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WESTERN ASSOCIATION OF VERTEBRATE PALEONTOLOGY ANNUAL MEETING

PROGRAM WITH ABSTRACTS

ANZA-BORREGO DESERT STATE PARK®
BORREGO SPRINGS, CA

FEBRUARY 13–14, 2016

Host Committee:
Lyndon K Murray and **George T Jefferson**
Colorado Desert District Stout Research Center
Joanne S Ingwall and **Myrl Beck**

Anza-Borrego Desert State Park®
Anza-Borrego Desert State Park® Paleontology Society
The Anza-Borrego Foundation
University of California Irvine Steele/Burnand Anza-Borrego Desert Research Center

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ORAL PRESENTATIONS

8:30-8:45 am		**WELCOME**	
8:45-9:00	Thomson et al.	**Potential Research Avenues Provided by a Nine-Ton Field Jacket Containing Baby, Juvenile and Adult Utahraptors (Theropoda; Dromaeosauridae)**	Cretaceous, Cedar Mountain Formation
9:00-9:15	Gensler	**Working in Wilderness Areas and Wilderness Study Areas: The Removal of Two *Pentaceratops* Partial Skeletons by Helicopter**	Cretaceous, Fruitland/Kirtland Formation
9:15-9:30	Wedel et al.	**Pneumatic Diverticula Associated with the Spinal Cord in Birds, Sauropod Dinosaurs, and Other Ornithodiran Archosaurs**	Cretaceous/Paleocene, Cloverly and Black Hills Formations
9:30-9:45	Scherzer	**An Archaic Mysticetid from The Vaqueros Formation, and Other Fossil Material from The Skyridge Project, Orange County, CA**	Oligocene/Miocene, Vaqueros Formation, invertebrates, cetaceans
9:45-10:00	Zhang	**Deflating The Taxonomic Diversity of *Merycodus* (Family: Antilocapridae)**	Miocene, Valentine and Barstow Formations
10:00-10:30		**BREAK AND POSTER VIEWING**	
10:30-10:45	Bevers	**The Milk Creek Fauna: a Late Miocene Mammal Site from Central Arizona**	Miocene, Milk Creek AZ, faunal diversity
10:45-11:00	Sankey et al.	**Survival of the Tuskiest: Giant, Tusk-Toothed Salmon from California**	Miocene/Pliocene, west coastal marine vs. freshwater deposits
11:00-11:15	Wagner et al.	**An Early Pliocene Microtine Rodent from the Lower San Joaquin Formation from the Kettleman Hills Facility, Kings County, California**	Pliocene, San Joaquin Formation, microfossil fauna
11:15-11:30	Chandler et al.	**The Terror Bird, *Titanis* (Phorusrhacidae) from Pliocene Olla Formation, Anza-Borrego Desert State Park, Southern California**	Pliocene, Salton Trough
11:30-11:45	Gilbert J	**Tracking the Tracks with Photogrammetry**	Photogrammetry
11:45-12:00	Molnar	**Cognitive Bias in Paleontology**	cognitive bias
Noon –2 pm		**LUNCH AND POSTER VIEWING**	
2:00-2:15	Murray and Gilbert L	**Data Improvement: Repairing Data Errors in a Vertebrate Paleontology Collection**	repairing data errors in paleontology collections
2:15-2:30	Lindsay and Stafford	**Widespread Collagen Radiocarbon Date Contamination Resolved Through XAD Resin Purification**	Quaternary, radiocarbon dating contamination
2:30-2:45	Stewart and Hakel	**Pleistocene Paleosol Developed on Ancestral Mojave River Sediments Near Hinkley CA**	Pleistocene, Mojave River

2:45-3:00	Springer et al.	**The Paleoclimate, Paleohydrology and Vertebrate Paleontology of Tule Springs Fossil Beds Nationl Monument**	Pleistocene, Tule Springs Fossil Beds National Monument, radioisotope dating
3:00 – 3:30		**BREAK AND POSTER VIEWING**	
3:30-3:45	Demere et al.	**A Middle Pleistocene Mammoth (*Mammuthus columbi*) from the Coastal Plain of San Diego County, California**	Pleistocene, San Diego CA
3:45-4:00	Dooley and Scott	**How small Are California Mastodons, Really?**	Pleistocene, North America
4:00-4:15	McDonald	***Eremotherium* Bones and the Cenote of Doom: New Pleistocene Records from Belize**	Pleistocene, Belize cenotes
4:15-4:30	Murray et al.	**A New Fossil Assemblage in the Anza-Borrego Desert**	Pleistocene, Carrizo Badlands in the Anza-Borrego Desert
4:30-4:45		**CLOSING REMARKS** **SELECTION OF 2017 WAVP VENUE**	

POSTER PRESENTATIONS

Poster #			
1	Homidan and Lofgren	**Late Eocene Ischyromids from Pipestone Springs, Montana**	Eocene, Pipestone Springs Main Pocket
2	Jamal and Farke	**Dental Pathology in *Hoplophoneus occidentalis* (Nimravidae)**	Oligocene, Brule Formation,
3	Senise and Farke	**A Proboscidean Trackway from the Barstow Formation of Southern California**	Miocene, Barstow Formation, photogrammetry
4	Chu et al.	**Reinterpretation of Felid Footprints from the Barstow Formation (Miocene) of Southern California**	Miocene, Barstow Formation, photogrammetry
5	Weideman et al.	**Paleontology of Arizona and the Milk Creek Fossils**	Miocene, Mill Creek AZ, analysis of vertebrate taxa
6	Wilson et al.	**Depositional Environments of the Turlock Lake Paleoflora, Upper Mehrten Formation (Mio-Pliocene), Northern San Joaquin Valley, California**	Miocene/Pliocene, Turlock Lake CA, Mehrten Formation, paleoflora
7	Borce et al.	**Intraspecific Variation in Cranial And Mandibular Morphology of the Extinct River Dolphin *Parapontoporia sternbergi* from the Upper Pliocene San Diego Formation, Southern California**	Pliocene, San Diego Formation

8	Potapova	**The Taphonomy of the Avian Remains in the Northwestern Caucasus, Russia, and the Late Pleistocene (Mis 4-2) Environmental Changes**	Pleistocene, Matuzka Cave Russia
9	Potapova	**Taphonomy of the Bird Remains from the Postglacial Horizons of the Medvezhya Cave in the Northern Urals, Russia**	Pleistocene, Medvezhya Cave in Russia
10	Friedman et al.	**The Irvingtonian Type Locality (Alameda County California), a Historical Perspective**	Pleistocene, Irvingtonian, San Francisco Bay, fossil collection history, Boy Paleontologists of Hayward
11	Glenister and Walker	**New Rancholabrean Mammal Fossil Site from Warm Springs District, Fremont, California**	Pleistocene, Rancholabrean, Warm Springs District of CA
12	Fox and Blois	**Preliminary Analysis of Small Mammal Fossils from "Project 23" at Rancho La Brea, Los Angeles CA**	Pleistocene, Rancho La Brea, plant, pollen, microfauna
13	Rowland and Parry	**Age Profile of Terminal Pleistocene Columbian Mammoths from the Tule Springs Fossil Beds of Southern Nevada**	Pleistocene, Tule Springs Fossil Beds, Mammuthus columbi, teeth
14	Jackson-Shannon	**North America Research Group (NARG)**	North America Research Group

THE MILK CREEK FAUNA: A LATE MIOCENE MAMMAL SITE FROM CENTRAL ARIZONA

BEVERS, Jeb, Department of Biology, Yavapai College, Prescott, AZ, USA

The Milk Creek fossil site (late Miocene) of Yavapai County, Arizona was first announced by Reed (1950) from a joint collecting expedition between the Museum of Northern Arizona and the University of Arizona. After a brief hiatus, ongoing collections of the Milk Creek site have continued to the present time. The largest of these holdings is in the Frick Collections of fossil mammals held at the American Museum of Natural History. Most of the other collections are in regional museums across Arizona. A recent examination of these collections permitted a more comprehensive description of the known diversity of the Milk Creek mammal assemblage. This examination also located two previously unreported taxa from the site, including a canid *Leptocyon* sp. and a large camelid distinct from the two more common camelids from the genera *Michenia* and *Protolabis*. A current analysis of the Milk Creek fauna diversity is presented.

INTRASPECIFIC VARIATION IN CRANIAL AND MANDIBULAR MORPHOLOGY OF THE EXTINCT RIVER DOLPHIN *PARAPONTOPORIA STERNBERGI* FROM THE UPPER PLIOCENE SAN DIEGO FORMATION, SOUTHERN CALIFORNIA

BORCE, Bridget, San Diego State University, San Diego, CA, USA; DEMÉRÉ, Thomas A., San Diego Museum Of Natural History, San Diego, CA, USA; BERTA, Annalisa, San Diego State University, San Diego, CA, USA

Parapontoporia sternbergi is an extinct species of river dolphin. It has been distinguished from two closely related extinct species, *Parapontoporia pacifica* and *Parapontoporia wilsoni*. These differences served as a basis for the establishment of *P. sternbergi* as a separate species. This study examines morphometric features in new cranial specimens of *P. sternbergi* and compares them to previously described skulls of this species to determine if the range of variation in these features is similar to the variation seen in a sample of skulls of *Pontoporia blainvillei*. This study utilized specimens from collections at the San Diego Natural History Museum and the Natural History Museum of Los Angeles County. Specimens included three complete skulls of *P. sternbergi* and 13 complete skulls of *P. blainvillei*. The skull characters that define *P. sternbergi* as a species were identified as regions of focus. Variations of these characters are quantified by the following 15 skull measurements: left and right zygomatic process length, neurocranium width and length, left and right temporal fossa width, left and right temporal fossa height, left and right orbital length, width of rostrum at base, rostrum length, zygomatic width, width of rostrum at midpoint, and total length. Measurements were taken on each of the 16 specimens. For each of the skull measurements, means and standard deviations were calculated for *P. sternbergi* (n=3) and *P. blainvillei* (n=13). From these data, coefficients of variation (CV) were calculated for each skull measurement. Relatively high CV values for neurocranium length and both temporal fossae heights in *P. sternbergi* could suggest that the fossil sample contains more than one species. However, relatively similar CV values for the remaining skull measurements would argue against this. Left and right side skull differences in CV values in the fossil sample suggest the possibility of greater cranial asymmetry in *P. sternbergi*.

THE TERROR BIRD, *TITANIS* (PHORUSRHACIDAE), FROM PLIOCENE OLLA FORMATION, ANZA-BORREGO DESERT STATE PARK®, SOUTHERN CALIFORNIA

CHANDLER, Robert M., JEFFERSON, George T., LINDSAY, Lowell, and VESCERA, Susan P., Colorado Desert District Stout Research Center, Borrego Springs, CA, USA

During the Great American Biotic Interchange that took place after the formation of the Panamanian Land Bridge during the mid-Pliocene, *Titanis walleri* (family Phorusrhacidae, known as terror birds) entered southern-most North America. Specimens of the 2 m-tall, 150 kg flightless birds are known from Florida and a single specimen from the gulf coast of Texas. Unfortunately, most are postcranial remains and no premaxillae are known. The anterior-most part of a premaxilla (beak), ABDSP (LACM) 6747/V26697, from the Olla Formation, 3.7 Ma, Anza-Borrego Desert State Park, was recently re-identified as *Titanis* and is comparable to the South American *Patagonis marshi*. The specimen was previously assigned to *Aiolornis incredibilis*. This new identification is important for several reasons: 1. It represents a significant geographic range extension for the genus; 2. It may represent the oldest known *Titanis* remains from the US; and 3. It reinforces the tropical aspect of the paleoenvironment of the Pliocene Epoch ancestral Colorado River deltaic deposit within the Salton Trough, California.

REINTERPRETATION OF FELID FOOTPRINTS FROM THE BARSTOW FORMATION (MIOCENE) OF SOUTHERN CALIFORNIA

CHU, Emily, The Webb Schools, Claremont, CA, USA; LUEBBERS, Chandler, The Webb Schools, Claremont, CA, USA; FARKE, Andrew A., Raymond M. Alf Museum of Paleontology, Claremont, CA, USA

The Barstow Formation of San Bernardino County, California, preserves a rich vertebrate ichnoassemblage from the Miocene (Barstovian). Many previously described and figured specimens are housed at the Raymond M. Alf Museum of Paleontology (Claremont, California), but have not been studied in light of modern ichnological techniques. Here, we reexamine a sample of 19 individual tracks referred to Felidae. All were collected as individual prints, although some may be from trackways. Precise locality data are uncertain in some cases, hindering associations. Tracks were measured and digitized using photogrammetry, allowing a clearer differentiation of features on each individual print. The tracks range from 56 mm to 78 mm-long and 56 to 67 mm-wide. We were unable to verify previously reported claw marks with one particular specimen. The tracks were originally assigned to two ichnospecies (*Felipeda bottjeri* and *Felipeda scrivneri*) based on differences in shape (e.g., relative elongation and the angle between digits). We remeasured interdigital angles, but found no consistent pattern across the tracks. Differences between tracks are subtle, and even though measurements show some footprints are more elongated than others, we conclude that they likely just represent differences between manual and pedal tracks. Because these are isolated prints, and associations are uncertain, they cannot be confidently distinguished otherwise. Some may even represent variation within a single trackway. We thus hypothesize that there is only one felid ichnotaxon (*F. bottjeri*) in the Barstow Formation.

