SURVEY·NOTES

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UTAH GEOLOGI MINERAL SURVEY

fabulous!

HIGHLIGHTS OF THE SURVEY

FY 88-89 in review

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Survey Notes is published quarterly by **Utah Geological and Mineral Survey,** 606 Black Hawk Way, Salt Lake City, Utah 84108 (801) 581-6831. The UGMS inventories the geologic resources of the state, identifies its geologic hazards, disseminates information concerning Utah's geology, and advises policymakers on geologic issues. The UGMS is a division of the Department of Natural Resources. Single copies of Survey Notes are distributed free of charge to residents within the United States and Canada. Reproduction is encouraged with recognition of source.

FROM THE DIRECTOR'S CORNER

This is my final *From the Director's Corner* contribution. By the time this issue of *Survey Notes* is distributed my resignation as Utah State Geologist and Director of the Utah Geological and Mineral Survey will have become effective and M. Lee Allison will have assumed these responsibilities. When I was appointed in mid-1981, my commitment was to stay in the position for seven to ten years. I believed then, as now, that it would be adequate time for a division director to make a significant contribution to the State of Utah. I also feel that remaining in the position much longer would not have been in the best interests of either the UGMS or myself. The eight-plus years I have managed the UGMS have been exciting, enlightening and fun. I believe that during this period the UGMS has made major contributions to the State of Utah and that the division has the staff and resources to continue to perform its mission. This issue of *Survey Notes* highlights the UGMS accomplishments for fiscal year 1988-89. I would like to briefly review some of the major accomplishments of the last eight years.

The UGMS occupies the same offices as eight years ago, but the interior work space has been redesigned. Moving the Sample (Core) Library to its new location at 4060 So. 500 West, Suite 4, Salt Lake City, has provided improved access for the public to the material, and has allowed additional office space at the UGMS' Research Park center at 606 Black Hawk Way.

The way we operate in our space has changed as well. One major difference lies in the use of computers. Eight years ago the UGMS was using some word processing aspects; now we have over 40 networked units being used for word processing, as an integral part of our scientific endeavors, for communication between agencies, as a major accounting method, and for creating maps and databases. Many of these uses would not have been possible even a short time ago.

Several important changes have occurred in the UGMS scientific programs. I am particularly proud of two activities that have developed into major UGMS programs — the Geologic Mapping and Applied Geology Programs. The Geologic Mapping Program has provided greater emphasis on 1:24,000 scale multi-purpose quadrangle mapping and on county mapping. Through programs that involve UGMS geologists, U.S. Geological Survey geologists, and students and staff of several universities, the UGMS over the last few years produced 27 quadrangle maps, 6 Wasatch Front maps, a special Quaternary map, and a definitive study on Kane County including nine 1:100,000 plates. The UGMS has one of the strongest geologic mapping programs of any state geological survey.

The Applied Geology Program evolved from the earlier engineering geology effort. The focus of the program is to define the geologic hazards of Utah and to provide information on the hazards in a form that can be used by decisionmakers at all levels to reduce the threat these hazards pose to life and property. By 1991 any person in any section of the State will have access to a series of maps and short reports on Utah's 8 most significant geologic hazards. These publications depict what the hazards are, their locations, effects, and how to minimize risk. Both of these programs were made possible by new authorizations of staff and funding by the Utah Legislature.

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Director's Corner, continued

The UGMS and the U.S. Geological Survey share many interests and objectives relating to Utah geology and resources. The UGMS staff and I have worked hard in the last eight years to improve the cooperation between the UGMS and the USGS, and our efforts have paid off to the advantage of both organizations. The UGMS now has access to equipment and expertise in the USGS that add significant strength to our programs.

We have also worked hard at improving our relationships with other state agencies and local governments in an effort to increase the use of geologic information. Although we have not achieved everything we would like, we have made major progress, including a program that resulted in the hiring of county geologists by three Wasatch Front counties.

I am absolutely delighted to see the Economic Geology Program's "UMOS" Utah Mineral Occurrence System becoming easily accessible to other state agencies. This computerized data base contains field-checked geologic information for every mineral occurrence in Utah that has been located on any published map, mentioned in any published report, or known to any UGMS geologist.

The success of the UGMS over the last 8 years results from the work of a dedicated and skilled staff. I thank them for the support they have given me and the work they have done for Utah. I also want to note a special acknowledgement to the two Senior Geologists, Hellmut Doelling and Don Mabey, who worked very closely with me in establishing the new Geologic Mapping and Applied Geology Programs, and to Roselyn Dechart, who has been my administrative secretary for the last five years. Also critical to the the UGMS success has been the support of the UGMS Board, the Legislature, Governor and Department of Natural Resources.

The new State Geologist and UGMS Director is M. Lee Allison. I wish him and the UGMS staff success in their continuing efforts to use geology to make Utah safer, richer and better understood geologically.

Teacher's Corner*

by Sandra N. Eldredge

*(*Note: Teacher's Corner is a new feature in Survey Notes, addressed to earth science teachers. Information provided will include maps and publications of interest, activities and other pertinent news. Teachers are encouraged to contact the Utah Geological and Mineral Survey for additional information.)*

Available from the UGMS sales office is a brochure titled "Geologic Resources of Box Elder County, Utah." This is the first in a series of 29 brochures introducing the reader to the geologic resources in each of Utah's counties. The county's metallic, non-metallic, and energy resources are highlighted. A brief introduction discusses the relevance of geologic resources, followed by a general description of the county's geology. Several commodities in each resource category receive special attention, highlighting their origin, mining history, extraction, and uses. The remainder of the commodities are included in tables listing uses, locations, and occurrence types. A chart correlates resources with particular deposits found in specific geologic time periods. The text is also supplemented with maps, photos, and a list of recommended reading. Not only can this be used to provide information on a county's geologic resources, but very basic and general geologic descriptions and geologic maps are provided as well.

Geologic resources of Salt Lake County, Summit County, Tooele County, and Wasatch County will be published next.

For those teachers interested in petroleum geology, an open-file report is available. "A short course in petroleum geology with examples from Utah's petroleum provinces" contains four volumes with excellent materials for teachers and students. Key words and phrases, important concepts, worksheets, and references are provided for each chapter. Volume 4 is a simulation game called "Wildcat," which approximates the actual working of an oil and gas exploration company. The game has elements of luck (as in the uncertainty of oil and gas exploration), but also requires the students to fully understand the basic principles of geology and petroleum geology. Volume 3 is a teacher's guide for the simulation game.

— USEFUL TEACHER'S TOOLS —

Non-metallic mineral resources of Utah, Map 71, by H.H. Doelling, scale 1:750,000, 1983 ..... $5.00

Energy resources map of Utah, Map 68, compiled by the UGMS Geologic Staff and Illustrations Section, scale 1:500,000, 1983 ..... $6.00

Geologic map of Utah, compiled by L.F. Hintze, scale 1:500,000, 2 sheets, 1980 ..... $15.00

Geologic map of Utah, by L.F. Hintze, 1974. This map is in convenient hand-out form on 8½ x 11 ..... $1.00

Geological highway map of Utah, by L.F. Hintze, 1975, Brigham Young University, Special Studies 3. (This map may be purchased at Brigham Young University).

A short course in petroleum geology with examples from Utah's petroleum provinces, by Carol N. Tripp, Open-File Report 150:

Volume 1 — Short course, 186 p. $16.50
Volume 2 — Student manual, 208 p. $18.00
Volume 3 — Teacher manual, 61 p. $6.50
Volume 4 — Wildcat, a simulation game, 66 p. $6.50

Rockhound guide to selected rock and mineral localities in Utah, by M.R. Smith, fold-out, 1987 ..... .50¢

Semiprecious gemstones and ornamental stones found in Utah, by M.R. Smith, 17 p., 1987 ..... $1.00

Industrial commodities: Non-metallic resources of Utah, by M.R. Smith, fold-out, 1987 ..... .50¢

Mineral fuels and associated energy resources, by M.R. Smith, fold-out, 1987 ..... .50¢

HIGHLIGHTS OF THE 88/89 FISCAL YEAR

The Utah Geological and Mineral Survey is a multi-faceted state agency: the 52-person organization studies and reports on Utah's many geologic resources, thus making the state richer; investigates and reports on Utah's geologic hazards, thus making the state safer for its citizens and visitors; promotes maps and a better understanding of the geologic formations and their history, thus making the state's geology better understood; and disseminates geologic information in a non-technical way, thus making the state's decision-makers, citizens and visitors more knowledgeable. To effectively carry out this mission, the Survey consists of three fundamental programs (Economic Geology, Mapping Geology, Applied Geology) whose work is closely tied with the Administration, Information, Computer Resources and Editorial sections.

The diversity of personal and professional involvement by UGMS staff is reflected in the more than twenty-five advisory groups and committees being served on, and by membership in more than a dozen professional organizations.

Sunset Reauthorization

Following a "Sunset Review", the 1989 legislature reauthorized the UGMS for another decade (see *Survey Notes* v. 22, no. 1/2, p. 1-6). As part of the "sunset" process, an in-depth study of the agency was conducted and four conclusions reported:

* Services of UGMS are vital to industry and government.
* Caliber of work is very good.
* Staff is accessible, cooperative, helpful.
* Number of publications has increased dramatically.

The legislative report also noted that termination of the agency would adversely affect the public in the following manner:

* Overall costs of information gathering would mushroom as industries and government agencies duplicate efforts.
* Mineral development opportunities would be lost.
* Individual state agencies would have to hire geologists.
* Public safety would be threatened due to lack of awareness of hazards.

ADMINISTRATION

Administration provides the basic support necessary to the operations of the UGMS. It is responsible for division policy, budget and overall direction. It also administers the Mineral Lease Special Projects Program which has been essential in retrieving important Utah geologic information, stimulating new geologic work in the state, and helping UGMS manage its mineral lease revenues. Administrative personnel have met extensively with media representatives during coverage of a variety of events with geologic causes or results; they have also spoken to groups as diverse as the Legislature's Task Force on mining issues, Salt Lake Board of Realtors, U.S. Forest Service annual geological and engineering workshop, Women's Legislative Council, Community Impact Board, and the State/Local Intergovernmental Advisory Committee.

UGMS Board

The UGMS Board consists of eight representatives from industry, engineering, scientific, and business plus State Lands and the public at large. Board members met four times in FY 1988-89, including a field trip to the Rock Canyon trench near Provo to personally observe the Wasatch fault where it cuts recent sediments along the mountain front. The Board discussed UGMS priorities and policies and advised the agency on how to effectively inform other state agencies about geologic hazards, specifically those that may be encountered in engineering construction projects such as dams, highways and public buildings. Recently, the Board adopted policy guidelines for honoraria and compensation of UGMS employees for teaching courses at institutions of higher learning. During this fiscal year, the special projects to be funded with Mineral Lease Funds were selected and actively tracked.

Mineral Lease Special Projects Program

The Mineral Lease Special Projects Program (MLSPP) was developed in 1987 to solicit geologic proposals from the scientific community. Through the program, UGMS acquires new geologic information and accesses existing geologic data that would otherwise be lost (see *Survey Notes* v. 22, no. 4, p. 20-25).

By contracting for special types of geologic information, UGMS supplements its programs without adding permanent staff and utilizes expertise not currently available in the agency. The program also builds upon the knowledge and background of individual scientists and organizations who have invested time and money in geologic investigations in Utah but have not made the results of their investigations available to the public.

In 1989, a total of $153,451 was appropriated for 27 projects. The UGMS Board awarded contracts to: eight projects designed to improve the understanding of Utah's geology through mapping of rock formations; seven projects related to identifying the state's natural hazards; seven projects designed to expedite the inventory of geologic resources in Utah; and five projects to disseminate information to teachers, decision makers, state and local governments and the general public. The proposals were judged on geologic merit, expertise of the proposer and importance to Utah, and they were funded with mineral lease revenues. Since 1987, three rounds of informal proposal solicitation have been completed and forty-nine contracts have been awarded for a variety of geologic projects totaling $358,465.

UGMS COOPERATION WITH FEDERAL, STATE AND LOCAL AGENCIES.

UGMS can only succeed in its goals through cooperation with state and local agencies that implement economic development and public safety directly with the public and industry. UGMS continues to work closely with local governments throughout the state and particularly with the county geologists for Salt Lake, Davis and Utah counties. State agency requests for information and advice multiplied this year. Although federal agencies have cut back their financial support of state geologic surveys, UGMS continues to work closely with the Department of Energy, Bureau of Land Management, U.S. Bureau of Mines and the U.S. Geological Survey. The USGS is UGMS's federal counterpart and in 1988-89 the two agencies cooperated to accomplish:

* A new, 1:500,000 scale state map to be used as the official state map by all federal and state agencies. This map will be digitized in 1990.
* Revised topographic maps in 160 7.5 minute quadrangles along the Wasatch Front where cultural features have changed since original mapping and for 127 quadrangles of rural Utah which were originally mapped only from aerial photographs.
* Completed new topographic maps in four areas of the state and commenced topographic mapping in the last remaining part of the state that has not previously been mapped. This will complete the topographic coverage of the state in 1990, the culmination of over three decades of cooperative effort between the State of Utah and the federal government.
* Continued an aggressive program to identify the characteristics of Utah's coal resources.
* Continued mineral appraisal projects in western Utah, including mapping of mineral districts and sophisticated dating of regional metamorphisms.
* Translated technical information about Utah's earthquake hazards for local government use in implementing earthquake hazard reduction.
* Monitored the saline waters of Great Salt Lake and the Newfoundland Evaporation Basin.
* Added to the information available for understanding the geologic history and evolution of the Uinta-Piceance Basin.
* Worked out field relationships of faults and landslides on the Wasatch Plateau.
* Finalized and began production of the new Bouguer gravity anomaly map of Utah at 1:500,000.
* Coauthored a map of the active faults in the Cedar City 2-degree quadrangle.
* Supported a 1:500,000 map showing landslides in Utah 1983-87.

COMPUTER RESOURCES

Computer resources have long been an integral part of the scientific community as a research aid. In this age of information explosion, managing and disseminating volumes of data is a challenging task. Collecting, analyzing and disseminating geologic information is one of the Survey's primary responsibilities. Effective information management is crucial to remain responsive to other governmental agencies, private industry and Utah's citizens.

Personal computer (PC) technology is now the fundamental tool for storing, analyzing and disseminating geologic data at UGMS, allowing the development and maintenance of several large databases. Some of these databases contain confidential information used only by UGMS staff, but most are public.

UGMS personnel actively use computers to better understand Utah's geology and its many natural resources. They are also working with the information that addresses geologic hazards in the state. From this work, information is produced which is useful to scientists and non-scientists in government and the private sector.

Finally, the traditional way UGMS distributes geologic information is through its publications. Here, too, the PC has revolutionized the way information is produced. The agency uses computerized camera, typesetter, desktop publishing software and plotter software. As the agency's skills in this area increase, more publications will be prepared using these resources.

