SURVEY NOTES

GEOLOGICAL AND MINERAL SURVEY UTAH

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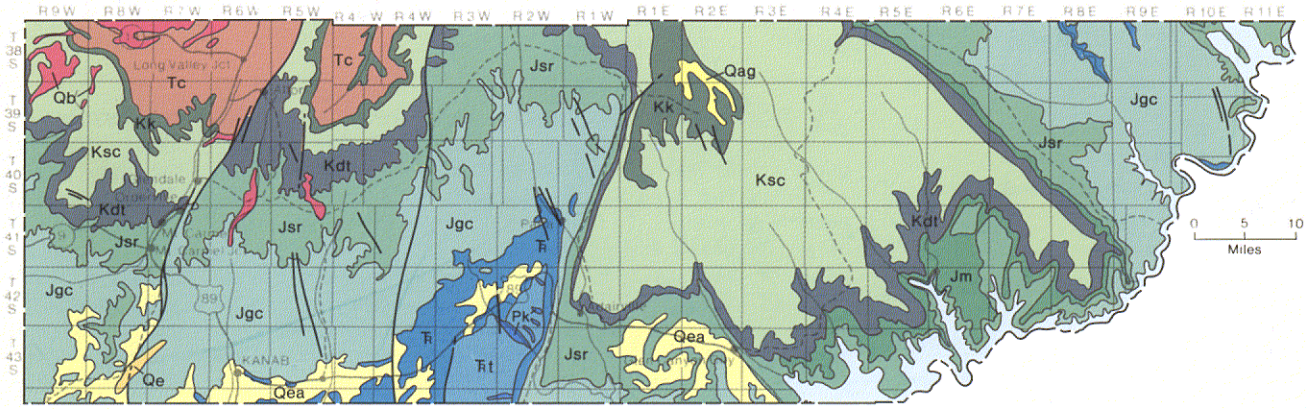
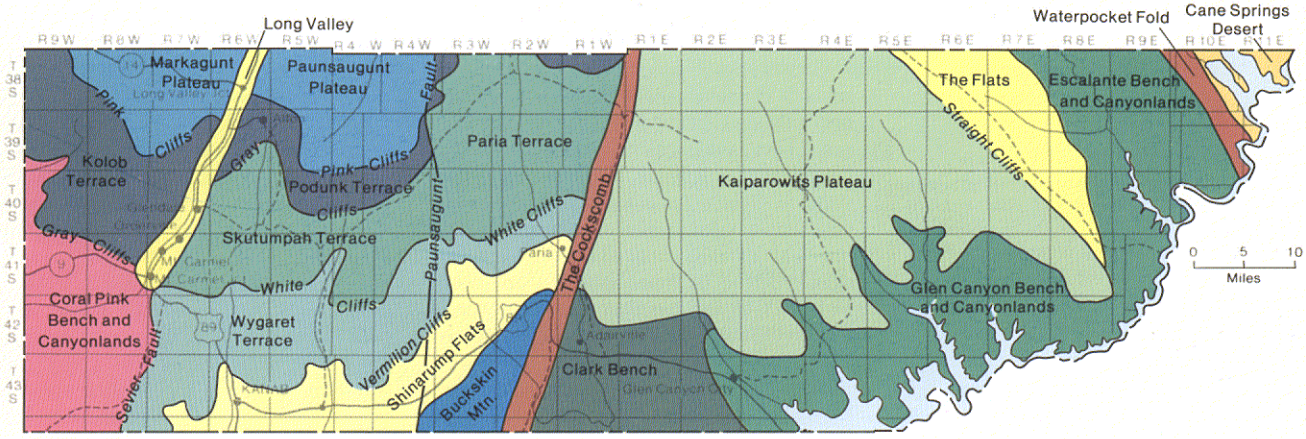


Qag	Qe	Qea	Qb	Tc	Kk	Ksc	Kdt	Jm	Jsr	Jgc	Ꞧ	Ꞧt	Pk
Alluvial gravel-Gravel in channels, terraces, and pediments.	**Eolian deposits**-Mostly windblown sand in dunes and sheets.	**Eolian/alluvial deposits**-Older sand, silt, and fine gravels in depressions and on benches.	**Lava flows**-Mostly basalt as flows and cinder cones.	**Claron Formation**-Mostly pink cliffy limestone as seen in Bryce Canyon.	**Kaiparowits Formation**-Salt and pepper sandstone forming a slope under the Pink Cliffs.	**Straight Cliffs Formation**-Interbedded sandstone, mudstone, and coal.	**Dakota-Tropic Formation**-Gray marine shale; interbedded mudstone, sandstone, and coal; conglomerate.	**Morrison Formation**-Mostly cliff or ledge-forming conglomeratic sandstone.	**San Rafael Group**- Summerville, Romana Mesa, Henrieville, Entrada, and Carmel Formations.	**Glen Canyon Group**-Sandstone of Navajo, Kayenta, Wingate, and Moenave Formations.	**Triassic rocks**-Chinle and Moenkopi Formations; shales at top, shales/sandstones below.	**Timpoweap member of Moenkopi Formation**-Tan-gray limestone on Buckskin Mountain.	**Permian rocks**-Kaibab, Toroweap, and Hermit Formations.



KANE COUNTY GEOLOGY

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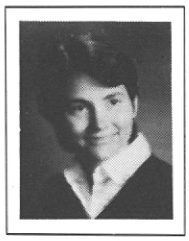


FROM THE DIRECTOR'S DESK

How High Will Great Salt Lake Rise?

AS Great Salt Lake continues its rampage, I am asked ever more frequently "how high will the lake go?" and am teased that geologists are doomsday types who predict the re-establishment of Lake Bonneville. In his article on historic levels of the lake (p.13), Don Mabey examines in detail the historic evidence of the rise and fall of the lake. What surprises most people is that the lake has given us several additional geologic clues to project lake levels back hundreds of years. This Director's Corner explains why the UGMS has been advocating a planning level of 4217 feet. We urge that policymakers look at the lake as if it were the proverbial gorilla...Question: where does a gorilla sleep? Answer: anywhere it wants to. The lake is like a gorilla and its bed is anywhere up to 4217 feet. I also am asked about other geologic hazards associated with the lake (earthquake, liquefaction, high ground water) and so this article responds to those questions as well.

The lake leaves several clues about its past history. Most of the information in this article is based on Donald R. Currey's work at the University of Utah, discussions with Don Mabey of the Utah Geological and Mineral Survey, and on information from Bob Smith, University of Utah.

Geomorphic evidence...waves and currents in the lake create beaches, benches, and other coastline-like features such as spits, bars, and lagoons. These are particularly well-developed when the lake stays at a level for a long period of time and where later, higher levels of the lake have not eroded away or covered the evidence. Some of these features are obvious, such as the bar that connects Stockton to South Mountain near Tooele, or the Bonneville-level spit that forms the skyline as it starts across Point of the Mountain toward the Jordan Narrows. Other shore features are more difficult to recognize at first but then look obvious, such as the gentle ridges of the Gilbert Shoreline at Little Mountain west of Corinne or the many transgressive shorelines intermediate between the Provo and Bonneville levels southwest of Wendover. Still other features are subtle even when they've been recognized. The "thresholds" to the West Desert and to the Bonneville Salt Flats can be located by accurate surveying but are very difficult to recognize in the field. The offset of shorelines by earthquake faulting can be imperceptible to the eye and can be detected only by sophisticated surveying technology. A discontinuous shoreline has been developed at about the 4217 foot level which can be recognized by surveying in several places and occasionally by the naked eye. Although storm lines below this level have been identified, the 4217 foot level appears to be a more persistent feature.

Geochemistry...as the chemistry of the lake's water changes in response to changes in volume, the chemistry of the sediments laid onto the lake's floor also change. Judith McKenzie of the University of Florida has examined sediments from the floor of the Great Salt Lake down to approximately six feet, and she calculates that in the last 500 years the lake has freshened to the salinity of a lake at least as high as 4212 at least 3 times and perhaps more often than that.

Fossil evidence...the lake, even at its most "hostile", supports life forms that are preserved in the fossil record. Soft-bodied creatures usually are not preserved, e.g., brine shrimp or algae; however, varieties of ostracodes that live in the lake die and settle to the lake floor where they look like small white beads. Because they are highly sensitive to changes of temperature and salinity, paleontologists use them as indicators of the environment that was present when they died. Snail shells and ostracodes are commonly found in the lake's sediments going back to before the initial rise of Lake Bonneville 25,000 years ago. Lake Bonneville itself was almost a fresh water lake and supported a limited variety of fish, some of whose descendants live in streams of the Deep Creek Mountains and other areas today. Paleontologists have not yet used the remains of these creatures to determine how often the lake has risen to 4217 feet or above, but work in progress by Currey and others in-

Continued on Page 15

KANE COUNTY GEOLOGY

by H. H. Doelling
F. D. Davis
and
Cynthia Brandt

KANE County, on the southern border in central Utah, contains the Glen Canyon National Recreation Area, parts of two national parks, the Paria River Primitive Area, Grosvenor Arch, and the state parks of Coral Pink Sand Dunes and Kodachrome Basin. The beauty and wonder of these areas arise from the special geological formations in the county, and there are few places that do not display gorgeous vistas and spectacular scenery. Of the 4,100 square miles that comprise the county, about one-quarter is presently withdrawn for tourism and more land is on the block.

Kane County has other superlative attributes. It contains most of Utah's coal resources, it has the largest assemblage of landslide deposits (most are inactive) and the shortest length of paved highways per square mile of any county in Utah. Although there are not as many arches as in Grand County (Arches National Park), there are at least 25 prominent ones. Kane County is one of the best places to see well exposed geologic formations, structures, and landforms in the world.

The Utah Geological and Mineral Survey, as part of its regional mapping program, conducts surveys of Utah counties. At least 10 county bulletins have been produced in the past (Emery, Salt Lake, Cache, Washington, Daggett, Uintah, Garfield, Sanpete, Piute, and Box Elder) and each study has added new features in its presentation. Kane County will soon be released and new surveys are slated for Millard, Juab, and Grand Counties.

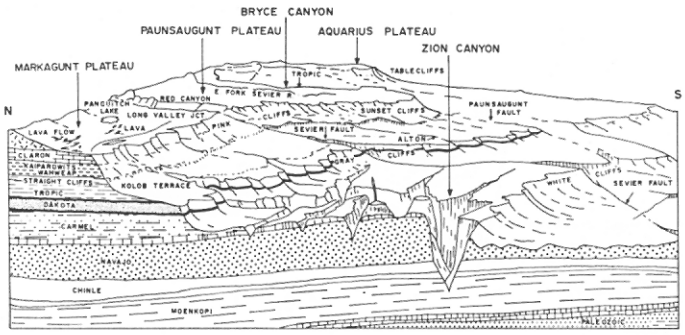


Figure 1. Sketch diagram illustrating the "Grand Staircase" of western Kane County. View is easterly from Washington County. The alternating cliff and bench topography is the result of alternating hard and soft rocks.

