



SURVEY NOTES

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UTAH GEOLOGICAL & MINERAL SURVEY

STATUS OF UGMS

AUGUST 14 & 18, 1988 EARTHQUAKE

UTAH GEOLOGICAL
AND MINERAL SURVEY

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FROM THE DIRECTOR'S CORNER

Utah's "Sunset legislation" requires that state agencies periodically be reviewed and reauthorized. This year, UGMS is one of several agencies undergoing this review by the legislature. The procedure for reauthorization of UGMS and most other state agencies is for a committee of legislators to hold at least one hearing to review the activities of the agency and determine whether the agency is fulfilling the purpose for which it was established and if the need for the agency still exists. The committee reports to the next session of the legislature which then must either reauthorize the agency or terminate it.

Some agency heads approach these hearings with considerable trepidation but I was enthusiastic about the UGMS hearing. I am proud of the UGMS and its program and the hearing provided an opportunity to describe to a group of legislators what the UGMS does and why it is needed by the State. In addition, it provided an excellent opportunity for the UGMS management and staff to review the accomplishments of the organization and to reflect on how well we are meeting the needs of the state. Believing in this "sunset" concept, I voted for the legislation requiring these reviews. It is always interesting to experience the effects of legislation one has helped develop.

The committee addressed the following questions: 1) For what public purpose was the UGMS created? 2) Is the purpose still relevant? 3) To what extent has the UGMS operated in the public interest and accomplished its objectives? 4) Do budget, resource, or personnel constraints interfere with the legitimate functions of UGMS? If so, what are the implications of those constraints? 5) To what extent has the public been encouraged to participate in the adoption of rules by the division? 6) To what extent are the programs and services of the division duplicative of those offered by other state or federal agencies? 7) What would be the adverse effects on the public if the division were terminated? 8) If reauthorized, what changes in statute should be made to enable the division to better fulfill its public purpose? To answer these questions, the legislative staff and UGMS personnel compiled information for the committee; and the committee staff conducted extensive interviews with users of UGMS services and products and with organizations and individuals with direct knowledge of the UGMS.

The committee staff request included information on UGMS history, purpose, and programs. Several members of the UGMS staff were involved in compiling this material. The lead article in this issue is a summary of this information.

The findings of the committee were summarized as follows:

"Has UGMS operated in the public interest?"

- ☐ Services of the UGMS are vital to industry and government.
- ☐ Calibre of work is very good.
- ☐ Staff is accessible, cooperative, helpful.

"How would termination adversely affect the public?"

- ☐ Overall costs of information gathering would mushroom as industries and government agencies duplicate efforts.
- ☐ Lost mineral development opportunities.
- ☐ Individual state agencies would have to hire geologists.
- ☐ Public safety threatened due to lack of awareness of hazards.

"What constraints interfere with UGMS' mission?"

- ☐ Fluctuating level of mineral lease money.
- ☐ Isolated location at Research Park.

I was pleased with the committee's reaction to the review of UGMS. The committee feels, as I do, that the UGMS is staffed with dedicated employees who are efficiently performing a service that is essential to the state.

Status of the Utah Geological & Mineral Survey, 1988

by Genevieve Atwood

Virtually all states have recognized the need for geologic expertise in developing and managing natural resources and providing protection from geologic hazards and have established state geological surveys. Some state surveys are even older than the U.S. Geological Survey. State surveys vary considerably in size and mission depending on the perceived needs and resources of the state.

Geology had an important effect on the prehistoric residents of Utah and became increasingly important when permanent settlements were established in the 1840s. Those attempting to develop the mineral resources of Utah were well aware of the importance of geology to the success of their activities, but those engaged in other types of development were often not aware of the importance of geology until problems related to geologic hazards developed. We still have not experienced all of the geologic hazards that Utah has in store.

HISTORY OF UGMS

The major early geologic studies (1870-1910) in Utah were made by federal surveys, especially by the U.S. Geological Survey. These federal surveys were concerned with all aspects of the geology of Utah and some of the outstanding research of that era was done in Utah by such "giants" of geology as Gilbert (Lake Bonneville and the Henry Mountains), Powell (the Colorado River), Dutton (the Colorado Plateau), and Butler (ore deposits of Utah). With no state or local government expertise in geology, the responsibility for local leadership on geologic problems fell largely upon the University of Utah. James E. Talmage, professor of geology and president of the university, was an early leader in developing geological expertise at the University of Utah.

Utah's geological survey was authorized by the legislature in 1931 but had no funding or staff until 1941. Then it was incorporated into the Utah State Department of Publicity and Industrial Development as the Utah Geological and Mineralogical Survey with a small staff and budget and with the primary objective of stimulating the development of the state's mineral resources. In 1949, the UGMS was transferred to the School of Mines and Mineral Industries in the University of Utah but the staff and budget remained small until 1961. Much of the UGMS effort in these early years was in the publication of work by non-UGMS authors.

In 1961, the UGMS began a period of growth with an expanding staff and budget. More attention was focused on economic geology and geologic problems of direct and immediate interest to the state. The Utah Geological and Mineral Survey was made a part of the Department of Natural Resources in 1973. Major cooperative programs were developed with the Federal government, which became an important source of funding for UGMS programs. Economic geology has remained the largest activity in the UGMS but in recent years applied geology (investigations related to engineering geology and geologic hazards) and multipurpose geologic mapping have received more emphasis.

The mission and legislation authorizing the UGMS are stated in the Utah State code. In order to address the questions posed in the legislative review as to whether the missions of UGMS is still justified, and if the UGMS is functioning effectively in these areas, the missions were grouped into the following:

STATUTORY MISSION I — Provide accurate, reliable geologic information to the public, industry, universities, governmental agencies and others by preparing, publishing, distributing and selling maps and reports embodying the work accomplished by the UGMS and others.

STATUTORY MISSION II — Collect and preserve reports, data and samples related to exploration, development and construction activities in Utah, and to maintain certain types of confidential information.

STATUTORY MISSION III — Advise state and local agencies. Specifically, assist governmental agencies in their planning, zoning, and building regulations related to geologic hazards and resources. Investigate the mineral resources of state lands to contribute to the beneficial administration of these lands.

STATUTORY MISSION IV — Collect and distribute information on mineral, energy and water resources (including geothermal energy and mineral-bearing waters such as Great Salt Lake) with special reference to economic content and availability for utilization.

STATUTORY MISSION V — Identify and investigate topographic and geologic hazards (particularly earthquake hazards) and, at the request of state and local governments, review the siting of critical facilities.

STATUTORY MISSION I

Provide accurate, reliable geologic information to the public, industry, universities, governmental agencies and others by preparing, publishing, distributing, and selling maps and reports embodying the work accomplished by the UGMS and others.

Is this mission still justified? The need to make geologic information readily accessible increases continuously. As the exploration for and development of geologic resources becomes more sophisticated, the need for and ability to use a wide variety of geological information increases. Most land-use decisions require geologic information, as do the design and construction of many structures. Many research projects build on a base of existing geologic information and the general public is becoming an increasingly important user of geologic information. To be effective in most uses, this information must be available upon demand and the maps, reports, data bases, and other sources must be available when the need develops. Thus, it is essential that the UGMS continue this mission of supplying this information.

Measurement of UGMS effectiveness. The primary measurement of UGMS effectiveness in performing this mission is the quality and number of publications produced. The list following this article gives an idea of the UGMS contribution to enhanced State revenues. The UGMS is continuously producing a wide variety of publications designed to meet the needs for geologic information in Utah. A glance through *Recent Publications* in each issue of *Survey Notes* should make this evident. In addition to the formal and informal publications, the UGMS has developed several data bases that can be accessed by the public. A special information group answers most public inquiries and the technical staff is available to respond to inquiries requiring special technical expertise. Special field reviews of major field projects are held and the potential users of the information that has been developed are invited to attend. Workshops are held to disseminate information and special instruction is provided to users of information.

Additional resources or legislation needed. The techniques for collecting, compiling, and disseminating geologic information are developing rapidly. Computers have become an essential part of the UGMS operation and this use is expanding rapidly. The UGMS has been able to keep abreast of these rapid changes with existing resources and no additional resources or legislation are required.

STATUTORY MISSION II

Collect and preserve reports, data and samples related to exploration, development and construction activities and maintain certain types of confidential information.

Is this mission still justified? This mission becomes increasingly important as the amount of geologic information increases. No other group has as a major mission the preservation of geologic information relating to Utah and if the UGMS does not perform this function, much valuable geologic information will be lost. It is important that the State of Utah have information available on the geology and resources of Utah to make decisions on State-Federal land exchanges and on land-use decisions such as wilderness designation. By having a central repository of geologic information, UGMS can encourage economic development of Utah's geologic resources and provide information about geologic hazards.

Measurement of UGMS effectiveness. The UGMS has the most up-to-date bibliography on Utah geology in existence. In addition to published reports, the bibliography contains references to many unpublished reports and maps. The UGMS maintains extensive collections of unpublished reports such as engineering geology studies, and maps such as old mine maps. Legislation approved in 1986 enables the UGMS to hold certain information confidential such as information donated by industry. The UGMS Sample Library contains cuttings and cores from many drill holes but until recently has not had the space or personnel to accept much of the material available. The sample library has recently moved into new space that is allowing for significant expansion.

New legislation or rules required. The UGMS does not have the funding or personnel resources to maintain a first-class sample library. UGMS Sample Library would be more beneficial to the state and to industry if companies were required to donate samples from significant wells. Likewise, industry should be

encouraged to provide geologic information on state lands; companies doing exploration could improve the state's effectiveness to manage these state lands and resources. When UGMS moves, the new facility should be designed to make as much information easily available to the public as possible. Some state geological surveys have large reading rooms equipped with copying facilities as part of their library of maps, air photos, published and unpublished reports.

STATUTORY MISSION III

Advise state and local agencies. Specifically, assist governmental agencies in their planning, zoning, and building regulation related to geologic hazards and resources. Investigate the mineral resources of State Lands to contribute to the beneficial administration of these lands.

Is the mission still justified? As the need of state and local government agencies for geologic information has increased, so has the importance of this UGMS mission. Most agencies cannot justify adding a full-time geologist to their staff. Being able to call on the UGMS staff for support is a satisfactory way of meeting their need. Agencies that have geologists on their staff (such as the Department of Transportation) occasionally need the services of UGMS experts to supplement the expertise of the geologist on their staff and are major users of UGMS basic geological information. The Division of State Lands and Forestry uses information on the resources of the lands they administer in order to manage these lands.

Measurements of UGMS effectiveness. The best measurement of UGMS' effectiveness is the continuing number of requests received for assistance. In 1987, 16 state agencies, five county planning agencies, one county health department, three city planning/engineering agencies, one school district, and four state colleges and universities requested assistance from the UGMS. In addition, ten federal agencies requested UGMS assistance on problems relating to Utah and two adjacent state geological surveys requested assistance.

New legislation or rules required. None.

STATUTORY MISSION IV

Collect and distribute information on mineral, energy and water resources (including geothermal energy and mineral-bearing waters such as Great Salt Lake) with special reference to economic content and availability for utilization.

Is the mission still justified? Utah has a wide variety of mineral and energy resources and these resources have been very important in the economic development of the state. Water resources are also extremely important to the state. Wise management and development of state resources requires information on these resources and the UGMS has the primary responsibility for assuring that this information is available when needed. The need for this information increases each year. The availability of information on resources has often been instrumental in attracting new industries to Utah and thus, the UGMS has an important role in encouraging economic development in Utah. Many land-use decisions that must be made by state, local and federal government agencies require information on the resources of the lands involved.

Measurements of UGMS effectiveness. The UGMS has obtained, through its own studies and through the work of others, much data on the resources of Utah. Much of this data has been included in reports published by the UGMS and is readily available. State-wide maps showing the location of known energy resources and major mineral deposits have been published by the UGMS. Several important developments of resources are a direct result of information in these UGMS reports. Much more information is in UGMS files and in the sample library. A primary objective of programs currently underway is to make this information easily accessible to the public.

New legislation or rules required. Geologic information acquired by private industry from exploration on state lands would be very useful to the state in the administration of these lands. We believe that the state should investigate ways to encourage industry to provide the information they collected on state lands to the state.

STATUTORY MISSION V

Identify and investigate topographic and geologic hazards (particularly earthquake hazards) and, at the request of state and local governments, review the siting of critical facilities.

Is this mission still justified? Utah is exposed to a wide variety of geologic hazards and actions. A knowledge of the hazards is required to minimize the risk from these hazards. As Utah becomes more developed, the importance of this information increases. An understanding by all decisionmakers, in government, private sector, and the public in general, is necessary to deal effectively with these hazards. Ordinances and codes relating to geologic hazards must be based on adequate geologic information.

Measurement of UGMS effectiveness. Through a cooperative program between the U.S. Geological Survey and the UGMS, topographic maps covering the entire state of Utah at a scale of 1:24,000 will be available at the end of 1989, and updating of these maps is a continuing part of the program. Topographic maps at this scale are essential to effectively work with geologic hazards. Also, by the end of 1989, the UGMS will have completed state-wide hazards maps showing the geographic distribution of major geologic hazards. Through efforts with the USGS, local universities, and numerous state and local agencies, the UGMS is working to make information on hazards available and to encourage the actions needed to reduce the risk from these hazards.

New legislation or rules required. The UGMS believes that legislation requiring the disclosure of information on geologic hazards when property is transferred would be a major advance in assisting companies and individuals in protecting themselves from geologic hazards. All critical facilities in the state should have a geotechnical site review, and the state should incorporate appropriate seismic standards into all public buildings built with state funds.

Coordination with other agencies

As part of the "Sunset" review, we examined the activities of the UGMS relative to other federal, state, and local government agencies and universities to determine if there was duplication

or overlap and also to determine if there were areas where the need for geologic information was being neglected. We also attempted to determine how the activities of the UGMS impacted the private sector and served the needs of the individual residents of Utah.

