Paleontological survey of Zion National Park, Utah.
Zion National Park
Jennifer McGuire

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Global Warming Toward Women Cont.

if the United States is to reduce its reliance on foreign-born scientists. It is also critical for the development of a technology-based economy. One of the major obstacles to increasing the proportion of women in the scientific workforce is the lack of role models in colleges and universities where most scientific training occurs. According to the NSF's biannual survey of the scientific and engineering workforce, the proportion of women full professors in science and engineering fields has not increased in twenty years. This lack of senior women faculty is often attributed to the "chilly climate" for women scientists and engineers on college campuses across the country.

Utah State University is one of several major institutions currently conducting climate surveys and revising policies that are inadvertently biased against women faculty. As the president of MIT has pointed out (Committee on Women Faculty 1999), however, that's the easy part. The hard part is changing departmental climates. Many institutions and national organizations, including Utah State, also are searching for successful models of organizational change in an attempt to warm up the weather, particularly for women scientists and engineers who, all too often, are left out in the cold.

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Note -
* Data from this survey are also summarized in the Academic Leader newsletter for academic deans and department chairs (April 2005, Volume 21, Number 4).

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Quote:

"If I'm not always happy, that doesn't mean I'm doing something wrong. It means I am doing something real."

--Laurie Seligman, composer of mini-mantras

(Quoted from the ***Wild Words from Wild Women*** Calendar 2006)

Paleontological Survey of Zion National Park, Utah

Jennifer L. McGuire, AWG GIP

In the summer of 1999, National Park Service (NPS) intern Joshua A. Smith began an inventory of paleontological resources within the park. Josh continued his work in the spring of 2000, and returned for several weeks in the summer of 2002 with the assistance of Don DeBlieux of the Utah Geological Survey (UGS).

I started my AWG GIP position in the spring of 2003 as a paleontology intern for three months to continue the inventory work. Don DeBlieux and Jim Kirkland (UGS) assisted me for several weeks along with volunteers from the Utah Friends of Paleontology (UFOP). Our work in 2003 took advantage of the cooler spring temperatures to concentrate on some of the stratigraphically lower formations, especially the Chinle Formation. Through these collaborative efforts, over 120 new fossil localities have been located within the park. These sites provide avenues for further scientific work, and enable us to make informed predictions about the distribution of fossils in the park's sedimentary rocks. The following is excerpted from our final report.

INTRODUCTION

The spectacular rocks exposed in Zion National Park, Utah, include many fossiliferous units ranging in age from Permian through Holocene. In cooperation with the Utah Geological Survey, National Park Service interns have been inventorying paleontological resources located within the park to establish baseline paleontological resource data to support the management and protection of non-renewable fossils. This goal was accomplished by identifying new fossil localities and assessing the diversity and distribution of fossils within geological formations.

Zion National Park covers 229 square miles in southwest Utah. The park lies in the transition zone between the Colorado Plateau and the Basin and Range Province, within a structural block bounded to the east by the Sevier fault zone and to the west by the Hurricane fault zone. Structurally, the main portion of the park is rather simple, containing relatively horizontal beds. Joints are mostly responsible for the orientation of the canyon network throughout the park. In the canyons of the Kolob District, the strata are folded to form the Kanarra anticline,

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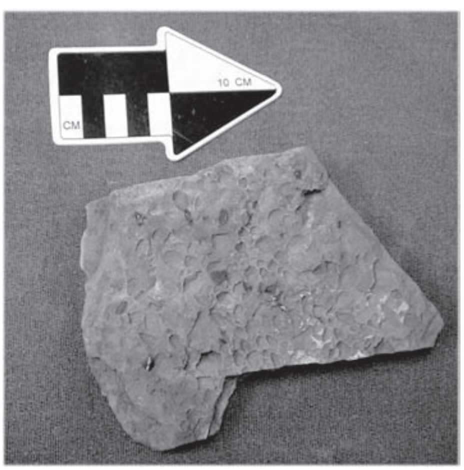
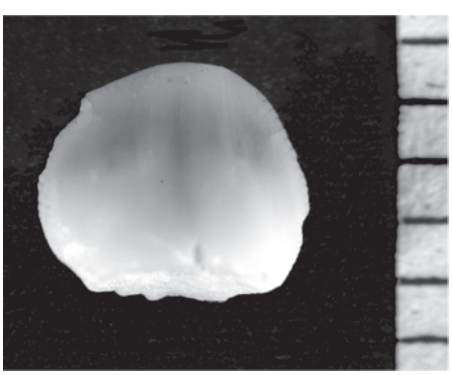
and thrust faults are present, causing the duplication of formations in several places. Over the past 2 million years, regional uplift, coupled with downcutting by the Virgin River, has carved out Zion Canyon, exposing strata that were deposited over a period of 275 million years, and record a multitude of environments ranging from shallow-marine, coastal, desert sand dunes, rivers, and lakes. Most of these rocks were formed in sedimentary environments with the potential for fossils. Numerous books and papers have been written about the geology of Zion, and the most recent is the excellent overview given in Biek and others (2003).

