SURVEY NOTES

VOLUME 25, NUMBER 2 — JUNE 1992

UTAH GEOLOGICAL SURVEY

The purpose of the Applied Geology Program is to collect, disseminate, and encourage the use of geologic hazards informa… benefit the people of the… Program include: (1) e… specific areas or specif… waste disposal and lan… and interpreting hazar… advice to government … engineering geology and… ing to requests from ta… tance in (a) … logic proble… ronment, an… ing geology. … key-worded … mation, com… data bases, and statewide 1:100,000-scale landslide maps. The A… sponsibiliti… formation and encourage implementation of loss-reduction measures related to earthquakes and other geologic hazards.

The Applied Geology Program of the Utah Geological Survey responds to, evaluates, and documents geologic hazards such as earthquakes, landslides, and floods within the state. These photos are of the recent Santa Clara landslide in Washington County, Utah.

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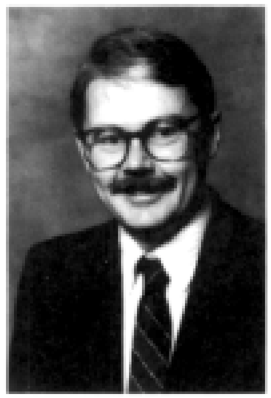

THE DIRECTOR'S PERSPECTIVE

by M. Lee Allison

THE POLITICS OF EARTHQUAKES

The past few months have been important for Utah's state earthquake program:

The magnitude 4.3 western Traverse Mountains earthquake near Herriman on March 16 was the biggest seismic event on the Wasatch Front in nearly a decade; The Earthquake Advisory Board (EAB) was established and is now developing its strategy and program; The Governor and the Legislature agreed on establishing a state strong-motion instrumentation program and authorized funding for it; Creation of seismic zone 4 of the Uniform Building Code (UBC) along the Wasatch Front became a front-page controversy, albeit for a short time.

The earthquake

An evaluation of the seismic event may be found in the article by Christenson and Olig in this issue, *Earthquake in southern Salt Lake Valley*.

Earthquake Advisory Board

The EAB includes in its membership some who have long been active in the state earthquake program and others who have great expertise and interest but have not had that same involvement. In the first few meetings, discussion has focused on the role of the EAB and its direction. As a member of the Technical Committee of the EAB, it is my hope that we will adopt some of the more successful activities of California's Seismic Safety Commission. In particular, I think it critical that Utah prepare a comprehensive listing of the earthquake activities that are presently underway and those that need to be implemented. The EAB should prioritize the needs and assess the resources necessary to achieve them.

Strong-motion program

A significant step in acquiring information needed to better design Utah's buildings and other structures was taken by the Utah Legislature which approved the Governor's recommendation to begin funding a strong-motion instrumentation program. For three years this program has been the cornerstone of a comprehensive earthquake instrumentation initiative that is the earthquake community's highest priority. Because of the total program's $3 million price tag, it has never fared well in the Legislature. This year, the UGS proposed that the strong-motion instrument part of the program be funded separately and incrementally over a long period of time. The Governor's office supported the concept and the Legislature approved it handily. The original proposal three years ago was for $1.6 million for a minimum statewide program. The package approved this year is for $75,000 per year. Thus, although it will take at least 20 years to establish the basic network, our belief is that it is better to start sooner with a small amount and build a good program than have no program while we wait for full funding that may never come. Continued on page 24...

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RADON STUDIES IN UTAH AND THE STATE INDOOR RADON GRANT PROGRAM

by Bill D. Black and Barry J. Solomon

Radon is an odorless, tasteless, colorless radioactive gas which forms primarily by decay of uranium (^{238}U). One radon isotope, ^{222}Rn, is the most significant contributor to the indoor radon problem and may accumulate indoors in concentrations sufficient to pose a significant health hazard. The U.S. Environmental Protection Agency (EPA) estimates that from 8,000 to 40,000 Americans will die each year from lung cancer caused by long-term inhalation of radon gas (Schmidt and others, 1990; figure 1). The EPA (1986) has established 4 pCi/l as the indoor radon concentration above which mitigation is recommended.

Concentrations of indoor radon are a function of a number of variables, including presence of a significant radon source, weather, building construction, and ventilation. The source of most radon is uranium in the geologic materials surrounding a building's foundation. Radon migration from the ground into buildings is affected by geologic factors such as soil or rock permeability. The Utah Geological Survey (UGS), in cooperation with the Utah Division of Radiation Control (UDRC), Department of Environmental Quality, is investigating the relationship between geology and the indoor radon hazard by participating in a statewide radon study under grants from the EPA.

pCi/l	Estimated number of lung cancer deaths due to radon exposure (out of 1000)	Comparable exposure levels	Comparable risk
200	440-770	1000 times average outdoor level	More than 60 times non-smoker risk
			4 pack-a-day smoker
100	270-630	100 times average indoor level	20,000 chest x-rays per year
40	120-380		
			2 pack-a-day smoker
20	60-210	100 times average outdoor level	
			1 pack-a-day smoker
10	30-120	10 times average indoor level	
			5 times non-smoker risk
4	13-50		
			200 chest x-rays per year
2	7-30	10 times average outdoor level	
			Non-smoker risk of dying from lung cancer
1	3-13	Average indoor level	
			20 chest x-rays per year
0.2	1-3	Average outdoor level	

Figure 1. Radon risk evaluation (modified from EPA, 1986).

EPA PROGRAM OBJECTIVES AND UTAH ACTIVITIES

In 1988, in response to the growing national concern over the threat of radon gas, Congress enacted Title III, Indoor Radon Abatement Act (IRAA), as an amendment to the Toxic Substances Control Act. The IRAA has the overall goal of reducing public health risks from radon gas by rendering air within buildings in the United States free of radon. Section 306 of the IRAA, the State Indoor Radon Grant (SIRG) Program, authorizes the EPA to provide grants to states to support the development and implementation of State radon assessment and mitigation programs (EPA, 1989).

The goals of the SIRG Program are to achieve widespread participation by states in radon programs, establish basic radon response capabilities in states that have not yet developed radon programs, stimulate innovation and expansion in states with established radon programs, foster radon program development within the states, and strengthen federal/state partnerships by helping states develop programs for communicating and reducing the radon risk beyond the life of the SIRG Program (EPA, 1989). All of these goals are considered equally important by the EPA for success of the program.

The SIRG Program is to be conducted over a period of 3 years. During the first grant year in Utah (1990), two principal activities were conducted. The first activity, coordinated by the UDRC, involved soliciting volunteers from the Sandy and Provo areas to monitor their homes for indoor radon over a one-year period. A survey to assess indoor radon levels statewide, conducted by the UDRC in the fall of 1987, indicated that there were indoor radon levels in these cities higher than the statewide average (Sprinkel and Solomon, 1990). In the second activity, the UGS and University of Utah Research Institute (UURI) conducted a detailed geologic study of the factors that influence indoor radon concentrations by reinterpretation of National Uranium Resource Evaluation (NURE) aerial radiometric data, collection of field radiometric data, and physical characterization of soils (Solomon and others, 1991). The first grant year provided valuable information required to examine the relationships between geology and elevated indoor radon levels, and developed geologic techniques for assessing radon hazard potential.

Second grant year activities, now completed, include detailed indoor radon surveys and radon-hazard-potential investigations in the Ogden Valley and St. George areas, as well as an update of the statewide radon-hazard map. The Ogden Valley and St. George areas were identified by the UDRC as having indoor radon concentrations higher than the statewide average (Sprinkel and Solomon, 1990). In these areas, the radon-hazard-potential investigations will consist of collection of field radiometric data and physical characterization of soils. The statewide radon-hazard map will be updated by compiling outcrop data of uranium concentrations from the NURE program and other uranium resource studies, and will show which geologic units in the state have the highest potential as uranium source areas.

Planned for the third grant year, as funded, are a detailed indoor radon survey and radon-hazard-potential investigation of the Sevier Valley area, and a radon-hazard-potential investigation of part of the Weber River flood plain west of the Wasatch Range. The Sevier Valley area, from Richfield to Monroe, was also identified as having indoor radon levels higher than the statewide average (Sprinkel and Solomon, 1990). The Weber River flood plain, a populous and rapidly growing suburban area near Ogden, was selected due to a cluster of high indoor radon measurements, ranging from 10.9 pCi/l in South Weber and 15.0 pCi/l in Roy to 68.2 pCi/l in Uintah (the highest value recorded in Utah) (Sprinkel and Solomon, 1990). The radon-hazard-potential investigations will be conducted in the same manner as the second grant year investigations.

GEOLOGIC INVESTIGATIONS OF RADON-HAZARD POTENTIAL DURING THE FIRST GRANT YEAR

In 1990, the UGS investigated the radon-hazard potential of the east Sandy and east Provo areas. The hazard potential was estimated by determining three geologic factors: (1) uranium content of soils, (2) concentration of radon in soil gas, and (3) depth to ground water (Solomon and others, 1991). Numerical scores were applied to each rating factor, and composite ratings were calculated to estimate the hazard potential for each major Quaternary (unconsolidated, basin-fill) geologic unit (Solomon and others, 1991). The objectives were: (1) to define geologic factors which influence radon distribution, (2) to establish rapid and inexpensive field techniques to delineate radon-hazard areas, and (3) to achieve more efficient testing and mitigation in existing construction, and hazard prevention in new construction by identifying hazard areas (Solomon and others, 1991). Airborne radiometric measurements were interpreted for the east Sandy area and adjacent Wasatch Range and field data were collected in both study areas.

The east Sandy study area is in southeastern Salt Lake County, extending from the mouth of Big Cottonwood Canyon on the north to Draper on the south, and from approximately State Street on the west to the Wasatch Range on the east (figure 2). The average indoor radon level in the east Sandy study area is 3.2 pCi/l, with 17 percent of measurements greater than 4 pCi/l (Solomon and others, 1991).

The Wasatch fault zone separates unconsolidated deposits in Salt Lake Valley from bedrock in the Wasatch Range. The valley is underlain by a complex sequence of unconsolidated Quaternary alluvial, deltaic, lacustrine, and eolian basin-fill deposits (Personius and Scott, 1990). Although a wide variety of bedrock types occur in the Wasatch Range east of Sandy, only some lithologies have the potential to provide source material with elevated uranium levels to the Quaternary deposits in the study area. They are: (1) Oligocene granitic rocks of the Little Cottonwood, Alta, and Clayton Peak stocks (Crittenden, 1976); and (2) Precambrian metamorphic rocks, including the Mineral Fork Formation (Condie, 1967). Quartzite, shale, and slate of the Precambrian Big Cottonwood Formation (James, 1979) have low uranium levels. Ground water occurs at depths greater than 50 feet (15 m) in the eastern part of the study area, but is less than 10 feet (3 m) deep to the west (Anderson and others, 1986b).

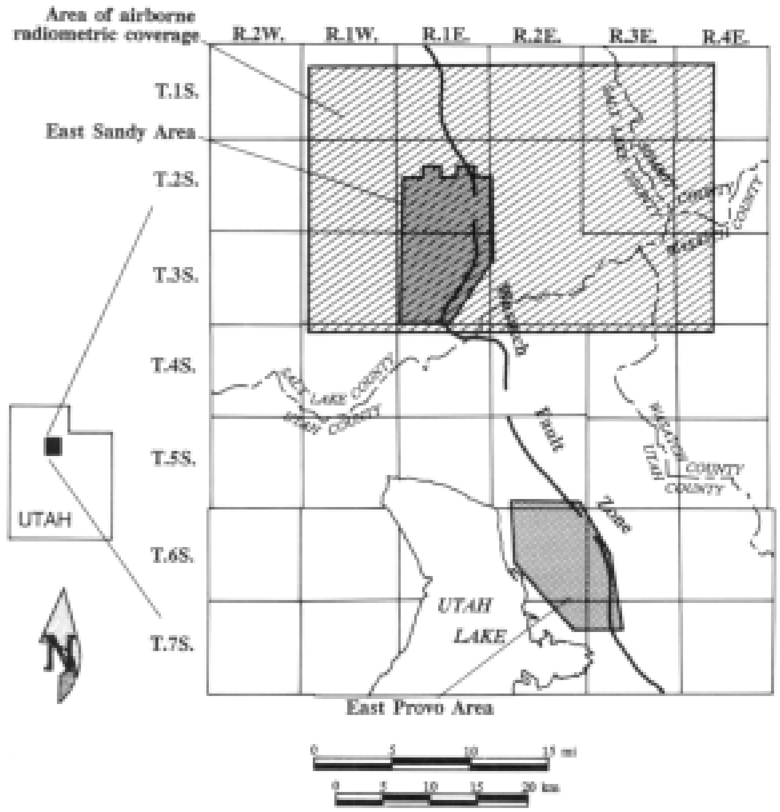

Figure 2. Location of the east Sandy and east Provo study areas.

The east Provo study area is in Utah County, extending from Orem on the north to Provo on the south, and from approximately Interstate 15 on the west to the Wasatch Range on the east (figure 2). The average indoor radon level within the east Provo study area is 2.6 pCi/l, with 12 percent of the measurements greater than 4 pCi/l (Sprinkel and Solomon, 1990). Although the indoor radon level in this study area is lower than the statewide average, Sprinkel and Solomon (1990) demonstrated that the east Provo area does contain anomalous areas with indoor radon levels in excess of the statewide average.

Like the east Sandy study area, the Wasatch fault zone separates unconsolidated deposits in Utah Valley from the bedrock in the Wasatch Range. The study area is underlain by Quaternary sediments similar in origin to those of east Sandy (Machette, 1989). Bedrock with the potential to provide source material with elevated uranium levels to the unconsolidated deposits in the valley includes: (1) the Pennsylvanian to Mississippian Manning Canyon Shale, a dark shale that underlies much of the range front, and (2) diamictite of the Precambrian Mineral Fork Formation, which underlies the drainage basins of Rock and Slate Canyons (Baker, 1964, 1972, 1973). Limestone and quartzite of the

Pennsylvanian and Permian Oquirrh Formation transported from the interior of the Wasatch Range by drainage through Provo Canyon have low uranium levels. Ground water occurs at depths greater than 50 feet (15 m) to the east, but is less than 10 feet (3 m) deep to the west (Anderson and others, 1986a).

The airborne radiometric survey completed under the NURE program delineates large areas of high surface uranium concentrations, and also serves as an indicator of areas that may have a potential indoor radon hazard (Duval and Otton, 1990). A contour map of equivalent uranium (eU) was generated by UURI from data compiled from the NURE radiometric survey for a part of the Salt Lake City 1:250,000 quadrangle, which covers the east Sandy study area (Solomon and others, 1991; figure 3). The average uranium concentration for the entire quadrangle is 1.65 parts per million (ppm) (EG&G Geometrics, 1979). The map shows three anomalous areas of uranium concentrations greater than 3.2 ppm. Area A is in the east Sandy study area and is associated with high indoor radon levels in the Sandy area. Anomalies with high uranium values (B and C) in the Wasatch Range east of anomaly A are located over the granitic stocks of Little Cottonwood, Alta, and Clayton Peak.

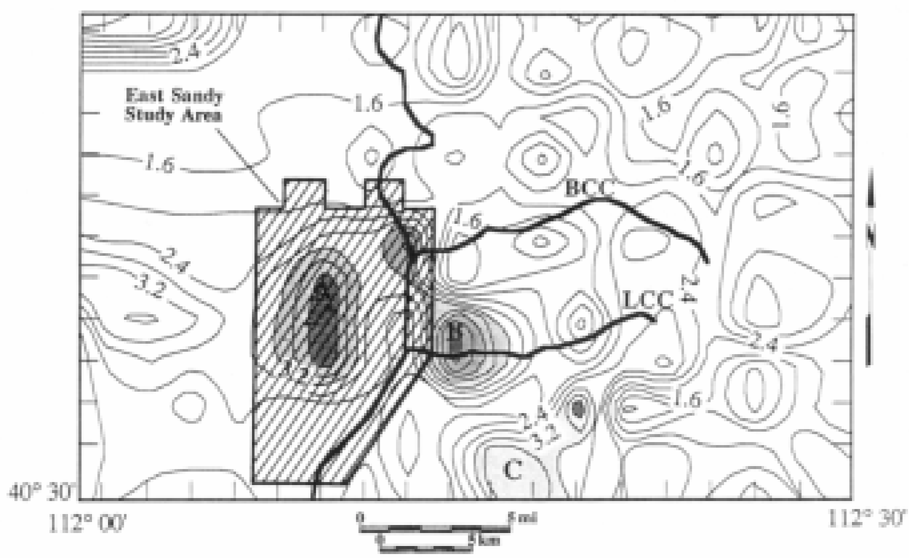

Figure 3. Uranium concentrations from airborne radiometric survey, east Sandy area. Heavy line is Wasatch Range front. BCC is Big Cottonwood Canyon, LCC is Little Cottonwood Canyon. Contour interval is 0.4 ppm (Solomon and others, 1991).

Field data collected from both the east Sandy and east Provo areas included: (1) gamma-ray spectrometry, (2) levels of radon in soil gas, (3) soil moisture and density, and (4) soil texture (Solomon and others, 1991). Gamma-ray spectrometry determines the concentration of radioactive parent material in the soil available for decay into radon gas. The level of radon in soil gas measures the amount of radon available for migration into buildings. Soil moisture, density, and texture all affect the mobility of radon gas.