A MIDDLE PLEISTOCENE MAMMOTH (*MAMMUTHUS COLUMBI*) FROM THE COASTAL PLAIN OF SAN DIEGO COUNTY CA

DEMÉRÉ, Thomas A., DONOHUE, Shelly L., and RANDALL, Kesler A., Department of Paleontology, San Diego Natural History Museum, San Diego, CA, USA

The fossil record of mammoths in southern California is preserved in Quaternary deposits that accumulated on offshore islands, along the coastal plain, and in inland valleys. This southern California Quaternary mammoth record spans from early Pleistocene (Irvingtonian NALMA) to latest Pleistocene time (Rancholabrean NALMA), with the majority of fossil remains being Rancholabrean in age. Mammoth specimens of Irvingtonian age are relatively rare and are known primarily from inland valleys. Here we report the discovery of a late Irvingtonian to possibly early Rancholabrean specimen of *Mammuthus columbi*, unearthed during construction of the Thomas Jefferson School of Law (TJSL) in downtown San Diego, California, USA. The skull and partial skeleton of this specimen likely represent the most complete mammoth known from coastal southern California south of Rancho La Brea. Recovered elements include a partial skull; partial mandible; complete dentition (left and right tusks, lower third molars, upper third molars); atlas; right radius, ulna, and scaphoid; and left cuneiform, unciform, lunar, and metacarpal III. Noting the general lack of taxonomic description of elements in the literature, we here describe these recovered elements and compare them to existing published accounts of species of *Mammuthus*, confirming assignment of the TJSL specimen to *M. columbi*. Further, we analyze tooth eruption and wear data, bone fusion data, and tusk size to determine that the specimen was likely a male between 47 – 50 years old at the time of death. Geologic age determination was assessed through site stratigraphy in the context of San Diego's regional Pleistocene geology. The mammoth was discovered in a fluvial sandstone lens of the normally shallow marine Bay Point Formation (~85,000 to 700,000 years old). This fluvial lens was sandwiched between two marine shell beds of the "Broadway faunal horizon", which has previously been assigned an amino acid racemization age estimate of ~570,000 years old. The "Broadway faunal horizon" is locally truncated by the Nestor Terrace, dated at 120,000, providing a minimum age for the TJSL specimen.

HOW SMALL ARE CALIFORNIA MASTODONS, REALLY?

DOOLEY, Alton C., Jr., Western Science Center, Hemet, CA, USA; SCOTT, Eric, Dr. John D. Cooper Center, Santa Ana, CA, USA

Several authors over the years have suggested that individuals of *Mammut americanum* from California tend to be smaller than those from the eastern United States, but little data have been presented to test this hypothesis. Measurements obtained from second and third molars (maximum crown length and width) and femora (length, distal width, and minimum diameter) from mastodons from various southern California localities, particularly Rancho La Brea and Diamond Valley Lake, enable comparison to published measurements of specimens from elsewhere in North America. Preliminary results indicate that California mastodon molars tend to be smaller in both length and width than those from mastodons from Florida or Indiana. Moreover, California mastodon molars tend to be narrower for a given length than those from Florida and Indiana; for data collected through December 2012, the narrowest for each tooth position was a California specimen. This trend is most pronounced in m3, but is also present in M3, M2, and m2. Although femoral data are still very limited, there are some indications that distal femoral width does not track closely to body size. Diamond Valley Lake specimen WSC 18743 has a distal femoral width of 270 mm, larger than either measured specimen from Rancho La Brea and nearly as large as the Watkins Glen, New York specimen, a large male individual. Yet the molars from WSC 18743 are not particularly long relative to other California specimens, and in fact are among the narrowest molars measured.

PRELIMINARY ANALYSIS OF SMALL MAMMAL FOSSILS FROM "PROJECT 23" AT RANCHO LA BREA, LOS ANGELES CA

FOX, Nathaniel S., Environmental Systems Graduate Group, School of Engineering, University of California, Merced, CA, USA; BLOIS, Jessica L., School of Natural Sciences, University of California, Merced, CA, USA

Since the discovery of fossils in the Rancho La Brea (RLB) tar pits over 140 years ago, collection and research of small mammal remains (e.g., rodents, soricomorphs, and lagomorphs) have been sparse relative to the Pleistocene megafauna. Several recently discovered RLB localities, named "Project 23", provide an ideal opportunity to study small mammal fossils with unprecedented temporal resolution. Project 23 initiated in 2006, after a series of new asphalt seeps uncovered during construction was salvaged and encased in 23 wooden boxes for future research. Several boxes are now undergoing excavation with emphasis on acquiring plant, microfauna, and pollen data, and radiocarbon dates demonstrate that the excavated deposits date to >50,000 to 30,000 years ago. In this project, we will systematically analyze Project 23 microfauna to gain a full picture of ecosystem dynamics prior to the Last Glacial Maximum and the global climate warming and human impacts that accompanied the last deglaciation. We have begun screening and sorting small mammal fossils, and identifying them to genus or species. Preliminary sorting of materials from ten Deposit 1 canisters, and one Deposit 14 canister, is currently underway. Thus far, at least ten rodent and lagomorph genera have been tentatively identified. Future objectives include stable carbon and oxygen isotope analysis to obtain dietary and environmental signatures from fossils within and among localities. Results will ultimately be paired with plant, pollen, and megafauna data to shed light on comprehensive terrestrial biodiversity changes over the past 50,000 years at RLB.

THE IRVINGTONIAN TYPE LOCALITY (ALAMEDA CO. CALIFORNIA), A HISTORICAL PERSPECTIVE

FRIEDMAN, Virginia, GORDON, Philip E., and BLUEFORD, Joyce R., Children's Natural History Museum, Fremont, CA, USA

The Pleistocene epoch was a time of extensive glacial ice deposition commonly known as the Ice Age. Although the San Francisco Bay area was not itself glaciated, it felt the effects of the Ice Age indirectly and, as a consequence, its landscape was altered. Floods of glacially eroded sediments were carried down from the Sierra Nevada by meltwater streams and much of these sands and gavels reached the Bay area. It is generally accepted that the fossil bearing Irvingtonian sediments were deposited by southern streams feeding into the evolving bay. The Calaveras fault had already been uplifted but the Hayward Fault had not created the East Bay Hills yet. In the 1940s and 1950s, a school teacher named Wes Gordon and his "Boy Paleontologists of Hayward "were nationally recognized throughout the United States. They were a group of boys ranging in age from 7 to 13 who unearthed one of the best preserved fossil sites in North America at that time. Fossils from the Irvington District created such international interest that a section of time was honored as the Irvingtonian Stage (1.8 – 0.24 Mya). The Irvingtonian mammal age was originally defined by Donald E. Savage in 1951 as the beginning of the Pleistocene in North America based on the fauna recovered from gravel and sand pits southeast of Irvington, Alameda County, California. The locality has yielded at least 20,000 specimens, belonging to 56 genera. The sediments adjacent to the locality are reversely magnetized are were dated as 700, 000 to 1.3 Mya based on paleomagnetic data analysis carried out back in 1975. The collection of the Irvingtonian Type locality is currently housed in five institutions: University of California Museum of Paleontology at Berkeley, Children's Natural History Museum, Ohlone College, The Museum of Local History in Fremont, California and in the collection of the family of one of the six surviving Boy Paleontologists, Philip E. Gordon. Nowadays, the type locality is mostly under Interstate 680 but the City of Fremont has created Sabercat Historical Park, which is adjacent to the locality and open to the public. Future plans include signage and tours. In summary, efforts are being made to resurrect what is left of this important paleontological locality for future generations.

WORKING IN WILDERNESS AREAS AND WILDERNESS STUDY AREAS: THE REMOVAL OF TWO *PENTACERATOPS* PARTIAL SKELETONS BY HELICOPTER

GENSLER, Philip A., Bureau of Land Management, New Mexico State Office, Santa Fe, NM, USA

The San Juan Basin of northwestern New Mexico is well known for the presence of late Cretaceous vertebrate fossils. These fossils are typically found in the Fruitland/Kirtland Formation exposed within the Bureau of Land Management administered Bisti/De-Na-Zin Wilderness Area and the Ah-shi-sle-pah Wilderness Study Area. Recently researchers from the New Mexico Museum of Natural History conducting paleontological surveys in the area discovered the remains of two separate *Pentaceratops* skeletons; one a juvenile in the Bisti/De-Na-Zin WA and an adult within the Ah-shi-sle-pah WSA. Since these two specimens were found in protected areas in-depth analysis was required to ensure that the "wilderness characteristics" were preserved within the Bisti/De-Na-Zin WA and that the "wilderness characteristics" within the Ah-shi-sle-pah WSA were not impaired so as to make it unsuitable for future Wilderness designation. Since the use of mechanized equipment is prohibited in both Wilderness Areas and Wilderness Study Area, the field crews had to stage outside of the protected areas and carry all equipment into both sites. Once jacketed the *Pentaceratops* specimens each weighed several thousand pounds making removal by hand impossible. We then analyzed the use of a helicopter for retrieval. This method was determined to be the "minimum tool" required to safely remove the specimens while meeting the rules for working in Wilderness Areas and Wilderness Study Areas. Since a helicopter is mechanical and would typically be prohibited, it was allowed for this 'one time' use providing it would not physically land on the ground. Because no private sector helicopters were available for this project, the New Mexico National Guard agreed to assist in the removal as part of a training exercise. The day before the airlift members of the BLM, NMMNH, and the National Guard worked together to flip the jackets into cargo nets. The following day the New Mexico National Guard brought in two Black Hawk helicopters, hooked onto the cargo nets, and flew the jacketed fossils outside the protected areas to trucks where they were transported to the NMMNH for preparation, exhibit, and permanent storage.

TRACKING THE TRACKS WITH PHOTOGRAMMETRY

GILBERT, Jon, Colorado Desert District Stout Research Center, Borrego Springs, CA, USA

Application of state-of-the-art technology to the management of paleontology resources in the Anza Borrego Desert State Park (ABDSP) requires capturing and cataloging digital imagery of ephemeral fossil tracks and track ways, as well as periodic re-photographing of sites for monitoring purposes. Three ABDSP Paleontology Society volunteers attended a photogrammetry seminar, gaining a basic knowledge of photogrammetry. This included selecting camera equipment, taking photographs, and becoming familiar with software available for processing digital images. The volunteers conducted tests to determine the feasibility of photogrammetric techniques, and to establish protocols for tracks and track ways. The resulting digital photographs were processed with Photoscan software, producing clear and precise digital 3D models. The models will provide data for record keeping, scientific research, and for long term monitoring of tracks and track ways, recording deterioration and early identification of newly exposed tracks nearby. The protocols are applicable to most types of fossils in the ABDSP collections.

NEW RANCHOLABREAN MAMMAL FOSSIL SITE FROM WARM SPRINGS DISTRICT, FREMONT CALIFORNIA

GLENISTER, Chase, Math Science Nucleus, Fremont, CA, USA; WALKER, James P., Applied Technology & Science, San Francisco, CA, USA

A new locality uncovered Rancholabrean fossils (Late Pleistocene) in the Warm Springs District of Fremont, California while retrofitting water pipelines that cross the Hayward Fault zone by San Francisco Public Utility Commission. The geology of the area around the fossil site is complex due to uplift and slip of the Hayward Fault, and associated down cutting of modern streams. The depositional facies of these fossils were fluvial, including sandstone and gravel grading up to cobbles and boulders. A radiometric dating of charcoal collected near the base of this unit (Unit 1b) by URS Corporation during construction provided an age of about 12,700 years before present. This date suggests a very Late Pleistocene age for the sample. The upper sand and gravel deposits cap a lacustrine facies that is primarily green-gray silty clay, and contains lenses of fine sand. The lacustrine facies has been tentatively correlated with the lacustrine clay beds of the Irvington Gravels. The upper fluvial facies yielded 54 mammalian fossils, including several specimens of partially fossilized bone from modern cow (*Bos taurus*) and horse (*Equus feris*) that were introduced by European settlers. These modern specimens were collected 78 m to the south of the older fully fossilized specimens. The most prominent find was the discovery of bison fossils in the fluvial facies, namely units 1c and 1d. Due to *Bison latrifons* becoming extinct 20,000-30,000 years ago, the bison fossils are assumed to be *Bison antiquus*. Also found were specimens representing several mammalian taxonomic orders including Artiodactyla, Carnivora, Lagamorpha, Perissodactyla, and Rodentia. Specimens from these include *Camelops*, *Equus*, Ursidae, Mustelidae, *Sylvilagus*, *Thomomys*, *Peromyscus* and a possible Felidae. The paleoenvironment of these fossilized organisms would be much like today. An evolving system of grassy areas would be bordered by chaparral and oak woodlands. Due to the C-14 age date and the presence of *Bison* cf. *antiquus*, it is inferred that the fossils found in the Warm Springs district are Rancholabrean in age. These fossils are an important addition in the study of the evolution of the East Bay.

LATE EOCENE ISCHYROMIDS FROM PIPESTONE SPRINGS, MONTANA

HOMIDAN, Jesslyn, The Webb Schools, Claremont, CA, USA; LOFGREN, Don, Raymond M. Alf Museum of Paleontology, Claremont, CA, USA

The presence of abundant well-preserved fossils of smaller sized Chadronian mammals at Pipestone Springs Main Pocket (PSMP) was reported more than 100 years ago. Ischyromid rodents comprise about 25% of the mammalian fauna recovered from the site. However, there is no consensus of how many ischyromid species are present as some workers recognize a single taxon (*Ischyromys veterior*), while others argue two are present (*Ischyromys veterior* and a larger species). The widths and lengths of the m2 and m3 of 67 ischyromid dentaries from PSMP in the Alf Museum collections were measured and then plotted on histograms. The resulting distribution indicates that 66 specimens represent *Ischyromys veterior*, while a single dentary (RAM 17621) is about 15% larger. This rarely found larger species at PSMP could represent *Ischyromys typus*, a species commonly recovered from Chadronian and Orellan strata in the Great Plains states. Alternatively, RAM 17621 could represent a new species of *Ischyromys* that represents only 1-2% of the total number of ischyromids found at PSMP, which is why its presence was rarely reported and it has never been described. The next step is to survey the collections of other institutions known to house a significant number of fossils from PSMP to identify additional specimens of this rare taxon and then determine if it represents a previously described species or a new taxon.

NORTH AMERICA RESEARCH GROUP (NARG)

JACKSON-SHANNON, Debra, North America Research Group, Hillsboro, OR, USA

Dedicated to scientific research and public education; NARG is structured as an IRS non-profit public charitable 501(c)(3) organization.

