SURVEY NOTES

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LANDSLIDES

COVER DESIGN: JULIA McQUEEN

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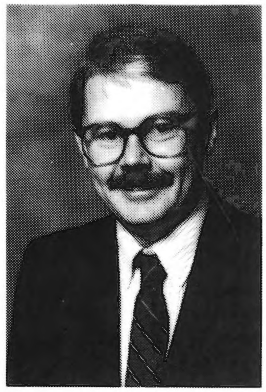

THE DIRECTOR'S PERSPECTIVE *by M. Lee Allison*

The Loma Prieta earthquake of October 17, 1989, wasn't just felt in Northern California. It reverberated across the country, shaking the complacency of those of us living in earthquake country as well as those who sit in the even more shakable halls of government. In the few months since that devastating earthquake there hasn't been a week without some kind of reminder of the dangers we face in Utah, particularly along the Wasatch Front.

Newspaper, radio, and television stories have addressed the potential for earthquakes, how to prepare for them, and what is likely to happen afterwards. An estimated 15,000-plus people attended the "After the Shock" earthquake program at the Salt Palace in February, 1990. The UGMS, along with our sister agencies that deal with earthquakes — Utah Division of Comprehensive Emergency Management and the University of Utah Seismograph Stations — have responded to vast numbers of inquiries from citizens, teachers, local officials, and builders about earthquakes in Utah.

With this heightened awareness, many of us in the geologic, seismologic, and engineering communities felt that the time had arrived when the state's shortcomings in evaluating and mitigating earthquake hazards should be dealt with in a thorough manner. State legislators who had been trying to deal with such problems for years suddenly found their colleagues much more receptive to taking legislative action. Other legislators, shocked at just how poorly prepared Utah is in many ways, proposed new legislation. The possibility of a revenue surplus for the state this year also helped fuel the perception that now was the time to address some long-neglected problems.

As a result, 6 bills were introduced into the Utah House or Senate dealing with various aspects of earthquakes and other natural hazards preparedness and mitigation. Unfortunately, none of them passed. Whether they cost nothing or $3 million, whether they sailed through committee unanimously or were loudly debated in the halls of the Capitol, not a single bill came out of the 1990 Utah legislative session. Most of them died quietly, of neglect, disappearing in the confusion of the last few days of the session as lawmakers dealt with more immediate issues. As one senator told me, "We didn't have thousands of people in the Capitol screaming for earthquake bills."

What is unfortunate is that we may have missed an opportunity that will not be repeated for many years to come. What are the chances that public and government awareness of the earthquake danger will stay at the high level it is now? What is the chance of surplus state revenues being available when (and if) these bills are brought forward again? I think a lot of the people of Utah believe that their state and local officials are prepared to handle a major earthquake here. They see the preparedness and response in California and expect that we can do the same here. The hard reality is, however, that Utah is decades behind California in a broad variety of earthquake-related issues.

Those of us who have a responsibility to deal with earthquakes are struggling to do everything we can, but I know it is not enough. My guess is that after the next big quake in Utah there are going to be a lot of recriminations and finger-pointing about why we weren't better prepared. It would be easy to sit back at that time and say "I told you so,"

continued on page 13.

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Landslide Mapping, Hazards, and Historical Landslides In Utah

by
Kimm M. Harty

INTRODUCTION

Landslides are one of the most commonly occurring geologic hazards in Utah and are responsible for significant annual economic loss. The wet years of 1982-1986 resulted in the largest economic losses ever sustained by the state due to natural hazards, and landsliding contributed greatly to those losses. Based on landslide damage incurred by the state between 1973-1983, Utah is among eight states that were recently given a landslide hazard rating of "severe," the highest of five hazard classes (Brabb, 1989). Utah also ranks third in the nation and its territories in terms of largest total landslide damage costs and cost per person during this period (Brabb, 1989). It is estimated that approximately 45 percent of the state is covered by mountains, hills and steep valleys (Brabb, 1989, table 1), terrain that is most conducive to landslides. As population and accompanying urbanization expand up these mountain slopes and hillsides, the risk, or exposure to landslide hazards also increases.

PREVIOUS WORK

Efforts to identify landslides and define the hazard from landsliding began in the 1970s. In this decade and continuing into the 1980s, detailed scale (larger than 1:100,000) landslide inventories were completed for some National Forests (for example, Manti-La Sal, Fish Lake, Wasatch-Cache, Ashley, and Sawtooth). At regional scales (1:100,000 or smaller), several landslide mapping projects were initiated. In the mid-1970s, R.B. Colton and others at the U.S. Geological Survey began a preliminary landslide inventory of Utah using high-altitude aerial photography. Landslides were mapped at 1:125,000 and 1:100,000 scales. Also at the statewide level, Shroder (1971) inventoried some of Utah's largest landslides, presenting data for approximately 600 slides.

Efforts to map landslides increased in the mid- to late-1980s due in part to the numerous slope failures, particularly debris flows, that occurred during the wet years. Several projects were initiated to map 1983 and/or 1984 landslides at detailed scales (for example, U.S. Forest Service, 1983, 1984; Wieczorek and others, 1983; Lips, 1985, Pack, 1985), and at regional scales (for example, Kaliser and Slosson, 1988; Brabb and others, 1989). In addition, Wasatch Front County geologists began mapping and compiling landslide inventory and susceptibility maps for Weber, Davis, Salt Lake, Utah, and eastern Juab Counties (Christenson and others, 1987). The increased awareness of landslide hazards realized during the 1980s also led to more attentive mapping of landslides on state geologic quadrangle maps.

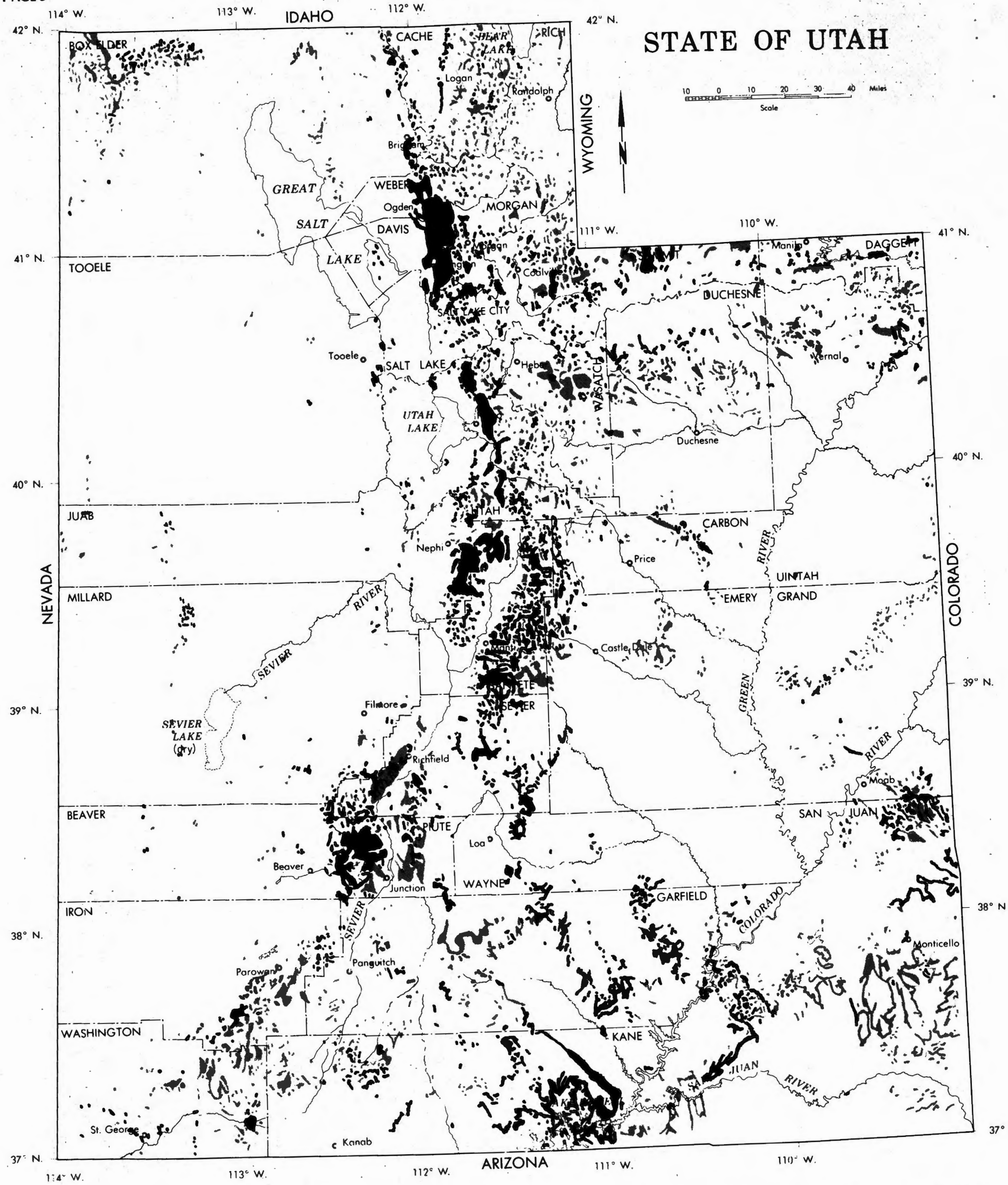
STATEWIDE LANDSLIDE MAP AND DATABASE

In early 1988, the Utah Geological and Mineral Survey (UGMS) began compiling a statewide, 1:500,000-scale landslide map. Compiled on the map are landslides that are common in Utah, such as debris flows, earth flows, slumps, and lateral spreads. The map differentiates between landslides compiled from detailed-scale (larger than 1:100,000) and regional-scale (1:100,000 or smaller) maps. Scheduled for release in 1990, the map is intended to provide researchers, government planners, geotechnical consultants, developers, and citizens concerned with landslide hazards a guide to areas where landslides have occurred and where further detailed study is warranted when making land-use decisions. Landslides on the map were compiled from all known published and unpublished references available, mainly geologic maps; landslide maps prepared by federal, state, and local governments; and consultants' reports. A computerized geologic-hazards bibliography and library maintained by the UGMS was essential to finding relevant unpublished sources. In all, approximately 450 references were found that contained useful landslide maps, and nearly 10,000 landslides appear on the map.

During the map compilation process, all landslides were first compiled onto 1:100,000-scale base maps that will be released in the future. In addition, data for about 2200 landslides for which references provided detailed information were placed in a computerized landslide database. Up to 22 characteristics per landslide can be listed, including information on landslide location, dimensions, slope angle, orientation, age, geologic formations involved, and probable cause of failure.

LANDSLIDE HAZARDS

Conditions favorable to landsliding in Utah exist primarily in mountain ranges and along the edges of high plateaus peripheral to but away from major population centers. However, shallow landslides (slide plane generally less than about 10 feet deep) such as debris slides on steep mountain slopes have generated debris flows that have caused damage and loss of life in urban areas at canyon mouths far-removed from the source. In northern Utah, Davis County communities with residential areas on alluvial fans were especially hard hit by debris flows in the 1920s, 1930s, 1950s, and 1980s. Many of the small towns in the Sanpete Valley at the western edge of the Wasatch Plateau have likewise been affected. In many instances, the debris flows that have caused damage to valley communities have also damaged vital pipelines (water, gas), reservoirs, and roads in canyons.



