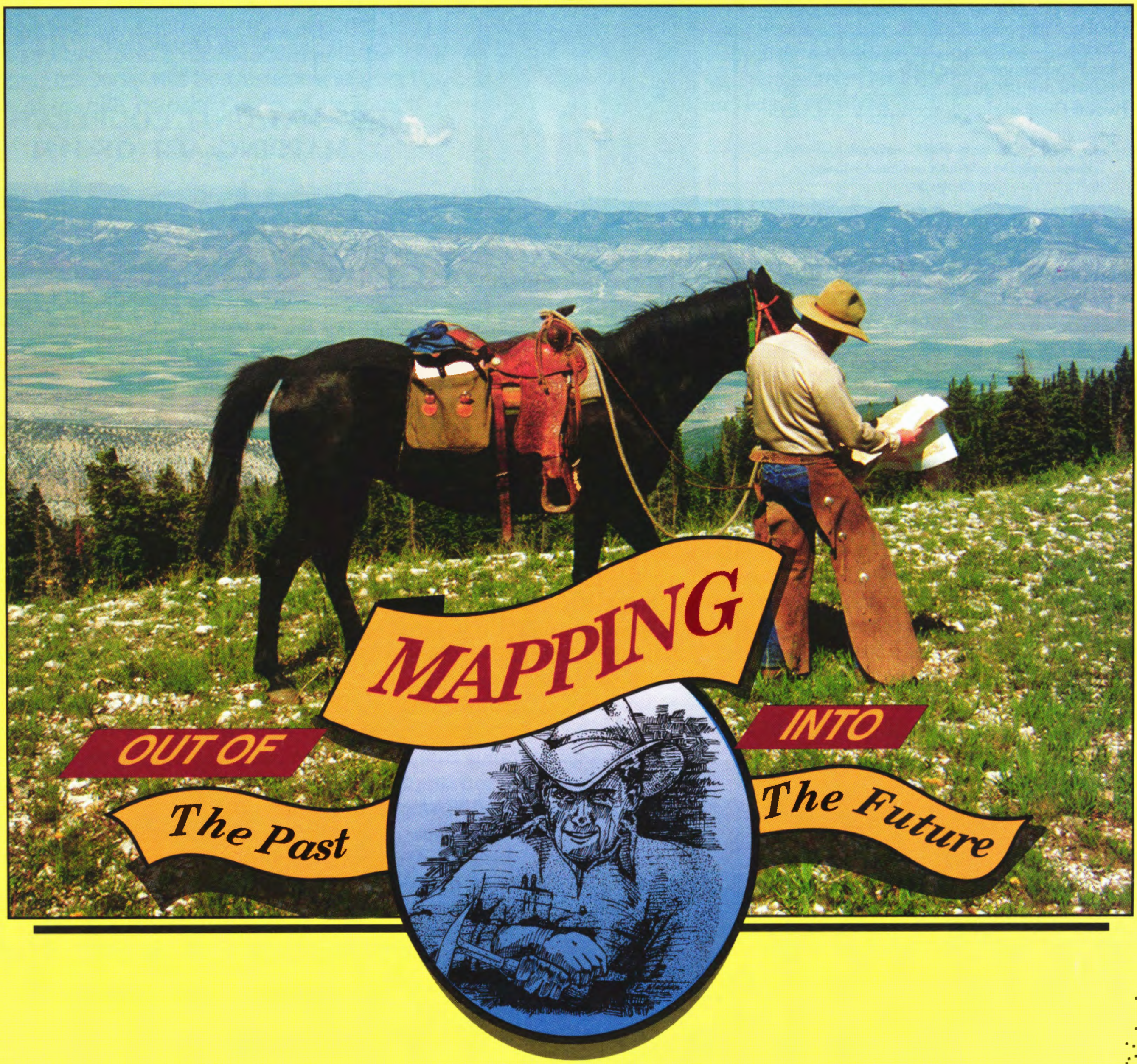
SURVEY NOTES

VOLUME 25, NUMBER 1 WINTER 1991
UTAH GEOLOGICAL SURVEY



Design by P. McGann / Photograph courtesy D. Sprinkel

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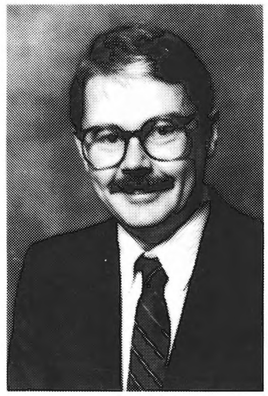
Cover design by Patti F. MaGann
Photograph: Doug Sprinkel and friend mapping on the plateau.



THE DIRECTOR'S PERSPECTIVE

by M. Lee Allison

THE NATIONAL COOPERATIVE MAPPING ACT OF 1991

The United States is the most poorly mapped of the developed nations. Fewer than 20% of the nation has been geologically mapped at the quadrangle scale (1:24,000) and unless dramatic steps are taken the chances are that the pace of geologic mapping will continue to decrease.

The "Cooperative Geologic Mapping Act of 1991" has been introduced into the U.S. Senate as bill S1179 and in the House as bill H.R. 2763. It is one of the most important acts affecting geology this year. The bill is the result of more than three years of efforts by the US Geological Survey and the Association of American State Geologists (AASG). It is aimed at completing detailed geologic mapping of every state within 25-35 years. For comparison, Utah, which has one of the most aggressive mapping programs in the country, will be mapped in 75 years at the present rate.

There are four components to the proposal:

I. Federal Geologic Mapping Component - this will get USGS mappers back out in the field doing 1:24,000 mapping like they used to.

II. State Geologic Mapping Component - this will provide matching funds, dollar for dollar, to state surveys for 1:24,000 geologic mapping.

III. Geologic Mapping Support Component - will provide for investigations into digital cartography, paleontology, geochronology, isotope geology, geophysics, and geochemistry; data that will be placed in national data bases to support mapping projects.

IV. Geologic Mapping Education Component - will develop academic mapping programs and support graduate programs including field studies.

Funding is proposed to start at $37 million the first year and increase to $55.5 million by the fourth year. The State component goes from $15 to $25 million, while the Education component goes from $500,000 to $1.5 million in that time.

If the bill passes and is funded (two very different operations at the federal level) the UGS will likely use only a part of the State component for internal programs. Because funding may vary from year to year I am hesitant to add many permanent state staff. Instead we hope to add cartographers and upgrade our digitizing and reproduction capabilities in order to publish the maps cheaper and faster. The remainder of the money would be made available to the Utah geologic community for geologic mapping.

The UGS presently allocates about $750,000 per year in one form or other to geologic mapping. If we receive matching funds of that amount I believe we would be contracting up to $500,000 out to others in the state, primarily universities and colleges. My understanding is that the money could be used for geologic mapping and to gather data in support of mapping projects such as isotopic, geochemical, geophysical, paleontological, and other geological information.

Continued on next page.

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Director's Perspective, continued.

The Utah geoscience community is strongly supportive of the measure. Most of the professional societies have endorsed the bills and written to Utah's congressional delegation. More support has come from the geology departments in the colleges and universities and from natural resource companies in Utah. Dr. Russell Babcock, Chief Geologist for Kennecott Corp., and a recent addition to the UGS Board, gave strong testimony to a Congressional hearing this summer in favor of the bills on behalf of the American Mining Congress.

The feeling in Washington as this is being written is that the act has a good chance of being passed. Funding for the measure is less certain but many feel that if the money is not allocated this year it would be next year. Whenever it comes, it will reverse a dangerous national trend of decreased geologic mapping that limits our ability to recognize and deal with geologic hazards and identify our mineral and water resources. The Cooperative Geologic Mapping Act could be a watershed for the geosciences.

ROCK FALL DAMAGES RESIDENCE IN HOBBLE CREEK CANYON, UTAH COUNTY

by Kimm M. Harty

At approximately 5:30 a.m. on August 4, 1991, four rock-fall boulders struck a home in the Holiday Hills Subdivision in the Left Fork of Hobble Creek Canyon. Damage to the house and an attached guest house was severe, but fortunately, all occupants were unhurt. The rock fall was likely triggered by infiltrating precipitation from an intense rainstorm that occurred the previous evening. The damaged home and others in the subdivision lie at the base of a steep (70 percent) mountain slope. The source of the rock fall was a bedrock outcrop about 900 feet above the elevation of the property, and approximately 1300 feet upslope from the residence. The boulders that fell from the outcrop were quartzite of the Wallsburg Ridge Member of the Pennsylvanian-age Oquirrh Formation.

Examination of the rock-fall travel paths showed that the boulders mainly bounced down the hillslope. Sheared tree limbs immediately behind the guest house indicated that some boulders bounced about 25-30 feet above the ground before hitting the structures. Two large boulders struck and entered the guest and main houses; two smaller clasts entered the attic of the main house through the roof (figure 1). The largest boulder measured 7 x 5 x 4 feet, entered through the guest house roof, plunged through the second floor into the first floor, exited through the back wall of the structure, and came to rest at ground level between the guest and main houses (figure 1). The other large boulder measured 7 x 4 x 4 feet, struck the south wall of the guest house, entered the main house at ground level, and came to rest in a ground-floor utility room (figure 1). Damage to the guest house and its contents was extensive, and the structure may require demolition. Structural damage to the main house appeared limited to the roof, attic, outer wall, and floor joists above the utility room.

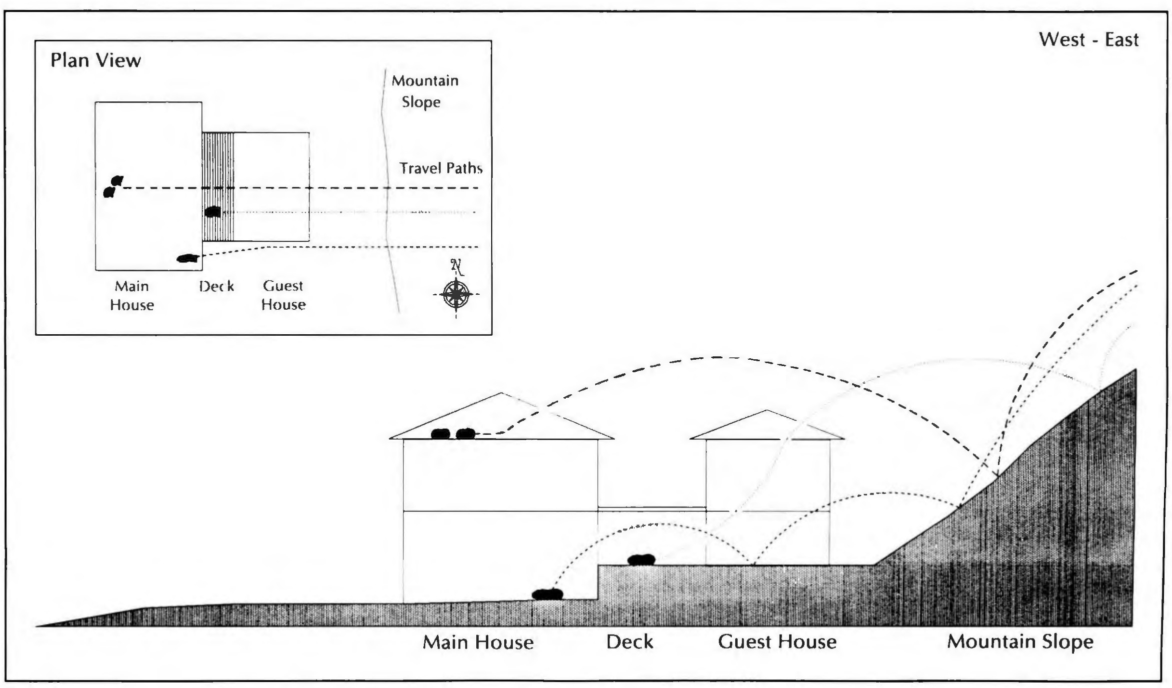


Figure 1. Schematic cross section (not to scale) of approximate travel paths (dotted and dashed lines) of four rock-fall boulders.

