UTAH GEOLOGICAL SURVEY
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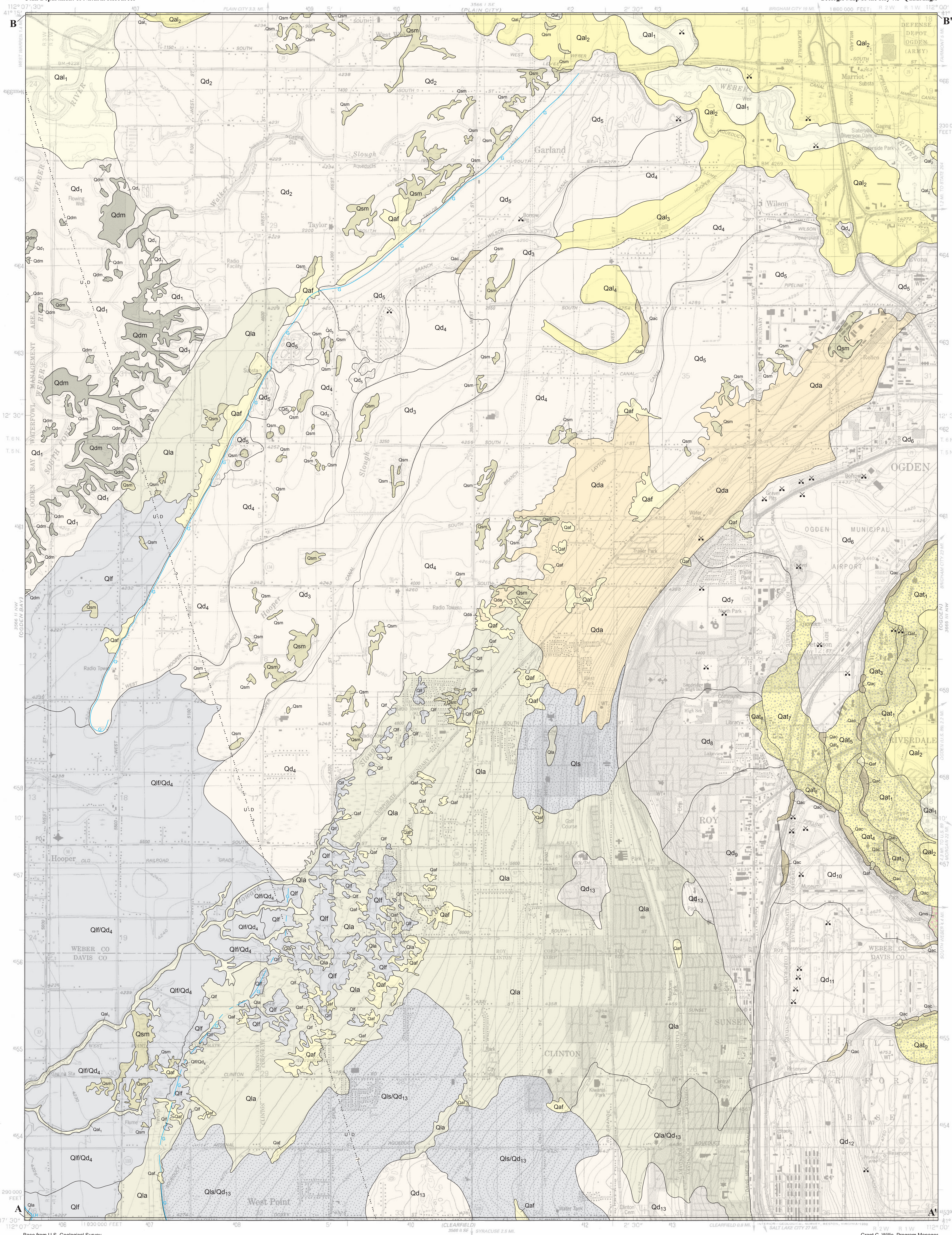
Plate 1
Utah Geological Survey Miscellaneous Publication MP-05-03
Geologic Map of the Roy 7.5' Quadrangle




Base from U.S. Geological Survey, Roy 7.5' quadrangle, 1990

Grant C. Willis, Program Manager
Douglas A. Sprinkel, Project Manager
James Parker, Cartographer

SCALE 1:24,000

CONTOUR INTERVAL 5 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

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13°18'
236 mils

2005 MAGNETIC DECLINATION AT CENTER OF SHEET

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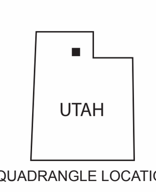



QUADRANGLE LOCATION

# GEOLOGIC MAP OF THE ROY 7.5' QUADRANGLE WEBER AND DAVIS COUNTIES, UTAH

by

Dorothy Sack

2005

## DESCRIPTION OF MAP UNITS

*Quaternary Surficial Deposits*

**Qac** Undifferentiated alluvium and colluvium - Wash-reworked mass wasting deposits and intertonguing alluvium and colluvium. Poorly sorted fines through cobble-sized clasts deposited from about 13.2 ka to present. Thickness probably less than 12 feet (3.7 m).

**Qaf** Alluvial-fan deposits - Predominantly sandy fine-grained sediment deposited from about 13.2 ka to present. Thickness probably less than 10 feet (3 m).

**$Qal_1$** Late Holocene channel and flood-plain alluvium - Well to poorly sorted fines to gravel deposited from about 3.3 ka to the present. Thickness probably less than 10 feet (3 m).

**$Qal_2$** Early to middle Holocene channel and flood-plain alluvium - Fine sandy mud to gravel deposited between about 9.4 and 3.3 ka. Thickness 3 to 10 feet (1-3 m).

**$Qal_3$** Channel and flood-plain alluvium of very latest Pleistocene age - Muddy to pebbly sand deposited from about 12.0 to 10.3 ka. Approximately 7 feet (3 m) thick.

**$Qal_4$** Channel alluvium of pre-Gilbert shoreline age - Mixed fine-grained to pebbly mixed fine-grained sediment deposited from about 12.1 to 12.0 ka. Estimated thickness is 3 feet (1 m).

**$Qat_1$-$Qat_9$** Fluvial terrace deposits - Mud to gravel deposited between about 13.2 and 12.0 ka in nine discrete terraces (1 = youngest) that range from 15 to 125 feet (5-38 m) thick.

**Qda** Undifferentiated deltaic and alluvial deposits - Sand-dominated fine-grained deltaic deposits washed downslope by small-scale fluvial processes from about 12.2 ka to present. Estimated maximum thickness is 6 feet (1.8 m).

**Qdm** Deltaic mud - Predominantly silt and clay deposited since about 0.4 ka. Thickness probably less than 3 feet (1 m).

**$Qd_1$** Late Holocene fine-grained deltaic deposits - Muddy to sandy fines deposited since about 0.4 ka. Thickness probably less than 10 feet (3 m).

**$Qd_2$** Early Holocene fine-grained deltaic deposits - Muddy to sandy fines deposited between about 9.7 and 9.4 ka. Estimated thickness 10 to 20 feet (3-6 m).

**$Qd_3$** Fine-grained deltaic deposits of approximately Gilbert shoreline age - Muddy to sandy fines deposited between about 11.0 and 10.3 ka. Estimated thickness at least 6 feet (2 m).

**$Qd_4$** Fine-grained deltaic deposits from very late in Lake Bonneville's post-Provo regression - Sandy fines, sand, and pebbly sand deposited between about 12.1 and 12.0 ka. Maximum thickness is probably at least 12 feet (3.7 m).

**$Qd_5$** Sand-dominated deltaic deposits from late in Lake Bonneville's post-Provo regression - Sandy mud through gravelly sand deposited between about 12.2 and 12.1 ka. Thickness varies from 1 to 35 feet (0.3-10.7 m).

**$Qd_6$-$Qd_{11}$** Sand-dominated deltaic deposits from the early and middle post-Provo regressive phase of Lake Bonneville - Primarily fine and medium sand, crossed by channel deposits of gravel or sand and gravel, deposited in six discrete delta components (6 = youngest) between about 14.0 and 12.2 ka. Maximum thicknesses range from 50 to 125 feet (15-38 m).

**$Qd_{12}$** Deltaic sand of Provo shoreline age - Sand-dominated sediments deposited between about 14.5 and 14.0 ka. Estimated maximum thickness is 75 feet (23 m).

**$Qd_{13}$** Deltaic sand from the transgressive phase of Lake Bonneville - Sand-dominated sediments deposited between about 27.5 and 20.4 ka. Estimated maximum thickness is 30 to 40 feet (9-12 m).

**Qla** Undifferentiated lacustrine and alluvial deposits - Fluvially reworked lake sediments and intermingled lake and alluvial-fan deposits. Sandy fines through gravelly sand deposited from about 12.6 ka to the present. Thickness generally less than 10 feet (3 m).

**Qlf** Fine-grained lacustrine deposits - Mixed fine-grained sediment, generally with a sand component, deposited by Lake Bonneville and Great Salt Lake between about 27.5 to 2.0 ka. Thickness probably less than 10 feet (3 m).

**Qls** Lacustrine sand - Sand-dominated sediments deposited between about 12.4 and 12.1 ka during the regressive phase of Lake Bonneville. Thickness probably less than 15 feet (4.6 m).

**Qms** Slump deposits - Predominantly gravelly silt and gravelly fine sand deposited from about 12.0 ka to present. Estimated maximum thickness is 30 feet (9 m).

**Qsm** Marsh deposits - Wet, fine-grained, organic-rich sediments in association with springs, ponds, and seeps. Deposited from about 12.1 ka to present. Thickness probably less than 5 feet (1.5 m).

**Qu** Undifferentiated surficial deposits - Represents surficial deposits along the line of cross section; includes alluvium, colluvium, deltaic, and lacustrine deposits. Shown only on cross section. Thickness generally less than 400 feet (122 m)

*Basin Fill*

**Qb** Quaternary basin fill - Weakly to unconsolidated mixture of alluvial and lacustrine clay, silt, sand, gravel, marl, and thin tuffaceous layers. Includes a thicker, gravel-bearing zone corresponding to the Delta aquifer. Shown only on cross sections. Thickness up to 1,300 feet (400 m).

**Tb** Late Tertiary basin fill - Weakly to strongly consolidated mixture of conglomerate, sandstone, mudstone, tuffaceous sandstone, tuff, and lacustrine limestone. Shown only on cross sections. Thickness up to 7,000 feet (2,042 m).

*Bedrock*

**-Ct** Tintic Quartzite - Main part of formation consists of cliff-forming, white to tan, thin- to thick-bedded, quartz-rich, well-cemented sandstone (orthoquartzite) with some lenses of quartz-pebble conglomerate and thin layers of argillite; argillite intervals increase in abundance and quartz pebbles decrease in abundance toward the top of the formation; basal part of the formation consists of heterogeneous mixture of green to purple to tan, arkosic sandstone, quartz-pebble conglomerate, and micaceous siltstone. Shown only on cross section. Thickness ranges from about 1,300 to 1,500 feet (400-500m).

**Xf** Farmington Canyon Complex, undivided - Metamorphic and igneous rocks of Early Proterozoic age. Shown only on cross section. Thickness unknown.

*Stacked Geologic Units*

**Qls/$Qd_{13}$** Stacked geologic units - Mapped where surficial deposits are thinly distributed over other surficial deposits; example is of lacustrine sand deposits thinly distributed over Lake Bonneville transgressive-phase deltaic sand deposits.

## GEOLOGIC SYMBOLS

Contact

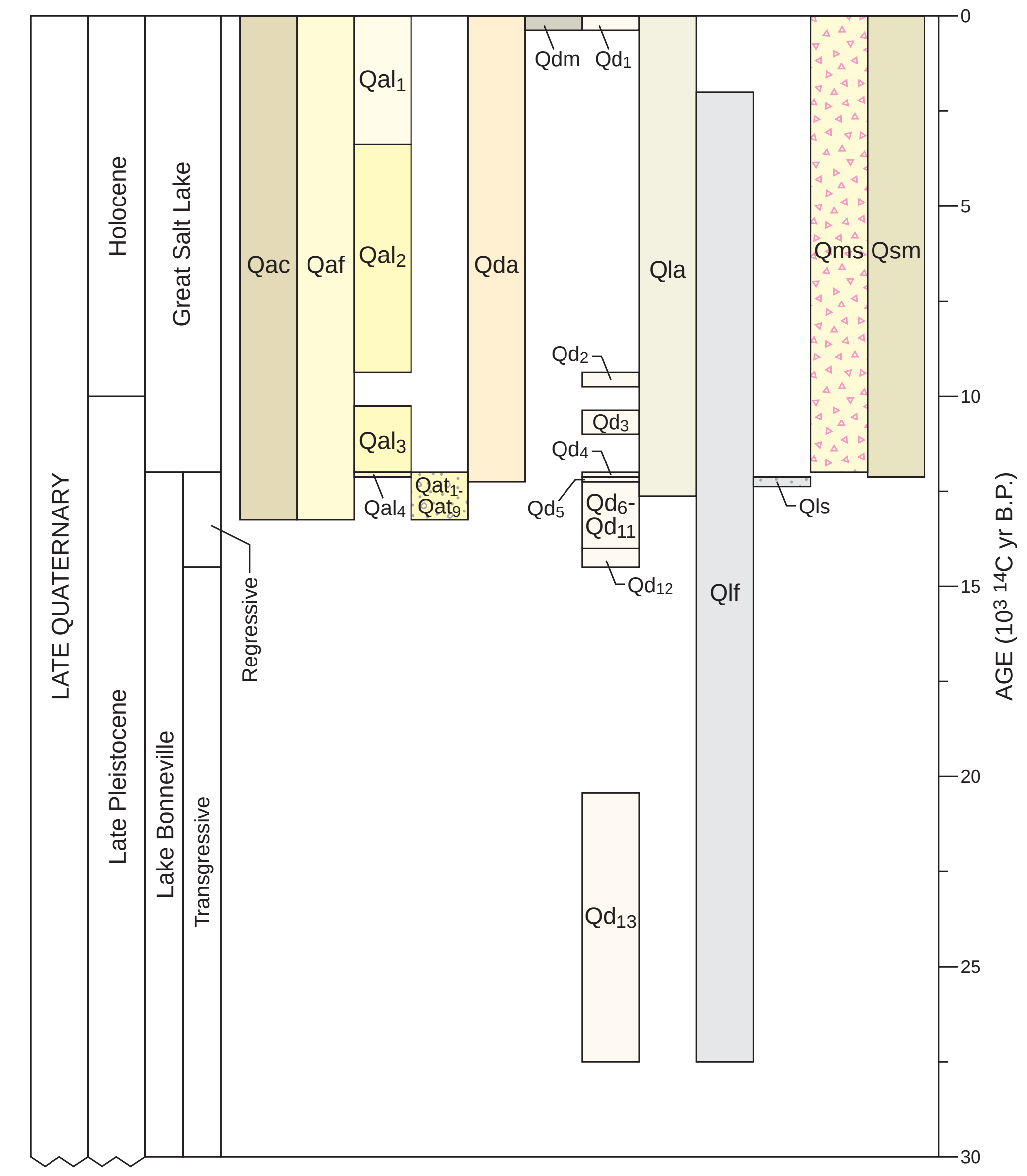
Concealed fault; identified from seismic data; D on downthrown side and U on upthrown side; query indicates approximate position at surface