Each study now includes a 1:100,000 scale geologic map, a minerals and/or structure map, and a geologic hazards map. The bulletin will provide compiled and original information on the geology, resources, and geologic hazards of the county. Hopefully the information will be of use to the citizens, school children, public officials, teachers, and geologists who want to know more about the geology of Kane County, the associated resource potential, hazard problems, and scenic wonders.

Kane County exposes its rocks in the classic Grand Staircase section. The idea of the staircase comes from the series of cliffs which extend east-west across the county in its western half. These include the Vermilion Cliffs, White Cliffs, Gray Cliffs and Pink Cliffs. The cliffs help divide the county into its physiographic areas (bottom figure on front cover), each with its own unique scenery and characteristics. The exposed rocks range in age from Permian to Quaternary; hard rocks having been deposited 275 to about 40 million years ago, Quaternary rocks having been deposited in the last 1.5 million years. The Quaternary rocks consist of lava flows, sand dunes and sheets, terrace gravels, landslide deposits, and alluvium. The older rocks were deposited in seas, flood plains, deserts, lakes, and lagoons and attest to a varied and complex geologic history.

The geologic formations exposed in Kane County are dominated by sandstone, but most sedimentary rock types are present. They undergo changes across the county as would be expected in such a large county. Some units thicken or thin, others pinch out, and still others change characteristics. Some of the features of Kane County rocks are illustrated in figures 1 and 2, as well as the simplified geologic map presented on the front cover. Essentially the formations of Kane County dip gently northward a few degrees, the rocks jointed, faulted, and folded along axes that trend N 15° to N 35° E and N 40° to N 55° W. In the western part of the county the dominant structures are the northeasterly trending Sevier and Paunsaugunt faults. Both are downfaulted to the west, the former with displacements to 2,000 feet, the latter to 500 feet. There are two magnificent monoclines, the East Kaibab monocline (The Cockscomb) and the Waterpocket Fold. The first trends northeasterly in the central part of the county and the latter trends northwesterly in the eastern part of the county. Both are downfolded to the east and both show displacements of several thousand feet. The rocks to the east of the East Kaibab monocline plunge into the Kaiparowits Basin, preserving Cretaceous coal-bearing rocks manifested in the Kaiparowits Plateau. The rocks in the basin participate in several northwest trending broad folds.

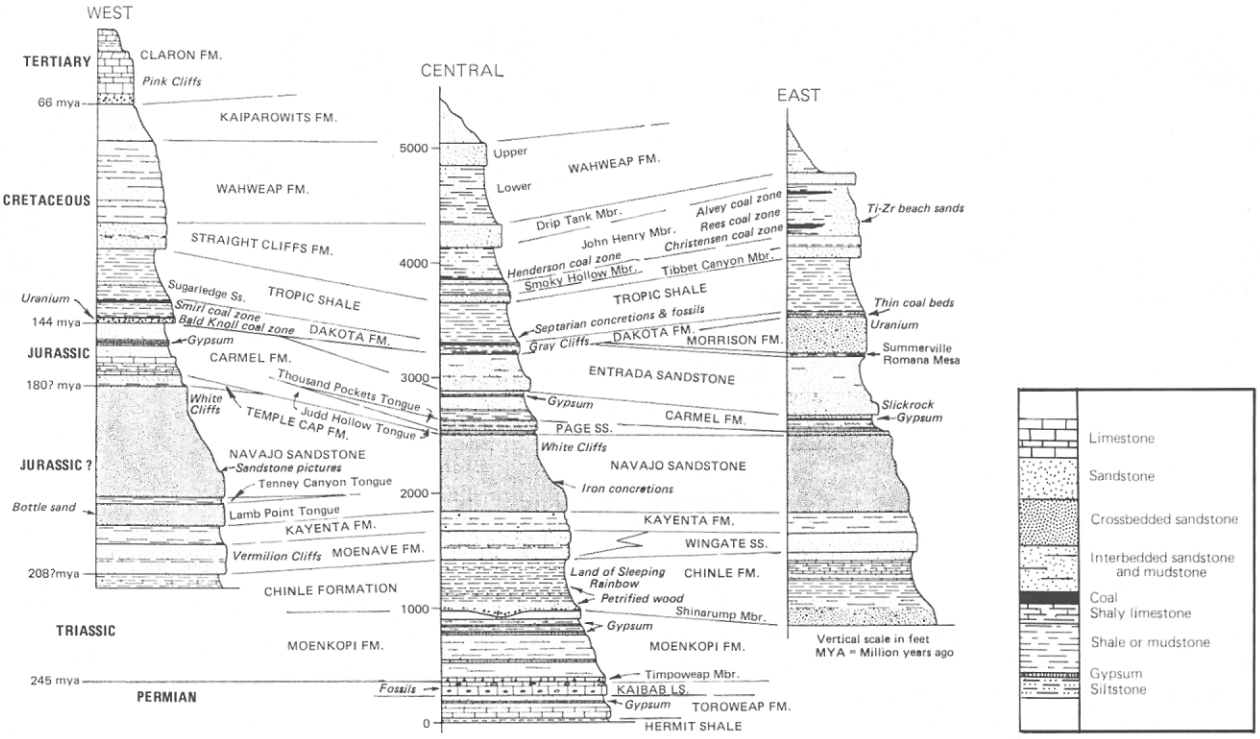


Figure 2. Lithologic columns of rock formations exposed in Kane County. The correlations indicate thinning and thickening, truncations by unconformities, facies changes, hardness and softness, and economic considerations.

ECONOMIC GEOLOGY

The total value of mineral production in Kane County, through 1985, is estimated at a little under 22 million dollars. Almost 96 percent of this sum is attributed to construction materials (sand and gravel) mined to build and maintain highways. In addition to sand and gravel the county has produced crushed stone, gem stones, coal, pumice and volcanic ash, sand, manganese ore, gold, uranium, silver, copper, and lead (figure 3). Presently the most important commodities continue to be construction and gem materials. The annual rate of production for sand and gravel is erratic and depends on the schedules of the Utah Department of Transportation and other road-building entities. The known metal occurrences of Kane County are too small and low grade to be significant, but careful prospecting might uncover some economic small tonnage deposits. The most hopeful opportunities for Kane County metals ventures probably rest in uranium, silver, titanium, and zirconium. Other mineral occurrences reported in Kane County include gypsum and anhydrite, limestone and dolomite, clay, and vanadium. Presently there are no large, regularly producing mining operations in the county.

The category of "gem materials" may give a false impression of what is produced in Kane County. The resource consists of rocks that can be polished or cut in such a way as to produce decorative bookends, "conversation pieces," tourist items, and rock pictures. These include concretions of all types, patterned sandstone ("picture rock"), petrified wood, colored sand for sand paintings and bottles, and fossils. Gem materials are mined in cycles. New deposits are prospected, quickly mined to exhaustion, and the products are stockpiled and steadily marketed to tourists and dealers. A cycle may take more than 10 years. Some of the gem materials are exported to collectors and rock shops all over the world.

Kane County has the largest coal resource of any in Utah (28.9%), more than 8 percentage points above number 2, Carbon County. Enigmatically only 90,000 tons have been produced to date. Small local markets, the difficult terrain, and the conflict between the environmentalists and developers have been responsible. The last regularly producing mine closed in 1970 (Alton mine) and in 1971 an experimental mine (Warm Creek mine) produced 12,000 tons to test mining cost estimates and was shut down. Parts of three coal fields extend into Kane County: Kaiparowits Plateau, Alton, and Kolob coal fields (figure 4). In the western part of the county the Dakota Formation is host to the thick coal beds. There are two coal zones with commercial beds, the first near the top of the formation (Smirl coal zone), the other near the base (Bald Knoll coal zone). The

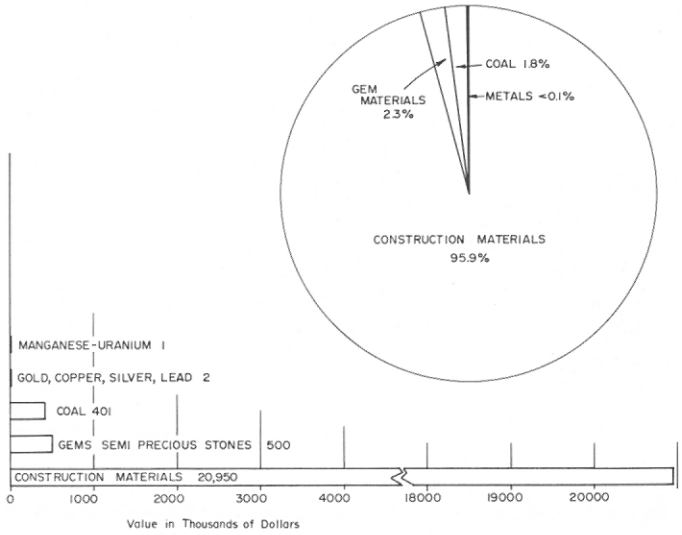
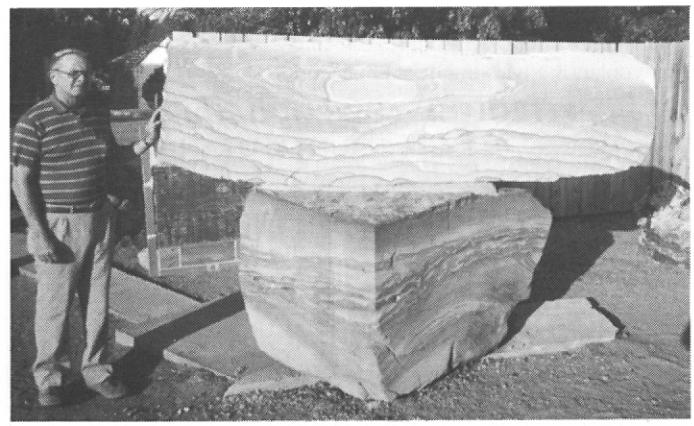


Figure 3. Pie and bar graphs showing the value of past mineral production, Kane County, Utah.

Kane County produces gem materials—rocks that can be cut and polished. These septarian nodules or concretions are infilled with honey-colored calcite. They are generally found at the base of the Tropic Shale.