CONTRIBUTORS TO GEOLOGIC MAPPING IN UTAH

ARTHUR ALAN BAKER

by Grant C. Willis

Arthur Alan Baker, 1956.

Each year the Utah Geological Survey honors an outstanding geologist who has made major contributions to the geologic mapping and understanding of our state. This year the UGS honors Arthur Alan Baker for his contributions during a professional career that spans more than five decades, most spent in Utah. Art has had a great impact on the geology of Utah, both through his own work and through his influence on other geologists. In fact, Art instructed past recipients W. Lee Stokes and Charles B. Hunt while they were his field assistants!

Today, geologists seldom get to be the first to study or map an area, or be the first to discover a major geologic phenomenon. Art Baker spent most of his career doing just such pioneering geology. For example, he was the first geologist to recognize the allochthonous nature of Mount Timpanogos. His papers and maps, some dating back more than 60 years, still serve as "foundation studies" on which current geologic investigations are based. Even at the age of 93, Art is still an active geologist at heart. In researching this paper, I had the pleasure of communicating with him; much of the biographical information contained herein was provided by Art himself. He remains a remarkable individual and a great contributor to the geology of Utah.

In 1881, Art's father, at the age of 16, left London and, with another youth, sailed to the exciting frontier of America. He married, and then settled in New Britain, Connecticut where Art was born on October 31, 1897. Art attended school there, after which he entered Yale University, graduating in 1919. He continued graduate studies at Yale, and earned a Ph.D. In 1921 he qualified for employment under Civil Service and was employed by the U. S. Geological Survey (USGS). His entire professional career was with the USGS, from which he retired in 1969 as Associate Director and again in 1971 (at the age of 74) as Special Assistant to the Director.

Moving day in Upper Indian Creek after road was washed out,1927.

During his first two summers (1921 and 1922) he was attached to field parties in Alaska. In 1923, his first field season in Utah, he worked in the Wasatch Plateau with the renowned geologist, Edmund Spieker. The following two summers (1924 and 1925) he worked in Montana. From that time on, most of his career was spent in Utah. Early field work in southeastern Utah was primarily for the purpose of obtaining geologic data needed for the administration of public lands. This data was acquired through geologic mapping, supplemented by regional studies of stratigraphy and geologic structure. Lacking base maps, mapping was done with plane table and telescopic alidade, often covering more than a thousand square miles in a season (Art was one of the best at this dying art). Saddle and pack horses were the principal mode of transportation from main camps and temporary spike camps, which were located near the few available water holes.

Art's mapping projects in southeastern Utah during the summers of 1926 to 1931 included: 1) the Moab district extending from Castle Valley to the head of Cataract Canyon, east of the Colorado River, 2) the Green River Desert extending from the town of Green River to the Dirty Devil River and from the San Rafael Reef on the west to the Green and Colorado Rivers on the east, and 3) the Monument Valley area, including the strip between the Utah-Arizona state line and the San Juan and Colorado Rivers, and from near Bluff to beyond Navajo Mountain. In 1933, accompanied by outfitter and horse wrangler Charles Hanks, Art undertook an extensive reconnaissance survey to obtain data for a structural geologic map of southeastern Utah.

Field life was always challenging in those pre-four-wheel-drive days. When Charlie Hunt first joined the field party, Art decided it was time to introduce him to the geology of the area. However, the excursion became an introduction to the treacherous driving conditions in southeastern Utah, as Charlie and Art ended up pushing their Ford pickup through 5 miles of deep sand. According to Charlie, Art often called that area the "sandiest s. o. b." in the world. In spite of the challenges, Art much preferred field work, and at the end of the season, he always regretted having to "go back to Washington and face those Senators and Representatives."

Art's wife Clarita was also a hardy soul and spent many of the field seasons in camp, always under considerably less than

Camp at Hart Spring, Moab area, 1927.

luxury conditions. She assisted with the camp cooking and other chores and was always well liked by the field party. Art and Clarita had one child, a daughter named Carolyn ("Lynne").

In 1937 Art began detailed geologic mapping studies in the Wasatch Range, eventually covering the area from Spanish Fork north to Park City and from the Wasatch Front east to Diamond Fork and Strawberry Reservoir. Again, satisfactory base maps were not available, thus he constructed his own using plane table mapping; this time supplemented with aerial photographs. Roads were more abundant than in southeastern Utah, so that travel by truck, supplemented by hiking, could reach the more remote parts of the area.

While mapping in the Wasatch Range, Art would stay with a good friend in Alpine who was the local Mormon bishop. Charlie Hunt, who lived nearby, always got rid of Art's beer bottles for him. Charlie remembers those days as good ones; Charlie's house in Alpine was the gathering place for all the local geologists, as well as those who were just passing through on their way to the Great Basin. Art and Clarita were usually at the center of these impromptu gatherings and often assisted with the meals. One weekend they provided for 25 to 30 geologists. The gatherings were always fun and sometimes humorous. One night Art was sleeping in a lower bunk when Doug Kinney, a large man, climbed into the upper bunk. The bed bowed down so far that Art could hardly move and got little sleep that night. Art loved to garden and often wandered out to Charlie's garden to hoe and pull weeds; Charlie never could understand why Art would want to do that kind of work.

Art has always had the highest professional standards; even today geologists know they can rely on whatever he mapped and wrote. Harold Bissell, a former field assistant and admirer of Art, said:

His greatest trait was his thoroughness to detail, he was never satisfied with shoddy work. Art was one of the hardest workers I knew; he always put in his time and then some. He was generous to a fault, always willing to share whatever he had. He was an excellent geologist but never proud; whenever anyone disagreed with him, which was seldom, he would always listen, and readily accepted their views if they were right.

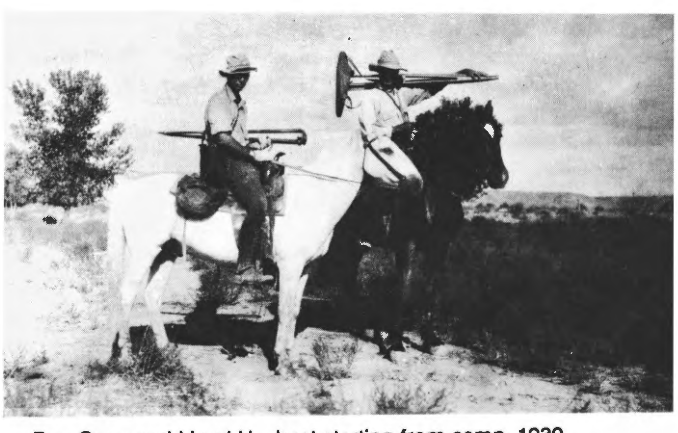
Art is also known for his ability to improvise, a needed trait in the remote field camps of earlier days. Once he made a stereoscope from an old dismantled kaleidoscope and a piece of inner tube, which he wore around his head. On another occasion he was riding a horse named "Moose" on Navajo Mountain in southern Utah. That particular day the mare decided to have a colt, so Art quickly transformed from geologist to veterinarian.

Art had many memorable experiences as a geologist. One day his field crew needed to cross the San Rafael River south of the town of Green River when the river was flooding and the bridge had been damaged. Normally, the bridge was suspended from two steel cables, but someone had disconnected one of them. He wrote:

We had a load of supplies for camp which at that time was at the end of the road, many miles south of the San Rafael River. After much study of the situation, we unloaded the truck. Then a driver, standing on the outside step, drove the empty truck across the precariously supported bridge. We made it! Then, after carrying the supplies across by foot, the truck was reloaded and continued on to camp. All's well that ends well, but it was a harrowing experience to say the least.

Art didn't explain how the driver was chosen, but I assume the duty was assigned to the greenest geologist. He also wrote of humorous experiences:

Those were the days of prohibition and I recall two episodes: One was at the spring on the river road just above Moab. We were driving a government truck and



Dan Curry and Lloyd Henbest starting from camp, 1930.

Bill Steel cooking at cave spike camp, 1928.

Marcus Goldman and E.T. McKnight extricating truck from difficulty on road in Salt Valley, 1927.

Spike camp in cabin under construction at Rainbow lodge, Navajo Mountain, 1928.

had a load of people. Bootleggers were working at the spring bottling their product. When they saw the trucks with government license plates, they picked up their supply and threw it into the river.

A second, similar episode occurred along the road south of the lower crossing of the San Rafael River,

We had parked our trucks in a little cul-de-sac while we were working on foot. Bootleggers bringing a load into town evidently came around a bend and saw the government license plates on the truck and immediately threw the jars containing their product into the roadway. We did

Flood in Indian Creek, endangering spike camp, 1927.

not observe any of this, except the broken glass, which had to be removed before we could move our trucks.

The administrative highlight of Art's career was his appointment as the first Associate Director of the U.S. Geological Survey. On the professional side, it was his collaboration with the renownea geologists John B. Reeside and Carle H. Dane that resulted in several important papers on the correlation of Utah strata. His greatest admiration is for the geologist Edmund Spieker, whom he credits with the early training that became the foundation of his career.

Art has seen many changes in geology throughout his life. He noted:

> *Field work has become less and less dependent upon 'shanks mare' and more and more dependent upon interpretations of data obtained by instrumental means. The plus side [of these changes] results from the utilization of new techniques to delve deeper and deeper into a subject and the minus is the loss of affinity with the great outdoors, which directly or indirectly accounted for the choice of profession by many geologists.*

Art was one who treasured that affinity with the great outdoors, indeed he was a true field geologist, one to whom Utah is deeply indebted.

Much of the information contained herein was provided by Art, Harold Bissell, and Charles Hunt. The photographs are from Art's personal collection. Thanks to all who helped.

Crew (l. to r.): Don Curry, Lloyd Henbest, A.A. Baker, Charles Hanks (packer), Max Knechtel, and Marshal Cowseret (cook), 1930.

Baker at triangulation station on Hatch Rock, Moab area,1927.

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Teacher's Corner

by Sandra N. Eldredge

GEOLOGISTS IN THE CLASSROOM

Students look forward to those visitors in their class ... what does a geologist do?... or ... what is a rock, a fossil, an earthquake? If you have been looking for scientists to visit your class, several organizations listed below may be able to help you.

Business Industry Community Education Partnership (BICEP) has a list of professional geologists, among other professions, in the Salt Lake Valley area. These people will visit a classroom to talk about careers in geology or address a geologic topic. Call 273-2146.

Utah Museum of Natural History (UMNH) has a wonderful docent program as part of their education department. Several docents are trained in four geologic topics: geologic hazards of Utah, earthquake safety and awareness, rocks and minerals, and fossils. Earthquake safety and awareness is generally provided for a whole school, while the other three topics are for single classrooms. Interesting materials, visuals, and hands-on activities are provided. They service Salt Lake, Granite, Jordan, and Davis school districts, and there is a fee. Contact the UMNH Education Department 581-4887.

U.S. Bureau of Mines staff can provide presentations on "Precious metals and early mining" for the elementary grades, and "Careers at the Bureau of Mines" for the secondary grades. Call Jerry Montgomery, 524-6117. For Ken Gardiner's "Chemicals Magic Show," call 524-6162.

Women and Mathematics (WAM) is a national organization encouraging young women to study mathematics and the sciences. WAM members represent a variety of careers: academic, business, medical, industrial, computer, social science, and natural sciences. These professional women will make presentations to your class or attend career days. Contact Carolyn Tucker, Math Department, Westminster College, Salt Lake City, 488-4174.