Our Origin: Around a campfire in the summer of 2004 five fossil hunters discussed how they might contribute to science as they pursued their passion. This core crew collaborated to develop the North America Research Group. Since our inception, and in a very short period of time, NARG has grown into a diverse and dynamic group of men and women sharing a mutual respect and passion for geoscientific study and fossil collecting. Our international membership of over a hundred ranges from 10 to 80+ years in age. This adventurous consortium of individuals has an amazing variety of backgrounds, interests, hobbies, educations, and professions; including biology, oceanography, paleontology, paleobotany, and geology. NARG sponsors the NW Fossil Fest and participates in many programs and shows devoted to public education. We collaborate with university scientists and museums to enhance and promote research. Significant specimens are donated to recognized museums to insure they remain in the scientific and public domain. We believe that research and boots-on-the-ground exploration will locate the next great specimen in our region. Join us in search of the next new species. They are out there!

DENTAL PATHOLOGY IN *HOPLOPHONEUS OCCIDENTALIS* (NIMRAVIDAE)

JAMAL, Haaris, The Webb Schools, Claremont, CA, USA; FARKE, Andrew A., Raymond M. Alf Museum of Paleontology, Claremont, CA, USA

Premortem breakage of the elongated upper canines was relatively common in many “saber-toothed” carnivorans, and documentation of this phenomenon provides information on the performance and evolution of the structures. To date, most detailed studies of tooth breakage have focused on felids, so observations on saber-toothed nimravids provide an important comparison. Here, we document the first described occurrence of dental pathology in the nimravid *Hoplophoneus occidentalis*. This particular specimen, RAM 10356 (Raymond Alf Museum of Paleontology, Claremont, California), was collected from the

Brule Formation (Orellan) in western Nebraska. The fossil is notable because the crown of the left canine is missing, and the bone around the alveolus has a porous surface texture that contrasts with the surrounding "normal" bone texture. Based on wear at the tooth surface as well as the abnormal bone, we hypothesize that this damage occurred premortem, and we interpret the bone lesions as osteomyelitis (bone infection). The individual apparently survived for some time after the tooth breakage and during the infection, and no abnormal wear is visible on the other teeth. Although this specimen is notable for its pathology, a broader survey of nimravid dental abnormalities is needed to establish their functional and ecological significance, and compare the features with those seen in *Smilodon*.

WIDESPREAD COLLAGEN RADIOCARBON DATE CONTAMINATION RESOLVED THROUGH XAD RESIN PURIFICATION

LINDSEY, Emily L., Department of Integrative Biology and Museum of Paleontology, University of California – Berkeley, Berkeley, CA, USA; STAFFORD, Thomas W., Jr., Stafford Research Laboratories, Inc., Lafayette, CO, USA

Radiocarbon dating is widely used in Quaternary paleontological research. Accurate and precise dates are necessary for understanding such processes as species interactions, biotic response to climatic changes, and the causes and consequences of extinctions. There is a growing recognition that there may be a widespread, global contamination issue with radiocarbon dates on bone collagen, as many researchers have recently re-dated previously analyzed specimens using different techniques and obtained substantially older dates. However, so far there is no scientific consensus on the source of the contamination or how it can be eliminated. One likely source of contamination is humates, especially small molecular weight fulvic acids. These plant- and animal-derived compounds are adsorbed by osseous remains during burial, covalently bind to collagen molecules, and therefore cannot be removed through most existing collagen dating methods, including ultrafiltration. However, this contamination issue can be resolved through amino acid-based dating techniques, e.g., isolation of hydroxyproline or purification with XAD resin. Both of these methods involve hydrolysis of purified bone gelatin in strong hot hydrochloric acid, which breaks the covalent bonds between the exogenous fulvic acids and the fossil's amino acids. We dated multiple chemical fractions of fossil bone from extinct Pleistocene mammals from across South America and found: (1) XAD preparation consistently yields older dates than conventional gelatin or ultrafiltration dates, sometimes by thousands of years; (2) When isolated, fulvic acids yield dates consistent with their hypothesized role as younger contaminants of bone collagen; and (3) Ultrafiltration not only does not eliminate these contaminants, but in some cases can concentrate them, resulting in an even younger age on specimens than would be obtained by a standard gelatin date. Unfortunately, this research calls into question the validity of thousands of previously published radiocarbon dates, and the paleoecological models based upon them. We recommend that all future fossil bone samples be dated using amino acid-based methods only.

EREMOTHERIUM BONES AND THE CENOTE OF DOOM: NEW PLEISTOCENE RECORDS FROM BELIZE

MCDONALD, H. Gregory, Bureau of Land Management, Salt Lake City, UT, USA

Isolated finds and small faunas of Pleistocene taxa have been well documented throughout Central America since the mid 1800's. The exception has been Belize, which has been over-looked in terms of studies of its Pleistocene fauna. Because a large part of Belize is karst this oversight is now being remedied with the recent exploration of caves. This has resulted in new discoveries and the documentation of Pleistocene taxa such as the sloth *Nothrotheriops*, making this the southern-most record for this genus. In addition to the caves, the karst topography of Belize also has many cenotes. The area of Cara Blanca in central Belize near Belmopan has a series of 25 documented cenotes formed along fault line. Preliminary dives in two of the more accessible cenotes have documented the remains of the giant sloth, *Eremotherium laurillardi*. *Eremotherium laurillardi*, ranged from southern Brazil to the Gulf and Atlantic Coasts of North America and had been previously documented in all of the countries of Central America except Belize, so its presence in Belize is not unexpected. During the Late Glacial Maximum with the maximum lowering of sea level, there was also a major lowering of the water table in Belize and the Yucatan Peninsula. Accessible water to support the Pleistocene fauna on the surface may have been limited so sinkholes such as those at Cara Blanca may have been critical water sources. The steep sides of the sinkholes may have prevented large animals such as the sloths from climbing out after entering them and acted as traps. The bones are found on ledges in the cenotes that are between 15 and 20 m below the current water level. Bones are found in clay deposits on these ledges and show limited weathering suggesting they were exposed for some time prior to burial and then subsequently became submerged as glaciers melted and sea level rose.

COGNITIVE BIAS IN PALEONTOLOGY

MOLNAR, Ralph E., University of California Museum of Paleontology, Berkeley, CA; Museum of Northern Arizona, Flagstaff, AZ, USA

Wikipedia lists ninety-six different kinds of cognitive bias, many of which are relevant to research and publication. Concerns have been raised during the past year regarding research publications tainted by cognitive (unconscious) bias. This has been reported in the social sciences, but seems to occur in other sciences as well. There is a large number of kinds of such bias. For example, the use of plausible but insufficiently-examined assumptions, as in the instance about a century ago of the dispute between von Tornier and Holland regarding the stance of sauropod dinosaurs. Parsimony (in the sense of Okham's razor, not cladistics) is a well- established principle in science, but it is less well-understood that parsimony is paradigm- dependent. A third kind is the implicit transfer of meaning, as has occurred regarding the nature of 'valid taxa'. Initially this referred to taxa that were distinct, but there is now a trend to restrict the meaning to those taxa that can be easily classified phylogenetically. A fourth kind is the confusion of methodology for ontology, in other words the assumption that the preferred methodology gives transparently accurate and reliable results in all cases and misses nothing of potential significance. What to do? Become aware of potential biases, so they can be recognized and avoided, both in one's own research and in reviewing the research results of others (which is often easier to do).

DATA IMPROVEMENT: REPAIRING DATA ERRORS IN A VERTEBRATE PALEONTOLOGY COLLECTION

MURRAY, Lyndon K., and GILBERT, Linda, Colorado Desert District Stout Research Center, Borrego Springs, CA, USA

A 2008 evaluation of all known data associated with the Anza-Borrego Desert State Park (ABDSP) vertebrate paleontology (mammal) collections revealed 17 major types of errors from four main sources (curation, publication, contracts, database conversion), with multiple proximate causes. A detailed examination of 1,000 catalogued specimens showed approximately 50% error in taxonomic identification at the more refined resolutions of species, genus, and family ranks, with as much as 15% error at the order rank. A compilation of over 150 published and unpublished lists of fossil taxa from ABDSP produced 830 variants of taxonomic names. These represented 100 mammalian taxa, mostly at genus rank, with fewer than 50 identified to species. Next followed an intense review of associated documentation and taxonomic updates, plus determination of the presence or absence in the collection of at least one voucher fossil specimen representing each listed taxon. The resulting updated faunal list contains 110 taxonomic names, with 66 genus and 46 species names that do not have qualifying modifiers, e.g., 'cf.' Although the total number of listed taxa actually rose (100 to 110), a total of 178 listed taxonomic names had one or more alternatively formatted equivalents, had been shown in general paleontology literature to represent synonymies, or had no voucher and were thus retired. Updating the catalogue information to correct these and other data errors involves a complex sequence of database management tasks in order to stabilize the previously catalogued information prior to capturing new data. The first critical step is the search for and recognition of corrupted database contents and identification of the error sources and proximate causes. The next important steps include standardization and streamlining of internal formatting and terminology and establishment of data entry protocols. Following this, all data must be validated by visual comparison with the source records of digital and paper documents, in curatorial files and specimen trays. Final steps include specimen-by-specimen review of element identification and taxonomic assignment, with concurrent production of updated specimen labels.

A NEW FOSSIL ASSEMBLAGE IN THE ANZA-BORREGO DESERT

MURRAY, Lyndon K., JEFFERSON, George T., KEELEY, Sandra, KEELEY, Robert, and MROZ, Arnold, Colorado Desert District Stout Research Center, Borrego Springs, CA, USA

Fossiliferous sediments of the Carrizo badlands, south of Vallecito Creek, in the Anza-Borrego Desert, have been poorly studied. Several dozen sites recorded there since the 1950s have produced Pleistocene age vertebrate material. However, taxonomic resolution of the specimens, identified mostly to generic level, has not been sufficient to determine whether the paleofauna had a middle Pleistocene (Irvingtonian North American Land Mammal Age - NALMA) or late Pleistocene (Rancholabrean NALMA) character, i.e., all of the named taxa are known elsewhere in North America, from both NALMAs. Although the Carrizo badlands are part of the Fish Creek-Vallecito Creek sedimentary basin block, they do not have as tight an absolute age control as the northern 2/3s of the block, based on magnetic polarity stratigraphy and dates from volcanic ash. In 2012, a new survey of the Bow Willow beds, in the Carrizo Badlands, produced several taxa previously unrecorded in the ABDSP fossil collections: vulture (? *Cathartes* sp.), dire wolf (*Canis* sp. cf. *C. dirus*), bighorn sheep (*Ovis canadensis*), and bison (*Bison* sp.). Also, prior to this time, only a single record of mammoth (*Mammuthus*) was known in the entire Vallecito – Carrizo badlands area, and this was based on several small pieces of a single tooth lamella. Yet in a single season, three new mammoth sites were discovered in the Bow Willow beds, including a skull, tusks, mandible and postcranial elements at one site and a partial tusk and half of an atlas (1st cervical vertebra) at two others. The verification of mammoth in the Bow Willow beds places the age of the beds between 1.4 Ma and 10 ka, based on the known time range of mammoth in North America below latitude 55° N. The *Bison* discovery further restricts the age range of the sediments to no older than about 210 ka. Recovery of other taxa new to the ABDSP vertebrate catalogue emphasizes the difference between the Bow Willow beds paleofauna and all the other known local paleofaunas.

THE TAPHONOMY OF THE AVIAN REMAINS IN THE NORTHWESTERN CAUCASUS, RUSSIA, AND THE LATE PLEISTOCENE (MIS 4-2) ENVIRONMENTAL CHANGES

POTAPOVA, Olga, The Mammoth Site of Hot Springs, SD, USA

The analysis is based on the bird fossil bones retrieved from strata within 7-m-thick lithological horizons of the Matuzka cave. The cave is located at 800 m a.s.l., in the Pshekha River (Kuban River Basin) terrace in the forested foothills of the northwestern Caucasus. The Pleistocene avifauna remains come from the 19 lithological units covering a period between ~20,000 (C14) - 60-70,000 (EPR) yr BP (Middle and Late Paleolithic). The avian assemblage is dominated by the remains of small-sized species (Passeriformes) and small-sized elements (carpoulnare, foot phalanges, etc.) of large-sized species (Anseriformes, Falconiformes, Galliformes). The remains likely originated from pellets left by owls, which inhabited the cave between several human occupation events. The avian "predator – prey" ratio (4.5% and 95.5%) in the overall assemblage reflects the species ratio in natural environment, where the latter species significantly outnumber the former. This ratio is opposite to the ratios observed in natural traps (Rancho La Brea, California and Binagady, Azerbaijan) where predators' remains dominate. The bird remains belong to the modern species of Anseriformes, Falconiformes, Galliformes, Strigiformes, Apodiformes, and Passeriformes. The Passerines are dominated by Corvidae, Turdidae and Fringillidae. Along with the species that are common in modern avifauna of the region, there are remains of species that are currently rare (*Carpodacus rubicilla*), or not abundant (*Lullula arborea*, *Chloris chloris*). At the same time, neither horizon yielded the Passerine species currently dominant in this area, such as tits, European nuthatch, Eurasian treecreeper, common chaffinch, European robin, chiffchaffs, wren and others, indicating quite different species ratios and dominants in the Late Pleistocene. Eleven avifaunal phases were recognized. They reflect the climatic and ecological changes in the region. Several species, including Caucasian grouse (*Lyrurus mlokosiewiszi*), Caucasian snowcock (*Tetraogallus caucasicus*), chukar (*Alectoris graeca*), and great rosefinch (*Carpodacus rubicilla*) were found in the lowest layers (6 and 7) of the cave, reflecting the coldest periods in the cave's history, when the alpine zone descended to the cave's altitude around 60-70,000 years ago.

