Geology and Paleontology Explorations and Resources at Tule Springs Fossil Beds National Monument

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CHAPTER 1

Overview and scope of project

by Aubrey Bonde

Tule Springs Fossil Beds National Monument (TUSK) was enacted into law December 19, 2014 by the 113th Congressional session; it has now moved into the nascent stages of planning and development (Figure 1). As such, the interim superintendent of TUSK, Vincent Santucci, appointed two GeoCorps positions to aid in the collection of researched materials and literature resources published on, or known from the monument. Fabian Hardy, M.S. from UNLV, was appointed to review the geology and Aubrey Bonde, Ph.D. from UNLV, was appointed to review the paleontology. Term appointments lasted from May-October of 2015 and during that time extensive literature searches and networking was conducted to gather the information that is contained in this report. This report summarizes over a century's worth of research efforts made by dozens of scientists. Hardy and Bonde have assembled a substantial database of information on the Upper Las Vegas Wash and expound on that history herein.

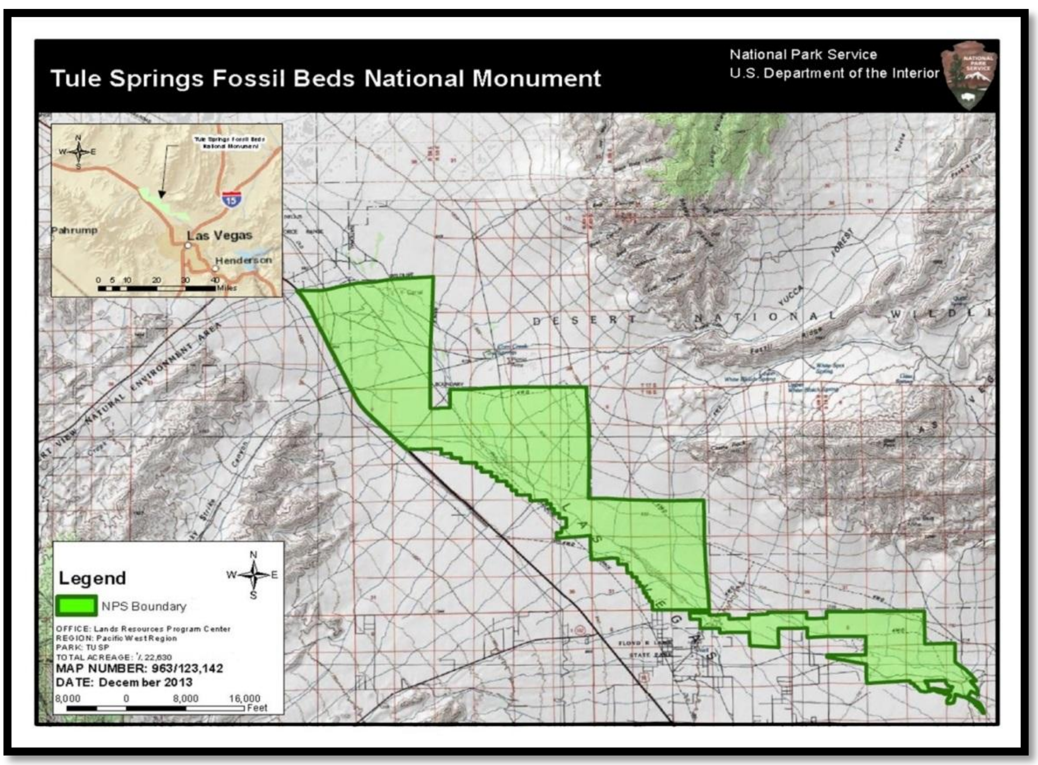

Figure 1. National Park Service map of the geographic extent of Tule Springs Fossil Beds National Monument.

In addition to the protection of rare plant and animal species (Las Vegas bearpoppy, Merriam's bearpoppy, Las Vegas buckwheat, Mojave desert tortoise), the importance of preserving the lands at TUSK extend to the over one hundred thousand fossils recovered from the area and the potential for many thousands more. TUSK preserves the largest open assemblage of Ice Age land mammal fauna from the Mojave and Great Basin deserts throughout 250,000 thousand years of depositional history. The badlands contained within this monument provide the unique opportunity to assess and interpret the composition of late Pleistocene terrestrial communities and understand how they respond to changing climates and environments.

TUSK represents one of the very few National Park units to preserve fossils from the Pleistocene. It can surely be considered an "Urban Park" as it is on the interface of North Las Vegas and affords the opportunity for visitors of all ages who may never get the chance to visit a park in a remote setting (Figure 2).

Figure 2. One of the first pieces of signage posted at an interface between the park boundary and North Las Vegas residential homes.

CHAPTER 2

Biographies of key people at TUSK
By Fabian Hardy

Tule Springs has a rich history of scientific investigation, and the site has received national attention several times in its history. Some of the top researchers in the fields of geology and paleontology have contributed to the understanding of this site over the years. This section is not a complete list, but aims to highlight some of their work. Their backgrounds and interest are varied, and it is a testament to the potential of Tule Springs that so many diverse people have found something here to study.

Josiah Edward Spurr and Robert B. Rowe (1903)
Spurr was a prominent USGS geologist. Considered one of the fathers of economic geology, he was mostly focused on ore deposits and resource exploration. He first achieved notoriety by leading a pair of historic expeditions in Alaska in 1896 and 1898. Spurr conducted the first geologic survey of Nevada in 1903, which led to the first geologic map of the state.

He was accompanied on this expedition by Robert B. Rowe, who contributed to the early understanding of Nevada stratigraphy and structural geology. Rowe is also notable in that he documented and collected a "mastodon" tooth (likely Columbian mammoth) near Tule Springs. This is the first mention of fossils from Tule Springs.

Chester Stock and Richard J. Russell (1919)
Stock was a vertebrate paleontologist who was associated with the University of California, Museum of Paleontology. He later moved to the California Institute of Technology, and then the Natural History Museum of Los Angeles County. Stock became famous for his work on the fossils of the Rancho LaBrea tar pits.

Russell, a geographer specializing in coastal morphology and structural geology, accompanied Stock in early Nevada field work. Their focus was in correlating the scattered mammal assemblages of the Great Basin with the Pleistocene fauna of Rancho La Brea. They reached Tule Springs in 1919, where their most notable discovery was a specimen of North American lion (*Panthera atrox*). Though unpublished, their specimens are the earliest recovered fossils from Tule Springs that are housed in museum collections.

Fenley Hunter and Albert C. Silberling (1932-1933)
Fenley Hunter was an archaeologist from the American Museum of Natural History, who conducted work at Tule Springs with the goal of formally documenting Pleistocene fossils from Nevada. Hunter discovered the infamous obsidian flake, which sparked a great deal of interest and further work.

A.C. Silberling, a Montana homesteader and self-taught paleontologist, collected fossils throughout his life. He was well-versed in excavation techniques, and often called upon by prestigious institutions such as Princeton University, the American Museum of Natural History, the United States Geological Survey, and the Smithsonian Institute.

George Gaylord Simpson (1933)
Simpson was the curator of paleontology at the American Museum of Natural History. A prominent figure in the acceptance of evolutionary research and theory during the 20th century, he was the driving force behind many important paleontological concepts. Simpson wrote the official report of Hunter and Silberling's expedition, which included the hypothesis of "probable association of man" with Pleistocene megafauna in Nevada.

Mark Harrington (1933, 1955-1956)
Harrington was the curator of archaeology for the Southwest Museum of the American Indian (now part of the Autry National Center) from 1928-1964. His interest in archaeology was lifelong, and he spent his childhood learning tribal languages and culture in the region near his hometown of Ann Arbor, Michigan. He made significant contributions to the study of the archaeology of the American Southwest throughout his career, including the discovery of ancient Pueblo Indian dwellings in Nevada. Harrington coordinated a last-minute salvage effort to preserve a notable Pueblo archaeological site, which was destined to be flooded by the creation of Hoover Dam and Lake Mead. He and his team excavated until "there was literally water lapping at their boots." His interests were broad, and included paleontological work alongside his usual studies, such as a site in Gypsum Cave, which contained both human artifacts and ancient ground sloth remains.

Ruth DeEtte Simpson (1933, 1955-1956)
Ruth DeEtte Simpson was the assistant curator at the Southwest Museum, and worked closely with Harrington. She was an integral part of his expeditions to Tule Springs, and participated in the Big Dig. She is perhaps best known for her work on the Calico Early Man Site, found in the central part of the Mojave Desert. Simpson led the excavation and study of thousands of artifacts, and eventually became Curator Emeritus of the San Bernadino County Museum.

Willard Frank Libby (1955)
Willard Libby was a Nobel Prize winning chemist who left behind a legacy of innovation. He received his doctorate from UC Berkeley in 1933, with a focus on radioactive elements. He worked on the Manhattan Project during World War II, developing a novel process for uranium enrichment.

Following the war, Libby was appointed to the Atomic Energy Commission in an advisory capacity. He resigned this position in 1959 and became a Professor of Chemistry at University of California, Los Angeles. Libby's greatest contribution to the fields of paleontology and archaeology was the development of radiocarbon dating, which he originally published in 1946. His lab was directly involved with the 1960's Big Dig at Tule Springs, and provided age control for materials excavated by the project.

Phil C. Orr (1956)
Phil Orr spent more than three decades as Curator of Anthropology and Paleontology at the Santa Barbara Museum of Natural History. In 1959, he discovered three ancient human bones in the wall of Arlington Canyon on Santa Rosa Island. These bones have were been dated to 10,000 years BP, making "Arlington Springs Man" the oldest human remains in North America known at the time.

Chester Longwell (1962-1963 Big Dig)
Longwell's experience with the geology of Southern Nevada placed him as one of the advisory committee members determining the potential of Tule Springs as an archaeological study site. Longwell began his studies at Yale, but was interrupted by the First World War, where he spent two years in the U.S. Army, achieving the rank of captain. Following the war, he returned to complete his studies and received his PhD in 1920.

Longwell worked throughout the summer and fall of 1919 in the Muddy Mountains and the surrounding area, mapping and making several major discoveries. His later contributions to the field of structural geology include work on geophysical data, and numerous investigations into orogenic theory.

Richard Shutler Jr. (1962-1963 Big Dig)
Richard Shutler Jr. had many important contributions to the understanding of Pacific archaeology. His interests were diverse, and included the study of early hominid remains in Southeast Asia, early work in radiocarbon dating at the University of Arizona, and archaeological expeditions throughout the Great Basin.

Shutler was the principal investigator for the famous Big Dig at Tule Springs, and personally led the archaeological teams in their excavations. One of his life goals was to beat a record for longevity in the field, and celebrated this accomplishment in 1995.

C. Vance Haynes Jr (1962-1963 Big Dig)
Vance Haynes was the primary geologist attached to the 1960s Big Dig. A member of the Air Force from 1950-1954, he received his PhD from the University of Arizona in 1965. He specializes in the archaeology of the American Southwest, and is perhaps best known for his contributions in the study of human migration through North America. Haynes coined the archaeological term "black mat," which is used for a layer of common 10,000 year old swamp soil. He was elected to the National Academy of Sciences in 1990, and is currently an emeritus Regent's professor at the University of Arizona.

John E. Mawby (1962-1963 Big Dig)
Mawby was a 1953 graduate of Deep Springs College, where he participated in the unique combination of ranch work and intellectual pursuits. Following this, he completed his doctorate at the University of California Berkeley, where he would go on to be a curator at the University of California, Museum of Paleontology (UCMP).

Mawby had a continuous presence in Nevada, leading expeditions throughout the state and investigating new areas throughout his tenure as curator of the UCMP.

Peter J. Mehringer (1962-1963 Big Dig)
Peter J. Mehringer contributed a highly detailed pollen analysis of Tule Springs during the Big Dig, which was the topic of his 1968 PhD from the University of Arizona. He holds degrees in zoology, biology, and geoscience, with a specialty in archaeology. His main focus is the stratigraphy and chronology of arid land late Pleistocene environments, and he specializes in relating them to the history of humans.

Jay Quade (1980s)
Jay Quade is a professor of soil geochemistry at the University of Arizona, whose research takes him throughout the world. He studied and extended the stratigraphy of Tule Springs and reinterpreted the fluvial deposits. Quade ventured to Chile's Atacama Desert and witnessed firsthand seismic activity that led to transportation of large boulders in an almost rainless environment, a previously unsolved mystery.

San Bernadino County Museum (2000s)
Kathleen Springer, Eric Scott, and Chris Sagebiel from the San Bernadino County Museum, in collaboration with Jeff Pigati and Craig Manker of the United States Geologic Survey conducted several long term projects at Tule Springs. The team found the most new fossil localities since the 1960s Big Dig, and helped to reignite interest in the site. Much like the earlier expedition, an interdisciplinary approach was used, examining the paleontology, hydrology, stratigraphy, geochronology of the whole area. This extensive study led to new discoveries, such as the first record of *Smilodon fatalis* (sabre-toothed cat) in Nevada. The stratigraphy of the site was reinterpreted, with a plethora of updated geochronological dates, providing a framework for future interpretation. The SBCM team investigated the hydrologic framework of Tule Springs, discovering unexpected connections to a larger climate record.

University of Nevada Las Vegas (2010+)
Multiple surveys and excavations have been conducted by researchers from the University of Nevada Las Vegas, led by professors Dr. Steve Rowland and Dr. Josh Bonde. These projects represent the increasing local interest in the site. The institution going forward plans to partner with the National Park Service to advise and contribute future scientific investigation.

Dr. Rowland is deeply involved with the history of geologic research, and a staunch supporter of celebrating the scientific heritage of Tule Springs. He has long been a proponent of educational outreach, and generates interest among high school students with a travelling lab exercise on mammoth teeth which were collected from a private site adjacent to TUSK. The purpose of the lab is to introduce students to a paleontological case study using materials related to deposits from Tule Springs.

Dr. Josh Bonde, a native to Nevada, is a professor at UNLV and a member of the Natural History Museum of Las Vegas' board of directors. He has been key to facilitating the return of Nevada's fossils to Las Vegas from several institutions, for which the people of the city have shown their gratitude. He is currently active in managing research conducted at TUSK.

CHAPTER 3

Geology of TUSK

By Fabian Hardy

Geologic Setting

Tule Springs Fossil Beds National Monument (TUSK) is found in the Upper Las Vegas Wash, just north of the city of Las Vegas. It is dominated by classic badlands topography, and a large active wash with a northwest to southeast drainage.

The Pleistocene to modern drainage patterns and geography of the TUSK site have been influenced greatly by its geologic history. Cretaceous tectonic activity is evident in the thrusts, folds, and normal faults seen within the Spring Mountains to the west (Donovan, 1996). A complex series of thrust blocks are exposed within this range, dating back to the Sevier orogeny (Donovan, 1996). The northern boundaries of the Las Vegas Valley are the Las Vegas and Sheep Ranges (Quade, 1986; Donovan, 1996).

Miocene extension of the region is visible throughout the Las Vegas Valley Shear Zone. This right-lateral fault displays roughly 65 km of strike-slip displacement (Donovan, 1996). The shear zone has a west-northwestern orientation, which had been noted by Longwell et al. (1965).

A low-angle escarpment known as Eglington Scarp lies roughly 3 miles southeast of the Tule Springs Site (Haynes, 1967). Several arroyos and many tributary rills dissect the foot of the scarp, and it becomes shallower, losing its identity south of Craig road (Haynes, 1967). The northeast section of the scarp is separated from an alluvial fan by Tule Springs Wash (Haynes, 1967). Outcrops of tufa and tufa rubble are common throughout the general area of the Eglington Scarp, and take the appearance of cylindrical or brachiate tubes of varying size (Haynes, 1967). Typically forming around sticks and reeds, this tufa commonly aligns along the wash, transecting topographic contours, and often lies on top of the caliche exposed throughout most of the site. Haynes (1967) documented a tectonic origin for Eglington Scarp, based on the common occurrence of tufa as a fault controlled spring product.

The Las Vegas Valley differs from the majority of the Basin and Range province in that it has large areas with exterior drainage to the sea, by means of the Colorado River (Longwell et al., 1965). The shear zone, normal faults, and other various structures may be conduits for groundwater movement between aquifers, but this has yet to be quantified (Donovan, 1996).

The South Unit of TUSK contains the nominal Tule Springs, home to the site of the famous 1960s "Big Dig" archaeological project. Trenches bulldozed during this dig are still visible, though erosion and flood deposits have begun to fill them (Figure 1).

The North Unit of TUSK contains the Corn Creek Flat, an area that has high fossil potential, based on numerous localities found throughout the history of research in both this and the South Unit. The geology, hydrology, and stratigraphy of the North Unit has been examined by several researchers, but it has not yet received the large-scale attention and close scrutiny of the South Unit.

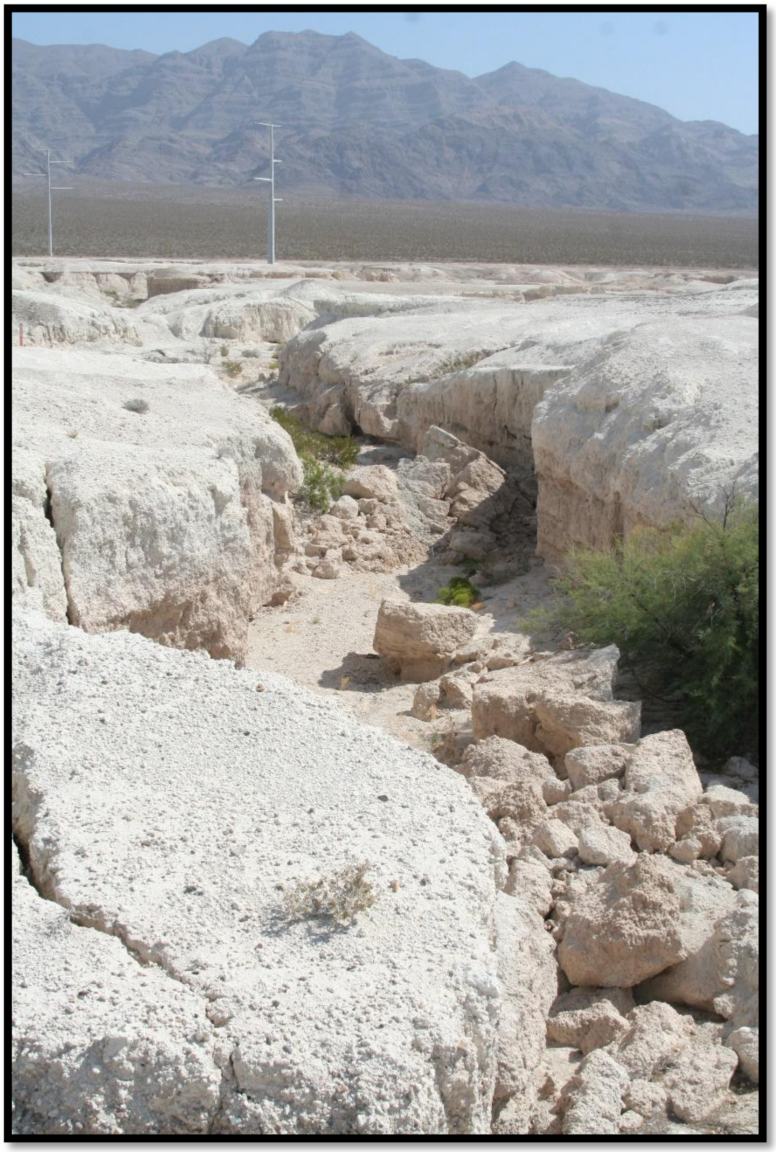

Figure 1. Trench A, partially filled from erosion.

General Structure and Stratigraphy of Las Vegas Valley

The Las Vegas Valley trends northwest, and denotes a zone of deformation separating the Spring Mountains from the Las Vegas and Sheep Ranges to the north (Longwell et al., 1965; Donovan, 1996). General folding in these mountain ranges resulted in a rough, shallow, and disturbed northeast-southwest striking syncline (Spurr, 1903). A nearly horizontal area in the central portion of the Las Vegas Range is interpreted to be the trough of this syncline (Spurr, 1903). A much sharper anticline succeeds the syncline and runs along a narrow valley separating the Desert and Las Vegas Ranges (Spurr, 1903).

The Las Vegas Valley is unusual when compared to typical Great Basin valleys due to its transverse nature in comparison to general strike of the rocks (Spurr, 1903; Donovan, 1996). Various parallel ridges of limestone run transverse to the general trend of the Las Vegas Range, interrupted by the Las Vegas Valley until continuing in the Spring Mountain Range (Spurr, 1903; Donovan, 1996).

The generalized bedrock geology of the Las Vegas Valley as described by Plume (1989), consists of four primary groups:

> Precambrian metamorphic rocks - A small exposure of gneiss is found at the base of Frenchman Mountain, and presumably underlies the valley.
>
> Precambrian and Paleozoic carbonate rocks – Notable formations include the Tapeates Sandstone, Lyndon Limestone, Bird Spring Formation, and Lone Mountain Dolomite.
>
> Permian, Triassic, and Jurassic clastic rocks – Including the Chinle Formation, Kaibab Limestone, Coconino Sandstone and others.
>
> Miocene igneous rocks – volcanic flows, flow breccia, and shallow dacites, andesite, and basalts.

The northern Spring Mountains consist primarily of late Paleozoic carbonate rocks (Donovan, 1996). The Sheep and Las Vegas Ranges possess similar lithology, and these rocks are assumed to underlie the Miocene to Quaternary alluvium throughout northern Las Vegas Valley, and the entirety of TUSK (Plume, 1989; Longwell et al., 1965).

Exposed alluvium within TUSK is primarily Quaternary in age, and mostly coarse-grained, due to close proximity to alluvial fans in the north and sediment influx from the Las Vegas Wash to the northwest (Spurr, 1903; Longwell et al., 1965; Quade, 1986; Ramelli et al., 2011). The alluvium has an average thickness greater than 1,225 m throughout the Las Vegas Valley, and most available lithologic data come from the uppermost 305 m (Donovan, 1996).

The type section of the Las Vegas Formation as originally described by Longwell et al. (1965) is located along the Las Vegas Wash east of Tule Springs. A large portion of the formation is deposited in relatively thin horizontal layers, and contains invertebrate and vertebrate fossils at many localities (Longwell et al., 1965). Along the Las Vegas Wash deposits contain abundant lenses of water-worn gravel in finer grained deposits, evidence of lateral cut and fill, and land animal fossils, which suggests an assemblage of aggrading streams with wide flood plains (Longwell et al., 1965).

The stratigraphy of the Tule Springs area was originally documented by Haynes (1967), and has been since refined by Quade (1986), Matti et al. (1993), Springer et al. (2003), and Manker et al. (2015). Quade (1986) in particular extended the stratigraphy from the 1962-63 excavation to the badland-fringed flats northwest of the site, including detailed study on the fine-grained deposits of Corn Creek Flat.

Similar deposits are exposed in parts of Pahrump Valley, and may directly correlate with the Las Vegas Formation, but Longwell (1965) grouped them with Quaternary alluvium due to incomplete mapping at the time.

Far to the south of the site, near Davis Dam, AZ, Pleistocene Lake Chemehuevi likely acted as a control for the drainage of the Las Vegas Valley, and there is some evidence for its contemporaneity with the Las Vegas Formation (Longwell et al., 1965). The formation consists of clay, silt, and sand its whitish beds are a stark contrast to the buff-colored units of the Muddy Creek Formation, which it incises

(Longwell et al., 1965). This formation is much less extensive and well defined than the Las Vegas Formation, but several late Pleistocene mammalian fossils have been recovered from it (Newberry, 1861, Longwell 1936).

Stratigraphy of Tule Springs

Haynes (1967) originally subdivided Longwell's (1965) Las Vegas Formation into seven units during the 1962-1963 "Big Dig" archaeological expedition (Figure 2). These units were designated "A" through "G," with A as the oldest unit (Haynes, 1967; Quade, 1986; Springer and Scott, 2003).

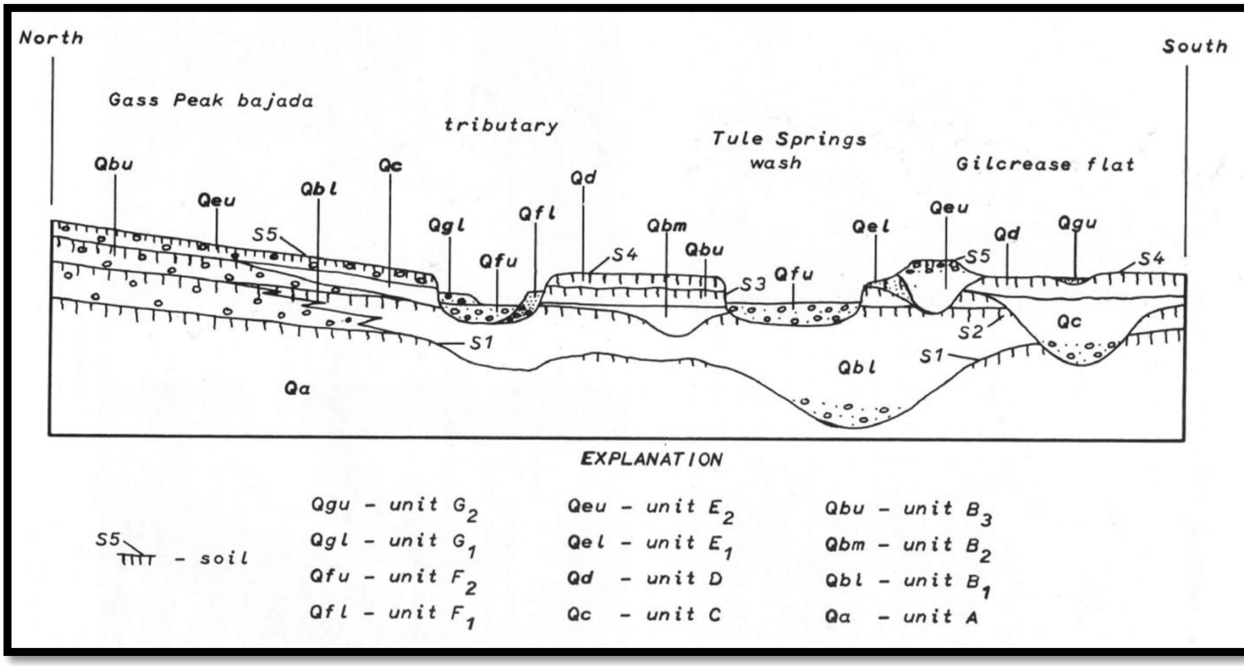

Figure 2. Cross section of Tule Springs stratigraphy, generalized and without scale. From Haynes (1967).