Gilbert shoreline of Great Salt Lake

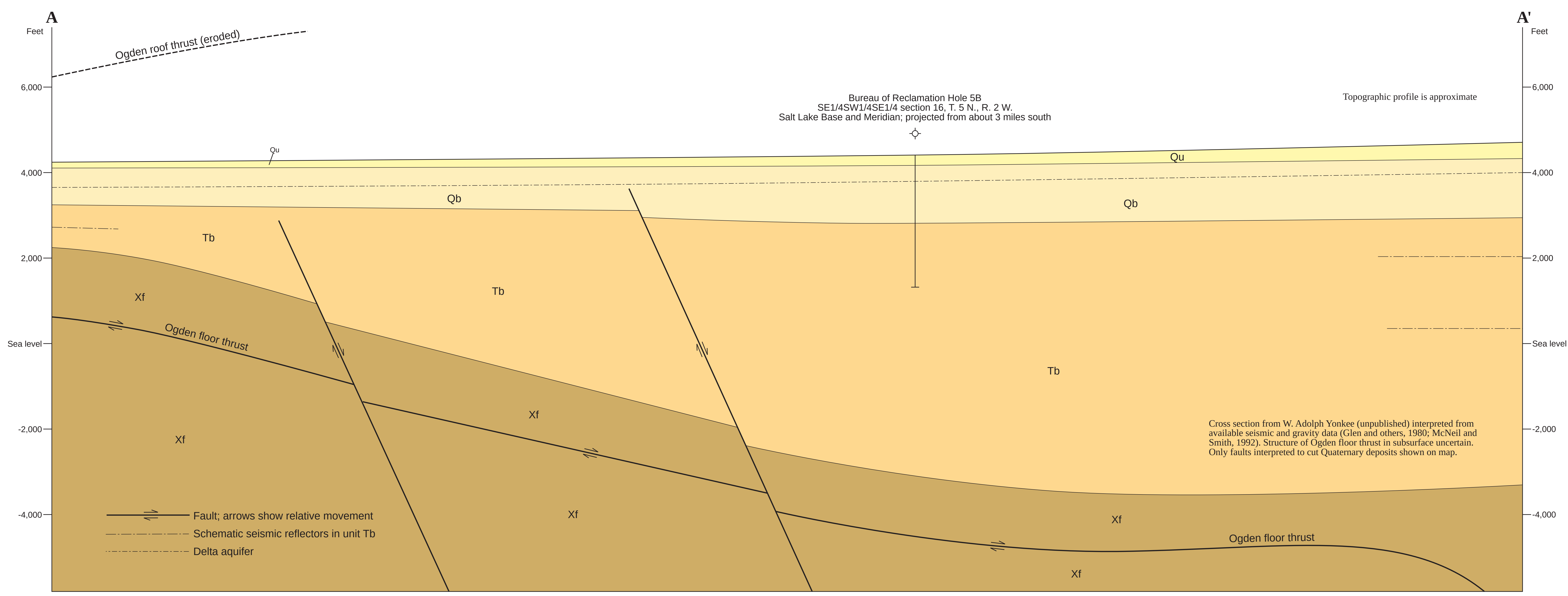
A late Holocene high shoreline of Great Salt Lake

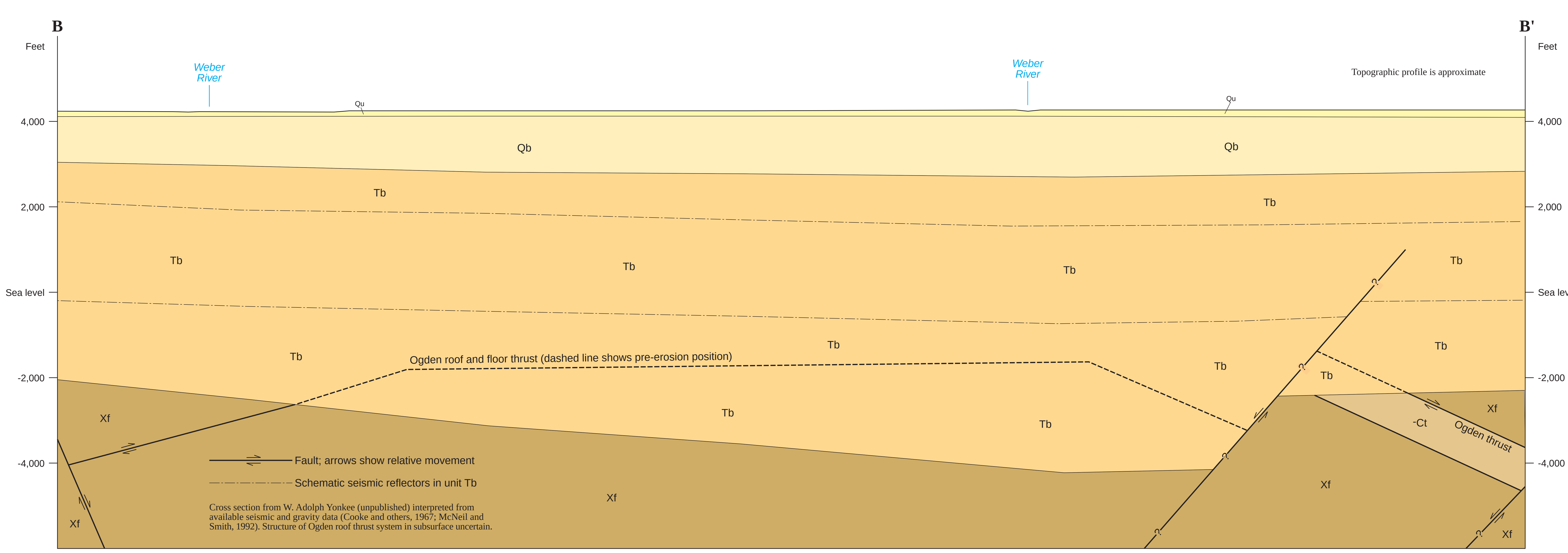
Sand, gravel, or borrow pits

## CORRELATION OF MAP UNITS





# GEOLOGIC MAP OF THE ROY 7.5′ QUADRANGLE, WEBER AND DAVIS COUNTIES, UTAH

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## ABSTRACT

The Roy quadrangle lies just west of Ogden on the lower to middle piedmont zone between Great Salt Lake and the Wasatch Range. Elevations increase from northwest to southeast across the quadrangle, and extend from about 4,208 feet (1,283.5 m) on the modern Weber River delta of Great Salt Lake to approximately 4,768 feet (1,453.5 m) on the Weber River's relict Provo-level delta of late Pleistocene Lake Bonneville.

Geologic map units represent the late Quaternary alluvial, deltaic, lacustrine, mass wasting, and marsh environments of deposition found in the study area. In addition, the map portrays preserved portions of the Gilbert shoreline of Great Salt Lake. Relative age control and age estimates for the map units derive primarily from the established chronology of Lake Bonneville and Great Salt Lake.

Roy quadrangle geology is dominated by the late Quaternary history of the Weber River, Lake Bonneville and its successor, Great Salt Lake, and especially the deltaic interface between the fluvial and lacustrine environments. At the start of the Bonneville lacustral cycle, shortly after 30 ka (thousand years ago), the Weber River must have flowed westward close to the southern boundary of the quadrangle, initiating construction there of the lakeward-projecting depocenter called the West Point projection. As the transgressing shoreline moved eastward across the quadrangle, so did deltaic sedimentation. Away from the West Point locus of deposition some transgressive-phase lacustrine fines were likely deposited, but little sedimentation probably occurred in the study area while it was deeply submerged during the higher levels of Lake Bonneville. When the lake fell to the Provo level in the Bonneville flood, about 14.5 ka, the study area was still submerged, but sediment supplied to the lake from the Weber River and from shoreline erosion began accumulating in the southeastern part of the quadrangle as the distal portion of the Provo-level delta. Rapid regression from the Provo shoreline, beginning about 14.0 ka, caused the Weber River to incise its Provo-level delta and to construct, then incise, a down-stepping series of several regressive-phase deltaic components, with each successive one located farther north in the eastern part of the quadrangle. Small, isolated fluvial terrace remnants were also created during the regression, while away from the river, lacustrine waves and currents reworked the abandoned delta sediments. By about 12.2 ka, additional lake-level lowering allowed the river to flow around the north end of the abandoned deltas and shift the deltaic environment to the north-central part of the Roy quadrangle. The Weber River probably flowed to the southwest across the quadrangle at the end of the Bonneville lake cycle. It appears to have switched to a position closer to its present course when transgression of Great Salt Lake to the Gilbert shoreline raised its base level. A platform-like feature in the northwestern part of the quadrangle, interpreted as a delta, seems to verify the occurrence of an early Holocene rise of Great Salt Lake to about 4,230 feet (1,289 m). That feature was partially eroded later in the Holocene when the Weber River's flood plain was a few feet above the modern level.

Fluvial and deltaic sand and gravel constitute the main geologic resources on the Roy quadrangle. Potential geologic hazards consist of flooding along the Weber River, mass wasting along steep stream-cut and delta-front scarps, and ground shaking, liquefaction, and mass wasting that could accompany earthquakes generated along the nearby Wasatch fault zone.

## INTRODUCTION

The Roy quadrangle is located just west of the city of Ogden on the lower to middle piedmont zone between Great Salt Lake and the Wasatch Range (figure 1). It extends from 41°07′30″N. to 41°15′N. and from 112°W. to 112°07′30″W. The map area appears in the southeastern part of both the 1:100,000-scale Promontory Point and the 1:250,000-scale Brigham City U.S. Geological Survey topographic maps. Elevations (all elevations discussed in this report are relative to modern sea level) generally increase from northwest to southeast across the quadrangle, and range from about 4,208 feet (1,283.5 m) on the modern Weber River delta of Great Salt Lake to approximately 4,768 feet (1,453.5 m) on a relict Weber River delta surface of ancient Lake Bonneville. Nearby geologic quadrangle maps include the Ogden 7.5-minute quadrangle (Yonkee and Lowe, 2004) and the Clearfield 7.5-minute quadrangle (Sack, 2005).

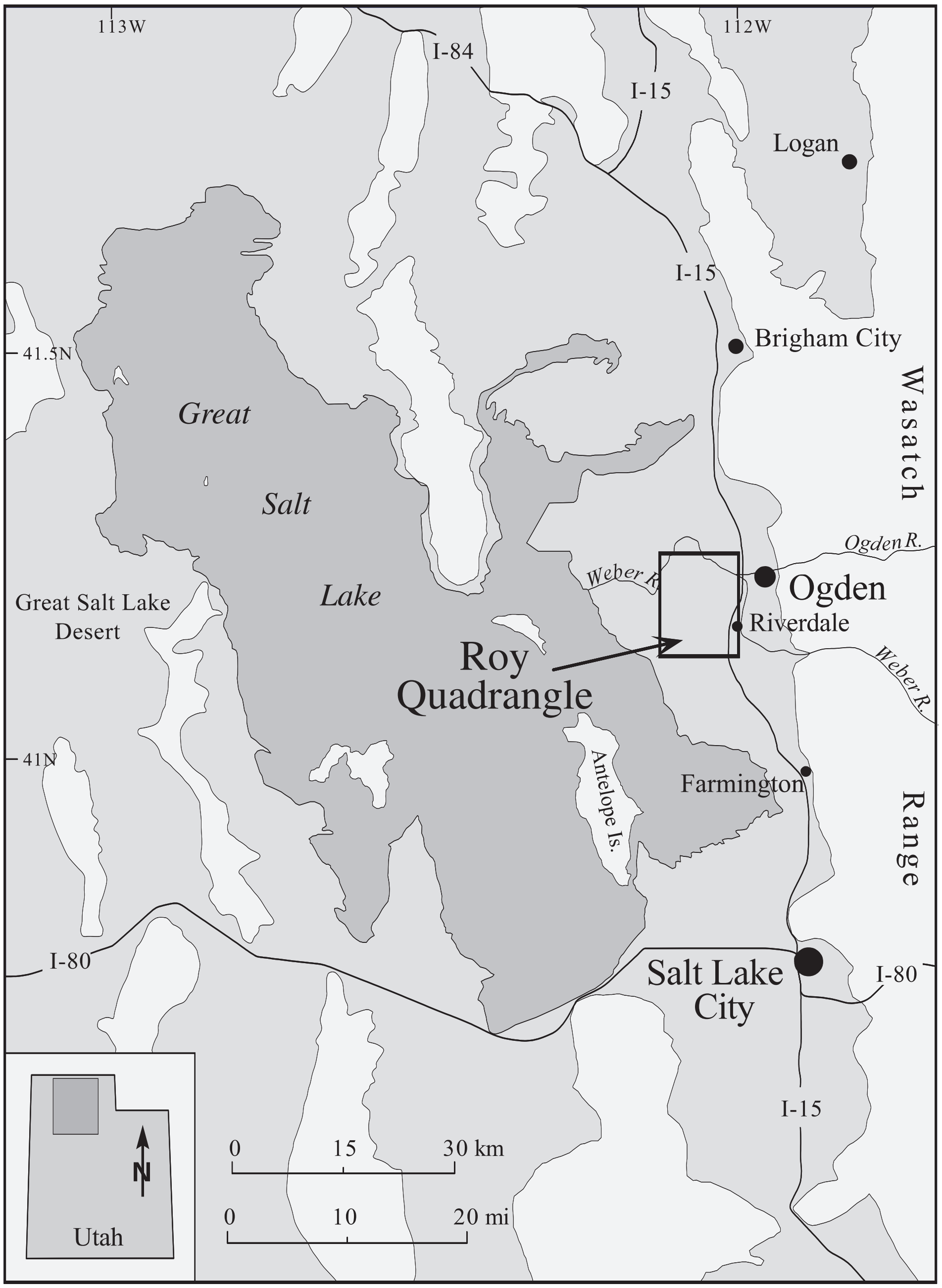



***Figure 1.*** *Location of the Roy quadrangle.*

Approximately 78 percent of the map area lies in Weber County; the southernmost 22 percent comprises part of Davis County. On the quadrangle are found the cities of Roy and Sunset, almost all of Clinton, and portions of Ogden, Riverdale, Marriott-Slaterville, and West Point. Hooper, Taylor, West Weber, Garland, and Wilson constitute some of the major unincorporated areas. Hill Air Force Base extends onto the southeastern portion of the map. An extensive road network, which includes Interstate Highways 15 and 84, provides good access to most of the quadrangle. The Union Pacific and Denver and Rio Grande rail lines and the Ogden Municipal Airport also lie on the map. Land cover/land use varies from wetlands and agriculture in the west, through a central patchwork of mixed agriculture and suburban residential land, to denser urban residential and commercial land in the east.

The quadrangle is located 3 to 10 miles (5-16 km) west of the Wasatch fault zone (Davis, 1985; Nelson and Personius, 1993) and overlies part of a deep, north-south-trending Basin and Range graben that contains 0.5 to 2.0 miles (1-3 km) of basin fill (Feth and others, 1966; Mabey, 1992). Much of this fill probably consists of lacustrine sediments deposited during the multiple lake cycles that the region has experienced in the Cenozoic (Feth, 1955; Morrison, 1966; Eardley and others, 1973; Oviatt and Currey, 1987; Oviatt and others, 1999). Fluvial, deltaic, marsh, and eolian sediments probably also contribute to the basin fill. No bedrock crops out at the surface of the Roy quadrangle; all surficial map units are composed of late Quaternary sediments.