TAPHONOMY OF THE BIRD REMAINS FROM THE POSTGLACIAL HORIZONS OF THE MEDVEZHYA CAVE IN THE NORTHERN URALS, RUSSIA

POTAPOVA, Olga, The Mammoth Site of Hot Springs, SD, USA

The taphonomy of the avifaunal assemblage was analyzed based on 6,635 bone remains from the Medvezhya cave, located in the western foothills of the Ural Mountains, 500 m from the Pechora River. The bones come from two Late Pleistocene horizons, with radiocarbon dates of the oldest layer (C14) between 16,130 +/-150 and 18,700 +/-180 yr BP. Since the cave deposits preserved human stone artifacts and butchered mammal bones, it was important to determine if the accumulation of the avifauna remains was a result of humans' selective hunting or birds of prey activities. The distribution of the bones mapped in the deposits showed that the places of their largest concentrations matched the highest concentrations of rodents and hares (*Lepus*, *Ochotona*), which were found in the deposits of the cave entrance. However, the bird remains covered larger areas and were more evenly distributed than the micromammal remains. The species identification showed that the majority (about 95%) of bones came from the willow grouse (*Lagopus lagopus*) and rock ptarmigan (*Lagopus mutus*). Other remains belonged to Anseriformes (3%), and Charadriiformes (2%). Bone remains of Podicipitiformes, Strigiformes, Falconiformes, Gruiformes, Cuculiformes, Piciformes, and Passeriformes were rare. Representation of the skeletal elements of the most numerous species (*Lagopus*), with dominating tarsometatarsus and carpometacarpus, matched the ratio of the bird bones discovered from the Late Pleistocene grottos and caves lacking human presence. The comparisons of the species composition of the Pleistocene avian assemblage with diets of the modern eagle owl (*Bubo bubo*), and gyrfalcon (*Falco gyrfalcon*) revealed significant similarities, indicating that these species were responsible for the bones deposits. However, few grouse bones possessed evidences that the birds were hunted and consumed by humans: a few distal humera possessed a single hole on the caudal surface, and few others had indentations from bites.

AGE PROFILE OF TERMINAL PLEISTOCENE COLUMBIAN MAMMOTHS FROM THE TULE SPRINGS FOSSIL BEDS OF SOUTHERN NEVADA

ROWLAND, Stephen M., and PARRY, Lauren E., Department of Geoscience, University of Nevada Las Vegas, Las Vegas, NV, USA

The Tule Springs Fossil Beds are highly fossiliferous Late Pleistocene deposits of the Las Vegas Formation located in northern Las Vegas Valley. The recently established Tule Springs Fossil Beds National Monument protects a large portion of these deposits, but significant fossil sites lie outside the boundaries of the new national monument. One such site, on property owned by Mr. Bill Gilcrease, has produced a large number of Columbian mammoth teeth (*Mammuthus columbi*). Radiocarbon dates of teeth from this site indicate an age range of at least five thousand years, from approximately 18 ka to 13 ka. The size and wear of Proboscidean molariform teeth can be used to determine the animal's age at death. In this study, we identified 52 mammoth molariform teeth that were either complete or complete enough to determine the age of the animal at death. An age profile was constructed from this set of teeth, representing a time-averaged assemblage of a mammoth population during the Terminal Pleistocene. The resulting age profile depicts a mammoth population with a high representation (>50%) of juveniles (0-12 African Elephant Years [AEY]), and without any senescent individuals (49-60 AEY). This age profile suggests a stable population with possible selective mortality of juveniles. These results suggest that between the Last Glacial Maximum and 13 ka, the *M. columbi* population in southern Nevada was not a declining population under considerable environmental stress.

SURVIVAL OF THE TUSKIEST: GIANT, TUSK-TOOTHED SALMON FROM CALIFORNIA

SANKEY, J.T., BASUGA, J., PALACIOS, F., and BIEWER, J., Geology Program, California State University, Stanislaus, Turlock, CA, USA

The giant, tusk-toothed salmon (*Onchorhynchus rastrosus*) existed from the mid-Miocene to early Pliocene, in California, Oregon, and Washington. A great deal is known about these amazing salmon from previous studies. They were approximately 1-3 m long and 177 kg; they were planktivorous, based on numerous gill-rakers, and few small teeth; their two large (2-3 cm- long) upper, tusk-shaped teeth were for fighting and display; and they migrated from the Pacific Ocean to inland rivers to spawn, as salmon do today. However, despite the wealth of information about this extinct, giant salmon, there are still gaps in our knowledge. For example, modern salmon developmentally change (especially in their skull) before their migration upriver to spawn. Did these extinct salmon do the same? To address this question, we compared specimens from coastal marine and freshwater deposits. We examined (photographed, described, and measured) the shapes and sizes of teeth and vertebrae from coastal marine specimens, and compared them to specimens from freshwater deposits. Coastal marine specimens examined are from the following formations and counties: Pinole Tuff (Contra Costa), Drakes Bay (Marin), San Mateo (San Diego), Purisima (Santa Cruz), and Santa Margarita (Santa Cruz). We compared these coastal marine specimens to specimens from freshwater deposits (upper Mehrten Formation; Stanislaus County). All specimens are from the Museum of Natural History of Los Angeles County and the University of California, Berkeley Museum of Paleontology. Our working hypothesis was that the tusk-teeth from the freshwater specimens should be larger, reflecting their function in display and fighting during the spawning period. The results supported this hypothesis. We found that the teeth from coastal marine specimens were not only smaller, but they were also straighter and sharper. The freshwater specimens were considerably larger and more recurved, and their tooth tips were more worn and blunt. This suggests that these giant, extinct salmon also developmentally changed between the marine and freshwater stages of their lives, as modern salmon do today, in preparation for the vigorous display and fighting that occurred during spawning in the inland rivers of California.

AN ARCHAIC MYSTICETID FROM THE VAQUEROS FORMATION, AND OTHER FOSSIL MATERIAL FROM THE SKYRIDGE PROJECT, ORANGE COUNTY, CALIFORNIA

SCHERZER, Benjamin, DUKE Cultural Resources Management, Lake Forest, CA, USA

The Skyridge Project is a 30 acre residential development in the city of Mission Viejo, Orange County, California. Mass grading for Phase II of the project began in January of 2015, with archeological and paleontological monitoring provided by DUKE Cultural Resources Management. The area contained in the project is composed of landslide deposits, sourced predominantly by beds from the Vaqueros Formation (Late Oligocene to Early Miocene). Due to the prevalence of landslide deposits, excavation reached depths exceeding 120 feet in order to meet geotechnical recommendations. Over the course of 12 months of paleontological monitoring, over 200 fossils specimens were found, including bivalves (*Panopea*, *Pecten*, Pteriomorphia, *Solen*, Tellenidae, Veneridae), molluscs (*Cancellaria*, Scaphoda, *Trophon*, *Turritella*, Vetigastropoda), barnacles (*Tamiosoma*), Chondrichthyes (Batoidea, Lamniformes), Crocodilia, and trace fossils (*Chondrites*, *Gastrochaenolites*, *Ophiomorpha*, *Thalassinoides*, coprolites). In addition, several hundred pounds of collected sediment remain to be screened for additional invertebrate and microvertebrate material. Also recovered were the remains of at least two cetaceans: (1) a right mandible and strongly associated articulated postcranial material (including at least one scapula) of a mysticetid (tentatively assigned to Aetiocetidae or Eomysticetidae), and (2) cranial material (braincase and tympanic bulla) with associated articulated postcranial material. The mysticetid individual is particularly significant, as material from this group is rare for similarly aged deposits in southern California. In addition, the right mandible exhibits archaic features, which are commonly found in aetiocetids/eomysticetids from Oligocene-age deposits, but are absent in similar members from Miocene-age deposits. Depending on the potential from current and future invertebrate specimens for precise dating of the deposits, the recovered material may represent a previously unknown archaic Miocene-age mysticetid.

A PROBOSCIDEAN TRACKWAY FROM THE BARSTOW FORMATION OF SOUTHERN CALIFORNIA

SENISE, Kennedy, The Webb Schools, Claremont, CA, USA; and FARKE, Andrew A., Raymond M. Alf Museum of Paleontology, Claremont, CA, USA

Proboscideans are a rare, but biostratigraphically and paleoecologically significant, component of the faunal assemblage in the Barstow Formation (Miocene, Barstovian) of southern California. Teeth and isolated postcrania are most common, although tracks are also known. The first known, and most extensive, trackway (RAM 187, Raymond M. Alf Museum of Paleontology, Claremont, California) was collected in 1969 by Raymond Alf and a team of students from The Webb Schools, within the Upper Member of the formation. Only a brief description has been published to date, hindering comparisons with trackways from other units. We have been restudying the trackway using modern photogrammetry techniques and careful mapping of reconstructed areas to document features of the specimen. The entire trackway is 475 cm-long, with four distinct tracks within mudstone. They are identified as proboscidean based on their overall size and shape, which conform with modern and fossil examples. The average length of the individual prints is 53.5 cm, the average width is 47 cm, and the average depth is 16.3 cm. The average stride length is 200 cm. No distinct toe impressions or other morphologies are visible in this trackway, due to the presumably muddy track substrate as well as reconstruction at the bottom of some prints. Thus, direction of travel cannot be confirmed. Furthermore, manus and pes tracks cannot be distinguished because proboscideans often place their hind feet into the same tracks made by their front feet, as is presumably the case here. Only a single individual is preserved in this occurrence, which may indicate a solitary habit for the particular individual that made the prints. Although proboscideans are a rare component of the Barstow Formation track assemblage, specimens such as this trackway are important for establishing the stratigraphic range of the clade.

THE PALEOCLIMATE, PALEOHYDROLOGY AND VERTEBRATE PALEONTOLOGY OF TULE SPRINGS FOSSIL BEDS NATIONAL MONUMENT

SPRINGER, Kathleen B., San Bernardino County Museum, Redlands CA; U.S. Geological Survey, Denver Federal Center, Denver, CO, USA; SCOTT, Eric, San Bernardino County Museum, Redlands, CA, USA; Dr. John D. Cooper Archaeological and Paleontological Center, Santa Ana, CA, USA; PIGATI, Jeffrey S., U.S. Geological Survey, Denver Federal Center, Denver, CO, USA; and MANKER, Craig R., San Bernardino County Museum, Redlands, CA, USA; U.S. Geological Survey, Denver Federal Center, Denver, CO, USA

Shannon A. Mahan, U.S. Geological Survey, Denver Federal Center, Denver CO

Tule Springs Fossil Beds National Monument (TUSK) is home to one of the most significant late Pleistocene vertebrate assemblages in the American southwest, the Tule Springs local fauna. The fossils are entombed in a sequence of groundwater discharge (GWD) deposits that afford a nearly complete record of dynamic hydrologic changes in the Las Vegas Valley spanning the past 250 ka. Desert wetlands are keystone ecosystems in arid environments and are preserved in the geologic record as GWD deposits. The fossil-bearing deposits in TUSK are exclusively GWD deposits, and like all such deposits, are inherently discontinuous and stratigraphically complex, which has previously limited our understanding of how desert wetlands responded to past episodes of rapid climate change. We have used targeted radiocarbon dating and detailed stratigraphic investigations to establish a high-resolution chronology for the last 35 ka, that shows cycles of wetland expansion and contraction that correlate tightly with climatic oscillations recorded in the Greenland ice cores, including Dansgaard–Oeschger cycles and other millennial and sub-millennial climatic perturbations. Cessation of discharge associated with rapid warming events, evidenced by widespread erosion and soils, resulted in the collapse of entire wetland systems at multiple times during the late Quaternary. This new paleohydrologic record documents the extreme sensitivity of desert wetlands to past climate change. We continue to refine the chronology and stratigraphy of the deposits in TUSK, and utilizing the vertebrate fossils and tufa, will elucidate outstanding questions regarding climate and paleoenvironmental conditions and the mechanism of atmospheric/ocean teleconnections. Oxygen isotopes will pinpoint the sources of water during the late Pleistocene that "fueled" the discharge; clumped isotopic studies will document temperature thresholds of ecosystem collapse. Detailed faunal analyses with the tight chronologic and stratigraphic framework can be accomplished by inserting the vertebrate faunas into precise bins of time, up to the end of the Pleistocene, allowing assessment of faunal responses to abrupt climate change as well as testing competing extinction hypotheses. Finally, the unique geological lens afforded by GWD deposits will provide invaluable focus when planning for the potential response of these fragile ecosystems to future climate warming.

PLEISTOCENE PALEOSOL DEVELOPED ON ANCESTRAL MOJAVE RIVER SEDIMENTS NEAR HINKLEY, CALIFORNIA

STEWART, J. D., AECOM, San Diego, CA, USA; and HAKEL, Marjorie E., AECOM, San Diego, CA, USA; Natural History Museum of Los Angeles County, Los Angeles, CA, USA

Pleistocene paleosols (fossil soils) have recently been recognized as an important paleontological resource in desert areas of California. We here announce another example of such a resource northwest of Hinkley CA. Geologic mapping in the Hinkley vicinity has identified fluvial deposits as sediments of the ancestral Mojave River. It is thought that the Mojave River at that time flowed into Lake Harper. Our research shows that an aridosol formed on these fluvial sediments after the Mojave River abandoned this area. Granitic hills occur in the study area, and it is counterintuitive that paleosol sediments should lie beneath many granite boulders. A fossil tibia of a jackrabbit was found in such a context. The tibia shows some development of manganese oxides, whereas fossil bone and tooth fragments from the paleosol sediments in the lowlands do not. Likewise, few of the vertebrate fossils from the Palo Verde Mesa late Pleistocene paleosols show manganese oxide development. As this paleosol is deflated, vertebrate fossil fragments and caliche nodules accumulate on the desert floor. There is a small vertebrate fauna from this paleosol. Vertebrate fossils from this paleosol include *Gopherus* sp., bird, *Lepus californicus*, *Sylvilagus* sp., and unidentified artiodactyl tooth fragments (enamel). With the exception of the bird fossil, these fossils are typical of paleosol faunas from California deserts. Artiodactyl tooth fragments, however, are more common and tortoise fragments less common than in Palo Verde Mesa late Pleistocene paleosols. Radiocarbon dates on unionid mussel shells from Lake Harper range from 40,000 to 25,000 years. The paleosol probably formed between those dates and the end of the Pleistocene Epoch. A paleosol is known to cap the George Surface in the Victorville area. The George Surface is formed of the same fluvial sediments as those in the Hinkley area. It would not be surprising if the two paleosols from those two areas were to produce similar radiocarbon dates. Pedogenic carbonates from the two paleosols would be the most likely source for comparative radiocarbon dates.

