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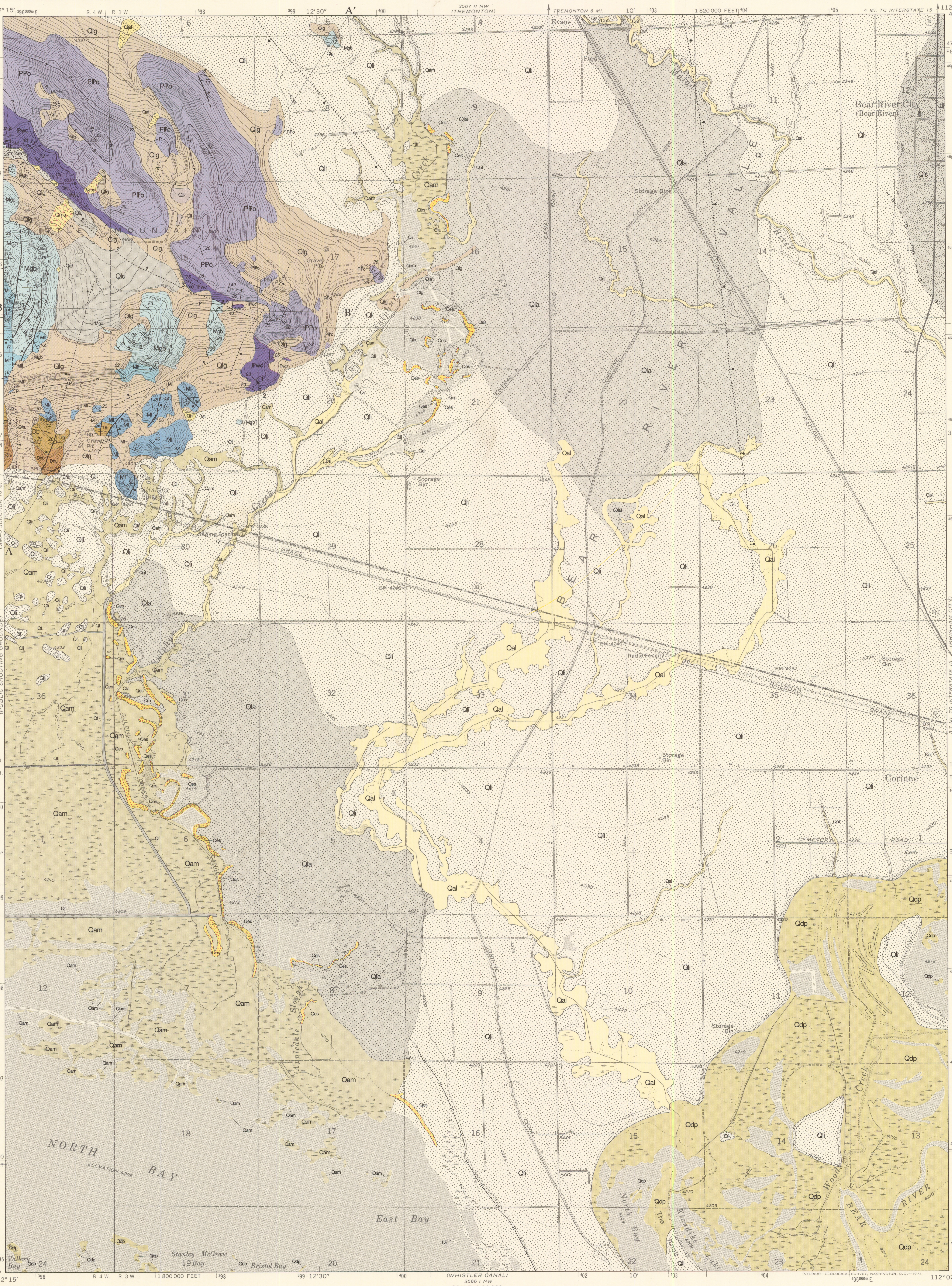