Generalized landslide map of Utah showing landslides compiled from detailed-scale (•) (larger than 1:100,000) and generalized-scale (/) (1:100,000 or smaller) maps.

Most deep-seated landslides (slide plane generally greater than 10 feet deep) such as rotational slumps and earth flows occur in mountainous regions. However, many also occur in urbanized valley areas along steep slopes bordering streams, particularly in the Wasatch Front where delta deposits of Pleistocene Lake Bonneville have been deeply entrenched by streams. Landslides have been especially common along the Weber and Ogden Rivers in Weber and Davis Counties. Unlike shallow failures that can mobilize into far-reaching, life-threatening debris flows, deep-seated landslides commonly move at a slower rate and cover a shorter distance. Thus, deep-seated landslides present a hazard primarily to the area immediately surrounding the slide, and some warning, such as the appearance of tension cracks at the crown or bulging at the toe, may precede significant landslide movement. Human activity has been a contributing factor to many landslides, and overwatering and oversteepening of slopes has led to damaging landslides throughout the state. In the mountains, large, deep landslides have damaged or destroyed buildings, broken vital life lines and transportation corridors, blocked major rivers, and caused damaging floods.

Rock falls generally occur on steep bedrock slopes lacking vegetation. The hazard from rock falls exists locally throughout the state, but is perhaps most concentrated in the Colorado Plateau of eastern and southern Utah, where vegetation is sparse, and steep, near-vertical cliffs bordering plateaus, mesas, and buttes, and deeply incised stream channels in bedrock are abundant. Rock falls are probably the most frequently occurring of the slope-failure types, but they have caused little damage to personal property and no reported loss of life in Utah. The greatest damage from rock falls has been to transportation corridors, such as roads and railroad tracks, and to utility conduits (pipelines, aqueducts). In the more populated Wasatch Front of northern Utah, the risk from damaging rock falls is rising, as both public and private development moves higher up bench slopes and hillsides.

Earthquake-induced lateral-spread failures, which typically occur on gentle slopes of only a few degrees, have the potential for damaging structures, lifelines, and property over broad areas in what are usually thought of as low-landslide-hazard valley bottoms. All of the mapped lateral-spread deposits in Utah are in the earthquake-prone northern part of the state, mainly near the shores of Great Salt Lake and Utah Lake, where geologic conditions conducive to liquefaction are present. The combination of sandy soils and shallow ground water required for liquefaction also exist along many river channels, reservoir shores, and in valley bottoms.

HISTORICAL LANDSLIDES IN UTAH

Most communities in Utah have experienced severe rainstorms that have caused flooding and landslide damage. The numerous destructive debris flows that struck towns in Davis County during the 1920s and 1930s resulted when summer and fall cloudburst storms eroded hillsides that were intensely burned and overgrazed (Copeland, 1960). Most landslide-triggering rainstorms, however, have been localized such that the dates of the most significant events usually differ from town to town. More geographically widespread than rainstorm-related landslides are those resulting from rapid snowmelt.

During April and May of 1952, a large portion of northern Utah (extending north from Sevier Lake into Idaho, and from Duchesne and Price west into Nevada) experienced severe flooding and landsliding due to rapid melt of a heavier-than-average snowcover (U.S. Geological Survey, 1957). Utah County was especially hard hit by landslides. Highway travel was temporarily blocked by landslides in both Spanish Fork and Provo Canyons, and many debris flows occurred in Hobble Creek Canyon. A water line servicing a number of communities in Carbon County was broken by a landslide in Price Canyon (U.S. Geological Survey, 1957).

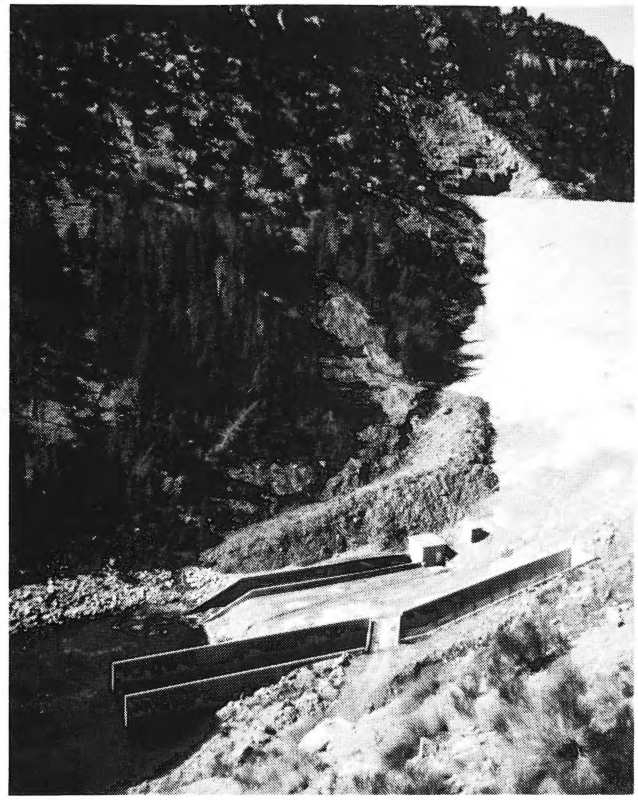
Rapid snowmelt combined with above-average fall and winter precipitation occurred during several consecutive years throughout much of Utah in the early 1980s, which prompted this period to be named the "wet years" or "wet cycle." The water years of 1982-1983 and 1983-1984 were record-breaking over most of the state, and the resulting damage from flooding and landsliding was so extensive in 1983 that 22 of Utah's 29 counties were declared eligible for national disaster assistance (Utah Geological and Mineral Survey, 1983). Like the 1952 rapid snowmelt year, Utah County again experienced destructive landslide events, with the 1983 Thistle landslide topping the list of the most damaging and costliest of the state's landslides. A reactivation of a largely prehistoric landslide, Thistle destroyed sections of Highways 6/50 and 89, and disrupted the tracks of the Denver and Rio Grande Western Railway. The slide blocked the Spanish Fork River to form a 220-foot-high (67 m) natural dam that created Lake Thistle, completely inundating the town after which it was named. A drain tunnel was constructed through the bedrock abutment of the dam to protect the downstream residents of Spanish Fork from the potentially catastrophic consequences of a natural breach and flood. It is estimated that losses due to the Thistle landslide amounted to $337 million (Stephens, 1984, in Kaliser and Slosson, 1988).

March 1989 Cedar Canyon landslide showing damage to Utah Highway 14. Photo by author.

Other notable landslides occurring during the wet years include: an earth flow/debris flow in Twelve Mile Canyon east of Mayfield in Sanpete County that dammed the canyon in late May, 1983, failed, and sent a 30-foot-deep (9.1 m) flood wave surging down the canyon (Anderson and others, 1985); a block slide in the Coal Hill landslide complex in Kane County that reactivated in May of 1983 and disturbed about ½ mile of Utah Highway 29, requiring reconstruction and realignment of one mile of the highway in 1985 at a cost of about $150,000 (F.D. Davis, UGMS, oral communication, April, 1989); the May, 1983 Rudd Canyon debris flow in Davis County that deposited 80,000-90,000 cubic yards (61,000-69,000 cubic meters) of debris throughout a 9-block-square residential area in Farmington, resulting in damage to 35 houses; and the Majors Flat landslide (1984) and Cottonwood Spring debris flow (1986), both in Ephraim Canyon in Sanpete County, that respectively broke a water line and destroyed several U.S. Forest Service buildings, and partially dammed the creek and covered an intake structure for a power plant supplying the town of Ephraim with electricity (Lund, 1986; Baum and Fleming, 1989).

Two deaths can be attributed to landslides that occurred during the wet years. On May 13, 1984, a Carbon County resident was killed by a debris flow issuing from a hillside into the town of Clear Creek (Kevin Drolc, former Deputy, Carbon County Sheriff's Office, oral communication, Sept. 22, 1989). One day later, a debris flow struck and killed a maintenance worker operating a bulldozer near the Carr Fork Mine in the Oquirrh Mountains of Tooele County (The Salt Lake Tribune, May 15, 1984, p. B1).

October 1988 earth flow in Hoytsville (Summit County). The landslide occurred on a steep slope of an old borrow pit. The top of the slope was flood irrigated and lined with canals, which probably contributed to the failure. Broken canal pipe is visible on slide body. Photo by Loren H. Rausher.



August 1988 debris slide-flow from right abutment area of Joes Valley Dam (Emery County) that nearly struck spillway structures. Photo by author.

The historical landslides discussed above were all associated with periods of high precipitation. However, there have been many landslides in Utah that have not been directly linked with specific rainstorms, snowmelt events, or periods of sustained above-average precipitation. In addition to and in conjunction with precipitation events, natural causes that contribute to slope instability include slope undercutting by stream erosion, slope weakening by in-situ weathering or erosion, and earthquake ground shaking. Human activities, such as removal or addition of slope materials for construction and mining, lawn watering and irrigation, removal of slope vegetation, and leaking of underground pipes or above-ground water conduits have also caused landslides in Utah. These factors may suddenly trigger landslides, or work gradually over a period of months, years, or longer.

Some of the more recent pre-wet cycle historical landslides that have caused major damage in the state include: the 1968 Echo Junction landslide that covered Interstate Highway 80, endangered a power line, and cost nearly $159,000 to remove from the highway (Hurley, 1972); the 1974-1976 reactivation of the Manti landslide in Sanpete County that destroyed the main waterline for the city of Manti, and forced a temporary shutdown of the city's hydroelectric plant, resulting in $1.8 million in documented expenditures (Fleming and others, 1988); and the May, 1980 reactivation of a landslide in the Washington Terrace landslide complex in Weber County that destroyed three electrical transmission towers and caused eight Union

September 1989 Mapleton debris-flow deposit. Set by juveniles, a September 2 brush fire denuded mountain slopes above Mapleton. Subsequent intense thunderstorms on September 17-18 and 19-20 generated two debris flows at this location. Photo by William R. Lund.

Pacific railroad cars to derail and plunge into the Weber River, which then caused flooding in four homes in the vicinity (Gill, 1981).

Statewide, annual precipitation has decreased to near or below average for the last three water years, respectively averaging 98, 101, and 79 percent of normal for 1986-87, 1987-88, and 1988-89 (Galen Ashcroft, Utah State Climatologist, oral communication, Oct. 27, 1989). The frequency of landsliding has also decreased in the past three years, returning to a more "normal" state. Whereas thousands of landslides occurred in Utah during 1982-1986, relatively few damaging landslides have been reported since then. While most landslides of the early to mid-1980s were caused by elevated levels of precipitation and rapid snowmelt, many of the post-wet-years landslides (excluding rock falls) were to some degree related to human activities. Of the landslides investigated by the UGMS during 1988 and 1989, most were attributed to improper hillslope modifications, overwatering of slopes, or denudation of slope vegetation by set fires. Recent damage caused by rock falls includes the 1988 rock fall west of Blanding (San Juan County) that temporarily blocked traffic on Highway 95; the July, 1988 Bloody Mary Wash rock fall near Arches National Park (Grand County) in which boulders crashed into and deformed tracks of the Rio Grande Railroad, and the March, 1989 Willow Creek rock fall near Castle Gate (Carbon County) which blocked Highway 191 and required blasting to remove a 25-cubic-yard boulder (W.F. Case, UGMS, oral communication, Nov. 7, 1989).