The government agency that most nearly parallels the UGMS is the U.S. Geological Survey (USGS). The USGS spends several times as much money on projects in Utah as does the UGMS and much of the research done by the USGS outside of Utah has application to Utah's geology. It is important that the UGMS coordinate with the USGS to minimize duplication and to maximize the usefulness to Utah of work done by the USGS. Twice a year, I meet for several days with the management of the USGS and other state geologists of the region to discuss the activities of the USGS and to describe the needs of Utah to the USGS. The UGMS and the USGS have an extensive cooperative program. It includes projects where scientists from both organizations work together toward common goals. An example of this kind of project is the mineral appraisal of the Delta 1x2 degree quadrangle. Other cooperatives involve joint funding support for work done by the UGMS (the Sevier Desert Quaternary geologic mapping project, for example, see *Survey Notes*, v. 21 no. 2-3) or joint funding for work done by the USGS (topographic and geologic quadrangle mapping). Some UGMS activities such as projects in the National Earthquake Hazards Reduction Program are supported entirely by the USGS. When responding to the floods and landslide events of 1983 threatened to overwhelm UGMS staff, we discovered another benefit of close cooperation with the USGS. They responded immediately to our request for assistance, sending experts to work directly with our staff to meet the emergency needs. The UGMS-USGS cooperation is an outstanding example of how two government agencies can work together to effectively accomplish the objectives of both state and federal programs.

The UGMS also has cooperative programs with the Bureau of Land Management and the Department of Energy involving work done by the UGMS on resource problems, and maintains contacts with the Bureau of Mines on resource issues and with the Forest Service and the Federal Emergency Management Agency (through the Utah Division of Comprehensive Emergency Management) on geologic hazards. Once each month, along with the directors of other Department of Natural Resources divisions, I meet with the heads of federal resource operations headquartered in Salt Lake City to discuss mutual concerns. The relations with federal agencies other than the USGS are not as effective as those with the USGS, but we do avoid major duplication and share information.

The UGMS has generally good working relations with individuals and departments in Utah State, Utah, and Brigham Young Universities concerned with earth science problems. Through our contract and grant programs, we furnish some support for research on geologic problems identified by the UGMS. The talent thus made available in these universities is an important supplement to the UGMS staff.

As the state's lead geologic organization, the UGMS provides advice and assistance to all state agencies requesting it and attempts to provide geologic input to all state policy decisions where geologic considerations are important. The Division of State Lands and Forestry and the Division of Oil Gas and Mining provide funding support to the UGMS for resource work related directly to their programs and the Division of Community and Economic Development supports several UGMS projects

designed to assist local communities and encourage economic development. When state agencies require continual participation of geologists in their programs, the UGMS encourages them to consider adding geologists to their staff with the specialties they require. UGMS continues to be available to assist these agencies with special problems and to assist the managers of these agencies in developing and administering these programs. Several state agencies now employ geologists. Some problems of duplication arise when the Utah State Code has assigned two or more state agencies overlapping functions. For example, the UGMS and CEM both have responsibilities relating to earthquake hazards. I meet periodically with the Director of CEM to discuss the activities of our two divisions to minimize the duplication and confusion. In some instances, the state's procedures and policies conflict with UGMS objectives. For example, the procedures for authorizing and funding state construction projects do not encourage adequate consideration of geologic hazards. In general, the UGMS is providing good geologic support to state agencies, but the information and talent available at UGMS is not always utilized by them.

The UGMS works well with most local government agencies. Because there is little geologic expertise within these organizations, there is little chance for duplication. Notable exceptions are Davis, Salt Lake, and Utah Counties. With funding and support from the USGS, the UGMS has assisted these counties in employing full-time geologists in their planning departments. The activities of these geologists are closely coordinated with related activities at the UGMS.

The UGMS avoids competition with the private sector. Our work clearly generates more work for private industry than we take away and our review activities are structured to improve the quality of some of this work. We are now involved on a project to

determine what kinds of UGMS information and activities are most effective in stimulating the development of Utah's geologic resources.

Funding needs

If the funding and personnel resources were available to the UGMS, there are many things that could be done that would benefit the state. But considering the funding available to state government and the numerous demands on these funds, I conclude that the state's level of support to the UGMS is appropriate. As Director of UGMS, I am very concerned that we are not providing adequate salaries for some staff. The salary scale for state employees makes this impossible but as a result the UGMS attracts geologists who are not "money drivers." Some have a hyperactive social conscience and receive compensation by seeing the geology they do make a difference to society. Others are risk adverse and trade off the lower salary for the greater security of state employment. Others have additional outside income. The net result is that many highly qualified individuals turn down service to the state on purely economic grounds.

Conclusion

I think the "Sunset" review of the UGMS has been very effective. It has accomplished exactly what it was intended to do—assure the legislature that the organization is needed and functioning well. It has also provided an opportunity for the UGMS to assess our activities and identify activities needing more emphasis and areas where our operation can be improved.

Specific Examples Where UGMS Publications Have Contributed to Economic Development Which Enhanced Revenues to the Division of State Lands.

BULLETINS

UGMS PUBLICATION	COMMODITY	LOCATION	COMPANY	NOTES
Bull. 38, 39, 43, 45, 53, 57	Petroleum	Central Utah	Placid Oil	Invested over \$100 million, specifically chose State sections as drilling locations
Bull. 41	Clay	Pelican Point	Interpace	
Bull. 44	Clay Silver	Pelican Point Silver Reef District	Interstate Brick 5M Mining Company	Leaching material from several mines (mining claims?)
Bull. 46	Vanadium, uranium	Thompson District	Cordero Mining Co., etc.	Pittsburg Mine expanded
Bull. 54	Petroleum	Upper Valley Field	Tenneco	10-15 holes on State leases
Bull. 56	Dolomite	Delle	Utah Marblehead Lime	
Bull. 62	Gold, tungsten	New Klondike Property	New Klondike Mining Co.	Mining claims
Bull. 63	Gold	Lookout Pass	Freeport McMoRan	Mining claims
Bull. 64	Petroleum	Cache County	Mountain Fuel/Placid Oil	Spent more than \$4 million on seismic exploration
Bull. 68	Copper, tungsten	Bwana, Maria, etc., Mines	West Toledo Mining Co.	Mining claims
Bull. 71	Oil shale	Kamp Kerogen	Geokinetics	State leases
	Oil shale	Sand Wash	Tosco	State leases
	Phosphate	Brush Creek	U.S. Steel	
	Tar sand	Raven Ridge	Western Tar Sands Inc.	
	Tar sand	Asphalt Ridge	Enercor	
	Tar sand	Asphalt Ridge	Sohio	
	Tar sand	Asphalt Ridge	Asphalt Ridge Energy	
Bull. 75	Clays, uranium	West Desert	Interstate Brick	
Bull. 78	Petroleum	Western Utah	Placid Oil	Exploration on state sections
Bull. 83	Gold	Yellow Hammer Mine	American Consolidated	Mining claims
Bull. 112	Coal	Trail and North Horn Mtn.	UP&L, Natomas	Increased reserves and value of all State sections
Bull. 116	Salts, brines	Great Salt Lake	Mineral companies, Public	Reference book
Bull. 115	Tungsten	Box Elder County	small companies	
Bull. 119	Petroleum	Kachina Field	Meridian	.5 million bbl production
	Petroleum	Kiva Field	Yates	

SPECIAL STUDIES

Spec. Studies 3	Coal	Escalante Area	UP&L	State lease
Spec. Studies 5	Petroleum	Rozel Point	All Minerals	
	Petroleum	Great Salt Lake	Amoco	
Spec. Studies 12	Alunite	Blawn Mountain	Alumet Inc.	
Spec. Studies 15	Coal	SUFCO Mine	Coastal States	
Spec. Studies 19	Tar sand	Asphalt Ridge	Enercor	
	Tar sand	Asphalt Ridge	Sohio	
	Tar sand	Asphalt Ridge	Asphalt Ridge Energy	
Spec. Studies 20	Coal	UP&L drilling project	UP&L	
Spec. Studies 22	Uranium	Woodruff Springs	Exxon	9 million ton ore body
	Uranium	Ticaboo	Plateau	9 million ton ore body
Spec. Studies 23	Clay	Pelican Point	Interstate Brick	
	Clay	Pelican Point	Interpace	
Spec. Studies 37	Tar sand	Tar Sand Triangle	Gulf Mineral Resources	
	Tar sand	Asphalt Ridge	Enercor, Sohio, Asphalt Ridge	
			Energy Corp.	
	Tar sand	Raven Ridge	Western Tar Sands	
	Tar sand	Sunnyside	Standard Oil (Indiana), Great	
			National, Mono Power,	
			Amoco, Enercor	
Spec. Studies 49	Methane	Price River Mine	Occidental Petroleum	
	Methane	Soldier Canyon Mine	REI/Soldier Creek Coal	
	Methane	SUFCO Mine	Coastal States	
Spec. Studies 54-55	Coal	North Horn Mountain,	Exxon, Arco	Leasing
		East Mountain, Muddy Creek		
Spec. Studies 63	Geothermal	Escalante Valley	Utah Municipal Power	
Spec. Studies 67	Geothermal	Washington County	Dixie Power & Light	Exploration

MONOGRAPHS

Monograph 1-3	Coal	Central Utah, So. Wasatch Plateau	IPP	Originally intended to go to New Mexico
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MISCELLANEOUS

RI 199	Land development	Washington County	Div. State Lands	Need to develop general management plan
RI 200	Minerals	West Desert	Div. State Lands, BLM	Information for land evaluations
RI 212	Land development	Washington County	Div. State Lands	Resort development
WRB 25	Brines	Great Salt Lake	AMAX, Great Salt Lake	Alternative sources of brine
			Minerals, Morton	
File Data	Brines, salts	Sevier Lake	W.D. Haden	Resource, processing data
Memo	Salts, brines	Sevier Lake	Mineral Leasing Task Force	Potassium lease holding increase analysis
Tech. Memo	Land development	Iron County	Div. State Lands	Ski resort
Tech. Memo	Land development	Garfield County, Bullfrog	Div. State Lands	Boat storage and restaurant
Tech. Memo	Land development	Iron County	Div. State Lands	Land exchange
Data Base	Oil well brines	Utah	Petroleum and mineral companies, Div. of Oil, Gas and Mining	Baseline data, reinjection programs, resource

MAPS

Map 24	Coal	Kaiparowits	Peabody Coal Co.	
Map 47	Tar sand	Tar Sand Triangle	Gulf Mineral Resources	
	Tar sand	Asphalt Ridge	Enercor, Sohio, Asphalt	
			Ridge Energy Corporation	
	Tar sand	Raven Ridge	Western Tar Sands	
	Tar sand	Sunnyside	Standard Oil (Indiana), Great	
			National,	
			Mono Power, Amoco,	
			Enercor	
Map 53	Sand and Gravel	Wasatch Front	Utah International	
Map 58	Petroleum	Laketown area	American Quasar	Test well
Map 63	Coal	Book Cliffs	Pinnacle	Land acquisition
Map 72	Coal	Soldier Canyon	Suneco	
Map 76	Coal	Pinnacle Mine	Tower Resources	Also used by BLM for leases
Map 77 and Bull. 115	Gold	Tecoma Deposit	Noranda/Western States	Mining claims
Map 90	Petroleum	T. 31 S., R. 9 E., sec. 24	Exxon	Exploration well

CIRCULARS

Circular 38	Diatomaceous earth	Bryce Canyon	Johns-Manville	Drilled deposit
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OPEN-FILE REPORTS

OFR 87	Brines	Great Salt Lake	All mineral companies	Great Salt Lake baseline data
OFR 114	Gold	Keg Mountain Prospect	Freeport McMoRan	Mining claims
Sample Library	Petroleum	Statewide	Virtually all exploration companies	
	Gold	Mercur	Getty Minerals	
	Coal	Wasatch Plateau	numerous	Federal leases

Rockfall in Hackberry Canyon, April, 1988

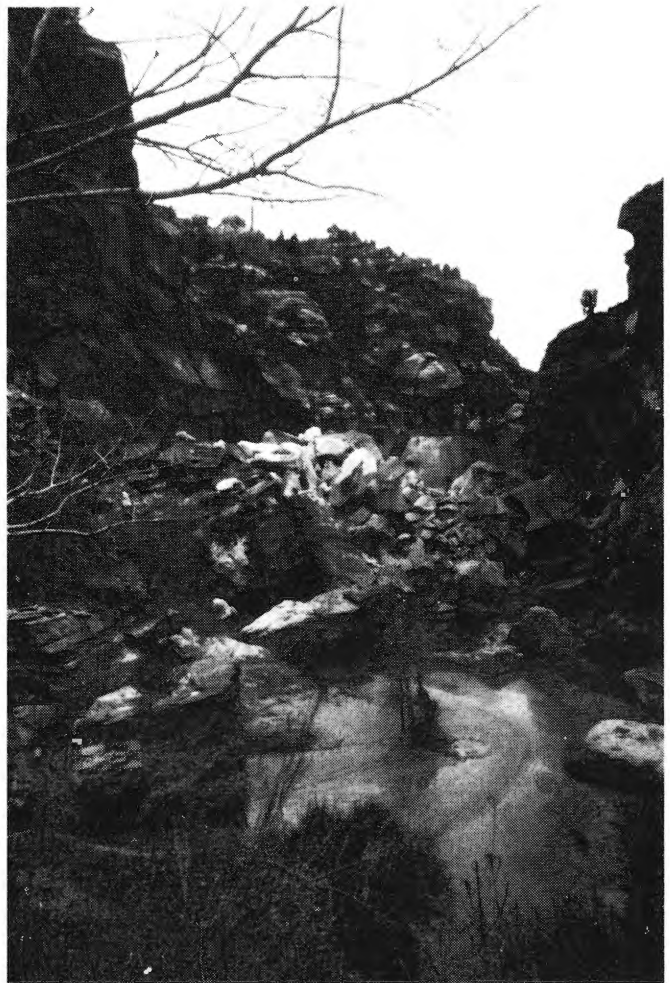
by Hellmut H. Doelling

A very large rockfall blocked off the trail in upper Hackberry Canyon, in SESWSW Sec. 21, T 40 S, R 1 W, in central Kane County. In mid-April, about 4½ miles from the mouth of the canyon, a section of cliff peeled off the west wall, and the debris knocked over and uprooted shrubs and brush on the far wall. The creek was dammed or restricted in its flow enough to create a small lake extending 100 yards upstream. At the time of my visit on April 28, the creek had worked through the debris and appeared unhindered in its flow, with the most extensive hole of the remaining lake about four feet deep.