Climate, vegetation, soils, and surface water reflect the quadrangle's intermediate position between the desert lake basin and the Wasatch Range. Data from the two meteorological stations located on the quadrangle show that the study area has temperature means of about 28°F (-2.5°C) for January, 75°F (24°C) for July, and 51°F (10.5°C) for the year, and variable annual precipitation with a mean of approximately 19 inches (47 cm) (table 1). Natural vegetation consists of shrub-steppe in the higher and better drained areas, riparian woodland along the flood plain of the Weber River, and marsh and salt-tolerant vegetation in the lower and more poorly drained areas, including wetlands of the Weber River delta. Soils are primarily mollisols, but alfisols and inceptisols occur locally (Erickson and others, 1968). Standing water is associated with the high water table and poor drainage of the lower elevations. It consists of deltaic ponds and marshes, spring and seep ponds and marshes, and wet meadows. In addition to many local ephemeral streams, two major perennial rivers, the Weber and Ogden, flow onto the study area as they make their way to Great Salt Lake from distant sources in the mountains to the east. The Weber River takes a circuitous path around the Roy quadrangle. After flowing northward along, but just east of, the quadrangle's eastern boundary, it finally enters the northeastern corner of the map where it flows only a third of a mile (half a kilometer) before its confluence with a major tributary, the Ogden River. The Weber then flows to the northwest and off the north end of the map, where it eventually turns to the southwest and meanders back across the northwestern corner of the quadrangle. One of its major distributaries, the South Fork of the Weber River, swings just inside the western edge of the map for a short distance.

## LAKE BONNEVILLE AND GREAT SALT LAKE CHRONOLOGIES

Late Pleistocene Lake Bonneville and its largely Holocene successor, Great Salt Lake, figure prominently in the geology of the Roy quadrangle. Major aspects of their histories are reviewed here and summarized in figure 2. All age estimates presented are in radiocarbon years.

The Bonneville lacustral cycle, which began about 30 ka (Oviatt and others, 1992), is the most recent in the series of deep lake cycles that the Bonneville basin experienced during the Quaternary (Gilbert, 1890; Eardley and others, 1973; McCoy, 1987; Oviatt and Currey, 1987; Oviatt and others, 1999). Between approximately 22 and 20 ka the transgressive phase of Lake Bonneville was interrupted by one or more oscillations that resulted in the formation of the Stansbury shoreline complex (Oviatt and others, 1992) at an elevation of roughly 4,500 feet (1,372 m). The fluctuation had a total amplitude of 150 feet (45 m), and in the vicinity of Great Salt Lake the Stansbury shoreline has been mapped at a wide range of elevations (Currey, 1980; Oviatt and others, 1990; Sack, 1995). The initially closed-basin Lake Bonneville became an open-basin lake about 15 ka when it reached the elevation of the lowest point on its drainage divide, 5,091 feet (1,552 m), and began spilling over into the Snake River drainage basin (Gilbert, 1890; Oviatt and others, 1992). Under this threshold control, the lake created its highest shoreline, the Bonneville. Approximately 14.5 ka, threshold failure caused catastrophic regression of the lake until it became restabilized by a bedrock sill at 4,737 feet (1,444 m), where it formed the Provo shoreline (Gilbert, 1890; Malde, 1968). Lake Bonneville began its rapid, climatically induced regression from the Provo shoreline about 14.0 ka. The Bonneville lake cycle ended, and Great Salt Lake began, close to 12 ka when the water fell to very low levels, probably below

***Table 1.*** *Selected climatic variables for meteorological stations on the Roy quadrangle (National Climatic Data Center, 2001).*

| Station Name | N lat./W long. (decimal deg.) | Elev. (m/ft) | Years averaged | Jan. mean temp. (°C/°F) | July mean temp. (°C/°F) | Annual mean temp. (°C/°F) | Annual mean precip. (cm/in) |
|---|---|---|---|---|---|---|---|
| Ogden Sugar Factory | 41.23/112.03 | 1,305/4,279 | 40 | -2.6/27.4 | 24.4/75.9 | 10.6/51.0 | 45.57/17.94 |
| Riverdale | 41.15/112.00 | 1,341/4,399 | 26 | -2.5/27.5 | 23.9/75.1 | 10.3/50.5 | 49.35/19.43 |

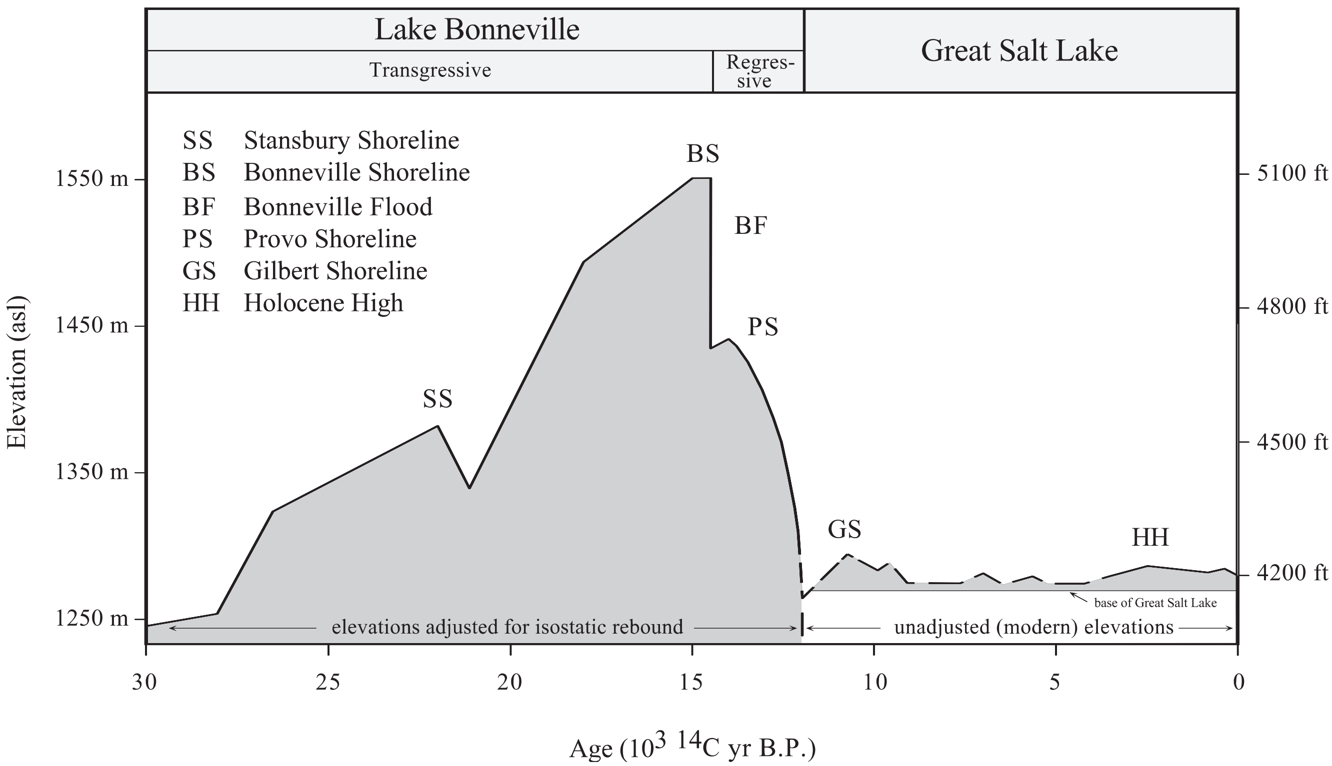



***Figure 2.*** *Generalized chronology of Lake Bonneville (Oviatt and others, 1992) and Great Salt Lake (Currey and others, 1984, 1988; Murchison, 1989; Benson and others, 1992).*

the average of modern Great Salt Lake (Currey, 1980; Oviatt and others, 1992).

Almost immediately, Great Salt Lake began a transgression and reached its highest level, the Gilbert shoreline, at about 4,245 feet (1,294 m), very late in the Pleistocene (figure 2) (Eardley and others, 1957; Benson and others, 1992). Between 9.7 and 9.4 ka, during the regression from the Gilbert level, Great Salt Lake may have experienced a small readvance to 4,230 feet (1,289 m) (Murchison, 1989), but the shoreline that formed at 4,221 feet (1,287 m) between 2.5 and 2.0 ka is generally considered Great Salt Lake's Holocene high (Currey and others, 1988). Great Salt Lake then fell to at least 4,210 feet (1,283 m) before reaching its late pre-historic high of 4,217 feet (1,285 m) approximately 400 years ago (Currey and others, 1984; Murchison, 1989). The historic high water level of 4,212 feet (1,284 m) was reached in 1873, 1986, and 1987.

Gilbert (1890) first noted that the present elevation of any given Lake Bonneville shoreline varies around the lake basin due to differential hydroisostatic loading and rebound. Constructing a hydrograph that represents the entire basin, however, requires that for each lake level a single shoreline elevation value is plotted against time. By convention, reconstructions of the chronology of Lake Bonneville, like figure 2, use the elevation that a shoreline had when it was originally formed.

## PREVIOUS WORK

Some previous mapping projects have involved the Roy area mostly as a small part of small- or medium-scale regional studies. Gilbert's (1890) Lake Bonneville monograph contains the first map of the extent of that late Pleistocene lake at its two principal deep-water stillstands, the highest level, marked by the Bonneville shoreline, and the prominent Provo shoreline, which lies about 360 feet (110 m) below the Bonneville (Burr and Currey, 1988). Gilbert's (1890, plate XIII) small-scale map depicts the Roy quadrangle area as being totally submerged when the lake stood at the Bonneville level. It suggests that the Provo shoreline passed onto and off of the eastern edge of the quadrangle in a westward-projecting arc around Weber River delta deposits. Gilbert (1890, plate III) apparently travelled across the quadrangle twice in the course of his Lake Bonneville investigations. Other than a brief discussion of the Weber River and its ancient delta system, Gilbert (1890) made no specific mention of the Roy quadrangle's geologic or geomorphic features.

In the mid-20th century, Feth (1955) described some of the late Quaternary deposits found between Great Salt Lake and the Wasatch Front in the general vicinity of Ogden from approximately 41°N. to 41°21′N., a region sometimes referred to as the east shore area of Great Salt Lake. Most of the exposures mentioned in that paper and all of the measured sections were located on the Ogden 7.5-minute quadrangle, which lies adjacent to the Roy quadrangle on the east, but observations from the recently dug Hooper pilot drain and from a few drillers' well logs were derived from the western edge of the Roy quadrangle (Feth, 1955, figures 10, 11b, and 12). Overall, Feth (1955) noted great heterogeneity in the deposits of the region, abrupt lateral changes in sediment type, and that depositional trends are very difficult to trace from east to west but somewhat easier to correlate from north to south. He found what he believed were stream channel, flood-plain, oxbow, delta, turbidity current, regressive coastal, slack-water lacustrine, mudflow, debris flow, playa, and sublacustrine spring deposits.

Feth later led a major ground-water study of approximately the same east shore region (Feth and others, 1966). That report contains two 1:62,500-scale isoline maps of generalized subsurface grain size data, which were compiled from numerous well logs. In addition, from air photos Feth and others (1966) created a general geologic map of the east shore area at the scale of 1:62,500. Their map and interpretation of the Quaternary geology of the region are based to some extent on the then-current notion that, like deposits of Lake Bonneville, deposits of a hypothesized earlier lake cycle, which was referred to as the Alpine, have surface exposure (Hunt and others, 1953; Morrison, 1965). Davis (1985) further generalized the map units of Feth and others (1966) when he compiled a 1:100,000-scale geologic map of the northern Wasatch Front.

Important new small-scale maps delineating the major shorelines of Lake Bonneville and Great Salt Lake were published in the 1980s (Currey, 1980, 1982; Currey and others, 1984). These later maps extend Gilbert's (1890) work by depicting other shorelines in addition to the Bonneville and Provo, but they also include local adjustments to Gilbert's positioning of those two shorelines. These more recent maps portray the lowest major shoreline of Lake Bonneville, the Stansbury, and the highest shoreline of Great Salt Lake, the Gilbert, crossing the Roy quadrangle area (Currey, 1980, 1982; Currey and others, 1984, figure 1). They locate the Provo shoreline to the east of the Roy quadrangle instead of on the quadrangle, which is where Gilbert had placed it. On another map, Currey and others (1984, figure 2) indicated the elevations, rather than preserved shoreline evidence, of other major Great Salt Lake levels. According to that source, elevations of the prehistoric high and historic high levels of Great Salt Lake lie within the Roy study area, but the quadrangle is subaerially exposed when the lake occupies its historic average level of 4,202 feet (1,281 m) (Currey and others, 1984).

## METHODS

The geology of the Roy quadrangle (plate 1) was mapped for this report using a combination of field work and the stereoscopic interpretation of vertical air photos. Most of the air photo interpretation was accomplished using 1:11,400-scale, U.S. Department of Agriculture (USDA) black-and-white photographs taken in 1952. In addition to being at a larger scale than the quadrangle, and therefore appropriate for generalizing onto the 1:24,000-scale base map, because of the early date those photos provided visual access to land surfaces that have since been obscured by development. Regional and more contemporary perspectives were obtained by viewing 1988 color infrared and 1997 black-and-white photographs, both at a scale of 1:40,000.

The map units are distinguished using a system of letter symbols, some of which are further differentiated with numerical subscripts. All units begin with an upper case Q to indicate that the sediments are of Quaternary age. The second symbol is a lower case a, d, l, m, or s, designating an alluvial, deltaic, lacustrine, mass wasting, or marsh environment of deposition, respectively. For many of the map units a second lower case letter provides additional information about material characteristics or depositional environment. Most of the deltaic deposits (Qd), however, are subdivided on the basis of relative age using numeric subscripts.

In the southern half of the quadrangle, areas are found in which one Quaternary map unit thinly covers, or is the product of a moderate reworking of, a different map unit. These areas are portrayed on the map by stacking the appropriate map unit symbols. For stacked units, the designation for the surficial unit is written above the designation for the underlying material. For example, where thin or patchy lacustrine sand overlies transgressive-phase deltaic deposits, the map area is labelled $Qls/Qd_{13}$. Locations on the map that consist of stacked units are colored according to the material at the surface.

Relative age control and age estimates for the map units derive primarily from the reconstructed chronology of Lake Bonneville and Great Salt Lake as they are currently understood (figure 2 and plate 2). A few published radiocarbon ages are also available from on or near the quadrangle (Feth and Rubin, 1957; Rubin and Alexander, 1958; Ives and others, 1967). Age estimates for map units that are not directly associated with dated shorelines or sediments were made using stratigraphic and geomorphic evidence to infer the maximum and minimum lacustrine water plane elevations during their deposition. Age estimates could then be obtained for the inferred shoreline elevations from the Lake Bonneville and Great Salt Lake hydrographs once isostatic rebound effects were subtracted from Lake Bonneville values. The elevations of the Bonneville water levels were adjusted for isostatic rebound using the technique of Currey and Oviatt (1985). The relative ages of the various map units with respect to the lakes and each other are presented with considerable confidence, but specific radiocarbon ages determined for the map units on the Roy quadrangle should be considered estimates that are subject to revision as adjustments are made to the scientific understanding of the Lake Bonneville and Great Salt Lake hydrographs.

