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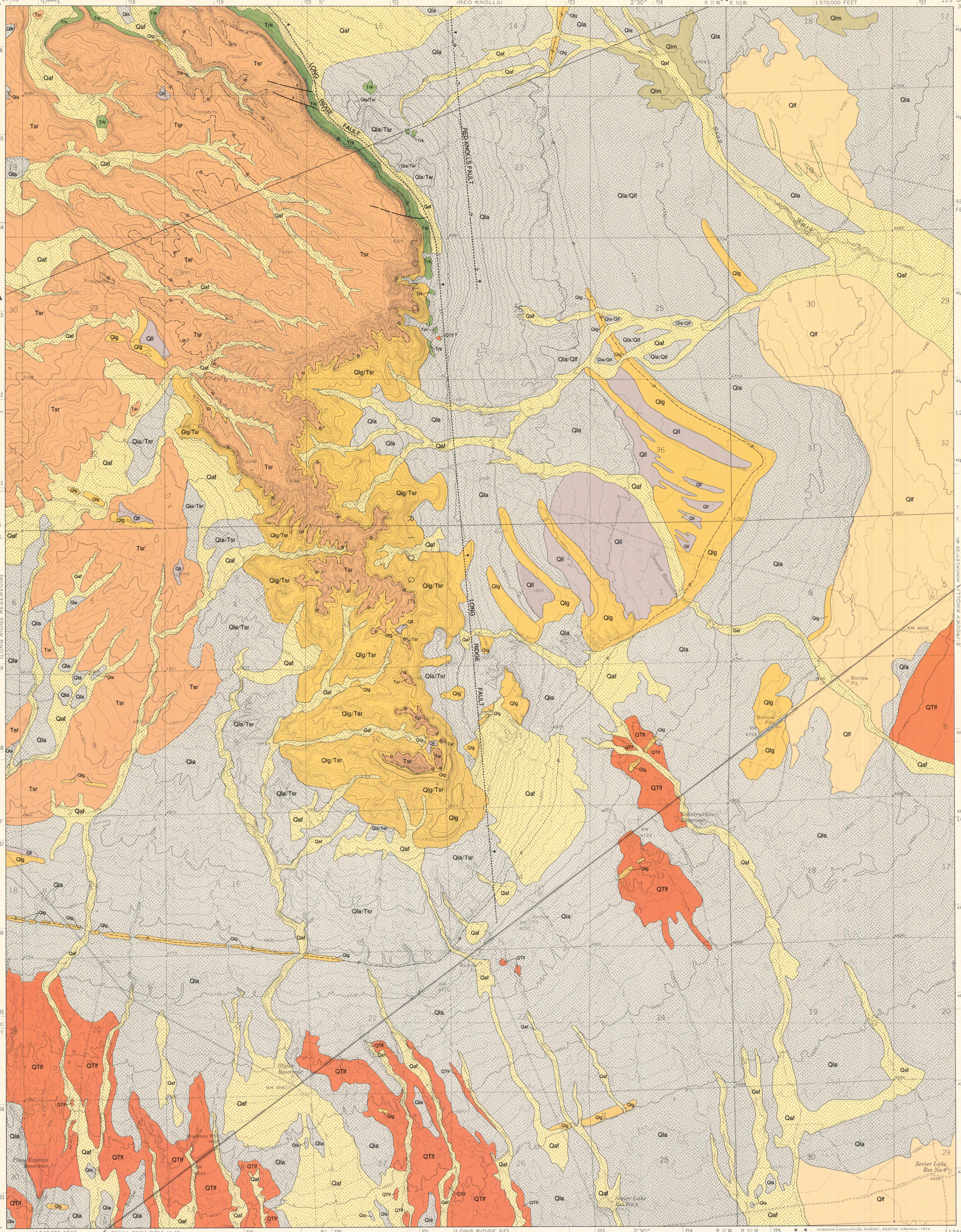
Plate 1
Utah Geological Survey Map 141
Geologic Map of the Long Ridge Quadrangle



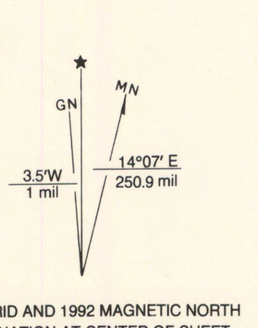
Base map from U.S. Geological Survey
Long Ridge 7.5' Quadrangle, 1972

Lori J. Douglas, Cartographer

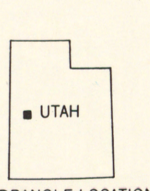
SCALE 1:24 000

1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929



UTM GRID AND 1992 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET



QUADRANGLE LOCATION

GEOLOGIC MAP OF THE LONG RIDGE QUADRANGLE, MILLARD COUNTY, UTAH

by
L.F. Hintze and F. D. Davis

1992

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Description of Map Units

Qaf Alluvial deposits in washes and on fans — *Silt, sand, and gravel deposited on piedmont slopes after regression of Lake Bonneville. Locally a few tens of feet thick.*

Qlf Fine-grained lacustrine deposits — *Clay, silt, and sand deposited in ephemeral lakes; locally may include minor evaporites. Interfingers with alluvium at edge of lake flats. May be a few tens of feet thick.*

Qll Lacustrine lagoon deposits — *White, tan, or light-gray fine sediments deposited in lagoons behind gravel bars of Lake Bonneville (Qlg) at many levels. Most deposits less than 10 feet (3 m) thick.*

Qlm Lacustrine marl — *White to light-gray, fine-grained, thinly bedded to laminated marl deposited in Lake Bonneville. As much as 12 feet (3.6 m) thick locally.*

Qlg Lacustrine gravel — *Sandy, pebbly, cobbly, and bouldery deposits along Lake Bonneville shorelines at many levels. Where shore impinged against Tsr these deposits are exceptionally bouldery. Individual shoreline deposits are usually less than 20 feet (6 m) thick.*

Qla Lacustrine and alluvial deposits undifferentiated — *Deposits on piedmont slopes where pre-Lake Bonneville alluvium has been reworked but where the lacustrine component is thin. Pre-Bonneville fan deposits may be several hundred feet thick locally.*

QTlf Older fine-grained lacustrine deposits — *Pre-Bonneville marly clay that is light red, light yellowish-gray, brownish gray or very light gray. Occupies low part of Sevier Lake Basin. May be a few hundred feet thick.*

Tsr Skull Rock Pass Conglomerate — *Unsorted, uncemented bouldery conglomerate with a partly bentonitic, silty to fine sandy matrix. Matrix erodes away to leave desert armor of cobbles and boulders almost all of which were derived from Cambrian, Ordovician, and Silurian strata west of the quadrangle. Conglomerate is more than 310 feet (95 m) thick.*

Trk Red Knolls Tuff — *Pink, crystal-rich, ash-flow tuff with various degrees of welding and resistance to erosion. Basal vitrophyre present locally; fiamme abundant in some horizons; lithic fragments widespread except near top. Tuff is about 200 feet (61 m) thick; thins southward and westward. Base not exposed.*

Explanation of Map Symbols

Geologic contact — *Dashed where less certain.*

Normal fault — *Bar and ball on downthrown side; dashed where inferred, dotted where concealed.*

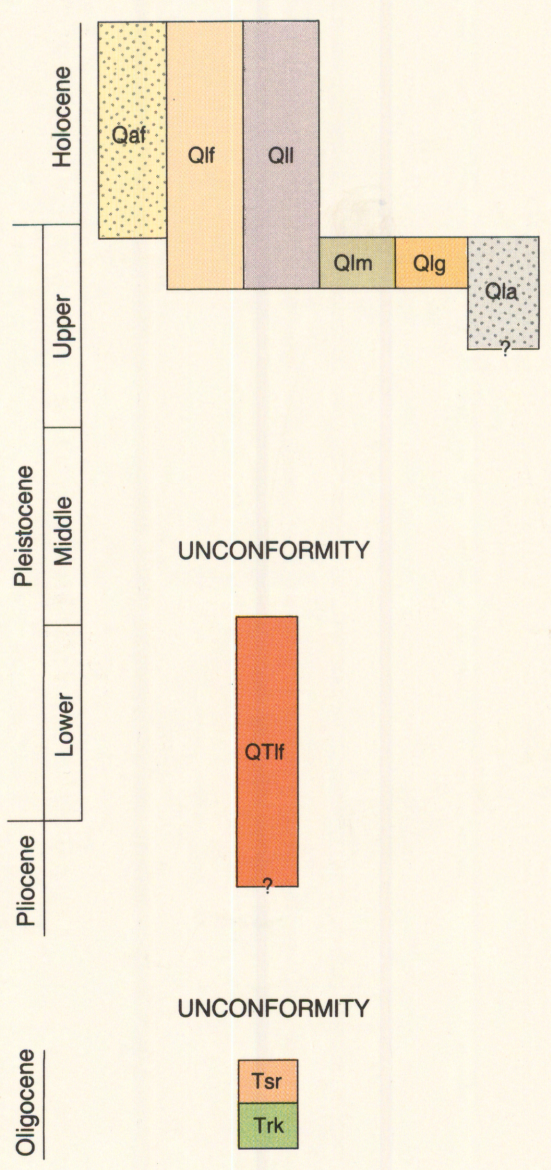
Provo shoreline of Lake Bonneville — *dotted where indistinct; about 4,787 feet (1,459 m).*