We evaluated previous work done in the park, and prospected fossiliferous strata for additional fossil sites, focusing our field survey primarily on the vertebrate fossil-bearing strata. Sites were recorded using hand-held Global Positioning System (GPS) units. We used the survey information, along with information from similar surveys conducted in correlative strata in neighboring regions, to create paleontological sensitivity maps using Geographic Information System (GIS) software. On these maps we rank the formations based on the potential for scientifically important paleontological discoveries. These maps are intended as tools to provide park managers with a framework within which to make informed decisions regarding the management and protection of fossil resources.





PALEONTOLOGICAL SENSITIVITY CLASSIFICATION

Because of the diversity of fossil-bearing rocks in Utah, we devised the following six-tiered classification system to rank the sensitivity of geological formations containing fossil resources.

0) Fossils absent – Formations with rock types, such as igneous or metamorphic rocks, that are very unlikely to contain fossils of any kind.

1) Fossils rare – Formations that contain fossils only in rare instances such that intensive survey is unlikely to uncover noteworthy occurrences of fossils.

2) Fossils present – Formations known to contain fossils, but these fossils are unlikely to be of unique scientific importance. For example, formations with abundant marine invertebrate fossils in which disturbance of small areas are unlikely to impact scientifically significant fossils.

3) Significant sites known – Formations from which scientifically important fossil sites are known, but many areas of the formation will not contain significant fossil resources because of either the large areal extent of the formation or rarity of sites.

4) Very sensitive – Formations known to contain abundant and significant vertebrate, invertebrate, and/or plant fossils in which a field survey is likely to result in discovery of scientifically significant fossils.

5) Extremely sensitive – Formations that can be considered "world-famous" because of the scientifically important fossils they contain, in which unique and scientifically important fossils are very likely to be discovered during field survey and in which there is a good possibility that any disturbance will impact critical fossil resources.

Top Left: Early Jurassic fish bones/scales from the Kayenta Formation.

Bottom Left: The oldest ornithiscian tooth found in UT... from the Petrified Forest Member of the Chinle (Late Triassic)

Below: Phytosaur skewts from the Petrified Forest Member of the Chinle (Triassic)

GEOLOGY AND PALEONTOLOGICAL RESOURCES

Paleozoic Rocks

Toroweap Formation [Early Permian, ~280-270 million years ago (Ma)]

The Toroweap Formation (western portion of the Kolob Canyons District at the base of the Hurricane Cliffs, 400 to 450 feet thick) is composed primarily of shallow marine limestones and siltstones known to contain marine invertebrate fossils. Due to limited exposure in Zion National Park, and the poor preservation of fossils, the Toroweap is ranked as *Category 1; fossils rare.*

Kaibab Limestone (Early Permian, ~ 270-260 Ma)

Like the underlying Toroweap Formation, the Kaibab Limestone (exposed only in a small portion of the Hurricane Cliffs) is highly faulted and altered as a result of movement along the Hurricane fault. This warm-water shallow-marine deposit has been reported to contain fossils of bryozoans, sponges, corals, crinoids, brachiopods, mollusks and conodonts. Due to the small area of exposure and abundant but generally poorly preserved fossils, the paleontological sensitivity of this formation is *Category 2; fossils present.*

Mesozoic Rocks

Moenkopi Fm (Early Triassic, ~248-242 Ma)

The Moenkopi Formation consists of three claystone/limestone members that represent marine transgressions, each overlain by a reddish-brown mudstone and sandstone member deposited in shallow marine and lowland continental environments representing marine regressions. Fossils include plants; invertebrates such as brachiopods, gastropods, bivalves, ammonoids, nautiloids, crinoids, and arthropods; vertebrates, including labyrinthodont amphibians and reptiles; and vertebrate tracks.