The Utah Geological Survey (UGS) provides field trips for teachers. These trips can be organized for teacher learning, or for ideas on where to take students on field trips. Contact Sandra Eldredge at 467-7970 if you are interested in a field trip.

Earthquake Activity in the Utah Region

April 1 — June 30, 1991

Susan J. Nava
University of Utah Seismograph Stations
Department of Geology and Geophysics
Salt Lake City, Utah

During the three-month period April 1 through June 30, 1991, the University of Utah Seismograph Stations located 308 earthquakes within the Utah region (see accompanying epicenter map). The total includes four earthquakes in the magnitude 3 range. (Note: Magnitude indicated here is either local magnitude, M_L, or coda magnitude, M_C. All times indicated here are local time, which was Mountain Standard Time.)

LARGER AND/OR FELT EARTHQUAKES

M_C 3.4, April 8, 10:53 p.m., 31 miles W of Ivins (see NW of St. George).

M_L 3.8, April 20, 6:56 a.m., 12 miles N of Paragonah (see NE of Cedar City), felt at Minersville (MMI IV), at Elsinore and Paragonah (MMI III), and at Hatch (MMI II).

M_L 3.1, April 26, 2:20 a.m., 12 miles N of Paragonah.

M_L 2.8, May 23, 1:38 a.m., 7 miles WNW of Orangeville (see SW of Price), felt at UPL Cottonwood Creek mine, and at Ephraim (MMI III).

M_C 3.0, June 25, 3:02 p.m., 45 miles WSW of Bluff (see SE Utah).

SIGNIFICANT CLUSTERS OF EARTHQUAKES

Southwest of Price (coal-mining related): Three clusters of earthquakes make up 23% of the shocks that occurred in the Utah region during the report period, including:

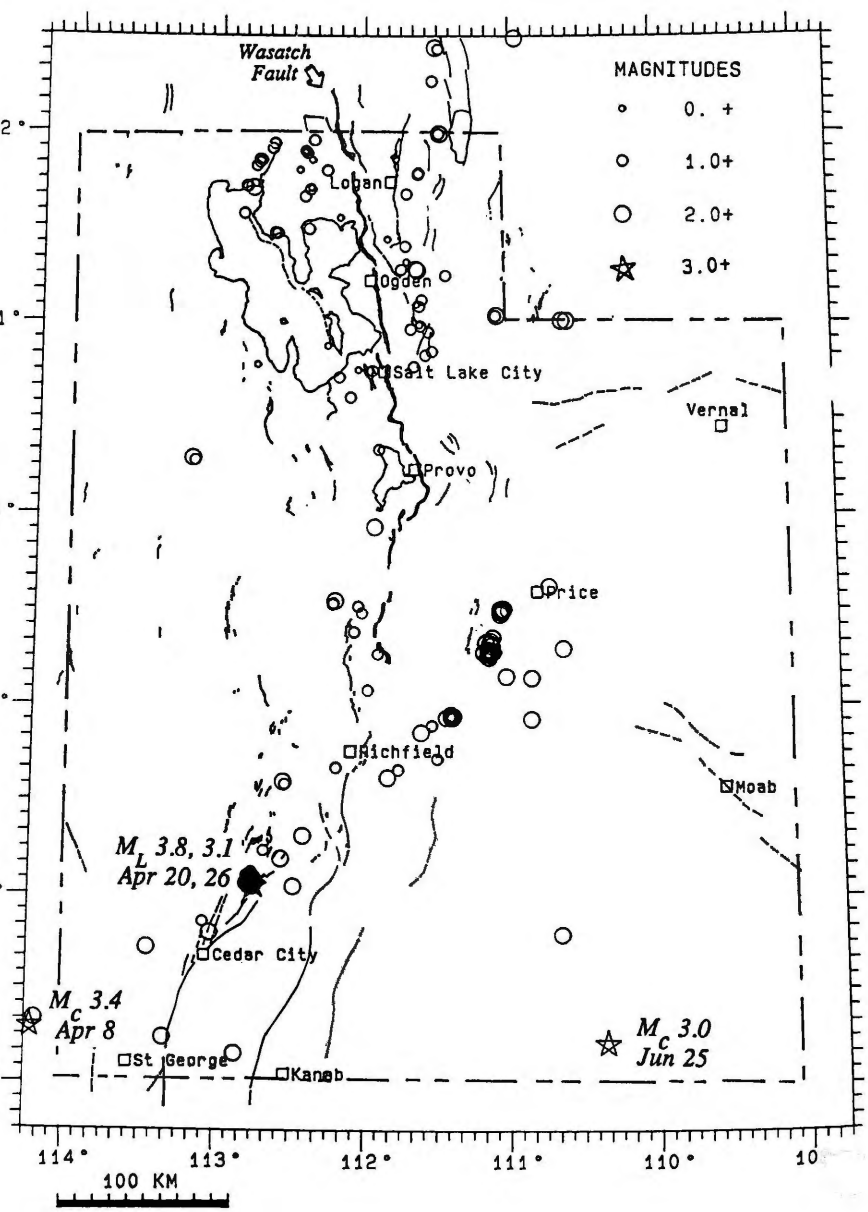
—8 earthquakes, magnitude 2.0 to 2.9, in the vicinity of the U.S. Fuel Company Gentry Mountain mine complex;

—53 earthquakes, magnitude 2.1 to 2.9, in the vicinity of the Utah Power & Light Huntington mine complex: and

—17 earthquakes, magnitude 1.8 to 2.6, in the vicinity of the Southern Utah Fuel Company Confusion Canyon mine complex.

North of Paragonah: A swarm of 119 earthquakes, located in the Parowan Valley of southwestern Utah, occurred mostly in late April 1991. The shocks ranged in magnitude from 0.9 to 3.8. Swarm activity such as this has been observed in southwestern Utah in the past and is not considered unusual.

Additional information on earthquakes within the Utah region is available from the University of Utah Seismograph Stations.



GEOLOGIC MAPPING AND FIELD REVIEWS

by H.H. Doelling

The first known geologic map was prepared 3100 years ago in Egypt on a sheet of papyrus 16 inches high and 9 feet long (Harrell and Brown, 1989). A gold mine and a 9-mile stretch of rocks along a wadi were mapped at an approximate 1:4000 scale. The need and demand for large-scale geologic maps continues to the present. In a recent survey, geoscientists were asked what kind of geologic map was most needed and the overwhelming answer was large-scale geologic maps (Mankin, 1988). The Illinois State Geological Survey (Bhagwat and Berg, 1991) has documented the economic value of detailed geologic mapping, with the ratio of quantifiable benefits-to-map-cost ranging from 5:1 to 11:1 for the worst scenario to 23:1 to 54:1 for the best-case scenario. The calculations were based only on avoided costs associated with the cleanup of landfills and industrial disposal sites. Other, less quantifiable benefits, such as using the maps to identify and recover earth resources and ground-water supplies, describing foundation conditions, identifying potential earthquake faults, and for land-use planning and academic research further increase their value. Without geologic maps, any geologically related investigation is difficult or impossible (Mankin, 1988).

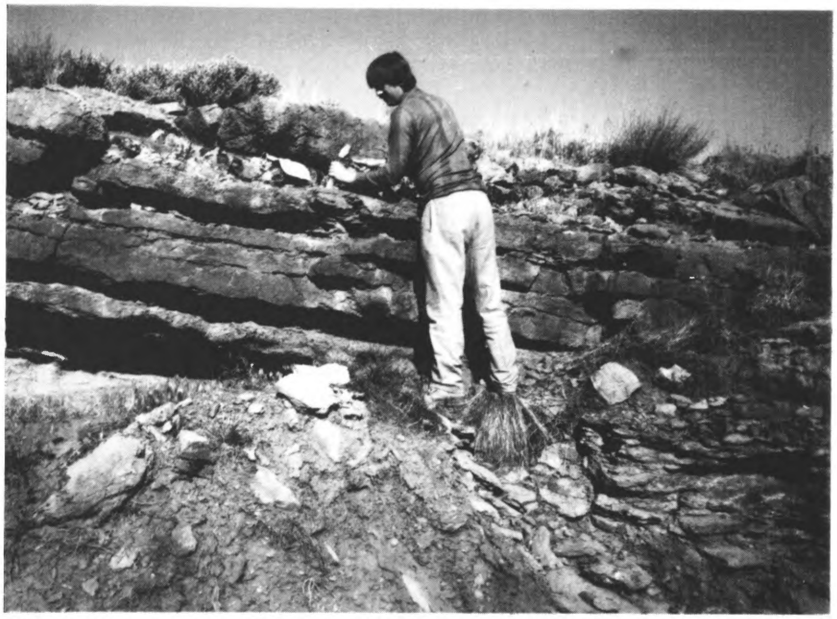


Figure 1. There is no substitute for careful fieldwork when mapping quadrangles.

The science of cartography (map making) has advanced considerably in the last decade. Geologic maps now benefit from the use of aerial photography, satellite imagery, and computer plotting and enhancements. The Kansas Geological Survey presently offers on-demand map publication through the use of a large-format, computer-driven color plotter, cutting down on hundreds of hours of map preparation time. This allows more frequent updating and correction of errors, and cuts down on the maintenance of large map inventories (Buchanan and Steeples, 1990). The U.S. Geological Survey uses computers to develop geologic models in three dimensions from map information. One application of these models is the creation of the traditional geologic cross section (Van Driel, 1989).

No matter how sophisticated the newer methods of cartography are or how advanced computer technology becomes, the map is no better than the quality of the data used to produce it. Good geologic maps result from intensive field work coupled with suitable cartographic techniques. The science of geologic mapping is one of the most demanding and difficult of the geologic disciplines. Photogeology can give rough interpretations, but for detail and accuracy there are no substitutes for walking out contacts, measuring stratigraphic sections, taking suitable samples, measuring strikes and dips, and simply observing and interpreting geologic phenomena first hand (figure 1).

UGS MAPPING PROGRAM

The Utah Geological Survey (UGS) received a legislative mandate to meet Utah's geologic mapping needs and has the responsibility to produce geologic maps at a scale of 1:24,000, the 7-1/2 minute series, covering 7 minutes and 30 seconds of latitude and longitude. Planning for the geologic mapping program was considerable and getting started was a difficult assignment (Doelling, 1985). The uses for geologic maps were found to be so numerous that a multi-purpose map and booklet format was adopted to meet most needs. Accuracy criteria, standards, and a thorough review system were developed and adopted. Prospective staff members were interviewed and tested to insure their ability to map and do field work.

Geologic maps published by the UGS for its 1:24,000 series are prepared by "in-house" staff geologists, by U.S. Geological Survey geologists, and by students and professors of several universities. Utah Geological Survey experience has shown that conscientious students, with suitable guidance, produce geologic maps that emulate those produced by more experienced geologists. The oft-times limited views of student mappers can be broadened by the suggestions of experts and lay users. Mapping geologists come with varying expertise, background, and experience. Since the geologic disciplines are now so complex that no geologist can master them all, it is essential that the mapping is (1) field checked, (2) thoroughly reviewed for clarity and accuracy, (3) examined for completeness and uniformity, and (4) checked for consistent usage of geologic terms and symbols in a peer review system.