The width of the canyon at this point is nearly ninety feet, with the height of the broken material some 35 to 40 feet above the creek

level. Originating in the Kayenta Formation, probably as the creek undermined the west side of the canyon, the rockfall fell away as a large slab and broke into fragments, the largest of which are 35 x 35 x 20 feet.

The canyon, part of the Hackberry Canyon Wilderness area, is in the Calico Peak 7½-minute quadrangle, currently being geologically mapped at a scale of 1:24,000 by the UGMS. The map area is one of great scenic beauty with many interesting geologic features including the East Kaibab monocline, great toreva block slides, large areas of mass-wasting deposits, petrified wood, strata attenuation, and, as it now appears, large rockfalls.

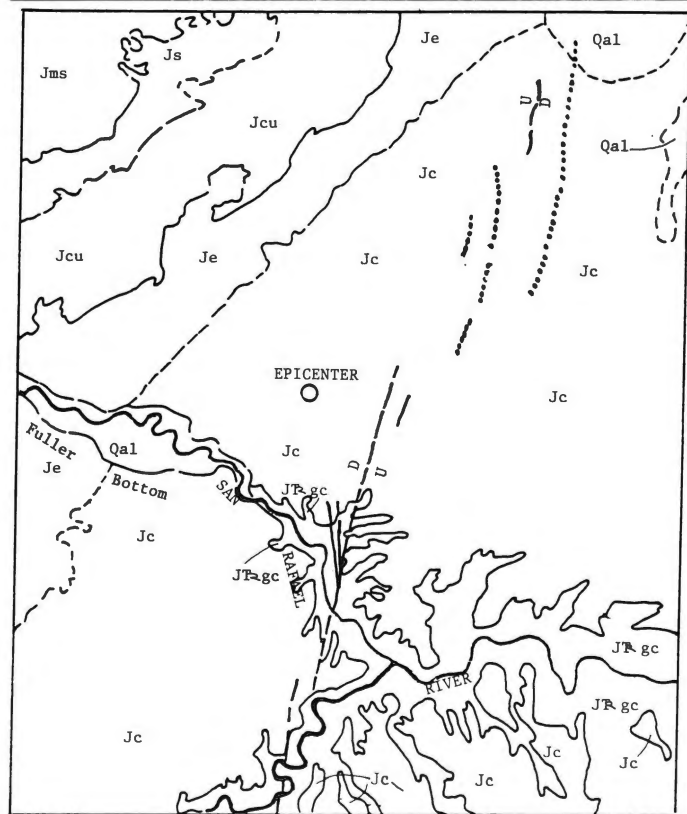


On Sunday afternoon at 2:03 PM, the 14th of August, the San Rafael Swell earthquake (magnitude 5.3) struck Castle Valley, east of Castle Dale, in central Utah on the west flank of the San Rafael Swell. Many governmental and academic agencies responded to the earthquake because: 1) the geologic effects and damage from magnitude 5 earthquakes represent a significant earthquake hazard since they are more frequent than larger earthquakes, 2) earthquakes of this size are uncommon in the area and the event afforded a unique opportunity for scientific research, and 3) the earthquake occurred in an area of transitional seismic character between the Basin and Range and the Colorado Plateau.

The three following papers discuss various aspects of the earthquake and its foreshocks and aftershocks. The Utah Geological and Mineral Survey (UGMS) presents a compilation of geologic effects of ground shaking during the earthquakes including preliminary modified Mercalli Intensity data provided by the USGS National Earthquake Information Center. The University of Utah Seismograph Stations (UUSS) recorded the earthquakes with their established seismograph network, and the aftershocks with a portable network; the second paper is a seismological summary. The last paper is a report of damage and emergency response written by the Utah Division of Comprehensive Emergency Management. Other agencies conducted post-earthquake studies which are also summarized briefly in these three papers. Water impoundment safety was evaluated by the Utah Division of Water Rights, Dam Safety group; the Bureau of Reclamation Dam Safety group; the U.S. Department of Agriculture, Soil Conservation Service, and Ferron Canal and Reservoir Company. The Castle Valley Special Service District checked pipes and springs. The National Earthquake Information Center sent questionnaires to post offices within 200 miles (300 km) of the epicenter to determine intensity distributions.

Geologic effects of the 14 and 18 August, 1988 earthquakes in Emery County, Utah

by
William F. Case
Utah Geological and Mineral Survey



Quaternary:	Qa1	alluvium
Jurassic:	Jms	Morrison Formation, Salt Wash Sandstone Member
Jurassic:	Js	Summerville Formation
Jurassic:	Jcu	Curtis Formation
Jurassic:	Je	Entrada Sandstone
Jurassic:	Jc	Carmel Formation
Jurassic/Triassic	JAgc	Glen Canyon Group: Navajo Sandstone, Kayenta Formation, Wingate Sandstone (Hintze, 1980)

contact: ————
 fault (U = up, D = down) ———— U
 photo lineament: D
 epicenter: ○

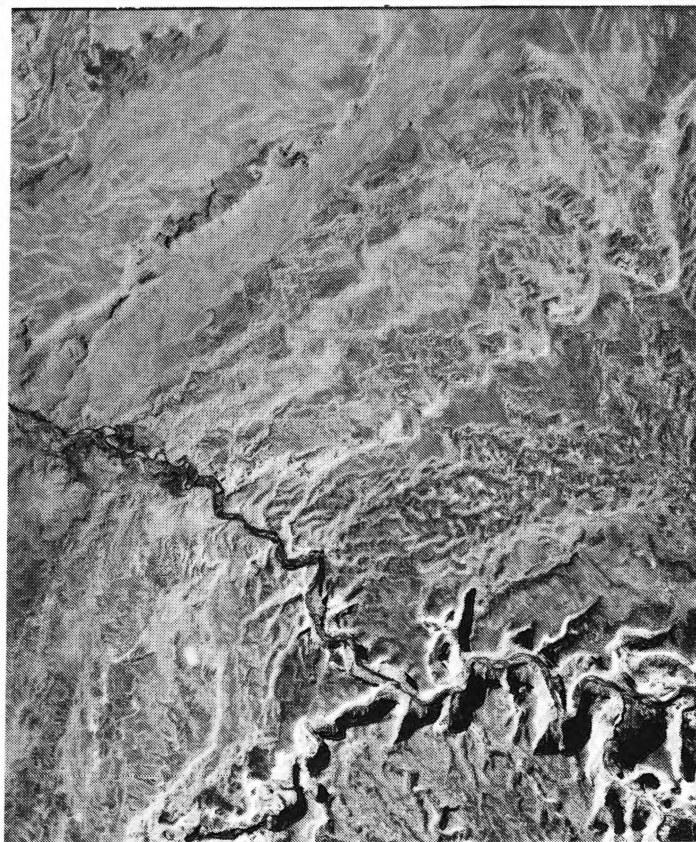
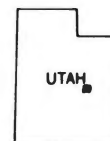


Figure 1. Geology and aerial photograph of the epicentral area (from Kent, 1956a, b).



Miles
Kilometers



Introduction

The Utah Geological and Mineral Survey (UGMS) investigated the epicentral region of the 14 and 18 August earthquakes in Emery County to document associated geologic phenomena, particularly rock falls and liquefaction features identified by T. L. Youd (Brigham Young University Civil Engineering Department, oral commun., 17 August, 1988). The local magnitudes (M_L) of the main shock (M_L 5.3) on 14 August and the largest aftershock (M_L 4.4) on 18 August are near the rock fall and liquefaction activation thresholds of M_L 4 and 5, respectively (Youd, 1985; Keefer, 1984).

The scope of work included literature research, personal interviews, telephone interviews, distribution of questionnaires, aerial photo interpretation, and a reconnaissance of the area within 30 miles (50 km) of the epicenter on 22-24 August, 1988. The reconnaissance included a search for rock falls and landslides in Buckhorn Draw and Wasatch Plateau canyons between Huntington and Emery, and liquefaction effects near the epicenter in Fuller Bottom on the San Rafael River, and at Huntington and Mill Site reservoirs. Because of the low magnitude of the earthquakes, there was no concentrated attempt to locate surface faulting in the epicentral region.

The most reliable proof of seismically triggered rock falls was eyewitness accounts of rocks falling or dust clouds. The accumulation of evidence from questionnaires and interviews indicates that perhaps hundreds of rock falls producing dust clouds, some enshrouding the eastern edge of the Wasatch Plateau, occurred within 25 miles (40 km) of the epicenter during the main shock. Isolated rock falls up to 70 miles (113 km) from the epicenter were sighted on 14 August. Circumstantial, post-event evidence of rock falls, such as rocks on roads or fresh cliff scars, were reported up to 80 miles (129 km) from the epicenter. The magnitude threshold of abundant, seismically induced rock falls appears to be between M_L 4.4 and 5.3; evidently no rock falls were noticed during the 14 August M_L 2.9 and 3.8 foreshocks, even as close as 11 miles (18 km); one rock fall was triggered by the M_L 4.4 aftershock on 18 August.

Cracks due to liquefaction of saturated San Rafael River alluvium, 2.5 miles (4 km) from the epicenter, were discovered by Youd on 15 August, (oral commun., 17 August, 1988). A field inspection on 23 August noted similar cracks and a sand boil in saturated alluvium at Fuller Bottom on the San Rafael River, 1.2 miles (1.9 km) from the epicenter.

Geology

The epicentral region is at the western edge of the Colorado Plateau in the San Rafael Swell (Stokes, 1977). Cliffs of the Wasatch Plateau are west and the Book Cliffs are north of the epicenter. Bedrock exposed within 10 miles (6 km) of the epicenter, from west to east, consists of the Jurassic Entrada Sandstone; shale members of the Jurassic Carmel Formation at the epicenter; and, exposed in incised valleys, the Jurassic/Triassic upper Glen Canyon Group which includes the Navajo Sandstone and Kayenta and Wingate Formations (figure 1) (Hintze, 1980; Kent, 1956a). Bedding is nearly horizontal, dipping gently to the west. North-trending faults displace the Mesozoic bedrock but there is no evidence of displaced Quaternary units (Kent, 1956a; Roger Fry, Utah Power and Light, oral commun., 1 September, 1988).

Preliminary Modified Mercalli Intensities

The United States Geological Survey National Earthquake Information Center (NEIC) sent questionnaires to 273 post offices within 200 miles (300 km) of the epicenter to determine the damage and estimate the intensity of ground shaking experienced by each community during the major shock on 14 August and the 18 August aftershock. Carl Stover (NEIC, written commun., 21 September, 1988) provided preliminary data for the main shock to UGMS for informational purposes. The distribution of intensities and questionnaire destinations are shown on figure 2. Although the data are too preliminary for scientific conclusions, they do indicate the general pattern of ground shaking effects.

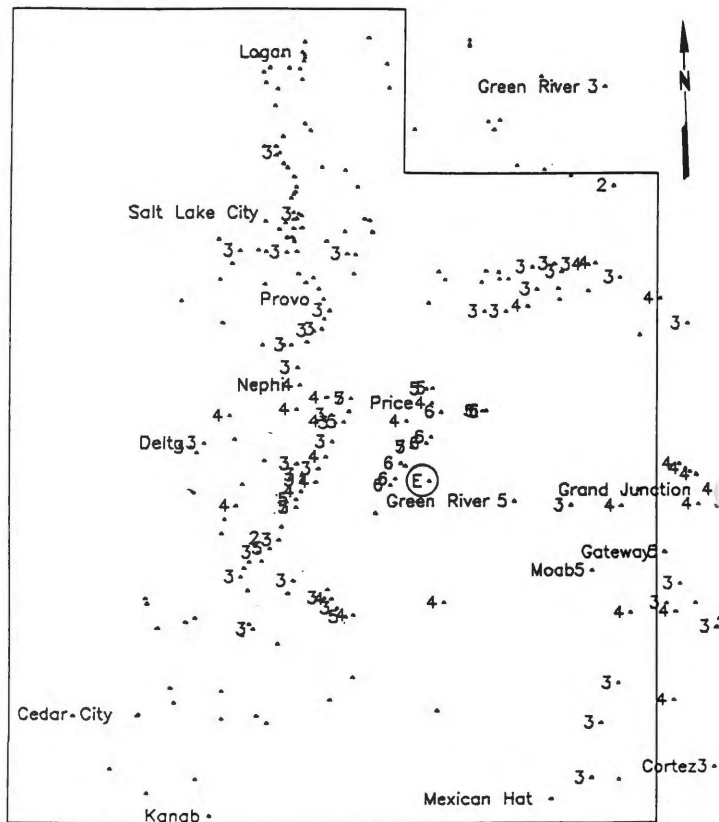


Figure 2. Preliminary Modified Mercalli Intensity Map of 14 August, 1988, 1403 hrs MDT (NEIC).

Ⓔ EPICENTER

Scale 1:3,000,000

▲ Post Office to which questionnaire was sent.

5 Preliminary Modified Mercalli Intensity

(note: Locations without designated intensity did not feel the shock or did not return the questionnaire)

The highest preliminary Modified Mercalli Intensity, VI, was assigned to the Emery County communities of Clawson, Cleveland, Elmo, Ferron, Orangeville, and Carbon County towns of Sunnyside and Wellington, all within 38 miles (61 km) of the epicenter. Shaking at intensity VI will crack low quality or aged masonry, and cause loose bricks, stones, or pieces of plaster to fall (table 1). Almost everybody in the area, indoors or outdoors, feels the shaking and has difficulty walking or standing. Intensity V effects were reported in 13 communities within 105 miles (170 km) of the epicenter including the Utah towns of Teasdale, Annabella, Fairview, and Moab; and Gateway, Colorado. The total felt area of the main shock ranged from Brigham City, 174 miles (280 km) north-

west of the epicenter; Delta, 97 miles (156 km) to the west; Albuquerque, New Mexico, 353 miles (567 km) to the south; Bluff, 145 miles (233 km) to the southeast; and Golden, Colorado, 295 miles (475 km) to the east (Carl Stover, NEIC, written commun., 1988; Salt Lake Tribune, 15 August, 1988; Nava and others, this issue). The distribution of reported effects shows higher intensities to the east through the Colorado Plateau than west into the Basin and Range. The lack of reporting stations to the west accentuates this effect, but it does indicate a difference in attenuation of ground shaking in different directions. The eastern extension of low attenuation through the Colorado Plateau may be due to the relatively continuous and unfaulted bedrock of the plateau. Gateway, Colorado, 106 miles (170 km) from the epicenter, showed effects of intensity V, whereas to the west into the Basin and Range which is characterized by intensely folded and faulted bedrock, the most

distant intensity V was at Salina only 58 miles (93 km) from the epicenter. There were few reports from communities southwest of the epicenter, and either the earthquake was not felt or the questionnaires were not returned.