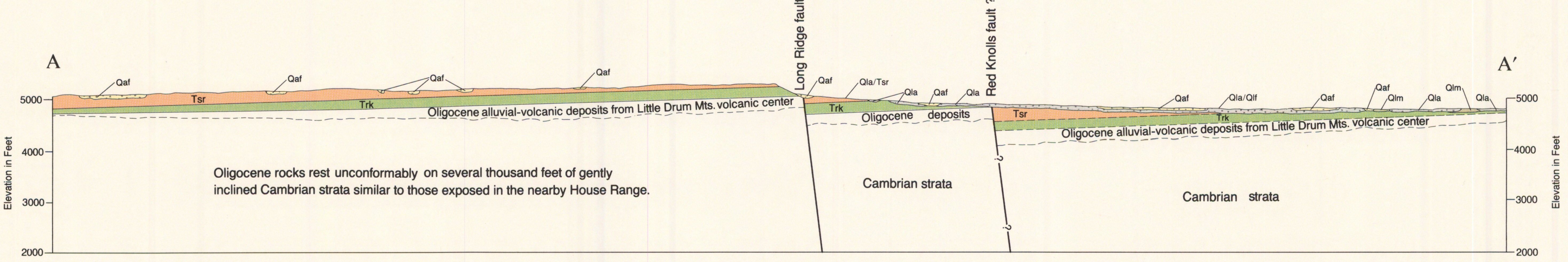
Bonneville shoreline of Lake Bonneville — *Elevation about 5,170 feet (1,576 m).*

Qlg/Tsr Surficial deposit is Qlg and underlying unit is Tsr. *Used where the surficial unit is thinner than in areas where it is mapped separately.*

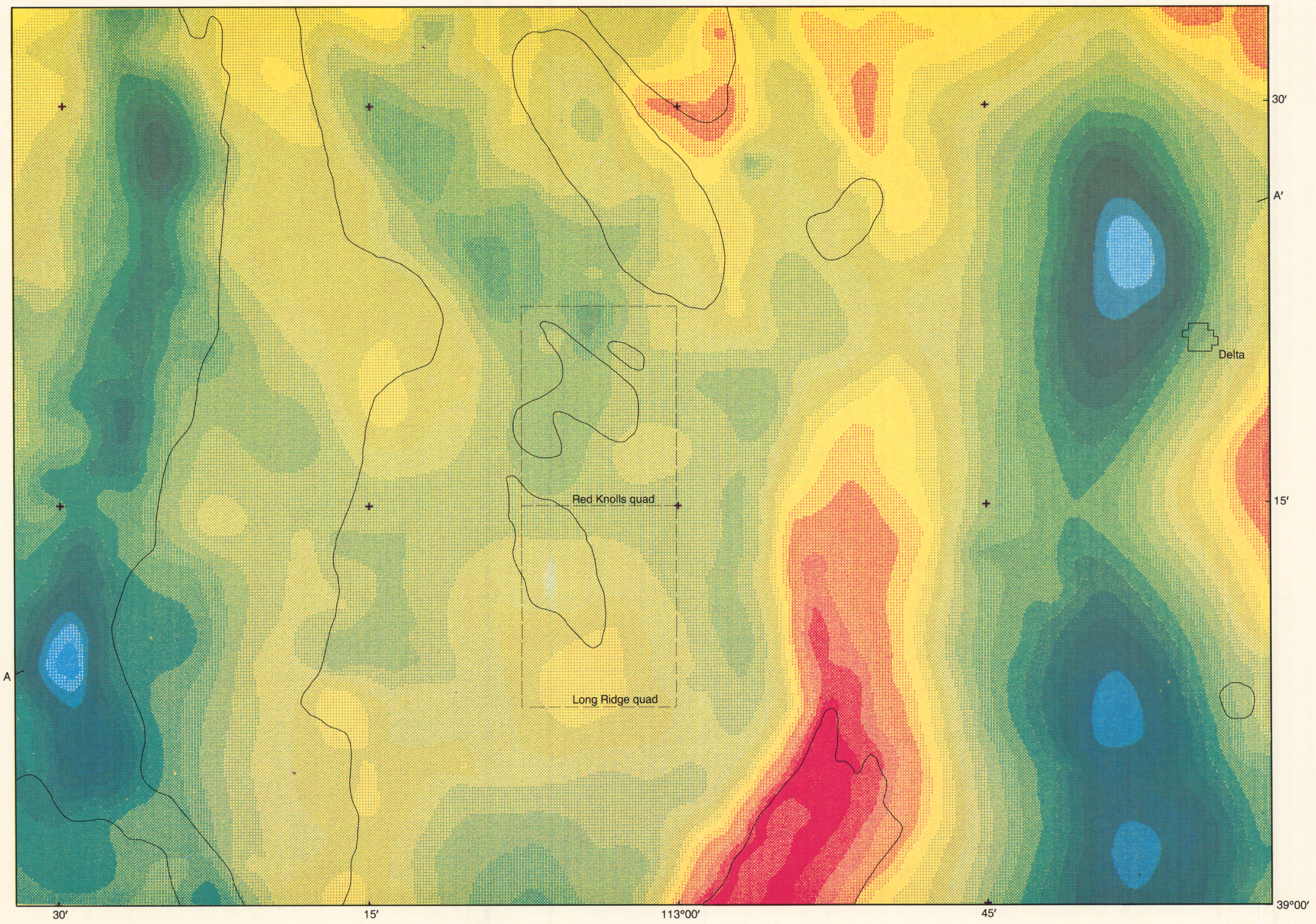
	Formation	Map Symbol	Thickness in Feet (m)	Lithology
OLIGOCENE	Skull Rock Pass Conglomerate	Tsr	320 (98)	top eroded; bentonitic matrix locally; boulders up to 15 feet (4.6 m) across occur rarely
				unconformity
	Red Knolls Tuff	Trk	200+ (61+)	local fiamme layers

Correlation of Map Units





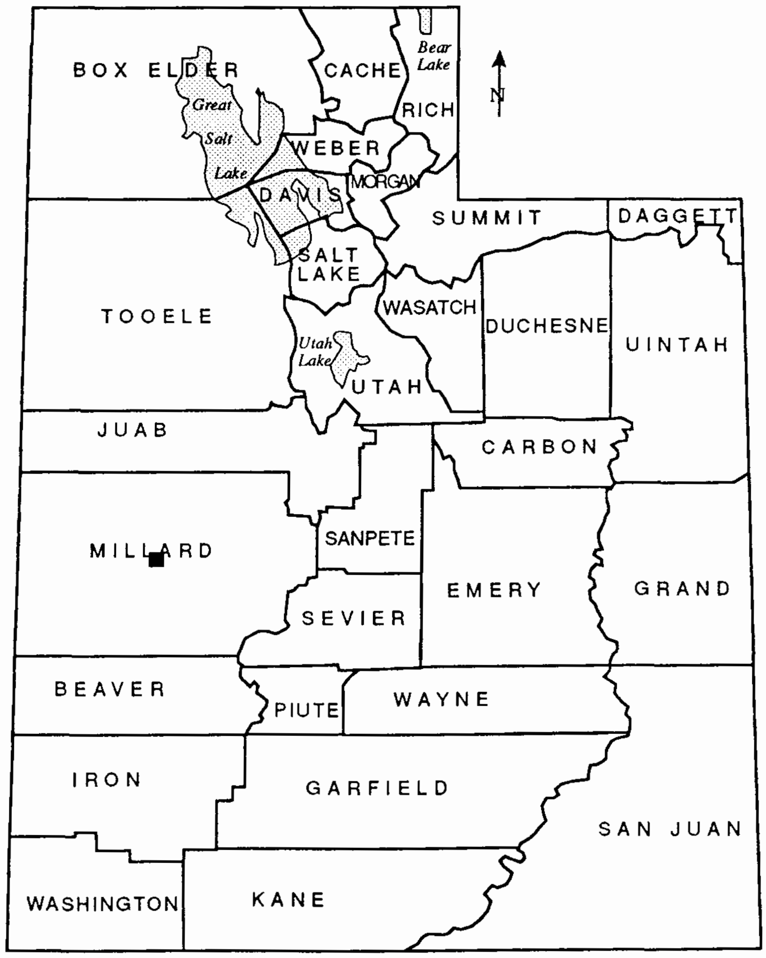
Scale 1:24,000. No vertical exaggeration.



Bouguer gravity map scale 1:250,000. This is part of an unpublished map of the Delta quadrangle prepared by the U.S. Geological Survey for the Delta CUSMAP minerals appraisal study. Furnished by David Campbell. Blue in deepest basins is minus 202 to 204 mgal; highest red value is minus 158 to 160 mgal. Black lines outline the bedrock exposures as identified in figures 1 and 7. Line of section of figure 8 is indicated; locations of Red Knolls and Long Ridge quadrangles are shown.

