UTAH GEOLOGICAL SURVEY
OPEN-FILE REPORT 348
in cooperation with
U.S. Geological Survey

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STATE OF UTAH
UTAH GEOLOGICAL AND MINERALOGICAL SURVEY

MONUMENT POINT QUADRANGLE
UTAH–BOX ELDER CO.
7.5 MINUTE SERIES ORTHOPHOTOMAP (TOPOGRAPHIC)

Mapped, edited, and published by the Geological Survey

Control by USGS and USC&GS

Topography by photogrammetric methods from aerial photographs taken 1965–66. Orthophotomosaic from aerial photographs taken 1969. Field checked 1968

Soundings compiled from chart furnished by U. S. Naval Reserve

Polyconic projection. 1927 North American datum
10,000-foot grid based on Utah coordinate system, north zone
1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue

UTM GRID AND 1968 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 10 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL
SOUNDINGS IN FEET—DATUM IS LAKE ELEVATION 4193 FEET

QUADRANGLE LOCATION

ROAD CLASSIFICATION
Light-duty ——— Unimproved dirt - - - - -

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
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MONUMENT POINT, UTAH
N4137.5—W11245/7.5
1968
AMS 3467 III NE—SERIES V897

INTERIM GEOLOGIC MAP OF THE MONUMENT POINT QUADRANGLE, BOX ELDER COUNTY, UTAH

With a booklet on the geology of eastern Curlew Valley, Box Elder County, Utah, and Oneida County, Idaho

by
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U.S. Geological Survey

1997

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INTRODUCTION

This group of maps includes much of the broad, gently south-sloping eastern Curlew Valley (figure 1) as well as parts of the Wildcat Hills, southern Hansel and southern Sublett Range, southwestern Hansel Valley, and the northwestern part of Great Salt Lake (Spring Bay) and its mud flats (figure 1). Part of Sage Valley, a small internally-drained valley west of the Hansel Mountains, also is present. Curlew Valley is traversed by Deep Creek; within the map area Deep Creek descends from 4,500 feet (1,372 m) to about 4,200 feet (1,280 m) where it enters Great Salt Lake. Since Great Salt Lake is not threshold-controlled the altitude of its surface varies considerably. The base maps used place its altitude at 4,193 feet (1,278 m) on the basis of aerial photography flown in 1966. During field investigations in the late 1980's, the lake surface was much higher and some of the inundated parts of the geologic map at low altitudes were inferred from 1953, 1966, 1967, and 1969 aerial photographs. The Sublett Range and Hansel Mountains have about 800 and 1,300 feet (245 and 400 m) of local relief, respectively, and Monument Peak in the Hansel Mountains is the highest point in the area at 5,999 feet (1,829 m). Interstate highway 84 and State highway 30 traverse the northern part of the area and a gravel road following the original transcontinental railway traverses the southern part.

Curlew Valley and adjacent mountains are intensively used for agriculture and grazing. Part of the valley is used for irrigated croplands, the main water source being shallow groundwater pumped from local wells. Upland areas of the Hansel Mountains and Sublett Range are utilized for dry farming. The southern part of the valley and hills underlain by volcanic rocks are utilized mainly for grazing. Locomotive Springs Wildfowl Management Area, in the southern part of the map area, consists of broad marshes and ponds supported by several fresh-water springs.

Curlew Valley contains an unusually well preserved depositional record of late Pleistocene Lake Bonneville. Coarse-grained deposits formed at wave-dominated shorelines are widespread on hills and mountains, and finer grained, deeper water deposits are widespread in the valleys; both have undergone little erosion. In general, only the upper foot or two of the deposits are reworked by eolian and alluvial processes. In a few places, small alluvial fans formed after retreat of the lake and in some wash bottoms and along Deep Creek alluvium is thick. Near Locomotive Springs Holocene highstands of the Great Salt Lake are represented by beach deposits and carbonate mud deposits that formed offshore.

Curlew Valley is an unusually broad valley in the northeastern part of the Basin and Range Province. The valley is probably a composite of two structural basins, with the intervening structural high very weakly expressed in the Paleozoic bedrock underlying Tertiary volcanic rocks in the Wildcat Hills. This group of maps therefore covers the eastern of these two structural basins that comprise Curlew Valley. These structural basins and adjacent structural horsts lie east of, and in the hanging wall of, the late Miocene detachment faults of the Raft River Mountains (Wells, 1992, 1996). The detachment faulting may have caused some of the tectonic tilting and block faulting in Curlew Valley. Pliocene volcanic rocks in the Wildcat Hills are flat-lying, and appear to post-date tilting of the underlying Salt Lake Formation (Miller and others, 1995). Pleistocene basaltic volcanism in Curlew Valley is the youngest in northern Utah (Miller and others, 1995), consisting of three intact basaltic shield volcanoes (figure 1) and nearby outcrops that may be fragments of flows or eroded shields.

Paleozoic bedrock of Curlew Valley, like that of many adjacent mountains of northern Utah and southern Idaho, is mainly the Permian and Pennsylvanian rocks of the Oquirrh Formation. This unit is exceedingly thick and represents sediment deposited in a huge northwest-trending basin (Jordan and Douglass, 1980).

Past geologic mapping in eastern Curlew Valley by Adams (1962) and Howes (1972) was incorporated by Doelling (1980) into a geologic map of Box Elder County. Subsequently, Shea (1985) and Kerr (1987) studied volcanic rocks in the area, Robison and McCalpin (1987) studied the Quaternary geology of Hansel Valley, and Miller and others (1995) described the ages of volcanic rocks.

NOTES ON STRATIGRAPHIC UNITS

Oquirrh Formation

The Oquirrh Formation is a thick unit of Pennsylvanian and Permian age in this part of Utah that is difficult to subdivide owing to rhythmic repetitions of lithofacies and fossils throughout the unit. We have mapped small, poorly exposed, and enigmatic outcrops as undivided Oquirrh Formation but elsewhere subdivide the unit into informal members. At Monument Peak, we subdivided the Oquirrh based on local criteria: a generally sandstone-rich sequence overlain by an informal member of variable rock type but commonly thin-bedded and silty. Both informal members contain sparse, large, poorly preserved fusulinids similar to Permian forms. The informal members are overlain by a cherty limestone unit that is similar to a cherty unit that overlies the Oquirrh in the Hogup Mountains west of Great Salt Lake (Jordan and Douglass, 1980). However, north of Monument Peak a distinctive facies of bioturbated laminated strata similar to a section of the Oquirrh in the North Promontory Mountains is present, in contrast to the Monument Peak section, suggesting that a concealed fault lies between the sections and has juxtaposed unlike facies. Strata in the western part of the Sublett Range are similar to strata in the Monument Peak section. However, Oquirrh (PIPo) strata that lie east of and therefore apparently above the Permian cherty limestone unit are typical of the Oquirrh Formation, although not typical of the local sequences. The eastern outcrops of the Oquirrh may be faulted against the cherty limestone unit. Poorly exposed strata in small hills south of Deep Creek in the Monument Peak NE quadrangle consist of thin-bedded silty limestone and minor sandstone and cherty limestone; the strata are similar to rocks in the variable lithology (Pov) and laminated limestone (Poll) members of the Oquirrh Formation.