POTENTIAL RESEARCH AVENUES PROVIDED BY A NINE-TON FIELD JACKET CONTAINING BABY, JUVENILE AND ADULT UTAHRAPTORS (THEROPODA; DROMAEOSAURIDAE)

THOMSON, Tracy J., University Of California, Davis, Davis, CA, USA; DEBLIEUX, Donald, Utah Geological Survey, Salt Lake City, UT, USA;KIRKLAND, James I., Utah Geological Survey, Salt Lake City, UT, USA; MADSEN, Scott, Utah Geological Survey, Salt Lake City, UT, USA; POLICELLI, Phillip Utah Friends Of Paleontology, Salt Lake City, UT, USA; GRAY, Dale, Utah Friends Of Paleontology, Vernal, UT, USA; CROSS, James, Cross Marine Projects, American Fork, UT, USA; BYBE, Paul, Utah Valley University, Orem, UT, USA; HUNTER, Rick, North American Museum Of Ancient Life, Lehi, UT, USA; and NICHOLLS, B.J., Utah Friends Of Paleontology, Salt Lake City, UT, USA

The ecology, functional morphology, phylogeny, and ontogeny of dromaeosaurid dinosaurs are subjects of strong interest, given their close relationship to birds. However, these topics are still under debate despite the large number of dromaeosaur taxa that have been described in recent years. In November of 2014, after nearly ten years of excavation work, the Utah Geological Survey removed a large field jacket measuring 10ft x 9ft x 3ft from the Early Cretaceous upper Yellow Cat Member of the Cedar Mountain Formation in central Utah. Encased in this jacket, which is currently housed at the North American Museum of Ancient Life, are at least seven *Utahraptor* individuals representing various ontogenetic stages. The amount of data and possible research avenues provided by the discovery of this *Utahraptor* "family" block are almost endless. The partially articulated and associated skeletons in this block will aid in confirming and informing the sparse, disarticulated material originally assigned to the holotype. These skeletons also offer a rare opportunity to study ontogenetic aspects of the largest known dromaeosaurid. Bone histology will provide insights into *Utahraptor* lifespans and growth rates. Qualitatively, limb proportions appear to exhibit strong allometry through ontogeny, demonstrated by more gracile juveniles and very robust adults. This trend in hind limb allometry, although it has yet to be quantified, is similar to that observed in the more basal *Allosaurus fragilis*, where older individuals are more robust than younger ones. Almost certainly, then, hind limb function changed considerably throughout the life of the individual. Although the enlarged and hypertrophied claw on the second digit typical of dromaeosaurids was originally inferred to have a predatory function, debate now continues as to what function it actually performed and whether that function was the same amongst all dromaeosaurids. Interestingly, claw shape appears to be isometric throughout *Utahraptor* ontogeny which raises questions as to whether or not claw function remained the same throughout the individual's lifespan, especially given the extreme allometry observed in the rest of the hind limb. These are a few examples of research that is currently underway or planned for the future as preparation work continues.

AN EARLY PLIOCENE MICROTINE RODENT FROM THE LOWER SAN JOAQUIN FORMATION FROM THE KETTLEMAN HILLS FACILITY, KINGS COUNTY, CALIFORNIA

WAGNER, Hugh M., FISK, Lanny H., MALONEY, David F., PFEIFFER, Brendan J., and PECK, Phil R., PaleoResource Consulants, Auburn, CA, USA

The mammalian taxa recovered at the microsite (PRP 13-11-14-02) contain one microtine rodent that appears to be intermediate in size between a vole and a muskrat. The five isolated cheek teeth recovered are diverse in size and morphology, but appear to represent one genus. The grade of evolution of the one microtine resembles that of the early Pliocene voles of the *Mimomys* complex. The complete m1 present is too large to be a Blancan age vole. This molar does resemble the m1 of a hypothetical primitive species of *Pliopotamys* with a very simple anteroconid, labial and lingual reentrants that extend to same depth, and no visible dentine tracts. All other preserved molars exhibit reentrent of the same depth with no dentine tracts. M3 has reentrent depths the vary with the curature of this tooth, and the anterior loop is larger relative to the overall occlusal surface than observed in any described vole with a weak or very poorly developed posterior loop. This microtine may represent the small primitive muskrat referred to as "*Dolomys* sp." by Repenning and others (1995) from the lower Pliocene age Etchegoin Formation in the southern Kettleman Hills stratigraphically near the Lawlor Tuff that has a published radiometric date of 4.1 Ma. The small woodrat *Paraneotoma* is represented by two cheek teeth in the microsite sample. The two upper molars (M1, M2) represented do not provide definite features providing a positive species identification, but the crown-height and grade of evolution of the teeth resemble that of *Paraneotoma fossilis*. The small rabbit, *Pewelagus* was identified from a single lower molar, but *Pewelagus* has been previously identified from other samples from the San Joaquin Formation in the PRC collections. This microfossil fauna recovered from the lower portion of the San Joaquin Formation apparently above the unconformity between the San Joaquin Formation and the underlying Etchegoin Formation is considered to be approximately 3.5 Ma.

PNEUMATIC DIVERTICULA ASSOCIATED WITH THE SPINAL CORD IN BIRDS, SAUROPOD DINOSAURS, AND OTHER ORNITHODIRAN ARCHOSAURS

WEDEL, Matthew J., Dept. of Anatomy, Western University of Health Sciences, Pomona, CA, USA; TYKOSKI, Ronald S., Dept. of Paleontology, Perot Museum of Nature and Science, Dallas, TX, USA; FIORILLO, Anthony R., Dept. of Paleontology, Perot Museum of Nature and Science, Dallas, TX, USA; MAXWELL, W. Desmond, Dept. of Biological Sciences, University of the Pacific, Stockton, CA, USA

By the dawn of the 20th century, paleontologists had realized that sauropod dinosaurs have small neural canals relative to their large size, and therefore their spinal cords must have been small as well. The neural canals of sauropods are also often taller than wide. This is unusual, because the spinal cords of vertebrates are highly constrained in cross-sectional shape, and almost always slightly wider than tall. Therefore not only are the neural canals of sauropods oddly small, it would appear that the meningeal sac containing the spinal cord almost certainly did not fill the entire space. In extant birds, much of the cross-sectional area of the neural canal is occupied by the canalis supramedullaris, a pneumatic diverticulum derived from the lungs and air sacs. The canalis supramedullaris is present in hummingbirds and ostriches and in most size-intermediate taxa where it has been surveyed, so its presence is likely ancestral for birds. It probably evolved much earlier, however. Occasionally in birds, foramina inside the neural canal lead into pneumatic spaces in the vertebrae, especially in large taxa such as ostriches, swans, and pelicans. These foramina are direct evidence of supramedullary pneumatic diverticula. Similar foramina in the neural canals have previously been identified on CT scans of vertebrae from adult sauropod dinosaurs, but these are physically inaccessible and essentially impossible to observe in any other way. We have identified supramedullary pneumatic foramina in unfused neural arches of a juvenile titanosauriform from the Cloverly Formation (Lower Cretaceous, Aptian-Albian) of Montana and a juvenile *Alamosaurus* from the Black Peaks Formation of Texas (Upper Cretaceous-Paleogene, Maastrichtian-Paleocene). These specimens provide the first opportunity to directly examine supramedullary pneumatic foramina in fossil archosaurs. The presence of supramedullary canals in sauropods is only the most recent of many lines of evidence for similar pulmonary anatomy in birds and non-avian dinosaurs. Furthermore, pneumatic features on the vertebrae tend to cluster around the neural canals in both saurischian dinosaurs and pterosaurs. Although the function of supramedullary diverticula is unknown, such diverticula are probably primitive for saurischian dinosaurs, and may have been present in most ornithodiran archosaurs

PALEONTOLOGY OF ARIZONA AND THE MILK CREEK FOSSILS

WEIDEMAN, Carley, CURTIS, Dirilee, BLAIR, Ian, MARCINEK, Sarah, and BEVERS, Jeb, Department of Biology, Yavapai College, Prescott, AZ, USA

Student directed research in paleontological studies is summarized. These include field activities on visits to four Arizona fossil sites: Petrified Forest National Park, Wickieup, Black Canyon City, and Milk Creek. The site with the largest effort and focus has been the Milk Creek formation in Yavapai County of central Arizona. The geologic age estimated of this site is late Miocene (12.0 to 9.5 million years). The predominant animal remains located in the Milk Creek formation are two camel genera, though a variety of other taxa (horses, carnivores, rabbits, rodents) have also been located. For the Milk Creek locality, historic descriptions and field notes from Ted Galusha, topographic maps and GPS coordinates were used to map out the original five quarry sites which were collected here for the American Museum of Natural History beginning in 1956. Surveys and collections of new specimens were also conducted to add to the Yavapai College collection in the Biology Department. Compilations of collection data of Milk Creek specimens were also made from the Sharlot Hall Museum (SHM) and the Mesa Museum of Natural History. One of the findings from the SHM was identification of a previously unrecorded taxon from the Milk Creek site. An ancient canid, between a fox and a coyote in size, of the genus *Leptocyon* sp. was identified from a partial maxilla with a first and second molar. Historic collection data from Ted Galusha's 1956 efforts were tallied to provide the number of various taxa obtained from these early efforts. A vast majority of the taxa collected are from two different genera of fossil camels, *Protolabis coartatus* and *Michenia yavapaiensis*.

DEPOSITIONAL ENVIRONMENTS OF THE TURLOCK LAKE PALEOFLORA, UPPER MEHRTEN FORMATION (MIO-PLIOCENE), NORTHERN SAN JOAQUIN VALLEY, CALIFORNIA

WILSON, W., Geology Program, California State University, Stanislaus, Turlock, CA, USA; SANKEY, J.T., Geology Program, California State University, Stanislaus, Turlock, CA, USA; GEORGE, M., Geology Program, California State University, Stanislaus, Turlock, CA, USA; BIEWER, J., Geology Program, California State University, Stanislaus, Turlock, CA, USA; GARBER, D., Modesto, CA, USA

The Turlock Lake Paleoflora is an important plant assemblage from the upper Mehrten Formation (early-Pliocene; Hemphilian LMA), northern San Joaquin Valley, California. The Mehrten consists of volcanic-sedimentary deposits representing lahar flows, stream, lake and floodplain deposits, and is exposed in the low foothills between Sacramento and Merced. The fossil plant leaves were collected by Dennis Garber from the upper Mehrten; they were exposed on two small islands within Turlock Lake. They were described and published by Axelrod in 1980. He documented 25 different plant species in the flora, including trees, shrubs, and herbaceous perennials. From these specimens, he was able to estimate the paleotemperatures and rainfall for this area. Importantly, they indicate a higher rainfall than today and less severe summers and winters, probably due to the lower Coast Range.

Axelrod concluded that the sites formed in a lacustrine depositional environment. However, in the original paper there were no lithologic or taphonomic descriptions and no stratigraphic sections to document this interpretation. We have accomplished the following: we described the lithology of the sites based on 30 specimens from each site housed in the University of California Museum of Paleontology; re-found and re-documented the sites using GPS and photographs; described the lithology of each site in the field; measured and described stratigraphic sections through these sites; and have just started to interpret and describe the taphonomic conditions of the leaves. What we found was the following: the sites are from thinly bedded, sandy shales, which we interpret as lacustrine deposits, in agreement with Axelrod's interpretation. Future work will involve a taphonomic study of the sites.

DEFLATING THE TAXONOMIC DIVERSITY OF *MERYCODUS* (FAMILY: ANTILOCAPRIDAE)

ZHANG, Zixiang, University of California, Berkeley, CA, USA

Merycodus Leidy (1854) is a basal antilocaprid of small, cursorial, mixed-feeding browsers that lived in the Miocene of North America. Today, the family Antilocapridae is represented only by *Antilocapra americana*, the American pronghorn. Currently, 11 species of *Merycodus* are recognized based on qualitative differences in morphology across different fossil assemblages. It remains unclear whether fossils from any given locality represent more than one species, or how many species of *Merycodus* existed. Here, I investigate the taxonomic diversity in *Merycodus* by addressing the questions: 1) how do intraspecific morphological variations in dental and horn core characteristics within *Merycodus* spp. compare to each other, and to that of the extant antilocaprid, *Antilocapra americana*? 2) were there multiple species of *Merycodus*? Barstovian *Merycodus* fossils collected from the Valentine Fm. in Nebraska and the Barstow Fm. in California and specimens of recent *Antilocapra americana* from across western North America were used for this study. I gathered linear measurements of cheek teeth and horn cores, and performed bivariate and principle components analyses. My findings suggest that *Merycodus* cannot be partitioned into more than one species based on dental measurements alone. *Merycodus* horn cores from the Valentine Fm. occupy a smaller subset of the total morphospace occupied by horn cores from the Barstow Fm., and are also smaller on average than those from the Barstow, although the difference is not significant. Based on the specimens considered in this study, I propose two morphological groups that overlap in morphospace but differ in their occupancy of the total generic range of variation: *Merycodus* sp. from the Valentine deposits, and *Merycodus* sp. from the Barstow deposits. Principal Components Analysis suggests that the total range of morphological variation in *Merycodus* teeth and horn cores is comparable to that within the living *Antilocapra americana*. I fail to reject the null hypothesis of a single species of *Merycodus*, and suggest that current taxonomic diversity in *Merycodus* is inflated, and requires continued revision.