Gamma-ray spectrometry showed that average uranium levels were significantly higher in the east Sandy area (5.6 ppm) than the east Provo area (2.6 ppm) (Solomon and others, 1991). In east Sandy, the highest average uranium levels (7.1 ppm) were found in upper Pleistocene sand and gravel of the Provo (regressive) shorelines of the Bonneville lake cycle (Solomon and others, 1991). High levels (6.9 ppm) were also found in the upper Pleistocene gravelly alluvium of terraces graded to the Provo shoreline near Little Cottonwood Canyon. In east Provo, the highest average uranium levels (3.1 ppm) were found in upper Pleistocene lacustrine gravel of the Bonneville (transgressive) shoreline (Solomon and others, 1991).

Measurement of radon in soil gas showed the average levels of radon were also higher in east Sandy (528 pCi/l) than in east Provo (449 pCi/l) (Solomon and others, 1991). In east Sandy, the highest average levels of radon in soil gas (641 pCi/l) were found in the upper Pleistocene terrace deposits noted above (Solomon and others, 1991). In east Provo, the highest levels of radon in soil gas (679 pCi/l) were found in middle Holocene to upper Pleistocene alluvial fans (Solomon and others, 1991).

Once radon gas is formed, it can migrate into buildings through the soil. The rate of migration depends on the soil permeability, which is affected by moisture content, density, and soil texture. Soil in east Sandy is generally gravelly sand, and is more permeable than the gravelly loam of the east Provo area (Solomon and others, 1991). Because pore water effectively traps radon and inhibits movement through the soils, low water content above the ground-water table facilitates the movement of radon. This phenomenon is graphically illustrated in east Sandy where Quaternary units high in uranium, but with shallow ground water, have low levels of soil gas (Solomon and others, 1991).

The relative radon-hazard potential of geologic units in the east Sandy and east Provo areas was estimated by three factors: (1) soil uranium concentration, (2) concentration of radon in soil gas, and (3) ground-water level (Solomon and others, 1991). Each geologic unit was assigned a hazard rating using a numerical rating scheme based on the field data. Using this hazard rating, radon-hazard-potential maps for the east Sandy and east Provo areas were constructed (figures 4 and 5). For a discussion of the methodology used consult Solomon and others (1991).

In both study areas, geologic units with the highest hazard rating were upper Pleistocene lacustrine sediments related to the transgressive phase of the Bonneville lake cycle, as well as younger deposits overlying the transgressive units (Solomon and others, 1991). However, the hazard rating is not indicative of actual indoor radon levels because a quantitative relationship does not exist between factors measured in the field and indoor radon. Factors not considered include building construction techniques, lifestyle, and weather, all of which can strongly affect indoor radon levels. Small localized areas of higher or lower indoor radon levels may still occur.

The indoor radon hazard potential of geologic units in the east Sandy and east Provo areas reflects common depositional patterns and physical conditions. Such patterns and conditions, as well as techniques used to identify them, are ap-

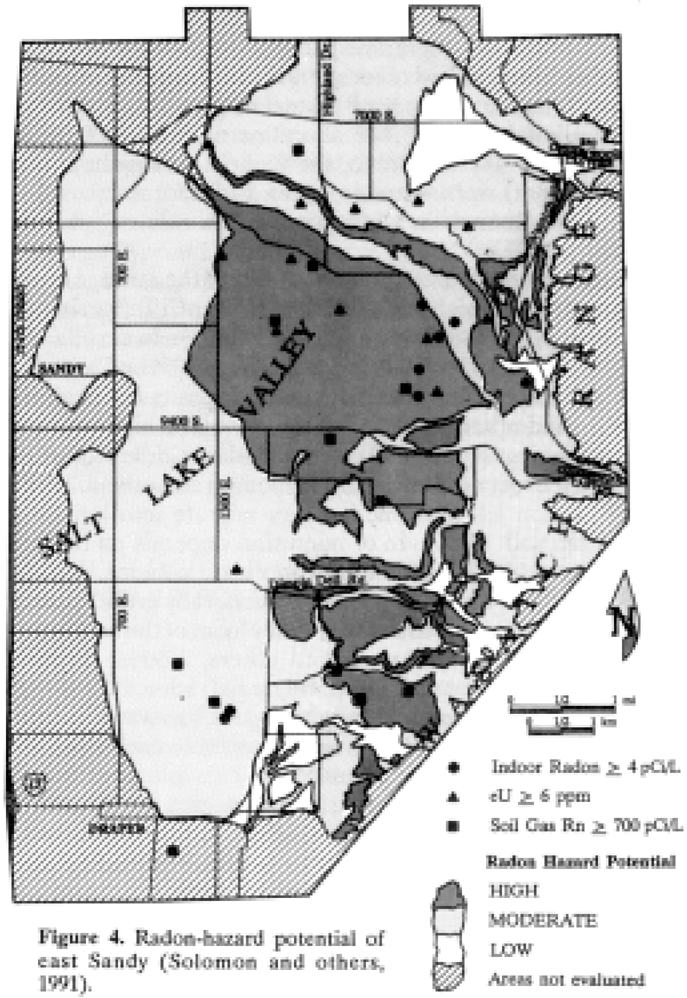

Figure 4. Radon-hazard potential of east Sandy (Solomon and others, 1991).

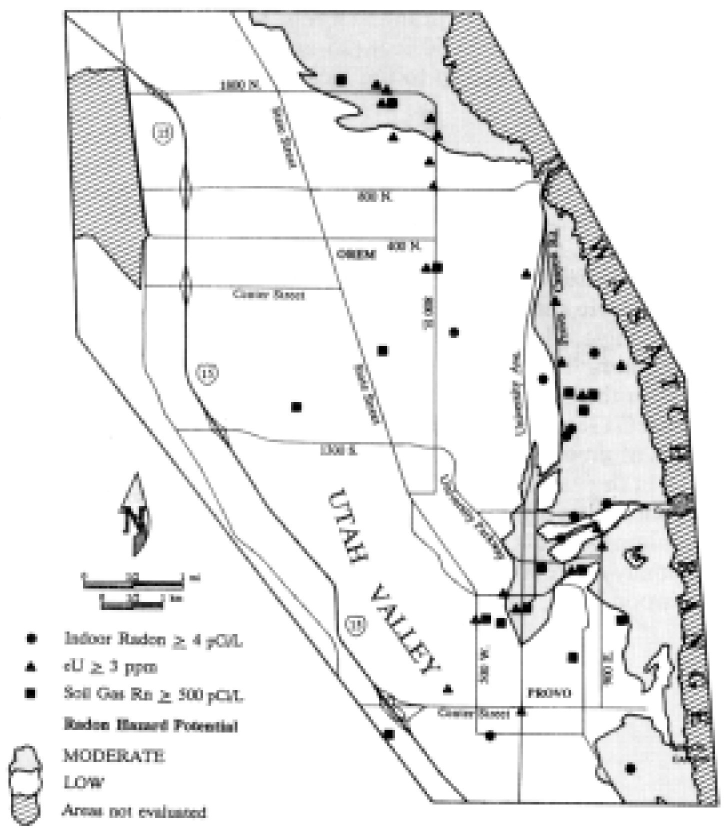

Figure 5. Radon-hazard potential of east Provo (Solomon and others, 1991).

plicable to identification of other indoor radon hazard areas along the Wasatch Front.

In east Sandy, drainage from Little Cottonwood Canyon transported material derived from Oligocene granitic rocks with relatively high uranium content to the Little Cottonwood delta at both the Bonneville (transgressive) and Provo (regressive) levels (Solomon and others, 1991; figure 6). Material transported through Big Cottonwood Canyon to the Big Cottonwood delta is relatively deficient in uranium, but is also derived in part from Oligocene granitic rocks and Precambrian metamorphic rocks with higher uranium contents. Below the Provo (regressive) level, sediments are not well drained and a significant part of radon gas at this level migrated with shallow ground water rather than with soil gas.

In east Provo, uranium-enriched sediment was derived from the Mineral Fork Formation and Manning Canyon Shale, transported locally through Rock and Slate Canyons and deposited at the Bonneville (transgressive) level along the range front (Solomon and others, 1991; figure 7).

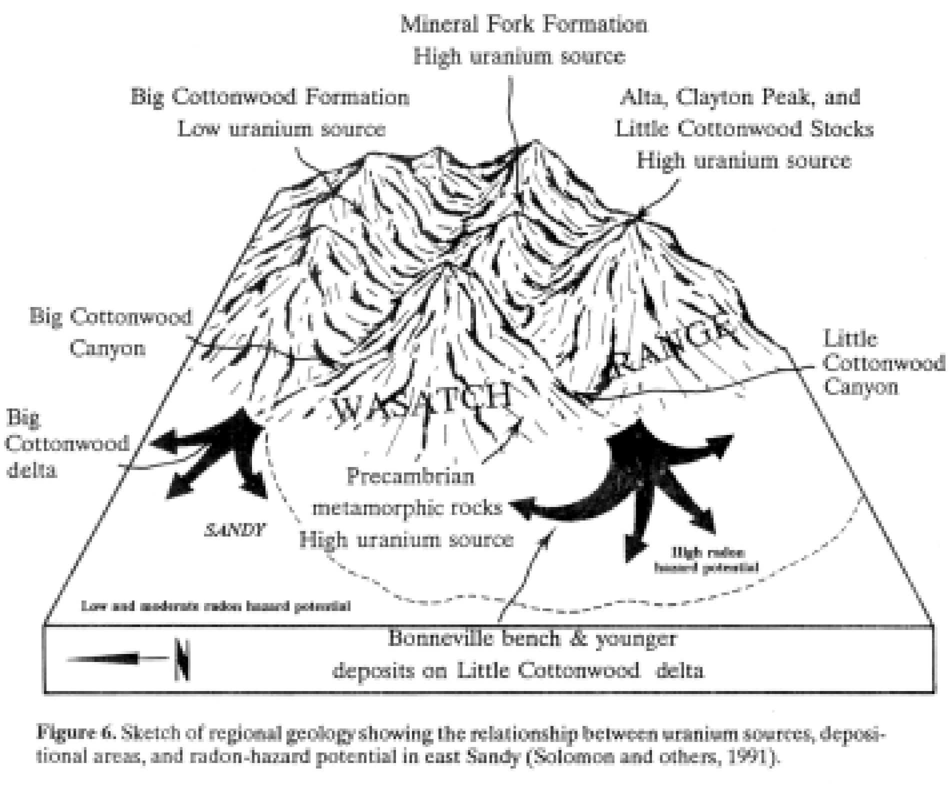

Figure 6. Sketch of regional geology showing the relationship between uranium sources, depositional areas, and radon-hazard potential in east Sandy (Solomon and others, 1991).

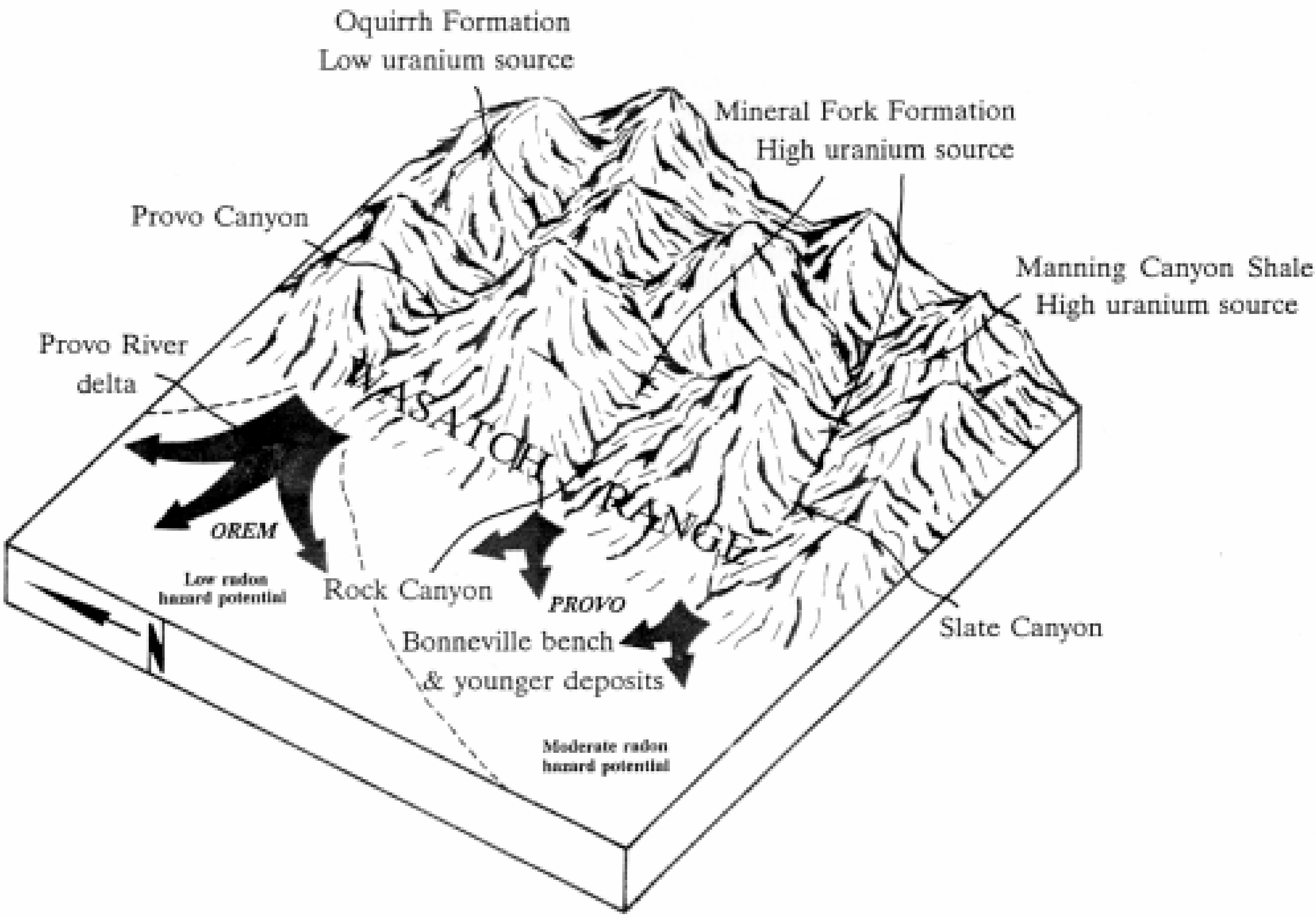

Figure 7. Sketch of regional geology showing the relationship between uranium sources, depositional areas, and radon-hazard potential in east Provo (Solomon and others, 1991).

Material derived from the Oquirrh Formation, transported through Provo Canyon and deposited on the Provo River delta, is deficient in uranium. As in east Sandy, the units with the highest potential for an indoor radon hazard are well-drained sediments that allow soil gas migration rather than migration with shallow ground water. Lower uranium levels in east Provo compared to east Sandy reflect the differences in source material.

GEOLOGIC INVESTIGATIONS OF RADON-HAZARD POTENTIAL DURING THE SECOND GRANT YEAR

In 1991, the UGS investigated the radon-hazard potential of the Ogden Valley and St. George basin. Three geologic factors were used to estimate the radon-hazard potential of these areas: (1) uranium content of soils, (2) soil permeability, and (3) depth to ground water. Unlike the first grant-year investigations, soil gas concentration has been replaced by soil permeability as a factor in determining the hazard potential, because permeability is a primary factor whereas soil gas concentration is derivative and depends on primary geologic factors. However, because the field work and analysis of data is not complete at this time, no hazard ratings have been assigned and the hazard potential of these areas is not yet determined.

The Ogden Valley study area is in Weber County, about 12 miles (19 km) east of Ogden, and includes the towns of Huntsville, Liberty, and Eden (figure 8). Indoor radon levels in the Ogden Valley area range from 2.1 pCi/l to 17.6 pCi/l (Sprinkel and Solomon, 1990). Only four indoor radon levels were measured in Ogden Valley; two were higher than 4 pCi/l (Sprinkel and Solomon, 1990).

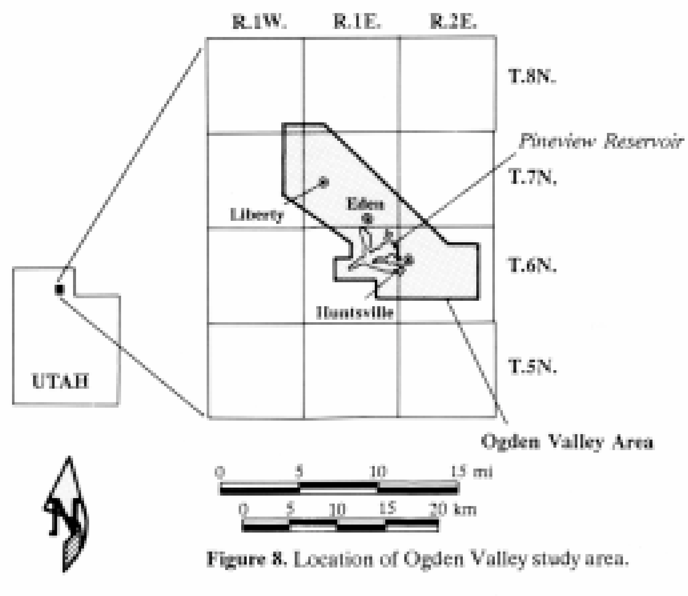

Figure 8. Location of Ogden Valley study area.