Quaternary Deposits

Lacustrine and alluvial deposits are the most common Quaternary materials in eastern Curlew Valley. Lacustrine sediments deposited during the rise and fall of Lake Bonneville, the youngest and deepest of several large pluvial lakes in northern Utah, are almost completely preserved. The lake started rising at about 28 thousand years ago (ka) and left a prominent series of beach gravels at the Stansbury shoreline during an oscillation of lake level about 25 ka. It reached a maximum depth about 15 ka (Oviatt and others, 1992), when the Bonneville shoreline formed. Shortly thereafter, the overflow threshold in southern Idaho catastrophically failed (Bonneville Flood) and the lake receded to a stable lower threshold, when the Provo shoreline formed until about 14 ka. From about 14 to 12 ka, the lake level fell to very low altitudes, leaving eastern Curlew Valley blanketed by marl, sand, and gravel. A small transgression of the lake formed the Gilbert shoreline between about 10.9 and 10.3 ka and left a wide blanket of sand north of Locomotive Springs. Subsequent erosion and alluvial and eolian deposition has modified the landscape only slightly, with the most notable feature being the entrenchment of Deep Creek and deposits that formed along its floodplains. The upper surface of the lacustrine marl that blanketed the area has been modified by wind and running water to produce a thin layer of reworked marl across most of the valley. Since the Gilbert shoreline was formed, the level of Great Salt Lake has fluctuated considerably. During its deeper phases it deposited carbonate muds near Locomotive Springs and formed sand and gravel shorelines. When shallower, it withdrew from the marsh area and alluvial and spring muds covered the lake deposits.

The highstand of Lake Bonneville (Bonneville shoreline) is at about 5,230 feet (1,594 m) altitude at Monument Peak. The Provo shoreline there is exposed at about 4,840 feet (1,475 m) altitude. The Bonneville and Provo shorelines decline in altitude 25 to 50 feet (7 to 14 m) from Monument Peak north to the Sublett Range as a consequence of isostatic rebound of the Bonneville basin. The shorelines between 4,500 and 4,400 feet (1,372 and 1,341 m) altitude are due to the Stansbury oscillation (Oviatt and others, 1990); the most prominent shorelines generally are near the top of this range. The Gilbert shoreline is at about 4,255 feet (1,297 m) altitude. The numerous other shorelines formed as a consequence of local factors, such as sediment budget and wave energy, in combination with possible stillstands and fluctuations in lake level.

The Provo shoreline in the Wildcat Hills is at 4,810 to 4,815 feet (1,466 to 1,468 m) altitude, where it forms a sharp wave-cut bench in rhyodacite. A Stansbury beach complex lies south of the Wildcat Hills, where it is consists of 11 easily recognized beach gravel accumulations and many more minor accumulations. The altitude range of these beaches is from 4,360 to 4,500 feet (1,329 to 1,372 m). The uppermost Stansbury beach on Cedar Hill is at 4,505 feet (1,373 m). A considerable amount of lacustrine gravel on Cedar Hill is mantled by marl, and so is transgressive. The most extensive accumulations of this covered gravel are from 4,430 to 4,450 feet (1,350 to 1,356 m) altitude, and probably formed in the lower reaches of the Stansbury oscillation. Many shorelines are preserved east of Monument Peak, but only the major gravel beaches are depicted on the map. The Provo shoreline is actually a complex of four or more shorelines in some places; wave energy was from the south and east, forming major build-outs to the north, including escarpments as high as 130 feet (40 m).

The internally-drained Sage Valley is separated from Curlew Valley by a low divide; the low point in the divide (figure 1) lies southwest of Johnson Hill (sec. 19, T.13N., R.8W.). A blanket of lacustrine sand lies in and west of this low point; ripples in the sand indicate west-directed currents during deposition. The rippled sand probably represents catastrophic failure of a beach in that low point, resulting in partial draining of the lake in Sage Valley. The tombolo was breached as Lake Bonneville receded and left water standing in Sage Valley at a higher altitude than in the main lake.

Lacustrine marl typically overlies coarser-grained lacustrine deposits such as sand (Qls) and gravel (Qlg). It forms sequences of laminated marl grading upward to dense gray marl, which in places is overlain by sandy marl. The laminated marl is conspicuous from a distance because it weathers white, in contrast to the gray marl above it. Bedding in the gray marl is indistinct. Matrix-supported pebbles, interpreted as dropstones, are relatively common in the unit and ostracodes are abundant throughout the unit. At the dam abutments for Rose Ranch reservoir, the marl lies on Pleistocene(?) massive silt interpreted as loess. Here, the Stansbury oscillation produced a thick wedge of sand in a delta-like environment. Overlying the deltaic sand is marl deposited during the Bonneville and Provo deep-water phases of the lake.

A dark brown ash deposit is present within the lacustrine marl deposited by Lake Bonneville. The ash is present northeast of Locomotive Springs and at Monument Point, but is absent in lower Deep Creek and points westward. The ash lies near the base of the marl and is about 0.4 inch (1 cm) thick. This ash exists in marl only below about 4,380 feet (1,335 m) altitude, presumably the altitude of Lake Bonneville at the time of the eruption. Its age was estimated at 26,500 years based on radiocarbon dates (Oviatt and others, 1992). Oviatt and Nash (1989) informally termed it the Thiokol ash for a locality near the Thiokol industrial plant in Blue Creek Valley, and it later was informally named the Hansel Valley ash by Miller and others (1995) for outcrops in that valley.

Strongly cemented gravels are present along the east side of Curlew Valley between the Stansbury and Provo shorelines. These gravels are unusual not only because they are strongly cemented by tufa, but the cemented gravel was eroded and a younger generation of tufa grew across the truncated surfaces. The gravels are steeply cross-bedded and formed in a high-energy beach environment. Ostracode shells collected from the tufa matrix in the gravel are late Pleistocene in age and typical of Lake Bonneville. Our interpretation is that the gravels record one or more oscillations of lake level in which the deposits formed and were cemented, the lake level declined and the deposits collapsed and were eroded, and then tufa was deposited across truncated surfaces as the lake rose again.