One of the more important findings of our survey was the identification of a verte-

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brate tracksite in the Moenkopi Formation in the Kolob Canyons District, where tracks, tentatively identified as belonging to a small lizard-like animal and a mammal-like reptile (therapsid), occur in a gray siltstone unit below the Virgin Limestone Member. If confirmed, this is a significant finding, and possibly the oldest Mesozoic tracksite in North America. Despite its vast exposure, the general lack of vertebrate fossils reduces the paleontological sensitivity of this formation, but it does contain common invertebrate fossils, so we place it in *Category 2; fossils present*.

Chinle Fm (Late Triassic, ~226-210 Ma)

The Chinle Formation consists of the Shinarump Conglomerate Member and the Petrified Forest Member and is composed primarily of sandstone, siltstone, and mudstone. The Shinarump Conglomerate was deposited mainly in braided streams, while the Petrified Forest Member was deposited in flood plains, lakes and stream channels in a low, wooded basin, where the majority of vertebrate body fossils are found.

The Petrified Forest Member, named for the strata at Petrified Forest National Park in Arizona, contains petrified logs, locally abundant enough to form “petrified forests,” in the lower Petrified Forest Member strata near the contact with the Shinarump Conglomerate. These “forests” are obvious enough to the casual visitor to be vulnerable to vandalism and theft. During our survey work we made special effort to record and document sites that contain fossil logs to provide park personnel with baseline data to assess the loss of fossil wood over time. In order to emphasize the sensitivity of the petrified wood, we highlighted the contact between the Shinarump Conglomerate and the Petrified Forest Member on our paleontological sensitivity maps and placed it in *Category 5; extremely sensitive*.

In the Petrified Forest Member we also found large quantities of bone fragments and teeth (commonly within nodules) belonging to fish, metoposaurs, phytosaurs and aetosaurs, in addition to coprolites, petrified wood, plant material and invertebrate burrows. One of the more significant finds is a small tooth that may belong to an ornithischian dinosaur. If confirmed, it will be the oldest evidence of an ornithischian dinosaur in Utah, and the only herbivorous dinosaur known from the Triassic of Utah.

Moenave Fm (Late Triassic - Early Jurassic, ~200-196 Ma)

The Moenave Formation lies above the Petrified Forest Member of the Chinle Formation and is separated by an unconformity (the J-0 unconformity) thought to represent roughly 10 million years. The Moenave is a continental deposit 325 to 440 feet thick in the Zion region and is divided into three members: the Dinosaur Canyon, Whitmore Point, and Springdale Sandstone.

Dinosaur Canyon Member: The basal member of the Moenave Formation, composed of slope-forming reddish-brown fine-grained sandstone and siltstone deposited in a river and floodplain environment, the Dinosaur Canyon Member contains few fossils, primarily trace fossils (invertebrate burrows and tridactyl dinosaur tracks) but also mollusks, plant fragments, and trace fossils. The slope-forming nature of this member in the park limits the exposure needed to discover significant tracksites. Because of the limited number of significant sites in the Dinosaur Canyon Member of the Moenave, we place it in *Category 2; fossils present*.

Whitmore Point Member: The distinctive Whitmore Point Member consists of reddish-brown sandstone and siltstone beds, reddish-purple to greenish-gray mudstone and claystone beds, as well as thin dolomitic limestone beds deposited in a river and floodplain environment that also included lakes.