INFORMATION GEOLOGY

The Utah Geological and Mineral Survey's mandate to research the state's geology is a valuable, crucial public service. While delineating strategic minerals, mapping the state's lithologies and structures, and defining natural hazards are the backbone of the Survey, translating this information for public use is an essential aspect. The UGMS Information Section communicates geological research and ideas to Utah's decision makers, residents, visitors, educators, geologists, engineers, investors, homeowners, civic groups and many others.

In cooperation with the Utah Department of Community and Economic Development (and funded by the Community Impact Board), the information team implemented the first of a series of brochures highlighting the geologic resources of each of Utah's counties. *The Geologic Resources of Box Elder County, Utah,* is a 24-page, stylishly illustrated, technically accurate promotional report which was sent to school teachers, Chambers of Commerce, local officials and others to promote their county's varied resources. Although the bulk of their time was spent responding to letters, visitors and telephone inquiries, section personnel also led geologic field trips, compiled requested information and served as technical advisors on five Mineral Lease Special Project contracts.

APPLIED GEOLOGY PROGRAM

The Applied Geology Program collects, disseminates, and encourages the use of information on geologic hazards and engineering geology to benefit the people of Utah. This is accomplished through: 1) engineering geology studies of specific areas or specific problems, chiefly related to waste disposal and land-use planning, 2) compilation and interpretation of

hazards information, 3) providing advice to government entities and citizens regarding engineering geology and geologic hazards, and 4) responding to requests from tax-supported entities (local governments, school districts, state agencies) for assistance in critical facilities siting, environmental health problems, or other engineering-geology applications.

Duchesne County Wastewater Disposal Project

This is one of two major projects the UGMS has undertaken with funding from the Community Impact Board. In cooperation with the Duchesne County Planning Department and the Uintah Basin Health Department, the project evaluates the potential for disposal of limited amounts of wastewater in bedrock in Duchesne County. Permits for septic tank soil absorption systems are difficult to get because of a lack of soil cover. A field trip for state and county health and planning officials was held in July, 1989 to present the results. The recommendations are being considered by Duchesne County and the Utah Wastewater Technical Review Committee for amending existing wastewater disposal regulations.

Sevier County Landfill Siting Project

Another project funded by the Community Impact Board evaluated geologic conditions for landfills in Sevier County. This county-wide assessment identified suitable areas for solid waste disposal from the standpoint of geology and hydrology. A field trip for local planning and health officials and representatives of the Utah Solid Waste Task Force was held in July, 1989. The report will aid the county and cities in identifying suitable areas for new landfills, and provides the information needed to satisfy new proposed EPA siting requirements.

Quaternary Faults of Southwestern Utah

A cooperative project with the U.S. Geological Survey to map Quaternary faults in southwestern Utah was published. The map is drawn from many years of work in the area by the USGS and UGMS, and completes a series of USGS maps of Quaternary faults covering most of western Utah at the 1:250,000 scale. One purpose of this study was to better assess earthquake potential, particularly with regard to large surface-faulting earthquakes.

Response to Geologic Hazards Emergencies

Several significant hazard events occurred in FY 1989. A magnitude 5.3 earthquake occurred in Emery County on August 14, 1988, and a magnitude 5.4 earthquake occurred in Sevier County on January 29, 1989. Neither caused extensive damage, but many interesting geologic effects, particularly rock falls, were documented in the Emery County earthquake. The Quail Creek dike in Washington County failed on January 1, 1989, and flooded St. George and other areas downstream, necessitating investigations both of the role the site geology played in the failure of the process used by the state in investigating, constructing, and inspecting dams. A major landslide closed Utah Highway 14 east of Cedar City on March 27, 1989, and UGMS, UDOT, and Utah CEM investigated and worked together on defining the hazard potential and evaluating the geology of the slide. A debris flood damaged homes and businesses in Emigration Canyon on June 9, 1989, and UGMS investigated and advised state and local authorities regarding potential hazards.

Aid to Local Governments and State Agencies

Applied Geology personnel responded to requests for technical assistance from many local government and state agencies. Most requests from local governments were for site investigations for water tanks, landfill sites, spring protection areas, and landslides. UGMS also reviewed reports for a proposed low-level radioactive waste repository just across the border in Colorado for possible impacts downstream in Utah for the State Health Department. Two compilations of technical reports for similar studies from previous years were published in FY 1989, one for the Applied Geology Program and one for the Wasatch Front County Geologists.

Statewide Hazards Map Compilations

This project, started in 1985, has the goal of compiling statewide maps of all the major hazards, and identifying all available hazards information. For the latter task, a computerized bibliography (HAZBIB) was compiled of all information sources ranging from published journal articles to relatively obscure internal government agency reports and consultant reports. Major steps were taken in FY 1989 toward completion of the last in the series of statewide hazards maps (scales 1:500,000 and 1:750,000).

Landslide Map of Utah: Following the disastrous landslide events of the early 1980s, particularly 1983-1984, much new information became available regarding landslides and landslide susceptibility. A 1:100,000 scale landslide inventory and computerized database were produced for use in preparation of the statewide map, which will be a comprehensive compilation of all mapped landslides in Utah. The Landslide Map of Utah will in turn be used to produce landslide susceptibility maps of Utah planned by the UGMS and USGS. The map is now in final review for publication in early 1990.

Quaternary Tectonics Map of Utah: One of the first steps needed in defining earthquake hazards in Utah is to map and determine the relative activity of Quaternary faults in the state. A great deal of information is now available as a result of studies by the UGMS and USGS under the National Earthquake Hazards Reduction Program, and by the U.S. Bureau of Reclamation for the Central Utah Project. This map is a digital compilation keyed to a computerized database giving all the available information on slip rates, time of last movement, and other parameters. The map will be completed this year for publication in 1990.

Earthquake Hazards Map of Utah: This map will take information from the Quaternary Tectonics Map and others in the

statewide map compilation series and depict the many earthquake hazards (ground shaking, surface faulting, liquefaction, seismic slope failure). The accompanying text will discuss the hazards in a format "translated" for the non-technical user. It is anticipated that the map will be completed in early 1990 for publication later in the year.

Problem Soils/Subsidence Map of Utah: Utah has many soil types which pose a hazard to structures and require special foundation designs or other engineering measures to prevent damage. These include expansive clays, collapsible (hydrocompactible) soils, and gypsiferous soils. In addition, subsidence from soil piping, dissolution of gypsum and limestone (karst), mine collapse, and ground-water withdrawal has occurred in the state. This map will show documented occurrences of each and, where possible, define areas of the state susceptible to each. It is scheduled for completion in 1990.

Tooele County Geologic Hazards Mapping: A folio of geologic hazards maps for Tooele Valley and the West Desert Hazardous Industry Area is being prepared as the first part of a multi-phase, multi-year project to produce hazards maps of the entire county. Tooele County has been considered for many large engineering projects (SSC, various Defence Department facilities, hazardous industries). Geologic information is very important when evaluating such proposals, and is generally needed early in the process.

Northern Utah Earthquake Handbook: A handbook directed toward local government officials and the lay public describing earthquake hazards and indexing sources of earthquake hazards information for the Wasatch Front. It is being prepared as a companion volume to handbooks being developed by the Utah Division of Comprehensive Emergency Management to provide the information necessary for local governments to determine basic risk management.

Wasatch Fault Paleoseismic Studies: As part of a multi-year effort to assess earthquake hazards along the Wasatch Front, UGMS excavated two trenches across the fault zone at the mouth of Rock Canyon in Provo, Utah to determine the size and timing of past earthquakes on the segment of the fault in Utah County. This information can be used to predict the characteristics of future earthquakes and to estimate the potential hazard for the Provo segment. A field review was held for elected officials, planners, and others to brief them on the project.

Geology of the Salt Lake City Metropolitan Area: Several years of study by the Applied and Economic Programs at UGMS, as well as the Salt Lake County Geologist, have contributed to this comprehensive report, which is now in final review. It stresses the engineering geology of the Salt Lake City area, with sections covering general geology, geologic hazards, environmental concerns (water supply, waste disposal), mineral resources, and the unique Great Salt Lake.

Other Activities: The UGMS co-sponsored the Fifth Annual Workshop on Earthquake Hazards and Risk along the Wasatch Front. In addition, 3 issues of the Wasatch Front Forum, a publication devoted to the timely dissemination of earthquake information, were edited and published by the UGMS. Applied Geology geologists published and/or presented papers at the Highway Geology Symposium and combined Cordilleran/Rocky Mountain Section meeting of the Geological Society of America. Papers are also being prepared for the U.S. Geological Survey Professional Paper entitled "Assessment of Regional Earthquake Hazards and Risk along the Wasatch Front, Utah" and the Bulletin of the Association of Engineering Geologists.

Geologists from Applied Geology served on the Utah Lake Policy Advisory Committee, Utah Water Atlas Steering Committee, Wellhead Protection Advisory Committee, Salt Lake Community College Advisory Board, and Inter-Agency Hazard Mitigation Committee. Staff also reviewed the State Water Plan, State Ground-Water Quality Protection Regulations, Wasatch Canyons Master Plan, Salt Lake County and Utah County draft natural hazards ordinances, numerous environmental impact statements, and a variety of technical papers both from within and outside the UGMS.

GEOLOGIC MAPPING PROGRAM

This UGMS program produces reliable geologic maps at several levels of detail for the state. UGMS geologists and mappers under contract produce maps at detailed (1:24,000) and regional (1:100,000) scale as well as bulletins, booklets and brochures to provide additional information about the stratigraphy, structure, economic geology and geologic hazards of the map areas. During this fiscal year, 15 detailed maps plus text were submitted for review and open-filed; another 15 were published. At the time of this report, Mapping Program personnel are in some phase of mapping 24 quadrangles while doing quality reviews and tracking 43 contracts for non-UGMS mappers working on quadrangles or special projects in Utah.

Detailed mapping (1 map inch equals nearly 2000 feet of ground) is the mainstay for most geologic work since the 7.5-minute quadrangle coverage is wide enough to show regional trends but fine enough to locate landslides, ore outcrops, small formations, minor faults, etc. Quadrangle mapping is the basis for all other mapping.

Regional geologic mapping efforts are divided between Quaternary studies and county studies. Quaternary maps provide data on Utah's most recent geological materials, those usually involved in geologic hazard phenomena and frequently used for construction materials. Geologically mapping a county generally takes several years. This year, UGMS celebrated the publication of the Kane County map and bulletin, and work is currently progressing in Grand and Millard counties.

The Kane County bulletin successfully examines all of the county's geologic resources and hazards. In addition to detailed geologic information, the bulletin offers extensive sections on economic geology and hazards, reviewing current and possible resources and discussing areas of past and present landsliding, flooding, soil problems and areas under development. Kane County's long, narrow, rectangular shape made it easy to divide into three areas: western, central and eastern. Three 1:100,000 scale maps were produced for each of these areas, depicting (1) basic geology, (2) the area's geologic struc-

tures, economic geology and scenic geology and (3) the area's geologic hazards.

In August 1987 the Utah Department of Parks asked UGMS for geologic input to the master plan for Antelope Island State Park and for visitor information. A UGMS task force of geologists studied the island's geology, ground water, geologic hazards, potential resources, and waste disposal capabilities. Most of this task was completed last year (see *Survey Notes* v. 23, no. 1, which details most of the work), papers have been written and reviewed, and results are currently in the process of publication: The geologic map of Antelope Island, at a scale of 1:24,000; a colorful non-technical brochure describing the geologic story of the island; and a bulletin containing the accumulated earth-science information.

Another major work documents salt diapirism in the Paradox region which has been the focus for geologic studies for well over a decade. This publication helps define basic concepts for understanding its geology and geologic history.

This fiscal year saw the development of three major databases (see *Survey Notes,* v. 23, no. 1, p. 18-19) by Mapping personnel for their use and to aid other professionals. The Utah Stratigraphic Information database, Utah Geochronometry database, and Geologic Map database are compilation-oriented uses for the computers, but geologists have also used computers to put together much of the Antelope Island map.

Mapping Program personnel conducted ten field reviews of quadrangles, provided informative geologic data to the Utah Geological Association, Salt Lake City School District, and Canyonlands Natural History Association. They also provided assistance to the Utah Department of Health and the Department of Natural Resources, and they delivered several papers at Geologic Society of America and Utah Geological Association meetings.

ECONOMIC GEOLOGY PROGRAM

The Economic Geology Program of the UGMS investigates and studies the various mineral and energy resources of the state. This work involves collecting and compiling existing information, gathering and evaluating new information, acting in an advisory capacity for other state agencies, participating in joint cooperative research with other government agencies and educational institutes, and answering numerous technical inquiries from industry and the public at large. Several of the program's activities and their potential economic impact are described below.

The Assessment Studies

The UGMS, in cooperation with the USGS, participated in pre-assessment studies of the Tooele and Cedar City 1:250,000 quadrangles. These studies summarize available geological, geochemical and geophysical information and identify the known and potential mineral resources of the area. In addition to becoming Open-File Reports, these studies will be used to determine which quadrangles in the United States will be selected for CUSMAP projects. Much research activity will be focused on Utah if UGMS attracts these large USGS projects to western Utah and their activities will in turn attract the attention of industry.

The Sample Library

The sample library continues to grow, expand and benefit the state. A large donation of core will be received from the U.S. Bureau of Mines and UGMS has initiated an agressive program to acquire samples from all new "wildcat" wells in the state. Use of the sample library by both industry and government is growing and last year the availability of samples for examination was a critical factor in developing several petroleum exploration plays in eastern Utah.

Information to Other State Agencies

During this fiscal year period, UGMS personnel provided information, comments, recommendations and advice to other state agencies on a variety of resource-related subjects, including a series of land trades for the Division of State Lands and Forestry, wilderness evaluation procedures and recommendations for the Office of Planning and Budget, proposals for exploratory drilling and development of various natural resources for the Resource Development Coordinating Council, technical review of funding proposals for the Utah Small Business Development Center, Great Salt Lake pumping and its consequences for the Division of Water Resources, as well as a number of other topics. This technical input and advice allowed the various agencies to make more informed decisions regarding the exploration, development, or preservation of Utah's mineral resources.

Mineral Occurrence Maps

Work continued on the 1:250,000 scale Mineral Occurrence Map series of the state. When completed in 1992, this series will consist of twelve reports (maps and text) documenting all known metallic and industrial mineral occurrences. In 1988-89, the agency completed the Tooele 1° x 2° map and made significant progress on the Delta, Richfield and Cedar City 1° x 2° maps. The Tooele report, serving as a prototype for the rest of the series, has 85 pages of text and three plates designating the location of various mineral commodities. Information in the text is arranged by mining district and offers a brief summary of the history, production and geology of each district followed by a listing of the mines and prospects that occur in the district. Although only recently released, this report has already been extremely helpful to companies exploring in this part of the state.