Keefer (1984) reports the minimum earthquake magnitude required to induce rock falls and rock slides is a 4.0. Since earthquakes of this magnitude occur on the average of once every two years in Utah (Arabasz and others, 1987), the recurrence period for earthquake-induced rock falls is relatively high. This was evident during the August 14, 1988 San Rafael Swell earthquake (magnitude 5.3), when hundreds of rock falls, identified by their dust clouds, were initiated by ground shaking (Case, 1988). Few structures were near these rock falls, thus little damage resulted.

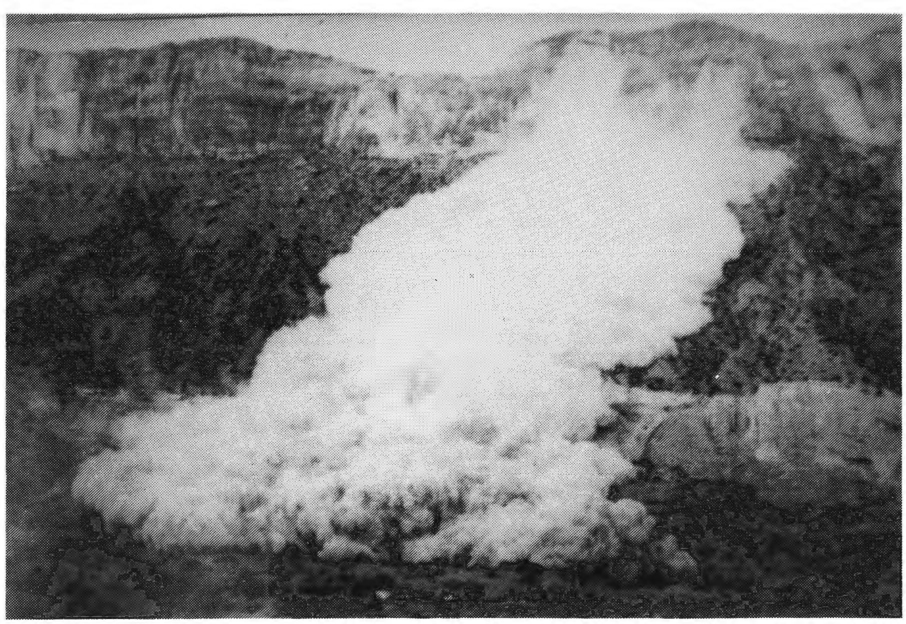
LIVING WITH LANDSLIDES

Reducing the risk posed by landslides can be achieved by avoidance or control. Avoiding development on or near alluvial fans, existing landslides, and unstable slopes is the safest and often the least expensive option. Many of the measures used to control flooding are effective in reducing the risk from debris flows on alluvial fans. Options include constructing debris basins, building deflection walls upslope of structures to be protected, and avoiding construction of ground-level windows facing upslope. Engineering methods used to control deep-seated landslides or stabilize unstable slopes include grading or dewatering, buttressing the base or toe, or reinforcing with piles driven through the slide into underlying bedrock. Rockfalls and slides are typically controlled using methods that include catchment fences, tie-back walls, rock bolts, cut benches, and pre-split rock faces. Controlling earthquake-induced lateral-spread failures is more difficult because they can cover extensive areas in environments otherwise considered safe from landslides. Some techniques include dewatering, soil treatment (densification, loading, removal), and use of special foundation designs. A comprehensive list of structural and administrative means of reducing landslide hazards and risk is given in Kockelman (1986).

Mapping landslides and identifying areas subject to landslide hazards are the primary means of predicting where landslides are likely to occur. However, predicting when landslides will occur is an extremely difficult task. Monitoring of landslides that have already experienced significant movement (for example, Cedar Canyon and Thistle landslides), and monitoring of slopes that have shown signs of incipient landslide movement are useful in assessing hazards and the likelihood of continued movement. During the wet years, several landslide/flood warning systems were installed in canyons considered a high risk for downstream inundation (for example, Emigration Canyon in Salt Lake County, and Farmington, Steed, Shepard Creek, and Rudd Canyons in Davis County). Warnings were sounded or issued based on meteorologic, hydrologic, or geomorphic changes including exceeding certain threshold precipitation or water levels over time, stream flow cessation, and extensometer readings. Few of these systems still remain in operation.

One of the most important aspects of reducing the landslide risk is awareness of the hazard, which includes recognizing that many landslides occurring in urban areas are caused by unwise land-use practices (for example, slope irrigation, undercutting, and oversteepening). Many urban landslides occur on slopes that have not experienced landslides in the past, and that are not particularly susceptible to landsliding under natural conditions. Therefore, when altering natural slopes, a proper assessment of existing and final slope conditions (particularly final grades, fill compactions, and drainage) should be made by geotechnical experts.

March 1989 Willow Creek rock fall in Carbon County. Large rock in center of photo was removed from Highway 191 by blasting. Photo by William F. Case.



Large rock fall in 1985 in Castle Valley (Grand County) deposited ½" of dust inside a nearby house (obscured by dust cloud). Photo by Ron Drake, Times Independent, Moab, Utah.

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Sixth Annual Wasatch Front Earthquake Conference

June 11-12, 1990
University Park Hotel
Salt Lake City, Utah

The Sixth Annual Wasatch Front Earthquake Conference, this year sponsored by the Utah Geological and Mineral Survey, Utah Division of Comprehensive Emergency Management (CEM), and the University of Utah Seismograph Stations (UUSS), will be held at the University Park Hotel in Salt Lake City on June 11-12, 1990.

The conference is intended to be of particular interest to users of earthquake hazards information such as planners, engineers, architects, building officials, and emergency response personnel. The principal objectives are to: 1) present information and discuss lessons learned from the October 17, 1989 Loma Prieta earthquake in California, 2) discuss 1990 earthquake-related legislation and how scientists, planners, engineers, architects, building officials, and emergency response personnel can influence public policy related to earthquakes, 3) discuss results and give progress reports on Wasatch Front earthquake research, 4) transfer Wasatch Front hazards information to planners and building officials and discuss its use in reducing losses, and 5) present training and discuss various Applied Technology Council procedures in pre- and post-earthquake assessments of structures.

All those interested are invited to attend. As with previous earthquake conferences, there will be a nominal registration fee. Announcements with a finalized agenda and registration information will be mailed out soon.

THE OCTOBER 17, 1989, Ms7.1 EARTHQUAKE NEAR SAN FRANCISCO

PRELIMINARY REPORT AND SUMMARY OF UGMS ACTIVITIES TO HELP REDUCE LOSSES FROM A SIMILAR EARTHQUAKE IN UTAH

by

Gary E. Christenson

The October 17, 1989, earthquake near San Francisco, now officially called the Loma Prieta earthquake, was the first magnitude 7.0+ earthquake in the conterminous United States since the October 28, 1983, Borah Peak, Idaho earthquake (Ms 7.3), and the largest earthquake to occur in the Bay area since the catastrophic 1906 earthquake. The magnitude of the earthquake has been determined to be Ms7.1, with the epicenter near the Loma Prieta lookout about 10 miles northeast of Santa Cruz and 50 miles southeast of San Francisco. To date, 62 deaths and an estimated $6 billion in damages were caused by the earthquake.

Preliminary information from the U.S. Geological Survey (Plafker and Galloway, 1989), Earthquake Engineering Research Institute (1989), and California Division of Mines and Geology was used to compile the following summary of the earthquake. The epicenter and aftershocks were along the Southern Santa Cruz Mountains segment of the San Andreas fault, and defined a 25-mile rupture zone from Los Gatos to San Juan Bautista. The main shock was about 11 miles deep, and preliminary focal mechanism studies indicate both vertical (west side or Pacific plate up) and right-lateral slip components. No discrete surface fault rupture such as typically occurs along the San Andreas fault has been identified. Extensive ground cracking has been found in the epicentral area, and some of it may be the surface expression of slippage at depth. However, much of it may also be the result of landslides and other earthquake-related ground deformation. Peak horizontal ground accelerations recorded in the epicentral area were about 0.64 g, while peak values on bedrock in the San Francisco Bay area were generally less than 0.15 g. Much of the damage in the Bay area occurred in areas of poor soil conditions around the edge of the Bay which may have amplified the ground motion (for example, accelerations of 0.29 and 0.33 g were recorded at the Oakland Wharf and San Francisco International Airport, respectively). Liquefaction has been reported around Monterey Bay near Santa Cruz and Moss Landing and around the southern San Francisco Bay in Oakland, San Mateo, and San Francisco.

> *"The October 17, 1989, earthquake near San Francisco, now officially called the Loma Prieta earthquake ... was the largest earthquake to occur in the Bay area since the catastrophic 1906 earthquake. The Applied Technology Council estimates that such an earthquake in Utah would cause 20 to 40 percent more damage than it did in California ..."*

The Loma Prieta earthquake was within the range of magnitudes of maximum earthquakes expected somewhere along the Wasatch fault every 340-415 years (Machette and others, 1989). Geologic investigations indicate that it has been at least that long since the last one, and it is possible that one could occur at any time. Because of vulnerable existing construction, the Applied Technology Council estimates that such an earthquake in Utah would cause 20-40 percent more damage than it did in California, and presumably a proportionately greater number of deaths and injuries, chiefly as a result of damaged and collapsed buildings. The dramatic difference that earthquake-resistant building practices can make is demonstrated by comparing the death toll from the 1988 Armenia earthquake (M_L6.9) of over 25,000 to that of the Loma Prieta earthquake of 62. Although part of the difference is attributable to the time of day and proximity of population centers to the epicenter, most is directly related to the more strict building codes in California.

As a result of the recently completed 5-year federally funded National Earthquake Hazards Reduction Program along the Wasatch Front, and related activities by UGMS and many others, much new information regarding earthquake hazards and risk is now available. Although the data base is less complete than in the high seismic risk parts of California, it is complete enough to provide a basis for taking many of the same hazards and risk reduction measures that significantly reduced losses in the San Francisco area.

The role of UGMS in earthquake hazards reduction is principally in scientifically studying and defining the hazards and collecting, translating, and disseminating earthquake hazards information for use in reducing losses. The information is used chiefly by planners, structural engineers, architects, policy makers, and emergency response personnel to better do their jobs to ensure public safety. As a part of these activities, the UGMS publishes earthquake hazards information, works with other State agencies and local governments to aid them in using the information, answers inquiries from the public and media, serves on policy-making and advisory committees relating to earthquake hazards, and responds to earthquakes in Utah to document geologic effects and advise local and State emergency responders as needed.