GEOLOGIC MAP OF THE LONG RIDGE QUADRANGLE, MILLARD COUNTY, UTAH

by
Lehi F. Hintze and Fitzhugh D. Davis
Utah Geological Survey



MAP 141 **1992**
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Hintze and Davis GEOLOGIC MAP OF THE LONG RIDGE QUADRANGLE, MILLARD COUNTY, UTAH UGS Map 141

Hintze and Davis

GEOLOGIC MAP OF THE LONG RIDGE QUADRANGLE, MILLARD COUNTY, UTAH

GEOLOGIC MAP OF THE LONG RIDGE QUADRANGLE, MILLARD COUNTY, UTAH

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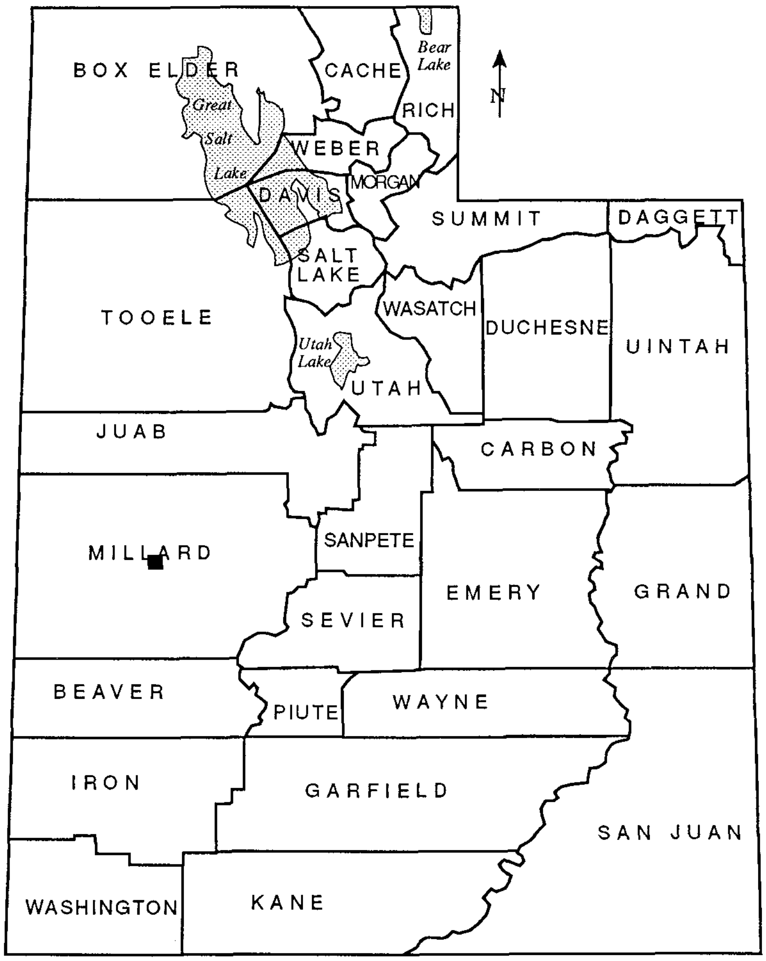

UGS Map 141

MAP 141 1992
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UTAH GEOLOGICAL SURVEY

2363 South Foothill Drive
Salt Lake City, Utah 84109-1491

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GEOLOGIC MAP OF THE LONG RIDGE QUADRANGLE, MILLARD COUNTY, UTAH

by
Lehi F. Hintze and Fitzhugh D. Davis

ABSTRACT

Pre-Quaternary bedrock exposed in this quadrangle consists of more than 500 feet (152 m) of nearly flat-lying Oligocene volcanic and sedimentary deposits divided into two formations. Oldest is the Red Knolls Tuff, a pink dacite ash-flow deposit more than 200 feet (61 m) thick, probably derived from the Drum Mountains area to the north. This is overlain by the Skull Rock Pass Conglomerate (new name), an unstratified, uncemented diamictite that consists mostly of Paleozoic carbonate and quartzite boulders and cobbles in a matrix of smaller clasts and comminuted clayey material derived from the weathering of volcanic rocks.

An older, fine-grained lacustrine deposit, pink, and locally cut by gypsum veins, is exposed in the southern part of the map around the margins of Sevier Lake. It is a pre-Lake Bonneville deposit that occurs in this quadrangle below 4,800 feet (1,463 m) elevation. Only a few tens of feet are exposed.

Most of the quadrangle is covered by various thin deposits of Lake Bonneville which existed here between 30,000 and 10,000 years ago. Only the highest portion of Long Ridge, above 5,170 feet (1,576 m) elevation, was untouched by the lake. The Provo shoreline of Lake Bonneville is marked by prominent gravel bars at an elevation of about 4,785 feet (1,459 m). Lake Bonneville wave action substantially modified the distribution of boulders and cobbles of the unconsolidated Skull Rock Pass Conglomerate on the east and south flanks of Long Ridge. The west slope of Long Ridge was much less affected by lacustrine erosion, apparently not having been subjected directly to storm waves.

There are no perennial sources of water in the quadrangle. Flash flooding is the most common natural hazard; the drainageway with the largest upstream catchment is Soap Wash. Earthquakes could occur here but the likelihood for significant earthquake damage is small because, except for U.S. Highway 6-50, there is no significant development in the quadrangle.

Pea-gravel from Lake Bonneville shorelines is the only mineral resource that has been developed in the quadrangle. Potential for metallic mineral production is slight; petroleum potential is also slight.

INTRODUCTION

Long Ridge (highest elevation, 5,329 feet (1,624 m) rises about 700 feet (213 m) above the floor of the Sevier Desert some 30 miles (48 km) west of Delta, Utah (figure 1). The Sevier Desert is a broad basin and range valley in which Quaternary surficial deposits conceal relationships of Tertiary and older rocks beneath. Interest in and ideas on the origin of the Sevier Desert basin have increased because of the recent availability of regional geophysical data: 1) the National Science Foundation-funded COCORP deep seismic-reflection survey (Allmendinger and others, 1983), 2) the U.S. Geological Survey's aeromagnetic and Bouguer gravity maps of the Delta 2-degree CUSMAP project (Hintze, 1986), and 3) shallow seismic data produced commercially and released through studies by McDonald (1976) and Planke (1987). Oligocene bedrock exposed on Long Ridge constrains subsurface interpretations of geophysical data by showing that the west edge of the Sevier Desert is not underlain by late Cenozoic valley fill; instead Long Ridge is probably underlain by more than 1,000 feet (305 m) of Oligocene conglomerate and tuff that rests directly on lower Paleozoic, probably entirely Cambrian, strata, as indicated by bedrock exposed in adjacent areas.

No previous geologic map of this quadrangle has been published except for reconnaissance mapping done in connection with regional map compilation (Hintze, 1963). Quadrangles to the west (Hintze, 1974b) and southwest (Hintze, 1974a) have been mapped, and Oviatt (1989) mapped and described Quaternary deposits of the Sevier Desert just east of this quadrangle. One of us (Davis) mapped the Quaternary deposits in the quadrangle during the 1987 field season, and the other (Hintze) mapped bedrock units of this area in the summer of 1988. Field work was facilitated by availability of excellent 1:25,000 color aerial photographs taken for the U.S. Department of Defense mobile missile site evaluation project in 1978.

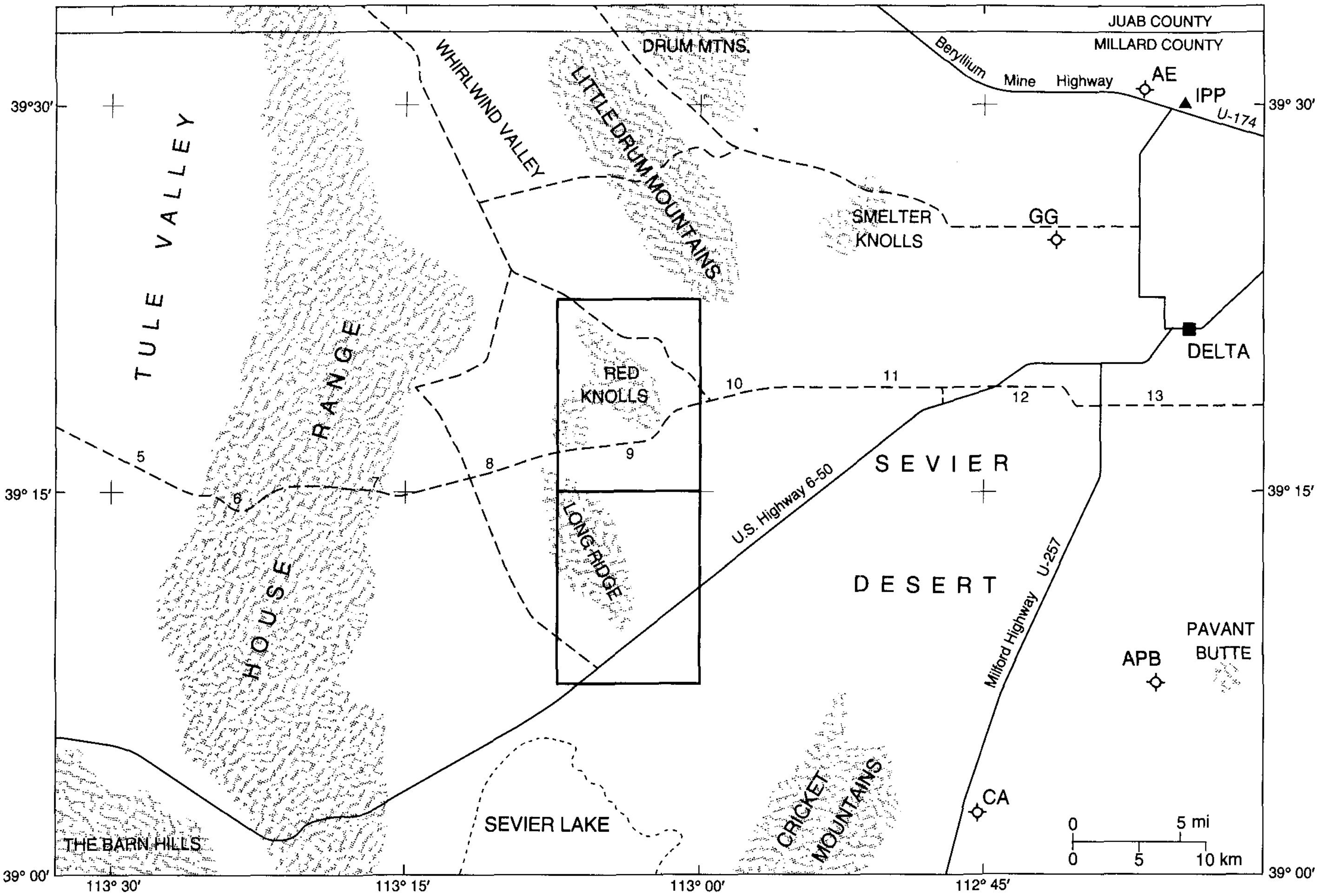

Figure 1. *Map of north-central Millard County showing location of Red Knolls and Long Ridge 7.5-minute quadrangles with respect to adjacent mountains and valleys. Paved highways are solid lines; selected graded dirt roads are dashed lines. AE, Argonaut Energy well; GG, Gulf-Gronning well; CA Cominco-American well; APB, Arco Pavant Butte well; IPP, Intermountain Power Plant. Numbers 5-13 along the east-west road across the middle of the map are reference points for the COCORP geophysical deep seismic-reflection traverse (Allmendinger and others, 1983).*