Large slabs of "picture rock" displayed in Kanab. Soft brown, red, pink, and yellow coloration vary with the complex crossbedding of the sandstone to produce "pictures" of landscapes, seascapes, clouds, and even geologic cross sections.

upper is the most valuable with higher quality coal and thicker seams, while the lower is often badly split and high in ash. Sulfur content increases from less than a percent in the east to more than 2 percent in the west. Most of the past production for Kane County has come from the Smirl coal zone of the Dakota Formation, especially from the Alton area.

The Straight Cliffs Formation hosts the thick commercial coal beds of the Kaiparowits Plateau coal field. Essentially there are three coal zones, Christensen, Rees, and Alvey (lower, middle, and upper), and all are found in the John Henry Member. The thick coal beds do not extend over the entire plateau area but are confined to an 18-mile wide band that trends N 35° E. The Christensen zone (Henderson coal zone in the Tropic area) is the most valuable and is generally valuable throughout the band. In the Escalante area both the Christensen and Alvey zone have thick minable beds. In the Smoky Mountain area the Christensen and Rees coal zones have thick minable beds. The Tropic area has only the Henderson coal zone with thick coal beds. To date, the thickest coal bed discovered in Kane County is 29.6 feet. In terms of quality (heat value, low sulfur), Smoky Mountain area coals excel over the other two areas and over the Dakota Formation coals. The rank of Kane County coals ranges from subbituminous C to high volatile bituminous C.

Geologic and overburden conditions are such that most of the coal of the Kaiparowits Plateau and Kolob coal fields will be mined underground. In the Alton coal field the overlying Tropic Shale is often stripped back from the coal bearing Dakota Formation to produce wide benches which will be surface-mineable. The Alton and Skutumpah coal areas both have large areas suitable for surface mining techniques. Coal resources of the county are divided among the three coal fields as follows (millions of short tons):

KANE COUNTY IN-PLACE COAL RESOURCES

Kaiparowits Plateau	4,428.6	63.1%
Alton	1,475.3	21.0
Kolob	1,113.0	15.9
Totals	**7,016.9**	**100.0**

The above were determined (Doelling, 1972, p. 549-553) to include measured, indicated, and inferred coal as extrapolated to 4 1/2 miles from a control point in reasonably continuous beds at least 4 feet in thickness and under less than 3,000 feet of cover. Experience in other Utah areas with similar geologic circumstances shows that about one-third of such a resource is usually recoverable in underground mining operations. Some estimates, which include all coal beds over 14 inches in thickness, indicate that the total coal resources of Kane County are at least four times higher. Although there is no coal activity at present, it is difficult to conceive that such a large economically retrievable resource will never be exploited. Presently there is a wonderful opportunity of time in which to

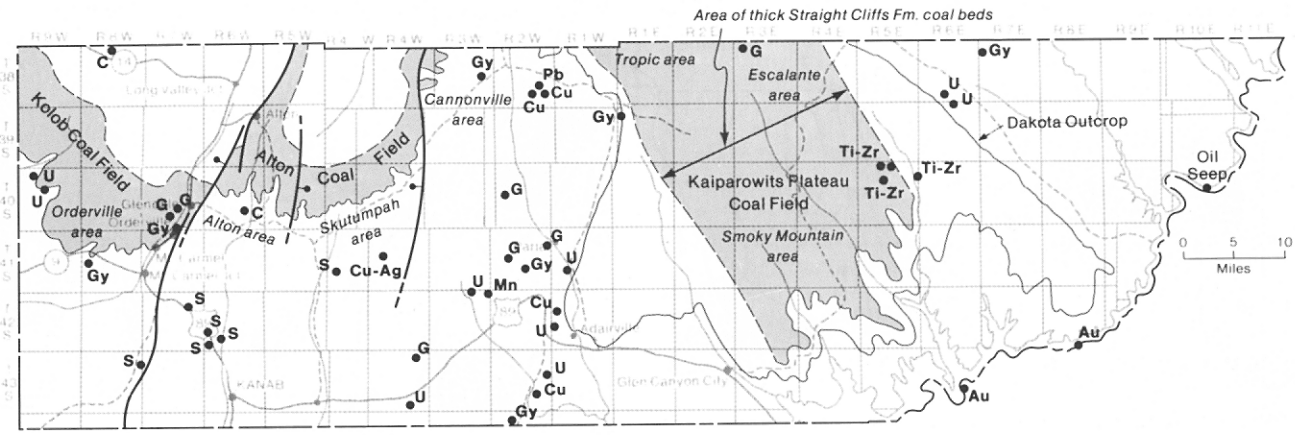


Figure 4. Coal fields map and mineral occurrences map of Kane County. U=uranium, C=cinders, Gy=gypsum, S=sandstone, Cu=copper, Ag=silver, Pb=lead, Au=gold, Ti-Zr=titanium-zirconium, Mn=manganese.

plan for proper and reasonable development to minimize the damage that could result to the fragile and beautiful bench and canyonlands environment of Kane County.

PETROLEUM AND CO_2 RESOURCES IN KANE COUNTY, UTAH

Kane County is located in the center of the Kaiparowits Basin Area, the geologic province spanning south-central Utah and northern Arizona. The Kaiparowits is a stratigraphic basin much like the Paradox Basin to the east. Paleozoic and Mesozoic seas deposited carbonates, sands, and shales in environments ranging from shallow marine to supratidal (Sharp, 1976). During the Laramide orogeny, Late Cretaceous through Eocene time, uplift and regional tectonism transformed the flat-lying sediments into broad uplifts, anticlines, and synclines. Late Cenozoic erosion and igneous activity sculptured the region further, giving it the distinctive look it has today.

To date, 29 wells have been drilled in Kane County (excluding activity in 1921 at Bennett's Oil Seep), but none produced commercial quantities of hydrocarbons (figure 5). Low formation pressures in many areas may be linked to dry holes. Moreover, some geologists question whether hydrocarbon reservoirs have been flushed because fresh water has been found in several formations in the subsurface. Despite these potential problems, shows of oil and gas are common.

Shows were reported in the Moenave Formation, Shinarump Member of the Chinle Formation, Timpoweap Member of the Moenkopi, Kaibab Formation, Toroweap Formation, Coconino Sandstone/White Rim, Hermit Shale, Cedar Mesa/Queantoweap Sandstone, other Permian zones; Redwall Limestone, Cambrian near Cambrian-Devonian unconformity (Giardina, 1979), Tapeats Sandstone, and other Cambrian zones. Shows varied from sample fluorescence to one barrel of oil produced and 26 barrels of oil bailed. Some of the best shows were reported in the Timpoweap, Kaibab, and Redwall carbonates. The Cambrian carbonates also appear to be prospective reservoirs, along with Hermit Shale and Cedar Mesa clastics.

Clearly, the numerous shows in wells drilled in Kane County indicate potential for significant oil and gas fields. The question arises as to why previous drilling has not discovered oil and gas in commercial quantities. One reason may be that most operators have drilled surface anticlines believing that the strata below conform to the surface structure. This assumption is probably not appropriate because of major unconformities and structural variety which characterizes the Kaiparowits Basin Area. Another reason may be the previous lack of emphasis on stratigraphic traps. Marine and near-shore carbonates, such as the Timpoweap, Kaibab, and Redwall, are superb traps but often have little or no structure associated with them. Porosity pinch-outs and facies changes can be great traps, but exploration for them is difficult. Seismic stratigraphic analysis, 3-D seismic survey interpretation, and seismic modeling in conjunction with detailed geologic studies can address this problem. Unfortunately, these methods are expensive and require a commitment of time and money to drill more than one dry well so that the data can be tied to subsurface well data.

Upper Valley Field in Garfield County, Utah is just a few miles north of Kane County. The closest producing well in Upper Valley is located approximately 4 miles north of the Kane county line. Although the anticline on which Upper Valley is located continues into Kane County, the production does not. Several wells have tested the southern extent of Upper Valley Anticline, but none have been productive.

Upper Valley has produced about 22 million barrels of oil to date and continues to produce. Four porous zones in the Timpoweap and Kaibab have produced the majority of the oil (Sharp, 1976); in addition, the Redwall has produced 17,000 barrels. Although Upper Valley Field is located on an anticlinal structure, production is not strictly associated with structure. A small CO_2-rich cap and hydrodynamic drive have apparently pushed the oil onto the southwest flank of the anticline. Consequently, many wells which have been drilled structurally higher than oil productive wells have produced water (Sharp, 1976). Stratigraphic complexities of the dolomitized reservoirs also play a role in determining where the oil will occur.

Virgin Field is located in Washington County, Utah, 15 miles west of the Kane County line. It was discovered in 1907, but has never been commercially important because the average well produces only 5 barrels of oil per day. Cumulative production from the Timpoweap (and probably also from the Kaibab) amounts to more than 209,000 barrels of oil. No structure can be clearly identified at the Virgin Field, but oil seeps nearby tantalized early oil explorers.

In addition to petroleum potential, Kane County may have CO_2 reserves also. Nearby, CO_2 has been found in significant quantities at Escalante Anticline in Garfield County. It is estimated that Escalante Anticline could contain as much as 3 trillion cubic feet of gas (Petroleum Information, Winter 1984). CO_2 is fast becoming a valuable commodity because of its new use in enhanced oil recovery in old oil fields. In the future, Kane County may benefit substantially from the discovery of CO_2 reservoirs in the county. The petroleum map shows the prospective area for CO_2 exploration. It is based on the presence of high heat flow, proximity to Tertiary intrusives and Tertiary volcanics, and CO_2 reported at Escalante Anticline, Upper Valley Anticline, and Virgin Field.