Base from U.S. Geological Survey
Bear River City 7.5' Quadrangle, 1972

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

Field mapping by author, 1986-88
Cartography by J. Parker

14°25' E
256 MILS

1994 MAGNETIC NORTH DECLINATION
AT CENTER OF SHEET

GEOLOGIC MAP OF THE BEAR RIVER CITY QUADRANGLE, BOX ELDER COUNTY, UTAH

by

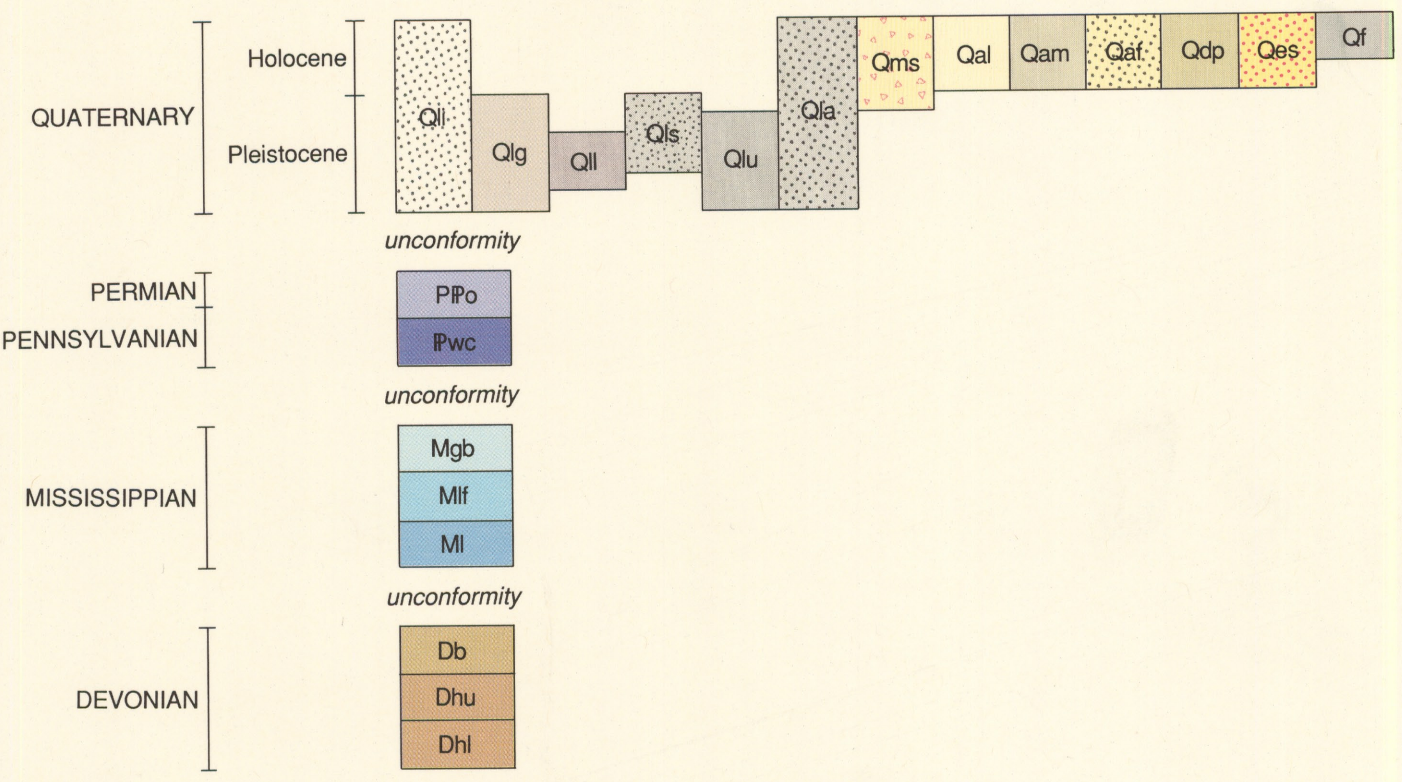
Mark E. Jensen

1994

UTAH

QUADRANGLE LOCATION

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

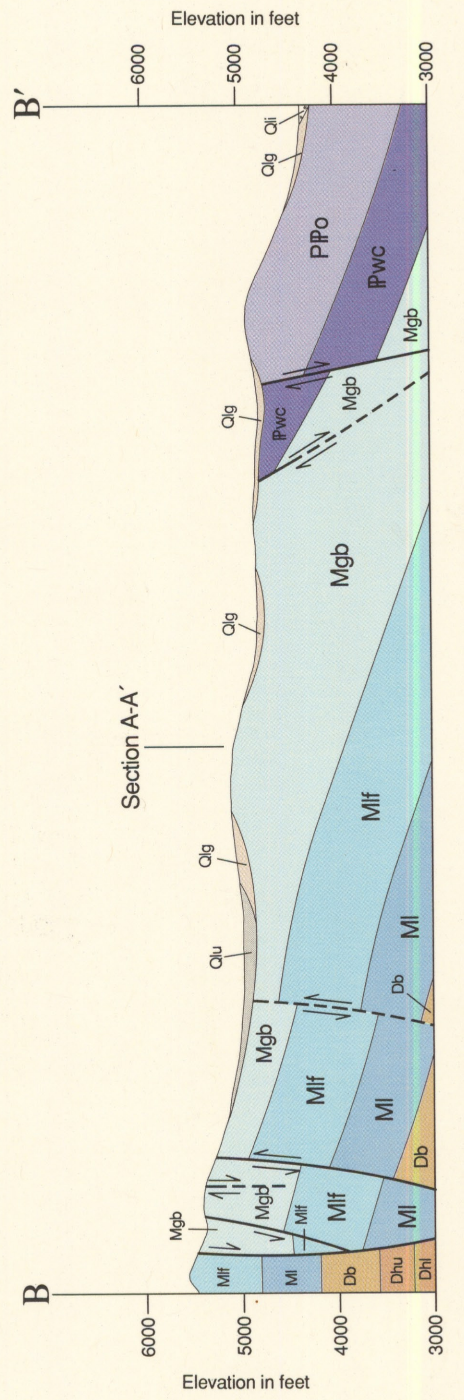
- **Qf** Fill material - *Silt, clay, sand, and gravel fill in dikes.*
- **Qal** Alluvium - *Sand, silt, clay, and gravel. Deposited along stream channels and flood plains of active and inactive streams.*
- **Qam** Alluvial-mud and marsh deposits - *Silt, clay, and sand deposited by low-gradient streams in mud flats and marshes. Near North Bay this unit also includes interbedded lacustrine clay and silt.*
- **Qaf** Alluvial-fan deposits - *Poorly sorted sand, silt, and gravel (granules, pebbles, cobbles, and occasional boulders). Formed on or near Little Mountain from local floods and debris flows.*
- **Qdp** Deltaic-plain deposits - *Sand, silt, and clay deposited in the Bear River delta. Includes deposits in marshes, oxbow lakes, channels, point bars, and natural levees.*
- **Qes** Eolian-sand deposits - *Very fine to fine sand and silt, forming mounds along edges of mud flats and shallow lakes.*
- **Qla** Mixed lacustrine and alluvial deposits - *Lacustrine silt, sand, and clay, overlain by alluvial channels and marsh deposits.*
- **Qli** Lacustrine-silt deposits - *Silt, clay, and very fine to fine sand deposited in Lake Bonneville.*
- **Qlg** Lacustrine-gravel deposits - *Subrounded to well-rounded gravel and sand, deposited in the shore zone of Lake Bonneville.*
- **Qll** Lacustrine lagoon-fill deposits - *Sand, silt, and clay deposited in lagoons behind lacustrine gravel bars.*
- **Qls** Lacustrine-sand deposits - *Very fine-grained sand overlying interbedded clay, silt, and sand. Deposited in Lake Bonneville.*
- **Qlu** Lacustrine deposits undifferentiated - *Sand, silt, clay, and gravel deposited in Lake Bonneville.*
- **Qms** Landslide deposits - *Poorly sorted to well-sorted lacustrine gravel and sand on Little Mountain.*
- **PIPo** Oquirrh Formation, undivided - *Interbedded yellowish-brown sandstone and light- to medium-gray limestone; forms slopes and ledges.*
- **IPwc** West Canyon Limestone - *Interbedded medium- to dark-gray, sandy limestone and sandstone, fossiliferous and cherty.*
- **Mgb** Great Blue Limestone - *Medium-gray to medium-dark-gray, ledge-forming limestone, fossiliferous and locally cherty.*
- **Mlf** Little Flat Formation - *Interbedded sandstone and cherty limestone; dominantly limestone in upper part.*
- **Ml** Lodgepole Limestone - *Medium-dark- to dark-gray limestone and cherty limestone, fossiliferous.*
- **Db** Beirdneau Formation - *Interbedded light-gray dolomite and dark-yellowish-orange quartzite.*
- **Dhu** Upper member of the Hyrum Dolomite - *Interbedded light- and dark-gray dolomite.*
- **Dhl** Lower member of the Hyrum Dolomite - *Dark-gray to grayish-black, cliff-forming dolomite.*

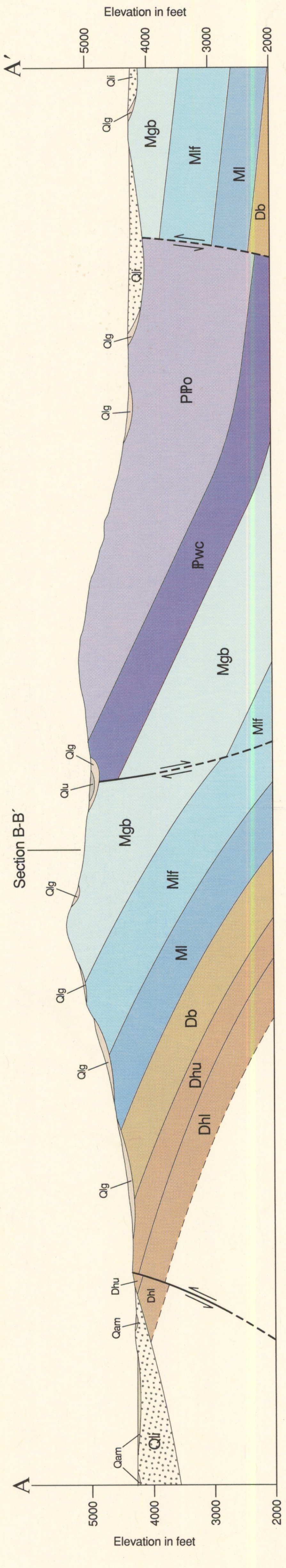
MAP SYMBOLS

- CONTACT - *Dashed where approximately located.*
- NORMAL FAULT - *Dashed where approximately located, dotted where concealed, bar and ball on downthrown side.*
- 6 STRIKE AND DIP OF BEDS
- HEAD SCARP OF LANDSLIDE - *Dashed where approximately located.*
- B BONNEVILLE SHORELINE - *Dashed where approximately located.*
- P PROVO SHORELINE - *Dashed where approximately located.*
- G GILBERT SHORELINE - *Dashed where approximately located.*
- H LATE HOLOCENE SHORELINE - *Dashed where approximately located.*
- 5 LOCATION OF PALEONTOLOGICAL SAMPLE - *See table 1.*