A gently-sloping platform of well-sorted lacustrine sand stretches southwest from (beneath) the Gilbert shoreline in lower Curlew Valley (figure 2). The sand lies on Bonneville marl, and must have been deposited by the lake during the Gilbert highstand. The sand platform is in turn cut by several wave-cut notches. The highest notch is at about 4,240 feet (~1,292 m) altitude and is generally bordered by small sand dunes. This may mark a temporary stillstand during the regression of the lake following the Gilbert highstand or a distinct Holocene highstand. Beneath this 4240-feet notch, most sediment is sand but it is commonly reworked (Qrs), probably both from lacustrine sand deposited during the Gilbert stage and from alluvial redbeds deposited after the Lake Bonneville regression and before the Gilbert stage. The reworked sand deposits are overlain by a gravel beach at 4,230 feet (1,289 m) and by a sand and gravel beach at 4,218 feet (1,286 m). The sand and gravel beach at 4,218 feet altitude rests on Holocene lake muds and represents one of the Holocene high stands of Great Salt Lake. It is well preserved and possibly the most recent of the highstands that buried platforms in the vicinity of Locomotive Springs. An older Holocene high at 4,230 feet altitude could be a Gilbert recessional beach or a later beach. Similarly, the wave-cut notch at 4,240 feet altitude is Holocene and probably relatively old. Sand commonly is reworked at this notch, and the notch served to focus eolian deposition to produce a line of dunes adjacent to the notch. Sand is more reworked below the notch, suggesting that the notch was cut during a Holocene highstand distinct from (later than) the Gilbert lake cycle.

NOTES ON STRUCTURE

Fault scarps that are Holocene in age are mapped in the Monument Point and Monument Peak quadrangles, and faults that are possibly Quaternary in age are mapped and inferred in several places in Curlew Valley. Faults along the western margin of the Monument Peak NW quadrangle are mapped on the basis of straight scarps in Pliocene basalt flows. The basalt overlies shattered limestone of the Oquirrh Formation in rare exposures. The scarps are rounded and overlapped by Lake Bonneville deposits, and are 10 to 40 feet (3 to 12 m) high. They trend north-northeast, parallel to the overall outcrop of basalt. A larger fault may be buried by sediment at the east side of basalt outcrops. These faults predate Lake Bonneville deposits, but probably are Quaternary in age because the scarps are not highly degraded. Lineaments mapped from aerial photographs lie east of and parallel to the fault scarps. The parallelism supports the interpretation of the lineaments as faults.

The Holocene fault scarps mapped in the Monument Point and Monument Peak quadrangles may have been produced by the Hansel Valley M 6.6 earthquake of 1934. Reports from early investigations (Adams, 1938) stated that 4 cracks crossed a road bordering the mud flat over a 2-mile zone, and one crack crossed and bent tracks of the Central Pacific Railroad. Three of the four cracks showed normal, down to the east offset and the fourth was normal, down to the west. The largest displacement measured was 20 inches (51 cm). The western two of these cracks might be those mapped as faults in the Monument Point and Monument Peak quadrangles, but the crack with largest offset lay east of the quadrangles and coincided with a fault with as much as 13 feet (4 m) of total offset. McCalpin and others (1992) inferred that previous displacements on this eastern fault took place during Lake Bonneville's highstand and earlier. After the 1934 earthquake, numerous springs were reported to have spurted water, and mud craters formed in several places in the mud flats. Springs were reported to issue from cracks in fractured quartzite at Monument Point. Interestingly, the general area subsided significantly during and following the earthquake, but the most pronounced subsidence coincided with and lay west of the ground cracks (Adams, 1938; Bucknam, 1979). Subsidence of 3 to 6 feet (1 to 2 m) was documented in Spring Bay between Stansbury's surveys of 1850 and surveys taken after the earthquake (Adams, 1938). Repeat leveling along the railroad grade (between 1911 and 1934) showed subsidence from the earthquake encompassed all of southern Hansel Valley and west to beyond Monument Point (Adams, 1938). This subsidence pattern may owe to primary westward downthrow on a fault along the east side of Spring Bay, with the observed downthrow for the 1934 scarps explained as occurring on a conjugate fault. The faults associated with the 1934 event do not border the valley, but rather strike discordantly; if the zone were extrapolated, it would project across the high part of the Hansel Mountains. These faults may not bound fundamental basin-and-range blocks, but rather be of a rifting origin (Miller and others, 1995). Supporting evidence for this fault system on the east side of Spring Bay is found in subdued fault scarps and numerous parallel lineaments along the east side of the bay in the Monument Point quadrangle. These faults and lineaments extend farther south to onshore equivalents that have offset Pliocene basalt flows by more than 50 feet (15 m) (Miller and others, 1995). Indeed, the east edge of Spring Bay as shown on the topographic map is straight and is probably fault controlled.

Lineaments of possible tectonic origin occur in much of Curlew Valley. Most are vegetation lines and appear dark on aerial photographs, but some are scarps, depressions, and lines of arid (light colored) ground. Although we have interpreted these features conservatively where they nearly parallel shorelines and straight stream drainages, lineaments are common and present throughout most of the valley and in a few hills. Deflected stream courses along some lineaments suggest that they had topographic relief in the past. Many lineaments trend north-northeast, although north trends and north-northwest trends are common and may represent antithetic sets for lineaments that are tectonic. Some lineaments are parallel to faults mapped on the basis of truncated bedrock, such as the faults cutting basalt in the Monument Peak NW quadrangle. In this quadrangle and in the Monument Point and Monument Peak NE quadrangles, lineaments also parallel topographic breaks that are inferred to represent concealed faults. The lineaments may have several origins, including: (1) man-made (fence lines or ditches), (2) lines of disturbed water flow due to underlying linear features, (3) faults, (4) fractures caused by settling, coseismic shaking, or ground-water withdrawal, (5) straight shorelines or alluvial drainages. Most lineaments are formed in Lake Bonneville deposits of latest Pleistocene age, so must be Holocene in age. Lineaments in Curlew Valley are generally, but not always, vague or invisible in deposits of alluvium (units Qal and Qla), suggesting that many are early Holocene in age. Lineaments in mud flats of the Monument Point quadrangle must be late Holocene in age. There, Great Salt Lake inundated part of the flats containing lineaments during the early 1950's; the lineaments visible on the late 1960's photography apparently formed between about 1955 and 1969. We consider the fairly uniform trend, parallelism with mapped faults, and evidence for topographic scarps along some lineaments to indicate that many are tectonic. These require trenching for more detailed investigations of their origin and age. Currey (1980) described fracture zones that trend from Dolphin Island (to the south on the west edge of Great Salt Lake) toward Monument Point, but he did not map them as far as Monument Point. He inferred early Holocene down-to-the-west movement on the fractures from topography associated with the fracture set.

