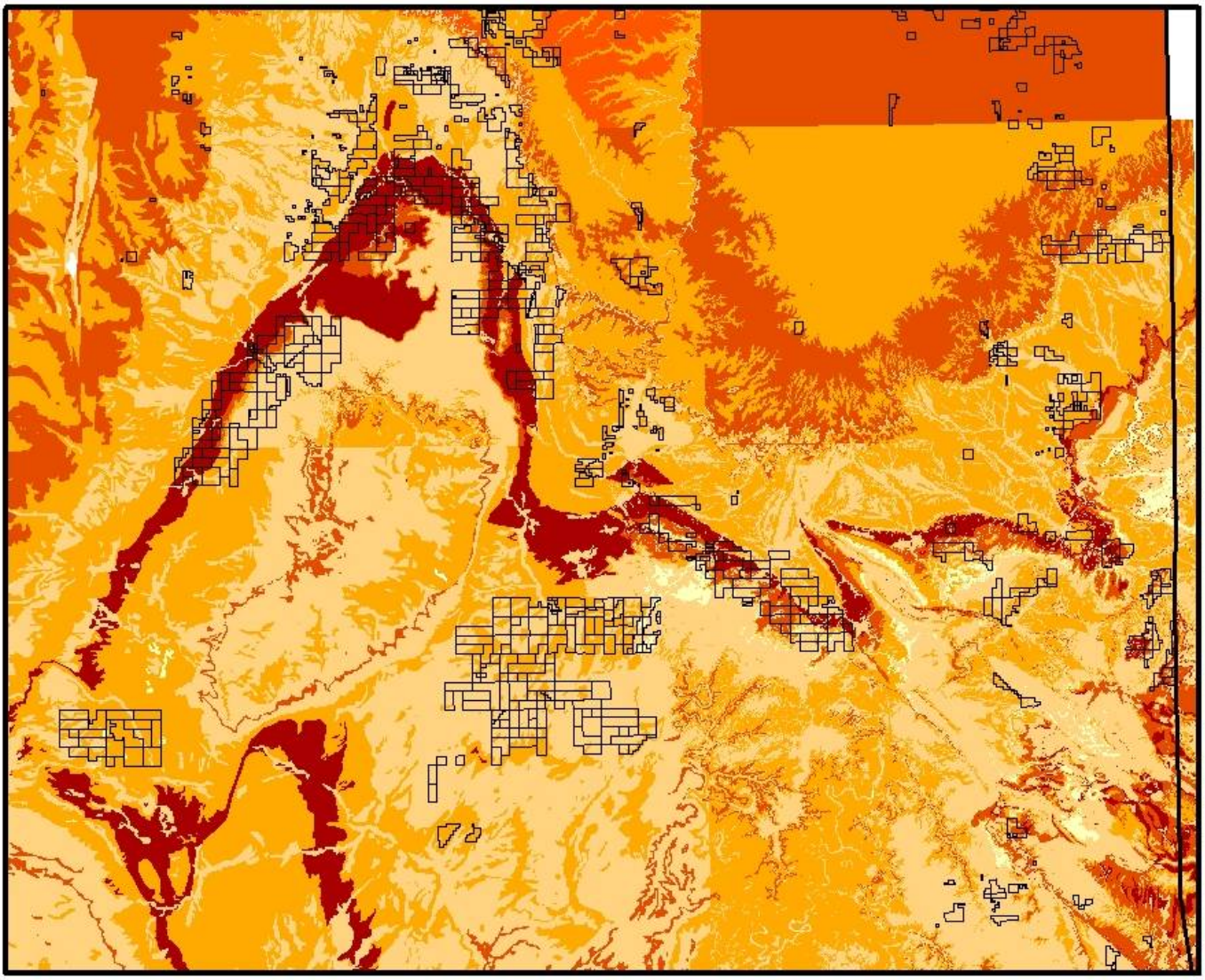
PROCEEDINGS OF THE EIGHTH CONFERENCE ON FOSSIL RESOURCES

Foss, Cavin, Brown, Kirkland, and Santucci



MAY 19-21, 2009 · St. George, Utah

Copies of this report are available from:

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Cover Illustration
Image of the Potential Fossil Use Classification (PFYC) GIS overlain with recent oil & gas lease parcels. The PFYC system allows local land managers to rapidly assess the potential for proposed land use decisions to impact paleontological resources.

PROCEEDINGS OF THE EIGHTH CONFERENCE ON FOSSIL RESOURCES

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May, 2009

About the Conference on Fossil Resources

Mission Statement

The Conference on Fossil Resources convenes periodically to provide an opportunity for public land managers, professional scientists and interested amateurs to come together to discuss successes, discoveries and land management policy in order to preserve and enhance publicly owned paleontological resources. Through this collaboration, participants seek to maximize scientific, educational and recreational opportunities on public lands.

History

The first Conference on Fossil Resources was hosted by the National Park Service in 1986 at Dinosaur National Monument. The theme of the conference focused on issues related to the management of paleontological resources on NPS lands. Subsequent fossil conferences have expanded in scope to include the management, protection, and interpretation of paleontological resources on all publically administered lands

Year City	Host
1986—Vernal, UT	Dinosaur National Monument
1989—Holbrook, AZ	Petrified Forrest National Park
1992—Kemmerer, WY	Fossil Butte National Monument
1994—Colorado Springs, CO	Forissant Fossil Beds National Monument
1998—Rapid City, SD	Badlands National Park and South Dakota School of Mines and Technology
2001—Grand Junction, CO	Colorado BLM, Gunnison National Forrest, and Colorado National Monument
2006—Albuquerque, NM	New Mexico Museum of Natural History and New Mexico BLM
2009—St. George, UT	Utah Friends of Paleontology, Utah BLM, and the Utah Geological Survey
Scheduled:	
2011— Kemmerer, WY	Fossil Butte National Monument

Dedicated to the memory of
Ann Schaffer Elder
1958—2009

Ann Schaffer Elder, Chief of Resource Management at Colorado National Monument, passed away on March 31, 2009 of complications from an emergency surgery. Too young, too vibrant, too *alive*; all of the usual phrases are true, but no words can express our shock and sense of grief over her loss.

Ann was a career National Park Service employee. She started as a seasonal Museum Technician at Fossil Butte National Monument in 1984. Shortly after that she began her long run at Dinosaur National Monument as a Museum Tech, Museum Specialist, Paleontologist, and, finally, as Park Curator. Her career was tragically cut short after a brief but productive and enriching time at Colorado National Monument, ending an amazing journey from novice fossil preparator to a highly competent and influential mover and shaker in the NPS curatorial world.

I worked with Ann at Dinosaur for 20 years, much of that time literally within an arms length of her. Our side-by-side work in the field and in a deteriorating building with tilted floors, in retrospect, reflected other aspects of our work environment. Yet, during that time I witnessed Ann's professional transformation within the NPS.

As a preparator Ann was equally capable of tackling the biggest dinosaur bones and the smallest of skeletons. The results consist of many visually spectacular and important specimens new to science: a new meat-eating dinosaur, new lizards, new sauropods, and the list goes on. Her work as a preparator includes displays in museums, web pages, and papers in scientific journals. Working in a park where the bone-bearing strata are steeply folded stretched Ann's imagination to the limit and she was always coming up with new ideas and innovations for how to excavate or

better protect a fossil. The only time I saw Ann cry was when a dinosaur we had excavated for years was finally flying over our heads, transported by a helicopter on its way to safety at the Quarry lab. Standing there, suddenly alone and quiet, we hugged while she wept like a baby.

But Ann's interests always went beyond the usual fieldwork and preparation. Ann was one of the first people in the fossil preparation community to seriously examine the materials being used on fossils from a long-term conservation perspective and actively promoted research and testing of adhesives and consolidants. She shared these ideas with professionals through her many publications and talks, and was well-respected by the scientific, conservation, preparation and curatorial fields alike. When Ann became Park Curator, her organizational skills, attention to detail, and boundless enthusiasm for the job moved mountains; the only difference with her earlier work was that the medium changed from rocks and fossils to paper and collections.

It is probably less well known that Ann, beyond her own needs, worked hard to better the lot of "the little person" in the NPS. Ann struggled hard against an all too often rigid and unyielding system to uphold her own dignity and that of others, and encouraged fellow employees to stretch their limits and reach "outside the box."

Above all, Ann was a people-person (who, as we all know, happened to love animals almost as much). She delighted in enlightening and entertaining the visitors at Dinosaur and had a marvelous knack for making everyone feel welcome and special, whether they were tourists, scientists or new volunteers and interns.

But as much as she enjoyed park social gatherings, potlucks and barbeques, what Ann most liked, was going home at the end of the day. Ann seemed to have a switch that flipped when she walked out the door. When she left work, paleo, geology, and her troubles at work stayed behind. When Ann took a hike, paddled a river or climbed a mountain, the world through her eyes ceased to be granite or limestone, and simply became beautiful and spiritual and just plain fun. I think she was happiest when sharing those times with her husband, Tom, her dogs, and closest friends.

It is fitting that so many of the wonderful treasures she worked to protect and preserve are now housed in the museums and institutions she served. The objects, and their curation, have become her permanent legacy. They will serve as a reminder of the value, beauty and fragility of all things, and the need for us to embrace all things and people with care, respect, and love while we have the chance.

Vaya con dios, amiga.

Scott K. Madsen
Utah Geological Survey
April, 2009

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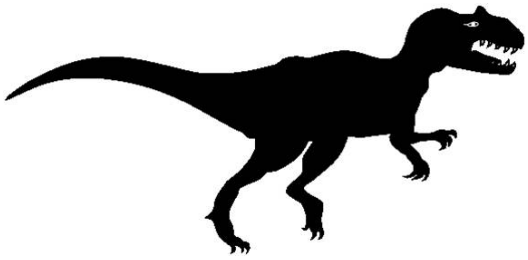

1:00—1:20, Sunbrook A-B (Session Moderators Jennifer Cavin and Darrin Pagnac)

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Emily Palus—National Curator and NAGPRA Coordinator,
Bureau of Land Management
Terry Childs—Archaeologist, National Park Service
Kara Hurst—Registrar, Utah Museum of Natural History

Thursday, May 21, 2009

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Dale Hanson—Regional Paleontologist, Bureau of Land Management
Lanny Fisk—PaleoResource Consultants Inc.
Robert E. Reynolds—LSA Associates, Inc.
Sue Ann Bilbey—Uinta Paleontological Associates, Inc.

8:00—11:20, Entrada B-C

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Ted Vlamis joined the Society of Vertebrate Paleontology (SVP) in 1993 and became Co-Chair of the Government Affairs Committee in 1995. He was president of Save America's Fossil For Everyone (SAFE) (a 501(c)4 formed by SVP) from 1995-2007, has served as Affiliated Geological Societies Liaison since 1996 and was elected as SVP Treasurer in 2007. Ted has prepared and executed the SVP strategies that culminated with the passage of the Paleontological Resources Preservation Act (PRPA).

While working for the passage of the PRPA, Ted helped form and execute a strategy to ensure input from SVP membership into the DOI Report "Fossils on Federal and Indian Lands". He helped draft model legislation, helped identify and recruit appropriate sponsors and co-sponsors, and worked with these sponsors to finalize and introduce the PRPA into congress.

Ted's insights into the politics and drama that lead to this comprehensive piece of legislation form the basis of a fascinating story, the events of which will forever stand out as a milestone in the history of the science of paleontology.

4:00—5:20, Sunbrook A-B (Panel Moderator: Scott Foss)
PANEL 3: PUBLIC LAW 111-011, THE PALEONTOLOGICAL RESOURCES PRESERVATION ACT. *As soon as practical after the date of enactment of this Act, the Secretary shall issue such regulations as are appropriate to carry out this subtitle, providing opportunities for public notice and comment.* (PRPA Section 6310)

Ted Vlamis—Society of Vertebrate Paleontology
Lucia Kuizon—National Paleontologist, Bureau of land Management
Vincent L. Santucci—Paleontology Program Manager, National Park Service
Cortney Cloyd—Geology and Paleontology Program Lead, USDA Forest Service

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Wednesday—Thursday, May 20—21

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Rare Earth Element signatures in fossil bone: A tool for mitigating fossil poaching on federal lands
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The nation's first BLM paleontological site stewardship program, established in Washington County, Utah
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A comparison of methods for effective management of fossil resources, Southwestern Region, USDA Forest Service
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Theodore J. Fremd, John Zancanella, and Scott E.Foss. 29

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California State University, Fresno and the California Department of Transportation (CALTRANS): Collaboration in paleontological resource assessment and impact mitigation
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Posters should be set up on Wednesday morning in Ballroom A-B and left up until Thursday afternoon.

FROM THE 1849 SURVEY OF THE TERRITORIES TO THE PALEONTOLOGICAL RESOURCES PRESERVATION ACT OF 2009, IT'S BEEN A LONG ROAD

FOSS, Scott E.[1] and KIRKLAND, James I.[2]

[1]Bureau of Land Management, Utah State Office, Salt Lake City, UT; [2]Utah Geological Survey, Salt Lake City, UT

2009 is a very exciting time to be a paleontologist. We are witnessing a renaissance in paleontological discovery, research techniques, and in public land management. In 2007 alone at least 12 new species of fossil vertebrates were discovered on public lands in the state of Utah by permitted researchers, keeping pace with the accelerated paleontological discoveries that are being made elsewhere in the world, including Mongolia, China, and Argentina.

2009 is the 30th anniversary of the Archaeological Resource Protection Act of 1979 (ARPA), which provides for the protection of cultural artifacts, the 103rd anniversary of the Antiquities Act of 1906, and the 150th anniversary of the publication of Charles Darwin's *Origin of Species*.

2009 is the 160th anniversary of Federally funded paleontology in the United States. In 1849, the David Doyle Owen Survey of the Territories produced the first publicly recorded fossils west of the Mississippi that were subsequently described by the naturalist and paleontologist Joseph Leidy. Later the F.V. Hayden Survey of the Territories followed with one of the most auspicious government publications of all time, Book 1, volume III, in the 1884 Report of the U.S. Geological Survey of the Territories, *The Vertebrata of the Tertiary formations of the west,* by Edward Drinker Cope (better known to paleontologists as "Cope's Bible").

2009 is the 130th anniversary of the US Geological Survey (USGS), which was created in 1879 and assumed responsibility for government sponsored paleontological surveys of the American west. Under the administration of the first and second directors of the USGS (Clarence King and John Wesley Powell respectively) paleontological discoveries were reported by Othniel C. Marsh. So, we could say that the first US government paleontologists were Leidy, Cope, and Marsh (although as the appointed USGS paleontologist, Marsh was the first to draw a salary).

The "bone wars" between Cope and Marsh, extensively reported in 1890, caused great embarrassment to the head of the USGS, John Wesley Powell, and then Secretary of the Interior, John W. Noble. In 1892, when congress cut the budget of the USGS by a crippling 40%, the paleontology program was immediately eliminated. Paleontology was not even mentioned in the Antiquities Act of 1906. Invertebrate paleontology would reemerge in the USGS under later directors, only to be cut again in 1994 following a new set of massive budget cuts to the USGS. What the U.S. Government has always lacked is a specific mandate to protect and study paleontological resources.

In 2009 everything has changed once again. On March 30th, President Obama signed into law the Paleontological Resources Preservation Act, which calls for paleontological resources on Federal lands to be managed using scientific principles and expertise. The magnitude of this event on the science of paleontology cannot be overstated and will play out in our talks, panel sessions, and hallway conversations over the next two days.

DAMAGE ASSESSMENT 101: DOCUMENTING UNAUTHORIZED EXCAVATIONS AND DETERMINING SIGNIFICANCE OF VERTEBRATE LOCALITIES

BEAT, Alicia D.[1] ;HANNA, Rebecca R.[2]

[1]Bureau of Land Management, Havre Field Station, P.O. Box 911, Havre, MT 59501;
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The increasing economic value of fossils puts paleontological resources on public lands at risk, and unauthorized collection of vertebrate fossils is becoming more common. The badlands of Montana are remote and rugged, and public lands in these areas are sometimes targeted by unauthorized collectors. Illegal removal of paleontological remains from unauthorized excavations often results in diminished specimen integrity and permanent data loss. Discovery of such evidence on Bureau of Land Management (BLM) land is followed by preparation of a "Damage Assessment," which thoroughly documents the unauthorized excavation, as well as any associated specimens or evidence that law enforcement officials are able to recover. The Damage Assessment should include: description of the damage/ specimens; chronology of the investigation; discussion of the scientific value; discussion of the paleontological significance; discussion about Fair Market Value and how it was derived; and discussion of the cost of response, restoration, and repair. A "Significance Determination" prepared by a qualified paleontologist should also be included in the Damage Assessment, because it forms the backbone for the scientific value and paleontological significance discussions. In the absence of paleontological resources legislation, portions of the Archaeological Resources Protection Act (1979, United States Code: Title 16, Chapter 1B, 470aa et seq., as amended) were used when assembling the components of the Damage Assessment, and the pros and cons of this necessity will be discussed.

The Significance Determination portion of the Damage Assessment provides a context for evaluating the scientific significance and research potential of the site and specimens. It should include: 1) background information (e.g., definition/description of paleontology; fossil types and their modes of occurrence; taphonomic data collection methods); 2) methodology (including significance and research potential assessment rationale); 3) detailed discussion of the geologic formation in which the unauthorized excavation took place, including its exploration history, geology, and paleontology; and 4) description and interpretation of the unauthorized excavation and any specimens held as evidence, including field inventory, specimen inventory, preliminary site interpretations, and assessment of significance and research potential. All vertebrate fossils and traces are considered to be significant by the BLM (2008, IM 2009-011 – Assessment and Mitigation of Potential Impacts to Paleontological Resources: U. S. Department of the Interior, USDI - BLM Washington Office directive, October 10). However, each discovery contributes to our understanding of past life in different ways, and some fossils/ localities clearly have more scientific significance and research potential in comparison to others. Using methodology outlined by William A. Clemens (1980, Analysis of the state of knowledge of paleontological resources in parts of Garfield and McCone counties, northeastern Montana:

unpublished consultant's report, prepared for Bureau of Land Management, Miles City Field Office, Montana), a fossil locality's degree of significance and research potential are proportional to the uniqueness of the fossils and their mode of occurrence, the diversity of types of information conveyed, and the quantity of specimens. Even though these determinations are inherently subjective, the underlying goal is to place an individual locality or group of localities in a broader context.

The scientific integrity of paleontology is compromised more every year by illegal collection of paleontological remains from unauthorized excavations, as specimens are often hastily excavated and permanently removed from the scientific realm (Figure 1). As the sale of fossils continues and their economic value increases, there is a heightened urgency for protection and management of paleontological resources on public lands. While fines for theft of public property deter some individuals from illegal collection, passage of the Paleontological Resources Preservation Act should strengthen paleontological resource protection by standardizing penalties for theft of fossils from federally owned lands. In most cases, the key to successful prosecution rests in a well-prepared Damage Assessment.

Figure 1. This unauthorized excavation on BLM land in Montana compromised the integrity of dinosaur bones that were excavated and left exposed to the elements, causing them to weather and degrade. Jacob's Staff for scale at right is marked in 10-cm increments.

RARE EARTH ELEMENT GEOCHEMISTRY OF FOSSIL BONE: USING GEOCHEMICAL PATTERNS TO TRACE ILLEGALLY EXCAVATED FOSSILS

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Rare earth elements (REE) in fossil bone have been used in a variety of scientific studies to understand the taphonomic history and depositional environment of fossil bone (Trueman, 1999; Metzger et al., 2004; Suarez et al., 2007), paleo-redox conditions (Elderfield and Pagett, 1986; German and Elderfield, 1990, Grandjean-Lecúyer et al. 1993), and to determine the provenance of float bone and potential time averaged sites (Staron et al., 2001; Patrick et al., 2004; Trueman et al., 2006; MacFadden et al., 2007). REE are incorporated into bone during the fossilization process, typically remain unaltered after initial incorporation (Trueman et al., 2008), and reflect REE patterns and concentration of surrounding pore-water (i.e. diagenetic fluids). REE pore-water chemistry is influenced by a variety of environmental factors including fluid pH, redox, and source rock (Erel and Stolper, 1993; Johannesson and Zhou, 1997; Dia et al., 2000; Johannesson et al., 2000; Gruau et al., 2004). These geochemical conditions generate characteristic REE patterns (plots of normalized REE concentration versus REE mass) that are light REE (LREE) enriched, middle REE (MREE) enriched, or heavy REE (HREE) enriched depending on the above outlined conditions (Trueman and Tuross, 2002). Fossil bone REE concentrations and patterns, thus, reflect pore-water chemistries specific to different depositional and burial conditions. Since such conditions are unique in time and space, REE can be used as a provenance tool. Bones within a bone bed, fossilized under the same geochemical conditions, should all show similar REE patterns. Therefore, autochthonous deposits will give similar REE patterns and have low REE variability from bone to bone. Bonebeds that are time-averaged accumulation or allochthonous material will give REE patterns that are varied from bone to bone and have a high degree of REE variability. Therefore, the unique geochemical constraints that determine the REE in fossil bone may also be practically useful to "fingerprint" fossil bone, allowing identification of illegally removed material based on its REE patterns.

Though this is theoretically possible, no exclusive trial studies exist in which REE are used to re-locate potentially poached bone (see the paleosol-bone REE study by Metzger et al. [2004] in which poached bone were analyzed and roughly related to location). We suggest the use of REE to fingerprint bonebed sites and the development of a database of REE geochemistry of potential at-risk sites. Though analyses using solution inductively coupled plasma mass spectroscopy (ICP-MS) are destructive, only small fragments or amounts of drilled samples (approximately, 0.05g) are required, which can be easily obtained without significant damage to the fossils. The chemistry involved in the preparation of samples is fairly simple and involves cleaning the bone in an acetic acid solution, followed by, dissolution of the sample in trace-metal grade nitric acid. Costs for solution analyses are $20 - $25 per sample

at an academic rate, which is a low to moderate cost for geochemical analysis.

Though use of solution-ICP-MS for REE analyses is promising, some complex fossilization environments may not correctly identify poached bone. For example, a single bone from the Crystal Geyer Dinosaur Quarry (CGDQ), curiously gives two different REE patterns (one pattern that is LREE-enriched and one that is HREE-enriched) when analyzed using laser ablation ICP-MS. In such cases, analysis by solution ICP-MS may not accurately characterize the REE pattern of suspected illegal material when compared to the rest of the bonebed. If, for example, the HREE-enriched part of the CGDQ bone is analyzed by solution ICP-MS and compared to the LREE-enriched part of another bone (that also has a HREE-enriched portion to it), the suspected bone would not be statistically related to the rest of the bone bed REE signature. Sites with bone exhibiting extreme intra-bone variability will likely manifest themselves as a reworked deposit (which was initially suggested for the CGDQ). Therefore, bonebeds analyzed by solution ICP-MS and interpreted to be a reworked deposit may potentially have extreme intra-bone variability rather than bone that was re-worked. A solution to such challenges is the use of laser ablation microprobe (LAM-) ICP-MS. Careful analysis using LAM-ICP-MS characterizes all REE patterns found in bone. LAM-ICP-MS uses a laser to analyze as little as a 30µm wide spot on the bone, allowing a multitude of REE analyses per bone. These data can then be used to create a REE map of the bone (Koenig et al., 2008). Compared to the solution method, which homogenizes much larger amounts of bone, LAM-ICP-MS more accurately characterizes intra-bone REE patterns. Cost per ablation pit for LAM-ICP-MS analysis is approximately $35 at an academic rate. LAM-ICP-MS analysis is more expensive than solution analysis because between10-20 pits per bone sample would be required for a good characterization of the bone sample; however, there is significantly more data per bone. For example, LAM-ICP-MS may be very useful in understanding the rate of bone fossilization. This is important for verifying the use of REE patterns in bone. Since it is assumed that bone from the same bonebed fossilized at the same rate, and that all bones fossilized in the same environment will have the same REE pattern, then bones from the same deposit having different fossilization rates could potentially have different REE patterns, thus resulting in REE variability not related to reworking and falsely "exonerating" a poached bone. CGDQ bone is again an example of this. It has been hypothesized that the thin nature of some bone from the site has allowed it to fossilize at a much higher rate that thicker bone. LAM-ICP-MS is a valuable tool in investigating the rate of fossilization of bone since it allows the visualization of REE distribution within the bone.

Though this and other challenges exist for the use of REE as a tool for identifying poached fossil material, partnership between universities and federal and state agencies may help to overcome such challenges. Since REE are a valuable tool for taphonomy and paleoenvironmental reconstruction, university research projects conducted at fossil localities can be co-funded by managing federal or state agencies. In return, REE data can be compiled by researchers into databases for managing agencies of paleontological sites. Based on the current literature and our research of REE in fossil bone, we strongly urge the use of REE geochemistry of bone for law enforcement and prosecution purposes. Simple analysis and statistical comparison to known material can be very powerful in prosecution of fossil theft. We also suggest REE would be best utilized in bone beds, rather than isolated occurrences of bone, since statistical significance of large bone accumulations are greater than that of isolated skeletons.

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THE USE OF RARE EARTH ELEMENT SIGNATURES IN VERTEBRATE FOSSILS AS A TOOL TO INVESTIGATE FOSSIL POACHING; A COOPERATIVE EFFORT BETWEEN NEBRASKA NATIONAL FOREST AND TEMPLE UNIVERSITY

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Bones of living organisms contain very low rare earth element (REE) concentrations; however, after death REE are adsorbed onto apatite surfaces and incorporated into the apatite crystals as they recrystallize and grow during fossilization (Trueman, 1999; Patrick et al., 2004). REE signatures are retained unless the apatite is dissolved or highly metamorphosed (Armstrong et al., 2001). The REE composition and signature incorporated in a fossil depends on the fluid composition and the amount and composition of REE released or sequestered by water/rock reactions with other minerals or colloidal phases. Fossilization and incorporation of REE, U, and other trace elements is accomplished while in the meteoric zone within a few thousands to tens of thousands of years after death (Kohn, 2008). Therefore, bones from successive stratigraphic units may contain significantly different REE patterns (Trueman et al., 2006; Suarez et al., 2007). Because combinations of REE in bones are distinct in specific locations and environments, REE have been used to determine:

1. provenance; fossils which are reworked or which have poor or missing collection information can be determined by comparison of signatures with known specimens (Staron et al., 2001; MacFadden et al., 2007; Patrick et al., 2007).

2. the relative extent of reworking or time averaging in various stratigraphic units from variance in REE signatures (Trueman and Benton, 1997; Suarez et al., 2007).

3. paleoenvironment: marine vs. terrestrial (Anderson et al., 2007), paleosalinity (Martin et al., 2005), and pedogenic environments (Metzger et al., 2004)

4. the paleo-redox state or REE carrier (Kemp and Trueman, 2003).

5. the duration of fossilization (Trueman et al., 2008)

In 2005, the Nebraska National Forest and Temple University entered into a challenge cost-share agreement aimed at determining the utility of REE signatures in fossil bone as a tool to mitigate fossil poaching. Since REE signatures of fossil bone vary as a function of geologic age and depositional environment, the influence of geology, taphonomy, and histology on REE signatures must be understood in order to apply REE to any particular suite of fossils. To address these concerns, we collected fossil bones in and around Toadstool Geologic Park on the Oglala National Grassland, north of Crawford, Nebraska, and we also collected on Buffalo Gap National Grassland in the Indian Creek Drainage, southwest of Scenic, South Dakota.

The samples at Toadstool Park were collected in order to test for variability of REE signatures as a function of changing paleoclimates and sedimentary environments across the Eocene-Oligocene Boundary.Other samples around Toadstool Park were collected to determine the degree of lateral variability and uniqueness of REE signatures between fossiliferous localities. Samples from Indian Creek were collected in order to determine the uniqueness of REE signatures of brontotheres from South Dakota to those in and around Toadstool Park, NE. To date, our key findings (Grandstaff and Terry, 2009) suggest that:

1). REE signatures are independent of animal type.
2). REE signatures are not affected by post mortem processing/scavenging, or degree of weathering before burial and fossilization.
3). Fossils from different regions have distinct REE signatures that can be identified and statistically discriminated.
4). Time series analysis of REE ratios reveals significant periodicities at ca. 1050, 800, 570, 440, and 225 ka, near some modulated Milankovitch orbital frequencies, suggesting that REE from vertebrate fossils may serve as high resolution geochronologic archives that can be used to "tune" the terrestrial record to a level of precision unattainable by current geochronologic methods.

Our efforts are currently focused on the peculiars of brontothere histology vs. REE signatures in order to refine the application of REE to fossil poaching, testing the geochronologic application of REE in fossil bone, and coupling REE data with stable isotopes to better understand paleoenvironmental and paleoclimatic change across the Eocene-Oligocene Boundary.

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RARE EARTH ELEMENT SIGNATURES IN FOSSIL BONE: A TOOL FOR MITIGATING FOSSIL POACHING ON FEDERAL LANDS

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Vertebrate fossils, a nonrenewable resource, provide valuable data on paleoenvironments and paleoclimatic change. To better manage fossil resources, the Nebraska National Forest (NNF-U.S Forest Service) and Temple University entered into a cooperative agreement to investigate the utility of rare earth element (REE) geochemical fingerprinting of fossil bone as a tool to interpret the geologic history of fossil-rich localities and test the hypothesis that REE analysis can be used to fingerprint bones from fossil beds particularly hard-hit by poaching. Because of its remote location, the abundant, large mammalian fossils of Toadstool Geologic Park in northwest Nebraska are frequently the target of fossil poaching. To test our hypothesis, brontothere and tortoise fossils were collected from three sites on NNF property within several kilometers of Toadstool Geologic Park and analyzed for REE composition. All three sites are within the Late Eocene Chadron Formation.

Since bones incorporate REE from interactions with groundwater during fossilization, various geochemical processes that fractionate REE impart distinctive chemical signatures on fossil bones (Denys et al, 1996; Grandstaff and Terry, 2009). In effect, associations of fossil bones that have been affected by different pore-waters should be distinguishable by their unique REE fingerprints. Samples from our three field sites represent temporal and spatial differences in terms of their interactions with ancient groundwaters.

Field observations suggest that fossils at all three sites accumulated on ancient floodplains. Paleosols containing brontothere fossils were analyzed at two of the three field sites (1 and 3) to determine the taphonomic mode of deposition and preservation of the bones. Site 1 is within the Peanut Peak Member (PPM) of the Chadron Formation. The PPM is primarily composed of fluvial mudstones and is topographically expressed as low-lying, hummocky mounds (Terry, 2001). This site is a brontothere bone bed covering several 100 square meters. Numerous large, weathered pits at this site indicate previous activity by fossil poachers. A paleosol profile was trenched lateral to the bone bed, and fossils were collected from the bone bed and the surrounding area for REE analysis. Two brontothere bone fragments were exposed in the uppermost horizon of the paleosol profile and also collected for REE analysis. The lower horizon of the Site 1 paleosol shows two stages of pedogenic development. Peds low in the profile are clay-rich, mottled and platy, indicating a low degree of pedogenic alteration due to hydromorphic conditions on a low-lying part of a floodplain. However, petrographic analysis indicates moderate accumulation of pedogenic carbonate within the lower portion of the paleosol. Accumulation of carbonate requires well-drained conditions (Birkeland, 1999), indicating a drop in relative water table level due to either a change in the geomorphic position of the floodplain, or possibly short-term climate change. The upper soil horizon,

which contained the two brontothere bones, is a zone of carbonate accumulation (Stage II of Birkeland, 1999). Root traces infilled with diagenetic calcium carbonate indicate pedogengic development. The paleosol was truncated above this horizon, preventing specific classification of this soil. This paleosol is distinguished by its highly alkaline chemical makeup and moderate degree of pedogenic development. The very fine grain size of the soil matrix argues against the likelihood that the brontothere bones were deposited in a flooding event. Associated brontothere remains collected at Site 1 show evidence of moderate weathering and gnaw marks, indicating exposure and pre-burial processing. Altogether, 16 fossil bone samples were collected and analyzed for REE content to characterize this site.

Site 2 is within the PPM as well but differs in its greater abundance of siltstone and numerous well developed petrocalcic horizons. Five samples of brontothere and tortoise remains were analyzed from this area and used for REE comparison with the other two sites. No paleosol profiles were excavated at this site.

Site 3 is within the Big Cottonwood Creek Member (BCCM) of the Chadron Formation. The BCCM is composed of sediments deposited in fluvial and lacustrine environments, as well as volcanic ash fallout (Terry, 2001). Fluvial sediments are most common and frequently contain mammal fossils. Brontothere bones at this site are more dispersed but traceable in outcrop over 100 meters within a zone 30-50 cm thick. Several weathered poach pits were observed at this site. A pedogenically altered, clayey siltstone was trenched through this zone of fossil accumulation, and oriented samples were collected for laboratory analysis. Field and laboratory observations confirm that the paleosol is equivalent to modern ustifluvents (Soil Survey Staff, 2006), weakly developed soils found in proximal floodplain settings. Microfossils were also found with the brontothere bones. Gnaw marks and other indicators of post mortem processing were absent from the bones, suggesting burial occurred shortly after death. The generally fine grain size and lack of coarse siliciclastic sediments suggest that the brontothere fossils were buried *in situ* and not fluvially transported. After burial, percolating water, shrink-swell processes, and root activity acted to pedogenically alter the sediments that buried the bones. Moderately to well developed skel-lattisepic microfabric and a lack of mottling or other hydromorphic features indicate that the soil was well drained. The presence of mildly developed pedogenic carbonate also corroborates this evidence. Horizonation in this soil is weak, indicating high rates of sedimentation associated with a floodplain position proximal to the channel. An overall coarser grain size and a low degree of pedogenic development differentiate this locality from Site 1. In total, 41 samples of brontothere and tortoise remains were collected from fluvial mudstones, siltstones, and sandstones in order to characterize the REE signature of this site.

Discriminant analysis of REE ratios suggests that fossils from Sites 1, 2 and 3 can be accurately associated with their original location 85.5% of the time (Figure 1). Furthermore, fossil bones from all three sites near Toadstool Park were compared with vertebrate fossil remains collected from the Lower Oligocene Brule Formation in Badlands National Park, South Dakota (Metzger et al., 2004; Figure 2). Discriminant analysis of REE data further shows that the fossils from the three sites near Toadstool Park can collectively be associated with their original location 98.6% of the time when compared with the fossils from Badlands National Park. These data demonstrate that fossil bones from individual localities carry unique REE signatures. The potential exists to match vertebrate fossils illegally removed from federal lands with their original location by comparing REE signatures, thus providing law enforcement with a new toola new tool to prosecute fossil poaching cases.

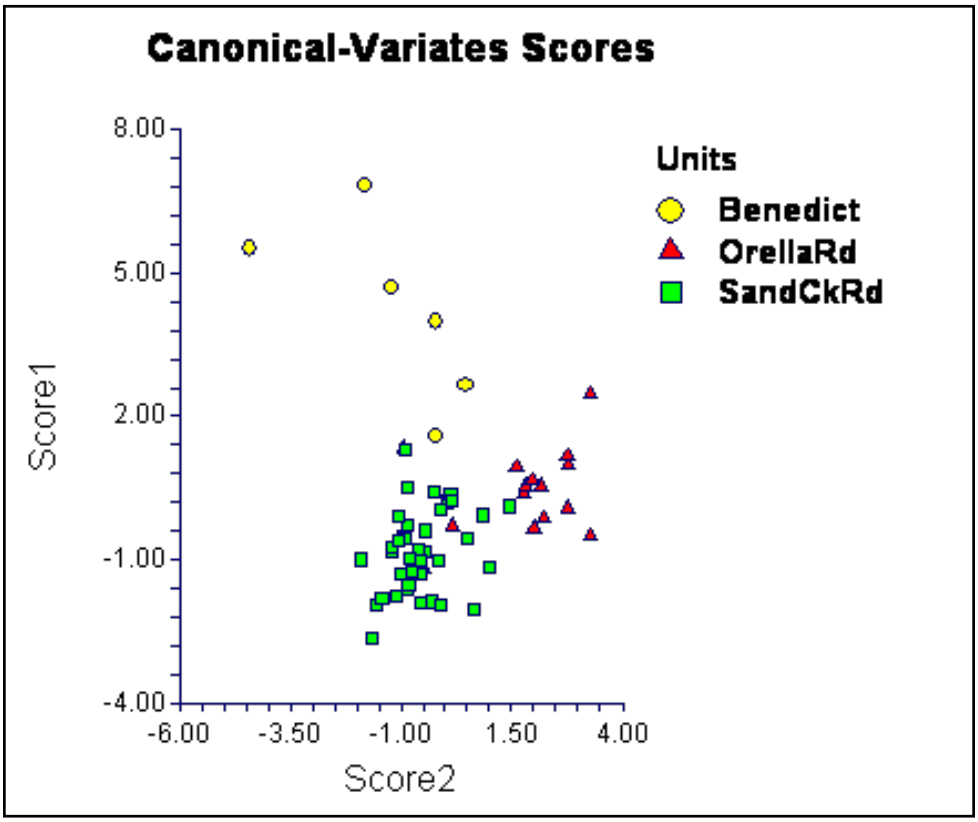

Figure 1. Discriminant analysis canonical scores comparing REE signatures at all Toadstool sites.

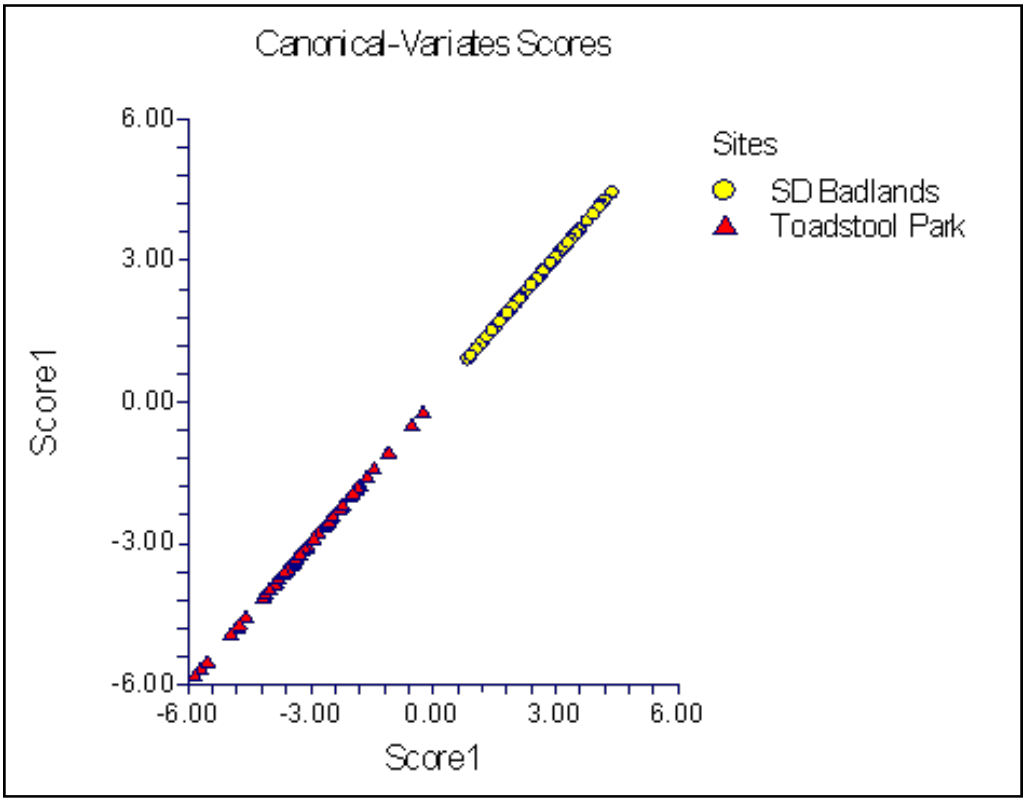

Figure 2. Discriminant analysis results of REE content at sites near Toadstool Park and the South Dakota Badlands sites of Metzger et al. (2004).

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AN AGENCY WIDE PALEONTOLOGICAL RESOURCE INVENTORY STRATEGY FOR THE NATIONAL PARK SERVICE

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In order to better document fossil occurrences and to provide baseline paleontological resource data in National Park Service (NPS) areas, the NPS Geologic Resources Division (GRD) and the NPS Inventory and Monitoring Program (I&M) have established three paleontological resource inventory strategies. These strategies include: comprehensive park-specific paleontological resource inventories, Servicewide thematic paleontological resource inventories, and Inventory & Monitoring Network-based baseline paleontological resource inventories, each established with their own goals and objectives. These inventory strategies have increased the number of NPS units with documented fossil resources from 12 in 1986 to at least 212 in 2009.

Comprehensive Park Paleontological Resource Inventories

Comprehensive park inventories are designed to identify all known paleontological resources within a single park unit. A team of specialists from within the NPS and from educational institutions and cooperators work with the targeted park to identify and address all aspects of its paleontological resources, including resource management, museum curation, law enforcement, and interpretation. Paleontology-specific training for park staff is an important component of many comprehensive paleontological inventories. Park-specific comprehensive paleontological resource inventories have been completed at Yellowstone NP (first park to have inventory completed), Amistad NRA, Arches NP, Bighorn Canyon NRA, Death Valley NP, Grand Teton NP, Santa Monica NRA, Walnut Canyon NM, and Zion NP.

Servicewide Thematic Paleontological Resource Inventories

Servicewide thematic paleontological resource inventories compile data regarding specific types of paleontological resources that occur in parks throughout the NPS. The first thematic paleontological resource inventory identified 19 NPS units that preserve fossil vertebrate tracks (Santucci et al. 1998). Subsequent discoveries have increased the number of parks identified with fossil vertebrate tracks to 25 and warranted an updated publication (Santucci et al. 2006). Another thematic inventory identified paleontological resources associated with NPS caves in 35 parks (Santucci et al. 2001). Cave fossils occur in two contexts. First, fossils can be preserved in the marine limestones in which caves develop; second, the remains of Pleistocene/Holocene animals and plants that

lived, died or were transported into caves after death are common types of cave fossils. Servicewide thematic inventories have also been initiated for fossil fish (Hunt et al. 2006) and fossils found in cultural resource contexts (Kenworthy and Santucci 2006).

Inventory and Monitoring Network Paleontological Resource Inventories

The third paleontological resource inventory strategy is the Inventory & Monitoring Network-based inventory strategy. The NPS Inventory and Monitoring Program established a system of 32 networks for grouping parks which share similar geographical, biological and ecological characteristics (Figure 1). Network-based paleontological resource inventories are designed to compile baseline paleontological resource data for each of the parks assigned to a particular network. This inventory strategy was initiated in 2002 and focused on the parks of the Northern Colorado Plateau Network. As of the date of this publication, network-based inventories have been completed for 26 of the 32 I&M Networks and the citations for these reports are listed below in alphabetical order. See Figure 1 for the geographic areas encompassed by the networks.

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and Monitoring—**Mediterranean Coast Network**. National Park Service TIC# D-177.

Kenworthy, J. P., C. C. Visaggi, and V. L. Santucci. 2006. Paleontological Resource Inventory and Monitoring—**Mid-Atlantic Network**. National Park Service TIC# D-800.

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Kenworthy, J. P. and V. L. Santucci. 2004. Paleontological Resource Inventory and Monitoring—**National Capital Region**. National Park Service TIC# D-289.

Kenworthy, J. P. and V. L. Santucci. 2003. Paleontological Resource Inventory and Monitoring—**Northeast Coastal and Barrier Network**. National Park Service TIC# D-340.

Koch, A. L. and V. L. Santucci. 2002. Paleontological Resource Inventory and Monitoring—**Northern Colorado Plateau Network.** National Park Service TIC# D-206.

Hunt, R. K., V. L. Santucci and J. P. Kenworthy. 2007. Paleontological Resource Inventory and Monitoring—**Pacific Islands Network**. National Park Service TIC# D-24.

Koch, A. L., J. P. Kenworthy, and V. L. Santucci. 2004. Paleontological Resource Inventory and Monitoring—**Rocky Mountain Network**. National Park Service TIC# D-436.

Elder, W. P., T. Nyborg, J. P. Kenworthy, and V. L. Santucci. 2008. Paleontological Resource Inventory and Monitoring—**San Francisco Bay Area Network**. Natural Resource Technical Report NPS/NRPC/NRTR—2008/078. National Park Service, Fort Collins, Colorado. TIC# D-20.

Santucci, V. L. and J. P. Kenworthy. 2007 Paleontological Resource Inventory and Monitoring—**Sierra Nevada Network**. Natural Resource Technical Report NPS/NRPC/NRTR—2007/053. National Park Service, Fort Collins, Colorado. TIC # D-21.

Tweet, J., V. L. Santucci, and J. P. Kenworthy. 2008. Paleontological Resource Inventory and Monitoring—**Sonoran Desert Network**. Natural Resource Technical Report NPS/NRPC/NRTR—2008/130. National Park Service, Fort Collins, Colorado. TIC# D-58.

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Through extensive data mining, literature review, and interviews with researchers, the paleontological resource inventory reports synthesize information regarding the scope and significance of fossils documented from each park. Fossils are assessed and organized

based upon taxonomy, stratigraphy, and paleoecology. Fossils are also assessed based upon the context of their occurrence. In addition to fossils which occur *in situ* within a geologic context, the reports summarize paleontological resources found in park collections as well as fossils found within cultural resource contexts. By addressing these three contexts, the reports take a holistic approach to documenting a park's paleontological resources. The reports are organized stratigraphically presenting the geologic and paleontologic information chronologically from oldest to youngest. Important fossils documented from localities outside a park are often reported in the park inventory, as this data may indicate the potential for fossils in similar stratigraphic units exposed within park boundaries. The inventory reports include information on the history of paleontological research, descriptions of fossils which occur in association with cultural resources, identification of any museum or universities serving as repositories for park fossils, and a comprehensive list of publications related to the geology and paleontology of the parks. Prior to publication, review comments are solicited from park staff well as geologists and/or paleontologists from local museums, state surveys, universities, or the U.S. Geological Survey. Beginning in 2006, the reports have been submitted as part of the NPS Natural Resource Technical Report series.

Given the tremendous diversity of past life, the existence of life for over a billion years, and the range of environments to which life has adapted, there is a broad spectrum of research interests in paleontology. It is not surprising that most of what is to be learned about the history of life remains to be discovered. Through research, more than 210 NPS areas have been identified as containing paleontological resources. However, the paleontological research for a particular park may vary widely from an incidental fossil discovery to over a century of intensive paleontological investigations.

Several objectives are being met through this agency-wide inventory for paleontological resources. First, the establishment of baseline paleontological resource data for the parks will enhance opportunities to incorporate the data into science-based management decisions. Second, the collective understanding of the scope, significance and threats related to paleontological resources throughout the parks will enable agency leaders at the Washington and Regional levels to develop policies, programs, and budget proposals best targeted for the needs of management, protection and interpretation of non-renewable fossil resources in parks. Third, the extensive utilization of interns and contractors as report authors and local geologists and paleontologists as peer reviewers provides numerous opportunities to form new or strengthen existing partnerships. Finally, the expanded database of documented park fossils will promote opportunities for new scientific research and education programs for the public.

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Figure 1: National Park Service map showing the 32 inventory and monitoring networks. For a complete listing of the networks and parks present in each, visit the NPS Inventory & Monitoring website (http://science.nature.nps.gov/im/networks.cfm).

MANAGING MAJOR PALEONTOLOGICAL LOCALITIES

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All paleontological localities are not equal. For example, invertebrate and botanical paleontological sites range from highly fossiliferous rocks of economic importance (ex., limestone and coal), to localities with abundant fossils and opportunities for casual collection that provide educational and scientific opportunities, and also to localities with exceptional preservation that should be managed as a unique scientific resource. Nearly all fossil vertebrate localities are of great significance because of the rarity of vertebrate fossil remains. Even so, there are a range of locality types that require different management styles.