STRATIGRAPHY

Pre-Quaternary rocks exposed in this quadrangle are entirely Oligocene in age and divided into two units. Oldest is the Red Knolls Tuff which is overlain by the Skull Rock Pass Conglomerate (figure 2). Oligocene volcanic rocks and related sedimentary deposits are generally less than 1,000 feet (305 m) thick where exposed in western Millard County (Hintze, 1988) and everywhere rest with angular discordance on tilted Paleozoic marine strata (Hintze, 1980). Oligocene rocks in this quadrangle likely conform to this regional pattern although the Tertiary/Paleozoic contact is not exposed here. The Red Knolls Tuff is an ash-flow tuff probably derived from the Drum Mountains area (figure 1). The Skull Rock Pass Conglomerate contains almost no cobbles and boulders of igneous rocks; and most of its clasts came from lower Paleozoic formations now exposed in the House and Confusion Ranges to the west. Its matrix includes comminuted volcanic debris, much of which was derived from weathering of the Red Knolls Tuff. Skull Rock Pass Conglomerate and Red Knolls Tuff are new names formally proposed in this report and in the concurrent UGS report on the Red Knolls quadrangle (Hintze and Davis, 1992) to replace previously used informal designations.

Formal names have not been applied to Quaternary units shown on the map. Rather, they are described according to mode of origin such as alluvial or lacustrine, and by type of material. Most of this quadrangle is covered by an irregular veneer of lacustrine and alluvial deposits, less than 100 feet (30 m) thick, formed in Lake Bonneville or along its shores approximately 30,000 to 10,000 years ago. These deposits have suffered some subsequent erosion.

Where Lake Bonneville wave action modified the bedrock units to the extent that their surface exposure was largely reworked, we have used a combination symbol showing both the bedrock and Quaternary designations. For example, Qlg/Tsr indicates that Tsr has been significantly reworked by lake processes, and the present boulder and cobble distribution is late Quaternary in age.

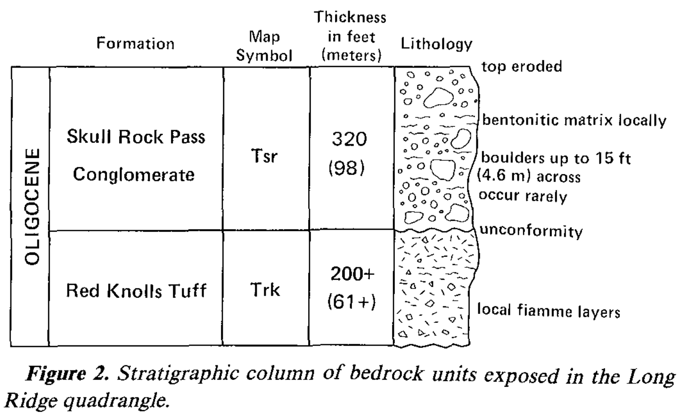

Figure 2. *Stratigraphic column of bedrock units exposed in the Long Ridge quadrangle.*

OLIGOCENE DEPOSITS

Red Knolls Tuff (Trk)

Red Knolls Tuff is exposed along the northeast face of the Long Ridge escarpment where its base is concealed by Quaternary deposits. It is a light-gray to grayish-orange-pink, non-resistant, crystal-rich dacite tuff that contains abundant lithic fragments except near its top; lithics are mostly of volcanic rock of generally similar composition. Phenocrysts comprise about half of the rock and are, in decreasing order of abundance, plagioclase, biotite, quartz, and hornblende, with a trace of augite. Type area for this formation is in the Red Knolls quadrangle (Hintze and Davis, 1992) which lies immediately north of this map. In degree of welding, the Red Knolls Tuff ranges from friable to partly glassy to densely welded. Massive portions near the top show exfoliation weathering, but less-welded zones show a honeycomb surface of cavities a few inches to a few feet in diameter. Breakup of this tuff has furnished much of the fine matrix of the overlying Skull Rock Pass Conglomerate, although coherent clasts of Red Knolls Tuff are extremely rare in the conglomerate. Because the base of the tuff is buried in this quadrangle, its total thickness is not known; in the adjacent Red Knolls quadrangle it is 210 feet (64 m) thick (Hintze and Davis, 1992).

Skull Rock Pass Conglomerate (new name) (Tsr)

This is an unsorted, uncemented, cobble and boulder conglomerate in a slightly bentonitic, silty to fine-sandy, matrix which weathers light yellowish to reddish gray. Matrix usually makes up 10 to 20 percent of the deposit, but locally it may make up as much as 80 percent and consists of weathered or comminuted volcanic rock. Clasts in the conglomerate are almost entirely of Paleozoic sedimentary rocks, mostly limestone and dolomite derived from Cambrian through Devonian units. Eureka Quartzite boulders are a conspicuous constituent and locally constitute up to 5 percent of the conglomerate. Clasts range in size from pebbles to boulders (figure 3) as much as 15 feet (4.6 m) long; roundness varies from subangular to well rounded, but subrounded is most common. Igneous rocks constitute less than one percent of the megaclasts; rare boulders of Jurassic granite from the House Range were noted, and dark basaltic andesite boulders from the Little Drum Mountains are present locally in the deposit. The unsorted, unstratified nature of the Skull Rock Pass Conglomerate suggests that it was deposited as mudflows or debris flows on an alluvial apron.

The term "Conglomerate of Skull Rock Pass" was used informally by Bushman (1973) and Hintze (1974a, b) for this same unit in quadrangles just west of Long Ridge. However, the Long Ridge quadrangle includes the thickest and most extensive known deposits of this unit, therefore it is here proposed as a formal stratigraphic unit, the Skull Rock Pass Conglomerate. The type section for this formation is on Long Ridge where it rests on the Red Knolls Tuff. The upper part of the Skull Rock Pass Conglomerate, above the highest Bonneville shoreline at 5,170 feet (1,576 m), is well displayed on the east face of Long Ridge, but its lower outcrops have been reworked by wave action of Lake Bonneville. Because the Skull Rock Pass Conglomerate is unstratified, the assessment of its attitude and, hence, thickness is based on the attitude of the underlying Red Knolls Tuff. The term comes from Skull Rock Pass which lies on U.S. Highway 6-50 about 12 miles (19 km) southwest of the quadrangle boundary. A measured section of the Skull Rock Pass Conglomerate at its type locality shows three poorly separable units as described below.

Type section of the Skull Rock Pass Conglomerate, east-central part of section 27, T. 18 S., R. 11 W., Millard County, Utah

Overlying rocks: Quaternary deposits cover unit 3 on the western dipslope of the type section; in nearby areas the conglomerate is overlain by volcanic rocks of the Oligocene Needles Range Group.

Unconformity
Skull Rock Pass Conglomerate:

Unit Number		Thickness feet (meters)
3.	Conglomerate, mostly cobble-sized clasts, predominantly of limestone and dolomite derived from Cambrian through Devonian formations similar to those now exposed in the Confusion Range to the west; less than 1 percent of the clasts are boulder-size, but some of these are as much as 12 feet (3.6 m) across. Boulders of Ordovician Eureka Quartzite and Upper Ordovician and Silurian dolomites are common. Matrix is uncemented and is exposed only in sides of gullies and artificial excavations where it is seen to be unstratified clayey silty material that contains small mica flakes. The top of this unit forms the western backslope of Long Ridge.	200 (61)
2.	Conglomerate, mostly cobbles and pebbles, but with some boulders up to 2 feet (0.6 m) across. Some cobbles were derived from the Lower Ordovician Fillmore Formation. Matrix is clayey and silty and uncemented, and is at least partly derived from comminuted soft tuffaceous volcanic rocks. Thus the middle unit is slightly less resistant than the others and forms gentler slopes. This may reflect a greater percentage of matrix and lesser percentage of clasts. In thin zones the clasts may constitute only 20 percent of the rock volume.	60 (18)
1.	Conglomerate, well-rounded boulders, cobbles, and pebbles of Cambrian and Ordovician quartzite, Cambrian through Devonian carbonates and, rarely, Notch Peak granite. Matrix is uncemented, unstratified, clayey siltstone derived in part from comminuted volcanic ash or tuff. Matrix is poorly exposed; most of the outcrop is armored with clasts because wave action in Lake Bonneville has winnowed the matrix out of the surifical exposures. This unit rests directly on Red Knolls Tuff on which an erosion surface had formed before deposition of this conglomerate.	60 (18)
	Total thickness	320 feet (98 m)

Unconformity (erosion surface)
Red Knolls Tuff: Pink, massive ash-flow tuff containing lithic fragments.

