Tule Springs Expedition, depicting early peoples hunting a western camel (*Camelops hesternus*) with spears and branches. COURTESY OF C. VANCE HAYNES, PERSONAL COLLECTION (B) Modern interpretations of the rock and fossil records of Tule Springs build upon what is known from legacy paleontological collections and contemporary research. Contemporary artwork by Julius Csotonyi depicting Tule Springs 23,000–18,000 years ago using the results of interdisciplinary research. A teratorn (*Teratornis merriami*) flies above a network of spring-fed streams. These habitats supported megafaunal mammals including (from left to right) western camel, Scott's horse (*Equus scotti*), bison (*Bison antiquus*), and Columbian mammoth (*Mammuthus columbi*). NPS ARTWORK

significance to Indigenous Tribes. Now that the Southwest Museum Expeditions Collection has been comprehensively inventoried, the stage is well-set for researchers and affiliated Tribes to reanalyze "human-modified" fossil bone fragments identified from the Tule Springs Collection to get a more accurate picture of the past (Step 6 of the framework). One bone fragment in the Tule Springs Collection now identified as belonging to a Pleistocene mammal was originally catalogued as human remains. Analysis during the inventory project determined that this collection was not subject to NAGPRA. Although Indigenous perspectives were largely excluded from historic expeditions, tribal engagement is a top priority for NPS moving forward. Fossils are not covered under NAGPRA, but natural resources are important to many Indigenous cultures. Including fossil resources when conducting tribal consultations strengthens Indigenous connections, enhances our nation-to-nation relationships, and upholds NPS trust and treaty responsibilities as a federal agency.

CONCLUSIONS

Fossils are unique in the way they inspire connections to past life and environments in both the scientific community and with the public. Paleontological collections and their associated archives help to fulfill the NPS mission by preserving these non-renewable resources unimpaired for the enjoyment, education, and inspiration of this and future generations. The Paleontological Resources Preservation Act of 2009 (PRPA) mandates the use of scientific principles and expertise in federal paleontological resource management (16 USC § 470aaa 1–11). To fulfill this obligation, legacy paleontological collections and historic fossil sites should be periodically reexamined and reinterpreted. After the Southwest Museum Expeditions at Tule Springs, Harrington and Simpson suggested that "we are laying the background for more exciting, more illuminating discoveries to come in the decades ahead as scientists of many fields combine their talents to enable America to learn the truth about her Past" (Harrington and Simpson 1961: 40). This will continue to be true as even more advances are made in the scientific and cultural understanding of these resources.

The diversity of the Pleistocene Tule Springs local fauna is known from both legacy fossil collections and recent field collections. Recent discoveries of coachwhip snake (*Masticophis* sp.), bobcat (*Lynx rufus*), Scott's horse (*Equus scotti*), saber-toothed cat (*Smilodon fatalis*), and dire wolf (*Canis dirus* or *Aenocyon dirus*), among others, came from new field collections between 2008–2014 (Scott and Springer 2016; Scott et al. 2017). Now that NPS is aware of diagnostic skeletal elements found in the recent legacy collection inventories, further research can be conducted to gain a greater understanding of the Tule Springs local fauna even without any new excavations. The understanding of the geologic and taphonomic contexts of these fossils has also evolved over time. It is now understood that it is much more plausible that vertebrate fossils from the Las Vegas Formation are weathered and fragmented because of natural processes, like physical weathering and erosion, than from deliberate butchering. Further research that uses modern standards and practices and that incorporates Indigenous perspectives will lead to a more holistic interpretation of the relationship between Pleistocene animals and peoples at Tule Springs. Since the Nevada State Museum Tule Springs Expedition of 1962–1963, focus and bias have shifted in modern paleontological and geological studies of the Tule Springs Area.

Contemporary research on the Las Vegas Formation has focused on investigating changes in local environments and how these changes fit into the bigger picture of regional and global climate changes during the Pleistocene–Holocene. Very detailed chronologies of the Las Vegas Formation have formed a precise timeline of wetland expansion and contraction that mirror global climate events and glacial/interglacial periods (Springer et al. 2015, 2018). The localized deposits of carbon- and charcoal-rich sediments observed in the Las Vegas Formation (Figure 2B), formerly identified as cooking hearths, can be found forming in desert wetlands today. Heavily vegetated desert springs and spring-mounds receive more organic carbon input into the surrounding soil than less-dense desert scrub habitat (Figure 2C). Revisiting the carbon-rich deposits and charcoal samples documented and collected at Tule Springs during the Southwest Museum Expeditions with updated provenience and more precise dating methods could make our understanding even more complete.