## ABANDONED SHORELINES

The ground surface of the Roy quadrangle displays geomorphic evidence of several abandoned late Quaternary shorelines, most of which are bluffs that extend for limited distances. Of the major relict Lake Bonneville and Great Salt Lake shorelines, mappable segments of only the Gilbert are found on the quadrangle (figure 3). Preserved portions of the Gilbert shoreline are delineated on the geologic map at elevations ranging from about 4,240 to 4,245 feet (1,292-1,294 m). The research conducted in the course of this investigation supports the interpretation of Currey (1980, 1982) and Currey and others (1984), as opposed to Gilbert (1890), regarding the position of the Provo shoreline in this region. This research affirms that the map area was entirely submerged during Provo shoreline time as well as during Bonneville shoreline time.

The Stansbury shoreline is not delineated on the geologic map even though small-scale maps by Currey (1980) and Currey and others (1984) depict it within the boundaries of the present study area. In the early 1980s, Lake Bonneville

*Figure 3. Gilbert shoreline bluff in the NE¼ of section 31, T. 5 N., R. 2 W. View is to the south.*

scholars accepted the interpretation of the Stansbury as a shoreline from the regressive phase of Lake Bonneville, in which case it might be expected to be easily discerned. Researchers, however, have subsequently demonstrated that it formed during the transgressive phase of Lake Bonneville (Currey and others, 1983; Green and Currey, 1988; Oviatt and others, 1990; Sack, 1995), which would help explain its "lack of clear definition on the landscape" (Oviatt and others, 1990, p. 291). On the Roy quadrangle, the approximate elevational range of the Stansbury oscillation is not crossed by a discrete, laterally continuous shoreline that can be mapped with confidence at this time as the Stansbury shoreline.

# DESCRIPTION OF MAP UNITS

## Alluvial Deposits

### Undifferentiated Alluvium and Colluvium (Qac)

Small map areas of poorly sorted fines through cobbles lie along the lower portions of steep scarps, especially those that mark the boundaries of relict, incised Weber River delta components (Qd) and fluvial terraces (Qat). The poorly sorted deposits consist of wash-reworked mass wasting sediments and intertonguing alluvium and colluvium, and are mapped as undifferentiated alluvium and colluvium, Qac. The colluvial component of some Qac areas has been noted previously (Lowe, 1988), and is comprised of fall, slump, slide, and flow deposits. Sheet wash, small alluvial fans, rills, and gullies accomplish the fluvial action. The scarps resulted from downcutting by the Weber River in response to its falling base level during the regressive phase of Lake Bonneville, and from undercutting by channel migration. Deposition of Qac sediments probably began soon after subaerial exposure of the highest outcrop of the unit, about 13.2 ka, and it continues today. Thickness of this unit is probably less than 12 feet (3.7 m).

### Alluvial-Fan Deposits (Qaf)

Typically mixed fine-grained, but locally gravelly, roughly fan-shaped deposits of alluvium, Qaf, have formed in various settings on the Roy quadrangle. A few alluvial fans have accumulated where steep gullies cut Weber River terrace (Qat) scarps or the steep fronts of relict Weber River delta components (Qd). Fluvial sediments dominate those fans, but some gravity-generated deposits are also present. On more gentle slopes, alluvial fans are associated with branching ephemeral channels and tend to head along shoreline bluffs or from springs, seeps, and ditches. Slope-wash deposits contribute locally to those fans. The Qaf map unit varies from less than 1 foot to approximately 10 feet (0.3-3 m) thick. Alluvial fan deposition may have started as early as 13.2 ka at the highest site and it remains an ongoing process.

### Late Holocene Channel and Flood-plain Alluvium ($Qal_1$)

Deposits of active and recently active stream channels and flood plains are mapped as $Qal_1$ (figures 4 and 5). This youngest category of stream deposits encompasses the present channels and flood plains of the Weber and Ogden Rivers, their recently abandoned channel stretches, including abandoned meanders, and channel alluvium of Howard Slough and its tributaries. Areas mapped as $Qal_1$ display evidence of relatively fresh deposition and erosion, and sharp channel form. $Qal_1$ sediments are probably less than 10 feet (3 m) thick. The age of these deposits is estimated to range from late Holocene to present. Late Holocene is arbitrarily drawn to start at 3.3 ka (plate 2).

Grain size and sorting of $Qal_1$ sediments vary with the location of an exposure as well as with depositional subenvironments. At lower map elevations, such as in the Howard Slough system and in Weber River alluvium in the northwest corner of the map, fine grain sizes predominate and the channels are narrow and deep. Farther upstream, along the Weber and Ogden Rivers in the northeastern and east-central parts of the map, wider and shallower channels reflect a coarser load (Lane, 1937). Pebbly sand, sandy gravel, and gravel bars, at times with a thin cover of fines, are found in the Weber River northeast of Garland. Ten largest clasts from a point bar there had an average long axis (A axis) of 7.7 inches (19.6 cm). An exposure of modern flood-plain deposits near I-15 at Marriott-Slaterville showed rounded channel gravels overlain by 21 inches (53 cm) of vertically accreted flood deposits that consisted of silty very fine sand grading upward to silt.

### Early and Middle Holocene Channel and Flood-plain Alluvium ($Qal_2$)

$Qal_2$ sediments comprise a low-relief terrace that is situated about 3 to 10 feet (1-3 m) higher than adjacent flood-plain areas of $Qal_1$. With textures varying from fine sandy mud through gravel, and muted meander scars on its surface, the $Qal_2$ deposits are interpreted as former flood-plain alluvium of the Weber-Ogden stream system. The alluvial terrace is incised into relict Weber River delta components $Qd_2$, $Qd_4$, and $Qd_5$, and the curved scarps cut into these higher surfaces also reflect the meandering-stream flood-plain nature of the

*Figure 4. The left (south) bank of the Weber River along a gravelly portion of its flood plain (Qal$_1$) north of State Highway 39. Shovel handle is 0.5 m long.*

***Figure 5.*** *The right (north) bank of the Weber River and its flood-plain deposits (Qal$_1$) north of State Highway 39. Fine-grained vertical accretion deposits overlie lateral accretion gravels.*

$Qal_2$ terrace. Because $Qal_2$ deposits postdate the $Qd_2$ delta and pre-date $Qal_1$ deposits, their age is estimated as early and middle Holocene, or 9.4 to roughly 3.3 ka.

### Channel and Flood-plain Alluvium of Very Latest Pleistocene Age ($Qal_3$)

Muddy to pebbly sands occupying a single zone in the northeastern part of the quadrangle between Garland and Wilson are mapped as $Qal_3$ deposits. This area is inset into delta component $Qd_4$ and it grades into delta component $Qd_3$, which is also incised into $Qd_4$. The $Qal_3$ map unit is about 7 feet (2 m) thick, and its surface displays broadly parallel, channel-like swales. $Qal_3$ sediments are interpreted as channel and overbank sediments associated with a former course of the Weber River that was active from slightly before Gilbert shoreline time to approximately Gilbert shoreline time, between about 12.0 and 10.3 ka.

A large trough that is slightly arcuate in plan view extends down the entire length of the $Qal_3$ map area from northeast to southwest. The depression contains Hooper Canal trenches, first dug in the 19th century (Roberts and Sadler, 1997), and may be entirely artificial. Its large width and the slope of adjacent land toward it, however, suggest that the depression might constitute a paleochannel that has been altered by the canal works (figure 6).

### Channel Alluvium of Pre-Gilbert Shoreline Age ($Qal_4$)

Sediments within a distinct abandoned meander that was cut into $Qd_4$, but which was probably approximately coeval with that surface, are mapped as $Qal_4$ (figure 7). Some marsh and colluvial sediments are found locally within this mixed fine-grained to pebbly mixed fine-grained alluvium, which is estimated to be about 3 feet (1 m) thick. $Qal_4$ sediments are interpreted as having been deposited late in the regressive phase of Lake Bonneville, that is, before Gilbert shoreline time, about 12.1 to 12.0 ka.

### Fluvial Terrace Deposits ($Qat_1$-$Qat_9$)

Areas mapped as Qat consist of high, abandoned, relatively small or isolated, moderately sloping terraces bounded by scarps that range from 15 to 125 feet (5-38 m) high. The surfaces display channel traces composed of sand and gravel and interchannel zones of finer texture, typically with a muddy component. These fluvial terraces are remnants of Weber River paleoflood plains.

Fluvial terraces are geomorphic features bounded by scarps which, although possibly impacted also by mass wasting, are fundamentally stream-cut. Fluvial terraces consist of flood plain lateral and vertical accretion deposits, that is, stream channel and flood alluvium, typically to a depth equal to the scour depth of the stream channel. Where terrace height exceeds that depth, the Qat unit includes whatever pre-existing material the channel scour bevelled into as the stream migrated laterally. For the Roy quadrangle, that lower material probably consists almost entirely of Weber River Lake Bonneville deltaic deposits.

Fluvial terraces representing nine different abandoned flood plain levels are distinguished on the geologic map using numeric subscripts that increase in value with increasing terrace age and height. Any given flood plain was abandoned when falling lake levels (i.e., falling fluvial base level) caused the Weber River to incise into it and to start forming a new flood plain inset into the older one. Widening of the new flood plain by lateral migration eroded substantial areas of the previous flood-plain terrace, in some places to the point where the river was trimming back even earlier terraces. The spatial distribution of successive terraces $Qat_9$ through $Qat_1$ clearly reveal a clockwise, or eastward rotational, shifting in the trend of the Weber River during the interval of terrace formation. Terrace formation probably started about 13.2 ka and may have ended as early as 12.0 ka.

## Deltaic Deposits

### Undifferentiated Deltaic and Alluvial Deposits (Qda)

Mixed deltaic and alluvial deposits consist of sand-dominated, fine-grained deltaic sediments that have been reworked and washed downslope by sheet wash, flow in shallow ephemeral channels, and flow associated with small alluvial fans. Qda also represents map areas where small, discrete outcrops of deltaic sediments and alluvium lie in very close proximity and in complex spatial arrangements. Pebbly deposits and marsh sediments occur locally within this unit, which is estimated to be as much as 6 feet (1.8 m) thick.

The Qda map area extends from the delta fronts of $Qd_6$ and $Qd_7$ downslope to $Qd_4$ and $Qd_5$. Because delta fronts are formed by subaqueous processes and because these Weber River deltaic components were formed during the regression of Lake Bonneville, it is not surprising that some regressive Lake Bonneville shoreline segments are visible within the Qda zone. This region is mapped as Qda rather than mixed lacustrine and alluvial deposits (Qla) because the fluvially reworked sediment here is mainly deltaic, whereas the lacustrine influence was comparatively minor. Fluvial reworking of the deltaic sediments may have begun as early as 12.2 ka, and it remains an ongoing process.

### Deltaic Mud (Qdm)

Within the subaerial portion, that is, the delta plain, of the present Weber River delta ($Qd_1$), along the northwestern border of the quadrangle, damp to flooded, largely unvegetated, low-gradient regions of very fine grained sediments are designated deltaic mud (figure 8). These delta pond deposits lie below an elevation of about 4,217 feet (1,285 m), which marks the approximate elevation of the late pre-historic high level of Great Salt Lake (Currey and others, 1984). Qdm sediments have been accumulating since the time of that high-water level, around 0.4 ka. This unit is probably less than 3 feet (1 m) thick.

### Late Holocene Fine-Grained Deltaic Deposits ($Qd_1$)

Channel, levee, splay, and overbank flood deposits of the subaerial component of the modern Weber River delta extend onto the Roy quadrangle, where they are mapped as $Qd_1$ (figure 8). $Qd_1$ sediments, which are estimated to be less than 10 feet (3 m) thick, consist of clay through sand-sized material; only the very fine grained delta pond sediments are delineat-

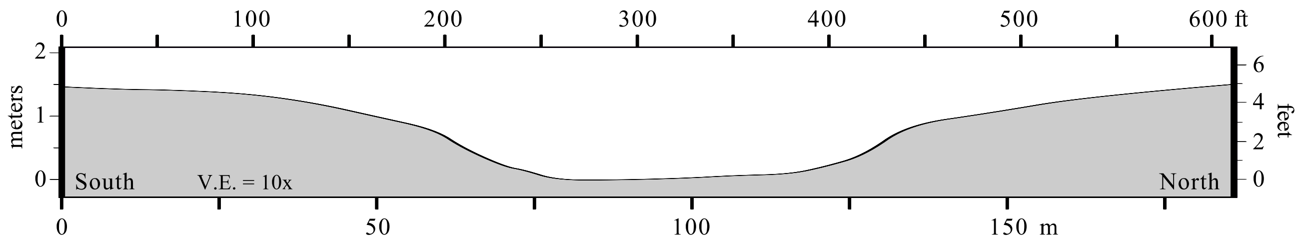



***Figure 6.*** *Topographic profile measured across a possible paleochannel of the Weber River in the SE¼ of section 27, T. 6 N., R. 2 W. The Hooper Canal currently occupies a small portion of the trough cross section.*

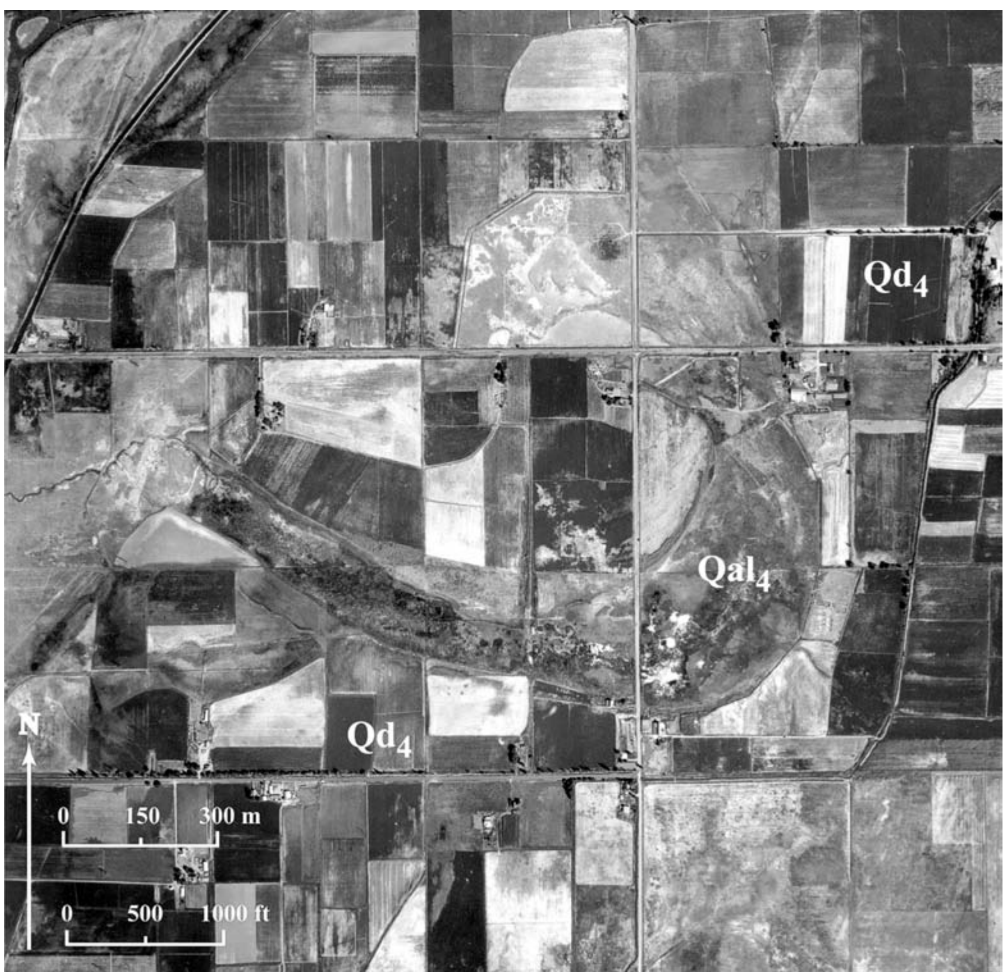



***Figure 7.*** *Portion of 1952 USDA aerial photograph AAJ-11K-21 showing $Qal_4$ deposits within the large meander on the $Qd_4$ delta.*