Commonly, vertebrate fossils are found as scattered fragments with no material found in place, representing isolated occurrences that have been largely destroyed through erosional processes. Isolated bones, teeth, and, in some cases, skeletons are readily managed by their excavation, stabilization, and curation into a proper museum repository. Microvertebrate sites, bonebeds, and areas with dense concentrations of individual sites (Paleontological Site Complexes; PSCs) require comprehensive and long term management—potentially in perpetuity.

Microvertebrate sites are accumulations of small vertebrate remains that are most commonly bulk sampled, screen washed, and sorted under a microscope. Microvertebrate sites are highly significant scientifically and may yield diverse faunas that provide critical taxonomic and paleoecological data. A single researcher may collect a microvertebrate site for many field seasons until new taxa are only rarely encountered. Subsequent researchers, working with other recognized repositories, may make additional collections in order to expand their own research collections and to apply new research methodologies to the site. Theoretically, a microvertebrate site may yield significant fossils for centuries. Because the fossils at these sites are so small and difficult to detect, casual or even purposeful vandalism is unlikely and extensive monitoring is often not needed. Conversely, sites yielding large teeth and claws may attract vandals and need to be monitored.

Bonebeds may yield isolated bones of one or many kinds of animals, as isolated bones and associated skeletons, or in rare instances, preserve an abundance of fully articulated skeletons. In some cases, bones are exposed on the surface, sheltered from erosion by a resistant sandstone or limestone, making excavation impractical. These localities may be managed by monitoring or may be developed as an interpretive area or trail. In this way, interested people can see the fossils in their "native habitat" and by their presence, help to police it. Excellent examples of interpreted bonebed localities are the *Trail through Time*, *Split Rock Trail*, *Fruita Paleontological Area*, and *Dinosaur Ridge* in Colorado, and the *Mill Canyon* and *Copper Ridge* trails in Utah. In many cases, relative to long-term management, fossil tracksites present many of the same challenges and opportunities as do bonebeds in resistant sandstone.

Bonebeds in softer rocks provide important research opportunities because they are easier to excavate, but they are also more readily destroyed by erosion and illegal collecting. While some of these bonebeds may be completely excavated in one or a few field seasons, many are laterally extensive requiring decades or more to excavate. In a

few cases, the excavations could extend into the foreseeable future for many generations, such as the *Carnegie Quarry* at *Dinosaur National Monument*. These extensive bonebeds need to be managed to ensure their protection from destruction in a way that they remain accessible for research and education. Between excavations, any remaining exposed bones should be stabilized and the entire site backfilled to hinder vandalism. Unfortunately, the process of burying and unburying causes some harm to the fossils and should be minimized. Additionally, moisture may readily enter the site though the disturbed earth, damaging the fossils. If the site is covered by a tarp, condensation under the tarp also causes moisture to build up against the bone, damaging the fossils. Over the winter, freeze-thaw may have a dramatic, damaging effect on fossils near the surface of the quarry. Where possible, suspending a tarp over the site, then burying, facilitates the wicking away of condensed moisture down slope away from the fossils.

For some major bonebeds along access roads, the ideal solution may be a temporary building that can be securely locked, protecting the fossils from both vandalism and weathering over the winter. Such buildings can be moved as the excavation proceeds. This also provides greater opportunities for the public to benefit from the excavation as an interpretive opportunity. A wonderful example of this are the long-term buildings over the *Cleveland-Lloyd Quarry* of Utah, managed by the Bureau of Land Management (BLM). Additionally, the *Mygatt-Moore Quarry* at the head of the *Trail through Time* in western Colorado is being discussed as a good candidate of an active excavation to protect with a temporary or long-term building, as this locality in the *McInnis Canyons National Conservation Area* even has its own highway exit.

Extensive bonebed localities can eventually yield more fossils than most single repositories can manage. Provision should be made to allow secondary institutions to continue research and excavation of a site after research interests have been exhausted by the initial institution. This may follow a reasonable interval without additional field work (ex., 5 years?). Restricting all fossils from an individual bonebed to a single repository may hinder future scientific research and educational opportunities to everyone's detriment.

Even in the most famous fossil bearing strata, such as the Upper Jurassic Morrison Formation, significant vertebrate fossils are not evenly distributed through the outcrop. A PSC is an area of restricted geographic extent that preserves an abundance of important fossil localities. The *Fruita Paleontological Area* of western Colorado is a good example of a PSC. In less than one square mile, there are dinosaur bone beds and nesting sites, microvertebrate skeletal sites, fish localities, fresh water molluscan localities, track sites, insect-burrow and root horizons, and plant localities, among other types of fossil localities which provide an unprecedented look at a Late Jurassic terrestrial ecosystem. In 1977, the Fruita Paleontological Area was the first site set aside by the Bureau of Land Management for its paleontological resources and is now included within the *McInnis Canyons National Conservation Area*. Other PSCs make up the core of some of America's most famous national parks and monuments as exemplified by the *Petrified Forest National Park*, *Fossil Butte National Monument*, *Badlands National Park*, *John Day Fossil Beds*, and *Agate Fossil Beds*.

In managing major paleontological sites it is critical that access be maintained for scientific research. In Colorado during the 1980s a number of PSCs on BLM administered lands were set aside as Research Natural Areas. These sites now fall under the heading of Areas of Critical Environmental Concern (ACEC). However, all ACECs should not be managed the same way. An area set aside because it is the breeding area for an endangered species needs to be managed very differently from an area set aside for a unique fossil resource.

A good example to consider is the PSC resulting from the many mid-Cretaceous fossil localities in the Mussentuchit Member near the top of the Cedar Mountain Formation on the southwest side of the San Rafael Swell. With more than 80 vertebrate species identified from this small area (~ 2 square miles), these rocks preserve one of the most diverse terrestrial vertebrate faunas in all the world (10 + fish species, 8 + amphibian species, 3 turtle species, 8 + lizard species, the oldest North American snake, 6 + crocodilian species, 14 +dinosaur species, 2 bird species, and 20 + mammal species including the oldest known true marsupial). Additionally, these rocks preserve an abundance of fossil plants including petrified wood of some of the oldest flowering trees in the world.

In addition to preserving a diverse vertebrate fauna from the time when flowering plants first began to dominate floras, this is the earliest North American fauna with strong ties to Asia and thus helps date the origins of Alaska. Finally, this is the only Early Cenomanian age (~98 ma) terrestrial fauna in the world. Although there are other sites in the Mussentuchit Member, none has a similar concentration of paleontological localities. This area lies near the heart of the Mussentuchit Badlands Wilderness Planning Unit. In the initial maps of this planning unit, (Figure 1) two small bentonite clay pits were cherry-stemmed into the area; maintaining access to these unique fossil resources will continue to benefit all our citizens by providing continued knowledge about a critical time in Earth's history. Utah has several additional PSCs that are of similar significance.

Major paleontological localities are rare and finite resources that need to be managed for future scientists and educators. The western United States has an abundance of such localities, which serve as reference for much of Earth's biological history. While America's fossiliferous formations will continue to yield isolated fossils of great interest, major paleontological sites will always serve as keystones in our understanding of Earth history. The management of such areas must continue to reflect this.

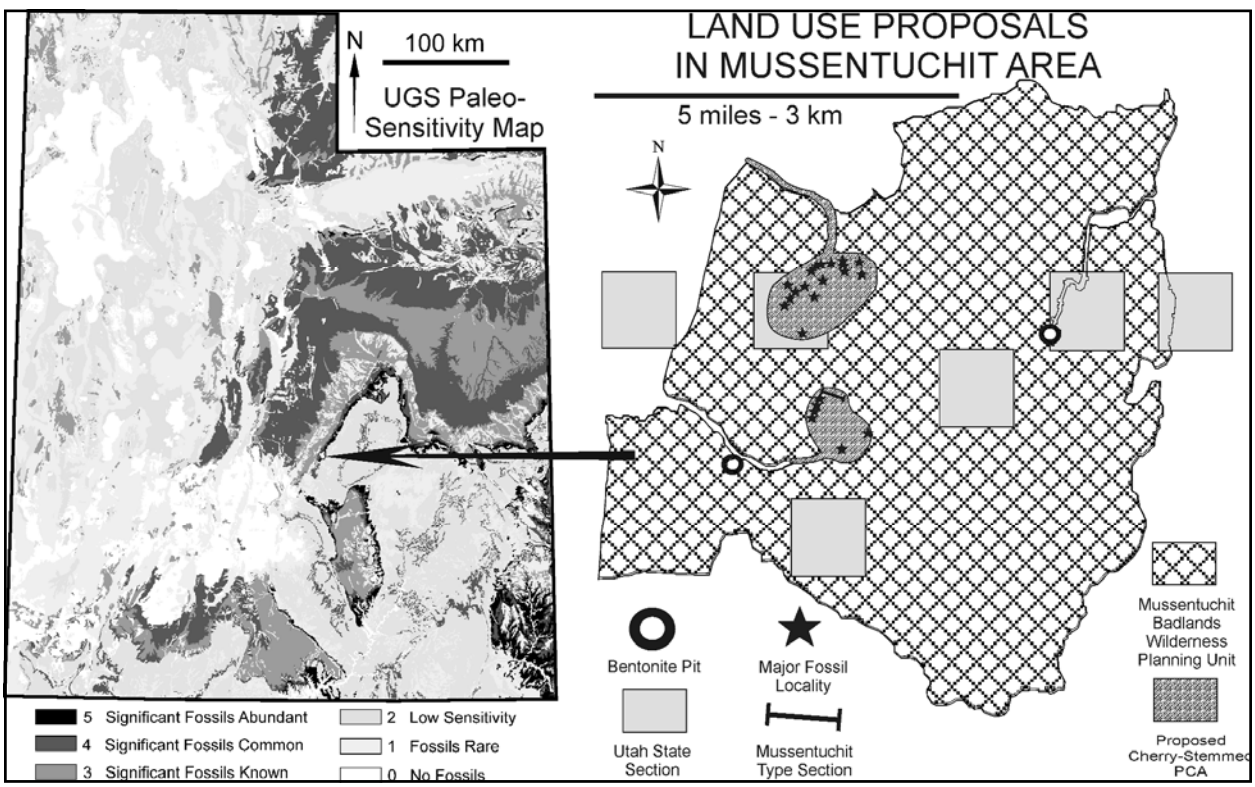

Figure 1. Land use in the southern San Rafael Swell of Utah.

DEVELOPING A PALEONTOLOGICAL RESOURCE MANAGEMENT PROGRAM WITHIN THE SOUTH UNIT OF BADLANDS NATIONAL PARK

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The South Unit of Badlands National Park is located on 133,300 acres of the Pine Ridge Indian Reservation. Since 1976, this parcel of land has been managed under the guidelines outlined in a Memorandum of Agreement between the National Park Service and the Pine Ridge Indian Reservation. The South Unit contains some of the most spectacular geologic and paleontological deposits within the White River Badlands and has been an important center for paleontological research. During the summer of 2008, the author was invited to assist personnel from the Oglala Sioux Parks and Recreation Authority (OSPRA) in the management of fossil resources on the South Unit. Working in partnership with OSPRA, the South Dakota School of Mines and Technology and Oglala Lakota College, plans were developed to open a small pilot project involving a paleontological research quarry during the summer of 2009. The plan was presented to the Tribal Land Committee and was approved. Each time the proposal was presented, it was made clear that this was a project managed by the Tribe, and partnering agencies were asked to assist. The paleontological pilot project was presented at several public meetings with a mixed response. Many tribal members supported the project and felt it was important to protect the fossil resources preserved in the South Unit. Other individuals, belonging to the tribal Oyate group, were strongly against the project proposal because of their distrust of the Federal Government. The proposal was also presented to the Tribal Permit Review Board with no resolution. Unfortunately, the review process has taken longer than planned, so the proposed research quarry has been delayed until the summer of 2010. Much of the planning now resides within the various Tribal offices to determine who has jurisdiction over the management of resources contained within the South Unit.

Since 2007, staff from Badlands National Park and the Midwest Regional Office have been working in partnership with representatives of the Oglala Sioux Tribe to develop a General Management Plan (GMP). The purpose of the GMP is to direct the management of resources in the South Unit for the next 20 years. In the spring of 2009, the GMP planning team will refine the proposed alternatives and select a preferred alternative. In late 2009 or early 2010, the alternatives will be presented to the public in the draft GMP. Public meetings will be held about 30 days after the draft GMP is available to the public.

THE NATION'S FIRST BLM PALEONTOLOGICAL SITE STEWARDSHIP PROGRAM ESTABLISHED IN WASHINGTON COUNTY, UTAH

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In 2006, the Bureau of Land Management's (BLM) St. George Field Office partnered with the St. George Dinosaur Discovery site at Johnson Farm (SGDS) and the Southwest Chapter of Utah Friends of Paleontology (UFOP) to establish the first "site stewardship" program for paleontological localities in the nation. BLM expanded its Color Country Site Steward Program, a volunteer program for archaeological site monitoring, to include at-risk paleontological localities on public lands managed by the BLM in Washington County, Utah. Volunteers primarily monitor site conditions regularly, but they may also assist qualified paleontologists to conduct field surveys and record paleontological sites. To become a BLM site steward, volunteers must complete a training course and agree to abide by a Code of Ethics and the terms of a federal Volunteer Agreement.

The St. George Field Office receives assistance from SGDS in the identification of paleontological localities to be included in the monitoring program. Staff from SGDS evaluates individual localities for importance and/or sensitivity using standards established by the Office of the State Paleontologist of the Utah Geological Survey. Scientifically important sites that are at risk of loss or damage are given priority for monitoring and assigned to site stewards. SGDS staff assists BLM by preparing information packets for each site. These include topographic locality maps, locality coordinates, site descriptions, and photos showing location and fossils from the site. The stewards visit their assigned areas at least four times annually, checking for evidence of destruction, vandalism, theft, and natural impacts. Any vandalism or theft is immediately reported to BLM Law Enforcement Rangers for investigation. Site stewards donated approximately 1500 hours of site-monitoring time to the St. George Field Office in both 2007 and 2008. Many federal land managing agencies already host volunteer archaeological site stewardship programs, and the expansion of these existing programs to include at-risk paleontological localities would be an easy and cost-effective way to increase the level of protection that can be provided for these important and threatened resources.

A PRELIMINARY REPORT OF FIRE EFFECTS TO PALEONTOLOGICAL RESOURCES: THE PALEOZOIC CARBONATE PERSPECTIVE

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There are little data regarding fire effects to paleontological resources, even though protection and preservation of these resources are extremely important management objectives, as also is the widespread use of fire among federal and state agencies to help maintain normal ecological processes. The only study of which we are aware was performed during a prescription fire at Badlands National Park where the study setting included phosphatic vertebrate remains contained within soft, dominantly volcanoclastic sediments of the Paleogene White River Group. Because geological resources at Guadalupe Mountains National Park are of congressionally legislated significance, we undertook a study to determine fire effects to paleontological resources preserved in an entirely different geologic setting.

Fossils in the Guadalupe Mountains are mostly contained within generally dense, well lithified, Permian marine limestones. The more common types by far are the invertebrates that persistently dominated Late Paleozoic marine ecosystems. They are usually preserved in two manners common to carbonate rock units, either as calcitic preservations and replacements, or as silicified replacements. Slow dissolution by rainwater normally causes calcitic fossils to weather evenly with the surface of the entombing rock, whereas silicified fossils usually extend some distance above the weathering surface, potentially making the latter highly susceptible to damage from thermal shock.

Prior to a planned 7021 acre Foothills prescribed fire, GMNP staff set up 23 observation plots within the planned burn

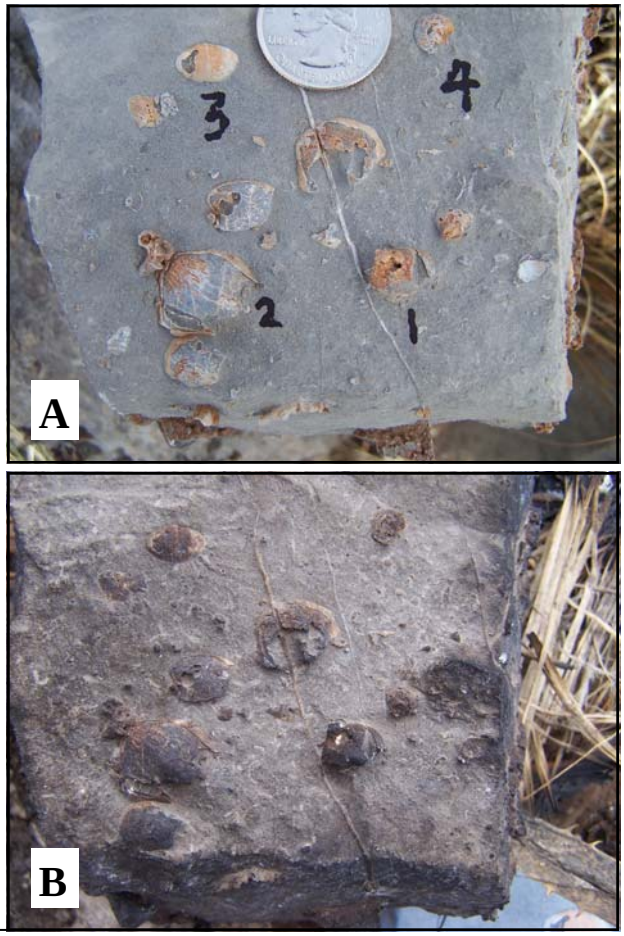

Figure 1. Pre-burn **(A)** and post-burn **(B)** conditions of silicified fossils in densely lithified Permian limestone. Note no damage or exfoliation has occurred, but that a strong layer of soot formed on the surface of both rock and fossils.

area. The number of plots were planned to accommodate a wide variety of local conditions of preservation types, fuel loads, and aspect, as well as hopefully provide a statistically significant sample. The Foothills burn is situated within Chihuahuan Desert mixed grassland/scrubland community. Data recorded at observation plots included GPS coordinates, photographs for assessment of fuel loading, fuel proximity, aspect and slope, fossil condition photographs, general taxonomy, preservation type, and extension of fossils above surface. On Nov. 7, 2008, approximately 1500 acres of the Foothills area was burned and 5 weeks later all six plots within that area were found and assessed for fire effects. Each of these plots contained only silicified fossils.

Post-burn assessments indicate that generally there were very little readily observable detrimental effects to the silicified fossils as a result of the fire. None were found to have suffered exfoliation or breakage. A large number were covered with a thin layer of black carbon soot. Those relatively closer to green or waxy fuels were generally coated with a thicker film of soot than those further away (see Figure 1 A and B). It is not known how persistent this discoloration will be, however judging from areas exposed to fire a number of years before, it is apparent that weathering does mitigate this effect. However, our work does bear one caveat, because collateral observations in the widespread burn areas, while not noted specifically at plot locations, give strong indication that some exposed ledges of limestone bedrock are themselves susceptible to effects of thermal shock. In at least two places, surficial exfoliations 1-2 cm thick were observed. Breakage truncated every fossil that intersected on the fracture surface, thereby detrimentally affecting a significantly greater number of fossils than the few specifically targeted for assessment at each of the plots. This thermal shock response seems to be more pronounced for very fine-grained, dense limestones.

Additional collateral observations indicate that calcified fossils are not obviously detrimentally affected by fire, except that again a coloration change is most commonly observable (see Figure 2). In this case however, the color change results from the conversion of low concentrations of iron deletriants to varying hues of yellow and red. Presumably, low concentrations of reduced iron oxides originally deposited within the limestones are altered first to limonitic iron oxides at slightly elevated temperatures and then to hematitic iron oxides at higher temperatures. This color change is a chemical change that penetrates well into the interior of the rock and is not a reversible process.

Figure 2. Limestone reef breccia containing calcitic crinoid fossils found in proximity to a previously burned stump. The lower left corner of this piece is strongly reddened as a result of high temperatures. The central part is yellowed as a result of slight oxidation of iron minerals due to lower temperatures. The right end is essentially the same color as unaltered limestone nearby.

PRESERVING CALIFORNIA'S ONLY DINOSAUR TRACKWAYS BY COLLECTION – AN UNPRECEDENTED OPPPORTUNITY FOR PUBLIC PROTECTION AND INTERPRETATION OF FOSSIL SPECIMENS FROM FEDERAL LAND

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In 2008, the San Bernardino County Museum (SBCM) and the Dinosaur Institute of the Natural History Museum of Los Angeles County (LACM) entered into a partnership with the Needles office of the California Bureau of Land Management for the preservation, analysis and exhibition of southern California's only known dinosaur trackways. These trackways occur as an isolated outcrop of the Middle-Late Jurassic Aztec Sandstone in the Mescal Range in eastern San Bernardino County, California, surrounded by, but not within, the Mojave National Preserve. As part of this agreement, the SBCM and the LACM collaborated in the collection of trackway slabs in April of 2008 with a team of museum curators, employees and volunteers.

The trackway slabs were removed only after careful documentation of the disposition of these fossils in the field. Each piece of rock was mapped at 1:1 scale and specifically labeled. Collection included the description of the geological context, the construction of measured sections and basic rock descriptions. Every effort was made to preserve the natural aesthetic of the rock outcrops for professors, students and others interested in visiting the site. After the team removed slabs from the field, they were carefully packed and transported to the LACM. Each slab was checked against field maps and laid out in geographically correct position to reconstruct the entire trackway. The trackway slabs will be displayed in two of southern California's largest museums, both of which have large expansions/refurbishments underway. The SBCM will display the trackways in its new Hall of Geological Wonders, interpreting the history of the site and the original field collections made by the SBCM, as well as reconstructing the paleoenvironment of the middle Jurassic. An engaging interactive on dinosaur gait and stride will accompany the exhibit. The LACM is also creating exhibits for their new dinosaur wing and has planned one large exhibit that will interpret dinosaurs from California, highlighting the trackways from the Aztec Sandstone. These planned exhibitions will afford an unprecedented opportunity for educational interpretation of these trackways to the public, literally reaching millions of patrons who visit these institutions.

As part of the agreement with the BLM, the LACM and SBCM will also design onsite interpretation of the Aztec Sandstone and its trackways. This will involve the construction of a kiosk at the base of the outcrops. These display designs include exhibition of trackway replicas, photographs, and up-to-date interpretations of the geology of the Aztec Sandstone and paleontologic interpretation of the tracks and animals suspected of creating them. All parties involved with the Aztec Sandstone project were in agreement that this program of collection, display and onsite interpretation was the best method for

preservation of this rare and endangered piece of California's natural heritage. The BLM considered preservation in Federal repositories to be the most reasonable way to ensure the long-term preservation of this resource for both an interested California public and scientific researchers. Displaying these specimens in two museums with heavy patronage also insures that the greatest number of interested public patrons will be able to learn about the Aztec Sandstone, thereby increasing the potential for public outreach and interpretation of public lands. Conservation of trackways for the LACM and SBCM collections provides for increased access by researchers and, as is now ongoing, more detailed and precise description of the tracks than is possible in the field.

A COMPARISON OF METHODS FOR EFFECTIVE MANAGEMENT OF FOSSIL RESOURCES, SOUTHWESTERN REGION, USDA FOREST SERVICE

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The Southwestern Region (Region 3) of the USDA Forest Service manages about 22.3 million acres, with a diversity of fossil resources spanning the Phanerozoic. The paleontology program in the Region currently consists of Forest Service geologists and archaeologists interested in paleontology who work with museums and academic institutions to protect federal fossil resources. The Rocky Mountain Region has two paleontologists, who are called upon by the Southwestern Region if a project requires additional expertise.

The Region has explored two methods to supplement the effectiveness of the paleontology program by recruiting paleontological skills from outside the FS for specific projects. This report presents the analysis of the direct costs and other factors which may influence whether a particular method will be useful for a particular project. Programs analyzed here are: 1) the Geological Society of America's GeoCorp America program and 2) requiring proponents for surface disturbing Special Use Permits (such as roads, power lines, or pipelines) to have a paleontological consultant and arrange for curation of fossils found during the project. Experience has shown that both alternatives assessed are beneficial to particular management needs, with each possessing strengths and weaknesses dependent upon the overall goal and timing of activities.

The other factors considered in the comparison of the methods included flexibility of scheduling the assistance, ability to focus the project, and amount of specialized supervision required.

The GeoCorp program exposes college students to the Forest Service as a possible career and gives them field experience at a very reasonable cost. The amount of time required to oversee the project varies depending on the complexity of the project, how well defined the project is, and the skills the summer interns bring to the project. One of the drawbacks of the project is that it must be submitted to the Geological Society of America before the Forest Service budget is finalized.

Requiring the proponent of a surface disturbing project to contract for paleontological services requires Forest Service time during the preparation of the Special Use Permit, and after the permit is issued, Forest Service oversight is required to assure the requirements are being met. However, the proponent carries the cost of the paleontologist, the cost of properly preserving any fossil resources found during the project, and any cost associated with transferring the fossils to an approved institution.

INTERAGENCY MANAGEMENT OF FOSSIL RESOURCES

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John Day Fossil Beds National Monument (NPS) initiated a program of cooperative management of fossil resources in 1987 that has grown to include all four BLM districts of eastern Oregon, and certain localities within Region 6 of the USFS. Scientific investigators representing museums, academic institutions, and federal agencies have been working in collaboration to meet common resource management goals of research and educational outreach. The many research projects that cover this 10,000 square-mile area have resulted in documentation of a complete composite stratigraphic section in eastern Oregon that preserves detailed records of 45 million years of global climate change (Figure 1). This "blurring of the boundaries" of scientific disciplines and stewarding agencies has allowed workers to understand the lateral and temporal variability of paleontological deposits. The maintenance of such useful data results in an environment in which researchers prefer to work in collaboration with the agencies, rather than as freelance permitted investigators.

SCIENTIFIC PERSPECTIVE

Temporal continuity, organismal diversity, and geographic extent of distribution are among the many identifiable (or potentially recognizable) factors useful for evaluating and comparing the biostratigraphic and paleoecological significance of terrestrial preservational basins. Comparisons of long-term sequences of "lithosympatric assemblages" tend towards largely qualitative, anecdotal accounts that lack demonstrable isochroneity established from chronologies developed independently of the faunas.

The sequences of widely distributed Tertiary deposits throughout eastern Oregon contain abundant and diverse plant and animal assemblages. Hundreds of localities, roughly correlated previously, now provide more precisely comparable and laterally variable interbasin depositional environments that can be ordered chronologically. This insures the accurate tracking of "staggered" processes and events in multiple local paleoenvironmental settings. Collections and stratigraphic correlations conducted in the classic John Day region are newly supplemented by recent efforts in several basins in Oregon, including the Owyhee region, the Northeast basins, and sites proximal to the ancestral Cascades. These materials provide a useful and intriguing framework for gauging the significance and utility of event chronologies developed from other North American locality complexes and faunal compilations.

Interdisciplinary study, conducted over a wide area throughout the available sections in a basin, emerges as a necessary precursor to the development of broad-scale "paleobiomes", supplemented by information from neighboring time-equivalent facies. Interesting lateral variation of assemblages has been detected from extensive collections, correcting oversimplified representations of what clearly were complex systems. Conversely, apparently isolated basins may be integrated into more expansive paleoecological models as a result of the discovery of overlooked depositional "links" between areas.

An integrated approach to land management:

Over the past fifteen years, the paleontological staff at John Day Fossil Beds National Monument (JODA) has worked with neighboring land management agencies and private landowners to develop an integrated approach to managing fossil resources. In addition to continuing collaboration with private landowners, JODA has active cooperative agreements with four eastern Oregon districts of the BLM, Region 6 of the USFS, the Oregon Museum of Science and Industry (and their science camps), the Nature Conservancy, the Confederated Tribes of the Warm Springs, the Fish and Wildlife Service, the High Desert Museum, and multiple educational organizations, including the University of Oregon and Oregon State.

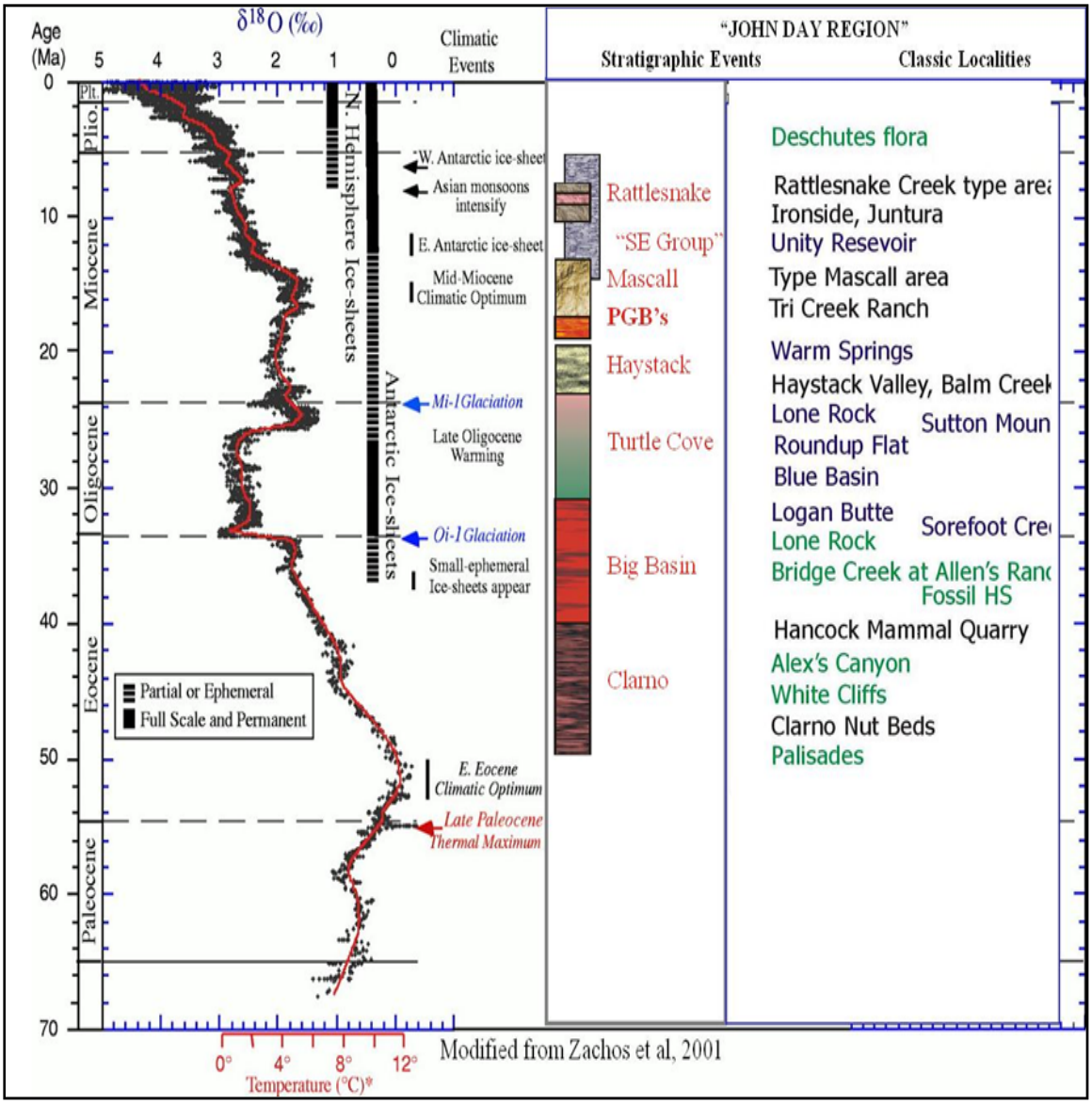
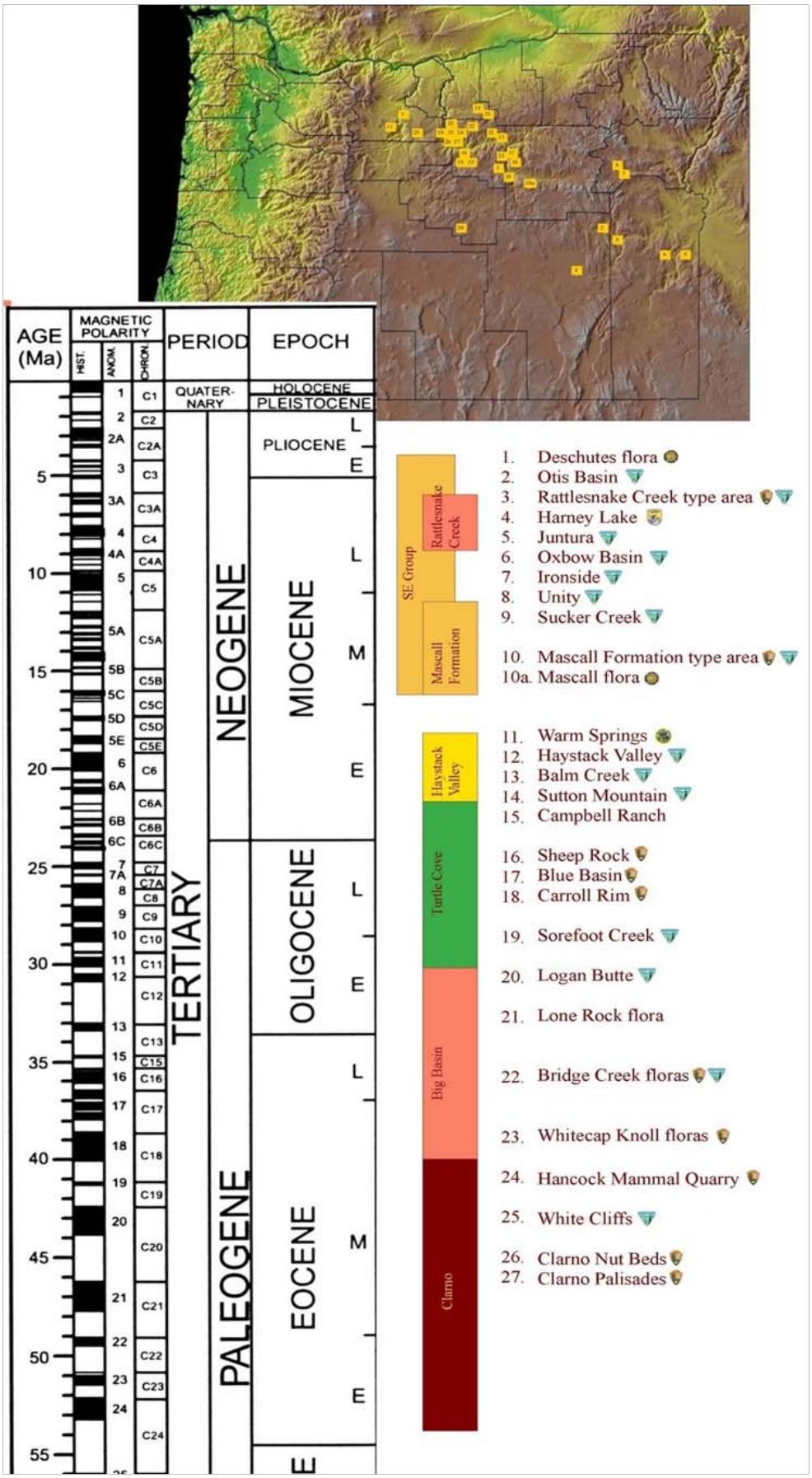


Figure 1. Stratigraphic cartoon showing temporal extent of John Day strata and a few of the more well-known assemblages, plotted relative to global temperature change as figured by Zachos et al. (2001) based on benthic forams. The John Day region preserves continuous terrestrial sediments capable of yielding fine resolution of climatic variables.

Figure 2 (facing page). Map of Oregon showing the interagency administration of important fossil localities.


AGE (Ma)
MAGNETIC POLARITY
HIST.
ANOM.
CHRON.
PERIOD
EPOCH
QUATERNARY
HOLOCENE
PLEISTOCENE
PLIOCENE
MIOCENE
OLIGOCENE
EOCENE
NEOGENE
PALEOGENE
TERTIARY
L
M
E
SE Group
Rattlesnake Creek
Mascall Formation
Haystack Valley
Turtle Cove
Big Basin
Clarno
1. Deschutes flora
2. Otis Basin
3. Rattlesnake Creek type area
4. Harney Lake
5. Juntura
6. Oxbow Basin
7. Ironside
8. Unity
9. Sucker Creek
10. Mascall Formation type area
10a. Mascall flora
11. Warm Springs
12. Haystack Valley
13. Balm Creek
14. Sutton Mountain
15. Campbell Ranch
16. Sheep Rock
17. Blue Basin
18. Carroll Rim
19. Sorefoot Creek
20. Logan Butte
21. Lone Rock flora
22. Bridge Creek floras
23. Whitecap Knoll floras
24. Hancock Mammal Quarry
25. White Cliffs
26. Clarno Nut Beds
27. Clarno Palisades

THE USE OF Arc GIS AS A PALAEONTOLOGICAL RESOURCE MANAGEMENT TOOL IN ALBERTA, CANADA

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ArcGIS is a mapping program that allows for the addition, layering and analysis of information in a visual format. The Resource Management Program at the Royal Tyrrell Museum has started to use this program in the protection and exploration of fossils in Alberta. This includes maintaining the *Listing of Historic Resources*, a document used by industry in Alberta to identify areas of cultural sensitivity. It is used as part of a project assessing geological formations in an effort to plan fieldwork and protect our palaeontological resources. ArcGIS is also being used to track and update palaeontological research permits within Alberta, making it one of our most useful tools in the Palaeontological Resource Management program.

In 2007, the Palaeontological Resources Management Program in Alberta adopted ArcGIS technology as part of the on-going fossil protection program in the province. Fossils in Alberta have been protected under the *Historical Resources Act* since 1978. The Act states that any projects impacting bedrock may require the company to hire a professional palaeontological consultant to perform an impact assessment and/or monitoring. To help companies determine what their requirements may be ahead of time, the Alberta Heritage Division has developed a *Listing of Historic Resources* for all cultural resources in the province, including palaeontological resources. This document informs companies of specific legal land divisions that are known to have cultural resources or have a high potential of finding resources. The document then provides guidance on the appropriate actions that need to be taken. In the past, the *Listing of Historic Resources* was created using paper topographical maps and grid overlays. All of the legal land information that was considered important was then put into a spreadsheet, printed, and distributed to companies. Today, using ArcGIS, we are able to create layers that include topographical maps, grids and the *Listing of Historic Resources* (as polygons outlining sensitive areas). Information from our collections has also been incorporated in our ArcGIS system as a point layer indicating where our fossils were found. Having all of this information together in one system allows for accurate results when outlining sensitive areas. Through its editing functions, the system also supports efficiency in changes that need to be made to the *Listing of Historic Resources*. Having the collections data on our maps also allows us to provide palaeontological consultants with site information so that they can make accurate assessments of project impacts to fossil resources.

In 2006, the Resource Management undertook a project assessing the geological formations in the province in an effort to protect our palaeontological resources and plan future field work. It is our objective to better understand which formations and areas of Alberta have yielded significant fossils and which areas are relatively unexplored. Through plotting our collections and

consultant data, ArcGIS has given us a visual aid to help with this project. Using its querying capabilities, we are able to define important palaeontological areas and are hoping to refine this in the future with the statistical analysis available with ArcGIS.

In Alberta, a palaeontological researcher is required to obtain a permit before any excavation work can be done. It is the responsibility of our department to issue and track these permits. To prevent conflicts in research interests, individuals cannot obtain permits in areas that are already being worked in without permission from those already holding permits there. By plotting all permits, we are better able to manage these types of situations. Using the querying abilities of ArcGIS, we are also able to track permit expiry dates and edit changes to permits, keeping our system consistently up to date. Overall, ArcGIS has allowed for more accurate and efficient management of Alberta's palaeontological resources.

Above: Royal Tyrell Museum of Paleontology

THE NATIONAL LANDSCAPE CONSERVATION SYSTEM AND NEW MEXICO'S OLDEST TO NEWEST NLCS "PALEO" UNITS

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Bureau of Land Management, Albuquerque, NM

The Bureau of Land Management's National Landscape Conservation System (NLCS) contains some of the West's most spectacular landscapes included in 924 federally recognized areas and approximately 27 million acres of National Conservation Areas, National Monuments, Wilderness Areas, Wilderness Study Areas, Wild and Scenic Rivers, and National Scenic and Historic Trails. The NLCS mission is to conserve, protect, and restore these nationally significant landscapes of exceptional cultural, ecological and scientific values for the benefit of current and future generations. The recently signed (March 31, 2009) Public Lands Omnibus Bill (PL 111-11) provides a statutory basis for the (NLCS), which was established administratively in 2000. In 2007, NLCS developed a Science Strategy and included: Objective 1: Promote scientific study within NLCS units. BLM now has a "multiple use" mandate which includes "conservation and preservation" as a "use". A brief discussion of New Mexico's oldest and newest NLCS units containing Paleontological Resources is an attempt to highlight some of BLM's management challenges and opportunities in these unique landscapes for fossil resources.

New Mexico's oldest NLCS unit was established in 1984 with the passage of the San Juan Basin Wilderness Act (1984) which created the Bisti and De-Na-Zin Wilderness Areas and the Fossil Forest Research Natural Area. In 1996, these two wilderness areas were linked and expanded to 45,000 contiguous acres. The Ah-shi-la pah was not designated Wilderness in the 1984 legislation

Figure 1: The BLM's newest NLCS unit, Prehistoric Trackways National Monument.

and remains in Wilderness Study status. The WA and WSA contain the late Cretaceous Kirtland-Fruitland Formations and the Paleocene Nacimento Formation which have produced significant fossils since the 1850's.

In 1998, the first paleontological excavation permit was issued for excavation of a large therapod (a.k.a. the "Bisti Beast") within a designated BLM wilderness. The fossil was discovered by a New Mexico Museum of Natural History and Science volunteer. The paleontological resources are considered supplemental values of the wilderness and the decision to protect this supplemental value in a museum collection was made. Removal from the excavation site was by a US Army Black Hawk helicopter. Inventory, assessment and collection of paleontological resources within these areas might be challenging, but is not impossible. Currently, ongoing surface collection continues in the Bisti-De-Na-Zin and Ah-Shi-she-pah WSA. Assessment of fossil resources within WA's and WSA's could be possible though future funding opportunities within the NLCS.

New Mexico's newest NLCS unit is the Prehistoric Trackways National Monument established in P.L 111-11(March 31, 2009) to conserve, protect, and enhance the unique and nationally important paleontological, scientific, educational, scenic, and recreational resources and values of the Robledo Mountains in southern New Mexico. The Monument includes a major deposit of fossilized footprint megatrackways within approximately 5,280 acres. The megatrackway consists of extensive outcrop of Permian terrigenous red beds sandwiched between marine limestones. These layers of red beds contain footprints of numerous amphibians, reptiles, and insects, plant impressions and petrified wood. The history of this unit began in 1988 when a local resident brought attention to the paleo resources and a study was mandated by legislation "The Prehistoric Trackway Study Legislation" in 1990. The study was completed in 1994 but the only action taken was establishment of a Research Natural Area in the BLM's land use plan. Over the next fifteen year a variety of activities occurred within the study area including the development of an OHV recreational trail. A rock quarry where red beds were exposed with the limestones continued operation and expanded to a much larger operation. With the passage of the Omnibus Bill, the Preshistoric Trackway became a National Monument. Although the rock quarry is excluded from the National Monument boundary, the quarry is very visible and offers both challenges and opportunities as it is reclaimed.

Figure 2: Airlifting the "Bisti Beast"

PALEONTOLOGICAL INVENTORY OF CRETACEOUS ROCKS, BRYCE CANYON NATIONAL PARK – A MODEL FOR COOPERATIVE PARTNERSHIPS

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Initial paleontologic exploration of Cretaceous rocks within Bryce Canyon National Park (BRCA) and the Paunsaugunt Plateau, in general, was undertaken by Eaton in 1988. Over the next seventeen years, several significant microvertebrate, marcovertebrate and invertebrate localities were discovered within and near the park boundaries. It became evident that BRCA contained significant fossil resources which offered the prospect of long term scientific research, but also presented land management issues in terms of protecting this resource and utilizing the resource for educational purposes. In 2006, a paleontologic inventory of Cretaceous rocks within BRCA was initiated. The project was designed with a possible duration of up to six years. The design included the partnering of many institutions and initially involved the Park Service, the Bryce Canyon Natural History Association, Weber State University, Southern Utah University, and Bryce Valley High School. In the second year, the Geological Society of America GeoCorp program was added to the project, and many other institutions have become involved. In the first three years of the inventory, 127 new fossil localities were discovered. Of these localities, 63 are within BRCA, and 48 are on immediately adjacent USDA Forest Service and BLM (Grand Staircase-Escalante National Monument) administered lands. To date, we have found 111 localities that contain mostly vertebrate fossils. Thirteen localities have been found that contain primarily invertebrate fossils, and three paleobotany localities were found. The project has so far generated a host of research projects. Seven students have been involved in undergraduate research projects with three presentations having been made at the Rocky Mountain Section of the Geological Society of America in 2006-2007. Dinosaur fossils recovered during this project have attracted the attention of the Utah State Paleontologist, Dr. James Kirkland, who will become involved in the project during the 2009 field season. Other investigators that have become involved in research on fossils recovered from BRCA during this project include: Dr. Zbyňek Roček (frogs), Czech Academy of Sciences, Prague; Dr. J. Howard Hutchison (turtles), University of California Museum of Paleontology, Berkeley; Dr. Jim Garner (amphibians) and Dr. Don Brinkman (fish), Royal Tyrrell Museum of Paleontology, Drumheller, Canada; Dr. Randy Nydam (lizards), Midwestern University, Glendale, Arizona; Dr. Neil Tibert, University of Mary Washington, Fredericksburg, Virginia and Dr. Elizabeth Brouwers, U.S. Geological Survey, Denver, who are jointly describing ostracods (small freshwater arthropods); and Dr. Joe Hartman (freshwater invertebrates), University of North Dakota, Grand Forks.

Furthermore, our first GeoCorp student, Cory Redman (Texas A & M University) will undertake a study of vertebrate paleocommunities involving one locality in BRCA and two localities along its margins (a National Science Foundation proposal has

been submitted to support this research). To date, this project has generated the best record of Coniacian and Santonian vertebrates in our hemisphere. It has also contributed to the recovery of the most complete sequence of Late Cretaceous ostracods (Arthropoda) in the world. The project has involved many institutions, as well as high school, undergraduate, and graduate students. This kind of project has the potential to grow and increase collaborations and partnerships, which is as valuable as the inventory itself.

NEW TERTIARY VERTEBRATE FOSSIL SITES ON U.S. FOREST SERVICE LAND IN CENTRAL UTAH

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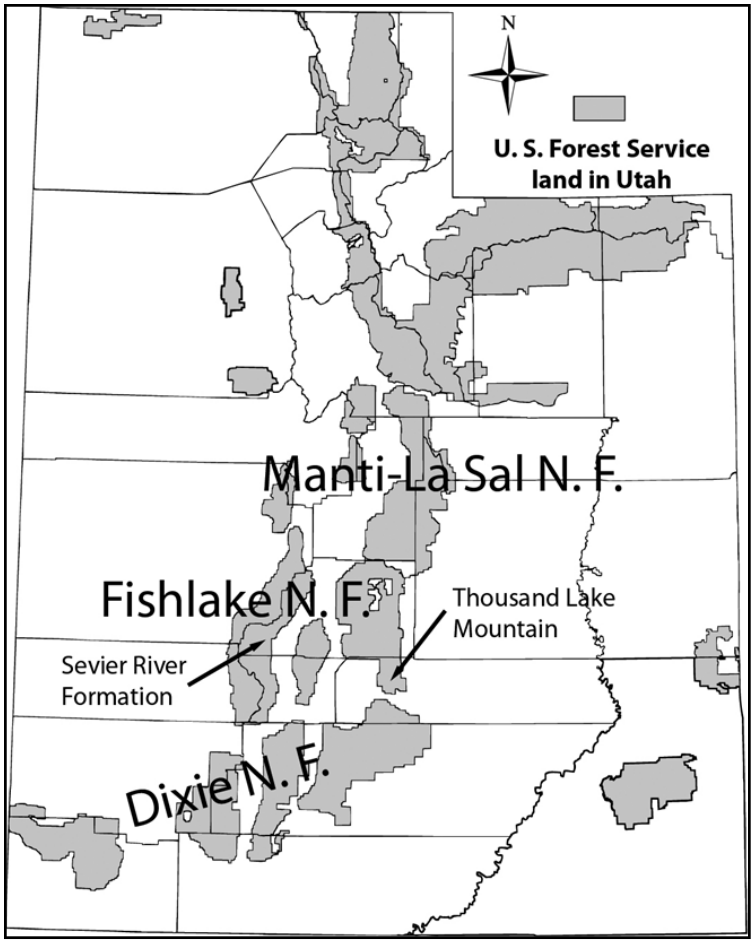
For many years, researchers have been collecting and studying vertebrate fossils from U.S. Forest Service (USFS) administered land in Utah. Numerous Cretaceous and Paleocene localities of the North Horn Formation are found in the Manti-La Sal National Forest on the Wasatch Plateau of central Utah. The Dixie National Forest of south-central and southwestern Utah also contains many important fossil sites including numerous Late Cretaceous vertebrate sites, an assemblage of middle Eocene vertebrates from the Turtle Basin Local Fauna, and a significant Miocene mammal tracksite from Enterprise Reservoir. Recently, the Utah Geological Survey (UGS) has been investigating new fossil mammal sites on USFS land in central Utah.