Coal Bed Methane

The UGMS, in conjunction with the University of Utah, is investigating the methane potential of Utah's coal beds under a grant from the Department of Energy. The study involves measurement of the released and residual methane, the per-

meability of the system and the petrographic nature of the coal with a view toward development. Work to date on two Utah coal beds suggests that as much as 2 million cubic feet of gas per square mile could be extracted from a six-foot coal seam.

In addition to the obvious energy production, utilization of the valuable resource has two other advantages: it increases safety by lowering the methane hazard prior to mining and it protects the environment by removing methane before it can be released to the upper atmosphere. The agency has received numerous inquiries on methane during the past year, and the energy industry is aggressively working toward methane development. In 1990, it is expected that commercial attempts will be made to extract methane from the Book Cliffs coal field and UGMS information will be invaluable to the companies involved.

Coal Field Resource Analysis

Significant progress was made on the Coal Resource Analysis of the Alton Coal Field. This project involves many years of data collection covering over 12,000 drill holes and measured sections and is part of a nationwide NCRDS sponsored program to evaluate the coal resources of the entire country. When completed in late 1989, the publication will be the first of a series for the state of Utah and one of the prototypes for the NCRDS program. The information will be used by land planners, industry developers, and government agencies in formulating wise, prudent, and informed long-term plans for Utah's coal resources development.

Public Inquiries

UGMS personnel have answered virtually hundreds of public inquiries on various aspects of Utah's mineral and energy resources. Although most were for information purposes only, a number of industry inquiries have had some potential economic impact. Some of the more important are summarized below:

* At least four mineral exploration and drilling programs have been initiated as a result of conversations with the UGMS.
* Numerous inquiries have been received on Utah's methane resources from energy firms contemplating development.
* More than a dozen inquiries have been received on coal quality from potential purchasers resulting in at least one overseas purchase of Utah coal.
* Major industrial mineral firms have inquired about the limestone, dolomite, clay, zeolite and feldspar resources of the state, including one inquiry on plant sites locations.

Newcastle Geothermal Study

A multidisciplinary approach involving geology, geophysics, geochemistry and drilling has greatly increased knowledge of the Newcastle geothermal system. As a result of these studies, the hot upflow region of the system has been pinpointed in an area a considerable distance from what was previously thought to be the center of the thermal anomoly. This new information should encourage renewed exploration by private firms and may result in commercial development.

Coal Quality

A summary of coal quality characteristics was completed, covering four major Utah coal fields, 56 individual coal beds and including nearly 1,000 samples. Information is presented on the physical and chemical nature of the coal including BTU value, ash, volatile, sulfur, methane content and chemical composition. This information is valuable to coal producers and, more importantly, to potential buyers of Utah coal. A number of individuals have already used the report in investigating Utah coal for potential overseas purchasers from countries in the Pacific Rim and northern Europe.

Kane County Wilderness Studies

A study of the mineral resources of proposed wilderness areas in Kane County is in final review. This study mainly concentrated on the coal and petroleum resources of the area. Two major accomplishments of the study were: 1) Providing an independent yardstick to judge the wilderness evaluations done by the USGS and the U.S. Bureau of Mines for the Bureau of Land Management; 2) Collecting and organizing data to be later incorporated into a coal resource evaluation series.

Coal Correlation

A study of the Wattis and Castlegate A seams in the Book Cliffs area is nearing completion. This work will determine if the two seams actually represent one continuous bed. If so, it would drastically change reserve estimates and would be valuable to current and potential producers for long-term planning; to government agencies for determination of land value; to resource appraisal and land planners; and to scientific researchers for evaluating the depositional environment of the coal.

Emigration Canyon Debris Flood June 9, 1989

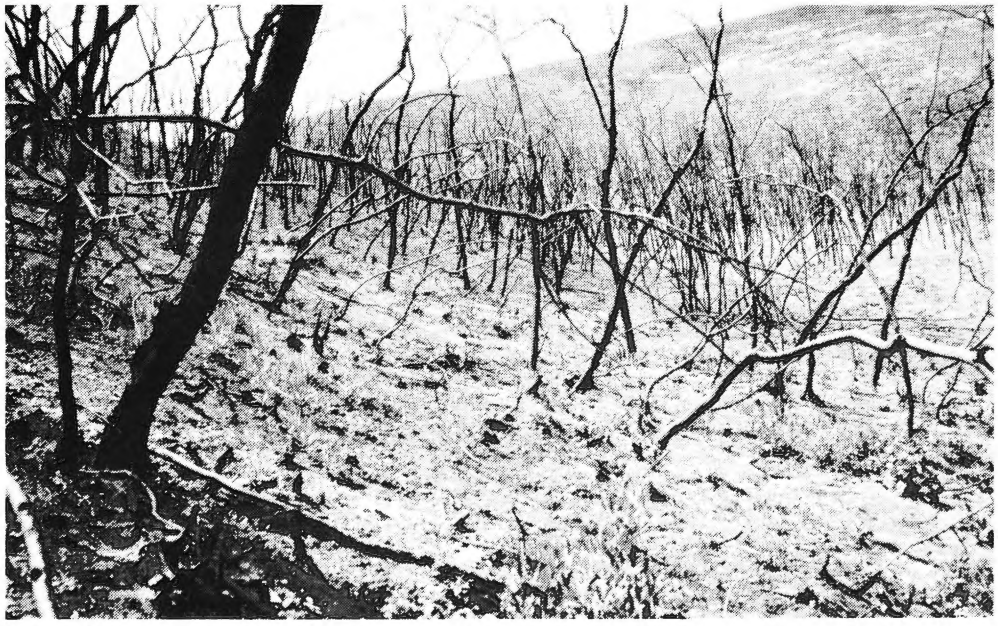
by Kimm M. Harty and Christine M. Wilkerson

On the evening of June 9, 1989, the Freeze and Brigham Fork Canyon areas of Emigration Canyon in Salt Lake County experienced a damaging debris flood as a result of an intense thunderstorm in which over 1 inch of water fell between 9:30 and 11:30 p.m. It was estimated that floodwaters seven-feet deep surged down the canyons toward Emigration Canyon and residences below (Rasely and others, 1989). No lives were lost, but damage in residential areas included flooding and sediment deposition in yards, basements, garages, driveways, and access roads. Other damage included culvert and bridge washouts and blockages, undercutting and partial collapse of roads by stream erosion, and shearing of underground utility lines (Harty, 1989).

Nine months earlier, in September of 1988, a wildfire burned over 5600 acres of woodland in this portion of Emigration Canyon (Nelson and Rasely, 1989). The fire burned roughly 90 percent of Freeze Canyon, and 80 percent of the adjacent Brigham Fork watershed. At the head of the east fork of Freeze Creek is a bowl-shaped amphitheater that was severely burned during the fire. Before the fire, this area had supported mostly shrubs and grass, with trees only at the bottom of the hollow along the channel. The amphitheater is covered by a deep, loose, friable organic soil. With little vegetation remaining after the fire to retard overland flow, the amphitheater funneled runoff into the narrow channel, causing floodwaters to rise quickly. Most of the coarse debris (cobbles, boulders) transported by the floodwaters was scoured from the channel below this area.

Recognizing the potential for flooding and erosion on the denuded watersheds, the U.S. Soil Conservation Service in cooperation with Salt Lake County installed numerous short wire fences and gabion structures (rock baskets) in the channels of Freeze and Brigham Fork Creeks within 30 days after the September wildfire. These structures were designed to decrease the channel gradient causing deposition of mud and larger size sediments and to slow water velocity, thereby reducing the potential for catastrophic flooding. Much of the coarse material transported in the channel of Freeze Canyon was deposited in the middle and lower reaches of the watershed, where the channel gradient decreases naturally and flood-control structures were located. Damage to downstream residences could have been greater had not the gabions and fences been installed. The floodwaters that damaged residences carried finer sediment such as silt, sand, and gravel which was deposited in basements and garages of homes and buildings near the mouths of the creeks. U.S. Soil Conservation hydrologists estimate the depth of the floodwaters could have reached at least 14 feet instead of 7 feet had not the flood control structures been emplaced (Rasely and others, 1989).

Flood damage generally occurred at the mouth of the canyons and along Emigration Creek where the channel flow was restricted or blocked by undersized culverts and other structures. The outlet of Brigham Fork Canyon is totally blocked by residential structures and landscaping and the channel is diverted into a 36-inch culvert pipe. The Freeze Canyon outlet is controlled by



Woodland near the head of Freeze Canyon burned in the September 1988 fire. Photo taken in June 1989 by Miriam Bugden.

Wire fence installed in Freeze Creek by the U.S. Soil Conservation Service after the September 1988 wildfire. Photo by U.S. Soil Conservation Service.

The same fence after the June 1989 debris flood. Note deposition of coarse material upstream. Photo by authors.

Residential structure in Freeze Canyon showing high-water mark. Restricted by the size of the culvert beneath the driveway, sediment-laden floodwaters flowed out of the channel, onto the driveway and through the garage at far right. Photo by authors.

a 24-inch culvert pipe and is partially blocked by residential structures or landscaping.

Today, the head regions of the watersheds remain subject to continued erosion and possible flooding. The stream beds of Freeze and Brigham Fork Creeks now contain sediment and debris deposited behind flood-control structures. If another severe storm occurs, this material could become entrained in a debris flood or flow and cause damage in downstream areas. The U.S. Soil Conservation Service is planning to repair some of the flood-control structures. These repairs, re-establishment of the vegetation to a pre-fire state, especially at the head of the watersheds, and/or installation of larger culverts could help lessen the impact of such an event.

CITED REFERENCES

Harty, K.M., 1989, Freeze Canyon debris flood, Salt Lake County, Utah: Utah Geological and Mineral Survey unpublished report, 6 p.

Nelson, C.V., and Rasely, R.C., 1988, Affleck Park fire sediment yield analysis: Salt Lake County Public Works Department unpublished memorandum, 5 p.

Nelson, C.V., and Rasely, R.C., 1989, Evaluating the debris flow potential after a wildfire; rapid response using the PSIAC method, Salt Lake County, Utah: Geological Society of America Abstracts with Programs, v. 21, no. 5, p. 121.

Rasely, R.C., Petersen, M.M., Hanson, J.E., and Stevenson, T.K., 1989, Emergency Watershed Protection — Emigration Canyon Watershed Reconnaissance of June 9, 1989, Storm and Flooding: U.S. Soil Conservation Service unpublished report, 6 p.

Staff Changes

Several temporary geotechs are wandering around the UGMS. *Scott Sterratt* and *Terry Hawkins* are working with the Mapping group while *Pam Roop* and *Tom Meuzelaar* are with Economics.

Carol Park joins us as the Sales staff after working in the State Personnel unit. Our new receptionist is *Jo Miller,* who moved to Utah recently and has worked with the Department of Commerce. *Chris Wilkerson,* who was Receptionist/Geotech, has been promoted to Geotech full time in the Information Section.

The Computer Section is once again in evidence with the placing of *Bill Case,* geologist with Applied, as the Computer Geologist and *Vajdieh Marxen,* geotech with Mapping, as our new programmer.

Five-year service awards and a variscite plaque were given to *Pat Speranza, Kimm Harty,* and *Mike Shubat;* ten-year awards and a septarian concretion plaque were given to *Bill Lund, Carolyn Olsen, Mage Yonetani,* and *Bryce Tripp.* Congratulations to all!

New Publications from UGMS

Geologic map of the Smithfield quadrangle, Cache County, Utah, by Mike Lowe and C.L. Galloway, 75 p., 1 pl., Open-File Report 155. .....$7.50

An evaluation of the travel distance potential of debris flows, by S.H. Cannon, 35 p., Miscellaneous Publication 89-2. .....$4.00

This report uses data for 29 Utah debris flows of the 1983-84 wet year to determine lag rate and its potential for modeling travel distance. With the steepness of canyons in the Intermountain West, trying to gauge debris flow travel distances is imperative. Susan Cannon, Engineering Geologist with the Colorado Geological Survey, examines multiple regression modeling and considers lag rate to be a more effective determinant.

Water-related geologic problems of 1983 — Utah occurrences by county, by B.N. Kaliser, 24 p., Miscellaneous Publication 89-4 .....$3.50

One of many publications dealing with the problems created by excessive water in 1983. Many studies were done both to assess the damage and conditions and to provide a base of information to help prevent as much damage in a future situation. This report, in conjunction with Fitz Davis' report (UGMS OFR 149), lists all the reports of damage by water and discusses the impacts and reasons. Related publications: *Floods of May to June 1983 along the northern Wasatch Front, Salt Lake City to north Ogden, Utah,* UGMS Water Resources Bulletin 24; *An evaluation of the travel distance potential of debris flows,* UGMS Miscellaneous Publication 89-2; *Water-related geologic problems of 1983 in southwestern Utah,* UGMS Open-File Report 149; *The Davis County flood warning and information system,* UGMS Open-File Report 151; *Geologic consequences of the 1983 wet year in Utah,* UGMS Miscellaneous Publication 88-3; *Map showing 1983 landslides in Utah,* USGS Map MF 2085. *Landslides and debris flows in Ephraim Canyon, central Utah,* USGS Bulletin 1842; *The Utah landslides, debris flows, and floods of May and June 1983;* National Academy Press; and all the Thistle slide-related publications.

Geologic resources of Box Elder County, Utah, by Sandra N. Eldredge, Miriam H. Bugden, and Christine M. Wilkerson, 28 p., color brochure, Miscellaneous Publication 89-3 .....$3.00

This is the first brochure in a series of 29 introducing the geologic resources in each of Utah's counties. A brief introduction discusses the relevance of metallic, non-metallic, and energy resources, followed by a general description of the county's geology. Several commodities in each resource category receive special attention, highlighting their origin, mining history, extraction, and uses. The remainder of the commodities are included in tables listing uses, locations, and occurrence types. A chart correlates resources with particular deposits found in specific geologic time periods. The text is also supplemented with maps, photos, and a list of recommended reading. Not only can this be used to provide information on a county's geologic resources, but very basic and general geologic descriptions and a geologic map are provided as well.

Analysis of cleats in Utah coal seams, by B.P. Hucka, 156 p., 2 pl., Open-File Report 154 .....$9.60

The geology of Kane County, Utah, geology, mineral resources, geologic hazards, by H.H. Doelling and F.D. Davis with sections on petroleum and carbon dioxide by C.J. Brandt, 194 p., 10 pl., 1989, Bulletin 124. .....$15.00

Kane County map set: geology, hazards, structure (Bulletin 124 maps), 1:100,000, color, Map 121. .....$7.00

Bulletin 124 is the culmination of many years of mapping and study. As part of our on-going county series, *The Geology of Kane County, Utah* is a fine achievement of in-depth examination of the resources and hazards. Three maps of the county accompany the 194-page text, each 79½ x 24 at a scale of 1:100,000: the geologic map with explanation sheet, a generalized structure contour map with mineral resources, and a geologic hazards map. They are available separately as Map 121.

Kane county includes geology so striking that it contains parts of Bryce and Zion National Parks, Paria Canyon Primitive Area, Glen Canyon National Recreation Area, and the Utah State Parks of Coral Pink Sand Dunes and Kodachrome Basin. The deposits range from Precambrian through Holocene in age and a multitude of depositional environments, but the sculpturing by wind and water shaped the sandstones into all the fascinating shapes that appear in thousands of photographs.