Limited exposure of pre-Quaternary deposits makes assessment of the structure of eastern Curlew Valley difficult, but gravity data provide insights. Gravity data for Curlew Valley (Cook and others, 1989; data recontoured in more detail for figure 3) do not show any sharp anomalies, but rather a general trend of high values in the Cedar Hill area, decreasing southward and northward by as much as 30 mgals. A 20 mgal decrease that takes place northward along bedrock in the Hansel Mountains is assumed to be a regional gradient. Superimposed on this regional gradient, a wide gravity high with 5 to 10 mgal of relief encompasses the two major basaltic edifices and is probably caused by thick piles of dense basalt, some of which may be in the subsurface. No high coincides with the small edifice at Locomotive Springs. Sage Valley has no gravity relief, suggesting that it is floored by shallow Paleozoic bedrock rather than by low-density basinal deposits such as the Salt Lake Formation. Curlew Valley along Deep Creek has as much as negative 10 mgal of relief compared to the volcanic edifices, but little or no relief compared to adjacent bedrock, so is probably floored by shallow Paleozoic bedrock. This interpretation is consistent with the lack of outcrops of the Salt Lake Formation. The most pronounced gravity lows are in northern Monument Peak NW quadrangle and in Spring Bay (southern Monument Point quadrangle). Each of these lows has about 15 mgal of relief, which could correspond to a thickness as great as 4,000 feet (1,200 m) of low-density Tertiary and Quaternary strata. Test wells drilled in and next to the gravity low in northern Monument Peak NW quadrangle encountered 440 feet (134 m) of rocks assigned to the Salt Lake Formation at the southwest edge of the gravity low, 2,700 feet (823 m) of rocks farther into the low, and 3,080 feet (939 m) of rocks near the center of the low (Peace, 1956; modified by Baker, 1974). Other than the faults bounding these gravity lows, any faults bounding Curlew Valley must have total throw comparable to the present topographic relief, unlike the much larger faults bounding many basins in northern Utah in which thick Tertiary deposits have accumulated.

Pre-Quaternary faults are exposed a few places in bedrock outcrops and are inferred in places by contrasting bedrock facies. The poorly defined, thick late Paleozoic bedrock units make identification of all but the largest faults difficult. At Monument Peak, a west-northwest–striking fault is mapped. Two parallel faults are inferred on the basis of offset members and contrasting facies of the Oquirrh Formation. The faults are left-lateral and (or) down to the north, and have several miles (km) of offset.

Structures observed in outcrops of the Oquirrh Formation and the overlying cherty limestone unit range in scale from microscopic to the size of mountain sides. Minor folds and incipient cleavage are commonly present in rocks of the variable lithology member (Pov) at Monument Peak and in the southern Sublett Range. At Monument Peak, the minor folds seem to be related to a major fold that causes the peculiar map pattern there. At the north end of the structure, the rocks form a northwest-facing monocline, or anticline-syncline pair, that has nearly horizontal limbs and a 60°-dipping inclined sector. Farther south, this structure is an overturned fold with obscure axes, but the cherty limestone unit (Pc) underlies the Oquirrh in a zone of abundant minor isoclinal to tight folds with axes plunging shallowly to 210°. In the southern Sublett Range, minor folds are common in much of the variable lithology member. The folds plunge moderately (25-40°) to the northeast, and range from open to tight in shape. Vergence was not determined for the folds. Contacts between units in this location do not show evidence for larger-scale folding.

VOLCANISM

Early Pliocene (5.3 to 3.5 Ma) volcanism was widespread near northern Great Salt Lake (Miller and others, 1995). At Curlew Valley, this eruptive pulse is represented by basalt and rhyodacite flows in the Wildcat Hills. Subsequent volcanism was more strongly concentrated in Curlew Valley itself. Latest Pliocene (~2.1 Ma) rhyolite flows and minor cauldron subsidence with an inferred explosive eruption took place in the Wildcat Hills; these volcanic rocks are exposed just west of the map. From 1.2 to 0.4 million years ago basalt erupted to form the three shields along the east side of Curlew Valley. Basaltic ash was erupted from an uncertain location west of Hansel Valley, probably from eastern Curlew Valley, about 26,500 years ago.

The Wildcat Hills contain three types of lava: rhyolite, rhyodacite, and basalt (Howes, 1972; Shea, 1985). Basalt and rhyolite flows overlie the Miocene Salt Lake Formation on an angular unconformity but rocks under the rhyodacite are obscured. Medium- to dark-gray rhyodacite contains a moderate amount of plagioclase, clinopyroxene, orthopyroxene, and quartz in decreasing abundance (Shea, 1985). Black basalt is fine-grained and crystalline, containing plagioclase and olivine in a groundmass of plagioclase, augite, olivine, and oxides. Miller and others (1995) dated the rhyolite at 2.1 ± 0.1 Ma on sanidine, rhyodacite at 4.4 ± 1.1 Ma on plagioclase, and a basalt flow at 3.6 ± 0.1 Ma using whole-rock.

Three remnant basaltic shield volcanoes in eastern Curlew Valley were previously considered to be Tertiary (Doelling, 1980), Pliocene (Hintze, 1980), and Quaternary (Baker, 1974; Shea, 1985) on the basis of geomorphology. The two northern shields retain summit collapse features and individual flows can be traced down the flanks. The southern shield is small and may have been eroded more by waves of pluvial lakes; it shows only a flat summit that may have once been a crater. Basalt in all three volcanic shields is black or reddish black, aphanitic to fine grained lava that contains plagioclase and olivine in a groundmass of those minerals plus augite (Kerr, 1987).

The three main exposures of basalt in Curlew Valley retain the form of shield volcanoes: broad, gentle-slopes, and conical shapes. Cedar Hill is 705 feet (215 m) high and 3.4 miles (5.5 km) in diameter; the intermediate shield is 460 feet (140 m) high and 2.5 miles (4 km) in diameter; and Locomotive Springs shield is 115 feet (35 m) high and 1.2 miles (2 km) wide. Because the lower reaches of the shields have been buried by lacustrine and alluvial materials, the decreasing size to the south may be due either to smaller eruptions or greater subsidence and burial, or both. Many flows are pahoehoe, and all seem to have issued from summit craters. Smaller outcrops of basalt east and north of these volcanoes are poorly exposed and of uncertain origin, but most likely represent remnants of flows from these volcanoes. All flows are overlain by late Pleistocene deposits of Lake Bonneville .

Samples collected from the youngest flows from each volcano contained fresh plagioclase in a dark matrix; the sample from the Locomotive Springs shield has particularly abundant plagioclase. K-Ar age determinations on these samples were replicated with splits of the same sample because precision is poor with young low-K rocks. The following ages and analytical data were reported in Miller and others (1995):

Cedar Hill (M89CV-43):	1.16 ± 0.08 Ma
Middle shield (M89CV-44):	0.72 ± 0.15 Ma
Locomotive Springs (M87LS-135):	0.44 ± 0.10 Ma

On the basis of chemical similarity and the location of the ejecta blanket the Hansel Valley ash was probably erupted from eastern Curlew Valley (Miller and others, 1995). It could be the fourth in a series of eruptions, but its small volume compared to the shields suggests that it should be considered a minor event. The explosive eruption that created the Hansel Valley ash likely was caused by interaction of magma with water in the near surface or at the surface. A source within water-charged lowlands of Curlew Valley or within Lake Bonneville is likely, but no tephra ring, coarse proximal deposits, or other indicators of the vent has been discovered. It is possible that the Hansel Valley ash eruption was triggered by the load of Lake Bonneville; several other basaltic eruptions took place during the lifetime of Lake Bonneville (Oviatt and Nash, 1989). A superb exposure of the Hansel Valley ash may be found at Monument Point, where wave-cut bluffs expose the marl section on both sides of the point and the ash forms a thin brown layer that can be traced for considerable distance.