LITHOLOGIC COLUMN

SYSTEM	SERIES/STAGE	FORMATION		SYMBOL	THICKNESS Feet (Meters)		LITHOLOGY
PERM.	Lower	Oquirrh Formation		PIPo	2000+ (610+)		
PENNSYLVANIAN	Desmoinesian-Virgilian						
	Mor.-At.	West Canyon Limestone		IPwc	643+ (196+)		
MISSISSIPPIAN	Chesterian	Great Blue Limestone		Mgb	1300+ (396+)		
	Meramecian	Little Flat Formation		Mlf	854 (260)		
	Osa-gean						
	Kinder-hookian	Lodgepole Limestone		Ml	466+ (142+)		
DEVONIAN	Upper	Beirdneau Formation		Db	597 (182)		
	Middle	Hyrum Dolomite	upper	Dhu	759+ (231+)	320 (98)	
			lower	Dhl		439+ (134+)	

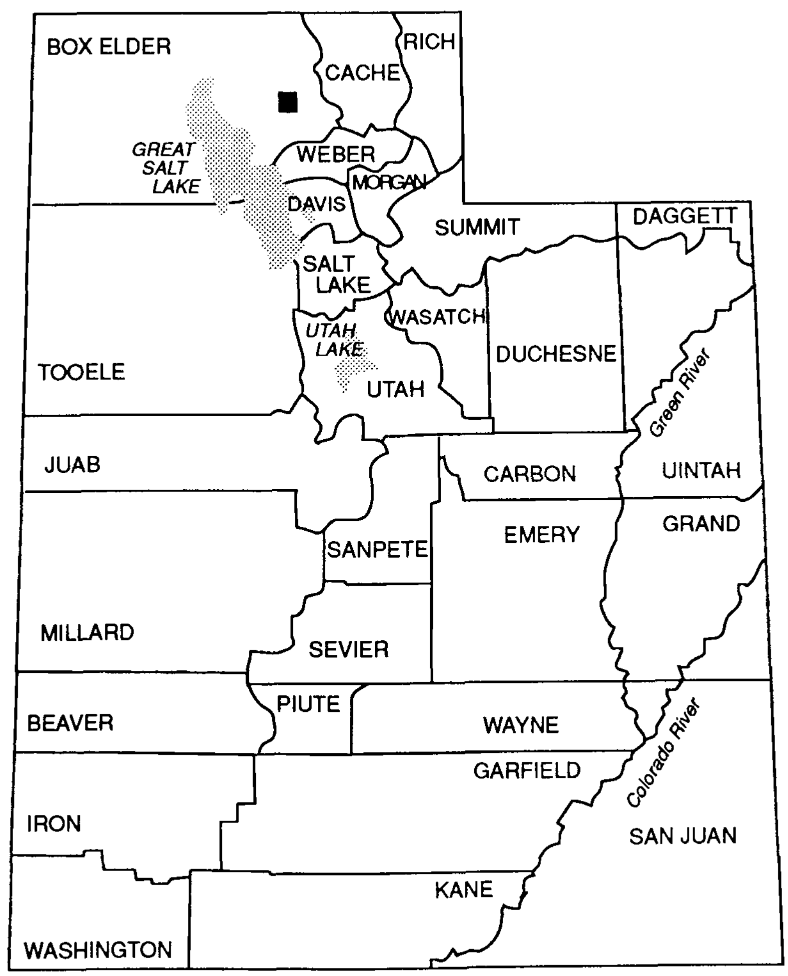




Jensen GEOLOGIC MAP OF THE BEAR RIVER CITY QUADRANGLE, BOX ELDER COUNTY, UTAH Utah Geological Survey Map 151

GEOLOGIC MAP OF THE BEAR RIVER CITY QUADRANGLE, BOX ELDER COUNTY, UTAH

by
Mark E. Jensen
Utah Geological Survey



MAP 151 **1994**
UTAH GEOLOGICAL SURVEY
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GEOLOGIC MAP OF THE BEAR RIVER CITY QUADRANGLE, BOX ELDER COUNTY, UTAH

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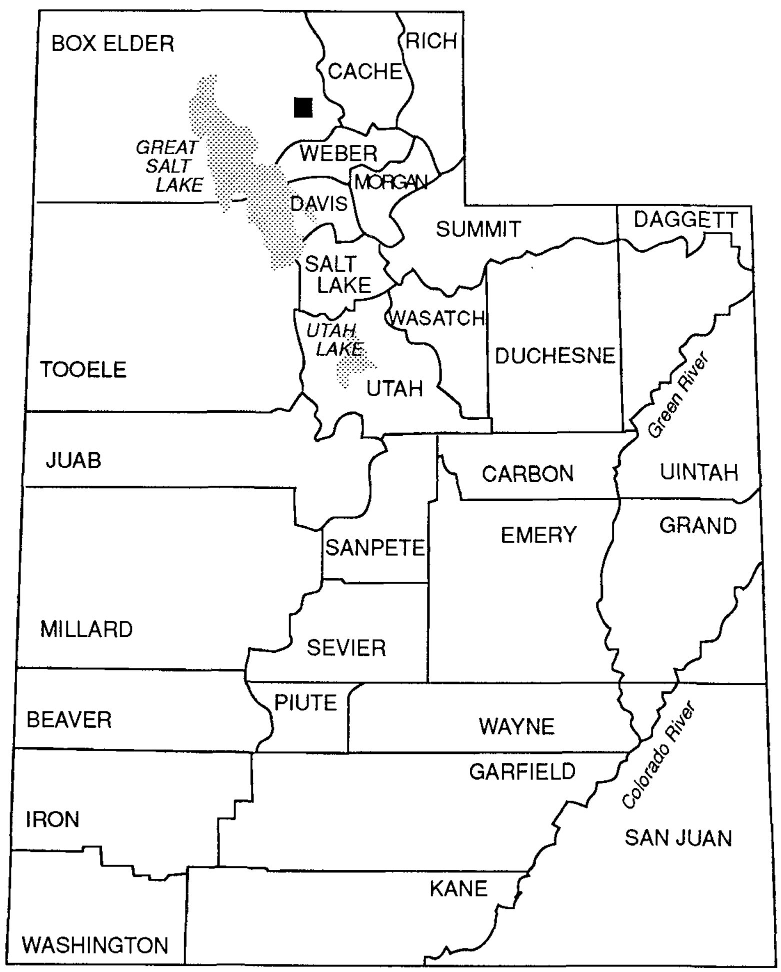

MAP 151
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UTAH DEPARTMENT OF NATURAL RESOURCES

1994

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

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GEOLOGIC MAP OF THE BEAR RIVER CITY QUADRANGLE, BOX ELDER COUNTY, UTAH

by
Mark E. Jensen [1]
Utah Geological Survey

ABSTRACT

The Bear River City 7.5-minute quadrangle is located in northern Utah on the eastern margin of the Great Basin. Most of the quadrangle is covered by unconsolidated lacustrine and alluvial deposits that are Quaternary in age. Bedrock is only exposed on and near Little Mountain on the northwest border of the quadrangle. These rocks are Middle Devonian to Permian in age, and have been affected by Sevier (Cretaceous) folding and thrust faulting, and Cenozoic normal faulting. No Holocene fault offsets have been found in the quadrangle, although scarps about 4 miles (6 km) east of the quadrangle along the Brigham City segment of the Wasatch fault zone indicate that several earthquakes have produced surface ruptures during the past 10,000 years. Unconsolidated materials are mostly lacustrine lake-bottom and nearshore deposits of Lake Bonneville and the Great Salt Lake, and alluvial and deltaic deposits of the Malad and Bear Rivers. During the Pleistocene prior to the formation of Lake Bonneville, at least two other lake cycles probably inundated lowlands in the quadrangle.