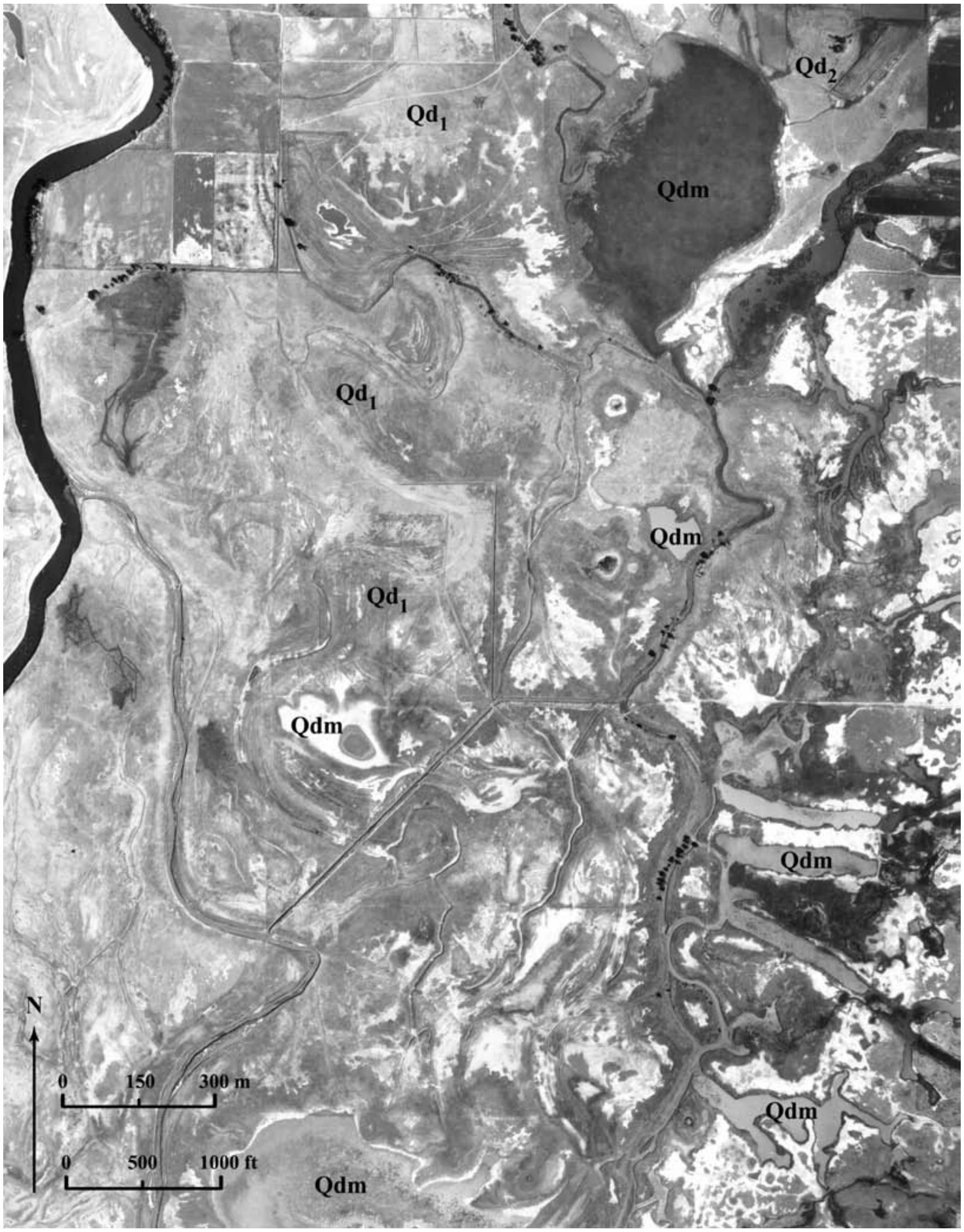



*Figure 8. Portion of 1952 USDA aerial photograph AAJ-9K-62 displaying part of the present delta of the Weber River ($Qd_1$ and Qdm) and a small area of an early Holocene deltaic component ($Qd_2$). The far left edge of the figure is located on the Ogden Bay quadrangle just west of the study area.*

ed separately, as Qdm. The existence of several present and abandoned distributary channels and the widespread evidence of active channel switching, avulsion, and splaying distinguish the delta plain from the landward-adjacent flood plain of the Weber River ($Qal_1$). Lying at elevations below about 4,217 feet (1,285 m), deposition of the modern delta plain started after about 0.4 ka, that is, since the late prehistoric high of Great Salt Lake. Although the $Qd_1$ map area is fundamentally subaerial, it is partially and temporarily flooded when Great Salt Lake approaches its historic high level of 4,212 feet (1,284 m), which the lake attained in 1873, 1986, and 1987.

## Early Holocene Fine-Grained Deltaic Deposits ($Qd_2$)

Stretching to the northeast from the modern Weber River delta plain ($Qd_1$) lies a large map area labelled $Qd_2$. The $Qd_2$ region exhibits an approximately planar, or platform-like, topographic form and an average elevation near 4,235 feet (1,291 m), making it roughly 20 to 25 feet (6-8 m) higher than the modern delta plain and 10 feet (3 m) lower than the Gilbert shoreline of Great Salt Lake. The platform sediments are muddy to sandy, and traces of sinuous channels are visible on air photos above 4,232 feet (1,290 m). Marsh deposits (Qsm) are mapped separately where poor drainage or seepage springs have kept the ground wet, such as in channel depressions. Moderately weak, contour-parallel lineations, interpreted as shorelines, traverse the western part of the $Qd_2$ map area between the 4,217 and 4,232 foot (1,285 and 1,290 m) contours. Thickness of this map unit probably ranges from about 10 to 20 feet (3-6 m).

The evidence suggests that this map area is an abandoned delta component. Especially above 4,232 feet (1,290 m), $Qd_2$ sediments were probably deposited in delta-plain channels, levees, splays, sloughs, ponds, or as overbank flood deposits. The marginal strip along the long southeastern edge of the $Qd_2$ map area seems to have experienced less intense deltaic processes than the rest of the $Qd_2$ surface. Some nearshore lacustrine fines (Qlf) related to the Gilbert shoreline are probably intermixed with the deltaic sediments there, and reddish-colored muds found in that zone might represent the pre-Gilbert red beds described by Currey and others (1988) and Currey (1990).

When the Weber River occupied the $Qal_2$ flood plain it cut into the $Qd_2$ delta, thus $Qd_2$ deposits predate $Qal_2$ deposits. Because the delta plain (i.e., subaerial) portion of the $Qd_2$ map area, that part above about 4,232 feet (1,290 m), is not crossed by shorelines and lies below the Gilbert level, the $Qd_2$ delta postdates Gilbert shoreline time. After falling from the Gilbert level, Great Salt Lake is believed to have re-risen to approximately 4,230 feet (1,289 m) between about 9.7 and 9.4 ka (figure 2) (Murchison, 1989). The $Qd_2$ delta very likely relates to that early Holocene high water level, and the shorelines observed on the subaqueous portion of this delta, between 4,217 and 4,232 feet (1,285 and 1,290 m), simply record the drop in Great Salt Lake from its ~4,230-foot (1,289 m) level. It is inferred, therefore, that the $Qd_2$ map unit was deposited between 9.7 to 9.4 ka.

## Fine-Grained Deltaic Deposits of Approximately Gilbert Shoreline Age ($Qd_3$)

$Qd_3$ deposits are muddy to sandy sediments located in a single, elongate, northeast- to southwest-trending, and northeast- to southwest-sloping region near the center of the Roy quadrangle. The surface of the $Qd_3$ map area extends from about 4,238 feet (1,292 m) to slightly above 4,250 feet (1,295 m). The Gilbert shoreline, however, which appears elsewhere on the Roy quadrangle between the elevations of about 4,240 and 4,245 feet (1,292-1,294 m), could not be traced across the $Qd_3$ sediments.

At its northeastern end, the apex of the $Qd_3$ map area heads at the downstream end of the channel and flood-plain alluvium of $Qal_3$. Air photo interpretation reveals that the most northeastern 55 percent of the elongate $Qd_3$ region displays numerous sinuous, branching channels, and is interpreted as a delta-plain depositional environment. The irregular and chaotic-looking surface with more muted channel evidence that characterizes the southwestern 45 percent of the map area, starting approximately in the northern half of the SW¼, section 4, T. 5 N., R. 2 W., is believed to be a transgressive sequence of subaqueous deltaic deposits overlying and partially filling channels of the pre-existing delta plain. This interpretation is supported by the discovery of plant stems in a gray sand 6 feet (2 m) below the land surface within the distal portion of the $Qd_3$ exposure (Feth and Rubin, 1957; Rubin and Alexander, 1958).

The $Qd_3$ map area is situated between two large expanses of the next higher surface, $Qd_4$ (figure 9). The sinuous inward-facing scarps that form the contact between $Qd_3$ and the bounding pair of $Qd_4$ segments show that $Qd_3$ sediments were deposited within a space that was originally a large, meandering-stream flood plain set into, and therefore slightly younger than, the $Qd_4$ areas. It is inferred that the flood plain was created by the ancestral Weber River when it followed a different course than it does today. In order to have taken this southwest trajectory across the Roy quadrangle, after entering the study area approximately where it does now, the river would have had to turn to the southwest just north or north-northwest of the present community of Wilson.

From the above discussion it is concluded that $Qd_3$ consists of a transgressive sequence of Weber River delta sediments, with a maximum thickness of at least 6 feet (2 m), that was deposited while Great Salt Lake rose up to and occupied the Gilbert shoreline. $Qd_3$ sediments were deposited within the feature that was probably a part of the flood plain of the Weber River from close to the end of the Bonneville lake cycle until Gilbert shoreline time. With the Gilbert transgression under way, the spatial sequence of active Weber River flood plain, delta plain, and delta-front also transgressed landward, with delta-front sediment being deposited over delta-plain sediment, and the delta-plain environment invading the former flood plain. The influx of fluviodeltaic sediment could explain the absence of the Gilbert shoreline across the $Qd_3$ map area. It is estimated that $Qd_3$ sediments were deposited on the Roy quadrangle between about 11.0 ka and the minimum age-estimate for the Gilbert shoreline, which may be 10.3 ka (Currey, 1990) or perhaps as young as 10.0 ka (Oviatt and others, 2003). Radiocarbon analysis of the plant stems previously collected from the $Qd_3$ map area yielded an age of 9,730 ± 350 years B.P. (W-386) (Feth and Rubin, 1957; Rubin and Alexander, 1958).

## Fine-Grained Deltaic Deposits from Very Late in Lake Bonneville's Post-Provo Regression ($Qd_4$)

Sandy fines, through sand, to pebbly sand comprise the $Qd_4$ map unit, which is also considered deltaic. The $Qd_4$ delta surface lies roughly 13 feet (4 m) above the $Qd_3$ delta and 20 feet (6 m) below another deltaic component, $Qd_5$. Multiple channel depressions, some occupied by marsh deposits (Qsm), indent the surface of the $Qd_4$ delta. Sediments within the largest and most prominent of these channel remnants, a distinct meander bend, are mapped separately as channel alluvium ($Qal_4$). Northeast of that meander, channel traces appear less chaotic in orientation than they do to the southwest. The Gilbert shoreline forms a bluff along the western boundary of the western $Qd_4$ map area and the Gilbert, or slightly lower water levels, left some minor sandy spit and beach deposits along its southwestern point. The region southwest of $Qd_3$ and $Qd_4$, the Qlf/$Qd_4$ map area, exhibits subdued channel topography due to the presence of faint shorelines and a cover of lacustrine fine-grained sediment.

The $Qd_4$ delta is interpreted as the last Weber River delta component on the quadrangle to form during the regression of Lake Bonneville. As the lake fell in the final stage of its regression, the deltaic environment shifted lakeward with it,

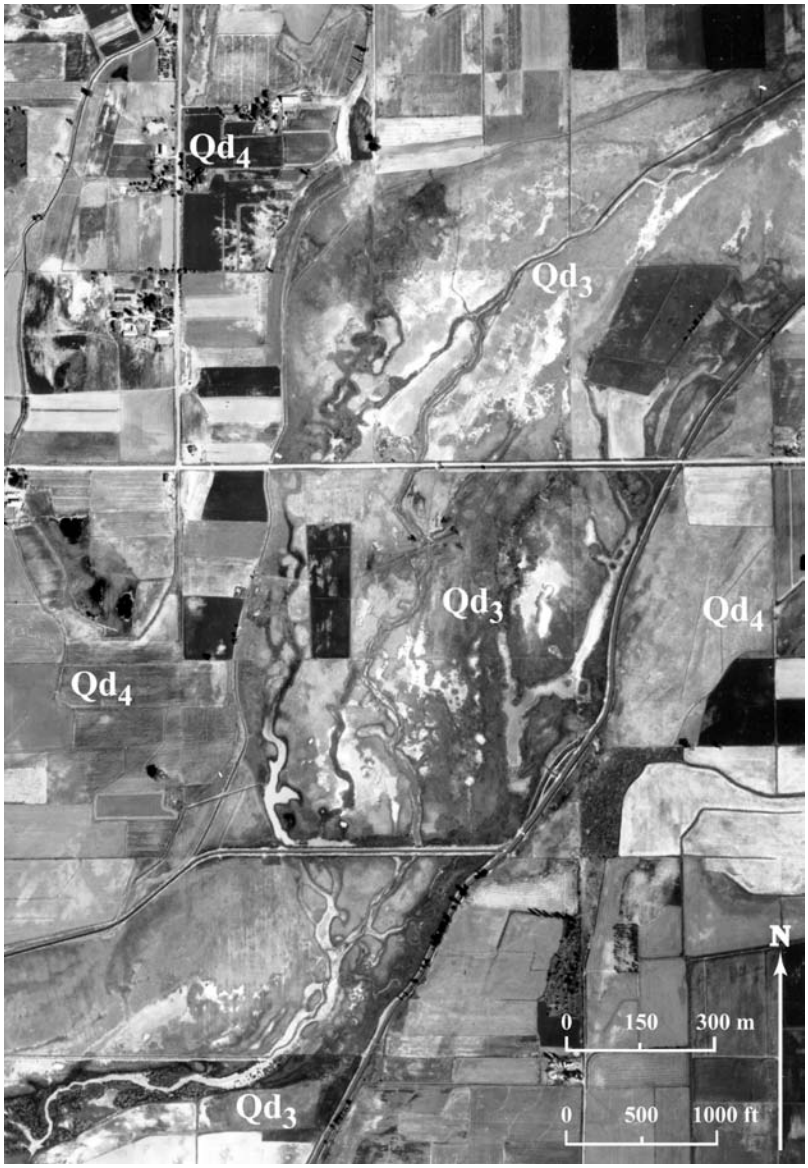



***Figure 9.*** *$Qd_3$ deposits, interpreted as deltaic sediments from the Gilbert transgression, lie within a probable flood-plain zone carved out of the $Qd_4$ map area. From 1952 USDA aerial photograph AAJ-9K-145.*

while Weber River discharge probably decreased somewhat under the desiccating climatic regime. Existence of the oxbow of $Qal_4$ deposits and the less chaotic appearance of channel traces at the proximal end of the delta surface may reflect flood-plain advance onto the delta surface in that area, as would be expected in the deltaic sequence of a regressing lake. According to the current understanding of the Lake Bonneville hydrograph (figure 2), regressive-phase deltaic sediments in the elevation range of the $Qd_4$ sediments would have been deposited between about 12.1 ka and the end of the Bonneville lake cycle, about 12.0 ka. Maximum thickness of this unit is probably at least 12 feet (3.7 m).