The principal earthquake-related publications in progress at this time include an updated Quaternary fault map of Utah (1:500,000 scale), an earthquake hazards map of the State (1:750,000 scale), a summary volume of paleoseismic (fault trenching studies in the Wasatch fault, and a document explaining earthquake ground shaking which will summarize and clarify the many confusing and sometimes contradictory publications now available. Each UGMS publication is directed at a specific audience, ranging from geologists and seismologists to non-technical users and the general public.

In addition to these publications, the UGMS has been active in promoting the use of the information to formulate public policy. From 1985 through 1988, the UGMS conducted the Wasatch Front County Geologist Program which used federal funding to place geologists in Wasatch Front counties to help collect and promote the use of geologic hazards information by local governments in planning. As a result, hazards maps have been completed and new hazards ordinances have been passed or old ordinances enforced to control new development in hazard areas. We have worked with the State Division of Facilities Construction and Management to ensure that geologic hazards are considered in the siting of State buildings. UGMS has made presentations regarding earthquake ground shaking and seismic building codes to the Structural Engineers Association of Utah and International Conference of Building Officials (Utah Section), two of the groups with great influence in recommending changes to existing building codes. We also served on the Salt Lake City School District Policy Advisory Committee which recommended actions to address seismically unsafe school buildings in the district.

The UGMS, Utah Comprehensive Emergency Management (Utah CEM), and University of Utah Seismograph Stations have presented recommendations for steps to be taken by government to reduce earthquake losses to the Utah Advisory Council for Intergovernmental Relations, an advisory committee to the Governor's Office of Planning and Budget for science and technology. The recommendations chiefly addressed steps to ensure that new school and other government buildings are seismically safe and to assess seismic safety of existing government buildings and develop plans to upgrade or retire unsafe buildings. At present, only Ogden City has a seismic retrofit ordinance, although both Salt Lake City and the Salt Lake area school districts are presently taking steps to evaluate and in some cases retrofit unsafe structures. The Council voted to support the principal recommendations, and to help promote action on the items through sponsorship of legislation.

The three agencies also held a workshop, chaired by members of the Utah legislature, to determine Utah's needs for earthquake instrumentation. As a result of this workshop, legislation was introduced to fund upgrading and expansion of the existing seismic monitoring network and to initiate a statewide strong-motion instrument program.

Finally, UGMS, Utah CEM, and the Utah Museum of Natural History are attempting to get natural hazards, including earthquake hazards, taught at the high school level. We have met with school district science coordinators and received approval to develop curriculum materials covering all geologic hazards including earthquake hazards, directed at making students more aware of where hazards occur or should be expected so that they can be more responsible when determining where to live and work in an area like the Wasatch Front.

In summary, the UGMS is active in providing the information needed and promoting its use in earthquake hazards reduction, and the last five years have seen major strides taken. However, there are many unsafe conditions remaining from many years of construction and development in which earthquake hazards were not considered, and modern practices can still be greatly improved. The earthquake in San Francisco was a timely reminder that this work cannot be postponed, and that Utah still has a long way to go before it is prepared for a major earthquake. What is needed most to accelerate the process now is support from high levels in state and local government, and the San Francisco earthquake did much to heighten their awareness of the need for action.

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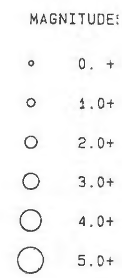
Call for Papers Issued for 1991 Rapid Excavation and Tunneling Conference

The Conference will be held June 16-20, 1991, at Seattle Washington. Deadline for submissions is June 15, 1990. Interested participants should submit: 1) an abstract of 100 words or less and 2) a brief statement explaining why the proposed paper is of interest to the conference and to whom it will appeal. Please send to RETC (Rapid Excavation and Tunneling Conference), c/o Meetings Dept., SME, P.O. Box 625002, Littleton, CO 80162, Telex 881988, Fax 303 979-3461. *Final papers will be due January 16, 1991.*

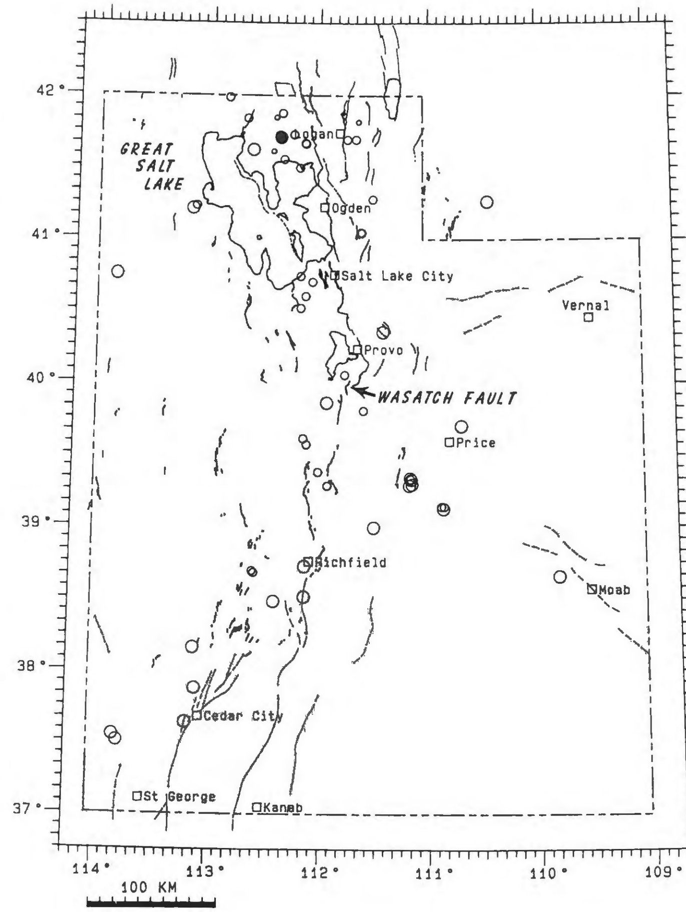
Earthquake Activity in the Utah Region

October 1, — December 31, 1989

Susan J. Nava
University of Utah Seismograph Stations
Department of Geology and Geophysics



During the three-month period October 1 through December 31, 1989, the University of Utah Seismograph Stations located 76 earthquakes within the Utah region (see accompanying epicenter map). Of these earthquakes, 22 had a magnitude (either local magnitudes, M_L, or coda magnitude, M_C) of 2.0 or greater, and two were reported felt. There were no earthquakes which had a magnitude of 3.0 or greater during this report period.



Twenty-four aftershocks associated with the July 3, 1989, Blue Springs Hills earthquake (M_L 4.8) were located during the period from October 1-December 31, 1989. Two earthquakes were reported felt in the Utah region during the report period: an M_C2.2 event on November 13 at 12:39 AM MST, which was felt by several employees at the Thiokol Corporation plant, about 20 km west of Tremonton, and an M_C2.0 event on November 30 at 05:33 AM MST, felt in the vicinity of Montpelier, Idaho.

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

(801) 581-6274

UGMS Participates in EPA State Indoor Radon Grant Program

by
Barry J. Solomon

The Utah Department of Health, Bureau of Radiation Control (UBRC), has received approval for a grant from the U.S. Environmental Protection Agency (EPA) to study the indoor radon hazard in the Wasatch Front region. The UBRC will receive approximately $64,000 through the EPA State Indoor Radon Grant Program.

The radon study, to be conducted during 1990, will consist of two parts. The first part will be coordinated by the UBRC, which has solicited the participation of 400 volunteers in the Sandy and Provo areas to monitor their homes for indoor radon during a year-long period. A statewide indoor radon survey in 1988 indicated that the average indoor radon concentration was higher in these cities than the statewide average. During the second part of the study, the UGMS will investigate geologic factors that influence indoor radon concentrations by the measurement, on a grid pattern, of radioactive soil material with a portable gamma-ray spectrometer, radon gas with a radon emanometer, and soil permeability with a neutron-density meter. These measurements will define the distribution of radon gas derived from the source, and the effect of soil permeability on the migration of radon. Study results should help explain why the Provo and Sandy areas were "hot spots" in the statewide survey, test geologic models of radionuclide distribution in sediments, and identify relevant geologic factors where radon levels may be high and mitigation necessary.

Surficial Geologic Maps of the Wasatch Fault Zone, Utah

by
Michael N. Machette, Alan R. Nelson and Stephen F. Personius

Surficial geologic mapping along the trace of the Wasatch fault zone in north-central Utah has been completed by the authors, and their respective maps are in various stages of publication (see Maps listing at end). Our mapping, conducted from 1983 to 1988, provides a stratigraphic framework for analyzing the late Quaternary history of the Wasatch fault zone. Each map was compiled from reconnaissance mapping (1:24,000 scale) and detailed mapping (1:10,000 scale) of special study areas along the fault zone. The resulting strip maps were compiled at a scale of 1:50,000 and will be published by the U.S. Geological Survey as black-and-white author-drafted MF maps, and later as professionally prepared full-color I maps.

High slip rates (1-2 mm/yr) and short recurrence intervals (average about 2,000 yr) indicate that the Wasatch fault zone is one of the most active and potentially devastating normal faults in North America. The fault zone extends from Malad City, Idaho to Fayette, Utah, a straight-line distance of 343 km (383 km along trace). It forms the structural boundary between the extensional terrain of the Basin and Range Province and the more passive, but uplifted terrain of the Colorado Plateaus and Middle Rocky Mountains Provinces. The fault zone lies astride the Intermountain Seismic Belt, an active seismic zone that extends from central Idaho to southern Nevada.

The Wasatch fault zone has been the focus of recent study largely because of the proximity and hazard to a metropolitan area. Almost three-fourths of Utah's population (currently approaching two million) live in the Wasatch Front Urban Corridor, which is coincident with the central part of the fault zone. This part of the fault has five discrete fault segments, each of which has had repeated movement in the Holocene. These segments range from about 40 km in length (Brigham City segment) to as much as 70 km in length (Provo segment). These fault segments have average recurrence intervals of about 1,200-4,000 years, but as a whole the fault zone has a *composite* recurrence interval of about 415 years. The five distal, less active segments of the fault zone average about 30 km in length and have recurrence intervals of >10,000 years.

Although most of the Wasatch Front previously had been mapped at varying scales, there had been no effort to construct modern detailed surficial geologic maps based on the results of recent stratigraphic and radiometric studies. In addition, we mapped the fault and characterized its scarps in more detail than previously. On our four maps, we used as many as 40 surifical geologic units that are based on genesis, lithology, and age. Five different modes of deposition (genesis) are recognized in the mapping areas: lacustrine, alluvial, glacial, eolian, and colluvial. Within these modes, units are subdivided by lithology and age. For example, lacustrine deposits of the Bonneville lake cycle (32-10 ka) are subdivided into a fine-grained facies (m), sandy facies (s), gravelly facies (g), and delta-forming facies (d). This lake cycle is further subdivided into a mainly transgressive phase (the Bonneville, b; 32-15 ka) and a mainly regressive phase (the Provo, p; 15-10 ka). Age subdivisions are based largely on inferred correlation with pluvial (glacial) and interpluvial (interglacial) stages of the basins and ranges. The Holocene (post-Bonneville lake cycle) deposits (designated y for younger) are divided into age categories 1 (late Holocene) and 2 (middle and early Holocene). Deposits associated with the latest Pleistocene Bonneville lake cycle (category 3) are subdivided into regressive (p) and transgressive (b) phases. Deposits that predate the Bonneville lake cycle are either undifferentiated (designated o for older) or are divided into age category 4 (late Pleistocene and latest middle Pleistocene) or age category 5 (middle to early Pleistocene).