Ogden Valley is a northwest-trending valley east of the Wasatch Range front, and is bounded on the east and west by faults that dip toward the valley (Leggette and Taylor, 1937). The valley is underlain by a thick sequence of sedimentary basin-fill deposits that have accumulated since early Tertiary time (Lofgren, 1955). Bedrock lithologies in the Wasatch Range surrounding Ogden Valley with a potential to provide source material with elevated levels of uranium are: (1) the Tertiary Norwood Tuff, which underlies many of the western and southwestern slopes bordering the valley, and (2) argillite weathered from the Precambrian Inkom, Kelley Canyon, and Maple Canyon Formations and transported to the valley by drainage through the North Fork, Middle Fork, and South Fork of the Ogden River (Crittenden, 1972; Crittenden and Sorensen, 1979). Ground water occurs at depths greater than 50 feet (15 m) around the edges of the valley, but is less than 10 feet (3 m) in much of the valley interior.

Three types of field data were collected in Ogden Valley: (1) gamma-ray spectrometry, (2) levels of radon in soil gas, and (3) soil texture. Gamma-ray spectrometry showed that uranium concentrations were higher in the north and west part of Ogden Valley (figure 9). High uranium levels occurred generally in Quaternary alluvial sediments derived from bedrock with elevated uranium levels (Lowe, in prep.). High soil-gas measurements occurred generally in uranium-rich, permeable, and well-drained alluvial sediments. Preliminary data analysis indicates that the potential for elevated indoor radon levels in the Ogden Valley is highest in the northwestern part of the valley, north and west of Liberty, and is lowest to the southeast, east of Huntsville.

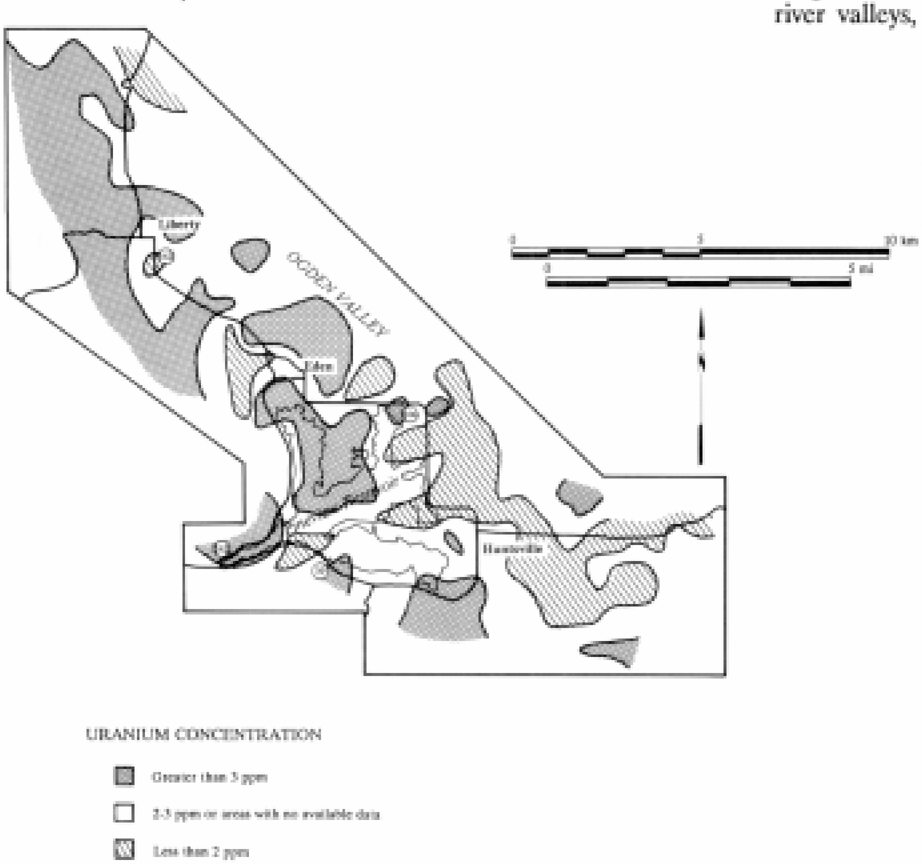

Figure 9. Relative uranium concentrations in the Ogden Valley area.

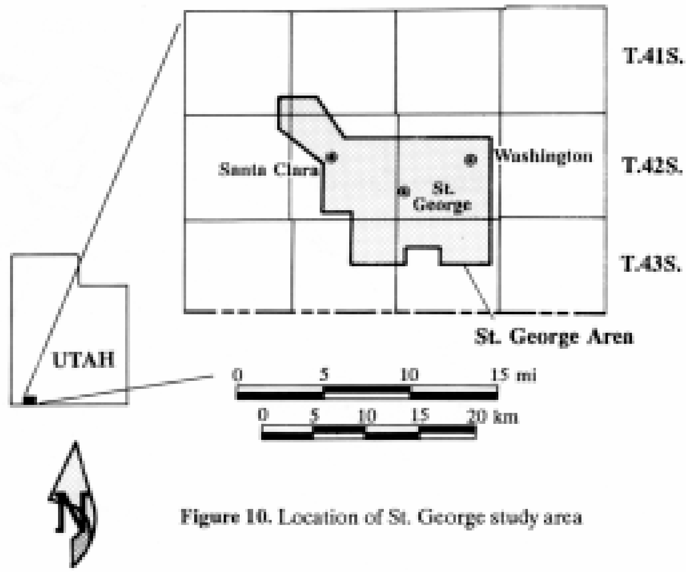

Figure 10. Location of St. George study area

The St. George study area is in Washington County, and includes Santa Clara, Middleton, Washington, Bloomington, and St. George (figure 10). Indoor radon levels ranged from 0.8 pCi/l to 6.2 pCi/l (Sprinkel and Solomon, 1990). Like Ogden Valley, only four indoor radon levels were measured in the statewide survey in the St. George area; one was greater than 4 pCi/l (Sprinkel and Solomon, 1990).

The St. George basin is centered on the confluence of the Virgin and Santa Clara Rivers. Population centers lie in the river valleys, which are underlain by Quaternary alluvium. Bedrock units with the potential to provide source material with elevated levels of uranium are: (1) the Triassic Moenave Formation, which was mined for uranium in the nearby Silver Reef mining district, (2) the Triassic Chinle Formation, a prolific producer of uranium ore in Utah, and (3) the Triassic Moenkopi Formation (Doelling, 1974). These units crop out over a large area in the southern part of the study area and alluvium derived from them has uranium levels of up to 4.7 ppm. Distribution of uranium in alluvium derived from these bedrock sources is governed by Quaternary sedimentation patterns. The Navajo Sandstone of Jurassic age is common to the north part of the study area and is exceptionally deficient in uranium, with levels generally below 1.5 ppm.

Field data collected in the St. George area included 1) gamma-ray spectrometry, 2) levels of radon in soil gas, and 3) soil texture. Airborne radiometric surveys of the area, conducted for the NURE program, indicate that the St. George basin has low average apparent uranium concentrations. However, because the resolution of these surveys is insufficient to detect localized concentrations of uranium, ground-based gamma-ray spectrometry was used to determine the detailed distribution of uranium in the area. The field data, combined with evaluation of ground-water depth and distribution of surficial geologic units, was used to evaluate the radon-hazard potential of the St. George basin.

GEOLOGIC INVESTIGATION OF RADON-HAZARD POTENTIAL DURING THE THIRD GRANT YEAR

In 1992, the UGS plans to investigate the radon hazard potential of the Sevier Valley area and Weber River flood plain, using techniques similar to those used in the Ogden Valley and St. George study areas.

The Sevier Valley study area is in Sevier County and includes Monroe, Joseph, Richfield, and Sevier. Indoor radon levels in the Sevier Valley area ranged from 0.8 pCi/l to 22.4 pCi/l, with 35 percent of the measurements greater than 4 pCi/l (Sprinkel and Solomon, 1990). Geologic units with the potential to provide source material with elevated levels of uranium to the unconsolidated valley fill may be calc-alkaline volcanic flows and tuff bedrock of the Marysvale volcanic field (Cunningham and others, 1983).

The Weber River flood plain is in Weber County, and includes Uintah, South Weber, and Roy. Indoor radon levels in the Weber River flood plain ranged from 0.8 pCi/l to 68.2 pCi/l (the highest value recorded in Utah), with 75 percent of the measurements greater than 4 pCi/l (Sprinkel and Solomon, 1990). Only four indoor radon levels were measured in the statewide survey in the Weber River flood plain; three were greater than 4 pCi/l (Sprinkel and Solomon, 1990). A geologic unit that may have potential to provide source material with elevated levels of uranium to the Quaternary deposits in the area is the Precambrian Farmington Canyon Complex, which consists of argillite, gneiss, and schist (Davis, 1985; Nelson and Personius, 1990).

CONCLUSION

Radon is an environmental concern throughout the country because of its suspected link to lung cancer. The SIRG Program developed by the EPA has been successful in fostering an indoor radon program in Utah. Because of the complex relationship between geologic and non-geologic factors that control radon levels, successful interagency cooperation between the UGS and the UDRC has played an important role in the indoor radon program. Additional grants by the EPA will strengthen federal/state partnerships and continue to provide valuable information for communicating and reducing the radon risk in the state.

Geology can be successfully used as a predictor of areas with elevated indoor radon levels. Airborne radiometric surveys can be used in conjunction with regional geologic maps to identify regional uranium anomalies. Ground surveys then determine detailed uranium distribution in geologic units and identify other geologic factors such as shallow ground water and soil permeability. This combination of airborne and ground studies enables identification of areas that have a higher potential for elevated indoor radon levels.

Although geologic investigations can show the relative hazard potential of an area, indoor testing is still the only reliable way to determine indoor radon levels in an individual building. Non-geologic factors such as weather, lifestyle, and building construction and design make predicting radon levels from building to building difficult even in areas of high geologic potential for radon. In the past 15 years, the building industry has made structures more energy efficient by restricting ventilation and air flow, which has to some extent increased the indoor radon hazard. Indoor testing can be used in existing structures to monitor indoor radon levels and show which buildings may require mitigation. However, it is still important to determine the indoor radon hazard potential of an area so that in high-hazard areas, mitigation techniques can be incorporated into building design prior to construction.

ACKNOWLEDGMENTS

We are indebted to Dane Finerfrock and John Hultquist, UDRC, for managing the SIRG Program. The UDRC is the lead agency for the program, and has conducted investigations of indoor radon levels throughout the state. These investigations establish the basis for validation of geologic models. Dennis Nielson, UURI, studied aerial radiometric data in the Sandy area, and provided many helpful suggestions for the interpretation of geologic data.

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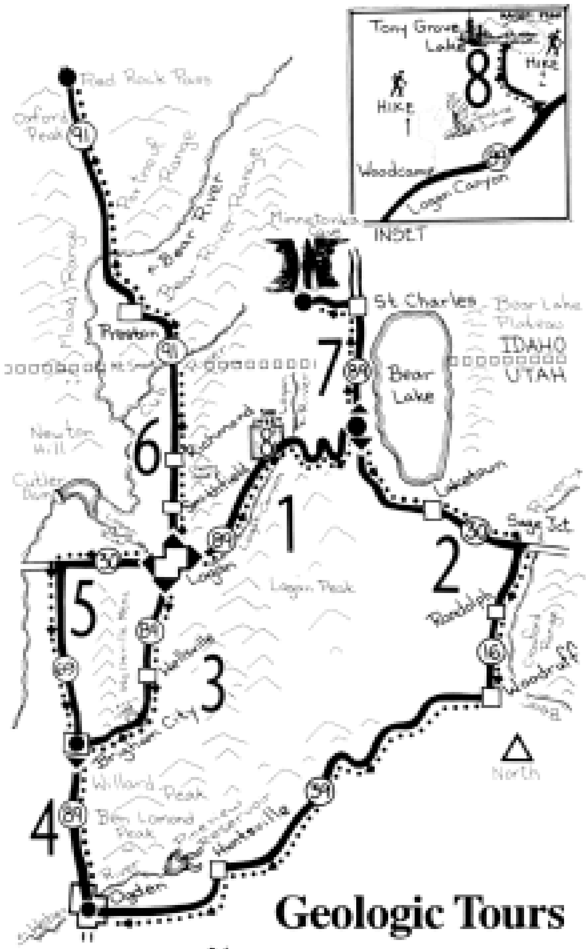
REPORTS ON RADON AVAILABLE FROM THE UTAH GEOLOGICAL SURVEY

Radon hazards in Utah by D.A. Sprinkel and B.J. Solomon, a 24-page report giving a thorough introduction to radon, why it is a hazard, where its occurrence may normally be expected, and what measures are needed for mitigation. Half of the book then details the beginning of the indoor radon study in Utah.
Circular 81, 1990, $3.50

Potential radon hazard map of Utah by D.A. Sprinkel. An overview of radon hazard areas in Utah at 1" = 17 miles, produced in 1987 and revised to 12/89. The accompanying text defines map methodology.
Open-File Report 108, 1987 (1989), $3.00

Utah indoor radon data by D.A. Sprinkel and B.J. Solomon. This is essentially the data from the indoor radon study in a computer-searchable file format on a diskette.
Open-File Report 175-DF, 1.2 Mbyte, April 1990, $5.00

"The unique and spectacular scenery of northern Utah is fashioned by dynamic processes that occur on and within the Earth's crust. Imagine that for over 200 million years the mountains and valleys we see today in northern Utah were previously the site of a shallow tropical sea."



Geologic Tours of Northern Utah

NEW!

by Sue Morgan

Skillfully illustrated, photographed, and written, this new 98 page compilation leads the reader through the diverse geology and scenic beauty of northern Utah's rocky mountain passes. A brief introduction on basic geologic principles and a time scale acquaints the amateur geologist with the rocks and scenery of northern Utah, after which the reader is guided through the following scenic drives and hikes:

- Tour 1 - Logan Canyon
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- Tour 7 - Minnetonka Cave
- Tour 8 - Tony Grove Lake
- Hike 1 - Jardine Juniper
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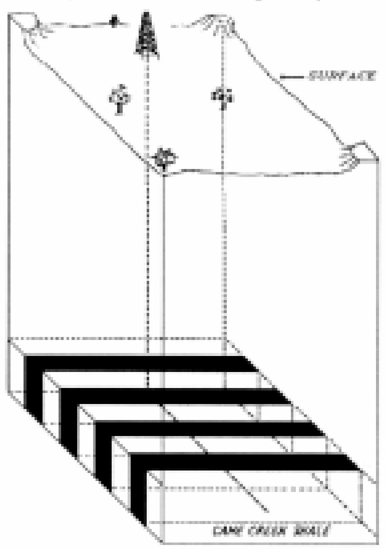
Available for $6.00 from Sales, Utah Geological Survey; Utah residents please add 6.25% sales tax. VISA and Mastercard accepted.

HORIZONTAL DRILLING FOR OIL AND GAS IN THE MOAB AREA

by Craig D. Morgan

National attention has focused on the Moab area as a result of the successful completion in 1991 of a horizontally drilled oil well. Columbia Gas Development's Kane Springs Federal 27-1 (Grand Co., Utah) has a nearly 1,000-foot horizontal leg drilled at a depth of over 7,000 feet below the surface. The horizontal leg goes beneath the surface location of two wells drilled in the 1960s. One of the older wells produced a minor amount of oil before it was abandoned, and the other was a dry hole.

Horizontal drilling, as the name implies, involves drilling horizontally or nearly horizontally (parallel to bedding) for distances commonly of 1,000 to 3,000 feet in an oil-producing horizon. An oil-producing horizon or "pay" zone may have a true thickness of only 20 feet but can have 1,000 to 3,000 feet of pay open to the wellbore if penetrated horizontally. Horizontal drilling is an ideal technique to explore for pay zones that depend on fractures to contain the oil and provide pathways for oil trapped within the rock. Fracture density in rock is seldom uniform, often occurring in fracture sets separated by unfractured or poorly fractured intervals. There is a small probability of encountering numerous fractures in a 20-foot-thick pay zone with a small-diameter vertical well. If the same zone is drilled horizontally, through 3,000 feet of rock instead of 20 feet, the probability of encountering fractures is greatly increased.

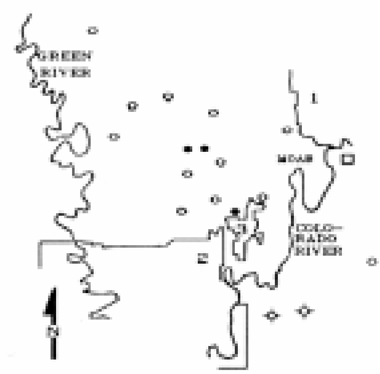


Cross-section sketch of a horizontally drilled well intersecting several fracture sets in the "Cane Creek" Shale (from Columbia Gas Development Corporation exhibits before the Board of Oil, Gas, and Mining, Docket 91-022, Cause 196-28

In the past year, five wells have used horizontal-drilling techniques in the Moab area. Two wells drilled by Columbia Gas Development have been highly successful. Columbia's first well, Kane Springs Federal 27-1, was completed flowing 914 barrels of oil and 290,000 cubic feet of gas per day from the "Cane Creek" Shale. The well was drilled in the Bartlett Flat field which was abandoned in 1965 after producing less than 40,000 barrels of oil. The 27-1 well produced nearly 100,000 barrels of oil during the first nine months of production. Columbia drilled their second well, the Kane Springs Federal 19-1A, six miles to the southeast and completed it flowing 1,158 barrels of oil and 234,000 cubic feet of gas per day also from the "Cane Creek" Shale. Columbia's third well, the Kane Springs Federal 28-1, 1 mile west of the 27-1 well, is currently being tested.