Dominated by a thorough explication of the geology, this bulletin has, however, extensive sections on economics and hazards. The economic geology section reviews current and possible deposits of value; the geologic hazards part concentrates on areas of past and present mass movement, landsliding, flooding, soil problems, and development areas. 194 pages, 10 plates in color, 197 illustrations, extensive bibliography.

Oil development and potential of Mississippian and older formations in San Juan County, Utah, by Harvey W. Merrell, 40 p., 5 pl., Open-File Report 156 ..... $10

One of our Mineral Lease Special Projects (MLSP) publications (see Survey Notes vol. 22, no. 4, p. 20-25) by Merrell, a consulting petroleum geologist. His theme is that the Lisbon field in San Juan County is productive and that insufficient testing has been done to prove potential in Mississippian and older strata. Includes a compilation of available drilling and production history.

Multi-characteristic correlation of upper Cretaceous volcanic ash beds from southwestern Utah to central Colorado, by B.J. Kowallis, E.H. Christiansen, and Alan Deino, 22 p., Miscellaneous Publication 89-5 .....$3.75

A Mineral Lease Special Projects publication, this report on correlation of ash beds utilizes the characteristics of the ashes. The authors, from Brigham Young University and the Berkeley Geochronology Center, use types and abundance of phenocrysts, zircon crystal morphology, types and abundances of mineral inclusions in zircons, and other factors for the direct correlation of beds over a distance of 700 km.

The Cedar Canyon Landslide

by Kimm Harty
Geologist, Utah Geological & Mineral Survey

Landsliding has created problems in Cedar Canyon (near Cedar City, Utah) since at least 1949 when the Iron County Record reported in their June 30th issue that reconstruction of Highway 14, destroyed by a landslide, was nearly complete. Sometime between midnight and 6 a.m. on March 27, 1989, a landslide again destroyed about one-third of a mile of the road in Cedar Canyon. About seven miles east of Cedar City, the landslide occurred in sections 26 and 35, T. 36 S., R. 10 W.

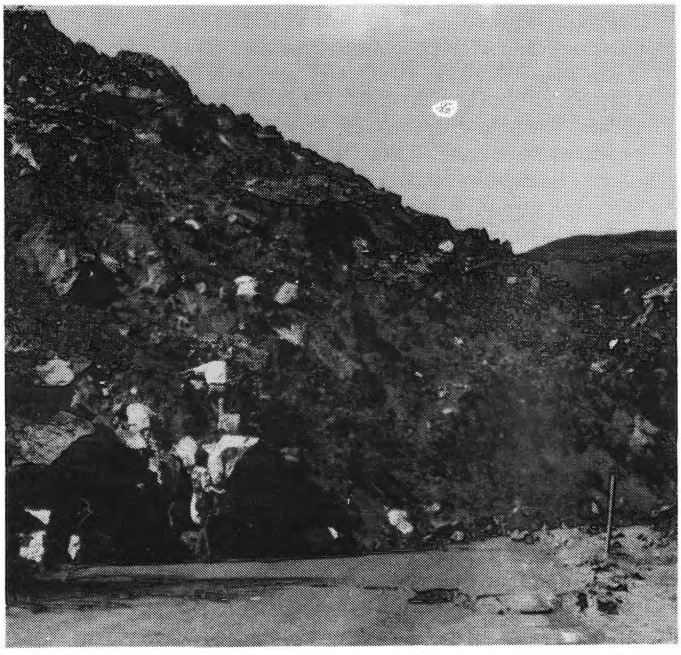
Field examination of the slide by UGMS staff suggests that the failure occurred in bedrock of the Cretaceous Tropic and Dakota Formations. The predominantly shaley Tropic Formation is especially prone to landsliding in southern Utah. In the slide area, the Tropic grades into the underlying Dakota sandstone, referred to on geologic maps as the Tropic-Dakota Interval. The upper part of the interval is a gray shale containing thin layers of brown, fine-grained sandstone; the lower part is a "... fine- to medium-grained sandstone alternating with gray shale, sandy shale, carbonaceous shale, and thick beds of coal ..." (Doelling and Graham, 1972, UGMS Monograph 1, p. 302). Much of the landslide surface is covered with loose, buff-colored material ranging from clay to car-sized boulders — probably colluvium and rock of the Cretaceous Straight Cliffs Formation which forms the nearly vertical main scarp of the landslide and a portion of the cliffs above.

Approximately 1700 feet wide and 1000 feet long, the slide covered 40 acres with a total relief of about 600 feet and an approximate volume of two million cubic yards. As well as disrupting Highway 14, the slide sheared off and carried downslope the portal of the MacFarlane coal mine, which had been abandoned and recently sealed. The failure plane of the landslide appears to be complex; the slide moved downslope in a series of slumps and slides rather than as a single cohesive mass. In the western part of the slide, an intact but severely damaged portion of the highway moved about 100 feet downslope but was not buried. Thus, in this area the surface of rupture is below the present position of the highway.

Determining the probable cause of the landslide is difficult at best. Older (probably prehistoric) landslide scarps near the top of the slope suggest a history of instability problems on the slope. It is possible that the 0.4 inches of rain that fell in the area the day before the landslide occurred may have triggered the event on an already weakened slope. Man-related factors may have contributed to slope instability, including highway- and mine-related alterations to the slope geometry, drainage, and ground-water hydrology.

A paved temporary road was constructed across the landslide and opened on May 1, and a permanent road will probably be built on the north side of the canyon sometime in the future. In the meantime, the Utah Department of Transportation established slope monitoring points in late April to detect further movement.

Portion of Highway 14 that moved 100 feet downslope atop the landslide. Photo by author.



View looking west of landslide mass covering Highway 14. Note figure standing on boulder on left side of road. Photo by author.

Books and Papers

Gold potential of the Dugway Mining district, Tooele County, Utah, D.L. Kelley: Colorado School of Mines M.S. thesis, 212 p., 1989.

Inventory of reservoirs and potential damsites in The Virgin River Basin; Utah Division of Water Resources, 66 p., 1988.

Ground-water conditions in Utah, Spring of 1989, by C.B. Burden and others: Utah Division of Water Resources, Cooperative Investigations Report Number 29, 83 p., 1989

Geology of the Farmington Canyon Complex, Wasatch Mountains, Utah, by Bruce Bryant. 1988. 54 p., 1 plate, U.S. Geological Survey Professional Paper 1476.

The Farmington Canyon Complex forms the main exposures of Precambrian basement rock in north-central Utah. Continent-derived sediments were deposited on oceanic crust and metamorphosed during the late Archean. These rocks at the south margin of the Archean continent were metamorphosed, migmatized, and partly melted to form anatectic magma in the early Proterozoic. Pervasive shearing and retrogressive metamorphism of parts of the complex occurred in middle Proterozoic and possibly late Mesozoic time.

Mineral resources of the Fish Springs Range Wilderness Study Area, Juab County, Utah, by D.A. Lindsey, D. R. Zimbelman, D.L. Campbell, R.J. Bisdorf, J.S. Duval, U.S. Geological Survey; K.L. Cook, University of Utah; M.H. Podwysocki, D.W. Brickey, R.A. Yambrick, U.S. Geological Survey; and S.L. Korzeb, U.S. Bureau of Mines. 1989. p. A1-A18. 1 plate in pocket. (Mineral resources of wilderness study areas; northwestern Utah.) U.S. Geological Survey Bulletin B-1745-A.

Mineral resources of the Canaan Mountain and The Watchman Wilderness Study Areas, Washington and Kane counties, Utah, by R.E. Van Loenen, E.G. Sable, H.R. Blank, Jr., R.L. Turner, U.S. Geological Survey; T.J. Kreidler, J.E. Zelten, U.S. Bureau of Mines; and K.L. Cook, University of Utah. 1988. p. A1-A21. 1 plate in pocket. (Mineral resources of wilderness study areas; southwestern Utah.) U.S. Geological Survey Bulletin B-1746-A.

Mineral resources of eight wilderness study areas bordering Zion National Park, Washington and Kane counties, Utah, by R.E. Van Loenen, E.G. Sable, H.R. Blank, Jr., H.N. Barton, P.H. Briggs, U.S. Geological Survey; J.E. Zelten, U.S. Bureau of Mines; and K.L. Cook, University of Utah. 1989. p. E1-E23. 1 plate in pocket. (Mineral resources of wilderness study areas; southwestern Utah.) U.S. Geological Survey Bulletin B 1746-B.

The eight wilderness study areas are Orderville Canyon, North Fork Virgin River, Deep Creek, Goose Creek Canyon, Beartrap Canyon, LaVerkin Creek Canyon, Taylor Creek Canyon, and Red Butte.

Petroleum geology and principal exploration plays in the Uinta-Piceance-Eagle Basins Province, Utah and Colorado, by C.W. Spencer and R.J. Wilson, 35 p., U.S. Geological Survey Open-File Report 88-450.

Field trip guide for the West Tintic mining district, western Utah, by H.J. Stein, D.L. Kelley, J.F. Kaminsky and I.R. Gordon. 12 p., U.S. Geological Survey Open-File Report 88-558.

The Frontier Formation and associated rocks of northeastern Utah and northwestern Colorado, by C.M. Molenaar and B.W. Wilson, p. 15, U.S. Geological Survey Open-File Report 88-643.

Surface thermal maturity map of the Uinta, Piceance, and Eagle basins area, Utah and Colorado, by V.F. Nuccio and R.C. Johnson, p. 21, U.S. Geological Survey Open-File Report 88-643.

The physical record of lakes in the Great Basin in North America and adjacent oceans during the last deglaciation, by Larry Benson and R.S. Thompson (W.F. Ruddiman, editor and others). Boulder, CO: Geological Society of America K-3, 1987, p. 241-260.

Stratigraphy, correlation, and tectonic setting of Late Cretaceous rocks in the Kaiparowits and Black Mesa basins. Special Paper — State of Arizona, Bureau of Geology and Mineral technology, *in* Geologic diversity of Arizona and its margins; excursions to choice areas, by J.G. Eaton, J.I. Kirkland, E.R. Gustason, J.D. Nations, K.J. Franczyk, T.A. Ryer and D.A. Carr (G.H. Davis, editor and others). 5, 1988, p. 113-125.

An evaluation of thermoluminescence dating of paleoearthquakes on the American Fork segment, Wasatch fault zone, Utah, by S.L. Forman, M.N. Machette, M.E. Jackson, and Paula Maat. Journal of Geophysical Research, B. Solid Earth and Planets, v. 94, no. 2, February 10, 1989. p. 1622-1630.

Mineral resources of the Steep Creek Wilderness Study Area, Garfield County, Utah and the Escalante Canyons Tract V, Kane County, Utah, by Susan Bartsch-Winkler, R.J. Goldfarb, J.W. Cady, J.S. Duval, U.S. Geological Survey; R.F. Kness, P.A. Corbetta, U.S. Bureau of Mines; and K.L. Cook, University of Utah. 1988. p. B1-B20. 1 plate in pocket. (Mineral resources of wilderness study areas—Escalante Canyon region, Utah). U.S. Geological Survey Bulletin B-1747-B.

Analytical results and sample locality map of stream-sediment, heavy-mineral-concentrate, and rock samples from the Red Mountain Wilderness Study Area (UT-40-132), Washington County, Utah, by D.E. Detra, J.E. Kilburn, J.L. Jones and D.L. Fey. 16 p., 1 sheet, scale 1:24,000. U.S. Geological Survey Open-File Report 88-248.

Large earthquakes in Sevier County, Utah, in 1901 and 1921, by M.G. Hopper, 18 p. U.S. Geological Survey Open-File Report 88-404.

Geology of the Sugar House Quadrangle, Salt Lake County, Utah, by M.D. Crittenden, Jr. 1988. Lat 40°37'30" to 40°45', long 111°45' to 111°52'30". Scale 1:24,000 (1 inch = 2,000 feet). Sheet 31 by 33 inches. (This map was reproduced by electronic color scanning of an earlier (1965) printing.) U.S. Geological Survey Map GQ 380.

Geologic map index of Utah, revised and updated by H.K. Fuller, 1988, from original compilation by W.L. McIntosh and M.F. Eister. 1979. Eight sheets. Lat 37° to 42°, long 109° to 114°. Each sheet 11 x 17 inches. (Accompanied by 16-page text.) Free on application to U.S. Geological Survey.

Geomorphology and Quaternary history of Canyonlands, southeastern Utah, by D.R. Harden and S.M. Colman, Professional Contributions of the Colorado School of Mines, *in* Geological Society of America field trip guidebook, 1988; Centennial meeting, Denver, Colorado. (G.S. Holden, editor). 12, November 1988. p. 336-369.

Field notes for a gravity survey in Dinosaur National Monument, Moffat Co. Colorado and Uintah Co. Utah, by D.M. Kulik, 14 p., U.S. Geological Survey Open-File Report 88-579.

More Books & Papers

The Manti, Utah landslide. 1988. 69 p., 1 pl., U.S. Geological Survey Professional Paper P 1311.

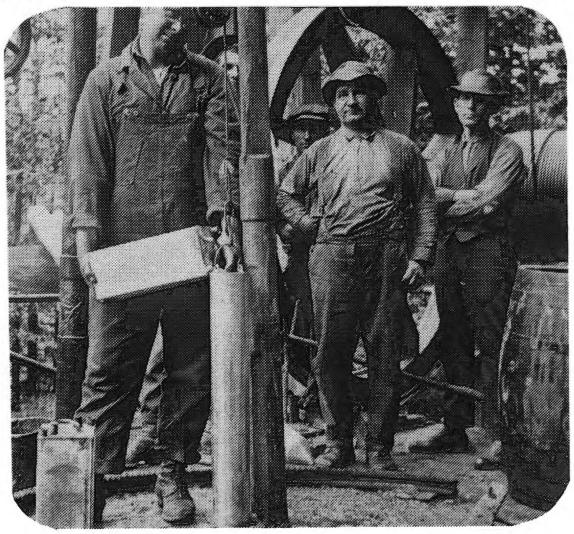
In late spring 1974, a debris flow from the rim of Manti Canyon was deposited in the head region of the old Manti landslide and triggered a reactivation of movement. During 1974 and 1975, movement propogated about 3 km from the head of the old landslide to the floor of Manti Canyon, producing displacements of more than 100 m and involving about 19 x 10^6 m^3 of debris. A study of sequential aerial photographs provided a record of displacement and information on the three-dimensional shape of the landslide, as well as on morphologic and hydrologic changes caused by landslide movement.

Mineral resources of the Horseshoe Canyon North Wilderness Study Area, Emery and Wayne Counties, Utah, by S.J. Soulliere, G.K. Lee, U.S. Geological Survey; and C. M. Martin, U.S. Bureau of Mines. 1988. 13 p., 1 plate, U.S. Geological Survey Bulletin B-1750.