The Whitmore Point Member contains remains of fish and plants as well as numerous trace fossils of invertebrates and the tracks of dinosaurs. Invertebrate burrows are common in many horizons and can be found in virtually any exposure of this member. The most significant trace fossils in the Whitmore Point Member are the tracks and trackways of dinosaurs; tracks of three-toed theropod dinosaurs are attributed to the ichnogenera *Eubrontes* and *Grallator*, common in many horizons in Zion. Dozens of new localities have been located as a result of our survey. The tracks of the Whitmore Point Member are one of the most significant paleontological resources in the park, second only to the Kayenta Formation in the quantity of tracksites. Due to the important track-bearing horizons in the Whitmore Point Member, we place it in *Category 3; significant sites known.*

Springdale Sandstone: This uppermost member of the Moenave Formation consists of reddish-brown sandstone and conglomerates deposited in river channels in braided-stream and minor floodplain environments. The fossils in this unit consist primarily of poorly preserved plant fragments, bioturbated sediments (invertebrate burrows), and rare dinosaur tracks. Because the Springdale forms steep cliffs, it does not provide exposures conducive to finding fossils. We place the Springdale Sandstone Member of the Moenave Formation in *Category 2; fossils present.*

Kayenta Fm (Early Jurassic, ~196-184 Ma)

The Kayenta Formation ranges from 550 to 700 feet thick in the Zion region and forms the prominent slope above the Springdale Sandstone and below the Navajo cliffs. The rocks of the Kayenta consist primarily of interbedded, thin- to medium-bedded, siltstone, sandstone, and mudstone that are mainly reddish-brown in color, deposited in fluvial, distal fluvial/playa, and minor lacustrine environments.

Fossils include petrified wood; invertebrates such as bivalves and gastropods; vertebrates including frogs, turtles, lizards, dinosaurs, pterosaurs, and mammals and abundant reptile tracks including those of dinosaurs such as the ichnogenera *Eubrontes* and *Grallator*. One of the highest concentrations of dinosaur tracks occurs at the base of the Kayenta Formation at the contact with the Springdale Sandstone. We have emphasized the contact between these units on our paleontological sensitivity maps by underlining it in red as *Category 5; extremely sensitive.*

In addition to the tracks, we have located fish scales of *Semionotus kanabensis* in the Kayenta Formation. Due to the numerous track localities, the presence of fish fossils, and the possibility of other vertebrate body fossils, we place the rest of the Kayenta Formation in *Category 3; significant sites known.*

Navajo Sandstone (Early Jurassic, ~184-180 ma)

The Navajo Sandstone forms the towering vertical cliffs that give Zion its distinctive scenic character, ranging from 1800 to 2200 feet thick in the Zion region. The Navajo Sandstone was deposited in a desert environment similar to that of the modern Sahara, and records a part of what is thought to be the world’s largest ancient coastal and inland dune field, and is therefore almost entirely devoid of fossils; however tracks (dinosaur footprints, prints of several different animals) are known from the Navajo Sandstone in Zion and elsewhere. Tracks in the Navajo may actually be fairly common, but the conditions needed for revealing these tracks are such that most of these will never be seen. Erosion is typically needed to bring the tracks into relief. Also, the bedding planes on which tracks where made are not generally exposed because the sandstone forms cliffs, and bedding planes are only exposed on fallen blocks and on the tops of the cliffs. Because tracks are relatively rare in the Navajo Sandstone, and vertebrate body fossils are even more rare, we place it in *Category 1; fossils rare.*

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Temple Cap Fm (Middle Jurassic, ~175-170 Ma)

The Temple Cap Formation (40-250 feet thick) was deposited on top of the Navajo Sandstone after a period of erosion. The Temple Cap is divided into two members. The Sinawava Member is a red mudstone that is responsible for the red staining common at the top of the Navajo Sandstone, and represents the return of warm shallow seas to the Zion area. The White Throne Member is an eolian sandstone deposited in seaside dunes. No fossils are known from the Temple Cap Formation, so we place it in *Category 0; fossils absent.*

Carmel Fm (Middle Jurassic, ~167-160 Ma)

The Carmel Formation (100-300 feet thick) is composed of sandstone, siltstone, mudstone, limestone, gypsum, and shale representing the return of marine and near-shore marine conditions during the Middle Jurassic. The majority of fossils are of marine organisms including stromatolites, foraminiferans, radiolarians, bryozoans, corals, brachiopods, ostracodes, crinoids, starfish traces, ammonoids, bivalves and gastropods. In Zion National Park, the Carmel is divided into four members, with the majority of fossils found in the basal Co-op Creek Limestone Member consisting of tan and gray limestone beds that contain marine bivalves, gastropods, and columnals of the crinoid *Isocrinus* sp. The invertebrate fossils in the Carmel are important, but are generally quite common, so we place it in *Category 2; fossils present.*