INTRODUCTION

The Bear River City quadrangle is located in Bear River Valley in northern Utah, and includes parts of the towns of Bear River City and Corinne. The Malad River flows through the northeast corner of the quadrangle, and the Bear River flows through the southeast corner. North Bay of the Bear River Migratory Bird Refuge occupies the southwest corner of the quadrangle. Elevations within the Bear River City quadrangle range from 4,206 feet (1,282 m) at North Bay to 5,607 feet (1,709 m) on the highest peak of Little Mountain. Most of the Bear River City quadrangle shows unconsolidated lacustrine and alluvial deposits at the surface; consolidated bedrock is exposed only on and near Little Mountain. Most of the valley floor is cultivated farm land.

Previous geologic maps which include the Bear River City quadrangle are the Box Elder County geologic map (Doelling, 1980), a geologic map of the northern Wasatch

[1] *Currently, Utah Department of Environmental Quality, Division of Drinking Water, Salt Lake City, Utah.*

Front compiled by Davis (1985), and a map of the surficial geology (Miller, 1980). The surficial geologic map of Personius (1990) covers the northeastern part of the quadrangle. Schaffer (1984) studied the Holocene paleoecology and geomorphology along part of the Malad River within this quadrangle. A soil survey of eastern Box Elder County (Chadwick and others, 1975) includes the Bear River City quadrangle. Oviatt (1986) mapped the geology of the adjoining Honeyville quadrangle to the northeast, and Jordan and others (1988b) mapped the adjoining Thatcher Mountain quadrangle to the northwest.

STRATIGRAPHY

Rocks of Middle Devonian to Early Permian age crop out on and near Little Mountain. This exposed Paleozoic section is about 6,600 feet (2,012 m) thick, including 1,356 feet (413 m) of Devonian strata, more than 2,620 feet (799 m) of Mississippian strata, and more than 2,643 feet (806 m) of Pennsylvanian-Permian strata. Quaternary lacustrine, alluvial, and eolian deposits cover the valley floor and parts of Little Mountain. Late Pleistocene Lake Bonneville once covered all of the quadrangle except that part of Little Mountain above 5,220 feet (1,591 m).

Devonian System

Hyrum Dolomite

The Middle to Upper Devonian Hyrum Dolomite is the oldest stratigraphic unit exposed in the Bear River City quadrangle. This age assignment for the Hyrum is based on fossils from a section in the Bear River Range (Williams, 1971). The Hyrum crops out only on the southwest part of Little Mountain. On Little Mountain, this formation is more than 759 feet (231 m) thick in a section measured just to the west of the Bear River City quadrangle. The Hyrum Dolomite has been divided into two members on Little Mountain.

Lower member (Dhl): The lower member of the Hyrum Dolomite is thick- to very thick-bedded dolomite which is dark gray to grayish black, with some lighter bands in the upper part, and forms dark cliffs. The dolomite is very finely to medium-crystalline, and sandy. Some beds contain small vugs filled with white dolomite; crinoid stems are rare. The lower contact is covered, but the exposed thickness of the lower member is 439 feet (134 m) in a measured section on the southwest part of Little Mountain.

Upper member (Dhu): The upper member of the Hyrum Dolomite crops out as ledges of interbedded light- and dark-gray dolomite in thick beds. The dolomite is very finely to medium-crystalline, sandy, and locally contains low-angle cross-bedding. The upper part of this member contains minor interbedded siltstone and sandstone as laminated partings. The upper member is 320 feet (98 m) thick.

Beirdneau Formation (Db)

The Beirdneau Formation consists of 597 feet (182 m) of interbedded dolomite and quartzite in a measured section on the southwest corner of Little Mountain. Its contact with the underlying Hyrum Dolomite is placed above the banded dolomite of the Hyrum and below the lighter colored and more finely crystalline dolomite of the Beirdneau. The Beirdneau Formation crops out on the southwest part of Little Mountain.

The lower 180 feet (55 m) of the Beirdneau is dolomite which weathers medium-light-gray interbedded with dark-yellowish-orange to grayish-orange quartzite. The dolomite in the lower part of the formation is very finely crystalline and thin to thick bedded. The quartzite is very fine grained and contains cross-bedding. The quartzite is mostly medium bedded, but is laminated where it grades vertically into the dolomite.

A ledge-forming quartzite unit is present 108 feet (33 m) above the base of the Beirdneau. This unit is 49 feet (15 m) thick, and the quartzite is fine to coarse grained. The grains are rounded and moderately sorted, with minor calcareous cement. The quartzite is medium to thick bedded, with laminations and low-angle cross-bedding. Beus (1963) noted that this unit at Little Mountain is lithologically similar to a quartzite bed in about the same stratigraphic position in the central Blue Springs Hills, about 30 miles (48 km) north of Little Mountain.

The upper 417 feet (127 m) of the Beirdneau, which forms slopes and ledges, is interbedded light- and dark-gray dolomite which is very finely to finely crystalline. This upper part is very thin to medium bedded, with yellowish silty layers, rare quartzite layers, and rare sedimentary breccia layers which contain silty clasts.

The Beirdneau is Late Devonian in age, based on stratigraphic position and fossils in the Bear River Range (Williams, 1971). A major regional unconformity is present between the Beirdneau Formation and the overlying Lodgepole Limestone (Sandberg and Gutschick, 1979).

Mississippian System

Lodgepole Limestone (Ml)

The Lodgepole Limestone crops out as cliffs and ledges along the south part of Little Mountain, and consists of medium-dark to dark-gray limestone and cherty limestone. It is mostly very fine grained, thin to very thick bedded, and contains crinoid stem fragments, horn corals, and brachiopods. Flat nodules of black chert are present in the lower and upper parts of the unit, making up 20-40 percent of the rock in the lower part. A partial measured section of the Lodgepole measured near the center of section 24, T.10 N., R. 4 W. is 466 feet (142 m) thick; the upper part of this unit is covered by lacustrine gravel at the location of the measured section. A thickness of 650 feet (200 m) is estimated from cross section A-A´. Age of the Lodgepole Limestone is early Mississippian (Kinderhookian to Osagean), based on conodonts (Sandberg and Gutschick, 1979).

Little Flat Formation (Mlf)

The Little Flat Formation, formally named in the Chesterfield Range of southeastern Idaho by Dutro and Sando (1963), is hereby extended to strata on Little Mountain. The Little Flat terminology has been applied to similar rocks in the Wellsville Mountains east of Little Mountain (Hintze, 1988), and has also been recognized in the Bear River Range, also in northern Utah (Sandberg and Gutschick, 1979; Berry, 1989). At Little Mountain, this stratigraphic unit is lithologically similar to the Little Flat Formation of southeastern Idaho (W.J. Sando, personal communication, 1988). The Little Flat Formation is Early to Middle Mississippian (Osagean to Meramecian) in age, based on conodonts, and is an approximate time-equivalent of the Deseret Limestone in the Oquirrh Mountains (Sandberg and Gutschick, 1979; Sando and Bamber, 1985).

The Little Flat Formation consists of about 850 feet (260 m) of interbedded sandstone, cherty limestone, and minor siltstone in a section measured over the highest peak along the west side of Little Mountain. Sandstone predominates in the lower part, and thin-bedded limestone predominates in the upper part. The sandstone is pale yellowish brown to grayish orange, very fine to fine grained, moderately sorted, and has calcareous cement. It is very thin to medium bedded and forms ledges and talus slopes. Horizontal worm burrows are present in the sandstone. Sandstone in the middle part of this formation is darker, carbonaceous, laminated to thin-bedded, and contains cross-bedding. The limestone is medium gray and contains black chert as thin stringers, layers, and nodules. It is fine grained, sandy, and thin bedded, and contains cross-bedding.