Units A and B are the oldest and most poorly exposed units as described by Haynes (1967). Outcrops of A and B are almost exclusively found in the Tule Springs Area, and are buried by younger sediments in Corn Creek Flat (Quade, 1986).

Unit A is a fluvial unit, and is not well exposed except in some areas near the base of the wash wall (Haynes, 1967; Quade, 1986). A soil (S1) overlies the unit, and was strongly calichefied post erosion. Unit A is estimated to be roughly 250 – 225 k yrs old (Springer et al., 2011).

Unit B occupies channels inset into unit A (Figure 2), and is divided into three subunits, B_1, B_2, and B_3. This series records an alternating sequence between dry and wet conditions (Haynes, 1967; Quade, 1986). Palynological data suggests that the valley contained predominantly sagebrush, an indicator of Great Basin flora during the deposition of Unit B (Quade, 1986).

Vertebrate and invertebrate fossils are found throughout Unit B, along with fossil wood (Haynes, 1967). Multiple localities containing bones also contain evidence of spring feeders (Haynes, 1967).

Figure 3. Hills displaying AB contact. Unit A consists of poorly sorted carbonate rubble with aridosol overprinting, and high incidence of fluvial/alluvial discharge. Unit B is inset partially into Unit A, and is finer grained.

Unit B_1 is a gravel facies, topped by a strong paleosol (S2) which is superimposed upon S1 in places. Erosion following the development of S2 left remnants of the resistance Cca horizon (Haynes, 1967). S2 is primarily found in the Corn Creek area of the North Unit, and absent from

Unit B_2, sometimes referred to as the "green-pond unit," is the middle portion of the B series, and holds evidence that conditions at the site were moister than modern (Haynes, 1967; Quade, 1986). Shallow aquatic mollusk shells are commonly found throughout channels and clays likely deposited in shallow, spring-fed ponds which follow the ancestral Las Vegas Wash (Haynes, 1967; Quade, 1986). Aquatic pollen types have been collected from this unit in trench D, which also support this interpretation (Haynes, 1967). The lower part of Unit B_2 is host to a number of buried spring-feeder conduits which were exposed during the 1962-63 excavation (Haynes, 1967). Unit B_2 contains wood fragments that were dated in excess of 40 k yrs, and this date is further supported by the presence of extinct elephant, horse, camel, and bison remains (Haynes, 1967; Quade, 1986).

Unit B_3 conformably overlies Unit B_2 and contains lithology similar to the alluvial silt of B_1 (Haynes, 1967). This unit represents a brief return to alluvial depositional conditions following the stream discharge episode of Unit B_2 (Haynes, 1967). A strong soil designated S3 is evidence of a period of erosional-depositional stability, and is more well developed than soil S2 on Unit B_1 (Haynes, 1967).

Unit C has been phased out of the traditional Las Vegas Formation nomenclature, but appears in older literature. Haynes (1967) previously denoted a fluvial Unit C, which had the appearance of being interbedded with Unit D. This unit was re-examined and dated by ^{14}C and luminescence techniques which yielded ages consistent with both Unit B_3 and Unit D (Manker et al., 2015). Trench K contains deposits of both B_3 and "C" that yield similar dates. The exposures that match with Unit D are tan, cliff-forming deposits in the west flank of the Upper Las Vegas Wash, and grade into dry marginal facies of Unit D (Manker et al., 2015).

Unit D is the most widespread and best-exposed unit in the area, and has produced numerous significant localities containing megafauna (Quade, 1986; Springer and Scott, 2003). It is a whitish, carbonate-littered outcrop that visually dominates the badlands of Corn Creek and Tule Springs (Quade, 1986). The unit is comprised primarily of fine-grained valley margin deposits, preserving fluvial bedforms and cicada burrows (Springer and Scott, 2003). Gastropod shells in this unit are dated with a range of 31,300 ± 2,500 yrs BP to 22,600 ± 2,500 yrs BP, and corrected by Haynes (1967) based on the age of other carbonate-carbonized wood pairs and a rough estimation of sedimentation rate to 15,000 yrs BP at the top of Unit D. Green mudstones which are likely part of Unit D underlie the southern and lower portion of Corn Creek Flat (Quade, 1986). The full thickness of this unit is rarely observed due to deflation and erosion of the upper portion.

Unit D lends itself to paleoenvironmental reconstruction, due to its record of well-preserved paleoclimatological indicators (Rowland and Bonde, 2015). Abrupt transitions between cold and warm climate, wet and dry conditions, and the response by a wetland system are all recorded in the sediments of this unit (Manker et al., 2015). Unit D is at least partially correlative with late Wisconsin glaciation lacustrine deposits throughout the Great Basin, such as Lake Lahontan and Searles Lake (Quade, 1986).

Several subunits were denoted by Haynes (1967), D_1 shows evidence of discharge episodes separated by erosion and soils which represent periods of surface stability (Manker et al., 2015). This unit is dated to about 35,000 to 34,000 yrs BP and exhibits lithology consistent with both pond (limnocrene) and stream (rheocrene) discharge (Manker et al., 2015) (Figure 4).

Unit D_2 has been dated to between 31,000 to 27,500 yrs BP and exhibits lithology consistent with marsh discharge (helocrene). Unit D_3 has a similar lithology, but has been dated to 25,800 to 24,400 yrs BP (Manker et al., 2015).

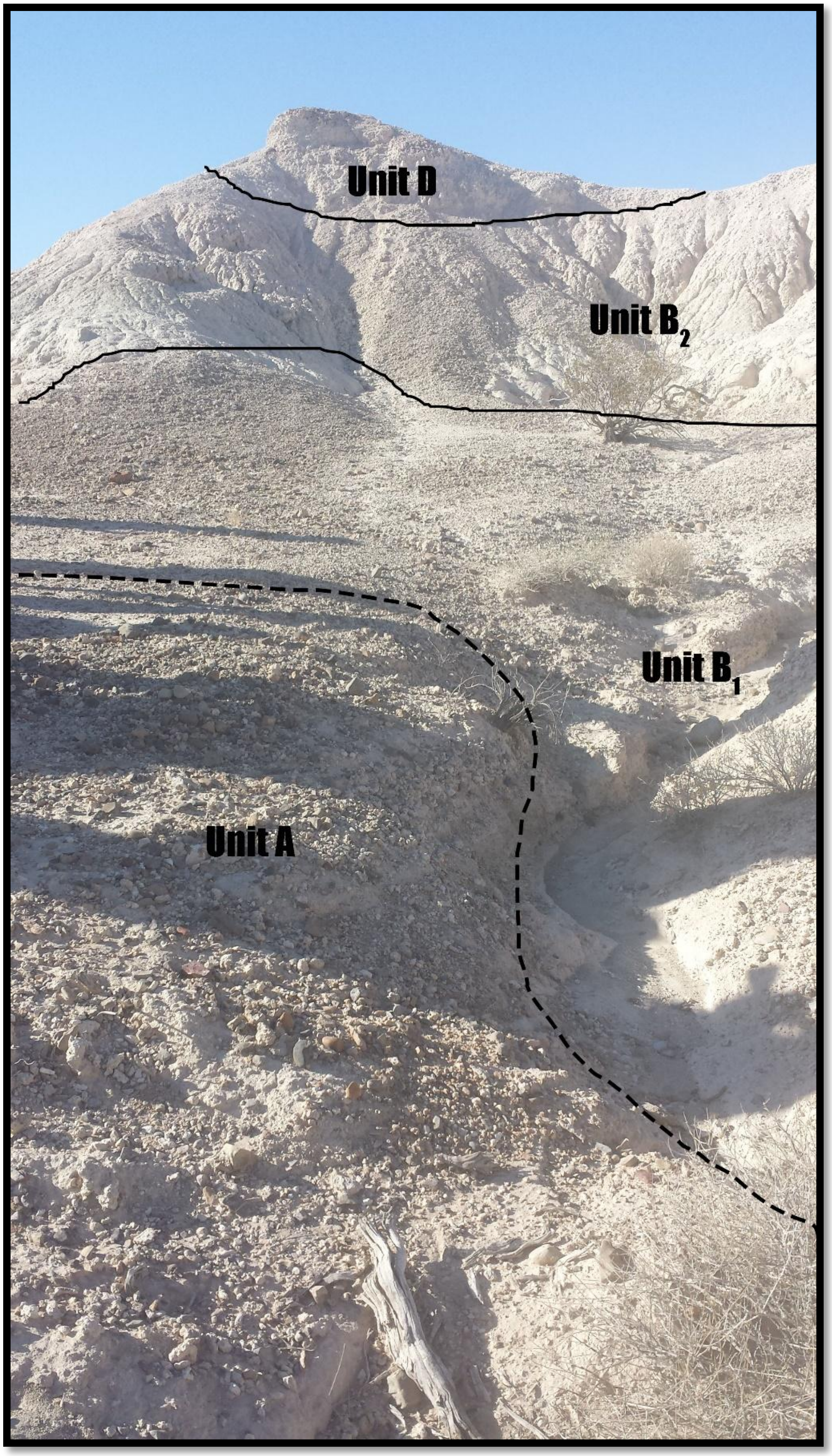

Figure 4. Units B_1 and B_2 overlying Unit A. Unit B_1 represents a dry period, with storm/flood intervals. Unit B_2 represents a wet interval, with spring discharge features. Unit D is a carbonate cap formed very quickly in wet conditions.

Soil 3 divides Unit D from the overlying Unit E, and was partially eroded in most areas prior to deposition of Unit E (Quade, 1986). The pedogenic interval forming Soil 3 ended by 133,500 yrs BP in Tule Springs, and by 14,000 yrs BP in Corn Creek (Quade, 1986). Cicada burrows throughout the soil are indicators of moist conditions during formation (Quade, 1986). Soil 3 not preserved well enough to determine the full length of the pedogenic interval (Quade, 1986).

Unit E is an alluvial gravel and silt deposit that represents the final desiccation of the Tule Springs area (Haynes, 1967). The unit dates from between 14,000 yrs BP to 8,600 yrs BP (Quade, 1986). Haynes (1967) divided the unit into two subunits, based on their phases

Unit E_1 contains abundant rolled caliche fragments, with origins in Unit D (Haynes, 1967). The original Fenley Hunter obsidian flake and camel remains were recovered from either this layer or Unit E_2 (Simpson, 1933, Haynes, 1967). Definite lithic artifacts were recovered from this layer, and dated between 10,000 and 11,200 yrs BP (Haynes, 1967). Concentrations of animal bones, fossil plants, and spring-feeder tufa are also present (Haynes, 1967). Carbonized wood, mollusk shells, and tufa have produced radiocarbon dates between 11,800 and 13,500 yrs BP (Haynes, 1967; Quade, 1986).

Soil S4 is a moderately strong organic soil present in upper parts of Unit E_1, but is typically eroded away (Haynes, 1967). This soil has been interpreted to be the remnants of wet-meadow soil restricted to the Unit E_1 channel fill (Haynes, 1967).

A period of degradation subsequently excavated a new, smaller channel along the same path as the E_1 channel, removing much of the subunit (Haynes, 1967). Unit E_2 is composed of silts and alluvial gravels, and filled began near 11,200 yrs BP, with an end point at 7,000 yrs BP (Haynes, 1967). The modern channel of Tule Springs Wash has its origin during an intense period of degradation, where stream overflowed the gravel channels and washed away silt facies (Haynes, 1967). The Gass Peak bajada is covered with alluvial-fan facies of this unit (Haynes, 1967). The upper portion of E_2 produced one carbon sample suitable for dating in the 1960s, and has an age of 7,500 years (Haynes, 1967).

Soil S5 lies above gravel ridges of Unit E_2, and is a weak surface representing weathering since abandonment of the channels (Haynes, 1967). E_2 ceased aggradation and began degrading roughly between 6,000 and 7,000 years ago (Haynes, 1967). The area began to shift toward its current topography, and occupation by Desert Culture peoples is evident (Haynes, 1967).

Unit F consists of gravels and finer grained facies which represent the establishment of a stream grade at the end of the degradation period (Haynes, 1967). Unit F is divided into subunits F_1 and the overlying F_2, which display a repetition of the same cycle (Haynes, 1967).

Unit G consists of gravel that extends from the Gass Peak bajada into Tule Springs, and has not been eroded much since deposition (Haynes, 1967). This unit represents the last significant deposition of sediment at Tule Springs (Haynes, 1967).

Eglington Scarp and fault activity

The Nevada Bureau of Mines and Geology concluded in 2013 that there is evidence for a higher slip rate for the Eglington fault in the Las Vegas Valley than the 0.1 mm/yr previously recognized (DePolo et al., 2013). Radiocarbon dates constraining the age of Unit D and an upper portion offset by 10 to 14 m support the higher slip rate hypothesis (DePolo et al., 2013). The age of this offset is estimated to be 18 to 40 ka, with a preferred value of 22 ka (DePolo et al., 2013). The likely slip rate of the Eglington fault is therefore 0.6 mm/yr, with a range of 0.25 to 0.9 mm/yr (DePolo et al., 2013).

Eglington fault is marked at the surface by a flexure, rather than a discrete scarp, which may represent the fault-propagation fold of a relatively immature fault (DePolo et al., 2013). Southern Nevada is known to exhibit an episodic pattern of strain accommodation, which helps to explain this current high rate of displacement (DePolo, 2013).

History of Geologic Research

Josiah Spurr, 1903

Josiah Spurr, who is most well-known for leading two historic expeditions into Alaska for the United States Geologic Survey, published the first geologic survey of Nevada while working for the USGS in 1903. Considered one of the fathers of economic geology, his main focus in the area was ore deposit survey. Spurr described in broad detail the Las Vegas Valley and its surrounding mountain ranges in the first official map published of the region (Figure 5).

Figure 5. J. Edward Spurr (Middle), San Francisco, CA, 1896. (USGS Survey Portrait Photo 3321).

Though primarily concerned with the structure of the region, Spurr and his team investigated the Paleogene through Pleistocene deposits of Corn Creek and Tule Springs (Spurr, 1903). R.B. Rowe, the assistant geologist attached to the Spurr expedition, collected "Mastodon" teeth from a valley "some distance" west of Las Vegas (Spurr, 1903). These remains were likely misidentified and belonged to *Mammuthus columbi* (Columbian mammoth), but there is still uncertainty as they were not entered into formal collections. Another instance of "mastodon" teeth and bones were collected midway between Corn Creek and Tule Springs, from a clay bank between 3 to 4.5 m thick (Spurr, 1903). This represents the first record of collected fossils from a TUSK locality.

Spurr interpreted the Las Vegas Wash to be comprised of lake deposits, based on what appeared to be playas (Spurr, 1903). These deposits did not have the appearance of Tertiary lake deposits, but resembled clay deposits commonly found in modern dry lakes (Spurr, 1903). These fine grained deposits were noted as overlying gravel or talus deposits (Spurr, 1903). It is likely that Spurr had been inspecting what are now termed Unit B and Unit A. This interpretation would hold through subsequent investigations until the 1970s, when Mifflin and Wheat (1979) documented stratigraphic and fossil evidence of a paludal depositional environment.

Rowe also noted an apparent series of old, dry lake deposits in the Las Vegas Valley being cut into by arroyos (Spurr, 1903). These deposits, linked with a surficial rise of about 120-180 m between Tule Springs and Corn Creek, indicate comparatively recent elevation of the upper end of the Las Vegas Valley (Spurr, 1903). On the East side of the Las Vegas Range, Paleogene beds dip slightly toward the Colorado river at an angle of 4-5^{o}, which suggests that the range has been raised slightly since the general elevation of the region, encouraging flow through the Las Vegas Wash (Spurr, 1903; Quade, 1986; Donovan, 1996).

In the end, Spurr and his team found little in the way of ore prospects near the Las Vegas Valley, and only in the extreme southern part of the Spring Mountain Range. The Potosi or Yellow Pine mining districts were referred to as "old," even at the time of the 1903 report, but new veins of argentiferous galena (silver ore) were found in limestones of these sites (Spurr, 1903).

Chester Stock, 1919

Chester Stock, a well-known professor of vertebrate paleontology from the California Institute of Technology and the Los Angeles County Museum, conducted field work in southern Nevada shortly after his graduation from the University of California Berkeley. His main areas of study were the Pleistocene fauna of Rancho La Brea and correlation of the scattered mammalian assemblages throughout the Great Basin and Pacific Coast regions (Simpson, 1952). This work was conducted in 1919, where he and his field partner Richard J. Russell recovered fossil material from Tule Springs (Simpson, 1952).

A journal entry by Russell embodies the dedication and sardonic wit of these early fossil hunters:

> "Fossil hunting was terrible along Muddy Valley. Day after day, and in terrific heat, we would walk along the topographic complexities of the badlands, Chet on one ledge and I on another nearby. At length a prayer would be heard from Chet, a prayer of request starting with a petition for the complete skeleton of some extremely rare Tertiary mammal. In continuation it would ask for a jaw, for a tooth, for a tooth fragment, for a leg bone, a vertebra, and eventually

> terminate with some such statement as, 'If Thou seest not fit to reward Thy sweating but humble servants, the lowly paleontologists who scan with care each mineral grain of Thy creation under the rays of Thy ever-shining sun, with even the astragalus of a camel, wilt Thou grant unto Thy humble supplicants the pleasure of finding at least one bone fragment, one splinter, or the tiniest chip of some animal creation which once lived, loved, and roamed in these Thy broad dominions.'"

Stock and Russell collected mammoth tooth fragments, horse (*Equus*), bison (*Bison*), and partial phalanx of North American lion (*Panthera atrox*), but never formally published (Springer et al., 2011). These specimens are currently housed at UCMP Berkeley, and are the oldest located vertebrate fossils from the region.

Hunter and Silberling, 1932-1933

Fenley Hunter and Albert C. Silberling conducted field work from Dec. 30, 1932 to Feb. 3, 1933 (Simpson, 1933). Hunter donated the majority of material collected to the American Museum of Natural History (AMNH) (Simpson, 1933).

Preparators included: Albert Thomson, Carl Sorensen, and others. Dr. N.C. Nelson provided consulting regarding the "probable" association of man (at the time) with the fossil mammals. Edwin Colbert also provided research assistance. Simpson was not directly involved with the expedition, but contributed the write-up for publication by the AMNH.

The majority of work was done in two separate camps along the main drainage of the Las Vegas Valley, and northwest of 1930s Las Vegas. One camp was located at Indian Springs, but did not yield major discoveries. A more productive camp was located "five miles east of the Tule Springs turnoff from the main highway" (Figure 6) (Simpson, 1933).

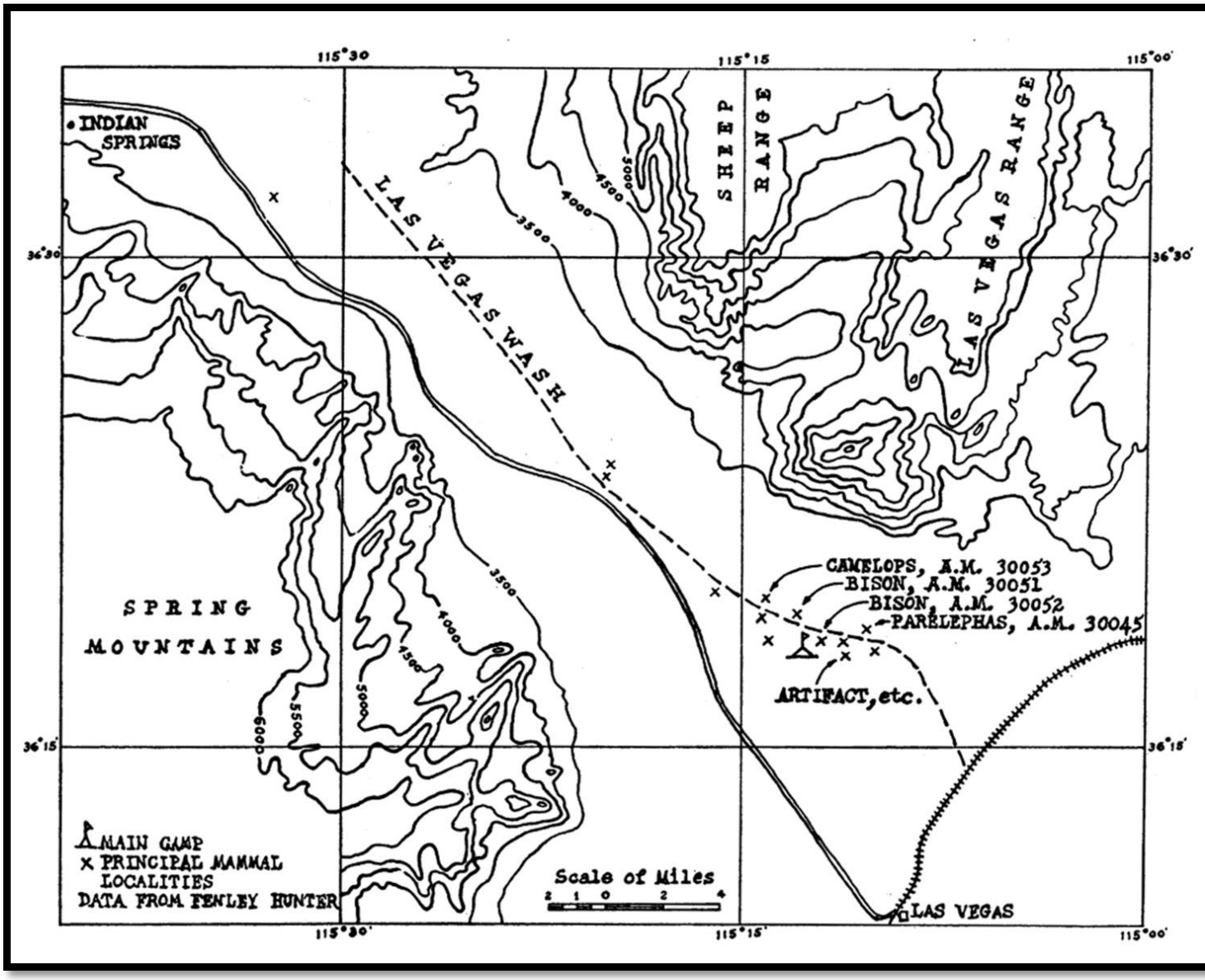

Figure 6. Simpson's (1933) map of the Las Vegas Wash, with Hunter and Silberling's fossil localities denoted. Note distance between Las Vegas and Tule Springs (Main Camp), which has decreased with urban development.

Hunter and Silberling described the Las Vegas Valley as a structural valley between ranges of block-faulted mountains, the bases of which are covered by fanglomerates. The older parts were interpreted to be contemporaneous with the less coarse but more distinctly stratified Pleistocene beds from the middle of the Las Vegas Wash (Simpson, 1933). The oldest part of the exposed series was noted as being comprised of tan-colored clays, which are either incised or disconformably superimposed by light-colored beds that the workers interpreted as stream channel and flood plain deposits (Simpson, 1933). This description matches well with Haynes (1967) Units A and B. The authors mentioned that directly above these beds is a series of buff sandy clays, also overlain by a series of lighter color, which is a likely description of Haynes (1967) Units C through E or F. The upper beds did not yield identifiable fossils, and most closely correlate to Haynes (1967) Unit F or G. Hunter and Silberling interpreted the formation to be aeolian, with the exception of the possible stream deposits in the lower section of the Pleistocene beds.

All fossils from this expedition were noted to have been collected from these light-colored strata. The discovery of aquatic molluscan fauna throughout the mammal-bearing beds informed the authors of past climate change. The presence of these molluscs suggests a similar environment to the shallow freshwater lakes or ponds of the modern Great Basin (Simpson, 1933). Periods of higher precipitation were followed by more arid times (Simpson, 1933, Longwell et al., 1965).

They noted that erosion had altered the series of old sediments, and small changes in the sedimentary balance are visible in the sand and gravel which comprise the floor of the Las Vegas Wash. The Wash itself cuts into the more extensive deposits of a previous cycle.