Geologic Effects

Rock Falls

Dust clouds produced by rock falls were the most visible effect of ground shaking. Falls and dust continued for almost an hour after the shocks, giving residents the time to take pictures and video tape the dust clouds (figures 3, 4).



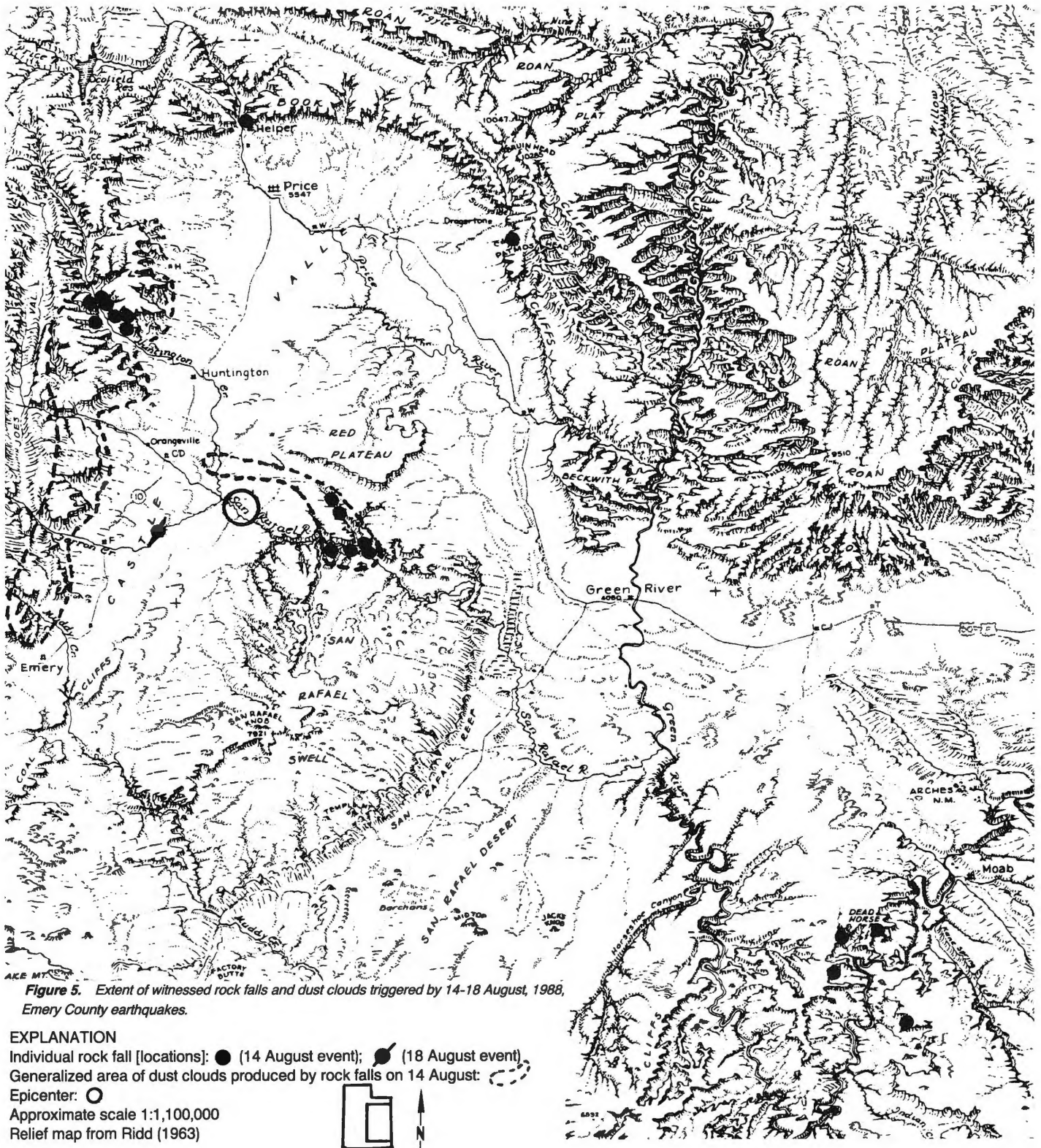
Figure 3. Dust on Wasatch Plateau cliffs resulting from rock falls triggered by main shock on 14 August, 1988. The cliffs are west of Huntington, approximately 20 miles (30 km) northwest of the epicenter. Photograph by Darrel V. Leamaster, Castle Valley Special Service District, Huntington, Utah.

Figure 4. Dust from rock falls triggered by main shock, approximately 2 pm, 14 August, 1988. View looking toward epicenter, 11 miles (18 km) south of BLM Cedar Mountain picnic area. Photograph by Terry A. Humphrey, Bureau of Land Management, Price, Utah.



A tabulation of UGMS questionnaires revealed that rock falls were triggered by the main shock and the 18 August aftershock. Figure 5 shows the distribution of rock falls caused by ground shaking based on eyewitness accounts of rocks falling and the associated extent of dust clouds. The earthquakes occurred in an

area where many sandstone cliffs provide source material, that is, the Wasatch Plateau, the Book Cliffs, and the Canyonlands area. It is fortuitous that the main shock occurred on Sunday afternoon; sightings of rock falls from isolated population centers were supplemented by reports from people on Sunday afternoon outings.



The majority of rock falls and/or associated dust were reported along the eastern cliffs of the Wasatch Plateau from Huntington Canyon south to the Emery area, about 24 miles (40 km) from the epicenter, and in Buckhorn Draw, a tributary of the San Rafael River, within 12 miles (19 km) of the epicenter. Most of the questionnaires reported dust which obscured the cliffs of the Wasatch Plateau (figure 3). Individual rock falls were seen in Huntington Canyon and east of Ferron. The rock falls were so numerous in Buckhorn Draw that a "curtain of dust" was produced which was visible from the Cedar Mountain picnic site on Red Plateau (figure 4), and the community of Huntington. Rock falls were also witnessed in Buckhorn Draw. Isolated rock falls were seen in the Book Cliffs at Columbia and Balanced Rock near Helper, and near Dead Horse Point State Park 70 miles (115 km) from the epicenter. Evidence of rock falls such as a boulder in the road, an unusual accumulation of clasts below a road cut, or a fresh scar on a cliff with rock fall clasts at its base were noted in Spanish Fork Canyon, Soldiers Summit, and Price Canyon (U.S. Highway 50); Salina Canyon (Interstate 70); and on the La Sal Mountain loop road near Moab. These reports are considered less reliable because the rock falls were not witnessed and were not necessarily attributable to ground shaking. Evidence indicates that, based on the dust cloud extent, possibly hundreds of rock falls occurred within 25 miles (40 km) of the epicenter; isolated rock falls were initiated up to 70 miles (113 km) from the epicenter; and there is a possibility that some rock falls, as much as 80 miles (129 km) from the epicenter, were triggered by ground shaking.

Geologic units involved in the rock falls included the: 1) Cretaceous Mesa Verde Group sandstone (Hintze, 1980) along the eastern face of the Wasatch Plateau and at isolated spots in the Book Cliffs, particularly cliffs of red "clinker" beds consisting of sandstones that were melted and hardened by prehistoric underground coal fires (Sam C. Quigley, oral commun., 23 August, 1988); 2) Jurassic Entrada Sandstone (Kent, 1956a) within 3 miles (5 km) of the epicenter; 3) Jurassic/Triassic Glen Canyon Group (Hintze, 1980) sandstone in Buckhorn Draw and near Dead Horse Point; 4) Jurassic/Triassic Glen Canyon Group and/or Permian Cedar Mesa sandstone (Helmut Doelling, Utah Geological & Mineral Survey, oral commun., 18 October, 1988) in Lockhart Basin near Canyonlands National Park (Salt Lake Tribune, 15 August, 1988); and 5) Tertiary intrusive (Hintze, 1980) rocks which rolled down scree slopes onto the La Sal loop road southeast of Moab.

The magnitude threshold of abundant rock falls triggered by ground shaking appears to be between M_L 4.4 and 5.3. No rock falls were noticed during the 14 August M_L 2.9 and 3.8 foreshocks, even as close as 11 miles (18 km) at Cedar Mountain picnic area (Terry A. Humphrey, BLM, written commun., 6 September, 1988). Guy Seely (written commun., 12 September, 1988) saw a single rock fall east of Ferron triggered by the M_L 4.4 aftershock on 18 August.

Liquefaction

Cracks caused by liquefaction of saturated alluvium were noted by T. Leslie Youd (oral commun., 17 August, 1988) on 15 August. Youd found small cracks parallel to the San Rafael River approximately 2.5 miles (4 km) from the epicenter. Possible liquefaction cracks were noted in recent alluvium at Fuller Bottom on the San

Rafael River, 1.1 miles (1.8 km) from the epicenter on 23 August, 1988 (figure 6). The cracks were parallel to the river, and ranged from 3-5 feet (1-1.5 m) long and as much as 1 inch (2.5 cm) wide and deep near the stream bank, and less pronounced approximately 10 feet (3 m) from the river's edge. A 5-inch (13 cm) diameter sand boil was ejected from a crack in the alluvium. Tingey and May (this issue) report no conclusive evidence of liquefaction in Cottonwood and Huntington Creeks.



Figure 6. Ground cracks in wet alluvium, Fuller Bottom, San Rafael River, approximately 1.5 miles (2.25 km) southwest of epicenter. Black bars on scale are centimeters on left and inches on right side. San Rafael River is evident in upper left-hand corner. Photograph taken 23 August, 1988 by William F. Case, Utah Geological and Mineral Survey.

Miscellaneous Observations and Recordings

Darrel V. Leamaster, district manager, Castle Valley Special Service District, reported increased spring flow following the 14 August earthquakes. Flow increased from a four-year maximum of 85 gallons per minute ($0.005 \text{ m}^3/\text{s}$) before the earthquakes to 133 gallons per minute ($0.008 \text{ m}^3/\text{s}$) after the shocks. The spring is located in Tie Fork Canyon, a tributary of Huntington Canyon drainage, 30 miles (48 km) from the epicenter. Two other nearby springs in Big Bear Canyon and Little Bear Canyon did not experience any change in flow.

Paul Crawford (Ferron Canal and Reservoir Company) reported seeing water that had been wave-splashed on the upstream face of Mill Site Dam, approximately 3 feet (1 m) above static water level. The surge may have been caused by ground shaking; no landsliding into the reservoir was noticed. Standing waves on the water surface were not evident. Crawford noted that the lake water was slightly turbid. Mill Site Dam is located about 20 miles (32 km) from the epicenter. Surges or standing waves were not noticed on Huntington Lake, 17 miles (27 km) from the epicenter, according to Kean Luke, Huntington Lake State Park superintendent (oral commun., 23 August, 1988). Luke noted that since the lake was covered with Sunday afternoon boaters, standing waves or surges were probably obscured.

The strong-motion seismograph database of Utah earthquakes more than doubled in size with the addition of recordings of ground accelerations during the main shock and the 18 August aftershock at Joes Valley Dam, 26 miles (42 km) from the epicenter. Accelerometers recorded peak accelerations of 0.11 g on the crest of the dam and 0.06 g midslope during the largest shock, with 0.05 g at the crest while the midslope instrument was untriggered during the aftershock (Dan Grundvig, Bureau of Reclamation Dam Safety, oral commun., 11 October, 1988).

Acknowledgements

Carl Stover and Lindie Brewer (NEIC) freely provided their questionnaire data and offered valuable assistance. The following geologists and scientists who experienced the shaking provided essential data for the investigation: Sam C. Quigley (Andalex Resources), Roger Fry (Utah Power & Light), Darrell Leamaster (Castle Valley Special Service District), and Paul Crawford (Ferron Canal and Reservoir Company). Dan Grundvig (Bureau of Reclamation), Robert C. Rasely (U.S. Soil Conservation Service), and T. Leslie Youd (Brigham Young University Civil Engineering Department) freely provided much data. Dottie D. Brockbank (Public Information Officer, Department of Natural Resources) called for rock fall data in local newspapers and Chris Wilkerson (UGMS) forwarded questionnaires and background materials to

respondents and collected replies. The response to the newspaper request was heartening. Much important rock fall information, such as distribution and timing of rock falls, was reported. Many had very scientific and useful commentary. Photographs were included with the completed questionnaires and there were several offers to copy video tape scenes. Questionnaires were returned by: Terry A. Humphrey, Price; Allan Sorensen, Clawson; Sharon A. Emery; Lillian L. Cassano, East Carbon; Elisa Pehler, Price; Arvetta Satterfield, East Carbon City; Leslie Royce, Price; Guy Clawson; Susie Baca, Sunnyside; Lee Sjoblom, Dead Horse Point Park; J. Rulon Nelson, Ferron; Renee Callor, Helper; and Darrell Leamaster, Castle Dale.