The pay zone that the horizontally drilled wells are exploiting is a 40- to 60-foot-thick interval in the "Cane Creek" Shale. The "Cane Creek" Shale is a naturally fractured, organic-rich bed in the Pennsylvanian Paradox Formation occurring at a vertical depth of 6,000 to 9,000 feet in the Moab area. The "Cane Creek" Shale is both the source of the oil (generated from the organic-rich matter) and the reservoir with oil trapped in sets of densely fractured rock. The first oil drilling in the Moab area occurred along the Colorado River at Cane Creek anticline and Shafer dome during the 1920s. These wells encountered numerous shows of oil and even experienced one blowout that flowed oil for two weeks. Actual production was never established. In the 1950s and 1960s, drilling did establish oil production in the area.

Many of these older fields, all drilled vertically, are considered highly favorable areas to explore using horizontal-drilling techniques. The Shafer Canyon field, on the northern flank of Shafer dome, was discovered in 1962 and consisted of two productive wells, one on each side of the Dead Horse Point State Park overlook. The field produced less than 68,000 barrels of oil before being abandoned in 1967.



Completed and planned horizontally drilled wells. 1 = Arches National Park, 2 = Canyonlands National Park, ● = oil well, ⯑ = dry hole, o = planned well. Only horizontal wells are shown.

Long Canyon and Bartlett Flat fields were discovered on Big Flat, the tableland area near Dead Horse Point State Park and Canyonlands National Park. The Long Canyon field was discovered in 1962 and continues to produce oil from the "Cane Creek" Shale from one well. This is the only truly successful vertically drilled "Cane Creek" well, having produced over 900,000 barrels of oil as of December 31, 1990. The Bartlett Flat field was discovered in 1961 and abandoned in 1965. The field is the site of Columbia's first horizontally drilled well.

Columbia Gas, Chevron, Meridian, Coors Energy, Exxon, and McCormick Energy have all announced drilling plans to test the Cane Creek Shale in the Moab area in the near future. Horizontal drilling is very expensive (Columbia spent over $4 million/well), but continued success will result in activity in this area for years to come.

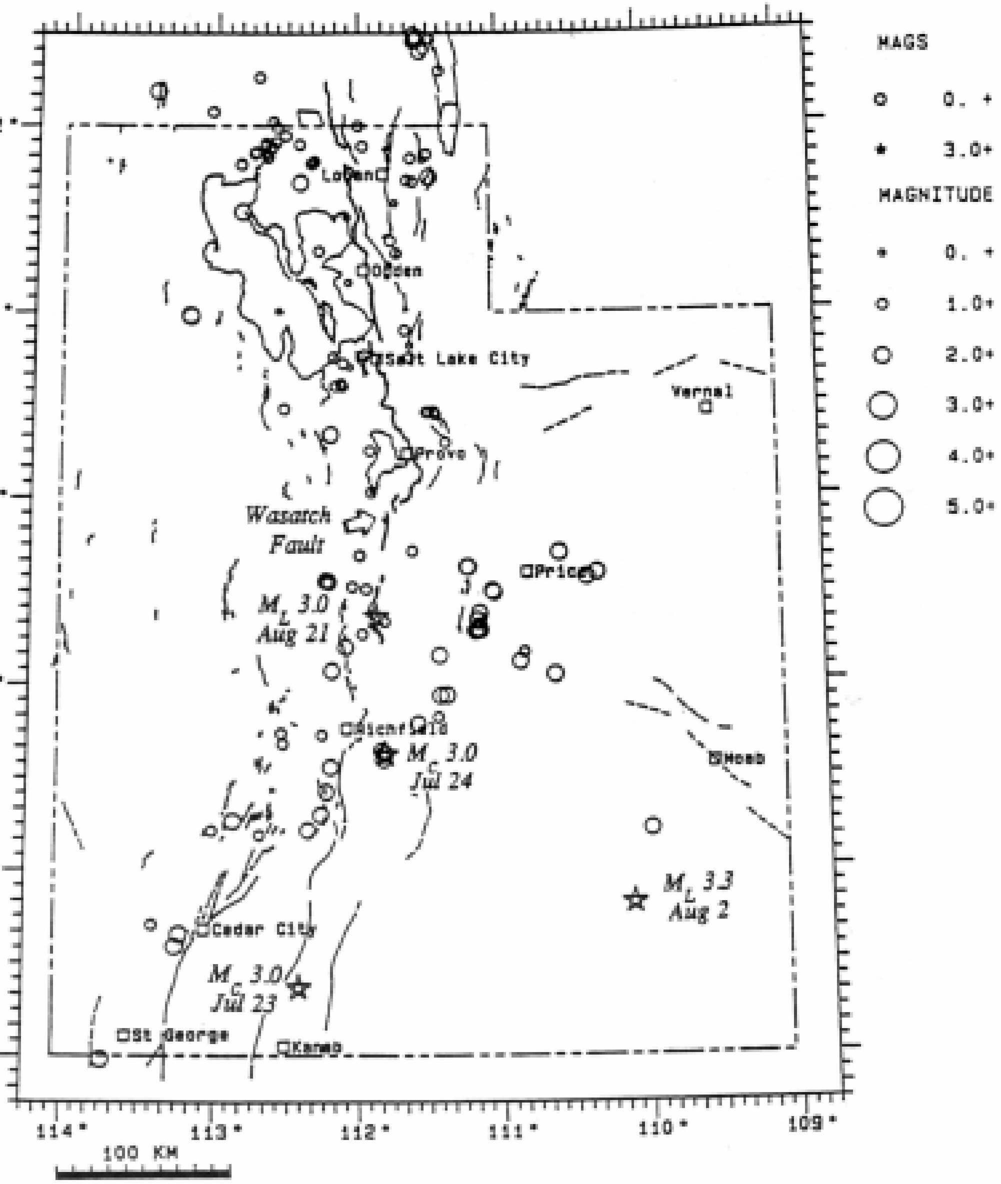
EARTHQUAKE ACTIVITY

IN THE UTAH REGION

July 1 - September 30, 1991

Susan J. Nava
University of Utah Seismograph Stations

During the three-month period July 1 through September 30, 1991, the University of Utah Seismograph Stations located 132 earthquakes within the Utah region (see epicenter map). The total includes four earthquakes in the magnitude 3 range, specifically labled on the epicenter map, and 60 in the magnitude 2 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 Daylight Time.)



Large and/or Felt Earthquake

•	M_C 3.0	July 23	10:00 p.m.	6 miles SE of Alton (see N of Kanab)
•	M_C 3.0	July 24	5:16 a.m.	9 miles NNE of Koosharem (see SE of Richfield)
•	M_L 3.3	Aug 2	1:59 p.m.	37 miles W of Blanding (see SW of Moab)
•	M_L 3.0	Aug 21	7:47 a.m.	10 miles NNW of Fayette (see N of Richfield)

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

SOIL AND ROCK CAUSING ENGINEERING PROBLEMS IN UTAH

by William E. Mulvey

Geologic materials with characteristics that make them susceptible to volumetric changes, collapse, subsidence, or other engineering-geologic problems are referred to in this study as *problem soil and rock*. Geologic and climatic conditions in much of Utah provide a variety of both localized and widespread occurrences of these materials, as may be seen in figure 1. This article is condensed from a map (1:500,000 scale) and report soon to be published by the UGS as part of a series of geologic-hazard maps of the state (see Mulvey, in press).

Nine types of problem soil and rock are discussed: (1) expansive soil and rock with high shrink/swell potential; (2) collapsible soil or hydrocompactible soil; (3) gypsum and gypsiferous soil susceptible to solution; (4) limestone susceptible to solution under some hydrogeologic conditions; (5) soil subject to piping (localized subsurface erosion); (6) active dunes; (7) highly compressible peat, subject to decomposition; (8) underground mines which may subside and collapse; and (9) soil containing sodium sulfate. Some materials such as expansive soil and limestone cover large areas of the state; others, like dunes and peat, are of limited areal extent.

Geology and climate are the main factors which influence the distribution of problem soil and rock. The geologic parent material largely determines the type of problem present. For example, expansive soil is most often associated with shale, and karst dissolution features form in limestone and gypsiferous formations. Weathering and erosion are controlled by local and regional climate. A prime example of the influence of climate is collapsible soils, found predominantly in arid regions where annual rainfall is low.

As urban development encroaches on less suitable terrain, damage from problem soil and rock has increased. Detailed geotechnical studies are needed in areas of problem soil and rock to identify and mitigate potential problems, and to avoid costly corrective measures.

METHODS AND SCOPE

Information on problem soil and rock in Utah was compiled from investigations conducted by numerous agencies and authors, and from limited aerial photograph interpretation and field work.

Two types of information are shown on the map: (1) documented occurrences of problem soil and rock which commonly cause damage to structures, and (2) geologic units with the potential to cause problems. Documented occurrences provide the basic information used to identify problem geologic units. Deposits with the potential to cause damage are more widespread than documented occurrences, which are clustered in urban areas where problem soil and rock are encountered by development. Available data concerning problem materials consist primarily of unpublished consultants' reports, and investigations by state, local, and federal governments. Documented occurrences include instances of damage to structures and roads, and soil-test results.

PROBLEM SOIL AND ROCK

The various categories of problem soil and rock are discussed according to the processes that created the deposits, their distribution within Utah, their associated engineering geologic hazards, and the mitigation techniques used to reduce the hazards.

Expansive Soil and Rock

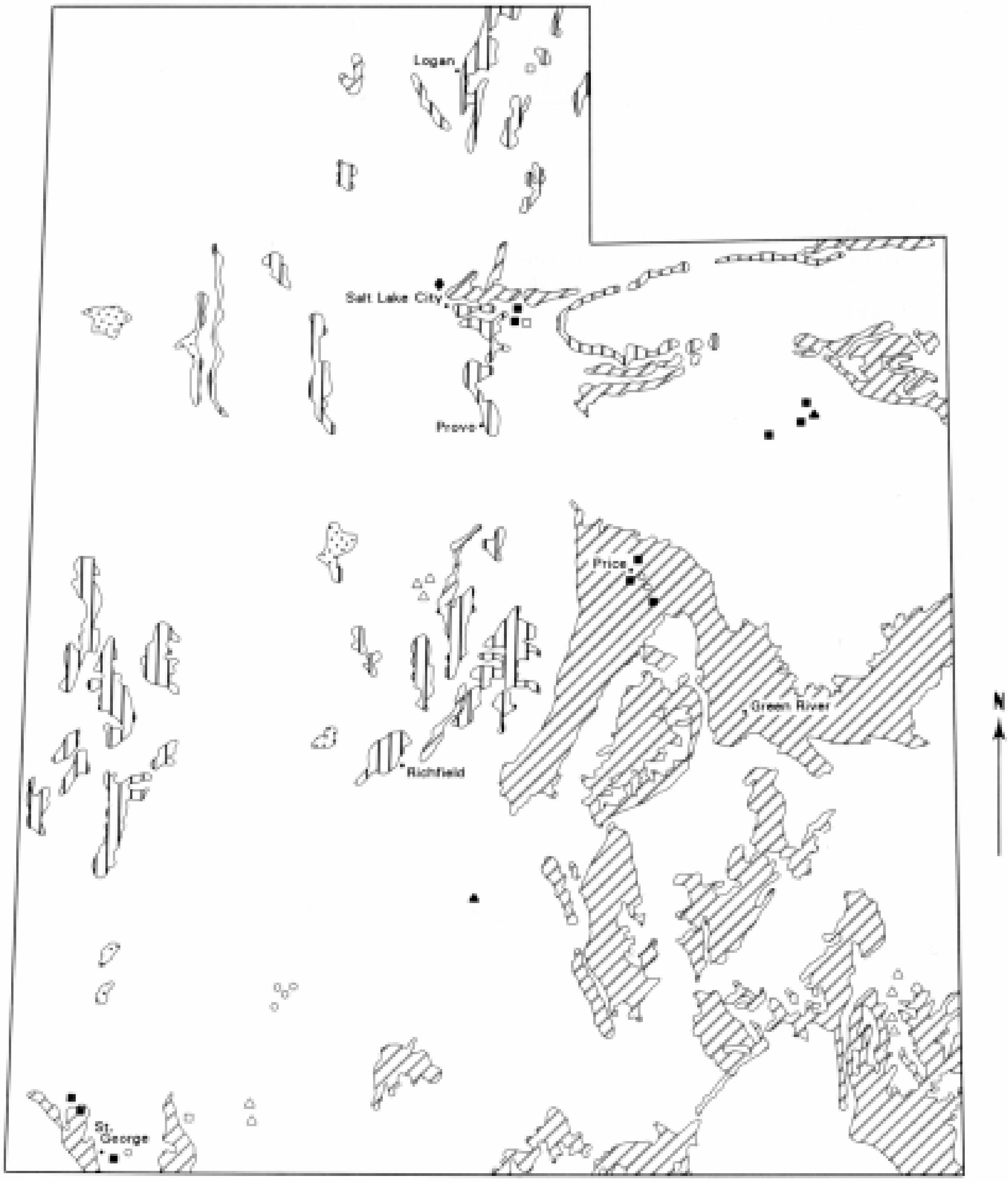
Expansive soil and rock contain clay minerals that expand and contract with changes in moisture content. Clays absorb water when wetted, causing the soil or rock to expand. Conversely, as the material dries, the loss of water between clay crystals or grains causes the deposit to shrink. The most common clay mineral associated with expansive deposits in Utah is montmorillonite (Bauman, 1964). Certain types of montmorillonite can swell 2,000 times their original dry volume (Tourtelot, 1974).

Problems associated with expansive materials are cracked foundations, heaving and cracking of road surfaces, and failure of wastewater disposal systems. Sidewalks and roads are particularly susceptible to damage. Wastewater disposal systems using soil absorption fields are damaged when clay-rich deposits go through the wet-dry cycle. When dry, cracks develop leaving voids that allow large volumes of water to infiltrate until the clay minerals swell and close the voids. The soil then becomes impermeable, and systems clog and fail, often causing wastewater to rise to the ground surface.

Expansive soil and rock are the most common type of problem deposit in Utah, covering approximately 10 to 15 percent of the state. Most of the expansive soil and rock was originally deposited in seas or lakes that at one time or another covered much of the state. Mesozoic-age marine shales are the source of most expansive deposits. These shales crop out over a large area of the state and are a particular problem in southeastern Utah due to their wide exposure there (figure 1). Other problem deposits include Lake Bonneville and other deep-lake sediments in the western basins and volcanic tuffs in the north-central part of the state. The extent of expansive Lake Bonneville sediments in the central basins of western Utah is unknown.

In Utah, homes and other structures built on Mesozoic-age marine shales (for example the Mancos, Tropic and Arapien Shales) have suffered extensive damage in Price, Green River, near Moab, Vernal, and St. George (figure 2). Expansive volcanic tuff has damaged structures in Morgan, Davis, and Summit Counties.

Mitigation measures for expansive soil and rock include installing gutters and downspouts that direct water at least 3 m (10 ft) away from foundation slabs; landscaping with vegetation that does not concentrate or draw large amounts of water from the soil near foundations; insulating floors or walls near heating or cooling units to prevent evaporation that could cause local changes in soil moisture, strengthening founda-



EXPLANATION

Other areas not shown

TYPE		Map		ENGINEERING-GEOLOGIC PROBLEM OR HAZARD
Expansive soil or rock	■		Clayey soils in central basins of western Utah; playas and lake beds	Shrinking and swelling with changes in water content; subsidence or heave of sidewalks, roads, floor slabs, structures; plugging of soil absorption fields; unstable in slopes
Collapsible soil	○		Young alluvial-fan deposits along steep mountain fronts, particularly in southwestern Utah	Subsidence due to hydrocompaction (collapse upon wetting) and loading; collapse time variable
Gypsiferous soil or rock	▲			Gradual subsidence from dissolution; low bearing strength
Limestone (karst)	□			Ground water highly susceptible to contamination; collapse of underground caverns; variable subsidence from dissolaution; sinkholes form
Piping	△		Young, fine-grained (silty and sandy) alluvium in valley bottoms incised by streams	Subsurface erosion causing collapse or gradual subsidence of ground surface; gullying and sinkholes
Dunes (silica, gypsum, oolitic)				Burial by actively migrating dunes; failure to filter wastewater in soil absorption systems; clogging of wastewater disposal systems
Peat	◆		Shoreline areas of Great Salt Lake, Utah Lake; localized Lake Bonneville deposits in basin floors; around alpine ponds or bays	Low bearing strength; highly compressible and subject to decomposition when drained; gradual subsidence and settling under load; possible methane gas

Figure 1. Map of soil and rock causing engineering-geologic problems in Utah. Symbols indicate documented occurrences.

Figure 2. Heaving in foundation at the Moab airport due to expansive soils developed on the Macos Shale. Photo by W.R. Lund.

Figure 3. Damage to foundation and shed due to collapsible soils in the Nephi area. Photo by G.E. Christenson.

tions, excavation and replacement of expansive foundation soils with non-expansive granular fill; and the use of piles or caissons to place the foundation on deeper non-expansive material or expansive material that is protected from changes in moisture content by virtue of its burial.

Collapsible Soil

The phenomenon of hydrocompaction, which causes subsidence in collapse-prone soil, occurs in loose, dry, low-density deposits that decrease in volume or collapse when saturated for the first time following deposition (Costa and Baker, 1981). Collapse occurs when susceptible soils are wetted to a depth below that normally reached by rainfall, destroying the clay bonds between grains. Collapsible soil is present in geologically young materials such as Holocene-age alluvial-fan and debris-flow sediments, and in some wind-blown silts. These deposits have a loose "honeycomb" structure and high dry strength, resulting from rapid deposition and drying. When saturated, the honeycomb structure collapses and the ground surface subsides, damaging property and structures. The most common cause of hydrocompaction is human activity that involves some form of water application such as irrigation, water impoundment, lawn watering, alterations to natural drainage, or wastewater disposal.