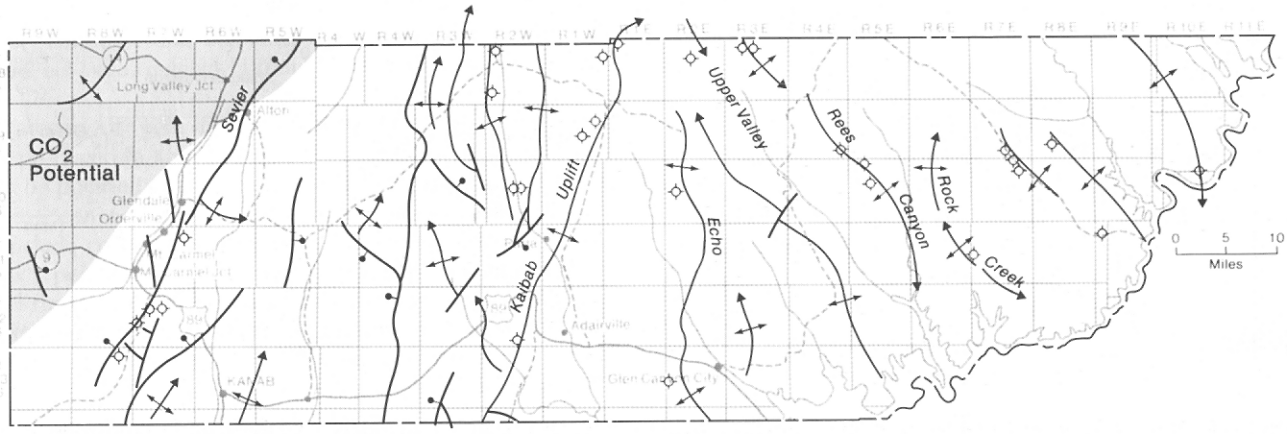
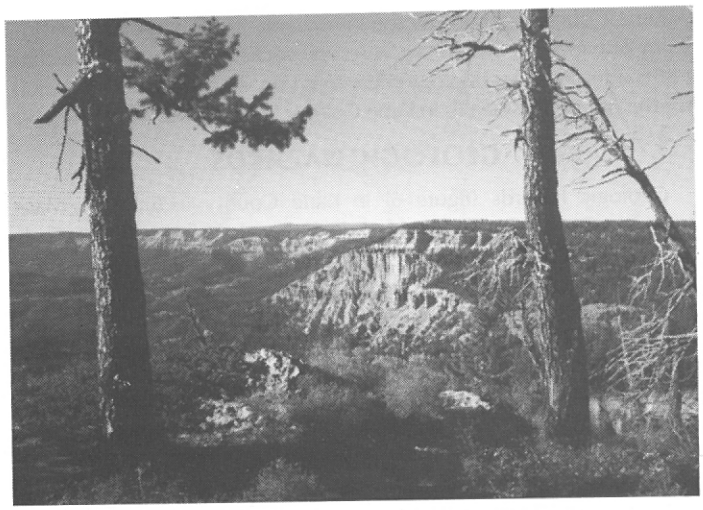
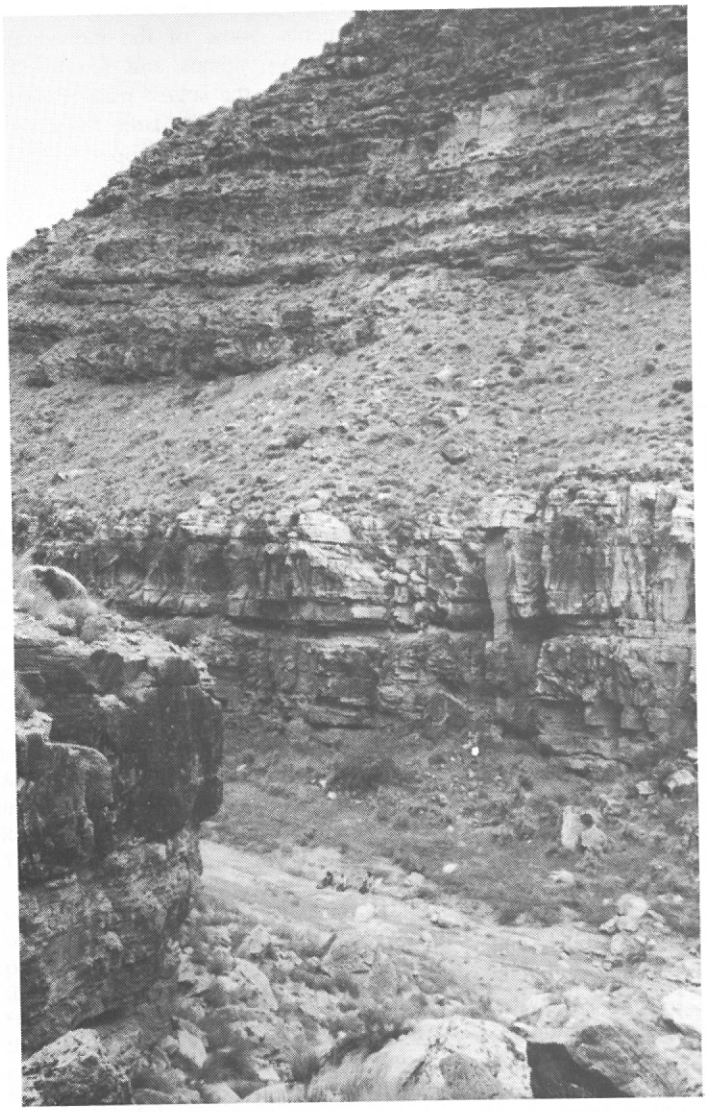


Figure 5. Petroleum map.

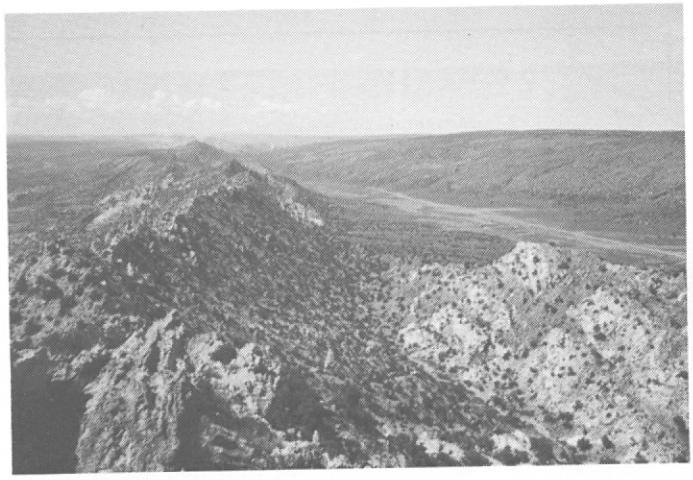


View westerly from Strawberry Point of the Pink Cliffs of the Claron Formation. One of Kane County's greatest assets are the beautifully exposed geologic formations.

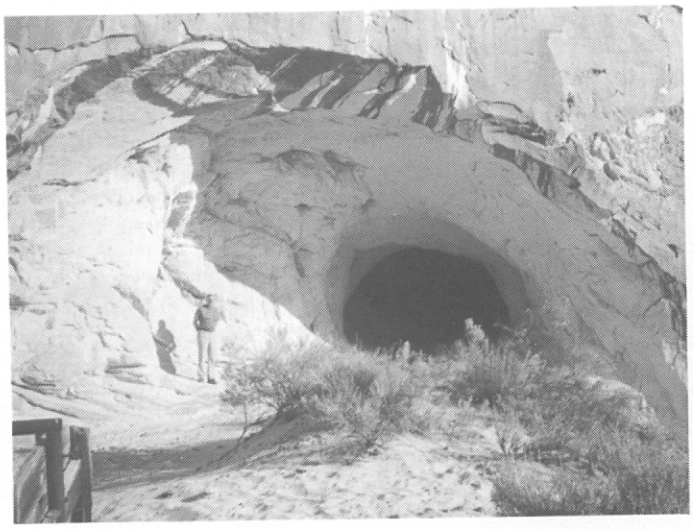
Exposure of the colorfully banded Chinle Formation as exposed near the ghost town of Paria.



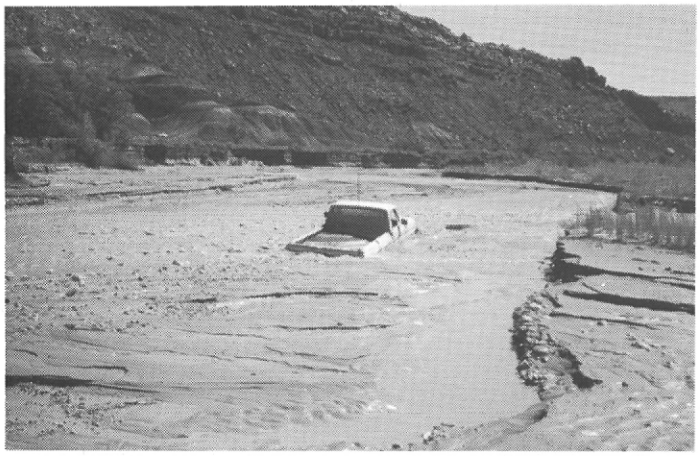
The oldest rocks of Kane County are exposed in Bucksckin Gulch in the south-central part. Shown here are the upper slope-forming and lower cliffy parts of the Toroweap Formation.



View southward along The Cockscomb looking at the whale-back of Buckskin Mountain. Kane County has its geology exposed along two such magnificent monoclines.



Entrance to an abandoned sand mine in the Lamb Pont Tongue of the Navajo Sandstone. Sand mines in Kane County have been opened as a source of silica, for colored sands to make decorative bottle fillings, and for picture rock.



Flash flooding is a perennial problem in Kane County. This unlucky tourist attempted to cross the Paria River to visit the old ghost town during flood. "Walls" of water several feet high often take out sections of dirt roads that parallel streams. It pays to heed the warnings, "impassable when wet."

Landslide problems along a state road. The active "Coal Hill" landslide area shifts the highway up to a foot annually. This photo shows the annual offset. The black asphalt softens the bump caused by the vertical displacement.

The "Coal Hill" landslide area—the old road, abandoned in 1963, is presently offset 19 feet and is cracked and undulating, excellently displaying the relentless damage.

Kane County contains all the ingredients for an important petroleum province: source rocks, reservoir rocks, and trapping mechanisms. Ideas and technology must team up with exploration capital for the petroleum wealth in Kane County to be found.

GEOLOGIC HAZARDS

Geologic hazards (figure 6) in Kane County include (1) Mass movements, (2) Swelling and shrinking rocks and soils, (3) Flash flooding, (4) Faults, earthquakes, and liquefaction, (5) Hydrocompaction, (6) Sand dune encroachment, (7) High ground water tables, and (8) Peat bogs. The first five hazards are deemed to be of most concern. The Spring, 1986 Survey Notes deals with Utah's geologic hazards.