Investigations by the U.S. Geological Survey and the U.S. Bureau of Mines indicate that the Horseshoe Canyon North Wilderness Study Area, about 30 mi. south of Green River, Utah, has no known economic resources, has inferred subeconomic resources of common variety sandstone, and has occurrences of common variety sand and gravel. The entire study area has a moderate mineral resource potential for uranium, vanadium, and copper and for oil and gas; the northernmost part of the study area has a moderate resource potential for potash. The entire study area also has a low mineral resource potential for all other metals and geothermal energy.

Mineral-rock handbook, by Paul Dean Proctor, P. Robert Peterson, and Uwe Kackstaetter, 75 p.

A complete guide for students, prospectors, and weekend rockhounds with easy-to-follow identification charts and tests. From Paulmar Publishers of Utah.



Depositional controls on the late Campanian Sego Sandstone and implications for associated coal-forming environments in the Uinta and Piceance basins, by K.J. Franczyk. 1989. 17 p., 2 pl., U.S. Geological Survey Bulletin B-1787-F.

The late Campanian Sego Sandstone formed during the last regression of the Cretaceous sea from eastern Utah. Described in this report are the physical characteristics, depositional environments, and subsurface correlations of this unit along the Book Cliffs of Utah and Colorado. Coal-forming environments associated with the prograding shoreline and regional controls on deposition are also discussed.

Stratigraphic sections of the Middle Jurassic Wanakah Formation, Cow Springs Sandstone, and adjacent rocks from Bluff, Utah, to Lupton, Arizona, by S.M. Condon. 1989. Lat about 35° to about 37°15′, long about 108°30′ to about 109°30′. Sheet 40 by 46 in., U.S. Geological Survey OC-131.

Lateral facies changes are demonstrated in selected Jurassic rocks along 160 mi. of exposure from Bluff, Utah, to Lupton, Arizona.

Implications of rhyolitic ignimbrite boulders in the Middle Jurassic Carmel Formation of southern Utah, by M.G. Chapman. Geology (Boulder). v. 17, no. 3, March 1989. p. 281-284.

Significance of new potassium-argon ages from the Goldens Ranch and Moroni Formations, Sanpete-Sevier Valley area, central Utah, by I.J. Witkind and R.F. Marvin. Geological Society of America Bulletin. v. 101, no. 4, April 1989. p. 534-548.

The following technical documents are available free from Federal Emergency Management Agency; Earthquakes Programs - Room 625; Washington, D.C. 20472.

A handbook for seismic evaluation of existing buildings (preliminary), 169 p., FEMA 178.

Seismic evaluation of existing buildings: supporting documentation, 160 p., FEMA 175.

Techniques for seismically rehabilitating existing buildings (preliminary), 240 p., FEMA 172.

Establishing programs and priorities for the seismic rehabilitation of buildings, a handbook, 122 p., FEMA 174.

Establishing programs and priorities for the seismic rehabilitation of buildings, supporting report, 190 p., FEMA 173.

ERRATA

We regret that the authorship of the "Antelope Island State Park" article, appearing in our Spring issue, is in error. The article was authored by Grant C. Willis, Mark E. Jensen, and Hellmut H. Doelling. As shown, the junior author was erroneously given full credit. Apologies are extended to Grant and Mark, who did the lion's share of the work.

Pre-Jeep Fieldwork by the USGS
Some Packtrain Experiences

By Charles B. Hunt and Arthur A. Baker

WHY THE PACKSTRING?

Following World War I, there was much interest in eastern Utah's deposits of mineral fuels. The abundant, excellent-quality, low-sulfur coal already was extensively developed in the Wasatch Plateau and western part of the Book Cliffs, and there were numerous additional deposits elsewhere in eastern Utah. Oil shale was abundant in the Uinta Basin. Considerable gas and some oil had been found at scattered locations. The discovery of helium created interest bordering on excitement. There was interest but less excitement about the occurrence of carbon dioxide. Asphalt deposits were present, notably west of Cataract Canyon of the Colorado River, in the San Rafael Swell, in the Book Cliffs, and on the Circle Cliffs. The Paradox Formation contained petroliferous shale plus various commercially desirable salts — potash, for example. Scattered small deposits of vanadium were known early in the century, but interest was slight because of the cost of separating the vanadium from the contaminating uranium.

But the plateau country in the drainage basin of the Colorado River was true wilderness (not just the legal kind) and difficult of access. It included an area of rugged desert the size of New York State without a railroad, and a third of that area was essentially roadless. Most all of it was and still is public land.

USGS administrators could foresee a long series of projects mapping the geology there to provide a basis for land classification. Horses would be essential for field work and for pack trains to service the field parties, a return to the circumstances under which the King, Hayden, Wheeler, and Powell Surveys had been conducted. So the Survey acquired a government-owned string of horses and mules.

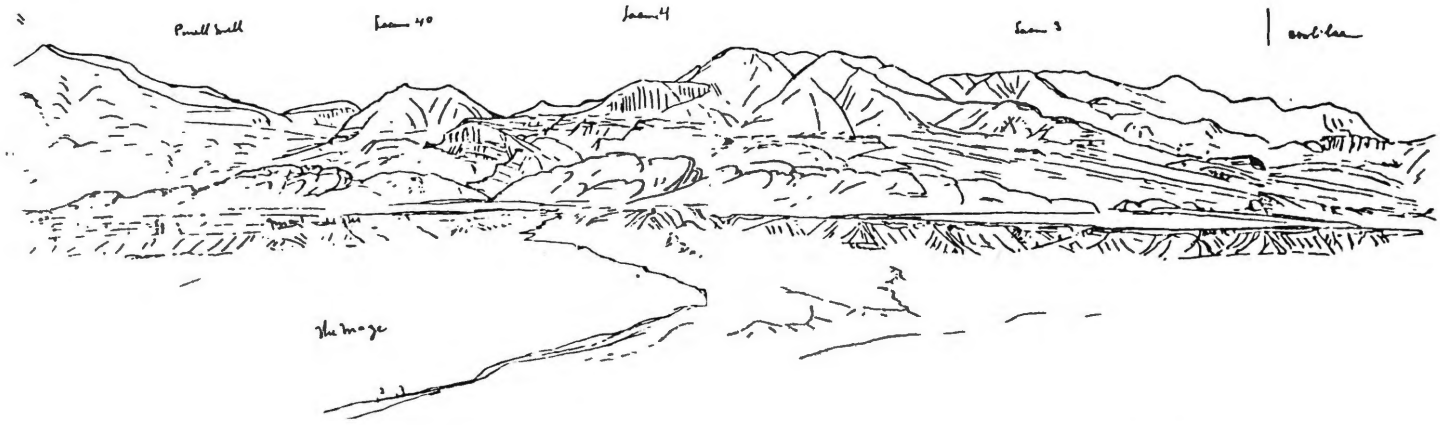
By the mid-twenties, the string numbered 16 animals in the Moab area and half as many on the Wasatch Plateau. Some of the horses were mares being used in a country where wild horses roamed; occasionally a colt would have to be added to the string and entered in the property records.

OVERVIEW OF POWELL SURVEY EXPERIENCES

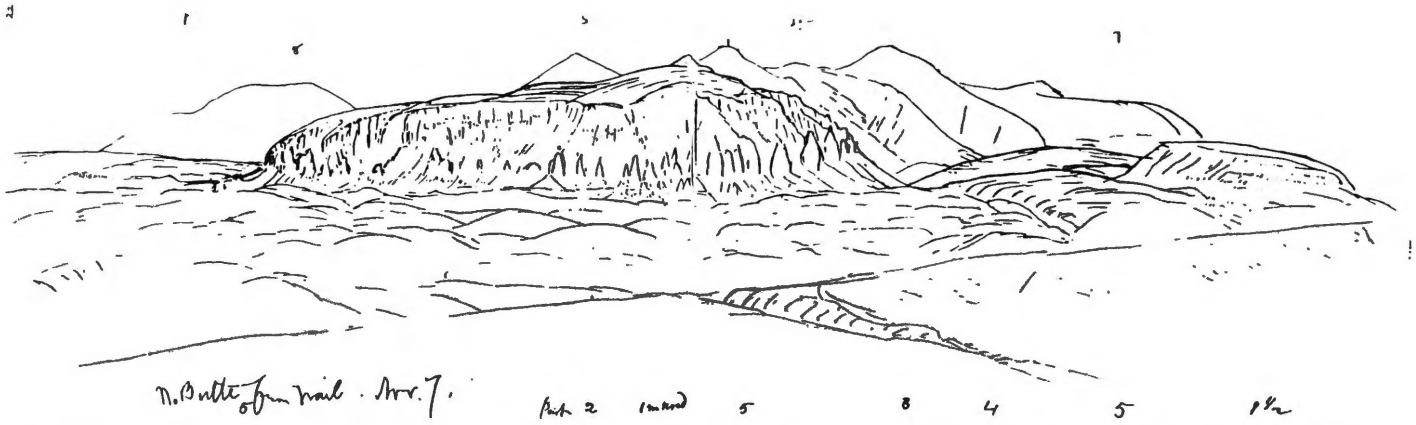
In 1880, G.K. Gilbert was completing his Lake Bonneville project, the Powell and other surveys had been merged into the USGS, and Gilbert had the task of arranging for winter pasture for government-owned pack and saddle animals used by field parties.

That was Gilbert's first administrative assignment. He was soon assigned other administrative duties, which is the chief reason why his Lake Bonneville report was delayed until 1890. Since the first year of the USGS, other geologists have been heard to complain about their scientific work being delayed by administrative duties.

Gilbert's account of the pasturing of the animals is given in his notebook 28, pages 57 to 60. It described each of the 13 mules and a bell mare in the herd of 25 to 27 animals to be pastured at the California Ranch, thought to have been located by the Beaver River south of what now is Delta, Utah. "Rate for a full herd (27 horses), $40; for partial herd, $1.60 per head. Herder responsible for loss except by sickness or other natural cause." Each mule is described by name, height (in hands), distinguishing color markings, brands, and other markings (Hunt, 1982, p. 208-209).



Sketch by Gilbert showing the southeast side of Mt. Ellen. The view is from Trochus Butte by Crescent Creek (foreground) where Gilbert found Indian tracks November 1, 1876. Gilbert had no camera but he made drawings like this one at each of the stations he occupied. (See Hunt, ed., 1988).



Another of Gilbert's sketches. This is view southeast to Table Mountain (Gilbert's North Butte). The intrusion, a bysmalith that lifted its roof by faulting, is at the northwest base of Mt. Ellen. Near here on November 8, 1876, Gilbert again found moccasin tracks where he crossed the recently travelled Indian trail again. West of here Gilbert used that trail en route to the Henry Mountains in 1876.

These animals apparently were owned by the Powell Survey and transferred to the USGS when it was created by merger of the earlier surveys. The Powell Survey also rented animals. Gilbert's notes for July 1, 1877 (his notebook 11, p. 11), when he was beginning his Lake Bonneville project, records: "I have hired horses and wagon of Oscar Young from July 2d at $65, I taking responsibility for loss of horses."

When beginning his winter field season in the fall of 1879, now a member of the USGS, Gilbert records at the end of his notebook 22 (Hunt, 1982, p. 117):

"Memo of agreement with Mr. Nelson.

"He to furnish 2 mules and 4 horses or 6 horses as per conversation; one wagon with cover; two sets double harness; and driver. I to pay $125 with mules or $115 with all horses. Pay to begin when outfit leaves Logan; to end when Tom is paid off in Salt Lake. I to pay all road expenses including board, feed, and repairs, and return the outfit without detriment except from ordinary wear and fatigue."

So Gilbert conducted his Lake Bonneville study by horse and wagon. He had no important misadventures. He missed locating his wagon and camp, which was moved almost daily, only once. On January 4, 1880 he explored Tule Valley between the House and Confusion Ranges while his camp was moving eastward from Snake Valley. He was ahead of and missed his wagon's tracks, had to spend the night on the trail he had followed, and did not reach camp until 4 AM.

In the Lake Bonneville basin, the nearly flat beaches and bars enabled Gilbert to approximately measure estimated distances and dimensions by using his horse's pace, about 5½ feet. Thus, on a Provo level beach December 19, 1879 (notebook 24, p. 32) (see Hunt, 1982), he records a measured estimate of the width of the Provo bar as "150 Kits = 825 ft (Kit is the name of Gilbert's horse). Such measured estimates were not feasible in the mountainous terrain of the Henry Mountains.

Traveling to the Henry Mountains was very different from travel in the Lake Bonneville basin. By the mid-1870s, there were numerous settlements in the Lake Bonneville basin, but the Henry Mountains were remote. Four pages of his Henry Mountains monograph are used to describe "How to reach the Henry Mountains." His description begins "No one but a geologist will ever profitably seek out the Henry Mountains."

They are indeed an uncommonly well exposed complex of stocks, one at the center of each mountain, with 3 dozen laccoliths and 5 large bysmaliths radiating from them. Gilbert's great discovery there was more than simply finding and describing the laccoliths; he discovered that intrusions deform the host rocks into which they are intruded — truly a major breakthrough in geological science. Additionally, the Henry Mountains could be regarded as type locality for pediments, Gilbert's hills of planation.

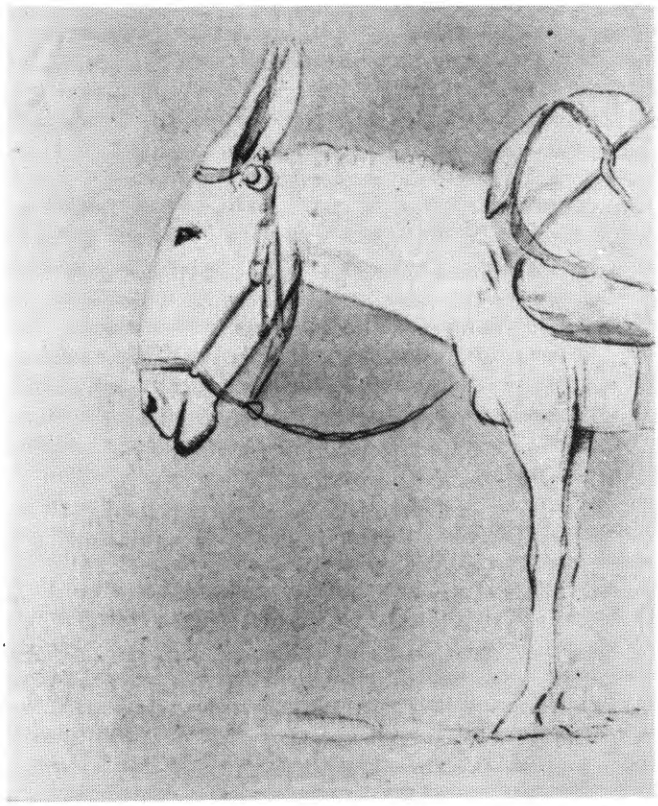
Yet despite their place in the history of geology, the mountains still are isolated enough that the Geological Society of America did not plan a field trip there as part of the Society's centennial celebration. Gilbert spent 3 weeks getting there, illustrating that "getting there can be half the fun;" getting there still is time consuming.