The lower part of the Little Flat Formation on Little Mountain is poorly exposed, and phosphatic sediments indicative of the Delle Phosphatic Member of Sandberg and Gutschick (1984) are covered or missing. The Delle is present in the northern Wellsville Mountains (in rocks mapped as Deseret Limestone by Oviatt, 1986), but phosphatic rocks were not found in the Brazer Formation (Little Flat equivalent) in the Dry Lake area on the east flank of the Wellsville Mountain (Williams, 1948). The upper contact of the Little Flat Formation is covered on Little Mountain.

Great Blue Limestone (Mgb)

The Great Blue Limestone crops out as ledges and cliffs in the central and west parts of Little Mountain. The formation consists of medium-gray to medium-dark-gray limestone which is very fine to medium grained and thick to very thick bedded. The Great Blue locally contains black chert as elongated nodules and as layers up to 1.5 feet (0.5 m) thick. *Faberophyllum* sp. coral and crinoid stem fragments are common to abundant, and one large brachiopod was collected from the small outcrop northeast of Little Mountain. This small outcrop northeast of Little Mountain has localized concentrations of calcite-filled fractures. A distinctive bed of pale-orange siltstone and light-gray limestone, 10 to 20 feet (3 to 6 m) thick, is present in some outcrops in the upper part of the Great Blue on Little Mountain. A minimum estimated thickness in this quadrangle from cross section A-A´ is 1,300 feet (396 m), but the top of the unit is truncated by a fault.

Coral samples collected from the Great Blue Limestone of Little Mountain (table 1) indicate an age of late Meramecian for the lower part of the Great Blue (Coral zone IV of Sando and Bamber, 1985). Regionally, the complete Great Blue Limestone is Meramecian to Chesterian (Middle to Late Mississippian) in age (Sando and Bamber, 1985).

The Great Blue and overlying West Canyon Limestone are in fault contact in the east part of Little Mountain; this contact area is covered or poorly exposed elsewhere. The Manning Canyon Shale, which usually is found between the Great Blue and West Canyon Limestones, is not exposed on Little Mountain. It is not known whether it is present or absent in the subsurface here. The Manning Canyon Shale is present between the Great Blue and West Canyon Limestones in the southern Wellsville Mountains 10 miles (16 km) east of Little Mountain (Dutro, 1979; Jensen, 1988), and in the Blue Springs Hills about 12.4 miles (20 km) northwest (Jordan and others, 1988a). In the Wellsville Mountains, the Manning Canyon Shale pinches out northward near Honeyville (Oviatt, 1986; Jensen, 1988).

Pennsylvanian System

West Canyon Limestone (IPwc)

The West Canyon Limestone consists of interbedded sandy and silty limestone and sandstone which form more

***Table 1.** Paleontological data for the Bear River City Quadrangle.*

Map Location	Sample Number	Stratigraphic Unit	Fossil Age	Paleontologist (Date of report)	Faunal Description	Latitude Longitude
1	BR 255-21	West Canyon Limestone	Atokan to Lower Permian (most abundant in Desmoinesian and Missourian)	W. J. Sando, USGS (9-19-88)	*PSEUDOZAPHRENTOIDES* sp. Corals of this type are common from Atokan to Lower Permian (most abundant in Desmoinesian and Missourian) in the Western Interior (Sando, 1985). This would support a West Canyon Limestone identification.	41°35' 19" 112°12' 59"
2	BR 255-19	West Canyon Limestone	Atokan to Lower Permian (most abundant in Desmoinesian and Missourian)	W. J. Sando, USGS (9-19-88)	*PSEUDOZAPHRENTOIDES* sp. (same as above)	41°35' 16" 112°12' 58"
3	BR 255-22	West Canyon Limestone	Atokan to Lower Permian (most abundant in Desmoinesian and Missourian)	W. J. Sando, USGS (9-19-88)	*PSEUDOZAPHRENTOIDES* ? sp. This is a young specimen, hence the questionable identification. It probably has the same significance as BR 255-19 and 21.	41°35' 53" 112°13' 30"
4	BR 20-7	Great Blue Limestone	late Meramecian	W. J. Sando, USGS (9-19-88)	*FABEROPHYLLUM* sp. Coral Zone IV of Sando and Bamber (1985). Suggests lower part of Great Blue Limestone.	41°35' 36" 112°14' 47"
5	BR 3 and BR 5	Great Blue Limestone	late Meramecian	W. J. Sando, USGS (1-16-87)	*FABEROPHYLLUM* sp. This is the principal index to Coral Zone IV of Sando and Bamber (1985), which is of late Meramecian age. This dating is compatible with a stratigraphic level in the lower part of the Great Blue Limestone.	41° 35' 33" 112°13' 58"

resistant ledges than the overlying Oquirrh Formation. It is distinguished from the underlying Great Blue Limestone by the presence of interbedded sandstone, generally lighter outcrop color, and thinner beds in outcrops of the West Canyon Limestone. The limestone is medium to dark gray, generally darker than limestone in the overlying Oquirrh Formation, and is very fine to fine grained. It contains laminations of sand, and chert as nodules and irregular beds. The West Canyon Limestone contains abundant crinoid stem fragments; rugose corals are common and brachiopods are rare. The sandstone is fine grained, moderately sorted, and contains calcareous cement. Both the limestone and sandstone are medium to thick bedded and locally cross-bedded. The West Canyon Limestone is more than 643 feet (196 m) thick in a partial measured section on the east part of Little Mountain; the base of the West Canyon is not exposed within this quadrangle.

Based on lithology and stratigraphic position, this unit is correlated with the West Canyon Limestone, the basal formation of the Oquirrh Group in the southern Oquirrh Mountains (Tooker and Roberts, 1970). Coral samples from this unit at Little Mountain permit a possible age range from Middle Pennsylvanian to Lower Permian (table 1) (Sando 1984; 1985). This age range partially overlaps with an age of Early to Middle Pennsylvanian (late Morrowan to Atokan) suggested by Jordan and others (1988b), based on conodonts, for the correlative limestone member of the Oquirrh Formation in the adjacent Thatcher Mountain quadrangle. Gordon and Duncan (in Tooker and Roberts, 1970) suggested a Morrowan age for the West Canyon Limestone in the Oquirrh Mountains, based on the abundance of *Linoproductus nodosus* (Newberry) in one section.

Pennsylvanian-Permian System

Oquirrh Formation (PIPo)

The Oquirrh Formation underlies the northeast half of Little Mountain, and is the most widely exposed bedrock unit in the quadrangle. The undivided Oquirrh Formation of Little Mountain consists of interbedded calcareous sandstone, limestone, and sandy limestone which form slopes or crop out as rubble, talus, and scattered ledges. The sandstone is yellowish brown to pale reddish orange, very fine to fine grained, with subrounded grains, and moderately sorted. It is thin bedded, and locally contains low-angle cross-bedding and laminations. Its base was mapped above the darker limestone of the West Canyon Limestone and below the sandy and lighter beds of the Oquirrh.

The limestone and sandy limestone weather to light to medium gray, and are very fine to fine grained and thin to thck bedded. The limestone contains crinoid-stem debris, shell fragments, and burrows and is locally bioclastic. It is locally cross-bedded, and contains pale-reddish-orange to grayish-orange-pink chert as irregular nodules, thin lenses, and small outcrops. The lighter colored limestone beds locally contain burrows which are 0.08-0.12 inches (2-3 mm) in diameter and up to 4.2 inches (110 mm) in length, but are usually branching and much shorter. The lower contact is poorly exposed. A minimum thickness for the Oquirrh Formation of 2,000 feet (610 m) is estimated from cross section A-A′, although the top of the unit is not exposed.

The Oquirrh Formation was raised to group status in the Oquirrh Mountains by Tooker and Roberts (1970). The formations that make up the type Oquirrh Group (except the West Canyon Limestone) have not been formally recognized on Little Mountain or in mountain ranges of the Bear River City area (Oviatt, 1986, Jordan and others, 1988a, b). For this reason, formational status is retained for the undivided Oquirrh rocks above the West Canyon Limestone on Little Mountain. Equivalent in age to the bioturbated limestone member of Jordan and others (1988b) in the adjacent Thatcher Mountain quadrangle, this undivided unit ranges in age from Late Pennsylvanian to Early Permian. The overlying thinly bedded member of Jordan and others (1988b) does not crop out on Little Mountain.