1) Mass movements include rockfall, colluvium, creep, talus, detrital masses, and landslides of all types. Hundreds of active individual mass movement deposits, including two extensive mass movement zones, are present in the county. The "Coal Hill" mass movement area covers about 2.5 square miles and is located 6.6 miles west of Mt. Carmel Junction on State road 9. The area is termed a landslide complex because separate hummocky masses are found within it or adjacent to it. Each have different geometries and have undergone differential downslope movements. Some of the individual masses are blockslides, earthflows, slumps, and composite rotational slump-blocks. At present the largest mass movement area is between Meadow Creek and Little Meadow Creek. Two longitudinal shear faults were mapped in the southern part of the mass. These faults are 2,500 feet apart and the most active part of the slide is moving south between the faults. Regrading and resurfacing the highway cost about $150,000 in the spring of 1985. On May 30, 1986, there was 0.85 feet of horizontal and 0.4 feet of vertical offset on the new pavement at the west shear fault and at least 0.5 feet of offset at the east shear fault. Along the remains of the old roadway, which was abandoned in 1963, south of the present highway, the indicated offset is about 19 feet.
2) Formations and derived soils that contain either expansive clays or sulfates are the Tropic Shale, Dakota Formation, Carmel Formation, Chinle Formation, and Moenkopi Formation. Swelling and shrinking soils can be the cause for extensive damage to anything built by man.
3) Summer cloudburst floods are more recurrent and severe than floods associated with spring snowmelt, and flash floods can occur in, or issue from, nearly any canyon. Summer flash floods and erosion result in damages to Kane County roads that amount to $50,000 to $60,000 annually. Culverts and creek crossings on county roads are constantly in danger of being washed out. At times road sections, several hundreds of feet in length, have been destroyed. For years the abutments of the Hog Canyon bridge on U. S. Highway 89, two miles north of Kanab were weakened by flash floods. In 1985 a new bridge was built that cost approximately $300,000.
4) Western Kane County is within the Intermountain Seismic Belt. Within the county are the seismically active Paunsaugunt fault, the Johnson Canyon fault zone, the Kanab Creek fault zone, and the Sevier fault zone.
5) Covering large areas in the county are loose, dry, low-density alluvial deposits that compact when wet. As a precaution, and to minimize damage, wetting and precompacting these deposits before construction begins is a necessity.

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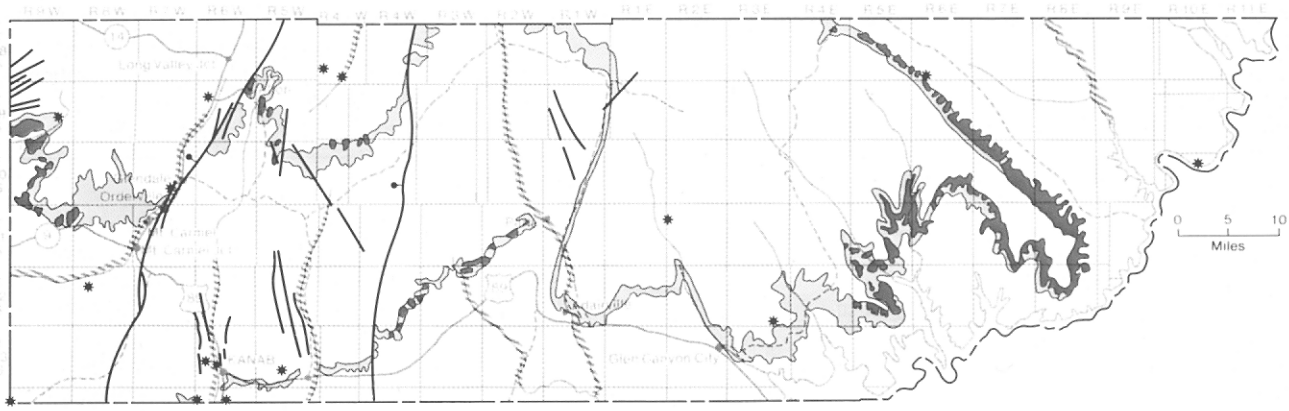


Earthquake epicenter.

Mass movement zones and larger mass movements.

Swelling and shrinking rocks and soils.

Flood-prone areas; mostly along major drainages. Does not include potential flash floods that can occur in, or issue from, any canyon.

Figure 6. Hazards map.

REFERENCES

Doelling, H. H., 1972, Central Utah coal fields; Sevier-Sanpete, Wasatch Plateau, Book Cliffs and Emery, 572 p.

Giardina, S., Jr., 1979, Geologic review of northwestern Arizona for petroleum exploration investigators: Arizona Oil and Gas Conservation Commission Special Puplication 4, 69 p.

Petroleum Information, Winter 1984, Kaiparowits Basin — an old frontier with new potential: Petroleum Frontiers, v. 1, no. 1, p. 4-25.

Sharp, G. C., 1976, Reservoir variations at Upper Valley field, Garfield County, Utah, *in* Symposium on Geology of the Cordilleran Hingeline: Rocky Mountain Association of Geologists, p. 325-345.

UGMS STAFF CHANGES

The following staff changes have taken place:

Miriam Bugden has left her geotech/receptionist post for motherhood and **Janine Jarva**, who held a similar post, is the new geotechnician for Applied Geology.

With the completion of the geothermal projects, **Karin Budding** is off to Menlo Park, California.

Doug Sprinkel, recently with the Placid Oil Co., has accepted the position of Senior Geologist for Applied Geology.

A former mapping geologist with UGMS, **Jack Oviatt,** is back for this summer to map in the Sevier Desert area.

NEW PUBLICATIONS

Maps

Map 80, *Geologic Map of the Circleville Mountain Quadrangle, Beaver, Piute, Iron and Garfield Counties, Utah,* by John J. Anderson, U.S. Geological Survey, 1986, two plates, four color, scale 1:24,000, with six page booklet. Price $5.00*.

Map 81, *Geologic Map of the Fremont Pass Quadrangle, Iron and Garfield Counties, Utah,* by John J. Anderson, U.S. Geological Survey, 1986, two plates, four color, scale 1:24,000, six page booklet. Price $5.00*.

Map 82, *Geologic Map of the Circleville Quadrangle, Beaver, Piute, Iron, and Garfield Counties,* by John J. Anderson and Peter D. Rowley, U.S. Geological Survey, 1986, two plates, four color, scale 1:24,000, five page booklet. Price $5.00*.

The above three geologic maps show a portion of the Marysvale volcanic field which straddles the High Plateau subprovince in southwestern Utah including the southeastern Tushar Mountain, a portion of the Markagaunt Plateau, and the Sevier River Valley (Long Valley) west of Circleville. The oldest rocks, exposed in the Fremont Pass quadrangle, are the fluvial and lacustrine sediments of the Claron Formation of early Tertiary age. Up to 7000 feet of Oligocene and Miocene volcanics have been measured, including lava flows, ash flow tuffs, and breccias. The only intrusive rock is the Spry intrusion, a quartz-latite porphry laccolith, exposed in the southeast edge of the quadrangle. Structurally, the area is dominated by NNE- and NNW-trending normal faults. Major movement was in Pliocene and Pleistocene time, and may continue today. Geologic hazards include possible earthquakes, floods and flash floods, and landslides. Small amounts of mercury, hematite, limonite, fluorite and gypsum have been reported at the contact of the Spry intrusion and the Claron Formation, but except for gravel and fill, no mineral production has been reported in the mapped area.

Open File Reports

Open File Report 89, *Geology of Active Uranium Mines During 1982 in Parts of Paradox Basin, Southeastern Utah: A Preliminary Review,* by Hasan Mohammad, 1986, 44 pages. Price: $3.00*.

The geology and uranium deposits near the Gibson Dome area were inventoried for the Paradox Basin U-waste isolation studies in 1982. Nine mines were active at that time, producing altogether about 2000 tons of ore per day. The ore occurs in the Permian Cutler Formation, Triassic Chinle Formation, and Jurassic Morrison Formation.

Open File Report 90, *Provisional Geologic Map of the Hells Kitchen Canyon SE Quadrangle, Sanpete County, Utah,* by Steven R. Mattox, 1986, 38 pages, tables and figures, two plates (black and white), scale 1:24,000. May be seen in UGMS library or University of Utah Marriott Library.

The Hells Kitchen Canyon SE quadrangle is located about 100 miles south of Salt Lake City on the southwest side of the Gunnison Plateau. About 4000 feet of Late Cretaceous and Eocene sediments exposed in the quadrangle record the waning activity of the Sevier

Continued on Page 10

Orogenic belt on the west and the infilling of the foreland basin and younger lakes.

Diskettes

The UGMS Great Salt Lake brine sampling data are now available on floppy diskettes. The two diskettes can be read and printed on any IBM PC or IBM PC-compatible system using PC-DOS or MS-DOS. Included are all the data in ***UGMS Open File Report 87,*** by Paul A. Sturm, Great Salt Lake specialist. Included with the diskettes are instructions for use, maps, a table from the original report, and printouts showing examples of typical report formats from basic and averaged data files. Price $5.00*.

This is the first of a series designed to make available information from the UGMS database for owners and users of IBM-compatible personal computers. Soon to be released will be specialized bibliographies (coal, geothermal and other mineral commodities) and other sampling data.

Miscellaneous

SSAC Reports, *Reprints of the Seismic Safety Advisory Council's Reports.* This series of reports was originally prepared in 1977-81 to provide assessment of various public facilities such as office buildings, schools, hospitals, utilities, dams and water supplies, and to give recommendations for risk reduction measures, such as building codes, in the event of damaging earthquakes. Price for the three-volume set is $30.00*.

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

BOOK REVIEW:

The *Geology and Geochemistry of Cenozoic Topaz Rhyolites from the Western United States,* by Eric H. Christiansen, Michael F. Sheridan and Donald M. Butt, 1986, 82 p., Geological Society of America Special Paper 205. Price is $16.00, postpaid for surface mail.

Topaz bearing rhyolites found widely distributed in the western United States, are characterized by a suite of minerals uncommon in silicic volcanics (topaz, fluorite, garnet, beryl, pseudobrookite and bixbyite), and have characteristic major as well as trace-element chemistry. Many are associated with mineral deposits of uranium, beryllium, fluorite and tin. Most occur as small volcanic domes and may have associated basalt flows.

Congratulations! Governor Bangerter presented **Gwen B. Anderson**, Budget and Accounting officer for UGMS, with a Certificate of Achievement for her dedicated effort which enabled the State of Utah to receive the highest honor for the 1985 Comprehensive Annual Financial Report.