MAP STATUS

The status of the UGS mapping program is shown and tabulated in figure 2 and table 1. To date, 52 maps have been published, 37 maps are available in preliminary form, and 25 map projects have completed field reviews. Most of the pub-

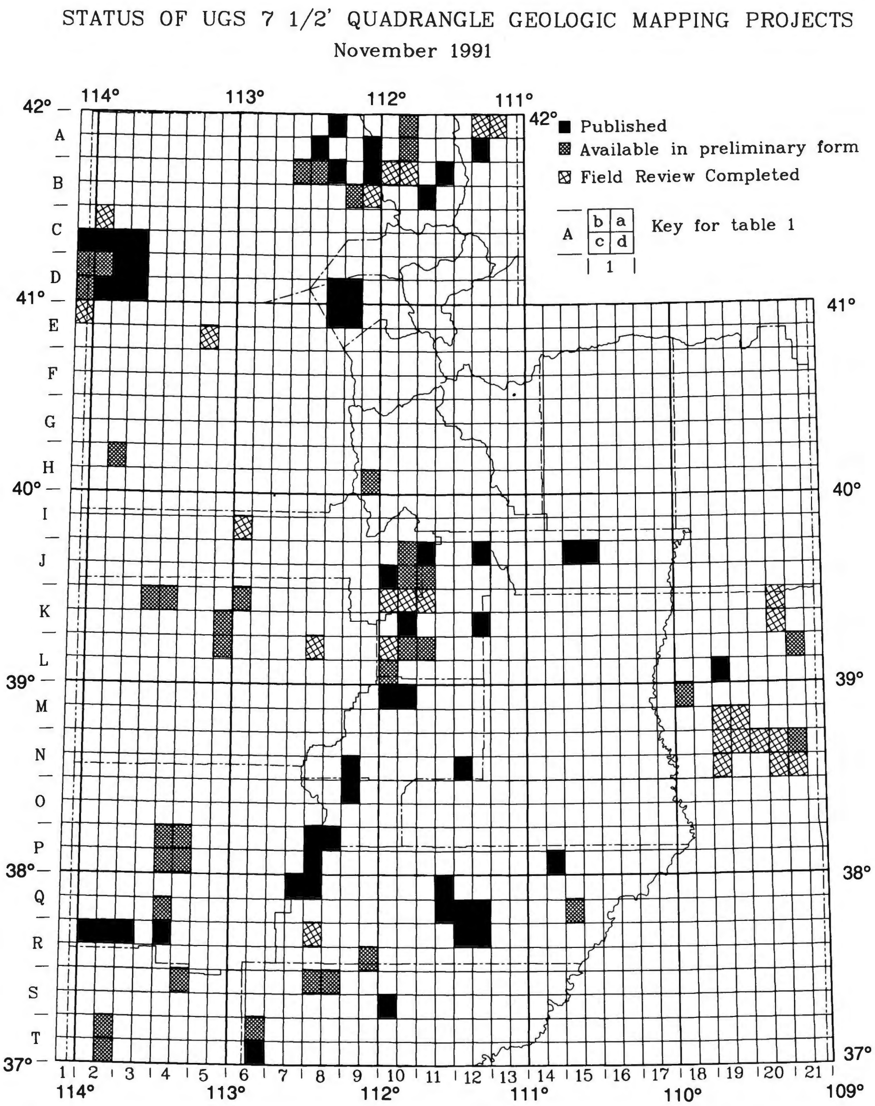


Figure 2. Status of Utah Geological Survey 1:24,000 geologic mapping, November 1991.

lished maps are in color and sell for $5.00. The open-filed maps are available to the public in preliminary form. When published they will be removed from open-file status. Just under 6000 square miles have been mapped since the program began in 1983. That amounts to 750 square miles or about twelve and one-half 7-1/2 minute quadrangles per year.

FIELD REVIEWS

The field review process is one area in which the UGS has had great success. The first few reviews proved their value, even for the more experienced mappers. At first the UGS believed the most important participants of field reviews would be those who had worked professionally in the area or who were experts in the geologic processes that most influenced the geology of the map area. However, laymen and other interested professionals were found to have valuable ideas and comments that help make the maps more useful to a broader audience. Their ideas are often the most useful for planners, recreationists, engineers, teachers, and other prospective users.

Proper planning is essential for a successful field review. It is scheduled when the field work nears completion, but with enough time remaining for the recommendations to be implemented. The mapping geologist plans the field trip and the UGS sends invitations to those with an interest in the area: federal, state and local governmental workers; members of the industry and academia; the public at large; educators; and politicians who are interest in knowing more about the geography and geology of the areas being mapped. The UGS maintains a mailing list to notify interested individuals of the future field reviews. Those wishing to participate in future field reviews should submit their name and address, along with the geographic area(s) of interest.

Field reviews usually last a day. To minimize costs, those wishing to attend field reviews are asked to provide their own lunches, lodging, and transportation. A few seats are generally available in UGS vehicles (first come, first served). The mapping geologist begins the field review by displaying a colored geologic map of the area, descriptions of rock units, and cross sections, and then discusses the geologic highlights of the area (figures 3-5). At each successive stop the geology of the site is reviewed and questions are asked and answered. Stops are mainly geared to stratigraphy, structure, economic geology, or geologic hazards, but may include regional overviews, geologic curiosities, or other features of interest (figures 6 and 7). The review also provides an opportunity for the mapper to seek guidance and suggestions about specific problems from ex-

Figure 3. At the beginning of a field review the geologist displays his field map and describes the general geology to the participants.

Table 1: Status of Utah Geological Survey 1:24,000 geologic mapping, November 1991.

Map Key	Quadrangle	Author	Avail. as UGS #.	Year Released	Price
A--8a	Limekiln Knoll (B&W)	Murphy et al.	Map 79	1985	$3.75
A--8c	Howell	Jordan et al.	Map 107	1988	$5.00
A--9d	Cutler Dam	Oviatt	Map 91	1986	$5.00
A-10a	Richmond	Brummer et al.	OFR 174	1990	$6.10
A-10d	Smithfield	Lowe et al.	OFR 155	1989	$7.50
A-12a	Bear Lake South	Coogan			
A-12d	Laketown (B&W)	Valenti	Map 58	1982	$7.50
A-13b	Sheeppen Creek	Coogan			
B--7a	Sunset Pass	Miller et al.	OFR 201	1990	$6.00
B--8a	Thatcher Mountain	Jordan et al.	Map 109	1988	$6.00
B--8b	Lampo Junction	Miller et al.	OFR 141	1988	$7.00
B--9a	Honeyville	Oviatt	Map 88	1986	$5.00
B--9c	Bear River City	Jensen	OFR 145	1989	$5.00
B--9d	Brigham City	Jensen			
B-10a	Logan	Evans			
B-10b	Wellsville	Barker			
B-11a	Boulder Mountain	Mork	Map 125	1990	$5.00
B-11c	Porcupine Reservoir	Berry	Map 113	1989	$5.00
C--1d	Tecoma	Miller et al.	Map 77	1985	$5.00
C--2b	Lucin NW	Miller			
C--2c	Lucin	Miller	Map 78	1985	$5.00
C--2d	Pigeon Mountain	Glick et al.	Map 94	1987	$5.00
C--3c	Jackson	Miller et al.	Map 95	1987	$5.00
D--1a	Patterson Pass	Miller et al.	OFR 172	1990	$7.50
D--1d	Pilot Peak	Miller et al.	OFR 208	1991	$7.80
D--2a	Lemay Island	Miller et al.	Map 96	1986	$5.00
D--2b	Crater Island NW	Miller	OFR 173	1990	$6.50
D--2c	Crater Island SW	Miller	Map 129	1990	$5.00
D--2d	Crater Island	Miller et al.	Map 128	1990	$5.00
D--3b	Lucin 4 NW	Glick et al.	Map 93	1986	$5.00
D--3c	Lucin 4 SW	Miller	Map 130	1990	$5.00
D--8d	Buffalo Point (Ant. Is. map	Doelling et al.	Map 127	1991	$11.00
D--9c	Antelope Is. N (Ant. Is. map)		Map 127		
E--1a	Miners Canyon	Miller			
E--5c	Grayback Hills	Doelling et al.			
E--8a	Plug Peak NE (Ant. Is. map)		Map 127		
E--9b	Antelope Is. (Ant. Is. map)		Map 127		
H--2a	Gold Hill	Robinson	OFR 118	1988	$4.15
H--9d	Allens Ranch	Proctor	OFR 69	1985	$6.95
J-10a	Nephi	Biek	OFR 148	1989	$11.00
J-10c	Juab	Clark	Map 132	1990	$5.00
J-10d	Levan	Auby	OFR 120	1988	$6.50
J-11b	Fountain Green North	Banks	Map 134	1991	$5.00
J-11c	Fountain Green South	Fong	OFR 204	1991	$10.50
J-12a	Fairview Lakes (B&W)	Oberhansley	Map 56	1980	$5.00
J-15a	Pine Canyon (B&W)	Anderson	Map 72	1983	$7.50
J-15b	Deadman Canyon (B&W)	Nethercott	Map 75	1985	$7.50
K--3a	Coyote Knolls	Sack	OFR 165	1989	$4.00
K--4b	Swasey Peak NW	Sack	OFR 164	1989	$4.00
K--5d	Red Knolls	Hintze et al.	OFR 136	1988	$2.50
K--6b	Smelter Knolls West	Hintze et al.	OFR 205	1991	$7.00
K-10a	Chriss Canyon	McDermott			
K-10b	Skinner Peaks	Felger			
K-10d	Hells Kitchen Canyon SE	Mattox	Map 98	1987	$5.00
K-11b	Wales	Weiss			
K-12d	Joes Valley Reservoir (B&W)	Kitzmiller	Map 67	1982	$7.50
K-20a	P.R. Spring	Willis			
K-20d	Dry Canyon	Willis			
L--5a	Long Ridge	Hintze et al.	OFR 137	1988	$2.50
L--8b	McCornick	Davis			
L-10a	Gunnison	Mattox	OFR 146	1989	$6.50
L-10b	Hayes Canyon	Peterson			
L-10c	Redmond Canyon	Willis	OFR 163	1989	$5.20
L-11b	Sterling	Weiss	OFR 195	1990	$16.50
L-19c	Sego Canyon	Willis	Map 89	1986	$5.00
L-21b	Harley Dome	Willis	OFR 216	1991	$8.00
M-10a	Salina	Willis	Map 83	1986	$5.00
M-10b	Aurora	Willis	Map 112	1988	$5.00
M-18b	Hatch Mesa	Chitwood	OFR 194	1990	$7.80
M-19c	Klondike Bluffs	Doelling			
M-19d	Mollie Hogans	Doelling			
N--9c	Antelope Range	Rowley et al.	Map 106	1988	$5.00
N-12c	Geyser Peak	Nelson	Map 114	1989	$5.00
N-19a	The Windows Section	Doelling			
N-19b	Merrimac Butte	Doelling			
N-19c	Gold Bar Canyon	Doelling et al.			
N-20a	Fisher Towers	Doelling			
N-20b	Big Bend	Doelling et al.			
N-20d	Warner Lake	Ross			
N-21b	Fisher Valley	Goydas	OFR 167	1990	$8.00
N-21c	Mt. Waas	Ross			
O--9b	Marysvale	Rowley et al.	Map 105	1988	$5.00
P--4a	Burns Knoll	Hintze et al.	OFR 179	1990	$2.30
P--4b	Blue Mountain	Weaver et al.	OFR 180	1990	$7.10
P--4c	Lund	Grant et al.	OFR 178	1990	$2.20
P--4d	Latimer	Hintze et al.	OFR 177	1990	$2.20
P--8a	Circleville	Anderson	Map 82	1986	$5.00
P--8b	Circleville Mountain	Anderson	Map 80	1986	$5.00
P--8c	Fremont Pass	Anderson et al.	Map 81	1986	$5.00
P-14d	Mount Ellen	Morton	Map 90	1986	$5.00
Q--4c	Antelope Peak	Grant et al.	OFR 130	1988	$3.50
Q--7a	Little Creek Peak	Anderson et al.	Map 104	1987	$5.00
Q--8b	Panguitch NW	Anderson et al.	Map 103	1987	$5.00
Q-11a	Roger Peak	Weir et al.	Map 115	1990	$5.00
Q-11d	Escalante	Williams et al.	Map 116	1990	$5.00
Q-12c	Calf Creek	Weir et al.	Map 120	1990	$5.00
Q-12d	King Bench	Weir et al.	Map 119	1990	$5.00
Q-15c	Copper Creek Benches	Jackson et al.	OFR 209	1991	$5.50
R--2a	Pinon Point	Siders	Map 84	1985	$5.00
R--2b	Mount Escalante	Siders	Map 131	1991	$5.00
R--3b	Beryl Junction	Siders	Map 85	1985	$5.00
R--4b	Silver Peak	Shubat et al.	Map 108	1988	$5.00
R--8b	Hatch	Kurlich			
R--9d	Cannonville	Hereford	OFR 142	1988	$3.50
R-12b	Tenmile Flat	Weir et al.	Map 118	1990	$5.00
R-12a	Red Breaks	Weir et al.	Map 117	1990	$5.00
S--4a	New Harmony	Grant	OFR 206	1991	$6.00
S--8a	Podunk Creek	Tilton	CR 91-2	1991	$7.00
S--8b	Alton	Tilton	CR 91-1	1991	$7.00
S-10c	Calico Peak	Doelling et al.	Map 123	1989	$5.00
T--2a	Shivwits	Hintze et al.	OFR 213	1991	$8.50
T--2d	Jarvis Peak	Hammond	OFR 212	1991	$8.50
T--6a	The Barracks	Sable et al.	OFR 196	1990	$4.70
T--6d	Elephant Butte	Sable et al.	Map 126	1990	$5.00

B&W indicates map is published in black and white rather than in color.

perienced geologists. Anyone can ask a question and anyone can make a suggestion. Attendance at the reviews range from five to 35 people depending on interest. Invariably, three or four experienced geologic mappers are present.