2016 FIELD GUIDE AND ROAD LOG TO THE LATE MIOCENE AND PLIOCENE STRATIGRAPHY AND PALEONTOLOGY OF THE FISH CREEK BASIN ANZA-BORREGO DESERT STATE PARK®, CALIFORNIA

JEFFERSON, George T., MROZ, Arnold, and MURRAY, Lyndon K., Colorado Desert District Stout Research Center, Borrego Springs, CA, USA

This field trip guide and road log is a modified version of Jefferson et al. (2012a Searching for the Pliocene: field trip guide to the southern exposures, Day 2; pp. 19-30 in R.E. Reynolds (ed.), Searching for the Pliocene: Southern Exposures. The 2012 Desert Research Symposium [Field Guide and Proceedings], California State University Desert Studies Center.).

Road log Stop numbers and mileage have been adjusted for the WAVP excursion (Figure 1). This road log starts at the intersection of State Highway (SR) 78 and Split Mountain Road in Ocotillo Wells. The first stop will be at the Fish Creek Campground. We will proceed up Fish Creek Wash for a 30-mile round trip. Four-wheel-drive and high clearance vehicles are highly recommended. Bring your lunch and water. We will return down Fish Creek Wash, so car-pooling also is highly recommended. Remember that parking is permitted within one car length off of the main dirt road. Please note that collecting specimens of any kind is prohibited within the State Park.

Stratigraphic names, sequence and dates for units in the Fish Creek/Vallecito Creek Basin are provided in the stratigraphic column shown in Figure 2. Listed fossil assemblages from the various formations and members are found in Tables 1-8. These are extracted and amended from Jefferson et al. (2012b). For a comprehensive treatment of the geology and paleontology of the region see Jefferson and Lindsay (2006).

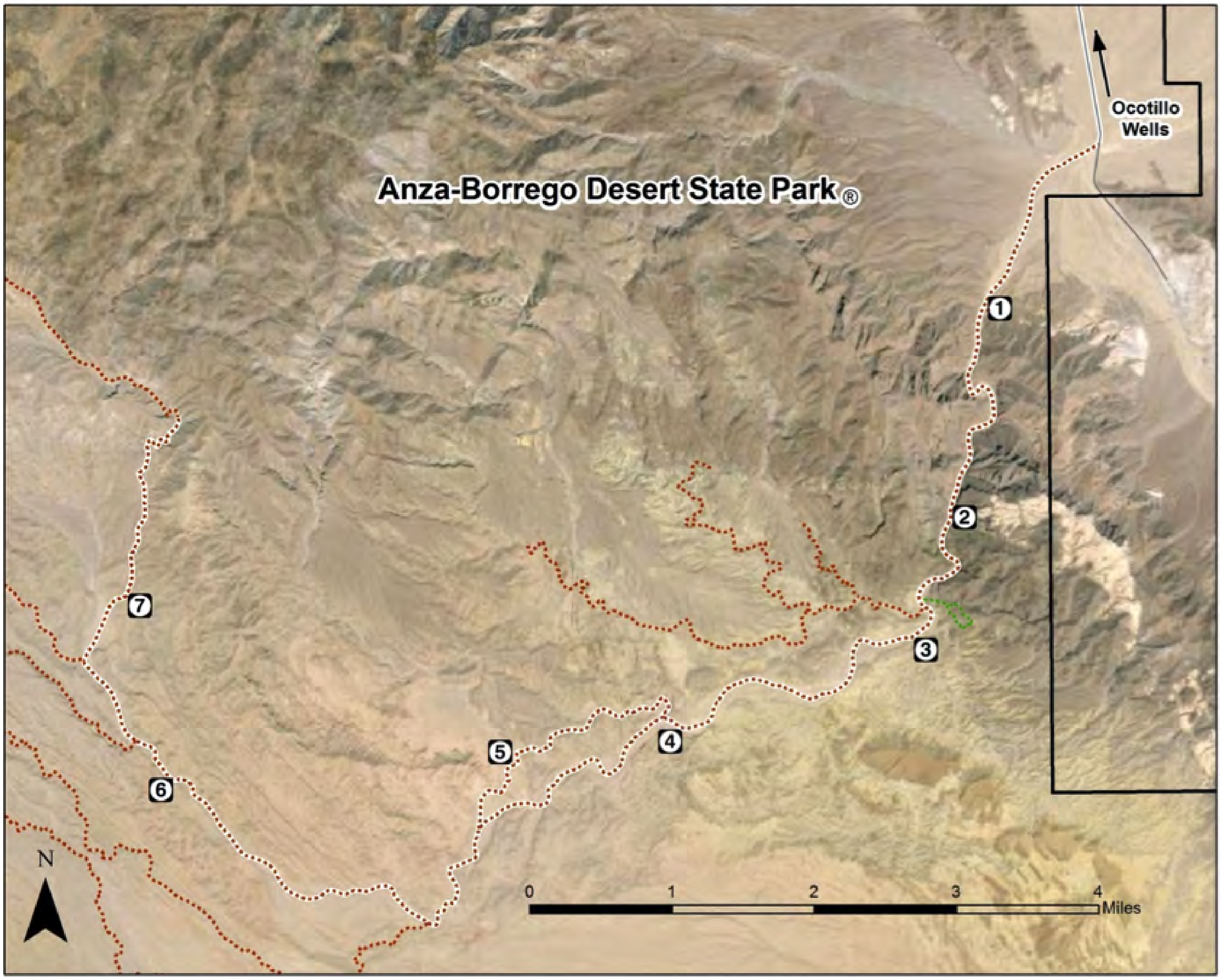

Figure 1. Field Trip Road Log Map

Stop 1 is at the Fish Creek Campground
Stop 2 the Lower sturzstrom and the base of the Latrania Formation
Stop 3 the Mud Hills member of the Deguynos Formation
Stop 4 the Yuha member of Deguynos formation
Stop 5 the Arroyo Diablo Formation
Stop 6 the Olla Formation, and Stop 7 the Olla Formation and Canebrake Conglomerate

(modified from Jefferson et al. 2012a)

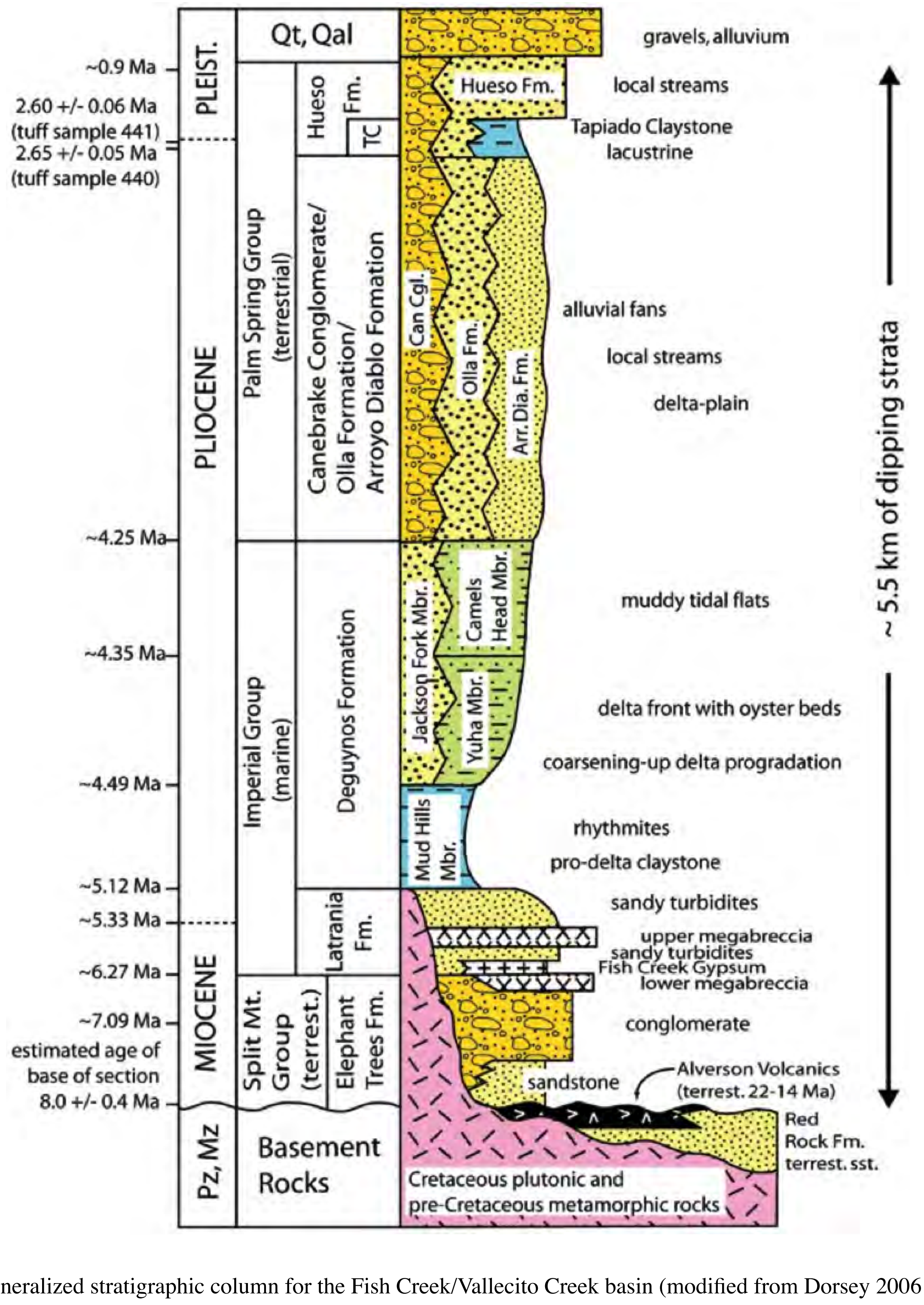

Figure 2. Generalized stratigraphic column for the Fish Creek/Vallecito Creek basin (modified from Dorsey 2006, fig. 5.3, Dorsey et al. 2011, fig. 5).

DIRECTIONS FROM HIGHWAY 78 TO FIELD TRIP STARTING POINT

00.0 (0.0) **TURN RIGHT** (south) from SR 78 onto Split Mountain Road in Ocotillo Wells. Services (gas, markets, motels) are 35 miles northwest in Borrego Springs. **PROCEED** from Ocotillo Wells on Split Mountain Road to Fish Creek Wash dirt road.

0.5 (0.5) The Split Mountain Store is on the left.

2.6 (2.1) The road bends southeast and becomes Old Kane Springs Road.

3.7 (1.1) **BEAR RIGHT** (south) on Split Mountain Road.

5.6 (1.9) Enter Anza-Borrego Desert State Park (ABDSP).

5.7 (0.2) Continue past a right (west) turn to the Elephant Tree area. Information on this site and other interesting hikes is available at the ABDSP Visitor Center in Borrego Springs.

7.9 (2.2) **TURN RIGHT** (southwest) onto the Fish Creek Wash dirt road. Split Mountain Road dead ends at the US Gypsum mine (visible ahead and to the east from the Fish Creek Campground).

The hills to the north of Fish Creek Wash, and west of the south end of the pavement on Split Mountain Road were mined for Celestine during WWII (Durrell 1953). The clastic marine late Miocene Latrania Formation and underlying Fish Creek Gypsum compose the base of the Imperial Group (Figure 2). The base of the Fish Creek Gypsum deposit overlies crystalline basement rock east of the mine, interfingers with the top of the Elephant Trees Conglomerate near Fish Creek Campground, is in part separated from the Elephant Trees Conglomerate by a sturzstrom, and is laterally equivalent to the base of the near shore Latrania Formation (Stop 2).

The approximately 80 m-thick gypsum deposit has been interpreted as a sabkha-like deposit (Dean 1996) but it lacks calcite, and has the distinctive metallic trace element and temperature signal of a geothermal vent (Peterson and Jefferson 1997). The gypsum yields marine nanoplankton and pollen (Table 1, Dean 1996). It is 90% pure, and has been mined since 1920s. The Celestine deposit is lens-shaped within the base Latrania Formation. Elsewhere, the base of the Latrania Formation yields a diverse tropical invertebrate fauna with east Atlantic and Caribbean Ocean affinities (Démeré and Rugh 2006).

9.5 (1.4) **PARK** to the right in Fish Creek Campground. Restrooms are available in the campground.

00 (00): STOP 1: Fish Creek Campground (Figures 1 and 2)

REGROUP at the Fish Creek Campground entrance road in Fish Creek Wash at 09:30 am, **SET TRIP ODOMETERS TO ZERO**. **PROCEED** up Fish Creek Wash. This field trip traverses the late Miocene and Pliocene part of the Fish Creek/Vallecito Creek Basin 5 km-thick stratigraphic section. Starting at 6.3 Ma, these deposits record the opening of the Salton Trough, filling by the ancestral Gulf of California, and deposition of the Colorado River delta across the Salton Trough. The stratigraphic section is summarized in Figure 2. The stratigraphic units visited on this route fall within the upper part of the Imperial Group and lower part of the Palm Spring Group. Nomenclature for these deposits is presently under revision (G. Jefferson and C. Powell, personal communication, 2012). That used herein follows Jefferson and Lindsay (2006), where the lower and upper parts of the Imperial Formation have been designated the Latrania and Deguynos formations respectively and placed within the Imperial Group, elevated to group rank by Remeika (1998, Winker and Kidwell 1996). The Palm Spring Group and its subordinate formations are defined by

Cassiliano (2002). For an historical summary and correlation of stratigraphic nomina see Remeika (1998) and Lindsay and Jefferson (2006). Also, see Winker and Kidwell (1996) and Dorsey et al. (2011; Dorsey, 2006) for a discussion of the regional geology.