In addition to mapping, the authors are coinvestigators on several trenching studies at selected sites along the Wasatch fault zone. In the past 10 years, about 20 sites have been studied along the fault zone, its splays, and its subsidiary faults. About 50 trenches have been dug and logged in moderate to excruciating detail. In just the past three years, D.P. Schwartz (USGS), W.R. Lund (UGMS) and the authors have studied six major sites and obtained more than 50 radiocarbon dates and 15 thermoluminescence age estimates associated with faulting events. We know of no other normal fault zone in the world that has garnered so much scientific attention. The results of this collaborative effort were summarized recently in USGS Open-File Report 89-315 (p. 229-242).

MAPS

Machette, M.N., 1989, Preliminary surficial geologic map of the Wasatch fault zone, eastern Utah Valley, Utah County and parts of Salt Lake and Juab Counties, Utah: U.S. Geological Survey Miscellaneous Field Studies Map, MF-2109, 30 p., scale 1:50,000.

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Nelson, A.R., and Personius, S.F., in prep., Preliminary surficial geologic map of the Weber segment, Wasatch fault zone, Weber and Davis Counties, Utah: U.S. Geological Survey Miscellaneous Field Studies Map, scale 1:50,000.

Nelson, A.R., and Personius, S.F., in prep., Surficial geologic map of the Weber segment, Wasatch fault zone, Weber and Davis Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map, scale 1:50,000.

Personius, S.F., 1988, Preliminary surficial geologic map of the Brigham City segment and adjacent parts of the Weber and Collinston segments, Wasatch fault zone, Box Elder and Weber Counties, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-2042, scale 1:50,000.

Personius, S.F., in press, Surficial geologic map of the Brigham City segment and adjacent parts of the Weber and Collinston segments, Wasatch fault zone, Box Elder and Weber Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map MF-1979, scale 1:50,000 (in press).

Personius, S.F., and Scott, W.E., 1990, Preliminary surifical geologic map of the Salt Lake City segment and parts of adjacent segments of the Wasatch fault zone, Davis, Salt Lake, and Utah Counties, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-2114, 58 ms p., scale 1:50,000.

Personius, S.F., and Scott, W.E., in press, Surficial geologic map of the Salt Lake City segment and parts of adjacent segments of the Wasatch fault zone, Davis, Salt Lake, and Utah Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map, scale 1:50,000.

GREAT SALT LAKE LEVEL

Date (1989)	Boat Harbor South Arm (in feet)	Saline North Arm (in feet)
Oct 01	4204.70	4203.80
Oct 15	4204.50	4203.70
Nov 01	4204.50	4203.45
Nov 15	4204.50	4203.40
Dec 01	4204.40	4203.45
Dec 15	4204.40	4203.45
1990		
Jan 01	4204.40	4203.45
Jan 15	4204.50	4203.50
Feb 01	4204.50	4203.60
Feb 15	4204.50	4203.60
Mar 01	4204.60	4203.50
Mar 15	4204.70	4203.50

Source: USGS provisional records.

Director's Perspective, continued

but that attitude won't solve our problems. Rather, the earthquake community (mostly geologists, engineers, and planners) is rethinking our strategy. How do we do better next time? What are the priorities? Who do we need to enlist in the effort? If you can help, let us know.

Earthquakes are not Utah's only geologic problem. While this state has an incredible variety of scenic geologic features, we also have virtually every kind of geologic hazard. Besides earthquakes, there are landslides, floods, avalanches, liquefaction, unstable soils, shallow ground water, radon, and even volcanoes! In fact, Utah may have had a volcanic eruption within the last 600 years (see *Survey Notes* vol. 19 no. 3 for Don Mabey's article, and v. 21, no. 2-3, p. 3 and 6).

However, it is landslides that have caused many of the biggest threats to life and property by geologic hazards in the historical past. Kimm Harty addresses the effect of landslides on Utah in this issue of *Survey Notes.* The Utah landslides of 1983-84 were among the most destructive, economically, in U.S. history. Kimm describes the impact of landslides in Utah and what is being done to prepare for and mitigate landslide hazards. Although the numerous landslides of the 1980s resulted largely from a series of exceptionally wet years, landslides also occur in relatively dry years as shown by the 1989 Cedar Canyon slide that destroyed part of Highway 14 east of Cedar City. We expect that other wet cycles will occur in the future and landslide dangers will increase once again. When that time arrives, we plan on being better prepared not only to deal with landslides but with all geologic hazards.

SURVEY NOTES INDEX

GEOLOGIC EVALUATION OF WASTEWATER DISPOSAL IN ROCK, DUCHESNE COUNTY, UTAH.

by William E. Mulvey

INTRODUCTION

The number of approved second-home and recreational subdivisions has increased dramatically during the last ten to fifteen years in western Duchesne County along the drainages of the Strawberry and Duchesne Rivers. Approximately 1500 lots have been platted and sold, but in many cases owners have been unable to obtain building permits because shallow rock creates unsuitable conditions for conventional wastewater disposal systems. Most of the subdivisions are classified as "dry", indicating they have no piped, public or private water system and/or no legal or demonstrated means of developing such a system. Depth to ground water in many of the subdivisions is up to 800 feet, and the water is often saline, severely restricting development of culinary wells. At present, lot owners must haul all water. Year-round residents indicate they use less than 10,000 gallons of water per household per year for domestic needs (Jim Blackner, oral commununication, 1988), as compared to approximately 437,000 gallons per year for an average three bedroom home in a metropolitan area (Utah Division of Health, 1985). Thus, the amount of wastewater produced in these subdivisions is very small. In response to concerns of landowners and county planning and health officials, the Utah Geological and Mineral Survey (UGMS) conducted an investigation (funded by DCED) to determine if geologic and hydrologic conditions would permit the safe disposal of limited quantities of domestic wastewater in the rock of western Duchesne County (see New Publications of the UGMS).

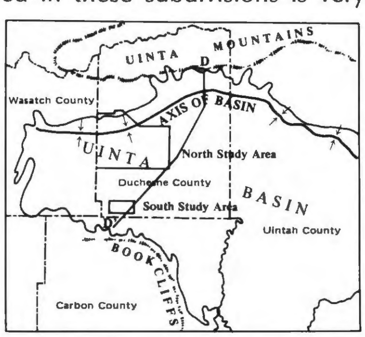

Figure 1A. North and south study areas in Duchesne County.

The study area covers a large part of west-central Duchesne County both north and south of the Strawberry River (figure 1A). The study boundaries were selected to include two widely separated clusters of subdivisions resulting in a northern and a southern study area. A total of 20 subdivisions are located in the two areas, 15 in the north and 5 in the south.

GEOLOGY AND GROUND WATER

The Uinta Basin is a topographic, structural, and sedimentary basin bounded on the north by the Uinta Mountains and on the south by the Book Cliffs. The basin is asymmetric with its axis to the north, and trending approximately northeast-southwest, near the south slope of the Uinta Mountains (figure 1A). The two most widespread rock units in the study area are the Green River and Duchesne River Formations (figure 1B). Both consist of sediments deposited in and along the margins of lakes that occupied the region during the Tertiary Period (Fouch, 1975). Finer grained sediments carried into deeper water are represented by the shales, siltstones, limestones, and claystones of the Green River Formation. Within the Green River Formation there are four distinct facies: the sandstone/limestone, saline, sandstone, and the main body (figure 2A & B)(Bryant, 1990). The main body is found only in the southern study area, underlying the entire area. Former lake margins are represented by conglomerates, sandstones, and siltstones of the Duchesne River Formation (figure 3).

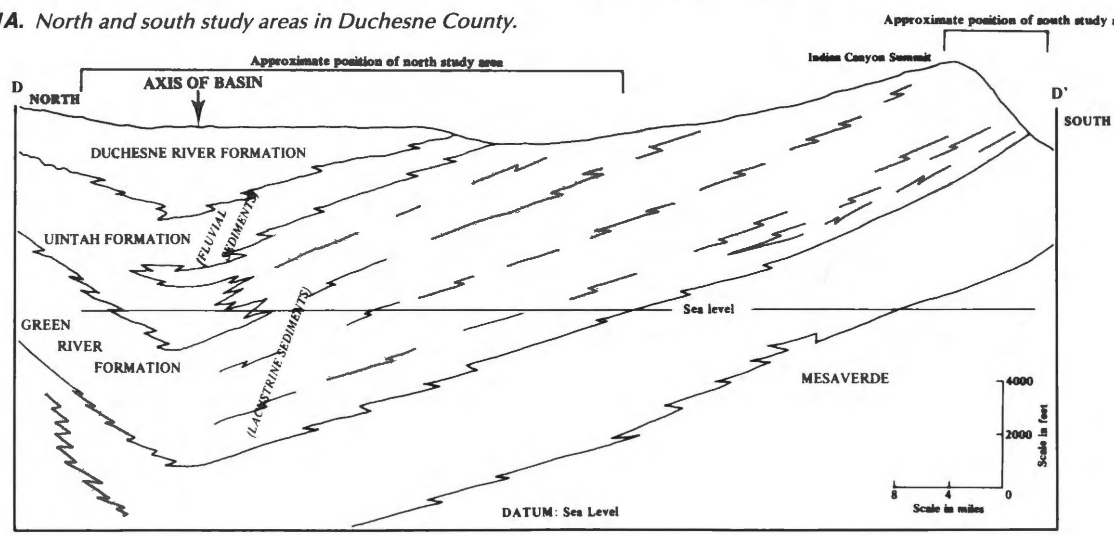

Figure 1B. Cross-section through study areas. Refer to figure 1.