## Sand-Dominated Deltaic Deposits from Late in Lake Bonneville's Post-Provo Regression ($Qd_5$)

Sediments comprising the fifth Weber River delta surface on the Roy quadrangle are dominated by fine and medium sands, but observed textures vary considerably from sandy mud through gravelly sand. Measured sections from two $Qd_5$ sites show some of the variability present in this unit (figures 10 and 11). Subaqueous deltaic deposits appear as the sandy, irregular topography found in all western $Qd_5$ map areas, whereas channeled subaerial deltaic deposits dominate the large terrace-like eastern exposure of $Qd_5$, which has an average elevation of about 4,292 feet (1,308 m). The originally continuous, subaerial to subaqueous $Qd_5$ delta surface was broken into ten separate map areas when the continued regression of Lake Bonneville and latest Pleistocene transgression of Great Salt Lake caused subsequent delta and stream systems associated with $Qd_4$, $Qd_3$, $Qal_4$, and $Qal_3$ to cut into and rework $Qd_5$ deposits. In addition, lakeward edges of western $Qd_5$ map areas were eroded by the Gilbert shoreline. Based on estimated elevation of the Lake Bonneville water plane, deposition of $Qd_5$ sediments probably occurred between 12.2 to 12.1 ka. This map unit varies in thickness from about 1 to 35 feet (0.3-10.7 m).

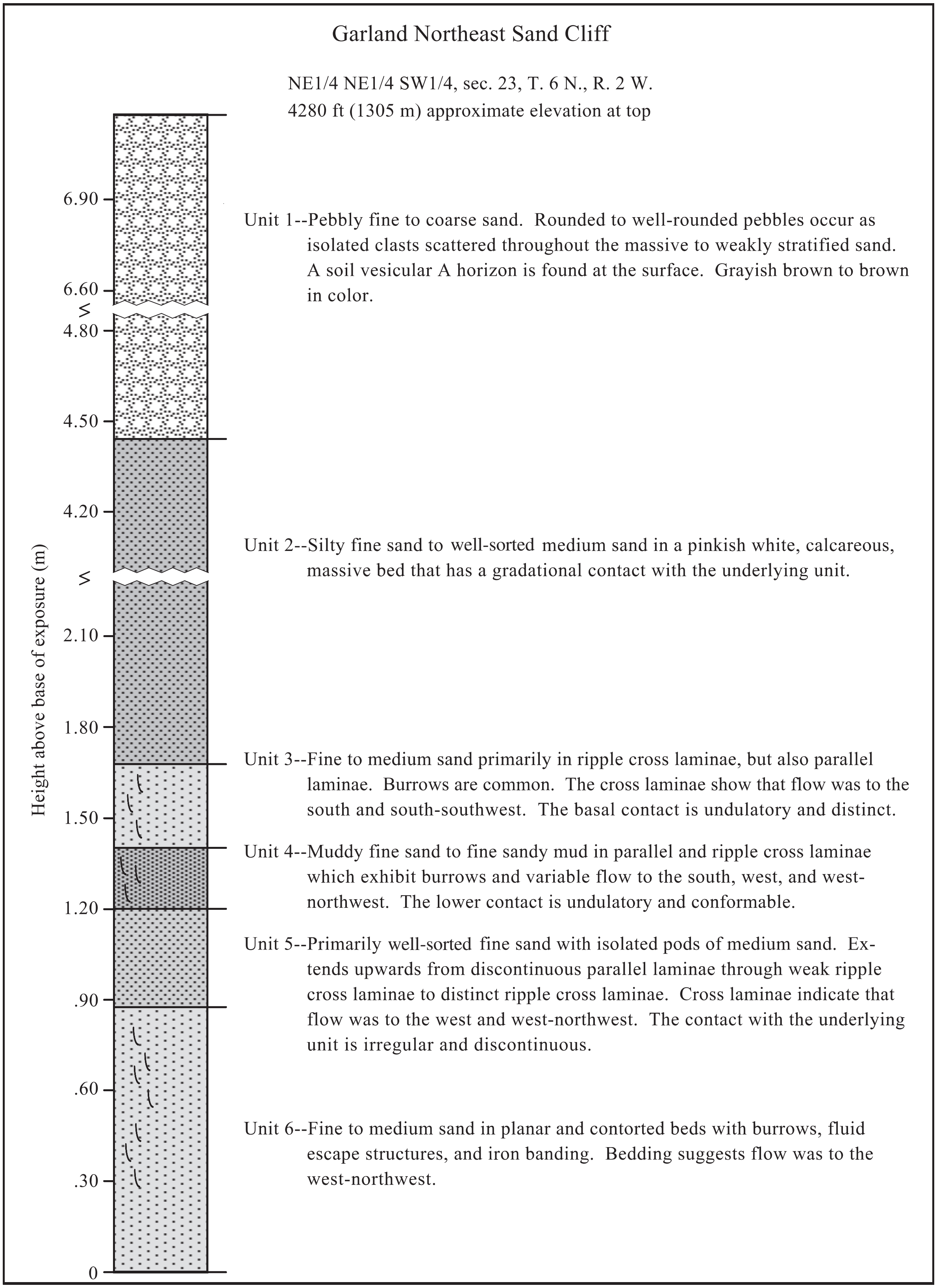



***Figure 10.*** *A measured stratigraphic section in $Qd_5$ deposits exposed in a cliff northeast of Garland.*

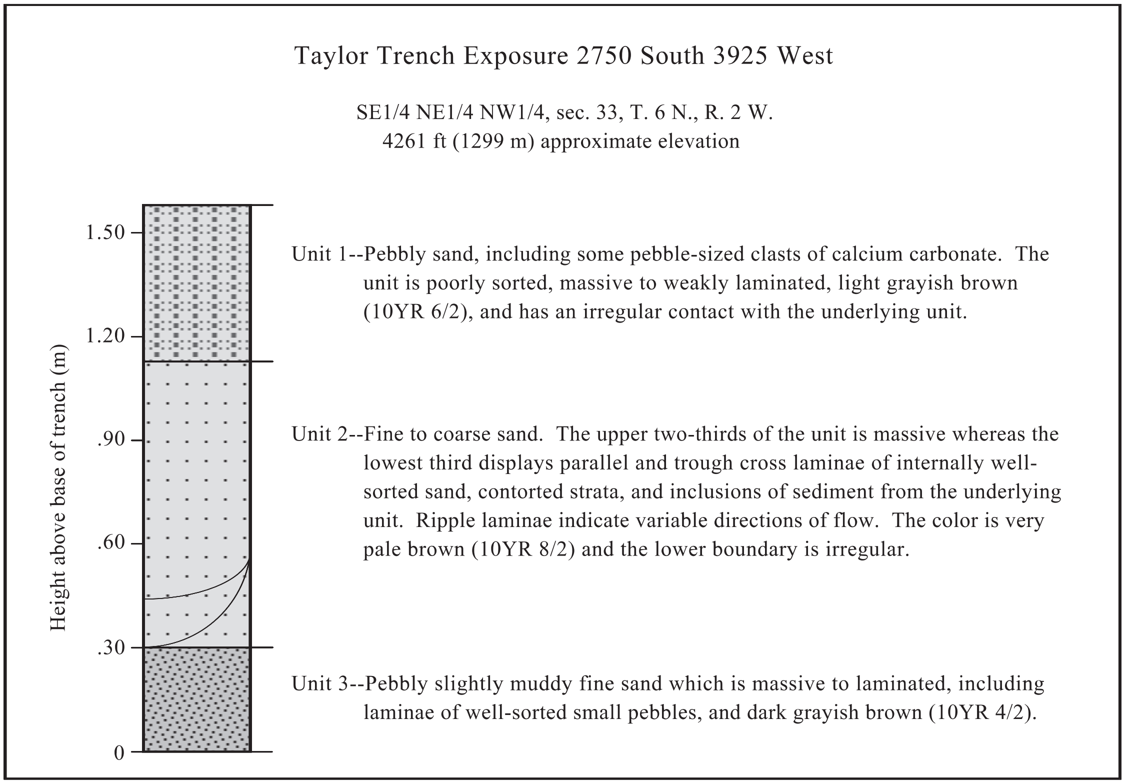



***Figure 11.*** *A measured stratigraphic section in $Qd_5$ deposits near Taylor, about 2.5 mi (4 km) southwest of the site described in figure 10.*

## Sand-Dominated Deltaic Deposits from the Early and Middle Post-Provo Regressive Phase of Lake Bonneville ($Qd_6$-$Qd_{11}$)

Map units $Qd_6$ through $Qd_{11}$ constitute a step-like set of similar, but successively higher and older, features in the eastern part of the quadrangle that are interpreted as essentially Weber River delta components, even though some channel deposits at their surfaces may be nondeltaic. Each numbered delta is separated from the next one by a major stream-cut scarp. Nevertheless, $Qd_6$, and possibly others, may actually be compound features representing more than one delta level. $Qd_6$ through $Qd_{11}$ all have steep lakeward edges that are crossed by minor Lake Bonneville shorelines; no shorelines are found on their surfaces. Small areas of lacustrine, mass wasting, sheet wash, and alluvial fan deposits are found locally along the steep boundary scarps and front slopes. $Qd_6$ through $Qd_{11}$ deposits extend from about 4,350 to 4,680 feet (1,326-1,426 m). Maximum thicknesses range from about 50 to 125 feet (15-38 m). The deposits consist primarily of fine and medium sand, and locally pebbly sand (figure 12). Their surfaces are traversed by channel deposits of gravel or sand and gravel (figure 13).

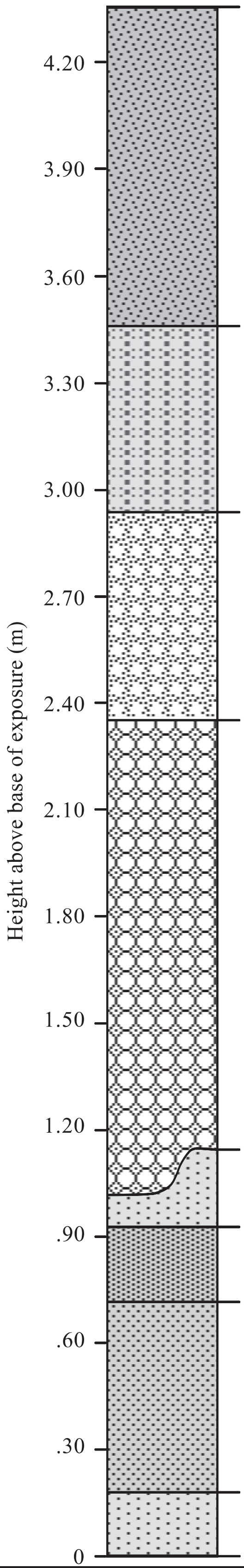
Given the channeled (i.e., subaerial) surfaces, shorelined delta-front scarps, and preserved stream-eroded lateral boundaries, these map units must comprise a regressive sequence of Weber River delta components, with the highest, $Qd_{11}$, being the oldest. Construction, then incision, of subsequent deltas migrated basinward with the falling lake level. As subaqueous deltaic sediments advanced farther into the lake basin, subaerial deltaic sediments advanced into the region of the previous delta front, while the Weber River flood plain migrated into the preceding delta plain. Like the spatial distribution of successive fluvial terraces $Qat_9$ through $Qat_1$, successive delta components $Qd_{11}$ through $Qd_6$ clearly exhibit a clockwise, or eastward rotational, shift in the trend of the Weber River during the interval of delta formation. Based on estimated elevation of the lacustrine water plane, this deltaic sequence was probably formed between approximately 14.0 and 12.2 ka. This estimate is supported by a radiocarbon age of 12,290 ± 350 yr B.P. (W-1824; $^{13}C$ unadjusted) determined from wood chips found in Roy City at 41°10′12″N., 112°02′18″W., in the area mapped here as $Qd_8$ (Ives and others, 1967). The sample was collected from on top of a clay layer that was overlain by clay with sand stringers at a probable elevation of 4,507 feet (1,374 m).

## Deltaic Sand of Provo Shoreline Age ($Qd_{12}$)

$Qd_{12}$ is mapped as a single area in the southeastern corner of the Roy quadrangle. This map unit is composed largely of sand-sized sediment forming an irregular, nondunal surface topography that lacks visible evidence of formative channels and is superficially crossed by several shorelines. Maximum thickness of the $Qd_{12}$ sediments is estimated to be about 75 feet (23 m). In the western part of the $Qd_{12}$ map area elevations increase steadily to the east from about 4,565 feet (1,391 m) to about 4,695 feet (1,431 m), at which point there is an abrupt 30- to 35-foot (9-11 m) step up. East of the scarp, elevations increase gradually to the highest point on the quadrangle, 4,768 feet (1,453.5 m), and continue the gradual rise for more than 2 miles (3 km) beyond the edge of the quadrangle to the Provo shoreline at 4,810 feet (1,466 m) (Currey, 1982). The Roy quadrangle's $Qd_{12}$ map unit, therefore, is interpreted as the subaqueous distal portion of the Provo level delta of the Weber River, including the steep delta front and the delta slope beyond that. As Lake Bonneville fell from the Provo shoreline, the subaqueous delta

## Roy Water Conservancy District Exposure

SW1/4 NE1/4 SW1/4, sec. 13, T. 5 N., R. 2 W.
4584 ft (1397 m) approximate elevation




Unit 1--Gravelly silty fine sand consisting of a very pale brown (10YR 8/2), 30 cm thick anthropogenically disturbed layer over a dark grayish brown (10YR 4/2) middle layer and a very pale brown (10YR 7/3) bottom layer. The middle and bottom layers are interpreted as part of the natural soil solum.

Unit 2--Poorly sorted sand and small gravel in inclined beds that dip to the north-northwest.

Unit 3--Sand and small gravel in well-sorted inclined beds that dip primarily to the north-northwest. Clasts are subrounded to well rounded and the ten largest have an average longest diameter of 9 cm.

Unit 4--Sandy gravel in inclined beds and lenses that dip up to 10 degrees to the north and north-northwest lower in the unit, and to the southeast higher in the unit. The gravel ranges from subrounded to well rounded. The ten largest clasts have an average longest diameter of 12 cm. Secondary calcium carbonate has accumulated on the base and sides of most clasts. The cut and fill erosional basal contact dips 10 degrees to the north.