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Table 1: MODIFIED MERCALLI INTENSITY: *Description and effects¹*

Intensity (Magnitude ²)	Personal Reactions	Vehicle Response	Structural Response of Buildings	Miscellaneous Effects	Geologic Effects
I (1-2) Microearth- quake	Barely felt by sensitive few, some dizziness, nausea.			Animals restless. Trees, structures, liquids, bodies of water may sway. Doors may swing very slowly.	Small fractures near epicenter of small earth- quakes or far from large quake epicenter ³ .
II (2-3)	Felt by a few indoors, especially on upper floors or while lying down.			Delicately-suspended objects may swing. Effects noticed in I are more obvious.	
III (3)	Felt by several while indoors. Similar to passing of light truck. Duration estimated.	Parked cars rock slightly.		Hanging objects may swing.	
IV (3-4) Small earth- quake	Felt by many indoors, a few outdoors, light sleepers awakened, a few frightened. Similar to passing of heavy truck or heavy object jolting and hitting wall.	Parked vehicles rock.	Wooden walls & frame creak.	Dishes, windows, doors, glassware and crockery rattle, clash, clink. Hanging objects swing. Liquids in open vessels slosh back and forth.	Rock falls may be triggered. ³

V (4-5)	Felt by almost everybody, indoors and outdoors. Most sleepers awakened, some are frightened and run outdoors. Shaking direction estimated. Buildings tremble throughout.	Some plaster walls, and rarely, windows crack.	Small, unstable objects e.g., glassware, dishes, objects d'art are displaced, upset, broken. Pictures are skewed or thrown against wall. Doors/shutters open or close abruptly. Liquids disturbed/spill. Pendulum clocks change rate or stop/start. Hanging objects swing greatly. Slight shaking of trees and bushes.	Liquefaction threshold. Fractures over several hundred meters long on fault plane but seldom breach ground surface ³ .
VI (5) Moderate earthquake	Felt by all, many are frightened and run outdoors ³ . Walking is unsteady. Some loss of life possible near epicenter.	Masonry D: plaster and brick walls crack and pieces fall.	Many small objects such as dishes, glassware, knickknacks, or books are broken or thrown off shelves. Pictures fly off walls. Heavy furniture moved, lighter pieces overturned. Small bells ring. Trees and bushes rustle and shake.	
VII (5-6)	Difficult to stand.	Drivers notice ground movement.	Masonry D damaged: cracks, falling of plaster, stucco, loose bricks/stones/tiles, cornices, parapets, and ornaments fall. Some cracks in Masonry C walls and foundations.	Hanging objects quiver. Furniture is overturned and broken. Large bells ring. Trees and bushes rustle moderately to strongly. Concrete irrigation ditches are damaged ³ .
VIII (6-7) Major earthquake		Steering is affected.	Masonry C buildings may partially collapse. Some damage to Masonry B, none to Masonry A. Stucco and some masonry walls fall. Chimneys, factory stacks, monuments, tombstones, towers, elevated tanks may twist or fall. Unbolted frame houses shift on foundation, loosely attached panels are thrown from frame. Solid stone walls are cracked and broken seriously.	Seiche waves are produced in ponds, water can become turbid with mud ³ . Small slumps and slides along sand and gravel banks ³ .
IX (7)	General panic ³ . Extensive loss of life possible ³ .		Masonry D. buildings destroyed. Masonry C heavily damaged, sometimes with total collapse. Masonry B structures are seriously damaged. General foundation and frame damage. Unbolted structures shift off foundations.	Spring or well water may change flow rate, odor, turbidity, or temperature ³ . Dry wells may renew flow ³ . Cracks develop in wet ground or steep slopes ³ . Sand boils may eject small amounts of mud/sand ³ .
X (7-8) Great earthquake			Most masonry and frame structures, and their foundations are destroyed ³ . Some well-built wooden buildings and bridges collapse ³ . Serious damage to dams ³ .	Conspicuous ground cracks ³ . Sand boils, earthquake fountains, sand craters occur in alluvial areas ³ . Serious damage to reservoirs. Fractures 20-30 km long breach ground surface ³ .
XI (8-9)			Well-built bridges collapse due to failure of ground at pillars, footings and piles ³ .	Underground pipes may be broken ³ . Decayed pilings are broken off ³ .
XII (8-9)	Lines of sight and level are distorted ³ .		Damage nearly total ³ .	Objects are tossed into the air ³ .
				Large rock masses are displaced ³ . Significant landslides are numerous and extensive ³ .

Note: 1: The effects given with each intensity level are taken from Wood and Neumann (1931) and Richter (1958).

2: Approximate earthquake magnitude which may produce the intensity effects near the epicenter.

3: These criteria may be misleading as measure of the strength of shaking (Dietrich and others; 1982, Keefer, 1984).

CONSTRUCTION TYPES:

Masonry A: The building shows good workmanship using good materials, the design includes reinforcement specifically intended to withstand lateral forces.

Masonry B: The building is reinforced and shows good workmanship using good materials, but the reinforcement was not designed to withstand lateral motion.

Masonry C: The unreinforced building shows ordinary workmanship with standard materials. The building has no extreme weaknesses, like failing to tie-in at corners, but it is not designed to resist lateral forces.

Masonry D: The building is constructed of weak materials, such as adobe or poor mortar, with low standards of workmanship, and the design is weak against horizontal forces.

MODIFIED MERCALLI INTENSITY SCALE (Wood and Neumann, 1931; Richter, 1958).

The intensity of an earthquake is a subjective measure of ground shaking experienced by humans and damage to their artifacts. The Modified Mercalli Intensity (MMI) scale ranges from I, shaking rarely felt, to XII, shaking which causes total damage. Ground shaking is the acceleration and velocity of particles at a site during an earthquake. It is dependent on: 1) seismic source characteristics such as peak acceleration, duration, and spectral components of seismic waves; 2) the attenuation of seismic wave amplitude and spectral filtering during travel from the earthquake focus to the site; 3) ground conditions at the site including the depth of the water table and the thickness, mineralogy, and textural composition of unconsolidated deposits; 4) the design, workmanship quality, and age of construction at the site; and 5) the expertise of people experiencing the shaking, and the investigator.

The MMI scale has been revised several times since Mercalli (1902) originally revised the 1883 Rossi-Forel Intensity Scale to include recent technological advances, such as tall buildings, motorized vehicles, and underground pipelines. The U.S. Coast and Geodetic Survey uses the 1931 version of the MMI scale which was amended by Wood and Neumann (1931) to conform to California conditions. The U.S. Geological Survey uses the 1956 version of the MMI scale which includes construction types characterized by Richter (1958). Simon (1976) believes that the 1956 MMI should be updated to include effects on a person resting on a waterbed and interruption of lifelines, such as telephone, water, gas, and electricity.

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Endowment

The **Allen H. James** Memorial Fund is a permanent endowed fund at Department of Applied Earth Sciences, Stanford University. James was a practicing geologist and mining engineer in Salt Lake City for many years. The fund to assist geology students is tax deductible. Contact Dr. Marco Einaudi, School of Earth Sciences, Stanford University, Stanford, CA 94305.

Obituary

Wilbur Smith passed away September 3, 1988 in Tooele, Utah. He was an economic geologist whose extensive mapping and mine studies for Kennecott of the Lark Mine and the Bingham district served to define operations for many years. He retired in 1978 after dedicating 19 years to the Bingham district and helping manage a younger generation of geologists.

GREAT SALT LAKE LEVEL

Date (1988)	Boat Harbor South Arm (in feet)	Saline North Arm (in feet)
Apr 01	4209.55	4208.65
Apr 15	4209.40	4208.55
May 01	4209.45	4208.45
May 15	4209.35	4208.45
Jun 01	4209.10	4208.30
Jun 15	4208.95	4208.15
Jul 01	4208.70	4207.95
Jul 15	4208.30	4207.60
Aug 01	4208.05	4207.25
Aug 15	4207.60	4206.90

Source: USGS provisional records.

The Magnitude 5.3 San Rafael Swell, Utah Earthquake of August 14, 1988:

A PRELIMINARY SEISMOLOGICAL SUMMARY

by S.J. Nava, J.C. Pechmann and W.J. Arabasz
University of Utah Seismograph Stations
Department of Geology and Geophysics

On August 14, 1988, an M_L (local magnitude) 5.3 earthquake occurred in central Emery County, Utah, at 2:03 PM (MDT). The epicenter of the shock—the largest earthquake to occur in the Utah region since the 1975 M_L 6.0 Pocatello Valley earthquake—was in an unpopulated area of east-central Utah on the northwest edge of the San Rafael Swell (figure 1). The epicenter was located 20 km southeast of Castle Dale (the nearest town) and 55 km south of Price. The earthquake was felt strongly throughout central Utah (Modified Mercalli intensity V to VI), where it caused some minor damage, and was reported felt as far away as Golden, Colorado, and Albuquerque, New Mexico (U.S. Geological Survey, 1988).

Historically, the two largest earthquakes in east-central Utah were both of estimated magnitude 4.3. They occurred 70 km northwest of Moab in 1953 and 50 km east of Price in 1961. Instrumental monitoring by the University of Utah since 1962 has shown sparse seismicity in the area of the San Rafael Swell, although locally intense microseismicity characterizes coal mining areas of the eastern Wasatch Plateau to the northwest. Shocks of M_L 3.1 and 3.0 occurred within 20 km of the August 14 main shock, in 1962 and 1964, respectively. Prior to August 14, the epicentral area had not experienced any earthquakes large enough to be detected by the University of Utah's regional seismograph network since January of 1988, when a swarm of seven events ($M_L \leq 2.5$) occurred there. On August 14, six foreshocks of magnitude 1.8 to 3.8 occurred during the 65 minutes prior to the M_L 5.3 main shock. The two largest foreshocks, of M_L 2.9 at 12:58 PM (MDT) and of M_L 3.8 at 1:07 PM (MDT), were felt in nearby small towns (U.S. Geological Survey, 1988).

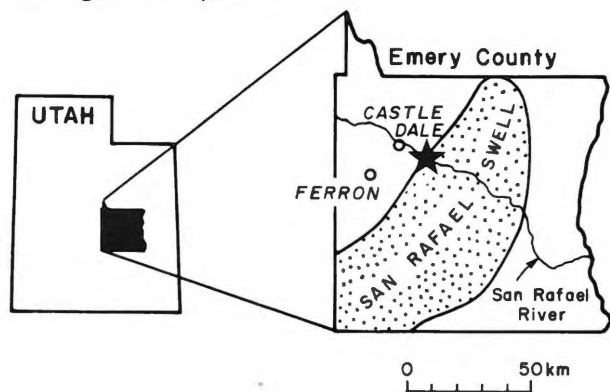


Figure 1. Reference Map depicting the geographic location of the August 14, 1988 San Rafael Swell, Utah earthquake sequence. The star represents the location of the main shock.

The University of Utah has located 147 earthquakes associated with the San Rafael Swell sequence that occurred from August 14 through September 30, 1988. The parameters of the five largest earthquakes of the sequence are described in table 1. Through September 30, there were 24 earthquakes of magnitude 2.0 and larger. A plot of earthquake magnitude vs time (figure 2) indicates a typical foreshock-main shock-aftershock sequence.

The nearest seismograph station at the time of the August 14 main shock was a permanent station of the University of Utah seismograph network located 20 km to the east at Cedar Mountain. Beginning the day after the main shock, the University of Utah installed five portable seismographs in the epicentral area (triangles, figure 3). Four temporary seismograph stations, directly linked to the University of Utah central recording lab in Salt Lake City, were installed on August 20 and 21 (inverted triangles, figure 3). These stations supplemented the portable seismographs until August 31, when the latter were removed. The telemetered stations continue to operate as of mid-November, 1988.

The local seismograph stations provide excellent control on the locations of aftershocks that occurred after 7:10 PM (MDT) on August 15. The locations of some of the earlier events in the sequence, particularly the focal depths, are less well constrained. For this reason, we have fixed the depth of the main shock and several events to 14 km (see table 1), a depth close to that of the deepest

TABLE 1
SAN RAFAEL SWELL, UTAH, EARTHQUAKE SEQUENCE
 $M_L \geq 2.9$

DATE (1988)	ORIGIN TIME (UTC)	LATITUDE (°N)	LONGITUDE (°W)	DEPTH (km)	MAGNITUDE		
					M_L (UU)	M_L (NEIS)	m_b (NEIS)
8/14	18:58:36.8	39°07.67'	110°50.10'	14.0R	2.9	3.5	--
8/14	19:07:58.8	39°07.51'	110°50.07'	14.0R	3.8	4.3	--
8/14	20:03:03.9	39°07.25'	110°50.28'	14.0R	5.3	--	5.5
8/15	14:50:23.5	39°07.59'	110°50.39'	14.0R	3.0	3.5	--
8/18	12:44:53.5	39°07.49'	110°50.72'	11.6	4.4	--	4.6