UTAH EARTHQUAKE ACTIVITY

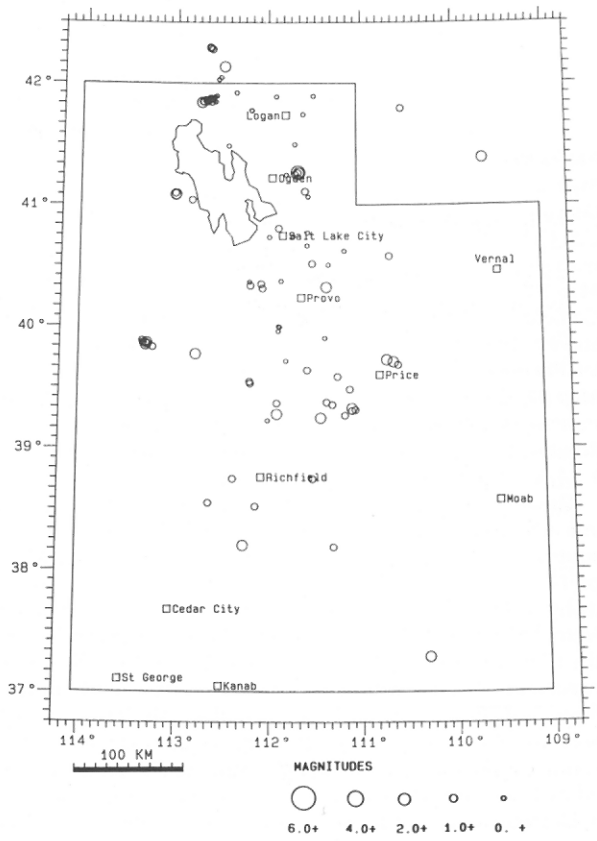
April through June 1986

By ETHAN D. BROWN

UNIVERSITY OF UTAH SEISMOGRAPH STATIONS
DEPARTMENT OF GEOLOGY AND GEOPHYSICS

THE University of Utah Seismograph Stations records an 81-station seismic network designed for local earthquake monitoring within Utah, southeast Idaho, and western Wyoming. During April 1 to June 30, 1986, 100 earthquakes were located within the Utah region including 18 greater than magnitude 2.0. The epicenters shown in the seismograph map reflect typical earthquake activity scattered throughout Utah's main seismic region. The largest earthquake during this time period, M_L 3.6, occurred 25 km southeast of Ogden, Utah on June 5. Although this earthquake was close to a populated area it was not reported felt.

Three clusters of epicenters shown here warrant mention. A cluster of nineteen earthquakes ($M_L \leq 2.3$) north of the Great Salt Lake occurred between April 5 and May 11. Spatial clusters in this area are common and have been observed since the 1975 Pocatello Valley earthquake. The cluster of five events located 25 km east of Ogden represents a sequence associated with the magnitude 3.6 earthquake mentioned above. All earthquakes in this group occurred on June 5, except for one preshock which occurred on May 24. A cluster of eight earthquakes ($M_L \leq 2.8$) shown in west-central Utah occurred between May 8 and May 28.



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

STATE OF UTAH
NATURAL RESOURCES
Utah Geological & Mineral Survey

Norman H. Bangerter, Governor
Dee C. Hansen, Executive Director
Genevieve Atwood, State Geologist

606 Black Hawk Way•Salt Lake City, UT 84108-1280•801-581-6831

Dear Fellow Geologists:

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

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

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

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

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

Genevieve Atwood

Genevieve Atwood, *Director*
Utah Geological and Mineral Survey

(Please pull out insert, fill out information and return to the UGMS)

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Investigator: _____

Organization/School: _____

Address: _____
City State Zip

Title/Subject: _____

Scope and class (i.e., detailed, reconnaissance, photo interpretation - with or without field checking, etc.): _____

Date of inception: _____

Date of proposed completion: _____

Probable location of information (i.e., University thesis, open-file - where; release date and provisions, where; state or technical agency - where; publication - where; company confidential.): _____

_____

May we have a copy of the completed report and map for our library: ☐ Yes ☐ No

What type of study? _____

☐ Geologic Mapping
Scale of map: _____

☐ Economic Geology
Commodities: _____

☐ Environmental Geology ☐ Engineering Geology

☐ Geochemistry ☐ Geophysics

☐ Hydrology ☐ Mineralogy ☐ Hard rock geology

☐ Paleontology
Formation, age: _____

☐ Quaternary Soils ☐ Petrology ☐ Volcanology

☐ Sedimentology ☐ Structural geology

☐ Stratigraphy
Formation, age: _____

☐ Other (please specify): _____

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Utah Geological and Mineral Survey
606 Black Hawk Way
Salt Lake City, Utah 84108-1280

Attn.: Information Section

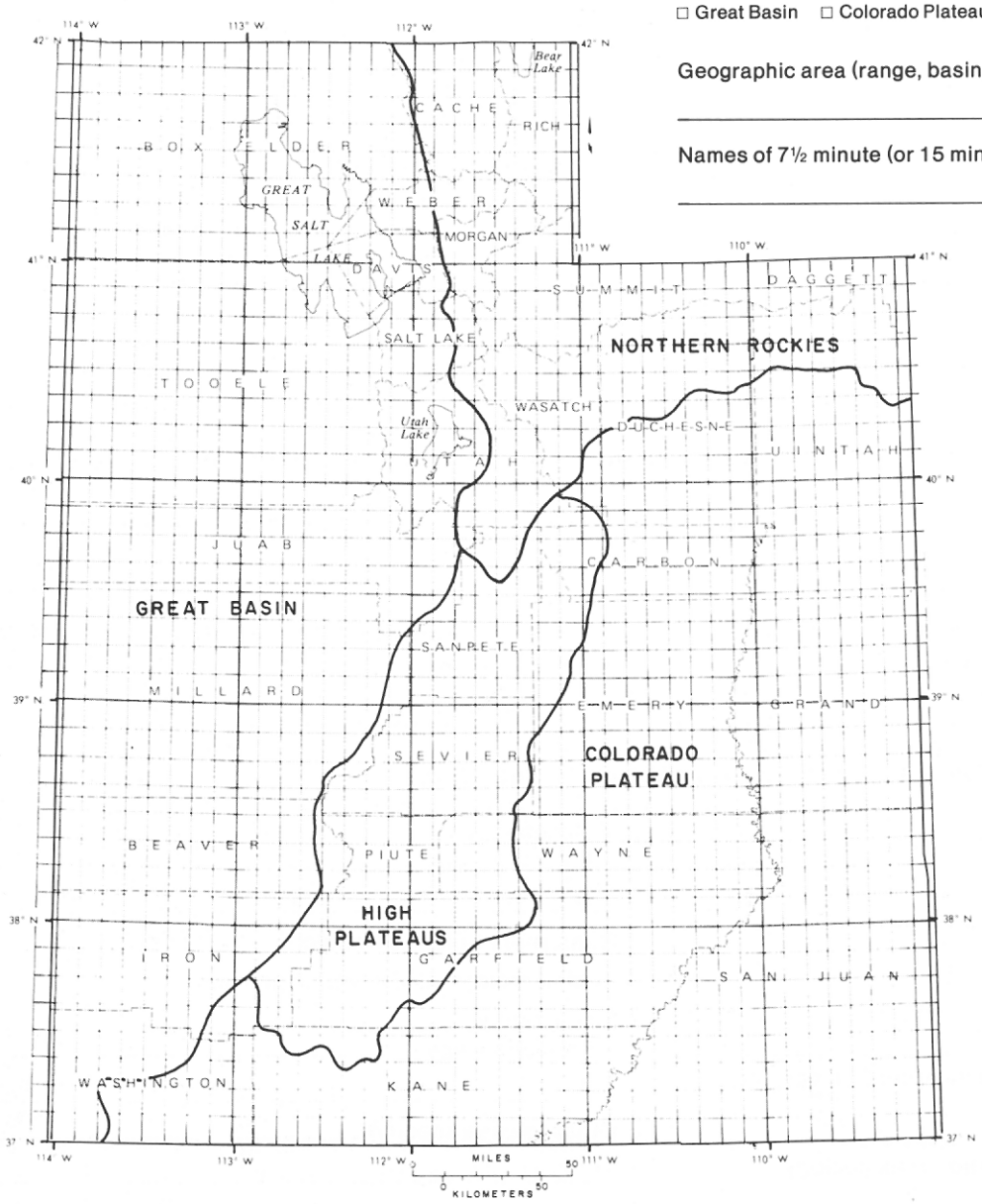
Please supply the following information, if applicable:

Principal physiographic provinces of Utah covered by this study:

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

Geographic area (range, basin, etc.): _____

Names of 7½ minute (or 15 minute) quadrangles: _____



Which Counties are covered by this study?
(please circle)

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

If possible, please fill in location of study area on this map of Utah. Each small square equals one 7½ minute quad.

NOTES ON THE HISTORIC HIGH LEVEL OF GREAT SALT LAKE

By DON R. MABEY

IN early June, 1986, the seasonal high level of the surface of Great Salt Lake was measured as 4211.85 feet above sea level. This exceeded by 0.95 feet the generally accepted value for the previous highest seasonal high ever measured, which was 4210.9 feet on June 30, 1876. The 1876 measurement was the first seasonal peak after the first lake-level gauge was installed on September 14, 1875. There is evidence that the high level of the lake in the last half of the nineteenth century occurred a few years before 1876. Considerable uncertainty exists as to what that highest level was and when that level was reached.

The very early historic data on the level of Great Salt Lake is fragmental and subject to differing interpretations. Several reports refer to an expedition of five trappers exploring the lake in the spring of 1826, but no contemporary reports contain first-hand observations of these men. In G.K. Gilbert's field notes for 1877 he records that a Mr. Carrington told him that trappers reported an unusually high lake level in 1833 and Gilbert thought that this might be the year the storm line was formed that Stansbury found at an elevation of about 4207 feet (Hunt, 1982). In 1846 James Clyman traveled around the south end of Great Salt Lake and wrote:

> Proceeded nearly east to the point of a high mountain that bounds the Southern part of the greate salt lake I observed that this lake like all the rest of this widespread Sterility has nearly wasted away one half of its surface since 1825 when I floated around it in my Bull Boate (Camp, 1960). (Clyman presumably refers to the 1826 exploration.)

Several of the islands in Great Salt Lake are connected to the mainland by bars and fords that provide access to the islands when the water is not too deep at the fords. By determining the water conditions at these fords from historic records the fluctuations of the elevation of the lake can be estimated. The approximate elevations of low point at two key fords are: Stansbury Island - 4206.7 feet, Antelope Island - 4199.7 feet. Referring to a conversation with a group of Indians in 1841, Osborne Russell wrote:

> The Chiefs son informed me he had come from the largest Island in the lake a few days previous having passed the winter upon it with his family which he had conveyed backwards and forth on a raft of bulrushes about 12 ft. square. He said there was large numbers of antelope on the Island and as there was no wood he had used wild Sage for fuel. The Old chief told me he could recollect the time when the Buffaloe passed from the main land to the island without swimming and that the depth of the waters was yearly increasing (Haines, 1955).