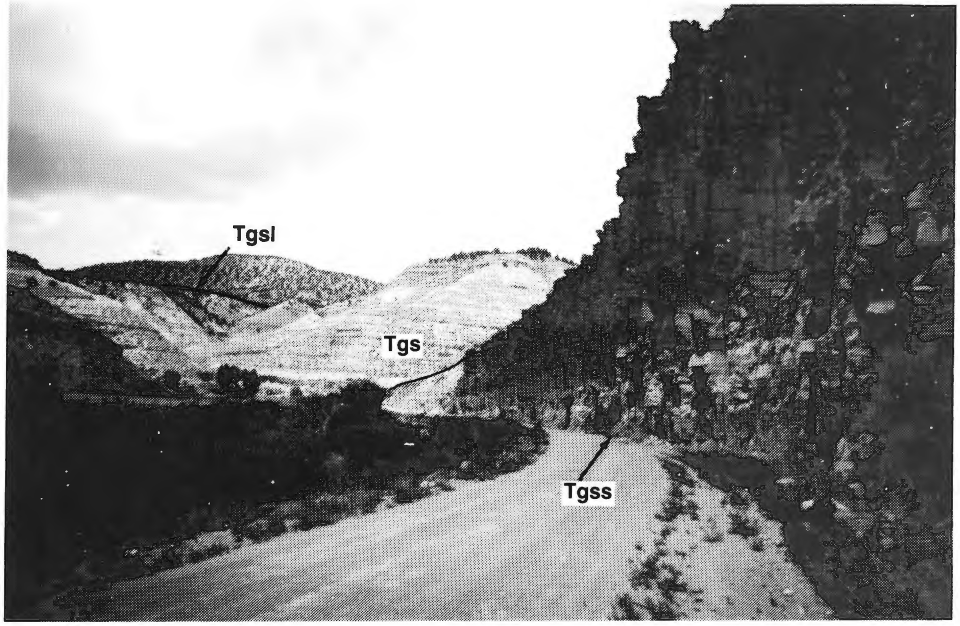

Figure 2A. *Green River Formation along Strawberry River. Facies shown are: sandstone/limestone (Tgsl), saline (Tgs), and sandstone (Tgss).*

Figure 2B. *Main body facies (Tg) along Utah Highway 33 in the south study area.*

Ground water in the region occurs in both rock and unconsolidated valley-fill aquifers. It ranges from fresh to highly saline and may occur under confined, unconfined, or perched conditions depending on the nature of the aquifer (Price and Miller, 1975; Hood, 1976). The Duchesne River and Green River Formations were identified as aquifers by Hood (1976) and Price and Miller (1975). Ground water from these units is of variable quality depending on distance from recharge areas and mineral composition of the aquifer. Due to its close proximity to recharge areas, the Duchesne River Formation contains ground water with the lowest total dissolved solids (TDS) (234 to 528 mg/l) and lowest salinity (Feltis, 1966). In general, ground water from the Green River Formation along the drainage of the Strawberry River is higher in TDS and salinity than ground water from the Duchesne River Formation. This is because the Green River Formation contains concentrations of salts and other minerals easily taken into solution. However, in the southern study area, ground water from the Green River Formation is low in TDS (less than 1000 mg/l) and generally fresh, as the percentage of saline minerals is much lower in this facies (McCormack and others, 1984). Ground water from these and other aquifers in the western Uinta Basin flows into either the Strawberry or Duchesne Rivers, which drain the region.

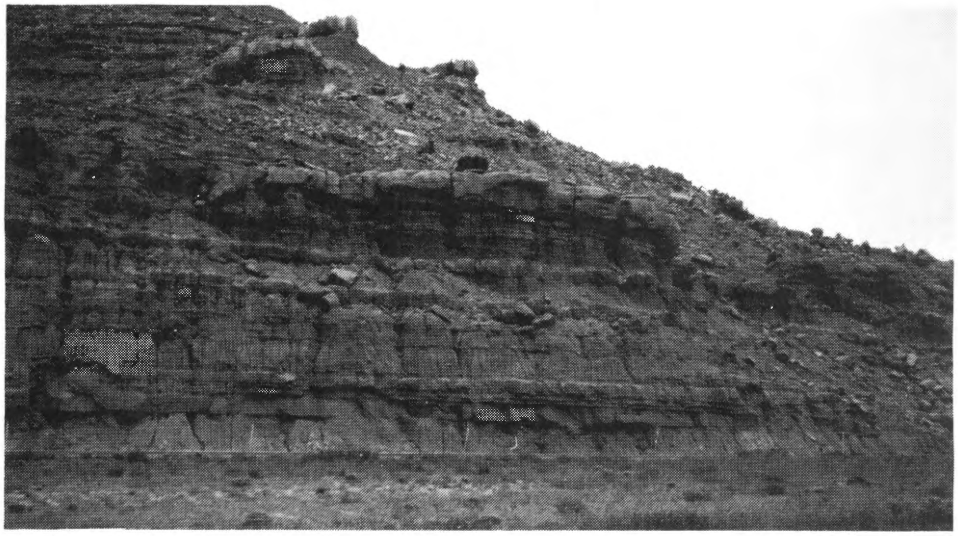

Figure 3. *Duchesne River Formation (Tdu) beside U.S. Highway 40 in the north study area.*

CONCLUSIONS AND RECOMMENDATIONS

Several geologic factors were found to influence the potential for disposal of small quantities of wastewater in rock in Duchesne County. The most important is the degree of fracturing of the rock units. This directly affects permeability, percolation rate, and hence, pollution potential. The lateral and vertical variability of rock units are also important as permeabilities vary as rock type changes, causing variations in rock percolation rates. Depth and quality of ground water, variability in soil thickness, dip of rock, and topographic slope also affect the potential for wastewater disposal.

Percolation rates in the Green River and Duchesne River Formations were variable and correlated closely with the degree of rock fracturing. The most highly fractured rock units, the sandstone/limestone and saline facies of the Green River Formation, had the highest percolation rates. Conversely, the Duchesne River Formation's impervious sandstone horizons, and shales in the main body of the Green River Formation had much lower percolation rates.

It is possible that limited amounts of wastewater can be disposed of in the Duchesne River Formation and the sandstone/limestone facies of the Green River Formation. Percolation rates for these units were comparable to acceptable rates (between 1 and 60 minutes per inch) for soils. Other facies in the Green River Formation did not have percolation rates that were acceptable. Other factors that must be evaluated besides percolation rate before a site is approved for a wastewater absorption system in rock include depth and quality of ground water, variability in soil thickness, dip of rock, and slope. The most important of these are summarized in tables and maps in the report (UGMS Special Study 72) and are to be used as guidelines when selecting sites for wastewater disposal systems. Maps in the report differentiate rock units on the basis of potential suitability for wastewater disposal. Each site will still require investigation prior to approval, and guidelines for conducting and reviewing geologic investigations are provided. The Utah State Department of Health and Uinta Basin District Health Department are currently considering the results of this study to determine whether or not to revise current regulations which prohibit disposal of even small quantities of wastewater in rock. Alternative systems such as low-pressure pipe, Wisconsin mound, and evaporative systems are also being considered. To increase the potential for finding a suitable site for wastewater disposal on a lot, the Duchesne County Planning Department currently recommends that lot sizes in new developments be a minimum of five acres (J. Wood, oral communication, 1988). The UGMS agrees with this policy and suggests that in the future a geologic investigation be conducted for entire subdivisions prior to platting of lots to help ensure that each lot has a suitable area for wastewater disposal prior to sale.

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Geology and Sanitary Landfills in Sevier County, Utah

by Barry J. Solomon

In FY 1986-87 the Community Impact Board (Utah Department of Community and Economic Development) committed cooperative funding to the Utah Geological & Mineral Survey to undertake several geologic projects of interest and economic benefit to Utah communities.

INTRODUCTION

Sevier County lies in central Utah, primarily in the High Plateaus section of the Colorado Plateau physiographic province. The Sevier County/Richfield municipal sanitary landfill near Glenwood, the only county landfill, is projected to be filled during the next few years, and the county is interested in identifying a new site. The Utah Geological and Mineral Survey (UGMS) undertook a regional assessment of geologic conditions for a sanitary landfill in Sevier County chiefly for use by the Central Utah District Health Department in siting the new facility.

Geologic and hydrologic criteria are important in siting a landfill to minimize construction and operation costs, and environmental contamination. Such criteria are best applied early in the planning process. The purpose of this project was to provide a tool for early planning by compiling regional maps depicting pertinent geologic and hydrologic conditions and using these maps to identify potentially suitable areas for landfills in the county. Suitability should then be confirmed by detailed site characterization. This study covers the entire county and can be used by municipalities, as well as the county, in choosing suitable sites.

GEOLOGIC SITING CONSIDERATIONS AND SUITABILITY EVALUATION

The purpose of a geologic siting investigation for a landfill is to determine if the site is capable of containing waste without contaminating the environment. Factors to be considered in such siting investigations fall within three broad categories:

1) *Geology and geologic hazards,* to show if the site possesses workable materials that can be excavated and will not provide a pathway to contaminate ground water. The study must also show that no natural geologic processes, such as surface flooding or faulting, will adversely affect the site and cause damaging leakage of its contents, or will otherwise interfere with the site's ability to contain wastes.
2) *Ground-water conditions,* to demonstrate that the site will not adversely affect ground-water quality and that shallow ground water will not flood the site.
3) *Soil conditions,* to show the distribution of soil types, the suitability of soils for cover material and for landfill excavation, and to indicate the engineering measures required to use on-site soils.

Existing data have been compiled on three maps which depict 1) unconsolidated deposits and selected geologic hazards such as flooding and active faults, 2) ground-water recharge and shallow ground-water areas, and 3) regional soil conditions including cover material suitability and soil permeability. Relative landfill suitability was determined by overlaying these maps, with potentially acceptable areas classified on a composite map into five site suitability categories:

I. Generally suitable — all site conditions evaluated are favorable and the danger of ground- and surface-water contamination due to geologic or hydrologic factors is low.

II. Generally suitable, but engineering measures may be required — most evaluated factors are favorable but unfavorable conditions exist locally. Soils may be of high permeability and/or unsuitable for cover material, but the areas are not subject to recharge, shallow ground water, or surface flooding.

III. Generally unsuitable but locally suitable—most evaluated factors are unfavorable but favorable conditions may exist locally; extensive investigation may be required to locate acceptable sites; special construction techniques may be required. Includes areas of ground-water recharge, shallow ground water, and/or high surface flood potential; soils may or may not be suitable for host and cover material.

IV. Generally unsuitable — site conditions are unfavorable; special construction techniques will likely be required which may be prohibitively expensive; alternative sites should be considered, if possible. Areas are generally underlain by bedrock and are unsuitable due to workability, soil, slope, and/or fracture permeability limitations.

V. Not evaluated — unconsolidated material occurs on the surface, but data to evaluate hydrologic and soil suitability are not available.

A detailed map on which these categories are shown, and a report (see New Publications), designates areas where conditions exist which make the category less suitable. Such conditions include shallow or exposed bedrock, flood hazard, potentially active faulting, shallow water table, ground-water recharge, high permeability soils, and unsuitable soils for cover material.

Ultimately, any site may be designed for successful landfill operations, but the cost of engineering measures needed to mitigate potential hazards at less suitable sites, and the effort and expense required to perform a thorough geotechnical investigation to characterize adverse conditions, may be prohibitive. The nature and detail of the field investigation will depend upon several factors including size and type of facility, the extent of existing information, and the requirement for engineering modifications where potential hazards are present.

CONCLUSIONS AND RECOMMENDATIONS

A review of the geology, ground water, and soils in Sevier County indicates that natural conditions are favorable in selected areas for siting sanitary landfills; the suitability of specific sites, however, will require detailed geotechnical characterization. Considerable areas of the county would be suitable for landfills if proper engineering measures are taken, but such measures will increase the cost of construction and operation. Still other areas are considered unsuitable on a regional scale but may yield favorable sites in limited areas after closer inspection.