He travelled "by the cars" on the Utah Southern Pacific Railroad from Salt Lake City to York at the north end of Juab Valley. At York, he obtained some of his animals including a mule, identified in his notebook No. 3 as "Lazarus, Duke of York" (following). The head of the mule was printed in the first edition of Gilbert's Henry Mountains monograph and labeled "Ways and Means." That figure was omitted from the 2nd edition of the monograph. Even in this jeep era, the best way to see those beautifully exposed Henry Mountains intrusions is by horseback.

In 1875, there were no roads beyond Salina. How did Gilbert and the other explorers of his day find their way through the wilderness, always ending up at a satisfactory spring? They followed prehistoric Indian and wild animal trails. In an empty wilderness these are plain as freeways, and they even have directional signs indicating whether one is approaching or going away from water. Those signs consist of the secondary branching trails made by animals such as coyotes, foxes, and rabbits. These secondary trails diverge away from the water, they converge towards it.

Such prehistoric trails still can be seen in Death Valley, where preserved segments were recognized in the course of a

joint geological and archeological survey by Charlie and Alice Hunt (Hunt, Charles B., 1975; Hunt, Alice, 1960). Trails there have been preserved because there has been little or no grazing.



Lazarus, Duke of York, as sketched and identified in G.K. Gilbert's notebook No. 2 (Hunt, ed., 1988 p. 60). Gilbert reproduced the head of Lazarus in the first edition of his monograph and entitled it "Ways and Means." For some reason the figure was omitted from the second edition of his monograph.

Discovering those old trails removed all mystery about how the pioneers were able to find their way across western United States. Gilbert makes numerous references to them in the notebooks describing his travels while examining the Henry Mountains.

Gilbert was faced with a hazard that has not been repeated during this century, the hazard of being confronted by hostile Indians. Seven years before Gilbert's trip to the Henry Mountains, some Shivwitz Indians had murdered the two Howland brothers and Dunn as they traveled towards Kanab after leaving Powell's party in the lower part of the Grand Canyon. Two years after that tragedy, 5 members of Wheeler's party with whom Gilbert had worked were among those killed when Indians ambushed the Ehrenburg-Wickenburg stage about 5 miles west of Wickenburg, Arizona.

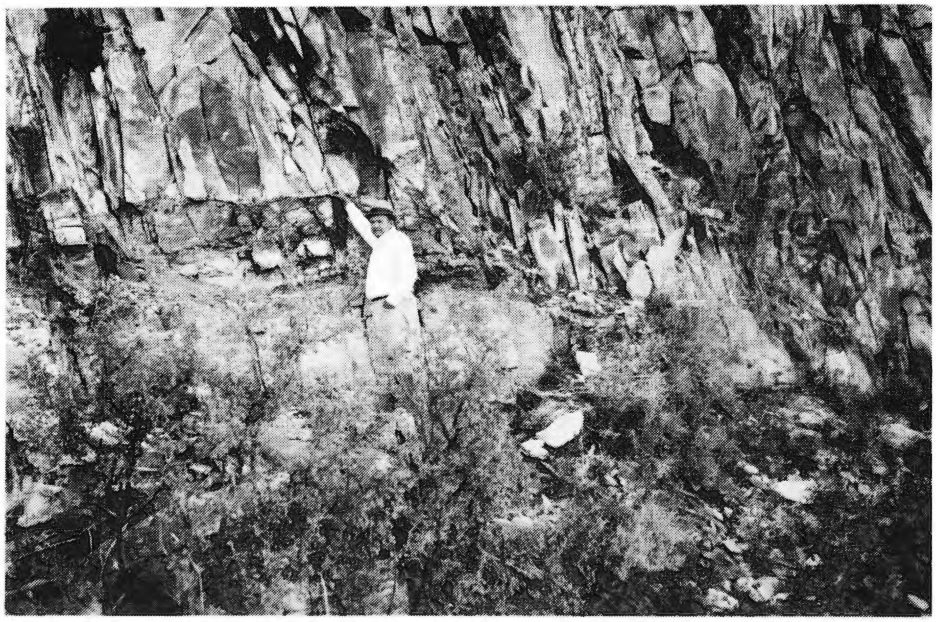
So, one may read deep thoughts when Gilbert recorded in his notebook November 1, 1887: "We find today a trail ... made by about 15 animals. There is a mocassin track with them."

Again on November 8, as he was leaving the Henry Mountains: "Yesterday we crossed the Indian trail twice ...."

Both entries were written in better penmanship, with greater care, than his routine geological notes.

Gilbert's packstrings of horses and mules had their share of falls. On November 13, 1876, he records, "Panguich rolled over today into Curtis Creek. This is her third roll on the trip. Beck has accomplished two and Gomas, Joel and Lousey one each. Our little train of nine animals has attained to seven (eight?) rolling scrapes."

It would seem that feed was better during the 1870s when Gilbert was in the Henry Mountains than a half century later when we were there. Gilbert did not haul in feed for his animals, and there was apparently adequate feed around their camps so the horses did not stray. When we were there a half century later, there was drought and feed was further reduced by overgrazing. Our horses needed about 150 pounds of



Exposure of the floor of the Horseshoe Ridge laccolith in the Henry Mountains. Beginning 1928, Hugh D. Miser, chief of the Fuels Section, pointing to the contact, was in general charge of the southeastern Utah projects mentioned in this essay. Where individual beds are cut off by the diorite porphyry, as may be seen just right of center, the missing beds can be found appearing in the equally well-exposed roof some hundreds of feet higher.

supplemental oats monthly. And during the 1920s and '30s, the horses were given a day to graze after each day of being ridden. Gilbert seems to have not had to alternate days working his animals, and they stayed well on local grasses and shrubs.

In Gilbert's time, ranches on the frontier were quite ready to help out travelers like Gilbert and his party. On their way out of the Henry Mountains in 1876 after traveling to Salina Canyon, they came to a ranch owned by Mr. Gillson. Gilbert's horse was not doing well so Gilbert arranged for loan of another horse (a mare with colt) to ride to Salina where he was to leave the borrowed mare to be picked up later by Gillson. In Gilbert's notes the arrangement seems uncommonly easy and natural.

PROCEDURES AND SOME EXPERIENCES DURING THE 1920s AND 30s

Some of the major USGS projects following World War I were in the western part of the Book Cliffs (F.R. Clark, Bull. 793), and in the Wasatch Plateau (E.M. Spieker, Bull. 819). Another early project that utilized a considerable number of pack animals as well as riding animals was the survey of the San Rafael Swell (James Gilluly, Bull. 806C).

Gilluly's party worked out of Green River, Utah. Like other projects of the 20s and 30s, it established two kinds of camps —base camps that could be reached by trucks and temporary spike camps that were reached and supplied by packtrain. A base camp might be used for a month or 6 weeks; spike camps might be used overnight or for a few days. Much of the routine field work was done from spike camps.

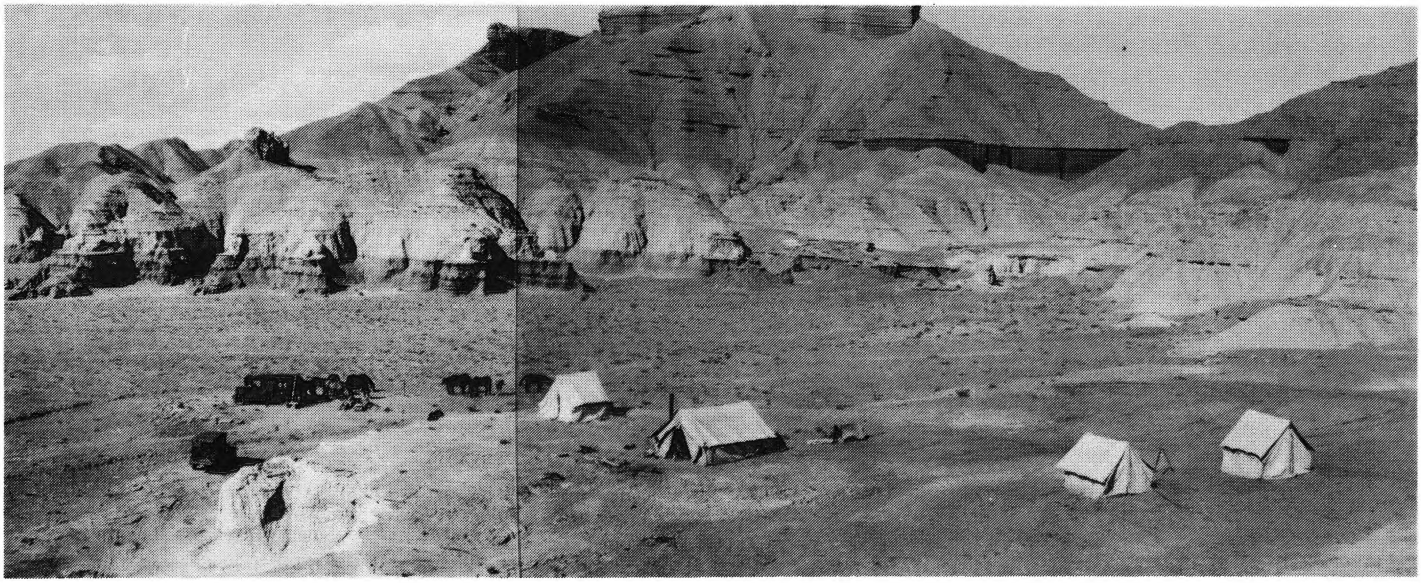
The following photographs show a typical base camp and road conditions. Generally near the cook tent, but not shown in the pictures, would be a refrigerator, a caged box covered with burlap that extended upward into a pan of water at the top. Capillarity kept the water moving from the pan, wetting the burlap covering the sides. The refrigerator was cool enough to keep fresh vegetables a few days. Butter, eggs, and dried or salt meats could be kept for 10 days or 2 weeks. Spike camps were less elaborate.

During the 20s and 30s eastern Utah suffered from drought. Poor grass and other feed was made worse by over grazing. Poor range conditions led to passage of the Taylor Grazing Act and creation of the Grazing Service. To supplement the grazing, survey teams would carry oats for the horses, which were kept in the back of truck (every animal in the string quickly learned which truck had the oats). Even so, feed was so poor that horses were rested on alternate days. Each geologist had 2 riding horses, and the extra animals were used as pack animals when camps were moved.

As noted earlier, grasses and shrubs for feed seem to have been better during the 1870s when Gilbert was there because at that time a horse was ridden daily. Petroglyphs and archeological excavations suggest that a thousand years earlier, mountain sheep and antelope were abundant.

The San Rafael Swell project was followed by one in the Moab area, which included part of the basin occupied by the Paradox Formation. This survey was under Art Baker (1933, Bull. 841). Another by E.T. McKnight (1940, Bull. 908), who had assisted Gilluly in the San Rafael Swell, covered the plateaus between the Green and Colorado Rivers, and a third project under C.J. Dane (1935, Bull. 863) covered the Salt Wash anticline and canyons upstream from Baker's Moab area to the Arizona State line. From 1935 to 1939 Charles Hunt, who had assisted Dane along the Colorado River in 1929, mapped the Henry Mountains area (Hunt, Averitt, and Miller, 1953, PP 228).

Meanwhile Baker (1936, Bull. 865) had another project in Monument Valley, south of the San Juan River, westward to



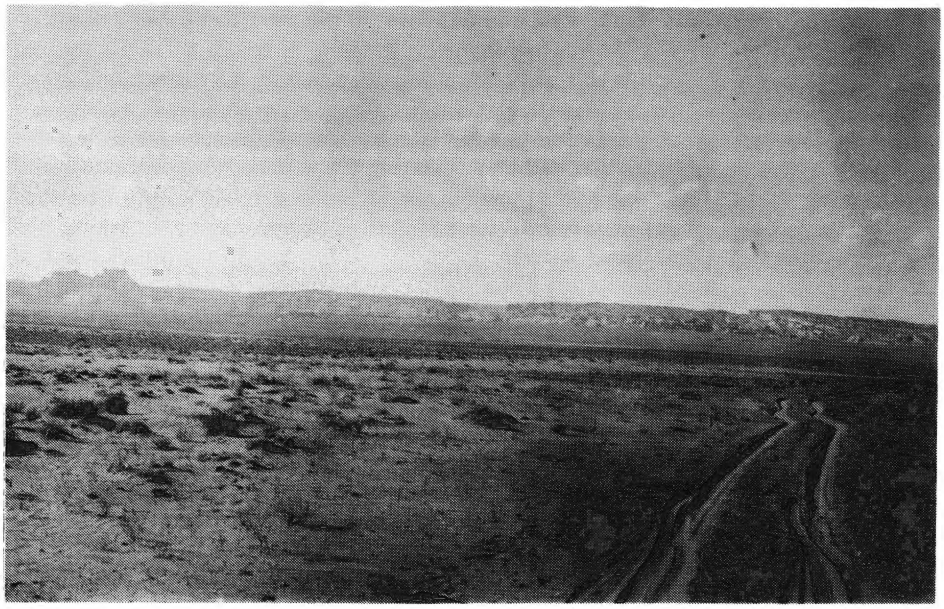
Base camps consisted of a cook tent about 14 by 20 feet with stove, table for meals and for drafting or writing, and folding chairs. Boxes along the walls provided shelving for groceries, kitchen supplies, drafting equipment, and library of reference books — dictionary, engineer tables, and drafting supplies. Drafting maps and calculating altitudes were regular nightly chores. A party of 6 persons would have 3 sleeping tents, about 10 x 14 feet and equipped with cots with space for duffle bags and personal supplies.

Navajo Mountain and the Colorado River at what now is Glen Canyon Reservoir. Following the Monument Valley project, Baker (1946, Bull. 951) had still another in the Green River Desert in the Plateau westward from the Green River to the Dirty Devil River and San Rafael Swell.

Although grazing was poor on most of the desert, irrigated lands along the Green River at Green River, and to a less extent at Hanksville along the Fremont River, produced abundant melons. A recent letter from Ralph Miller recalls this. "A memory I recall frequently was the delight we experienced during Green River cantaloupe season, feasting at breakfast on the night-chilled luscious fruit. Even when we were spike-camping way beyond base camp, the cantaloupe arrived undamaged by being buried by Charlie Hanks in the sacks of oats on the packhorses' backs."

Southeastern Utah can be as scenic at night as by day. Nights in southeastern Utah are gorgeous because the atmosphere is shielded by the High Plateaus, which cut out the dust from the Great Basin. The nightly stellar display probably is unmatched by any other of our southwestern deserts, and some of the geologists, including G.K. Gilbert, became interested in astronomy while working in the area. Gilbert's notebooks include a very satisfactory map of the Pleiades, which is composed of dim stars. On an average night, in southeastern Utah one can see more of those dim stars than can be seen from any of the other southwestern deserts — Chihuahua, Sonoran, Mohave, or Great Basin deserts.