Alluvial fans containing fine-grained deposits derived from shales, mudstones, and volcanic rocks are the most common sites for collapsible soil in Utah. Fans have steeper slopes at their apices that allow rapid runoff of surface water during fan-building depositional events. This allows deposits to dry quickly with little reworking by streamflow, and the sediments are commonly covered by material from subsequent depositional events before being saturated. This results in materials with voids formed by air entrapped at the time of deposition. Soils with high void ratios and low bulk densities are subject to settlement.

Collapsible soil is present around Richfield and Monroe in central Utah, and particularly near Cedar City and the Hurricane Cliffs (Iron County) in the southwestern part of the state (figure 3). In Cedar City approximately $ 3 million in damage to public and private structures has been attributed to collapsible soil (Kaliser, 1978). Other areas in Utah with a potential collapsible soil problem are along any mountain front where young alluvial-fan deposits containing fine-grained sediments are present. Climate also plays a role in the location of collapsible soils. Drier areas, such as the Basin and Range Province and Colorado Plateau Province, provide the best conditions for development of collapsible soil.

If collapsible soils are suspected to be present, soil consolidation tests should be performed. Mitigation methods include wetting and compacting a site prior to construction, excavating and backfilling with suitable materials, and landscaping to direct water away from a structure.

Gypsiferous Soil and Rock

Gypsiferous deposits are subject to settlement caused by the dissolution of gypsum, creating a loss of internal structure and volume within the deposit. Gypsum is a primary component in some rocks and the soils derived from them. Gypsum can also form in two other ways - as a secondary mineral deposit leached from surficial layers and concentrated lower in the soil profile, or as a material transported by wind from outside sources. The most common sources for airborne gypsum are playas, on which crusts of gypsum salts are formed as the wetted playa surface dries during the warmer months of the year. The gypsum crusts are broken into individual crystals that are easily transported by wind.

Gypsiferous rock and soil deposits can cause damage to foundations, and can induce land subsidence and sinkholes similar to those seen in limestone terrain (figure 4). Water introduced for irrigation and landscaping or into wastewater disposal systems can cause underground solution cavities to develop and ultimately cause surface collapse. Gypsum is also a weak material with low bearing strength, which can cause problems when loaded with the weight of a structure. In addition, when gypsum weathers it forms sulfuric acid and sulfate, which react with certain types of cement and weaken foundations (Bell, 1983).

Figure 4. Sinkhole in field due to dissolution of gypsum in Asphalt Ridge Member of the Green River Formation. Photo by G.E. Christenson.

Figure 5. Sinkhole in the Kaibab Limestone beneath alluvium along the Virgin River near St. George. Photo by B.L. Everitt.

Gypsiferous rock and soil deposits are common in the Uinta Basin near Vernal, and in southwestern Utah, particularly along the base of the Hurricane Cliffs. In southwestern Utah, much of the gypsum is derived from erosion of gypsum-rich rock units.

Soil tests can determine the presence of gypsum. If gypsum is present, the outer walls of structures can be coated with impermeable coatings, special types of concrete can be used that resist damage from gypsum, runoff from roofs and gutters should be directed away from structures, and landscaping close to a structure should not include plants that require regular watering.

Limestone and Karst Terrain

Karst terrain is characterized by closed depressions (sinkholes), caverns, and streams that abruptly disappear underground (figure 5). Karst features are caused by ground- and surface-water dissolution of calcareous rocks, such as limestone and dolomite. Fractures within the rock, frost shattering, and stream erosion also aid in the development of karst terrain.

Karst features directly affect both surface and subsurface drainage. The cavernous nature of karst terrain provides avenues for contaminants from surface or subsurface sources, such as wastewater disposal systems, landfills, and buried gasoline tanks, to enter the ground-water system. Contaminants can spread rapidly due to the interconnected system of conduits.

Cavernous subterranean openings in karst terrain often collapse, leaving sinkholes at the surface. Structures in the area may be damaged by the collapse. Although no documented occurrence of damage due to collapse has occurred in Utah, the potential for damage exists in known karst areas.

Karst is present in Paleozoic limestones and dolomites throughout northern and western Utah, with the best development in the northeastern part of the state. Most karst features found in the Basin and Range of western Utah are relict features that relate to moister climates during the Pleistocene, or may have been created by ground water prior to the rock being uplifted and tilted during basin and range faulting (F.D. Davis, Utah Geological Survey, verbal commun., January, 1990). Under present climatic conditions, the potential for continued karst development in western Utah is low, except in areas where sufficient ground water is present to cause solutional weathering of limestone and dolomite.

In northern Utah, surface and ground water are more abundant and karst features are widespread and well developed, especially in the Bear River Range and in the northeastern part of the state. South of the Bear River Range, sinkholes were found beneath a reservoir in Laketown Canyon in Rich County and in the excavation for Porcupine dam in Cache County. Other areas of the state containing karst terrain are the north and south flanks of the Uinta Mountains and the central Wasatch Range between Alpine and Spanish Fork Canyon (Utah County).

Avoiding areas of limestone and dolomite terrain where karst features have formed is the best method of preventing ground-water contamination and collapse problems. If avoidance is not possible, preconstruction planning based on thorough geologic and hydrologic investigations of construction sites can prevent ground-water and foundation problems.

Soils Subject to Piping

Piping is subsurface erosion by ground water that moves along permeable, noncohesive layers in unconsolidated materials and exits at a free face, usually a stream bank or cliff that intersects the layer (Cooke and Warren, 1973; Costa and Baker, 1981). Removal of fine-grained particles (silt and clay) by this process creates voids within the material that act as minute channels which direct the movement of water. As channels enlarge, water moving through the conduit increases velocity and removes more material, forming a "pipe." The pipe becomes a preferred avenue for ground-water drainage and enlarges as more water is intercepted. The increasing size of the pipe removes support from the walls and roof, causing eventual collapse. Collapse features form at the surface above the pipes, directing even more surface water into the pipes.

Figure 6. Piping damage to a road in Holocene alluvium along Montezuma Creek in San Juan County. Photo by G.E. Christenson.

Eventually, total collapse forms a gully that concentrates erosion along the line of collapse features.

Piping is common in arid climates where fine-grained, uncemented Holocene-age alluvium is incised by stream drainages (figure 6). When enough water is introduced, water soaks into the subsurface until it reaches layers that can conduct the water to a free face.

Piping can cause damage to roads, bridges, culverts, and any structure built over soils subject to piping. In areas where piping is common, roads are most frequently damaged because they often parallel stream drainages and cross-cut pipes. Road construction can contribute to the piping problem by disturbing natural runoff and concentrating water along paved surfaces, which allows greater infiltration and potential for pipes to develop. Earthfill structures such as dams may also be susceptible to piping.

Deposits susceptible to piping are found throughout Utah, but they are particularly common in the southeastern part of the state. Types of material susceptible to piping include fine-grained alluvium; weakly cemented, fine-grained rock (siltstone, mudstone, and claystone), and volcanic tuff and ash. Holocene-age alluvial fill in canyon bottoms in the Colorado Plateau is the most common material susceptible to piping in Utah. Claystone in this area is the next most likely material to develop pipes. Outside of the Colorado Plateau, fine-grained marl and silt deposited by Lake Bonneville are susceptible to piping in the western and northern deserts of Utah. In the Uinta Basin, piping caused by the irrigation of cropland adjacent to incised drainages has resulted in extensive damage.

Damage caused by piping can be reduced by limiting the degree to which natural drainage in soil susceptible to piping is disturbed by construction. Proper drainage along roads and around structures is the most cost-effective and successful mitigation procedure.

Sand Dunes

Dunes are common surficial deposits in arid areas where sand derived from weathering of rock or unconsolidated deposits is blown by the wind into mounds or ridges. Dunes form downwind of source areas which may contribute a variety of different types of wind-blown material.

In areas where development encroaches on dunes, inactive or vegetated dunes may be reactivated, allowing them to migrate over roads and bury structures (figure 7). Other problems include burial of structures that were originally constructed outside of, but near, active or migrating dunes; and contamination of local ground water from wastewater disposal in dunes. The uniform size of the sand grains comprising dunes makes them highly permeable. The fine sand in dunes can also clog wastewater disposal systems. Gypsiferous dunes would be an especially poor wastewater disposal medium because they dissolve when wetted.

In Utah, dunes are composed of three types of materials: silica, gypsum, and oolites. Silica (quartz) makes up approximately 60 percent of Utah's dunes, gypsum constitutes up to 30 percent of the dunes, and the remaining 10 percent are oolitic.

Figure 7. Oolitic dunes burying a structure on Antelope Island in the Great Salt Lake. Photo by Suzanne Hecker.

Basin-fill deposits consisting of alluvial and lacustrine fine sand, silt, and clay in the valleys of western Utah are the main source for silica dunes. The dunes are typically found on the west side of the mountain ranges; (east side of the valley) and are found from the southern end of Tooele and Skull Valleys to the Escalante Desert north of Enterprise.

Most of the gypsum found in dunes is derived from evaporation and eventual crystallization of gypsum minerals during the seasonal wetting and drying of playa lake surfaces. When these ephemeral lakes dry out, sand-size crystals of gypsum are moved by the wind and accumulate as dunes. Gypsum dunes are found in greatest concentration in the Great Salt Lake Desert south and east of the Bonneville Salt

Flats. They are also found along the lee side of many playas in the basins west of Delta.

Oolitic dunes are composed of calcium carbonate, generally precipitated around a nucleus of brine shrimp fecal pellets. Oolites form in shallow water near the wave zone in terminal lakes (for example, Great Salt Lake) in northern Utah, and are exposed as lake levels fluctuate. During low lake levels, winds rework oolitic beach deposits into dunes. Oolitic dunes are found only in association with oolitic sand beaches along Great Salt Lake and in the Great Salt Lake Desert where the dunes consist of reworked early Holocene-age beach deposits associated with high levels of Great Salt Lake.

Avoidance of dunes is the best way to prevent damage to structures. However, active dunes usually are a maintenance problem only and do not preclude development.

Figure 8. Sinkhole (circular hole in shadow to the right of the pit) formed by the collapse of underground mine workings in Limekiln Gulch above Salt Lake City. Photo by W.E. Mulvey.

Peat

Peat is an unconsolidated deposit of partially decomposed plant remains. Peat usually accumulates in areas of shallow ground water and near standing water where oxygen depletion limits the rate of decay. Low-lying areas and moist climates provide conditions conducive to peat formation. Plant parts are still recognizable and make up 25 percent of most peat; the remaining 75 percent is water.

Peat has a high water-holding capacity and shrinks and oxidizes rapidly when drained. Hazards affecting structures built on peat include rapid oxidization and subsidence when water is removed; compression and settlement when loaded by structures; and in the longer term, decomposition of organic material may cause further subsidence.

Due to a generally dry climate, peat deposits in Utah are very localized. Peat is found in poorly drained areas along the shores of Great Salt Lake, Utah Lake, and in low areas formerly occupied by Lake Bonneville. In mountainous areas, peat commonly forms in poorly drained depressions behind glacial moraines or in the head scarp areas of landslides.

Peat deposits should be removed or avoided at construction sites.

Mine Subsidence

Mine subsidence occurs above both active and abandoned mines in Utah. Underground rock removal leaves voids that, if not supported, can cause collapse of overlying material and subsidence of the ground surface (figure 8). Utah has a long history of mining and there are numerous areas with surface subsidence or sinkholes. Documented mine subsidence exists in the Park City mining district (Summit County) and the Tintic mining district (Juab County). In both of these areas, sinkholes have formed due to collapse of underground workings, damaging structures in Eureka (Tintic mining district), and creating, in one case near Park City, a sinkhole 14 meters (45 ft) across and 427 meters (1400 ft) deep. Subsidence also occurs over large active coal mines in the Book Cliffs (Carbon, Emery, and Grand Counties) and along the eastern slope of the Wasatch Plateau (Sevier, Sanpete, and Emery Counties). Future risk from mine subsidence is reduced by a law that requires companies to devise a mining method that reduces the potential for surface subsidence. If subsidence occurs, the mine is required to alter mining methods to prevent further subsidence. Lists of abandoned mines and their conditions are available from the Utah Division of Oil, Gas, and Mining.

Development in old mining districts should avoid construction over abandoned workings and, if possible, plans should be obtained for mine layouts so as to avoid areas prone to subsidence.

Sodium Sulfate

Soil with a high concentration of water-soluble sulfates are subject to expansion and contraction like expansive clays. Problems associated with sodium sulfate in soil are similar to those experienced in areas of expansive soil and rock.

Sodium sulfate is deposited upon evaporation of surface waters in playas, and is common in the Basin and Range Province of western Utah. Other occurrences not associated with playas appear to be introduced as airborne particulates. In some cases the sodium sulfate is derived from a bedrock source such as in Duchesne County where the saline facies of the Green River Formation introduces sodium sulfate into local surface and ground water. Sodium sulfate-rich soil is present in the highlands north of St. George and in dams impounding stock ponds in the Blue Creek-Howell watershed in Box Elder County. Most sodium sulfate in northern Utah is derived from fine-grained, deep-water sediments left by Lake Bonneville.

Mitigation measures for sodium sulfate-rich soils are similar to those listed for expansive soil.

SUMMARY AND CONCLUSIONS

Deposits of problem soil and rock are some of the most widespread and costly geologic hazards in Utah. They cover approximately 18 to 20 percent of the state and underlie many urbanized areas. Local and regional geology and climate are the main factors that influence the distribution of these hazards.

The two most widespread problems are expansive soil and rock derived from marine shale, and karst terrain developed from the dissolution of limestone, dolomite, and gypsum. Expansive soil occurs over much of southern Utah and in the central basin areas of western Utah. Limestone and dolomite are found throughout northern and western Utah, with the greatest concentration in the northeastern part of the state. Gypsiferous soil and rock are common in southwestern Utah and in the Uinta Basin. Sodium sulfate-rich soil is known to occur throughout western Utah. Along the mountain fronts from Provo south to the Arizona border, collapsible soils may be found in alluvial-fan sediments.

More locally occurring are the sand dunes with a variety of compositions found in isolated patches throughout the western deserts. Hazards associated with piping-susceptible soils are found primarily in incised Holocene-age alluvium in canyons of eastern Utah. Peat deposits are found around the shores of Great Salt Lake and Utah Lake, and in mountain drainages dammed by glacial moraines and landslides. Subsidence due to collapse of underground mine workings has occurred in Park City and Eureka, and above active mines in the Book Cliffs and on the eastern slope of the Wasatch Plateau.

The majority of damage to structures from problem soil and rock results from human activities, usually through addition of water or by excavation, both of which aggravate potentially unstable conditions. Many urbanized areas in the state are susceptible to damage from these hazards. As development encroaches on less suitable terrain, damage from problem soil and rock has increased, as has the need for awareness of these hazards.

Most of the hazards created by these problem soil and rock deposits can be mitigated or avoided if they are understood and their areal extent is known. Recognizing that problem soil and rock cover parts of the state and taking precautions to mitigate the potential hazards can reduce the need for costly corrective measures after damage to structures and roads has occurred.

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Tourtelot, H.A., 1974, Geologic origin and distribution of swelling clays: Bulletin of the Association of Engineering Geologists, v. XI, no. 4, p. 259-275.

The latest information on

CANE CREEK, UTAH'S HOTTEST OIL PLAY

UGS introduces three newly released publications related to recent major oil discoveries in the "Cane Creek" horizontal drilling play of southeastern Utah.

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- Well information which includes Long Canyon field
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PRICE: $8.50

EARTHQUAKE IN SOUTHERN SALT LAKE VALLEY

by Gary E. Christenson and Susan S. Olig

At 7:42 a.m. on Monday, March 16, 1992, Salt Lake and northern Utah Valleys were shaken by a magnitude 4.2 earthquake. It was reported felt from Kaysville in Davis County to Orem in northern Utah Valley, and from Brighton in the Wasatch Range to Tooele, west of the Oquirrh Mountains (Susan J. Nava and Jim Tingey, verbal communication, March 31, 1992). Shaking was strongest in the southern Salt Lake Valley (Bluffdale, Riverton, Draper, Sandy), where news reports indicated some foundation and building cracks, sidewalk and patio cracks, and at least one report of falling bricks dislodged from a chimney. Most other reports were of rattling dishes, swaying of hanging objects, and rocking motions. Shaking was of very short duration, and in many cases was a single jolt.

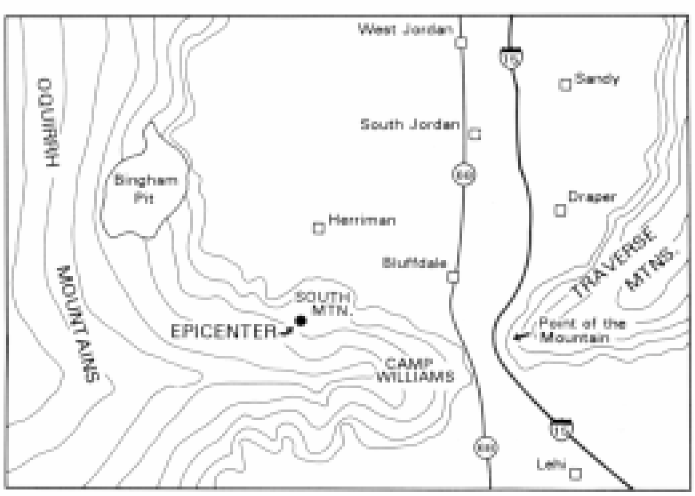
The epicenter was located in the Traverse Mountains near Camp Williams. Early reports from the U.S. Geological Survey's worldwide seismic network indicated a magnitude of 4.8, but later reports from the University of Utah Seismograph Stations' (UUSS) local network downgraded the magnitude to 4.2. They calculated a focal depth of 12.3 km (7.7 mi). Jim Pechmann and Gerard Schuster at the University of Utah had deployed 10 accelerometers in the Salt Lake Valley last fall under a 2-year grant from the National Science Foundation to look at low-strain (weak) earthquake ground motion in the valley. Records from these instruments are being retrieved and analyzed, and will hopefully yield information regarding ground motions in the valley. The level of ground shaking was too small to trigger any of the U.S. Geological Survey strong-motion instruments in the valley (Ground-shaking aspects are discussed fully in Susan Olig's article, *Survey Notes 24/3*).