Figure 3. Type section of the Skull Rock Pass Conglomerate on the east side of Long Ridge in section 27, T. 18 S., R. 11 W. The conglomerate rests on the Red Knolls Tuff, the top of which shows as the light-colored outcrops at the right-central part of this photo. The boulder in the foreground is part of the Skull Rock Pass Conglomerate, its size is shown by the black notebook which is 12 inches (30 cm) tall. The conglomerate is uncemented and unstratified; it is more than 300 feet (91 m) thick on Long Ridge.

The Skull Rock Pass Conglomerate has been extensively exposed in lines of shallow (four feet or one meter deep) prospect pits which dot the Long Ridge backslope (figure 4). Although no stratification has been seen in any exposures of the conglomerate, examination of aerial photographs reveals a less-resistant interval in the middle of the formation (unit 2) in the northwest part of the quadrangle.

The lowest 60 feet (18 m) of the formation is a resistant unit of coarse, bouldery conglomerate; above this, a slightly recessive interval, about 60 feet (18 m) thick, is less resistant than the rest of the formation because it has a greater proportion of matrix and fewer of the very large boulders; the upper 200 feet (61 m) of the formation is a resistant boulder conglomerate that includes a few very large boulders up to 15 feet (4.6 m) in diameter.

The stratigraphic top of the Skull Rock Pass Conglomerate is not exposed on Long Ridge; the conglomerate passes beneath valley alluvium and Lake Bonneville deposits in the valley west of Long Ridge. The stratigraphic top of the formation can be seen on The Barn quadrangle (Hintze, 1974a) where it is overlain by the Needles Range Group. The age of the Skull Rock Pass Conglomerate is known to be Oligocene because it lies between two volcanic units whose Oligocene age has been determined isotopically.

Locally the Skull Rock Pass Conglomerate has been hydrothermally altered. The alteration shows as small, isolated reddish-orange spots that can be seen on the ground and on color aerial photographs. The altered areas are scattered and small, ranging from 20 feet to 100 feet (6-30 m) across. The alteration affects the clayey matrix of the conglomerate, but not the clasts.

Quaternary-Tertiary Fine-Grained Lacustrine Deposits (QTlf)

Pre-Bonneville lake beds are exposed at a number of locations in the central part of the Sevier Desert from near Smelter Knolls (figure 1) to south of Pavant Butte. They are widely exposed around the margins of Sevier Lake; the outcrops shown on plate 1 are part of the Sevier Lake exposures. Oviatt (1989, 1991) mapped this unit in his studies of the Sevier and Black Rock Deserts. Oviatt found volcanic ash layers interbedded with the lake beds. On the northwest shore of Sevier Lake this unit contains the Bishop ash (740,000 yr. B.P); on the east side of the Cricket Mountains it includes the Huckleberry Ridge ash (2.02 Ma). Thus these lake beds range from late Pliocene to early middle Pleistocene in age.

These lacustrine deposits are light-red, light-yellowish-gray, brownish-green, or very light-gray clayey marl and calcareous silty clay. A sample of QTlf taken from the center of section 12, T. 19 S., R. 11 W. contained 10 percent calcium carbonate by weight; the residue was muddy clay. Oviatt (1989) reported that gastropods and ostracodes found locally in these beds suggest that the lake water was fresh. Maximum thickness of these beds may be a few hundred feet but they thin to zero around the somewhat indefinitely known edges of their basin.

QUATERNARY DEPOSITS

In the symbol for each Quaternary deposit, the first letter after the Q designates the general process responsible: a, alluvial; l, lacustrine. The last letter represents a more specific description of the deposit.

Lacustrine and alluvial deposits undifferentiated (Qla) — These are deposits in piedmont areas where pre-Lake Bonneville alluvial sediments are reworked by waves and currents in Lake Bonneville, but where the lacustrine sediment component is thin; includes pre-Lake Bonneville alluvial fans etched by wave action in Lake Bonneville as well as thin lacustrine gravel capping QTlf. The pre-Bonneville fan deposits may be several hundred feet thick locally and generally consist of interlayered coarse debris flows and

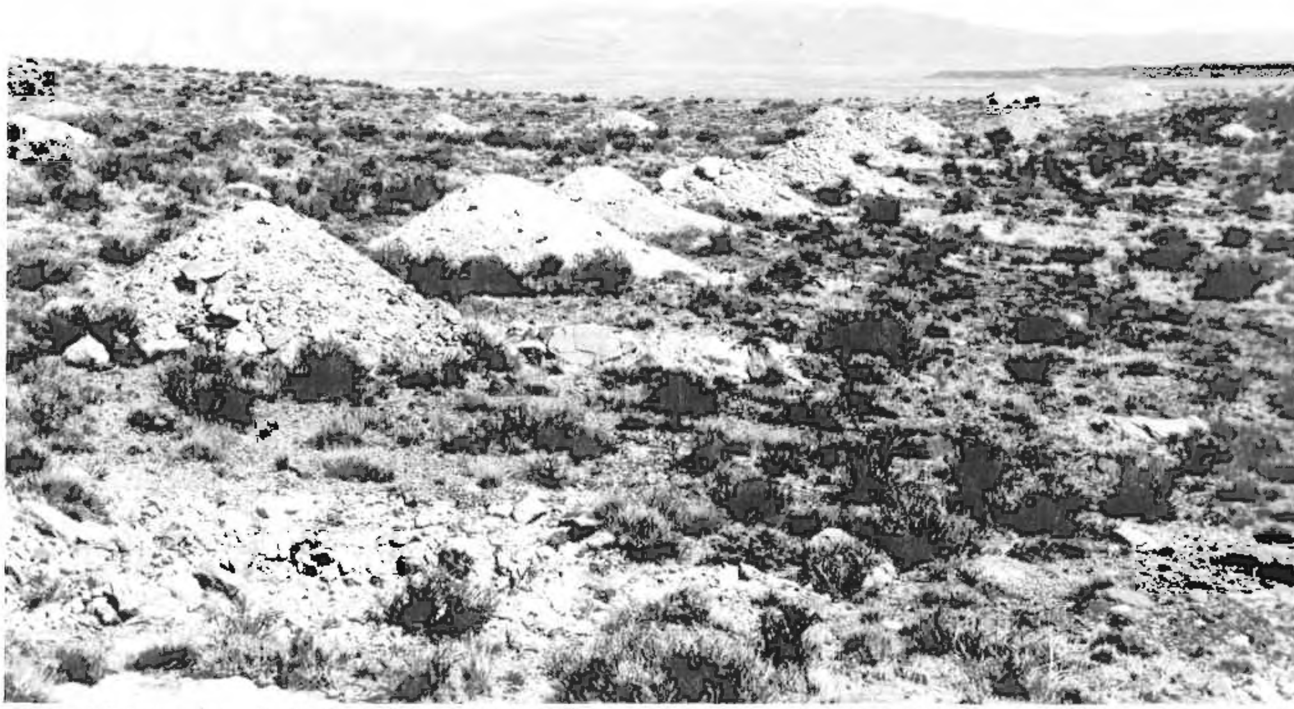

Figure 4. Prospect pits on the west flank of Long Ridge in section 27, T. 18 S., 11 W. are 3 to 4 feet (1m) deep and spaced 50 feet (15 m) apart. They were dug into the Skull Rock Pass Conglomerate and reveal its lack of bedding and lack of cementation. Prospecting was initiated during the uranium boom of the 1950s. A few of the pits show red oxidation of the clayey matrix of the Skull Rock Pass Conglomerate, probably caused by minor hydrothermal activity.

Figure 5. Typical Skull Rock Pass Conglomerate as exposed in the wall of a shallow prospect pit in section 27, T. 18 S., R. 11 W. The cobbles and boulders are limestone, dolomite, and quartzite derived from lower Paleozoic formations. Volcanic clasts are rare. The matrix is clayey and locally consists of comminuted tuff. Hammer is about a foot long.