At the end of the day, the mapper knows what is needed to complete the project and has a better idea of what information is of interest and of importance to prospective users. The mapper also knows what problems remain to be solved, and how to solve or explain them. The participants and UGS management know whether the mapping effort has been adequate, or whether supplemental work is required. Everyone feels more confident about the map that is to be published.

AFTER THE FIELD REVIEW

After the field review, the geologic mapper incorporates the review suggestions and the project continues to a successful conclusion. To date, suggestions have included the need for radiometric age-dating, measuring additional stratigraphic sections, adding locations of small shafts and adits, adding locations of small landslides, reviewing choices of geologic contacts, collecting and analyzing various samples, alternate and improved methods of portraying features on the map, and subdividing units (and how it might be done). These suggestions have been educational or useful to the attendees as well.

Participants often voice opinions about their geologic map needs, or what areas they would like to see mapped next. Many times good contacts are made between people having similar research interests; information is shared, duplication of effort is avoided, and other benefits are realized. Field reviews have stimulated some geologists to become partners with the UGS in mapping other quadrangles in Utah and inspired others to conduct related research, all of which is important to the state. In this manner, the field review process serves additional purposes.

The field review is the first milepost reached on the way to a published map. After the field review, the map and an accompanying manuscript can be finalized. The completed product is then submitted to the UGS where it receives a preliminary technical review. If all project requirements have been fulfilled, the work is open filed to quickly make the map available to the public. The open-filed document then undergoes an extensive peer review by at least two non-UGS and two UGS experts. Policy reviews are added, changes are made, and the map goes to press.

Normally, the review process takes as much time as the original field mapping. The result, however, is an improved and more useful map and text booklet.

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Figure 4. A field review group examines the map and discusses the geology in the Basin and Range of Utah.

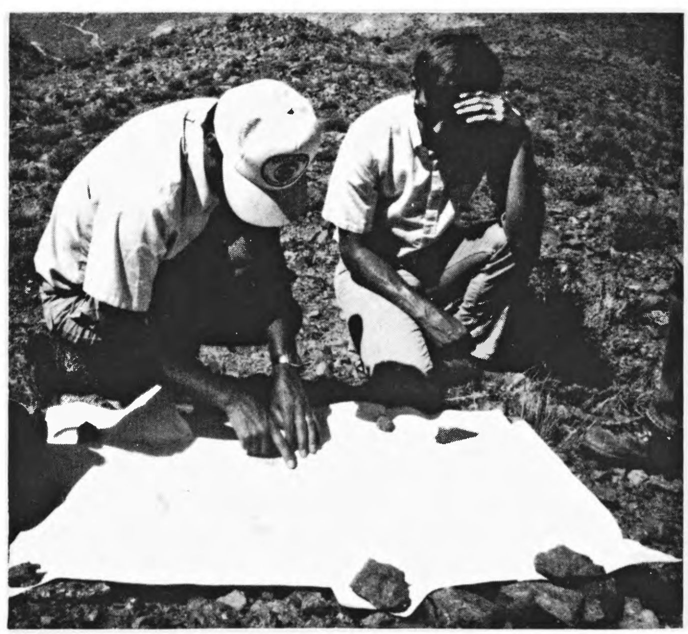

Figure 5. Two geologists discuss adjoining map problems during a field review.

Figure 6. Quaternary geology is an important aspect of quadrangle mapping. Here, two geologists examine a sample for microfossils in Lake Bonneville sediments.

Figure 7. Field review participants searching for a volcanic ash to be geochronologically dated.

MEETINGS

December 8-9, 1991: Arizona Conference of AIME in Tucson, Arizona at the Doubletree Hotel. A good range of technical sessions centered on mining industry will be presented. Contact Meetings Department, SME, P.O. Box 625002, Littleton, CO 80162, telephone (303) 973-9550.

February 24-27, 1992: SME Annual meeting and exhibit in Phoenix, Arizona. Symposia will include Comminution -- theory and practice; Native sulfur developments; and others. Contact Meetings Department, Society for Mining, Metallurgy, and Exploration, Inc., P.O. Box 625002, Littleton, CO 80162, telephone (303) 973-9550.

The first annual Utah Geographic Information Council was held October 30 to define the Council's role and discuss related topics. The stated purpose of the group is to provide an umbrella organization for all those with a common interest in geographic information and to promote communication. For information contact Bill Lund, Utah Geological Survey, (801) 467-7970.

December 4, 1991: Sixth Annual U.S. Geological Survey Poster Paper Review; Denver Federal Center; contact Anny B. Coury, (303) 236-5440.

Call For Papers: Cordilleran Section GSA; deadline is January 21; contact Jack M. Rice (503) 346-4573. Rocky Mountain Section GSA; deadline is January 29; contact Sidney Ash (801) 626-6908. GSA Annual; deadline is July 8; contact Abstracts Coordinator (303) 447-8850.

GSA Meetings: Cordilleran Section, May 11-13, 1992, Eugene, OR; Rocky Mountain Section, May 14-16, 1992, Ogden, UT; GSA Annual, October 26-29, 1992, Cincinnatti, OH.

U.S. Geological Survey 8th Annual McKelvey Forum on Energy Resources, February 18-20, 1992, Houston, Texas: Christine Turner, USGS, MS 939, 25046 Federal Center, Denver, CO 80225; phone (303) 236-1561.

Seventh International Symposium on Water-rock Interaction, July 13-22, 1992, Park City, UT: International Assn., of Geochemistry and Cosmochemistry, Dr. Yousif Kharaka, U.S. Geological Survey-MS 427, 345 Middlefield Rd., Menlo Park, CA 94025; phone (415) 329-4535, FAX 415-329-5110.

American Institute of Professional Geologists, Annual Meeting, Sept. 27-Oct. 1, 1992, Lake Tahoe, NV: Jon Price, AIPG, P.O. Box 665, Carson City, NV 89702.

New Publications of the Utah Geological Survey

The October 1991 Publications List is free on request.

Engineering geology of the Salt Lake City metropolitan area, Utah, W.R. Lund, editor, 66 p., 1990, Bulletin 126 **$8.00**

Provisional geologic map of the Fountain Green North quadrangle, Sanpete and Juab Counties, Utah, by R.L. Banks, 21 p., 2 pl., 1:24,000, 1991, Map 134 **$5.00**

Analysis and regional implication of cleat and joint systems in selected coal seams, Carbon, Emery, Sanpete, Sevier, and Summit Counties, Utah, by Brigitte Hucka, 47 p., 2 pl., 1" = 3¼ miles, 1991, Special Study 74 **$6.00**

Quaternary geology of Fish Springs Flat, Juab County, Utah by Charles G. Oviatt, 16 p., 1 pl., 1:50,000, 1991, Special Study 77 **$6.00**

Paleoseismology of Utah, Volume 3: The number and timing of paleoseismic events on the Nephi and Levan segments, Wasatch fault zone, Utah, by Michael Jackson, 23 p., 3 pl., 1991, Special Study 78 **$6.50**

Deltaic and shelf deposits in the Cretaceous Blackhawk Formation and Mancos Shale, Grand County, Utah, by M.A. Chan, S.L. Newman, and F.E. May, 83 p., 2 pl., 1" = approx 4950', 1991, Miscellaneous Publication 91-6 **$9.00**

Petrology, sedimentology and stratigraphic implications of the Rock Canyon Conglomerate, southwestern Utah, by R. LaRell Nielson, 65 p., 1991, Miscellaneous Publication 91-7 **$6.00**

Coalbed methane resource map, Castlegate D bed, Book Cliffs coal field, Utah, by A.C. Keith, J.S. Hand, and A.D. Smith, 1 pl., 1:100,000, August 1991, Open-File Report 176E **$2.00**

Geologic map of the Shivwits quadrangle, Washington County, Utah, by L.F. Hintze and B.J. Hammond, 77 p., 2 pl., 1:24,000, September 1991, Open-File Report 213 **$8.50**

Stratigraphic and time-stratigraphic cross sections of Phanerozoic rocks, western Uinta Mountains through the San Pitch Mountains-Wasatch Plateau to western San Rafael Swell, Utah" by D.A. Sprinkel, 55 p., 2 pl., 1:500,000, October 1991, Open-File Report 214 **$6.50**

Soil chronology of the Wasatch Front based on weathering profiles, by Heber D. Lessig, 46 p., 1 pl. approx scale 1 = ½ mile, August 1991, Contract Report 91-8 **$3.75**

Landward pinch-out of Cretaceous marine near-shore clastics in the Ferron Sandstone Member of the Mancos Shale and Blackhawk Formation, east-central Utah; potential petroleum stratigraphic traps, by Paul B. Anderson, 110 p., August 1991, Contract Report 91-12 **$9.00**

Skarn occurrences in Utah and the potential for associated gold mineralization, by Julia E. Reid, 29 p. plus 20 p. appendix, August 1991, Contract Report 91-13 **$4.00**

A short course for geostatistics and multivariate data analysis, by James R. Carr, 192 p., 2 disks (1.2 Mbytes), September 1991, Contract Report 91-14 **$15.00**

Quaternary geology of the northern Sevier Desert, Millard, Juab, and Tooele Counties, Utah, by C.G. Oviatt, Dorothy Sack, and T.J. Felger, 78 p., 1 pl., 1:62,500, November 1991, Open-File Report 215 **$7.50**

Geologic map of the Harley Dome quadrangle, Grand County, Utah, by G.C. Willis, 70 p., 2 pl., 1:24,000, November 1991, Open-File Report 216 **$8.00**

Structural setting of seismicity in northern Utah, by James P. Evans, 37 p., 3 pl., 1:100,000, November 1991, Contract Report 91-15 **$7.50**

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PETRIFIED MINI-FORESTS OF THE NAVAJO SANDSTONE, EAST-CENTRAL UTAH

William L. Stokes
Emeritus Professor of Geology, University of Utah

Ever since the Navajo Sandstone was first described well over a century ago, its origin has been a subject of intensive speculation. The homogeneity, large-scale crossbedding, and scarcity of other internal structures have been variously interpreted. The thought that these are positive indications of wind action has had to make its way against the conventional view that extensive clastic formations must be of marine or at least subaqueous origin. Evidences for an eolian mode of deposition have been proposed and countered by those who consider the same evidences as "ambiguous, non-diagnostic, and insufficient to substantiate an eolian interpretation" (Freeman and Visher, 1975, p. 651). Admittedly, most of the reported fossil evidence is ambiguous. For example, traces of vertebrate life consist of footprints and a few skeletons that may have been left by purely terrestrial forms trespassing into a dominantly near-shore environment. More diagnostic fossil evidence is definitely needed.