John C. Fremont used barometers to measure the elevation of the lake in September 1843 and concluded, "From a discussion of the barometrical observations made during our stay on the shores of the lake, we have adopted 4200 feet for its elevation above the gulf of Mexico" (Jackson and Spence, 1970). His journal report does not contain the information needed to estimate the accuracy of this determination. That he needed a boat to reach Fremont Island indicates that the lake was not at an extremely low level. In August 1846, Fremont rode his horse to Antelope Island and noted that the water nowhere reached above the saddle girths. This observation suggests an elevation a little above 4200 feet.

The first gauge to measure lake level fluctuations was installed at Black Rock in September 1875. This gauge was read periodically until November, 1877. New gauges were established in 1878, 1879, 1881 and 1886 and were read at irregular intervals. At that time there was no accurate sea level datum established in Utah so the readings provided only a relative elevation. In 1877, G.K. Gilbert and J.W. Fox set a block of granite furnished by Brigham Young as a "permanent" benchmark near Black Rock and by leveling determined the elevation of this benchmark relative to the Black Rock gauge. By leveling and simultaneous measurements, elevations of the other gauges relative to this "Black Rock bench" were determined.

To determine the approximate relative lake level before the first gauge was established, Gilbert interviewed ranchers who had been involved in moving livestock from the mainland to Antelope and Stansbury Islands. Gilbert determined that between 1847 and 1850 the bar connecting Antelope Island to the mainland was above water during the winter and covered by no more than 20 inches of water during the summer. From 1850 to 1855 or 1856 the water rose until the island could be reached only by boat in the summer and the bar was submerged in winter. The lake level than declined until in 1860 and 1861 when the Antelope Island bar was again exposed in the winter. Starting in 1862 the lake rose rapidly until 1868 with the ford to Antelope Island becoming impassable in 1865. Gilbert reports one source as stating "the rise was somewhat rapid until 1868 from which date until the establishment of the gauges, there occurred only minor fluctuations."

Relative to the period of high lake level Gilbert wrote:

> The Antelope Island bar thus affords a tolerably complete record from 1845 to 1865, but fails to give any later details. It happens, however, that the hiatus is filled at another locality. Stansbury Island is joined to the mainland by a similar bar, which was entirely above water at the time of Capt. Stansbury's survey, and so continued for many years. In 1866, the year following that in which the Antelope bar became unfordable, the water for the first time covered the Stansbury bar, and its subsequent advance and recession have so affected the pursuits of the citizens of Grantsville who used the island for a winter herd ground, that it will not be difficult to obtain a full record by compiling their incidental observations. While making the inquiry I had no opportunity to visit that town, but elicited the following facts by correspondence. Since the first flooding of the bar the depth of water has never been less than a foot, and it has never been so great as to prevent fording in winter. But in the summers of 1872, 1873 and 1874, during the flood stage of the annual tide, there was no access except by boat, and in those years the lake level attained its greatest height. In the spring of 1869 the depth was 4 1/2 feet, and in the autumn of 1877, 2 1/2 feet (Gilbert, 1890).

A hydrograph for the period 1847 to 1877 based on Gilbert's traditional data and two years of lake level measurements (fig. 1) was published in 1879 in Report on the Lands of the Arid Region of the United States (Gilbert, 1879). Gilbert constructed two hydrographs of Great Salt Lake based on the measurements after 1875 and the "traditional information." These hydrographs were published in USGS Monograph I (Gilbert, 1890). One covers the period from 1847-1882, the other from pre-historic to 1889. Gilbert's hydrographs show the seasonal peaks for the period 1868 through 1874 to cover a range of one foot. He stated that the lake attained its greatest height in the summers of 1872, 1873 and 1874, but apparently had no evidence other than the recollections of the Grantsville ranchers. There is no indication that Gilbert had any data indicating which of these years might have seen the highest lake level.

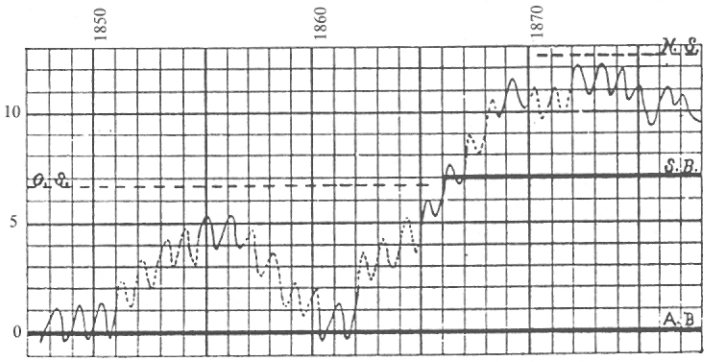


Diagram showing the rise and fall of Great Salt Lake from 1847 *to* 1877.

N.S. = Level of new storm line.
O.S. = Level of old storm line.
S.B. = Level of Stansbury Island bar.
A.B. = Level of Antelope Island bar.

Figure 1. G.K. Gilbert's (1877) hydrograph of Great Salt Lake.

Hydrographs of the lake published by the USGS in Water Supply Papers 330 and 333 cover the period from 1850 to 1913 (Henshaw and others, 1914) (fig. 2). These differ substantially from Gilbert's for the period between 1862 and 1875. These hydrographs credit Marcus E. Jones as the source of the information prior to 1875. The close correlation between the precipitation and lake level suggest that the lake level may have been based in part on the precipitation record. This pre-1913 hydrograph shows the highest level in 1868 and the second in 1877 and is not consistent with the measurements reported by Gilbert for 1876 and 1877.

In 1916, E.C. LaRue determined the elevation of the early gauges relative to sea level and was then able to convert the early lake level measurements. LaRue's records cannot be found and thus the accuracy with which the earliest measurements of the lake level are known relative to the current sea level datum cannot be determined. However, it is likely that elevations based on the early measurements are accurate to within a few tenths of a foot. Another hydrograph covering the period from 1851 to 1923 was published by the USGS in Water Supply Paper 517 in 1924 (Woolley, 1924). On this hydrograph LaRue is credited for the "traditional data" before 1875. For the period covered, this hydrograph is very similar to recent hydrographs prepared by the USGS and others (fig. 3) and indicates the lake elevation peaked in 1873 at an elevation about 4211.6 feet. No information is available on how LaRue prepared the pre-1875 part of the hydrograph but it appears to have been based on Gilbert's hydrographs.

The level of Great Salt Lake reached an historic low in the early 1960s and then rose several feet. In September 1982 the level was about 4200 feet, equal to the earliest historic estimates. A period of much above normal precipitation began with record rainfall in September of that year and the lake responded by rising more rapidly the next two years than at any time during the period for which measurements are available. Figure 4 shows the correlation of lake level with excess precipitation at the Salt Lake City International Airport in this wet cycle. A similar wet cycle in the 1860s was the cause of the lake rising to the high levels of the 1860s and 70s. In the five year period from 1865 through 1869, approximately 32 inches of precipitation in excess of normal was recorded at stations around Great Salt Lake and during this time the lake rose about 10 feet. In the four and one-half year period from 1982 through the first half of 1986, 32 inches of excess precipitation were recorded at the Salt Lake City airport and the lake rose about 11 feet.

The measured and traditional data on the level of Great Salt Lake are consistent with a maximum in the last half of last century occurring any time between 1869 and 1876 but most likely either in 1869 when Gilbert's reports indicated an elevation of about 4211.2 and when Marcus Jones concluded the level was highest, or in 1872, 1873 and 1874 when Gilbert reports that the Stansbury bar (elevation about 4207 feet) was covered with water to a depth that made it unfordable. The highest level was at least as high as the measured 1876 peak of 4210.9 feet above sea level and probably as high as the 4211.2 feet indicated by the water depth on the Stansbury bar in 1869. The maximum was not likely above the storm line observed by Gilbert on the east side of Antelope Island at an elevation of about 4213.5 feet (Gilbert, 1890) and was probably about one and a

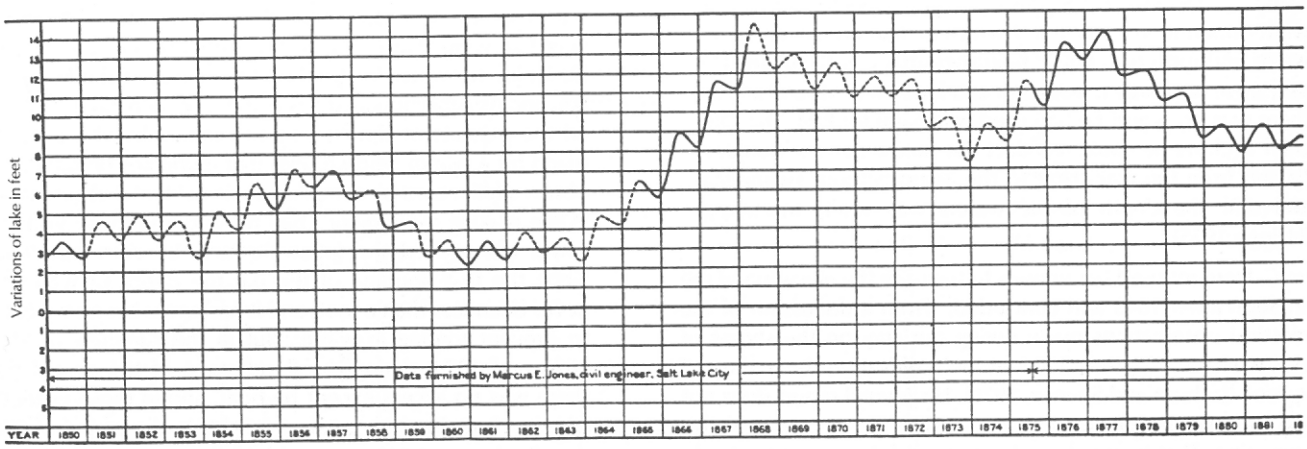


Figure 2. Hydrograph of Great Salt Lake from U.S. Geological Survey Water Supply Paper 330 (Henshaw and others, 1914).

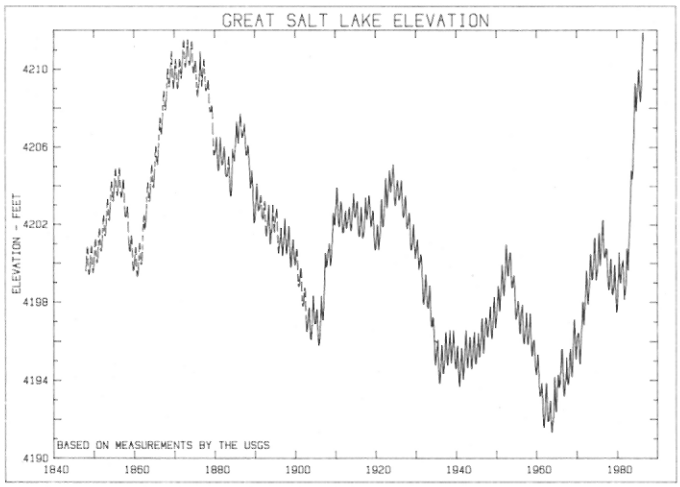


Figure 3. Current hydrograph of Great Salt Lake.