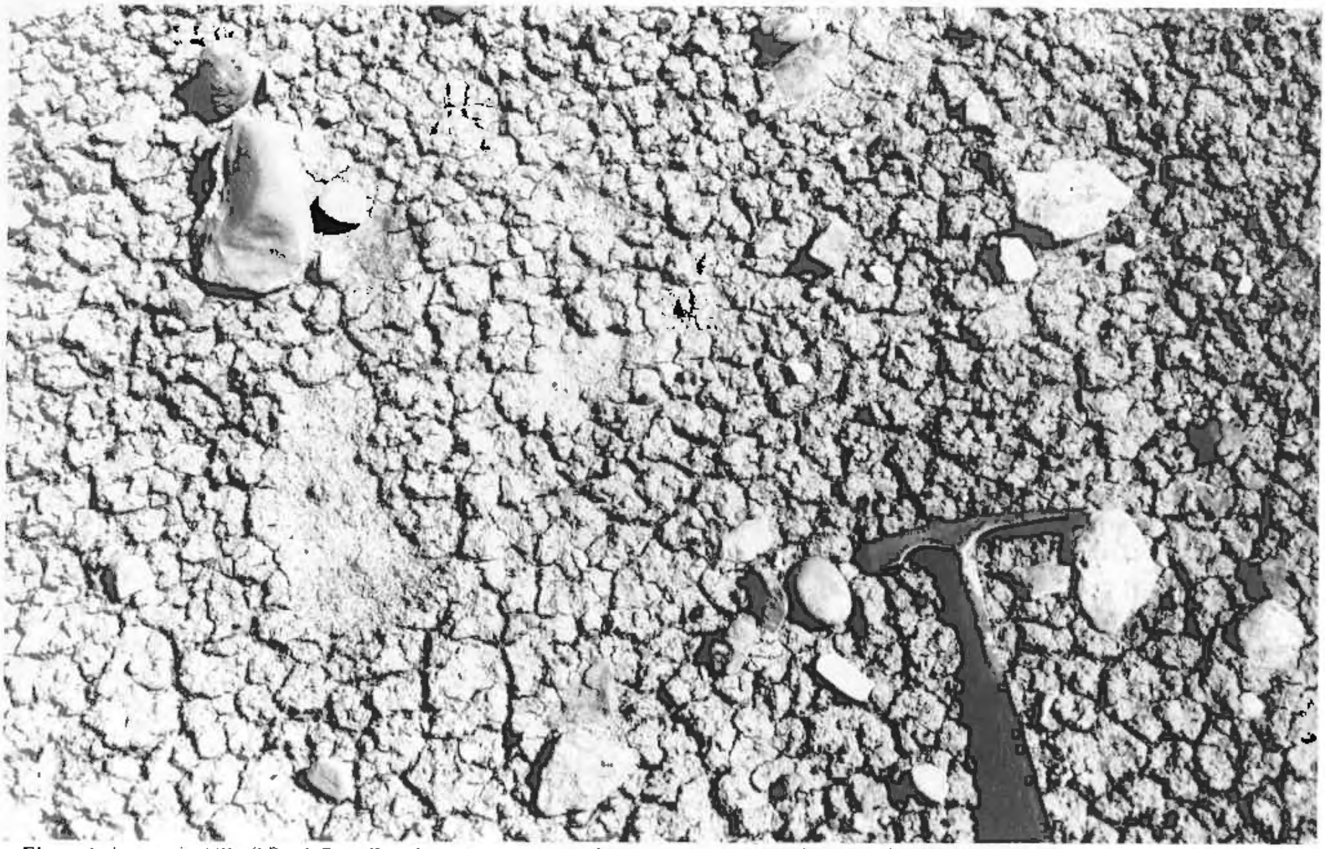

Figure 6. An atypical Skull Rock Pass Conglomerate exposure along prospector's road in SE section 21, T. 18 S., R. 11 W. Locally the Skull Rock Pass Conglomerate is mostly clayey matrix in which cobbles of sedimentary rocks are scattered, along with a few weathered tuff clasts. Hammer is about a foot long.

finer grained mud flows. The surficial lacustrine sediments and the fan deposits contain rock types derived from nearby sources.

Lacustrine gravel (Qlg) — Sandy gravel was deposited as barrier beaches, spits, bars, and embankments in Lake Bonneville. The gravel consists of subangular to rounded quartzite, limestone, dolomite, and volcanic rocks that are mostly pebble to cobble sized. In Qlg deposits above the Provo shoreline and below the Bonneville shoreline (e.g., Qlf/Tsr), the clasts range to boulders in size. Individual Qlg deposits are no more than about 20 feet thick (6 m).

In the southwest part of the quadrangle a westerly trending barrier beach denotes the Provo shoreline at an elevation of 4,785 feet (1,458 m). In the east-central part of the quadrangle a large and remarkable series of three partially superposed V-shaped barrier beaches and enclosed lagoons were deposited at the Provo shoreline and somewhat higher. The highest V-shaped barrier beach (Gilbert, 1890, termed them V-bars) and enclosed lagoon is the smallest. Eastwards, and topographically lower, is a slightly larger barrier beach and lagoon. The lowest, largest, and easternmost V-shaped barrier beach and lagoon is at the Provo shoreline and it extends for two miles in a north-south direction. In the enclosed lagoon, minor lake fluctuations at the Provo level produced several northwest-trending beach ridges. The Provo shoreline, on the landscape, is expressed in some segments as a barrier beach and in other places as a low, wave-cut cliff in the older fan materials. In still other places the shoreline has been obliterated by post-Provo erosion or deposition. From a radiocarbon date on lacustrine tufa, Oviatt (1991) reported the age of the Provo shoreline to be 14, 320 ± 90 yr B.P. This is a point date, of course, and the Provo shoreline persisted for about 300 years around that date.

Deposits associated with the Bonneville shoreline, at an elevation of 5,170 feet (1,576 m), are thin or absent except for one locality. In the NE/SE section 10, T. 19 S., R. 11 W. there is a short barrier beach that encloses a small lagoon at the top of a canyon. Oviatt (1991) stated that Lake Bonneville transgressed to the Bonneville shoreline about 15,350 yr B.P. and persisted for about 850 years (Burr and Currey, 1988).

At the south end of Long Ridge, the sloping ground between the Bonneville shoreline and the Provo shoreline is marked by a great many lake terraces formed of reworked Skull Rock Pass Conglomeratic materials. One of the most prominent of these is the Qlg deposit at an elevation about 5,130 feet (1,564 m).

Lacustrine marl (Qlm) — This is fine-grained, finely bedded to indistinctly laminated, white to light-gray marl deposited in Lake Bonneville. Includes Gilbert's (1890) "white marl" as well as reworked silty and sandy marl that contains abundant ostracodes and locally has gastropods near the base and top of the unit. Commonly, there is clastic-rich marl at the base and top of the unit. In this quadrangle the marl was deposited 10 to 60 feet (3-18 m) below the Provo shoreline of Lake Bonneville. The marl is the offshore deposit of Lake Bonneville at the Provo stage and is therefore synchronous in age with the Qlg of the Provo shoreline. Deposits may be as much as 12 feet (3.6 m) thick locally.

Lacustrine lagoon deposits (Qll) — This includes white, tan, or light-gray clay, silt, and sand deposited in lagoons behind gravel (Qlg) barrier beaches and bars of Lake Bonneville; includes local, thin, surficial influxes of younger alluvium. Most of the fine-grained sediment in these lagoons was deposited by waves that washed over the crests of the barrier beaches during storms. Lagoonal deposits are mostly less than 10 feet (3 m) thick.

Fine-grained lacustrine deposits (Qlf) — This includes varying percentages of clay, silt, sand, marl, and reworked marl that were deposited offshore or in deeper parts of Lake Bonneville; also includes local, thin, surficial influxes of Holocene alluvium. Thickness not determined but probably less than 15 feet (4.6 m).

Alluvial deposits in washes and on fans (Qaf) — This is coarse to fine-grained alluvium deposited mostly on piedmont slopes and in washes after regression of Lake Bonneville from the Bonneville shoreline and especially after regression from the Provo shoreline. They are predominantly poorly sorted silt, sand, and gravel which reflect bedrock lithologies in the surrounding highlands. Soap Wash probably contains the greatest expanse and thickness of alluvium. The deposits may be as much as a few tens of feet in thickness.

LAKE BONNEVILLE SHORELINES

Bonneville shoreline — The highest shoreline of Lake Bonneville is very well preserved on Long Ridge. It lies at an elevation of 5,170 feet (1,576 m) and extends from the high point at the south end of Long Ridge, where its elevation is marked by a small lagoonal deposit, to the northwest corner of the quadrangle. At the south end of Long Ridge, the sloping ground between the Bonneville shoreline and the Provo shoreline is marked by a great many lake terraces formed of reworked Skull Rock Pass Conglomerate materials.

Provo shoreline — The Provo shoreline is expressed in some sections as gravel-capped ridges and in other places as a wave-cut cliff in the older fan materials. In places the shoreline has been obliterated by post-Provo erosion in modern stream channel and alluvial-fan deposits. The Provo shoreline lies at an elevation of about 4,785 feet (1,459 m) in this quadrangle.

STRUCTURAL GEOLOGY

NORMAL FAULTS

Structure of the Oligocene bedrock in this quadrangle is very simple. Long Ridge is a gently tilted basin-range fault block made up of Oligocene rocks that dip about three degrees to the southwest. Small northwest-trending faults offset the Red Knolls Tuff-Skull Rock Pass Conglomerate contact a few tens of feet on the northeast face of Long Ridge but it is not known whether the slip of these faults is dip-slip, strike-slip, or oblique-slip. The largest identifiable fault in the quadrangle is the Long Ridge fault that drops the Red Knolls Tuff-Skull Rock Pass Conglomerate contact down to the northeast about 200 feet (61 m) (cross section A-A', plate 2). This fault is not exposed but its surface trace is followed approximately by the cattleman's road as shown on the map. The Red Knolls fault is a similar fault in adjacent Red Knolls quadrangle. It has been tentatively projected southward into this quadrangle. It is presumed that additional down-to-the-east faults of similar orientation may lie concealed by Quaternary deposits east of Long Ridge. The location of the surface trace of the Long Ridge fault is inferred from the topography of Long Ridge and has been placed close to the east base of the escarpment.