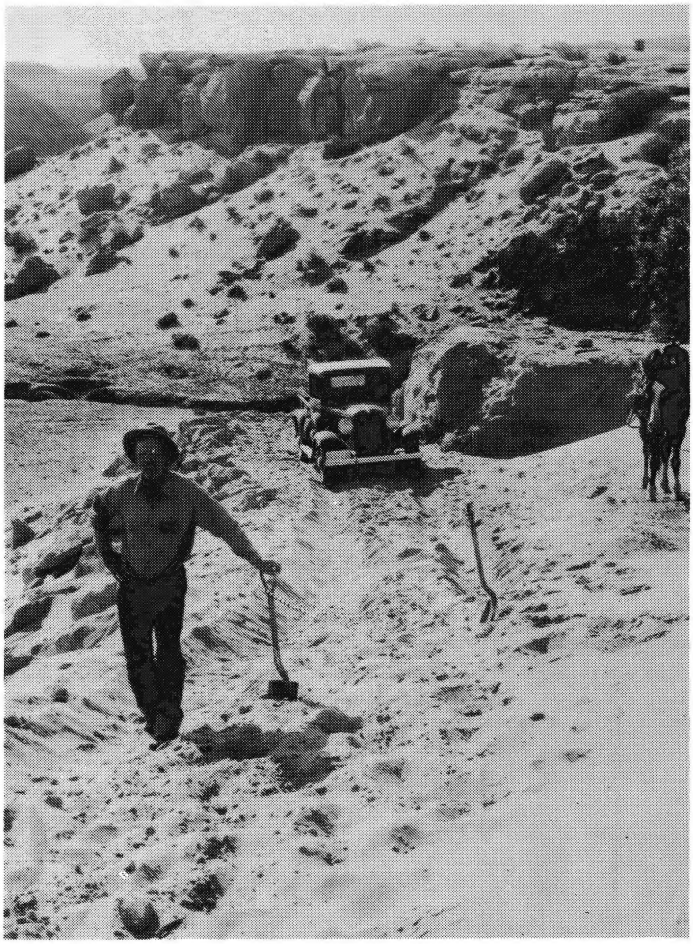
Most days in camp began with the packer rising at daybreak and gathering, watering, and feeding the horses. At spike camps the geologists prepared breakfast. The packer cleaned



U-24 where it crosses the sand desert between Hanksville and Green River. Note the tracks where the car was backed to take this 1935 view.

U-24 had to ford the Muddy River at Hanksville and could be an adventurous experience when the river flooded.

up afterwards while the geologists saddled their horses, collected their gear, and rode their mounts off to the areas to be mapped that day.



Charlie Hanks helping to clear sand from a dugway to obtain access to the top of the bench. Note horse waiting patiently.

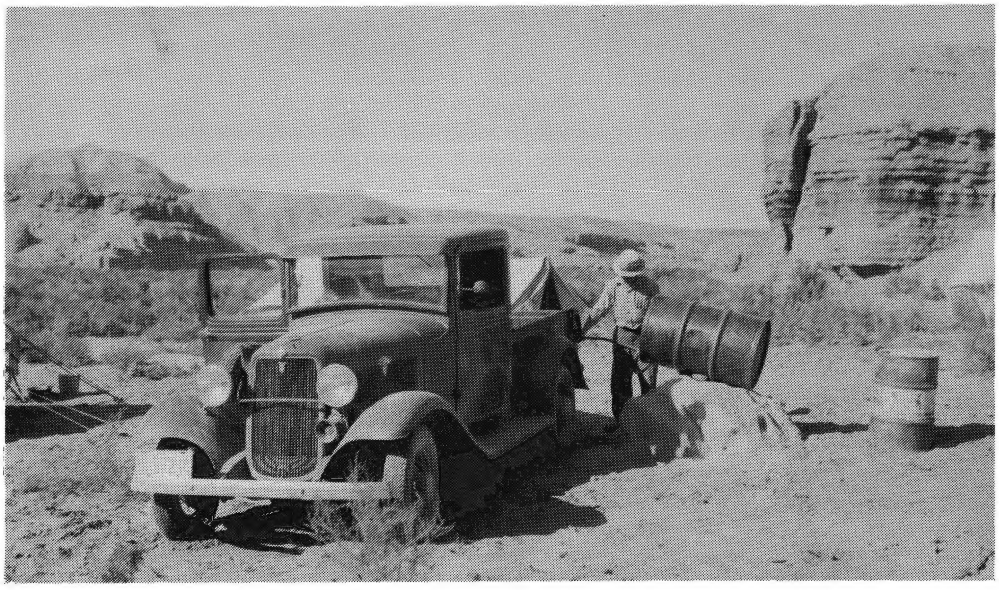
Gear included pocket transits, vertical angle tables, tables of corrections for curvature and refraction, geologist picks, collecting bags, lunch, and water. Most of the time canteens were used, but some days water bags were preferred. Along Glen Canyon the party based in the Henry Mountains carried burlap bags for collecting and transporting those pink rattlesnakes for the Washington Zoo (stay tuned).

It was feasible to map for a distance of about 5 miles from camp. Then camp would be moved 8 or 10 miles and a spike camp occupied. Mapping progressed at about 2½ inches of contact on the map daily. This amounted to about 2½ miles on the ground on the plateau where mapping was at 1/62,500. In the mountains, mapping was at a larger scale (1/31,680) and ground progress necessarily was slower, about 1½ miles of contact added daily to the map. On the mountains the geologists worked in pairs, an instrument man and a rodman. On the desert plateau geologists could map the contacts by intersection and resection and most of the time could work alone.

A day's work involved locating a dozen or two surveyed points with altitudes along the contacts. By the end of the day both the geologist and his horses were thirsty. Camp looked good! Evenings were spent inking the maps, calculating altitudes that had been measured, and recording other notes.

Even at base camps, which were accessible by trucks, mail was received infrequently, rarely as often as once a week. The personal service, though, was illustrated by an incident at Hanksville in 1936. While collecting the party's mail one day it was noted there was nothing for Ralph Miller so the postmistress looked again. She came back with a bundle, "here it is; somebody put it under the M's."

Mail service contributed importantly to the development of our democracy by helping to maintain a sense of unity among our widely scattered people. It had been made a federal responsibility during the 1840s; the Powell Survey operated at the fringes, where the service was attempting to keep up with exploration and settlement. That it did so effectively among the settlements in northern Utah is illustrated by an entry in



Gasoline at base camp was kept in 55 gallon drums. Not much gasoline was used because most of the work was done by horseback.

Gilbert's notes, October 25, 1877 (Hunt, 1982, p. 103) "Train behind please bring over my mail from post office." As noted, this service is no longer available.

The mail even found Gilbert in 1876 at a remote camp at a spring along Oak Creek where he camped by the Table Mountain bysmalith (his Marvine laccolith) while two of his men returned to the Red Gate to fetch supplies he had cached there. They returned a week later with the supplies and, Gilbert noted, "mail." We can only speculate how that mail reached him. "By the cars" southward from Salt Lake City to the ranch at York? From there by horseback (contracted carrier) to Gunnison and Salina. Somehow it was forwarded to a newly founded ranch in Rabbit Valley (not mentioned in Gilbert's notes) and somehow picked up there by his men recovering the cached supplies at the Red Gate.

SOME EXPERIENCES DURING THE 1920s AND 30s

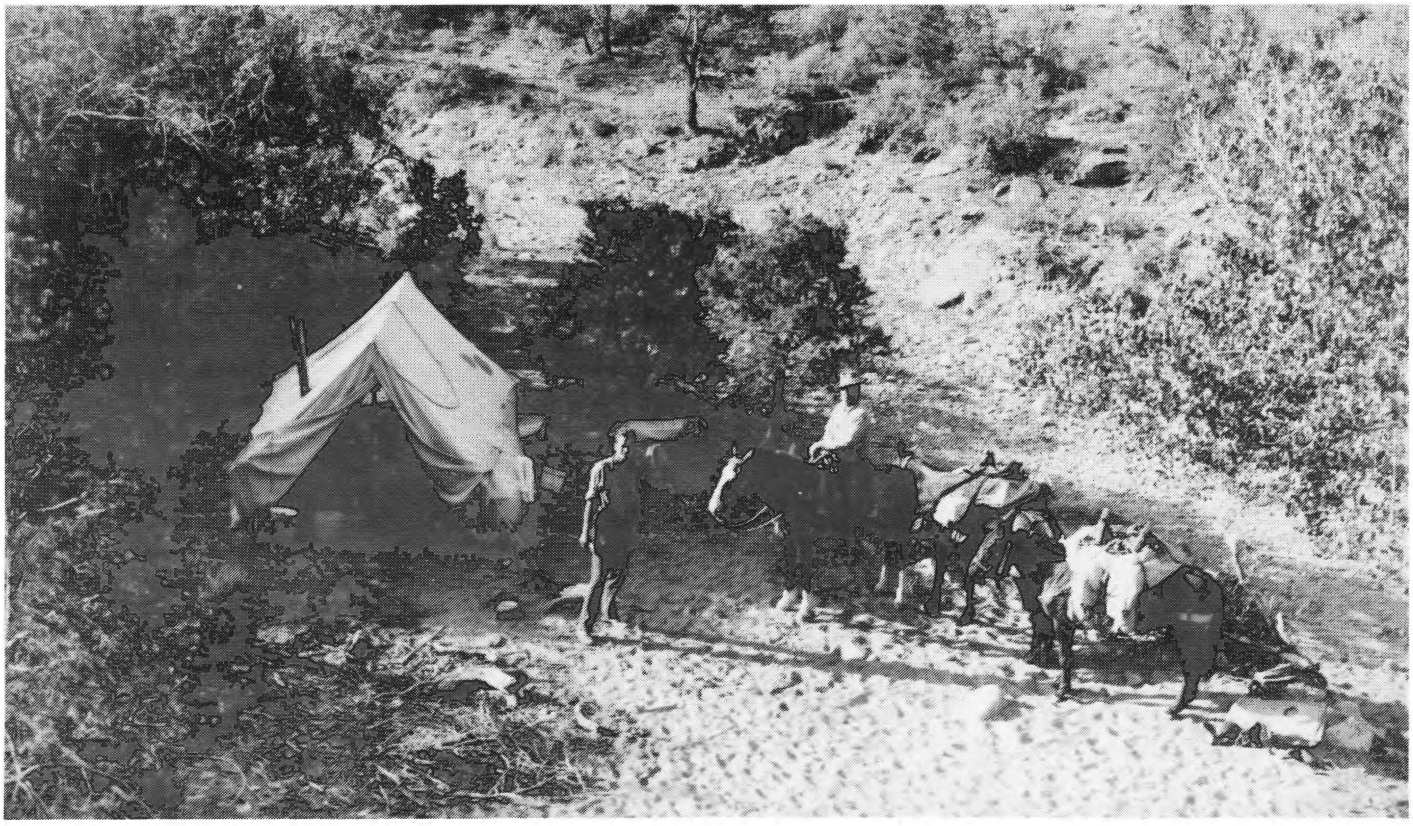
Needless to say, in connection with the hundreds of days of field work at the many packtrain projects in southeastern Utah, the geologists had all kinds of experiences — mostly humorous, a few sad but no real tragedies. Some are recounted in Hunt, (1977).

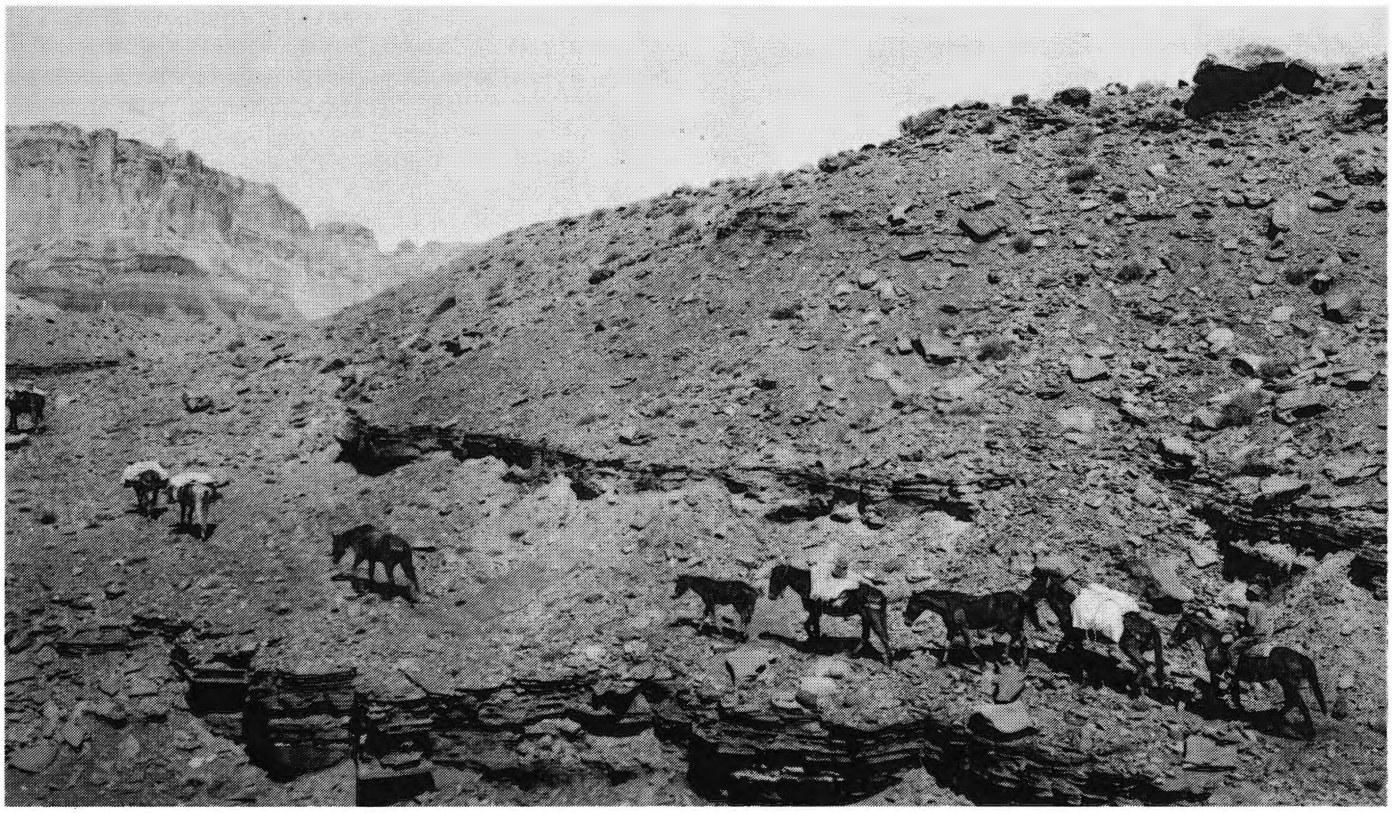
In 1936, amid the red rocks of Glen Canyon, some examples were found of the Grand Canyon rattlesnake, *Crotalus confluentus.* The snake's color, evidently adapted to the red rocks, is a vivid salmon pink. The National Zoo at Washington was contacted, and the geologists were asked to collect some. Three specimens were collected live by using a stick to steer them into a burlap sack which could be carried back to camp. There the snakes were collected in a barrel until ready to ship to Washington in screened boxes.