Numerous coniferous trees petrified in their place of growth exist within the Navajo Sandstone in the vicinity of Moab (figure 1) and must be taken into account in future paleoecological reconstructions of the Navajo. The present investigation documents the occurrence of this fossil evidence.

PREVIOUS PALEONTOLOGIC DISCOVERIES

From almost all viewpoints, the Navajo Sandstone in unfavorable for preservation of fossil remains. The prevailing mental concept of a Sahara-like desert environment has discouraged serious searches and most discoveries have been the accidental by-products of routine field work. Progress has been slow, but a variety of animal and plant microfossils, vascular plants, invertebrates and vertebrates have been found. Most of these are listed in a compilation by Picard (1977). His examples are about equally divided between those of the sandy facies, which pertain to vertebrates, and those from the limestone facies which are mostly plants and invertebrates. In rough order of abundance, but not necessarily of importance, an updated list includes algae (Gregory, 1950; Hatchell, 1967; Gilland, 1979; Lockley, 1986); invertebrate trace fossils; trails and burrows (Hatchell, 1967; Stokes, 1978; Gilland, 1979; Sanders, personal communications, 1990); multicellular plants: *Equisetum*, indeterminate impressions, and fern fragments (Gilland, 1979; Stokes, personal observation); invertebrate body fossils: ostracodes and brachiopods (Harshbarger and others, 1957, p. 1; Hatchell, 1967); and

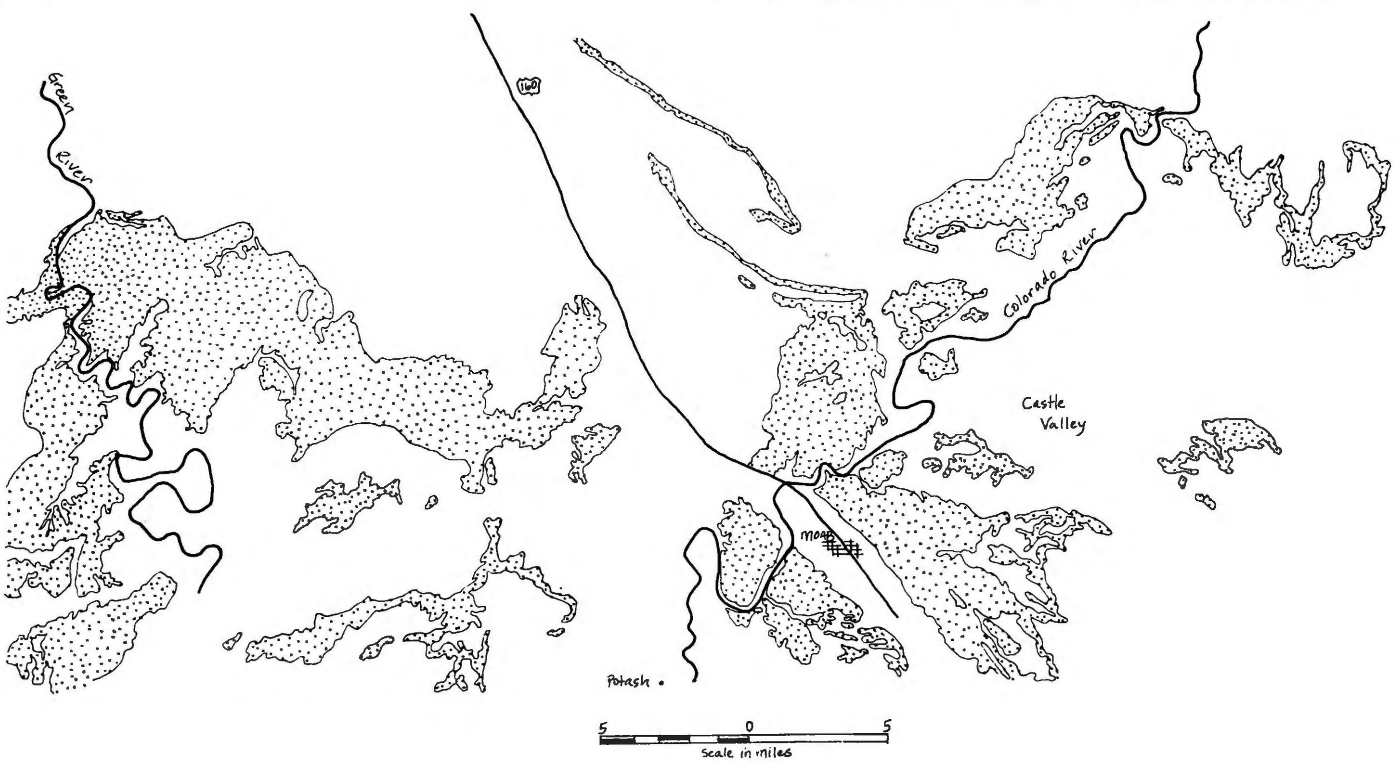

Figure 1. Location of Navajo Sandstone (Lower Jurassic) outcrops in the vicinity of Moab, Utah. There are at least 13 sites where fossil trees have been found in this area.

vertebrate body fossils, chiefly dinosaur bones (Brady, 1935, 1936; Camp, 1936; Galton, 1971).

Two facts seem significant: first, nothing listed currently has meaningful value as a guide or index fossil, and second, the fossils are not absolutely diagnostic for distinguishing between a land-locked, non-marine environment and one that is marginal marine. Ostracodes, which might be expected to be of value in age dating or environmental reconstruction, are represented in the Navajo by species that are particularly long ranging and non-diagnostic. When more is known about dinosaur tracks, the Navajo specimens will be of greater stratigraphic value than they now are.

This paper does not repeat in detail the subject matter of previously published material on the paleontology and paleoecology of the Navajo Sandstone. Rather, attention will be concentrated on the occurrence of in situ trees and their significance in establishing a non-marine origin for the formation. Arguments that have a bearing on the central problem will be noted but not expanded beyond what is necessary to establish basic facts.

STRATIGRAPHIC CONSTRAINTS ON PALEONTOLOGIC EVIDENCE

Stratigraphic refinement of the Navajo Sandstone indicates that it is not as indivisible and uniform as originally supposed. In 1979, the existence of a regional unconformity within what had previously been mapped as Navajo Sandstone was reported and documented (Peterson and Pipiringos, 1979). For the sandstone above the unconformity, these workers proposed the name Page Sandstone. At the type locality, Page, Arizona, it is 183 feet thick while the underlying main Navajo, seen in the abutments of the Glen Canyon Dam, is 400 to 500 feet thick.

The Page Sandstone is known to have been laid down marginal to the Carmel-Twin Creek formation with abundant fossil evidence for an early Late Jurassic age (Imlay, 1980). The older, restricted Navajo has no known connection with dated marine facies to the west. The present westward termination of the restricted Navajo against the Wasatch Line is tectonic, not stratigraphic and the nature of the pinchout or termination is a matter of speculation. Features observed in the Page Sandstone are thought of having originated in a marginal marine setting. The possibility exists that diagnostic marine fossils may be found beyond the margins of the limy or silty tongues that penetrate eastward from the Carmel. The Page thins eastward but the exact position of the boundary across much of eastern Utah and northeastern Arizona is uncertain. Maps and cross sections of Pipiringos and O'-Sullivan (1978, plate 1) show the eastern edge of the Page follows a fairly straight course across central Utah: east of the Kaiparowits Plateau and San Rafael Swell, across the western Uinta Basin and Uinta Mountains, to the Utah border near Manila, Daggett County. This is a simplification that has been corrected in later studies. The Page is now recognized in sections as far east as Kane Springs and evidently has an irregular eastern border (O'Sullivan, 1981, sections 2, 3, 4). O'Sullivan observed that the Page in the Kane Springs area occupies broad erosional depressions formed in the top of the Navajo Sandstone. How these depressions originated is not clear. Wind action may have been responsible, but there are alternative explanations. Considered in relation to the thick evaporite section that underlies the region, the possibility exists that local depressions in the Navajo may have been due to salt tectonics and not to surficial erosion. Perhaps a better reconstruction could be made by showing the Page outliers as protrusions above the general level and not filling depressions.

It is assumed, but not verified, that the fossil forests described in this report are in the main body of the Navajo Sandstone. The position of the tree horizons within the sandstone section is not accurately established. Although the contact with the underlying Kayenta Formation is exposed in all the deeper canyons of the region, the measurements and projections necessary to fix the position of the mini-forests have not yet been made. An exploratory drill hole near Spring Canyon in Grand County, put down by Buttes Gas and Oil Company and kindly furnished by Doug Maier, provided important data. According to Maiers's information, a limestone-capped hill is less than 200 feet from the well site. He estimated the limestone bed to be 235 feet above the top of the drill hole. Measurements and estimates of the Navajo Sandstone in the general area show it to be 300 to 500 feet thick, indicating that fossil trees near Spring Canyon are well within the main Navajo and not in the Page Sandstone.

DISCOVERY AND ACKNOWLEDGMENT

The discovery of petrified trees in the Navajo Sandstone, unreported before 1975, has encouraged a more thorough investigation. Thirteen separate mini-forests, many with trees of considerable size rooted and upright in their place of growth, have been located, firmly establishing a non-marine origin for the enclosing sediments.

First mention in the geologic literature of fossil wood in the Navajo Sandstone was by D. B. Loope (1979). He personally informed me that he located a number of sites during field work in south-central Utah but did not map or document them separately. In 1981, Doug Maier and Patric de Gruyter, working for Buttes Resources, discovered another occurrence while working on a nearby exploratory well. Their supervisor, Robert Norman, took me to the spot and I subsequently reported my observation in an oral presentation and short abstract (Stokes, 1983).

Other sites have been discovered and reported to me by F. A. Barnes, southeastern Utah author-photographer. Aided by his wife, Terby, and associate Jack Bickers, he has explored the Colorado Plateau for two decades in order to write his books on the region. Another site, in the Maze west of the Colorado River, was discovered and reported to me by Gary Cox, Park Ranger, Canyonlands National Park. Extensive mapping and field investigations in the Colorado Plateau to date have failed to turn up fossil wood outside of east-central Utah. The observed concentration in the Moab area may be explainable by local paleogeographical peculiarities.

PRESERVATION AND TAXONOMY

All Navajo wood so far collected is completely replaced by silica, no carbonaceous or calcitic material has been noted. Searches for specimens sufficiently well preserved for specific identification have been unsuccessful. Gross structure and growth rings are visible megascopically in many specimens, but Dr. William Tidwell, Brigham Young University, reports that wood submitted to him is not specifically identifiable. His opinion is that the trees are certainly conifers, most probably auracaurians. This is the group represented by the larger and more plentiful logs of the Chinle Formation of Late Triassic age and by the uranium-rich logs of the Salt Wash Sandstone of Late Jurassic age. This hardy tree still grows in scattered localities in the southern hemisphere, giving the genus an existence spanning at least 200 million years. The Navajo petrified wood is not of a quality to be of interest to collectors seeking materials for cutting and polishing. It is drab, opaque, and of uniform brown or gray color.