There are no mapped Quaternary faults in the epicentral area. Because of the relatively great focal depth, it is possible that the earthquake was on the west-dipping Wasatch fault (assuming a fault dip of 29 to 35 degrees). If so, it is near the boundary between the Salt Lake and Provo segments of the fault (see articles by Christenson and Hecker in *Survey Notes 24/1* for explanations of the segments). A preliminary focal mechanism determined by the UUSS indicates normal slip on either a northwest-striking plane dipping 38 degrees west or a north-northwest-striking plane dipping 56 degrees east (J.C. Pechmann, verbal communication, 1992). The west-dipping plane is consistent with the geometry of the Wasatch fault zone segment boundary at this location.

The earthquake was generally too small to expect any significant geologic effects other than local rock falls and stream-bank caving. Utah Geological Survey (UGS) teams were dispatched to the epicentral area within hours of the earthquake to search for possible geologic effects. The Traverse Mountains were combed for rock falls, landslides, and ground cracks, while the Jordan River and other areas of shallow ground water were searched for evidence of liquefaction. Nothing was found, as might be expected, but a later investigation by Kimm M. Harty (UGS) of a reservoir on the Jordan River near 9400 South (20.0 km or 12.4 mi north of the epicenter) that was drained the morning of the earthquake turned up possible evidence of liquefaction in freshly exposed reservoir sediments. Many small holes, some surrounded by cones of sediment (see photo), were found in the organic, silty, bottom sediment (avg. diam. 1 cm). Possible origins of these features include earthquake-induced liquefaction, expulsion of trapped gases, and de-watering of sediment following rapid draining of the reservoir. The investigation concluded that a combination of these processes, including liquefaction, probably formed the features.

Although this was not a large or damaging earthquake, it should yield some valuable ground-shaking information. It also served as an opportunity for many private companies and government agencies to test their emergency response and notification plans, which will now be revised and improved as necessary. Finally, it has served as a gentle reminder to everyone that we live in earthquake country, that earthquakes occur without warning, and that we must be prepared for the inevitable, large, damaging earthquake that will one day hit the Wasatch Front.

Location of the earthquake, 40° 27.90' N., 112° 2.69' W.



Holes in sediment of drained reservoir. Photo: Kimm M. Harty.

STAFF NEWS

Jon King, recently of the Wyoming Geological Survey, has accepted the position of mapping geologist.

Mike Lowe was voted in as vice president for the Utah Section of the Association of Engineering Geologists (AEG), while *Barry Solomon* has become the new president. Both are in the Applied Section at UGS.

Dan Burke is the new secretary for the Applied and Mapping Sections and replaces *Debbie Overmoe* who has gone back to school for a teaching certificate. He was formerly with the San Francisco City/County Architecture Department.

David Tabet has accepted the position of coal geologist in the Economic Section, coming to us from a background of New Mexico Bureau of Mines and Mineral Resources, the ARCO Coal Company, and most recently Pentastar Support Services.

CENTERVILLE CITY COMMENDS LOWE

On January 21, 1992, Centerville City presented a Resolution of Appreciation to the Davis County Commission and Davis County Public Works Department for help in appealing FEMA-designated flood-hazard areas in the city. The appeal significantly reduced the areas identified by FEMA, and consequently reduced costs to homeowners, to Centerville City, and to Davis County for flood insurance and flood-hazard mitigation measures. Mike Lowe, former Davis County Geologist (presently in the Applied Geology Program at the UGS) was named in the resolution, along with Sidney W. Smith, Director, and Scott R. Williams, Assistant Director, of the Davis County Public Works Department. All were also recognized for the help in preparing the "Debris-Flow Hazard Mitigation Plan for Centerville City" published by the Utah Division of Comprehensive Emergency Management. In the photograph, from left, are David A. Hales (Centerville City Manager), Williams, Smith, and Lowe.

William Mulvey of the UGS will be performing further work for Centerville City this spring at Lone Pine Canyon, an area not included in the FEMA study. The study will assess debris-flow hazards at the canyon mouth and will be used by the city to evaluate the need for hazard-reduction measures.

Mike Lowe receiving commendation from David A. Hales.

ATWOOD HONORED WITH JOHN WESLEY POWELL AWARD

Each year the U.S. Geological Survey (USGS) presents the John Wesley Powell award to persons or groups outside the Federal Government for voluntary actions that result in significant gains or improvements in the efforts of the USGS to provide "earth science in the public service."

Genevieve Atwood, former Director of the Utah Geological Survey, received the 1990 Powell award. In a letter from Dallas Peck, Director of the USGS, she was cited for several significant accomplishments. Genevieve played a pivotal role "in the formation of the Utah Seismic Safety Advisory Council (and the) successful completion (of its 4 years work,) which led to the adoption of improved seismic safety policies in Utah."

Her "advice and counsel as a participant in (the USGS) workshops and as a member of (the USGS) Earthquake Advisory Panel were of great benefit to the National Earthquake Hazards Reduction Program."

Her "management ability and scientific leadership" were vital in guiding the 5-year cooperative National Earthquake Hazards Reduction Program in Utah, whose ambitious goal was "assessing earthquake hazards along the Wasatch Front and translating the results for use by planners, emergency managers, and engineers." Utah's exceptionally successful program "has become a model for all to emulate." It included multiple trenches across the Wasatch fault to determine earthquake recurrence intervals, a County Hazard Geologist program, efforts to improve instrumentation along the Wasatch Front, efforts to get legislation passed to address Utah's seismic risk, and sponsoring annual earthquake workshops and awards.

Her "vision and influence" helped achieve a "close collaboration" between the Utah Geological Survey, the Utah Division of Comprehensive Emergency Management, the University of Utah Seismograph Stations, Utah State University, and the USGS Office of Earthquakes, Volcanoes, and Engineering, fostering efficient and coordinated actions on many fronts.

Her overall efforts to "deepen understanding of the scientific and social aspects of natural disaster reduction" have put Utah "in an excellent position to be a leader during the 1990s in the International Decade for Natural Disaster Reduction."

Wenzhi Zhao is the newest *Visiting Scientist* to the Utah Geological Survey. He comes from China and will be here until the end of August working on oil and gas projects in the Uinta Basin. Previous Visiting Scientists John Hubert and Guimei Ai (from U. of Massachusetts and the China National Petroleum Corporation, respectively) proved the efficacy of the program.

New Publications of the Utah Geological Survey

The March 1992 Publications List is free on request.

Rockhound guide to mineral and fossil localities in Utah, comp. by C.H. Stowe, 79 p., 1979, Circular 63 Reprint, $6.00

Oil and gas drilling in Utah, 1989, by T.C. Chidsey, Jr., and M.D. Laine, 31 p., 1991, Circular 83 $5.00

Geological considerations for oil and gas drilling on State potash leases at Cane Creek anticline, Grand and San Juan Counties, Utah, by C.D. Morgan, W.A. Yonkee, and B.T. Tripp, 24 p., 1991, Circular 84 $4.00

Geologic excursions in volcanology: eastern Snake River Plain (Idaho) and southwestern Utah, Geological Society of America guidebook - Part III, edited by K.D. Gurgel, 1983, 55 p. (reprint), Special Study 61 $6.00

Quaternary geology of the Scipio Valley area, Millard and Juab Counties, Utah, by C.G. Oviatt, 16 p., 1 pl., 1:62,500, 1992, Special Study 79 $6.00

Provisional geologic map of the Levan quadrangle, Juab County, Utah, by W.L. Auby, 13 p., 2 pl., 1:24,000, 1991, Map 135 $5.00

Geologic map of the Lampo Junction quadrangle, Box Elder County, Utah, by D.M. Miller, M.D. Crittenden Jr., and T.E. Jordan, 17 p., 2 pl., 1:24,000, 1991, Map 136 $5.00

Provisional geologic map of the Nephi quadrangle, Juab County, Utah, by R.F. Biek, 21 p., 2 pl., 1:24,000, 1991, Map 137 $5.00

Geologic map of the Redmond Canyon quadrangle, Sanpete and Sevier Counties, Utah, by G.C. Willis, 17 p., 2 pl., 1:24,000, 1991, Map 138 $5.00

Geologic tours of northern Utah, by S.K. Morgan, 98 p., February 1992, Miscellaneous Publication 92-1 $6.00

New $^{40}Ar/^{39}Ar$ ages of intrusive rocks from the Henry and La Sal Mountains, Utah, by S.T. Nelson, M.T. Heizler, and J.P. Davidson, 24 p., April 1992, Miscellaneous Publication 92-2 $4.50

Field guide to geologic excursions in Utah and adjacent areas of Nevada, Idaho, and Wyoming, edited by J.R. Wilson, 481 p., 1992 Miscellaneous Publication 92-3 $25.00

Mineral and energy resources in Kane County, Utah and their occurrence with respect to Wilderness Study Areas, by R.E. Blackett, C.J. Brandt, T.C. Chidsey, Jr., and C.E. Bishop, 42 p., April 1992, Report of Investigation 221 $3.50

Earthquake response strategies for UGS and the earth-science community, by G. Atwood, M. Noonan, W.F. Case, and D. Mabey (updated to December 1991 by G.E. Christenson), 31 p., Open-File Report 115 $2.75

Interim geologic map of the Oak City South quadrangle, Utah and Millard Counties, Utah, by L.F. Hintze, 1 pl., 1:24,000, November 1991, Open-File Report 217 $2.00

note: maps listed as interim are a) in review and production and will be released as finished color maps at a later date, or b) are maps that will not progress past this point but which are not finished enough for the formal map series.

Interim geologic map of the Scipio South quadrangle, Millard County, Utah, by L.F. Hintze, 1 pl., 1:24,000, November 1991, Open-File Report 218 $2.00

Interim geologic map of the Scipio North quadrangle, Millard County, Utah, by L.F. Hintze, 1 pl., 1:24,000, November 1991, Open-File Report 219 $2.00

Interim geologic map of the Fool Creek Peak quadrangle, Juab and Millard Counties, Utah, by L.F. Hintze, 1 pl., 1:24,000, November 1991, Open-File Report 220 $2.00

Interim geologic map of the Oak City North quadrangle, Utah and Millard Counties, Utah, by L.F. Hintze, 1 pl., 1:24,000, November 1991, Open-File Report 221 $2.00

Interim geologic map of the Scipio Pass quadrangle, Millard County, Utah, by L.F. Hintze, 1 pl., 1:24,000, November 1991, Open-File Report 222 $2.00

Interim geologic map of the Williams Peak quadrangle, Juab and Millard Counties, Utah, by L.F. Hintze, 1 pl., 1:24,000, November 1991, Open-File Report 223 $2.00

Interim geologic map of the Duggins Creek quadrangle, Millard County, Utah, by L.F. Hintze, 1 pl., 1:24,000, November 1991, Open-File Report 224 $2.00

Interim geologic map of the Holden quadrangle, Millard County, Utah, by L.F. Hintze, 1 pl., 1:24,000, November 1991, Open-File Report 225 $2.00

Interim geologic map of the Mills quadrangle, Juab County, Utah, by L.F. Hintze, 1 pl., 1:24,000, November 1991, Open-File Report 226 $2.00

Interim geologic map of the Coffee Peak quadrangle, Millard County, Utah, by L.F. Hintze, 1 pl., 1:24,000, November 1991, Open-File Report 227 $2.00

Interim geologic map of the Scipio Lake quadrangle, Millard County, Utah, by L.F. Hintze, 1 pl., 1:24,000, November 1991, Open-File Report 228 $2.00

Interim geologic map of the Logan quadrangle, Cache County, Utah, by J.P. Evans, J.P. McCalpin, and D.C. Holmes, 59 p., 2 pl., 1:24,000, December 1991, Open-File Report 229 $6.70

Interim geologic map of the Gold Bar Canyon quadrangle, Grand County, Utah, by H.H. Doelling, W.A. Yonkee, and J.S. Hand, 73 p., 3 pl., 1:24,000, December 1991, Open-File Report 230 $8.50

"Cane Creek" exploration play area, Emery, Grand, and San Juan Counties, Utah, by C.D. Morgan, 15 p., 10 pl., 1500,000, March 1992, Open-File Report 232 $20.00

Interim geologic map of the Hayes Canyon Quadrangle, Sanpete County, Utah, by David Peterson, 57 p., 3 pl., 1:24,000, March 1992, Open-File Report 233 $8.00

Interim geologic map of the Lucin NW Quadrangle, Box Elder County, Utah, by D.M. Miller and C.G. Oviatt, 44 p., 2 pl., 1:24,000, April 1992, Open-File Report 234 $6.20

Interim geologic map of the Keg Pass Quadrangle, Juab County, Utah, by M.A. Shubat and G.E. Christenson, 106 p., 2 pl., 1:24,000, April 1992, Open-File Report 235 $10.50

Landslide map of the Salt Lake City 30' x 60' quadrangle, by K.M. Harty, 17 p., 1 pl., 1:100,000, May 1992, Open-File Report 236 $3.50

Seismological analysis of four recent moderate (M_L4.8 to 5.4) earthquakes in Utah, by J.C. Pechmann, S.J. Nava, and W.J. Arabasz, 107 p., January 1992, Contract Report 92-1 $8.50

GOTHIC - gas, oil, and thermal history integrated code - source-code, user guide, and sample input and output file, by Dave Deming and D.S. Chapman, 30 p., 1 disk, 360k byte, January 1992, Contract Report 92-2 $4.00

Geology of the Grassy Trail Creek field, Carbon and Emery Counties, Utah, by S.J. Lutz and M.L. Allison, 36 p., February 1992, Contract Report 92-3 $2.75

The origin of gilsonite vein deposits in the Uinta Basin, Utah, by B. Monson and J. Parnell, 27 p., March 1992, Contract Report 92-4 $2.25

Uncovering Sevier overthrust structure and potential hydrocarbon source rock using magnetotellurics, by P. E. Wannamaker and J.M. Johnston, 12 p., April 1992, Contract Report 92-5 $2.00

Energy and mineral resources of Utah, edited by M.L. Allison, (1990 field trip), 1991, 222 p. , Utah Geol. Assoc. Guidebook 18 $12.00

Geology of east-central Utah, edited by T.C. Chidsey, Jr., (1991 field trip), 1991, 394 p., Utah Geol. Assoc. Guidebook 19 $25.00

Hydrocarbon and mineral resources of the Uinta Basin, Utah and Colorado, edited by T.D. Fouch, V.F. Nuccio, and T.C. Chidsey, Jr., (1992 field trip), 1992, 366 p., Utah Geol. Assoc. Guidebook 20 $30.00 (hardbound)

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BITS AND PIECES

MEETINGS

August 17-19 SEPM 1992 Theme Meeting: Mesozoic of the Western Interior, in Fort Collins, CO. Contact Frank G. Ethridge, Dept. of Earth Resources, Colorado State Univ., Fort Collins, CO 80523.

September 11-13 Association for Women Geoscientists meeting, in Denver, CO. Contact Leslie Landefeld, Barranca Resources (303) 278-1292

September 22-25 International Symposium on Radon and Radon Reduction Technology, in Minneapolis, MN. Contact Radon Symposium c/o Conference of Radiation Control, 205 Capital Avenue, Frankfurt, KY 40601. (502) 227-4543.

September 27- Oct 1 American Institute of Professional Geologists Annual Meeting, in Lake Tahoe, NV. Contact Jon Price, AIPG, P.O. Box 665, Carson City, NV 89702. (702) 784-6691.

September 30- Oct 2 National Ground Water Association Annual Meeting, in Las Vegas, NV. Contact NGWA, 6375 Riverside Drive, Dublin, OH 43017; (614) 761-1711.

October 2-9 Association of Engineering Geologists Annual Meeting, in Long Beach, CA. Deadline for submittals is May 1 to Martin L. Stout, AEG Program Chair, Dept. of Geological Science, California State Univ., Los Angeles, CA 90032-8203. For the meeting, contact John Byer, Kovacs-Byer Inc., 11430 Ventura Blvd., Studio City, CA 91604. (818) 980-0825.

October 5-7 Conference on Risk Assessment/Management Issues in the Environmental Planning of Mines. at St. Louis, Missouri. Contact SME Meetings at (303) 973-9550.

October 8-10 Utah Geological Association annual field trip, "Engineering and Environmental Geology of Southwestern Utah" in St. George, UT. Contact Robert C. Rasely, U.S. Dept. of Agriculture, Soil Conservation Service, P.O. Box 11350, Salt Lake City, UT 84092. (801) 524-5026.

October 17-22 American Institute of Hydrology Conference "Interdisciplinary approaches to hydrology and hydrogeology" in Portland, OR. Contact AIH, 3416 University Ave. SE, Minneapolis, MN 55414-3328; (612) 379-1030.