The first mammal fossils have been discovered and described from the Miocene Sevier River Formation of central Utah from a site in Sevier County in the Fishlake National Forest, Fillmore Ranger District. Teams from the UGS have collected several hundred fossils from this site including cranial, dental, and postcranial remains of camelids, lagomorphs, and rodents. Also found, but less common, are fossils of proboscidians (gomphotheres), carnivorans (felids and mustelids), and small artiodactyls. Four species of rodents (two heteromyids and two cricetids) and one lagomorph have been found. One of the heteromyids is a new genus and species, and the other belongs to a species known from other Miocene sites in North America. One of the cricetids is a new species, and the other belongs to a previously recognized species. The lagomorph also belongs to a previously recognized species. Identification of the rodents and lagomorphs places this site in the Hemphillian North American Land Mammal Age (NALMA). This fits well with published radiometric dates of 7-9 Ma for the sediments of the Sevier River Formation in this area. The fossils identified so far do not allow us to determine whether the fauna is early or late Hemphillian. Miocene fossils sites are rare in Utah, so these fossils fill an important geographic gap in the Miocene fossil record of the western U.S.

Another site that we have been investigating is located in the Fishlake National Forest, Loa Ranger District, in Wayne County, Utah. In 2005, we were mapping a coarse clastic rock unit of unknown age on Thousand Lake Mountain. This unit is composed of unconsolidated sand and coarse gravel of presumed fluvial origin, and is unconformably underlain by Late Cretaceous rocks and capped by Oligocene volcanics. Previous workers hypothesized that these rocks correlate with the Paleocene Flagstaff Formation. During our investigation, we found a right dentary fragment of a perissodactyl preserving three molars. Based on the molar morphology, we identify this jaw as belonging to the small basal rhinoceratid genus *Teletaceras*. Molar dimensions fall below the range of *T. radynskyi* from the Eocene Clarno. Formation of Oregon. At over 10,000 feet in elevation,

this is the highest-altitude vertebrate fossil found in Utah, and the first report of *Teletaceras* in Utah. During a subsequent visit to the area in 2006, we discovered a partial skull of a large (rhinoceros-sized) brontothere that preserves most of the anterior portion of the skull, including the palate and a damaged, but complete, set of upper teeth. Based on the presence of two upper incisors and details of the molar morphology, we identify this specimen as *Duchesneodus uintensis*. Together, the two recently discovered fossils indicate a middle Eocene, Duchesnean NALMA (42-37 Ma) for these rocks and the Duschesnean age establishes that they are not related to the Paleocene Flagstaff Formation. Another specimen of *Duchesneodus* was reported from the Eocene Green River Formation 100 kilometers north of this site in Sanpete County. The rocks on Thousand Lake Mountain may be correlative with the upper Eocene Crazy Hollow Formation that interfingers with the Green River Formation in central Utah. The discovery of identifiable vertebrate fossils has provided important age data in addition to providing significant paleontological information.



HIGH RESOLUTION BIOSTRATIGRAPHY AND LITHOSTRATIGRAPHIC REVISIONS OF THE POLESLIDE MEMBER OF THE BRULE FORMATION, BADLANDS NATIONAL PARK, SOUTH DAKOTA

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Two, of many, results of the recently completed Documentation of Significant Paleontological Localities within the Poleslide Member, Brule Formation, Badlands National Park NRPP project were: 1) a high-resolution stratigraphic documentation of almost 2400 fossil vertebrate sites in the Oligocene Poleslide Member, and 2) a revision of the lithostratigraphic units of the Poleslide Member. The Poleslide Member is characterized by thick siltstone beds interbedded with muddy sandstone sheets and rare mudstone beds. Fossil sites occur in all stratigraphic levels of the Poleslide Member, but fossils are concentrated in the siltstone beds. Unlike the Scenic Member of the lower Brule where bones are concentrated in distinct bone-beds, the Poleslide fossils are scattered throughout the siltstone units. Certain horizons within the siltstone units contain a large number of *in-situ* fossil sites, indicating discrete stratigraphic intervals of bone accumulation. Sandstone sheets, and widespread mudstone units, in the Poleslide contain fewer fossil sites. The NRPP study was conducted in the eastern-most outcrops of the Poleslide, in which 12 widespread stratigraphic units occur in a 49 m thick section. A total of 2383 fossil sites were documented by the paleontologists, and all of these sites were measured into the stratigraphic column to within the nearest 0.1 m. The preliminary analysis of the collected fossils indicate that the transition between the Orellan and Whitneyan Land Mammal Ages occurs at approximately 26 m above the base of the Poleslide Member.

Continuing stratigraphic studies of isolated Poleslide Member outcrops, extending 65 km to Sheep Mountain Table on the west side of the North Unit, show that the 49 m thick Poleslide Member on the east side of the Park correlates with the lower half of the 95 m thick Poleslide Member on the west side of the Park. The basal fossiliferous beds of the Poleslide Member on Sheep Mountain Table have an Orellan fauna similar to that of the lower half of the Poleslide sequence on the east side of the Park. The upper Poleslide sequence, that is well preserved on Sheep Mountain Table, is largely truncated by Arikareean paleovalley fills of the Sharps Formation on the east side of the Park. These newly recognized stratigraphic relations between the Poleslide Member and overlying Sharps Formation have great significance in understanding the boundary between the Whitneyan and Arikareean Land Mammal ages within the Park.

ONE DATABASE TO RULE THEM ALL, ONE ALGORITHM TO FIND THEM, ONE MANDATE TO BRING THEM ALL, AND IN CYPERSPACE BIND THEM: A DATABASE THAT INTEGRATES PALEONTOLOGICAL RESOURCE USE PERMITTING, RESEARCH, AND MANAGEMENT

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The Bureau of Land Management is charged with managing nearly 260 million acres of America's public lands. These lands comprise 13 percent of the total land surface of the United States and more than 40% of all land managed by the Federal government. The lands BLM manages contain a vast array of natural resources, landscapes, and open spaces which are managed with a multiple use approach. These multiple uses are evolving over time as the needs of rapidly expanding urban interface impact natural areas and wind farms take the place of oil and gas development.

Several coordinated initiatives are being implemented within the Bureau that support management decisions for BLM lands and resources. Among these initiatives are Enterprise GIS (EGIS), the Geospatial Services Strategic Plan (GSSP), and the National Integrated Land System (NILS) and GeoCommunicator. The EGIS system will enable Bureau employees and stakeholders to centrally access geospatial data and effectively integrate geospatial information into the agency's business processes and is responsive to the Federal Enterprise Architecture Framework. The GSSP establishes a governance model for the management of BLM's geospatial information and institutes a structure to coordinate the use of geospatial technology within BLM. The plan also addresses data management, data acquisitions, data standards and the establishment of corporate data themes. NILS and GeoCommunicator provide interactive geospatial web access, both internally and externally, to Bureau datasets.

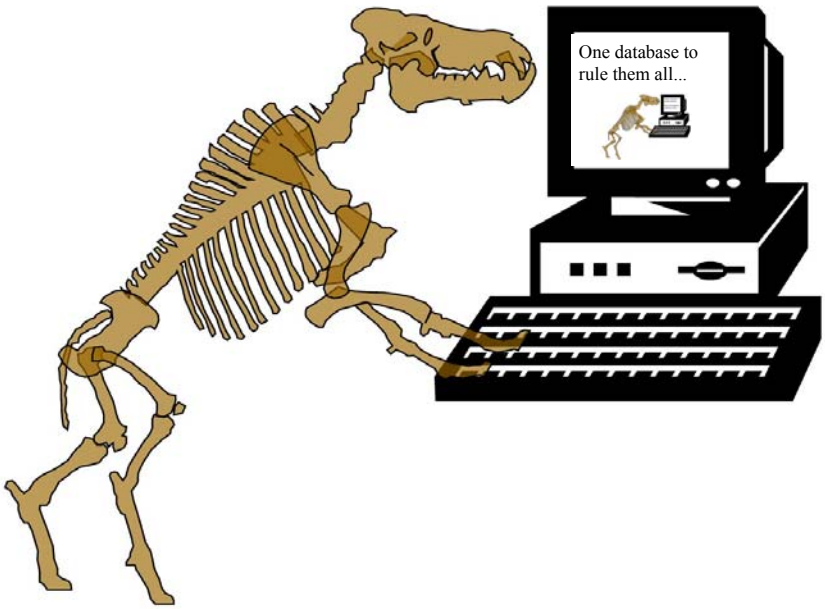
The common thread that runs through the above systems is the geospatial component, which ties information to the land. The newly signed Paleontological Resources Preservation Act (PRPA) further sets the stage for developing a national level approach to

integrating the various components of paleontological resource management. Section 6302 of the PRPA calls for greater cooperation between the Departments of Interior and Agriculture and states "*The Secretary shall manage and protect paleontological resources on Federal land using scientific principles and expertise*."

Currently, the BLM is in the process of developing a relational database management framework containing the information on which the BLM relies to manage paleontological resources and permits. These databases include permit, locality, and research, and collections. Managers, resource specialists, analysts, researchers, and policymakers will have access to appropriate levels of this data from a single system, greatly reducing redundancy while increasing accuracy and completeness.

Development of this system of integrated paleontology database has been conducted in consultation with a parallel system that is in development by the USDA Forest Service. USGS, NPS, and other Federal systems and standards will also be reviewed. A national data standard will be implemented that integrates current smaller scale database efforts within the BLM (including Canon City and Carlsbad Field Offices, and the Utah State Office). Both the management needs of the BLM and the research needs of the paleontology community are of principal consideration. Section 6309 or PRPA calls for the confidentiality of paleontological locality information. This system will address issues of confidentiality regarding both paleontological locality data and intellectual property.

A web based system is planned for final implementation and will support online permit application and reporting. Locality information will be input directly into the system through an interactive geospatial (map) component or uploaded via GIS shape files or spreadsheets. Links will be established within the databases to photographs, field notes, publications, repository and collections data, and a variety of other information that supports the implementation of the PRPA, data reporting requirements for the Government Results and Productivity Act (GPRA), and the overall management and preservation of BLM's paleontological resources. By enhancing current practices and transferring data and information (commonly maintained in hardcopy) into electronic and automated formats, current business practices will be greatly improved and streamlined.



PALEOECOLOGY OF THE SUNDANCE SEAWAY, CENTRAL WYOMING

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For over a decade, the Bureau of Land Management has permitted our collection of a diverse assemblage of marine reptiles from the Jurassic Sundance Formation of central Wyoming. The fauna of the Redwater Shale member includes at least four species: an ichthyosaur, *Ophthalmosaurus natans*; two cryptocleidoid plesiosaurs, *Pantosaurus striatus* and *Tatenectes laramiensis*; and *Megalneusaurus rex*, the only known Jurassic pliosaur from North America. Specimens collected include juveniles and adults of ichthyosaurs and plesiosaurs, as well as, additional material from the type (and only) specimen of *M. rex*. The increased number of specimens has allowed new interpretations of population demographics, taxonomy, paleoecology, and paleoenvironment.

A nearly complete ichthyosaur skull (Fig.1), preserved in three dimensions, is yielding new information on the structure of the skull and rostrum. Articulated ichthyosaur vertebrae have enabled us to reconstruct a substantial portion of the vertebral column of the Sundance ichthyosaur and demonstrate that it was quite different in its mode of swimming from a closely related British species, *Ophthalmosaurus icenicus*. Additionally, we have identified diagnostic features of the vertebrae that support the validity of *O. natans* as a separate species from the British species.

Specimens of plesiosaurs and ichthyosaurs have been found with preserved gastric contents, revealing that cephalopods made up a major portion of their diet. One ichthyosaur (UW 34653) had a dark mass of cephalopod hooklets preserved between the ribs (Fig. 2). At least two plesiosaurs had scattered hooklets throughout the matrix associated with partial skeletons (UW24801, UW 24215). Furthermore, we discovered cephalopod hooklets in irregular pieces of soft, carbonate concretion adjacent to the pit where *M. rex* was collected. It is likely that these represent stomach contents of the pliosaur. Thus, even the largest member of the Sundance fauna relied on cephalopods for at least a portion of its diet. The only hybodont shark remains known from the upper Sundance Formation were associated with gastric contents.

Rediscovery of the pliosaur excavation site has added stratigraphic and paleoenvironmental data to this unique specimen, originally collected in 1895. Found near the top of the Redwater Shale, it appears that the pliosaur frequented shallower portions of the seaway. Last summer we discovered an articulated distal portion of the forelimb of the type specimen. Notable are the tightly packed phalanges and slight backward curve to the limb. It has verified an earlier reconstruction of the limbs as narrow, streamlined hydrofoils.

Even isolated bones of juvenile plesiosaurs have produced new information. Examination of bone microstructure indicates that juveniles have denser bone than the adults. This suggests differences in the preferred environment, and/or swimming style, between juveniles and adults, possibly leading to partitioning of the resources available in the seaway. The juvenile specimens seemed to be concentrated in a small geographic area, further suggesting that perhaps young plesiosaurs were gathering for feeding or safety. Beyond the specimens

themselves, features of the preservation have provided new details about the paleoenvironment. Concretions around the bones are frequently composed of fossil hash, suggesting that the carcasses laid on the sea floor for a long time and served as baffles for storm currents carrying coarse sediments. In one concretion, we found carapace and burrows of crustaceans that fed on the soft, organic rich mud adjacent to decaying carcasses. One ichthyosaur was found with the skull at nearly 90º to the bedding (and its vertebral column), indicating that the carcass sank head first into a very soft substrate.

Field-based paleontological research proceeds at a slow pace, so the consistent, long-term support of the BLM in Wyoming in granting permits for reconnaissance and excavation has been vital to advancing our research on the Sundance Seaway.

Figure 1: Posterior portion of the skull of the largest ichthyosaur specimen that we have found (UW 24216).

Figure 2: Cephalopod hooklets interpreted as stomach contents of an ichthyosaur.

MINERAL WELLS FOSSIL PARK – A PROJECT BY THE CITY OF MINERAL WELLS, TEXAS WITH ASSISTANCE FROM THE DALLAS PALEONTOLOGICAL SOCIETY (WWW.DALLASPALEO.ORG)

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The City of Mineral Wells, Texas, closed their landfill permanently September 30, 1993. In 1997, Linda and Roger Farish, Dallas Paleontological Society (DPS) members, while searching for possible field trip locations, discovered that the 8 acre heavily disturbed and eroded borrow pit of the closed landfill was laden with Pennsylvanian fossils which included crinoids, brachiopods, echinoids (urchins), pelecypods (clams, oysters), bryozoans, corals, petalodus teeth, and trilobites. Afterwards, fossil groups and individuals from Houston, Austin, and Dallas regularly collected from this location. Texas has very little public land, and it is illegal to remove fossils from State and Federal land. The rules do not apply to private or city owned property.

In early 2008, the city of Mineral Wells was approached about selling the 75 acre former landfill which included the borrow pit. No buyers contacted the city of Mineral Wells regarding the property, and prior to a City Council meeting, DPS member Lance Hall informed the City Manager, through words and photos, that part of the landfill was a fossil collecting location. The city was unaware that persons came to Mineral Wells to hunt for fossils, and more specifically, to hunt the borrow pit of the city-owned landfill. DPS member Lee Higginbotham had a previous relationship with the Mineral Wells City Manager, Lance Howerton, and presented a DPS proposal to convert the former borrow pit of the closed landfill into a public fossil park where folks could keep the fossils that they find (Figure 1).

The April 2, 2008 proposal was presented to Lance Howerton, City Manager, Beth Watson, Executive Director of the Chamber of Commerce, and Christina Childs, Tourism Director. The group drove to the landfill, looked over the site, bent down and picked up fossils and gave the site an overview. A riker box, with a representative group of fossils from the borrow pit, was given to the group. The proposal for a fossil park was presented, which included letters of support from Dr. Louis L. Jacobs, Professor of Earth Science and President of Institute for the Study of Earth and Man at SMU, Dr. Anthony R. Fiorillo of the Museum of Nature & Science Dallas, Texas, Dr. Aaron D. Pan and Irene Stemple of the Fort Worth Museum of Science and History, and Dr. Merlynd Nestell of the University of Texas at Arlington.

The City Manager requested cost proposals and more ideas from DPS. The City Manager requested that persons cease collecting fossils from this location unless they were to sign a waiver to protect the city. During the months that the park concept was being developed, more than 40 persons signed the release forms to be able to collect at the landfill.

Some of the persons who signed release waivers included geology classes from Brookhaven College, middle school teachers on a convention trip to Fort Worth, a UTA student group, and others. During the time of the development of the park idea, DPS raised almost $3000 in pledges from members, and others, in support of this fossil park concept. The requested cost proposals and ideas were delivered to the city in August 2008. At the January 2009 Mineral Wells Park Board meeting, a presentation was made by Lee Higginbotham with four other DPS members in attendance.

On February 15, 2009, a front page article titled, "Welcome to Mineral Wells Fossil Park," was published in the Mineral Wells Index, the local paper. The Mineral Wells Park Board will decide, in March 2009, whether to send this fossil park idea to the City Council to see if the idea should be pursued. The final decisions by the City of Mineral Wells, Texas, regarding the proposed Mineral Wells Fossil Park should be made prior to the presentation at the 8th Conference on Fossil Resources, May 19-21, 2009.

Figure 1. Proposed site for the Mineral Wells Fossil Park. Photo taken by: Roz Morgan

MY CO-WORKER IS A DINOSAUR: USING PALEONTOLOGY TO REACH OUT TO CHILDREN AND THE COMMUNITY

BROWN, Tina

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The hadrosaur, *Gryposaurus monumentensis*, was discovered on the Kaiparowits Plateau region of the BLM's Grand Staircase-Escalante National Monument by the Webb School expedition from Claremont, CA. The excavation took almost 2 years and was followed by another 2 years for fossil preparation.

Gryposaurus is a "duck billed" dinosaur. This skull is the first, mostly complete dinosaur skull ever collected from Grand Staircase-Escalante National Monument. A skin impression was found near the skull, which is approximately 75 million years old and measures nearly three feet long. *Gryposaurus* weighed over 3 tons, stood 12 feet tall and was 25-30 feet long.

A cast of the skull (Figure 1) is part of the BLM Utah's Traveling Exhibit Program. The skull tours schools all over the state and fulfills the BLM's mission (PRPA Sec. 6308, Education and Public Outreach) to get children interested and involved in Paleontology. The Traveling Exhibit program is a great way to get children involved with science and the outdoors and further the mission of the Bureau of Land Management. We expect to showcase more dinosaurs as part of the Traveling Exhibit Program in the near future.

Figure 1. Cast of *Gryposaurus monumentensis*, found in the BLM's Grand Staircase-Escalante National Monument

THE UTAH GEOLOGICAL SURVEY'S INTEGRATED APPROACHES TO GEOSCIENCE EDUCATION AND OUTREACH USING APPLIED AND WEB-BASED RESOURCES

HAYDEN, Martha; DAVIS, Jim; WEAVER, Lance

Utah Geological Survey, Salt Lake City, UT

The Utah Geological Survey (UGS) offers a variety of education and outreach services for teachers, geoscience professionals, and the general public. Specifically, the UGS Geologic Information & Outreach Program (GIO) provides various educational resources and promotes geology to the general public through publications, lectures, and responses to inquiries. Accordingly, GIO works closely with all UGS programs—Energy & Minerals, Geologic Mapping, Ground Water & Paleontology, Geologic Hazards, and the State Energy Program—to generate engaging, scientifically accurate content that is accessible through our Web site. Although GIO embraces many geoscience topics, we strongly emphasize paleontology because of the immense fossil resources in Utah.

Educational programs and services provided by GIO include teaching kits (Figure 1), teacher workshops and field trips, Earth Science Week activities, high-school internships, and the paleontological volunteer program. We focus on integrating materials and activities with the Utah State Science Core Curriculum and, working with program specialists, such as the State Paleontologist, incorporating the latest scientific knowledge and research. Recent upgrades to teaching kits include expanded fossil components of the Rock/Mineral/Fossil and Dinosaur teaching kits, and the design of new kits—Landforms/Geologic Processes and Ice Age kits.

Development of UGS Web resources plays a vital role in distributing educational products to the widest possible audience, enhancing the availability and usefulness of our geoscience resources. The UGS Web site provides innovative ways for students and teachers to learn and also gives curricula and other materials (image galleries, virtual tours, geologic "current events") for use by science educators. Combining educational material with Web-based resources not only expands our audience beyond the educational community, but it also allows for opportunities to build interactive resources that further increase the effectiveness of our outreach programs.

Figure 1. Fossils from the Ice Age kit exhibit Pleistocene fossil finds from Utah. The relief map of Utah shows the maximum extent of Lake Bonneville during the last Ice Age.

IDENTIFYING COMMON HEALTH ISSUES IN FOSSIL PREPARATION- A SURVEY; A GUIDE FOR INSTALLING AN EFFECTIVE DUST COLLECTING AND VENTILATION SYSTEM IN A FOSSIL PREPARATION LAB

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Fossil preparation and fieldwork is seldom regarded as a hazardous occupation, however, the relative safety preparators enjoy may be somewhat illusory. This paper will present information regarding injuries and illnesses resulting from an informal survey of preparators done in 2002. In addition, the hazards associated with airborne silica dust generated by preparation activities will be addressed along with practical suggestions on how to design an efficient dust evacuation system.

In 2001, a questionnaire was distributed to participants of the Preparators' Symposium at the meeting of the Society of Vertebrate Paleontology in Bozeman, Montana. Questions were designed to identify the causes of common, recurrent and long-term injuries and illness among preparators, as well as get a sense of the "safety culture" in the museums they work for. In addition to a series of "yes or no" questions, respondents were also asked for comments. Though only 26 people participated, they represented both large and small institutions from Federal, State, Provincial and private institutions in the United States and Canada. Respondents ranged in age from 25-58 years (average age of 43) indicating the profession has an aging workforce; 16 males and 10 females responded. The average time in service was 14 years with several having served for 20 or more years, indicating preparators as a group are a dedicated workforce committed to pursuing preparation as a life-long profession.

On average, preparators spend between 50% and 100% of their time in the lab working with a variety of hand tools (dental tools, airscribes, pneumatic and percussion tools, etc), are regularly exposed to solvents, caustics, acids and other chemicals, as well as fiberglass and other micro-fibers. Most related stories of long hours and days doing repetitive tasks and some noted they spent less time doing hands-on lab work as they grew older due to either injuries, a career shift to more administrative duties, or both. Most of the respondents also participate in fieldwork ranging from a few days a year to several months (averaging 31 days); this occurs year after year. Tools used include hammers, chisels, shovels, pry-bars, picks, percussion and pneumatic tools, heavy generators and air compressors, rock saws and others. As in the lab, these tools are used with great frequency and duration.

Of the 26 respondents, 19 reported having been injured on the job, a full 75% of the workforce; however, even those who initially said they had not been injured reported "ailments" later in the survey. Respondents were asked to list which body parts had been injured; the following are injuries with the number of people affected: Hands (8); Back (5); Elbows (3) Ankle (2); Arms (2); Joints (1); Neck (1); Clavicle (1); Hip (1); Leg (1); Knee (1); Feet (1); Eye (1); Respiratory/lungs (1).

The follow-up question asked if they had experienced specific "ailments" due to preparation work: Tendonitis to any joint:

Elbow (5); Hands (5); Back strains (14); Arm or forearm (3); Wrist (3); Shoulder (2); non-specific (2): Respiratory problems attributed to fumes (6); Respiratory problems attributed to dust (5); Hearing loss (5); Severe eye strain (3). Other "ailments" reported by respondents include: blunt trauma, cuts and bruises, carpal tunnel, a cut eye, liver problems, mild asthmatic reactions to certain chemicals, anxiety and depression. Only 6 respondents had ever filed a Workers Compensation Claim for any of their injuries. The amount of time lost on the job ranged from "minimal" to "several months".

When asked which, if any, of their injuries were persistent, recurring, chronic or permanent, they responded as follows: Tendonitis to any joint: Elbow (5); hands (5); arm or forearm (3); Wrist (3); Shoulder (2); non-specific (2): Back strains (4); Respiratory (2); Persistent cough (1); Hearing loss (1); Liver problems (1).

Only 6 respondents claimed to have had baseline data gathered on their physical condition (respiratory and hearing tests). 50% of employers had programs to fit and test the effectiveness of respirators. 60% said their employer had safety programs that adequately addressed their safety issues, but only 40% said their employer provided funding to remedy problems; all preparators acknowledged using personal protective equipment (such as ear and eye protection) "when available". Roughly half of the respondents admitted they felt they had put their own health at risk at some point in their careers due to "wanting to get the job done", and 30% felt they had put themselves at risk due to pressure from someone else.

It is notable that 75% of respondents did not have ergonomic furniture, but as one person said, it is "always difficult to convince an employer of the need." This survey highlights a high number of preparators claiming short and long term injuries due to tendonitis (a repetitive stress injury), back strains and respiratory issues. Changing work habits can reduce the occurrence of some injuries, but increased funding is needed for items as simple as ergonomic chairs or basic lifting equipment. The same is true for respiratory issues; though relatively expensive, effective dust and fume control in preparation labs will reduce the potential for serious health issues.

A series of industrial hygiene surveys conducted at Dinosaur National Monument (DNM) documented health issues associated with paleontological lab and fieldwork. One issue identified was the lack of an effective means of controlling airborne rock dust generated by preparation activities, the primary culprits being silica dust and radioactive dust or its byproduct, radon. Silicosis is a lung disease caused by inhaling free silica dust which breaks cell tissue and may accumulate in portions of the lungs causing a fibrous tissue to develop; the damaged lung will not allow gasses to pass through freely and the functional size of the lung will decrease. Radioactive fossils and rock (common in many Mesozoic formations) also may produce radon, a known carcinogen.

One of the tests at DNM captured and analyzed dust being generated through typical lab activities (airscribes and grinders) and showed free quartz dust levels to be 22 times the OSHA (Occupational Health and Safety Administration) PEL (Personal Exposure Limit). In addition, radon levels in some closed cabinets containing dinosaur bones showed levels 1000 times above permissible limits. In consultation with National Park Service and private sector engineers, DNM personnel designed a dust and fume evacuation system to remove these hazards from work areas. After installation, NIOSH (National Institute for Occupational Safety and Health) personnel ran follow-up tests to insure the effectiveness of the system by comparison with other industrial hygiene standards; airflow tests proved the system worked as designed. As many paleontological labs have dust control systems that may have been designed in a haphazard fashion, the DNM system may serve as a model for other labs hoping to address these safety issues.

Preparation at the UFH in the spring of 2008. With this increase in the use of various airscribes, microjacks and Aromarkers, there was a notable increase in the volume of airborne particulates being produced during the process of removing the rock that encased the fossils.

In spite of already having a dust collecting unit in operation, it became apparent this particular unit was not sufficient for removing the fine rock dust, fumes and other particulates from the air that can create a health hazard over the long term. Fine dust was accumulating on work surfaces and lab equipment, another indication that the system we had was inappropriate for the type of work being done.

By taking a proactive approach, the UFH consulted with DNM lab personnel for information about the ventilation system they had installed in 1996. Their system was an excellent example of one that was successful at removing the unsafe levels of rock dust and radon from their work areas. According to NIOSH and OSHA guidelines and recommendations, to prevent most industrial dust (granite, silica, limestone, clay, etc.) from settling and blocking ductwork, a minimum airflow of 304-400 cfm is required at the intake hose. Other recommendations include designing a system with duct work having a circular cross-section to achieve a more uniform air velocity and duct work that branches at low angles to decrease drag (Fig. 1).

Because no formal safety standards have been developed for what would be considered an optimal system for a paleontological lab, it was determined that the work environment of the stone cutting industry was the most comparable. It was subsequently decided to use OSHA and NIOSH recommendations and guidelines for the stone cutting industry when figuring the specifications for UFH's new system. Airflow tests of the old unit scored well below the recommendations of OSHA and NIOSH, at about 90 cfm at the intake hoses. Specifics like the dimension of the room being used, the length and diameter of ductwork, the number of work stations, the amount of airflow needed for sufficient dust removal, and the appropriate type and size of unit had not been taken into account. Tests were also done for radon in the lab and storage areas. The Environmental Protection Agency (EPA) states that action must be taken for radon measurements of above 4 picocuries per liter (pCi/L). The UFH had measurements between 1.5 and 1.6 pCi/L, well within safe exposure limits.

With the help of a mechanical engineer, these specifics were all taken into consideration during the design phase of the new dust collecting system. The UFH also had to consider its low budget, needing to keep renovations to a minimum, small lab space, excessive noise, and potential nuisance and health hazards to the public. In the end, a small, closed (filter and re-circulating) system was designed (Fig. 2). Once installed, follow-up tests determined the system to be safe and successful (pulling about 500 cfm at the intake hose) as it met or exceeded all OSHA and NIOSH guidelines and recommendations.

Like DNM, The Utah Field House of Natural History State Park Museum (UFH) in Vernal, UT had a substandard dust collecting and ventilation system in their lab. The use of tools that run on compressed air increased substantially after hiring an intern to do some fossil preparation at the UFH in the spring of 2008. With this increase in the use of various airscribes, microjacks and Aromarkers, there was a notable increase in the volume of airborne particulates being produced during the process of removing the rock that encased the fossils.

Figure 1 (above). New duct work at UFH

Figure 2 (right). New dust collecting unit at UFH

THE IMPORTANT ROLE OF PROFESSIONAL PREPARATORS IN MANAGING FOSSIL RESOURCES

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Professional Preparators play many important roles in research, education, and preservation of fossil resources, but the significance of their efforts is often overlooked. Preparators are frequently the first people to see a fossil specimen uncovered, either in the laboratory or in the field. After hours spent in the lab carefully removing matrix to reveal the embedded fossil, Preparators have intimate knowledge of that fossil's structure. Well-trained professional Preparators will be able to observe and recognize important morphological or contextual features in the fossil during the preparation process, thus, making them a valuable part of the research team.

Educating the public is an important way to raise public awareness of the science behind paleontology and gain public support in preserving fossil resources. Not only are Preparators an essential part in any display of fossil specimens, but they can be utilized to present information to the public - through talks, activities or demonstrations - about paleontological processes and the significance of fossils. Having on-site Preparators who can demonstrate a fossil's journey from excavation to display gives the public an appreciation and better understanding of the work involved recovering these precious treasures from the past (Figures 1-2).

The most important role Preparators play is that of Conservator; preservation of fossil material in order to maintain its value to future generations being the number one goal. Professional Preparators have been trained in the techniques that best preserve our fossil resources. Through professional meetings and organizations, they keep up with the latest research in conservation techniques in order to provide the best, most appropriate, treatment possible to the fossils placed in their care. This practice ensures that our fossil resources will be around for future contributions to scientific research and public education/enjoyment.

When agencies managing fossil resources do not directly involve professional Preparators, problems can occur. As an example, there are over 100 National Park Service (NPS) managed sites that contain nationally significant paleontological resources; of these, only two have a full-time, permanent, professional Preparator on staff. In an alarming trend, two NPS sites have lost their Preparators within the last year. In parks that have no Preparator, a number of regrettable practices are occurring: 1) fossils are not being collected, exposing them to erosion, vandalism or theft; 2) collected fossils are being added to an enormous back-log of specimens with little chance of ever getting prepared; or 3) fossils are being "farmed out" to less qualified and, often, unsupervised individuals who lack formal training.

Without professional Preparators, and the resources to support them, the preservation of our nation's fossil resources will deteriorate. Qualified, professional Preparators are instrumental in research, education, and conservation. Fossils are the raw data of paleontology. Preparators expose this data and preserve it, providing the backbone of paleontology and should, thus, be recognized for their contributions to our science.

Figure 1. Window looking into the paleontology fossil preparatory lab at John Day Fossil Beds National Monument gives visitors the opportunity to observe paleontologists at work. Television screen above the window shows the view, in real time, as seen through the microscope.

Figure 2. Visitors view into the John Day Fossil Beds National Monument fossil preparatory laboratory.

PIG DIG REPORT OR TOLSTOY? COMPILING A RECORD OF FIFTEEN YEARS OF STUDENT ACTIVITY AT CONATA PICNIC GROUND, BADLANDS NATIONAL PARK, SOUTH DAKOTA

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Conata Picnic Ground Site (SDSM V9310), better known as the "Big Pig Dig", has been an overwhelmingly successful collaborative effort between Badlands National Park and the South Dakota School of Mines and Technology. The site, in operation from 1993 to 2008, contains an Orellan faunal assemblage dominated by four taxa: the entelodont *Archaeotherium*, the rhino *Subhyracodon*, the equid *Mesohippus*, and the small, deer-like *Leptomeryx*. With the recent close of field activities, both parties begin the daunting process of compiling a final report of activities, a significant portion of which were conducted by over 100 SDSM&T (Tech) students.

Student participation began early. After its discovery in 1993 by park interns Scott Foss and Kim Stevens, the site was almost immediately set up as an in-situ excavation and interpretative site. Tech students were employed from June through August to conduct fieldwork. The site was used as a working classroom to teach field techniques including field stabilization, excavation and jacketing techniques, grid mapping, and digital mapping using a total station and GIS. Additional educational opportunities included student interpretation for thousands of visitors; molding, casting, and mounting an *Archaeotherium* skeleton; laboratory preparation of material; and final curation of specimens. For fifteen years, the Pig Dig served as an integral part of Tech's paleontology educational experience.

Student participation continues in the form of research. Over the years, the site has produced numerous abstracts, two undergraduate research projects and four Master's theses. Current research focuses on treating the faunal assemblage as a biological sample for systematics of *Subhyracodon* and *Archaeotherium*. As data are compiled, future projects will emerge involving detailed taphonomic interpretations and population dynamics. Students have also become involved in writing the final report of activities as a project for a recently offered resource management course.

THE BADLANDS NATIONAL PARK BACKLOG CATALOGUE PROJECT: AN EXERCISE IN EFFICIENT COLLECTIONS MANAGEMENT OF FEDERAL SPECIMENS

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Researchers from the South Dakota School of Mines and Technology (SDSM) Museum of Geology have been collecting paleontological resources in the Big Badlands of South Dakota since 1897. SDSM has also acted as steward to federal specimens after the designation of Badlands National Monument, in 1929, and continued to do so after the status change to a National Park, in 1978. From the time when these collections began, SDSM utilized an ultimately outdated method of specimen organization. The arrangement of the SDSM paleontology collections consisted of an unholy trinity of strictly systematic organization, arrangements of specimens within a special research interest, or random deposition where space was available as specimens were transferred from the preparation lab.

In 1999, Badlands National Park (BADL) funded the Backlog Catalogue Project. The goal of this project was to enter known collections into the Automated National Catalog System (ANCS+). This program allows all BADL specimens to be utilized to their maximum benefit. Reorganization of the collections stemmed independently, and concurrently, to optimize the management of BADL fossil specimens housed at SDSM. The modern system of fossil specimen organization had previously been established at other institutions such as the Los Angeles County Museum and the University of California Museum of Paleontology at Berkeley. This system emphasizes the importance of the fossil specimen within its appropriate geographic and biostratigraphic context, not the specimen alone. This makes specimens easier to track as taxonomic and phylogenetic information is revised. The BADL collections at SDSM, prior to 1987, are currently being sorted in order of geologic period, country and state, biostratigraphic age, geologic formation, locality, systematics, anatomy, and finally, by assigned number. All reorganized specimens are concurrently curated into the collections management software ANCS+, while specimen information is updated when appropriate. More recent collections are immediately curated using this modern standard.

Those currently involved with the backlog project are in the final stages of organizing what is left of the BADL specimens collected in the earlier decades of SDSM's field work. This new system of organization and documentation also encourages optimal efficiency in management and research of all other SDSM collections beyond those in the BADL system.

WHO'S RULES? WHO'S STUFF? RESPONSIBILITIES AND REQUIREMENTS FOR CURATING FEDERAL PALEONTOLOGICAL COLLECTIONS

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Paleontological resources from Federal lands are property held in trust to benefit the public in the interests of science, research, and education. Fossils are irreplaceable heritage assets, and as such must be managed in ways to preserve their inherent scientific values and to ensure their availability for current and future use. These goals can only be achieved through mandated, yet cooperative, arrangements among the Federal land management agencies that own the resources, the permittees that excavate and research the specimens, and the curatorial repositories that preserve, protect, document, and use the collections.

This paper will review the roles and responsibilities of Federal agencies, consulting and research permit holders, and museum and university repositories in the collection, management, documentation, preservation, and use of Federal fossil collections. Professional curation by institutions with the requisite capabilities and research interests is vital. Therefore, methods and criteria for evaluating institutions as repositories for Federal collections will be discussed, with reference to curatorial assessment models adapted from the Department of the Interior's museum property policy (Part 411 of the Departmental Manual), American Association of Museums' Accreditation Program, and Federal regulations for the Curation of Federally Owned and Administered Archaeological Collections (36 CFR Part 79).

Lastly, this paper will introduce the oversight entities and their monitoring and auditing systems established to ensure the accountability of Federal museum collections that are designed to safeguard the fossil resources and sustain these important collections for the future.

LESSONS LEARNED ABOUT CURATION FROM ARCHEOLOGY: COSTS AND POTENTIAL COSTS TO OUR RESOURCES

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Over the last 30 years, an increasing number of repositories across the U.S. charge for curatorial services when archeological collections are deposited with them. These fees are instituted to meet the costs of providing high-quality collections care and upholding professional standards. An informal yet systematic study of repository fees was performed in 1997/98, 2002 and, most recently, in 2007/08 to examine this movement. This paper provides current information on curation fee structures across the U.S., criteria used to establish fees, and the variability of fees.

A number of related trends and issues are evident from the repository fee data compiled over the last ten years, which are discussed as lessons learned. These include: the need to understand the real costs of curation budgeting for curation at the beginning of a project; the importance of curating the records associated with the physical resource; the types of fees and the cost implications for different collections owners; the effects of repository fees on the collections received; the effects of repository fees on fieldwork; enforcement of curation standards; and deaccessioning collections.

NAVIGATING THE REPOSITORY MAZE

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From a provisional repository agreement to formally repositing collections at the museum, learn the ins and outs of museum repository procedures and their importance. Just as fossils are tracked in the field, so are these collections (the fossils and associated records) tracked in the museum. Repositories, in pairing with federal and/or state land agencies, have a fiduciary responsibility to the citizens of the U.S. to manage resources acquired from public lands appropriately. How does a museum repository uphold this duty in perpetuity and how does it affect research and consulting paleontologists?

This presentation discusses the role of a museum repository; tracking methods; fossil preparation and documentation standards; appropriate museum storage methods and accepted general standards; and research use concerns.

OIL SHALE, GAS WELLS, AND TRANSMISSION CORRIDORS: THE BLM'S POTENTIAL FOSSIL YIELD CLASSIFICATION (PFYC) SYSTEM AND STANDARDS FOR ASSESSMENT AND MITIGATION OF PALEONTOLOGICAL RESOURCES

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The Bureau of Land Management (BLM) administers a large percentage of the land in the western United States, both as surface acres and subsurface mineral rights, for the benefit of the citizens of the United States. Part of that responsibility includes protection and preservation of paleontological resources. This protection must be balanced against mandates for mineral and energy development, recreational activities, wilderness designations and other restrictive measures, including the infrastructure needed to support these programs. Development of resources or activities will often adversely impact paleontological resources, so mitigation measures must be developed and implemented to protect and preserve the public's fossils.

Mitigation measures consist of identification of the fossil resource, assessment of the potential impacts, formulation of possible actions to eliminate or reduce adverse impacts, recovery of threatened resources and associated data, and the long-term curation of those fossils and data.

The BLM has developed a policy to help focus mitigation efforts to those places most likely to contain significant fossil resources, based on the geologic units exposed in the affected area. The Potential Fossil Yield Classification (PFYC) system was issued as formal BLM policy in 2007. Under this system, geologic units are classified based on the relative abundance of vertebrate fossils or scientifically significant invertebrate or plant fossils contained within them, and the overall sensitivity to adverse impacts. The system uses a 1 to 5 ranking, with a higher number indicating a higher potential. This classification is applied to the geologic formation, member, or other distinguishable unit, as an average rating across the region.

Class 1 - Very Low potential. Geologic units are not likely to contain recognizable fossil remains. Management concern is usually negligible or not applicable.

Class 2 - Low potential. Sedimentary units that are not likely to contain vertebrate fossils or scientifically significant invertebrate or plant fossils. Management concern is generally low.

Class 3a - Moderate Potential. Units are known to contain vertebrate fossils but these occurrences are widely scattered. Management usually is applied at a sampling

level, with field checks sometimes appropriate. Class 3b - Unknown Potential. Units exhibit geologic features and preservational conditions that suggest significant fossils could be present, but little information about the unit or area is known. Management approaches should be carefully considered, with field surveys possibly warranted.

Class 4 - High Potential. Geologic units contain a high occurrence of significant fossils, but these may be variable in distribution and predictability. Management concern is generally high, and field surveys and monitoring are often warranted.

Class 5 - Very High Potential. Highly fossiliferous geologic units that consistently and predictably produce significant paleontological resources. Management concern is quite high, with field surveys and monitoring of all bedrock disturbance nearly always necessary.

Mitigation actions for paleontological resources should be tailored to the potential to affect significant fossils. Areas of low fossil potential (PFYC Class 1 or 2), or actions that won't disturb the bedrock often will not require pre-disturbance mitigation efforts. Conversely, actions that will disturb Class 4 or 5 units will probably necessitate a pre-work survey and possibly on-site monitoring during construction activities. BLM recently (2008) issued a policy outlining mitigation assessment and procedures, including permit and curation requirements relevant to paleontological consulting work. The procedures step through a series of analyses, and the assessment made at each step determines whether further analysis is necessary. Key points include assessments of: 1. the potential to affect significant fossils from the proposed action; 2. known locality data within and near to the area; 3. the PFYC rating of the affected bedrock unit; 4. the local presence of deep soils or thin alluvial material, and the potential for the action to penetrate through the protective layer; 5. the possibility of relocating the proposed project to avoid significant fossil resources; 6. the need for pre-work field surveys; and 7. the need for on-site monitoring during disturbance activities.

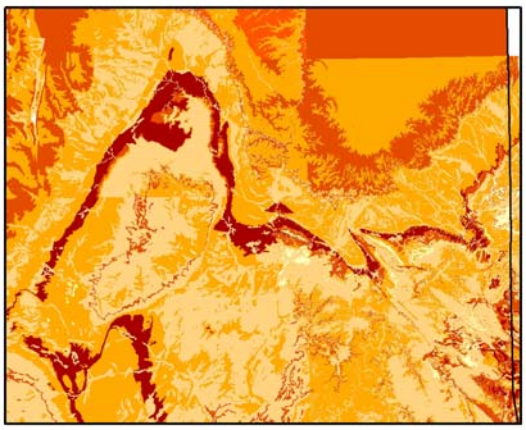

Figure 1: PFYC Map of public lands near Moab, Utah. The darker colors indicate Geological units with a higher potential to have significant paleo resources.

This mitigation analysis is done at the BLM's Field Office level, or for large-scale projects, at the State Office level. Because mitigation efforts may vary on a project-by-project basis, understanding the sensitivity of paleontological resources and the potential impacts from project activities is important.

The mitigation field work and background data research must be performed by a qualified paleontologist, usually a paleontological consultant holding a permit issued by BLM and hired by the project proponent. Although hired by the proponent, the consultant is acting as an agent for the BLM to gather all relevant information to allow BLM to make informed management decisions regarding paleontological resources.

Because of this management approach to mitigation, the BLM is prepared to implement the protection and preservation goals outlined in the recently-signed Paleontological Resources Preservation Act of 2009 (PRPA), and will continue to apply management using the best "scientific principles and expertise" in accordance with Section 6302 of the PRPA.

A PALEONTOLOGIC DATABASE CREATED USING THE INTEROPERABILITY OF AN ACCESS DATABASE AND ARCMAP INCLUDING CASE STUDIES IN THE GARDEN PARK FOSSIL AREA

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The BLM, Royal Gorge Field Office, (RGFO) uses the five tiered Fossil Yield Potential Classification (FYPC) ranking system as a planning tool whereby, geologic units at the formation level are classified according to the probability of yielding paleontological resources that are of concern to land managers. In addition to geologic formations, point information representing locations of fossils found on the ground were used to distinguish between classes. The RGFO paleo database is unique in its use of an Access database that is linked to ArcGIS shapefiles. The Access database contains information pertaining to locality data, including: geologic formation, fossil type, and source of data, including a locality number that corresponds to the appropriate institution.

The RGFO-FYPC was created in response to Federal Land Policy Management Act of 1976 (FLPMA), which requires that public lands be managed "to protect the quality of scientific" and other values. FLPMA also requires that Public Lands and their resources be periodically inventoried and assessed through a land use planning process, and that permits be issued to regulate the use of public lands and resources. The RGFO-FYPC is used to identify BLM lands that contain paleontologically important resources that must be protected. It is also used to identify Public Lands that should be periodically inventoried. In addition to the paleontologic classification of Public Lands, the RGFO FYPC contains guidance for BLM managers considering ground disturbing activities that are proposed on lands with paleontologic classifications 1 through 5. The value of the database is demonstrated through two case studies where the database was used to evaluate a powerline replacement project and to determine the preliminary size of a paleo survey on newly acquired public lands.

PALEONTOLOGICAL RESOURCE PROTECTION: A CRITIQUE OF THE CALIFORNIA MODEL

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The State of California was one of the first to introduce laws and regulations protecting paleontological resources (fossils) and is often looked up to as a leader in this regard. As a leader in environmental legislation, the California model is often considered by those planning to introduce similar protection for fossils into their own state's regulations. I urge caution in using the California model because it is less than ideal.

In California, paleontological resources are protected by several state statutes, but most notably, by the California Environmental Quality Act (CEQA) and related policies and regulations. CEQA requires that potential impacts to natural resources be considered when assessing the environmental consequences of any proposed project. One of the weaknesses of CEQA is that it was designed to be "self policing"; that is, there is no government oversight body responsible to see that CEQA is properly implemented or that projects are completed in compliance with CEQA. In contrast, the parallel National Environmental Protection Act (NEPA) established the Environmental Protection Agency (EPA), whose responsibility is to insure compliance with NEPA. In the absence of a state EPA-equivalent, compliance with CEQA is dependent on public vigilance through threats of legal action and actual lawsuits to insure CEQA compliance. Without advocacy or watch-dog environmental groups to review environmental documents to insure that fossils are being protected, CEQA itself does not provide protection.

Another major problem with CEQA is the conflict of interest present when the CEQA lead agency having jurisdiction over a project is also paying the bill for environmental compliance. In such cases, the state agency managing the project often skimps on environmental protection or completely ignores some environmental consequences to reduce the costs of construction. Since there is no EPA-like policeman to oversee CEQA compliance, sensitive resources, such as paleontological resources, are simply not protected. The only risk to an agency choosing not to comply with CEQA is that some watch-dog environmental group may threaten legal action. Since there are no watch-dog environmental groups specifically looking out for the protection of fossils, this risk is really nonexistent, and fossils are often not protected.