ENVIRONMENTAL TERMINOLOGY

That coniferous trees were able to grow in the midst of the Navajo sand sheet proves that it was not a totally lifeless desert. Water must have been available to the root zones of the relatively large trees that grew in scattered patches across the area. An oasis is a fertile or green area in an arid region, and a playa is the flat-floored bottom of an undrained desert basin that may become a shallow temporary lake. Both of these may have been present in the Colorado Plateau area when the Navajo Sandstone was accumulating. This is not to ignore the commonly used term interdune lake or pond, which implies that the water is of surface origin and is there because of confining dunes.

Playas are salt enriched and sterile and are located in interior upland areas where drifting sand is usually absent. The term "underfed" oasis comes to mind. This makes a useful comparison with other oases which might be designated as surface fed or spring fed.

SOURCE OF FRESH WATER

The source of water for the Navajo oases is a paleohydrologic problem. Either the water was supplied directly by surface precipitation and streams or it came indirectly from subsurface sources. The first possibility seems improbable because of the absence of high-energy linear structures associated with fluvial action. What evidence would a river leave that had only uniform loose sand to act upon?

A reasonably good case can be made that fresh ground water at shallow depth was supplied by recharge along the margins of the Navajo dune field where it lapped onto already consolidated rocks of nearby highlands. All recent reconstructions of Early Jurassic paleogeography show the Uncompahgre element of the ancestral Rockies (Uncompahgria) was a prominent positive feature in southwestern Colorado and east-central Utah. It had an abrupt south-facing front and topographic relief amounting to several thousand feet. Comparisons with the modern Sierra Nevada come to mind. Uncompahgria collected enough precipitation to feed fairly large permanent streams flowing in opposite directions from an irregular divide. The south-flowing discharge entered the Navajo dune field where it was absorbed and continued at a slower pace as a dispersed sheet of ground water. The entire body of Navajo Sandstone in the east-central Colorado Plateau was completely and continuously saturated to the level of the surficial migrating sand sheet. This is indicated by widely and uniformly distributed multiple

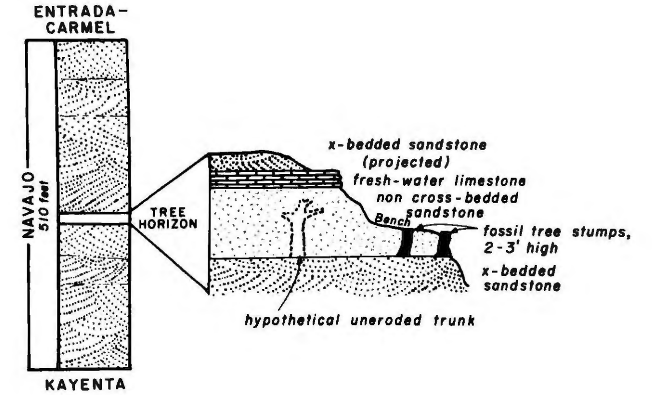

Figure 2. Semi-diagrammatic cross section of stratigraphic conditions at one of the fossil tree localities in the Navajo Sandstone. The photographs of figure 3 were taken here.

truncation planes interpreted as deflation surfaces cut to the level of a water table rising at an equal rate with sediment accumulation (Stokes, 1968). A very long time period, perhaps millions of years, was available to charge and keep the Navajo Sandstone full of water. Numerous multiple truncation bedding planes and many scattered lenses of limestone and/or dolomite constitute additional evidence that the water table rose to create small local ponds environmentally favorable for the development of various organisms including coniferous trees.

CARBONATE LENSES AND MULTIPLE TRUNCATION PLANES

A consistent invariable relationship between mini-forests, carbonate lenses, and multiple truncation planes cannot be verified by presently available observational data. What is known about a few specific localities is sufficient for a preliminary analysis. Stratigraphic relationships are well displayed at one location (figure 2) where several erect trunks, up to 9 inches in diameter and in position of growth, are seen in cross-section on a flat erosional surface and longitudinally in a nearby cliff face (figure 3). These are exposed a few yards downhill from an eroding limestone lens capping a small mesa-like hill. A puzzling but important observation is that the tree-bearing horizon is about 10 feet below the limestone lens. This is contrary to the logical visualization of vegetation growing in saturated ground around the margins of small water bodies. But any evidence of relationship by proximity is important and the assumption seems logical that tree growth and surface ponds are associated because they depend on rising ground water in the localized area where both occur. Why relatively restrictive areas are favorable to the transmittal of ground water over relatively long time periods must have a paleoecological explanation.

Outcrops of the Navajo Sandstone in southern Utah and northern Arizona usually include scattered, relatively thin lenses of limestone and/or dolomite. Comments on the possible origin of such lenses are frequently mentioned in connection with descriptions of the formation. Judging from scattered personal observations and notations in pertinent literature, the average thickness of Navajo carbonate lenses is between 1 and 4 feet, the average diameter 100 to 300 feet, and the shape roughly equidimensional.

To the present, only one of these lenses has been singled out for detailed study (Gilland, 1979). This unusually extensive lens is located near a prominent bend in the Colorado River along Utah Highway 279. Among the features noted by Gilland are reed-like plant impressions, many tracks of three-toed carnivorous dinosaurs, many burrows, an extensive pollen flora, boron values of 10 to 39 ppm, and vanadium values ranging from 7 to 42 ppm. Gilland concluded from his geochemical studies, "...that the depositional environment of this carbonate lens was fresh water" (page 36). Units laid down before the carbonate facies clearly show aqueous influences and prove that the area was receiving or transmitting fresh water long before a well defined pond appeared at the surface (Gilland, 1979, figure 4).

The dinosaur tracks, some of which are well displayed on detached blocks, are a local tourist attraction and have been more fully described by Lockley (1986). Gilland has informed me that the pollen flora is still unstudied.

ARGUMENTS AGAINST A SUBAERIAL ENVIRONMENT

Brief mention should be made of published and unpublished opinions supportive of non-eolian origin for the Navajo Sandstone. The first description of the yet-to-be-named Navajo in the geologic literature was by C. E. Dutton in 1880. In his opinion, the sands that compose the Navajo were deposited in the sea: "The Jurassic sandstone appears to have been a coast of the Mesozoic mainly, which occupied the region now forming the Great Basin..." (Dutton, 1880). In an obscure reference Asa A. L. Mathews (1931) reported having found a fossilized *Trigonia* shell at the base of an outcrop of the Nugget Sandstone (Navajo equivalent) in the Wasatch Range near Salt Lake City. From eye-witness reports this is known to have been an eroded piece of rubble and not a fossil at all (Stokes, personal investigation). R. K. Grater (1948, p. 311) from observations in Zion Park concludes: "Large lenses of dolomite and the presence of extensive deposits of green sand, believed to be glauconite, in the lower portion of the Navajo serve as indicators of water origin. Sand-grain studies also indicate a non-eolian origin. Indications are that these deposits were formed in a shallow water basin." F. E. Digert (1955), from data gathered in the southwestern Colorado Plateau, found evidence in the style of crossbedding that the Navajo Sandstone "represents a gigantic fluvial deposit originating from a series of interlacing streams whose manner of deposition was controlled by fluctuations in sea level." Large-scale crossbedding is the most striking feature of all outcrops of the Nugget and Navajo Sandstone. Most geologists who have studied these formations are convinced that the crossbedding indicates wind action, a few others consider it an aqueous phenomena. Jordan (1965), who defended the aqueous interpretation, concluded that "The weight of all evidence indicates that both formations consist of a complex of shallow-marine, littoral, and coastal dune deposits ...laid down within and in advance of an east- and southward-transgressing sea." Without denying the reality of evidence for massive southward transport, Jordan stated that paleocurrent directions "...reflect marine currents and coastal on-shore wind regimes rather than simply ancient trade-wind circulations."

Jordan's analysis required immediate proximity to the Pacific Ocean with an extensive sandy coastline. He and two co-authors proposed a new model for production and dispersal of Jurassic sediments adjacent to the western margin of the United States (Stanley, Jordan, and Dott, 1971). In effect, their interpretation eliminated the Mesocordilleran Highland

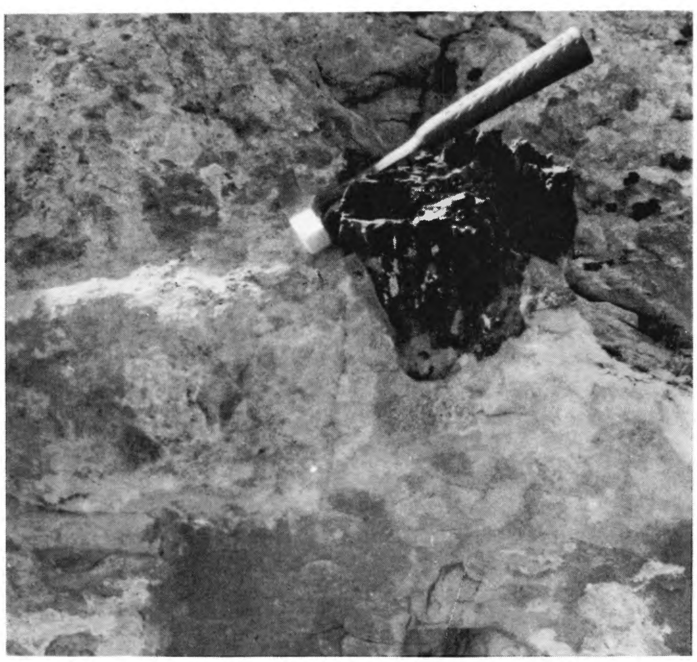

Figure 3a. Well-preserved fossil tree trunk along a Navajo Sandstone cliff. The trunk continues downward and is exposed in the vertical crevice below its surface cross section. The probably root zone is at the base of the photo. Hammer gives scale.

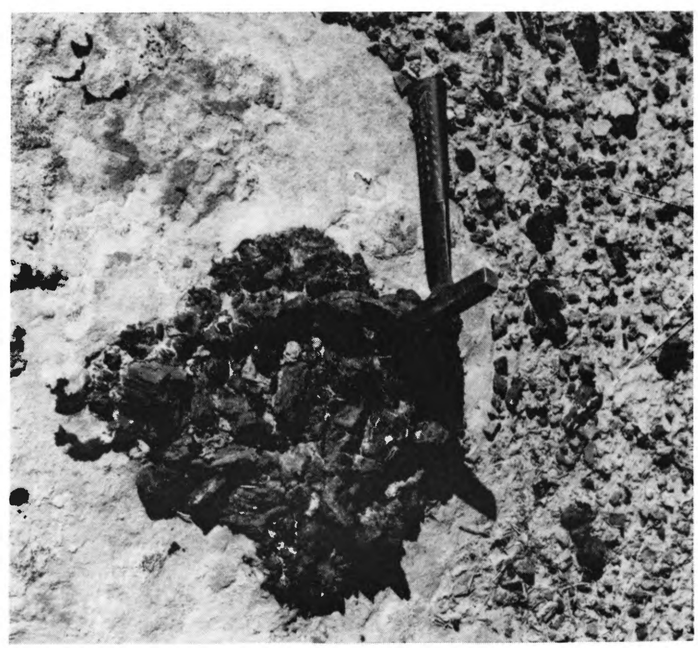

Figure 3b. Vertical view of fossil trunk seen on a horizontal erosion surface. The space originally occupied by the trunk is now filled with a rubble or breccia of petrified fragments that must have originated before petrification as the wood disintegrated and fell downward into a partly hollow cavity. Hammer gives scale.