Unit 5--Alternating beds of massive fine sand and sets of ripple cross-laminated fine to medium sand. Current ripples show a flow direction to the north-northwest.

Unit 6--Silty very fine sand. Massive. Basal contact slopes 18 degrees to the north-northwest.

Unit 7--Very fine to medium sand, with rare coarse sand, granules, and pebbles. Primarily ripple cross-laminated, but occassional parallel laminae. Root casts are present. Cross laminae indicate a north and north-northwesterly direction of flow.

Unit 8--Fine to medium sand in low- and high-angle cross laminae that indicate flow was to the north and north-northwest.

***Figure 12.*** *A measured stratigraphic section in $Qd_{10}$ deposits.*

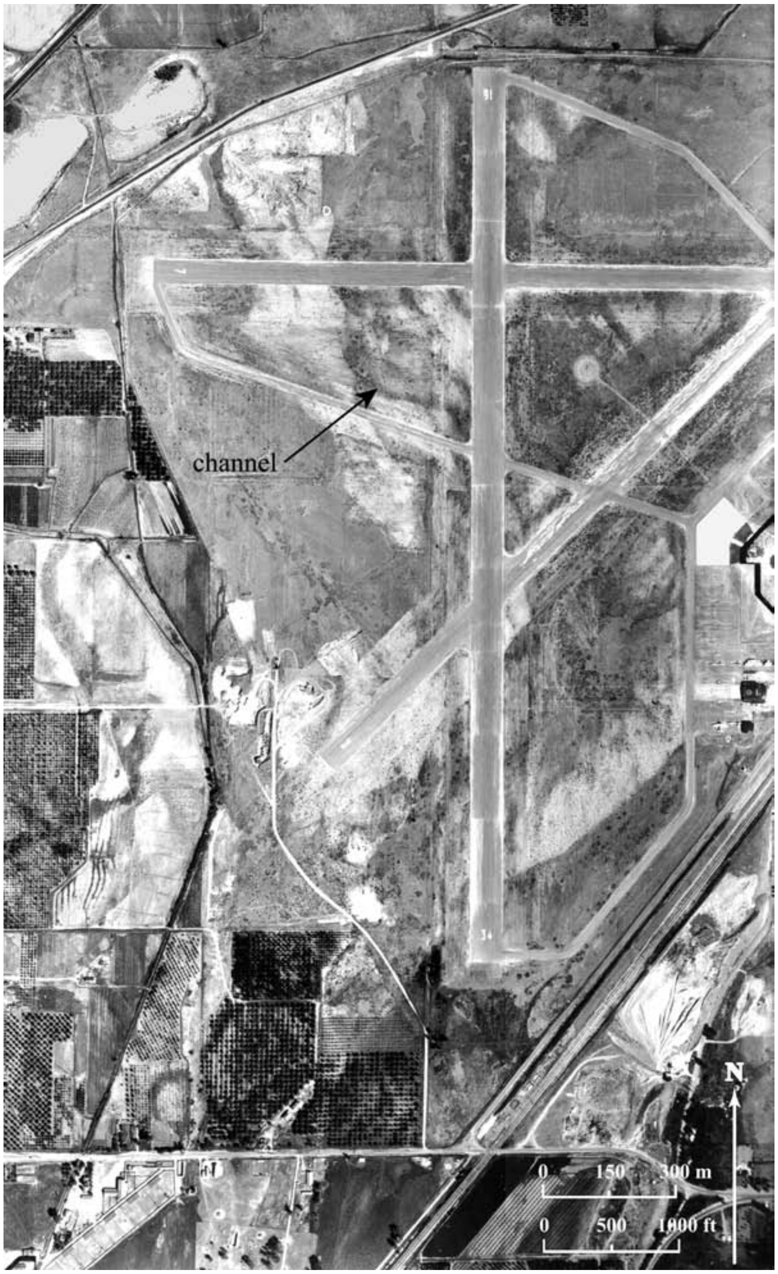



*Figure 13. Portion of 1952 USDA aerial photograph AAJ-11K-71 exhibiting channel traces (dark sinuous tones) on the surface of $Qd_6$ in the vicinity of the Ogden Municipal Airport.*

deposits were reworked slightly by coastal processes leaving some shoreline lineations but no significant constructional landforms. $Qd_{12}$ sediments, therefore, were deposited between about 14.5 to 14.0 ka.

Four factors probably contribute to the overall massiveness of the Weber River's Provo-level delta. First, because the Provo level constituted the first stillstand of the lake after the Bonneville flood, the Weber River would have been able to rework a considerable amount of easily eroded lacustrine and deltaic sediments associated with the higher transgressive-phase shorelines and from the Bonneville shoreline (Gilbert, 1890). Large amounts of those sediments had accumulated upstream in Morgan Valley, which acted as a sediment storage reservoir during higher lake levels. Second, because the Provo lake level was stabilized by threshold control, all of the Weber River sediment during that entire period was concentrated into a single delta. Third, direct Provo shoreline coastal erosion of transgressive-phase deltaic sediments very likely contributed material that became incorporated with the Provo deltaic sediments. Fourth, the massiveness of the Provo level delta of the Weber River may be partly caused by the presence of transgressive-phase coastal or deltaic landforms buried beneath it (Sack, 1999).

### Deltaic Sand from the Transgressive Phase of Lake Bonneville ($Qd_{13}$)

The piedmont in the south-central part of the quadrangle, west of and downslope from $Qd_9$ through $Qd_{12}$, contains some sandy areas of irregular topography that display multiple, meandering channel-like curves (figure 14). These sediments are interpreted as Weber River fluviodeltaic sands deposited during the transgressive phase of Lake Bonneville. Where $Qd_{13}$ sediments are crossed by minor shoreline bluffs and the channel-like topography has been somewhat muted by lacustrine or mixed lacustrine and small-scale fluvial processes, they are mapped as $Qls/Qd_{13}$ or $Qla/Qd_{13}$, respectively. Including the stacked units, $Qd_{13}$ sediments crop out as low as the Gilbert shoreline, which erosionally truncates them, and as high as 4,562 feet (1,390 m). $Qd_{13}$ sediments were probably deposited between about 27.5 and 20.4 ka. Maximum thickness is estimated at 30 to 40 feet (9-12 m).

A transgressive-phase, Bonneville lake cycle age is inferred for $Qd_{13}$ using the established chronologies of Lake Bonneville and Great Salt Lake (figure 2) combined with the fact that shorelines cross and appear to have reworked the unit. Shoreline reworking of pre-existing fluviodeltaic channels in the 4,245 to 4,562 foot (1,294-1,390 m) interval had to have happened during the transgression and/or the regression of the Bonneville water level across them. Because this area was totally submerged between Lake Bonneville's transgression and regression, formation of the subaerial fluviodeltaic channels must have taken place no later than during the transgressive phase of the lake, before the Lake Bonneville shoreline first attained these elevations. The Stansbury oscillation spanned part of the elevational range of these deposits (Oviatt and others, 1990), but it is not interpreted as a major factor in the unit's formation because $Qd_{13}$ sediments lie within and beyond the estimated oscillation zone. In any case, Stansbury oscillation time is automatically included within the broader designation of transgressive phase.

Additional evidence in support of a transgressive-phase, deltaic origin for these deposits derives from the geomorphology of the piedmont zone on which they appear. This piedmont zone lies between about 4,245 and 4,562 feet (1,294-1,390 m), west of and downslope from the Provo and early to middle post-Provo delta components of the Weber River. Near the south end of the Roy quadrangle, the increasingly southwest-trending contours of the piedmont zone turn abruptly and begin a southeasterly trend that extends across the Clearfield quadrangle to the south, and beyond. In other words, the piedmont zone exhibits a broad, westward-projecting arc of land whose right (northern) flank and axial ridge, respectively, lie near and along the southern boundary of the Roy quadrangle. West Point City occupies the truncated lakeward end of this West Point projection, or bulge, and its left flank lies to the south on the Clearfield quadrangle.

Like deposition of $Qd_{13}$ sediments, the West Point projection cannot be explained as a product of the regressive phase of Lake Bonneville. Regressive-phase coastal processes superficially reworked sediments comprising the bulge, but they reworked sediments that comprised a large, pre-existing landform. The Weber River could not have created the piedmont projection or its deltaic features during Lake Bonneville's regression because the river was depositing and terracing its delta components to the east and north of this site at that time. Once the Weber River started to incise its Provo-level delta, then the subsequent deltas, it was blocked from the area downslope from them by that deltaic material.

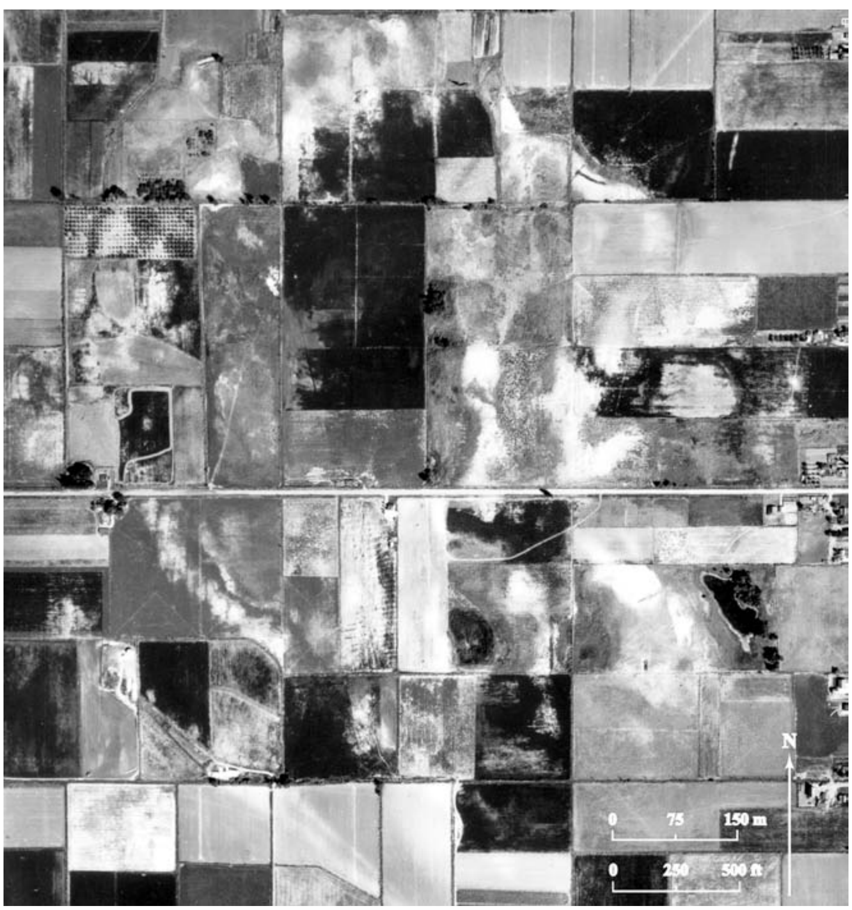



***Figure 14.*** *Portion of 1952 USDA aerial photograph AAK-9K-196 with sandy $Qd_{13}$ sediments displaying an irregular topography and curvilinear channel-like traces. Relatively weak shorelines, like the northwest-trending linear feature in the southwest corner, are common within much of the $Qd_{13}$ area.*

The West Point projection can be explained as a landscape component created during the transgressive phase of Lake Bonneville. The Weber is a major river, the second largest that discharges into Great Salt Lake today and the second largest that discharged into Lake Bonneville. The modern Weber River delta of Great Salt Lake is an expansive, digitate landform extending for 13 miles (21 km) along the lake's eastern shore. The Weber River deposited a very large mass of deltaic sediments, a portion of which appears on the Roy quadrangle, during Lake Bonneville's Provo stillstand and during the lake's regressive phase (Gilbert, 1890). The river also flowed into the basin during the transgressive phase of Lake Bonneville and likewise should have left some depositional evidence of its transgressive positions as delta, fan-delta, or underflow fan deposits. Deltaic sediments could have been deposited throughout the Lake Bonneville transgression, but perhaps especially during stillstands and low-amplitude oscillations. Although the river may not have had sediments from higher deltas and embayments to rework during the transgressive phase of Lake Bonneville like it did during the regressive phase (Gilbert, 1890), the effectively wetter climate that enabled Lake Bonneville to expand would also have caused an increase in river discharge and load. Additional support for the transgressive deltaic origin of the West Point projection comes from the position of the axis of the bulge approximately due west of the mouth of Weber Canyon.

## Lacustrine Deposits

### Undifferentiated Lacustrine and Alluvial Deposits (Qla)

The Qla category is used where lacustrine and alluvial sediments are complexly interlain so that they cannot be adequately delineated at the scale of the map, and where sheet wash, gullies, small alluvial fans, and shallow ephemeral channels have reworked lake sediments so that neither depositional signature dominates. Shoreline bluffs that traverse these areas are partially eroded and buried by those fluvial processes. Observed textures for this unit, which is generally less than 10 feet (3 m) thick, include sandy mud, muddy sand, sand, and gravelly sand. The stacked unit, Qla/$Qd_{13}$, designates locations where wash and lacustrine processes thinly cover transgressive-phase deltaic deposits. The unstacked Qla map unit may locally contain deltaic deposits. Qla sediments are post-Provo through modern in age, deposited approximately 12.6 to 0 ka.

### Fine-Grained Lacustrine Deposits (Qlf)

Mixed fine-grained lacustrine sediments of Lake Bonneville and Great Salt Lake were deposited on the quadrangle in low-energy coastal, in nearshore, and in offshore settings below a modern elevation of 4,278 feet (1,304 m). Sandy mud, silty sand, and muddy sand are common textures observed in this unit. Qlf deposits are typically less than 10 feet (3 m) thick.

Shorelines from the regressive phase of Lake Bonneville cross Qlf map areas lying above the Gilbert shoreline. Regressive-phase Lake Bonneville fines probably comprise most of the Qlf deposits found above the Gilbert level, but the unit may also include some sediments from the transgressive phase of Lake Bonneville. Qlf sediments, therefore, may have started accumulating as early as 27.5 ka.

Areas mapped as unstacked Qlf below the Gilbert shoreline display faint shoreline lineations that probably date from the post-Gilbert recession of Great Salt Lake. Most of those Qlf sediments, therefore, were deposited during the Gilbert oscillation and, up to an elevation of 4,221 feet (1,287 m), during Great Salt Lake's subsequent Holocene high level. Some lacustrine fines, therefore, may be as young as 2.0 ka (Currey and others, 1988).

Below the Gilbert shoreline to the southwest of the $Qd_3$ and $Qd_4$ map areas, lacustrine fine-grained sediments thinly cover a large plain that has an average elevation of about 4,240 feet (1,292 m) and that slopes gently to the southwest. The presence of multiple, muted channel forms points to a fundamentally deltaic origin of the gently sloping plain, which, under the cover of lacustrine fines, is believed to consist mostly of deltaic sediments from late in the regressive phase of Lake Bonneville, $Qd_4$. It can be inferred that somewhere within the Qlf/$Qd_4$ region, a narrow corridor of $Qd_3$ sediments might actually underlie some of the lacustrine fines. Because no means were available to verify the specific presence of buried $Qd_3$ deposits or to distinguish them from buried $Qd_4$ sediments, the underlying deltaic sediments in this stacked unit are all mapped as $Qd_4$.