The Quaternary basalt shield volcanoes of eastern Curlew Valley are similar in mineralogy and geochemistry but decrease systematically in age and size southward toward the Great Salt Lake, suggesting a progressive movement of an eruptive center with time at a rate of about 0.8 inch/year (2 cm/year). The volcanoes seem to have formed every 300,000 to 400,000 years. By this analysis, and if the Hansel Valley ash is considered to be a minor event, the next eruption is overdue.

GEOLOGIC HAZARDS

Earthquake Hazards

Northern Utah is part of a seismic belt characterized by numerous small-magnitude seismic events and by potential for infrequent major events (Smith and Sbar, 1974; Christenson and others, 1987). Historic felt earthquakes include the magnitude 6+ events in Hansel Valley during 1909 and 1934 (Arabasz and others, 1994). Frequent smaller-magnitude earthquakes ($M<4$) occur in a broader area including Hansel and Curlew Valleys, northern Great Salt Lake, and the Rozel Hills (Christenson and others, 1987; Hecker, 1993).

Quaternary faults in Hansel Valley include those mapped in the Monument Point and Monument Peak quadrangles and subparallel faults within one mile (1.6 km) to the east that were studied by Robison and McCalpin (1987) and McCalpin and others (1992). Quaternary faults also are inferred by several workers to lie within the northwestern part of Great Salt Lake (Hecker, 1993). Pleistocene(?) faults cut basalt in a few places in western Monument Peak NW quadrangle. Lineaments in Curlew Valley may in part be faults of Holocene age. These faults and lineaments suggest a Quaternary record of surface rupture due to seismic events.

The 1934 magnitude 6.6 earthquake in Hansel Valley (Christenson and others, 1987) produced surface rupture along four cracks (Adams, 1938), some of which show evidence for earlier displacements (Robison and McCalpin, 1987; McCalpin and others, 1992). The earthquake caused severe damage in local towns and ranches, and it even caused damage in cities along the Wasatch Front. An earlier earthquake in 1909, estimated at M 6.0, apparently did not produce surface rupture. The evidence for repeat faulting at this location makes clear that a threat for future earthquakes is real, but the pattern of recurrence is complex and not easily converted as a predictive tool. The recurrence interval appears to be several thousands of years (McCalpin and others, 1992).

The regional history of seismic activity (Christenson and others, 1987; Hecker, 1993) and evidence for Quaternary faults in Curlew and Hansel Valleys raises the possibility of moderate to large local earthquakes. If even a small proportion of the lineaments identified by this study represent Holocene fault ruptures, the potential for M>6 earthquakes in Curlew and Hansel Valleys is much greater than has been previously estimated. The active Wasatch fault zone and related faults 45 miles (70 km) to the east (Smith and Bruhn, 1984) present a potential for a major seismic event that also could strongly shake the Curlew Valley area. In addition to ground shaking and surface rupture, earthquake hazards in this region include lateral spreads and liquefaction, and rockfalls.

Landslides

Landslides are uncommon in eastern Curlew Valley; a few isolated slumps within lacustrine materials were noted east of Monument Peak. These small slumps (not mapped) have occurred on steep, unstable slopes where thick lacustrine gravel deposits were built northward over finer grained sediments.

Flooding

Floods are a potential in much of Curlew Valley. A potential exists for debris flows and floods on alluvial fans, and on broad alluvial terraces and plains near streams such as Deep Creek. The narrow canyon occupied by much of Deep Creek is a likely site for powerful floods.

Gullying has occurred in many areas underlain by unconsolidated to moderately consolidated materials; the uplands undergoing intensive agriculture in the Hansel Mountains show especially pronounced gullying. The fine-grained Quaternary materials are highly susceptible to the erosion that results from destroying natural ground cover.

The mud flats between Great Salt Lake and the lowlands of Locomotive Springs and Monument Point were flooded several times during the Holocene by rise of Great Salt Lake. Several of these floods were more extensive than the flood of the late 1980's, when Great Salt Lake occupied beaches at Monument Point and flooded much of the marshland in Locomotive Springs Wildlife Management Area. Based on this Holocene record, Great Salt Lake may flood more extensively than it did in the 1980's.

Volcanic Hazards

The youthful ages of Quaternary volcanic rocks in Curlew Valley, the youngest of which is a basaltic ash about 26,500 years old, suggest a possibility of future eruptions. Modern seismicity coincides with the eruptive centers, strengthening the suggestion that volcanic activity is part of the modern tectonics in the area. Although most eruptions produced basaltic lava flows, which is a hazard generally relatively easily mitigated in sparsely populated areas, the presence of basaltic ash indicates that explosive eruptions also took place. If the southward progression in ages of basalt in Curlew Valley is extrapolated, future eruptions would take place within Great Salt Lake, a likely setting for an explosive hydromagmatic eruption. Even a small explosive eruption could impact the people and infrastructure of the Wasatch Front and could heavily impact local ranches and communities. In addition to these data, we have observed probable Holocene ground deformation in the form of multiple fault-controlled(?) lineaments and one moderate-temperature (43 °C) spring (Coyote Spring) north of the Wildcat Hills that might reflect shallow magma.

RESOURCES

Water

The depth to rock beneath unconsolidated sediment is uncertain in most of Curlew Valley, as is the likely permeability and transmissivity of the rock, much of which is probably fractured. As a result, estimating ground-water resources and flow paths is difficult. It is probable that a nearly unbroken blanket of sand and gravel lies at the base of the lacustrine marl section; this blanket and locally underlying alluvium may provide fast transmission of water down topographic gradient in the valley floor. In addition, widespread buried basalt is very likely. Brecciated lava flows, lava tubes, and cinder deposits could store water and provide rapid transmission of water. Ranchers describe a water-bearing zone in the valley bottom south and southeast of Cedar Hill as composed of red cinder. Above the cinder is about 150 feet (45 m) of basalt lava, overlain by 20 feet (6 m) of unconsolidated materials that probably represent Lake Bonneville deposits. The lack of a playa in internally-drained Sage Valley implies exceptionally good drainage, possibly due either to solution cavities in limestone or to buried cinder or gravels that connect to discharge points down-gradient.

Baker (1974) described the ground water systems of Curlew Valley, indicating that most recharge occurs in the mountains of Idaho and most storage and transmission occurs in inferred "valley-fill" deposits and interbedded volcanic rocks. Baker (1974) suggested that pumping from irrigation wells in the northern part of the valley can decrease the discharge at Locomotive Springs. Locomotive Springs, a group of six springs that provide surface water for two artificial lakes and extensive marshes, discharge moderately saline water that is mostly transpired by vegetation or evaporated; relatively little water is discharged to Great Salt Lake.