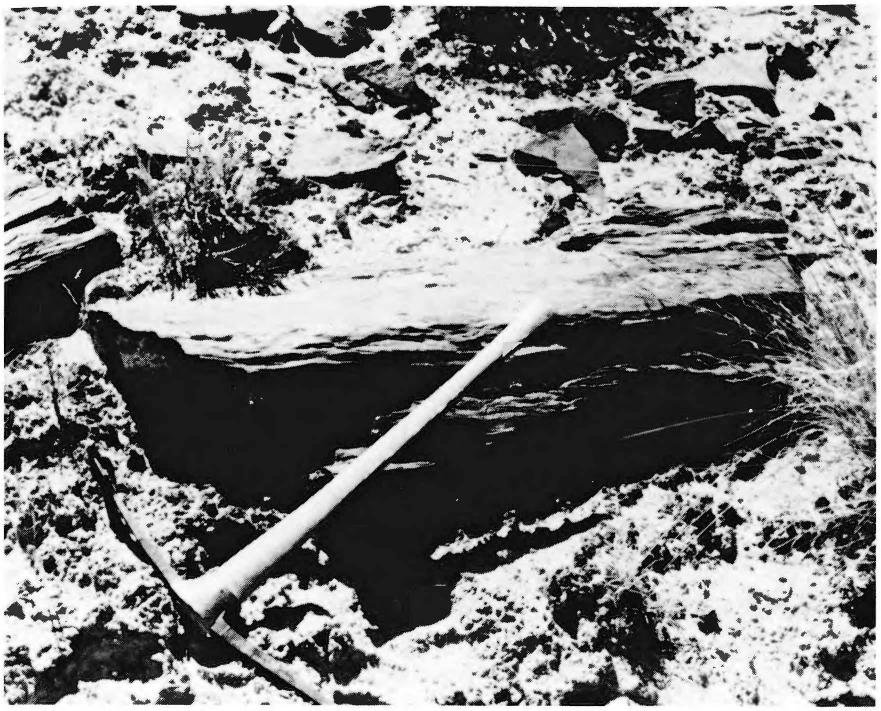

Figure 4a. Section of smooth-textured log seen in outcrop at an unspecified locality. Angular fragments in the slope behind the log are from a limestone lens lying at a slightly higher level. Pick gives scale.

as a feature of the Jurassic paleogeography. In contradiction, Imlay (1980) in his definitive study of Jurassic paleogeography shows the area of what is now the Great Basin as being occupied by a peninsula-like landmass between the Pacific Ocean and the region occupied by the Navajo (restricted) Sandstone. Imlay's paleogeographic reconstruction shows the area of Navajo deposition as an entirely landlocked interior basin several hundred miles from the ocean. From detailed studies at several localities in southern Utah, Marzolf (1970) interpreted the lower and middle portions of the Navajo as having been deposited by marine currents, in a marginal marine environment, flowing first southerly and then easterly and southeasterly. He concluded that only the upper portion of the formation can be eolian.

Freeman and Visher (1975), who advocated a non-eolian origin for the Navajo reported: "The Navajo Sandstone has been interpreted as desert-eolian in origin principally based on "eolian-type" crossbedding; well-rounded, well-sorted, frosted grains; and lack of fossil evidence. Reevaluation of these criteria reveals that they are ambiguous, non-diagnostic, and insufficient to substantiate an eolian interpretation." The non-biologic criteria marshalled by Freeman and Visher have been adequately discussed by those who disagree with them (Ruzyla, 1975; Picard, 1977; Folk, 1977; and Steidtmann, 1977).

The designation of the Page Sandstone is of basic significance. The Page is so similar to the underlying restricted Navajo that it was not mapped separately until quite recently. With this in mind, the argument of those who see evidences of a marine origin for the restricted Navajo must be reconsidered.

SUGGESTIONS FOR FURTHER INVESTIGATION

This paper records the fact that petrified coniferous trees in position of growth are fairly common in the Navajo Sandstone of east-central Utah. Many incidental observations suggest other related topics that could be investigated. These include the influences of water in the burial and replacement process; time and sequence of cementation processes; the successive events that may have operated to bury, exhume, and possibly rebury erect trees; the sediments and processes involved in filling cavities left by decaying logs or hollow trunks; age of trees by ring counting; effects of sandblasting on wood and stone; compaction effects associated with buried trunks; and laboratory analysis of associated sediments, particularly limestone, with the aim of recovering pollen and spores.

A subject of wider scope and regional significance is the history and influences of the Mesocordilleran High. If it can be proven to have existed in Navajo time, all arguments that this formation is marine or marginal marine become meaningless. Finally, a paper on the subject of aqueous influences in the Navajo Sandstone would be valuable in interpreting the overall environment. Who will write it?

Figure 4b. Oblique view of rough-textured partly exposed log seen at a locality near Moab. Matrix is light-colored sandstone. Exposed section about two feet long.

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STAFF CHANGES

Bea Mayes has accepted the geotech position in the Applied Section. She has been part time with Economic for several years.

Lori Douglas is the new cartographer in Editorial. Frustrated CAD users are eyeing her since she is very proficient on our system.

Michael Ross will fill the mapping geologist position vacated by Adolph Yonkee. Congratulations to all.

GEOLOGIC PROJECTS IN UTAH

A SURVEY OF ACTIVITY

Dear Fellow Geologists:

We have many inquiries regarding Utah geology in areas where published geologic coverage is unavailable or inadequate, and where unpublished field mapping or other geologic studies have been done, or are planned. Therefore, the Utah Geological Survey is soliciting your cooperation for our computerized listing of those areas in Utah being studied by geoscientists in your university or agency during the upcoming field season.

Please circulate this form among your staff for the required information, and return the information as soon as possible. On the map on the reverse side of this page, indicate the quadrangles covered (or to be covered). More copies are available on request.

If you know of any other universities or organizations who are doing geological work in Utah, please send us their names.

To assist those doing geological work in Utah, the Utah Geological Survey has compiled a bibliography of the Geology of Utah on computer. Special searches can be made by quadrangle, formation, commodity, type of study, etc. Please write for more information.

Many thanks for filling out this form. A copy can be obtained by request at no charge.

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Date of proposed completion: ______________________________

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What type of study? ______________________________

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☐ Great Basin ☐ Colorado Plateau ☐ Northern Rockies ☐ High Plateaus

Geographic area (range, basin, etc.): ____________________
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Names of 7½ minute (or 15 minute) quadrangles: ____________________
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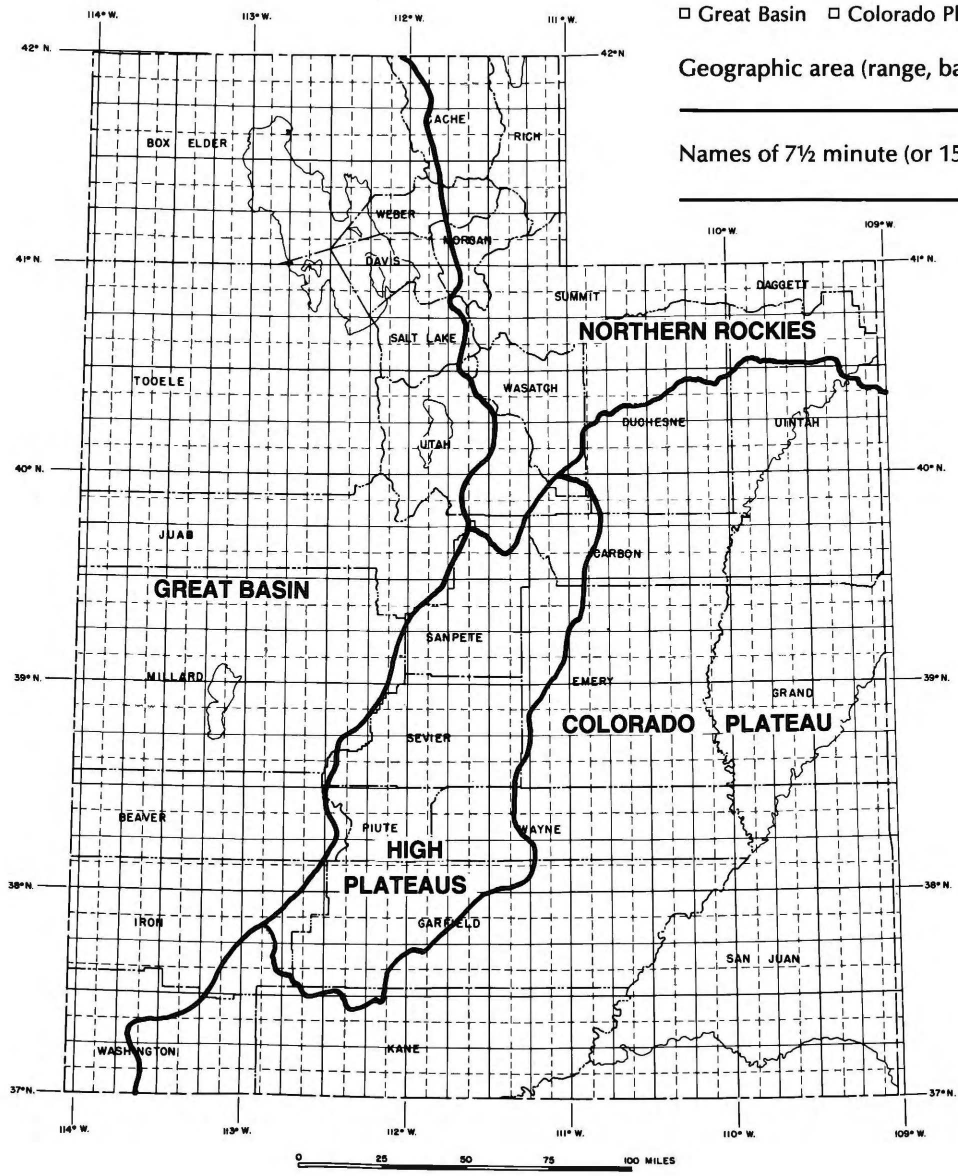

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All counties	Morgan
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Cache	Salt Lake
Carbon	San Juan
Davis	Sanpete
Daggett	Sevier
Duchesne	Summit
Emery	Tooele
Garfield	Uintah
Grand	Utah
Iron	Wasatch
Juab	Washington
Kane	Wayne
Millard	Weber

If possible, please fill in location of study area on this map of Utah. Each small square equals one 7-1/2 minute quad.

Recent Geologic Publications

These publications are not available from the UGS.

Stratigraphy of the Mesaverde Group in the central and eastern greater Green River basin, Wyoming, Colorado, and Utah, by H.W. Roehler. 1990. 52 p. 2 pl. in pocket. U.S.G.S. Professional Paper 1508.

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The Directory of Mining Programs: Gibbs Associates, 1991; Boulder, Colorado.

Chidsey to Lead Rocky Mountain Petroleum Geologists

Tom Chidsey, petroleum geologist with the Utah Geological Survey, is the 1992-93 president of the 3,700-member Rocky Mountain Section of the American Association of Petroleum Geologists (AAPG).

One of Chidsey's main duties is to direct preparations for and preside over the 1993 AAPG Rocky Mountain Section annual meeting to be held in Salt Lake City. The Utah Geological Association is the host society for the 1993 meeting.

"We anticipate that 500 to 800 geologists from around the country will attend the 1993 convention in Salt Lake City," says Chidsey. "There is a great deal of interest in Utah's petroleum potential, particularly in light of horizontal drilling activity in the Cane Creek area of southeastern Utah. By convention time, we'll have a lot more information about the oil and gas potential in that part of the state.

"Horizontal drilling is also fueling some renewed activity in the Uinta Basin," says Chidsey. "In addition, interest in coalbed methane is starting to take off." Coalbed methane involves the production of natural gas from coal layers.

"There are four companies drilling or planning to drill for coalbed methane in Utah right now. And we have indications that more companies are looking at Utah's potential."

Chidsey says he will focus the 1993 meeting on the Rocky Mountain area's oil, gas, and coalbed methane resources.

There are 33,000 AAPG members worldwide. The AAPG advances the science of petroleum, natural gas and other energy mineral resources while promoting research, education, exploration and production.

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