UTC (Universal Coordinated Time) = MDT - 6 hours

R = Restricted Focal Depth

M_L = Local Magnitude

m_b = Body Wave Magnitude

UU = University of Utah Seismograph Stations

NEIS = National Earthquake Information Service, Golden, Colorado

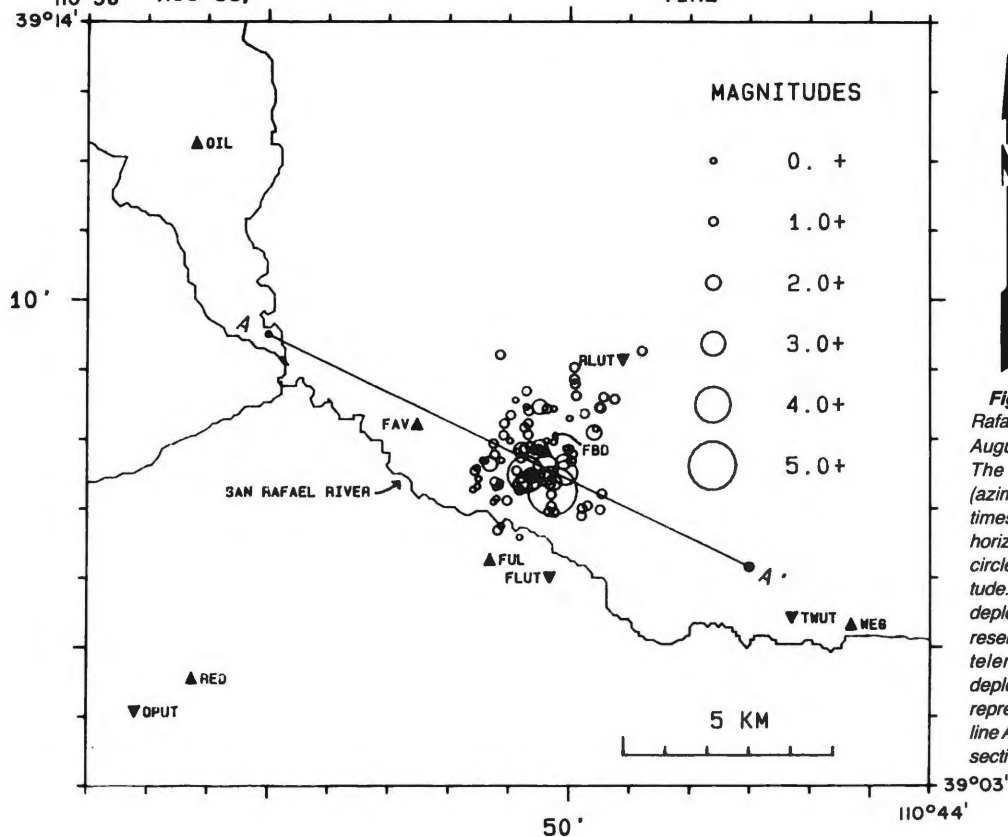
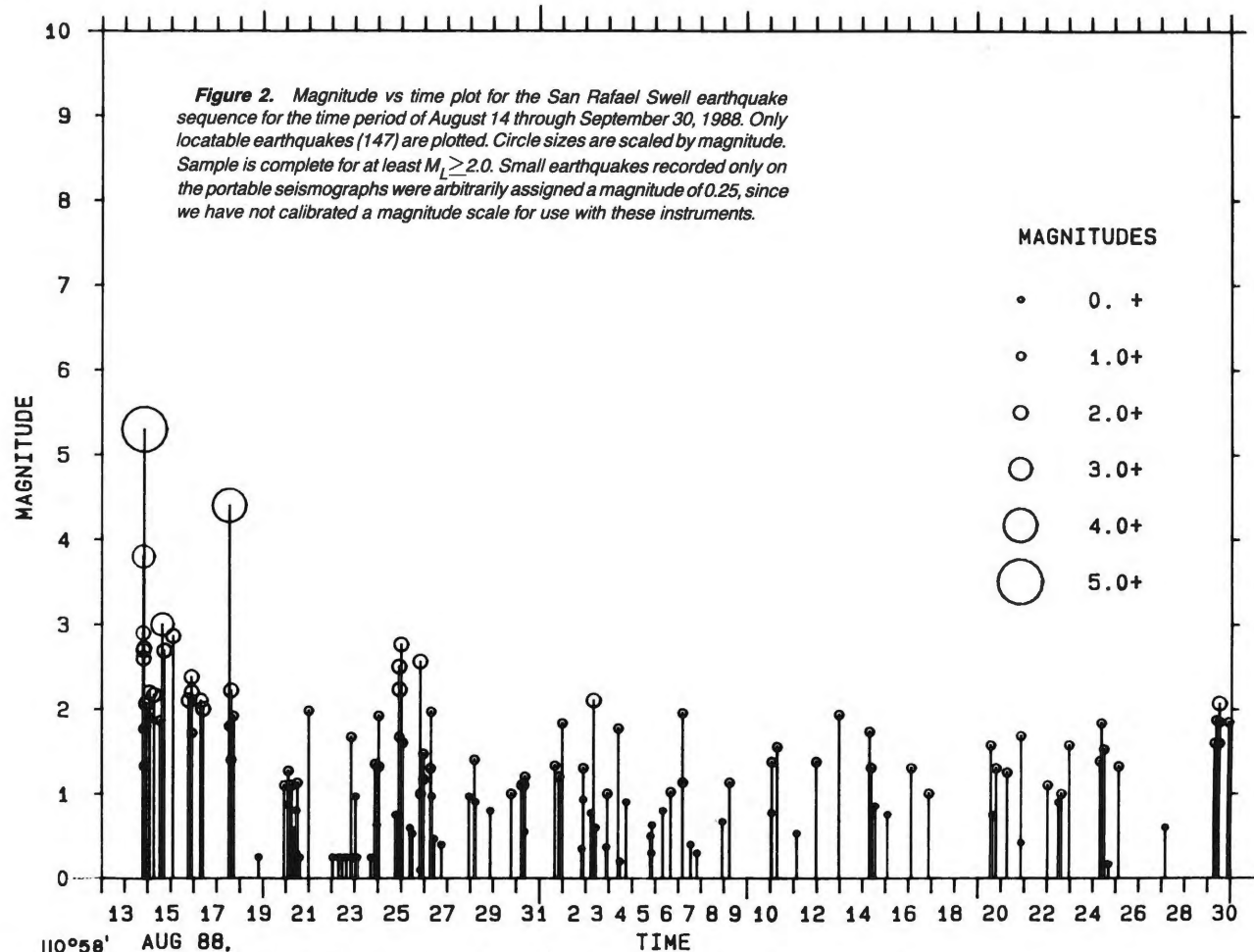


Figure 3. Epicenter map of the San Rafael Swell earthquake sequence from August 14 through September 30, 1988. The 91 best located earthquakes (azimuth gap $\leq 180^\circ$, number of arrival times used in location ≥ 6 , vertical and horizontal error ≤ 1.5 km), are plotted as circles, with the sizes scaled by magnitude. Portable seismograph stations, deployed from August 16-31, are represented by triangles, and the temporary telemetered seismograph stations, deployed from August 20 to present, are represented by inverted triangles. The line A-A' shows the direction of the cross section in figure 4.

well-located aftershocks. Figure 3 is an epicenter map of 91 of the best located earthquakes in the sequence. In map view, the earthquakes occupy a 3 x 4 km zone, adjacent to the main shock epicenter, elongated slightly in a north-northeast direction. In three dimensions, the hypocenters define an aftershock zone extending from 8 to 15 km depth and dipping 60° - 70° east-southeast, with a length along strike of 4 km and a downdip extent of 8 km.

The focal mechanism for the main shock is unfortunately not well constrained by the P-wave first motion data that we have acquired to date (figure 5). We are in the process of obtaining additional data from seismograph stations operated by other institutions, which should help to constrain the solution. The data presently available require one nodal plane to strike southeast and dip 50° - 75° southwest and the other nodal plane to strike north-northeast to northeast and dip between 40° east-southeast and 75° northwest. If the latter nodal plane is assumed to dip 60° east-southeast, parallel to the aftershock zone, then the resulting focal mechanism shows oblique normal faulting with a rake angle of -35° (solid lines, figure 5). Despite the uncertainty in the nodal plane orientations, the T axis of the main-shock focal mechanism is constrained to have a shallow plunge and an azimuth within 25° of east-west. The focal mechanism for the largest aftershock indicates oblique normal faulting on a plane that dips either to the east or southwest, and has a shallowly plunging T axis oriented N60°E-S60°W ($\pm 10^\circ$).

Figure 4. Hypocentral cross section, with no vertical exaggeration, of the earthquakes of figure 3, taken along line A-A'. Circle sizes are scaled by magnitude.

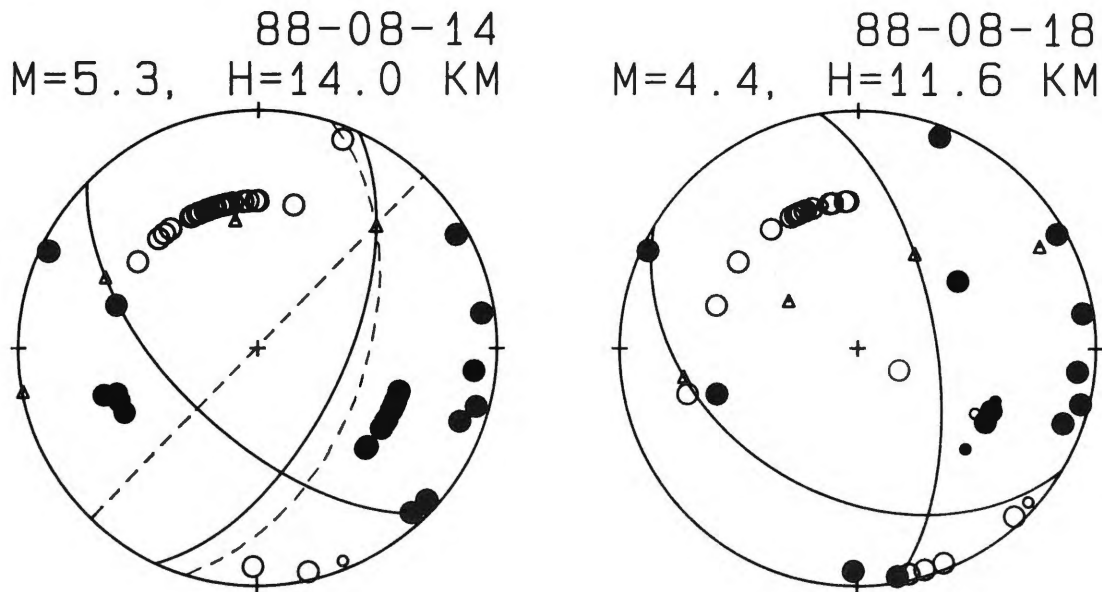
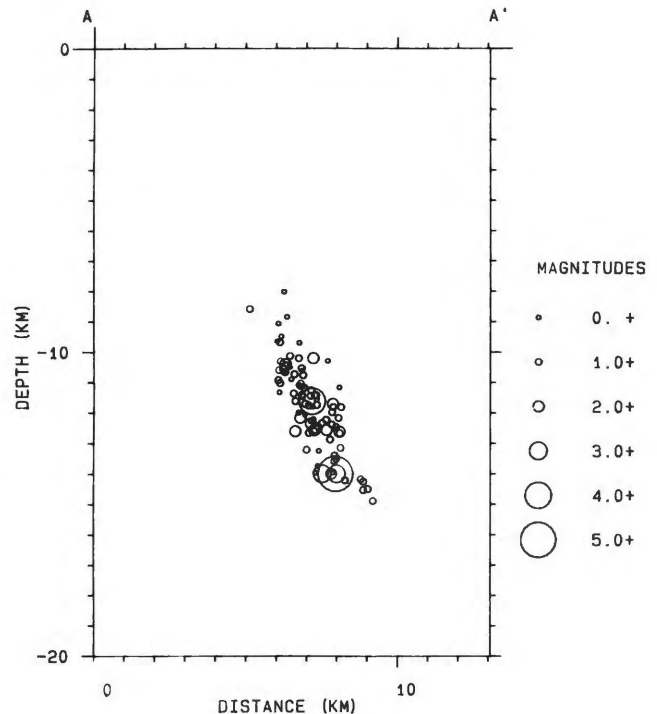


Figure 5. Preliminary focal mechanisms for the M_L 5.3 San Rafael Swell earthquake and its largest aftershock (M_L 4.4). P-wave first motions are plotted on a lower hemisphere projection, with compressions shown as solid circles and dilatations shown as open circles. The triangles show slip vectors and P and T axes. The focal depth (H) of the main shock is not very well constrained, and was fixed at 14 km to compute the focal mechanism. The first motion plot is not very sensitive to the assumed focal depth. We have drawn our preferred solution for the main shock focal mechanism (solid lines) to have one nodal plane parallel to the aftershock zone, with a strike of 25°, dip of 60°, and rake of -35°. The dashed lines show two of the alternative orientations for the northeast-striking nodal plane that are allowed by the first motion data if the southeast-striking nodal plane is held fixed. For the aftershock, the east-dipping nodal plane has a strike of 351°, a dip of 63°, and a rake of -62°.

The relatively deep focal depths of the earthquakes of the San Rafael Swell sequence, together with the main-shock focal mechanism, are important for attempting to correlate the earthquakes with local geologic structure. No surface faulting associated with the San Rafael Swell earthquakes has been reported, although no one, to our knowledge, has thoroughly searched the epicentral area. The fact that all of the well-located aftershocks are between 8 and 15 km in depth suggests that the earthquake rupture was confined to this depth range and did not penetrate to the surface. The apparent absence of surface faulting is consistent with a threshold magnitude of about 6.0 to 6.5 for surface faulting in the Utah region (Arabasz and others, 1987).

The depth of the San Rafael Swell earthquakes places them within Precambrian basement; gently-dipping sedimentary cover rocks of Mesozoic and Paleozoic age are about 3 km thick in this area (e.g., Neuhauser, 1988). Jurassic and Cretaceous strata in this part of the San Rafael Swell are known to have been affected by east-verging imbricate thrust faulting of Sevier-age deformational style (Neuhauser, 1988), but this shallow faulting did not involve Precambrian basement. Northwest- and northeast-trending basement fracture zones appear to provide important structural control on crustal blocks within the Colorado Plateau (Davis, 1978). Such basement faults presumably controlled the Laramide development of the San Rafael Swell as a broad anticlinal upwarp with a monoclinial flexure on its southeastern flank some 65 million years ago (Davis, 1978; Stokes, 1986).

Geological maps of the San Rafael Swell (e.g., Hintze, 1980) show faults of north-northeast and northwest trend cutting Mesozoic rocks in the general vicinity of the recent earthquake activity. Data in hand suggest the association of the 1988 San Rafael Swell earthquake with buried slip on a Precambrian basement fault striking north-northeast

and dipping moderately to steeply to the east-southeast. The aftershock distribution and magnitude versus fault length relations suggest that the causative fault need not be more than several kilometers long. Focal mechanisms imply a response to horizontal extension in a roughly east-west direction. This is similar to contemporary deformation inferred for the Basin and Range-Colorado Plateau transition to the west (Arabasz and Julander, 1986), but at variance with the north-northeast — south-southwest to northeast-southwest extension recently discovered to characterize the interior of the Colorado Plateau (Wong and others, 1987; Wong and Humphrey, 1988).

Earthquakes of moderate size ($M_L \leq 6.5$) are capable of causing considerable damage in urban areas, as evidenced by the M_L 5.9 Whittier Narrows earthquake that struck southern California on October 1, 1987 (Hauksson and others, 1988). The occurrence of the M_L 5.3 San Rafael Swell earthquake in an area where there are no active faults mapped at the surface and where historical earthquake activity has been minimal emphasizes the potential for moderate but potentially damaging earthquakes on buried faults anywhere in the Utah region—including the Colorado Plateau.

Acknowledgements— We thank Ted Olson and Allan Stevens of Snow College and Erwin McPherson, Ken Whipp, Julie Shemeta, and Mary Murphy of the University of Utah for installing and operating seismograph instrumentation in the field. Linda Hall of the University of Utah timed the records of the portable seismographs. Rick Martin of the U.S. Bureau of Reclamation, Pingsheng Chang of the U.S. Geological Survey, Joyce Wolff of Los Alamos National Laboratory and Doug Bausch of Northern Arizona University kindly supplied data from seismic networks in Colorado, New Mexico and Arizona. This research was supported by the U.S. Geological Survey, Department of the Interior, under award numbers 14-08-0001-A0265 and 14-08-0001-G1349, and by the state of Utah.

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CEM ALERT Report Summary of August 14, 1988 Earthquake in Emery County

*by Jim Tingey and Fred May Ph D.
Utah Division of Comprehensive Emergency Management*

The Utah Division of Comprehensive Emergency Management (CEM) responded to the moderate earthquake activity in Emery County by its usual state-to-county response procedures, and through two CEM Affected Location Emergency Response Team (ALERT) efforts, to follow-up on possible county and city damage and public needs and reaction.