Sand and Gravel

Lacustrine sand and gravel deposits of Lake Bonneville form thick platforms surrounding most mountains and hills, some of which may be suitable for use in road construction and as fill for local construction. The largest accumulations of gravel are indicated on the map as lacustrine gravel (Qlg). Eolian sand deposits generally contain mud pellets, gypsum, and ooids, making it unsuitable for many construction purposes.

A source for silica may be found in the sandstone member of the Oquirrh Formation. Rock in this member commonly is highly fractured and silicified, possibly making it of value as an easily mined somewhat impure silica source. It is probably also a good source for road metal.

Minerals

No prospects for mineral ores or evidence of mineralization in bedrock were observed in the area mapped. Coyote Spring near the Wildcat Hills yields hot water and has associated sinter as thick as 1 feet (30 cm), but no minable mineral deposits were observed. The sinter is siliceous, brown, and based on a framework of plants. Also, no material of potential value as decorative stone was observed.

Energy

The hydrocarbon resource potential for the area has not been rigorously assessed. Three test wells in the Monument Peak NW quadrangle to depths of 4,765 to 7,569 feet (1,452 to 2,307

m) were abandoned with only minor shows of gas (Peace, 1956). The wells encountered structurally complex upper Paleozoic strata, some of which were metamorphosed (Peace, 1956).

Coyote Spring, north of the Wildcat Hills, yields hot water (43.5 °C; Baker, 1974) that may be of value as a low-temperature geothermal resource, such as for heating greenhouses or other buildings. The hot water probably circulates from depth to the surface by pathways related to the faults north of the Wildcat Hills.

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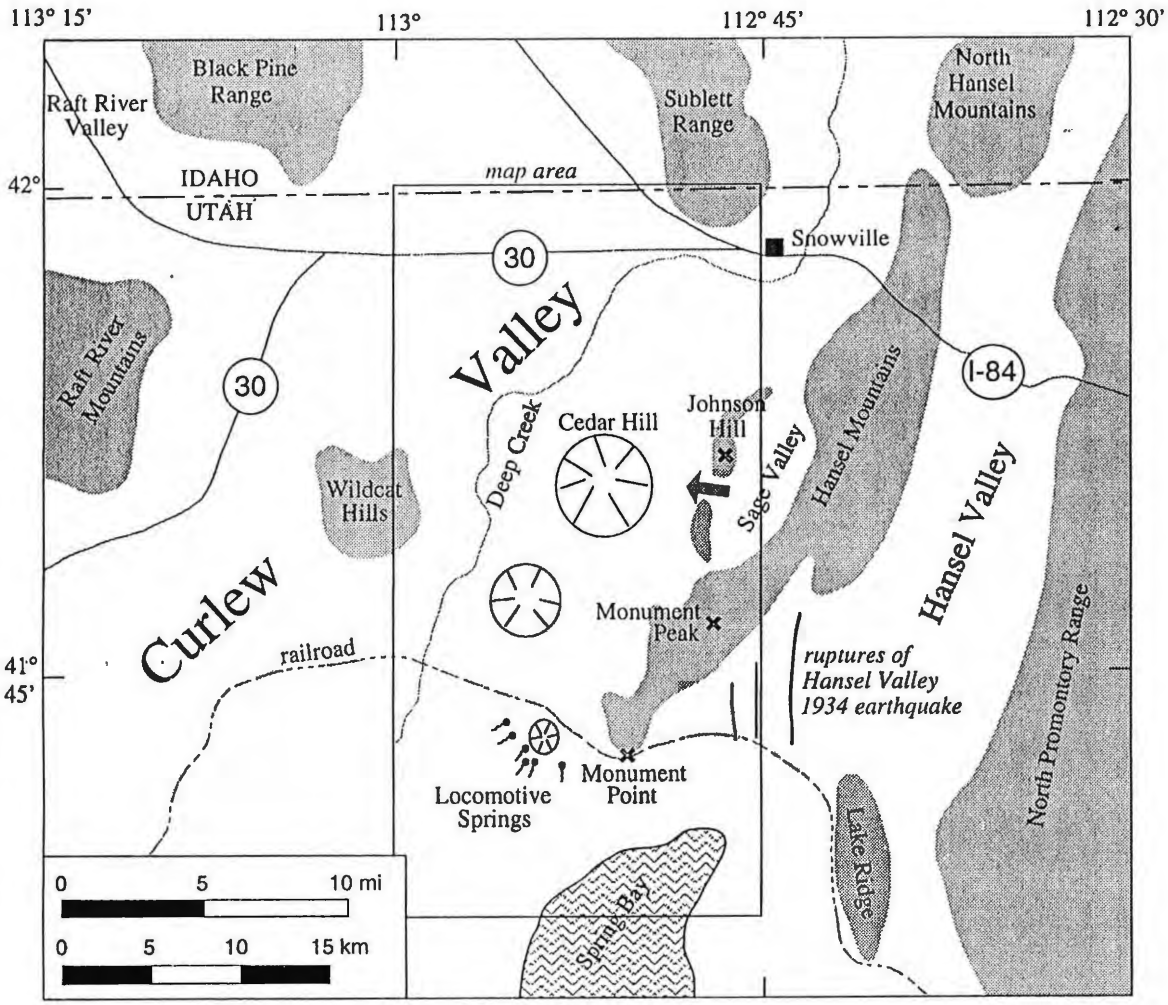

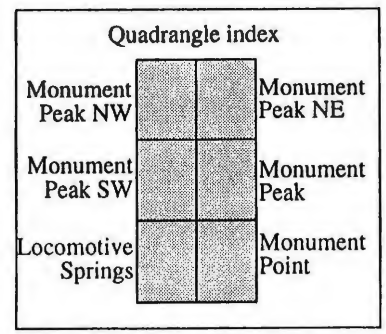

Figure 1. Location map of geologic quadrangles in eastern Curlew Valley. Quaternary shield volcanoes and 1934 ruptures of the Hansel Valley earthquake are shown. Arrow west of Sage Valley shows outflow direction during catastrophic draining of Sage Valley as Lake Bonneville receded.