Quaternary System

Poorly consolidated to unconsolidated Quaternary sediments cover most of the Bear River City quadrangle. These include lacustrine lake-bottom and near-shore deposits of Lake Bonneville and Great Salt Lake; alluvial deposits of the Malad River, smaller streams, and marshes; deltaic-plain deposits; landslide deposits; and eolian deposits.

Lacustrine-Silt Deposits (Qli)

Lacustrine-silt deposits of Lake Bonneville and Great Salt Lake make up most of the valley floor of the Bear River Valley within the Bear River City quadrangle. These sediments were laid down in relatively quiet lake water that may have been as much as 1,000 feet (305 m) deep at one time. The sediments consist of silt, clay, and very fine to fine sand, which is laminated to thin bedded. This unit locally contains ostracodes and has cross-bedding in some sand layers. This unit also includes thin eolian deposits south of Little Mountain.

This unit includes an unconformity which represents the termination of Lake Bonneville about 11,000 years ago (Currey and Oviatt, 1985). South of Little Mountain this unconformity is represented by a thin layer of well-rounded gravel which crops out in the remnants of lacustrine deposits that stand above the alluvial mud flats. Sediments exposed directly below this unconformity are pale reddish brown, and Currey and others (1988b) have noted that this reddish coloration is a regional characteristic of sediments in this stratigraphic and altitudinal zone.

Exposures of this unit in the delta of the Bear River, in the southeast corner of the quadrangle, appear to be remnants of lacustrine sand and silt around which the Bear River has flowed and downcut. These deposits consist of silt and very fine- to medium-grained sand. The tops of the terrace deposits are approximately the same elevation as the adjacent valley floor to the west and east, and the terraces slope gently southward with the valley floor.

Lacustrine-Gravel Deposits (Qlg)

Lacustrine-gravel deposits cover extensive areas of Little Mountain and part of the small hill northeast of Little Mountain. The gravel deposits (which consist of subrounded to well-rounded pebbles, cobbles, and boulders, mixed with sand) were deposited in beach and near-shore environments of Lake Bonneville. Some deposits near outcrops of the Oquirrh Formation contain subangular to angular material. Gravel deposits on the south side of Little Mountain are as much as 40 feet (12 m) thick (Utah State Department of Highways, 1965). The gravel is locally cemented by calcareous tufa, and on the east part of Little Mountain (SW ¼ section 17, T. 10 N., R.3 W.) these cemented gravel deposits form mound-like features up to 40 feet (12 m) thick.

East of Little Mountain and on both sides of Sulphur Creek lies a northeast-trending linear deposit of lacustrine gravel, the crest of which is at an elevation of about 4,250 feet (1,295 m). This deposit is a gravel bar that was deposited when Great Salt Lake was at the Gilbert shoreline.

Lacustrine Lagoon-Fill Deposits (Qll)

Lagoon-fill deposits are present on Little Mountain at and above the Provo shoreline of Lake Bonneville. These deposits consist of sand, silt, and clay deposited behind (shoreward of) wave- and current-built gravel barriers in quiet-water lagoons of Lake Bonneville. The largest deposit of this type in the quadrangle is at the Provo shoreline in the north-facing canyon of Little Mountain. Some alluvium may also be included in this map unit.

Lacustrine-Sand Deposits (Qls)

Lacustrine-sand deposits underlie Bear River City, in the northeast corner of the quadrangle. The Gilbert shoreline forms the southwest boundary of the outcrop area of this unit. The lacustrine sand deposits consist of very fine-grained sand which overlies interbedded clay, silt, and sand. The sand is 0-25 feet (0-8 m) thick, laminated to medium bedded, and cross-bedded. It is exposed in banks of the Bear River east of Bear River City, in the adjoining Brigham City and Honeyville quadrangles. This unit grades into the lacustrine silt unit (Qli) but is coarser grained. The soils map of Chadwick and others (1975) aided in differentiating this unit from the lacustrine silt unit.

Lacustrine Deposits Undifferentiated (Qlu)

Undifferentiated lacustrine deposits consist of mixed and interbedded lacustrine gravel, sand, silt, and clay deposited in Lake Bonneville. This unit is mapped in the central part of Little Mountain, and within the northwest-trending canyon which drains the central part of Little Mountain. This unit includes nearshore gravel and sand, and deeper water sand, silt, and clay.

Mixed Lacustrine and Alluvial Deposits (Qla)

Mixed lacustrine and alluvial deposits consist of lacustrine silt, very fine sand, and clay, which have been reworked and covered by stream channels and marsh deposits. East of Little Mountain, this unit includes abandoned channels of the Malad River. Abandoned channels of the Malad River are filled with gray to grayish-yellow silt which is very thin to thin bedded, cross-bedded, and calcareous. These channel-fill deposits include plant fragments and abundant gastropods. Gastropods from one of these filled channels near the north end of the quadrangle yielded a radiocarbon date of 3,910 ± 80 yr B.P. (Miller, 1980, sample W- 4400).

This map unit also includes two small deposits of interbedded lacustrine and alluvial sediments on the northwest part of Little Mountain, along the west edge of the quadrangle.

Landslide Deposits (Qms)

Landslide deposits are present on both sides of the canyon on the northwest part of Little Mountain. The slide material is poorly sorted to well-sorted lacustrine gravel and sand that slid from between the Provo and Bonneville shorelines. The elevation of the head scarps is approximately 5,000 feet (1,525 m) for the slide on the southwest side of the canyon and 5,150 feet (1,570 m) for the one on the northeast side. The landslide on the south side of the canyon crossed the Provo shoreline, and at least part of the slide appears to be uneroded by shoreline action at the Provo shoreline; so some of the landslide movement apparently occurred after the lake receded from the Provo level. The deposit on the north side of the canyon does not cross the Provo shoreline.

Alluvium (Qal)

Alluvial deposits along the Malad River, part of Sulphur Creek, and other active and abandoned stream channels consist of sand, silt, clay, and gravel. Meandering stream channels that postdate the Gilbert shoreline have cut into the lacustrine sediments in the central part of the quadrangle. The Malad River apparently flowed in some of these meandering channels before cutting its present channel to the Bear River. This unit locally includes marsh deposits.

Alluvial-Mud and Marsh Deposits (Qam)

The mud flats and marshes south and east of Little Mountain contain alluvial silt, clay, and sand. The mud flats are characterized by slow-moving, low-gradient streams and high salt content. Near Little Mountain this unit is 12 to 20 inches (30 to 51 cm) thick, and locally includes interbedded gravel. These alluvial deposits overlie lacustrine silty clay. Large areas of the mud flats have been diked and flooded with fresh water to remove the salt and encourage the growth of marshes for waterfowl habitat.

Near North Bay this unit also includes interbedded lacustrine and alluvial clay and silt. The construction of North Bay has artificially influenced the distribution of sediments. During low stages of Great Salt Lake, most of the sediment influx to North Bay is deposited by alluvial processes; but during high-water stages, such as during the historic high level of 4,212 feet (1,284 m) in 1986 and 1987 (U.S. Geological Survey provisional records), the area is inundated and lacustrine processes dominate.

Alluvial-Fan Deposits (Qaf)

Small alluvial fans formed by local floods or debris flows are present on Little Mountain. These alluvial fans postdate the recession of Lake Bonneville. These deposits consist of unconsolidated and poorly sorted sand, silt, and gravel, with occasional boulders.