Favorable geologic conditions described for category I areas conform with most of the RCRA subtitle D siting criteria proposed for municipal solid waste landfills (U.S. EPA, 1988). However, this study presents a tool for early planning and, as such, represents a compromise between a comprehensive presentation of all potential geologic factors and presentation of those factors most crucial to regional screening for potential sites. This regional assessment will guide the user toward areas in which the probability of successful siting is increased, and will serve as an indication of the level of detail and expenditures required for characterization and construction. Regardless of the size of the areas identified in this regional assessment, and regardless of the suitability category of each area, a site-specific investigation must be carried out prior to construction. The UGMS can assist local agencies in their review of the adequacy and accuracy of site investigation reports and the feasibility of engineering proposals to mitigate hazards.

REFERENCE CITED

U.S. Environmental Protection Agency, 1988, Solid waste disposal facility criteria; proposed rule (40 CFR parts 257 and 258): Federal Register, August 30, v. 53, no. 168, part III, p. 33314-33422.

View across the Sevier Valley, looking northwest near the town of Vermillion. Four site suitability categories are visible. Gently sloping, plowed fields in the foreground are underlain by fine-grained deposits of category I. Steeper piedmont slopes at the base of mountains across the valley are underlain by coarser, high-permeability deposits of category II. Category III flood plains of the Sevier River lie in the low, central portion of the valley. Steep mountains on the far side of the valley are composed of Tertiary sedimentary rocks, principally limestone and shale, and are in site suitability category IV.

POSSIBLE PRECAMBRIAN OIL PLAY IN UTAH

Geologists at the U.S. Geological Survey recently published two abstracts that describe very high petroleum source rock potential of Precambrian rocks exposed in the Grand Canyon. These rocks are believed to extend south into Arizona and north into Utah in the subsurface.

Precambrian rocks have generally been considered unlikely to ever generate any significant quantities of oil. However, the Proterozoic-aged sediments of the Chuar Group have total organic contents ranging up to 11% which is very high. The organic matter is sub-mature to mature, i.e., it is capable of generating oil at depth right now.

UGMS is determining how extensive these source rocks are and whether any Precambrian oils are presently found in the state. There is speculation that equivalent rocks may reach as far north as the western Book Cliffs, or even to the Uinta Mountains. If this is confirmed, then there is the possibility of a major new oil play underlying much of the eastern and southern parts of the state. Prospects would be either in Precambrian rocks or overlying units.

The Tooele County Geologic Hazards Project

by Barry J. Solomon

The UGMS is actively involved in working with local governments to provide geologic hazards maps for use in planning. Under the UGMS-sponsored Wasatch Front County Hazards Geologic Program, such hazards maps were completed or are in progress for Weber, Davis, Salt Lake, Utah, and eastern Juab Counties by the county geologists. We are now working to complete similar mapping by our own staff in other counties in Utah, and work has begun in Tooele and Wasatch Counties.

Geologic hazards are being mapped in Tooele County in a multi-year project consisting of two phases. The first phase, currently underway, was initiated in early 1989 with a detailed literature search of available geotechnical data pertaining to two areas: 1) Tooele Valley, and 2) the West Desert Hazardous Industry Area, as defined by Tooele County, near Clive. The data has been gathered from both published and unpublished sources, and includes considerable material related to ground water and seismicity of the Tooele Army Depot. Following the literature search, a comprehensive air-photo interpretive study was undertaken to supplement, and in some cases reinterpret, available geologic maps. Air-photo maps of Quaternary deposits were field checked and are being transferred to 1:24,000 scale base maps; bedrock geology will be compiled from available sources. Basic data maps will also be compiled for such factors as soil permeability and depth to ground water, and derivative maps will be constructed to delineate the potential for various geologic hazards, including landslides and liquefaction.

Geologic mapping during the first phase has revealed several interesting features which may bear upon development in the county. Some of the more significant features are: 1) a possible fault in Quaternary, unconsolidated sediments near the town of Stockton; 2) circular depressions with sand rims north and east of Grantsville, possibly related to liquefaction during a seismic event; 3) previously unmapped sand dunes in the West Desert Hazardous Industry Area; 4) a large lateral spread, or movement of sandy material on a gentle slope, in the foothills of the Cedar Mountains; and 5) a previously unrecognized high proportion of permeable, sandy lake beds between the Grayback and Cedar Mountains in the Hazardous Industry Area. The mapping does not necessarily serve only to indicate problem areas; several linear features between Tooele and Stockton described as Quaternary faults in preliminary maps published by the USGS (Tooker and Roberts, 1988) appear, upon closer inspection, to be erosional features formed by Lake Bonneville, and are unrelated to earthquake activity.

The second phase of the Tooele County project will consist of regional mapping of Quaternary deposits in the remainder of the county, compilation of basic data and derivative maps at a scale of 1:100,000, and the field investigation of significant features identified during air photo interpretation. At this time, trenching of the possible fault near Stockton, noted above, will be considered, and compilation of a county-wide map showing suitability for sanitary landfills will be completed. This landfill map will be similar to one constructed for Sevier County (see article in this issue; Solomon and Klauk, 1989), and should provide information needed to comply with the RCRA Subtitle D geologic criteria proposed by the U.S. Environmental Protection Agency for the siting of municipal solid waste landfills (U.S. EPA, 1988).

Results from the Tooele County geologic hazards evaluation project should prove a useful tool for county and city officials to guide future development. The work is particularly timely in light of proposed projects in the West Desert Hazardous Industry Area, and proposed revisions by the U.S. EPA to RCRA Subtitle D for sanitary landfill facilities. Project results should fill a gap in current compilations of geologic data for the Tooele Army Depot and have already identified specific features county-wide that should be investigated in more detail to clarify the seismic history and hazards of the county. The project will serve as a prototype for geologic hazards reports in other Utah counties.

REFERENCES CITED

Solomon, B. J., and Klauk, R. H., 1989, Regional assessment of geologic conditions for sanitary landfills in Sevier County, Utah: Utah Geological and Mineral Survey Special Studies 71, 15 p., 4 pl.

Tooker, E. W., and Roberts, R. J., 1988, Interim geologic maps and explanation pamphlet for parts of the Stockton and Lowe Peak 7.5-minute Quadrangles, Utah: U.S. Geological Survey Open-File Report 88-280, scale 1:24,000.

U.S. Environmental Protection Agency, 1988, Solid waste disposal facility criteria; proposed rule (40 CFR parts 257 and 258): Federal Register, August 30, v. 53, no. 168, part III, p. 33314-33422.

New UGMS Publications

Correlation of Jurassic sediments of the Carmel and Twin Creek Formations of southern Utah using bentonitic characteristics, by B.H. Everett, B.J. Kowallis, E.H. Christiansen, and Alan Deino, Open-File Report 169, 60 p., $4.80. The Jurassic Carmel Formation and Twin Creek Limestone of southern and central Utah are thought to be time equivalent deposits of marine carbonate and terrigenous sedimentary rocks that document a transgression of a shallow epeiric sea that extended southward from Canada to slightly beyond Carmel Junction, Utah. Lithologies of the two formations are similar to some extent. The interpretation of time equivalency is based on similar fossil assemblages of pelecypods and gastropods placing the age of the lower portions of both formations as Bajocian. However, in some areas fossils are not diagnostic or are non-existent, making correlation within and between the two formations difficult.

Both formations contain bentonites (altered volcanic ash layers) that can be used in correlations based on zircon morphology, phenocryst assemblages, ^{40}Ar-^{39}Ar dating, and geochemical fingerprinting. Bentonite samples were collected from five sections of the two formations and were compared using the above characteristics.

Geothermal resources map of Utah, by UGMS staff, 1 pl., approx. scale 1:100,000, 1990, Public Information Series 4, $1.50.

A reference map 24" x 19" with thermal springs, known geothermal areas, and areas favorable for the discovery of warm water. The information on the map is updated from UGMS Map 68, Energy resources map of Utah, and is meant for general reference and as a teaching device.

Earthquake instrumentation for Utah, report and recommendation of the Utah Policy Panel of Earthquake Instrumentation, edited by W.J. Arabasz, 164 p., Open-File Report 168, $13.00. The Wasatch Front area is a classic example of a seismically active region having only moderate historical seismicity but high catastrophic potential from future large earthquakes.

It is well established that the disastrous effects of earthquakes can be significantly lessened by proper siting and construction practices and by effective disaster-response planning. But these strategies critically depend upon accurate information that reliably characterizes and predicts the earthquake hazards beforehand and earthquake information that is rapidly transferred to emergency management officials when a destructive event occurs.

In a fundamental way, earthquake-related information is linked to instrumentation. Unfortunately, existing earthquake-related instrumentation in Utah is out-of-date and seriously inadequate for meeting the state's needs—for earthquake monitoring, hazard identification and mitigation, defensive engineering design, and emergency response and public safety. This briefing paper consists of six parts: Introduction; A. Modernizing seismic-network instrumentation; B. Strong-motion instrumentation for earthquake engineering; C. Portable seismographs for strategic data collection; D. Communication systems for information transfer; and, E. Earthquake deformation monitoring from global positioning satellite measurements.

Earthquake fault map of a portion of Weber County, Utah, by UGMS staff, 1 page, approximate scale 1 inch = 2 miles, Public Information Series 1. A generalized map showing the location of Holocene faults in the Wasatch Front portion of Weber County. Street names and geographic points of reference are identified. This handout is free.

Earthquake fault map of a portion of Davis County, Utah, by UGMS staff, 1 page, approximate scale 1 inch = 3 miles, Public Information Series 2. A generalized map showing the location of Holocene faults in the Wasatch Front portion of Davis County. Street names and geographic points of reference are identified. Free.

Earthquake fault map of a portion of Salt Lake County, Utah, by UGMS staff, 1 page, approximate scale 1 inch = 3 miles, Public Information Series 3. A generalized map showing the location of Holocene faults along and west of the Wasatch Front in Salt Lake County. Street names and geographic points of reference are identified. Free.

Complete Bouguer gravity anomaly map of Utah, 1989, by Kenneth L. Cook, Vicki Bankey, Don R. Mabey, and Michael DePangher, Map 122, scale 1:500,000. . . . . $5.00

The Complete Bouguer gravity anomaly map of Utah is the result of a cooperative effort by the Utah Geological and Mineral Survey, the United States Geological Survey, and the University of Utah Department of Geology and Geophysics under the auspices of COGEOMAP. To prepare this map, observed gravity values from approximately 46,000 gravity stations were adjusted and reduced to simple Bouguer anomaly values, and then terrain-corrected to produce complete Bouguer anomaly values, and then terrain-corrected to produce complete Bouguer anomaly values. The complete Bouguer anomaly values were gridded at 2.5-km spacing and contoured at a 5 milliGal interval and prepared on a topographic base with a contour interval of 500 feet.

Evaluation of seismicity relevant to the proposed siting of a superconducting supercollider (SSC) in Tooele County, Utah, by W.J. Arabasz, J.C. Pechmann, and E.D. Brown, Miscellaneous Publication 89-1, 107 p., 1989. . . . . . . $8.50

This report characterizes seismicity within a 100-mile radius of two proposed superconducting supercollider sites in Tooele County, Utah. Discussion of the regional seismotectonic setting takes the following factors into account: each site's proximity to the Wasatch fault zone, Utah's physiographic provinces, and local seismic zones as defined in the 1985 Uniform Building Code. Historical earthquake records and earthquake-related hazards are also discussed.