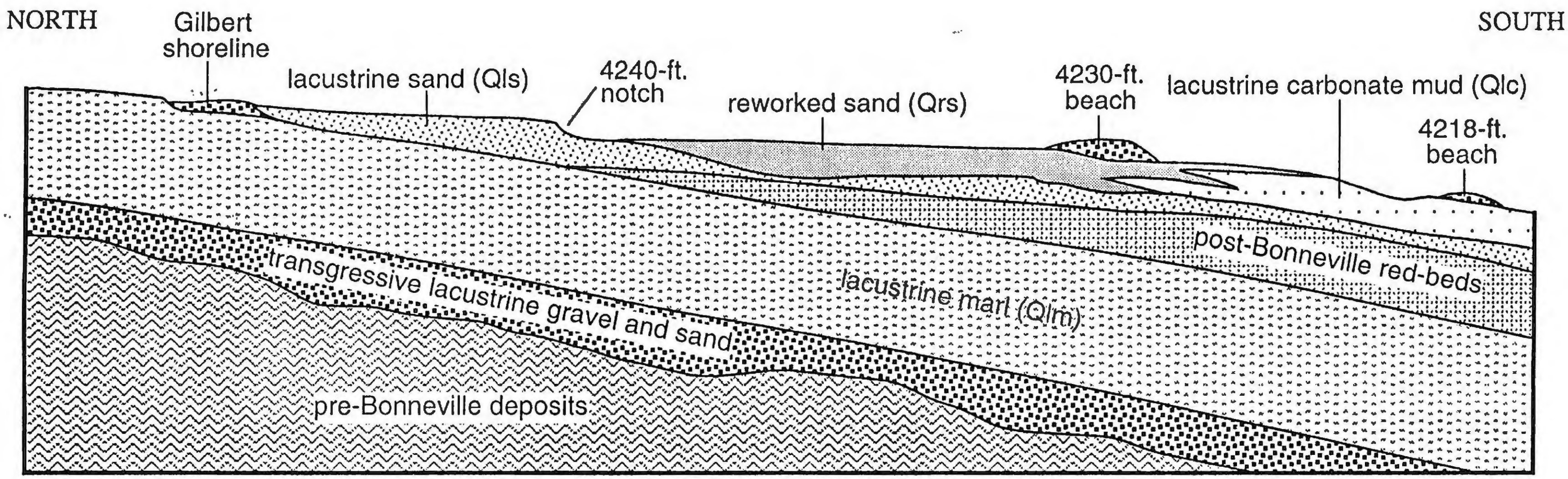

Figure 2. Diagrammatic section through late Pleistocene Bonneville lake deposits and post-Bonneville (Holocene) continental and lake deposits as exposed near Locomotive Springs, southern Curlew Valley.

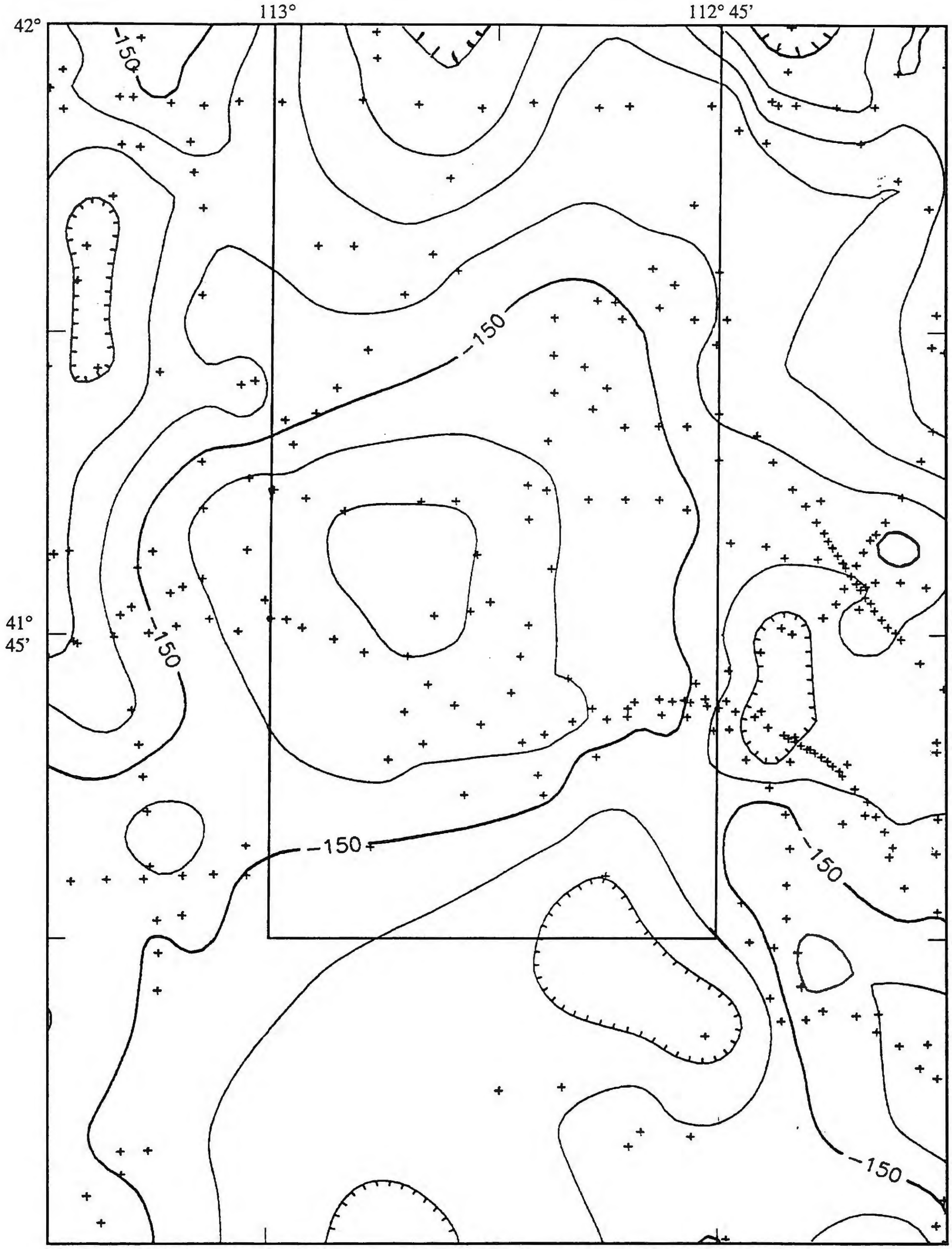

Figure 3. Contoured gravity data for Curlew Valley area; contour interval is 5 mgal. Crosses indicate data stations. Rectangle shows location of six quadrangle maps for this report.

DESCRIPTION OF MAP UNITS

[All listed units may not be present on this map]

Note on mapping conventions: Where a Quaternary map unit is present as a thin veneer, that unit is mapped with the slash notation (/) to denote the unit it is overlying; for instance, Qlg/Pc indicates that a thin sheet of Qlg overlies unit Pc.