PRPA also charges agencies with increasing the public's awareness of the significance of paleontological resources. Legacy paleontological collections are tangible pieces of history that can inspire learning about not only scientific interpretations, but also cultural values. Making legacy fossil collections more accessible to Tribes, students, educators, researchers, park managers, and the public cultivates a more holistic interpretation of shared geoheritage. Doing so may require consolidation of legacy paleontological collections into more accessible, centralized repositories (Step 7 of the framework). Acknowledging the history of implicit bias in paleontological expeditions is the start of taking steps to be more objective. Interpreting science as a dynamic way of knowing instead of a static body of knowledge will help cultivate a better understanding and appreciation of paleontology and paleontological resources. By taking an interdisciplinary approach to managing historic fossil sites and paleontological collections, we gain the ability to discover missing pieces of our heritage, encourage innovation, and advocate for the value of paleontology and paleontological resources in national parks.

ACKNOWLEDGMENTS

The authors would like to thank Madeline Ware Van der Voort (BLM, Nevada), and Karimah Richardson and Margarita Villarreal (the Autry Museum of the American West) for facilitating collections access and loan agreements. Eric Scott and Ascanio Rincón (Cogstone Resource Management, Inc.) facilitated fossil preparation on plaster field jackets from the legacy collection. Kathleen Springer (US Geological Survey) evaluated charcoal samples from the legacy collection. The authors would like to thank Nancy Johnson, Will Joseph, and Aubrey Bonde for providing edits on preliminary drafts of this manuscript. Finally, thank you to Vince Santucci and Justin Tweet (NPS Paleontology Program) for providing edits and the invitation to contribute to this volume. Special thanks to Helen Mortenson for the inspiration for this project and for providing the preliminary inventory of the Tule Springs Collection at the Autry Museum of the American West.

ENDNOTES

1. Finding aids preserve the historic legacy of sites, enhance research and interpretation opportunities, and provide a single source of information to determine what museum collections exist and where they are located.
2. Collections subject to NAGPRA include human remains, funerary objects, sacred objects, and objects of cultural patrimony of lineal descendants, Native American tribes, and Native Hawaiian organizations.

REFERENCES

Figgens, J.D. 1927. The antiquity of man in America. *Natural History* 27: 229–239.

Harrington, M.R. 1955. Man's oldest date in America. *Natural History* 64: 512–517.

Harrington, M.R., and R.D. Simpson. 1961, *Tule Springs, Nevada with Other Evidences of Pleistocene Man in North America.* Southwest Museum Papers 18. Los Angeles: Southwest Museum.

Haynes, C.V., Jr. 1967, Quaternary geology of the Tule Springs area, Clark County, Nevada. In *Pleistocene Studies in Southern Nevada.* Nevada State Museum Anthropological Papers no. 13. Carson City: Nevada State Museum, 15–104.

Public Law 113–291; 128 Stat. 3292, 113th Congress, Carl Levin and Howard P. "Buck" Mckeon National Defense Authorization Act for Fiscal Year 2015. https://www.govinfo.gov/content/pkg/CRPT-113srpt178/pdf/CRPT-113srpt178.pdf

Scott, E., and K.B. Springer. 2016, First records of *Canis dirus* and *Smilodon fatalis* from the late Pleistocene Tule Springs local fauna, upper Las Vegas Wash, Nevada. *PeerJ* 4: e2151. https://doi.org/10.7717/peerj.2151

Scott, E., K.B. Springer, and J.C. Sagebiel. 2017, The Tule Springs local fauna: Rancholabrean vertebrates from the Las Vegas Formation, Nevada. *Quaternary International* 443: 105–121. https://doi.org/10.1016/j.quaint.2017.06.001

Simpson, G.G. 1933. A Nevada fauna of Pleistocene type and its probable association with man. *American Museum Novitates* 667: 1–10.

Springer, K.B., C.R. Manker, and J.S. Pigati. 2015. Dynamic response of desert wetlands to abrupt climate change. *Proceedings of the National Academy of Sciences* 112: 14522–14526. https://doi.org/10.1073/pnas.1513352112

Springer, K.B., J.S. Pigati, C.R. Manker, and S.A. Mahan. 2018. *The Las Vegas Formation.* Professional Paper 1839. Washington, DC: US Geological Survey. https://doi.org/10.3133/pp1839

Spurr, J.E. 1903. *Descriptive Geology of Nevada South of the Fortieth Parallel and Adjacent Portions of California*. Bulletin 208. Washington, DC: US Geological Survey. https://doi.org/10.3133/b208

Wormington, H.M., and D. Ellis, eds. 1967. *Pleistocene Studies in Southern Nevada.* Nevada State Museum Anthropological Papers no. 13. Carson City: Nevada State Museum.

Paleo
NPS PALEONTOLOGY