Five major exposures of the old sediments were visible in the study area, but only two were eroded deeply enough to expose a diagnostic fossil horizon (Simpson, 1933). The lower levels of the upper beds contained unidentifiable bone fragments. The mammal-bearing series yielded mammoth remains at fifty-two different localities. The majority of these fossils were dissociated, and consisted of broken bones and teeth, but some skulls and jaws were present. The bones were relatively light in color and had lost some organic matter, but almost no secondary mineralization was present.

Hunter and Silberling noted that poor weather conditions prevented them from further studying the stratigraphy and surface geology. Simpson recommended further study in order to properly place the various beds into context. Preliminary interpretations at the time suggested that the fossiliferous deposit was Pleistocene or earliest post-Pleistocene, determined by the faunal assemblage (Simpson, 1933).

Harrington, 1934

Enough interest was generated by subsequent findings to warrant paleontological investigation by the American Museum of Natural History in the early 1930s. Simpson (1933) described the famous obsidian flake of human manufacture as being found in a deposit that contained material from an extinct camel. Peripheral research by M.R. Harrington (1933) pointed to the possibility of early man associated with extinct ground sloths at Gypsum Cave, 25 miles southeast of Tule Springs.

Earlier work had shown that the Las Vegas Valley was occupied by aboriginal people as long as 10,000 years ago likely due to the plentiful springs found in the region (Harrington, 1933; Harrington and Simpson, 1961; Shutler and Shutler, 1962).

Harrington conducted archaeological excavations in 1933 and again from 1954 – 1956, and the location became known as the Tule Springs Site. Throughout his career, he favored the Masterkey journal, published by the Southwest Museum of Los Angeles, CA. This journal was primarily filled with transcripts and summaries of personal accounts, in the style of narratives or field notebooks, and captures the voice of the time.

Longwell, 1965

Chester Ray Longwell spent five months in 1919 mapping for his doctoral dissertation, but did not focus on Tule Springs until much later in his career (Rodgers, 1982). During his initial study, the area was still primitive, and travel was done by mule or horse, camping with local hermits, prospectors, and natives of the region (Rodgers, 1982).

In cooperation with the USGS and the Nevada Bureau of Mines, Longwell and others published a new geologic map of Clark County in 1965. The comprehensive report subdivided the Cenozoic deposits of Tule Springs, along with synthesizing information from through throughout the county. The Las Vegas Formation was initially characterized in this report, documented as being exposed from the vicinity of 1960s Las Vegas to a point several miles west of Indian Springs (Longwell et al., 1965). The authors noted that Pahrump Valley contains deposits very similar to those of the Las Vegas Formation, but cautions that this conclusion is based on incomplete mapping (Longwell et al., 1965).

Deposits near Indian Springs are at altitudes greater than 1,000 feet higher than exposures near Las Vegas, and are separated in areas where coarse alluvium from the surrounding ranges has reached its maximum development (Longwell, et al. 1965). The largest of these fans described by Longwell et al. was built by a stream originating in Kyle Canyon, and lies opposite a similar fan extending south from the Sheep Range. The junction of these fans may have separated shallow lakes from the wide flood plains evident in the exposures of Corn Creek and Tule Springs.

Further south, near Davis Dam and other various scattered localities, Longwell et al. noted deposits of clay, silt and sand, in a similar sequence to those of the Las Vegas Formation. These units were grouped into the Chemehuevi Formation. Whitish lake deposits extend through the Virgin and Muddy Valleys and contrast strongly with the buff-colored deposits of the Muddy Creek Formation (Longwell et al., 1965). The Chemehuevi Formation fills a valley cut into cemented river gravel and sand near the junction of the Virgin and Muddy Rivers, indicating that it existed much later than the deposition of the earliest exposed river gravels (Longwell et al., 1965). An elephant tooth and a bison horn were recovered from sediments of the Chemehuevi Formation, which help to confirm a late Pleistocene date (Newberry, 1861, Longwell 1936). It is possible that the Chemehuevi Formation is contemporaneous with the Las Vegas Formation, but further work is needed to confirm this. Pleistocene Lake Chemehuevi may have partially controlled the drainage from the Las Vegas Valley, as evidenced by widespread deposits at elevations near 2,000 feet (Longwell et al., 1965).

Between numerous fossils collected and the overall characteristics of the deposits, Longwell et al. concluded that the Las Vegas Formation preserves a solid record of climatic conditions during the Wisconsin glaciation (~85 k to 11 ka).

Haynes, 1967

C. Vance Haynes was the primary geologist attached to the 1962-1963 “Big Dig.” Haynes (1967) had three primary goals during the project: to determine the stratigraphic relationships of its artifacts and fossils in order to establish a stratigraphic framework; to determine the relationships between the geology of the Tule Springs site and the surrounding region; and to place data recovered from Tule

Springs in correct perspective with late Pleistocene events of North America. This expedition took place during 4 and a half continuous months from 1962 to 1963.

The main site of the "Big Dig" lies in the right bank of a badland area known as Tule Springs Wash. This site is 10 miles north of Las Vegas (at the time) and 5 miles east of Tule Springs Ranch. The site datum stake (36^{o} 19' 00" N and 115^{o} 11' 23" W) was placed at 2,307 ft above sea level (Haynes, 1967).

A pair of radiocarbon dates taken by Harrington and Simpson (1961) yielded dates of greater than 23,000 years, which renewed interest in the prospect of investigating the presence of early man. The purpose of the Nevada State Museum Tule Springs Expedition was to bring together a multidisciplinary team to determine the geochronological position of the animal and artifacts of the site.

Haynes conducted a series of mapping projects throughout the area, at a scale of 1:240. The initial site mapped was referred to as the Tule Springs Site, and measured 700 x 2,200 ft. Low altitude aerial photography at a scale of about 1:1,200 was utilized here to further verify the precision of the mapping. Additional sites were included, and the mapped portion became known as the Tule Springs Site Area. The total area mapped during the expedition was 1.47 square miles, on a scale of 1:4,800.

Further geological studies were conducted on a reconnaissance basis, extending an area of the Las Vegas Valley from 2 miles north (of 1960s Las Vegas) to 4 miles beyond Corn Creek Springs (Desert Game Range Headquarters). Four sites of particular interest were examined in greater detail: Eglington Scarp area; Tule Springs Ranch; Gilcrease Ranch area; and the Corn Creek Springs area. Information for each may be found in the 1967 Nevada State Museum Papers.

During the Big Dig, localities within the TUSK area were numbered 1 – 38, with those outside the area numbered subsequently. Bulldozer trenching provided the means to view and construct detailed cross sections of the stratigraphy. More than 2 km of trenching was dug, with each trench approximately 15 feet deep, and mapped at a horizontal scale of 1" to 20 feet, and a vertical scale of 1" to 10 feet. Erosional contacts and paleosols were the main criteria for determining how to divide the strata into units (Haynes, 1967).

Haynes further divided relevant units of the Las Vegas Formation into the Tule Springs strata with letter designations A through G, with subscript numerals 1 through 3, and soils designated S1 through S6. Based on previous work and the sediments sampled, Haynes (1967) originally interpreted the presence of a tule-fringed lake occurring in Tule Springs during the deposition of Unit D. He termed this past body of water "Pluvial Lake Las Vegas," but subsequent work, particularly by Quade (1986) does not support this model.

Longwell, 1974

In 1974, Longwell consolidated evidence for a major strike-slip fault zone in the Las Vegas Valley (Rodgers, 1982). This was the first official recognition of the Las Vegas Valley Shear Zone, which has a large-scale, right lateral offset extending northwest across the mountain ranges bordering the Las Vegas Valley (Longwell, 1974). Large landslide masses of metamorphic and granitic rock are found in the Thumb Formation of Frenchman Mountain, east of Las Vegas (Longwell, 1974). These blocks moved southward from an area where only sedimentary strata are exposed (Longwell, 1974). Isotopic dating of the Thumb Formation in Frenchman Mountain indicates an age of ± 17 million years, placing this movement in the Miocene (Longwell, 1974).

Quade, 1980s

Jay Quade, a student of C.V. Haynes conducted field work for his 1967 thesis at Corn Creek Flat and Tule Springs. Quade (1986) is his formal publication with the goal to examine the possible paludal origin of the fine-grained deposits.

A large portion of Quade's project was to test the validity of Haynes stratigraphy throughout Tule Springs, and to extend the correlation of units further to Corn Creek.

Quade (1986) noted secondary carbonate in Unit D, with lesser amounts in Units A and B. This carbonate forms resistant ledges and is commonly found as nodular rubble throughout the site. It is likely the result of capillary fringe cementation, and not formed by a lacustrine (Quade, 1986). The carbonate is found with a vertical distribution, and does not correlate with other pedogenic features or stratigraphic breaks (Quade, 1986). Bioturbation by burrowing cicadas is apparent in subaerial deposits of Unit D, and the secondary carbonate takes on a pseudomorphic character after the burrows, silty horizons, and cross-bedded sand (Quade, 1986). The frequency of occurrence of this secondary carbonate increases toward the valley center, especially within mudstones of Unit D.

Quade determined that deep lacustrine environments capable of producing strandlines were not found in the Las Vegas Valley during glacial intervals. The fine grained sediments of Corn Creek and Tule Springs were therefore determined to be deposited by spring-fed channels and marshes. A shallow "Pluvial Lake Las Vegas" may have been present near Tule Springs, but is not representative of the overall depositional setting of Unit D (Quade, 1986). His evidence suggests that paludal conditions produced small, shallow bodies of water in the center of the Las Vegas Valley, surrounded by a broad fine-grained alluvial flat.

Multiple lines of evidence, including sediments, pollen, and fossil middens were recorded by Quade (1986) to suggest decreasing effective moisture since 14,000 yr BP. Conditions similar to modern were achieved roughly between 8 to 7 k yr BP, but the timing and duration of the change do not necessarily reflect other pluvial lake chronologies within the Great Basin (Quade, 1986).

Donovan, 1990s

Donovan (1996) proposed the term "Tule Springs Alloformation" to incorporate some of the sediments assigned by Haynes (1967) to the Las Vegas Formation. The geologic units mapped in both the alluvial fans and playa in the northwest Las Vegas Valley are stratiform bodies of sediment characterized by bounding discontinuities that are marked, in part, by caliche horizons (Donovan, 1996). The stratigraphic units as defined by Donovan (1996) were stratiform but vary internally in lithologic character. These allostratigraphic units are useful to define aquifers in the Las Vegas Valley, but traditional units are more appropriate for geologists and paleontologists who are examing the depositional regime which produced an assemblage of fossils. (Springer and Scott, 2003).

Donovan (1996) contains complete descriptions of the Tule Springs Allostratigraphic units, which combine the traditional Haynes (1967) units according to their importance to the understanding of the hydrogeology of the site. TUSK has potential for future hydrologic research, particularly in the study of the effects of structure on groundwater movement and aquifer recharge (Donovan, 1996).

SBCM and USGS, 2000s

The Division of Geological Sciences of the San Bernadino County Museum (SBCM) was contracted by Nevada Power in the early 2000s to examine and mitigate adverse the impacts to significant nonrenewable paleontologic resources of a transmission line and associated roads. SBCM identified 36 previously unrecorded localities and recovered nearly 10,000 fossil specimens from the Las Vegas Formation (Springer and Scott, 2003).

The SBCM team recognized a system of braided fluvial tufas and black mats within the deposits at TUSK, and determined them to be groundwater-fed and of late Pleistocene age (Figure 7) (Springer, et al., 2012). The tufas formed at ambient temperatures, and are controlled in part by the presence of microbial mats (Springer et al., 2011). Varying morphologies are seen throughout this system, including phytoclasts, oncoids, cyanoliths, and stromatolites (Springer et al., 2011). Surficial lag deposits of tufa are commonly found placed by eroded fluvial sediments and resting on top of Unit D (Springer et al., 2011). The resulting alignments may be traced for several kilometers, providing insight into paleocurrents (Springer et al., 2011). The presence and character of tufas at TUSK provide a chronology of the transition from last glacial maximum climatic conditions and patterns of spring discharge.

During their tenure at the site, SBCM teamed with the USGS to obtain new thermoluminescence dates on Haynes (1967) units at multiple localities. A publication containing final dates and further information is under review at the time of writing.

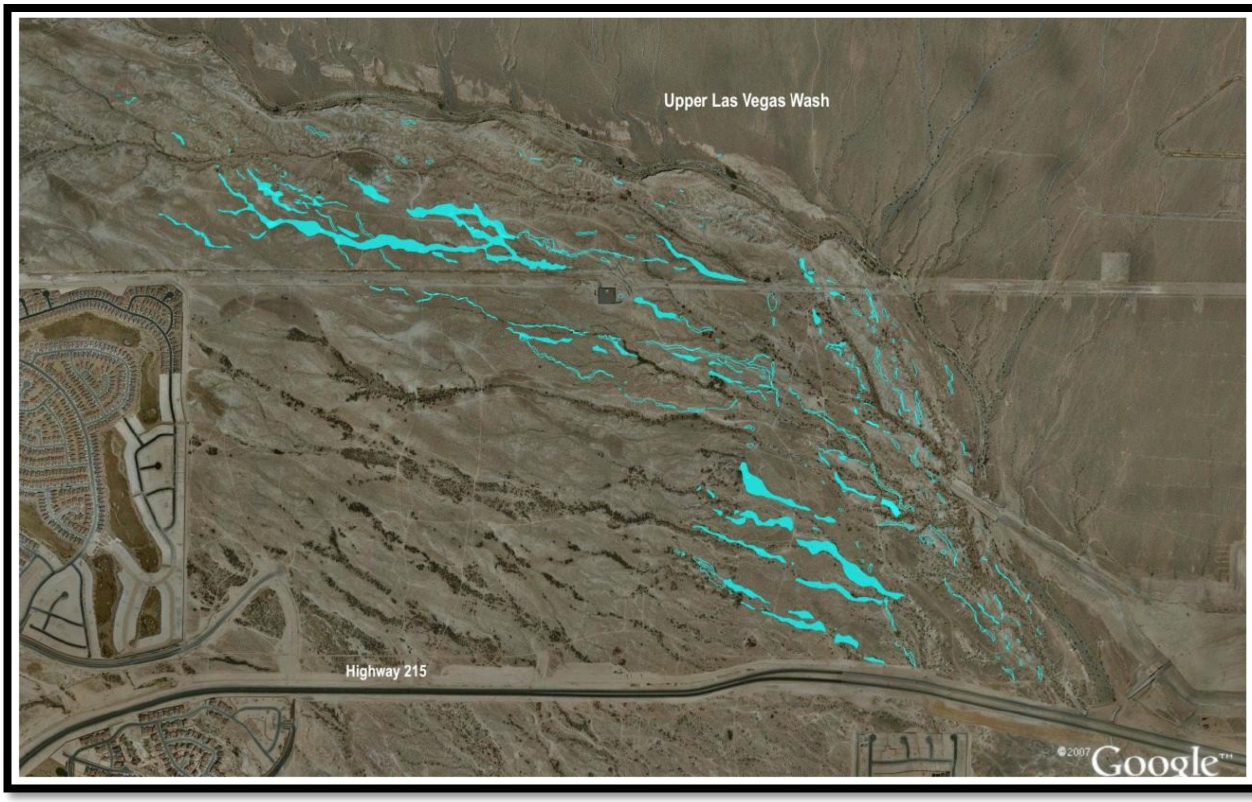

Figure 7. Groundwater-fed tufa system found throughout TUSK (From Springer et al., 2011).

UNLV, 2000s

In 2005, Stephen M. Rowland, from University of Nevada Las Vegas (UNLV) partnered with instructors at Shadow Ridge High School (SRHS) in order to create a pilot course in earth science curriculum (Teran et al., 2005). The objective of this project was to create an engaging and hands-on study that utilized the close proximity of SRHS to TUSK in an effort to generate interest and excitement for earth science in high school students (Teran et al., 2005). Sediments were collected from of TUSK, particularly from the remains of the 1960s trenches, and screened for microfossils. Several distinct invertebrates, notably gastropods were recorded, and population density was estimated.

Columbian mammoth teeth recovered from the nearby Gilcrease Ranch site were used as a basis for cast replicas used in a multiple-unit high school and college exercise in the paleontology and population dynamics of mammoth. The program was largely successful, and received funding from the National Science Foundation. Rowland has since expanded the availability of the course to multiple high schools throughout Las Vegas.

Researchers and students from UNLV previously surveyed and excavated the state park land associated with TUSK, notably collecting a partial tusk of a Columbian mammoth in 2010.

CHAPTER 4

Paleontologic investigations at TUSK

By Aubrey Bonde

Overview of paleontological investigations

Tule Springs Fossil Beds National Monument (TUSK) has been the subject of numerous studies since the early 20th century. The focus of these studies evolved throughout this time beginning with geologic mapping, in 1903, and then transitioning to an archaeological focus and later to paleontological investigations. The latter, of which, was not fully appreciated until the second half of the century. In 1962, the natural history resources from TUSK were analyzed with the direct intention of studying the fossils, albeit relating that back into the human-megafauna interaction hypothesis. It was at this time that the most significant realizations were made when it was recognized that the fossils from TUSK were not just a tool to correlate culture with beast, but afforded the opportunity to gain a much larger understanding of regional environmental dynamics of the Late Pleistocene. TUSK fossils are a critical component in interpreting the biogeography and paleoecology of Late Pleistocene mammals and for reconstructing the last vestige of the Ice Age environments in southern Nevada.

Through the decades, many thousands of fossils have been recovered from TUSK and from over 500 recorded localities (Figure 1). The following section captures the role that paleontology played in each investigation to the site. All catalogued specimens currently housed in museum collections have been collected into one database and are listed in Appendix B. The exception to this, are San Bernardino County Museum (SBCM) collections; theirs are too abundant to include in this database (numbering over 100,000 accessioned specimens) and have their own database which is not included in this report. By far, the most well represented taxa, in terms of sheer numbers of elements recovered, are camel, bison, horse, and mammoth. In addition to these taxa, a number of other large mammals, microvertebrates, herpetofauna, aves, and invertebrates have been recorded and each reveals a unique story of environmental tolerances and requirements. When analyzed in combination they may reveal distinct community dynamics such as ecological interactions, competition and partitioning.

The paleontology resources of TUSK are overwhelmingly abundant, as outlined in the following section and evident in the reason for establishing the monument. Yet, it is worthy of noting that the magnificent thing about the monument is that the potential for fossils starts anew after every rainstorm with the exposure of buried material. This creates a sense of excitement and underlying mystery for the potential of many, many resources that remain to be discovered and preserved because of the protection of TUSK.

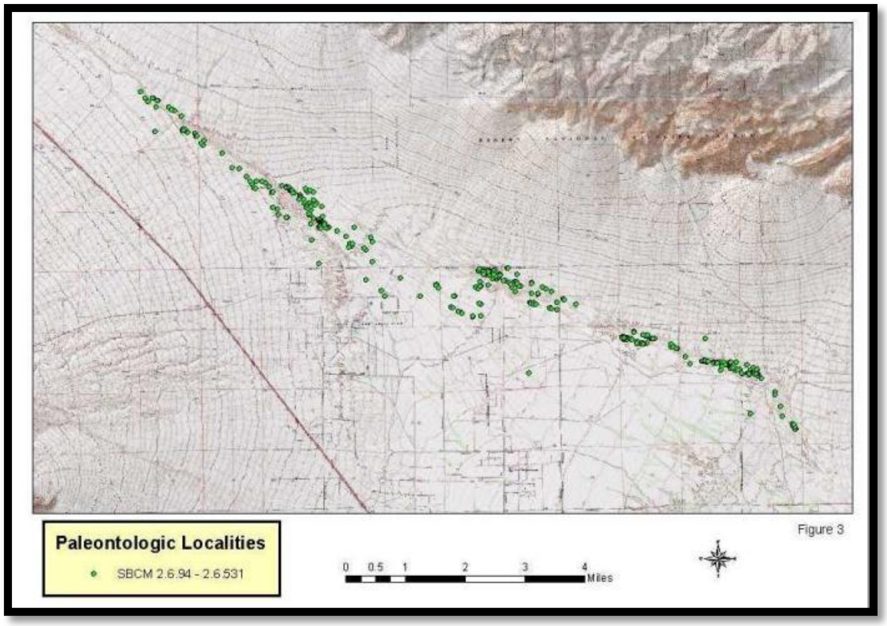

Figure 1. Fossil localities placed on a geologic map of southern Nevada. All green dots represent paleontology resource sites and it is apparent how they follow the exposures if the Las Vegas Formation in the Upper Las Vegas Wash. Image from Springer *et al*. (2005).

Chronology of paleontological investigations

Josiah E. Spurr & R.B. Rowe, 1903

Spurr and Rowe's investigations into southern Nevada predated even the establishment of Las Vegas (est. 1905). Spurr was contracted by the U.S. Geological Survey (USGS), and Rowe an associate of the USGS set out to map the geology of Nevada and it was on this survey that they discovered one fossil site located between Corn Creek and what is now considered the south unit of TUSK. The site is represented by a small number of bones and teeth (Spurr, 1903). Rowe's initial designation of these elements was mastodon (*Mammut americanum*) but given the overall lack of mastodon from TUSK and the surrounding area, and the abundance of mammoth material, the specimens can likely be attributed to mammoth (*Mammuthus columbi*). Further clarification of these specimens is not possible at this time as it is unbeknownst as to where the collected material was reposited. However, recent communication with USGS personnel reveals that Rowe and Spurr's material was never housed within the USGS vertebrate paleontology collection as the 1903 expedition predates any regional divisions and a catalogue for vertebrate fossils (Kevin McKinney, USGS fossil collection curator, pers. comm. August 4, 2015 to Aubrey Bonde). The USGS personnel imply that the only logical place Spurr's collection would reside is at the National Museum of Natural History (NMNH). To this end, the curator and the collections manager of vertebrate paleontology at NMNH have been contacted and are currently combing their collections to aid in solving this cold case (Kay Behrensmeyer, NMNH curator of vertebrate paleontology, & Michael Brett-Surman, NMNH collections manager of vertebrate paleontology, pers. comm. August 5, 2015 to Aubrey Bonde).

University of California Museum of Paleontology, 1919

Chester Stock & Richard J. Russell

Stock and Russell, both associated with the University of California Museum of Paleontology (UCMP) located in Berkeley, were keen to expand the paleontology collections at the museum. Which led to their motivations into investigating the exposures in southern Nevada; collect Quaternary fossils for the UCMP. Stock and Russell's expedition was productive and their collected material was accessioned into the UCMP vertebrate paleontology collections [locality number 3552 and specimen numbers 23918-23926 (see Appendix B for full inventory)]. The material includes fragmentary bones and teeth from *Equus* sp., *Bison* sp., and *Mammuthus* sp., but most important of all was their discovery of specimen number 23918, *Panthera atrox*. This taxon was identified by a right proximal phalanx, pes digit IV (Figure 2) and is one of only a handful of elements recovered for this species. These specimens were never formally described in published literature but are important as they represent the earliest known fossils from TUSK that can be located in museum collections (Springer *et al*., 2011).

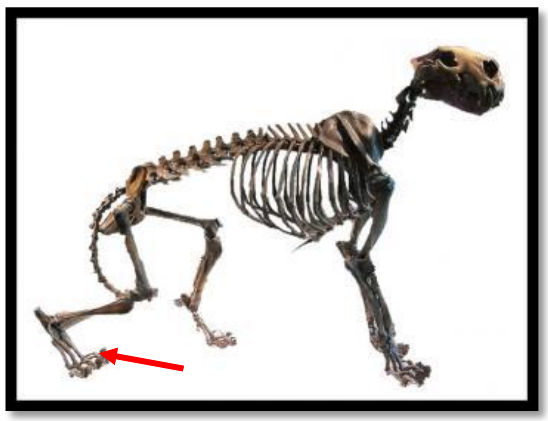

Figure 2. Skeletal mount of *Panthera atrox*, red arrow indicates the collected and identified element by Stock in 1919 (right proximal phalanx, pes digit IV). This element establishes the first record of *P. atrox* at TUSK.

American Museum of Natural History, 1932-1933

Fenley Hunter, A.C. Silberling, & Frank Bell

Fenley Hunter (American Museum of Natural History (AMNH)), A.C. Silberling (Montana), and Frank Bell (Tonopah, NV) explored the exposures of TUSK in hopes that they would be the first to scientifically record Pleistocene fossils collected from the state (Harrington, 1985). Fossils were collected from three main areas which were each subdivided into smaller sub-localities, in total, they discovered approximately 52 paleontological localities (Simpson, 1933). Most sites produced isolated, fragmentary bones and/or teeth, rare occasion provided associated pieces and complete bone, such as the nearly complete skull of *Bison latifrons* [=Simpson (1933) "*Bison occidentalis*"] and the partial mandibles of *Mammuthus columbi* [=Simpson (1933) "*Parelephas columbi*"], *Camelops hesternus,* and *Nothrotheriops shastensis* [=Simpson (1933) "*Nothrotherium*"] (Simpson, 1933). This latter species was the first record of ground sloth from TUSK. Small mammals were represented by jackrabbit (*Lepus* sp.) and pocket gopher (*Thomomys* sp.). The discovery of one small obsidian flake (Figure 3) encased within charcoal at a fossil site spurred decades worth of investigation and intrigue. This obsidian flake was interpreted to be a man-made tool, thereby assumedly placing megafauna overlapping with the presence of early humans in southern Nevada (Simpson, 1933). Obsidian does not naturally occur in the vicinity of Las Vegas Valley, so it was surmised that the flake was introduced by early humans for purposes of hunting and the charcoal was the evidence of their campfire. This was a novel idea at the time (e.g., Folsom, NM circa 1926) and TUSK provided a scientifically significant avenue of research in the identification of the cultural association of man/woman and megafauna. Researching this idea further had been tabled as the Hunter *et al*. expedition ended and all items were sent back to the AMNH. A few months later AMNH contacted the Southwest Museum, of which M.R. Harrington was head curator at the time, suggesting that a team from the Southwest Museum further the idea and investigation (Harrington, 1985). Recovered specimens from this expedition are still in holding at the AMNH along with maps, notes, and photographs. A list of all known fossil material in their collection can be viewed in Appendix B. NOTE - A partial skull of *Bison latifrons*, AMNH specimen 30051, which was transferred to the Canadian Museum of Nature in 1936; it remains in their collections today. Similarly, AMNH still retains a different partial *B. latifrons* skull in their collections, AMNH specimen 30052 (Figure 4).