Qal Alluvium (Holocene)--Poorly sorted gravel, sand, silt, and clay in ephemeral and perennial stream channels. Most mapped deposits are in Blue Creek channel; many other channels are too narrow to depict on map

Qai Alluvial silt (Holocene)--Dark-brown silt and sand that formed as ponded deposits behind undissected barrier beaches of Lake Bonneville, following water withdrawal. Unit commonly overlies lagoon deposits of late Pleistocene age

Qaf Alluvial fan deposits (Holocene)--Poorly sorted gravel, sand, silt, and clay forming small fans, mostly in upland areas such as the Hansel and Sublett Mountains

Qam Alluvial mud (Holocene)--Brown clay and silt underlying flats in vicinity of Locomotive Springs and Monument Point. Sticky, soft, and wet. Probably includes some lacustrine mud from Holocene highstands of Great Salt Lake which is similar in appearance. Organic-rich spring muds included in this unit in vicinity of Locomotive Springs Wildfowl Management Area

Qsm Spring mud (Holocene)--Dark-brown to black organic-rich clay and silt in mud flats in vicinity of springs near Monument Point

Qc Colluvium (Holocene)--Slopewash and talus forming moderate to steep slopes at base of cliffs. Only mapped on Monument Peak; smaller talus slopes not mapped

Qrm Reworked marl (Holocene and Pleistocene)--Thin (< 3 ft [1 m]) mantle of fine-grained marly material reworked by alluvial and eolian processes, overlying lacustrine marl (Qlm)

Qlm Lacustrine marl (Pleistocene)--White to pale brown marl containing abundant ostracodes and sparse dropstones. Lower part typically white and laminated; upper part white to pale brown and less distinctly bedded. Locally includes one brown basaltic ash bed, sand beds, and gravel lenses. About 3 to 15 ft (1 to 5 m) thick

Qlf Lacustrine fines (Pleistocene)--White, pale brown, and tan, laminated to thin-bedded, fine-grained sediment deposited by Lake Bonneville. Represents environments where rate of terrigenous influx overwhelmed rate of marl deposition; only mapped on Cedar Hill

Qls Lacustrine sand (Pleistocene)--Brown, well-sorted sand. Thickest deposits are below Provo shoreline. Underlies broad delta plain, later entrenched by Deep Creek, near and west of Rose Ranch Reservoir; deposited during Stansbury stage of Lake Bonneville. Sand deposited during Gilbert stage forms a broad platform westward from Monument Point

Qlgs Lacustrine gravel and sand (Pleistocene)--Well-sorted gravel and sand. Commonly forms barrier beaches similar in shape to the gravel (Qlg) beaches, but differs from them by containing a high proportion of sand. Unit probably represents deposition in lower energy environment than that of gravel beaches

Qlg Lacustrine gravel (Pleistocene)--Cobble and pebble gravel with silt or tufa matrix. Forms bars and barrier beaches, and mantles steep slopes. Especially common at Stansbury, Provo, and Bonneville shorelines

Qlgc Cemented lacustrine gravel (Pleistocene)--Highly indurated cobble and pebble gravel, well cemented by tufa matrix. Represents eroded remnants of spits in Sage Valley. Formed early in Lake Bonneville cycle based on ostracodes in matrix of gravel

Qb Basalt (Pleistocene)--Black vesicular basalt containing plagioclase, olivine, and pyroxene in aphanitic matrix. Forms three shield volcanoes from Locomotive Springs north to Cedar Hill dated at 0.44 ± 0.10 Ma, 0.72 ± 0.15 Ma, and 1.16 ± 0.08 Ma, respectively (Miller and others, 1995). Outlying non-contiguous basalt outcrops may represent remnants of lava flows from those volcanoes

QTel Eolian loess (Pleistocene and Pliocene)--Light brown and red loess in locally thick accumulations; fine sand- and silt-sized. Underlies late Pleistocene marl at Rose Ranch Reservoir dam. Overlies Paleozoic rocks east of Monument Point

Tb Basalt (Pliocene)--Black basalt containing plagioclase, olivine, and pyroxene in aphanitic matrix. Remnants of flows north of Wildcat Hills. Similar to basalt south of Wildcat Hills dated at 3.6 ± 0.1 Ma (Miller and others, 1995). As thick as 65 ft (20 m)

Trd Rhyodacite (Pliocene)--Dark gray rhyodacite containing pyroxene and plagioclase in aphanitic to glassy matrix. Several thick lava flows with black vitrophyre margins exposed in Wildcat Hills. Dated at 4.4 ± 1.1 Ma (Miller and others, 1995). Greater than 200 ft (60 m) thick

Ts Salt Lake Formation (Miocene)--Moderately consolidated, gray to brown air-fall tuff and tuffaceous sandstone. Air-fall tuff is mainly glass shards. Outcrops east of Monument Point contain tuff 10 ft (3 m) thick. Also present 1.5 mi (2 km) west of the map area in the Wildcat Hills, where it underlies with angular unconformity Pliocene volcanic rocks of the Wildcat Hills

Pc Cherty limestone (Lower Permian)--Medium-gray, thin-bedded chert and cherty limestone. Chert locally makes up 95% of unit. Minor but distinctive rock types are thick beds of clastic limestone and calcareous quartzite. Soft-sediment folds and slumps common. Greater than 6,000 ft (1,800 m) thick east of Monument Point, but upper part may be structurally complex

PIPo Oquirrh Formation (Permian and Pennsylvanian)--Light-gray to brown weathering, thin- to thick-bedded limestone and sandstone and lesser siltstone; cherty in places. In most of map area, divided into:

Pov Variable lithology member (Lower Permian)--Interbedded platy and laminated silty limestone, coarse clastic limestone, medium-grained calcareous quartz sandstone, and brown siltstone. Diagnostic rock type is platy silty limestone. Generally thin bedded, but some limestone beds are thick. Common bioturbated beds. Generally forms recessive slopes. About 6,000 ft (1,800 m) thick

Pos Sandstone member (Lower Permian)--Light gray, calcareous very-fine-grained quartz sandstone and orthoquartzite, commonly cross-bedded. Commonly highly fractured and silicified. Contains rare fusulinid foraminifera similar to Permian forms. Greater than 9,500 ft (2,900 m) thick but base is not exposed

IPoll Laminated limestone member (Upper Pennsylvanian)--Light- to medium-gray, silty and sandy clastic limestone and brown, calcareous very-fine-grained quartz sandstone. Thinly interbedded to laminated; common bedding characteristic is wavy lamination caused by extensive bioturbation. Thickness uncertain; contacts with other members of the Oquirrh Formation not exposed. Thickest continuous exposure in Johnson Hill area is 2,000 ft (610 m) thick. Similar to Upper Pennsylvanian irregularly laminated limestone, sandstone and clastic limestone, and thin-bedded limestone and sandstone members of Jordan (1985) in the North Promontory Mountains

Map Symbols

(All symbols may not be present on this map)

Contact–Dashed where inferred or gradational; dotted where covered

Fault–Dashed where inferred; dotted where covered; bar and ball on downthrown side were sense of offset known

Anticline–Trace of axis

Syncline–Trace of axis

Bedding

Igneous foliation

Lineament–Possible fault or fracture mapped from aerial photographs

Lava flow direction

Geochronology sample location

Approximate location of drill hole

Shorelines: Labels are B, Bonneville; P, Provo; S, Stansbury; G, Gilbert; R, Regressive; I, Intermediate; T, Transgressive; unlabeled shorelines are undetermined

Geologic mapping was conducted 1989-1995.

CORRELATION OF MAP UNITS

[All units shown may not be present on this map]