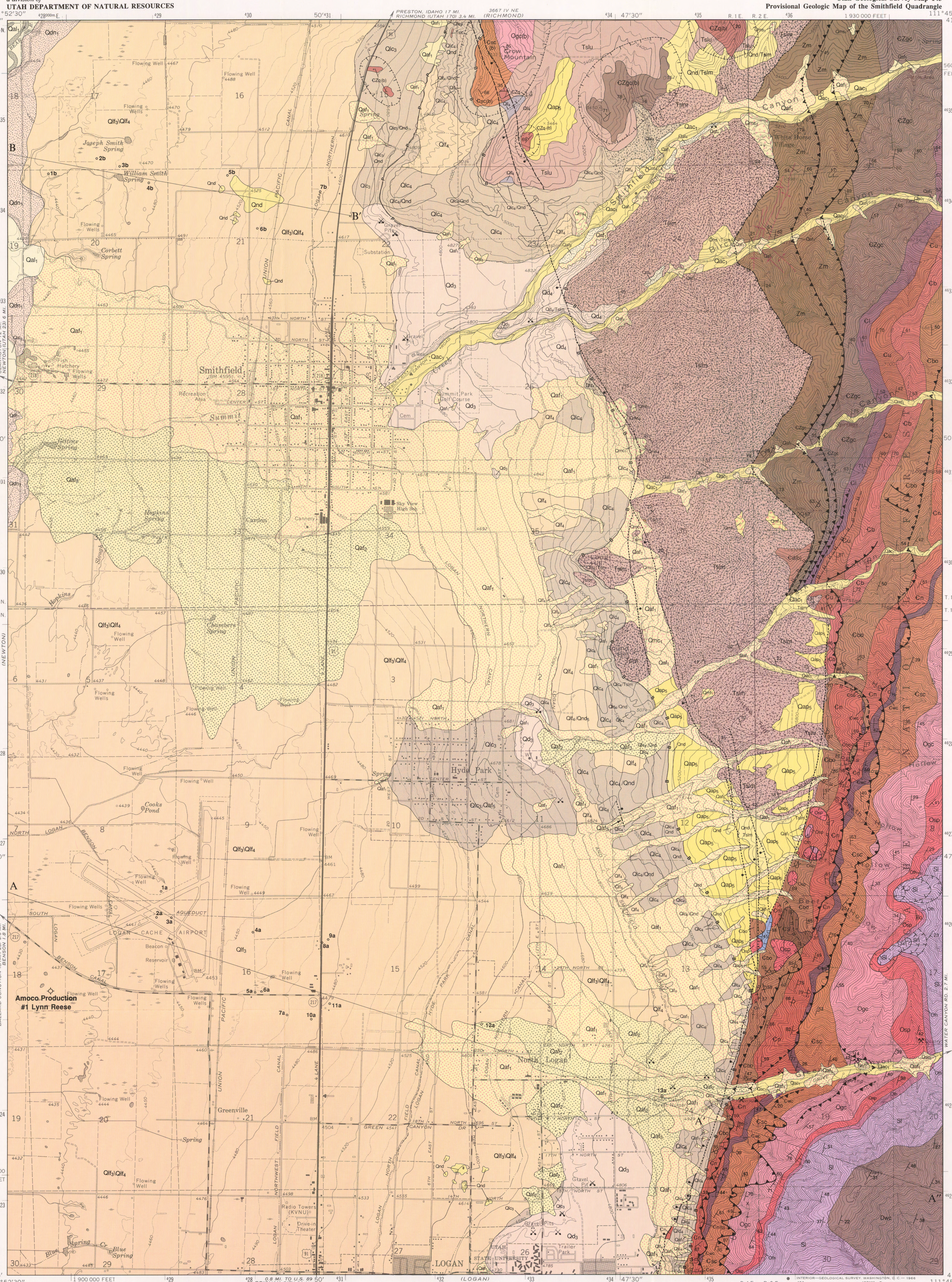


Base map from U.S. Geological Survey, Smithfield Quadrangle, 1964.

Bedrock mapping by Galloway, 1967
Quaternary mapping by Lowe, 1983-84
Revisions by Jon King, U.G.S.,1993
P.H. Speranza, Cartographer

SCALE 1:24 000

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

CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 10 FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