Guidelines for the Implementation of CEQA define the procedures, types of activities, persons, and public agencies required to comply with CEQA and include an Environmental Checklist of questions to be answered as part of the Initial Study of potential environmental impacts. This Checklist contains only one question specifically regarding paleontological resources. Unfortunately, language in the Checklist specifically states that not all questions have to be answered. Some California agencies chose to ignore paleontological resources completely and have removed the question related to fossils from the CEQA Checklist for projects in their jurisdiction. Consequently, fossils are

not mentioned in environmental documents and are not protected during project construction.

Questions included in the CEQA Environmental Checklist are grouped under descriptive headings. Unfortunately, the one question specifically addressing potential impacts to paleontological included along with historical and archaeological resources under the heading Cultural Resources. By definition, fossils are *not* Cultural Resources and cultural resource specialists are ill prepared to answer questions regarding a project's potential impacts on fossils. Consequently, cultural resource impact reports routinely ignore potential impacts to paleontological resources.

The one question in the Cultural Resources section of the CEQA Environmental Checklist pertaining to fossils is: "*Will the proposed project directly or indirectly destroy a unique paleontological resource or site?*" Some CEQA lead agencies interpret the "*unique*" in this question to mean "one of a kind" and routinely answer "No" to the question, reasoning that a second specimen of *Archaeopteryx* would by definition not be "*a unique paleontological resource*" and therefore, would not be protected under CEQA regulations.

The CEQA Checklist applies markedly unequal criteria regarding the severity of potential impacts that need to be considered to biological and archaeological versus paleontological resources. For biological and archaeological resources, the criteria are "*have a substantial adverse effect on*" biological resources or "*cause a substantial adverse change*" to archaeological resources. In stark contrast, for paleontological resources the criteria are "*destroy a unique paleontological resource.*" In other words, to be considered a potentially significant impact, paleontological resources must not be just adversely affected, as must biological resources or adversely changed, as must archaeological resources; instead, paleontological resources must be destroyed! In addition, in the Checklist, the only significant impacts to be considered are impacts to "*unique*" paleontological resources, rather than adverse impact to any or all paleontological resources. To be consistent, the Checklist should consider only adverse impacts that have the potential to "*destroy unique*" biological and archaeological resources. Of course, this language is absurd, but it is just as absurd for paleontological resources. To correct this unequal treatment of equally significant resources and to be consistent, the CEQA Checklist language for paleontological resources should be changed to "*have a substantial adverse effect on paleontological resources*."

The problems, limitations, and weaknesses of CEQA discussed above, along with others, mean that other states and regulatory agencies would do well to study the California model for paleontological resource protection but not follow it closely. I recommend taking the best and leaving the rest. The California model has serious flaws; other states can and should do better.

PALEONTOLOGICAL SENSITIVITY MAPPING: A CASE STUDY, NORTHEASTERN WIND RIVER BASIN, WYOMING

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The Wind River Basin in central Wyoming is renowned for its Eocene-age rock units that have yielded abundant and diverse vertebrate fossil assemblages. A portion of the northeastern Wind River Basin is currently being studied in conjunction with the Gun Barrel, Madden Deep and Iron Horse (GMI) Environmental Impact Statement (EIS), a natural gas development project.

Approximately 80% of the 147,000-acre GMI study area is underlain by the very highly paleontologically sensitive Eocene-age Wind River Formation. The geologic mapping that exists for the area is not detailed enough to distinguish areas that contain well exposed bedrock in badland topography, areas with more weathered and partially vegetated bedrock, or areas in which bedrock is covered by surficial sedimentary deposits of varying thicknesses.

As part of the paleontological resources analysis for the GMI EIS, we developed a paleontological sensitivity mapping technique that builds upon the Bureau of Land Management's existing predictive resource management planning scheme, the Potential Fossil Yield Classification (PFYC). Our sensitivity mapping methodology employs a combination of aerial photography, soils data and field reconnaissance to classify the landscape into one of five categories based on the topography and surficial geology: types A to E, from most to least sensitive, respectively.

These five area types do not directly correspond to PFYC classes because the area types are defined at a sub-formational level. However, the sensitivity types do correspond to the recommended resource management mitigation guidelines outlined in the PFYC. The results of our ongoing paleontological sensitivity mapping, in combination with the results of other resource analyses, will permit the project applicants and participants in the EIS process to make informed decisions.

Additionally, the sensitivity mapping represents a tool that can be utilized to protect and manage paleontological resources by decreasing the potential for adverse impacts resulting from surface and subsurface disturbance associated with energy development activities.

THE SUCCESSFULNESS OF PALEONTOLOGICAL RESOURCE MITIGATION ON FEDERAL, TRIBAL, AND STATE ADMINISTERED LANDS

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During the past several years, numerous oil and natural gas exploration and development projects have taken place on federal, state, and tribal administered lands in Utah, Colorado, and Wyoming. The Bureau of Land Management, U.S. Forest Service, and Energy and Minerals division of the Ute Nation require a paleontological survey prior to surface disturbance and, if necessary, a monitor during site construction. Due to these stipulations, abundant new discoveries of fossil localities and recovery of scientifically significant resources for curation and repository at museums has occurred. These fossil resources may not have been recovered under conventional excavation procedures because of the speed with which abundant amounts of fresh rock is exposed.

Recovered vertebrate fossil resources include: multiple, partial Rodentia specimens (including cranial material); partial potential mesonychid skull; an 80+% complete *Protoreodon*; two complete, and numerous partial, crocodylian skulls, as well as post cranial material; *Hemiacodon gracilis* including cranial, partial jaw, and post cranial material; hundreds of disarticulated turtle carapace and plastron; numerous artiodactyl and perisodactyl postcranial material; gar scales, cranial material, and fin material; amphibian jaw material; endocast material from Agriochoeridae; fragmentary dinosaur material; and at least five different species of shark, based on teeth.

Invertebrate fossil resources include: many different species of ostracods, gastropods, ammonites, and pelycopods.

Trace fossil resources include: two tridactyl tracks, numerous expamples of the *Cruziana* inchnofacies, paleopathologies on turtle carapace (burrowing, gnawing, etc.), tapir tracks, and a carnivore coprolite.

Plant fossil resources include: new fern species, disc-like plant structures (yet to be described), *Salix*, *Accer*, *Equisetum*, *Lygodium*, *Populus wilmatte*, *Quercus, Zelkova*, *Macginitiea wyomingensis*, *Cedrelospermum nervosum,* seed pods, root balls, and petrified wood.

Cooperative efforts between land management agencies, oil and natural gas exploration and development companies, and paleontological consultants have had a significant impact on fossil resources. Currently, paleontological resource surveys are a stipulation in the application to permit to drill. These current stipulations are beneficial; however, legislation will intensify protection of these American treasures.

MONITORING AND MITIGATION PROCEDURES FOR PALEONTOLOGICAL RESOURCES ON FEDERALLY MANDATED ENERGY PIPELINE PROJECTS

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The Bureau of Land Management (BLM), United States Department of Agriculture Forest Service (USFS) and the Federal Energy Regulatory Commission (FERC) have approved these recommendations for monitoring for and mitigation of paleontological resources during numerous Uinta Paleontological Associates, Inc. (Uinta Paleo) consulting projects. The paleontological sensitivity determination of geologic units to be impacted along a pipeline are made after formal reports of existing paleontological data and the results of pedestrian field surveys are submitted to the agencies. If a geologic unit or fossil locality is deemed to be of high sensitivity for containing significant pale-onto-logic resources, monitoring and mitigation measures are recommended by the Federal and state agencies to protect those re-sources. These procedures are outlined here.

FEDERAL AND STATE REQUIREMENTS

The BLM, USFS, and FERC have requested the evaluation of the paleontological sensitivity of all geological formations along pipeline right-of-way corridors under the mandates outlined in the following laws and rulings:

The National Environmental Policy Act of 1969 (NEPA). 42 U.S.C. § 4321. et. seq., P.L. 91-190.

The Federal Land Policy and Management Act of 1976 (FLPMA). 43 U.S.C. § 1701, et. seq., P.L. 94-579.

BLM Paleontology Resources Management Manual and Handbook H-8270-1 (revised 1998 & 2008).

Omnibus Public Land Management Act of 2009 – Subtitle D, Paleontological Resources Protection, Sections 6301-6312, Congressional Record – House, p. H3900-H3901.

Most western states have laws and regulations regarding paleontological resource protection on state, county, and municipal lands established with similar guidelines (e.g., Colorado CRS 1973, 24-80-401 through 409).

These federal and state guidelines authorize:

Environmental assessments or impact studies for vertebrate fossil resources, as well as scientifically significant plant and/or invertebrate paleontological resources on their lands;

Permitting of paleontologists to perform pedestrian field surveys and collection of fossil specimens;

Evaluation of formal reports with resultant recommendations for and authorization of monitoring and mitigation (which can include avoidance) work in sensitive areas to be impacted during ground disturbance; and

Preparation, identification and curation of recovered specimens and associated geologic data in an approved repository. Final reports must be submitted to the appropriate federal or state agencies for review and approval.

RESOURCE ASSESSMENT GUIDELINES

The USFS initially developed the Potential Fossil Yield Classification (PFYC) in 1996 as part of its Paleo Initiative. More recently the BLM has released and updated the BLM Paleontology Resources Management Manual and Handbook H-8270-1 (revised 1998 and 2008) that clearly established classification systems for ranking paleontological areas as to their potential for noteworthy occurrences of fossils. These regulations are now formalized under the Omnibus Public Land Management Act of 2009 – Subtitle D, Paleontological Resources Protection, Sections 6301-6312.

CONSTRUCTION MONITORING AND MITIGATION

The purpose of the monitoring and mitigation program used by Uinta Paleo in cooperation with federal and state agencies is to protect paleontologic resources by documenting and collecting those fossils of scientific significance that are found within the pipeline right-of-way (ROW) and ancillary facilities. This includes monitoring of clearing, grading, and excavation work (e.g., pipeline trenching). Whenever significant fossil material (vertebrate, invertebrate, plant, or trace) is likely to be encountered during ground disturbance along a pipeline project, the following mitigation measures are implemented:

Monitoring - If critical or significant fossil material in a PFYC Class 4 or 5 unit is likely to be encountered during the construction of the pipeline, paleontological monitoring is recommended. This is determined from the known data field survey results.

Sampling - During field survey and monitoring, fossil material is sampled to facilitate further analy-ses to determine signifi -cance. Frequently, fossil taxa are not sufficiently well known to allow the determination of sig-nifi-cance in the field.

Rerouting - A request for a pipeline reroute prior to construction may be made if critical or significant fossil material is encountered directly on the proposed corridor or associated facilities during the field survey. Fossil salvage and delay costs can be high.

Salvage - Salvage is requested through the federal/state agency officer-in-charge or the appropriate land owner whenever scientifically significant fossils are impacted (e.g., Rocky Mountain Expansion and Entrega/Rex Pipeline dinosaur discoveries).

During construction Uinta Paleo arranges for adequate paleontological monitoring of significant units as defined by the analysis of existing data and the field survey. In sedimentary units established as highly paleontologically significant (PFYC 4 or 5), a qualified paleontolog-ical monitor is present during 100 percent of the ground-disturbing activity, unless it is subsequently determined by the project paleon-tologists and the BLM (or lead agency) that reduced monitoring is appropriate. In geologic units classi-fied as moderately significant (PFYC 3) a paleontological monitor performs spot checks during con-struction based on the lithology of the unit. Some significant vertebrate fossil resources can be small to micro-scopic in size and may not be readily apparent during construction activity. Sampling and testing of rock debris for fossils is done expeditiously during construction, to avoid delays, and in a safe manner that does not impede work or traffic. Under no circumstances are fossils removed from private lands for any reason, including curation, without the written consent of the landowners obtained by the proponent's land agents.

A paleontologic resource protection presentation is given to the Environmental Inspector (EI), construction foreman, and for crew orientation during preconstruction meetings and sporadically during daily meetings. Unauthorized collection by workers or the general public can occur due to the increased access to the area. All workers are advised that unauthorized collection of vertebrate fossils is illegal. This is a law enforcement issue and is handled accordingly.

Inadvertent discoveries of significant fossils: Monitors, contractors, and construction workers are made aware that the Environmental Inspector, the paleontological supervisor, and the appropriate agencies must be con-tacted immediately if verte-brate or other significant fossil material are un-earthed during con-struction, even on segments where monitoring is not being required. Construction temporarily should be halted in the imme-diate area of fossil discovery until they are evaluated by these personnel. Generally, work is allowed to continue within 100 feet of the area of discovery without interruption unless further verte-brate fossil mate-rial is encountered. Salvage, removal, and documentation of fossil specimens are conducted as efficiently as possible to avoid delays to construction, while taking appropriate measures to avoid damaging the fossils. Well-delineated safety procedures meeting OSHA standards are mandatory.

All significant fossil localities are recorded by UTM and/or Latitude/Longitude coordinates with a GPS, generally to sub-metric accuracy. The types/taxa/numbers of fossils observed and/or collected are recorded in field notes, on individual specimen identification tags/field labels (TyVeck). The Trimble/ArcGIS database as well as field notes also include geologic units with stratigraphy and rock descriptions, photograph numbers, collector, date, and milepost. All fossils collected are stabilized as necessary prior to their removal from the field.

PREPARATION AND IDENTIFICATION OF FOSSIL COLLECTIONS

All fossils collected during the project may require preparation which involves cleaning (including rock removal) and stabi-lization (treating with appropriate preservatives and assembly of individual bones). Identification of fossils involves their assignment to a known (or possibly new) taxon, usually to genus. Numbering, boxing, and storage are done as prescribed by the designated curation facilities. Fossil locali-ties are plotted on USGS 7.5' quadrangle maps. A set of field and laboratory records as well as photographs with an itemized specimen invento-ry are compiled and filed at the cura-tion facility. The final paleontological report to the agencies includes these data and is approved prior to final acceptance of the entire pipeline project.

PIPELINE PALEONTOLOGY: OPPORTUNITIES FOR EXPLORATION, DISCOVERY, AND COOPERATION

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The current boom in oil and gas across the West is creating unique opportunities for paleontologists. Because of state and federal regulations and scientifically responsible energy companies, paleontologists are finding and collecting fossils from areas that were previously inaccessible. Recent examples of this are the fossils found on both Bureau of Land Management (BLM) and private land along Segment 2 of Kinder Morgan's Rockies Express-Entrega (REX) natural gas pipeline across southern Wyoming. Because of the oversight of this project by the Federal Energy Regulatory Agency (FERC), BLM guidelines for protection of fossil resources were followed on all lands.

Prior to construction of the pipeline, paleontologists with Uinta Paleontological Associates, Inc. (UPAI) surveyed the proposed right-of-way and access roads. Construction began in July 2006, and UPAI personnel were on hand to monitor construction activities in areas previously determined to be paleontologically sensitive based on literature and ground surveys. Fossils were found both in the wall of the trench and in the debris piles in areas all along the pipeline corridor and included plant, invertebrate, and vertebrate fossils. Among the vertebrate fossils found were scales and skull pieces of fish in the Upper Cretaceous Niobrara Fm., and dinosaurian fossils in the Upper Jurassic Morrison Fm.

On September 20, 2006, sauropod caudal vertebrae were found in both the debris pile and the ditch wall itself just south of Laramie on private land in the Upper Jurassic Morrison Fm. (Fig. 1) Excavation of the area began on Sept. 21, 2006, and continued for 5 weeks. Overall, the excavation did not slow down construction of the pipeline, and workers were able to observe the excavation as they moved around it. An estimated 10 tons of material was removed from the site, including many large plaster jackets. The excavation was aided greatly by a backhoe and operator supplied by Associated Pipeline, Inc.

In December of 2006 an agreement was

Figure 1: Excavation of the Laramie Pipeline Dinosaur.

reached between UPAI and the University of Wyoming to prepare the fossils in the UW Geological Museum. An existing preparation station was expanded, and full-time work on the fossils began in January 2007. As of March of 2009, taxa included adult and juvenile *Camarasaurus*, juvenile *Apatosaurus*, adult and juvenile *Allosaurus*, turtle, crocodile, and fish.

The preparation of the pipeline fossils in the museum has had many benefits for all involved parties. (Fig. 2) Community members, visitors, and students from preschool through college have been able to observe the preparation and talk to the working paleontologists, bringing science into their everyday lives. One of the most unique opportunites has been the involvment of student interns of UWTV who shot and produced weekly segments on the progress of the preparation. These segments were aired on Wyoming Public TV, YouTube, and as podcasts on the UW website. The students' work has not only allowed the public to see the preparation of fossils, but it has also helped educate them in how the largest industry in Wyoming can be beneficial to science.

Figure 2: Preparation of pipeline fossils at the University of Wyoming Geological Museum.

SITE SPECIFIC DATA USED TO EXPEDITE THE APPLICATION FOR PERMISSION TO DRILL PROCESS WHILE PROTECTING FOSSIL RESOURCES

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The San Juan Basin has been an important producer of oil and gas resources for over the past 60 years. There are approximately 22,000 currently producing wells in the Basin. Drilling activity continues and approximately 10,000 new federally administered wells are anticipated over the next 20 years. Providing processes to expedite oil and gas development while considering and mitigating for fossil resources has become a priority in the Farmington Field Office (FFO).

Formations of the San Juan Basin have, and continue to produce, significant vertebrate and invertebrate fossils. The fossils have made major contributions to the scientific record and are used for continued scientific study, education, and recreational enjoyment. The San Jose Formation yields one of the largest and most diverse vertebrate faunas of early Eocene age collected in North America. The Nacimiento Formation fossils document the most diverse early Paleocene mammal faunas known. Vertebrate fossils of the Kirtland Formation, including dinosaurs, crocodiles and turtles, continue to be discovered and studied by research teams.

There are approximately 1.4 million acres of public land (BLM) that fall inside the administrative boundaries of the FFO of which 118,074 acres of Special Designated Paleontological Areas (SDA's) are included in this figure. Potential Fossil Yield Classification (PFYC) maps of the San Juan Basin were also developed to provide limited utility for site specific projects. The PFYC offers a predictive model based on the geologic formations to produce significant fossils.

The Farmington Field Office Resource Management Plan (RMP) requires a target of 46% twinning of new wells on legacy well pads to reduce the environmental footprint. The RMP was published prior to the PFYC but did establish the Special Designated Areas where fossil resources were known from previous surveys. Legacy wells drilled in the 50's and 60's are slated to be twinned and were approved to drill without any paleontological surveys.

The existing PFYC maps of the San Juan Basin were developed on a small scale map (1:500K). Site specific paleontological 7.5 minute topographical maps are being generated from field surveys, existing locality NMMNHS data base, new oil and gas surveys, existing geological maps, and aerial photos of legacy well pads and associated surrounding terrain. The site specific maps will be overlain on USGS 7.5 minute series maps. Criteria used for this map development are: (1) industry high priority drilling areas, (2) legacy wells located in Special Designated Areas, (3) legacy wells located in #4 Ranked areas (PFYC maps), and (4) recently discovered fossil producing outcrops located within #2 and #3 Ranked areas.

GPS data is gathered while walking the perimeter of disturbed ground around legacy well locations. If fossil resources are located within the perimeter, it is entered into the data base as no new or additional disturbance location (no twinning permitted). Potential fossil outcrops are surveyed around the perimeter, and this data is entered into the data base as suitable for new disturbance, or not,

due to the results of the field surveys. Site specific fossil resource maps are then generated from the collected GPS data by GIS staff using ArcMap.

These maps will be a useful management tool for the planning stages of the APD process and in expediting high priority well APD packages while protecting fossil resource areas. Data from the maps will clearly identify site specific areas where additional time for planning and field surveys might be required because of a higher or lower potential to produce significant fossils. This information will provide industry and BLM a screening and planning tool for future oil and gas development. The use of this map by the FFO and industry will expedite the APD process and protect fossil resources.

THE BIODIVERSITY OF A WELL PAD: AN EXAMPLE OF THE IMPORTANCE OF PALEO-MITIGATION

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In the fall of 2008, paleontological consulting services were required for a natural gas well pad construction site near Lonetree, WY. Due to the time sensitive nature of the project and the assumed low potential for fossil resources, a paleontologist was requested for a pre-monitor survey and possible onsite monitor of the project. The project area was situated in a low rolling, drainage cut scrubland surrounded by the typical badlands topography of the Bridger Formation in the southern Green River Basin.

Heavily vegetated, low relief topography is usually a setting considered to be of low sensitivity for fossil resources. The survey of the access road and well pad yielded numerous isolated fossil fragments and fragmentary scatters throughout the colluvium in the project area.

Identifiable fossil material included: turtle shell fragments, crocodylian scutes, reptile vertebrae, fish vertebrae, mammal vertebrae, mammal post-cranial fragments with articular surfaces, mammal teeth fragments, gastropod shells and petrified wood fragments.

If not for the observed fossil material in the colluvium, the well pad could have been classified as a modern alluvial/colluvial feature, or class 2, which is of low fossil potential and would not have required a monitor of the project. A full onsite monitor of the construction was conducted, revealing a diverse assemblage of vertebrate fauna.

Identifiable material included: three classes, seven orders, seven families, eight genera and at least ten species of vertebrates. Several species of mollusk were also found during the monitor. The site was revealed to be a highly sensitive area (class 5) and a vertebrate fossil locality containing an abundance of scientifically significant material.

RESOURCE VS. RESOURCE: TERTIARY FOSSIL MAMMAL LOCALITIES IN THE WAKE OF OIL AND GAS DEVELOPMENT

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Both oil and gas development have impacted fossil resources throughout the Rocky Mountain intermontane basins with varying degrees of severity. In the Uinta Formation, Uinta Basin of northeast Utah, we collect middle Eocene fossil mammals, and we share these fossiliferous outcrops with the exponentially increasing presence of petroleum wells. Fossil mammal localities in the Uinta Formation, more often than not, preserve a great deal of species diversity, represented generally by teeth, skeletal elements, or trace fossils (e.g., coprolites). Over the last 15 years, we have collected more than 3,000 individual fossil mammal elements from the Uinta Formation, which is the type formation for the Uintan North American Land Mammal Age.

Figure 1. Former site of paleontological locality WU-33

Our efforts have increased both the number of new species and the number of individuals in known species, both components of overall diversity.

Since the onset of increased oil and gas development in the Uinta Basin, particularly after the year 2001, many of our fossil localities have been either destroyed or severely impacted by development activities in the basin (Figure 1). In 2006, Townsend and colleagues published a stratigraphic section detailing the relative positions of the most productive fossil mammal localities (61 measured localities; >250 total localities). Of those measured localities, 43% (N = 27) have been destroyed or severely impacted by development activities (well-pad construction or road construction) with 30% (N = 8) of these localities destroyed. During the last count, in 2008, at least 16 of the localities not included in the stratigraphic section have been severely impacted, and 31% (N = 5) of these localities have been completely destroyed. Based on these numbers, our current collecting paradigm in the Uinta Basin has shifted to include salvage operations on all localities.

The exploration for both petroleum and fossil resources in the Uinta Basin has proven successful for both the oil and gas companies and paleontologists alike. Nevertheless, it is apparent that a source of knowledge regarding the evolutionary history of life during the middle Eocene in North America is at stake.

STATUS OF THE SVP STANDARD GUIDELINES FOR THE ASSESSMENT AND MITIGATION OF ADVERSE IMPACTS TO PALEONTOLOGICAL RESOURCES

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The Society of Vertebrate Paleontology (SVP) Standard Guidelines for the Assessment and Mitigation of Adverse Impacts to Nonrenewable Paleontologic Resources have functioned well since their introduction thirteen years ago, in 1995. They become *the* standard against which the adequacy of all paleontological resource impact assessments and mitigation programs are judged. Many federal and state regulatory agencies have either formally, or informally, adopted the SVP's Standard Guidelines for the mitigation of construction-related adverse impacts on paleontological resources. The SVP's guidelines outline acceptable professional practices in the conduct of paleontological resource impact assessments and surveys; monitoring and mitigation programs; data and fossil recovery; sampling procedures; and specimen preparation, identification, analysis, and curation. The SVP's Standard Guidelines were approved by a consensus of professional vertebrate paleontologists, and most practicing professional paleontologists involved in mitigation adhere closely to the SVP's assessment, mitigation, and monitoring requirements as specified in the standard guidelines.

Briefly, SVP Standard Guidelines recommend that each project involving ground disturbance have literature and museum archival reviews, a field survey, and, if there is a high potential for disturbing significant fossils during project construction, a mitigation plan that includes monitoring by a qualified paleontologist to salvage any fossils discovered. They further recommend identification of the salvaged fossils, determination of their significance, and placement of curated fossil specimens into a permanent public repository, such as a museum or university.

Although the SVP Standard Guidelines have been successful in protecting paleontological resources, several paleontologists have recently suggested that the SVP should review the guidelines to determine their effectiveness and adequacy. In response, the SVP has decided to reconvene the Conformable Impact Mitigation Committee, which wrote the previous editions of the guidelines. The SVP has given this committee a new name, the "Ad hoc Committee on SVP Impact Mitigation Guidelines Revision," but it contains many of the previous committee members, along with some new members. Chair and Vice Chair of the new SVP committee are Bob Reynolds and Lanny Fisk.

Consideration of possible revisions to the SVP Standard Guidelines is particularly timely since several pieces of legislation are coming into effect that may apply to large tracts of land that contain paleontological resources.

1)The Energy Policy Act of 2005 is now being implemented by federal agencies and mandates that energy development take place on federal lands. Energy development projects must follow NEPA and conduct paleontological resource impact assessments prior to project. Persons currently involved in

these mitigation programs may not be qualified (e.g., archaeologists, historians, biologists, and inadequately trained geologists). SVP standard guidelines on adequacy of professional qualifications will help the BLM regulate the qualifications of consultants involved in these paleontological resource impact assessments and mitigation programs.

2)The Paleontological Resources Preservation Act has been included in the Omnibus Public Lands Management Bill that passed the Senate, January 15, 2009, with strong bipartisan support and which may soon be passed by the House of Representatives. If so, SVP Standard Guidelines will be helpful in guiding federal regulators in what is viewed as a large potential increase in paleontological impact mitigation programs.

The professional paleontological community must be proactive in establishing "best practice" guidelines for the protection of paleontological resources. The profession must step forward with standard guidelines so that individual federal and state agencies do not establish separate guidelines without professional input and, consequently, without consistency between guidelines. Likewise, the SVP Standard Guidelines should be acceptable to the community of professional paleontologists so that they do not develop their own individual guidelines independent of the SVP.

Suggested revisions to the 1995 edition of the SVP Standard Guidelines received so far have been only minor, involving primarily cosmetic, editorial corrections. If it were not for its potentially serious consequences, one suggested revision would actually be comical. This revision is the substitution of the word "*salvage,*" anyplace where the guidelines use the word, with the word "*recover*." This revision is necessary because some construction contractors have attempted to use the word "*recover,*" in the SVP Standard Guidelines, to argue that the SVP advocates simply recovering (i.e., covering back up) fossils when they are discovered, rather than salvaging them to be placed into public museums. Unfortunately, covering over archaeological resources "*to protect them*" <u>*is*</u> an accepted and even preferred alternative to salvaging the resources. To ensure that fossils are not "*protected*" in the same way archaeological resources are, the language in the SVP guidelines needs to be revised.

Other revisions being considered by the committee are standardizing verbs such as "*will be*", "*should be*", and "*may be*". Standardizing these verbs could help clarify, for environmental compliance managers and regulators, exactly what actions the community of professional paleontologists consider important and necessary, versus those that are optional or only recommended. The SVP Standard Guidelines should clearly and unequivocally state what the community of professional paleontologists considers to be the "*best practices*" for the protection of paleontological resources.

The SVP committee is actively seeking input, advice, and assistance in the development of its revised Standard Guidelines. If you have suggested revisions, amendments, or comments on the SVP Standard Guidelines that you would like to share with the SVP committee, please send them to the committee chair and vice chair at the addresses listed above. The SVP committee members will synthesize all comments received from the paleontological community to produce a more usable set of impact mitigation guidelines. The committee's goal is to develop guidelines that will result in even wider acceptance, approval, and application, resulting in greater protection of paleontological resources.

CALIFORNIA STATE UNIVERSITY, FRESNO AND THE CALIFORNIA DEPARTMENT OF TRANSPORTATION (CALTRANS): COLLABORATION IN PALEONTOLOGICAL RESOURCE ASSESSMENT AND IMPACT MITIGATION

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The California Department of Transportation (Caltrans) annually undertakes many road construction projects that can potentially impact significant fossil resources. Conditions such as land ownership and funding sources determine whether a project is affected by federal, state, and/or local laws and regulations. At a minimum, California state highway projects fall under the provisions of the California Environmental Quality Act (CEQA), which requires Caltrans to identify potential impacts to paleontological resources, determine the significance of project related activities to the resource, and identify alternatives or propose mitigation measures to reduce or eliminate the project related impacts. Over the past ten years, California State University, Fresno (CSUF) has assisted Caltrans with three dozen paleontological resource assessment and mitigation projects.

The recently completed State Route 180 West project in the city of Fresno, California, is an example of the collaboration between Caltrans and CSUF. In 2004, CSUF completed a paleontological resource assessment for Caltrans that identified three paleontologically sensitive strata in the proposed project area; Turlock Lake Formation, Riverbank Formation and Modesto Formation. These three formations have yielded significant vertebrate fossils elsewhere in the central valley of California. CSUF recommended that monitoring of construction related activities be conducted for disturbance of any *in situ* sediment below 2 m in depth. CSUF prepared a mitigation plan for the project and was contracted by Caltrans to conduct the monitoring.

In late April 2007, construction, excavation and paleontological monitoring for the State Route 180 West began. The monitoring crews consisted of a mix of local paleontological monitors, hired part-time by CSUF, and university students. Paleontological monitoring continued through mid-August that year until construction excavation ended. Three locations produced fossils; Drainage Basin D, Drainage Basin W, and the Hughes-West Diagonal underpass. Specimens were plaster jacketed and transported to the paleontology lab at CSUF for preparation. Bulk sediment samples were collected from Basin D and two sites at the Hughes-West Diagonal underpass and screened in an effort to recover microvertebrate remains. Screen washing failed to produce any fossils.

Two of the Quaternary strata produced fossils; the Riverbank Formation (~130,000 - 330,000 years old) and the upper unit of the Turlock Lake Formation (~615,000 years old). Basin D yielded specimens RCB 4-30-1 and RCB 4-30-2, mammoth tusk fragments recovered from the Riverbank Formation. Likewise, the Riverbank Formation at Basin W yielded specimen DHT 6-4-1, a partial mammoth femur and pelvic fragment; DHT 6-4-2, a partial mammoth molar; and specimen AAT 6-4-3, a partial lower mammoth molar.

At the Hughes-West Diagonal underpass, specimen MOU 15 ’07 5-31-1, a proximal end of a right scapula belonging to *Camelops*, came from the Turlock Lake Formation. Other specimens from the Hughes-West Diagonal underpass site came from the Riverbank Formation, including: MOU 15 ’07 8-14-1 and MOU 15 ’07 8-14-2, both mammoth rib fragments; MOU 15 ’07 8-14-3, a mammoth partial pelvic fragment; MOU 15 '07 8-14-4, a mammoth partial tusk; and MOU 15 ’07 8-14-5, a mammoth pelvic fragment.

This project provides a good example of how public agencies can work with educational institutions to undertake paleontological resource assessment and impact mitigation. For the university, the project provided students with valuable experience that otherwise could not be attained in a formal classroom setting. Students benefit from exposure to the field of applied paleontology, an opportunity to network with individuals from agencies that may be potential employers, the opportunity to refine laboratory skills in fossil preparation and identification, and a source of supplemental income. Because the university is restricted to charging state rates, the benefit for Caltrans is less money expended in mitigation than if using a private consulting firm. The success of a project like this also allows Caltrans to demonstrate how paleontological resource assessment and mitigation programs work to help preserve scientifically significant fossil resources.

BETWEEN A ROCK AND A HARD PLACE: SCIENCE AND THE COMMERCIAL FOSSIL TRADE

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Although collected for over 150 years, scientists studying Fossil Lake largely ignored the fossil plants until Fossil Butte National Monument FOBU began a project in 2004. Fossil leaves are rare relative to the abundant fossil fish for which Fossil Lake is famous. Of the fossil leaves found, only about one in fifty preserve enough detail to use in a scientific study. This project was not possible without the support and assistance from local commercial fossil collectors: a case study for a mutually beneficial relationship between science and commercial fossil collectors.

Legal commercial fossil quarries on private and state lands surround (FOBU) making it unique among fossil parks. These quarries extract, prepare and sell the same fossils the park is set aside to preserve, protect and interpret. This situation is not as alarming as it may appear. The land available for legal extraction of fossils is less than 5% of the remaining fossil-bearing sediments. Because of the NPS mission to preserve for future generations, the park does not aggressively excavate rock within the park to extract fossils. Therefore, the likelihood of park staff discovering rare fossils such as horse, snake, bird, bat or leaves is infinitely small. The commercial quarries, on the other hand, excavate large volumes of rock each year to collect the abundant fossil fish and, in the process, find rare fossils. Although sold on the free market, these fossils add to our knowledge of the 50 million year old ecosystem of Fossil Lake. The park has nurtured this mutually beneficial relationship with the local commercial fossil collectors. The collectors benefit by getting the most current science regarding fossils and sedimentology of Fossil Lake. The park benefits by photographing their rare fossils, later used for science and interpretation. Both sides benefit when a project requires fossils, such as a paleobotanical study. The collectors alert the park when they find fossil plants, and the collectors and the park get new information when the project is complete.

THE FOSSIL TREASURES OF UTAH'S WEST DESERT

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Fossils are long known to have been collected in the west Deserts of Utah. The early native American inhabitants frequented the House Range in Millard county because of the numerous springs and game animals. They observed that large numbers of unusual looking stones blanketed the ground near Antelope Springs. The Pahvant Ute Indians considered them to have magical powers and they gathered them out of superstitious beliefs that they gave them power over the enemies weapons. After all, these were obviously some kind of bug with a covering of armor.

As America began to extend its borders to the west, parties were sent out to survey the lands. One party, the Wheeler Survey Team, was working in western Utah and eastern Nevada. They came upon the same fossil beds in the House Range, west-central Utah. Specimens were sent back east for study. These fossil bearing rocks have since become world famous for their abundant, superbly preserved trilobites. Collectors from all parts of the world come to experience the enjoyment of collecting these little gems. Millions of these fossils have been collected for more than a century. Among the many persons collecting there have been commercial collectors, the occasional scientist, and a huge army of amateurs and hobbyists from around the world.

Figure 1. Trilobite from the west desert of Utah

Initially only the common trilobites were pursued, but with time, the adventuresome began wandering the hills in all directions, finding not only new locations but also new types of fossils. Trilobites have long been recognized and prized by the public. However, as it turns out, there are more than just trilobites to be found (Figures 1-3). Representatives of every Phylum of animal living today plus several extinct Phyla have are represented by fossils found there. They are primarily Cambrian in age, preserving the first radiation of multicellular organisms with hard parts; but there are older and younger time periods represented as well.

Many of the fossils of the Utah's west desert are rare and invertebrate scientifically important. Some are represented by a single specimen. Many species that lived here during the Cambrian age left fossil remains that will never be discovered. Some were found, only to be destroyed, lost, discarded or reburied in a box under someone's bed. They remain lost to science. A few of them are collected by individuals who know their monetary value and sell them to the highest bidders. These often end up in personal collections. A few are sold to museums or universities and a few others are donated and end up in the hands of responsible persons for study.

Unfortunately, too many important specimens are being overlooked, lost destroyed, etc. Also, valuable information about the location (provenience data) is also lost or never recorded. There are a number of factors that come into play regarding the loss of these resources:

A.) Commercial collectors for the most part are interested in turning fossils into cash. If they know that a certain specimen is scientifically important, that only ups the

value of the specimen. However, it is unfair to characterize all commercial collectors into this category. Some do offer these specimens to science for sale and others do donate them.

B.) Amateur collectors/rock hounds, are much more likely to share specimens with academia. Some have had unhappy experiences in this regard though. Specimens given to academia often fail to be properly utilized. Specimens remain unstudied for years and the finder is left feeling disappointed and disillusioned by the failure of science to publish their discoveries. They had hopes that the material was important enough to warrant the immediate attention from the scientist, who in fact is taking his time to study them at his own pace or has left them in a collection to be studied by others at some future date. The donor then feels that he has been let down and may not donate again.

Let me share a personal experience. Among the most unusual and most sought after fossils of the Cambrian Period is the rarely preserved soft-body, taxon Anomalocaris. This was the great predator of the Cambrian and for many years thought to be found only in the Burgess Shale of Canada. It is like finding the "T. rex" of the Cambrian Ocean. There have only been two complete specimens known to have been found in the United States. One was found by us in the Spence Shale of Northern Utah and the other by us in the House Range. The west desert specimen was found sitting on top of a debris pile from someone else's workings and had been dumped there not long before we happened on the site. The counterpart was not located and our discovery would have certainly weathered away if we hadn't recovered it that day. It is interesting to note that while we account for only a tiny bit of the fossil collecting, we do account for both specimens of Anomalocaris that have been found here. Both specimens were promptly sent to Dr. R. A. Robison at the University of Kansas

C.) Scientists have limited time and resources for doing field work. In the West Desert, most of them only surface collect and never turn a shovel or split open a bedding surface. Some of them are also uninformed about the potential for important scientific finds of rare soft body fossils, which may be quite indistinct to the untrained eye and thus, even scientists often overlook them. Scientists rely heavily upon the masses of amateur collectors who by their shear numbers provide the eyes and muscle to make the important discoveries of the rare fossils in this region.

So we ask the question, What can be done to preserve this great scientifically important resource and maximize its potential to benefit all our citizens?

1. Should commercial collecting on state lands be stopped?

2. Should the public be restricted from collecting on public lands?

3. Should the work be left to just the scientists?

The answer to all these questions should be NO. There will be no benefit to science if nearly all of the source for new discoveries is cut off. Certainly the illegal collecting and selling of fossils from public lands needs to be stopped. The location where the *Anomalocaris* mentioned above was found is presently being quarried for building stone.

There is a great potential for valuable specimens to be lost or destroyed. On the other hand, there are literally millions of common trilobites and were it not for the commercial diggers, these would have never made it into the thousands of museums, schools and universities all over the world. The wonder of a common trilobite in the hands of a child has the potential to change their life. Unfortunately, there is no incentive

for the commercial workers to do the responsible thing.

As for the casual collector, they are more likely to do the responsible thing if they know what they should do. Over the years, we have helped to educate hundreds of individuals to make them aware of how valuable these things are to science. Many collectors have been persuaded to share their important fossils finds with the proper persons. Our family has been collecting fossils for more than 75 years. Even so, the number of fossils we have collected are insignificant when compared to the millions of fossils collected by others. On the other hand, the contributions we have made to science are significant and the understanding of the Cambrian has been greatly enhanced by our donations as well as those whom we have influenced.

The effort to manage these lands and the valuable resources they contain should emphasize the promoting of responsible collecting through education. We need to let people know that they can potentially help science while having an enjoyable recreational experience.

*Note: Here is a short list of some of the important finds that have come from the west desert.

- *Anomalocaris*
- Aglaspids
- *Leanchoilia*
- Phyllocarids
- *Naroia*
- New Trilobites
- Other Arthropods
- Several new species of sponges
- New species of algae
- New species of echinoderms
- New worms
- Many other new plants and animals.

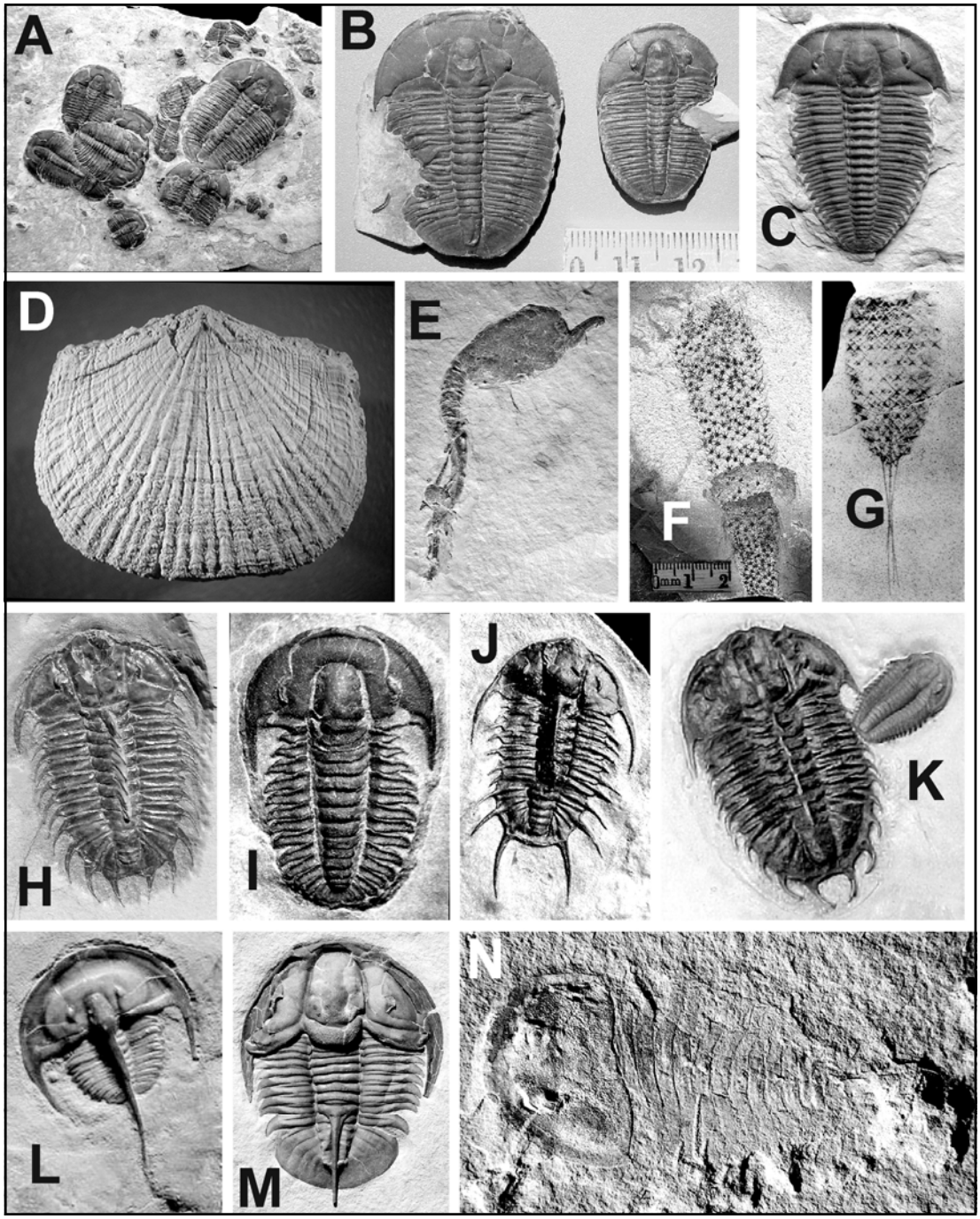

Figure 2. Some Cambrian fossils from Utah's west desert, courtesy of the University of Utah's "Utah Fossil Page" website: http://www.earth.utah.edu/utahfossil/. Middle Cambrian Wheeler Shale (approx. 520 million years ago), House Range, Millard County, Utah. **A**: *Elrathia kingi* with *B. housensis*; **B**: *Elrathia kingi* w bite marks from *Anomalocaris*; **C**: *Elrathina*; **D**: Brachiopod; **E**: *Castercystis vali* with "clinging" baby; **F**: Sponge *Chancelloria*. Middle Cambrian, Marjum Formation, House Range, Millard County, Utah, **G**: *Diagonella* sp.; **H**: *Olenoides pugio*, ; **I**: *Jenkinsonia varga*. Middle Cambrian, Pierson Cove Formation, Drum Mountains, Millard County, Utah, **J**: *Olenoides trispinus*; **K**: *Dorypyge swasii* with *Modocia*. Upper Cambrian, Weeks Formation (approx. 500 million years ago), House Range, Millard County, Utah. **L**: *Norwoodia bellaspina*; **M**: *Democephalus granulatus*; **N**: Aglaspid, *Beckwithia typa*.

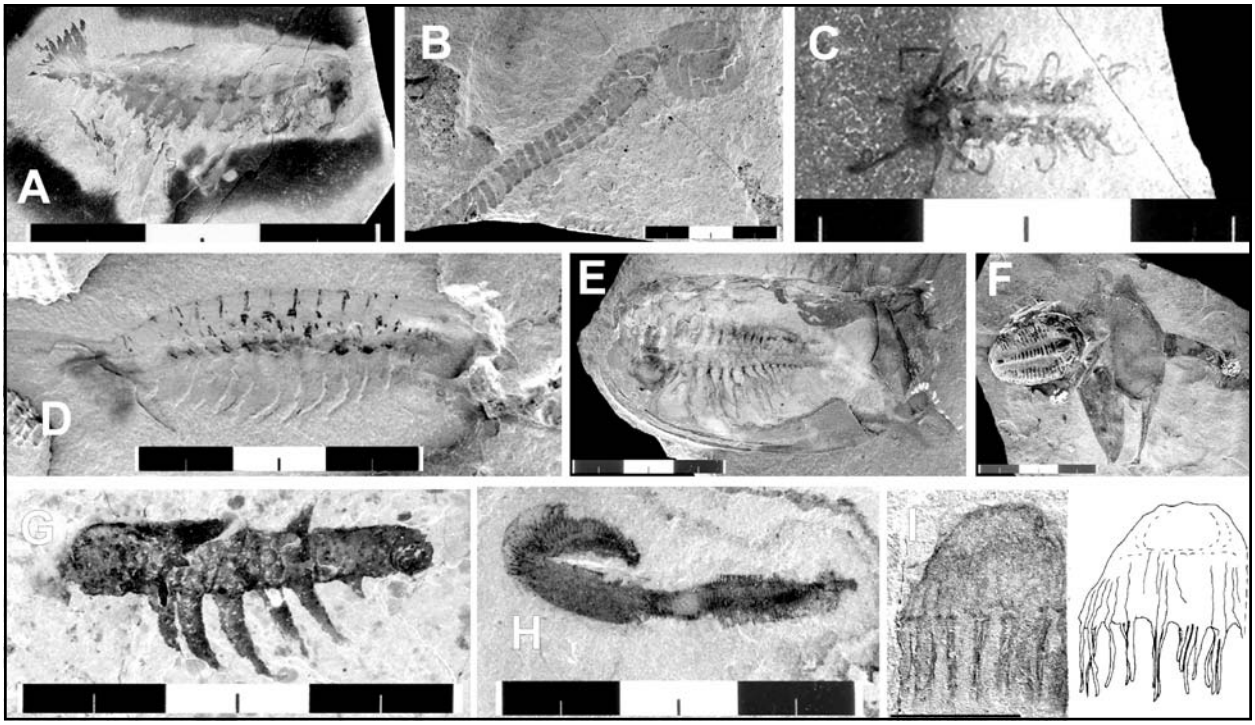

Figure 3. Some rare soft-bodied Cambrian fossils from Utah's west desert, courtesy of the University of Kansas's "Utah's Cambrian Life" website: http://www.kumip.ku.edu/cambrianlife **A**: Anomalocaris sp. Whiteaves, 1892, KUMIP 314087. Wheeler Formation, House Range, Millard County, Utah; **B**: Skeemella clavula Briggs, Lieberman, Halgedahl & Jarrard, 2005, KUMP 310501 (Holotype; part). Pierson Cove Formation, Drum Mountains, Millard County, Utah. Counterpart is University of Utah specimen UU 04083.01; **C**: Cambropodus gracilis Robison, 1990, KUMIP 204775 (Holotype; part, counterpart). Wheeler Formation, Drum Mountains, Millard County, Utah; **D**: Dicranocaris guntherorum Briggs & Lieberman et al., 2008, KUMIP 314079, Wheeler Formation, House Range, Millard County, Utah; **E**: Brachiocaris pretiosa (Resser, 1929), KUMIP 204797 (Part, counterpart). Marjum Formation, House Range, Millard County, Utah; **F**: Pseudoarctolepis sharpi Brooks & Caster w Elathria kingi, 1956, KUMIP 135142, Wheeler Formation, House Range, Millard County, Utah; **G**: Aysheaia prolata Robison, 1985, KUMP 153923 (Holotype). Wheeler Formation, House Range, Millard County, Utah; **H**: Pirapulid "worm", Ottoia prolifica Walcott, 1911, KUMIP 204770 (Part, counterpart). Marjum Formation, House Range, Millard County, Utah; **I**: Hydrozoan medusa, "jellyfish," UU 07021.03. Marjum Formation, House Range, Millard County, Utah. Scale bars in cm.