INITIAL CEM RESPONSE

CEM Director Lorayne Frank was informed of the magnitude 5.3 quake by UGMS Director Genevieve Atwood who was notified by the press. Although this is not the "standard" emergency communications procedure, it probably reflects or typifies how initial notification does happen in a "real world" situation, and even how it may happen in a larger event in a more heavily populated area. The important fact is that these two high-level state officials were notified within minutes and began to respond using "standard" procedures. Lorayne Frank then contacted the following officials in the order listed, who took the indicated action or gave information relating to the earthquake.

Official Notified

1. Doug Bodrero, Deputy Commissioner,
Utah Department of Public Safety.
2. University of Utah Seismograph Stations
3. Dave Levanger, Carbon County Emergency Director
4. Lamar Guymon, Emery County Sheriff/Emergency
Director
5. Utah Power and Light
6. Gene Surzenegger, Utah DOT Assistant Director
7. Bob Morgan, Utah State Engineer

Action

Reports to Commissioner of Public Safety who then may contact the Governor. Records information on damage and resources needed.

Magnitude, location of epicenter, any reported damage.

Reported on damage, down utilities and was to report back on possible mine problems.

Report damage to towns, mines, power facilities.

Report on operating mines and power facilities in Emery and Carbon counties.

Report on condition of roads, any damage for possible DOT response.

Report on conditions of dams which were in the risk area.

Note: The state engineer in coordination with Lorayne Frank of CEM and Doug Bodrero of Public Safety arranged for the use of a fixed wing aircraft to make an immediate examination of the dams and reservoirs. Two dams had "on ground" visits, Millsite and Grass Trail. Others surveyed by air in the Green and Colorado drainages were:

Smith Reservoir
Lower Gooseberry Reservoir
Fairview Lakes
Cleveland Reservoir
Electric Lake (checked by UP&L)
Miller Flat

Scofield Reservoir (checked by BOR)
Duck Fork Reservoir
Farron Reservoir
Wrigleys Spring Reservoir
Rolfson Reservoir
Joes Valley Reservoir (checked by BOR)

The Thistle slide was also surveyed by air.

Reservoirs surveyed in the Sevier River drainage were:

Nine Mile Reservoir
Gunnison Reservoir
Sevier Bridge Reservoir
Chicken Creek Reservoir
Mona Reservoir and Huntington North (BOR)

CEM requested reports on damage or any effects to mines, road, dams, bridges or personal property. Reports of any injuries resulting from the initial ground motion or secondary effects such as rock fall were also requested. No affirmative reports were received, although later reports indicated some minor damage in Castle Dale.

This moderate event provided a good test of the response mechanism of the state and proved the value of written and exercised emergency notification and reporting procedures.

The morning after the event CEM ALERT members Jim Tingey and Bill Damery accompanied a University of Utah Seismograph Stations team to install portable seismographs in the epicentral area east of Castle Dale. Examination of this area provided only inconclusive evidence of recent seismic-related rockfall and liquefaction cracks in the Cottonwood, Huntington Creek and San Rafael drainages.

Two pieces of video tape footage taken during the earthquake were acquired by CEM ALERT and are available through the CEM Earthquake Preparedness Program.

Subsequent to their first "on site" visit CEM ALERT contacted the major insurance agencies in the area. Surprisingly, although no reports of serious damage had been reported to local government officials, the insurance companies had received reports of over 25 claims. Many of the insurance representatives were out inspecting damage the week of the earthquake. A second CEM ALERT field survey was planned along with a public meeting on earthquake awareness and preparedness focusing on citizen concerns surrounding the Sunday, August 14, 1988 event. The public meeting was held the evening of August 22nd at the Emery County Courthouse in Castle Dale. Notification of the meeting was put in both the Carbon County and Emery County newspapers. The CEM ALERT group consisted of Earthquake Planning Coordinator Jim Tingey, Bureau Chief DeeEll Fifield, Hazard Mitigation Officer Dr. Fred May, Planning Geophysicist Bill Damery, and Intern Steve Pratt.

The meeting and damage survey was coordinated through the Emery County Emergency and Sheriff's offices. Much non-structural damage was reported, such as broken dishes, overturned bookcases and falling ceiling tiles. The most common structural problems reported were damaged chimneys. A maximum Modified Mercalli Intensity of VI was indicated by damage in Castle Dale, Orangeville and Ferron.

The quake produced impressive dust clouds from numerous rock falls in nearby canyons. It shook bricks off some chimneys and produced cracks in foundations, patios, and driveways. In residences, some furniture shifted and some dishes fell out of cabinets, and one large front window was broken. In a nearby church, earthquake waves were seen moving through tiled-concrete hallway floors. A paradox was found in a Castle Dale ceramics shop where nearly all delicate ceramic pieces hanging over the edge of a long shelf did not fall off. No one sustained a loss of electrical power, and large coal-fired power plants in the area continued to operate with only minor interruption. No one lost water pressure and wells continued functioning. All fuel lines remained intact. A few people temporarily lost the use of their telephones.

The public meeting attracted over 150 people from Emery and Carbon Counties. The purpose of the meeting was to educate locals about simple earthquake mechanisms, regional tectonics, scientific observations regarding the August 14 quake, and to gather response through two written surveys. A lengthy question and answer session followed the formal presentations. During the question and answer session, several long-time residents related their knowledge of the epicentral area including location of faults and mines not shown on geological maps displayed at the meeting. Miners working in mines along the Wasatch Plateau to the west said they did not feel any motion during the time of the quake. Several others related interesting stories of their response. Many questions related to concern over the reason no warning was issued even though minor seismic activity had been recorded since January, and the reason why studies have concentrated on the Wasatch Front.

The results of the area informational surveys were interesting. For example most surveyed:

- a) felt that earthquake scientists do know enough about earthquake threat to cause government to take steps to protect them.
- b) *would not* sue anyone if a loved one were killed in an earthquake.
- c) *do not* feel that a supreme being causes major earthquakes.
- d) *do not* feel adequately prepared for a major earthquake.
- e) *do not* feel that local governments are prepared for a major earthquake.
- f) do feel that government should do more to inform them about earthquake threat and risk.
- g) *did* hear a loud noise before feeling ground motion.

Additional results:

- a) 52 percent were at home, 25 percent were in church.
- b) 25 percent had dishes and objects fall out of cupboards.
- c) 20 percent had minor cracks in foundations, patios, driveways, etc.
- d) 14 percent had bricks fall from chimneys or walls.

For information contact: Jim Tingey or Dr. Fred May, Utah Division of Comprehensive Emergency Management, 1543 Sunnyside Ave., Box 8136, Salt Lake City, Utah 84108-8136. Telephone (801) 533-5271.

ITEMS OF INTEREST

Call For Papers

A call for papers for U.S. Geological Survey Professional Paper *Assessing Regional Earthquake Hazards and Risks Along the Wasatch Front, Utah, Part B* was issued in early December, 1987. Manuscripts will be accepted until January 1, 1989. Persons interested in submitting papers, and who seek information regarding style and peer review should contact:

Paula Gori
U.S. Geological Survey
905 National Center
Reston, VA 22092
(703) 648-6707

Those wishing to present papers at the *World Gold '89 — Gold Forum Technology & Practices* meeting to be held October 22-25, 1989 are invited to submit a 200-word abstract. Held at Bally's Hotel, Reno, Nevada, the meeting is sponsored by Society of Mining Engineers and The Australasian Institute of Mining and Metallurgy. Submit abstracts to:

Meetings Department—World Gold '89
Society of Mining Engineers
P.O. Box 625002
Littleton, CO 80162
(303) 973-9550

The Western Surface Coal Mining meeting is calling for papers for the May 3-5, 1989 meeting in Gillette, WY. Deadline for abstracts is October 15th. Contact:

Meetings Department, SME
P.O. Box 625002
Littleton, CO 80162
(303) 973-9550

Utah Geological Association requests papers for a 1989 conference/field trip focusing on geology and hydrology of hazardous-waste, mining-waste, wastewater or brine-disposal, and waste-repository sites in Utah. Tentatively scheduled for October 6-7 in Salt Lake City, the meeting will have papers printed in The Proceedings Guidebook and given orally. Brief descriptions are due December 1 and drafts by April 1, 1989. Contact:

Joseph S. Gates
U.S. Geological Survey, WRD,
1745 W. 1700 S., Salt Lake City, UT 84104.
(801) 524-4073 or (801) 524-4244.

A call for papers has been issued for the 1990 Society of Mining Engineers Annual Meeting, February 26-March 1, Salt Lake City, Utah. The deadline for receipt of preliminary abstracts is February 1, 1989.

To receive details of the proposed session topics, contact:

Meetings Department
Society of Mining Engineers
P.O. Box 625002
Littleton, CO 80162
(303) 973-9550, Telex: 881988, Fax: 303-973-3845.

Meetings

February 13-14, 1989 Geophysics of the Rocky Mountains. Meeting in Golden, CO. Contact Front Range AGU Service Center, Box 18-P, Denver, CO 80218. (303) 831-6338.

February 27-March 2, 1989 **Society of Mining Engineers 1989 Annual Meeting** will be in Las Vegas, Nevada at the Las Vegas Convention Center. Contact Meetings Dept., SME, P.O. Box 625002, Littleton, CO 80162, (303) 973-9550.

February 27, 1989 **118th AIME Annual Meeting.** AIME Will meet at the Las Vegas Hilton.

May 3-5, 1989 **Western Surface Coal Mining meeting,** Gillette, Wyoming. Contact Meetings Dept., SME, P.O. Box 625002, Littleton, CO

July 9-19, 1989 **28th International Geological Congress,** Washington, D.C. For information contact Bruce B. Hanshaw, Box 1001, Herndon, VA 22070-1001, (703) 648-6053.

September 10-14, 1989 **Editing Into the Nineties.** Joint meeting at the Westin Hotel in Ottawa, Canada of Council of Biology Editors, European Assoc. of Science Editors, Assoc. of Earth Science Editors, and National Research Council of Canada. Contact Ken Charbonneau, Executive Secretary, National Research Council of Canada, Ottawa, Canada K1A 0R6, (613) 993-9009.

Books & Papers

Geologic Map of Arizona; new release from the Arizona Geological Survey. This new map, compiled by Stephen J. Reynolds, is at a scale of 1:1,000,000 and incorporates a multitude of new data based on more detailed geologic mapping. It is a marked improvement over the 1969 version in the treatment of the Basin and Range and Transition areas, reflecting new mapping and new concepts.

Available from Arizona Geological Survey
845 N. Park Avenue #100
Tucson, AZ 85719.

DELINEATION OF LANDSLIDE, FLASHFLOOD, AND DEBRIS FLOW HAZARDS IN UTAH: PROCEEDINGS OF A SPECIALTY CONFERENCE (D.S. Bowles, editor), General Series G85-3, from Utah Water Research Laboratory, Utah State University, 1985. A collection of papers and abstracts from the conference with some valuable models and information.

MINERAL RESOURCES OF THE BULL MOUNTAIN WILDERNESS STUDY AREA, GARFIELD AND WAYNE COUNTIES, UTAH, by R.F. Dubiel et al., Bulletin 1751-B, U.S. Geological Survey.

BASIN CONTOURS OF THE NORTHERN SECTION, GREAT SALT LAKE DESERT, UTAH, by W.H. Chapman and W.L. Sappington, 1:96,000, 1988, Open-File Report 86-0009, U.S. Geological Survey.

A VIBRATION STUDY OF THE ARCHEOLOGICAL RUINS, HOVENWEEP NATIONAL MONUMENT, UTAH-COLORADO, BY K.W. King and S.T. Algermissen, 1988, Open-File Report 87-0181, U.S. Geological Survey.

PRELIMINARY GEOLOGIC ANALYSIS OF THE TAR SANDS NEAR SUNNYSIDE, UTAH, by C.J. Schenk and R.M. Pollastro in *Exploration for heavy crude oil and natural bitumen* (R.F. Meyer, editor), 1987, AAPG studies in Geology 25.

RECENT USGS GEOLOGIC MAPS cover Hamlin Valley and Escalante Desert (I-1774), Pine Valley area in Beaver and Iron Counties (I-1794), Indian Peak Range in Beaver and Iron Counties (I-1795), and the southern Mountain Home and northern Indian Peaks Ranges in Beaver County (I-1796).

A TRACE OF DESERT WATERS: THE GREAT BASIN STORY by S.G. Houghton, 1986, Howe Brothers of Salt Lake City. A personal overview of the geography, geology, and hydrology of The Great Basin focusing strongly on the ancient lakes (such as Lake Bonneville) and their remnants (Great Salt Lake). An excellent and personable study of water and the Great Basin.

IN THE FOOTSTEPS OF G.K. GILBERT — LAKE BONNEVILLE AND NEOTECTONICS OF THE EASTERN BASIN AND RANGE PROVINCE, Michael N. Machette, editor. This GSA field trip guide for the GSA centennial meeting held October 31 should be a must to anyone interested in Lake Bonneville, neotectonics associated with the lake and the Wasatch fault and, of course, Gilbert and his exemplary work.

The trip on Oct. 28, 29, and 30, led by Mike Machette (USGS, Denver) and Don Currey (Univ. of Utah, Salt Lake), covered much of the northern Wasatch front on the first day while exploring the Lake Bonneville cycles and faulting along the Wasatch. Day 2 explored the Old River Bed west of Salt Lake City, the Stockton Bar, and Stansbury Island. The central Wasatch front was the focus of Day 3, exploring various lake cycles, trenching sites, and the Dry Creek area. 120 pages, Utah Geological and Mineral Survey, Misc. Pub. 88-1.

GEOLOGY OF THE TULE VALLEY, UTAH 30 x 60-MINUTE QUADRANGLE, by Lehi F. Hintze and Fitzhugh D. Davis. The Tule Valley quadrangle is located in western Millard County, Utah. It features the eastern portion of the north-south-trending Snake Valley bounded on the east by the Confusion Range. Central to the quadrangle is the Tule Valley which is flanked by the Confusion Range on the west and the House Range on the east. The eastern portion of the map includes portions of Sevier Desert and Lake, Whirlwind Valley, and Little Drum Mountains. Lithologies present in the valleys include floodplain deposits, alluvium, playa and deltaic muds, eolian sediments, marsh deposits, mass movement deposits, and lacustrine features.