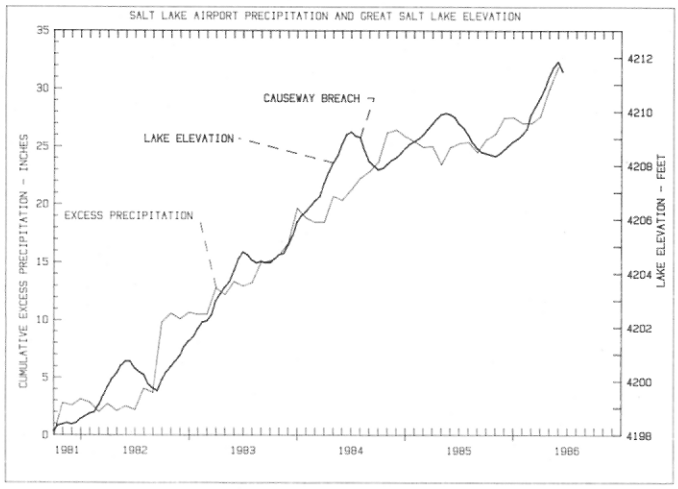


Figure 4. Elevation of Great Salt Lake and excess precipitation of the Salt Lake City International Airport.

half feet lower. In the spring of 1986 when the lake was at a level of 4211.85, a storm line was formed on the east side of Antelope Island at 4213.5 feet, the same elevation measured by Gilbert for the storm line formed in the 1870s. It thus appears that the historic high was probably between 4211.2 and 4212 feet above sea level. This is consistent with Ted Arnow's (1984) conclusion that the historic high was "about 4211.5 feet."

The historic high levels of Great Salt Lake appear to have been controlled entirely by weather. The historic high level, even if timing and elevation were precisely known, do not suggest the maximum levels that are likely to be reached in the present or future cycles of the lake. When the elevation of the lake increases from 4214 to 4217 feet, the lake extends over a large area of the Great Salt Lake Desert, increasing surface area and thus substantially increasing evaporation. In this elevation range the level of the lake tends to stabilize. Recent precision surveying of the desert surface south and southwest of the Newfoundland Mountains by the USGS has revealed that this expansion onto the Great Salt Lake Desert occurs in three stages at approximately 4214, 4215 and 4216 feet. Archeological evidence and analysis of lake sediments indicate that the lake reached an elevation of about 4217 feet within the last 400 years, probably about 300 years ago (Currey and others, 1984; McKenzie and Eberli, 1985). Unless substantial volumes of water are diverted from entering Great Salt Lake, the lake is likely to rise to near the 4217 foot level at some time in the future despite efforts to control the lake by diking or pumping water into ponds on the lake bed.

REFERENCES

Arnow, Ted, 1984, Water-level and water quality changes in Great Salt Lake, Utah, 1847-1983: U.S. Geological Survey Circular 913, 22 p.

Camp, C.L., 1960, James Clyman Frontiersman: Champoeg Press, 352 p.

Currey, D.R., Atwood, G., Mabey, D.R., 1984, Major levels of Great Salt Lake and Lake Bonneville: Utah Geological and Mineral Survey Map 73.

Gilbert, G.K., 1879, Water Supply *in* Powell, J.W., Lands of the arid region of the United States with a more detailed account of the lands of Utah: Government Printing Office, p. 57-80.

Gilbert, G.K., 1890, Lake Bonneville U.S. Geological Survey Monograph I.

Haines, A.L., 1955, Osborne Russell's Journal of a Trapper: Oregon Historical Society, 179 p.

Henshaw, F.F., Portor, E.A., Stevens, G.C., 1914, Surface water supply of the United States 1912, Part X, The Great Basin: U.S. Geological Survey Water Supply Paper 330, 275 p.

Hunt, C.B., 1982, Pleistocene Lake Bonneville, ancestral Great Salt Lake, as described in the notebooks of G.K. Gilbert, 1875-1880: Brigham Young University Geology Studies v. 29, pt. 1, 231 p.

Jackson, Donald, and Spence, M.L., 1970, The expeditions of John Charles Fremont, Volume I, travels from 1838 to 1833: University of Illinois Press, 854 p.

McKenzie, J.A., and Eberli, G.P., 1985, Late Holocene Lake-level fluctuations of the Great Salt Lake (Utah) as deduced from oxygen-isotope and carbonate content of cored sediments, *in* Kay, P.A. and Diaz, H.F., eds., Problems of and prospects for predicting Great Salt Lake levels: University of Utah Center for Public Affairs and Administration, p. 25-39.

Woolley, R.R., 1924, Water powers of the Great Salt Lake basin: U.S. Geological Survey Water Supply Paper 517, 270 p. ■

FROM THE DIRECTOR'S DESK

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dicates that ages of a layer of these fauna show that the lake has not risen above 4228 or 4230 feet since the Gilbert stage approximately 10,000 years ago. That may not seem reassuring, however, it means that our climate has to change considerably from what it has been for 10,000 years in order for the lake to continue its upward rampage beyond the 4230 foot level.

Archeological evidence... some of the Indians that lived in the Great Basin hunted, camped, and lived near the lake. By means of sophisticated laboratory techniques as well as by the type of arrowheads and tools they used, we can date approximately when they camped along the banks of the lake. From this archeologic evidence, it appears that camping areas of Indians living on the Weber River delta near the lake were inundated by the rise of the lake probably less than 400 years ago. Geologists have concluded that this rise took place 300 to 400 years ago during the "Little Ice Age" that affected the world's climate and was documented in detail in Europe.

Geometry of the lake's bed...the lake bed's topography results in very different volume to surface area ratios at different lake levels. As the lake rises, it spills into basins to the west and south and its surface area increases considerably. With better understanding of the detailed topography of the West Desert area, we now distinguish three thresholds that the lake crosses on its way to a level of 4217 feet: a threshold at

4214-4215 feet that enters a very small basin to the southeast of the Newfoundland Mountains, a larger basin to the west of the Newfoundland Mountains controlled by a 4215-4216 foot threshold that will be used by West Desert pumping, and a 4216 foot threshold southwest of there that allows the lake to flood the Bonneville Salt Flats and associated area. At that stage, the lake's surface area is 140% of its surface area at 4202 feet. This greatly increased surface area seems to result in a stabilization of the lake at approximately the 4217 foot level.

So what does all this tell us about the present rise of the lake? Most importantly, it tells us that the lake's present behavior is completely "normal" and this rise is not just a unique phenomenon of the 1980's ...the lake can be expected to rise to this level, and somewhat higher, again and again over the next few centuries. Its geologic history seems to indicate a behavior of not exceeding the 4217 foot level in recent centuries because of the shape of its basin. If we lived in Europe, historians would have recorded this level at least once in detail during the 1600s or 1700s and if we lived in China several such episodes would be recorded.

These multiple lines of evidence also do not support the argument that the lake could take off and fill to where it spills north into the Snake River drainage (4,740 foot level). Most importantly, the geologic information coupled with the historic records gives substance to arguments for a "planning" level of the lake. Unlike statistical projections based on the historic record that provide probabilities, the geologic record provides evidence that the 4217 foot level will not be exceeded without some change in our climate. The UGMS supports Comprehensive Emergency Management's suggestion for a Beneficial Development Area up to 4217 feet as a state, local, and federal government policy. We also urge policymakers to make less use of probabilities based on 140 years of historic observation. Is it more important to know the chances in 10 or 100 or 10,000 of what the lake level could be next year? or the year after? or to know where the lake will go during the forseeable lifetime of our community? As for projections of the lake's level for just the next year, we think it makes more sense to project the range of the lake's peak for the next year assuming the driest and wettest weather reasonable. Each month the forecast range would be revised and the prediction would be narrowed. Reduction in lake level through pumping could be factored into this type of forecast. This would provide everyone with better information upon which to base decisions.

As for pumping to the West Desert, it is an artificial way to increase the surface area of the lake to stabilize it at a lower elevation (4211 ± feet) than it would stabilize without the pumping. It surely will slow the rise of the lake and could be successful in keeping the lake from rising above the 1986 high, at least for this cycle.

Earthquakes and Other Hazards

We also remind policymakers that although there is no reason to think that the wet weather or recent rise of the lake significantly increases the likelihood that an earthquake will occur, the effect of an earthquake would be most severe when the lake is high, most reservoirs are full, and the soils are saturated. The effect of liquefaction caused by even a moderate earthquake should be considered in any plan to control the lake by building structures on the lake bed. Dikes that are not engineered to withstand liquefaction would likely fail in a liquefaction event, thus changing what is presently a property damage hazard into a life safety hazard.

Every proposal to construct a major dike or causeway in the lake also should include an evaluation of the effect of the seiche hazard, the water waves created in a lake by an earthquake. The USGS stated that the 1909 Hansel Valley earthquake "sent seiche waves over the railroad causeway at the north end of Great Salt Lake...." The lake level then was approximately 4200 feet. Lake control measures also should consider the impacts of the lake shifting to the east because of tilting of the lakebed as a result of an intense earthquake along the Salt Lake or Ogden segments of the Wasatch Fault.

Even without an earthquake the rise of the lake poses peripheral concerns. Rises in ground water associated with wet conditions and the rise of the lake result in flooded basements, flooded septic systems, surfacing sewage, and other public health problems. It should be remembered in any diking project that the manipulation of the lake waters and other surface waters impacts the ground water, and some of these problems could be serious.

In conclusion, geologic information is required to understand the flooding hazard of the rise of the lake and the solutions we devise to control it; no matter whether these solutions are pumping, diking, diverting drainage, or constructing dams. As we take action on the lake and other problems caused by geologic hazards, we should attempt to understand the possible consequences of our actions. ■

Genevieve Atwood

GREAT SALT LAKE LEVEL

Date (1986)	Boat Harbor South Arm (in feet)	Saline North Arm (in feet)
Apr 1	4210.50	4209.55
Apr 15	4210.85	4209.80
May 1	4211.30	4210.25
May 15	4211.65	4210.50
June 1	4211.80	4210.80
June 15	4211.50	4210.70
July 1	4211.40	—
July 15	4211.30	4210.45

Source: USGS provisional records.

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