AN OVERVIEW OF PALEONTOLOGICAL RESOURCES ON FEDERAL AND STATE LANDS IN WASHINGTON COUNTY, UTAH

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Prior to the discovery of dinosaur tracks and associated fossils at the St. George Dinosaur Discovery Site at Johnson Farm (SGDS) in southwestern Utah, knowledge of paleontological resources within Washington County was limited. Several sites reported and recorded by the Utah Geological Survey were either from literature of older studies or found during paleontological resource assessments in the area. Prior to the SGDS discovery, the only well-known fossil locality in Washington County was the Warner Valley dinosaur tracksite. Because of the establishment SGDS and its staff efforts, over 160 new sites have now been recorded in the county.

The Upper Triassic Chinle Formation in Washington County has produced abundant metoposaur and phytosaur material, as well as, rare poposaurid and aetosaur remains. An excavation, in 2007, salvaged a partial metoposaur skeleton; two other discovered sites producing phytosaur material will require excavation permits. Abundant petrified trees have been recorded in the upper part of the Shinarump Member and lower Petrified Forest Member. Large areas have been looted for petrified trees and the landscape has been severely damaged in the process.

The Lower Jurassic Moenave Formation has produced abundant dinosaur tracksites. In the lower part of the Dinosaur Canyon Member, a unique site was discovered that is dominated by *Batrachopus* footprints and trackways. *Grallator* tracks are also present, and it is not known if this is Late Triassic or Early Jurassic in age. Several new plant localities in the Dinosaur Canyon Member have been found within a 25 mile radius of St. George, all containing identifiable conifer fossils. Fishes (hybodontids, semionotids, coelacanths, dipnoans, and palaeoniscoids) are very common in the Whitmore Point Member within the southern and eastern portions of Washington County but are, seemingly, much rarer in the northern part of the county. Rare, isolated theropod teeth have also been found associated with fish material.

The lower part of the "Silty Facies" of the Lower Jurassic Kayenta Formation is proving to be productive, not only for abundant dinosaur tracksites, but also petrified conifer trees displaying cellular structure, as well as, important fishes, thus far including semionotids and coelacanths. Larger bone fragments from possible tetrapods have been found but cannot be positively identified.

The Lower Permian Kaibab Formation, Lower Jurassic Navajo Formation, Middle Jurassic Carmel Formation, and Upper Cretaceous Iron Springs Formation in Washington County each have fossil-bearing sites discovered in recent years but require more intensive investigation.

AN OVERVIEW OF PALEONTOLOGICAL RESOURCES FROM STATE AND BLM LANDS IN LISBON VALLEY, SAN JUAN COUNTY, UTAH

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New exploration and research in the Upper Triassic Chinle Formation in Lisbon Valley, San Juan County, Utah, (Figure 1A) began in 2004 with a reinvestigation of fossil fish sites described by Bobb Schaeffer, in 1967, that lie primarily on State Institutional Trust Lands. Fishes turned out not to be the only important fossils in the region: abundant plants, invertebrates, tetrapods, and a variety of invertebrate and vertebrate traces were also found.

In 2005, 200 individual fish specimens were recovered from Walt's Fish Quarry, including *Hemicalypterus weiri,* the coelacanth *Chinlea sorenseni*, a complete specimen of the poorly understood *Tanaocrossus kalliokoskii* with a complete skull (Figure 1B), and several species of palaeoniscoids and semionotids. The *Tanaocrossus* specimen is particularly important because the holotype specimen lacks the front of the skull.

A brief return to the area in 2006 resulted in the discovery of a small, partially articulated, probably dinosauromorph hindlimb, part of the tail, and thoracic vertebrae from a conglomeratic horizon (part of the informal "Kane Spring Beds") within the Owl Rock Member of the Chinle Formation.

Prior to 2008, all research was conducted only on State lands. Surface collecting-survey permits were obtained by the SGDS in 2008, expanding the scope of exploration onto BLM land, and the number of new localities increased greatly, as did the membership list of the Chinle fauna of the area. Important discoveries include: a four foot long pseudopalatine phytosaur skull (Figure 1C) preserved in a thick conglomeratic unit (also part of the "Kane Spring Beds") in the Church Rock Member; a crocodylomorph and a large, articulated aetosaur skeleton in the Petrified Forest Member; and hundreds of tetrapod tracks (Figure 1D) in the Owl Rock and Church Rock members of the Chinle Formation and the basal Wingate Sandstone Formation. Other finds include fragmentary remains of metoposaurs, "rauisuchians," *Typothorax*, and *Desmatosuchus*.

Permits also allow for future exploration of the Permian Cutler Group and the Lower Jurassic Kayenta Formation. To date, as a result of our research, approximately new 70 sites have been discovered in the Lisbon Valley area.

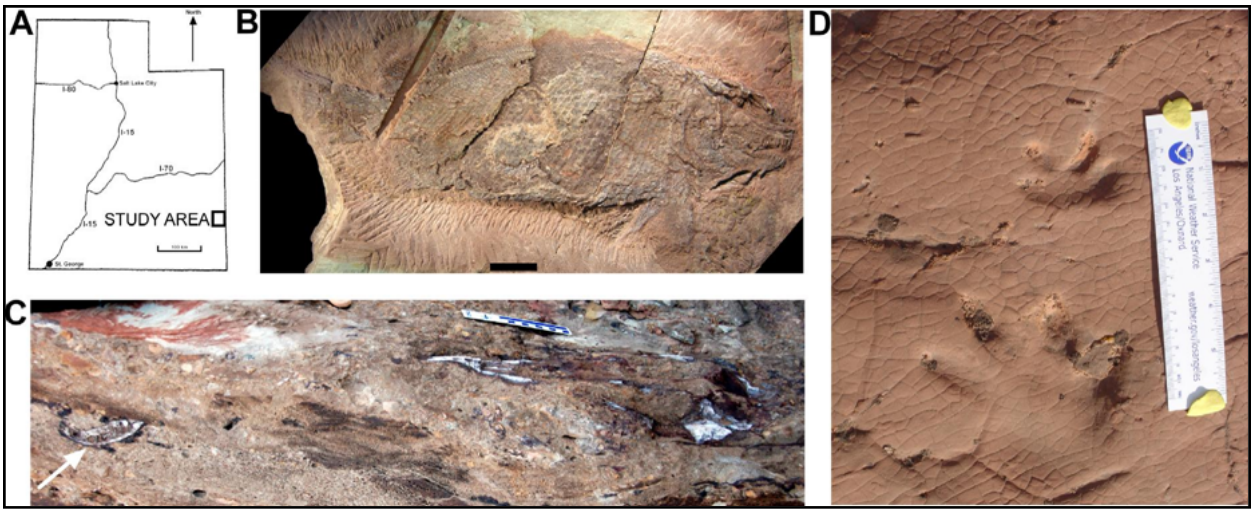

Figure 1. A: Locality map and some examples of fossils from the Chinle Formation in Lisbon Valley, San Juan County, Utah. A, Generalized locality map. **B:** *Tanaocrossus kalliokoskii* skeleton with complete skull. Scale bar = 1 cm. **C:** One half of a pseudopalatine phytosaur skull laying on its dorsal surface in conglomerate (white arrow points to the rostrum). **D:** *Brachychirotherium* trackway showing manus and pes prints from the Church Rock Member.

VERTEBRATE TRACKS AND TRACES ON PUBLIC LANDS: THE MANAGEMENT OF THE "OVERLOOKED STEPCHILDREN" OF VERTEBRATE PALEONTOLOGY

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New vertebrate tracksites are being found at an astonishing rate, as scientists and the general public increase their search image and pattern recognition for these types of fossils. These new discoveries indicate the need to properly locate, document, preserve, manage, and interpret these sites for current and future generations. Although the discoveries of fossil tracks are on the rise, the general understanding of the complexities of vertebrate ichnology and significance of these resources remains remarkable low. Unfortunately, tracks are often perceived as curiosities or as biogenic sedimentary structures, and as such, a casual approach may be taken to their study and documentation. Associated with this ichnological ignorance is the resulting misinformation and mismanagement that may result, which leads to difficult situations for scientists, land managers, and the general public. A much more serious approach to fossil footprints should be taken, as in fact, they are invaluable vertebrate fossil resources, which should be studied and managed in a similar fashion to significant body fossils. Fossils are any naturally occurring evidence of past (i.e., 10,000 years or older) life, including both actual remains and traces. Trace fossils can be found in any type of rock (e.g., sedimentary, igneous, and metamorphic) and reflect the activities of ancient organisms.

Although vertebrate body fossils (e.g., bones and teeth) are often the resources that are dealt with most by land managers, vertebrate tracks and traces are equally (if not more) important. Vertebrate trace fossils reflect the complex interrelationship between an animal and the substrate, providing information about, not only the trackmaker, but also the environment in which it lived. Thus, vertebrate traces must be documented, protected, studied, and managed in a similar fashion to vertebrate body fossils by individuals trained to do so. As thus, vertebrate paleontological research and collecting permits need to be issued for any research, collecting, or molding done at vertebrate tracksites, as all of these activities will affect the resource. In addition, an official repository must be established for formal track localities to be catalogued, along with molds, casts, and photographs, as well as, other field and lab data. These ichnological data need to be accepted and maintained as part of the permanent record for a tracksite, even though actual specimens may not be collected.

Not only do *in situ* tracks reflect the behaviors of ancient animals, they preserve the stratigraphic and geographic location of where these organisms once moved. Trace fossils indicate the paleoenvironment and paleogeography of the areas in which they are found. Unlike vertebrate body fossils, which in most cases should be carefully collected and removed from the ground once they have been uncovered, vertebrate ichnites (especially *in situ* trackways) should, in many cases, remain in place to preserve their preservational context. However, exposed tracks need to be protected from erosion and vandalism if possible. Fencing, covering, or enclosing a tracksite are some of the various strategies that have been developed to protect

trace fossils *in situ*. In addition, a permanent, accurate, three-dimensional (3D) record of the track is extremely important and should be collected as soon as possible to prevent scientific degradation. When conventional molds of tracks and traces are made, a soft, pliable molding material is placed on the track-bearing surface. In certain cases, the rock surface needs to be treated with a preservative or a separating compound prior to molding. Subsequently, hard casts are created from these flexible molds. In general, tracks should rarely (if ever) be replicated with a hard medium (e.g., plaster or resin), as these materials almost always remove some of the track-bearing surface. Unfortunately, in some cases, hard molds have been made directly from fossil footprints, resulting in significant damage and even complete destruction of the track. Even soft, pliable molding material can degrade a track-bearing surface when applied inappropriately or by those inexperienced with the track-bearing lithologies. Just as it is necessary for a qualified scientist (i.e., those experienced with proper paleontological collection methods) to remove vertebrate body fossils, it is equally important that paleontologists experienced in the complexities of vertebrate ichnology be the ones permitted by the appropriate land management agency to conduct molding, when deemed appropriate. In addition, it is recommended that 3D digital documentation (e.g., LIDAR or photogrammetric imaging) of tracks be conducted prior to molding. As every site is unique, with its own special set of tracks, preservation, and management decisions, each site needs to be dealt with on a case-by-case basis to make certain the best documentation, research, and management decisions are made. Proper communication between scientists and land managers is essential to guard against information loss inherent with bad scientific study or decision-making. Fortunately, with the development of state-of-the-art documentation techniques, various non-invasive, 3D data collecting techniques can now be used. Photogrammetry, LIDAR, and hand-held lasers are just a few techniques being utilized in the collection of tracksite data. These data can be used to develop a digital archive that can be shared and utilized by scientists around the world today and in the future. In addition, some of these techniques (e.g., photogrammetry) are excellent for collecting 3D data in remote locations.

One site which epitomizes the technological advances in vertebrate ichnology is the Red Gulch Dinosaur Tracksite in northern Wyoming. This Middle Jurassic dinosaur tracksite (discovered in 1997) currently is the most extensively and intensively documented dinosaur tracksite in the world. To properly preserve the scientific and educational resources at this Bureau of Land Management paleontological site, the data collected included traditional measuring, mapping, hand-sketching, and Mylar tracings, as well as, state-of-the-art documentation collection incorporating aerial photography, laser imaging, and photogrammetry. All of these data were integrated utilizing Geographic Information Systems analysis. Unique documentation technologies (especially low and high level photogrammetry) used at this site have spawned companion studies in various western states (i.e., Wyoming, Colorado, New Mexico, Oklahoma, Nebraska, Utah, Alaska, and Arizona), as well as sites in England, Scotland, and Korea. As each site presents a different set of unique conditions and resources, various documentation technologies have been tailored to the individual sites. The use of state-of-the-art documentation technology allows ichnologists to better interpret the formation, preservation, and location of vertebrate footprints in the context of their unique paleoenvironments. This morphologic, temporal, and spatial data also allows ichnologists to better understand the fascinating behaviors and community dynamics of prehistoric animals through only

their footprints.

Once properly studied, tracks left *in situ* can become wonderful "outdoor museums," as ancient spoors are fascinating to the public. For those fossil footprints on state and federal lands, showcasing these specimens to the public requires that important documentation and visitation decisions be made early in the management of the site. Unfortunately, the more visitation a tracksite gets, the more human erosion (sometimes including vandalism) is possible. Again, that is why it is imperative, prior to any tracksite being promoted to the public, that a thorough documentation of the site by trained vertebrate ichnologists occurs. Once "official" visitation begins, visitor surveys and erosional monitoring should be done on a regular basis. Proper documentation and study is critical to the preservation, interpretation, and management of a tracksite. At these "outdoor museums" the general public can learn to appreciate the educational, scientific, and recreational values of "their" fossil resources and become involved in helping to find new tracks, as well as, monitor and preserve pre-existing tracksites. Finally, scientists also need to practice the same guidelines expected of the public at tracksites, and thus, walking on, collecting, or casting certain tracks needs to be done with forethought as to the consequences of others acting as "amateur paleontologists."

As mentioned previously, each vertebrate tracksite is unique, and thus, qualified and permitted paleontologists (preferably ones trained in vertebrate ichnology) should be intimately involved with the documentation and research. These individuals also need to be in communication with the appropriate land managers of the tracksite. When these simple guidelines are not followed, problems can result in the location, documentation, study, interpretation, preservation, and management of a tracksite, as well as, the information disseminated to the scientific and popular presses. Poorly documented, studied, and interpreted tracksites are not only an embarrassment to science, but to the land management agencies as well. Tracksites without tracks; tracksites misinterpreted as to their extent or with over inflated numbers, miscalculations, or poor documentation; and tracksites with unsubstantiated behavioral interpretations are just some of the examples of poor science and misinformation that have been presented in the past, and often hyped by the media. Unfortunately, the lure of "prehistoric hyperbole" (or the race to the paleontological superlative) is strong in paleoichnology. Paleobehavorial interpretations are often highly subjective and become even more so when inadequate data is collected and compared. Limited evidence leads to greater inferences, assumptions, and speculations. In all cases, the data needs to direct the final interpretations not vice versa. Sometimes the research standards applied to the study of body fossils (e.g., literature searches, specimen comparisons, and detailed descriptions) are disregarded when it comes to vertebrate trace fossils. This results in scientists, who have previously seen few other tracksites, to wax poetic on the superlatives of their study area. Thus, proper documentation and comparative studies are critical. Similar to other areas of vertebrate paleontology, the lust for paleo-superlatives is often the goal. Naming the newest, the best, the biggest, or the smallest, almost always has more of an appeal than the search for the most average. Just as the "Bone Wars" of the 19th century were driven by competition for fame, the "Track Wars" of this century have resulted from scientists dealing with tracksites (many untrained in the science of ichnology) to vie for public and peer attention. Unfortunately, in some cases, the resource has suffered from these activities. In addition, as more vertebrate tracks are found and their abundance and localities become known, commercial operations have begun to collect and sell tracks, just as they do with other vertebrate fossils. Again, the removal of tracks from their original context can be devastating for subsequent research, especially if thorough locality information is not provided.

As trace fossils become more and more in demand for study, visitation, and sale, land management agencies must increase their regulatory oversight with the help of vertebrate paleontologists. In addition, land managers need to take care when using predetermined paleosensitivity levels for geological formations, as these are generally based on body fossils. In the past, vertebrate ichnites have been overlooked by paleontologists and geologists focused on other areas of study. Thus, field surveys may be warranted in many cases to truly determine the paleontological importance of an area.

Finally, the public needs to understand a) how tracks are formed, b) what tracks look like, c) why tracks are significant, d) how tracks should be documented, and perhaps most importantly, e) how they can help preserve tracks as part of our natural heritage. It is essential that those doing ichnological studies and those managing tracksites for the federal government also comprehend these five areas of understanding. As more tracks are found and more interest is generated around these significant paleontological sites, clear communication and cooperation must occur between vertebrate ichnologists and land mangers. With a positive teamwork approach to documenting and managing vertebrate trace fossils into perpetuity; great strides will be made to preserve this part of the geologic record of past life.

CLOSE-RANGE PHOTOGRAMMETRIC TECHNOLOGY FOR PALEONTOLOGICAL RESOURCE DOCUMENTATION, PRESERVATION, AND INTERPRETATION

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The United States Department of the Interior, Bureau of Land Management (BLM) is charged with managing almost 104 million hectacres (256 million acres) of surface land. This vast landscape includes some of the most scientifically important, as well as, ecologically and culturally diverse lands in Federal ownership. Documenting and evaluating the present and past conditions of this land is a critical part of the Bureau's mission. These data provide information on the status of the scientific and educational resources on the land and serve as a basis for future decision-making, as well as, providing tools for determining the effectiveness of present management practices. To most efficiently support the BLM's management effort, documentation methods that are quantifiable and repeatable are needed.

A tool for capturing current data is photography. While visually enlightening, a single photograph is in many ways anecdotal and can be biased by the perceptions of the photographer. However, photographs taken in such a way as to provide detailed and measurable three-dimensional (3D) data provide a more robust dataset from which an analyst can derive quantifiable information. The science and technology of this process is called photogrammetry. The formal definition of photogrammetry is: the art, science, and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring, and interpreting photographic images and patterns of electromagnetic radiant energy and other phenomena. In many instances, the use of photogrammetry can be more efficient, less labor-intensive, and more cost-effective than other types of field 3D data collection, resulting in products that have a level of detail, accuracy, range, and price that are difficult to match with other technologies. The basic requirement for photogrammetry is an overlapping pair of photographs taken to mimic the perspective centers of human stereoscopic vision (Figure 1). Photography, at virtually any scale (from a pair of images taken from an earth-orbiting satellite to extremely close-up images of minute features of a dinosaur track), can be processed using photogrammetric techniques. The resulting datasets integrate both corrected imagery and 3D surface data that can be viewed, manipulated, and measured by using Geographic Information Systems(GIS) and other similar software. The stereo images may be captured by a large variety of cameras at almost any height or platform (from tripod to earth-orbiting satellite). The advancement of digital cameras, along with the increasing capabilities of computers and analytical software, has dramatically expanded the variety of situations in which photogrammetry may be applied, while simultaneously decreasing the costs of acquisition, processing, and analysis. A variety of resource specialists (e.g., paleontologists, archaeologists,

hydrologists, soil scientists, biologists, range conservationists, and engineers) have benefited greatly from 3D products derived from modern photogrammetric techniques. This is especially true in the field of ground-based, or close-range, photogrammetry.

Terrestrial, ground-based, and close-range are all descriptive terms that refer to photos taken with an object-to-camera distance of less than 300 m (1,000 feet). This distance equates to the minimum safe flying height above populated areas, as required by the FAA. Since the same basic principles apply to photographs either taken from a camera mounted on a tripod (terrestrial) or suspended from an ultralite aircraft (low-level aerial), both types of nontraditional photogrammetry are referred to in this report as close-range photogrammetry (CRP). A variety of cameras and platforms may be used to obtain the photographic images used in CRP processing, including cameras housed in unoccupied airborne vehicles, suspended below helium-filled blimps, or mounted on tripods. Through the use of these nontraditional methods, a resolution, or ground sample distance, of 0.25 mm and a spatial accuracy equivalent to 0.025 mm can be achieved. Theoretically, there is no limit to the resolution that can be achieved from CRP images. Previously, extreme close-range photogrammetry was based on distance. as a point precision of less than one centimeter.

However, with the rapid innovations in digital sensor technology, the definition should be recast according to the precision of the data points, and thus, extreme close-range photogrammetry should be defined.

The BLM's national center in Denver has used close-range photogrammetric techniques to document resources since the late 1980s. At that time, although producing high quality results, the close-range photogrammetric process could be tedious and time-consuming, mainly because of the need to apply traditional techniques, workflow, and equipment to close-range image capture and processing. However, within the last decade, advances in digital imagery and photogrammetric software, combined with lower equipment costs, have enabled the use of photogrammetric methods over a wider range of applications, while at the same time reducing equipment costs and decreasing computing times, making the entire process more cost-effective. These advances have revolutionized close-range photogrammetry by removing many of the rigors of traditional aerial photogrammetry, thus, moving stereoscopic image collection from the hands of the photogrammetric expert to those of field personnel. A significant advantage of close-range photogrammetry is that images for a small project can be acquired with minimal field equipment and a small amount of training. Once taken, these images can be processed to a detailed, 3D grid of thousands of precise data points or archived and processed when needed to provide quantifiable measurements. This can support scientific study, long-term comparisons, and provide a visual and metric dataset that cannot be achieved through any other method. Because accurate measurements can be made from the dataset, the resulting measurements are more reliable than simple anecdotal evidence (e.g., a single photo). In addition, these datasets can be more persuasive, thus supporting better-informed observations, interpretations, and conclusions.

In addition, on-line services for processing imagery to a 3D surface are available. While cost and availability may be a current limiting factor, it is almost certain that in the near future similar software will be available from a wider variety of venders and at greatly reduced costs. However, with current digital cameras and low cost data storage, the capability to take the needed photographs for close-range photogrammetric projects is available today. Scientists, resource professionals, and field personnel with a vision toward the future can realize the value in capturing stereoscopic photographs now.

To aid in the proper collecting of the stereoscopic imagery, the BLM, National Operations Center, Division of Resources Technology has develop a document that

describes image collection for a small CRP project. BLM Technical Note 428, "Resource Documentation, Preservation, and Interpretation: Aerial and Close-Range Photogrammetric Technology in the Bureau of Land Management" is now available in digital format. The Technical Note contains an overview of photogrammetry in general, and specific examples in the use of CRP.

It also includes technical information to assist in the successful completion of the imagery collection portion of a basic, close-range photogrammetry project, including the basics of stereoscopic photography, features that should be considered when choosing a camera, factors that can affect picture quality, and the general steps for conducting the field collection.

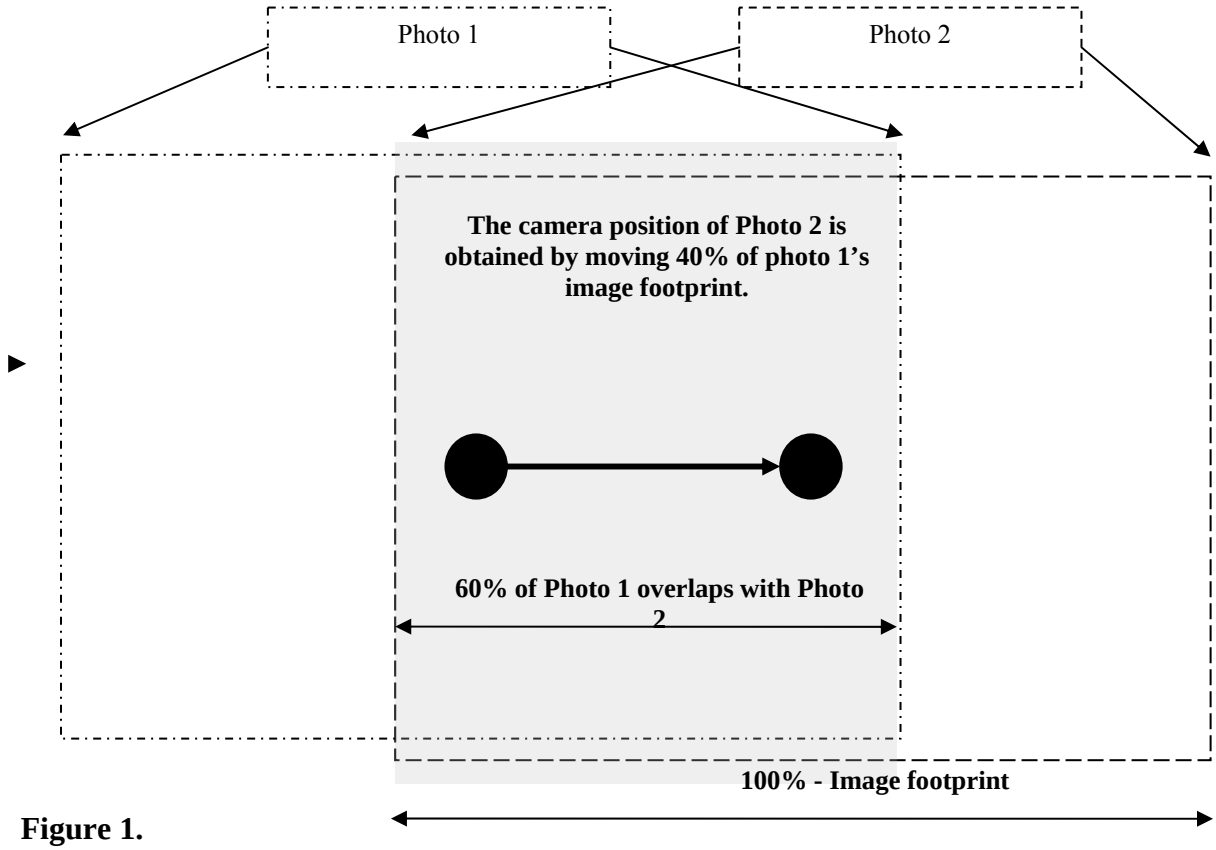

Figure 1.

DOCUMENTING THE ICHNOLOGICAL MENAGERIE AT THE NORTH MOCCASIN MOUNTAIN TRACKSITE, UTAH: SCIENCE, TECHNOLOGY, AND RECREATION MEET FOR PALEONTOLOGICAL RESOURCE MANAGEMENT

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In the fall of 2007, an occurrence of dinosaur tracks was reported to the Bureau of Land Management (BLM), Kanab Field Office by a group of hunters. The tracks are located in Kane County about 3 miles west of Coral Pink Sand Dunes State Park (a popular off-highway vehicle area) on land managed by the BLM, Kanab Field Office (see Figure 1A). Upon investigation by the BLM, a spectacular vertebrate paleontological resource was brought to light. The North Moccasin Mountain Tracksite (NMMT) reveals multiple track levels in the Early Jurassic Navajo Formation (age ~185 million years) in a slickrock sandstone area covering about 1,000 m^2. The Navajo Formation is about 550 meters (1800 ft.) thick in the area. This unit was deposited at a time when the North American continent lay just north of the equator. This geographic position led to extremely dry, hot, interior conditions in which very little vegetation could survive. As a result, tropical winds blowing from what is now the north carried sand from the northern Wyoming and Montana area into what became the largest deposit of windblown sand in earth's history. Tracks are difficult to preserve in unconsolidated dry sand, and thus, those preserved at the NMMT indicate that the loose sand in interdune areas was frequently saturated with water, perhaps due to local scouring by windstorms or strong persistent winds down to the local water table. Evidence of small oases or playa lakes (common in the Namibian Desert today) are preserved at the Navajo Formation as thin layers of grayish limestone, which often contain tracks and algal remains.

The North Moccasin Mountain Tracksite provides an ideal opportunity for the successful synergy of management, science, technology, interpretation, and recreation. Off-highway vehicle (OHV) recreational activity is extremely popular in southern Utah, as in much of the West. Coral Pink Sand Dunes State Park and nearby areas are experiencing a rapid increase in this type of use. Unfortunately, OHV activity and vandalism has impacted the track surface at the NMMT, necessitating the closure of the track-bearing area to vehicular traffic to protect the significant paleontological resources located there. The Kanab Field Office enlisted local volunteers and OHV clubs to help install a protective fence, monitor and patrol the area, and educate visitors regarding the resource values, as well as, encourage minimally impact travel across

the site.

Scientifically, the NMMT contains a high ichno-diversity and several important preservational features. At least six different track types have been observed, including small and large bipedal forms attributable to tridactyl theropods (represented by *Grallator* and *Eubrontes*); a facultative tetradactyl biped (represented by *Otozoum*), attributed to a prosauropod; a quadrupedal form (represented by *Batrachopus*), attributed to a crocodylomorph; and possible synapsid tracks (see Figure 1B). Tracks occur on both the dune foreset beds and the interdune bounding and truncation surfaces. However, due to the large number of tracks and the unique morphologies (no doubt influenced by slip and shear at the time of track formation, and later by cross-cutting erosion of the Navajo Formation dunes), more ichnogenera may well be present. These ichnites are preserved as underprints, in convex hyporelief, and more rarely in concave epirelief. The morphology of the footprints varies from the distinct preservation of anatomical features (such as pads and claw impressions) to heavily trampled surfaces exhibiting the mottled bedding of dinoturbation. Invertebrate traces are also present and consist of both horizontal burrows (*Planolites*), found on inter-dune bounding surfaces and vertical forms that crosscut dune bedding.

A range of ichnite sizes are present. The largest tridactyl tracks are commonly greater than 25 cm in length and exhibit a digital divarication angle of less than 35°. These are readily referable as *Eubrontes*, the most common large theropod track known from the Colorado Plateau. Several *Eubrontes* trackways (from 6 to 10 steps) are present and appear to occur along the dune face. Morphological features indicate weight being placed on the down slope side of the foot. In addition, slip and shear features, combined with surface exposures at various levels within the track formation continuum (from the point when the foot enters the sediment to when it leaves it), result in many uncommon ichno-morphologies. Other large tridactyl tracks (roughly 25 cm long by 22 cm wide) exhibit widely splayed digits with a divarication angle of about 45°. These forms have been classified as belonging to the ichnogenus *Kayentapus*. Smaller tridactyl tracks are present and fall within two size ranges. Those approximately 10 cm long with narrow divarication angles are assigned to the common ichnotaxon *Grallator*. Tiny tracks (as small a 2.5 cm) are also present and may possibility represent juveniles or a previously unnamed ichnotaxon of theropod dinosaur. Distinct tetradactyl tracks also occur. Large (> 30 cm long) ichnites of this type, with a rather symmetrical orientation of the digits (about 15° between each) and distinct claw impressions, represent the track genus *Otozoum*. In addition, partial manus tracks have been found associated with some of these footprints. Smaller (approximately 10 cm long) tetradactyl forms are present and may represent the ichnotaxon *Batrachopus*. Small, rounded tetradactyl (and occasionally pentadactyl) tracks (diameter ~6-7 cm) may represent synapsid trackmakers.

Due to the high occurrence, ichnotaxonomic diversity, and morphological variations, the tracks at the NMMT provide an uncommon glimpse of an oasis in the midst of the vast Jurassic Navajo desert. This evidence of a diverse menagerie alone warrants a high level of study and documentation that coupled with the opportunity for scientific study, public interpretation, and recreational opportunities make NMMT worthy of special consideration. To better understand the track diversity present and to provide a baseline, documentation and mapping of the site began in March of 2008. At that time, determinations were made of the possible methods and resources needed to map the site as a whole. In addition, selected tracks and trackways were documented using close-range photogrammetric techniques. The photographs were processed in a three-dimensional measuring and modeling photogrammetric software program to produce very high-resolution (0.05 millimeters), three-dimensional image

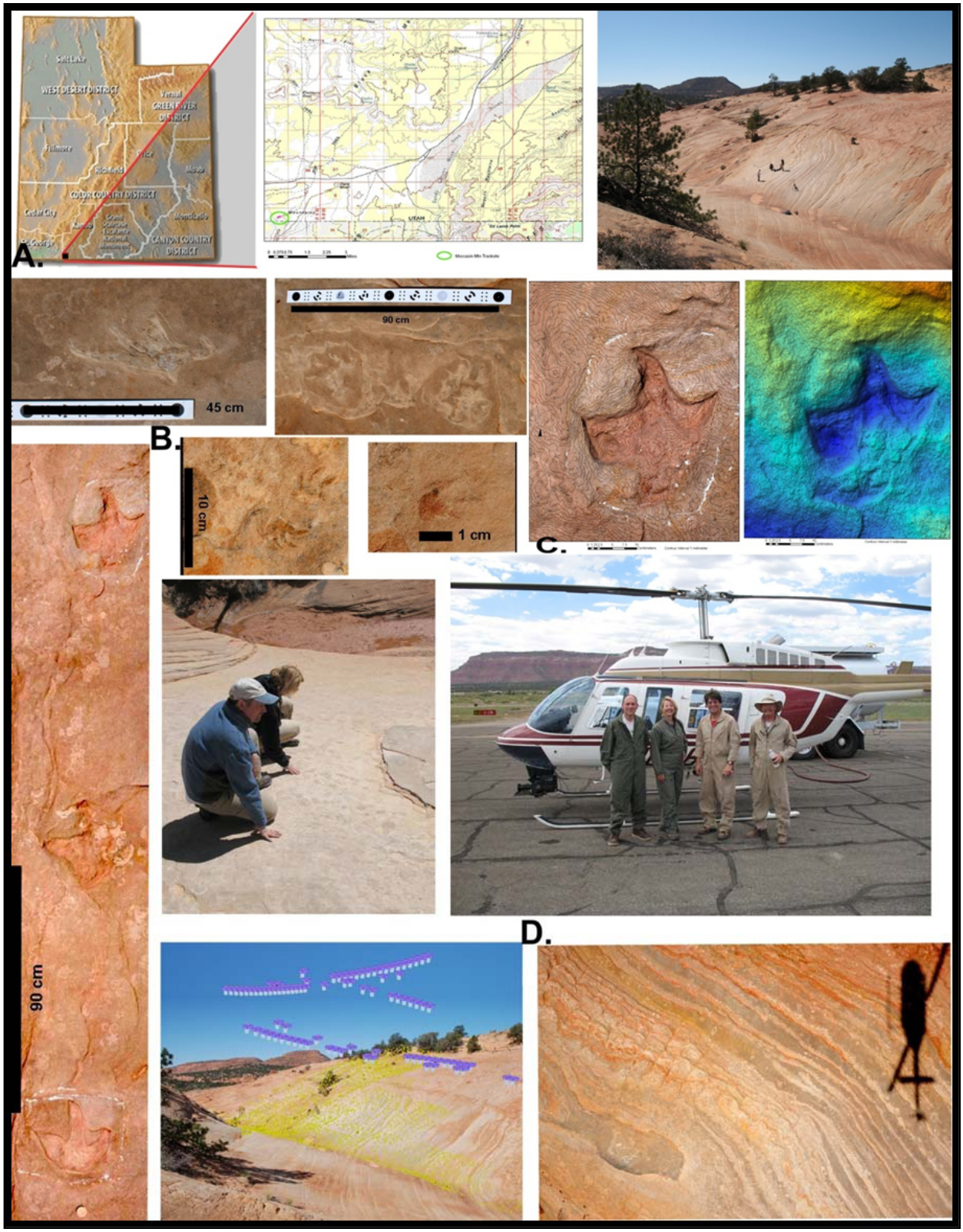

Figure 1. A. Location map of NMMT; B. Sampling of the variety of sizes, preservation, and track types present at NMMT; C. Photogrammetric images of a NMMT track with the terrain surface represented as 1 mm contours; and D. Aerial photogrammetric documentation including helicopter team, image of site with aerial camera stations in lavender, and low-level aerial image.

datasets. This non-destructive method provides a permanent 3D digital record of the tracks and trackways (see Figure 1C).

In June of 2008, low-level aerial photography of the site was conducted through the joint efforts of the BLM and Bureau of Reclamation (see Figure 1D). A specially outfitted Bellranger helicopter was used to make a number of passes over the site. During these passes, high-resolution (3 to 5 cm), digital stereoscopic photographs and video footage were acquired. Preliminary products from this flyover include various 3D image models and an overall mosaic of the area.

The digital virtual representations provided an effective tool for presenting the uniqueness of the site to OHV enthusiasts and other members of the general public, to land managers, and to the scientific community. These 3D image models will also be excellent tools for interpreting this unique site and increasing the awareness and concern for such natural treasures.

INTEGRATED LIDAR & PHOTOGRAMMETRIC DOCUMENTATION OF THE RED GULCH DINOSAUR TRACKSITE (WYOMING, USA)

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At the First International Symposium on Dinosaur Tracks and Traces in 1989, concerns were expressed about the ability of the paleoichnological community to preserve the unique fossil resources at many vertebrate tracksites. The last two decades have seen a coordinated effort from the political and scientific communities to achieve sustainable conservation of paleontological heritage sites for future generations of scientists and the general public. Although concerns persist about many of the most fragile sites, the sheer number of successful schemes is testament to the advances made in attitudes and approaches to fossil site management.

A noteworthy feature in management of paleoichnological sites has been the on-going adoption of digital data collection and imaging techniques used to document fossil resources. Digital techniques are typically non-invasive, fast, and highly accurate, with the quality of site visualization extremely high and superior to traditional methods of documentation in terms of accuracy, resolution, and functionality. Digital models are also fully interactive, allowing the user to later explore and quantitatively interrogate sites in the 3D realm without physically being there, facilitating collaborative research without geographical restrictions, a facility that is hampered by traditional paper-based methods of documentation.

Since its discovery and formal description in 2001, the Red Gulch Dinosaur Tracksite (RGDT) in northern Wyoming (USA) has been a test bed for many new innovative digital documentation techniques (Figure 1). This recent work at RGDT illustrates the benefit of integrating new non-intrusive visual technologies with traditional field methods. The resulting image database can be developed for site visualization, education and resource management, as well as, functioning as a research tool that can be repeatedly utilized to assist in paleontological and geological interpretation.

This paper reports the results of a preliminary Light Detection And Range (LiDAR) and photogrammetric survey at the RGDT carried out in the summer of 2008 (Figure 2). A fully integrated digital camera allows photographic images to be combined with LiDAR point clouds to produce photo-realistic 3D models. Photo-textured Digital Outcrop Models (DOMs) are a powerful visualization tool and function as fully interactive 3D databases that preserve information about the site that would otherwise be permanently lost. The Differential Global Positioning System (DGPS) built into the LiDAR unit provides sub-metre global position information and

allows data to be integrated with other georeferenced datasets. In addition to LiDAR and photogrammetry, a short range laser scanner capable of generating sub-millimetre resolution point clouds has also been tested as a means of imaging the 3D geometry of individual tracks in the field.

The data collected in the field provides full 3D coverage of RGDT and its surrounding landscape. The overall result is a highly flexible spatially integrated data set from which a wide variety of 3D DOMs can be produced for specific research, conservation and educational purposes. Work to-date has concentrated on producing a generic 3D model of the RGDT. The model is currently composed of the entire LiDAR scan data set (i.e. panorama and fine scans from all scan stations), with points coloured using digital photographs.

The model provides full coverage of the spatial extent of the RGDT and its immediate surrounds, and, as a 'medium-resolution' model, it is easily manipulated and rotated to view the outcrop from any perspective. The resolution is sufficient to provide detailed representation of the geometry of the outcrops and certain geological features (e.g. bedding), as well as, the topography and many small-scale features in the surrounding landscape (e.g. roads, vegetation). However, the resolution was not sufficient to depict tracks and trackways even when the track-bearing surface was viewed at close proximity. Work on higher resolution models, particularly photo-textured DOMs of the track surface, is currently in progress. Alignment and georeferencing of the entire data set has also made integrating the short-range laser scan data in its true spatial position and orientation straightforward. These high resolution (sub mm) models of individual tracks can be 'dropped' into the colour LiDAR site model in their correct locations, and subsequently be contoured and colour-coded according to depth, allowing highly accurate and repeatable 2D and 3D measurements.

In addition to further model development, future work will include integration of this new data with existing digital and traditional records of RGDT. This again is made possible by georeferencing of present and past data sets and will allow the development of a comprehensive 3D image-based GIS archive.

By combining photogrammetric and LiDAR-derived 3D digital outcrop models with previously collected and collated ichnological data, statistical analyses can be made that are both far more comprehensive and objective than was previously possible. Repeat surveying will also allow scientists and conservation agencies to monitor the deterioration of the site and evaluate potential protective measures. For example, high-resolution surveying could be performed annually to quantify and visually display the the erosion of fossil tracks on an exposed bedding surface. The striking visual presentation achieved through these digital methods will improve the ability to compare results and subsequently draw more informed conclusions from wider ranging datasets. This similarly means that digital models of fossils can be effectively used to visually communicate what would otherwise be complex or technical information to a non-academic audience.

Digital, or 'virtual,' fossils can also be used in stand-alone interactive educational displays for museum exhibits or websites in addition to public engagement events. The electronic 'life' in these fossils is particularly attractive to the generation of computer literate students who start using computer-based learning packages from an early age. Working animations and interactive displays can be constructed for museums and websites providing remote access to the fossil resource or situated on site to allow close examination without risking damage, encouraging geotourism, and promoting awareness of palaeontology.

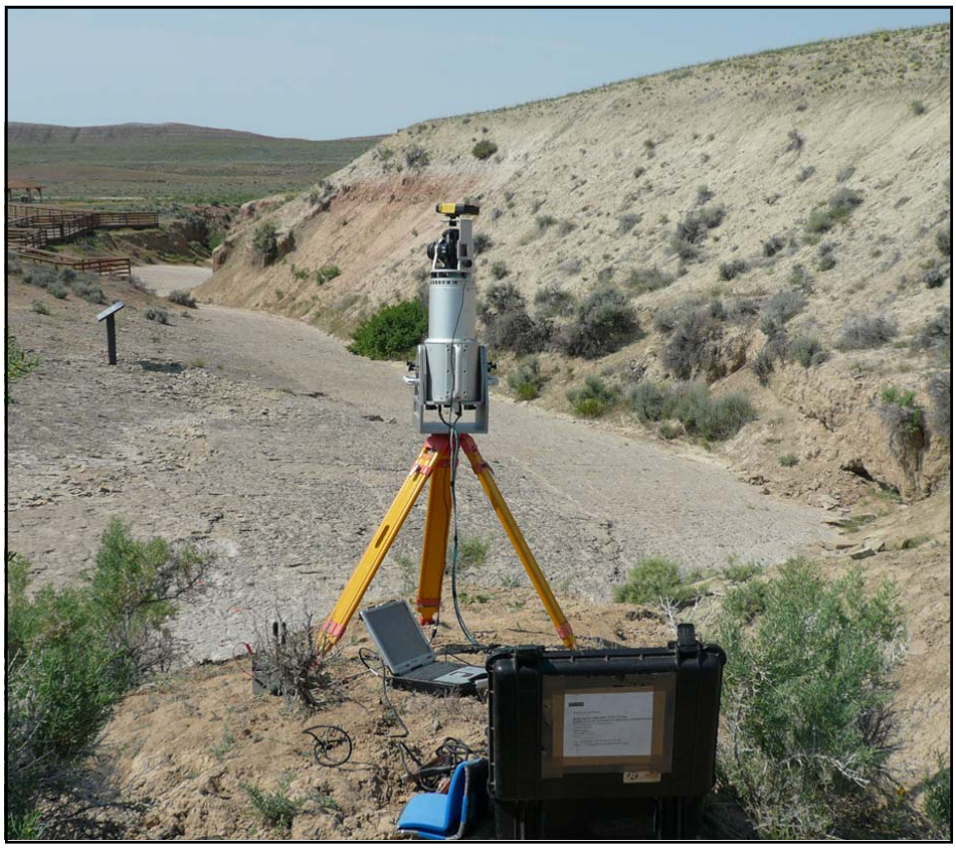

Figure 1. Red Gulch Trackway site in northern Wyoming.

Figure 2. Integrated LiDAR and photogramic survey at the Red Gulch trackway site in northern Wyoming.

LATE JURASSIC PTEROSAUR AND SAUROPOD TRACKS FROM THE SEMINOE RESERVOIR TRACKSITE, WYOMING

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Outcrops of the Jurassic Sundance Formation in Seminoe State Park, Carbon County, Wyoming, contain an extensive array of pterosaur and sauropod tracks managed by the State Park and U.S. Bureau of Reclamation. At the Seminoe Reservoir Tracksite (SRT), pterosaur tracks are located approximately one meter below a very fine-grained sandstone layer that contains dozens of sauropod tracks. All of these tracks are found in the Windy Hill Sandstone Member (late Oxfordian-early Kimmeridgian) of the Upper Sundance Formation.

At the SRT (University of Wyoming locality V-2006-018), track-bearing layers of the WHSM contain natural casts and impressions of pterosaur tracks preserved in well-sorted, fine-grained quartz sandstones. Pterosaur tracks are visible on the undersides of overhanging ledges, on fallen sandstone blocks, and on upper surfaces of sandstone beds in the Seminoe Reservoir area.

Quantitative and comparative analyses of the pterosaur tracks and trackways at the SRT with those previously described from other sites were part of a McNair/EPSCoR sponsored project run through the University of Wyoming Geological Museum's Undergraduate Research Program. Immediate documentation was important due to the recent exposure of the blocks containing pterosaur tracks related to low water levels, the fragileness of the layer containing sauropod tracks, and the destruction by natural erosion and humans on the trace fossils in the area.

The objectives of this nearly two year-long undergraduate study (2006-2008) were to locate and document the newly discovered pterosaur and sauropod tracks, determine the ichnotaxon of the pterosaur tracks through comparative analysis, and investigate the quadrupedal motion of pterosaurs. Pterosaur tracks were documented and analyzed using a combination of conventional measurement techniques, sketches, and photography. The documentation of the individual pterosaur tracks included measurements of length, width, and depth. Trackway measurements included pace, stride, straddle, and gait width. Mylar tracings were made of individual tracks and trackways found both *in situ* and on fallen sandstone blocks. Digital photos were used for off-site track examination and close-range photogrammetric analysis.

The intrinsic accuracy of data captured by the photogrammetric process allowed for improved interpretations of the tracks. Although the project focused primarily on the pterosaur tracks, the sauropod tracks were documented preliminarily in a similar fashion. The sauropod tracks are found along a 20-meter long sandstone outcrop above the pterosaur track-bearing layers. Dozens of sauropod footprints are preserved as undertracks with high impact rims; many of these ichnites display overprinting. At the SRT, track-bearing stratum of the WHSM unconformably overlies fossiliferous sandstones and shales of the Redwater Shale Member of the Sundance Formation.

Numerous invertebrate body and trace fossils are found within this unit. The marine nearshore transition sands of the Sundance Seaway contain the sauropod tracks. The contact between the Sundance and overlying Morrison Formation is difficult to pinpoint at the tracksite location due to the gradation of Sundance nearshore marine strata into terrestrial, cross-bedded dune deposits of the Morrison Formation. During the Late Jurassic, the inland Sundance Sea extended southward into Wyoming from the northern Pacific and Arctic Oceans. Deposition in this shallow sea began in early Bathonian time and continued through Oxfordian time in a series of steady advancing pulses. Coastal tidal flats, developed in the Late Jurassic as the Sundance Sea, retreated northward.