Geologic units in the Confusion Range are predominantly Permian, Pennsylvanian, Mississippian, and Devonian age rocks. Older Paleozoic rock types (Silurian, Ordovician, and Cambrian) are found in the House Range along with Mesozoic extrusive lithologies. Tertiary volcanics dominate the Little Drum Mountains. UGMS Open-File Report 134.

GEOLOGY AND MINERAL POTENTIAL OF THE ANTELOPE RANGE MINING DISTRICT, IRON COUNTY, UTAH, by Michael A. Shubat and W. Skip McIntosh. The Antelope

Range Mining District is twenty miles west of Cedar City, Utah in the west-central portion of the Antelope Mountain Range. The district is situated on a volcano-tectonic boundary that has been active since the Late Cretaceous. Prospecting in the southern part of the district began in the 1870s. The first shaft was sunk in the early 1900s and exploration has continued intermittently until the present.

Neogene extensional thrust faulting formed northwest-striking faults and fractures that became the structural hosts for epithermal base and precious metal mineralized veins. The date for mineralization and hydrothermal alteration is approximately 8.5 million years and it is related to rhyolitic and dacitic volcanism. Factor analysis results of geochemical data indicate that at least two episodes of mineralization occurred in the district. Geochemical anomaly and precious metal anomaly maps for various vein systems are included in the report. Area stratigraphy includes Mid- to Late Jurassic marine sediments (Carmel Formation), fluvial, braided stream sediments of the Iron Springs Formation, and ash-flow tuff of the Isom Formation and Quichapa Group.

Two plates at 1:24,000 accompany the report: the geologic map and hydrothermal alteration map. UGMS Map 108 (Geologic map of the Silver Peak quadrangle, Iron County, Utah, by Shubat and Mary A. Siders) covers all but a small portion of the district and is a useful companion piece to the report. UGMS Bulletin 125.

ACID NEUTRALIZING CAPACITY MAP OF UTAH by William F. Case. The acid neutralizing capacity (ANC) map of Utah and its accompanying report is a product of (1) the Utah Division of Environmental Health, Bureau of Air Quality endeavoring to determine areas in the state that are sensitive to acid deposition and (2) The Utah Geological and Mineral Survey's efforts to show where geologic materials will not buffer the acid deposition.

Chemical bonding of water with carbon dioxide in the air or by-products from fossil fuel combustion, a saline lake deposit, or lightning can cause precipitation to be as acid as vinegar. This precipitation, along with the settling of airborne chemicals, causes increased amounts of acidity in Utah's surface waters. Ultimately, the acidity of Utah's lakes and rivers is determined, in part, by the neutralizing properties of the geologic materials through which acid deposition moves. The map included in this report is designed as an overlay for the 1980 Geologic Map of Utah by Lehi Hintze. It shows the regional distribution of ANC classes as outlined in the report. Utah Geological and Mineral Survey Open-File Report 132.

AN OVERVIEW OF LANDSLIDE INVENTORIES PREDOMINANTLY OF NORTH AMERICA by Sandra N. Eldredge. This report summarizes 38 landslide inventories, mostly from the U.S. and Canada. The 1986 survey shows the diversity of landslide inventories with emphasis on small-scale work at the state level. Objectives, methodologies, map scales, terminology, products and data, and the relative successes of these are discussed with a view to improving the informational quality and collection methods of future surveys. UGMS RI 217.

QUATERNARY GEOLOGY OF THE BLACK ROCK DESERT, MILLARD COUNTY, UTAH by Charles G. Oviatt. Tertiary and Quaternary basalts, rhyolite domes, volcanic vents, lacustrine and alluvial deposits, and thin eolian sands dominate the surface of this project, based on an area covered by twelve 7½-minute quadrangle maps. The study area is in Millard

County and encompasses the southern extension of the Sevier Desert between the Cricket Mountains and the Pahvant Range.

Radiocarbon age dates from samples illustrate relationships between local eruptive events and Lake Bonneville historical levels. Regional structural features include Quaternary faults and the doubly plunging Cove Creek Dome anticline.

Part of an ongoing set of studies on the Quaternary geology of western Utah, this report is a COGEOMAP product (see Survey Notes v. 21, no. 2-3,), available as UGMS Open-File 128.

UGMS Personnel

Annona Youngdell, long-time secretary for the Mapping and Economic sections, moved to the State Board of Education. We hope they realize the jewel they've received. She is replaced by **Jean Muller**, most recently with the school board in Kemmerer, Wyoming.

Barry Solomon, of Battelle's Project Management Division where he was geotechnical advisor, begins work in the Applied section and brings extensive experience in oil shale, and nuclear power plant siting.

Plans for more schooling have drawn **Jackie Ledbetter** from her work as the UGMS Salesperson. Best of luck — 8 to 5 now becomes 8 to midnight.

Robert W. Gloyn has accepted the position of Geological Manager for the Economic Geology Program at the UGMS. Twenty years of varied exploration and production experience comes into play, and his work with a broad spectrum of commodities and deposit types will certainly be useful in our evaluation of Utah's resources. He has recently worked with BHP International and with Getty Oil for many years.

Congratulations to **Grant Willis** who had a photograph accepted for the GSA geologic photo album which should be coming out in time for the annual meeting.

Bob Klauk, geologist in the Applied Section for many years, has opted to work for Warzyn Engineering, Inc. in Novi, Michigan. Going back to renew his acquaintance with *REAL* winters!

And we'll have to take into account the loss of **Gwen Anderson**—the only accounting officer we've known who smiles all the time. She's off to the State's Administrative Services to help them along.

Carolyn Olsen, our curator for the Sample Library, was in a serious traffic accident on the last day of June. We are happy to report she is doing very well at her home in Bountiful, and we are anxious for her complete recovery.

New Publications

Open-File Reports

- OFR-128** Quaternary geology of the Black Rock Desert, Millard County, Utah, by Charles G. Oviatt, 53 p., 1 pl. 1:100,000, 1988 ... available for public inspection at the UGMS Library.
- OFR-129** Causes of shallow ground-water problems in part of Spanish Valley, Grand County, Utah, by Robert H. Klauk, 46 p., 1988 \$4.00
- OFR-130** Geologic map of the Antelope Peak quadrangle, Iron County, Utah, by S.K. Grant and P.D. Proctor, 32 p., 1 pl. 1:24,000, 1988 ... available for public inspection at the UGMS Library.
- OFR-131** Sample Library Catalog, by UGMS staff, 374 p. ... available for public inspection at the UGMS Library; sections available through the Sample Library Curator.
- OFR-132** Acid-neutralizing capacity map of Utah, by William F. Case, 9 p., 1 pl. 1:500,000, 1988 \$4.50
- OFR-133** West-central Kane County state lands evaluations for State Lands and Forestry, by Hellmut H. Doelling, 517 p., 1988 \$51.00
- OFR-134** Geology of the Tule Valley 30 x 60 minute quadrangle Utah, by Lehi F. Hintze and Fitzhugh D. Davis, 33 p., 1 pl. 1:100,000, 1988 ... available for public inspection at the UGMS Library.
- OFR-136** Preliminary geology of the Red Knolls 7.5-minute quadrangle, Millard County, Utah, by Lehi F. Hintze and Fitzhugh D. Davis, 12 p., 1 pl., 1:24,000, 1988 ... available for public inspection at the UGMS Library.
- OFR-137** Geologic map of the Long Ridge 7.5-minute quadrangle, Millard County, Utah, by Lehi F. Hintze and Fitzhugh D.

Davis, 11 p., 1 pl., 1988 ... available for public inspection at the UGMS Library.

Report of Investigation 217 An overview of landslide inventories predominantly in North America, by Sandra Eldredge, 98 p., 1988 \$5.25

Miscellaneous Publication 88-1 In the footsteps of G.K. Gilbert-Lake Bonneville and neotectonics of the eastern Basin and Range Province, guidebook for field trip twelve, Geological Society of America annual meeting, 120 p., 1988 \$8.50

Miscellaneous Publication 88-2 Geology and Antelope Island, by Hellmut H. Doelling and others, 20 p. \$1.50

Bulletin 125 Geology and mineral potential of the Antelope Range Mining District, Iron County, Utah, by Michael A. Shubat and W. Skip McIntosh, 26 p., 2 pl., 1:24,000, 1988 \$6.50

Map 43 Physiographic subdivisions of Utah, by W.L. Stokes, 1 pl., 1:2,500,000, 1977 (reprint) \$1.00

Map 111 Flood hazards from lakes and failures of dams in Utah, by Kimm M. Harty and Gary E. Christenson, 8 p., 1 pl., 1:750,000, 1988 \$6.00

Map 55-C Ground-water resources of the southern Wasatch Front, Utah, by Don Price and Loretta S. Conroy, 6 p., 3 pl., 1:100,000, 1988 \$6.00

Map 55-D Mineral resources of the southern Wasatch Front, Utah, by Fitzhugh D. Davis with petroleum resources by Floyd C. Moulton and Raymond L. Kerns, Jr., 17 p., 2 pl., 1:100,000, 1988 \$6.00

These Prices Do Not Include Postage or Utah Sales Tax

UTAH EARTHQUAKE ACTIVITY

by James C. Pechmann

UNIVERSITY OF UTAH SEISMOGRAPH STATIONS, DEPARTMENT OF GEOLOGY AND GEOPHYSICS

January through March 1988

Figure 1 shows the epicenters of 157 earthquakes located by the University of Utah Seismograph Stations within the Utah region during the three-month period January through March 31, 1988. The seismicity sample includes 51 earthquakes of magnitude 2.0 and greater and two earthquakes of magnitude 3.0 and greater.

The largest earthquake during the report period, and the only one reported felt, had a local magnitude (M_L) of 3.5 and occurred on January 2 on the southern border of Utah, 30 km west of Kanab. This earthquake was felt at Rockville, Springdale, and Virgin, Utah, and at Fredonia, Arizona.

Clusters of earthquakes occurred at five localities labeled on the map:

(1) a cluster of 10 aftershocks (coda magnitude (M_C) ≤ 1.6) of an M_L 2.7 earthquake that occurred near the Utah-Idaho border on December 11, 1987;

(2) 72 aftershocks ($M_L \leq 3.1$) of the 1987 Lakeside earthquake sequence west of the Great Salt Lake, which included 8 shocks of M_L 3.8 to 4.8 during September and October of 1987;

(3) 26 seismic events of $M_C \leq 2.5$ located 40 km southwest of Price in an area of active underground coal mining;

(4) a swarm of 7 earthquakes of $M_L \leq 2.5$ that occurred 50 km south of Price between January 14 and 20; and

(5) seven earthquakes ($M_C \leq 1.7$) 40 km west of Richfield, representing a continuation of small magnitude activity that began in this area in December 1987.

The UGMS Sales Office carries printed catalogs of earthquake information collected by the University of Utah Seismograph Stations, as listed below

Earthquake Studies in Utah, 1850 to 1978, edited by Walter J. Arabasz, Robert B. Smith and William D. Richins, 1979, 552 pages, spiral bound; this is the catalog of the University of Utah Seismograph Stations as well as several earthquake-related papers.

Available as MP87-7 \$28.00.

Earthquake data for the Utah region, by W.D. Richins and others (July 1, 1978 to December 31, 1980), October 1981, 127 pages, UGMS Miscellaneous Publication F-1 \$5.00

Earthquake data for the Utah region, January 1, 1981, to December 31, 1983, by W.D. Richins, and others, 111 pages, 6 figures, 4 tables, UGMS Miscellaneous Publication F-2 \$5.00

Earthquake data for the Utah region, January 1, 1984 to December 31, 1985, by E.D. Brown, and others, 83 pages, 1986, UGMS Miscellaneous Publication F-3 \$5.00

April through June 1988

During the three-month period April 1 through June 30, 1988, the University of Utah Seismograph Stations located 87 earthquakes within the Utah region (see figure 2). Of these earthquakes, 32 had a local magnitude (M_L) or coda magnitude (M_C) of 2.0 or greater, four had a magnitude of 3.0 or greater, and one was reported felt.

Aftershock activity from the 1987 Lakeside sequence west of the Great Salt Lake (M_L 4.8; location L on map) has now decreased to a very low level. Only two aftershocks—one of M_C 1.5 on May 6 and one of M_C 2.0 on June 14—were located in the Lakeside area during the report period. For comparison, 72 aftershocks, including 10 of magnitude 2.0 or greater, were located in the Lakeside area during the first three months of 1988. Only the comparison of the numbers of magnitude 2.0 or greater aftershocks can be considered reliable because the earthquake detection and location capability of the network in the Lakeside area deteriorated after late March. This deterioration was due to intermittent failures of the four temporary stations installed in this area in October 1987 to supplement the coverage of the permanent network stations. Aftershocks of magnitude 2.0 and greater in the Lakeside area can be readily detected and located using only the permanent network stations, although the locations are much less accurate without the local station coverage.

The two largest earthquakes during the report period occurred twelve minutes apart on May 22, but 350 km away from each other. The first was an M_L 3.6 event that occurred 10 km west of the Utah-Nevada border at 1:10 PM MDT. The second was an M_C 3.8 earthquake at 1:22 PM MDT, located 10 km south of the Utah-Arizona border and 45 km WSW of Kanab. The other two earthquakes of magnitude 3.0 or greater were an M_L 3.3 event north of the Great Salt Lake on May 11 and an M_C 3.0 earthquake 45 km SW of Price on May 4. The earthquake southwest of Price was the largest of 11 earthquakes that occurred in this area during the report period. An earthquake of M_C 2.2 on June 13, located 10 km SE of Richfield, was reported felt in Richfield.

Additional information on earthquakes within Utah is available from the University of Utah Seismograph Stations, Salt Lake City, Utah 84112; telephone (801) 581-6274.

In addition, the UGMS carries:

Reprints of the Seismic Safety Advisory Council's Reports. This series of reports was originally prepared in 1977-81 to provide assessment of various public facilities such as office buildings, schools, hospitals, utilities, dams and water supplies, and to give recommendations for risk reduction measures, such as building codes, in the event of damaging earthquakes.

Three volume set \$30.00

All prices quoted are over-the-counter prices. For prices plus mailing costs, please contact the UGMS at 581-6831.