### Lacustrine Sand (Qls)

Sand-dominated sediments deposited in a shorezone setting by Lake Bonneville waves and currents are mapped as Qls. Qls is found between the Gilbert shoreline and the 4,445 foot (1,355 m) contour, and may be as much as 15 feet (4.6 m) thick. Sandy beaches and shoreline bluffs are common features within this map unit. Lacustrine sand is found unstacked in one map area near the center of the Roy quadrangle and as Qls/$Qd_{13}$ in two areas along the map's southern edge. The unstacked Qls region consists of regressive-phase beaches and southward-trending spits composed of sediment eroded from the sandy delta fronts of $Qd_6$ and $Qd_7$ and from the delta slope now composed of Qda. In the Qls/$Qd_{13}$ regions, evidence of deltaic distributary channels from the transgressive phase of Lake Bonneville can be seen through the cover of coastal and nearshore sand reworked from the underlying deltaic deposits. Shorelines in the stacked unit tend to be bluffs rather than constructional landforms. It is possible that a small amount of lacustrine sand on the Roy quadrangle may have been deposited as Lake Bonneville initially transgressed over the 4,245 to 4,445 foot (1,294-1,355 m) interval, between about 27.5 and 21.4 ka. The Qls map unit, however, essentially consists of pre-existing sandy deltaic sediments reworked into lacustrine sand when the Lake Bonneville shoreline regressed over this zone between about 12.4 and 12.1 ka.

## Mass Wasting Deposits (Qms)

When the ancestral Weber River cut down into its Provo and post-Provo deltas during the regressive phase of Lake Bonneville, it left an especially steep scarp on the north side of $Qd_{10}$. That scarp is particularly steep at its eastern end, where it merges at the top with $Qd_{11}$ and extends down to the lowest terrace, $Qat_1$. Failure there has left a slope of irregular, hummocky topography and recessional head scarps that continues off the map to the east in a feature referred to as the South Weber landslide complex (Pashley and Wiggins, 1972). On the Roy quadrangle, Qms deposits consist largely of gravelly silt and gravelly fine sand. The map unit has an estimated maximum thickness of 30 feet (9 m). From air photo interpretation it appears that large-scale failure began during $Qat_1$ time, perhaps about 12.0 ka, and that head scarp retreat is an ongoing, episodic event. Smaller scale mass wasting at this site, however, may possibly have started as early as incision into $Qd_{11}$, about 14.0 ka. Elsewhere along the steep delta and terrace scarps, very small areas of mass wasting are locally included within Qd, Qat, and Qac map units.

### Marsh Deposits (Qsm)

Fine-grained, saturated, dark-colored, organic-rich sediment found in wetlands associated with springs, seeps, ponds, and other areas of poor drainage and/or high water table are mapped as Qsm deposits. On the early to middle Holocene flood plain ($Qal_2$) and latest Pleistocene through early Holocene delta ($Qd_2$-$Qd_4$) surfaces, Qsm deposits occupy some of the depressions formed by channels and abandoned meanders. Even seepage from long-standing canals and ditches has locally expanded the area of marsh deposits on the quadrangle. Qsm sediments are probably less than 5 feet (1.5 m) thick and have been accumulating since about 12.1 ka.

## QUATERNARY HISTORY

Shortly before the initiation of the Bonneville lake cycle, about 30 ka, the ancestral Weber River probably flowed fairly directly from its canyon mouth in the Wasatch Range to the low-level, pre-Bonneville standing water body. Without the large mass of Lake Bonneville deltaic deposits to skirt around, there would have been little reason for the river to take the extremely circuitous route to the lake that it does today. The pre-Bonneville Weber River very likely meandered over a flood plain before splitting into the multiple distributary channels of a deltaic plain adjacent to the lake.

Early in the Lake Bonneville transgression, a major component of the sediment-laden Weber River must have flowed westward close to the southern boundary of the quadrangle, thus beginning construction of a lakeward-projecting depocenter of transgressive-phase deltaic deposits, $Qd_{13}$. That transgressive-phase depocenter, referred to here as the West Point projection, originally extended somewhat farther to the west than it does today. As the lake continued its relatively slow transgression across the quadrangle (figure 2), the locus of this $Qd_{13}$ sedimentation shifted higher and generally eastward. The most extensive accumulations of $Qd_{13}$ sediments may have formed in association with lake-level stillstands, but a unique Stansbury shoreline could not be identified with confidence on the quadrangle. Some nearshore lacustrine sand (Qls) and fines (Qlf) may have been deposited during the transgression in quadrangle locations away from the deltaic depocenter. Deep-water fines probably settled out onto the quadrangle as the transgression continued, but once Lake Bonneville reached the Wasatch Front to the east, and beyond, expanding into Weber Canyon and Morgan Valley, delivery of sediment out of the Weber basin was virtually shut off by the sediment-trapping embayment (Gilbert, 1890). While Lake Bonneville occupied its highest levels white marl precipitated out of the open lake water, but the marl is not exposed on the Roy quadrangle.

The Bonneville flood and restabilization of the lake at the Provo level occurred about 14.5 ka (Oviatt and others, 1992). This new threshold-controlled lake level, however, still lay above the submerged quadrangle with the Provo shoreline off the map to the east. At that time, deltaic deposits from the transgressive phase of Lake Bonneville were being eroded by coastal processes along the Provo shoreline while the Weber River began eroding and transporting to the lake newly exposed upstream embayment and deltaic sediments. As a result, a large sandy delta was constructed in association with the Provo shoreline, with part of the subaqueous component extending onto the southeastern portion of the Roy quadrangle as $Qd_{12}$ sediments. Some transgressive deltaic sediments may lie buried beneath Provo deltaic sediments.

When climate change caused Lake Bonneville to drop from the Provo level about 14.0 ka, it fell quickly (figure 2). In response to the falling lake level, the Weber River began to cut down into the Provo-level delta ($Qd_{12}$) and to rework those excavated sediments, along with continued load from upstream, into a new, slightly lower, delta component, $Qd_{11}$. Further regression caused incision of $Qd_{11}$, deeper erosion of $Qd_{12}$, and reworking of those sediments into an even lower new delta, $Qd_{10}$. In this way, construction, then incision, of subsequent deltas trailed after the falling lake level. As the delta front advanced farther into the lake basin, the delta plain advanced into the previous subaqueous portion of the delta, while the Weber River flood plain advanced into the preceding delta plain. The spatial arrangement of delta and terrace remnants records a clockwise shift in the Weber River during this interval from westerly to northwesterly then northerly flow. The set of regressive deltas $Qd_{11}$ through $Qd_6$ formed rapidly between about 14.0 and 12.2 ka, while fluvial terraces $Qat_9$ through $Qat_7$ record former flood-plain positions from that time interval.

Also beginning about 14.0 ka, coastal waves and currents reworked emerging delta front and slope sediments, especially at sites away from the direct impact of the contemporary fluvial influx. This lacustrine activity is preserved as minor shoreline bluffs on the relict delta fronts and within the map region of Qda. Major accumulations resulting from this regressive-phase Lake Bonneville wave and current action are found in the Qls and Qla map areas above the Gilbert shoreline.

At about 12.2 ka, the Weber River was flowing around the northern end of regressive delta $Qd_6$ and depositing $Qd_5$ sediments on the former lake plain located northwest of the $Qd_6$ to $Qd_{13}$ delta components. As the slope between the older delta fronts and $Qd_5$ became subaerially exposed, slope wash, small fans, and shallow channels began to rework the deltaic and lacustrine sediments in the regions mapped as Qda and Qla. The nested sequence of delta components $Qd_5$ through $Qd_3$ suggests that by approximately 12.1 ka, the lower course of the Weber River flowed to the southwest across the Roy quadrangle in the vicinity of what is today the

Hooper Slough. At about that time, additional base-level lowering instigated erosion of the $Qd_5$ delta and construction of what is interpreted to be the last regressive-phase delta on the Roy quadrangle, $Qd_4$. $Qal_4$ represents a large meander scar from $Qd_4$ time that remains well preserved on the delta surface. Further lake-level retreat caused deltaic sedimentation to shift off the map to the west, and the Weber River flood plain ($Qal_3$) to advance into the $Qd_4$ delta region of the Roy quadrangle by the end of the lake cycle. Climatic conditions that caused the termination of the Bonneville lacustral cycle about 12 ka probably also negatively impacted the discharge of the Weber River. All of the rest of the fluvial terraces, that is, $Qat_6$ through $Qat_1$, may date from the 12.2 to 12.0 ka interval.

Transgression of Great Salt Lake to the Gilbert shoreline started soon after 12.0 ka, with the Weber River still flowing to the southwest across the Hooper Slough area of the Roy quadrangle. As the lake level rose, the subaqueous and subaerial components of the Weber River delta transgressed along with it. This migrating sequence eventually entered the incised Hooper Slough flood-plain zone, depositing $Qd_3$ sediments within it. Away from the locus of deltaic deposition and in deeper water, lacustrine fines began to blanket the pre-existing $Qd_4$ deltaic topography. While the lake was nearing the Gilbert level, waves and currents began to erode the western part of the West Point projection. Between about 10.9 and 10.3 ka Great Salt Lake attained the 4,245 foot (1,294 m) level, where it created the Gilbert shoreline (Currey, 1990). By approximately this time, the subaerial portion of the $Qd_3$ delta had also reached its maximum elevation, slightly higher than 4,250 feet (1,295 m). Just beyond the subaerial part of the delta lay the Weber River flood plain, a portion of which is preserved on the Roy quadrangle as $Qal_3$. Close to Gilbert shoreline time, the Weber River, which had backed up in its Hooper Slough course, abandoned that path in favor of a new course farther to the north.

The drop in base level associated with regression from the Gilbert shoreline may have initiated Weber River erosion along the northern ends of the $Qd_5$, $Qd_4$, and $Qal_3$ map areas. Re-rise of the lake between 9.7 and 9.4 ka to approximately 4,230 feet (1,289 m) resulted in the formation of the $Qd_2$ delta. Sometime after the lake fell from that early Holocene high, the Weber River occupied the $Qal_2$ flood plain. While the meandering river migrated over that flood plain, it trimmed back the northern end of the $Qd_2$ exposure and continued its erosion of the $Qd_4$, $Qd_5$, and $Qal_3$ map areas. The present Weber River flood plain, $Qal_1$, and its delta plain, $Qd_1$ and Qdm, probably came into existence in the late Holocene.

## SAND AND GRAVEL RESOURCES

Sand and gravel constitute the principal geologic resources on the quadrangle. Considerable quantities of deltaic sand have been stripped from the large, western map area of $Qd_5$ and from the $Qd_7$ and $Qd_{11}$ deltas. Areas of lacustrine and transgressive deltaic sand, on the other hand, have received little attention from extraction industries. Flood-plain, fluvial terrace, and $Qd_6$ through $Qd_{11}$ deltaic channel gravels have been quarried at numerous sites on the Roy quadrangle, but the number of active pits on the terraces and regressive deltas is decreasing with increasing urbanization.

## POTENTIAL GEOLOGIC HAZARDS

Geologic hazards in the study area consist of flooding, mass wasting, and earthquake-related events. Flooding of the Weber River particularly impacts the modern flood-plain zone ($Qal_1$), but it may also affect adjacent areas of $Qal_2$ during extreme flooding events. The $Qal_1$ map area could expand at the expense of $Qal_2$ deposits through erosive widening of the modern flood plain during floods or lateral migration of meanders. Meteorological conditions giving rise to natural flood hazards might also instigate overflow or breaches along the dense network of canals and ditches that has been constructed on the quadrangle. It is not known if geologic or human-induced factors caused the 1999 failure of the Weber-Davis Canal along the scarp at the northern edge of the $Qd_{10}$ map area that resulted in sedimentation damage to at least 75 homes on the Roy quadrangle (McDonald, 2000). In addition to stream flooding, climatically induced high levels of Great Salt Lake will likely occur periodically. That expansion, however, has an effective upper limit of 4,217 feet (1,285 m), the elevation at which the lake spills over to the Great Salt Lake Desert. Flooding effects due to high levels of Great Salt Lake, therefore, would be to submerge the delta plain of $Qd_1$ and Qdm deposits, including ecologically valuable wetlands. A rise in lake level to or near 4,217 feet (1,285 m) could also change the flow dynamics for the portion of the Weber River that traverses the quadrangle. Increased sinuosity and flood-plain widening could result.

Mass wasting has occurred in the study area and will undoubtedly happen again especially along the steep scarps created by Weber River incision into fluvial terraces and the Provo and later Lake Bonneville delta components. In addition to continued activity within the Qms map area, new mappable slumps, earthflows, or slides could develop elsewhere along the steep scarps. The contribution of small falls, slumps, slides, and flows to the Qac deposits along the scarps previously noted by Lowe (1988) likewise will continue. Mass wasting hazards increase during wet years, during earthquakes, and because of some actions by people, such as adding water to a slope or removing material from the base of the slope.

No fault scarps were found on the quadrangle, but interpretation of seismic reflection data suggests that a possible buried fault (Fault D) under the quadrangle cuts Quaternary deposits, and therefore would be a potential earthquake source (plate 2). Because of the possible buried fault and the quadrangle's proximity to the Wasatch fault zone, ground shaking and accompanying liquefaction and mass wasting pose significant hazards to this area (figure 15) (Hecker and others, 1988; Anderson and others, 1994a, 1994b).

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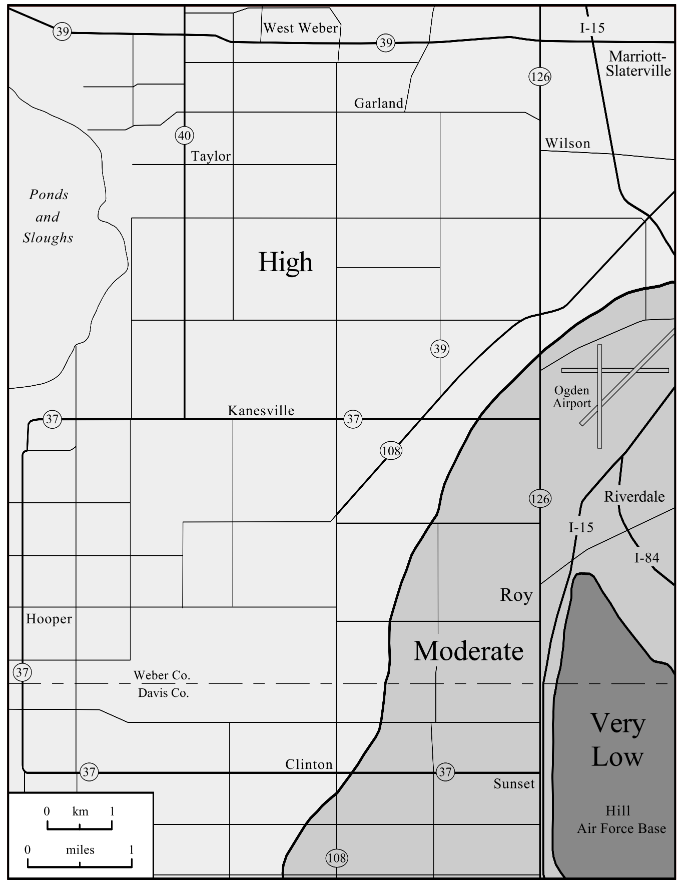


***Figure 15.*** *Liquefaction potential map (after Anderson and others, 1994a, 1994b).*

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