Cedar Mountain/Dakota Formations (Early Cretaceous, ~112-99 Ma)

Cretaceous rocks have limited exposure on top of Horse Ranch Mountain in the northwest portion of the park, where freshwater bivalves and plant impressions have been reported. Access to the Cretaceous exposures on Horse Ranch Mountain is restricted because it is surrounded by private land. We attempted to visit this area several times but encountered logistical problems; in addition, the exposures are limited due to thick forest cover. Considering the difficulty in reaching this area, any fossils in this vicinity are unlikely to be sensitive to theft or vandalism. For this reason we place it in *Category 2; fossils present.*

Cenozoic Rocks and Sediments

Early Tertiary Rocks (~33-55 Ma)

No early Tertiary rocks crop out within Zion National Park, but there are extensive outcrops of Eocene-age sedimentary rocks that make up the Claron Formation northeast of the park. The brightly colored stream and lake sediments of the Claron Formation make up the spectacular scenery of Bryce Canyon National Park and Cedar Breaks National Monument. Clasts preserving stromatolites from the Claron Formation have been found within drainages in Zion.

Late Tertiary and Quaternary Basalt Flows (~10 ma –100 ka)

During the late Tertiary and Quaternary there were episodes of volcanic activity in and around Zion National Park. The cinder cones and basalt flows are not expected to contain fossils. The basalt flows provide a time scale with which to study the erosional history of the park and indicate that the majority of canyon cutting that produced the spectacular cliffs of Zion occurred over only about the past 2 million years.

Quaternary Lake Deposits (<2 Ma)

The youngest fossils found in Zion are those of Pleistocene and Holocene vertebrates, invertebrates, trees, and pollen deposited in several lakes formed as a result of landslides or basalt flows that blocked streams in canyons forming lakes from the impounded water. These include a bison vertebra, a radius/ulna of a sheep (*Ovis*), a fish vertebra and snails, track fossils of a bird, a large artiodactyl, and various invertebrates. Twelve species of mollusks were identified from sediments of two of the mid-Holocene lake sequences, while 6 species were recovered from Pleistocene-age lake sediments. Pollen samples from lake clays indicate that the late Pleistocene climate was cooler and wetter than at present. Because of the extensive work done by Hamilton and our limited field time, we did not prospect any of the known lake deposits in the park. We place the Quaternary lake deposits in *Category 2; fossils present.*

Quaternary Alluvium/Colluvium/Eolian/ Mass Movement Deposits (<2 Ma)

Numerous Quaternary alluvium deposits include unconsolidated boulders, gravel, sand, silt, and clay found primarily along the river channels, washes, and tributary channels. Colluvium, landslide deposits and debris fans are common in the park. Large slide masses in which the bedrock remains largely intact will still potentially contain fossils, and in some cases, movement can expose fossils within the bedrock. In general, the paleontological sensitivity of these Quaternary deposits is low, but fossil material potentially can be found in any of these sediments. The rarity of such material, such as extinct ice-age mammals, means these fossils, if present, can be of great scientific importance.

The collection at Zion contains several pieces of travertine or tufa (a calcium carbonate deposit associated with springs) with the imprints of leaves collected from the Zion Narrows. We noted travertine deposits in the Zion Narrows near the Temple of Sinawava. Travertine can build up quite rapidly and the leaves are likely those of modern species found in the park. It is possible, however, that in places, these deposits could contain the remains of more ancient plants and/or animals that could provide important information about the Quaternary flora and fauna of the park.

Because of the scarcity of fossils in Quaternary deposits and the vast areal extent of these surficial deposits, we place them in *Category 1; fossils rare*, and for eolian deposits, *Category 0; fossils absent.*

PALEONTOLOGICAL SENSITIVITY MAPS

We prepared five paleontological sensitivity maps for this report, including one of the entire Zion National Park, and four 7.5-minute quadrangles prepared from recently completed geological maps. These quadrangles cover the most accessible parts of the park, representing the regions with the most paleontologically sensitive geologic formations.

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Reference:

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Fossil track track specimen from the Kayenta Formation (early Jurassic)