Deltaic-Plain Deposits (Qdp)

Deltaic-plain deposits of the Bear River delta include silt, clay, and sand deposited by the Bear River south of Corinne and in North Bay. The deltaic plain south of Corinne includes deposits in marshes, oxbow lakes, channels, point bars, and natural levees. The deltaic plain is subject to flooding from high water levels in the Bear River and Great Salt Lake, such as during the 1986-87 high stand.

Eolian-Sand Deposits (Qes)

Eolian-sand deposits are present along the margins of mud flats and shallow lakes south and east of Little Mountain. These deposits consist of very fine- to fine-grained sand in ridges up to 5 feet (1.5 m) high. These small ridges commonly form where the wind deposits fine sand when it encounters a slight topographic high along the eastern edges of mud flats and dry lake beds.

Fill Material (Qf)

Deposits of fill material include dikes built on the mud flats south of Little Mountain. The dike materials include local alluvial mud and underlying lacustrine sediments. Gravel has been transported from other locations and placed on the dikes to build roads. Most of these dikes were built by hunting clubs to control the distribution of water and increase the marsh habitat for waterfowl. Also included in this unit is a dam built just south of Highway 83 to divert Sulphur Creek.

OVERVIEW OF QUATERNARY HISTORY

The Quaternary sediments of the Bear River City quadrangle have resulted largely from deposition in Lake Bonneville and Great Salt Lake, and deposition by the Malad and Bear Rivers. At least two, and possibly several more, pre-Bonneville lake cycles occupied the Bear River Valley during Pleistocene time (Scott and others, 1983; Oviatt and others, 1987; Oviatt and Currey, 1987), but no evidence for these lake cycles is exposed in the Bear River City quadrangle. The ages and interpretations of regional lacustrine events described in the following paragraphs are adapted from Currey and others (1984), except where otherwise noted.

Lake Bonneville formed as lake waters started to rise about 25,000 years B.P. The lake reached the Stansbury shoreline, approximately 4,500 feet (1,372 m) elevation, about 23,000 years B. P. Abundant tufa deposits on Little Mountain provide evidence of Lake Bonneville near the Stansbury shoreline. The Stansbury shoreline is not prominent or well preserved over most of Little Mountain, so it is not included on this map. After oscillating at levels near the Stansbury shoreline for about 3,000 years, the lake began its rise to its highest level, the Bonneville shoreline, which was reached about 16,000 years B.P. The water level at the Bonneville shoreline was controlled by a threshold near Zenda, Idaho. The Bonneville shoreline on Little Mountain is at an elevation of approximately 5,220 feet (1,591 m); Currey (1982) identified the same elevation (1,591 ± 2 m) on the west side of Little Mountain. At the Bonneville shoreline, the lake covered all of the Bear River City quadrangle except the highest parts of Little Mountain.

Lake Bonneville fluctuated near the Bonneville shoreline until about 14,500 years B.P., when the threshold at Zenda failed and the ensuing Bonneville flood eroded the outlet down to resistant bedrock at Red Rock Pass, Idaho. This flood lowered the lake level approximately 350 feet (107 m) to the Provo shoreline. The Provo shoreline is at an elevation of approximately 4,830 feet (1,473 ± 2 m) on the northeast ridge of Little Mountain (Currey, 1982). Lagoonal sediments were deposited behind a Provo-level gravel bar in the northeast canyon of Little Mountain. Threshold control of Lake Bonneville was maintained at the Provo level for about 1,000 years before the lake declined to at least as low as historic lake levels by about 12,000 to 11,000 years ago, signalling the end of Lake Bonneville. During this subsequent period of low water level, reddish sediments and a thin gravel layer were deposited on fine-grained lacustrine sediments south of Little Mountain by alluvial action (Currey and others, 1988b).

Between 11,000 and 10,000 years B.P. Great Salt Lake rose to the Gilbert shoreline, which is expressed as a wave-cut notch south of Bear River City. While at the Gilbert shoreline, Great Salt Lake formed the gravel bar east of Little Mountain. The crest of this gravel bar is at an elevation of approximately 4,250 feet (1,295 m).

Great Salt Lake receded from the Gilbert shoreline about 10,000 years B.P., and the mud flats south of Little Mountain, the Bear River delta, Malad River channel, and the alluvial channels in the central part of the Bear River City quadrangle, have been formed since that time. The Malad River previously flowed in channels west of its present channel, forming some of the alluvial channels which now cut through the central part of the Bear River City quadrangle.

Since 10,000 years B.P., Great Salt Lake has fluctuated from levels lower than the present level of the lake to highs between 4,217 and 4,221 feet (between 1,285 and 1,287 m)

(Currey and others, 1988a). About A.D. 1700, Great Salt Lake formed a shoreline at about 4,217 feet (1,285 m) in the southern part of the Bear River City quadrangle. This shoreline is shown on plate 1 as the late Holocene shoreline. Great Salt Lake attained a level of approximately 4,212 feet (1,284 m) in 1873. The lake again rose to the historic high of 4,212 feet (1,284 m) in 1986 and 1987 (U.S. Geological Survey provisional records), flooding areas in the southwestern and southeastern parts of the Bear River City quadrangle.

STRUCTURE

The Bear River City quadrangle is located in the hinterland of the Sevier orogenic belt and in the eastern Basin and Range physiographic province; thus, the Paleozoic rocks of Little Mountain have been influenced by both Mesozoic thrust faulting and late Cenozoic normal faulting. No Holocene fault offsets have been noted in the Quaternary surficial deposits which cover most of the quadrangle.

Bedding of Paleozoic strata on Little Mountain is mostly inclined between 10° and 50° in generally northeasterly directions. The major exception is the Oquirrh Formation on the east side of Little Mountain, east of a mostly concealed northeast-trending normal fault. There, the lower West Canyon Limestone dips northeast, but the dip changes upsection to between 20° and 35° to the southeast in the overlying Oquirrh and the easternmost exposure of the Oquirrh.

According to the gravity survey of Peterson (1974), the Cenozoic valley fill is about 4,600 feet (1,400 m) thick at the east edge of the Bear River City quadrangle, near Corinne.

Thrust Faulting

Paleozoic rocks of Little Mountain were thrust eastward during the Cretaceous Sevier orogeny according to regional interpretations (Hintze, 1988), but no thrust faults are exposed within the Bear River City quadrangle. Jordan and others (1988b) inferred that the Samaria Mountain thrust fault separates the bedrock of Little Mountain from bedrock in the southern Blue Springs Hills to the northwest, and that this west-dipping fault is buried beneath the lacustrine and alluvial sediments in the valley northwest of Little Mountain.

Jordan and others (1988b) interpreted the bedrock of Little Mountain to be below the Samaria Mountain thrust fault, and in the upper plate of the Willard thrust. Their interpretation is based on differing structural trends in Little Mountain and the Blue Springs Hills, the apparent absence of the Manning Canyon Shale on Little Mountain, and the apparent thinness of the upper Paleozoic rocks on Little Mountain as compared to those in the Blue Springs Hills. The Paleozoic strata over most of Little Mountain dip northeastward; in contrast, bedding in Thatcher Mountain (in the Blue Springs Hills) dips to the west or is overturned to the west (Jordan and others, 1988b).

The Manning Canyon Shale is not exposed on Little Mountain, and the Great Blue and West Canyon Limestones are either in fault contact or the contact is covered. The Wellsville Mountains, just to the east of this quadrangle, are part of the upper plate of the Willard thrust. In the Wellsville Mountains the Manning Canyon Shale is 0-1,130 feet (0-344 m) thick, and pinches out in the northern Wellsville Mountains (Sadlick, 1955; Oviatt, 1986; Jensen, 1988). The Manning Canyon Shale is much thicker in the Blue Springs Hills, where Jordan and others (1988a) estimated a thickness of 2,400 feet (732 m) from a cross section, although they felt that this thickness may be influenced by folding.