Figure 3. Obsidian flake, 38 mm in length, collected by Fenley Hunter in 1932-33. This unassuming flake is what spurred decades of research into the question of cohabitation between early human and megafauna at TUSK. Image courtesy of the American Museum of Natural History, figured in Wormington and Ellis (1967).

Figure 4. Skull and maxillary teeth of *Bison latifrons*, AMNH 30052. One thing worth noting is that this specimen records exceptional preservation for TUSK, most recovered material is disarticulated and fragmentary.
SBCM image, figured in Springer *et al*. (2011).

George G. Simpson

Simpson, a renowned vertebrate paleontologist at the American Museum of Natural History, studied Hunter, Silberling, and Bell's collections and published the article "A Nevada fauna of Pleistocene type and its probable association with man" (Simpson, 1933). Simpson wrote and published this paper without ever having visited Tule Springs; his report was based off of Hunter *et al*.'s notes and photographs during the 1932-1933 expedition. Simpson reported on the general geology and paleoenvironment, described the fauna collected (see above section on Fenley Hunter and full list in Appendix B), and discussed the potential for contemporaneity with early humans based off of one obsidian flake comingled with a bone locality. Simpson strongly suggested that the obsidian was delivered to the bone locality by early peoples and the presence of charcoal indicated the site was used as a campfire during butchering. He further substantiated his claim by declaring the presence of more bone located stratigraphically above this site, insinuating the subsequent deposition of Late Pleistocene mammals after evidence of occupation. Simpson concluded that there was a promising future for researching human arrival in North America prior to the megafaunal extinction and the ensuing need for understanding the interaction of human and megafauna (Simpson, 1933).

Southwest Museum, 1933-1934 & 1955-1956

Mark R. Harrington

Harrington's story is one of length, as his is one of the most influential scientific contributions made not only to Tule Springs but to the state of Nevada. Commissioned by George Heye of the Museum of the American Indian in Washington D.C., Harrington first entered Nevada in 1924 to explore the archeological treasures of Lovelock Cave (Harrington, 1925). He ultimately formed a strong attachment to Nevada and found a life-long career exploring archeology across the state, even being christened "The Father of Nevada Archaeology" (Harrington, 1985). By 1925, Harrington had observed enough fossil material alongside cultural remains from prior expeditions to allude to their co-habitation. It was this same time that Gypsum Cave presented an opportunity for him to explore the idea in intricate detail. Harrington's early explorations and seminal works on Gypsum Cave began in 1925 while the bulk of excavation occurred between 1929-1931 and resulted in an great number of publications [refer to Harrington's biography for full list of publications (Harrington, 1959)] (Figure 5). Excavations in Gypsum Cave were assisted by the Southwest Museum, followed by the California Institute of Technology (with Chester Stock & E.L. Furlong), and then later the Carnegie Institute of Washington (with Merriam). Harrington concluded in his landmark composition of "Gypsum Cave, Nevada, Southwest Museum Paper #8" (1933) that this was an unambiguous instance of early man and Pleistocene animal interaction. Harrington's idea was subsequently tested in 1934 when he encountered Pleistocene camel and horse in association with cultural artifacts in southern Nevada's Smith Creek Cave (Harrington, 1934b). At that time, he interpreted charcoal and split bones to be a campfire meal by early peoples (Harrington, 1985). All of this was a precursor of what was to come and what he was yet to research at Tule Springs.

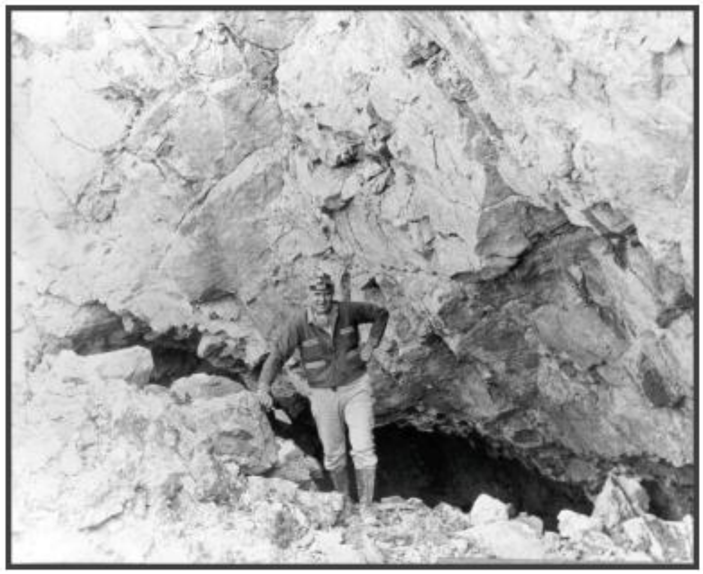

Figure 5. Mark Harrington standing at the entrance of Gypsum Cave, 1930. Gypsum Cave is located about 30 miles to the East of TUSK and contains a similar late Pleistocene fossil assemblage. Image from McBride (2005).

Harrington's first exploration to Tule Springs was in 1933 and was instigated by the collections of Hunter *et al*. and G.G. Simpson's 1933 paper. By this time, Harrington had moved West and was now curator of the Southwest Museum. He had been directly contacted by the AMNH requesting that he further the work at Tule Springs because the AMNH was unable to explore the project further and it was "with high probability, an authentic record of most ancient North American man" (Harrington, 1933a & b). With the assistance of Fay Perkins (Lost City Museum), Harrington made the first of several expeditions to TUSK in 1933. Paleontological resources collected during this dig included bones and teeth in various preservational states of *Camelops hesternus* (most abundantly represented), *Mammuthus columbi*, *Bison latifrons*, and invertebrate material (Harrington, 1934a). This expedition also yielded charcoal (interpreted to be fire hearths for cooking the bones), ash (considered a refuse dump which beared bones of camel and long-horned bison [later interpreted by SBCM to be *Bison latifrons* (Springer *et al*., 2010)] split for the extraction of marrow), and artifacts including a scraper, crude chopper, and other implements (Harrington, 1934a). The occurrence of bone, charcoal, and artifacts occurring in any one place was disappointing to Harrington, and the expedition was ended (King *et al*., 1978; Harrington, 1985).

With the exception of one reminiscent paper on the site describing a bone implement recovered during the 1933 dig, which Harrington gleefully found tucked into collections (Harrington, 1941), Tule Springs lay dormant until 1952. At this point, interest in Tule Springs resumed with the advent of radiocarbon dating, discovered by Willard Libby. In 1952, Harrington made a return trip to Tule Springs to gather charcoal for dating. Unfortunately, this trip proved to be unsuccessful as he and Ruth DeEtte Simpson (assistant curator at the Southwest Museum) failed to identify any more fresh charcoal for sampling. However, not all was lost. Two years later, in 1954, Ruth Simpson discovered charcoal samples from the 1933 expedition which had been unknowingly stored in a cabinet at the Southwest Museum. Simpson briskly sent Libby the samples, supplemented by Fenley Hunter's charcoal collection from the AMNH as to constitute a sizable amount needed for dating (King *et al*., 1978; Harrington, 1985). Revolutionary news revealed that the charcoal had been dated to over 23.8 Ka which was, at the time, the oldest date of human activity in the New World (Harrington, 1955; Harrington and Simpson, 1961). This prompted Harrington to expeditiously organize another outing beginning in 1955 and continuing into 1956. In attendance was Harrington, Simpson, and Charles Rozaire (also of the Southwest Museum), among other volunteers (Harrington, 1955). This second expedition uncovered more bone, seven fire hearths some of which contained "burnt bone" of a camel interpreted to have been butchered and cooked, and just one crude tool (Harrington, 1955). With the lacking presence of artifacts, Harrington concluded that the outcome of the expedition did not greatly differ from those prior. One significant result of this expedition was that a sample of charcoal was dated from one of the fire hearths and yielded a date of 28 Ka, the oldest date yet for TUSK (Broecker and Kulp, 1957; Harrington and Simpson, 1961). Given the disappointment of this second expedition, Harrington promptly arranged for a third, and final, excursion to Tule Springs, this time with the aid of paleontologist Phil Orr (curator of the Santa Barbara Museum of Natural History). This intensive 3-week expedition yielded more bone, fire hearths (some of which entombed "burned" bones of camel), and artifacts including a scraper correlated to the deposit which yielded the 23.8 date (Harrington, 1956; Simpson, 1956). Mammal bones were mostly fragmentary which was, in Harrington's opinion, the result of butchering and roasting by early humans (Harrington, 1934). Meanwhile, Simpson declared that this "proves beyond the shadow of a doubt that man was present at Tule Springs", although the temporal association is in question (Simpson, 1956; Harrington and Simpson, 1961). It was later determined that the date of 23.8 Ka was the result of mixed samples taken from the deposits of different formations (Shutler, 1967). The dated sample originated from two collections, charcoal from the 1933 expedition made by the Southwest Museum and charcoal from the 1932-1933 expedition made by Fenley Hunter. When combined, yielded an inaccurate and non-representative, time-averaged date. Vertebrate remains collected from the 1955-1956 field seasons include the aforementioned taxa from the 1933 dig as well as two species of *Equus*, *Odocoileus* sp., and *Nothrotheriops shastensis* (Harrington, 1955; Harrington, 1956). A full inventory of collected fossils from the 1933 & 1955-1956 expeditions are stored between two institutions, Autry National Center (Figure 6) and the Natural History Museum of Los Angeles County (LACM)* and can be viewed in Appendix B**. Historical photos of the 1955-1956 expeditions can be located in the archives of San Bernardino County Museum (SBCM). This was made possible by Ruth Simpson, who joined SBCM after her tenure at the Southwest Museum ended.

*NOTE – Upon its closure, Harrington's collection at the Southwest Museum was transferred to the Autry National Center. Communications reveal that Autry National Center has no long-term plans for the specimens and verbally agree to transfer them to a Nevada institution upon the completion of a multiple year survey and transition into a new facility (Vincent Santucci, senior paleontologist for the NPS, pers. comm. August 7, 2015 to Aubrey Bonde). In regards to the collection at LACM, Harrington had consulted Eustace Furlong (paleontologist at Caltech) for help identifying some material. These specimens were then retained at CalTech and later transferred to the LACM in 1957.

**NOTE – the taxa listed in Harrington's papers do not all cross-reference with museum collections. For example, Harrington published on the presence of deer (*Odocoileus* sp.) and ground sloth (*Nothrotheriops shastensis*) (Harrington, 1955; Harrington, 1956), at this time, the fossil inventory constructed for this report does not reflect the presence of these species in collections from the Autry National Center or LACM. Furthermore, two elements in the LACM collections (154687 & 154688) have been identified as *Hemiauchenia* sp., this taxon has not at all been acknowledged from TUSK and its actual presence would be a significant contribution if valid. Therefore, it is recommended that these fossils be visited within museum collections to confirm actual identification.

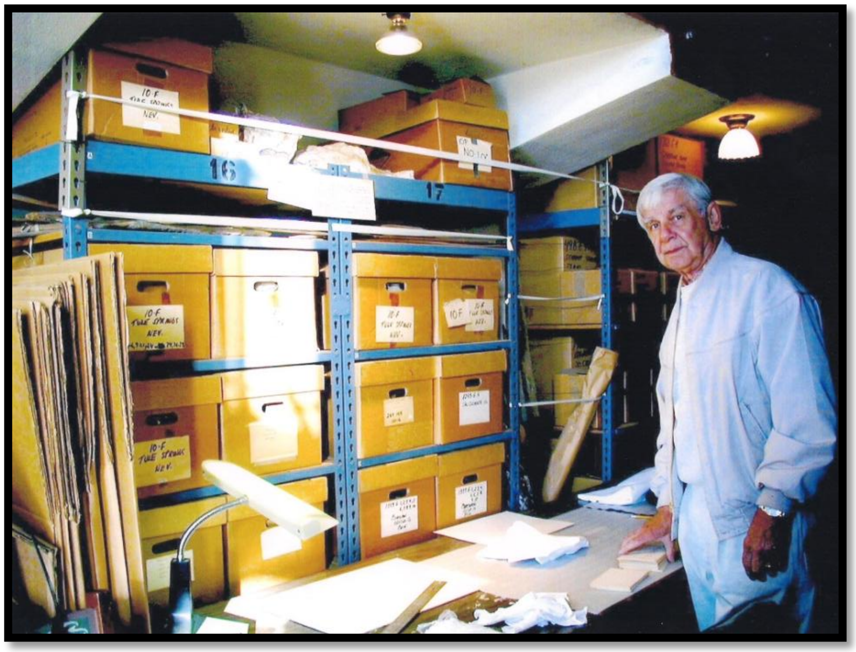

Figure 6. Photo of Tule Springs collections at the Autry National Center. All fossils, artifacts, and sediment samples are contained within the boxes labeled Tule Springs, site locality 10F. Figured is George Kritzman, former curator of collections. Photo taken by Helen Mortenson in 2009.

Phil Orr

Orr (curator of the Santa Barbara Museum of Natural History) was the first trained paleontologist to visit Tule Springs since Chester Stock in 1919, all others were accomplished geologists and archaeologists. Orr assisted the Harrington 1956 expedition to the upper Las Vegas Wash for two weeks and contributed to the mission through various fossil discoveries. He discovered new localities and an abundance of fossil material, but found the recovery of fossils difficult because of the poor preservation. Only the most sturdy of specimens were extracted and the rest were covered and remained in the ground. Regardless of his time and discoveries, no convincing evidence was found to place any of the fossils in direct association with man. If one thing is made clear in the literature about the contributions of Phil Orr, it would be that he was tremendously thanked for the use of his “Jeep-tractor” in moving mountains of overburden (Harrington, 1956; Simpson, 1956; Harrington and Simpson, 1961).

Willard F. Libby

Libby, a physicist with the University of Chicago, developed the radiocarbon dating technique in 1949 and used it to process charcoal from collections made by Harrington (Libby, 1955). The first date came back at 23.8 Ka, which was the absolute earliest record of man in North America. Libby later transitioned his career to the University of California, Los Angeles (UCLA), in 1959, and became an integral component in the initiation of the “Big Dig” commencing in 1962 (more on this below). Libby’s involvement in this Big Dig was viewed a perfect opportunity to further exact his technique and answer the question of whether early North American peoples interacted with megafauna (Shutler, 1967). Libby made his lab at UCLA available to gather, process, and quickly turn around dates so that researchers in the field had a one-week turnaround time on dating samples. This allowed researchers conducting work in the field a sense of “real-time” dating as they integrated the dates into a chronostratigraphic framework. Libby’s lab processed more than 80 dates for the Big Dig crew of 1962-1963 (Shutler, 1967).

Nevada State Museum, 1962-1963

John E. Mawby

Mawby was the paleontologist on the 1962-1963 expedition, coined “The Big Dig”. This was a joint expedition between the Nevada State Museum, Southwest Museum, UCMP, and UCLA. Interest in Tule Springs was resurrected in 1962 by Nevada State Museum archaeologists Richard Shutler and Charles Rozaire (Rozaire formerly of the Southwest Museum). With the accomplishment of radiocarbon dating, a renewed sense of excitement was found upon a reconnaissance trip to the site and financial support was sought to pursue a novel, large-scale, interdisciplinary study (the largest of its time) at TUSK. The project was financed by the National Science Foundation among many others to produce a comprehensive report on the paleontology, palynology, archaeology, biology, geochronology, and geology of Tule Springs (Wormington and Ellis, 1967). The 1962-1963 excavations had three major objectives outlined by C. Vance Haynes Jr. (1967): elucidate the fossils and artifacts in a chronostratigraphic context, correlate the Las Vegas Formation of Tule Springs with the surrounding regional geology, and draw an understanding of how the Tule Springs information fits into the overall picture of Late Pleistocene events in North America. Interest in the dig was not limited to the researchers themselves but also created excitement amongst Las Vegans. Local media took an interest in covering the expedition, demonstrated in Figure 7, and wrote newspaper articles as well as the an article in The Nevadan magazine on October 28, 1962 (Figure 7).

Sunday, Oct. 28, 1962 The NEVADAN 25

Tule Springs Dig Offers Scientists Choking Dust Scholarly Thrills

By Barbara Drum

Some of them dig daintily with trowels and some use ponderous bulldozers. But all of the archeologists at the Tule Springs site swallow enough dust in an hour to kill the average asthmatic.

Grey ghosts in dust-covered khakis, the diggers trudge across the sunny, parched badlands 11 miles northwest of Las Vegas. There, near the Tule Springs Ranch, bulldozers cutting into the desert have dug a half-mile long trench so deep that the population of Las Vegas could be packed neatly inside.

The bulldozers and scrapers, driven by members of Local 12, International Operating Engineers Union, carefully scoop up just three inches of dirt from the trench at each sally. Bulldozers and scrapers maneuver efficiently to remove this thin covering of dirt from the trench. Behind the heavy equipment, in the choking dust, walks an archeologist, or perhaps an archeology student.

Scientists at the site

gold or uranium to Nevada's more avaricious diggers.

Figure 7. Local interest in the Big Dig created excitement in the Las Vegas community.

This dig was remarkably productive in many ways and was successful in addressing the primary objectives. An overview of the results are that the team retrieved an impressive 80 radiocarbon dates, excavated 11 linear trenches (a technique not typically employed by todays scientists) of various length in a geometry perpendicular to the wash as to expose stratigraphy and place the fossils and recovered artifacts into a chronostratigraphic framework, discovered 12 new fossil localities and identified several new taxa to the site, and discovered and dated fire hearths although *sans* burned bone (Haynes, 1967).

Vertebrate paleontology resources collected during the Big Dig were identified and described by Mawby (1967). Twelve new fossil localities were discovered during the duration of the project. Fossils were correlated to units B_2, D, and E_1 of the Las Vegas Formation, with E_1 being the most productive of the units (Haynes, 1967; Mawby, 1967). This was the first time that stratigraphy and precise age control were researched at TUSK, so the possibility of integrating the fossil resources into this type of framework was of tremendous significance. In attempting to do this, Mawby had hoped to understand vertebrate patterns of change through time. Although with the very small assemblage size, he cautioned misrepresentation of these patterns, what he was able to identify was a generalized transition in herbivores. The presence of *Bison* was observed more prominently in older units (B_2) while this transitioned into the lack of Bison and the presence of ?*Tetrameryx* sp.and *Odocoileus* sp. in the younger units (E_1) (Mawby, 1967). Mawby's further contributions to the Wormington and Ellis (1967) manuscript was the elemental identification and taxonomic descriptions of the fossils; he also clarified antiquated terminology used to identify taxa from the works of Simpson (1933) and Harrington (1934 & 1955). Most considerably was his contribution of adding new taxa to the list of existing fossils recovered from the site. These new taxa include the megafauna *Megalonyx jeffersoni*, *Canis latrans*, *Felis* sp. cf. *F. concolor*, *Lynx rufus*, ?*Tetrameryx* sp., and *Panthera atrox* (first collected by Stock in 1919 but first described by Mawby in 1967). Mawby also identified a number of new microvertebrate taxa: *Sylvilagus* sp., ?*Brachylagus idahoensis*, *Dipodomys* sp., *Microtus* sp., and *Ondatra zibethicus*. Lastly, the first record of birds were identified during this project: *Mareca americana*, *Aythya collaris*, *Aythya affinis*, *Athya americana*, *Mergus merganser*, *Teratornis merriami*, *Fulica americana*, *Fulica americana minor*, *Bubo* sp., Anseriformes, and Buteoninae. A limited number of specimens were sent to the Nevada State Museum in Carson City (NSMCC) for display purposes, including an impressively preserved mandible of *Equus* sp. (Figure 8) [original figure in Mawby, 1967 (Fig. 4, pg. 116)]. Communications with the collections manager at the NSMCC reveal that the number of paleontology specimens housed there are very small and a list of inventoried material does not exist in hardcopy or digital (Rachel Malloy, collections manager, NSMCC, pers. comm. June 2, 2015 to Aubrey Bonde). All other vertebrate paleontology fossils were sent to the UCMP collections, where they reside today in 2 large cabinets (Figure 9) . A full inventory of these fossils collected from the Big Dig can be viewed in Appendix B. National Geographic photographer Bill Belknap was onsite during the Big Dig and snapped more than 1200 images. These historical images are now stored in the archives of the Nevada State Museum in Carson City with a mirror copy at the Nevada State Museum in Las Vegas.

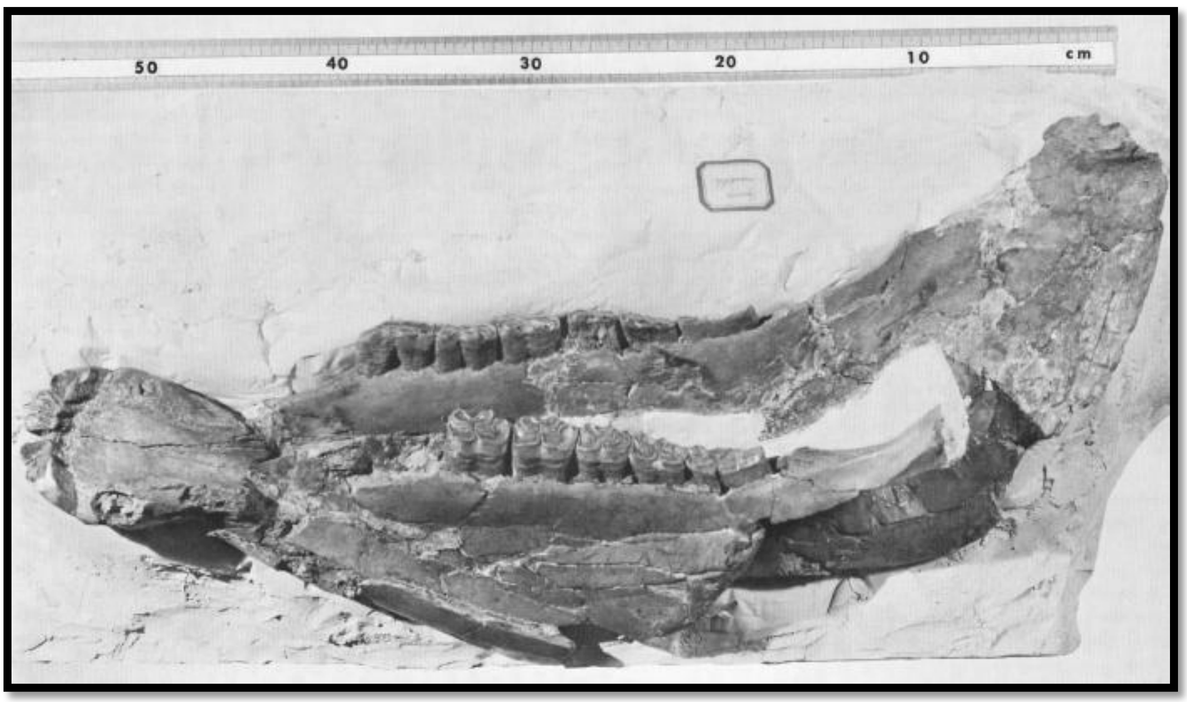

Figure 8. *Equus* mandible from the large species of horse found at TUSK, now referred to as *E. scotti*. This is one of the few vertebrate specimens that have been retained at the Nevada State Museum, Carson City. Image from Mawby (1967).