The Seminoe Reservoir Tracksite contains more than 250 pterosaur tracks, with 85 pes and 75 manus tracks formally documented to date. Pterosaur tracks are preserved as natural casts (i.e., hyporelief) and as impressions (i.e., epirelief). Presently, tracks have been found on 20 *in situ* blocks and over 25 float blocks at the site. The pes tracks are plantigrade, exhibiting a symmetrical, narrow V-shaped heel, with four slender, clawed toe impressions (Digits I-IV). Pes track length measurements vary from 60 to 121 mm, while the widths range from 18 to 59 mm. Pes depths vary from 0.3 to 14.1 mm. The outward rotation of most of these tracks varies between 0° to 45°, with a mean of 15°. Manus tracks are digitigrade, asymmetrical, and exhibit three digit impressions.

Digit impressions I and II are smaller and blunt, while digit impression III is longer and tapers to a point. Manus track lengths vary from 55 to 157 mm, widths from 16 to 50 mm, and the depths range from 0.7 to 50 mm. Manus prints have a greater outward rotation than the pes tracks and are found behind, and lateral to, the pes tracks. The tracks were measured along the direction of travel and displayed an outward rotation ranging from 156° to 178° from the trackway midline. Manus tracks are deeper than matching pes tracks. Over twelve trackways (two to six sets of pes and manus tracks) have been located. *In situ* trackways are generally oriented to the northwest and northeast. Trackways indicate differences between pes and manus motion. In these trackways, pes pace varies from 165 to 333 mm and stride varies from 331 to 499 mm. The pes trackway midline varies from 25 to 45 mm, and pes pace angulation varies from 130° to 160°. The pes gait width ranges from 60 to 127 mm. Likewise, the manus pace varies from 193 to 316 mm and stride varies from 301 to 515 mm. The manus trackway midline varies from 50 to 119 mm and the manus pace angulation from 98° to 178°. The manus gait width ranges from 129 to 170 mm.

The collection of this large ichnological dataset from the Seminoe Reservoir Tracksite provides important information for the understanding of size distribution, terrestrial quadrupedal locomotion, and behavior of Jurassic pterosaurs, as well as, the Late Jurassic paleoecology of south-central Wyoming. As the pterosaur tracks are well preserved, a detailed morphologic comparative analysis of *Pteraichnus* ichnospecies can be attempted. In addition, the large quantity of tracks within this small area shows interesting variation in size and morphology. Differences in track size supports the idea that various sized animals were walking along the shoreline of the Sundance Seaway. Variance within trackways and between trackways (such as distance between the pes and matching manus, pace angulation, and trackway width) is probably related to kinematics of the step cycle, animal behavior, and substrate consistency. Most of the pterosaur tracks found at the SRT are assigned to the ichnospecies *Pteraichnus saltwashensis*, as they are morphologically similar, found within the same stratigraphic level, and track measurements statistically fall in a comparable range.

These tracks are of scientific and educational importance. The presence and abundance of tracks at the Seminoe Reservoir Tracksite are valuable and represent a

dynamic ecosystem of animals living along the Sundance Seaway. The pterosaur tracksite is significant because of the documentation of a large number of ichnites, representation of both casts and impressions, preservation of good morphological characteristics, variation of track sizes, and location of various trackways.

This site is accessible for research and interpretation to the public and has been used as an educational resource for the past three years for college classes.

Preliminary conservation methods have been taken at the SRT. The Seminoe State Park has signed and blocked off a dirt road to the site to deter driving of vehicles to the site. Off-highway vehicle tracks have been seen on the sauropod footprints prior to the road blockage. In addition, small, loose sandstone blocks containing pterosaur tracks have been collected, cataloged, and curated into the University of Wyoming Collections. Finally, interpretive signage and trails are planned for this unique paleoichnological area in the future.

COOPERATIVE MANAGEMENT OF PALEONTOLOGICAL RESOURCES ON PUBLIC LANDS IN MESA COUNTY, COLORADO

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The Museum of Western Colorado has long had a history of working in cooperation with the local public land agencies, particularly the Bureau of Land Management (BLM), to help manage and preserve the unique and important paleontological finds of Mesa County, Colorado. Some of the most important areas on BLM land (most within McInnis Canyons National Conservation Area) have been designated as Museum/BLM cooperative management Research Natural Areas, set aside for their paleontological resources.

The Late Jurassic-age Mygatt-Moore Quarry is located in the middle Brushy Basin Member of the Morrison Formation. Excavations have taken place every year since 1984 (25 seasons) at the Mygatt-Moore Quarry. On this BLM-managed land the Museum leads public fossils digs for four months a year, with 250-350 public diggers per year participating under the supervision of staff paleontologists. This hands-on opportunity gives the museum the opportunity to convey important scientific information, while also education the public on the importance of stewardship and fossil resource protection on federal lands. Over 800+ cataloged specimens from seven species of dinosaur, including the type specimen of the first Jurassic ankylosaur *Mymoorapelta*, have been recovered from this bonebed. The most abundant taxon at the quarry is the theropod *Allosaurus* (29%), which is represented by 233 skeletal elements indicating a minimum of 6 individuals (5 adults, 1 juvenile); in addition, more than 190 mostly shed teeth of *Allosaurus* have been recovered from the site. The sauropod *Apatosaurus* is next most abundant (20%) with 160 elements representing 5 individuals (3 adults, 1 sub-adult, 1 juvenile). Approximately 19% of the sample consists of bones of the ankylosaur *Mymoorapelta*, mostly osteoderms and lateral spines (2 individuals). The three most abundant sauropods in the Morrison Formation (*Camarasaurus*, *Apatosaurus*, and *Diplodocus*) also are preserved at the Mygatt-Moore Quarry, but unlike within the formation as a whole, at the MMQ *Apatosaurus* accounts for 85% of the sauropod bones at the site; in the formation overall, *Camarasaurus* is the most abundant sauropod. Also preserved at the site are the carnivorous dinosaur *Ceratosaurus* (6 teeth) and the small ornithopod dinosaur *Othnielosaurus* (one jaw fragment), the latter first identified during the 2008 season. Non-dinosaurian taxa preserved at the site are very rare but include a turtle, a crocodilian, and a probable pterosaur.

Above the main bone layer at MMQ is a shallow lake deposit, which preserves some of the only articulated fish skeletons in the Morrison Formation, including "*Hulettia*" *hawesi* and the type and referred specimens of *Morrolepis schaefferi*. Also found in this unit have been the fish cf. *Leptolepis* and an as yet unnamed crayfish.

The Museum of Western Colorado and the Grand Junction Field Office of the BLM are investigating the possible installation of a permanent protective building over the Mygatt-Moore Quarry. Given the abundance of large, well preserved dinosaur bones at this site, the building could serve as a permanent and educational exhibit that would help to interpret the quarry in the long term, while also providing year-round access and a secured, on-going excavation area.

THE TULE SPRINGS LOCAL FAUNA: LATE PLEISTOCENE VERTEBRATES FROM THE UPPER LAS VEGAS WASH, CLARK COUNTY, NEVADA

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The Tule Springs site, located in the Upper Las Vegas Wash north of Las Vegas, was the focus of intense archaeological scrutiny from the 1930s through the 1960s that concomitantly documented a diverse, regionally significant, late Pleistocene fauna from fewer than a dozen localities. Forty years later, renewed paleontologic field investigations by the San Bernardino County Museum have resulted in the discovery of hundreds of fossil localities and specimens across the Upper Las Vegas Wash, greatly extending the geographic and temporal footprint of the original investigations.

Based upon these new data, coupled with expanded and better-defined geologic interpretations and more refined dating of older sedimentary units, we recognize that the Upper Las Vegas Wash encompasses the single largest open-site Rancholabrean vertebrate fossil assemblage anywhere in the Mojave Desert and the southern Great Basin. This assemblage, therefore, warrants designation as a local fauna, named for the original Tule Springs site.

The depositional setting is a series of fine-grained paleo-spring deposits originally described at Tule Springs with an informal stratigraphic nomenclature that has been subsequently extended throughout the southern Great Basin. Seven stratigraphically ascending units, designated A through E, have been recognized, spanning the last 200,000 years. Units B, D, and E were the known fossiliferous units from the early studies. Recent work has documented unit C as sparsely fossiliferous.

Newly recognized faunal components include the microvertebrates *Rana* sp., *Masticophis* sp., cf. *Arizona* sp., *Marmota flaviventris*, *Neotoma* sp. cf. *N. lepida*, and cf. *Onychomys* sp. The list of megafauna has also been expanded to include a large bovid similar in size to *Euceratherium* and the first definitive fossils of *Bison antiquus* from Unit E, which represent the youngest reliably dated *Bison* fossils from the Mojave Desert.

Tule Springs Local Fauna Composite Taxa List
New additions to fauna in bold

Bufo sp.	toad
Hylidae	tree frog
***Rana* sp.**	**frog**
Gopherus sp.	tortoise
Sceloporus sp. cf. *S. occidentalis*	sagebrush lizard
Callisaurus sp. cf. *C. draconides*	zebra-tailed lizard
Phrynosoma sp.	horned lizard

Tule Springs Local Fauna Composite Taxa List
New additions to fauna in bold (continued…)

Colubridae	nonvenomous snakes
***Masticophis* sp.**	**coachwhip**
cf. *Arizona* sp.	**glossy snake**
Mareca americana	widgeon
Aythya collaris	ring-necked duck
Aythya affinis	lesser scaup
Mergus merganser	common merganser
Teratornis merriami	extinct teratorn
Buteoninae	indeterminate soaring hawk
Fulica americana	coot
Fulica americana minor	extinct small coot
Bubo sp.	owl
Megalonyx jeffersoni	Jefferson's ground sloth
Nothrotheriops shastensis	Shasta ground sloth
Mammuthus columbi	extinct Columbian mammoth
Sylvilagus sp.	cottontail rabbit
Lepus sp.	jack rabbit
?*Brachylagus idahoensis*	possible pygmy rabbit
Ammospermophilus leucurus	antelope ground squirrel
Marmota flaviventris	**yellow-bellied marmot**
Thomomys bottae	Botta's pocket gopher
Dipodomys sp. (large)	large kangaroo rat
Dipodomys sp. (small)	small kangaroo rat
Perognathus sp.	pocket mouse
***Onychomys* sp.**	**grasshopper mouse**
Peromyscus sp. cf. *P. maniculatis*	deer mouse
Neotoma sp.	wood rat
Neotoma* cf. *N. lepida	**desert woodrat**
Microtus sp. cf. *M. californicus*	meadow vole
Ondatra zibethicus	muskrat
Taxidea taxus	badger
Canis latrans	coyote
Felidae cf. *Puma concolor*	puma-sized cat
?Lynx sp.	possible lynx or jaguarundi
Panthera atrox	extinct North American lion
Equus sp. (large)	extinct large horse
Equus sp. (small)	extinct small horse
Camelops sp.	extinct large camel
Odocoileus sp.	Deer
?Tetrameryx sp.	extinct pronghorn
Bovidae	large bovid
Bison sp. cf *B. antiquus*	extinct bison

[after Simpson, 1933, Mawby (1967), Reynolds and others (1991), Scott and Cox (2002)]

FIRST REPORT OF MAMMALIAN TRACKWAYS AND ASSOCIATED VERTEBRATE FOSSILS FROM MESQUITE LAKE, SANDY VALLEY, CALIFORNIA

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Prior to 2007, fossil vertebrates were virtually unknown from Mesquite Dry Lake in Sandy Valley on the California-Nevada border, and trackways had never been reported. In November of 2007, geologists from the USGS Western Surface Process Team, researching deflation rates in the basin, contacted the San Bernardino County Museum (SBCM), to report the discovery of fossil vertebrates and trackways. (Fig. 1)

The San Bernardino County Museum conducted a reconnaissance of the playa surface and discovered six discrete vertebrate localities with fossil bones. In addition, scattered vertebrate fossil fragments were noted as float across the playa in the area with exposed bone. These localities were documented, collected, and taken to the SBCM, under permit from the Needles, California field office of the Bureau of Land Management.

In addition to the vertebrate body fossils, there was a large exposed playa surface with numerous trackways. These tracks were preserved by differential cementation of layers in the playa deposits. The cementation was weak, however, and these trackways were an ephemeral feature of the exposed playa surface. The reason the trackways were exposed at all was the result of the highly gypsiferous nature of the sands in Mesquite Lake. Although deflation rates in Mesquite Lake are very high, the wind-blown sediment gently abraded the weakly cemented playa surface, exposing the trackways without completely destroying them in the process.

The high density of fossil tracks on the exposed playa surface was such that it was difficult to discern any individual set of tracks. Because the trackways were exposed by sandblasting, most of the tracks lacked detail. The majority of tracks in the trackway were made by a large camelid, presumably *Camelops hesternus*. Preliminarily, a few poorly preserved tracks appear to have been made by a proboscidean.

All body fossils recovered from the playa floor were identified as *Camelops hesternus*. Notably, this included vertically oriented, articulated limbs from one individual. An OSL date of the playa sediment at this locality demonstrated a late Pleistocene age of 11,300 +/- 1025 C^{14} ybp for these fossiliferous sediments. Also notable was the high organic content of the playa sediment at this locality; it awaits radiocarbon dating.

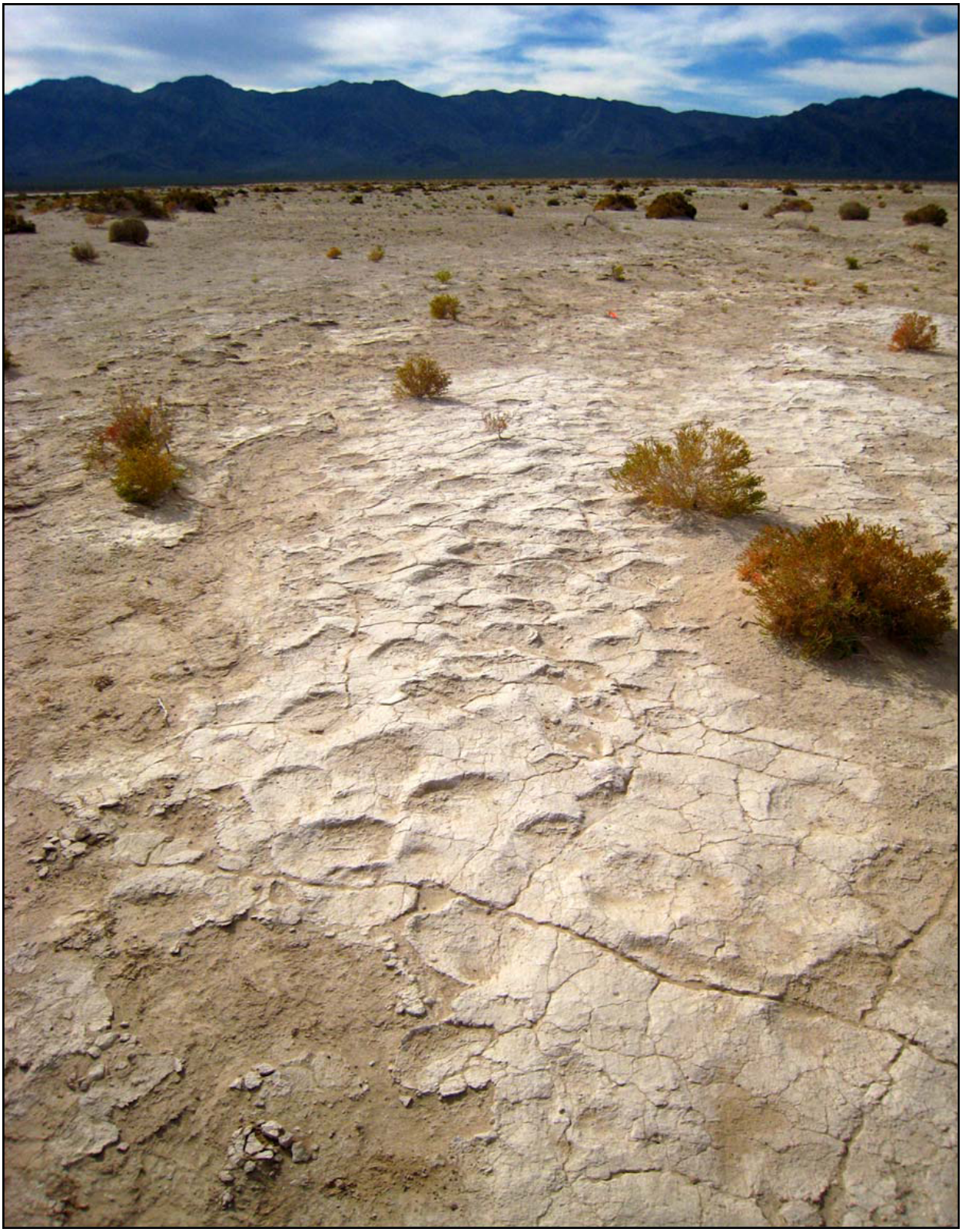

Figure 1: Fossil trackways in Mesquite Lake, Sandy Valley, California.

MIOCENE *THOMOMYS* AND PLEISTOCENE (RANCHOLABREAN) *BISON* FROM JOSHUA TREE NATIONAL PARK, CALIFORNIA

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The Pinto Basin in Joshua Tree National Park, (JOTR) is an increasingly recognized site for Quaternary fossil remains. Fluvio-lacustrine exposures in this area, informally designated the "Pinto Formation," have yielded abundant, but usually fragmentary, vertebrate fossils. These fossils are Pleistocene in age, as demonstrated by the presence of mammoth (*Mammuthus* sp.) in the assemblage.

Ongoing investigations by the San Bernardino County Museum (SBCM) have recovered and identified fossil teeth of extinct bison (*Bison* sp.) from the Pleistocene sediments in this region. These remains represent the first confirmed record of Pleistocene *Bison* from JOTR and constrain the age of the vertebrate fossils from the fluvio-lacustrine beds to the Rancholabrean North American Land Mammal Age (≤ 240 ka).

Studies conducted in the 1960s and early 1970s suggested that the fossil-bearing "Pinto Formation" was laterally correlative with sediments located below basalt flows in the northeastern Eagle Mountains, along the southern border of JOTR. These flows have been radiometrically dated to ~7.8 my; the underlying sediments exhibit evidence of having been heated by the basalts and are, therefore, clearly older. The discovery of *Bison* in addition to the previously-recognized *Mammuthus,* from the "Pinto Formation" confirms that this unit cannot be laterally correlative with the sediments below the basalts.

Sampling of the sedimentary deposits below the Eagle Mountains basalts has produced remains of pocket gopher (*Thomomys* sp.). Based upon the stratigraphic position and context of these remains, located below basalts dated to ~7.8 my, this record is the earliest *Thomomys* known from North America. Continued sampling from these sediments for more complete remains of *Thomomys* and fossils of more temporally-diagnostic Miocene species is ongoing.

Similarly, sampling of potentially fossil-bearing sediments in the Coxcomb Mountains along the eastern border of the park has also been initiated. Here, sediments are stratigraphically below basalts dated to ~4.5 my. These previously-unsampled exposures offer the promise of adding a Pliocene faunal component to the fossil record of JOTR.

THE LATE IRVINGTONIAN FAIRMEAD LANDFILL LOCALITY, MADERA COUNTY, CALIFORNIA: PARTNERSHIP IN MANAGEMENT AND RESEARCH AT THE LOCAL LEVEL

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In May 1993, while excavating for a new 5 acre expansion cell at the Madera County Fairmead Landfill, scraper operators discovered Pleistocene vertebrate remains. Because the site is on public land, the fossil find falls under the provisions of the California Environmental Quality Act (CEQA). Madera County requested a professional evaluation of the paleontological resource. The University of California Museum of Paleontology (UCMP) at Berkeley examined the locality and recommended that a mitigation program be implemented to salvage fossils as excavation proceeds throughout the lifespan of the landfill. Following the UCMP crew's departure from the site in August 1993, local paleontological monitor Diane Blades carried out the mitigation program until her resignation in 2004. Madera County then contracted with environmental consulting firms Tetra Tech and later AMEC to continue monitoring until mid 2007, at which time the County sought a partnership with California State University, Fresno (CSUF) in order to reduce mitigation costs and bring an educational institution on board with the project. Added benefits for the County included the University's proximity to the site and extensive experience in paleontological resource assessment and impact mitigation at the Federal (BLM) and State (Caltrans) levels.

During spring 2007, CSUF developed a comprehensive paleontological mitigation plan for Fairmead Landfill. A few months later, the University entered into a long-term contract with Madera County to conduct the mitigation program for the site. In addition to monitoring and excavation of fossils, CSUF prepares, curates, and handles all other aspects of collections management for the County. The University also conducts the site's research program. This partnership aids Madera County in its compliance with CEQA regulations and the University benefits from training undergraduate and graduate students in field, laboratory and research techniques.

The mitigation program consists of monitoring excavation of *in situ* sediment below 2 m in depth; flagging, documenting and excavating specimens exposed by scraper operations; collecting bulk sediment samples of microfossils; collecting samples for palynological analysis; and documenting site stratigraphy and sedimentology. Field wrapped material and plaster jacketed specimens are transported from the landfill to the County's fossil repository in downtown Madera. Preparation occurs at the County repository and the paleontology lab at CSUF. A backlog of over 500 plaster jackets from the past decade is stored in Madera. Another 300+ plaster jackets are stored at the UCMP, where specimens from early years of excavation were accessioned. Most specimens collected during the past ten years are accessioned into the Madera County paleontology collection, as will be all future finds.

Over the past 16 years, the locality has produced thousands of specimens, dominated by large mammal remains. Fairmead Landfill sits on the Chowchilla River alluvial fan. Fossils have been encountered at depths of 3.5

to 20 meters below the surface, over an area of 40+ acres. Specimens occur as isolated elements and in bone beds, preserved in alluvial fan, fan channel, and marsh/lacustrine sediments of the upper unit of the Turlock Lake Formation. Elsewhere in the region, the base of this unit contains the Friant Pumice, potassium-argon dated at 615,000 ± 31,000 years in age. The presence of *Nothrotheriops texanus*, *Megalonyx* cf. *wheatleyi* and *Tetrameryx irvingtonensis*, coupled with the absence of *Bison*, supports a late Irvingtonian age for the fauna. Paleomagnetic analysis indicates the sediments preserve a normal remanent magnetic signature, representing the Brunhes magnetic polarity chron, considering the lithostratigraphic and biostratigraphic data. This establishes an upper bound on the site's age at about 780,000 years (Matuyama/ Brunhes boundary).

The Fairmead Landfill biota is diverse, including: cocklebur (*Xanthium*), clam (Bivalvia), snail (Gastropoda), salamander (Caudata), frog (Anura), western pond turtle (*Clemmys marmorata*), desert tortoise (*Xerobates agassizii*), snake (Colubridae), duck (Anatidae), shrew (*Sorex*), Harlan's ground sloth (*Paramylodon harlani*), Texas ground sloth (*Nothrotheriops texanus*), Wheatley's ground sloth (*Megalonyx* cf. *wheatleyi*), coyote (*Canis* cf. *latrans*), undetermined wolf (*Canis*), fox (*Vulpes*), scimitar cat (*Homotherium*), sabertooth cat (*Smilodon* cf. *fatalis*), American cheetah (*Miracinonyx*), badger (*Taxidea taxus*), short-faced bear (*Arctodus*), ground squirrel (*Spermophilus*), packrat (*Neotoma*), deer mouse (*Peromyscus*), vole (*Microtus*), pocket gopher (*Thomomys*), kangaroo rat (cf. *Dipodomys*), rabbit (*Lepus*), Columbian mammoth (*Mammuthus columbi*), horse (*Equus*), camel (*Camelops*), llama (*Hemiauchenia*), Irvington pronghorn (*Tetrameryx irvingtonensis*), small pronghorn (*Capromeryx*), deer (*Odocoileus*), and peccary (*Platygonus*).

In addition to the mitigation and research programs, the next phase of the Fairmead Landfill project is underway: development of public educational programs. On February 17, 2009, with initial support of $2.4 million in grant money, Madera County broke ground for a 7,500 ft^2 Fossil Discovery Center at the site to showcase the Fairmead Landfill biota. The facility will be operated by the San Joaquin Valley Paleontology Foundation. The Foundation will develop and implement educational programs for the general public and area schoolchildren. As a partner in the process, California State University provides professional advice on the Discovery Center's design and exhibit development.

THE GEOPARK SYSTEM AND ITS USE IN PROTECTING PALEONTOLOGICAL RESOURCES IN CHINA: A COMPARATIVE EXAMINATION FOR BROADER APPLICATION

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The Global Geopark Network (GGN) (http://www.globalgeopark.org/publish/portal1/tab59) is a United Nations Educational, Scientific and Cultural Organization (UNESCO) initiative to protect geoscience resources worldwide. UNESCO's recognition of the importance of geoscientific heritage conservation was most notable in 1997 when its General Conference approved an initiative to promote a global network of sites having special geological features. The UNESCO Geoparks Programme was formally commenced in 2000, coupling geoscience-specific initiatives with the World Heritage Convention and bilateral cooperation through its Division of Earth Science. UNESCO defines a geopark as "a nationally protected area containing a number of geological heritage sites of particular importance, rarity or aesthetic appeal." There are presently 57 geoparks in 18 countries, primarily in Europe and Asia; several more countries have also initiated national and provincial geopark committees as well (Fig. 1).

Resources protected and promoted in these parks range from glaciers to karst topography to volcanoes to paleobotanical, invertebrate, and/or vertebrate fossils.

China has been a driving force in the geopark initiative. Thus far, it also has been the most prolific nation in employing the system (20 global, 138 national, and even more provincial geoparks) to protect, develop for economic and educational purposes, and interpret its geoscientific resources for the general public. Many of the geoparks were established specifically to protect and interpret paleontological resources; seven are dedicated to dinosaurs. Some of the more famous examples include:

Zigong Geopark in Sichuan Province in Sichuan Province (Figs. 2A-B): this area encompasses the Dashanpu and Qinglongshan dinosaur fossil sites, which produce one of the most complete Middle Jurassic terrestrial vertebrate faunas in the world, as well as a historical salt well area. This is currently the only one of the Global geoparks devoted to dinosaurs.

Lufeng Dinosaur National Geopark in Yunnan Province (Figs. 2C-D): this area encompasses fossiliferous outcrops of the Lufeng Formation that produce one of the most complete and diverse Early and Middle Jurassic terrestrial vertebrate faunas anywhere in the world.

Liujiaxia Dinosaur National Geopark in Gansu Province (Figs. 2E-F): establishment of this park included a spacious museum over a unique set of Early Cretaceous vertebrate footprints; the museum also contains extensive interpretive material.

Chengjiang Fauna Paleobiology National Geopark in Yunnan Province (Figs. 2G-H): this park developed for interpretation and education is in a remote region that has

produced the earliest diverse Phanerozoic biota, includingthe oldest known chordates and, possibly, vertebrates.

Chaoyang Bird Fossil National Geopark in Liaoning Province (Figs. 2I-J): establishment of this geopark enabled construction of a 12,000 m^2 museum to conserve and exhibit thousands of fossils from the Early Cretaceous Jehol Biota, including basal birds and feathered theropod dinosaurs.

Within China, geopark-related activities are the responsibilities of every level of government, from national to provincial to regional. Proposals for geopark status are generated at a local level, and provincial geopark status can be granted. Subsequently, national geopark status can be sought through a dedicated geopark committee within the Ministry of Land and Resources; this committee includes a scientific advisory group that evaluates geopark proposals. The focus the geopark initiative has brought to bear on paleontological resource protection and development has been highly successful in convincing the Chinese government to dedicate monetary resources for the protection of such resources: the 138 Chinese national geoparks have been established just since the inception of the program, in 2001.

While the geopark system does not in and of itself provide financial assistance for preservation or construction, the GGN provides: (a) a "brand" name that calls global attention to the importance of a body of resources, (b) a platform for national and international scientific information exchange, and (c) logistical support for communication of knowledge to the public. For example, the "World Dinosaur Valley" exhibit in Lufeng Dinosaur National Geopark attracted over 10,000 visitors on a single day after being granted "national" status. The "global" status of the Zigong Geopark helped persuade the Chinese government to provide 70% of the geopark budget last year alone. The United States is fortunate to include a wealth of sites suitable for inclusion with in the global geopark network. Perhaps it is time to join with other countries in promoting our shared geological and paleontological heritage.

The 4th International UNESCO Conference on Geoparks will be held at the first geopark, Langkawi Geopark, Malaysia, (http://www.Geoparks 2010.com) April 9-15, 2010. Through the GGN, UNESCO is concentrating its effort for protecting and promoting geological sites while enriching human capital through more holistic environmental protection and creating new opportunities through sustainable recreation and education tourism.

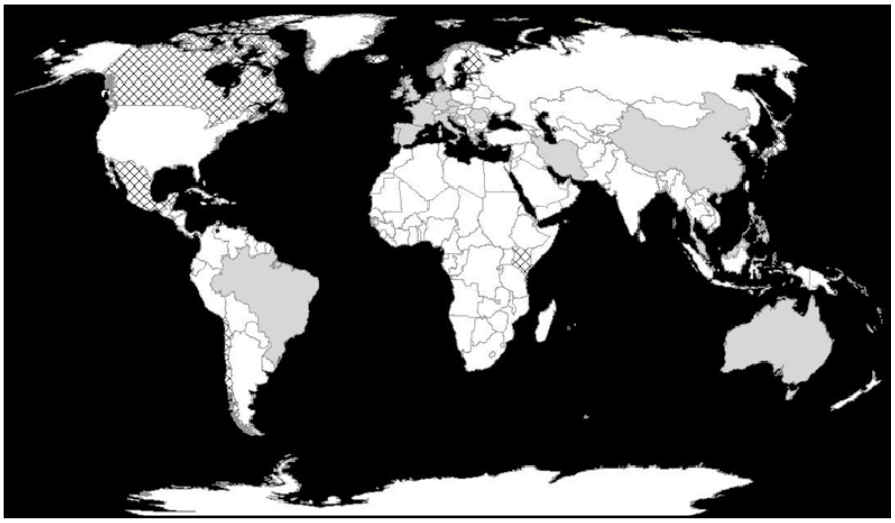

Figure 1: Nations that participate in the Global Geopark Network (gray) and countries that are currently preparing applications for one or more geoparks (cross-hatching).

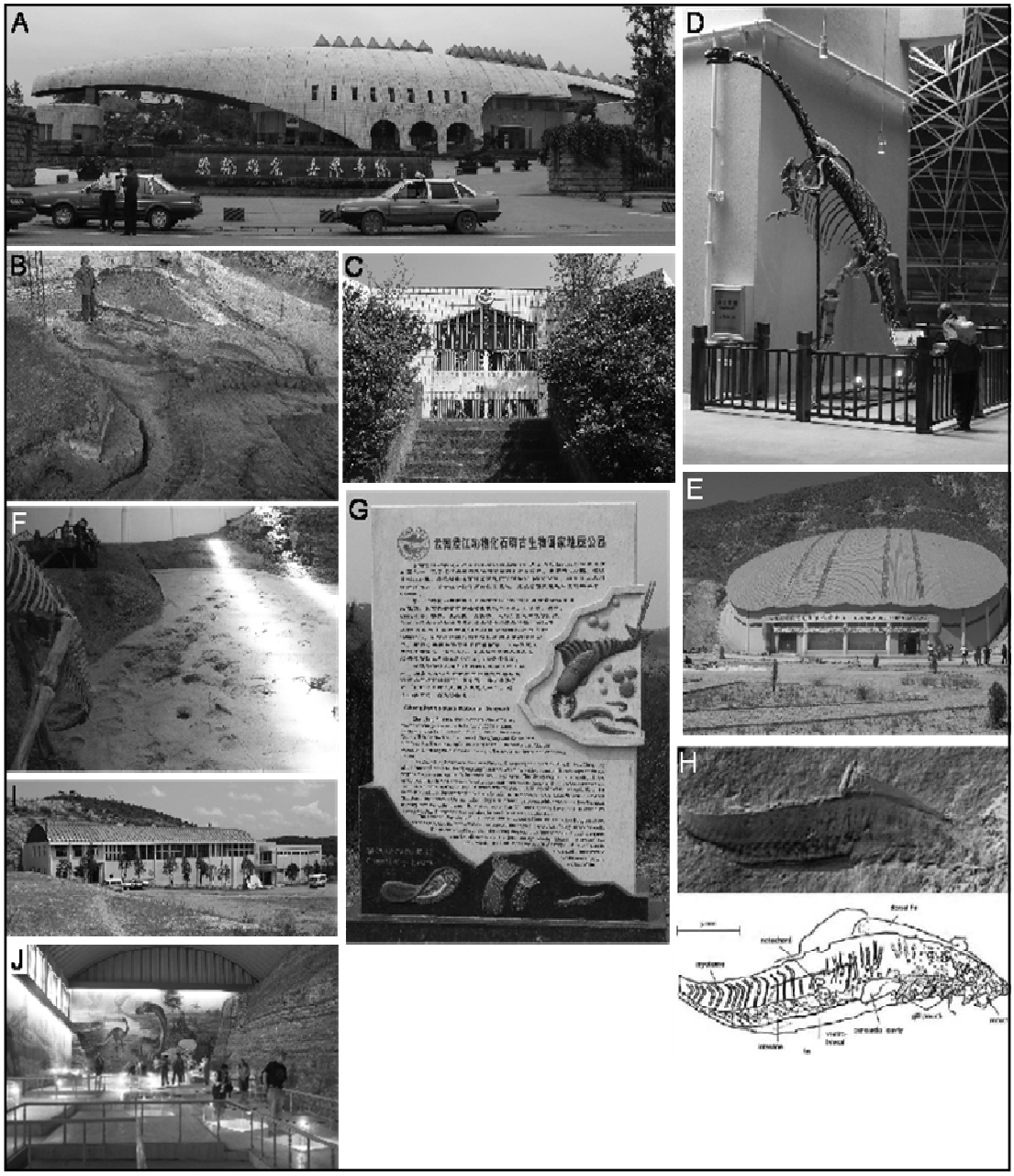

Figure 2. Examples of Chinese geoparks and their paleontological resources. **(A)** One of several museum buildings at the Zigong Dinosaur National Geopark, Sichuan Province. **(B)** Partial skeleton of the sauropod dinosaur *Omeisaurus* preserved at Zigong. **(C)** Museum building at Lufeng Dinosaur National Geopark, Yunnan Province. **(D)** Large basal sauropodomorph dinosaur on display at the World Dinosaur Valley museum; this and other specimens come from the Lufeng Fm. that is developed in Lufeng Geopark. **(E)** Primary facility at Liujiaxia Dinosaur National Geopark, Gansu Province. **(F)** Portion of the Lower Cretaceous (Hekou Gp.) track-bearing surface at Liujiaxia that preserves pterosaur, ornithopod dinosaur, sauropod dinosaur, and avian and non-avian theropod dinosaur tracks. Part of the skeleton of the ornithopod *Lanzhousaurus magnidens*, from the same unit, is visible at left. **(G)** Sign at entrance to Chengjiang Fauna Paleobiology National Geopark, Yunnan Province. **(H)** Holotype and schematic diagram of the anatomy of the earliest known vertebrate, *Myllokunmingia fengjiaoa*, from the Lower Cambrian Qiongzhusi Fm. from Chengjiang. **(I)** Museum at the Chaoyang Bird National Geopark, Liaoning. **(J)** Portion of interior of the Chaoyang Geopark museum exposing actual stratigraphic sequence (right) and *in situ* specimens (floor). (A-D, G by JIK; E-F, I-J by JDH; H from http://macroevolution.narod.ru/ancestor/images/img_047.jpg.)

MANAGEMENT PHILOSOPHY AND THE CURRENT STATUS OF FOSSIL STEWARDSHIP ON NATIONAL FORESTS AND GRASSLANDS

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Prior to passage of the Paleontological Resources Preservation Act (PRPA), management of fossils on the nation's forests and grasslands was self-imposed by the USDA Forest Service (FS). Other than regulation to prohibit the unlawful collection of vertebrate fossils, there existed no specific policy or direction to mandate responsible management of the public's fossil resources except in a few small areas of Forest System lands. Nevertheless, some regions of the agency realize the importance of fossil stewardship and have already instituted a fledgling paleontological program with full-time positions solely or partially obligated to fossil management. This sends a powerful message within the modern FS, an agency over-committed in management of complex sociological and ecological systems with competing, mandated priorities. To institute and commit financial resources toward a 'discretionary' activity such as paleontology deserves recognition. In the past decade, the FS paleontology program has recorded an simply and precisely what will constitute 'reasonable amount', 'common invertebrate and plant paleontological resources', and 'negligible disturbance' as a unified group, and effectively convey this information to the public. And we should make every effort to ensure enacted rules will not create conflict with other resource areas, in particular archaeology. Without precise language that is easily understood by the general public, our efforts to improve fossil resource management could carry unintended negative consequences.

Beyond the strict interpretation of that stated in the PRPA, it is my belief that the lines drawn as to 'common' fossils should not be based upon a vertebrate/non-vertebrate distinction. While it is true that the majority of vertebrate fossils are significant, this distinction downplays the significance of invertebrate and plant fossils as a whole. In particular, I believe that shark teeth could play a pivotal role in how the concepts and consequent policies of 'casual collection' evolve.

The importance of shark teeth in the birth of the paleontological discipline cannot be over-stated. In large part, the 17th century works of Steno and Scilla with glossopetrae, or shark teeth, formed a critical link to definitively state that fossils as a whole represent evidence of past life, rather than figured stones or some other non-scientific explanation. In the present day, both fossil and modern shark teeth carry special appeal because of their aesthetic quality. Shark teeth are also arguably one of the vertebrate fossils most commonly encountered by amateurs. Shark teeth thus inspire the imagination of inquisitive minds, as with the earliest paleontological workers, and for many serve as the link to connect with the nature of fossils, ancient environments,

and ‘deep time’. In this regaimpressive list of accomplishments made possible largely through highly cost effective collaboration with partnering institutions and volunteers - but it is time to do more.

With efforts to enact the PRPA now successful, there is no longer a question as to the necessity of a fully implemented paleontological stewardship program. The existing program in the FS must now internally market this message, and build more assets, support, and positions within the program. A negative perception of the compliance driven, ‘obstructing’ nature of other federal laws (NEPA, NHPA, TES) has evolved amongst some decision makers and planners in the FS, and to some degree this perception is already being attributed to the PRPA. A weighty, compliance driven program should not be our focus in the FS, nor do I believe it to be the intent of the PRPA. Implementation of the law may not provide a large increase in funding or new positions within the FS, but should provide minimally the resources necessary for responsible stewardship of the nation’s forests and grasslands.

Enforcement of penalties related to unlawful collection or handling of fossils, although important, should not be the stated primary purpose or need for the PRPA. The title of the PRPA is a ‘preservation’ act, not a ‘protection’ act, and I believe this to be an important distinction between the PRPA and related laws such as the Archaelogical Resources Protection Act of 1979. Rather, the primary focal point of PRPA should be to enhance management of the public's fossils resources. By providing unambiguous authority for paleontological stewardship, the PRPA will pave the way toward more managers on the ground to work with and educate the public, and ultimately to conserve more fossils for us all to learn from and enjoy. More FS paleontologists will equate to more collaborative projects with volunteers and museums, and thus fewer significant fossils on the surface to be vandalized/stolen/lost to elements. This sends a positive message to citizens, concentrating on opportunity and privilege rather than enforcement and limitation.

This message is all the more important now that we have the ‘casual collecting exemption’ to implement through the PRPA. The controversial and emotional nature of fossil collecting resonated so strongly as to stand out amidst a huge omnibus lands package containing a multitude of land exchanges, management provisions, and over two million acres of wilderness designation. As the paleontological community witnessed, attitudes toward casual collecting are all across the board, not just from detractors of the PRPA, but also ethical professionals and amateurs alike, who sense conflict in the lack of specificity about privileges of casual collecting, coupled with a lengthy section devoted to prohibited acts and criminal/civil penalties. The primary antagonists can no longer be stereotyped as selfishly motivated fossil vandals, who argued against the law’s passage for fear of potential revenue loss or increased likelihood of incrimination. As responsible managers for the public, federal agencies must articulate rd, I believe that shark teeth constitute an educational tool like none other. Some have said 'paleontology is the gateway drug to science'.

I think that for many, shark teeth are the gateway drug to paleontology. These objects inspire young and old alike to learn, and ultimately for some, to care more about the science of the teeth than their undeniable aesthetic appeal. Based upon this, and in the opinion of one who has intimate involvement in the science of shark teeth, I am personally in favor of allowing casual collection of some shark teeth in some certain situations. I encourage the multi-agency group charged with implementation of the PRPA to consider adopting casual collection rules allowing for the conservative collection of shark teeth, and to test whether this is possible given the language of the PRPA. Through this, I believe the agencies stand to harvest a more ethical conscience among the hobby collecting community.

THE DAWN OF THE PALEOCRAT

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2009 is the year of many important anniversaries, including the 150th anniversary of the publication of Darwin's *Origin of Species* and the 30th anniversary of the Archaeological Resource Protection Act of 1979 (ARPA). However 2009 will forever be remembered by paleontologists as the birthday of the Paleontological Resources Preservation Act (PRPA) of 2009 (see Appendix 1, this volume).

The PRPA of 2009 is the most important paleontological legislation ever in the United States covering all aspects of paleontological resources on public lands, including land management decision making, permitted collecting, casual use collecting, museum curation, theft, and confidentiality as they relate to paleontological resources. The act (now public law 111-011) provides the unified authority that Federal agencies need in order to manage paleontological resources, issue permits, promote recreational collecting, develop educational programs, and, when necessary, issue citations and prosecute criminal theft.

> *The secretary shall manage and protect paleontological resources on Federal land using scientific principles and expertise.* (PRPA Section 6302)

Before PRPA, amateurs were allowed to collect "reasonable" amounts of invertebrate or plant fossils on BLM and USFS lands. This was allowable at the discretion of each agency, but was not guaranteed by law. Amateurs now have a legal right to pursue their collecting hobbies. Casual collecting is now a right guaranteed by law. The PRPA also offers a mandate for Federal agencies to develop public awareness and education programs to increase awareness about the significance of paleontological resources. Providing paleontological education and facilitating recreation is now not just a good idea, it is the law.

Fossil theft and the destruction of paleontological resources continue to present a great challenge to land management agencies. Fossil resources constitute some of the greatest treasures in this country; they are unique; they are non-renewable; and they belong to the people of the United States. They do not belong to me. They should not be sold to a physician in Japan, or a businessperson in Italy. They do not belong in the private collection of a wealthy banker or movie star. They do not belong to a professor's research laboratory and they do not belong to any private museum. The Nation's paleontological treasures belong to the people of the United States. The PRPA requires that repositories that hold these fossils be compliant with basic curation facility standards.

The Obama administration, in its first 100 days, has issued multiple statements calling for science-based decision making in government agencies. The PRPA, also signed into law during the administration's first 100 days, calls for the same: *The secretary shall manage and protect paleontological resources on Federal land using scientific principles and expertise.* (PRPA Section 6302)

The mandate for science-based decision making means that government paleontology program leads (i.e. paleocrats) are going to be dependant on their professional collegues more than ever. It is not good enough to define a rigid definition to the term "significant fossil." Fossil significance is not

a singularly definable quantity, rather it is a concept (Table 1). The assessment of fossil significance requires knowledge in a fossil's identification, richness, diversity, and context. The determination of significance often requires collaboration. This requires a collaboration of professional and amateur paleontologists and paleocrats.

Paleontological consultants, hired by industry to advise Federal agencies, are currently caught in an impossible bind when they are required to consider all vertebrate fossils to be significant against their own professional training and contrary to the wisdom of professional museum curators who receive their collections. Not all gar scales are significant, but many are. Not all tortoise scute fragments are significant, but many are. Not all shark teeth are significant, but many are. The concept of significance is crucial to the success of science-based decision making in the management of paleontological resources.

The current state of museum collections should cause everybody in our profession to take pause. The Department of the Interior has specific regulations to ensure that curation facilities that hold paleontological resources are compliant with basic regulations. The PRPA will require Federal agencies to enforce those regulations to a higher degree of rigor than has previously existed. The practice of storing Federally owned museum property in college research laboratories, departmental storage rooms, basements, and storage lockers will have to be revisited and either ended or incorporated into a best practice concept of curating paleontological museum property.

Table 1. Working definition of Paleontological Significance.

Significant Paleontological Resource *(syn.* ***Significant Fossil Resource****) – Any paleontological resource that is considered to be of scientific interest, including most vertebrate fossil remains and certain rare or unusual invertebrate and plant fossils. A significant paleontological resource may be considered to be scientifically important because it is a rare or previously unknown species, it is of high quality and well-preserved, it preserves a previously unknown anatomical or other characteristic, or provides new information about the history of life on earth. Paleontological resources that may be considered to not have paleontological significance include those that lack provenience or context, lack physical integrity because of decay or natural erosion, or that are overly redundant or are otherwise not useful for research.*

Consulting for assessment and mitigation of paleontological resources prior to proponent sponsored uses of public lands (i.e. energy development, road building, pipelines, mining, logging, etc.) has become big business. Issues of museum curation, permitting, and science-based decision making come to crossroads in the work that paleontological consultants engage in every day. Professional societies needs to work with consultants and government agency representatives to define the scope of work, ethical guidelines, and best practice statements for the paleontological consulting profession.

Permitting, now authorized in all of the agencies of the Department of the Interior and the Department of Agriculture by PRPA, must be both streamlined and expanded to incorporate all of the various types of research, survey, collecting, excavation, and consulting that occur. Streamlined permitting procedures must be fused with ethical guidelines and best practice concepts.

The as-yet unresolved policy implications of PRPA must now be met with constructive input from both public agencies and professional societies. Professional best practice statements should, when possible, be consistent with Federal and State laws. Ethics guidelines should be implemented by professional societies and not imposed by the Federal Government. The work of implementing both Federal code and Agency policy is ongoing, but with the passage of the PRPA has taken on a new immediacy and

mandate. Science-based decision making requires frequent and rapid contact between knowledgeable paleontologists and agency decision makers. A single person's opinion should not have the weight of policy without first demonstrating the results of rigorous scientific collaboration.

Currently, the Federal government does not employ many paleontologists. The US Government's Office of Personnel Management does not classify paleontologists, so while a few employees may have "paleontologist" in their job titles, actual job classifications are geologist, physical scientist, or curator. The various agency budget offices refuse to recognize paleontology as a unique program, continuing to assign it as a subset of either geology or archaeology.

The science of archaeology was recognized in the US Federal Government with the passage of the Antiquities Act of 1906, and has been reinforced by multiple other bills until the passage of the Archeological Resource Protection Act of 1979. At best, government paleontology programs are 30 years behind archaeology. Today, most jobs in archaeology are tied to government regulations and the U.S. Federal Government is the single largest employer of archaeologists. 2009 will mark a significant change in the way paleontology is viewed by the public and by the U.S. Government. It will also change the way Universities educate future paleontologists.

Currently, paleontologists are not trained in the minutia of government work, and have therefore missed out on the career ladder to become both technical experts and regional or national program leads in paleontology. With PRPA, the U.S. Government land management agencies will need to expand their paleontology programs; budget offices will have to recognize paleontology; the U.S. Government's Office of Personnel Management will be asked to develop a paleontology series. Land management agencies will need more paleontologists in program lead positions and the result will be that the US Government will hire more paleontologists at every level.

The profession of paleontology currently enjoys the highest caliber researchers, far sighted and progressive museum curators, and fantastically talented fossil preparators who employ rigorous methodology and the latest techniques. However, paleontologists are currently ill-prepared as program managers or administrators. Until now, only a fool got into paleontology for the monetary compensation or with the specific goal of becoming a manager or bureaucrat. Paleontologists are teachers, researchers, and diggers.

2009 will mark the dawn of the paleocrat, a breed of paleontologist who is versed in business management, public law, and diplomacy, while maintaining the quality of philomath, that passion and love of learning for the sake of learning, cherishing the thrill of discovery while continuing to dig in the dirt.