REGIONAL STRUCTURAL RELATIONSHIPS

Structure within this quadrangle is better understood when reviewed from a larger perspective. Figures 7 and 8 show major structural features of central Millard County as deduced from gravity maps, shallow and deep seismic-reflection data, and drilling data from four deep wells. Gravity data show the House Range-Long Ridge-Red Knolls platform is flanked by elongate basins; the Tule Valley basin on the west is narrow; the Chalk Knolls half-graben and the Sutherland basin on the east are broad and complex. The Sutherland basin is partially penetrated by the Gulf-Gronning well (Lindsey and others, 1981) and was surveyed by a shallow seismic-reflection line (McDonald, 1976). Von Tish and others (1985) and Planke (1987) have contoured both the bedrock-valley fill unconformity and the Sevier Desert detachment, and their contour maps have been used in preparing the eastern third of figure 8. The Sevier Desert detachment appears to be a regional low-angle fault that can be traced in COCORP deep seismic-reflection data for about 45 miles (72 km) dipping gently westward perpendicular to the north-south trend of major basins and ranges. Gants (1985) indicated that refraction data show that the Sevier Desert detachment occurs above a crustal low-velocity reversal. Rheologic considerations suggest that ductile deformation may be important at or just below the detachment surface which is believed to be a zone of lithospheric decoupling along which much crustal extension has occurred. Von Tish and others (1985) concluded that extension beneath the Sevier Desert has occurred in two stages: early extension of 12 to 18 miles (19-29 km) began after middle Oligocene and continued into the Miocene. Later extension of perhaps 5 miles (8 km) began about 4 million years ago and continued to the present as indicated by the Holocene fault scarps on the west side of the Sevier Desert as shown on figure 7. A key reflector that enabled Von Tish and others (1985) to recognize the two-stage extension history of the Sutherland basin was identified as a 4.2 million-year-old basalt sequence present in the Gulf-Gronning well. The basalt lies with angular discordance on older Miocene and Oligocene units as shown in figure 8.

Von Tish and others (1985) presented a systematic analysis of Cenozoic extension in the central Sevier Desert but they did not discuss pre-Cenozoic structural development of the area particularly with respect to two major Cretaceous thrusts that are believed to be present in Precambrian and Paleozoic strata beneath the Sevier Desert and within the House Range-Long Ridge-Red Knolls platform. However, Sharp (1984) equated the mid-Cenozoic Sevier Desert detachment with the latest Cretaceous Pavant Range thrust and he postulated that the same surface that had served for eastward thrust transport 70 million years ago was reactivated some 50 million years later to serve as a transport surface for westward extension. Even though it seems unlikely that similar rheological conditions would persist here this length of time, especially considering the great uplift of the Great Basin area in late Cenozoic time, his model nonetheless addresses the problem of trying to identify the location of a Mesozoic thrust surface in the COCORP data. Identifying the structurally higher Canyon Range thrust in the Sevier Desert subsurface is also a problem. This thrust was encountered at a depth of 8,364 feet (2,549 m) in the Cominco-American well (shown on figures 1 and 7), and it was tentatively identified by Sharp (1984) as one of the reflecting surfaces observed on the COCORP data beneath the House Range about 6 km (3.8 m) below the surface. We have shown this thrust about the same depth on figure 8, as a near-bedding-plane fault surface that cuts within the thick column of Precambrian sedimentary strata. Also on figure 8 we show the Cretaceous Canyon Range thrust as possibly coinciding with the late Cenozoic detachment that comes toward the surface on the east side of the Chalk Knolls half-graben. Both the Canyon Range thrust and the younger Pavant Range thrust are well exposed just east of the Sevier Desert in the Canyon and Pavant Ranges (Hintze, 1980).

As noted at the beginning of our discussion of structural geology, the bedrock structure of this quadrangle is simple, and that very

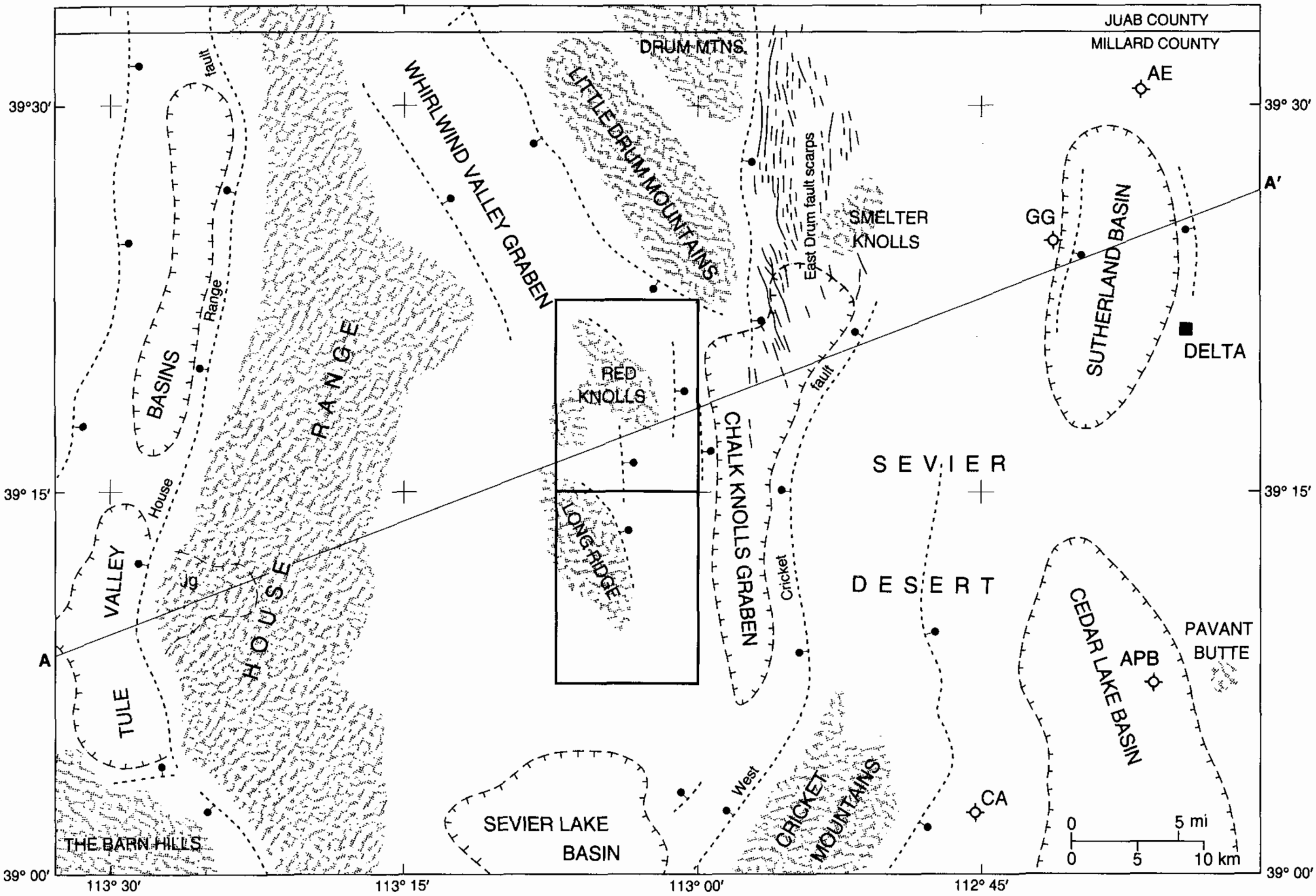

Figure 7. Map of same area as figure 1 showing bedrock exposures, major basins filled with low-gravity Tertiary deposits, inferred major basin-range faults, and Holocene fault scarps east of the Drum Mountains. Faults within the Long Ridge and Red Knolls quadrangles are not indicated because their displacement is small compared to the faults shown. Bouguer gravity map used to identify basins is shown on plate 2. Abbreviations for wells are shown on figure 1.

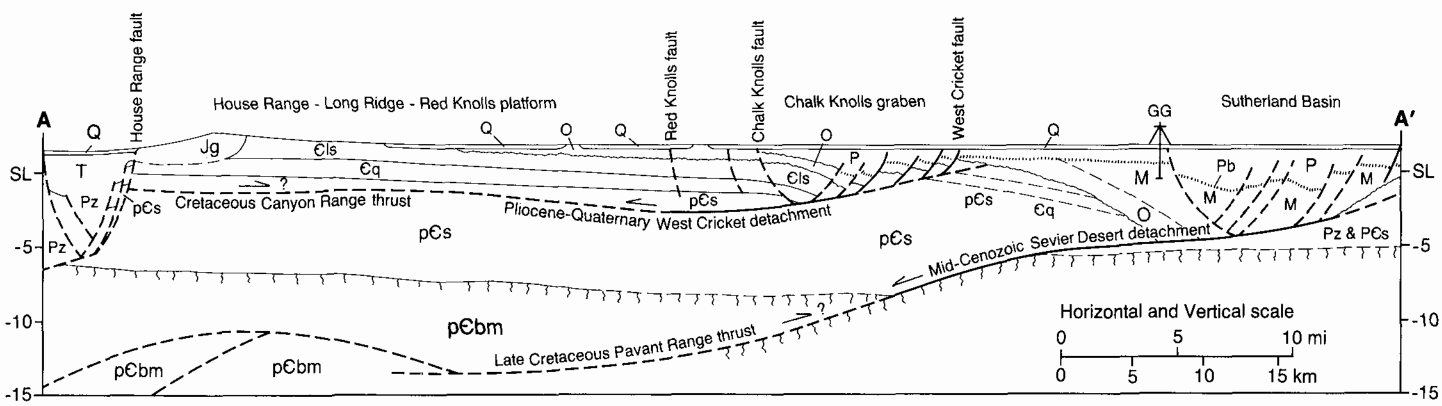

***Figure 8.** Schematic cross-section of figure 7 with no vertical exaggeration showing inferred structures to a depth of 15 km (9.4 mi), based on surface geology, deep seismic interpretations (Von Tish and others, 1985) shallow seismic interpretation (Planke, 1987; McDonald, 1976), well data (Lindsey and others, 1981), and unpublished gravity and magnetic maps prepared by the U.S. Geological Survey. The reflection Moho is off the bottom of the section at a depth of 25 to 30 km (15-18 mi). Symbols: pЄbm, Precambrian gneiss and schist; pЄs, Precambrian quartzite and argillite, Pz, Paleozoic strata undivided; Єq, Cambrian quartzite; Єls, Cambrian limestone and dolomite; Jg, Jurassic granite; O, Oligocene conglomerate and tuff; M, Miocene basin-fill; Pb, Pliocene basalt; P, Pliocene basin-fill; T, Tertiary basin-fill undivided; Q, Quaternary surficial deposits (thickness exaggerated).*

fact enables us to conclude that Long Ridge is the eastern part of a coherent platform that is bounded by major grabens as shown on figure 7.