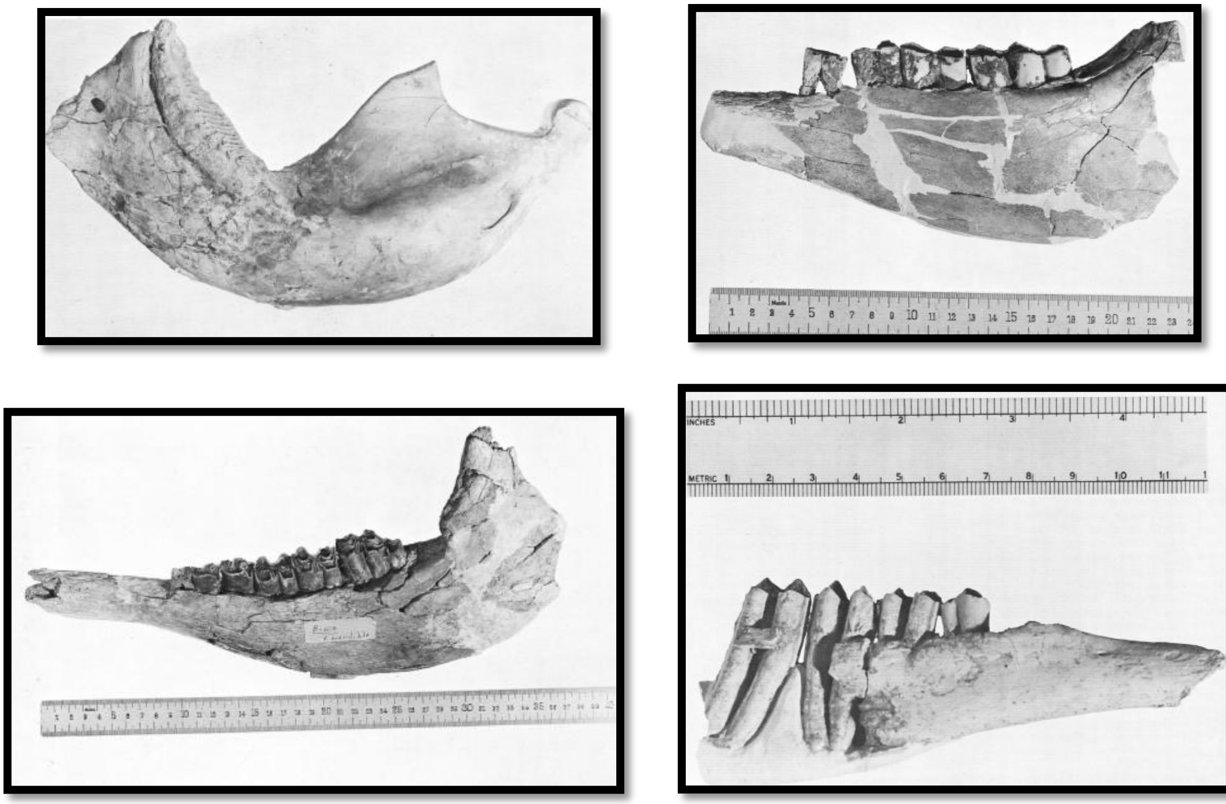

Figure 9. Images of mandibles extracted from the 1962-1963 Big Dig, all figured in Mawby (1967). Top left, *Mammuthus columbi*, scale is not known. Top right, *Camelops hesternus*. Bottom left, *Bison* sp. Bottom right, *Tetrameryx*. Sp.

Archaeological material was scant with minimal tools and flakes recovered and when present were always located stratigraphically above fossil bearing units (Shutler, 1965; Mawby, 1967; Shutler, 1967). Only 9 definitive human artifacts were recovered, and just one was possible to be constrained to an age of 10-11.2 Ka, putting the earliest undisputable date for human presence at TUSK at about 11 Ka*. In contrast, the latest date for megafauna was between 11-13 Ka, so the earliest evidence of human presence at TUSK barely, if at all, correlates with the latest evidence of megafauna before their extinction (Haynes, 1967). After months of efforts made by dozens of people, the end product of all this research was that they were able to demonstrate that the dates obtained by Harrington were null; the result of time averaging due to procuration of sediments of different ages. Furthermore, artifacts produced or influenced by the presence of early peoples were found to be younger than 11 Ka and were not in association and the coexistence of early humans and late Pleistocene megafauna could no longer be entertained (Wormington and Ellis, 1967). This colossal undertaking was then formally published between three main reports: Williams and Orlins (1963), Susia (1964), and, the most iconic of all, Wormington and Ellis (1967).

TUSK then sat mostly vacated since the 1962-63 since there was no definitive association between man and animal. An exception to this was the annual visit by Richard Brooks with his archaeology field class between the years of 1967-1977**. Upon these visits, Brooks "…lamented the deterioration of the locality. Creeping urbanism with its garbage, off road vehicle use,…… and vandalism, in general, has left its lasting imprint upon the locality." (King *et al*., 1978). The significance of this expedition was recognized for years to come including preserving the lands researched during the Big Dig as a National Historical Register Area and a 40 year reunion of the Big Dig took place in 2002, attended by most of the original scientists involved.

*NOTE - The Big Dig also strove to validate previous work and in that matter, they were unable to verify Harrington's dates of 23.8 and 28 Ka, but did declare it the result of mixed sampling. Also, the exact location of Fenley Hunter's obsidian flake was tested with the best effort and was found to be either 12-13 or 10-11 Ka, the majority of researchers lean toward the latter.

**NOTE – All work in the area, however, was not suspended, adjacent to Tule Springs is the Floyd R. Lamb Park which underwent a survey for resources (archaeological and paleontological) in 1978. Surveyors found no evidence for paleontological remains at that time, while archaeological resources had a limited presence (King *et al*., 1978). Results of this survey are discussed in the archaeology section of this report

San Bernardino County Museum, 1990-2014

Robert R. Reynolds, Kathleen Springer, and Eric Scott

San Bernardino County Museum (SBCM) was contacted in 1990 to provide a natural resource survey on future construction projects off of Centennial Parkway, this work was conducted under the lead of Robert E. Reynolds (earth sciences curator, San Bernardino County Museum, at the time). Reynolds and the SBCM crew recorded 94 paleontology localities in the Las Vegas Formation, and, from these sites, 44 taxa were identified including 18 previously unknown taxa (Reynolds et al., 1991). A list of these unknown taxa are as follows and can also be observed in Appendix A: *Ammospermophilus leucurus*, *Perognathus* sp., *Peromyscus* sp. cf. *P. maniculatis*, *Neotoma* sp., *Taxidea taxus*, *Antilocapra americana*, *Bufo* .sp., two species of *Hyla*, *Gopherus* sp., *Sceloporus* sp. cf. *S. occidentalis*, *Callisaurus* sp. cf. *C. draconides*, *Phyrynosoma* sp., *Lacertilia* sp., Colubridae, Passeriformes, and Teleostei (Reynolds et al., 1991).

Work then continued sporadically until 2001 when Kathleen Springer (senior curator of geological sciences, SBCM) and Eric Scott (curator of paleontology, SBCM) really established a presence by monitoring for a power transmission line (Springer and Scott, 2003; Springer et al., 2011). In 2001, Springer and Scott were were commissioned by Nevada Power to conduct a paleontology resource survey and then monitor and mitigate for the construction of a transmission line (Harry Allen Northwest 500 kV Transmission Line). Surveying and mitigation recovery was conducted along the transmission line corridor with a 200' buffer and associated access roads. This corridor survey resulted in the identification of 36 new fossil localities which yielded an astonishing 9,789 fossil specimens (Springer and Scott, 2003). The SBCM personnel prepared and stabilized all macrofauna and screenwashed fossil bearing sediments for the recovery of microfauna. Scott reports that the recovered specimens were isolated and poorly preserved (Springer and Scott, 2003). A full inventory of these fossils can be viewed in the Springer and Scott (2003) final report to Nevada Power.

The swift expansion of Las Vegas and North Las Vegas brought encroachment onto the Upper Las Vegas Wash. This prompted land management agencies (e.g., Bureau of Land Management, southern Nevada District) to sell off parcels of land from the Upper Las Vegas Wash Conservation Transfer Area.

However, prior to their actual disposal a resource inventory survey was required for natural, cultural, and biological resources. Based upon the impressively rich paleontology resources discovered in 1990 & 2001, Springer, Scott, and other SBCM personnel went back to Tule Springs in 2003-2004 to conduct a full survey of roughly 25,000 acres of land. This time commissioned by the Bureau of Land Management (BLM) Las Vegas office. The BLM found itself in the position to be able to dispose of sections of the Upper Las Vegas Wash under the compliance of federal regulations and in consideration for the protection of natural and cultural resources (Springer et al., 2011). SBCM was the chosen institution to inform the BLM of the presence of natural resources while making land management decisions. In this third major survey (2003-2004) conducted by the SBCM crew, they found over 438 new localities (Springer *et al*., 2005; Springer *et al*., 2006). This research trip turned out to be so productive because the focus was, for the first time, on rigorous prospecting for paleontology localities in order to establish a sense of richness for the area – and in that way was a sweeping success.

Several years later the BLM provided the SBCM with a 6-year grant (2008-2014) to collect and preserve paleontological resources and provide public outreach of said resources. This grant was to fund research specifically for understanding the geological context of Tule Springs (e.g., hydrologic deposits and spring mound localities, geologic mapping), collection of new paleontological resources and visiting other museum collections to fully document all known paleontology resources extracted from Tule Springs, and the mapping of fossils and fossiliferous horizons into a well-constrained chronostratigraphic framework (Springer *et al*., 2011; Springer and Scott, 2014). Included in this fourth major undertaking by SBCM personnel, they found dozens of additional new fossil localities and acquired a large number of radiocarbon and thermoluminescence dates . While working out the stratigraphy, they found that all units of the wash bear fossils except for unit A, with B, D, and E subunits being the most fossiliferous. This mirrors the findings of Haynes (1967), however they were able to further this by identifying that "ponding" events, seen in units B_2 and D_1, had a tendency to preserve bone better than the modes in unit E. They further declared that fossil deposition is attritional in nature and not representative of entrapment (Springer and Scott, 2003). SBCM personnel were able to verify the overwhelming presence of camel (*Camelops hesternus*) and mammoth (*Mammuthus columbi*) from TUSK, they state that camel remains are more prevalent in sheer abundance of recovered material but mammoth remains have been recovered from a larger number of localities (Springer *et al*., 2011). Another interesting observation made by SBCM is that camels are more abundant at Tule Springs than other similarly comprised assemblage of the same age (e.g., Diamond Valley Lake, Rancho LaBrea). They interpret this to mean that there is an observable and increasing gradient in the relative abundance of camel from the coast to the interior of the desert Southwest (Springer *et al*., 2010). SBCM supported that *Equus* and *Bison* are also very prominent, supporting the interpretations of researchers before them (Simpson, 1933; Harrington and Simpson, 1961; Maybe 1967), however, Springer and Scott (2014) were able to augment the known presence of *Bison*, it had previously been recorded only from unit B_2 and SBCM found undisputable evidence of its presence in the younger units D and E_1. In addition to recovering many of the taxa that have already been noted from the Las Vegas Formation, the 2001-2014 SBCM expeditions allowed them to, once again, extend the list of known taxa. Most notably these important additions include: ?Hirundinidae, egg shell, *Rana* sp., *Anniella* sp., *Masticophis* sp., cf. *Arizona elegans*, cf. *Uta stansburiana*, *Marmota flaviventrus*, *Neotoma* sp. cf. *N. lepida*, *Neotoma* sp. cf. *N. cinerea*, cf. *Onychomys* sp., *Spermophilus* sp. ?*S. variegates*, *Sciuridae* sp., *Reithrodontomys* sp., *Lepus californicus*, *Bison antiquus*, *Equus scotti*, a large bovid (similar in size to *Euceratherium*), *Hemiauchenia* sp. (Springer and Scott, 2014), *Smilodon fatalis* (Springer *et al*., 2005; Springer *et al*., 2008; Springer *et.al*., 2010; Springer *et al*., 2011) (Figure 10), and *Canis dirus* (Springer and Scott, 2014). Dates that SBCM acquired for TUSK concur with radiocarbon dates obtained from prior studies (Haynes, 1967; Quade, 1986; Quade and Pratt, 1989; Reynolds *et al*., 1991; de Narvaez, 1995; Scott and Cox, 2002). Relative ages based upon presence of taxa coincident with the North American Land Mammal Ages (NALMA) further confirm the temporal history of the strata placing it in the Rancholabrean NALMA (Lundelius *et al*., 1987). These temporal constraints allowed Springer and Scott to declare, without surprise, no temporal associations between early peoples and megafauna. Springer and Scott Published as a series of conference abstracts and papers from their investigations at TUSK between the years of 2001-2014 (Springer *et al*., 2005; Springer *et al*., 2006; Springer *et al*., 2008; Springer *et al*., 2010; Springer *et al*., 2011).

Figure 10. Proximal left humerus of *Smilodon fatalis*, the first element of the species to be discovered at TUSK. SBCM image (Springer and Scott, 2014).

With the abundance of recovered material and knowledge of stratigraphical placement, SBCM was able to identify several taxa to sample for $\delta^{18}O$ and $\delta^{13}C$, these taxa include *Mammuthus*, *Camelops*, *Equus*, and *Bison* (Drewicz *et al*., 2013). Results of stable isotope analysis indicate that the area received an increase in spring/summer moisture, $\delta^{18}O$ values reveal that increased precipitation may have been the result moisture from tropical origination aiding the establishment of paleowetlands in the region during the late Pleistocene (Drewicz *et al*., 2013). $\delta^{13}C$ data suggest that these genera were mixed feeding on C_3/C_4 vegetation (Drewicz *et al*., 2013).

University of Nevada Las Vegas, 2003-present

Steve Rowland and Josh Bonde

Rowland (paleontologist and professor of Geoscience at UNLV) began researching fossils within the Las Vegas Formation in 2003, not directly at Tule Springs proper but at the neighboring Gilcrease property which contains several fossilized spring cauldrons and is dominated by the teeth of *Mammuthus columbi*, and bone and teeth of *Bison* sp., *Equus* sp., and *Camelops hesternus*. Research of these spring mounds occurred in detail beginning in the early 1990's (De Narvaez, 1995; Vetter, 2007; Bonde et al., 2008; Scott and Cox, 2008) and provides an ideal opportunity to showcase vertebrate paleontology in an outreach setting with which Rowland is involved.

Bonde (paleontologist and faculty in Geoscience at UNLV) was approached by Nevada State Parks (NSP) to perform a paleontological resource survey on the National Historic Register parcel which contained 315 acres of Nevada State Parks lands. With a collection permit issued by NSP to Bonde, he led a team of volunteers (undergraduate/graduate paleontology students from UNLV and trained stewards with the Nevada Friends of Paleontology) to accomplish this survey over a period of four days. In just this short span of time, 23 new fossil localities were recorded and significant discoveries were made, including the collection of a 4-foot long mammoth tusk (*Mammuthus columbi*) (Bonde, 2011). This survey and work in subsequent visits yielded many other fossils were collected, commonly isolated elements and fragmentary yet identifiable elements of Camelops *hesternus*, *Mammuthus columbi*, *Bison* sp., *Equus* sp., and present but yet to be identified material includes small vertebrates (e.g., rabbit and rodents), birds, and herpetofauna (Bonde, 2011, 2012, and 2013). The most significant contribution made to the long list of taxa recovered from TUSK since 1919 was the discovery of a metacarpal of *Canis dirus* (in collections at the Las Vegas Natural History Museum, specimen number IL 2014.1.8) (Bonde, 2013; Rowland and Bonde, 2015) (Figure 11). Dire wolf had not yet been recorded during the many decades of research and represents in important carnivore in the Late Pleistocene landscape. It is tremendously abundant in the deposits of Rancho LaBrea but, interestingly, has been glaringly absent from the state of Nevada. This discovery sealed its presence in southern Nevada during the Late Pleistocene and supplies another unique character into the dynamic megafauna story . Another important result of this survey was that the NSP parcel was mapped out in terms of fossil abundance where the most fossiliferous horizons were given a status of high risk and then ranged from moderate to low risk (Bonde, 2011). This map highlights the most critical areas in need of preservation to reduce potential risks to fossil resources in contrast to prior maps that characterize the Upper Las Vegas Wash as a whole.

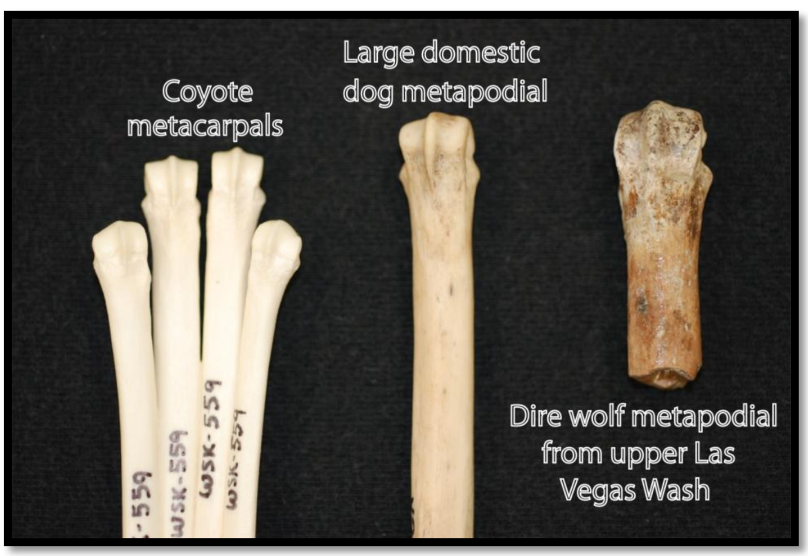

Figure 11. Osteological comparison of the dire world metapodial recovered from TUSK. Comparison is made to coyote and common dog elements to highlight size between the three taxa. The dire wolf metapodial is the element of the species to be discovered at TUSK Image from Rowland and Bonde (2015).

Las Vegas Natural History Museum, 2013-present

The collaborations between the NSP and UNLV resulted in a strong alliance and research is still being granted on the NSP lands today. Another important collaboration that resulted from these efforts was with the Las Vegas Natural History Museum (LVNHM). LVNHM, under the direction of Marilyn Gillespie, became the official repository for the fossils collected from the NSP lands at Tule Springs (2013-present). To be clear, the fossils remain the property of NSP, however they are agreed to be curated and preserved in the collections at LVNHM with the responsible accessibility of education and research. Vertebrate fossils are presently being accessioned into the collections, at the current time only a small number have been issued specimen identifications and these can be viewed in Appendix B.

Environmental reconstruction using invertebrate paleontology

The recovery of invertebrate taxa from TUSK indicate varying levels of moisture at the site during the Late Pleistocene. The peaclam genus *Pisidium*, which has been identified from numerous localities, is the hugely dominant taxon in terms of number of identified specimens (NISP) (Springer and Scott, 2003). Its presence suggests a freshwater, low-energy, mesic wetland environment (Quade and Pratt, 1989). This interpretation can be corroborated by the prominent presence of aquatic snails (*Physa*, *Helisoma*, *Valvata*) over a much more limited presence of terrestrial snails (*Succinea*, *Discus*, *Vertigo*). The aquatic versus terrestrial genera occur sporadically at identified fossil localities (Springer and Scott, 2003) resulting in the interpretation of temporally observed fluctuations in water levels. Therefore, in addition to the variety of fossilized hydrologic systems observable at TUSK (e.g. active springs, wetlands, and marshes (Quade and Pratt, 1989)), there was also the dynamic fluctuation of water into these systems through the late Pleistocene. Water levels must have remained deep and constistent enough to support aquatic vertebrate taxa such as teleost fish, frog (*Rana* sp.), and waterfowl (*Aythya collaris* and *A. affinis*). The microvertebrate assemblage found at TUSK indicate a variety of habitats in past times, from the mesic conditions mentioned above to more arid conditions with desert adapted plants (e.g., sagebrush, desert scrub plants, and piñon-juniper).

CHAPTER 5

Chronology of the establishment of TUSK

By Aubrey Bonde

The efforts of many people went into the establishment of TUSK. This is a snapshot of how these efforts developed. The first act of preservation at Tule Springs was made April 20, 1979, when it was listed on the National Register of Historic Places. The multifaceted Big Dig should be credited for its role in understanding paleoenvironments, bringing awareness to the site, and for testing advances in scientific methods and analysis, such as radiocarbon dating.

1996-2006 The Tule Springs Preservation Committee (TSPC) was erected as a citizen advisory group for the protection of natural resources of Floyd R. Lamb State Park (later designated as a city of North Las Vegas park) and the state parcel of Tule Springs. At Floyd Lamb, they coordinated the restoration of historic buildings, researched historic dwellings and families, conducted bird studies, and compiled information for public use. Several members later spun off into Protectors of Tule Springs (2006-present). TSPC and Helen Mortenson were instrumental in orchestrating the 2002 Big Dig Reunion which assembled the researchers of the 1962-1963 dig together for a museum exhibit opening and field trip to the site.

2002 The first real efforts to conserve the lands were made when the BLM declared the 13,000 acres of the Upper Las Vegas Wash as part of the disposal area. Because of rapid growth from Las Vegas, the BLM was preparing to sell off parcels to provide land for organized local community development. This was met with concern by locals familiar with the resources from the area and the BLM initiated the first Environmental Impact Survey (EIS). This was followed by the construction of the Harry Allen transmission line (36 poles installed) by NV Energy. SBCM was charged with recovery and preservation of paleontology resources along the transmission corridor. This was followed in subsequent years by SBCM research on behalf of the BLM.

2005 The BLM designated a second EIS and.

2006 Protectors of Tule Springs (POTS) was established, under the former name “Friends of the Upper Las Vegas Wash” and began interacting with the BLM on educational field trips to fossil sites. The founding board members of POTS include Jill DeStefano, Sandy Croteau, Sandy Valley, Kathryn Brandel, and Lil Rothstein. Another key member of POTS joined shortly after its founding and is a key person in the Tule Springs story, this person is Helen Mortenson.

2007 POTS collected 1200 signatures to protect the Upper Las Vegas Wash 13,000 acres as a National Conservation Area managed by the BLM. They obtained over 6,000 public comments for the administration of a second EIS to be performed. The BLM contracted Utah State University to do this second EIS. Utah State conducted a survey and based on their findings provided support for the protection of lands at a BLM Conservation Transfer Agreement meeting.

2008 POTS acquired over 10,000 signatures on a petition to save 13,000 acres in the disposal area, these signatures were submitted to Senators Harry Reid and John Ensign

2009 National Parks Conservation Association (NPCA) opened an office in Las Vegas in 2008, this was managed by Lynn Davis, who became involved with Tule Springs in 2009. NPCA coordinated NPS paleontologist Theodore Fremd to examine the site. Fremd composed and submitted the Las Vegas Wash Paleontology Expanded Report to the NPS Regional Director - Pacific West. Fremd advocates that the site is one of the most significant Ice Age fossil sites in North America and worthy of preservation of the area as a National Monument managed by the NPS. Fremd's report spurred NPS interest in the area and focus switched from having the area as BLM managed land to NPS managed land. Lynn Davis gathered the Tule Springs Coalition, a massive collection of organized institutions and groups to progress the protection of TUSK. By this time, the site now had the support of the cities of North Las Vegas and Las Vegas, Clark County, Las Vegas Paiutes, and U.S. Air Force. All these groups came together in a concerted effort and passed a unanimous resolution to protect the area as a NPS National Monument. This was then accompanied by the support of many more organizations including UNLV, Scenic Nevada, Archeo-Nevada Society, Nevada Friends of Paleontology, State of Nevada, BLM, U.S. Fish and Wildlife, U.S. Forest Service, Las Vegas Metro Chamber of Commerce, Las Vegas Conventions and Visitors Authority, Sierra Club, bipartisan support from Nevada's congressional delegation and local elected officials, among others.

2010 Advocation for TUSK continues for bring an NPS unit. NPCA spearheads further support and POTS provides full support in the direction that NPCA steers. POTS does presentations, gathers media events, such as the SBCM excavations of mammoth tusk, and writes letters to delegates.

2011 Congresswoman Shelley Berkley and Senator Harry Reid introduce the Tule Springs Fossil Beds National Monument bill into the 112th Congress.

2012 Legislation in the 112th Congress does not pass a committee hearing and dies. At this same time, the BLM determines that it will save 11,000 of the 13,000 acres from development.

2013 Legislation introduced in the 113th Congress with all 6 Nevada delegation signed on as sponsors. The bill passed the Senate Resources Committee and passed the House subcommittee on public lands. Companion bills were also introduced with all members of Nevada's delegation signed on as sponsors (HR2015). The Senate subcommittee on Public Lands passes the bill (S974) to full committee which is followed shortly after by the Senate committee on natural resources. The bill passes to the floor.

2014 Full House Committee set to vote on amendments to bill that guts Southern Nevada Public Lands Management Act and cuts 18 pages out of the bill including NPS management. Dissension gets the bill pulled by the House committee on natural resources. Congressman Bishop (of Utah) tours Tule Springs, verbally agrees to leave NPS management in the bill, and then submits amendments to the bill which is later that year resubmitted and attached to the Defense Authorization Bill. It passes House of Representatives on December 4th, passes Senate on December 12th, December 14th is declared a National Monument, and on December 19th President Obama signs it into law. Tule Springs Fossil Beds National Monument was established as the 405th unit of the National Park Service. As stated on the NPS website, it was established to "conserve, protect, interpret and enhance for the benefit of present and future generations the unique and nationally important paleontological, scientific, educational and recreational resources and values of the land."

Figure 1. Society of Vertebrate Paleontology 71st Annual Meeting field trip to Tule Springs. Many key people from POTS, and other organizations, who are credited with making TUSK happen are in this photo.

CHAPTER 6

Brief overview of the archeology and history of TUSK

By Aubrey Bonde

The paleontology and archeology stories are intertwined. Prospecting and collection of archaeological materials began in 1912 [a detail and full timeline can be viewed in King *et al*. (1978)] with the majority of interest taking place several decades later, in the 1955-1963.