THE PALEONTOLOGICAL RESOURCES PRESERVATION ACT: BEGINNING OF A NEW CHAPTER IN THE HISTORY OF PALEONTOLOGY

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On March 30, 2009, President Barack Obama signed into law the Paleontological Resources Preservation Act (PRPA; P.L. 111-11) contained within the Omnibus Public Land Management Act of 2009. Nearly three decades in the making, this new legislation provides a specific authority and mandate for the management, protection, and public education of paleontological resources on federal lands. The Bureau of Land Management (BLM), Bureau of Reclamation (BOR), Fish and Wildlife Service (FWS), and National Park Service (NPS) within the Department of Interior (DOI) and the U.S. Forest Service (USFS) within the Department of Agriculture are the primary land managing agencies which will assimilate this new legislation into regulations and policy.

A brief review of the legislative history associated with fossil resource preservation dates to the period preceding the passage of the Archeological Resources Protection Act of 1979 (ARPA). In general archeologists and paleontologists identified fundamental differences between archeological artifacts and fossils leading to the decision to not include fossils within the proposed ARPA legislation. The following language relative to fossils is contained within the final version of the ARPA legislation, "*Nonfossilized and fossilized paleontological specimens, or any portion or piece thereof, shall not be considered archaeological resources, under the regulations under this paragraph, unless found in archaeological context.*"

During the 1980s National Park Service officials recognized the need to distinguish archeological resources from paleontological resources. Although both categories of resources are often viewed as *"old remains dug from the ground",* there are significant differences in their scientific, historic and educational values. Archeological objects are essentially the remains or evidence of past human remains and activities, whereas fossils are the remains of past life preserved in a geologic context. Academic training for archeologists often focuses on human culture and history, while paleontologists typically study biology and geology. By 1988, the National Park Service officially shifted paleontology from the Cultural Resources Program to the Natural Resources Program.

In 1983 Senator Larry Pressler (South Dakota) introduced a bill (S-1569) in the 98th Congress which proposed to enable commercial collection of paleontological resources on federal lands. This proposed legislation led to a very contentious and polarized discussion between the professional paleontologists and commercial fossil collectors. The debate was fueled by a controversial report produced in 1987 by a committee representing the National Academy of Sciences (NAS). The recommendations set forth in the NAS report were generally not supported by the scientific community and were not adopted by the federal land managing agencies. The integrity of the NAS report was later questioned when it was determined that important information was misrepresented in the document.

Three important paleontological resource preservation achievements were gained through legislation during the 1990s. First, the National Park Service Omnibus Management

Act of 1998 mandates that park managers incorporate science into decision-making. Additionally within this legislation, Section 207 includes an exemption from disclosure of confidential or sensitive paleontological resource locality information. The other achievement was obtained through the National Park System Resource Protection Act (P.L. 101-337) which authorizes the NPS to recover costs associated with any resource damages through civil penalty and litigation. All of these resource protection provisions are incorporated within PRPA.

The Paleontological Resources Preservation Act provides specific mandates to promote and support: public awareness and education programs (Section 6303), a permit system for paleontological resource collecting on federal lands (Section 6304); the curation of fossil collections from federal lands (Section 6305); protection of federal fossils through resource specific penalties for unauthorized collecting and other activities (Section 6306); opportunities for cost recovery through civil penalties and litigation where paleontological resources have been lost or damaged through human activities (Section 6307); and, the protection of sensitive paleontological resource locality information through an exemption from disclosure (Section 6309).

Through the authority provided within PRPA, federal land managing agencies will have greater opportunities for interagency cooperation to enhance paleontological resource stewardship, science and public education. Since the fossil record does not end at administrative boundaries, the interagency cooperation involving the management, protection and interpretation of fossils on federal lands will support the mandates identified in PRPA.

Some of the specific interagency efforts include cooperative management, joint scientific research, development of an interagency paleontological resource protection taskforce, coordination of joint paleontological resource training programs, development of interagency programs for public education in paleontology, and other partnerships for preservation.

The Paleontological Resource Preservation Act should foster greater opportunities to develop partnerships with academic and museum institutions, professional and amateur organizations, and educators. The National Park Service plans to establish a scientific advisory committee for paleontology to provide recommendations and guidance to ensure science-based decision-making is incorporated into agency programs.

Finally, it is important to revisit the organizational and operations changes experienced by federal land managing agencies with the adoption of the Archeological Resources Protection Act (ARPA) in 1979. Prior to ARPA there were only a few archeologists employed by federal and state land managing agencies. In fact, the employment opportunities for a professional archeologist were very limited. After ARPA and other cultural resource legislation were passed into law, there has been a tremendous infusion of professional archeologists throughout federal and state land managing agencies. Today most graduate academic programs in archeology include coursework on law, regulations, policies, permits, resource management, conservation, curation, any many other topics which are essential for a career as a federal or state archeologist. Employment opportunities for paleontologists in federal service are likely to expand in order to meet the mandates within PRPA. The federal agencies should work closely with academic institutions with paleontology programs to develop coursework in paleontological resource management, protection, interpretation and legislation.

Beginning immediately after the PRPA legislation became law, representatives of the BLM, BOR, FWS, NPS, and USFS met to plan the future of a unified federal paleontology program. The new authorities provided in PRPA, combined with the cooperation of the federal agencies will strengthen the collective opportunities for preserving the fossil record and history of life preserved on federal lands and thus begins a new chapter in the history of paleontology.

PALEONTOLOGICAL RESOURCES PRESERVATION ACT: AN UPDATE

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In the 107th Congress, the Paleontological Resources Preservation Act (PRPA) was first introduced by Rep. Jim McGovern (D-MA) in the House of Representatives and by Sen. Daniel Akaka (D-HI) in the Senate. It was re-introduced in subsequent Congresses, up to and including, the 111th Congress. The PRPA is modeled after the Archaeological Resources Protection Act (ARPA) and incorporates the recommendations of the May, 2000 Report of the Secretary of the Interior, "Assessment of Fossil Management on Federal and Indian Lands," regarding future actions to formulate a consistent paleontological resources management framework. Congress, with the passage of the PRPA, would officially recognize the importance of paleontological resources from Federal lands by declaring that fossils from Federal lands are federal property that must be preserved and protected using scientific principles and expertise. The PRPA provides uniform definitions for "paleontological resources" and "casual collecting;" uniform minimum requirements for paleontological resources use permit issuance – terms, conditions and qualifications of applicants; uniform criminal and civil penalties for illegal sale and transport, theft, and vandalism of fossils from Federal lands; and the uniform requirements for curation of federal fossils in approved repositories. The PRPA essentially codifies existing policies of the Bureau of Land Management (BLM), the National Park Service, the U.S. Forest Service (USFS), the Bureau of Reclamation (BOR), and the Fish and Wildlife Service (FWS), such as prohibition of commercial collection, paleontological permit issuance, curation of fossil specimens, inventory and monitoring of paleontological resources, confidentiality of paleontological locality data, and area closures to protect paleontological resources. The PRPA emphasizes the scientific and educational values of paleontological resources from Federal lands by mandating the establishment of a program to increase public awareness about the significance of paleontological resources. The PRPA authorizes, by law, the longstanding practice of the BLM and the USFS to allow hobby or casual collecting of common invertebrate and plant fossils without a permit and, where appropriate, on their respective agency-managed lands. On March 30, 2009, the Paleontological Resources Preservation Act finally became law when President Barack Obama signed the Omnibus Public Lands Bill. The following table (Table 1) lists the main provisions of the Paleontological Resources Preservation Subtitle in the Omnibus Public Lands Act of 2009, Public Law 111-011.

Table 1. Summary of Major Provisions of the Paleontological Resources Preservation Subtitle in the Omnibus Public Lands Act of 2009, P.L. 111-011.

Paleontological Resources Preservation, Title VI, Subtitle D in the Omnibus Public Lands Act, Public Law 111-011

Purpose: The Secretary [Interior and Agriculture] shall manage and protect paleontological resources on Federal land using scientific principles and expertise. (6302)

Action Items Summary:

- The Secretaries of the Interior and Agriculture (the Secretary) are authorized to manage and protect paleontological resources on Federal land using scientific principles and expertise. (6302)
- The Secretary shall develop appropriate plans for inventory, monitoring, and the scientific and educational use of paleontological resources. (6302)
- The Secretary shall establish a program to increase public awareness about the significance of paleontological resources. (6303)
- As soon as practical after the date of enactment of this Act, the Secretary shall issue such regulations as are appropriate to carry out this subtitle, providing opportunities for public notice and comment. (6310)
- Implementation of this Act shall be coordinated between the Secretary of the Interior and the Secretary of Agriculture. (6302)

Policy Items Summary:

- Formal recognition of the importance of paleontological resources from Federal lands. (6302, 6303)
- Paleontological resources from Federal lands are Federal property. (6304)
- Formal definition of paleontological resources. (6301)
- Formal definition of casual collecting of common invertebrate and plant fossils. (6301)
- Collecting paleontological resources from Federal lands requires a permit. (6304)
- Establishes criteria for permit issuance, modification, suspension, and revocation. (6304)
- Permits must contain terms and conditions to protect paleontological resources.
- Paleontological resources collected under permit must be curated in an approved repository. (6304, 6305)
- Formal authorization of casual collecting of common invertebrate and plant fossils from BLM, USFS and BOR administered lands where consistent with other management laws. (6304, 6311)
- Casual collecting of common invertebrate and plant fossils does not require a permit. (6304, 6311)
- Casual collecting of rocks and minerals does not require a permit. (6311)
- No commercial collection of paleontological resources. (6304, 6306)
- Confidentiality of paleontological localities for areas under permit. (6304)
- Area closures are authorized to protect paleontological resources. (6304)

- Establishes criminal and civil penalties for vandalism and theft of paleontological resources. (6306, 6307)
  - Criminal penalties (6306):
    Value > $500, imprisonment not more than 5 years and/or fines in accordance with 18 U.S.C.
    Value ≤ $500, imprisonment not more than 2 years and/or fines in accordance with 18 U.S.C.
    Multiple Offenses: the amount of the assessed penalty may be doubled.
  - Civil penalties (6307):
    Amount of penalty will be determined by the Secretary and take into consideration scientific value, fair market value, cost of response, restoration and repair, and any other factors considered relevant by the Secretary.
    Multiple Offenses: the amount of the penalty may be doubled, but the amount for any one violation shall not exceed the amount equal to double the cost of response, restoration and repair of site damage plus double the scientific or fair market value.
    Civil penalties are available to the Secretary without further appropriation, but can only be used for certain activities involving protection of paleontological resources, education, and payment of rewards.
- Provides for rewards for information leading to criminal convictions or civil violations. (6308)
  - Maximum amount of the reward may be up to ½ of the penalty paid, or in accordance with already established regulations.
- Provides for forfeiture of paleontological resources found in connection with a criminal or civil violation. (6308)
- Provides for disposition of paleontological resources recovered as a result of a violation. (6308)
- Provides for confidentiality of information concerning the nature and specific location of a paleontological resource with provisions for disclosure. (6309)

THE HISTORY OF THE PALEONTOLOGICAL RESOURCES PRESERVATION ACT

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The Society of Vertebrate Paleontology (SVP) has worked for many years to protect fossils on federal land through the enactment of the Paleontological Resources Preservation Act (PRPA). Communicating the need for and the effects of passage of this proposed legislation to disparate audiences including legislators and the general public provides a case history in the challenges encountered in articulating paleontological and public lands issues to a wide variety of audiences, and in overcoming misinformation which has been received by these groups.

This paper traces the legislative history of the PRPA and the strategies that culminated with its enactment as a public law. The behind the scenes maneuverings that proponents of the PRPA could not overcome in the 107th, 108th, 109th, and 110th were different in each Congress and are discussed, as are the much shorter, but more complex maneuverings that resulted in enactment of the PRPA in the 111th Congress.

Three bills preceded the PRPA. In the 98th Congress Sen. Larry Pressler introduced S. 1569 which proposed to allow commercial fossil collecting on federal lands.

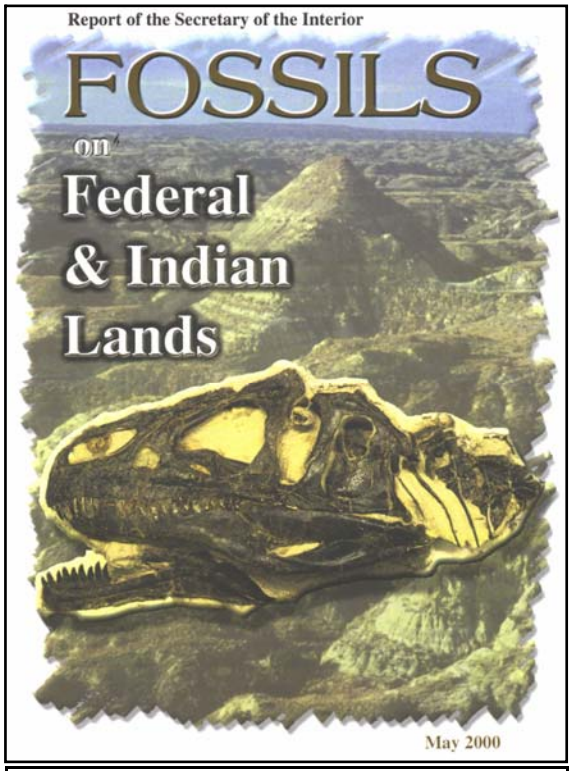


Figure 1: The May 2000 report of the Secretary of the Interior, "Fossils on Federal Indian Lands" provided the Legislative intent for the PRPA.

Responding to increased illegal collecting on federal lands, SVP members reached a consensus on how fossil collecting on federal lands should be managed and Sen. Max Baucus introduced S. 3107 in the 102nd Congress.

In the 104th Congress, Rep. Tim Johnson introduced H.R. 2943 which proposed to open up the possibility of commercial fossil collecting on federal lands.

In the 105th Congress, S. Rept. 105-227 directed the Secretary of the Interior to develop a report regarding the management of fossils on federal lands. The recommendations and principles in the resultant DOI Report, "Fossils on Federal and Indian Lands" provided the legislative intent for the PRPA (Fig. 1).

It was first introduced in the 107th Congress by Rep. Jim McGovern as H.R. 2974. A subsequent companion bill, S. 2727 was introduced in the Senate by Sen. Daniel Akaka and after a favorable report from the Energy and Natural Resources Committee was passed by the Senate as part of an omnibus package.

H.R. 2416 was introduced in the 108th Congress by Rep. McGovern and a joint hearing was held by the House Resources Committee Subcommittees on Fisheries and

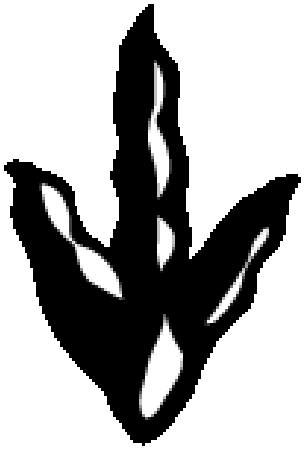
Forests. The Resources Committee did not hold a markup session following the hearing. Sen. Akaka introduced S. 546, which passed the Senate, but did not receive action in the House.

S. 263 was introduced in the 109th Congress by Sen. Akaka. It was passed by the Senate, but was not acted upon by the House.

In the 110th Congress, Rep. McGovern's bill, H.R. 554 received a favorable report from the Natural Resources Committee; however, it was not reported out of the Agriculture or Judiciary Committee. Sen. Akaka's bill, S. 320 was reported out favorably by the Energy and Natural Resources Committee. It was subsequently incorporated into several omnibus packages, all of which were not taken up on the floor due to a filibuster threat.

Sen. Bingaman incorporated the PRPA into The Omnibus Lands Bill of 2009, S. 22. S. 22 was passed by the Senate; however, an attempt to pass the House under Suspension of the Rules failed as it fell two votes short of the 2/3 required for passage under suspension.

Sen. Bingaman subsequently amended H.R. 146, which had already passed the House. After passage of H.R. 146 as amended by the Senate, it was signed into law (Appendix 1, Public Law 111-011).



URBAN INTERFACE PALEONTOLOGY IN WASHINGTON COUNTY, UTAH

8th Conference on Fossil Resources
St. George, Utah
May 19, 2009

FIELD TRIP LEADERS

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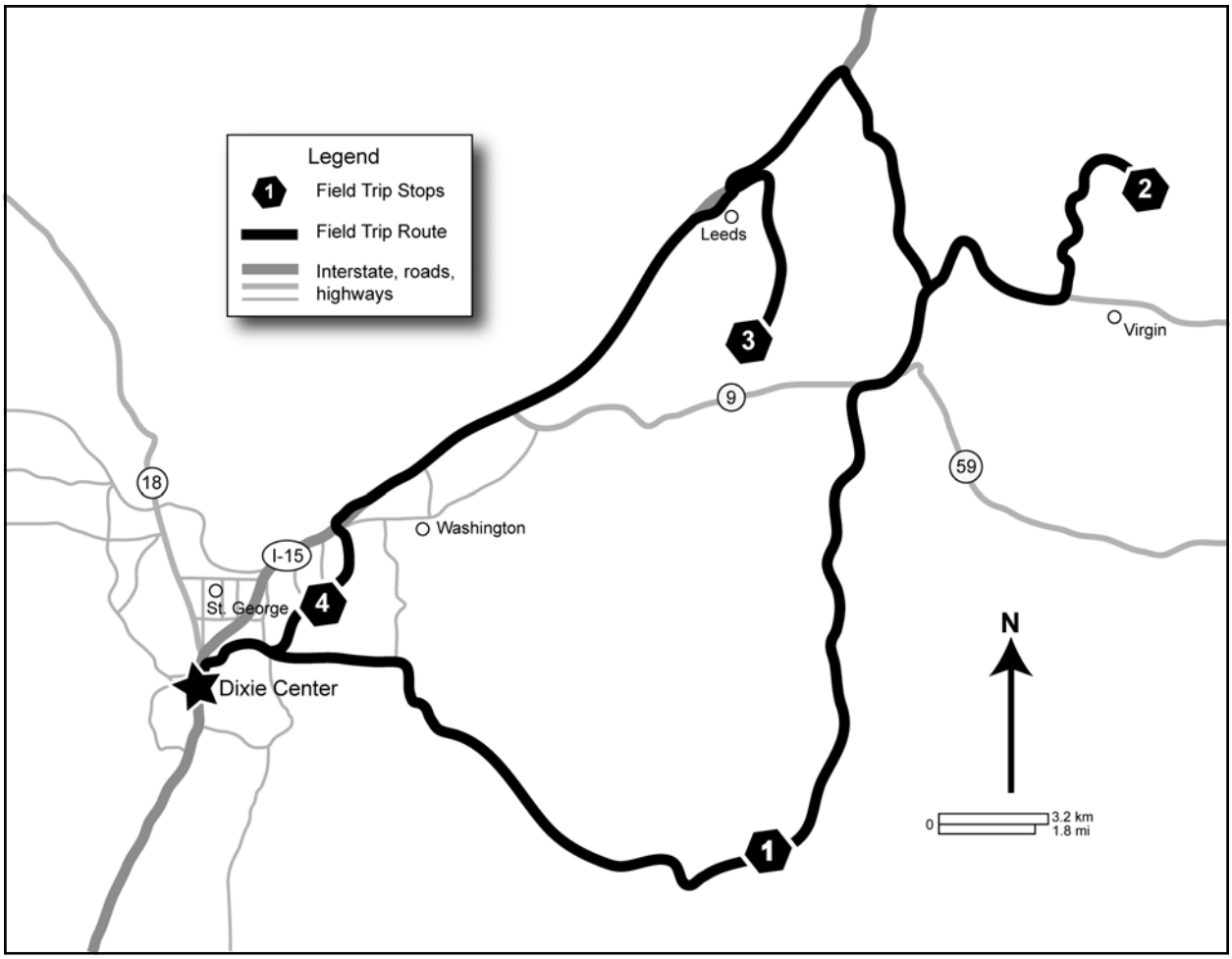

Figure 1. Field trip route and stop locations.

INTRODUCTION

Rapid development within the St. George area of southwestern Utah has resulted in many significant paleontological discoveries with the most important being the St. George Dinosaur Discovery Site at Johnson Farm (SGDS) situated within St. George city limits. This same rapid development is also having an effect on regional paleontological resources because of increased public use such as tourism, off-road vehicle use, vandalism, and in some cases theft. As with archaeological resources, the need for a paleontological site stewardship program on public lands has been established in Washington County to monitor important paleontological sites (Milner et al., 2006a; Spears et al., 2008).

This full-day field trip begins at the Dixie Center in St. George, heading east through Warner Valley situated between Sand Mountain to the north and the Utah-Arizona border to the south. We will stop at the famous Warner Valley Dinosaur Tracksite then head north through the towns of Hurricane and La Verkin, up onto Hurricane Mesa located immediately west of Zion National Park. Here we will observe outcrops of Triassic Moenkopi and Chinle Formations, and evidence of vertebrate fossils and abundant petrified trees. We will then backtrack through La Verkin, drive through the town of Toquerville, and head south on Interstate 15 to Leeds. From here we will drive down into the Babylon Historic Area to view extensive outcrops of Lower Jurassic Kayenta Formation containing abundant theropod dinosaur tracks. The fieldtrip then concludes with a brief overview of the SGDS

and paleontological localities within St. George city limits (Figure 1).

STOP 1 – WARNER VALLEY DINOSAUR TRACKSITE

Dinosaur tracks from Warner Valley were first reported in 1982 (Miller et al., 1989). Miller et al. (1989) mapped 161 footprints in 23 trackways (Figure 2a), but misidentified their stratigraphic position, stating that they were from Dinosaur Canyon Member of the Moenave Formation. These tracks are in fact at the top of the Springdale Member of the overlying Kayenta Formation and are Early Jurassic (Sinemurian) age (Figure 2a). Exploration through the downstream portion of the wash reveals an unconformable contact between the underlying Whitmore Point Member of the Moenave Formation and the base of the Springdale Member. Ironically, the Springdale used to be considered the upper member of the Moenave Formation until very recently (Figure 2b; Lucas and Tanner, 2007).

At least 19 of the trackways at this site represent *Grallator* footprints which are attributed to coelophysid dinosaurs such as *Megapnosaurus* ("*Syntarsus*" or *Coelophysis* according to some authors) (Figure 2c). *Grallator* footprints here range in size 12 to 18 cm (Miller et al., 1989). Four larger trackways show well-preserved *Eubrontes* tracks. A *Dilophosaurus*-sized theropod is widely accepted as the producer of *Eubrontes* footprints. Two track-bearing surfaces are recognized at this site that would have had different substrate consistencies. Both were sandy, although the lower surface appears to have been much wetter than the upper when footprints were made.

Erosion and vandalism to this site, among several others in the region, is an ongoing problem. In the 1980's a diversion wall was constructed through the middle of the tracksite in an attempt to channel water away from the better preserved footprints (Figure 2a). Unfortunately, dinosaur tracks on the east side of the wall are now more heavily eroded due increased water flow, and during heavy flood conditions, the south side of the diversion wall is sometimes breached. Most of the areas around the tracksite are open for OHV use, however a 40 acre parcel around the locality is not, but frequently OHV users have been witnessed driving across the eastern side of the diversion wall on the tracksite surface.

On many occasions it has been observed that plaster, and even concrete replicas have been made from some of the nicer *Eubrontes* and *Grallator* tracks at the site. Premade forms were brought to the site, placed around the footprint(s), and then the form was sealed to the bedrock using caulking (Figure 2c). This same damaging technique has been observed at several other dinosaur tracksites in southern Utah as well. In the early 1990's the BLM placed interpretive signage at the Warner Valley Tracksite, which has also been vandalized.

This locality and others within Washington County are now being monitored by trained BLM volunteers under the Color Country Site Stewardship Program (Milner et al., 2006a; Spears et al., 2008). Site stewards have been reporting on the conditions at the Warner Valley Tracksite since 2007. Every time a site steward visits the locality, they place rocks around obvious dinosaur tracks in a serious attempt to keep off-road vehicles from driving over them. In early 2009, the BLM improved fencing near the public access road and installed range fencing around the entire non-OHV use area. In 2005 similar fencing was placed around the Spectrum Dinosaur Tracksite located on State Land (Hamblin, 2004, 2006; Hamblin et al., 2006; Milner et al., 2006a; Milner and Spears, 2007). Recently, carsonite signs that outline site etiquette have been installed and efforts are being made to stabilize the fragile surface of the trackways. The St. George BLM Field Office is also looking into the possibility of using ethyl silicates and silane-based chemicals to alter the chemical composition of the rock matrix in order to make it more resistant to weathering. Similar compounds are used to preserve stone on historic

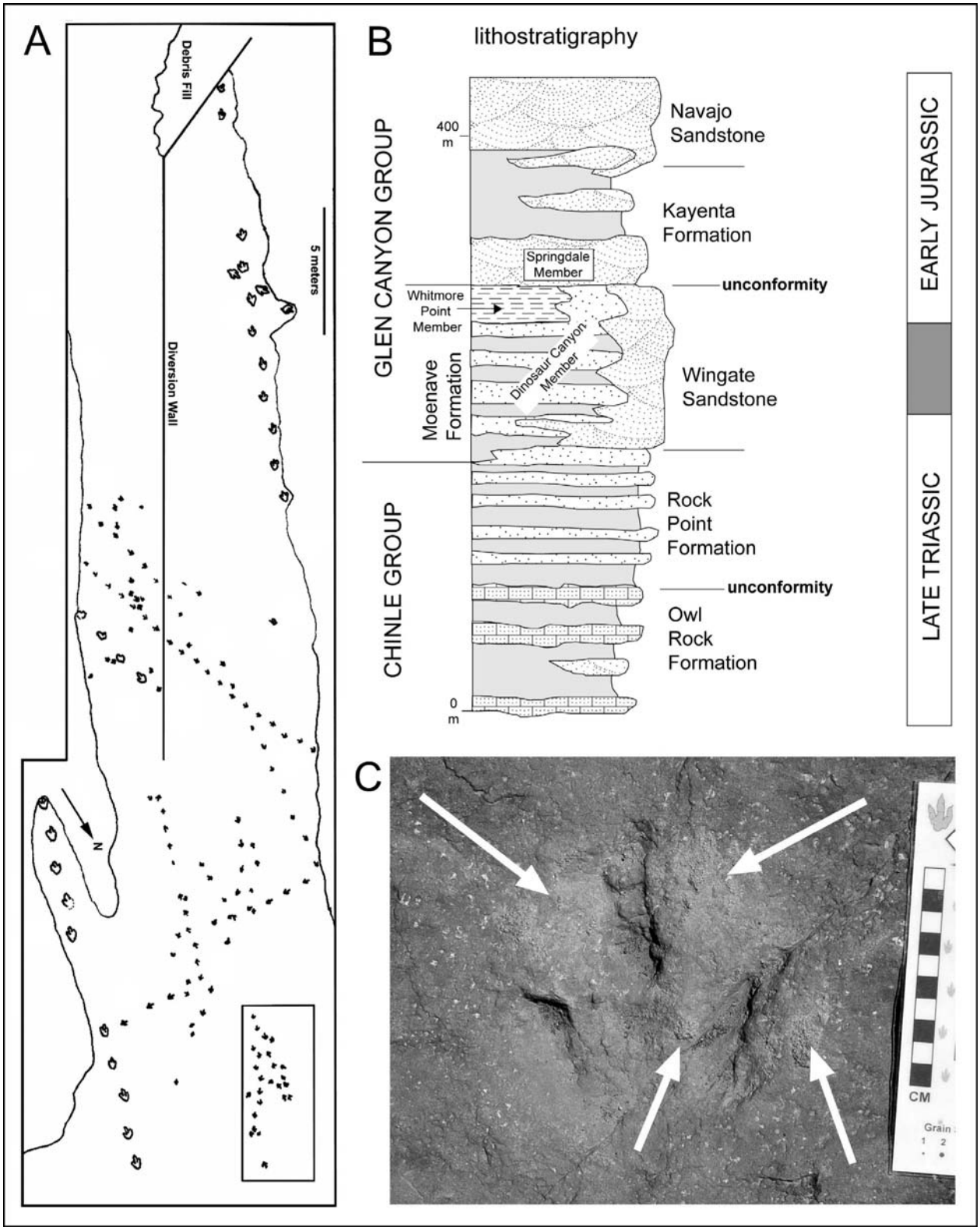

Figure 2. Warner Valley Dinosaur Tracksite. **A.** Original tracksite map from Miller et al., 1989, Figure 21.5. **B.** Generalized stratigraphy of upper Chinle Formation (or Group by some authors) to the base of Navajo Formation from Warner Valley on the left to Four Corner region on the right (From Lucas and Tanner, 2006, figure 5). **C**. Concrete damage in and around *Grallator* footprint. Photo by Dan Whalen.

buildings and certain archaeological sites (R. Denton, personal communication, 2006; Grisafe, 2000, 2001, 2002).

STOP 2 – HURRICANE MESA

Hurricane Mesa is famous because of the Hurricane Mesa Test Facility, which was constructed in 1954 by the U.S. Air Force to test ejector seats and other aviation systems. Since 1963 the facility has been used by private enterprises and is presently operated as the Goodrich Supersonic Test Site. The test track is 12,000 feet long. Along with Little Creek and Gooseberry mesas, Hurricane Mesa is a popular "rockhounding" area (Stowe and Perry, 1979; Kappele, 1996). These areas have always been popular for the collection of petrified wood, agate, and vertebrate fossils, particularly phytosaur and metoposaur teeth (federal policy prevents the unlawful collection of these vertebrate fossils).

Starting at the base of Hurricane Mesa are exposures of the Moenkopi Formation, with the following members from oldest to youngest (Lower Triassic to lower Middle Triassic): "lower red" member, Virgin Limestone Member, "middle red" member, Shnabkaib Member, and "upper red" member (Figure 3a). Three of these members have not been formally named and the Virgin Limestone is a marine sequence.

Tracksites are known from the base of the Virgin Limestone in Kolob Canyon at the north end of Zion National Park (Mickelson et al., 2006) continuing all the way north to Cedar City in Iron County. Fossil trackways from the base of the Virgin Limestone have not been documented to the south of Kolob Canyon. The upper red member has abundant tracksites distributed over of wide area in southwestern Utah and northwestern Arizona. The cap rock of Hurricane Mesa is the Shinarump Member of the Late Triassic Chinle Formation. Abundant petrified trees are widespread in the Shinarump nearly everywhere it is observed. Vertebrate fossils (including metoposaur and phytosaur) and some identifiable plant fossils (conifers and horsetails) are also present in the Shinarump in Washington County.

Above Hurricane Mesa is Smiths Mesa, which extends to the east into the southern portion of Zion National Park. Petrified trees are common through the lower Petrified Forest Member which has a locally thick middle unit referred to by some as the Sonsela Member (Heckert and Lucas in Heckert et al., 2006). Most continue to refer to the entire Chinle Formation above the Shinarump Member as "undifferentiated" Petrified Forest Member. Vertebrate fossils in the lower half of the Petrified Forest Member are quite common, and many important localities have been found in the past eight years. Most of these have not yet been excavated and/or studied in great detail (DeBlieux et al., 2003, 2004, 2006; Milner et al., 2006a; Milner et al., this volume). To date, Hurricane Mesa has revealed two potential microvertebrate localities, one phytosaur locality, and one site that has produced multiple vertebrate fossils, including a metoposaurid, poposaurid, phytosaur, and coprolites (Milner et al., 2006a, this volume). Three potential microvertebrate localities occur above the middle channel unit (Milner et al., this volume). Above the Chinle is the Moenave Formation with the Springdale Sandstone Member of the Kayenta Formation forming the capping rock of Smiths Mesa (Figures 2b and 3a).

Because Hurricane, Little Creek, and Gooseberry mesas are well-known for petrified wood and have been identified in literature as mineral collecting localities (Stowe and Perry, 1979; Kappele, 1996), unauthorized excavation, removal, theft, and vandalism of many petrified trees has occurred. In the early summer of 2002, the first author discovered and documented, but did not collect, a partial metoposaur (Milner et al., 2006a). This fossil was later illegally collected between March and June of 2003. The theft was reported to the BLM in 2003 and the remaining bones were salvaged by paleontologists from the Yale-Peabody Museum of Natural History. In 2007, a local

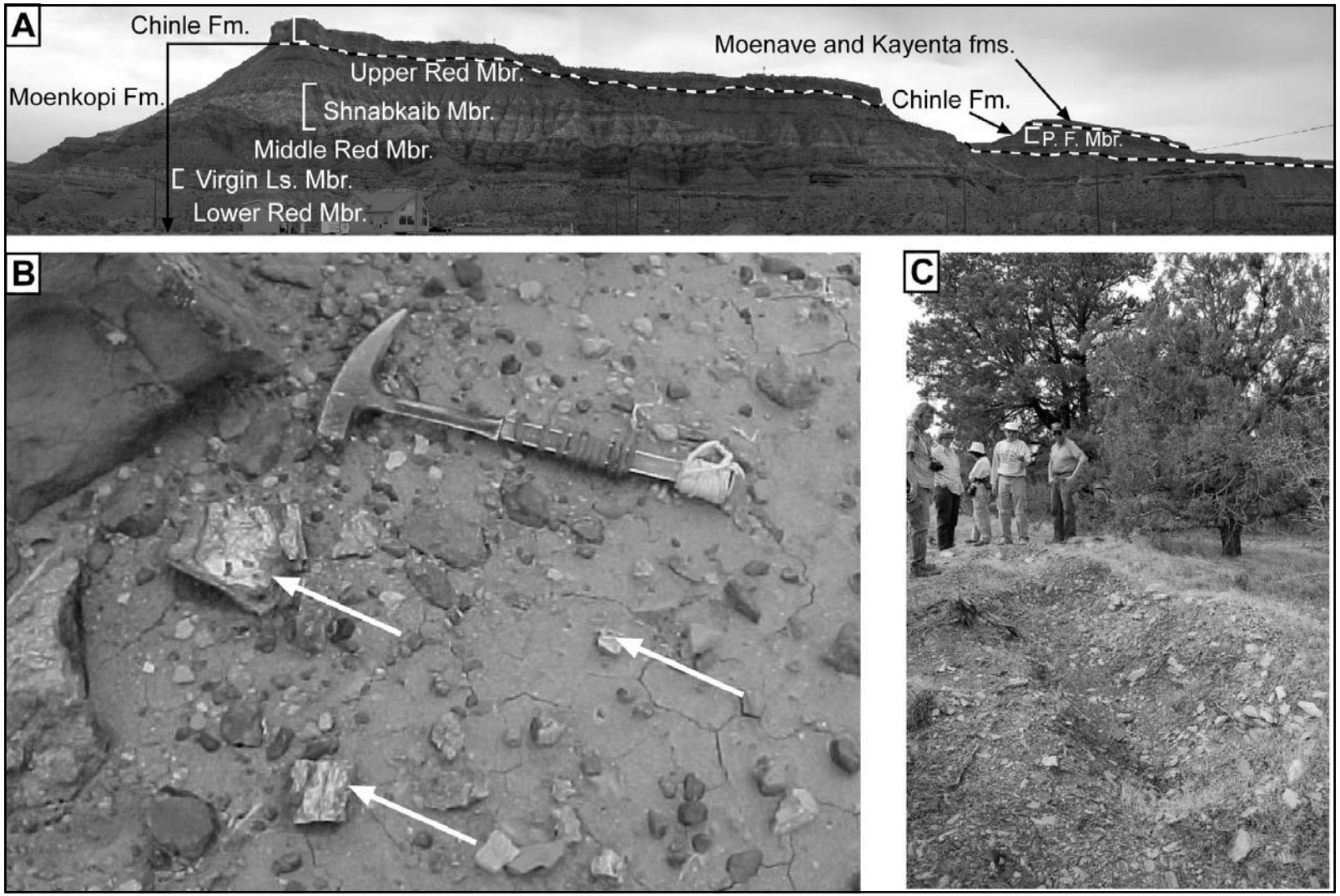

Figure 3. Hurricane Mesa. A. View of Hurricane Mesa showing the Moenkopi Formation capped by the Shinarump and Petrified Forest members of the Chinle Formation. B. Metoposaur bones as they were found in 2002. They were stolen from the site in 2003 and recovered in 2007. C. Sixty-foot trench that used to contain a petrified tree that was stolen from Hurricane Mesa in 2007.

rockhound brought "dinosaur bones" to the SGDS for identification, which were immediately recognized as the missing metoposaur bones from the site discovered in 2002 (Figure 3b). This was reported to BLM law enforcement and the stolen bones have since been reunited with those that were salvaged later by Yale-Peabody Museum and SGDS paleontologists.

In 2003, it was noticed that an increasing number of petrified trees were being illegally removed (Figure 3c). This escalated extensively in 2007with the disappearance of some enormous trees measuring up to 90 feet long. Back-hoes were used to excavate the trees and bulldoze living trees to get to the fossils. Garbage was often dumped by the perpetrators as well. In late 2007 and early 2008 seven people were charged with theft and vandalism of federal property. The same people were also stealing petrified tree from Gooseberry and Little Creek mesas. The petrified wood was being sold for landscaping and to local rock shops. Several tons of petrified wood were confiscated by the BLM. In 2008, the BLM transferred the confiscated logs to the SGDS museum. On Hurricane Mesa, vertebrate remains are being found in close association with petrified trees.

CAN I COLLECT PETRIFIED WOOD?

It is permissible to collect reasonable amounts of common invertebrate fossils and petrified wood. (43CFR8365.1-5)

What is a reasonable amount?
BLM regulations allow the collection of 25 pounds per day of petrified wood plus one piece, provided that the total removed by one person does not exceed 250 pounds in one calendar year. Pooling of quotas to obtain pieces larger than 250 pounds is not allowed. (43CFR3622.4)
Power equipment, explosives, or heavy digging or hauling equipment may NOT be used to excavate or remove petrified wood. (43CFR3622.4)

STOP 3 – THE DESERT TORTOISE TRACKSITES (DT)

The Bureau of Land Management, State of Utah, and Washington County collaboratively manage the Red Cliffs Desert Reserve, which was established in 1996 to protect habitat capable of sustaining wildlife populations threatened by rapid development and habitat loss across Washington County in southwestern Utah. On March 30, 2009, President Obama signed the Omnibus Public Lands Act of 2009. Subtitle of that bill elevates this reserve to National Conservation Area, (NCA), status. The BLM is working with its partners to develop a new Resource Management Plan for the Red Cliffs Desert NCA. Protecting habitat critical to the endangered desert tortoise has also allowed for the protection of paleontological resources. Five major tracksites at three stratigraphic levels are present here, and four additional track-bearing stratigraphic levels are know from this valley, for a total of seven track-producing layers thus far identified. Lockley et al. (2006) mapped four of the five major sites, and measured the lower portion of the stratigraphic section for a preliminary study of the area (Figure 4). The first tracksite discovery (DT1) was made by the first author during the field trip for a 2005 Triassic-Jurassic Transition Conference entitled *Tracking Dinosaur Origins* (Harris, 2005).

The described tracksites (Lockley et al., 2006; Milner and Spears, 2007) are on steeply dipping slopes (between 35° and 50°) within

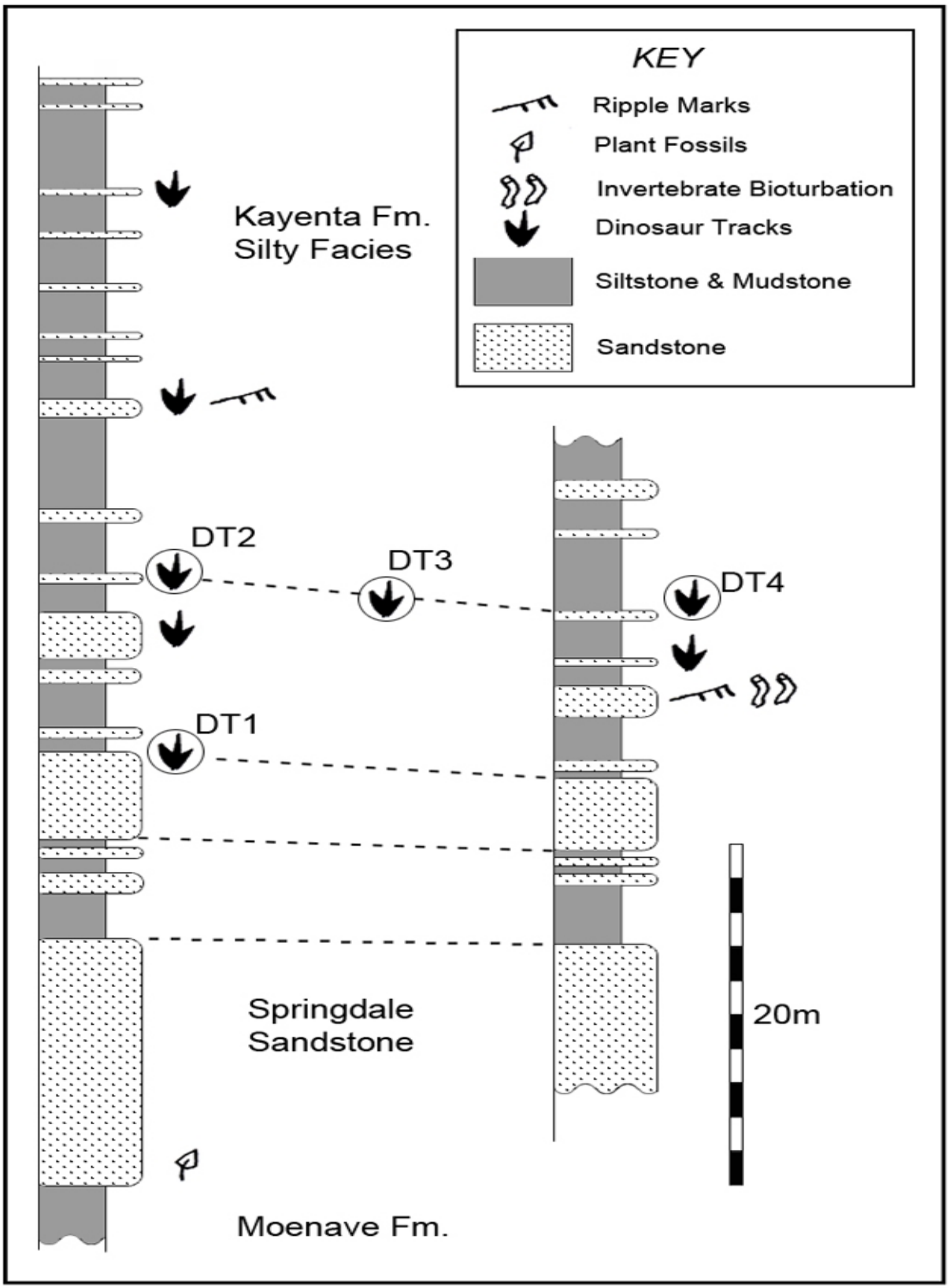

Figure 4. Generalized stratigraphic section showing the positions of Desert Tortoise tracksites (DT1-DT4) in the silty facies of the Kayenta Formation. The section on the left shows the northeastern area and on the right is the southwestern area (from Lockley et al., 2006).

the "silty facies" of the Kayenta Formation (figure 5). The silty facies in this area consist of alternating mudstones, siltstones, sandstones, and thin carbonate sandstone beds with dinosaur tracksites mostly on carbonate sandstone and sandstone surfaces. The mudstones and siltstones represent shallow and marginal lacustrine environments, although some are interpreted as possible paleosols (Lockley et al., 2006). Some thin, fine-grained sandstone beds are also interpreted as shallow lacustrine and/or marginal lacustrine environments because of *Grallator*-type theropod swim tracks, disarticulated semionotid fish remains, and rare coprolites (Milner and Spears, 2007). Sandstones are deposited in fluvial channels, reworked marginal lacustrine, and occasional eolian deposits, particularly toward the top of the silty facies. The major tracksites are preserved on red-brown sandstone (DT1) and white carbonate sandstones (DT2-4).

Desert Tortoise Tracksite 1 (DT1) is divided into two parts (north [N] and south [S] sites) that were mapped separately (Figure 6), and first illustrated and described by Lockley et al. (2006). The smaller site (N) has 16 *Eubrontes* tracks in at least five trackways

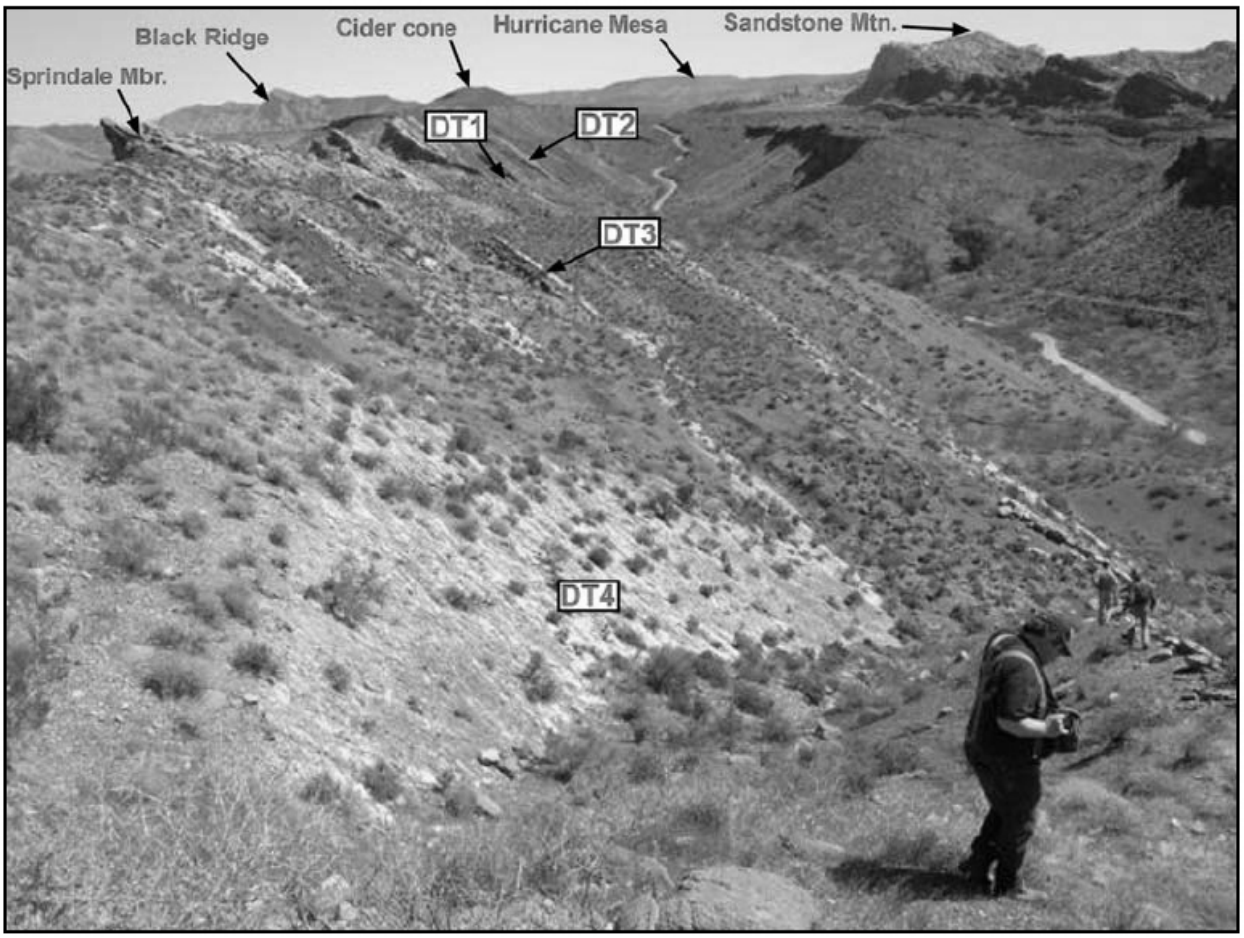

Figure 5. View to the north-northeast showing the Desert Tortoise tracksites (DT1 to DT4) on the eastern flank of the Virgin anticline. The prominent ridge (East Reef) stratigraphically below the tracksites is the Springdale Sandstone Member of the Kayenta Formation. Below this are the Moenave Formation (out of view) and the Upper Triassic Chinle Formation (partially visible in the upper left corner in Grapevine Wash valley). Sandstone Mountain in the upper right is comprised of Navajo Sandstone. Other geologic features indicated on the horizon (Hurricane Mesa, a cinder cone volcano, and Black Ridge) (From Milner and Spears, 2007).