SUMMARY OF STRUCTURAL HISTORY

More than 40,000 feet (12,192 m) of Late Precambrian and Paleozoic shallow marine strata accumulated in central Millard County prior to being pushed eastward and upward as part of the Sevier orogenic hinterland in Late Cretaceous time (Hintze, 1988). Erosion concurrent with Sevier uplift removed all Paleozoic strata above the Cambrian over a broad arch centered over the present House Range-Sevier Desert area (Harris, 1959). Erosion of the Sevier hinterland continued until volcanism commenced in the Tintic-Keg Mountain-Drum Mountain area about 40 to 38 million years ago in latest Eocene time. Oligocene tuffs and volcanic-related sediments filled local basins. A large basin, the Sutherland basin was opened by westward extension on the Sevier Desert detachment sometime after 28 million years ago and continued opening through most of Miocene time. After a short period of erosion that truncated Oligocene and Miocene deposits a Pliocene basalt (4.2 m.y.) covered the truncated beds. Subsequently, extension was renewed in the Sutherland basin and in the Chalk Knolls half-graben, resulting in the filling of these downwarps by terrestrial deposits of alluvial, playa, and volcanic origin.

ECONOMIC GEOLOGY

GRAVEL DEPOSITS

Lake Bonneville left a wealth of gravel deposits in the quadrangle. They have been exploited at various places along U.S. Highway 6-50 as shown by the "borrow pit" symbols on the map. In general, lacustrine gravel deposits (Qlg) are the thickest and most uniform but, in places, undifferentiated lacustrine and alluvial deposits (Qla) have a high gravel content. The materials range greatly in degree of sorting and average grain size. Most of the clasts are of Paleozoic carbonates derived from the House Range or the Skull Rock Pass Conglomerate of Long Ridge, or of basaltic andesite from the Little Drum Mountains.

The Utah Department of Transportation (U.D.O.T.) investigated and inventoried two gravel pits in the quadrangle (U.D.O.T., 1966). Pit number 14089 is in the SENW section 7, T. 19 S., R. 10 W. A sample of material contained 94.2 percent gravel, 5.0 percent sand, and 0.8 percent silt and clay (this was probably a sampling bias). The material had a liquid limit of 18.1 percent, was non-plastic, and had a swell of 0.010 percent. Pit number 14090 is in the NWNW section 23, T. 19 S., R. 11 W. A sample of material contained 62 percent gravel, 26 percent sand, and 12 percent silt and clay. The material had a liquid limit of 16.0, was non-plastic, had a swell of 0.003 percent, and had a wear of 22.6 percent. Material from both pits was used as base and surfacing gravel in the construction of U.S. Highway 6-50. Abundant reserves are present north and south of pit 14089, as well as in other areas of lacustrine gravel (Qlg) in the quadrangle.

MINERAL EXPLORATION

The entire top of Long Ridge and its western slope have been staked with mineral claims. Some of the claim notices are dated 1969; the latest claim notices are September, 1974 and were taken out in the names of Scott D. Huntsman and Richard D. Moody. The latter still lives in Sutherland, near Delta, Utah. The senior author talked to Mr. Moody who said that exploration activity on Long Ridge had passed through several phases. The initial activity in the 1960s sought manganese. In the 1970s uranium was the goal. Currently, gold mining activity in Nevada may inspire reactivation of claims on Long Ridge seeking that metal. A minor amount of hydrothermal alteration in the Skull Rock Pass Conglomerate appears to be the basis for the exploration activity.

Most of the exploratory method has consisted of scooping lines of shallow pits on 50-foot (15 m) centers spaced at 1,000-foot (305 m) intervals into the Skull Rock Pass Conglomerate (figure 4). Some drilling has also been done as evidenced by a few mounds of drill cuttings. The senior author took samples from three of the most altered-looking pits located as follows:

1. Top of Long Ridge near road junction 5296, section 27, T. 18 S., R. 11 W.
2. Top of Long Ridge in SESE section 21, T. 18 S., R. 11 W.
3. Long Ridge Reservoir quadrangle along road, NE, section 18, T. 19 S., R. 11 W.

The samples were analyzed by Dr. Willis H. Brimhall who submitted the following report on August 18, 1988:

> *As per instruction, I have made an ICPAES (Inductively Coupled Plasma Atomic Emisson Spectrophotometry) scan of three samples submitted to me some weeks ago. Nearly 70 elements were surveyed, but special consideration was given to elements of economic interest.*
>
> *The analysis was performed on solutions obtained by treatment of 10 gm of rock powder with strong, hot, oxiding acid dissolution. The acid media used was concentrated hydrochloric doped with hydrogen peroxide. The analysis represents chemical elements available from strong, hot acids, not from composition of the total rock. Inasmuch as the intent was to search for metals of economic interest, the former treatment is sufficient.*
>
> *None of the samples contain elements of economic interest (Sn, Hg, Se, Mo, Cr, W, Zn, Cd, Pb, Ni, Co, Mn, Th, V, Cu, Ag, U) in more than what might be considered background or perhaps somewhat more than background concentrations. Copper in specimens 2 and 3 can be considered to occur at a level somewhat above background, sufficient to provoke interest as a potential prospect.*
>
> *The noble metals were not examined because the ICP method is not sufficiently sensitive to detect these metals at concentrations which might be considered economically interesting. Special procedures are needed to separate and concentrate these elements for determination.*

Campbell and Labson (1989), noted that mineralized zones border the Jurassic granite in the House Range (see figure 7 for location) to the northwest and west. The alteration on Long Ridge cannot be associated with the intrusion of the Jurassic granite because the Long Ridge host rocks were not yet deposited when the Jurassic granite was intruded. The minor hydrothermal activity on Long Ridge must be related to post-Oligocene volcanic activity in western Utah.

BENTONITIC ZONES IN THE SKULL ROCK PASS CONGLOMERATE

As shown on figure 6 certain portions of the Skull Rock Pass Conglomerate have more matrix than clasts. Locally there may be enough of clayey material to be useful for lining nearby livestock reservoirs. There is probably not enough tonnage except for local use on small projects.

PETROLEUM POSSIBILITIES

This quadrangle shows little likely potential for commercial discovery of oil or gas. Quaternary lake deposits are too thin and too lacking in organic material to be productive. Beneath the

Quaternary deposits the Oligocene conglomerates and tuffs are improbable source or reservoir rocks without a cap or trap. And Paleozoic rocks at a depth of a few thousand feet are probably Cambrian carbonates and quartzites which might have little petroleum potential. However, no exploratory wells have been drilled within the quadrangle. Figures 1 and 7 show the locations of four deep wildcat wells to the east of this quadrangle. None of these showed commercial promise.

WATER RESOURCES

There are no perennial water sources within this quadrangle. Several small earthen reservoirs have been built to catch runoff for watering livestock. These occasionally contain water for short periods. Water-test wells, shown on the quadrangle along Highway 6-50, encountered ground water at a depth of 200 to 300 feet (61-91 m) (Thomas and others, 1986). The wells are not being used at present.

GEOLOGIC HAZARDS

The only geologic hazards of major concern in the quadrangle are related to flash floods. Such floods can either erode channels across U.S. Highway 6 and 50 during a summer cloudburst or they can bury the highway beneath rocky debris. Soap Wash, in the northeast part of the quadrangle, bears much evidence that it has been severely flooded and eroded. Motorists should not attempt to cross roadways and washes during a flood. The flooding usually subsides in a few minutes to an hour but dangerous erosion scars may make the highway unfit until fixed.

Certain engineering precautions should be taken if a house, a building, or any other fairly heavy structure is contemplated for construction within the quadrangle area on fine-grained lacustrine deposits (Qlf and QTlf). These deposits contain layers and lenses of silt and silty clay, plus perhaps a small to moderate percentage of soluble salts, and may not provide adequate foundation support. The lacustrine marl (Qlm) may not furnish satisfactory foundation support either. If construction is absolutely necessary on it, the best remedy would be to excavate these deposits completely.

In this part of Millard County there have been no historical earthquakes of magnitude 4.0 or greater. The Long Ridge quadrangle is in seismic zone U-2 of the seismic zones for construction in Utah (Ward, 1979) and in seismic zone 2b on the 1988 Uniform Building Code Zone Map. The U-2 zone indicates a slight to moderate earthquake potential.

Except for the paved highway and graded roads there is no significant development within the quadrangle at present.

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