The trip covers over 3 million years and 5 km of continuous stratigraphic section starting with late Miocene deposits in the base of the Latrania Formation at ca. 6.3 Ma (Figure 2). The entire marine depositional record lasts from about 6.3 to 4.25 Ma. The first evidence of terrestrial input from the ancestral Gila River (Kimbrough et al., 2011) or the Colorado River (Gastil et al. 1996; Dorsey et al. 2007, Dorsey 2012) is at ca. 5.3 Ma, within the top of the Latrania Formation. The route will traverse the marine prodelta, delta front, and near shore marine delta; respectively the Mud Hills, Yuha, and Camels Head members of the Deguynos Formation (see Jefferson et al., 2012a). The latter part of the route covers the transition to terrestrial deltaic deposits of the 4.2 to 2.4 Ma Arroyo Diablo Formation and the lateral equivalent fluvial Olla Formation of the lower Palm Spring Group.

CONTINUE southwest along Fish Creek Wash into Split Mountain Gorge.

1.2 (1.2) In route at mile 1.2 are excellent exposures of the reddish-brown, poorly sorted matrix and clast-supported boulder Elephant Trees Conglomerate along the west (right) side of Split Mountain Gorge. The Elephant Trees Conglomerate is cut by the antecedent Fish Creek drainage, which runs north through the Gorge, following the north-south Split Mountain Fault that is perpendicular to the axis of the Split Mountain anticline. This erosion exposes the conglomerate, primarily debris flows and fanglomerates, in the core of the fold. The conglomerate is about 8 to 6.5 Ma, and coarsens upward. The largely fluvial sandstone base of this unit was previously and erroneously correlated with the early Miocene, 22 Ma, "Red Rock" formation that crops out several km to the south (Dorsey et al. 2011). Locally a lower megabreccia or sturzstrom (Abbott 1996) separates the top of this unit from the base of the Latrania at mile 2.9. The sturzstrom crops out along the east (left) side of the canyon. Note the very large, house-sized clasts in this medium-gray, very poorly sorted megabreccia.

1.6 (0.4) The sturzstrom dips from eastern ridge top to canyon floor ahead.

1.9 (0.3) STOP 2: Lower sturzstrom and the base of the Latrania Formation (Figures 1 and 2)

PARK on the LEFT side of the road.

The most spectacular of all mass movements occur when rapidly moving debris flows travel far, causing massive inescapable devastation to plant and animal life and habitat. Specifically, rock falls with volumes in excess of one million cubic meters may flow horizontally up to 25 times farther than their vertical fall and reach speeds up to 280 km/hr, running up and over sizable hills in their paths. For example, in 1970 in Peru, a 230 m-high hill was overrun by an earthquake-triggered, high-speed mass, burying 18,000 people beneath a 30 m-thick layer of debris. Heim described events following the disaster in Elm, Switzerland, September, 1881, where a 10 million m3 dry mass dropped 600 m, and flowed 2.2 km, moving at 180 km/hr. Eye witnesses [indicated] a dry mass flowed like a "torrential flood" or "boiling stew". The shattered pieces of bedrock lay in a jigsaw-puzzle fabric where broken pieces could mentally be placed back together. Heim coined a new name—sturzstrom [German] from sturz = fall & strom = stream. These events are flows, not slides (Abbott 1996; see also Hsu 1975). The base of the Latrania Formation of the Imperial Group is exposed on the east (left) side of canyon. Here these locally-derived pale-olive, silty sandstones and siltstones lap onto the top of the lower megabreccia (sturzstrom) and over the Fish Creek Gypsum. The gypsum is seen pinching out between these units several hundred meters to the southeast. An invertebrate ichnite-rich, near-shore facies of the Latrania is not present in these exposures, but crops out above the Elephant Trees Conglomerate about 1 km to the northwest along strike from the Fish Creek Campground. Exposures of the Latrania Formation in the Coyote Mountains 16 km to the south of Split Mountain Gorge yield a rich marine shelly paleofauna (Rugh 2014).

2.0 (0.1) For the next 0.3 miles along Fish Creek Wash (both sides of canyon) are exposures of turbidites in the middle and upper Latrania Formation. These relatively deep water marine turbidites are moderately sorted, medium-grained, pale brown sandstones and siltstones that are locally derived and devoid of Colorado or Gila River transported clastic materials. They have been variously called the Lycium and/or Wind Caves members of the Latrania Formation (see Winker and Kidwell 1996), yield marine microfossils, and contain invertebrate ichnites. A second, upper megabreccia occurs within the top of the Latrania (between the lower Lycium and upper Wind Caves members of the Latrania) at the upper end of Split Mountain Gorge.

2.6 (0.5) The first evidence of the ancestral river deposits (from either the Gila River [Gastil et al. 1996, Kimbrough et al. 2011] or the Colorado River [Dorsey et al. 2007, Dorsey 2012]), or both, or possibly other speculative river systems, are located in this outcrop of the Wind Caves member. These pale gray-brown, fine to medium-grained sandstones, within the top of the Latrania Formation and below the Mud Hills member of the Deguynos Formation, yield the first evidence of extra-local river-transported clastics. The quartz-rich sands typically contain fine grains of magnetite, and are better sorted and rounded than the locally derived sediments (turbidites?). They typically lack appreciable amounts of locally-derived biotite, which is present in the underlying sediments that crop out immediately down-section. These fluvially-derived sediments contain a distinctive zircon signature compared to deposits of the lower Latrania Formation (Kimbrough et al. 2011, Dorsey 2012). Based on magnetostratigraphy (Dorsey et al. 2007) and zircon dating techniques (Cloos 2014), this event occurred ca. 5.3 Ma (Figure 2).

2.8 (0.2) **STAY LEFT** where the wash bends to the left and widens, near the intersection with North Fish Creek Wash located to the right side of the main wash.

In this time period (5–4.5 Ma), elsewhere in Imperial and San Bernardino counties, are

exposures of the Lawlor Tuff (4.83 Ma). This dated ash has yet to be recognized in the Fish Creek/Vallecito Creek Basin sequence, possibly due to the fact that most of the sediments at this time are turbidites.

3.0 (0.2) STOP 3: Mud Hills member of the Deguynos Formation (Figures 1 and 2)

PARK on either side of the road.

The 400 m-thick Mud Hills member includes all but the top-most beds of the prominent strike ridge or “flat iron” seen to the southwest called the Elephant Knees. Deposited in relatively deep water, this medium olive-colored, very fine-grained, well-sorted marine claystone largely predates progradation of the ancestral Colorado River delta front to the west across the Salton Trough. It yields a small, primarily molluscan invertebrate assemblage, bony fish and the deep-water shark *Squalus* (Table 2) (M. Roeder personal communication 2012, McDougall 2008, Jefferson et al. 2012b).

3.1 (0.1) Pass Fossil Reef dune rehabilitation area on left.

3.8 (0.7) Excellent exposures of Colorado River delta rythmites are present for the next half-mile along both sides of Fish Creek Wash. These ca. 10 cm-thick cyclic packages of fine-grained sandstone, silty sandstone, and siltstone deposits occur in the top of the Mud Hills member of the Deguynos Formation. They represent delta front sediments and range from 4.49 to 4.4 Ma. The physical drivers for this depositional phenomenon (climatic, tidal, or other) and the duration of a single cycle are presently undetermined (Lynch and Adams 2009).

5.5 (1.7) STOP 4: Yuha member of Deguynos formation (Figures 1 and 2).

PARK on the LEFT side of the road at junction.

Tempestite coquinas exposed in the wash are primarily composed of mixed single valves of *Dendostrea vespertina*, *Anomia subcostata*, and *Argopecten deserti* (Tables 3, 4) (Deméré and Rugh 2006, Jefferson et al. 2012b, Rugh 2014). The deposits are lens-shaped and have a short outcrop pattern along strike. This, and taphonomy of the bivalve taxa, suggest high-energy erosion of estuarine materials and re-deposition into channels on the distal marine delta plain or upper delta front. The 600 m-thick primarily pale yellowish-olive silty sandstone and medium brown shell coquina member records upward shallowing water depths. Jefferson et al. (2012a) tentatively correlate the upper part of the Yuha member with marine deposits at Willis Palms in the Indio Hills.

TURN RIGHT (north) into Loop Wash.

6.0 (0.5) The next mile exposes the 600 m-thick Camels Head member. The ca. 4.4 to 4.25 Ma Camels Head member of the upper-most Deguynos Formation records the transition from the marine to the continental delta plane. It represents near shore mudflat and beach deposits. Note the interbedded pale yellow, pink, and grayish brown silty claystones and sandstones through this part of the section, in comparison to the pale yellowish-olive silty sandstone and medium brown shell coquinas of the Yuha member.

6.9 (0.9) STOP 5: Arroyo Diablo Formation (Figures 1 and 2).

PARK on either side of the road.

The 4.25 to 2.8 Ma Arroyo Diablo Formation is primarily composed of pale reddish to pale yellowish-brown, moderately well-sorted sandstones, and in some exposures, consists of fining upward sand-silt sequences. The 2.5 km-thick unit represents the terrestrial delta plane and interfingers with locally derived fluvial deposits of the Olla Formation (Stop 6) along the basin margin. A variety of different shapes of sandstone concretions and fossil woods typify this unit. The fossil wood assemblage (Table 5) contains taxa whose modern relatives occupy lowlands and coastal areas, and suggests up to 62 cm of annual precipitation (Remeika 2006a). Fossil vertebrates include an elephant-like gomphothere, camels, and the horse *Dinohippus* (Jefferson et al. 2012b).

The ancestral Colorado River extended its delta across the ancestral Gulf during Arroyo Diablo time, isolating the Salton Trough to the north about 3.9 Ma ago. To the north, the Arroyo Diablo Formation interfingers with pale reddish claystones and siltstones of the lacustrine and playa deposits of the Borrego Formation. The Borrego Formation is not exposed in the Fish Creek Basin. To the south, deltaic deposits spilled into the ancestral Gulf of California as they do today.

BEAR LEFT to the upper intersection of Loop Wash and Fish Creek Wash.

7.7 (0.8) **TURN RIGHT** (west) into Fish Creek Wash. (Note: Do not re-enter Loop Wash when returning down Fish Creek Wash at the end of the tour.)

8.2 (0.5) Note fluvial and deltaic sands, and channels cut through the sandstone.

10.8 (2.6) STOP 6: Olla Formation (Figures 1 and 2).

PARK on the RIGHT side of the road and walk to top of the right bank of the wash.

In Fish Creek exposures, the Olla Formation dates from approximately 4.25 to 2.8 Ma (Dorsey et al. 2011). Here the formation interfingers basinward with the pale reddish to pale yellowish-brown, moderately well-sorted sandstones of the Arroyo Diablo Formation. Toward the basin margin it interfingers with the Canebrake Conglomerate (Stop 7), and at its base with the basin margin Jackson Fork member of the Deguynos Formation. Winker (1987, Winker and Kidwell 1996) described the Olla Formation in Fish Creek Basin as composed of locally derived fluvial sandstones and siltstones interbedded with Arroyo Diablo Formation-like Colorado River sediments. The formation produces a rich and diverse fossil vertebrate assemblage (Table 8) (Mroz et al. 2011, Jefferson et al. 2012b). In the Truckhaven Rocks of northern ABDSP, the 620 m-thick Olla Formation is composed of pale brown fluvial channel sandstones (3+ m-thick cross-bedding) that are interbedded with pale olive overbank sandy and silty claystones (Mroz et al. 2011). Here, tongues of Arroyo Diablo Formation-like sediments appear only in the uppermost part of the unit where it also interfingers with lacustrine claystones of the Borrego Formation. Lacking absolute dates, precise correlation of these rocks with the type Olla Formation in the Fish Creek Basin is uncertain (Mroz et al. 2011). However, current directions in the Fish Creek Wash exposures are from the north and northwest (Winker 1987), and in the Truckhaven Rocks current directions are from the northwest (Mroz et al. 2011). During Olla time, the mouth of the ancestral Colorado River was located east of ABDSP. These observations suggest that the Olla Formation at Truckhaven Rocks may represent sediment derived from an additional and significant fluvial source distinct from the ancestral Colorado and Gila Rivers and local sources in the Peninsular Ranges.

11.5 (0.7) **STAY RIGHT**—avoid Sandstone Canyon.

11.7 (0.2) **BEAR RIGHT** past Olla Wash.

12.7 (1.0) STOP 7: Olla Formation and Canebrake Conglomerate (Figures 1 and 2).

DRIVE a short distance past this stop, **TURN AROUND and PARK** on the RIGHT side of the wash. Walk a short distance down the wash to a saddle on southeast side for an overview.

The Olla Formation interfingers on the basin margin with the pale brown, poorly sorted coarse-grained sandstones and conglomerates of the Canebrake Conglomerate. To the north the Canebrake Conglomerate on the skyline is composed of granitic and metamorphic rocks (present in wash) shed from the Vallecito Mountains (Kairouz 2005). To the south and southeast the Olla Formation, pale olive, thin-bedded silty sandstone, is seen interfingering with the pink-colored Arroyo Diablo Formation-like well-sorted, medium to coarse-grained sandstones.

EXIT FIELD TRIP AND RETURN TO HIGHWAY 78

RETRACE 13 miles east and north back through Split Mountain Gorge to Split Mountain Road.

Do not re-enter Loop Wash when returning down Fish Creek Wash at the end of the tour.

13.2 (0.5) BEAR LEFT past Olla Wash.

13.9 (0.7) BEAR LEFT past Sandstone Canyon.

16.7 (2.8) CONTINUE past Arroyo Seco del Diablo

17.6 (0.9) PROCEED northeast on Fish Creek Wash. Do not enter Loop Wash.

19.4 (1.8) BEAR RIGHT past Loop Wash entrance. Proceed northeast in Fish Creek Wash.

24.7 (5.3) LEAVE Split Mountain Gorge and pass Fish Creek Camp.

26.2 (1.5) Split Mountain Road (paved).

30.5 (4.3) SLOW for left bend in road.

34.5 (1.0) SLOW for right bend in road.

36.2 (1.7) Ocotillo Wells, the intersection of SR-78 and Split Mountain Road.

There are several route options to either return home or continue your visit in ABDSP.