October 22-29 Geological Society of America annual meeting in Cincinnati, OH. Abstracts deadline is July 8 to Abstracts Coordinator, GSA, 3300 Penrose Place, P.O. Box 9140, Boulder, CO 80301. Contact GSA Meetings Department, P.O. Box 9140, Boulder, CO. (303) 447-2020.

ERRATUM

The last issue of Survey Notes p. 14, column 2, penultimate line should read "... ostracodes and branchiopods..." rather than brachiopods. Apologies to Dr. Stokes and all crustaceans are in order.

The Harris mine in the Wah Wah Mountains of Utah is the only place in the world where red beryl is found - they are nearly always green, pink, blue, or yellow (emeralds and aquamarine are members of the beryl family). The reds are hot red and rarer than rubies.

RECENT PUBLICATIONS OF INTEREST

(not available from UGS Sales)

Earthquakes in Utah 1884-1989, by S.K. Goter, 1991, U.S. Geological Survey Open-File Report 91-0128, scale 1:500,000.

Rates of soil development from four soil chronosequences in the southern Great Basin, by J.W. Harden and others, 1991, Quaternary Research, v. 35, p. 383-399.

Hydrology of Heber and Round Valleys, Wasatch County, Utah with emphasis on simulation of ground-water flow in Heber Valley, by D.M. Roark and others, 1991, Utah Department of Natural Resources Technical Publication 101, 93 p.

Is there enough water for both farms and cities along the Wasatch Front, Utah Science 1991, published by Utah State Univ. Agricultural Experiment Station.

The Academy of Natural Sciences has just published a seventy-five page reference for earth science educators called *Resource Guide to Earth Sciences*. It explores a range of earth science topics and includes numerous activities, illustrations and resource suggestions. The first printing is available free to educators in the earth sciences by writing to the Academy on school letterhead. Send request to: Scott Stepanski, Education Department, Academy of Natural Sciences, 1900 Ben Franklin Parkway, Philadelphia PA 19103-1195.

USU/SALT LAKE COUNTY QUAKE VIDEO WINS AWARD

The Utah Chapter of the American Planning Association gave an Award of Merit for Information Technology to three Utah State University (USU) faculty and two Salt Lake County professionals for their videotape "Earthquake Awareness and Hazard Mitigation." USU participants were sociologist Gary Madsen, civil/environmental engineer Loren Anderson, and producer Steve Soulier from the Instructional Technology Department. Salt Lake County geologist Craig Nelson and Jerold Barnes, Director of the Salt Lake County Planning Division, were the other participants in preparing the video.

The 23-minute video presents much general information on earthquake hazards as well as specific information on hazards in Salt Lake County. Created as a joint project of USU and the Salt Lake County Planning Division with grant funds from the U.S. Geological Survey's National Earthquake Hazard Reduction Program, the video's production costs ran approximately $6,000 (typical video programs run about $1,000 per minute). It represents the first local government earthquake education video in the United States. It is also the first collaborative effort to integrate information about planning, geological, engineering, and sociological aspects of Wasatch Front earthquake hazards. This innovative use of information technology has succeeded in translating complex technical information into an easy-to-understand format to educate and inform Utah citizens about earthquake hazards and risk in their own backyards.

The video explains why earthquakes occur and where they occur in the western United States. The program also discusses potential earthquake hazards and the types of damage that are likely to occur. It provides suggestions on reducingrisks, including building to code standards, strengthening existing structures, planning and zoning to control building in high-hazard zones, and preparing individually for earthquakes.

By helping people understand earthquake hazards, this program helps bridge the gap between "what will happen" and "what I can do about it." A better understanding by the public of the potential impacts posed by earthquake hazards means better acceptance and support of natural-hazard ordinances and promotion of responsible land-use policies as well as promoting personal preparedness.

The Salt Lake County Planning Division ((801) 468-2061) keeps 10 copies of the video available for free checkout by the public. Over 2,500 viewers in the past year including local government officials, members of community councils, individuals from school classes at all education levels, church groups, and neighborhood organizations have had an overwhelmingly positive response to the video. Interest in earthquakes and support for public policy steps such as building code and zoning improvements was found to be surprisingly high in a survey of Salt Lake County residents and community leaders conducted as part of the project. Because Utah has earthquake hazards over much of the state, not just in Salt Lake County, Drs. Madsen and Anderson obtained funds to produce a more generic version of the video, useful in communities throughout Utah. This video is available from the Utah Geological Survey as Public Information Series 10, Earthquake Awareness and Risk Reduction in Utah. Its cost is $6.00 plus $2.50 for shipping (Utah residents must add 6.25 % sales tax).

TEACHER'S CORNER

by Sandra Eldredge

There are several workshops and field trips available this summer for teachers.

The Mining Education Project. The National Energy Foundation and the Utah Mining Association offer teacher workshops through this project. The conferences and workshops combine field experiences and classroom activities. For information on the 3-day summer conference in Salt Lake City, the 2-day summer conference in Price, or the 10-hour fall workshops in Delta and along the Wasatch Front, contact Dari Scott at 278-9117 or Bob Poulson at 539-1406.

Volcanoes, deserts, and more - St. George/Cedar City (sponsored by the Utah Geological Association). On October 24 and 25 come explore ancient volcanoes and deserts, and see present landforms in the St. George, Snow Canyon State Park, Cedar City, and Cedar Breaks areas. Credit (1.0) will be offered to teachers through the Utah Museum of Natural History. Keep these dates marked on your calendar for an exciting event, including a catered dutch oven dinner in Snow Canyon! Details will be advertised later, or call Sandy Eldredge at the Utah Geological Survey 467-7970, or Deedee O'Brien at the Utah Museum of Natural History 581-6928 for more information.

Director's Corner, continued

The money was appropriated to the UGS to begin the program. We are committed to working with other agencies with seismic instrumentation in Utah such as the University of Utah Seismograph Stations, the U.S. Geological Survey, and the U.S. Bureau of Reclamation to establish a state strong-motion consortium. There is a good chance that the state's financial commitment can be leveraged with matching funds from federal and private sources.

Uniform Building Code

Usually, the UGS is not a very controversial agency. We don't have any regulatory powers but rather provide unbiased technical and scientific information for a variety of users. So we were more than a little surprised at the controversy generated by a proposal based on our work to amend the UBC to upgrade much of the Wasatch Front from seismic zone 3 to seismic zone 4. After five years of intensive study as part of the U.S. Geological Survey's National Earthquake Hazard Reduction Program, much new information is now available on earthquake ground shaking. The zonation proposal resulted from a UGS evaluation of the building-code implications of this new data. For more than a year UGS staff presented and explained our conclusions to building officials, professional groups, and the public. The UBC Commission, after receiving input at a well-attended public hearing, endorsed the change but decided to let the final decision go to the national body of the International Conference of Building Officials (ICBO) which publishes the UBC and has more experience in these issues. Then, in the last weeks before the national meeting, opponents generated widespread apprehension about the proposal. The Utah Chapter of the ICBO abandoned its neutral stance to come out against the proposed change just before the decision was to be made. As a result of the controversy and the mixed signals coming out of Utah, the national ICBO voted against the proposal.

None of this changes scientific reality, however. Our interpretations and conclusions stand. The Wasatch Front exceeds the minimum criteria for seismic zone 4 and the UGS has fulfilled its duty to inform the appropriate authorities of the potential for greater ground shaking along the Wasatch Front. Those responsible for amending the UBC apparently decided that other, non-geologic concerns of implementing seismic zone 4 are more important than dealing with the effects of greater ground shaking.

The western Traverse Mountains earthquake is a gentle reminder of the seismic danger that hangs over all of us. I believe an important opportunity to strengthen at least our new buildings has been missed, and I fear that future generations will end up paying for this decision.■

CAMERON COVE SUBDIVISION DEBRIS FLOW

by W.E. Mulvey and Mike Lowe

On September 7, 1991, approximately 8 p.m., a debris flow damaged several houses in the Cameron Cove Subdivision in North Ogden, Utah. The debris flow originated in an unnamed canyon in the Wasatch Range northeast of the subdivision and was triggered by unusually heavy rainfall in the North Ogden area. Over a 24-hour period, rainfall in the area ranged from 2.5 to 8.4 inches, setting a new state record for a 24-hour period (Brenda Graham, National Weather Service, oral commun., September 11, 1991).

Broad levees; view to SW.

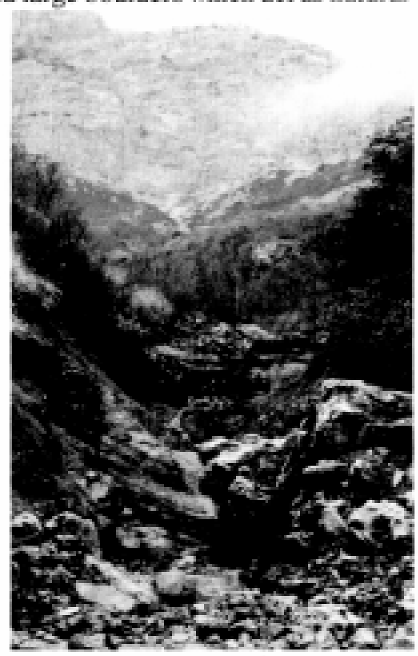
Runoff from the storm concentrated in channels on the Lower Cambrian Tintic Quartzite cliffs at the head of the unnamed canyon. During heavy rains, these channels often form waterfalls, cascading several hundred feet to talus slopes below (Bruce Dursteler, Mayor, North Ogden, oral commun. September 9, 1991). The concentration of heavy runoff apparently mobilized talus and other debris along seasonal tributary channels at the base of the cliffs. The tributary flows moved down the canyon, combined with the flow in the main channel, and scoured additional material from the channel for the debris flow. The flow exited the canyon mouth and traveled down an alluvial fan for a distance of 1,300 feet before reaching the subdivision. One house was destroyed, eight others had considerable damage, and 79 had minor damage due to the debris flow, while flood waters damaged an additional 640 homes.

Overview of debris-flow deposit and damaged houses. Ogden Divide highway visible in lower center.

The debris in the flow was mostly coarse clastic material with boulders up to 7 feet in diameter. The matrix material was a sandy silt, with very few organics. Silts concentrated around the homes, which apparently slowed the flow and ponded debris.

The estimated volume of material deposited by the flow is 26,000 cubic yards. Examination of the main and tributary channels showed that the debris flow incorporated material in channels from the base of the cliffs to the mouth of the canyon. Scour in the main channel averaged 5 to 6 feet deep, but in places was as much as 17 feet. Much debris remains in the channel, primarily behind large boulders which act as natural dams.

Although a wildfire damaged vegetation on slopes in the drainage basin below the cliffs in August 1990, debris and sediment contribution from the burned slopes was minor, due to rapid revegetation. On slopes below the cliffs, slope-wash erosion locally removed 1 to 2 inches of soil. Grasses were absent in these areas, and cobbles were left standing on pedestals of soil surrounded by small rills.



Boulders and scoured bedrock in the channel with source area visible in background.

Heavy rainfall, steep topography (specifically the cliffs at the canyon's head), and an abundance of available channel debris combined to cause the 1991 Cameron Cove Subdivision debris flow. At present, stream channels in the unnamed canyon still contain debris that could be mobilized and incorporated into another debris flow. Thus the hazard from debris flows continues.

Levees from prehistoric debris flows on the alluvial fan at the mouth of the canyon indicate that the recent large debris flow was not a geologically unusual event for this canyon, but instead is part of an ongoing alluvial-fan-building process. Debris flows will likely occur again on this fan. Houses remain at risk and a long term, permanent solution to the problem is needed. State and local officials are looking at various alternatives to protect the subdivision from future debris flows. Debris-flow hazard maps prepared under the UGS-sponsored County Geologist Program are now available for North Ogden and much of the Wasatch Front, and these are being used to guide new development in hazardous areas.

Geologic Projects in Utah 1991

by Michael Ross

The Geologic Projects in Utah summary for 1991 (although a bit late) provides geoscientists with information on reported active or nearly completed geologic studies in the state. The summary contains information on: 1) Investigator(s), 2) Organization(s), 3) County(ies), 4) Specific geographic or geologic area(s), 5) Type of study, 6) Title or topic of project, and 7) Scale of mapping (if relevant). Special searches of the database can be made on the following fields: investigator, county, type of study, and scale of mapping.

The UGS is beginning to compile the 1992 summary and would greatly appreciate receiving replies from all investigators expecting to work in Utah next year. Please fill out the information form enclosed in this issue of Survey Notes and mail to the UGS. The 1992 summary will be published in the next issue of *Survey Notes,* therefore please respond as soon as possible. Thank you.

EXPLANATION FOR COUNTY CODES

Beaver	BE
Box Elder	BX
Cache	CA
Carbon	CR
Daggett	DG
Davis	DA
Duchesne	DU
Emery	EM
Garfield	GA
Grand	GR
Iron	IR
Juab	JU
Kane	KA
Millard	MI
Morgan	MO
Piute	PI
Rich	RI
Salt Lake	SL
San Juan	SJ
Sanpete	SA
Sevier	SE
Summit	SU
Tooele	TO
Uintah	UI
Utah	UT
Wasatch	WS
Washington	WA
Wayne	WN
Weber	WE
Statewide	SW

EXPLANATION FOR TYPE OF STUDY CODES

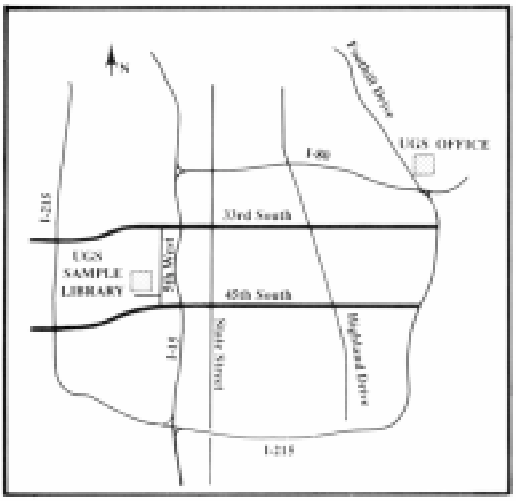
Economic Geology:	
a. General	EC
b. Coal	CG
c. Geothermal	GG
d. Minerals	MG
e. Petroleum	PG
f. Salines	SG
Engineering Geology	EG
Environmental Geology	EV
Geochemistry	GC
Geochronology	GR
Geologic Hazards	GH
Geologic Mapping	GM
Geophysics	GP
Hydrogeology	HG
Mineralogy	MN
Paleomagnetism	PM
Paleontology:	
a. Undiferrentiated	PU
b. Invertebrate	PI
c. Vertebrate	PV
Palynology/Paleobotany	PY
Petrology	PT
Quaternary Geology	QG
Sedimentology	SD
Stratigraphy	SR
Structural Geology/Tectonics	ST
Volcanology	VO