Regional assessment of geologic conditions for sanitary landfills in Sevier, County, Utah, by B.J. Solomon and R.H. Klauk, 17 p., 4 pl., Special Study 71, 1989. Geologic and

More New UGMS Publications

hydrologic criteria are important in siting a landfill to minimize construction and operation costs, and environmental contamination. Such criteria are best applied early in the planning process. The purpose of this project is to provide a tool for early planning by compiling regional maps depicting pertinent geologic and hydrologic conditions and using these maps to identify potentially suitable areas for landfills in the county.

This regional study has identified several potential sites for sanitary landfills within Sevier County, all of which must be confirmed by site-specific investigations. Factors used for this regional study conform with most of the Resource Conservation and Recovery Act (RCRA) Subtitle D criteria proposed by the U.S. Environmental Protection Agency (1988) for the location of municipal solid waste landfills; the remainder of the criteria, if adopted, must utilize site-specific data. All of the sites are located in unconsolidated Quaternary deposits, where the effects of slope and fracture permeability are minimized and where material workability is relatively good. The most suitable sites are in the Sevier, Grass, and Plateau Valleys of west and central Sevier County, where finer-grained alluvial deposits are common.

Geochemical characteristics of hydrothermally altered black shales of the southern Oquirrh Mountains and relationships to Mercur-type gold deposits, by Paula N. Wilson and W.T. Parry, Open-File Report 161, 64 p., 1989 .... $4.50

K/Ar age dates on vein and clay-sized fractions of whole rock indicate that the hydrothermal alteration of the Manning Canyon and Long Trail Shales in the southern Oquirrh Mountains of Utah is 193 to 122 m.y. in age and suggests that the Mercur gold deposits may be Mesozoic in age.

We propose that a large-scale, gold-bearing hydrothermal system existed throughout much of the southern Oquirrh Mountains during the mid-Jurassic to earliest Cretaceous and that this system occurred at varying stratigraphic levels throughout the area. The Mercur Mine is in an area where the hydrothermal system was stratigraphically lower and so most hydrothermal activity occurred well below the Long Trail Shale. In areas surrounding the Mercur Mine, the hydrothermal system reached much higher stratigraphic levels, at least into the Long Trail Shale and possibly into upper Great Blue Limestone and lower Manning Canyon Shale.

The results of this study suggest modification of exploration models for Mercur-type gold deposits to include areas higher in the stratigraphic section and areas remote from igneous rocks.

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Books and Papers

Mineral resources of the Scorpion Wilderness Study Area, Garfield and Kane Counties, Utah, by Susan Bartsch-Winkler, J.L. Jones, J.E. Kilburn, J.W. Cady, J.S. Duval, K.L. Cook, M.E. Lane, and P.A. Corbetta, U.S. Geological Survey Bulletin 1747-C, 1989, 15 p., 1 plate in pocket.

Mineral resources of the Fiddler Butte (East) Wilderness Study Area, Garfield County, Utah, by R.F. Dubiel, G.K. Lee, P.P. Orkild, and D.D. Gese, U.S. Geological Survey Bulletin 1759-B, 1989, 13 p., 1 plate in pocket.

Geology and geochemistry of the Broken Ridge area, southern Wah Wah Mountains, Iron County, Utah, by K.A. Duttweiler and W.R. Griffitts, U.S. Geological Survey Bulletin 1843, 1989. 32 p., 1 plate in pocket.

United States gold terranes: Part I, by E.W. Tooker, W.C. Bagby, T.H. Kiilsgaard, F.S. Fisher, E.H. Bennett, J.A. Redden, and G. McN. French, U.S. Geological Survey Bulletin 1857-B, 1989, 74 p.

Assessment of regional earthquake hazards and risk along the Wasatch Front; Volume III, edited by P. L. Gori and W.W. Hays, U.S. Geological Survey Open-File Report 88-0680, 1988. 155 p.

Water-resources activities in Utah by the U.S. Geological Survey, July 1, 1987 to September 30, 1988, compiled by S.L. Dragos and J.S. Gates, U.S. Geological Survey Open-File Report 89-0240, 1989, 71 p.

Measured stratigraphic sections of West Canyon Limestone and equivalent strata (Upper Mississippian-Middle Pennsylvanian), lower Oquirrh Group, northern Utah and southeastern Idaho, by L.E. Davis, T.S. Dyman, G.D. Webster and D. Schwarz, U.S. Geological Survey Open-File Report 89-0292, 1989, 47 p.

Analytical results and sample locality map of stream-sediment samples from the Turtle Canyon Wilderness Study Area, Emery County, Utah, by J.H. Bullock, Jr., H.N. Barton, P.H. Briggs and T.A. Roemer, U.S. Geological Survey Open-File Report 89-0304, 1989, 10 p.

A tabulation of meterological variables and concentrations of helium, carbon dioxide, oxygen, and nitrogen in soil gases collected regularly from four sites at the Roosevelt Hot Springs Known Geothermal Resources Area, Utah, by M.E. Hinkle. 30 p., U.S.G.S. Open-File Report 88-0685.

Preliminary geologic map, cross-sections, and explanation pamphlet for the Bingham Canyon 7½-minute Quadrangle, Salt Lake and Tooele counties, Utah, by E.W. Tooker and R.J. Roberts, 33 p., 2 over-size sheets, scale 1:24,000. U.S.G.S. Open-File Report 88-0699.

Geologic map of the Lynndyl 30- by 60-minute quadrangle, west-central Utah, by E.H. Pampeyan. 1989. Lat 39°30' to 40°, long 112° to 113°. Scale 1:100,000. Accompanied by 9 pg. text. U.S.G.S. Miscellaneous Investigations Map 1830.

Complete Bouguer gravity map and related geophysical maps of the Delta 1° x 2° quadrangle, Utah, by Viki Bankey, and K.L. Cook, U.S. Geological Survey MF-2081-A, 1989. Lat 39° to 40°, long 112° to 114°. Scale 1:250,000 (1 inch = about 4 miles). Sheet 40 x 49 inches (in color).

Map showing the areal distribution of oil shales with associated mineral resources and metal anomalies in the Western United States and Alaska, by L.J. Schmitt, U.S. Geological Survey MF-2091, 1989. Two Sheets, Scale 1:2,500,000 (1 inch = about 40 miles).

Surficial geologic map of the East Cache fault zone, Cache County, Utah, by James McCalpin, 1989, U.S. Geological Survey MF-2107. Lat 41°30' to 42°, long 111°45' to 111°52'30". Scale 1:50,000 (1 inch = about 4,200 feet). Sheet 38 x 47 inches.

Hydrogeology of the Dakota Sandstone in the San Juan structural basin, New Mexico, Colorado, Arizona, and Utah, by S. D. Craigg, W.L. Dam, J.M. Kemodle and G.W. Levings, U.S. Geological Survey HA-0720-1, 1989. Two sheets. Lat 35° to about 37°30', long about 107° to about 109°. Scale 1:100,000 (1 inch = about 16 miles). Each sheet 34 x 44 all in color.

The effects of volcanic ash on the maceral and chemical composition of the C coal bed, Emery coal field, Utah: in ***A selection of papers from the 4th annual meeting of the Society for Organic Petrology,*** by S.S. Crowley, R.W. Stanton and T.A. Ryer, Organic Geochemistry, v. 14, no. 3, 1989. p. 315-407.

Evolution of hydrothermal fluids in the Park Premier Stock, central Wasatch Mountains, Utah, by D.A. John, Economic Geology and the Bulletin of the Society of Economic Geologists. v. 84, no. 4, July 1989.

Coal, classification, coalification, mineralogy, trace-element chemistry, and oil and gas potential, by P.C. Lyons and Boris Alpern (editors). International Journal of Coal Geology, v. 13, no. 1-4, July 1989, 626 p.

Analytical results and sample locality map of stream-sediment, heavy-mineral-concentrate, and rock samples from the North Stansbury Mountains Wilderness Study Area, Tooele County, Utah, by B.M. Adrian, K.A. Duttweiler, J.D. Gacetta and D.L. Fey. 1988. 20 p., 1 over-size sheet, scale 1:62,500 (1 inch = about 1 mile). U.S. Geological Survey OF 88-0520.

Debris flows and hyperconcentrated floods along the Wasatch Front, Utah, 1983 and 1984. By G.F. Wieczorek, E.W. Lips and S.D. Ellen. Bulletin of the Association of Engineering Geologists, v. 26, no. 2, May 1989, p. 191-208.

Teacher's Corner

by Sandra N. Eldredge

Earthquake Curriculums? Yes! Available now is a **K-6 curriculum** developed by the National Science Teacher's Association (NSTA) under a contract with the Federal Emergency Management Agency. This teacher's manual has six units: each of the first five units is divided into three grade levels (K-2, 3-4, 5-6), and the last unit addresses earthquake safety and survival. The curriculum includes background information, activities, overhead and worksheet masters. A teacher inservice will be held at the Utah Museum of Natural History May 4-May 5 (see details below). Another workshop for using this curriculum will be held May 18-19 through the Granite School District. Call the Utah Division of Comprehensive Emergency Management (584-8370) for further information.

The **high-school curriculum** earthquake materials are now being developed by the Utah Division of Comprehensive Emergency Management (lead agency), Utah Geological and Mineral Survey, and the Utah Museum of Natural History in cooperation with a Steering and Review Committee. The content includes earthquake hazards, and other geologic and natural hazards as well. The series name is "Places with Hazards" focusing on where in Utah these hazards occur or could be expected to occur. The materials will be provided with instruction. A pilot project will be implemented at a few schools for the 1990-1991 school year, with the goal for full implementation during the 1991-1992 school year.

April is National Earthquake Safety Month! Contact the following agencies for earthquake information:

For earthquake preparedness:
Utah Division of Comprehensive Emergency Management
1543 Sunnyside Avenue
Salt Lake City, UT 84108
(801) 584-8370

For geology, faulting, and earthquake hazards in Utah:
Utah Geological and Mineral Survey

For earthquakes:
University of Utah Seismograph Stations
705 William Browning Building
Salt Lake City, UT 84112
(801) 581-6274

For specific geologic information in Salt Lake County:
Craig Nelson, Salt Lake County Geologist
Salt Lake County Planning
2001 South State Street, Room N3700
(801) 468-2061

For general earthquake information:
U.S. Geological Survey
Earth Science Information Center
125 South State Street
8th Floor, Federal Building
Salt Lake City, UT 84138
(801) 524-5652

In addition to numerous geologic-hazard publications provided by the UGMS Applied Geology Program, also available at UGMS are brief information sheets on geologic hazards in Utah, several of which are about earthquake hazards. Highlighted in this issue's "New Publications" are three separate maps showing earthquake faults in Weber, Davis, and Salt Lake counties, **Public Information Series 1, 2, and 3.**

Inservice classes offered this spring at the Utah Museum of Natural History (UMNH) include: "Footed fossils and the like from Utah's ancient seas," April 21, 22 and April 28, 29; "Earthquake Curriculum (USTA/FEMA)," May 4, 5; and "Archetypal Geology" (i.e. geology lessons in Arches National Park), May 8, 12, 13. Call Deedee O'Brien at UMNH (581-6927) for more information.

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