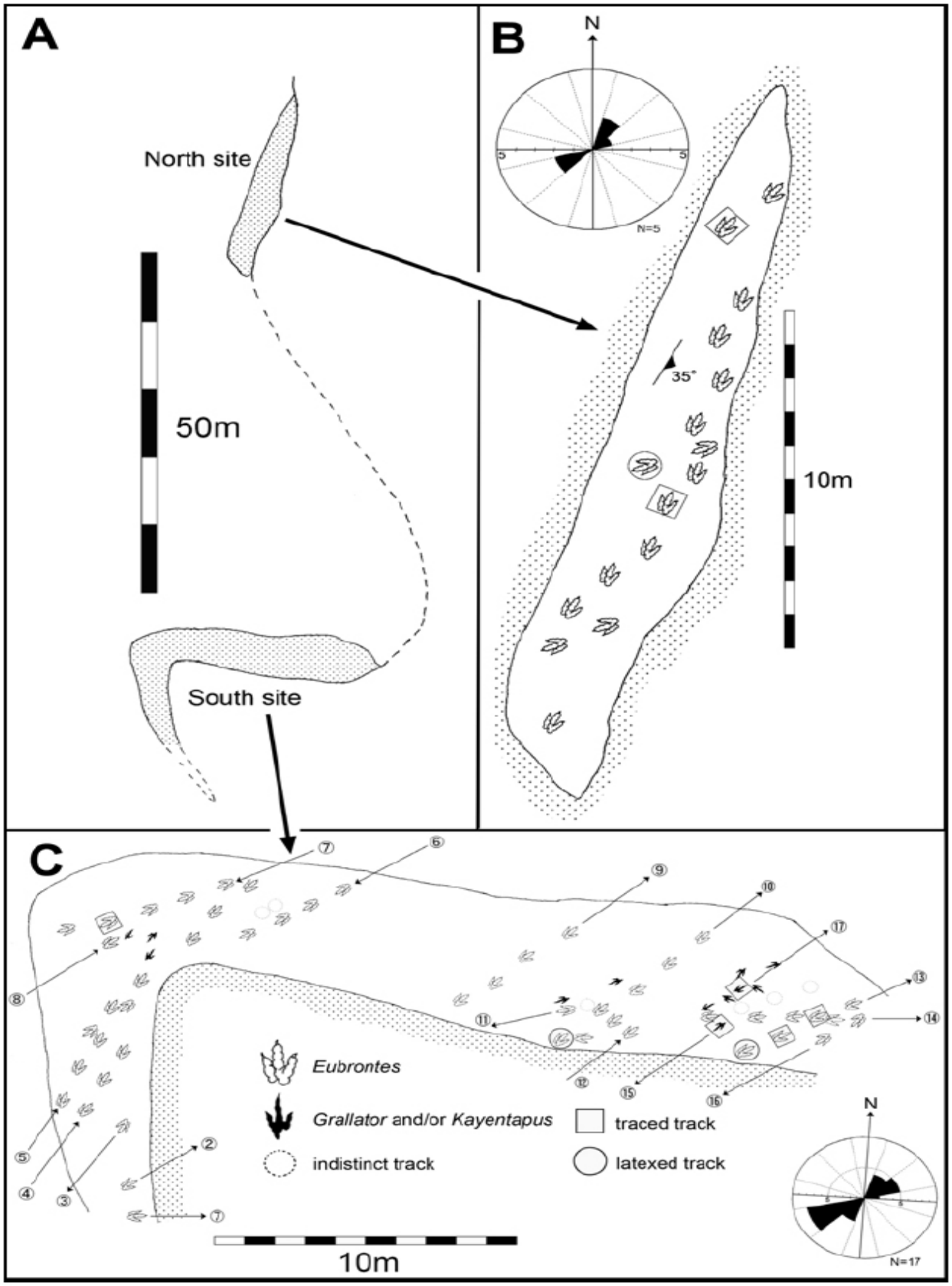

Figure 6, A. Map showing the relation between Desert Tortoise 1 (DT1) north (N) and south (S) sites. Both DT1 north and south tracksites are separated by about 50 meters. **B.** Detail of DT1 (N) tracksite. **C.** Detail of DT1 (S) tracksite. From Lockley et al., 2006.

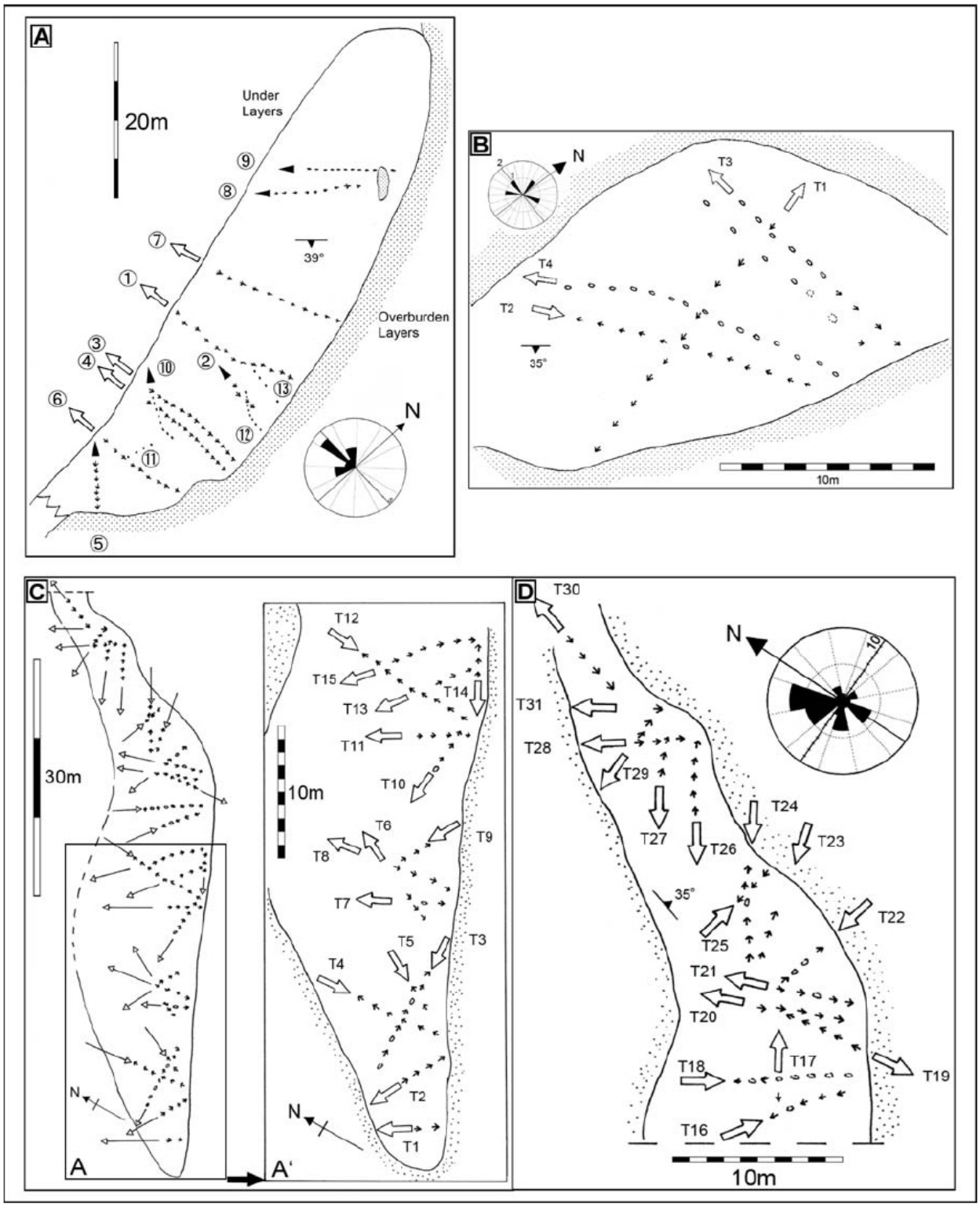

Figure 7. Maps of Desert Tortoise Tracksites DT2, DT3, and DT4 showing trackway orientations on the maps and in rose diagram form. A, Map of DT2 Tracksite showing 13 trackways. B, Map of DT3 Tracksite showing five trackways, but orientation can only be recognized on four. C, A shows map of whole Desert Tortoise Tracksite DT4 preserving 31 trackways. A' Detail of trackways 1-15 from the western half of DT4 Tracksite. D, Detail map showing trackways 16-31 on the eastern half of DT4 Tracksite. All illustrations from Lockley et al., 2006.

of large theropod dinosaurs (Figure 6a-b; Lockley et al., 2006). The larger DT1 (S) tracksite has at least 60 recognizable tracks in 17 identified trackways and several isolated footprints. This site has good track preservation and is dominated by larger *Eubrontes*, although *Grallator* tracks are present (Figure 6c). There is a strong bimodal trackway orientation along a NE-SW trend (Lockley et al., 2006).

Desert Tortoise tracksites 2, 3 and 4 (DT2-4) are much larger surfaces than DT1 and are stratigraphically higher (Figure 4). Of these, DT2 is the largest, measuring approximately 60 by 20 m. More than 100 poorly preserved footprints have been mapped in 13 trackways (Figure 7a; Lockley et al., 2006). Most of the tracks at DT2 are deep and elongate (12-44 cm long) showing metatarsal impressions. These tracks are provisionally identified as *Eubrontes*, but severe weathering and track deformation of soft substrate during time of track formation makes this identification uncertain (Lockley et al., 2006). Also of interest at DT2 is that five trackways are parallel and may indicate gregarious behavior (Figure 7a; see Lockley et al., 2006 for further discussion).

DT3 is the smallest site in terms of number of recorded trackways, with only five (Figure 7b; Lockley et al., 2006) that show clear trackway patterns. Preservation at this site is very poor. The DT4 site is very large, with 30 recorded trackways (Figure 7c-d; Lockley et al., 2006). At least 30 recognized trackway segments were mapped, all of which gave reliable information on orientations. The trackways are mostly deep, as at Desert Tortoise tracksites DT2 and DT3, but the preservation is slightly better in certain trackways, particularly toward the north end of the site.

Tracksite DT5 was discovered in 2005 by SGDS volunteer David Slauf of St. George, Utah. Situated near the top of the silty facies, it is the youngest of the DT tracksites. DT5 is unique because it preserves rare *Eubrontes* tracks as well as the more common and much smaller *Grallator* footprints. This tracksite also preserves quadrupedal footprints similar to *Batrachopus*. Mapping this locality will be challenging due to the 50° slope and extensive vegetative cover (Milner and Spears, 2007).

The BLM is currently considering the placement of trails and interpretive signs that outline site etiquette at some of the more popular tracksites. All of these sites, including several petrified tree and bone localities in the nearby Chinle Formation are monitored by the

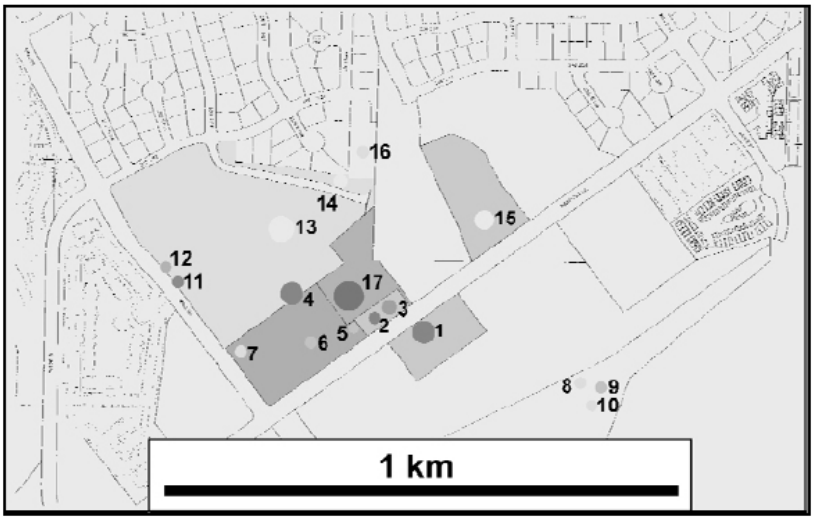

Figure 8. Map of the immediate vicinity of the SGDS in St. George, Washington County, Utah. Locality numbers: (1) SGDS 1st phase museum and original discovery site, (2) Hildale Tracksite, (3) Stewart-Walker Tracksite, (4) Swim Tracksite, (5) Walt's Quarry #1, (6) Walt's Quarry #2, (7) DS Plant Locality, (8) JO Plant Site #1, (9) Jensen Ridge Tracksite, (10) JO Plant Site #2, (11) Mall Drive Tracksite, (12) Mall Drive Stromatolite Site, (13) Ah!Quarium Fish Stick Site, (14) Freeman Quarry, (15) Chapman Fish Site, (16) Kayenta Tree Site, and (17) LDS Tracksite. Nearly all of the above localities are correlated with locality abbreviations shown on figure 9

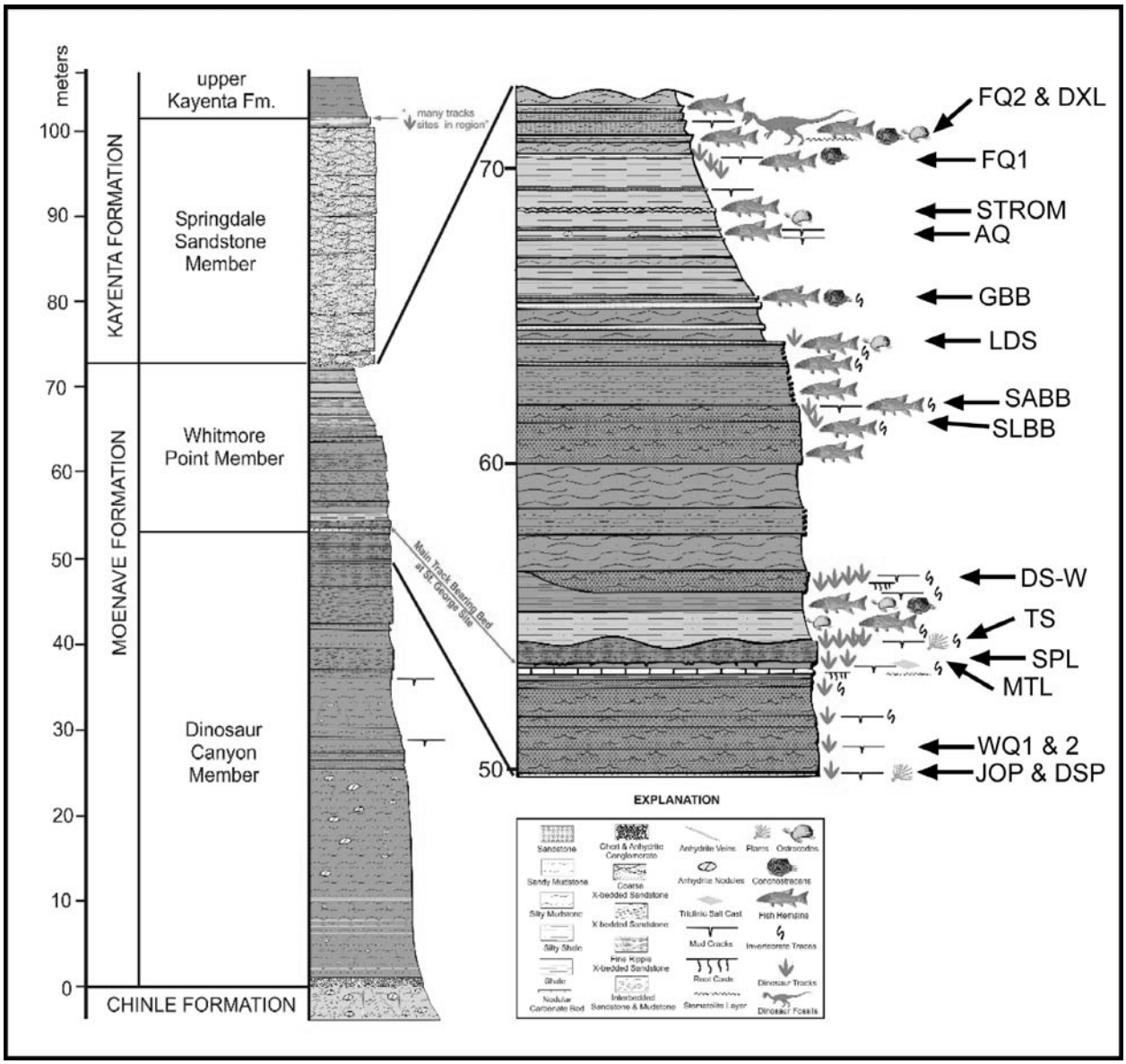

Figure 9. Stratigraphic section of the Moenave Formation at the SGDS showing the positions of significant fossils. Abbreviations (abbreviations followed by corresponding localities from figure 8): AQ, Ah!Quarium Fish Stick Quarry (loc nos. 13 and 15); DSP, Darcy Stewart Plant locality (loc. no. 7); DS-W, Stewart-Walker tracksites (loc. no. 3); DXL, Dixie Lube Locality (see figure 57 below); FQ1, Freeman Quarry lower fish beds (loc. nos. 14, 15); FQ2, Freeman Quarry upper fish beds (loc. nos. 14, 15); GBB, "Green Burrow Bed" (loc. nos. 11, 15, 17); JOP, Jensen Ridge Plant localities (loc. nos. 8, 10); LDS, "Jesus Christ of Latter-day Saints property tracksite" and "Mall Drive tracksite" (locs. no. 12, 17); MTL, "Main Track Layer" at the base of the "Johnson Farm Sandstone Bed" or main track-bearing sandstone (loc. nos. 1-5, 9); SABB, "Sally's Burrow Bed" (loc. nos. 15, 17); SLBB, "Slauf Burrow Bed" (loc. nos.15, 17); SPL, "Split Track Layer" of the Johnson Farm Sandstone Bed (loc. nos. 1-3); STROM, Stromatolite Bed (loc. nos. 12, 13); TS, "Top Surface" of the Johnson Farm Sandstone Bed (loc. nos. 1-3, 5); WQ1 & 2, Walt's Quarry 1 (loc. nos. 5) and Walt's Quarry 2 (loc. nos. 6) (modified from Kirkland and Milner, 2006).

Color Country Site Stewardship Program, and roads are patrolled regularly by the Washington County Sheriff. BLM and Washington County law enforcement are aware of the importance of monitoring and preserving these sites.

STOP 4 – ST. GEORGE DINOSAUR DISCOVERY SITE AT JOHNSON FARM (SGDS)

Owned and operated by the City of St. George, the SGDS is an important treasure to the people of St. George and a popular tourist attraction to visitors to the area. The first dinosaur tracks were discovered by Dr. Sheldon Johnson on February 26, 2000, while he was leveling a hill on this property (no. 1 on Figure 8). A few months after the initial discovery, paleontologists making investigations of the tracksite and surrounding area recognized abundant fish fossils and bones on an undisturbed hill north-northwest of Riverside Drive, and the present location of the St. George Dinosaur Discovery Site at Johnson Farm (SGDS) (no. 13 on Figure 8).

Very soon after discovery the site received much public and media attention and by late June of 2000 had been visited by more than 50,000 people. Following this, interest was greatly increased by further discoveries at many nearby localities within the Moenave Formation. Some of these discoveries include: (1) the trace of a crouching theropod dinosaur with hand impressions (Figure 10a; Milner et al., 2007, 2009); (2) the world's largest and best preserved collection of dinosaur swim tracks, ending all controversy on whether theropod dinosaurs could actually swim (Milner and Lockley, 2006; Milner et al., 2006b, d; Milner and Kirkland, 2007; Milner and Spears, 2007); (3) and an unprecedented assemblage of well-preserved dinosaur tracks, some of which include detailed skin, scale, and claw impressions.

Researchers from the Utah Geological Survey (UGS), the University of Colorado at Denver Dinosaur (UC), and many others have worked closely with the City of St. George, resulting in many publications (Kirkland et al., 2002; Lockley et al., 2004; Lucas et al., 2005; Cornet and Waanders, 2006; Hudson and Chan, 2006; Kirkland and Milner, 2006; Hunt and Lucas, 2006; Lucas and Milner, 2006; Lucas et al., 2006a, b; Milner and Kirkland, 2006; Milner and Lockley, 2006; Milner et al., 2005, 2006b, c, d; Schudack, 2006; Tidwell and Ash, 2006; Williams et al., 2006; Milner and Kirkland, 2007; Milner and Spears, 2007; Milner et al., 2007, 2009). Several significant results of this scientific activity have culminated with several scientific conferences being held in St. George, Utah: (1) a March 2005 international symposium called "Tracking Dinosaur Origins: the Triassic-Jurassic Terrestrial Transition" (Harris, 2005); the Annual Meeting of the Rocky Mountain Section, Geological Society of America in May 2007; and (3) two coinciding conferences in May, 2009 (8th Conference on Fossil Resources and Advances in Cretaceous Research).

PDF's of many of these publications may be downloaded from, http://www.sgcity.org/dinotrax/

Other significant discoveries at the SGDS include early fossil plants (Cornet and Waanders, 2006; Tidwell and Ash, 2006), collections of fossil fishes (Milner and Kirkland, 2006; Milner and Lockley, 2006; Milner et al., 2006b), invertebrate body fossils (Lucas and Milner, 2006; Schudack, 2006), and theropod dinosaur remains (Kirkland et al., 2005), all found in close association with the tracks and other traces. Collectively, the SGDS provides a window into an Early Jurassic ecosystem associated with the shores of a large lake or series of lakes called Lake Dixie (cf. Kirkland et al., 2002; Milner et al., 2004). The proceedings of the 2005 conference mentioned above were published in the New Mexico Museum of Natural History and Science Bulletin 37, which provided a dedication to all those who helped preserve fossils at SGDS (Harris et al., 2006). Unfortunately, the importance of this contribution was overshadowed by the controversy over "Aetogate" (Dalton, 2008)

The Moenave Formation (latest Triassic(?) to earliest Jurassic in age) in the area of the SGDS is 73.97 m thick, and is divided into the underlying Dinosaur Canyon Member (56.41 m thick) and the overlying Whitmore Point Member (17.56 m thick) (Kirkland and Milner, 2006). Unconformities locally separate the Moenave Formation from the underlying Upper Triassic Chinle Formation, and the overlying Lower Jurassic Kayenta Formation (Figure 9).

The Triassic-Jurassic boundary is somewhere within the Dinosaur Canyon Member; however, its stratigraphic location has not been narrowed down in southwestern Utah. The Dinosaur Canyon Member has been divided into three intervals: (1) the basal conglomerate about 80 cm thick, immediately above the unconformity at the top of the Chinle Formation, (2) the lower mudstone interval about 34.8 m thick, and dominated by mudstone, and (3) the upper sandstone interval measuring about 20.46 m thick (Kirkland and Milner, 2006). The uppermost part of the upper sandstone interval of the Dinosaur Canyon Member preserves plant and

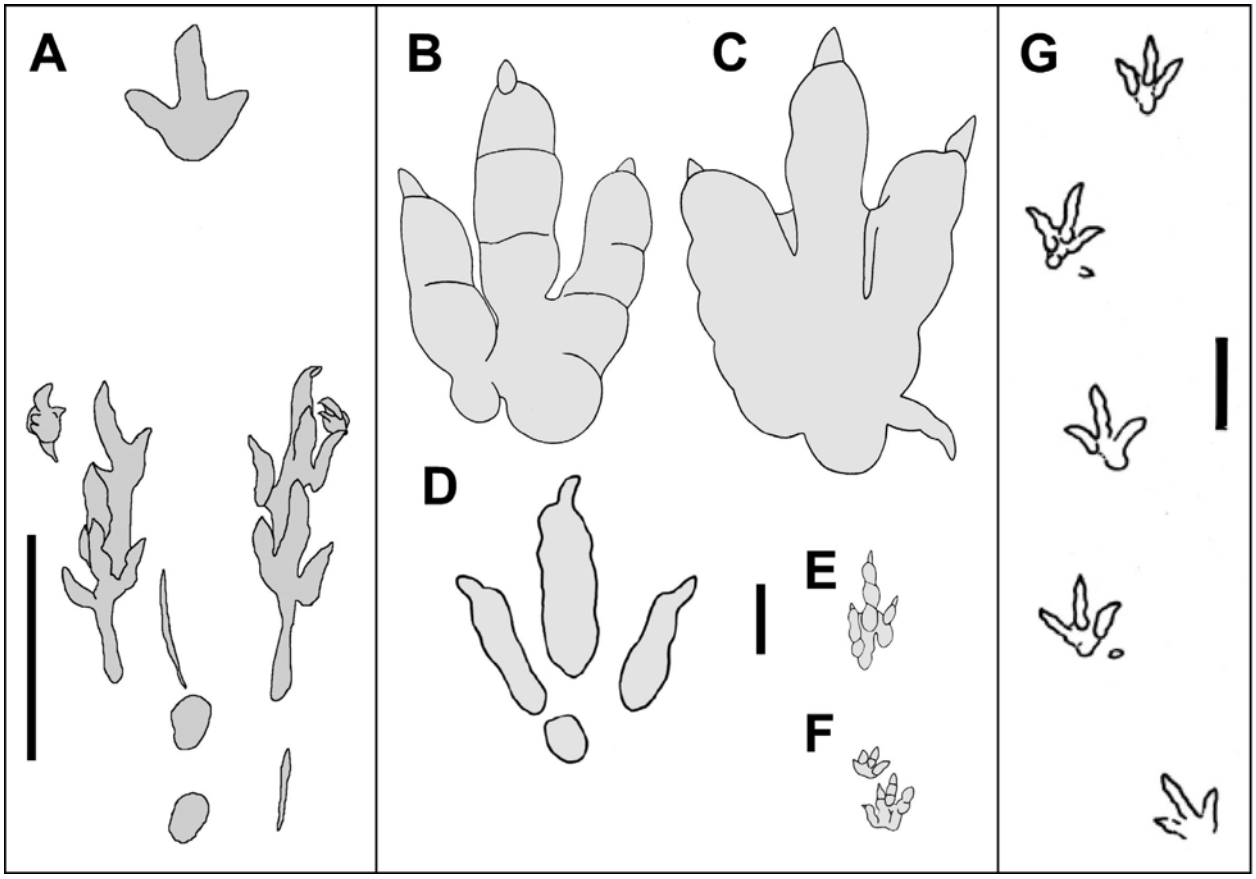

Figure 10. Schematic drawings of vertebrate tracks types found at SGDS localities. A, *Eubrontes* crouching trace from "Top Surface" Tracksite within SGDS Museum (SGDS 18-T1). This *in situ* specimen shows clear left and right manus impressions, pes tracks with metatarsal impressions, ischial callosities, and tail drag marks. B, *Eubrontes* right pes, from Lull, 1953. C, *Gigandipus* left pes, from Lull, 1953. D, *Kayentapus*, right pes footprint from holotype trackway (UCMP 83668 modified from Welles, 1971). E, *Grallator*, left pes from Lull, 1953. F, *Batrachopus*, crocodylomorph right manus and pes set from Lull, 1953. G, *Anomoepus* trackway from the Kayenta Formation, Lisbon Valley Oilfield Tracksite, San Juan County, Utah (from Lockley and Gierliński, 2006). Scale bars for the following equal: A = 0.5 m; B-F = 5 cm; and G = 10 cm. UCMP = University of California Museum of Paleontology, Berkeley, California.

trace fossils. Though *Grallator* tracks are by far the most abundant, *Eubrontes*, *Batrachopus*, and *Anomoepus* tracks indicate these rocks are Early Jurassic (Hettangian) in age.

The lower interval of the Whitmore Point Member at the SGDS (4.48 m thick) represents shoreline deposits of subaerial and subaqueous environments that indicate lake level transgression and regression along the western margin of Lake Dixie (Kirkland and Milner, 2006). Above this is the middle sandstone interval (7.64 m thick) and the upper shale-dominated interval (6.55 m thick). The upper shale-dominated interval is unconformably overlain by the Springdale Sandstone Member of the Kayenta Formation (Kirkland and Milner, 2006).

Tracks have been identified on 25 stratigraphic levels in the immediate vicinity of the SGDS (Figure 9), and many of these layers have been mapped *in situ*.

Four track-producing layers have been recognized in the uppermost part of the Dinosaur Canyon Member at the SGDS (Figure 9). Two very important localities, called "Walt's Quarry 1" and "Walt's Quarry 2" (named in honor of Walt Stead who discovered both sites) were mapped *in situ* during careful excavation on former DS property in 2004-2005 (nos. 5 and 6 in Figure 8). Part of the WQ1 site was recovered as a single 23.59 metric ton block now displayed in the SGDS museum. It contains 47 *Grallator* tracks in 11 trackways and is by far one of the most visually spectacular specimens in the SGDS collection. Part of WQ2 was incorporated into a 13.11 m long by 4.57 m high wall in the first phase of the SGDS museum. About 200 dinosaur tracks (mostly *Grallator*), fish swim traces, and crocodylomorph tracks are documented on this wall.

The original tracks discovered at the SGDS are from a horizon called the "Main Tracklayer" (MTL in figure 9) at the base of the "Johnson Farm Sandstone Bed" (JFSB is referred to as the "main track-bearing sandstone" in Kirkland and Milner, 2006), a unit that is quite extensive in the St. George area. Tracks from the MTL are preserved as robust sandstone casts (negative relief) associated with mud cracks, salt-crystal casts, flute casts, and many other sedimentary structures. The JFSB generally varies in thickness between 30 and 70 cm, although it does pinch out in some areas. It is well-sorted, fine-grained sandstone about 53 m above the formation base (figure 9). The track casts have up to 20 cm of relief, and can only be seen after the JFSB has been turned over. This process requires heavy equipment, and necessitated removing blocks from their original *in situ* position.

Another track-bearing horizon within the JFSB is the "Split Layer," approximately 4-15 cm above the base of the JFSB and MTL horizon (SPL in figure 9; Milner et al., 2006d). Also, four additional track-bearing horizons are on top of the JFSB, all referred to as the "Top Surface" (TS in figure 9). An enormous portion of the "Top Surface" still remains preserved *in situ* within the First Phase museum at the SGDS. These important and complex, undulating surfaces reveal several laterally variable layers in a thin stratigraphic interval, and display a complex of irregular current ripples, regular oscillation ripples, ridges, swales, mud cracks, scour and depositional features, in addition to tracks and/or under-tracks with variable preservation.

One of the striking features of the SGDS is the relation between trackways, topography, and the local paleogeography. We cannot map the paleogeography at every track level, as surfaces are only exposed sporadically and the cost of additional excavation would be prohibitive. However, it is possible to map the MTL on which most of the trackways were made by walking animals on an undulating surface. In contrast to this "onshore" location, an extensive track-bearing continuation of the MTL surface discovered to the northwest on WCSD and DS properties preserves abundant dinosaur swim tracks (*Characichnos* Whyte and Romano, 2001) representing an "offshore" location equivalent to the

"onshore" surface marked by well-preserved *Eubrontes* tracks (Milner et al., 2006c).

To-date, over 6000 individual vertebrate tracks have been recorded at SGDS. Track types include common *Grallator* footprints (Figure 10e), representing approximately 95% of all dinosaur tracks recorded at the site, *Eubrontes* (Figure 10b), *Kayentapus* (Figure 10d), rare *Gigandipus* (Figure 10c), abundant quadrupedal footprints called *Batrachopus* produced by crocodylomorphs (Figure 10f; Olsen and Padian, 1986), possible synapsid tracks, and very rare *Anomoepus* tracks (Figure 10g) produced by ornithopod dinosaurs. Many of the dinosaur trackways at the SGDS parallel the paleoshoreline, although some are perpendicular to shoreline trends. This same kind of trend for trackways is noted at many other tracksites elsewhere in the world (Lockley and Hunt, 1995). The shore-perpendicular trackways tend to follow the orientations of ridge and swale on the SGDS "Top Surface." Although many quadruped trackways also tend to parallel the "Top Surface" paleoshoreline, there also appears to be a concentration of *Batrachopus* tracks along ridge tops (i.e. shore-perpendicular), therefore walking across higher terrain (Milner and Lockley, 2006; Milner et al., 2006d).

The SGDS also produces an abundance of fish swim trails and coprolites. Fish swimming traces include some fine examples of *Undichna*, formed by the caudal fin of a fish scraping on a submerged lacustrine substrate. Another type of fish swimming trace from the SGDS resembles the ichnogenus *Parundichna*, known elsewhere from the Middle Triassic (Ladinian) Lower Keuper of Rot am See, Baden-Württemberg, Germany (Simon et al., 2003). Both the German and St. George specimens were probably made by pectoral and pelvic fins of a coelacanth scraping along a muddy substrate. Possible fish nests and "tadpole nests" are currently being described by researchers and regional college students involved with the SGDS.

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Subtitle D--Paleontological Resources Preservation

SEC. 6301. DEFINITIONS.

In this subtitle:

(1) CASUAL COLLECTING- The term `casual collecting' means the collecting of a reasonable amount of common invertebrate and plant paleontological resources for non-commercial personal use, either by surface collection or the use of non-powered hand tools resulting in only negligible disturbance to the Earth's surface and other resources. As used in this paragraph, the terms `reasonable amount', `common invertebrate and plant paleontological resources' and `negligible disturbance' shall be determined by the Secretary.

(2) FEDERAL LAND- The term `Federal land' means--

(A) land controlled or administered by the Secretary of the Interior, except Indian land; or

(B) National Forest System land controlled or administered by the Secretary of Agriculture.

(3) INDIAN LAND- The term `Indian Land' means land of Indian tribes, or Indian individuals, which are either held in trust by the United States or subject to a restriction against alienation imposed by the United States.

(4) PALEONTOLOGICAL RESOURCE- The term `paleontological resource' means any fossilized remains, traces, or imprints of organisms, preserved in or on the earth's crust, that are of paleontological interest and that provide information about the history of life on earth, except that the term does not include--

(A) any materials associated with an archaeological resource (as defined in section 3(1) of the Archaeological Resources Protection Act of 1979 (16 U.S.C. 470bb(1)); or

(B) any cultural item (as defined in section 2 of the Native American Graves Protection and Repatriation Act (25 U.S.C. 3001)).

(5) SECRETARY- The term `Secretary' means the Secretary of the Interior with respect to land controlled or administered by the Secretary of the Interior or the Secretary of Agriculture with respect to National Forest System land controlled or administered by the Secretary of Agriculture.

(6) STATE- The term `State' means the 50 States, the District of Columbia, the Commonwealth of Puerto Rico, and any other territory or possession of the United States.

SEC. 6302. MANAGEMENT.

(a) In General- The Secretary shall manage and protect paleontological resources on Federal land using scientific principles and expertise. The Secretary shall develop appropriate plans for inventory, monitoring, and the scientific and educational use of paleontological resources, in accordance with applicable agency laws, regulations, and policies. These plans shall emphasize interagency coordination and collaborative efforts where possible with non-Federal partners, the scientific community, and the general public.

(b) Coordination- To the extent possible, the Secretary of the Interior and the Secretary of Agriculture shall coordinate in the implementation of this subtitle.

SEC. 6303. PUBLIC AWARENESS AND EDUCATION PROGRAM.

The Secretary shall establish a program to increase public awareness about the significance of paleontological resources.

SEC. 6304. COLLECTION OF PALEONTOLOGICAL RESOURCES.

(a) Permit Requirement-

(1) IN GENERAL- Except as provided in this subtitle, a paleontological resource may not be collected from Federal land without a permit issued under this subtitle by the Secretary.

(2) CASUAL COLLECTING EXCEPTION- The Secretary shall allow casual collecting without a permit on Federal land controlled or administered by the Bureau of Land Management, the Bureau of Reclamation, and the Forest Service, where such collection is consistent with the laws governing the management of those Federal land and this subtitle.

(3) PREVIOUS PERMIT EXCEPTION- Nothing in this section shall affect a valid permit issued prior to the date of enactment of this Act.

(b) Criteria for Issuance of a Permit- The Secretary may issue a permit for the collection of a paleontological resource pursuant to an application if the Secretary determines that--

(1) the applicant is qualified to carry out the permitted activity;

(2) the permitted activity is undertaken for the purpose of furthering paleontological knowledge or for public education;

(3) the permitted activity is consistent with any management plan applicable to the Federal land concerned; and

(4) the proposed methods of collecting will not threaten significant natural or cultural resources.

(c) Permit Specifications- A permit for the collection of a paleontological resource issued under this section shall contain such terms and conditions as the Secretary deems necessary to carry out the purposes of this subtitle. Every permit shall include requirements that--

(1) the paleontological resource that is collected from Federal land under the permit will remain the property of the United States;

(2) the paleontological resource and copies of associated records will be preserved for the public in an approved repository, to be made available for scientific research and public education; and

(3) specific locality data will not be released by the permittee or repository without the written permission of the Secretary.

(d) Modification, Suspension, and Revocation of Permits-

(1) The Secretary may modify, suspend, or revoke a permit issued under this section--

(A) for resource, safety, or other management considerations; or

(B) when there is a violation of term or condition of a permit issued pursuant to this section.

(2) The permit shall be revoked if any person working under the authority of the permit is convicted under section 6306 or is assessed a civil penalty under section 6307.

(e) Area Closures- In order to protect paleontological or other resources or to provide for public safety, the Secretary may restrict access to or close areas under the Secretary's jurisdiction to the collection of paleontological resources.

SEC. 6305. CURATION OF RESOURCES.

Any paleontological resource, and any data and records associated with the resource, collected under a permit, shall be deposited in an approved repository. The Secretary may enter into agreements with non-Federal repositories regarding the curation of these resources, data, and records.

SEC. 6306. PROHIBITED ACTS; CRIMINAL PENALTIES.

(a) In General- A person may not--

(1) excavate, remove, damage, or otherwise alter or deface or attempt to excavate, remove, damage, or otherwise alter or deface any paleontological resources located on Federal land unless such activity is conducted in accordance with this subtitle;

(2) exchange, transport, export, receive, or offer to exchange, transport, export, or receive any paleontological resource if the person knew or should have known such resource to have been excavated or removed from Federal land in violation of any provisions, rule, regulation, law, ordinance, or permit in effect under Federal law, including this subtitle; or

(3) sell or purchase or offer to sell or purchase any paleontological resource if the person knew or should have known such resource to have been excavated, removed, sold, purchased, exchanged, transported, or received from Federal land.

(b) False Labeling Offenses- A person may not make or submit any false record, account, or label for, or any false identification of, any paleontological resource excavated or removed from Federal land.

(c) Penalties- A person who knowingly violates or counsels, procures, solicits, or employs another person to violate subsection (a) or (b) shall, upon conviction, be fined in accordance with title 18, United States Code, or imprisoned not more than 5 years, or both; but if the sum of the commercial and paleontological value of the paleontological resources involved and the cost of restoration and repair of such resources does not exceed $500, such person shall be fined in accordance with title 18, United States Code, or imprisoned not more than 2 years, or both.

(d) Multiple Offenses- In the case of a second or subsequent violation by the same person, the amount of the penalty assessed under subsection (c) may be doubled.

(e) General Exception- Nothing in subsection (a) shall apply to any person with respect to any paleontological resource which was in the lawful possession of such person prior to the date of enactment of this Act.

SEC. 6307. CIVIL PENALTIES.

(a) In General-

(1) HEARING- A person who violates any prohibition contained in an applicable regulation or permit issued under this subtitle may be assessed a penalty by the Secretary after the person is given notice and opportunity for a hearing with respect to the violation. Each violation shall be considered a separate offense for purposes of this section.

(2) AMOUNT OF PENALTY- The amount of such penalty assessed under paragraph (1) shall be determined under regulations promulgated pursuant to this subtitle, taking into account the following factors:

(A) The scientific or fair market value, whichever is greater, of the paleontological resource involved, as determined by the Secretary.

(B) The cost of response, restoration, and repair of the resource and the paleontological site involved.

(C) Any other factors considered relevant by the Secretary assessing the penalty.

(3) MULTIPLE OFFENSES- In the case of a second or subsequent violation by the same person, the amount of a penalty assessed under paragraph (2) may be doubled.

(4) LIMITATION- The amount of any penalty assessed under this subsection for any 1 violation shall not exceed an amount equal to double the cost of response, restoration, and repair of resources and paleontological site damage plus double the scientific or fair market value of resources destroyed or not recovered.

(b) Petition for Judicial Review; Collection of Unpaid Assessments-

(1) JUDICIAL REVIEW- Any person against whom an order is issued assessing a penalty under subsection (a) may file a petition for judicial review of the order in the United States District Court for the District of Columbia or in the district in which the violation is alleged to have occurred within the 30-day period beginning on the date the order making the assessment was issued. Upon notice of such filing, the Secretary shall promptly file such a certified copy of the record on which the order was issued. The court shall hear the action on the record made before the Secretary and shall sustain the action if it is supported by substantial evidence on the record considered as a whole.

(2) FAILURE TO PAY- If any person fails to pay a penalty under this section within 30 days--

(A) after the order making assessment has become final and the person has not filed a petition for judicial review of the order in accordance with paragraph (1); or

(B) after a court in an action brought in paragraph (1) has entered a final judgment upholding the assessment of the penalty, the Secretary may request the Attorney General to institute a civil action in a district court of the United States for any district in which the person if found, resides, or transacts business, to collect the penalty (plus interest at currently prevailing rates from the date of the final order or the date of the final judgment, as the case may be). The district court shall have jurisdiction to hear and decide any such action. In such action, the validity, amount, and appropriateness of such penalty shall not be subject to review. Any person who fails to pay on a timely basis the amount of an assessment of a civil penalty as described in the first sentence of this paragraph shall be required to pay, in addition to such amount and interest, attorneys fees and costs for collection proceedings.

(c) Hearings- Hearings held during proceedings instituted under subsection (a) shall be conducted in accordance with section 554 of title 5, United States Code.

(d) Use of Recovered Amounts- Penalties collected under this section shall be available to the Secretary and without further appropriation may be used only as follows:

(1) To protect, restore, or repair the paleontological resources and sites which were the subject of the action, and to protect, monitor, and study the resources and sites.

(2) To provide educational materials to the public about paleontological resources and sites.

(3) To provide for the payment of rewards as provided in section 6308.

SEC. 6308. REWARDS AND FORFEITURE.

(a) Rewards- The Secretary may pay from penalties collected under section 6306 or 6307 or from appropriated funds--

(1) consistent with amounts established in regulations by the Secretary; or

(2) if no such regulation exists, an amount up to 1/2 of the penalties, to any person who furnishes information which leads to the finding of a civil violation, or the conviction of criminal violation, with respect to which the penalty was paid. If several persons provided the information, the amount shall be divided among the persons. No officer or employee of the United States or of any State or local government who furnishes information or renders service in the performance of his official duties shall be eligible for payment under this subsection.

(b) Forfeiture- All paleontological resources with respect to which a violation under section 6306 or 6307 occurred and which are in the possession of any person, shall be subject to civil forfeiture, or upon conviction, to criminal forfeiture.

(c) Transfer of Seized Resources- The Secretary may transfer administration of seized paleontological resources to Federal or non-Federal educational institutions to be used for scientific or educational purposes.

SEC. 6309. CONFIDENTIALITY.

Information concerning the nature and specific location of a paleontological resource shall be exempt from disclosure under section 552 of title 5, United States Code, and any other law unless the Secretary determines that disclosure would--

(1) further the purposes of this subtitle;

(2) not create risk of harm to or theft or destruction of the resource or the site containing the resource; and

(3) be in accordance with other applicable laws.

SEC. 6310. REGULATIONS.

As soon as practical after the date of enactment of this Act, the Secretary shall issue such regulations as are appropriate to carry out this subtitle, providing opportunities for public notice and comment.

SEC. 6311. SAVINGS PROVISIONS.

Nothing in this subtitle shall be construed to--

(1) invalidate, modify, or impose any additional restrictions or permitting requirements on any activities permitted at any time under the general mining laws, the mineral or geothermal leasing laws, laws providing for minerals materials disposal, or laws providing for the management or regulation of the activities authorized by the aforementioned laws including but not limited to the Federal Land Policy Management Act (43 U.S.C. 1701-1784), Public Law 94-429 (commonly known as the `Mining in the Parks Act') (16 U.S.C. 1901 et seq.), the Surface Mining

Control and Reclamation Act of 1977 (30 U.S.C. 1201-1358), and the Organic Administration Act (16 U.S.C. 478, 482, 551);

(2) invalidate, modify, or impose any additional restrictions or permitting requirements on any activities permitted at any time under existing laws and authorities relating to reclamation and multiple uses of Federal land;

(3) apply to, or require a permit for, casual collecting of a rock, mineral, or invertebrate or plant fossil that is not protected under this subtitle;

(4) affect any land other than Federal land or affect the lawful recovery, collection, or sale of paleontological resources from land other than Federal land;

(5) alter or diminish the authority of a Federal agency under any other law to provide protection for paleontological resources on Federal land in addition to the protection provided under this subtitle; or

(6) create any right, privilege, benefit, or entitlement for any person who is not an officer or employee of the United States acting in that capacity. No person who is not an officer or employee of the United States acting in that capacity shall have standing to file any civil action in a court of the United States to enforce any provision or amendment made by this subtitle.

SEC. 6312. AUTHORIZATION OF APPROPRIATIONS.

There are authorized to be appropriated such sums as may be necessary to carry out this subtitle.

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The organizers wish to thank all of the volunteers and members of the Utah Friends Of Paleontology

the tireless time and organization put forth by our public employees who devote so much time and effort to managing paleontological resources for everyone

and the museum professionals, professors, students, and professional, avocational, and amateur paleontologists who care about paleontological resources on public lands.

Thank you to PaleoResource Consultants for the generous assistance and student travel grants

PaleoResource Consultants

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8CFR Program of Events

	TUESDAY	WEDNESDAY		THURSDAY	
	May 19	May 20		May 21	
		Posters should be set up on Wednesday morning in BALLROOM A-B and left up until Thursday afternoon			
		Speaker ready room will be available from 7:30am – 4:00pm in Sunbrook C			
		Sunbrook A-B	Entrada B-C	Sunbrook A-B	Entrada B-C
8	Field Trip: ***Urban Interface Paleontology in Washington County, UT*** Meet in Front of the Hilton Garden Hotel at 7:45am, Depart promptly at 8:00am. Return to Dixie Center at 5:30 pm.	**WELCOME** Beat Suarez Terry Santucci **BREAK**		Bilbey Trujillo Landon Temme Townsend **BREAK**	Aase Gunther Milner1 Milner2 Breithaupt **BREAK**
9					
10		Kirkland Benton Spears Bell Springer1	Hester Eaton DeBlieux Evanoff Matthews1	Fisk2 PANEL 2: PALEO CONSULTING MITIGATION	Matthews2 Matthews3 Bates Meyers Hunt-Foster
11					
12		**LUNCH**		**LUNCH**	
1		Higginbotham Madsen Cavin Pagnac Welsh **BREAK**	Hansen Smeins Fisk1 Knauss Masters	Harris Schumacher Foss Santucci Kuizon **BREAK**	Springer2 Sagebiel Scott Dundas
2					
3		Palus Childs Kara Hurst PANEL 1: CURATION OF PUBLIC RESOURCES		Vlamis PANEL 3: PALEO RES PROTECTION ACT - PRPA	
4					
5					
6		Evening Social: **St. George Dinosaur Discovery Site at Johnson Farm** (Appetizers and refreshments will be served. Busses depart Dixie Center from 5:45 – 6:30pm and return from 8:00 – 8:45pm)			
7	Welcome Mixer: **Hilton Garden Hotel – Patio** 7:00 – 10:00pm				
8					
9					