Normal Faulting

Normal faults are exposed mostly on the south part of Little Mountain. The westernmost faults strike generally north, and faults on the south and east parts of Little Mountain have variable strikes from northwest to northeast. All the faults appear to be steeply dipping normal faults; however, many of the faults are poorly exposed. These faults are probably caused by late Cenozoic basin-and-range extension.

The best exposed of these normal faults is the westernmost fault, directly east of the highest peak of Little Mountain. This fault shows an offset of about 1,000 feet (305 m) down to the east in cross section B-B´, displacing Devonian and Mississippian strata. This fault forms the west side of a graben containing Great Blue Limestone and Little Flat Formation. Two east-striking faults terminate eastward against this westernmost fault. The northwest-trending fault in the central part of Little Mountain forms the contact between Great Blue Limestone and West Canyon Limestone. Sparse evidence indicates that this fault continues to the northwest, but with diminishing offset. The normal fault beneath the valley fill west of Bear River City is inferred from gravity studies by Peterson (1974) and Zoback (1983).

A karst collapse hole 30 to 40 feet (9 to 12 m) deep is present at the intersection of three faults near the Bonneville shoreline (NE ¼ NW ¼ section 24, T. 10 N., R. 4 W.). This karst hole does not appear to contain a great thickness of lacustrine sediments, so the collapse probably occurred after water receded from the Bonneville shoreline or near the end of the Bonneville shoreline stage.

ECONOMIC RESOURCES

Gravel and Sand

Several gravel pits have been opened in the extensive lacustrine gravel deposits (Qlg) of the Bear River City quadrangle, some of which are still used intermittently. Many of the lacustrine gravel deposits are potential future sources of gravel and sand. Materials data for some of these deposits are contained in a materials inventory by the Utah State Department of Highways (1965).

Geothermal Resources

The most obvious indication of geothermal resources within the Bear River City quadrangle is the presence of Stinking Springs. Stinking Springs are located on the south side of Little Mountain, and discharge near the base of an outcrop of Mississippian Lodgepole Limestone. The springs are on the north side of State Highway 83, and the water is piped under the highway to a small abandoned building that was used for bathing.

Water temperature measurements for Stinking Springs from 1951 to 1967 varied from 39.5° to 51°C, the dissolved solids content from 1911 to 1967 ranged from 29,000 to 36,600 ppm, and estimated discharge was 5 to 45 gpm (19 to 170 liters per minute) (Mundorff, 1970). Klauk and Budding (1984) measured 44°C and total dissolved solids of 31,080 ppm. The high dissolved-solids content of Stinking Springs results from the high saline content of the surface and subsurface materials through which the water passes (Mundorff, 1970). Stinking Springs and Little Mountain are within an area recommended by Klauk and Budding (1984) for further evaluation of the low-temperature geothermal potential.

A 300-foot (91.4 m) water well, which yielded a water temperature of 28°C, was drilled in 1936 about 3 miles (4.8 km) southeast of Stinking Springs (SW¼ NE¼ SE¼ section 33, T. 10 N., R. 3 W.) (Bjorklund and McGreevy, 1973).

Petroleum

No producing wells have been drilled in the Bear River City quadrangle, but at least three wells in and near the Bear River Migratory Bird Refuge, south of the Bear River City quadrangle, have produced natural gas for local use (Doelling, 1980). Gas was also reported in the 300-foot (91.4 m) water well drilled southeast of Stinking Springs that was discussed in the previous paragraph (Bjorklund and McGreevy, 1973).

Mineralization

Calcite fills fractures and small veins locally; two examples are a prospect in the West Canyon Limestone on the east end of Little Mountain, and in part of the outcrop of Great Blue Limestone northeast of Little Mountain. Other than minor localized oxidation, no metallic mineralization was noted in this quadrangle.

GEOLOGIC HAZARDS

Seismic Hazards

The Bear River City quadrangle is within the Intermountain seismic belt, and Bear River City is approximately 2.5 miles (4 km) west of the Brigham City segment of the Wasatch Fault zone. This quadrangle lies within Uniform Building Code Zone 3, which is the zone of highest seismic risk within the State of Utah (International Conference of Building Officials, 1991). Earthquake activity occurs intermittently in the Bear River City area, as illustrated by four earthquakes which occurred about 16 miles (25.7 km) northeast of Bear River City between October 29, 1986 and April 1, 1987, with magnitudes from 3.5 to 3.8 (Person, 1987a and 1987b). Scarps along the Brigham City fault segment indicate that several earthquakes producing surface rupture have occurred during the past 10,000 years, and that most of the earthquake activity took place during the early and middle parts of this period (Personius, 1990). Potential seismic hazards within the Bear River City quadrangle include ground shaking, surface fault rupture, liquefaction, and earthquake-triggered landslides.

Ground shaking during an earthquake is a potential hazard throughout the Bear River City quadrangle. Liquefaction of sediments, and the subsequent loss of support to overlying structures, is also a potential hazard in most of the Bear River City quadrangle except on Little Mountain. Liquefaction is most likely to occur when ground shaking takes place in areas underlain by shallow ground water and by fine sand-size sediments (such as units Qls, Qli, Qam, Qdp, Qla, and Qal). Earthquake-triggered landslides could occur on the slopes of Little Mountain or on steep banks such as some locations along the Bear and Malad Rivers.

No scarps attributed to surface fault rupture have been recognized in the Quaternary sediments of the Bear River City quadrangle. Two concealed faults east of Little Mountain that could have Quaternary offsets have been inferred from this mapping and from the gravity studies of Peterson (1974) and Zoback (1983).

Landslides

Two landslides are present on the northwest part of Little Mountain. Both of these slides are in Lake Bonneville gravel, but neither slide shows signs of Holocene movement.

Small slides and slumps of recent origin have occurred along the banks of the Malad River, and could occur along banks bordering the Bear River delta. Sediments in these areas consist of fine-grained, unconsolidated, lacustrine deposits. Slides, slumps, and lateral spreads could be triggered by shaking due to an earthquake.

Shallow Ground Water

Shallow ground water is a potential hazard in the Bear River City quadrangle, especially when constructing excavations. All of the quadrangle except Little Mountain generally has a depth to ground water of less than 10 feet (3 m) (Hecker and others, 1988). In some areas of the valley floor, such as in some of the marshes, ground water discharges at the ground surface. Shallow ground water in fine sandy sediments also increases the possibility of liquefaction during an earthquake.

Flooding

Areas of the Bear River City quadrangle below 4,212 feet (1,284 m) elevation were flooded during the historic high level of Great Salt Lake in 1986 and 1987. These areas are adjacent to North Bay, and within the Bear River delta south of Corinne. The late Holocene shoreline mapped in the southern part of the quadrangle was formed by a prehistoric high of 4,217 feet (1,285 m) in about A.D. 1700 (Currey and others, 1984). The 4,217 foot (1,285 m) elevation is the probable maximum extent of modern flood hazard due to rising of Great Salt Lake (Currey and others, 1988a; Harty and Christenson, 1988).

Flooding caused by failure of Cutler Dam (approximately 19 miles (30.6 km) north-northeast of Bear River City, and northeast of Fielding, Utah) is a potential hazard for parts of the eastern Bear River City quadrangle. Assuming a "worst-case" scenario in which Cutler Dam fails completely and instantaneously, Case (1984) calculated that the elevation of the flood-wave crest along the Bear River would be about 4,257 feet (1,298 m) at Bear River City and about 4,232 feet (1,290 m) at Corinne. This "worst-case" flood would inundate parts of eastern Bear River City, the main part of Corinne, parts of west Corinne including the city cemetery, and all of the Bear River delta area (Case, 1984).

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