Bill Steele was hired as packer by Baker in 1927 and 1928. Bill lived on the desert south of the La Sal Mountains, and he frequented Moab where he was first hired. In 1928 he took the packstring from Moab to Monument Valley and served as packer on that project. In 1929 he was packer for Carle Dane mapping the geology along the Colorado River above Moab. Hunt first met Bill on Dane's project.

Each of the animals, whether horse or mule and whether used for riding or packing, not only had its own personality, it had its own tracks. All this was well known to the packers. When Bill Steele was employed by Carle Dane in 1929, Bill's first job was to locate a horse that had strayed. Bill spent the first day acquainting himself with the individual tracks of each of the 16 horses at camp; on his second day he took off from

Spike camps, like this one on Mt. Holmes 1937, used tents with a 2 x 3 foot pit 12 to 18 inches deep at one end. A light sheet metal stove was set on rocks at the front side of the pit. Collapsible stove pipe was stored in the firebox when the tent was being moved. Depending on talent in camp, there might be a jug of sourdough maintained at the front entrance. Side walls of the tent were used for storing groceries, oats, and other supplies. In case of rare, severe rainstorms 3 bedrollls could be accommodated. Most of the time, sleep was under the stars. Being in the rain shadow of the high plateaus, storms are infrequent in the vicinity of Mt. Holmes.





Charlie Hanks driving packtrain around ledges of the Moenkopi Formation on the northeast side of Mt. Holmes, 1937. Old timers in that area at that time credited Charlie Hanks with being first to encircle Mt. Holmes with a packtrain. The trip did involve some trail building and at one place a portage at a place too narrow for animals carrying packs.

camp and returned with the missing animal. Such incidents were impressive examples of the kind of artistry required for properly managing the packstrings.

One of the more unusual horseback experiences happened to Art Baker, riding Moose. Moose became involved with a wild stallion and became pregnant. On Navajo Mountain one day she decided it was time to deliver her colt and did so without consulting Art. Art's progress with his plane table mapping was delayed that day!

Moose was wily and contributed to other incidents. On the Henry Mountains project Charlie Hanks was moving camp one day and Moose strayed up the mountainside away from camp. Alice Hunt, trying to be helpful, tried to fetch Moose back to camp. Alice had a carrot. Moose got the carrot but Alice did not get Moose. She returned to camp to report that Moose was now farther from camp than ever. But when Charlie Hanks was ready to load Moose, he lost no time getting her back to camp and loaded. Every horse had its own personality and Charlie knew them all.

One of the Survey's animals was a mule, misleadingly named Violet. She was unfriendly, suspicious, and always ready to kick anyone who approached her. Generally, she was not ridden by the geologists, but Ralph Miller recalls an experience riding Violet one day on the Green River Desert. He was headed for a plane table station at the end of a long, narrow flat-topped spur projecting out into Cataract Canyon. "About half way out Violet and I came to a vertical-sided cleft in the rock that extended almost completely across the spur. There was no way around it. It was only about a yard wide at the narrowest, so I dismounted, took the reins and jumped across. I rather expected Violet to balk, but to my surprise she never hesitated, but easily jumped the cleft, and we proceded on out to my desired and very scenic location at the end of the spur."

"It was a different story on the way back. When we got to the cleft, Violet refused to jump. I jumped myself, and pulling on the reins I cajoled, pleaded, begged, and cursed, but she would not jump. Finally I found a stick and beat on her rump, which was as effective as if she was a statue and not made of flesh and blood. Mindful of Violet's reputation, the only thing I did not do was get behind and push. We must have spent at least an hour mutually hating each other, and she was still on the wrong side of the cleft."

"Finally, I decided on what seemed to me a desperate, almost a Hobson's choice. At the end of the cleft across the spur was a steeply sloping ledge which did span the cleft, but the lower ledge terminated at a sheer cliff. I could climb it with my rubber-soled shoes, but if I or Violet fell or lost our footing climbing the ledge it would be curtains. It seemed that the only way I was going to get back to the camp with or without Violet was if she would follow me up the incline and then we could move sideways on the ledge to safety. I led Violet over to the ledge. To my amazement she didn't look twice. With me

pulling gently on the reins, she tackled the ledge without hesitation. Half way up she fell to her knees, but she scrambled back up, and we arrived on safe ground with Violet grinning, if mules can be said to grin, and me with a case of near heart failure."

On the desert plateau geologists could work alone, locating themselves and the contacts being mapped by triangulation.

Charlie Hunt and Bill Steele had an experience in 1929 at a spike camp near the mouth of the Dolores River. Camp was in the bottom of a small canyon with a narrow rocky trail leading upward to the canyon rim. That night the horses and mule tried climbing the trail to the rim but were stopped by a ledge near the top. While Bill prepared breakfast, Hunt went to return the horses and mule to camp and found them standing on the narrow trail with Violet at the rear. Hunt climbed around her in order to make his approach from the front. The horses were unhobbled and turned around, but when Violet was approached, she whirled, still hobbled, and fell rolling 200 or 300 feet down the steep slope.

When she reached the bottom she just lay there, bruised and bloodied. Hunt was horrified, much as he disliked Violet, and hurried down to join Bill who walked over from the camp fire. Bill took off the hobbles, gave Violet a kick, got her up, examined her, then turned to Hunt and said, "I think if we load her up double today we can kill the sunnovabitch."

Mention was made earlier of the occasion when Gilbert, mapping Lake Bonneville, had to spend most of the night on the trail because he failed to reach camp by dark. This happened to him again near the south end of the Waterpocket Fold where he became rimmed as darkness fell and he had to wait for the moon to rise to find the trail off the sandstone cliffs.

In 5 years in the Henry Mountains area, Hunt missed making connections with Charlie Hanks at a spike camp only once. Heading towards the planned rendezvous, Hunt came on a trail with fresh tracks. Feeling sure they belonged to Hanks and the packstring, he followed them and discovered too late they were the tracks of some other riders. So he returned to base camp. About two o'clock in the morning he heard horses and there was Charlie Hanks, out looking for Charlie Hunt! He looked after geologists as well as horses.

Charlie Hanks and Charlie Hunt erecting triangulation flag on Ellen Peak, 1936.

Arthur Baker reports that when one of his outfits pulled into Sweetwater Spring, near the Flattop Buttes, upon seeing the horse tracks, Charlie Hanks informed the group who had been there and when.

To people as experienced as Bill Steele and Charlie Hanks, life in that packtrain country was easy. In 1935 the Henry Mountains project had rented some horses from Sam Adams of Green River. When one of the geologists had to leave the party on account of illness, Charlie Hanks went to Green River to determine where Sam wanted the unneeded horses to go; the field party did not want to use their limited funds for unused horses. Hanks missed Adams in Green River, "Adams had left that morning by wagon for Rabbit Valley."

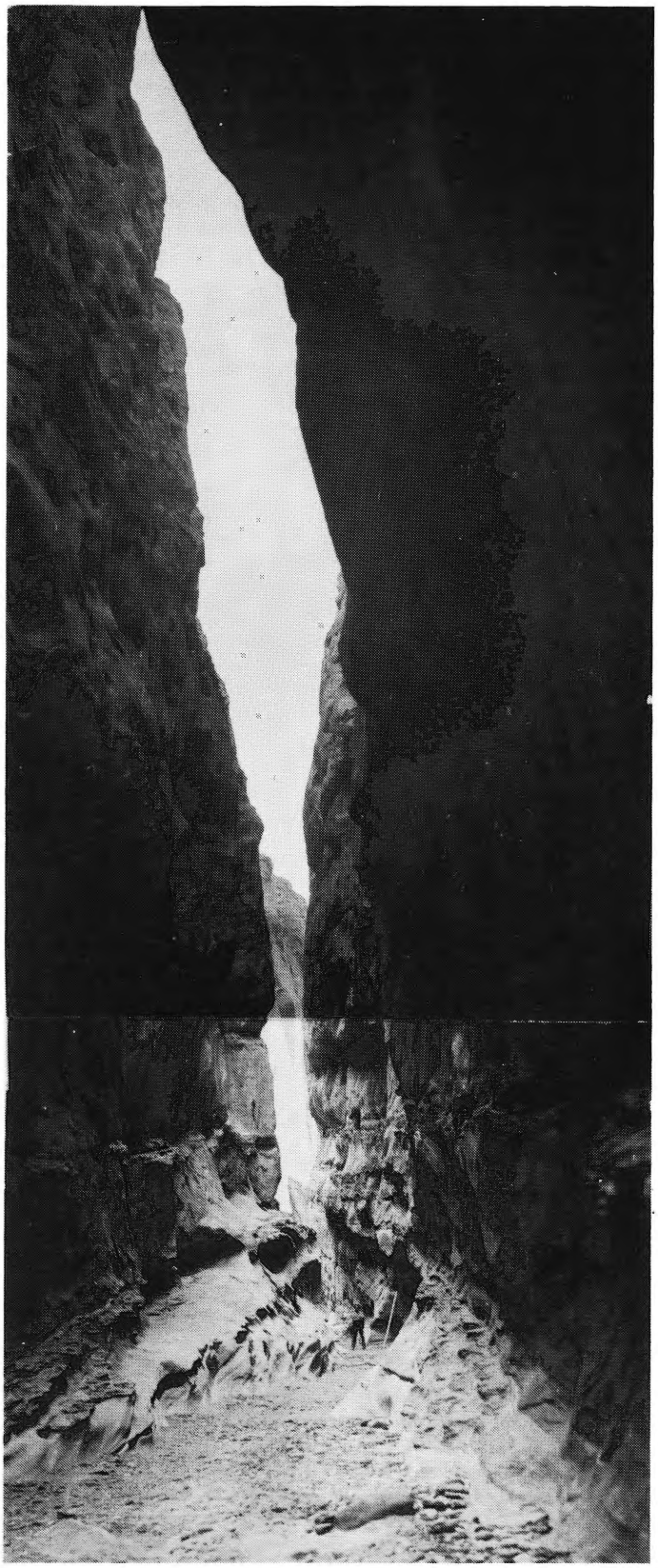
It would be a month before Adams would be back so Hanks began thinking out loud. "Sam will spend tonight at San Rafael and tomorrow he'll go to Garvan's. Wednesday evening he'll pull into Hanksville, and he'll stop at Andrew's place. He won't get away very early Thursday and in town he'll stop to see Les and Nelus. I think if I go down to the road about the middle of the afternoon next Thursday, I'll see Sam." And Hanks did just that. In fact, he had to wait only 30 minutes for Sam to pass en route to Rabbit Valley, one hundred miles on his way from Green River. It was an impressive four day prediction! The moral is, don't try to hide from the sheriff in that wilderness.

All of us were impressed by the apparent eye sight of both Bill Steele, Charlie Hanks, and later George Wolgamot. They could see a horse, a cow, or a deer in the distance long before the rest of us. The secret came out one day when Charlie Hunt was riding on the desert with Hanks looking for a geologist mapping that part of the area. Charlie Hunt saw him first! Hanks did not see him until suddenly he exclaimed, "There's his horse. Now I see him. He's at his plane table near the base of that hill." Charlie Hanks knew what a horse, cow, or deer looked like; Charlie Hunt knew what a geologist at a plane table looked like!

At a camp on Mt. Pennel, Paul Averitt and Charlie Hunt planned a move, and the packer, George Wolgamot, was to follow their tracks. That evening they found George had moved camp as scheduled, but when asked if he had followed the geologists' tracks, George replied "Naw, I followed some wild cow tracks." "Do you mean to say you would rather follow wild cow tracks than geologists' tracks?" he was asked. "Yes, you see, the wild cow knew where it was going." Following the geology did take geologists to weird places, so there was a good deal of truth in George's answer!

Bill Steele and Charlie Hanks thrived on the rugged outdoors life and lived to advanced years; neither one died in bed. Bill Steele was riding a trail near Johns Canyon, a tributary to the San Juan River, when he had a heart attack and fell to the ground. Charlie Hanks was in his ninety-first year when he fell from the passenger seat of a moving automobile on a curve in Salt Lake City and was fatally injured.

When the Henry Mountains project was completed in 1939, question arose what to do with the 4 government horses still alive. They were healthy but now old — Moose was one of them and there was another mare, Dolly, gentle, sure footed, friendly, with a keen sense of where the oats were located.



One of the canyons through the reef of the San Rafael Swell. Scale from Paul Averitt and stadia rod. 1935.

They had been with geologic field parties since the early to mid-twenties. The two geldings had been excellent pack animals and were old timers too. When asked what they were worth, Charlie Hanks replied, "Do you wanta buy 'em or wanta sell 'em?" Consensus at Hanksville was that they were each worth about $20 to $25.

Hunt notified Washington that he could sell the horses so no need to pay for any pasturage. Oh no, he was told. Those horses cannot be disposed of until it has been determined that no other agency wants them. It would have cost many times their worth just to fetch them. So how were the horses given good care in their retirement and the government spared the expense of paying pasturage? As Art Buchwald would say, "I think I don't remember."

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Editors Note: As the last issue of Survey Notes was being put together and Mike Ross was seeking photographs for his article on Charlie Hunt (Survey Notes vol. 23, no. 1, p. 15-17), Charlie wrote to us asking if we wanted to reprint this article. It had appeared in three issues of the U.S. Geological Survey newsletter, THE CROSS SECTION, vol. 19, no. 7-8-9. We were delighted with the coincidence and the article. It is adapted and reprinted with the kind permission of the U.S.G.S. Office of Scientific Publications.

SME Meeting

Salt Lake City will welcome the **Annual Meeting and Exhibit of the Society for Mining, Metallurgy, and Exploration** from February 26 to March 1, 1990. The 119th Annual Meeting theme is "Increased Competitiveness Through Technology," reflecting the positive attitude and atmosphere of innovation that characterize today's resurgent mining industry.

Contact Meetings Department, Society for Mining, Metallurgy, and Exploration (SME), Inc., P.O. Box 625002, Littleton, CO 80162 or call (303) 973-9550.

GREAT SALT LAKE LEVEL

Date (1989)	Boat Harbor South Arm (In feet)	Saline North Arm (In feet)
May 01	4206.65	4205.75
May 15	4206.65	4205.70
Jun 01	4206.50	4205.55
Jun 15	4206.35	4205.40
Jul 01	4206.00	4205.10
Jul 15	4205.80	4205.00
Aug 01	4205.35	4204.40
Aug 15	4205.30	4204.70
Sep 01	4205.00	4204.10
Sep 15	4204.80	4203.85

Source: USGS provisional records.

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