Much of the deep archaeological history of TUSK is explained within the paleontology section above, this section outlines the younger, Holocene material recovered. Susia (1964) reported on the surface surveying of archeological artifacts amidst a firm understanding of geological and climatic context. This report was particularly functional as the first report after the 1962-1963 Big Dig to reconstruct the cultural history of the site. Susia's focus for the artifacts recovered from TUSK was to determine the prehistoric sequence. In essence, did the evidence provide a true assemblage indicative of an occupation site by early peoples, or was it the result of the presence of early human at the site and the continual accumulation of artifacts since their first appearance. Her work entailed a site survey of the entire TUSK area where she partitioned the land into a number of unequal grid sections and described the lithology and cultural remains from each. Susia's survey resulted in over 500 flakes and 278 artifacts including projectile points, disk choppers, cores, scrapers, gravers, drills, ground stone, and heavy scrapers. She conclusively found certain sections of the gridded area were representative of intermittent, discontinuous occupation sites by small parties of early peoples, with the caveat that time averaging cannot be quantitatively identified. The age of the artifacts could not be found to be greater than 6,000 years old (Susia, 1964) and also deemed noncontemporary with the artifacts dated from the neighboring area of Corn Creek, 4,030-5,200 BP (Williams and Orlins, 1963). This designation is made on the premise that the differences in the cultural artifacts between Corn Creek and Tule Springs were great enough that the peoples are considered to be from different groups (Susia, 1964). Further, the youngest age consideration for the archeological remains at TUSK is no less than 2,200 BP based upon the absence of pottery (Schroeder, 1961; Shutler, 1961), known thereafter in other areas of the Southwest (Susia, 1964). According to Susia (1964), this then brackets the majority of the native occupation of Tule Springs to be roughly between 2,000-4,000 and 5,000-6,000 years ago.

An archeology survey of the adjacent Floyd R. Lamb Park city park, formerly a state park, resulted in the identification of two main prehistoric sites containing rock circles, pottery sherds, a turquoise ornament, points, knife fragments, scrapers, shell bead, and arrow shaft smoother. These findings substantiated the importance of Susia's work and recommendations were made to pursue archaeological research at Floyd Lamb, preserve the sites, and use the sites as the beginnings of an interpretive program for the park (King *et al*., 1978). This was done on a small scale and could be a model for which TUSK could follow about its own archaeological remains.

The history of TUSK is a unique and entertaining story all to itself. Because Haynes (1967) eloquently and succinctly summarized the history of TUSK, this history is an excerpt from his writing. Another source, King *et al*. (1978) explores a much more detailed history of the area, filling in many gaps that Haynes (1067) did not discuss.

> *"Exploration of the area began about 1770 with Spanish exploring parties under the direction of Father Junipero Serra. They journeyed up Las Vegas Wash from the Colorado River and discovered an oasis of spring-fed meadows…..at the present site of Las Vegas. John C. Fremont and his party camped at Las Vegas Springs in 1844 (Fremont, 1845), and explorer Kit Carson passed through the region at about the same time. These explorations were followed in 1847 by a wagon train enroute to southern California from Salt Lake City and led by Captain Jefferson Hunt, a Mormon missionary.*
>
> *During the early 1850's, Mormons led by William Bringhurst established Las Vegas and constructed an adobe fort north of the present city. They successfully farmed this part of the valley and mined lead in the mountains until 1857 when they were recalled to Utah by Brigham Young because of the troubles with the U.S. Government.*
>
> *After 1857, several large cattle ranches operated in the valley, but the State Land Act of 1885 made agricultural lands cheaply available and farmers again prospered. The alfalfa industry became dominant after the discovery of artesian water in 1905, the same year that the Union Pacific Railroad was completed through Las Vegas.*
>
> *Rapid decline of ground water levels since 1905 has all but eliminated ranching and farming in the valley. Hoover Dam, Lake Mead, military installments, mining and milling and the casinos are all responsible for rapid growth of Las Vegas since the 1930's. The Tule Springs and Gilcrease Ranches no longer raise cattle and are the only operating farms in the valley north of Las Vegas."*

This then brings the story right into the early days of paleontology and archeology explorations into the Upper Las Vegas Wash area.

CHAPTER 7

Recommendations for future research and additions to this report

By Fabian Hardy and Aubrey Bonde

TUSK had a reputation for cutting-edge scientific research in the 1960s, a status that could be renewed as interest in the site builds as a result of greater exposure as a national monument. Its proximity to a large urban area is an excellent opportunity for educational outreach and continued public involvement in active paleontologic research programs.

Multiple subjects may be examined at TUSK, which notably has a similar fauna to other well-established sites such as Rancho La Brea and Diamond Valley Lake, both in California. Further correlation of TUSK to other sites in the region has implications for biogeography and paleoclimatology. More research could better refine the biostratigraphic placement of fossils with stratigraphy as well as how that would relate to an understanding of fossil emplacement spatially and temporally.

Questions surrounding the extinction of mammoth, camels, horses, and giant ground sloths may be investigated at TUSK (e.g., climate change, impact, hyperdisease). The wash provides a phenomenal sequence of exposed units for addressing these questions. Faunal statistical analysis, MNI, NISP, age representation of species and population dynamics are subjects to be explored, especially with the recovery of a juvenile mammoth jaw, and the high potential for added localities as research at the site progresses. Stable isotopes may be used at the site to examine diet and the degree of seasonality in climate.

The American southwest was subject to many instances of drastic climate change during the Pleistocene, and the response of a wetland ecosystem may be examined through study of the fossils and sedimentary structures of TUSK. The record of climate change over the past 100,000 years is robust at TUSK, and may be further refined through future research. An understanding of how environments changed, at what time scales, and the resulting biotic responses could contribute to projecting future ecosystem changes in the region.

In addition to the research that can be conducted on the geology and paleontology within the exposures, there is also the task of following up on collected fossils that have been scattered about the country over the past century. Appendix B lists all institutions known to house TUSK specimens and discussions to bring some of these collections to Las Vegas have been pursued (e.g., Autry National Center and SBCM).

References

Bonde, J.W., Shirk, A.M., Rowland, S.M. (2008) Taphonomy of the Gilcrease spring mound paleontological site, Clark County, Nevada. Geological Society of America Abstracts with Programs, v. 40, no. 1, p. 50.

Bonde, J.W. (2011) Paleontology resource survey of the Tule Springs State Park property. University of Nevada Geosciences Annual Report to Nevada State Parks, Number 1, p. 1-12.

Bonde, J.W. (2012) 2012 Year End Report for Paleontological Activities Conducted at Tule Springs State Park. University of Nevada Geosciences Annual Report to Nevada State Parks, Number 2, p. 1-12.

Bonde, J.W. (2013) Year End Report for Paleontological Activities Conducted at Tule Springs State Park. University of Nevada Geosciences Annual Report to Nevada State Parks, Number 3, p. 1-12.

Broecker, W.S., Kulp, J.L. (1957) Lamont natural radiocarbon measurements IV. Science, v. 126, no. 3287, p. 1324-1334.

De Narvaez, C. (1995) Paleohydrology and paleotolography of a Las Vegas spring. Northern Arizona University, Masters thesis, p. 1-89.

dePolo, C.M., Taylor, W.J., Faulds, J.E., 2013, Evidence for high contemporary slip rates along Eglington Fault, Clark County, Nevada: Nevada Bureau of Mines and Geology Open-File Report 13-12, 8 p.

Donovan, D.J., 1996, Hydrostratigraphy and allostratigraphy of the Cenozoic alluvium in the Northwestern part of Las Vegas Valley, Clark County, Nevada [M.S. thesis]: Las Vegas, University of Nevada, 199 p.

Drewicz, A.E., Kohn, M.J., Evans, S., Springer, K.B., Manker, C.R., Scott, E. (2013). Desert wetland moisture sources during the late Pleistocene in the American Southwest. Geological Society of America Abstracts with Programs, v. 45, no. 7, p. 345.

Harrington, M.R. (1925) Archaeological researched in Nevada. Museum of the American Indian, Heye Foundation, v. 2, no. 2, p. 125-127.

Harrington, M.R. (1933a) Notes. The Masterkey, v. 7, no. 5, p. 155.

Harrington, M.R. (1933b) A new Nevada expedition. The Masterkey, v. 7, no. 6, p. 183.

Harrington, M.R. (1933c) Gypsum Cave, Nevada. Southwest Museum Papers, Number 8. pg. 1-197.

Harrington, M.R. (1934a) A camel-hunter's camp in Nevada. The Masterkey, v. 8, no. 1, p. 22-24.

Harrington, M.R. (1934b) American horses and ancient men in Nevada. The Masterkey, v. 8, no. 6, p. 165-169.

Harrington, M.R. (1941) Our oldest bone implement. The Masterkey, v. 15, no. 6, p. 232-233.

Harrington, M.R. (1955) A new Tule Springs expedition. The Masterkey, v. 29, no. 4, p. 112-114.

Harrington, M.R. (1956) The latest from Tule Springs. The Masterkey, v. 30, no. 4, p. 108-109.

Simpson, R.D. (1956) Finding the scraper at Tule Springs. The Masterkey, v. 30, no. 4, p. 110.

Harrington, M.R. (1959) Mark R. Harrington…Author… Los Angeles Corral, no. 49, p. 10-16.

Harrington, M.R., Simpson, R.D. (1961) Tule Springs, Nevada with other evidences of Pleistocene man in North America. Southwest Museum Papers, Number 18, p. 1-146.

Harrington, M. (1985) On the trail of forgotten people: A personal account of the life and career of Mark Raymond Harrington. Great Basin Press, p. 1-318.

Haynes, C. V., Jr. (1965) Quaternary geology of the Tule Springs area, Clark County, Nevada. Dissertation. University of Arizona, Tucson, Arizona.

Haynes, C. V. (1967) Quaternary geology of the Tule Springs Area, Clark County, Nevada. *in* H. M. Wormington and D. Ellis, eds. Pleistocene studies in southern Nevada. Nevada State Museum, Anthropological Papers Number 13, p. 15–104.

Jefferson, G.T., McDonald, H.G., Livingston, S.D. (2004) Catalogue of Late Quaternary and Holocene fossil vertebrates from Nevada. Nevada State Museum Occasional Papers, Number 6, p. 12-23.

King, J.P., Brooks, R.H., Brennen, L., Wilson, R., Ritenoue, D., Tuohy, D., Seelinger, T. (1978) Archaeological, historical, and paleontological survey of Floyd R. Lamb State Park. Archaeological Research Center, Museum of Natural History, University of Nevada, Las Vegas. Contract # 8-2-330-4752-044.

Libby, W.F. (1955) Radiocarbon dating. Second Edition, University of Chicago Press.

Longwell, C.R., 1936, Geology of the Boulder reservoir floor, Arizona-Nevada: Geological Society of America Bulletin, v. 47, no. 9, p. 1393-1476.

Longwell, C.R., Pampeyan, B.B., and Roberts, R.J., 1965, Geology and mineral deposits of Clark County, Nevada: Nevada Bureau of Mines and Geology Bulletin, v. 62, 218 p.

Lundelius E.L Jr., Churcher, C.S., Downs, T., Harington, C.R., Lindsay, E.H., Schultz, G.E., Semken, H.A., Webb, S.D., Zakremski, R.J. (1987) The North American Quaternary sequence. *In* Woodburne, M.O., *ed*., Cenozoic Mammals of North America: Geochronology and Biostratigraphy, University of California Press, Berkeley, p. 211-235.

Manker, C.R., Springer, K.B., Pigati, J.S., Geochronology and lithostratigraphy of the late Pleistocene Las Vegas Formation: California State University Desert Studies Center 2015 Desert Symposium, Abstracts, p. 330.

Matti, J.C., Castor, S.B., Bell, J.W., Rowland, S.M., 1993, Las Vegas NE quadrangle: Nevada Bureau of Mines and Geology Map 3Cg, scale 1:24,000.

Mawby, J. E. (1967) Fossil vertebrates of the Tule Springs site, Nevada. *in* H. M. Wormington and D. Ellis, eds., Pleistocene studies in southern Nevada. Nevada State Museum Anthropological Papers, Number 13, p. 105–128.

McBride, T. (2005). Archaeological research in southern Nevada. Nevada State Historic Preservation Report, p. 1-11.

Newberry, J.S., 1861, Part III. *in* Report upon the Colorado River of the West by J.C. Ives: Government Printing Office, Washington D.C.

Page, W.R., Lundstrom, S.C., Harris, A.G., Langenheim, V.E., Workman, J.B., Mahan, S.A., Paces, J.B., Dixon, G.L., Rowley, P.D., Burchfiel, B.C., Bell, J.W., and Smith, E.I., 2005, Geologic and geophysical maps of the Las Vegas 30’ x 60’ quadrangle, Clark and Nye Counties, Nevada, and Inyo County, California: United States Geological Survey Scientific Investigations Map 2814, scale 1:100,000, 55 p. text.

Plume, R.R., 1989, Ground-water in Las Vegas Valley, Clark County, Nevada, part I. Hydrogeologic framework: U.S. Geological Survey Water Supply Paper 2320-A, 15 p.

Quade, J. (1986) Late Quaternary environmental changes in the upper Las Vegas Valley, Nevada. Quaternary Research, v. 26, no. 3, p. 340–357.

Quade, J. and Pratt, W.L. (1989) Late Wisconsin groundwater discharge environments of the Southwestern Indian Springs Valley, southern Nevada. Quaternary Research, v. 31, p, 351-370.

Ramelli, A.R., Page, W.R., Manker, C.R., and Springer, K.B., 2011, Geologic map of the Gass Peak SW quadrangle, Clark County, Nevada: Nevada Bureau of Mines and Geology Map 175, scale 1:24,000, 8 p.

Reynolds, R. E., J. H. Mead, and R. L. Reynolds (1991) A Rancholabrean fauna from the Las Vegas Formation, North Las Vegas, Nevada. *in* R. E. Reynolds, ed., Crossing the borders: Quaternary studies in eastern California and southwestern Nevada. Mojave Desert Quaternary Research Center Symposium, Special Publication, p. 140–146.

Rodgers, J., 1982, Chester Ray Longwell 1887-1975: National Academy of Sciences Biographical Memoirs, p. 247-262.

Rowland, S.M., Bonde, J.W. (2015) Paleontology and paleoclimatology of Tule Springs Fossil Beds National Monument and adjacent Nevada State Parks land. *In* Reynolds, R.E., ed., Mojave Miocene, California State University, Desert Studies Consortium, Fullerton, p. 301-309.

Schroeder, A.H. (1961) The archaeological excavations at Willow Beach, Arizona, 1950. University of Utah Anthropological Papers, Number 50.

Scott, E., Springer, K. (1993) Paleontology survey of the Upper Las Vegas Wash Detention Basin. San Bernardino County Museum.

Scott, E. and Cox, S.M. (2002) Late Pleistocene distribution of *Bison* in the Mojave Desert, southern California and Nevada. Journal of Vertebrate Paleontology, v. 22(supplement to 3), p. 104A - 105A.

Scott, E. and Cox, S.M. (2008) Late Pleistocene distribution of *Bison* (Mammalia; Artiodactyla) in the Mojave Desert of southern California and Nevada. *In* Wang, X. and Barnes, L.G., *eds*., Natural History Museum of Los Angeles County Science Series, Number 41, geology and vertebrate paleontology of Western and Southern North America: Contributions in honor of David P. Whistler, p. 359-382.

Shutler, R.S. (1961) Lost City, Pueblo Grande de Nevada. Nevada State Museum Anthropological Papers, Number 5.

Shutler, R.S. (1965) Tule Springs Expedition. Current Anthropology, v. 6, no. 1, p. 110-111.

Shutler, R. S. (1967) Archaeology of Tule Springs. *in* H. M. Wormington and D. Ellis, eds., Pleistocene studies in southern Nevada. Nevada State Museum Anthropological Papers, Number 13, p. 298-303.

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

Simpson, G.G., 1952, Chester Stock 1892-1950: National Academy of Sciences Biographical Memoirs, v. XXVII, p. 333-362.

Springer, K., Scott, E. (2003) Paleontologic resources mitigation and treatment program final report for Nevada Power Harry Allen Transmission Line. Bureau of Land Management Report prepared by San Bernardino County Museum, p. 1-169.

Springer, K., Sagebiel, J.C., Scott, E., Manker, C., Austin, C. (2005) Additions to the late Pleistocene vertebrate paleontology of the Las Vegas Formation, Clark County, Nevada. Journal of Vertebrate Paleontology, meeting abstracts.

Springer, K., Sagebiel, J.C., Manker, C., Scott, E. (2006) Preserving the past: Geologic mapping and paleontologic investigation, Las Vegas Formation, North Las Vegas. New Mexico Museum of Natural History and Science Bulletin, v. 34, p. 38–39.

Springer, K., Sagebiel, J.C., Manker, C., Scott, E. (2008) Paleontologic exploration and geologic mapping of the Rancholabrean age Las Vegas Formation, Las Vegas, Nevada. Geological Society of America Abstracts with Programs, v. 40, no. 1, p. 50.

Springer, K., Scott, E., Sagebiel, J.C., Manker, C.R. (2010) The Tule Springs local fauna: Late Pleistocene vertebrates from the upper Las Vegas Wash, Clark County, Nevada. Geological Society of America Abstracts with Programs, v. 42, no. 5, p. 250.

Springer, K., Scott, E., Manker, C.R., Rowland, S.M. 2011. Vertebrate paleontology of Pleistocene lakes and groundwater discharge deposits of the Mojave Desert and southern Great Basin. *In* J. W. Bonde and A. R. C. Milner, eds., Field trip guide book, 71st annual meeting of the Society of Vertebrate Paleontology Las Vegas, Nevada November 2-5, 2011. Nevada State Museum, Carson City, Nevada, Paleontological Papers Number 1, p. 156–230.

Springer K., Scott, E. (2014). Upper Las Vegas Wash Conservation Transfer Area, Clark County, Nevada: Treatment, protection, and interpretation of the heritage paleontological resources through public involvement. Bureau of Land Management Report prepared by San Bernardino County Museum, p. 1-96.

Spurr, J.E. (1903) Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California. U.S. Geological Survey, Washington, D.C. Bulletin no. 208, p. 1-236.

Susia, M.L. (1964) Tule Springs archaeological surface survey. Nevada State Museum Anthropological Papers, Number 12. pg. 1-34, pl. 1-19.

Vetter, L. (2007) Paleoecology of Pleistocene megafauna in Southern Nevada, USA: Isotopic evidence for browsing on halophytic plants. University of Nevada, Las Vegas, Masters thesis, p. 1-91.

Williams, P.A. and Orlins, R.I. (1963) The Corn Creek Dunes Site: A dated surface site in southern Nevada. Nevada State Museum Anthropological Papers, Number 10. pg. 1-66

Wormington, H.M., Ellis, D. (1967) Pleistocene studies in southern Nevada. Nevada State Museum Anthropological Papers, Number 13, p. 1-411.

APPENDICES

Appendix A – Correlation of TUSK taxa to literature

Class/Order Mammalia	Family	Genus/Species	Common Name	Publication where referenced
Lagomorpha	Leporidae	*Sylvilagus* sp.	cottontail rabbit	Mawby, 1967; Reynolds et al., 1991; Scott and Springer, 1993; Springer and Scott, 2003; Springer et al., 2005
		Lepus sp.	jack rabbit	Simpson, 1933; Mawby 1967; Reynolds et al., 1991; Scott and Springer, 1993; Springer and Scott, 2003; Springer et al., 2005
		Lepus californicus	jack rabbit	Springer and Scott, 2003
		?*Brachylagus idahoensis*	possible pygmy rabbit	Mawby, 1967; Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005
Rodentia	Sciuridae	*Ammospermophilus leucurus*	antelope ground squirrel	Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005; Rowland and Bonde, 2015
		Spermophilus sp. ?*S. variegatus*	rock squirrel	Scott and Springer, 1993
		Sciuridae sp.	squirrel	Springer and Scott, 2003
		Marmota flaviventris	yellowbellied marmot	Springer and Scott, 2003; Springer et al., 2005; Springer et al., 2008; Springer et al., 2010
	Geomyidae	*Thomomys bottae*	Botta's pocket gopher	Simpson, 1933; Reynolds et al., 1991; Scott and Springer, 1993; Springer and Scott, 2003; Springer et al., 2005
	Heteromyidae	*Dipodomys* sp. (large)	large kangaroo rat	Mawby, 1967; Reynolds et al., 1991; Scott and Springer, 1993; Springer and Scott, 2003; Springer et al., 2005
		Dipodomys sp. (small)	small kangaroo rat	Mawby, 1967; Reynolds et al., 1991; Scott and Springer, 1993; Springer and Scott, 2003; Springer et al., 2005

		Perognathus sp.	pocket mouse	Reynolds et al., 1991; Scott and Springer, 1993; Springer and Scott, 2003; Springer et al., 2005; Rowland and Bonde, 2015
	Cricetidae	*Peromyscus* sp.	deer mouse	Reynolds et al., 1991; Scott and Springer, 1993
		Peromyscus sp. cf. *P. maniculatis*	deer mouse	Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005; Rowland and Bonde, 2015
		Neotoma sp.	wood rat	Reynolds et al., 1991; Scott and Springer, 1993; Springer and Scott, 2003; Springer et al., 2005
		Neotoma sp. cf. *N. lepida*	desert woodrat	Springer and Scott, 2003; Springer et al., 2005; Springer et al., 2008; Springer et al., 2010
		Neotoma sp. cf. *N. cinerea*	bushy-tailed woodrat	Springer and Scott, 2003
		Microtus sp. cf. *M. californicus*	meadow vole	Mawby, 1967; Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005
		Microtus sp.	meadow vole	Mawby, 1967; Reynolds et al., 1991; Scott and Springer, 1993
		Reithrodontomys sp.	harvest mouse	Scott and Springer, 1993; Springer et al., 2010
		cf. *Onychomys* sp.	grasshopper mouse	Springer and Scott, 2003; Springer et al., 2005; Springer et al., 2008; Springer et al., 2010
		Ondatra zibethicus	muskrat	Mawby, 1967; Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005
Carnivora	Mustelidae	*Taxidea taxus*	badger	Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005
	Canidae	*Canis latrans*	coyote	Mawby, 1967; Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005

		Canis dirus	dire wolf	SBCM in 2014 BLM report - unpublished; Rowland and Bonde, 2015
	Felidae	*Felis* sp. cf. *F. concolor*	pumasized cat	Mawby, 1967; Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005
		Lynx rufus	bobcat	Mawby, 1967; Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2010
		Panthera atrox	North American lion	Mawby, 1967; Reynolds et al., 1991; Springer and Scott, 2003
		Smilodon fatalis	saber-toothed cat	SBCM in 2014 BLM report - unpublished
Perissodactyla	Equidae	*Equus scotti*	extinct large horse	Simpson, 1933; Harrington, 1955; Mawby, 1967; Reynolds et al., 1991; Scott and Springer, 1993; Springer and Scott, 2003; Springer et al., 2005; Springer et al., 2010
		Equus sp. (small)	extinct small horse	Simpson, 1933; Harrington, 1955; Mawby, 1967; Reynolds et al., 1991; Scott and Springer, 1993; Springer and Scott, 2003; Springer et al., 2005; Springer et al., 2010
Artiodactyla	Camelidae	*Camelops hesternus*	extinct large camel	Simpson, 1933; Harrington, 1934; Harrington, 1955; Mawby, 1967; Reynolds et al., 1991; Scott and Springer, 1993; Springer and Scott, 2003; Springer et al., 2005; Springer et al., 2010
		Hemiauchenia sp.	llama	SBCM in 2014 BLM report - unpublished
	Cervidae	*Odocoileus* sp.	deer	Simpson, 1933; Harrington, 1955; Mawby, 1967; Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005

	Antilocapridae	?*Tetrameryx* sp.	extinct pronghorn	Mawby, 1967; Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005
		Antilocapra americana	pronghorn	Reynolds et al., 1991; Scott and Springer, 1993; Springer and Scott, 2003
	Bovidae	? sp.	large bovid	Mawby, 1967; Springer and Scott, 2003; Springer et al., 2005; Springer et al., 2008; Springer et al., 2010; SBCM
		Bison antiquus	extinct bison	Simpson, 1933; Mawby, 1967; McDonald, 1981; Reynolds et al., 1991; Scott and Springer, 1993; Springer and Scott, 2003; Scott and Cox, 2002; Springer et al., 2005; Springer et al., 2008; Springer et al., 2010
		Bison sp. cf *B. latifrons*	extinct bison	Simpson, 1933; Harrington, 1934; Springer et al., 2010
Xenarthra	Megalonichidae	*Megalonyx jeffersoni*	Jefferson's ground sloth	Mawby, 1967; Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005
	Megatheriidae	*Nothrotheriops shastensis*	Shasta ground sloth	Simpson, 1933; Harrington, 1956; Mawby, 1967; Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005
Proboscidea	Elephantidae	*Mammuthus columbi*	Columbian mammoth	Simpson, 1933; Harrington, 1934; Harrington, 1955; Mawby, 1967; Reynolds et al., 1991; Scott and Springer, 1993; Springer and Scott, 2003; Springer et al., 2005; Springer et al., 2010
		Suggested but not confirmed		
		Chiroptera	bat	Springer and Scott, 2003
		Equus sp. (small)	stilt-legged horse	Simpson, 1933; Springer et al., 2010; Springer et al., 2011
		Bassariscus astutus		