1. **Exit trip east** (right turn) on SR-78 to SR-86 north (left turn) to I-10 west (left turn) and Riverside and Los Angeles counties, and north (right turn) on I-15 to San Bernardino County, or I-10 east (right turn) to Arizona. A south (right turn) on SR-86 south to I-8 returns to Yuma (left turn) or San Diego (right turn).
2. **Exit trip west** (left turn) on SR-78 to SR-67 in Ramona into San Diego County, and I-8.
3. **Visitor Center** To visit the ABDSP Visitor Center (closes at 05:00 pm), exit trip west (left turn) on SR-78 to Borrego Springs Road (right turn 6.7 miles) to Borrego Springs, at traffic circle go around the circle until reaching SR-22/Palm Canyon Drive. Exit from the circle west (right turn) on SR-22, Palm Canyon Drive, the Colorado Desert District Stout Research Center, State Park Visitor Center and Palm Canyon Campground (developed, reservation required).
4. **From the Visitor Center** continue on SR-22 west (left turn) to S-2 west (right turn) to SR-79 west (right turn) to Temecula and north (right turn) on I-15 to SR-91 west (left turn) into Orange and Los Angeles Counties. Or you can travel east on SR-22 to SR-86 (see above).

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Table 1. Fish Creek Gypsum Floral Assemblage (from Jefferson and Lindsay 2006).

Phylum Dinoflagellata

- *Hystrichokolpoma rigaudae* (marine dinoflagellate)
- *Operculodinium centrocarpum* (marine dinoflagellate)
- *Tectatodinium* sp. (marine dinoflagellate)
- *Spiniferites ramosus* (marine dinoflagellate)
- *Selenophix* sp. (marine dinoflagellate)
- Genera and species indeterminate (marine dinoflagellates)

Plantae

Class Gymnospermae

Order Coniferales
- Family Cupressaceae
  - Genus and species indeterminate (cypress, cedar, or juniper pollen)
- Family Taxodiaceae
  - Genus and species indeterminate (redwood or sequoia pollen)
- Family Pinaceae
  - Genus and species indeterminate (pine or spruce pollen)
- Family Ephedraceae
  - *Ephedripites* sp. (joint-fir pollen)

Class Angiospermae

Subclass Dicotyledones

Order Fagales
- Family Juglandaceae
  - *Juglanspollenites* sp. (walnut pollen)

Order Malvales
- Family Malvaceae
  - Genus and species indeterminate (mallow pollen)

Order Asterales
- Family Asteraceae
  - Genus and species indeterminate (sunflower pollen)

Order Myrtales
- Family Onagraceae
  - Genus and species indeterminate (evening-primrose pollen)

Table 2. Foraminifera from the Wind Caves member of the Latrania Formation and Mud Hills member of the Deguynos Formation (list extracted from Dorsey et al., 2007; McDougall, 2008).

Phylum Foraminifera

- *Amphistegina gibbosa*
- *Bolivina interjunctata*
- *Globocassidulina globosa*
- *Bolivina subexcavata*
- *Cibicides mckannai*
- *Hanzawaia nitidula*
- *Nonionella basispinata*
- *Trifarina angulosa*
- *Elphidium poeyanum*
- *Nonionella stella*
- *Valvulineria inflata*
- *Ammonia beccarii*
- planktonic foraminifers

Table 3. Marine invertebrate fossils from upper members of the Deguynos Formation, exposures in Fish Creek (extracted from Jefferson et al. 2012b, table 2).

Phylum Cnidaria

Class Anthozoa

Subclass Zoantharia (corals)

Order Scleractinia
- Family Rhizangiidae (= Astrangiidae) (cup corals)
  - *Astrangia haimei*
- Family Faviidae (star corals)
  - *Solenastrea*
- Family Poritidae (finger corals)
  - *Porites*

Phylum Annelidae

Class Polychaeta (worms)

Order Canilapalpata
- Family Serpulidae
  - *Serpula*

Phylum Mollusca

Class Gastropoda (marine snails)

Order Patellogastropoda
- Family Lottiidae (limpets)
  - *"Patella"*

Order Neotaenioglossa
- Family Calyptraeidae (cup and saucer snails)
  - *Crucibulum scutellatum*

Order Neogastropoda
- Family Buccinidae (whelks)
  - *Cantharus*
  - *Solenosteira anomala*
- Family Nassariidae
  - *Nassarius*
- Family Cancellariidae (nutmeg snails)
  - *Cancellaria*
- Family Terebridae (auger snails)
  - *Terebra*

Class Bivalvia (marine clams)

Order Arcoida
- Family Arcidae (ark clams)
  - *Anadara carrizoensis*

Order Pterioida
- Family Pinnidae (penshells)
  - *Pinna latrania*
  - *Atrina*

Order Ostreoida
- Family Ostreidae (true oysters)
  - *Myrakeena angelica*
  - *Dendostrea vespertina*
- Family Gryphaeidae (oysters)
  - *Pycnodonte heermanni*
- Family Pectinidae (scallops)
  - *Argopecten*
  - *A. deserti*
  - *Flabellipecten*
- Family Anomiidae (jingle shells)
  - *Anomia subcostata*

Order Veneroida
- Family Lucinidae (lucine clams)
  - *Miltha*
- Family Crassatellidae (crassatella saltwater clams)
  - *Eucrassatella*
- Family Cardiidae (cockles or heart clams)
- Family Veneridae (Venus clams)
  - *Chione*

Order Myoida
- Family Pholadidae (rock piddocks)
  - *Cyrtopleura costata*

Phylum Echinodermata

Class Asteroidea (sea stars)

Order Paxillosida
- Family Astropectinidae (sand stars)
  - *Astropecten armatus*

Subclass Ophiuroidea
- Family, genus and species indeterminate (brittle stars)

Class Echinoidea (sea urchins and sand dollars)

Order Echinoida
- Family Strongylocentrotidae (sea urchins)
  - *Strongylocentrotus purpuratus*

Table 3 (continued)**.** Marine invertebrate fossils from upper members of the Deguynos Formation, exposures in Fish Creek (extracted from Jefferson et al. 2012b, table 2).

Order Clypeasteroida
  Family Mellitidae (key-hole sand dollar)
    Encope tenuis

Phylum Bryozoa

Class Gymnolaemata (bryozoans)

Order Cheilostomata
  Family Membraniporidae
    Conopeum

Phylum Arthropoda

Subphylum Crustacea

Class Maxillopoda

Order Sessilia
  Family Balanidae
    Balanus

Class Malacostraca

Order Decapoda
  Family Callianassidae
    Callianassa (shrimp)

  Family indet.
    Genus and species indet. (crab)

Table 4. Marine vertebrate fossils from upper members of the Deguynos Formation (H. Fierstine pers. comm. 2008, Atterholt et al. 2008, M. Roeder pers. comm. 2012).

Phylum Vertebrata

Class Chrondricthyes

Order Galeomorpha
  Family Cetorhinidae
    Cetorhinus sp. (basking sharks)

  Family Carcharinidae
    Carcharhinus (requiem sharks)
    Hemipristus serra (east Indian Ocean shark)

  Family Lamnidae
    Carcharocles megalodon (giant white shark)
    Carcharodon (white sharks)

  Family Odontaspididae
    Odontaspis ferox (sand shark)

Order Myliobatiformes
  Family Myliobatidae
    Myliobatis (eagle rays)

Class Actinopterygii

Order Clupeiformes
  Family Clupeidae
    Genus and species indeterminate (herrings)

Order Tetraodontiformes
  Family Tetraodontidae
    Arothron (puffer fish)

  Family Balistidae
    Genus and species indeterminate (triggerfish)

Order Perciformes
  Family Labridae
    Semicossyphus sp. (sheepshead)

  Family Sphyraenidae
    Sphyraena sp. (barracudas)

Class Reptilia

Order Testudines
  Family Cheloniidae
    Genus and species indeterminate (sea turtles)

Class Mammalia

Order Carnivora

Superfamily Pinnipedia
  Family Odobenidae
    Valenictus imperialensis (Imperial walrus)

  Family indeterminate
    Genus and species indeterminate (seals and sea lions)

Order Cetacea

Suborder Odontoceti (toothed whales)
  Family indeterminate
    Genus and species indeterminate (dolphins and porpoises)

Suborder Mysticeti
  Family indeterminate
    Genus and species indeterminate (baleen whales)

Table 5. The Carrizo Local Flora (modified from Remeika 2006a).

Plantae

Class Gymnospermae

Order Coniferales
- Family Cupressaceae
    - *Pinoxylon* (cedar or juniper)

Class Angiospermae

Subclass Dicotyledones

Order Laurales
- Family Lauraceae
    - *Persea coalingensis* (avocado)
    - *Umbellularia salicifolia* (bay-laurel)

Order Malpighales
- Family Salicaceae
    - *Populus* sp. cf. *P. alexanderi* (Alexander's cottonwood)
    - *Salix goodingii* (Gooding's willow)

Order Lamiales
- Family Oleaceae
    - *Fraxinus caudata* (ash)

Order Fagales
- Family Juglandaceae
    - *Juglans pseudomorpha* (walnut)

Order Sapindales
- Family Hippocastanaceae
    - *Aesculus* (buckeye)

Subclass Monocotyledones

Order Arecales
- Family Arecaceae
    - *Washingtonia* (fan-palm)
    - Genus and species indeterminate (palm)

Table 6. Layer Cake Local Fauna from the Olla Formation, Fish Creek Basin (modified from Cassiliano 1999; Murray 2008; Chandler et al. 2013). Avian and mammalian ichno-taxa from the Olla Formation are listed in Table 7.

Phylum Vertebrata

Class Aves

Order Pelicaniformes
- Family Pelecanidae
    - *Pelicanus* (pelican)

Order Cariamiformes
- Family Phorusrhacideae
- *Titanis* (terror bird)

Class Mammalia

Order Lagomorpha
- Family Leporidae
- *Hypolagus vetus* (ancient rabbit)
- *Pewelagus dawsonae* (Dawson's rabbit)

Order Rodentia
- Family Geomyidae
    - *Geomys anzensis* (Anza gopher)
- Family Heteromyidae
    - *Dipodomys compactus* (extinct kangaroo rat)
    - *Dipodomys hibbardi* (Hibbard's kangaroo rat)
    - *Dipodomys* n. sp. A (extinct kangaroo rat)
    - *Perognathus* sp. (pocket mice)
- Family Cricetidae
    - *Neotoma* (woodrats)
    - *Sigmodon minor* (cotton rat)

Order Carnivora
- Family Felidae
    - *Felis* (size of *Felis (Lynx) rufus*) (bob cat)

Order Perissodactyla
- Family Equidae
    - cf. *Dinohippus* (extinct horse)

Order Artiodactyla
- Family Camelidae
    - *Hemiauchenia* (llama)

Table 7. The Fish Creek Canyon Ichnofauna (modified from Remeika 2006b).

Division Vertebratichnia

Class Avipedia

Order Gruiformipeda
- Morphofamily Gruipedidae
  - *Gruipeda diabloensis* (Diablo least sandpiper track)

Class Mammalipedia

Order Carnivoripedida
- Morphofamily Mustelipedidae
  - *Mustelidichnum vallecitoensis* (Vallecito river otter track)
- Morphofamily Canipedidae
  - *Chelipus therates* (claw-footed dog track)
- Morphofamily Felipedidae
  - *Pumaeichnum milleri* (Miller's lynx-sized cat track)
  - *P. stouti* (Stout's cheetah track)
  - *Pumaeichnum* sp. (bobcat-sized felid track)

Order Proboscidipedida
- Morphofamily Gomphotheriipedidae
  - *Stegomastodonichnum garbanii* (Garbani's gomphothere track)

Order Perissodactipedida
- Morphofamily Hippipedidae
  - *Hippipeda downsi* (Downs' horse track)

Order Artiodactipedida
- Morphofamily Tayassuipedidae
  - *Tayassuichnum* (peccary track)
- Morphofamily Pecoripedidae
  - *Lamaichnum borregoensis* (Borrego small llama track)
  - *Megalamaichnum albus* (White's large llama track)
  - *Camelopichnium* (camel track)
- Morphofamily Cervipedidae
  - *Odocoilichnum* (deer track)

Table 8. Fossil assemblage from the Olla and Borrego Formations, Truckhaven Rocks (modified from Mroz et al. 2011).

Plantae

- *Chara* (pond weed)

Phylum Mollusca

- *Anodonta* (fresh water clams)
- ?*Physa humerosa* (fresh water snail)
- *Gyraulus* (fresh water snails)

Phylum Arthropoda

Arthropoda (shrimps and/or insects)

Phylum Vertebrata

Class Osteichthyes?
- Genus and species indeterminate (boney fish)

Class Reptilia

Order Testudines
- Family Emydidae
  - ?*Clemmys* (pond turtle)
- Family Testudinidae
  - *Hesperotestudo* (giant tortoises)

Order Squamata

Suborder Lacertilia
- Family Iguanidae
  - ? Iguanidae genus and species indeterminate (iguanas)

Class Aves
- Aves genus and species indeterminate (birds)

Order Cariamiformes
- Family Phorusrhacideae
  - *Titanis*

Class Mammalia

Order Xenarthra
- Family Megalonichidae
  - *Megalonyx* (ground sloth)

Order Lagomorpha
- Family Leporidae
  - *Hypolagus* (extinct rabbits)
  - ?*Sylvilagus* (cottontails)

Order Rodentia
- Family Geomyidae
  - *Geomys* (gopher)
- Family Cricetidae
  - *Sigmodon* (cotton rats)

Order Carnivora
- Family ? Canidae (dogs)
- Family Ursidae (bears)

Order Perissodactyla
- Family Equidae
  - *Equus* (extinct large horse)
  - *Equus* (extinct small horse)

Order Artiodactyla
- Family Tayassuidae
  - *Platygonus* (flat-headed peccary)
- Family Cervidae (deer)
- Family Antilocapridae (pronghorns)
- Family Camelidae
  - *Hemiauchenia vera* (small llama)
  - *Hemiauchenia* or *Paleolama* (llamas)
  - *Blancocamelus* (stilt-legged camels)
  - cf. *Camelops* (camels)