Geologic Projects in Utah Summary - 1991

(UGS) - Cooperative Funding

Investigator(s)	Organization(s)	County(ies)	Location	Study Type	Title/Topic	Map Scale
Allison, M.L., and Lutz, S.J.	UGS & UURI	CR,EM	Northern San Rafael Swell area	PG	Geology of the Grassy Trail Creek Oil Field	24000
Allison, M. Lee	UGS	JU, MI, TO	Western Utah & B&R Trans. Zone	ST	In situ Stress & Geothermal Systems in B & R	-0-
Anderson, J.	Kent St. (UGS)	GA, IR	SW Utah/Southern Plateaus	GM,SR, ST	Nature & Origin of the Markagunt Megabreccia	24000
Bilbey, S.A.	UT Natural History	DU, UI	NE Utah/Split Mtn./Dinosaur Quarry Quadrangle	SP, PV	Morrison Fm NE Ut; emphasis Stegosaur site	-0-
Bishop, C.E., and others	UGS	JU, MI, TO	West-central Utah/Eastern B&R	MG	Mineral Resources of Delta 1 X 2 Quadrangle	250,000
Blackett, B., and others	UGS	BE, IR, PI	Southwestern Utah	MG	Mineral Resources of Richfield 1 X 2 Quadrangle	250,000
Bowman, J.R., & Barnett, D.E.	U of U (UGS)	DA	Antelope Island & N. Wasatch Mountains	GR, PT	Geochron. & Pet. of Farmington Canyon Complex	-0-
Bugden, M.G.	UGS	WA	Southwestern Utah	EC	Economic Resources of Washington County, Utah	-0-
Bugden, M.G., & Sprinkel, D.A.	UGS	WA	SW Utah, NE of BeaverDam Mountains	GM, SR, VO	Geology of Snow Canyon State Park	12000
Caputo, M.V.	Miss. State Univ.	EM, WN, KA	Colorado Plateau	SD, SR	Facies & Basin Evolution of Middle J Strata	-0-
Case, W.F., and others	UGS	SW	Statewide	MG	Dimension Stone Catalogue of Utah	-0-
Chan, M.A.	U of U (UGS)	WS	Wasatch Mtns/Big Cottonwood Canyon	SD, SR, GM	Tidal Rhythmites in PC Big Cottonwood Formation	-0-
Chan, M.A.	Univ. of Utah	CR, EM	CO Plateau/West side San Rafael Swell	SD, SR	Depositional Sequences in the K Emery Sandstone	-0-
Chenoweth, W.L.	Consult. (UGS)	SJ	SE Utah, Canyonlands	MG	Uranium Deposits of the White Canyon District	-0-
Chidsey, T.C., & Morgan, C.D.	UGS	SW	Statewide	PG	Summary of Drilling Activity in Utah	-0-
Chidsey, T.C., & Morgan, C.D.	UGS	SW	Statewide	PG	Source Rock Bibliobraphy of Utah	-0-
Chidsey, T.C., & Mayo, A.	UGS & BYU	SW	Statewide	PG	CO^2 Generation, Migration, & Potential in ...	-0-
Chisey, T.C., & Morgan, C.D.	UGS	SJ	Paradox Basin T26S R23E	PG	Mustang Field, San Juan Co., Utah	-0-
Chisey, T.C., & Morgan, C.D.	UGS	SW	Statewide	PG	Utah/Rocky Mountain Gas Atlas	-0-
Chisey, T.C., & Morgan, C.D.	UGS	SW	Statewide	PG	Crude Oil Sampling	-0-
Chisey, T.C., & Morgan, C.D.	UGS	SW	Statewide	PG	Horizontal Drilling Potential in Utah	-0-
Chidsey, T.C., and others	UGS	SW	Statewide	PG	Precambrian Source Rock Potential in Utah	-0-
Coogan, J.	Univ. WY (UGS)	RI	Black Mtn./Bear Lake Fault Area	GM	Geology of the Sheeppen Creek Quadrangle	24000
Coogan, J.	Univ. WY (UGS)	RI	Black Mtn./Bear Lake Fault Area	GM	Geology of the Bear Lake South Quadrangle	24000
Cook, K.	U of U (UGS)	JU, UT	Southern Wasatch Mountains	GP	Bouguer Gravity Map of Southern Wasatch Front	-0-
Davis, F.D.	UGS	MI	Sevier Desert	GM, QG	Geology of the McCornick Quadrangle	24000
Doelling, H.H.	UGS	GR	Arches National Park/N Paradox Basin	GM	Geology of the Windows Quadrangle	24000
Doelling, H.H.	UGS	GR	Arches National Park/N Paradox Basin	GM	Geology of the Fisher Towers Quadrangle	24000
Doelling, H.H.	UGS	GR	North Paradox Basin/Salt Anticline Ar	GM	Geology of the Merrimac Butte Quadrangle	24000
Doelling, H.H.	UGS	TO	Eastern Great Salt Lake Desert	GM	Geology of the Gray Back Hills Quad.	24000
Doelling, H.H.	'UGS	GR	Arches National Park/N Paradox Basin	GM	Geology of the Mollie Hogans Quadrangle	24000
Doelling, H.H.	UGS	GR	Eastern Utah/Colorado Plateau	GM	Geology of Southern Grand Co., Utah	100,000
Doelling, H.H., & Ross, M.L.	UGS	GR	N Paradox Basin/Salt Anticline Ar	GM, ST, SR	Geology of the Big Bend Quadrangle	24000
Doelling, H.H., and others	UGS	GR	N Paradox Basin/Salt Anticline Ar	GM, ST, SR	Geology of the Moab Quadrangle	24000
Eagan, Keith E.	Utah State Univ.	BX, CA	Wellsville Mountains, N. Utah	GR, PU, SD	Camb. Stromatolites as Geochronometers & ...	-0-
Eldredge, S.	UGS	SJ	Scenic Southeastern Utah	EC	Economic Resources of San Juan County, Utah	-0-
Eliason, G.C.	Star Min. Recovr	BE	Western Utah/Picacho Peak	MN, MG	Mineralogy & Metallurgy	24000
Evans, J.P.	USU (UGS)	CA	Cache Valley, Bear River Mountains	GM	Geology of the Logan Quadrangle	24000
Evans, J.P., & Oaks, R.Q. Jr.	Utah State Univ.	CA, RI	Northern Utah	ST	Subsurface structures -- western thrust belt	100,000
Felger, T.	UM-Duluth (UGS)	JU	Juab Valley/W. Gunnison Plateau	GM	Geology of the Skinner Peaks Quadrangle	24000
Fiesinger, D.W.	USU	BX	Northwestern Utah	SR, PT, GR	Tertiary-Quaternary Volcanism in W. Box Elder Co.	-0-
Forman, S.L. & Stafford, T.W., Jr	Univ. CO (UGS)	WE	Wasatch Front north of SLC	QG, GH	C-14 Dating Soil Horizons assoc. Holocene Faults	-0-
Gwynn, J.W.	UGS	SW	Statewide	SG, PG, GC	Characterization of Oil-well Brines in Utah	-0-
Hammond, B.	BYU/BLM (UGS)	WA	Beaver Dam Mountains	GM, ST	Geology of the Jarvis Peak Quadrangle	24000
Harty, K.M.	UGS	TO	Oquirrh and Stansbury Mountains	GH	Rockfall, Landslide & Debris-flow maps of...	24000
Harty, K.M., and others	UGS	SW	Statewide	GH	Geologic Hazards Bibliography of Utah	-0-
Hintze, L.F.	UGS	WA	SW Utah, Beaver Dam Mountains	GM	Geology of the Shivwitz Quadrangle	24000
Hintze, L.F.	UGS	MI	Burbank Hills - Western Utah	GM	Geology of the Big Jensen Pass Quadrangle	24000
Hintze, L.F.	UGS	WA	SW Utah, NW of Beaver Dam Mountains	GM	Geology of the Motoqua Quadrangle	24000
Hintze, L.F.	UGS	WA	SW Utah and SE Nevada	GM	Geology of the Scarecrow Peak Quadrangle	24000
Hintze, L.F.	UGS	MI	Burbank Hills - Western Utah	GM	Geology of the Burbank Pass Quadrangle	24000
Hintze, L.F.	UGS	MI	Burbank Hills - Western Utah	GM	Geology of the Deadman Point Quadrangle	24000
Hintze, L.F.	UGS	WA	SW Utah Beaver Dam Mountains	GM	Geology of the West Mountain Peak Quadrangle	24000
Hintze, L.F.	UGS	WA	SW Utah, South of Bull Valley Mountains	GM	Geology of the Gunlock Quadrangle	24000
Hintze, L.F.	UGS	MI	Burbank Hills - Western Utah	GM	Geology of the Cedar Pass Quadrangle	24000
Hintze, L.F.	UGS	WA	SW Utah, Beaver Dam Mountains	GM	Geology of the Castle Cliff Quadrangle	24000
Hintze, L.F., & Anderson, E.	UGS & USGS	WA	SW Utah & SE Nevada	GM, ST, SR	Geology of the Dodge Spring Quadrangle	24000
Hintze, L.F., & Davis, F.D.	UGS	MI	Western Utah/Great Basin	GM, EC, GH	Geology of Millard County, Utah	100,000
Hucka, V.J., & Bodily, D.	Univ. of Utah	CR, EM	Book Cliffs	CG	Formation & Retention of Methane in Coal	-0-
Huffman, A.C., and others	USGS	GA, GR, SJ	SE Utah, SW Colorado	PG, SR, ST	Geologic Evolution of the Paradox Basin	-0-

Investigator(s)	Organization(s)	County(ies)	Location	Study Type	Title/Topic	Map Scale
Jensen, M.E.	Dept. Environ. Qual.	BX	Northern Wasatch Mountains	GM	Geology of the Brigham City Quadrangle	24000
Jensen, M.E., and others,	State & Federal	BX, WA	Mantua Valley & Santa Clara	HG	Hydrogeologic mapping for protect. @ springs	24000
Kurlich, R.A., III	Kent State *(UGS)	GA	SW Utah/W. Paunsaugunt Plateau	GM	Geology of the Hatch Quadrangle	24000
Leatham, W.B.	CSU-San Bernad.	CA, RI, WE	Bear Lake Basin	PI	Taphonomy of Pleistocene Gastropods	-0-
Leatham, W.B.	CSU-San Bernad.	MI, TO	West-central Utah	PI	Conodant Biostratigrpahy of Ord. & Sil. Rocks	-0-
Leschin, M., & Kolesar, P.T.	Utah State Univ.	SU	North side of Uinta Mountains	GC, HG	Influence of rx type on H20 chemistry, Bear River	-0-
Little, W.W.	Univ. of CO	GA, KA	S Utah/Kaiparowits Plateau	PT, SD, SR	Study Fluvial Arch. & Ss Pet./K Kaiparowits Form.	-0-
Lowe, M.	UGS	WE	Ogden Valley	QG, GM	Surficial Geology of Ogden Valley, N. Wasatch	24000
Lowe, M.	UGS	WS	North-Central Utah	GM, QG, GH	Surficial Geology of Wasatch County, Utah	24000
Lowe, M., and others	UGS	DA, SL, UT	Wasatch Mountains	GH	Hazards of Liquefaction-induced landslides	24000
Maldonado, F., and others	USGS	WA, IR	SW Utah/B&R Col Plat Trans. Zn	GM	Geology of the St. George 30 x 60 Quadrangle	100,000
McCalpin, J.	USU (UGS)	CA	N Utah, Cache Valley	QG, ST, GH	Neotectonic Def. Along E. Cache Valley FZ	-0-
McDermott, J.G.	NIU (UGS)	JU	San Pitch Mountains	GM	Geology of the Chriss Canyon Quadrangle	24000
Miller, D.M.	USGS (UGS)	TO	B & R/Silver Island Mountains	GM	Geology of the Graham Peak Quadrangle	24000
Miller, D.M.	USGS (UGS)	BX	Promontory Mountains	GM	Geology of the Golden Spike Mtnl. Quadrangle	24000
Miller, D.M.	USGS (UGS)	TO	NW Utah/NE Nevada; S Pilot Mtns	GM	Geology of the Miners Canyon Quadrangle	24000
Miller, D.M.	USGS (UGS)	BX	Northern Pilot Range	GM	Geology of the Lucin Quadrangle	24000
Miller, D.M.	USGS (UGS)	TO	B & R/Pilot Valley Playa	GM	Geology of the Silver Island Pass Quadrangle	24000
Morgan, C.D.	UGS	BX, CA, WE	Northern Wasatch Mountains	PG	Petroleum Potential of N. Wasatch Front	100,000
Mulvey, W.E.	UGS	GR	East-central Utah/Colorado Plateau	GM, GH, QG	Geologic Hazards of Moab/Castle Valleys	24000
Mulvey, W.E.	UGS	GR	Eastern Utah/Colorado Plateau	GM, GH, QG	Quaternary Geology of S. Grand County, Utah	100,000
Nelson, S.T., & Davidson, J.P.	UCLA	GA, GR, SJ	La Sal Mountains/Henry Mountains	GC, PT	Geochemistry & Isotope Geology of the	-0-
Oaks, R.Q.	USU (UGS)	CA	Bear River Range	GM	Geology of the Temple Peak Quadrangle	24000
Olig, S.S.	UGS	SW	Statewide	EG, GH	Earthquake Ground Shaking in Utah	-0-
Olig, S.S.	UGS	TO	West flank of Oquirrh Mountains	EG	Paleoseismic Study of N. Oquirrh Fault Zone	-0-
Oviatt, C.G.	KSU/UGS	SU	Western Uinta Mountains	GM, QG	Quaternary Geology Upper Weber River Drainage	50000
Parry, W.T., & Wilson, P.N.	U of U (UGS)	TO, UT	Southern Oquirrh Mountains	GR, MG, MN	Argillic alter. & Au-bearing faults, Mercur District	-0-
Pashley, F.E.	Weber State (UGS)	SA	Wasatch Plateau	GM, SR	Geology of the Huntington Resvr. Quadrangle	24000
Pashley, F.E.	Weber State (UGS)	SA	Sanpete Valley/Wasatch Plateau	GM, SR	Geology of the Mount Pleasant Quadrangle	24000
Pequera, N., & Mitra, G.	U. of Rochester	JU, MI	Canyon Range, central Utah	ST	Growth History of Fault-Propagation Fold	-0-
Price, D.	U of Utah (UGS)	BE	Southern Mineral Mountains	GM, ST	Geology of the Cave Canyon Quadrangle	24000
Rollins, K.M.	BYU (UGS)	SL	Wasatch Front/Salt Lake Valley	EG, GH	Earthquake Damage Potential Map for SLV	-0-
Ross, H.P., and others	UURI & UGS	BE, IR	Escalante Desert	GG, GP	Exp. for Concealed Hydrothermal Sytyems in ...	-0-
Ross, M.L.	UGS	GR	Northern La Sal Mountains	GM, PT, GC	Geology of the Mount Waas Quadrangle	24000
Ross, M.L.	UGS	GR	Northern La Sal Mountains	GM, PT, GC	Geology of the Warner Lake Quadrangle	24000
Ross, M.L., & others	UGS	GR	N. Paradox Basin/Salt Anticline Ar	GM, SR, ST	Geology of the Rill Creek Quadrangle	24000
Rowley, P.D., and others	USGS	IR, WA	SW Utah/Basin & Range/Trans Zn	GM	Geology of the Cedar City 30 x 60 Quadrangle	100,000
Scott, R.B., and others	USGS & others	IR, KA, WA	SW Utah & SE Nevada	ST, SR, GC	Geology of B & R/Colorado Plateau Trans. Zn.	100,000
Shubat, M.A.	UGS	JU	West Tintic Mountains	GM, MG	Geology of the West Tintic Mountains	24000
Shubat, M.A., & Tripp, B.	UGS	IR, KA, WA	Southwestern Utah	MG	Mineral Occurences of Cedar City 1 x 2 sheet	250,000
Solomon, B.J.	UGS	WE	Ogden Valley, N. Wasatch Front	EV, GH	Identification of Radon Hazard in Q Deposits	-0-
Solomon, B.J.	UGS	WA	Southwestern UT/St. George Area	EV, GH	Identification of Radon Hazard in Q Deposits	-0-
Sorensen, M.L.O.	USGS (UGS)	JU, UT	Southern Wasatch Mountains	GM, ST, MG	Geology & Ore Deposits, Mt. Nebo/Santaquin Dis	24000
Sprinkel, D.A.	UGS	JU, SA, UT	CP/B & R Trans Zone/Wasatch Mountains	SR	Stratigraphy of J Twin Cr. Ls & Arapien Sh	-0-
Sprinkel, D.A., & Weiss, M.P.	UGS & Niu	SA	Sanpete Valley/Wasatch Plateau	GM	Geology of the Danish Knoll Quadrangle	24000
Sprinkel, D.A., & Weiss, M.P.	UGS & NIU	SA	Sanpete Valley/Wasatch Plateau	GM	Geology of the Ephraim Quadrangle	24000
Sprinkel, D.A., and others	UGS, NIU, USGS	SA	Sanpete Valley/S. Gunnison Plateau	GM, SR, ST	Lithofacies & Structure of Christianburg Area	24000
Trexler, J.J., & Cashman, P.A.	UN-Reno (UGS)	TO	Western Utah, Bs & Rg	SR, SD	Stratigraphy & Setting of D Stansbury Formation	-0-
Tripp, B.	UGS	SW	Statewide	MG	High-Ca Limestone Occurrences of Utah	-0-
Wannamaker, P.E.	U of U (UGS)	-0-	Western Utah	GP, PG	Uncovering Sevier Struc. w/ Magnetotellurics	-0-
Weiss, M.P. & Lawton, T.	NIU & NMSU (UGS)	SA, JU	San Pitch Mountains/Sanpete Valley	GM, SR, ST	Geology of the Wales Quadrangle	24000
Welsh, John E.	Univ. of Utah	EM, TO, WA	Central Utah, Au Hill, Beaver Dam	-0-	-0-	-0-
Willis, G.C.	UGS	GR	Colorado Plateau/Roan Cliffs	GM	Geology of the PR Springs Quadrangle	24000
Willis, G.C.	UGS	GR	Colorado Plateau/Westwater Canyon	GM	Geology of the Agate Quadrangle	24000
Willis, G.C.	UGS	GR	Colorado Plateau/Book Cliffs	GM	Geology of the Dry Canyon Quadrangle	24000
Willis, G.C.	UGS	GR	Colorado Plateau/Book Cliffs	GM	Geology of the Camp Canyon Quadrangle	24000
Yonkee, A.	Weber State Univ.	DA	Antelope Island/Northern Utah	GM, ST, PT	Structure & Petrology of Precambrian-Camb. Rxs	-0-



WHERE DID THOSE UGS PEOPLE GO?

Utah Geological Survey moved from Research Park to new offices located at **2363 S. Foothill Drive, Salt Lake City, UT 84109-1491, phone (801) 467-7970.** The new facilities include larger offices, sales and library areas, and an elevator for wheelchair access. Visit the new UGS Monday-Friday 8 a.m.-5 p.m. The **Sample Library** houses the cuttings and core for over 4,000 drill holes in Utah. Facilities are at **4060 S. 500 W. #4, phone (801) 266-3512.**

New UGA Guidebook Available

Hydrocarbon and Mineral Resources of the Uinta Basin, Utah and Colorado, 1992 Special Symposium Guidebook 20 is now available for sale at the Utah Geological Survey. This publication was a highlight of the recent Bureau of Indian Affairs Uinta Basin Symposium in Vernal, Utah. Topics covered in the guidebook include: *Leasing of Allotted Properties of the Uintah and Ouray Reservation; How to Secure a Mineral Access Agreement and Right-of-Way for the Development of an Indian Oil and Gas Lease on the Uintah and Ouray Indian Reservation, Utah; Oil and Gas in Uppermost Cretaceous and Tertiary Rock, Uinta Basin, Utah; Oil Shale Resources of the Uintah and Ouray Indian Reservation, Uinta Basin*, and the *UGA Eastern Uinta Basin Field Trip*. The guidebook was edited by Thomas D. Fouch, Vito F. Nuccio, and Thomas C. Chidsey, and the cover illustration was produced by Kessley LaRose and Erica L. Welsh, the winners of the BIA-sponsored poster design contest, with the cover design by Patti MaGann of the UGS. This 366-page hard-bound guidebook is $30 and can be ordered by filling out the Order Form on page 22 of this issue of *Survey Notes*.

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