Amphibea

Anura	Bufonidae	*Bufo* sp.	toad	Reynolds et al., 1991; Scott and Springer, 1993; Springer and Scott, 2003; Springer et al., 2005
	Hylidae	*Hyla* sp. (large)	large tree frog	Reynolds et al., 1991; Scott and Springer, 1993; Springer and Scott, 2003; Springer et al., 2005
		Hyla sp. (small)	small tree frog	Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005
	Ranidae	*Rana* sp.	frog	Springer and Scott, 2003; Springer et al., 2005; Springer et al., 2008; Springer et al., 2010
Reptilia				
Chelonia	Testudinidae	*Gopherus* sp.	tortoise	Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005
		?*Testudines*	turtle	Springer and Scott, 2003
Lacertilia	Phrynosomatidae	*Sceloporus* sp.	sagebrush lizard	Reynolds et al., 1991
		Sceloporus sp. cf. *S. occidentalis*	sagebrush lizard	Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005
		Callisaurus sp. cf. *C. draconides*	zebratailed lizard	Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005
		Phrynosoma sp.	horned lizard	Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005
		? sp.	? Lizard	Reynolds et al., 1991; Rowland and Bonde, 2015
		cf. *Uta stansburiana*	side-blotched lizard	Springer and Scott, 2003
	Annielidae	*Anniella* sp.	legless lizard	Springer et al., 2010
Serpentes	Colubridae	? sp.	nonvenomous snakes	Reynolds et al., 1991; Scott and Springer, 1993; Springer and Scott, 2003; Springer et al., 2005

		Masticophis sp.	coachwhip	Springer and Scott, 2003; Springer et al., 2005; Springer et al., 2008; Springer et al., 2010
		cf. *Arizona elegans*	glossy snake	Springer and Scott, 2003; Springer et al., 2005; Springer et al., 2008; Springer et al., 2010
Aves				
Anseriformes	Anatidae	*Mareca americana*	widgeon	Mawby, 1967; Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005
		Aythya collaris	ringnecked duck	Mawby, 1967; Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005
		Aythya affinis	lesser scaup	Mawby, 1967; Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005
		Athya americana		Mawby, 1967
		Mergus merganser	common merganser	Mawby, 1967; Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005
Ciconiiformes	Teratornithidae	*Teratornis merriami*	extinct teratorn	Mawby, 1967; Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005
Accipitriformes	Accipitridae	Buteoninae	indet. soaring hawk	Mawby, 1967; Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005
Gruiformes	Rallidae	*Fulica americana*	coot	Mawby, 1967; Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005
		Fulica americana minor	extinct small coot	Mawby, 1967; Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005
Strigiformes	Strigidae	*Bubo* sp.	owl	Mawby, 1967; Reynolds et al., 1991; Springer and Scott, 2003; Springer et al., 2005

Passeriformes	?Hirundinidae	? sp.	small perching birds	Reynolds et al., 1991; Springer and Scott; Rowland and Bonde, 2015
Anseriformes		? sp.	large goose	Mawby, 1967; Reynolds et al., 1991
			egg shell	Springer and Scott, 2003
Osteichthyes				
Teleostei		bony fish		Reynolds et al., 1991; Scott and Springer, 1993; Springer and Scott, 2003; Rowland and Bonde, 2015
Mollusca				
Pelecypoda	Sphaeriidae	*Pisidium casertanum*	ubiquitous peaclam	Simpson, 1933; Taylor, 1967; Quade, 1986; Quade and Pratt, 1989; Reynolds et al., 1991; Springer and Scott, 2003
		Pisidium compressum	ridged-beak peaclam	Simpson, 1933; Taylor, 1967; Quade, 1986; Quade and Pratt, 1989; Reynolds et al., 1991; Springer and Scott, 2003
		Pisidium insigne	tiny peaclam	Taylor, 1967
		Pisidium nitidum	shiny peaclam	Taylor, 1967
		Pisidium rotundatum	fat peaclam	Taylor, 1967
Gastropoda	Planorbidae	*Planorbis*	freshwater snail	Simpson, 1933; Springer and Scott, 2003
		Ferrissia	freshwater snail	Taylor, 1967
		Gyraulus parvus	freshwater snail	Taylor, 1967; Quade, 1986; Reynolds et al., 1991; Springer and Scott, 2003
		Gyraulus circumstriatus	freshwater snail	Taylor, 1967; Quade, 1986; Reynolds et al., 1991; Springer and Scott, 2003
		Helisoma sp. cf. *H. anceps*	freshwater snail	Springer and Scott, 2003
		Helisoma tenue	freshwater snail	Springer and Scott, 2003
		Helisoma trivolvis	freshwater snail	Reynolds et al., 1991

	Planorbella subcrenata	freshwater snail	Taylor, 1967; Quade, 1986; Springer and Scott, 2003
	Promenetus umbilicatellus	freshwater snail	Taylor, 1967
Physidae	*Physa virgata*	freshwater snail	Simpson, 1933; Taylor, 1967; Springer and Scott, 2003
Amnicolidae	*Amnicola*	freshwater snail	Simpson, 1933
Valvatidae	*Valvata humeralis*	freshwater snail	Taylor, 1967; Quade, 1986; Springer and Scott, 2003
Hydrobiidae	*Fontelicella micrococcus*	freshwater snail	Taylor, 1967; Quade, 1986; Springer and Scott, 2003
	Fontelicalla sp.	freshwater snail	Taylor, 1967
Lymnaeidae	*Stagnicola pilsbryi*	freshwater snail	Quade, 1986; Springer and Scott, 2003
	Fossaria parva	freshwater snail	Quade, 1986; Reynolds et al., 1991; Springer and Scott, 2003
	Fossaria obrussa	freshwater snail	Taylor, 1967; Quade, 1986; Reynolds et al., 1991; Springer and Scott, 2003
	Fossaria dalli	freshwater snail	Taylor, 1967
	Lymnaea caperata	freshwater snail	Taylor, 1967; Quade, 1986; Springer and Scott, 2003
	Lymnaea montanensis	freshwater snail	Taylor, 1967
	Lymnaea sp.	freshwater snail	Taylor, 1967; Quade, 1986; Reynolds et al., 1991; Springer and Scott, 2003
Physidae	*Physella virgata*	freshwater snail	Quade, 1986; Springer and Scott, 2003
Pupillidae	*Pupilla hebes*	terrestrial snail	Taylor, 1967; Quade, 1986; Springer and Scott, 2003
Vertiginidae	*Gastrocopta tappaniana*	terrestrial snail	Taylor, 1967; Quade, 1986; Springer and Scott, 2003
Agriolimacidae	*Deroceras* sp.	terrestrial snail	Reynolds et al., 1991
Vertiginidae	*Vertigo berryi*	terrestrial snail	Taylor, 1967; Quade, 1986; Reynolds et al., 1991; Springer and Scott, 2003
	Vertigo cf. *V. ovata*	terrestrial snail	Reynolds et al., 1991

	Valloniidae	*Vallonia cyclophorella*	terrestrial snail	Taylor, 1967; Quade, 1986; Reynolds et al., 1991; Springer and Scott, 2003
		Vallonia gracilicosta	terrestrial snail	Taylor, 1967; Quade, 1986; Reynolds et al., 1991; Springer and Scott, 2003
	Succineidae	*Catinella* sp.	terrestrial snail	Quade, 1986; Springer and Scott, 2003
		Succinea sp.	terrestrial snail	Taylor, 1967; Quade, 1986; Springer and Scott, 2003
		Oxyloma sp.	terrestrial snail	Taylor, 1967; Quade, 1986; Springer and Scott, 2003
	Pristilomatidae	*Hawaiia miniscula*	terrestrial snail	Taylor, 1967
	Euconulidae	*Euconulus fulvus*	terrestrial snail	Quade, 1986; Springer and Scott, 2003
	Limacidae	? sp.	terrestrial snail	Springer and Scott, 2003
	Discidae	*Discus* sp.	terrestrial snail	Springer and Scott, 2003
Crustacea			ostracodes	Reynolds et al., 1991; Springer and Scott, 2003
Plantae		cyanobacteria	blue-green algae	Springer and Scott, 2003
		Plantae	wood	Reynolds et al., 1991; Springer and Scott, 2003
		Tracheophyta	seed, wood	Springer and Scott, 2003
		Fraxinus	ash	Haynes, 1967
		Vitis	grape	Haynes, 1967
		Typha	cattail	Haynes, 1967
		Populus	poplar	Haynes, 1967
		Juniperus	Juniper	Haynes, 1967
		Cupressus	cypress	Haynes, 1967
Ichnofauna			cicada burrows	Quade, 1986; Springer and Scott, 2003
			root casts	Springer and Scott, 2003
			tufa phytoclasts	Springer and Scott, 2003
			wood rat middens	Springer and Scott, 2003

tufa cyanobacteria Springer and Scott, 2003

Appendix B – Inventory of TUSK paleontologic resources

Institution	Local number	Taxon/Article	Catalog number	Collector(s)	Element
American Museum of Natural History		*Mammuthus columbi*	FM 30045	F. Hunter and A.C. Silberling, 1932-33	molars, skull, lower jaw, skeletal fragments
		Mammuthus columbi	FM 30046	F. Hunter and A.C. Silberling, 1932-33	molars, skull, lower jaw, skeletal fragments
		Mammuthus columbi	FM 30047	F. Hunter and A.C. Silberling, 1932-33	molars, skull, lower jaw, skeletal fragments
		Mammuthus columbi	FM 30048	F. Hunter and A.C. Silberling, 1932-33	molars, skull, lower jaw, skeletal fragments
		Mammuthus columbi	FM 30049	F. Hunter and A.C. Silberling, 1932-33	molars, skull, lower jaw, skeletal fragments
		Mammuthus columbi	FM 30050	F. Hunter and A.C. Silberling, 1932-33	molars, skull, lower jaw, skeletal fragments
		Bison latifrons	FM 30051	F. Hunter and A.C. Silberling, 1932-33	nearly complete skull, isolated teeth
		Bison sp.	FM 30052	F. Hunter and A.C. Silberling, 1932-33	nearly complete skull, isolated teeth
		Camelops hesternus	FM 30053	F. Hunter and A.C. Silberling, 1932-33	mandible with teeth, isolated teeth, phalanx, skeletal fragments
		Camelops hesternus	FM 30054	F. Hunter and A.C. Silberling, 1932-33	mandible with teeth, isolated teeth, phalanx, skeletal fragments
		Camelops hesternus	FM 30055	F. Hunter and A.C. Silberling, 1932-33	mandible with teeth, isolated teeth, phalanx, skeletal fragments
		Camelops hesternus	FM 30056	F. Hunter and A.C. Silberling, 1932-33	mandible with teeth, isolated teeth, phalanx, skeletal fragments
		Equus sp.	FM 30057	F. Hunter and A.C. Silberling, 1932-33	lower teeth, astragalus
		Equus sp.	FM 30058	F. Hunter and A.C. Silberling, 1932-33	lower teeth, astragalus
		Odocoileus sp.	FM 30059	F. Hunter and A.C. Silberling, 1932-33	metapodials, and other fragments, base of antler

		Odocoileus sp.	FM 30060	F. Hunter and A.C. Silberling, 1932-33	metapodials, and other fragments, base of antler
		Nothrotheriops shastensis	FM 30061	F. Hunter and A.C. Silberling, 1932-33	skull, incomplete, no teeth
		Equus pacificus?(= E. scotti)	FM 30064	F. Hunter and A.C. Silberling, 1932-33	upper molars, lower teeth
		Camelops hesternus	FM 30065	F. Hunter and A.C. Silberling, 1932-33	mandible with teeth, isolated teeth, phalanx, skeletal fragments
		Mammalia	FM 30066	F. Hunter and A.C. Silberling, 1932-33	
		Lepus sp.	unable to locate in collections	F. Hunter and A.C. Silberling, 1932-33	fragmentary limb bones
		Thomomys sp.	unable to locate in collections	F. Hunter and A.C. Silberling, 1932-33	lower tooth
		maps, notes, and photographs	unable to locate in collections	F. Hunter and A.C. Silberling, 1932-33	
Autry National Center	10-F	*Mammoth*	10-F-12	M.R. Harrington, 1933	
		Camel	10-F-13	M.R. Harrington, 1933	
		Camel	10-F-14, a-c	M.R. Harrington, 1933	
		Camel	10-F-15	M.R. Harrington, 1933	
		Camel	10-F-16	M.R. Harrington, 1933	
		Camel	10-F-17	M.R. Harrington, 1933	
		Camel	10-F-18	M.R. Harrington, 1933	
		Bison	10-F-19	M.R. Harrington, 1933	
		Camel	10-F-20	M.R. Harrington, 1933	
		worked bone	10-F-22	M.R. Harrington, 1933	
		burnt bone	10-F-23	M.R. Harrington, 1933	
		Camel	10-F-25	M.R. Harrington, 1933	
		bone implement	10-F-26	M.R. Harrington, 1933	

Camel	10-F-27	M.R. Harrington, 1933
Camel	10-F-28	M.R. Harrington, 1933
bivalves	10-F-33	M.R. Harrington, 1933
univalves	10-F-34	M.R. Harrington, 1933
univalves	10-F-35	M.R. Harrington, 1933
bone, human?	10-F-37	M.R. Harrington, 1933
Camel?	10-F-38	M.R. Harrington, 1933
Mammoth	10-F-40	M.R. Harrington, 1933
snail	10-F-41	M.R. Harrington, 1933
bone	10-F-43	Southwest Museum Expedition, 1955
bone	10-F-51	Southwest Museum Expedition, 1955
Camel	10-F-54 a-d	Southwest Museum Expedition, 1955
bone	10-F-61	no catalogue card
bone	10-F-62	no catalogue card
bone	10-F-66	no catalogue card
bone	10-F-67	no catalogue card
bone	10-F-68	no catalogue card
bone	10-F-69	no catalogue card
bone	10-F-70	no catalogue card
bone	10-F-71	no catalogue card
bone	10-F-72	no catalogue card
Mammoth	10-F-74 a-e	no catalogue card
Camel	10-F-75	no catalogue card
bone	10-F-150	Southwest Museum Expedition, 1952
bone	10-F-151	Southwest Museum Expedition, 1952
bone	10-F-152	Southwest Museum Expedition, 1952
bone	10-F-153	Southwest Museum Expedition, 1952

		Mammoth plaster jacket plaster jacket plaster jacket	10-F-154	Simpson, 1960	
Canada Museum of Nature		*Bison*	CMNFV 8775 (AMNH 30051)	F. Hunter and A.C. Silberling, 1932-33	
Natural History Museum of Los Angeles	LACM 7797	*Carnivora*	LACM 154686	Harrington, 1933-34	
		Hemiauchenia	LACM 154687-154688	Harrington, 1933-34	
		Camelops	LACM 154689-154735	Harrington, 1933-34	
		Bison	LACM 154736-154747	Harrington, 1933-34	
		Equus	LACM 154748-154756	Harrington, 1933-34	
		Artiodactyla	LACM 154757	Harrington, 1933-34	
		Mammuthus	LACM 154758	Harrington, 1933-34	
		Proboscidea	LACM 154759	Harrington, 1933-34	
Las Vegas Natural History Museum	LVM-DC	*Mammuthus columbi*	IL 2014.1.1	Bonde, 2010-2014 on NV State Parks Land	tusk
		Camelops hesternus	IL 2014.1.2	Bonde, 2010-2014 on NV State Parks Land	metacarpal
		Camelops hesternus	IL 2014.1.3	Bonde, 2010-2014 on NV State Parks Land	metacarpal
		Mammuthus columbi	IL 2014.1.4	Bonde, 2010-2014 on NV State Parks Land	tusk
		Mammuthus columbi	IL 2014.1.5	Bonde, 2010-2014 on NV State Parks Land	tusk

	Bison sp.	IL 2014.1.6	Bonde, 2010-2014 on NV State Parks Land	radius
	Bison sp.	IL 2014.1.7	Bonde, 2010-2014 on NV State Parks Land	radius
	Canis cf. dirus	IL 2014.1.8	Bonde, 2010-2014 on NV State Parks Land	metacarpal
	Camelops hesternus	IL 2014.1.9	Bonde, 2010-2014 on NV State Parks Land	phalanx
Nevada State Museum, Carson City	*Equus*		Figured in NSM AP #13	mandible w/ teeth
	1200-2000 Historical Photos		1962 National Geographic Big Dig photos	
Nevada State Museum, Las Vegas	>1200 Historical Photos		1962 National Geographic Photos and 2002 Big Dig Reunion Photos	
	10,000 specimens - July 2015 repatriation collection from SBCM			
San Bernardino County Museum	10,000 specimens	36 fossil localities	2001-2002 Transmission Line survey (coordinated by BLM)	
	100,000 specimens	438 fossil localities	2003-2012 BLM survey	
	Historical Photos		1962 Big Dig photos	
	Historical Photos		1955-1956 Harrington expedition	
Santa Barbara Museum of Natural History	*Mammuthus*	SBMNH VP-321	Phil Orr, 1956	femur & tooth
	Camelops	SBMNH VP-381	Phil Orr, 1956	axis vertebrae

University of California Museum of Paleontology	3552	*Panthera atrox*	23918	C. Stock and R.J. Russell in 1919	right proximal phalanx, pes digit IV
	3552	*Bovidae*	23919	C. Stock and R.J. Russell in 1919	phalanx
	3552	*Equus*	23920	C. Stock and R.J. Russell in 1919	tibia
	3552	*Equus*	23921	C. Stock and R.J. Russell in 1919	tooth
	3552	*Equus*	23922	C. Stock and R.J. Russell in 1919	tooth
	3552	*Equus*	23923	C. Stock and R.J. Russell in 1919	rib
	3552	*Mammuthus*	23924	C. Stock and R.J. Russell in 1919	tooth fragments
	3552	*Bison*	23925	C. Stock and R.J. Russell in 1919	tooth
	3552	*Bison*	23926	C. Stock and R.J. Russell in 1919	cuneiform
	V6242-V6251	*Xenarthra*	64231	Mawby Party, 1963	UNGUAL
	V6242-V6251	*Nothrotheriops shastensis*	64232	Mawby Party, 1963	L M
	V6242-V6251	*Megalonyx*	64233	Mawby Party, 1963	C/
	V6242-V6251	*Megalonyx*	64234	Mawby Party, 1963	PROX PHALANX,DIGIT 3 ?,MANUS
	V6242-V6251	*Megalonyx*	64235	Mawby Party, 1963	MID PHALANX,DIGIT 3 ?,MANUS
	V6242-V6251	*Megalonyx*	64236	Mawby Party, 1963	MID PHALANX,DIGIT 3 ?,MANUS
	V6242-V6251	*Tetrameryx*	64237	Mawby Party, 1963	TIBIA
	V6242-V6251	*Tetrameryx*	64238	Mawby Party, 1963	METAPODIAL
	V6242-V6251	*Camelops*	64239	Mawby Party, 1963	PROX PHALANGES
	V6242-V6251	*Mammalia*	64240	Mawby Party, 1963	RIB
	V6242-V6251	*Mammalia*	64241	Mawby Party, 1963	RIB FRAG
	V6242-V6251	*Camelops*	64242	Mawby Party, 1963	CARPALS
	V6242-V6251	*Camelops*	64243	Mawby Party, 1963	TEETH
	V6242-V6251	*Camelops*	64244	Mawby Party, 1963	PHALANX
	V6242-V6251	*Camelops*	64245	Mawby Party, 1963	CALCANEUM FRAG
	V6242-V6251	*Leporidae*	64246	Mawby Party, 1963	TOOTH
	V6242-V6251	*Heteromyidae*	64247	Mawby Party, 1963	TOOTH
	V6242-V6251	*Mammuthus*	64248	Mawby Party, 1963	TOOTH
	V6242-V6251	*Equus*	64249	Mawby Party, 1963	/P2
	V6242-V6251	*Equus*	64250	Mawby Party, 1963	/M3
	V6242-V6251	*Equus*	64251	Mawby Party, 1963	
	V6242-V6251	*Equus*	64252	Mawby Party, 1963	/P2
	V6242-V6251	*Equus*	64253	Mawby Party, 1963	/DP3
	V6242-V6251	*Equus*	64254	Mawby Party, 1963	MAXILLA W P3-M2

V6242-V6251	*Equus*	64255	Mawby Party, 1963	
V6242-V6251	*Equus*	64256	Mawby Party, 1963	TOOTH FRAGS
V6242-V6251	*Equus*	64257	Mawby Party, 1963	M3/
V6242-V6251	*Equus*	64258	Mawby Party, 1963	M2/
V6242-V6251	*Equus*	64259	Mawby Party, 1963	DP/
V6242-V6251	*Equus*	64260	Mawby Party, 1963	M/ FRAG
V6242-V6251	*Equus*	64261	Mawby Party, 1963	
V6242-V6251	*Equus*	64262	Mawby Party, 1963	
V6242-V6251	*Equus*	64263	Mawby Party, 1963	DENTARY FRAG W DP3-DP4
V6242-V6251	*Equus*	64264	Mawby Party, 1963	L+R DP3/+L DP4/
V6242-V6251	*Equus*	64265	Mawby Party, 1963	D TEETH
V6242-V6251	*Camelidae*	64266	Mawby Party, 1963	ASTRAGALUS FRAG
V6242-V6251	*Camelops*	64267	Mawby Party, 1963	TEETH
V6242-V6251	*Camelops*	64268	Mawby Party, 1963	TEETH
V6242-V6251	*Antilocapridae*	64269	Mawby Party, 1963	LUNAR
V6242-V6251	*Lepridae*	64270	Mawby Party, 1963	DIST TIBIA
V6242-V6251	*Canis latrans*	64271	Mawby Party, 1963	TEETH
V6242-V6251	*Camelops*	64272	Mawby Party, 1963	CUBOID
V6242-V6251	*Camelops*	64273	Mawby Party, 1963	METAPODIAL
V6242-V6251	*Lepus*	64274	Mawby Party, 1963	CALCANEA
V6242-V6251	*Lepus*	64275	Mawby Party, 1963	DENTARY
V6242-V6251	*Antilocapridae*	64276	Mawby Party, 1963	FIBULA
V6242-V6251	*Sylvilagus*	64277	Mawby Party, 1963	TEETH,DENTARY FRAGS
V6242-V6251	*Camelops*	64278	Mawby Party, 1963	TOOTH FRAG
V6242-V6251	*Mammalia*	64279	Mawby Party, 1963	DIST FEMUR
V6242-V6251	*Mammalia*	64280	Mawby Party, 1963	RIB
V6242-V6251	*Sylvilagus*	64281	Mawby Party, 1963	SKULL FRAG
V6242-V6251	*Rodentia*	64282	Mawby Party, 1963	TOOTH FRAG
V6242-V6251	*Leporidae*	64283	Mawby Party, 1963	PROX ULNA
V6242-V6251	*Mammalia*	64284	Mawby Party, 1963	PETROSAL
V6242-V6251	*Camelidae*	64285	Mawby Party, 1963	TOOTH FRAG
V6242-V6251	*Odocoileus*	64286	Mawby Party, 1963	/R M3
V6242-V6251	*Sylvilagus*	64287	Mawby Party, 1963	DENTARY
V6242-V6251	*Rodentia*	64288	Mawby Party, 1963	I
V6242-V6251	*Lepus*	64289	Mawby Party, 1963	TEETH
V6242-V6251	*Canis*	64290	Mawby Party, 1963	C
V6242-V6251	*Sylvilagus*	64291	Mawby Party, 1963	TOOTH
V6242-V6251	*Antilocapridae*	64292	Mawby Party, 1963	TOOTH FRAG
V6242-V6251	*Sylvilagus*	64293	Mawby Party, 1963	
V6242-V6251	*Canidae*	64294	Mawby Party, 1963	ATLAS
V6242-V6251	*Camelops*	64295	Mawby Party, 1963	TOOTH
V6242-V6251	*Carnivora*	64296	Mawby Party, 1963	CALCANEUM
V6242-V6251	*Camelops*	64297	Mawby Party, 1963	TEETH
V6242-V6251	*Lepus*	64298	Mawby Party, 1963	TEETH
V6242-V6251	*Canis*	64299	Mawby Party, 1963	D TEETH
V6242-V6251	*Lepus*	64300	Mawby Party, 1963	TEETH
V6242-V6251	*Ondatra zibethica*	64311	Mawby Party, 1963	L DENTARY W M2

V6242-V6251	*Cricetidae*	64312	Mawby Party, 1963	TEETH
V6242-V6251	*Microtus*	64313	Mawby Party, 1963	DENTARY W M1-M2
V6242-V6251	*Microtus*	64314	Mawby Party, 1963	R DENTARY W M1-M2
V6242-V6251	*Microtus*	64315	Mawby Party, 1963	DENTARIES W M1-M2
V6242-V6251	*Sylvilagus*	64316	Mawby Party, 1963	DENTARY
V6242-V6251	*Lepus*	64317	Mawby Party, 1963	R DENTARY
V6242-V6251	*Lepus*	64318	Mawby Party, 1963	SKULL FRAGS
V6242-V6251	*Lepus*	64319	Mawby Party, 1963	SKULL+DENTARY
V6242-V6251	*Lepus*	64320	Mawby Party, 1963	L DENTARY W P4-M1
V6242-V6251	*Felis*	64321	Mawby Party, 1963	DENTARY W M1
V6242-V6251	*Lynx*	64322	Mawby Party, 1963	right distal tibia
V6242-V6251	*Lepus*	64323	Mawby Party, 1963	FEMUR
V6242-V6251	*Camelidae*	64324	Mawby Party, 1963	ASTRAGALUS
V6242-V6251	*Camelops*	64325	Mawby Party, 1963	MID PHALANX
V6242-V6251	*Mammalia*	64326	Mawby Party, 1963	I
V6242-V6251	*Camelops*	64327	Mawby Party, 1963	/M3
V6242-V6251	*Camelops*	64328	Mawby Party, 1963	TOOTH
V6242-V6251	*Camelops*	64329	Mawby Party, 1963	TOOTH
V6242-V6251	*Camelops*	64330	Mawby Party, 1963	/DP3
V6242-V6251	*Camelops*	64331	Mawby Party, 1963	TEETH
V6242-V6251	*Camelops*	64332	Mawby Party, 1963	I
V6242-V6251	*Camelops*	64333	Mawby Party, 1963	TOOTH
V6242-V6251	*Camelops*	64334	Mawby Party, 1963	TOOTH
V6242-V6251	*Camelops*	64335	Mawby Party, 1963	TOOTH
V6242-V6251	*Camelops*	64336	Mawby Party, 1963	TOOTH
V6242-V6251	*Camelops*	64337	Mawby Party, 1963	TOOTH
V6242-V6251	*Camelops*	64338	Mawby Party, 1963	TOOTH
V6242-V6251	*Camelops*	64339	Mawby Party, 1963	I
V6242-V6251	*Camelops*	64340	Mawby Party, 1963	I
V6242-V6251	*Camelops*	64341	Mawby Party, 1963	TOOTH
V6242-V6251	*Equus*	64342	Mawby Party, 1963	C
V6242-V6251	*Camelops*	64343	Mawby Party, 1963	TEETH
V6242-V6251	*Sylvilagus*	64344	Mawby Party, 1963	TEETH
V6242-V6251	*Lepus*	64345	Mawby Party, 1963	TEETH,DENTARY FRAGS
V6242-V6251	*Camelops*	64346	Mawby Party, 1963	MAGNUM
V6242-V6251	*Camelops*	64347	Mawby Party, 1963	ASTRAGALUS
V6242-V6251	*Camelops*	64348	Mawby Party, 1963	PHALANX
V6242-V6251	*Antilocapridae*	64349	Mawby Party, 1963	PHALANX
V6242-V6251	*Equus*	64350	Mawby Party, 1963	ASTRAGALUS
V6242-V6251	*Antilocapridae*	64351	Mawby Party, 1963	METAPODIAL EPIPHYSES
V6242-V6251	*Antilocapridae*	64352	Mawby Party, 1963	ASTRAGALUS
V6242-V6251	*Mammuthus columbi*	64353	Mawby Party, 1963	TOOTH
V6242-V6251	*Canis latrans*	64354	Mawby Party, 1963	FEMUR
V6242-V6251	*Camelops*	64355	Mawby Party, 1963	TEETH

V6242-V6251	*Camelops*	64356	Mawby Party, 1963	TOOTH
V6242-V6251	*Camelops*	64357	Mawby Party, 1963	TOOTH
V6242-V6251	*Camelops*	64358	Mawby Party, 1963	TOOTH
V6242-V6251	*Camelops*	64359	Mawby Party, 1963	TEETH
V6242-V6251	*Camelops*	64360	Mawby Party, 1963	/DP3
V6242-V6251	*Equus*	64361	Mawby Party, 1963	I
V6242-V6251	*Canis latrans*	64362	Mawby Party, 1963	P4/
V6242-V6251	*Equus*	64363	Mawby Party, 1963	C
V6242-V6251	*Antilocapridae*	64364	Mawby Party, 1963	TIBIA FRAG
V6242-V6251	*Mammalia*	64365	Mawby Party, 1963	THORACIC VERTEBRA
V6242-V6251	*Camelops*	64366	Mawby Party, 1963	TEETH
V6242-V6251	*Camelops*	64367	Mawby Party, 1963	TOOTH
V6242-V6251	*Camelops*	64368	Mawby Party, 1963	
V6242-V6251	*Equus*	64369	Mawby Party, 1963	P2/
V6242-V6251	*Equus*	64370	Mawby Party, 1963	P3 ?/
V6242-V6251	*Equus*	64371	Mawby Party, 1963	C
V6242-V6251	*Camelops*	64372	Mawby Party, 1963	JUV L METACARPAL
V6242-V6251	*Camelops*	64373	Mawby Party, 1963	JUV L METACARPAL
V6242-V6251	*Camelops*	64374	Mawby Party, 1963	JUV R METATARSAL
V6242-V6251	*Camelops*	64375	Mawby Party, 1963	JUV R METACARPAL
V6242-V6251	*Equus*	64376	Mawby Party, 1963	JUV METAPODIAL
V6242-V6251	*Mammalia*	64377	Mawby Party, 1963	HUMERUS FRAG
V6242-V6251	*Mammalia*	64378	Mawby Party, 1963	JUV RADIUS FRAG
V6242-V6251	*Equus*	64379	Mawby Party, 1963	DIST TIBIA
V6242-V6251	*Camelops*	64380	Mawby Party, 1963	L METATARSAL FRAG
V6242-V6251	*Camelops*	64381	Mawby Party, 1963	CALCANEUM FRAG
V6242-V6251	*Camelops*	64382	Mawby Party, 1963	ASTRAGALUS
V6242-V6251	*Camelops*	64383	Mawby Party, 1963	PROX PHALANX
V6242-V6251	*Mammuthus*	64384	Mawby Party, 1963	PHALANGES
V6242-V6251	*Leporidae*	64385	Mawby Party, 1963	ASTRAGALUS
V6242-V6251	*Antilocapridae*	64386	Mawby Party, 1963	FIBULA
V6242-V6251	*Mammuthus*	64387	Mawby Party, 1963	PETROSAL
V6242-V6251	*Antilocapridae*	64388	Mawby Party, 1963	CERVICAL VERTEBRA
V6242-V6251	*Camelops*	64389	Mawby Party, 1963	SCAPULA
V6242-V6251	*Mammuthus*	64390	Mawby Party, 1963	STERNEBRA
V6242-V6251	*Camelops*	64391	Mawby Party, 1963	JUV RADIUS
V6242-V6251	*Camelops*	64392	Mawby Party, 1963	JUV TIBIA
V6242-V6251	*Mammuthus*	64393	Mawby Party, 1963	M/ ?
V6242-V6251	*Mammalia*	64394	Mawby Party, 1963	SCAPULA
V6242-V6251	*Camelops*	64395	Mawby Party, 1963	ASTRAGALUS
V6242-V6251	*Equus*	64396	Mawby Party, 1963	PHALANX
V6242-V6251	*Camelops*	64397	Mawby Party, 1963	PHALANX
V6242-V6251	*Camelops*	64398	Mawby Party, 1963	PHALANX

V6242-V6251	*Equus*	64399	Mawby Party, 1963	JUV PHALANX
V6242-V6251	*Antilocapridae*	64400	Mawby Party, 1963	STERNEBRA
V6242-V6251	*Camelops*	64461	Mawby Party, 1963	FIBULA
V6242-V6251	*Camelops*	64462	Mawby Party, 1963	PHALANX FRAG
V6242-V6251	*Mammalia*	64463	Mawby Party, 1963	VERTEBRAL EPIPHYSES
V6242-V6251	*Equus*	64464	Mawby Party, 1963	C
V6242-V6251	*Camelops*	64465	Mawby Party, 1963	TOOTH FRAGS
V6242-V6251	*Camelops*	64466	Mawby Party, 1963	M1-M2/
V6242-V6251	*Camelops*	64467	Mawby Party, 1963	I
V6242-V6251	*Camelops*	64468	Mawby Party, 1963	I
V6242-V6251	*Equus*	64469	Mawby Party, 1963	TOOTH FRAG
V6242-V6251	*Mammuthus*	64470	Mawby Party, 1963	TOOTH FRAGS
V6242-V6251	*Antilocapridae*	64471	Mawby Party, 1963	PROX PHALANX
V6242-V6251	*Mammalia*	64472	Mawby Party, 1963	PHALANX
V6242-V6251	*Antilocapridae*	64473	Mawby Party, 1963	UNGUAL PHALANX
V6242-V6251	*Antilocapridae*	64474	Mawby Party, 1963	MID PHALNAGES
V6242-V6251	*Canidae*	64475	Mawby Party, 1963	MID PHALANX
V6242-V6251	*Canidae*	64476	Mawby Party, 1963	PROX PHALANX
V6242-V6251	*Mammalia*	64477	Mawby Party, 1963	FEMUR FRAG
V6242-V6251	*Canis*	64478	Mawby Party, 1963	AXIS FRAG
V6242-V6251	*Lepus*	64479	Mawby Party, 1963	TIBIA FRAGS
V6242-V6251	*Leporidae*	64480	Mawby Party, 1963	HUMERUS
V6242-V6251	*Rodentia*	64481	Mawby Party, 1963	PROX PHALANX
V6242-V6251	*Rodentia*	64482	Mawby Party, 1963	FEMUR FRAG
V6242-V6251	*Lagomorpha*	64483	Mawby Party, 1963	ULNA FRAGS
V6242-V6251	*Lagomorpha*	64484	Mawby Party, 1963	TOOTH FRAGS,DENTARY FRAGS
V6242-V6251	*Rodentia*	64485	Mawby Party, 1963	I FRAGS
V6242-V6251	*Aves*	64486	Mawby Party, 1963	CORACOID
V6242-V6251	*Mammuthus*	64487	Mawby Party, 1963	SKULL FRAGS
V6242-V6251	*Mammuthus*	64488	Mawby Party, 1963	ASTRAGALUS
V6242-V6251	*Mammuthus*	64489	Mawby Party, 1963	DIST RADIUS
V6242-V6251	*Camelops*	64490	Mawby Party, 1963	DIST HUMERUS
V6242-V6251	*Camelops*	64491	Mawby Party, 1963	SACRUM
V6242-V6251	*Camelops*	64492	Mawby Party, 1963	JUV R METATARSAL
V6242-V6251	*Camelops*	64493	Mawby Party, 1963	R NAVICULAR
V6242-V6251	*Mammuthus*	64494	Mawby Party, 1963	PHALANX
V6242-V6251	*Camelops*	64495	Mawby Party, 1963	JUV PHALANX
V6242-V6251	*Antilocapridae*	64496	Mawby Party, 1963	THORACIC VERTEBRA
V6242-V6251	*Mammuthus*	64497	Mawby Party, 1963	/M2 ?
V6242-V6251	*Mammuthus*	64498	Mawby Party, 1963	/M1
V6242-V6251	*Mammuthus*	64499	Mawby Party, 1963	P2-M1/
V6242-V6251	*Mammuthus*	64500	Mawby Party, 1963	DP
V6242-V6251	*Mammuthus*	64501	Mawby Party, 1963	/M3 ?
V6242-V6251	*Mammuthus*	64502	Mawby Party, 1963	M/
V6242-V6251	*Camelops*	64503	Mawby Party, 1963	TIBIA FRAG

V6242-V6251	*Camelops*	64504	Mawby Party, 1963	ASTRAGALUS FRAG
V6242-V6251	*Camelops*	64505	Mawby Party, 1963	L METATARSAL FRAG
V6242-V6251	*Camelops*	64506	Mawby Party, 1963	R CALCANEUM
V6242-V6251	*Camelops*	64507	Mawby Party, 1963	L CALCANEUM
V6242-V6251	*Camelops*	64508	Mawby Party, 1963	L NAVICULAR+CUBOID
V6242-V6251	*Camelops*	64509	Mawby Party, 1963	R MAGNUM
V6242-V6251	*Mammalia*	64510	Mawby Party, 1963	SESAMOID
V6242-V6251	*Mammalia*	64511	Mawby Party, 1963	THORACIC VERTEBRA
V6242-V6251	*Camelops hesternus*	64512	Mawby Party, 1963	/R P4-M3
V6242-V6251	*Camelops hesternus*	64513	Mawby Party, 1963	/L M3
V6242-V6251	*Camelops hesternus*	64514	Mawby Party, 1963	/L M1 FRAG
V6242-V6251	*Mammalia*	64515	Mawby Party, 1963	C
V6242-V6251	*Mammalia*	64516	Mawby Party, 1963	I
V6242-V6251	*Mammalia*	64517	Mawby Party, 1963	C
V6242-V6251	*Aves*	64518	Mawby Party, 1963	
V6242-V6251	*Aves*	64519	Mawby Party, 1963	PHALANX
V6242-V6251	*Lepus*	64520	Mawby Party, 1963	TOOTH FRAG
V6242-V6251	*Rodentia*	64521	Mawby Party, 1963	I,PHALANX
V6242-V6251	*Mammalia*	64522	Mawby Party, 1963	UNCIFORM ?
V6242-V6251	*Puma concolor*	64523	Mawby Party, 1963	left C/, P2/, P3/ FRAG+incisor root
V6242-V6251	*Microtus*	64524	Mawby Party, 1963	TEETH
V6242-V6251	*Camelops*	64525	Mawby Party, 1963	TOOTH FRAGS
V6242-V6251	*Camelops*	64526	Mawby Party, 1963	CALCANEUM FRAG
V6242-V6251	*Equus*	64527	Mawby Party, 1963	/P4 ?
V6242-V6251	*Equus*	64528	Mawby Party, 1963	DP
V6242-V6251	*Equus*	64529	Mawby Party, 1963	I
V6242-V6251	*Camelops*	64530	Mawby Party, 1963	L METACARPAL
V6242-V6251	*Tetrameryx*	64531	Mawby Party, 1963	DENTARY
V6242-V6251	*Tetrameryx*	64532	Mawby Party, 1963	/L M3
V6242-V6251	*Tetrameryx*	64533	Mawby Party, 1963	TEETH
V6242-V6251	*Tetrameryx*	64534	Mawby Party, 1963	DP3-M3/,DP2/ FRAG ?
V6242-V6251	*Tetrameryx*	64535	Mawby Party, 1963	R DENTARY W P4-M3
V6242-V6251	*Tetrameryx*	64536	Mawby Party, 1963	/DP4-M3
V6242-V6251	*Tetrameryx*	64537	Mawby Party, 1963	M1/ ?
V6242-V6251	*Tetrameryx*	64538	Mawby Party, 1963	/D TEETHTH
V6242-V6251	*Lepus*	64539	Mawby Party, 1963	BONES,TEETH
V6242-V6251	*Rodentia*	64540	Mawby Party, 1963	I
V6242-V6251	*Camelops*	64541	Mawby Party, 1963	PROX PHALANX
V6242-V6251	*Camelops*	64542	Mawby Party, 1963	TOOTH FRAGS
V6242-V6251	*Camelops*	64543	Mawby Party, 1963	TEETH
V6242-V6251	*Bison*	64544	Mawby Party, 1963	TOOTH
V6242-V6251	*Camelops*	64545	Mawby Party, 1963	/M2

V6242-V6251	*Camelops*	64546	Mawby Party, 1963	C
V6242-V6251	*Camelops*	64547	Mawby Party, 1963	PROX PHALANX
V6242-V6251	*Camelops*	64548	Mawby Party, 1963	I
V6242-V6251	*Camelops*	64549	Mawby Party, 1963	/M3,TOOTH FRAGS
V6242-V6251	*Canis latrans*	64550	Mawby Party, 1963	LEFT PROX ULNA
V6242-V6251	*Camelops*	64561	Mawby Party, 1963	L CUBOID
V6242-V6251	*Camelops*	64562	Mawby Party, 1963	/DP4
V6242-V6251	*Mammalia*	64563	Mawby Party, 1963	SESAMOID
V6242-V6251	*Equus*	64564	Mawby Party, 1963	TOOTH FRAG
V6242-V6251	*Equus*	64565	Mawby Party, 1963	METAPODIAL,PAHLANX FRAGS
V6242-V6251	*Equus*	64566	Mawby Party, 1963	DENTARY W DP2-M3
V6242-V6251	*Leporidae*	64567	Mawby Party, 1963	METAPODIAL FRAGS
V6242-V6251	*Rodentia*	64568	Mawby Party, 1963	I
V6242-V6251	*Anura*	64569	Mawby Party, 1963	INNOMINATE FRAG,LIMB BONE
V6242-V6251	*Camelops*	64570	Mawby Party, 1963	DENTARY FRAG W DP
V6242-V6251	*Camelops*	64571	Mawby Party, 1963	/P4
V6242-V6251	*Equus*	64572	Mawby Party, 1963	DI
V6242-V6251	*Mammalia*	64573	Mawby Party, 1963	I
V6242-V6251	*Camelops*	64574	Mawby Party, 1963	I FRAGS
V6242-V6251	*Mammalia*	64575	Mawby Party, 1963	I
V6242-V6251	*Aves*	64576	Mawby Party, 1963	STERNUM FRAG ?
V6242-V6251	*Equus*	64577	Mawby Party, 1963	SKULL FRAG
V6242-V6251	*Camelops*	64578	Mawby Party, 1963	L ASTRAGALUS
V6242-V6251	*Camelops*	64579	Mawby Party, 1963	L CUNEIFORM
V6242-V6251	*Camelops*	64580	Mawby Party, 1963	L LUNAR
V6242-V6251	*Camelops*	64581	Mawby Party, 1963	R SCAPHOID
V6242-V6251	*Camelops*	64582	Mawby Party, 1963	R MAGNUM
V6242-V6251	*Camelops*	64583	Mawby Party, 1963	R MAGNUM
V6242-V6251	*Camelops*	64584	Mawby Party, 1963	JUV R SCAPHOID FRAG ?
V6242-V6251	*Camelops*	64585	Mawby Party, 1963	PROX PHALANGES
V6242-V6251	*Camelops*	64586	Mawby Party, 1963	MID PHALANX
V6242-V6251	*Camelops*	64587	Mawby Party, 1963	JUV METAPODIAL FRAGS
V6242-V6251	*Mammalia*	64588	Mawby Party, 1963	SESAMOIDS
V6242-V6251	*Camelops*	64589	Mawby Party, 1963	R MESOCUNEIFORM
V6242-V6251	*Mammalia*	64590	Mawby Party, 1963	PETROSAL
V6242-V6251	*Camelidae*	64591	Mawby Party, 1963	SKULL FRAG
V6242-V6251	*Aves*	64592	Mawby Party, 1963	
V6242-V6251	*Leporidae*	64593	Mawby Party, 1963	METATARSAL 5 ?
V6242-V6251	*Camelops*	64594	Mawby Party, 1963	PATELLAE
V6242-V6251	*Camelops*	64595	Mawby Party, 1963	CALCANEUM FRAGS
V6242-V6251	*Camelops*	64596	Mawby Party, 1963	R METACARPAL

V6242-V6251	*Camelops*	64597	Mawby Party, 1963	JUV R METACARPAL
V6242-V6251	*Camelops*	64598	Mawby Party, 1963	JUV HUMERUS FRAG
V6242-V6251	*Equus*	64599	Mawby Party, 1963	HUMERUS
V6242-V6251	*Camelops*	64600	Mawby Party, 1963	DIST HUMERUS
V6242-V6251	*Camelops*	64611	Mawby Party, 1963	SCAPULA FRAG
V6242-V6251	*Camelops*	64612	Mawby Party, 1963	RADIUS+ULNA
V6242-V6251	*Camelops*	64613	Mawby Party, 1963	RIB
V6242-V6251	*Camelops*	64614	Mawby Party, 1963	DENTARY FRAG W M1-M3
V6242-V6251	*Mammuthus*	64615	Mawby Party, 1963	L CUNEIFORM
V6242-V6251	*Camelops hesternus*	64616	Mawby Party, 1963	DENTARY FRAG
V6242-V6251	*Bison*	64617	Mawby Party, 1963	D TEETH ?
V6242-V6251	*Camelops*	64618	Mawby Party, 1963	JUV L METATARSAL
V6242-V6251	*Camelops*	64619	Mawby Party, 1963	TEETH,PODIALS
V6242-V6251	*Sylvilagus*	64620	Mawby Party, 1963	DENTARY FRAG
V6242-V6251	*Lepus*	64621	Mawby Party, 1963	MAXILLA FRAGS,TEETH
V6242-V6251	*Camelops*	64622	Mawby Party, 1963	SKULL FRAG
V6242-V6251	*Antilocapridae*	64623	Mawby Party, 1963	PROX PHALANX
V6242-V6251	*Camelops*	64624	Mawby Party, 1963	PATELLAE
V6242-V6251	*Camelops*	64625	Mawby Party, 1963	CERVICAL VERTEBRA
V6242-V6251	*Mammalia*	64626	Mawby Party, 1963	SCAPULA
V6242-V6251	*Mammalia*	64627	Mawby Party, 1963	PODIAL
V6242-V6251	*Lynx rufus*	64628	Mawby Party, 1963	INNOMINATE FRAGS
V6242-V6251	*Camelops*	64629	Mawby Party, 1963	I FRAG
V6242-V6251	*Camelops*	64630	Mawby Party, 1963	I
V6242-V6251	*Camelops*	64631	Mawby Party, 1963	I
V6242-V6251	*Mammalia*	64632	Mawby Party, 1963	C FRAG
V6242-V6251	*Mammalia*	64633	Mawby Party, 1963	TOOTH FRAG
V6242-V6251	*Camelops*	64634	Mawby Party, 1963	/DP3
V6242-V6251	*Camelops*	64635	Mawby Party, 1963	P4/
V6242-V6251	*Camelops*	64636	Mawby Party, 1963	M/
V6242-V6251	*Camelops*	64637	Mawby Party, 1963	M
V6242-V6251	*Camelops*	64638	Mawby Party, 1963	/M
V6242-V6251	*Camelops*	64639	Mawby Party, 1963	M/
V6242-V6251	*Camelops*	64640	Mawby Party, 1963	M/
V6242-V6251	*Camelops*	64641	Mawby Party, 1963	PREMAXILLA
V6242-V6251	*Camelops*	64642	Mawby Party, 1963	MAXILLA FRAG W P4-M1
V6242-V6251	*Camelops*	64643	Mawby Party, 1963	DENTARY
V6242-V6251	*Bison*	64644	Mawby Party, 1963	R METATARSAL
V6242-V6251	*Bison antiquus*	64645	Mawby Party, 1963	R METACARPAL
V6242-V6251	*Bison antiquus*	64646	Mawby Party, 1963	left METACARPAL
V6242-V6251	*Bison*	64647	Mawby Party, 1963	PATELLAE
V6242-V6251	*Bison*	64648	Mawby Party, 1963	SESAMOIDS

V6242-V6251	*Bison*	64649	Mawby Party, 1963	PHALANGES
V6242-V6251	*Bison*	64650	Mawby Party, 1963	PHALANGES
V6242-V6251	*Bison*	64681	Mawby Party, 1963	PHALANGES
V6242-V6251	*Bison*	64682	Mawby Party, 1963	PHALANGES
V6242-V6251	*Bison antiquus*	64683	Mawby Party, 1963	r astragalus
V6242-V6251	*Bison*	64684	Mawby Party, 1963	L TARSALS
V6242-V6251	*Bison antiquus*	64685	Mawby Party, 1963	left magnum
V6242-V6251	*Bison antiquus*	64686	Mawby Party, 1963	right magnum
V6242-V6251	*Bison antiquus*	64687	Mawby Party, 1963	left magnum
V6242-V6251	*Bison*	64688	Mawby Party, 1963	HORN CORE FRAG
V6242-V6251	*Bison*	64689	Mawby Party, 1963	R HUMERUS
V6242-V6251	*Bison*	64690	Mawby Party, 1963	TIBIA FRAG
V6242-V6251	*Camelops*	64691	Mawby Party, 1963	DIST HUMERUS
V6242-V6251	*Bison*	64692	Mawby Party, 1963	DENTARY
V6242-V6251	*Bison*	64693	Mawby Party, 1963	L METATARSAL
V6242-V6251	*Bison*	64694	Mawby Party, 1963	CAUDAL VERTEBRAE
V6242-V6251	*Bison*	64695	Mawby Party, 1963	P
V6242-V6251	*Bison*	64696	Mawby Party, 1963	I
V6242-V6251	*Bison*	64697	Mawby Party, 1963	I
V6242-V6251	*Equus*	64698	Mawby Party, 1963	SKULL FRAGS
V6242-V6251	*Bison*	64699	Mawby Party, 1963	CERVICAL VERTEBRAE
V6242-V6251	*Aythya affinis*	69593	Tule Springs Expedition	L DIST ULNA
V6242-V6251	*Aythya collaris*	69594	Tule Springs Expedition	L DIST HUMERUS
V6242-V6251	*Aythya*	69595	Tule Springs Expedition	R DIST CORACOID
V6242-V6251	*Buteoninae*	69596	Tule Springs Expedition	R DIST ULNA
V6242-V6251	*Fulica americana*	69597	Tule Springs Expedition	R DIST TIBIOTARSUS
V6242-V6251	*Fulica americana*	69598	Tule Springs Expedition	L HUMERUS
V6242-V6251	*Anas americana*	69601	Tule Springs Expedition	R PROX HUMERUS
V6242-V6251	*Anas americana*	69602	Tule Springs Expedition	L CORACOID
V6242-V6251	*Mergus merganser*	69603	Tule Springs Expedition	R DIST HUMERUS
V6242-V6251	*Aves*	69604	Tule Springs Expedition	BONES
V6242-V6251	*Equus*	156013	NSM Expedition	molar frags
V6242-V6251	*Mammuthus*	197818	NSM Expedition	femur diaphysis, juvenile