GN
MN
14°22' E
255 mils

1993 MAGNETIC NORTH DECLINATION
AT CENTER OF SHEET

UTAH
QUADRANGLE LOCATION

PROVISIONAL GEOLOGIC MAP OF THE SMITHFIELD QUADRANGLE, CACHE COUNTY, UTAH

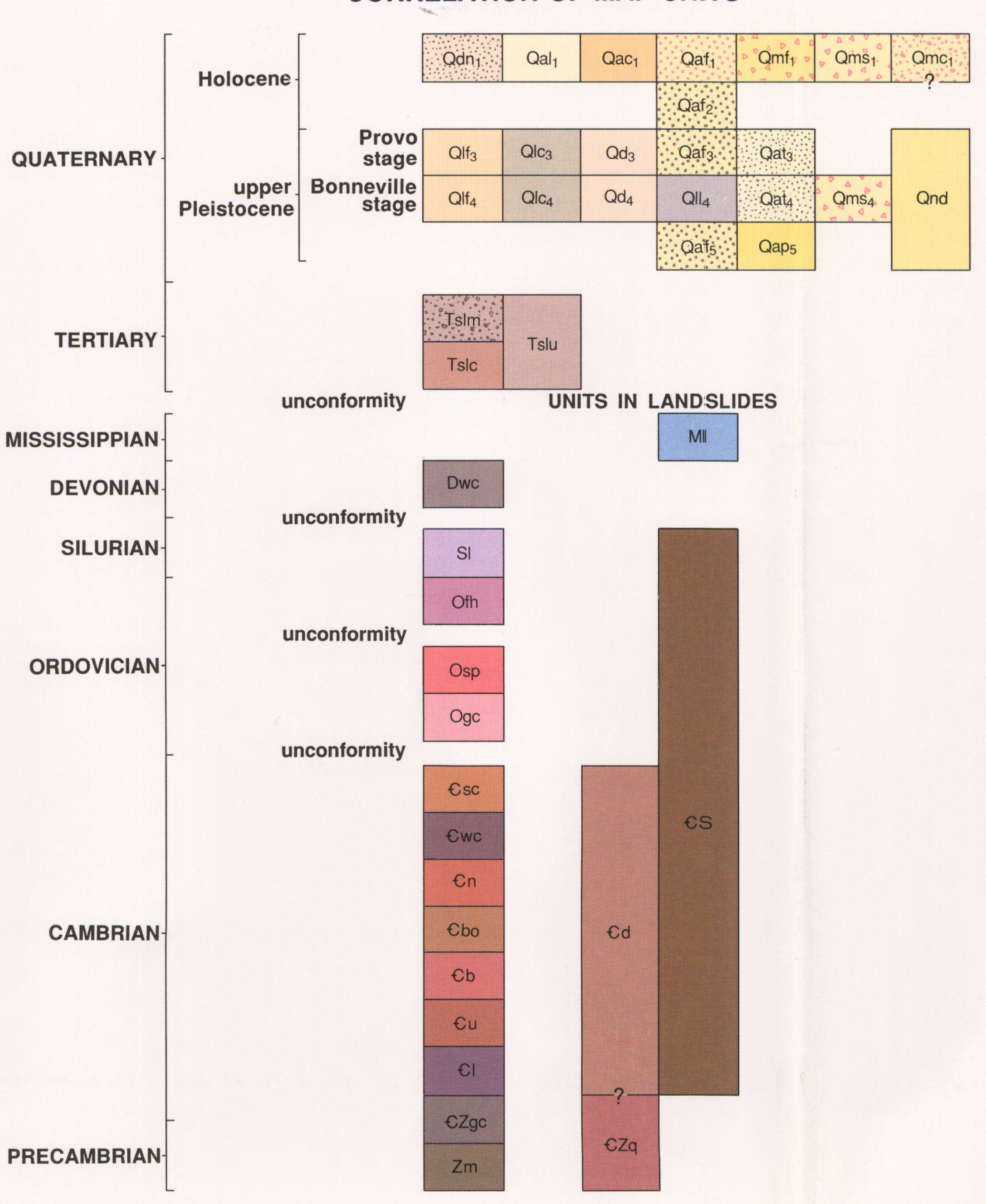
by

Mike Lowe and Cheryl Leora Galloway

1993

	FORMATION	SYMBOL	THICKNESS feet (meters)	LITHOLOGY	SOURCE AND LOCATION OF MEASURED THICKNESS (Some thicknesses were measured outside of the Smithfield quadrangle)
	SURFICIAL DEPOSITS				
SALT LAKE FM.	MINK CREEK MBR.	Tslm	800(244)		Adamson and others (1955), southeast of Smithfield
SALT LAKE FM.	CACHE VALLEY MBR.	Tslc			
	WATER CANYON FORMATION	Dwc	606(185)		Taylor (1963), Logan Canyon
	LAKETOWN DOLOMITE	Sl	1,459(445)		Budge (1966), Logan Canyon
	FISH HAVEN DOLOMITE	Ofh	140(43)		Williams (1948), Green Canyon
	SWAN PEAK FORMATION	Osp	401(122)		Galloway (1970), Green Canyon
	GARDEN CITY FORMATION	Ogc	1,405(428)		Williams (1948), Green Canyon
ST. CHAS. FM.	UPPER MEMBER	Ꞓsc	900 (274) 1,015 (309)		Maxey (1941), High Creek
ST. CHAS. FM.	WORM CREEK MBR.	Ꞓwc	115 (35)		
	NOUNAN FORMATION	Ꞓn	1,125(343)		Maxey (1941), High Creek
	BLOOMINGTON FORMATION	Ꞓbo	1,495(456)		Maxey (1958), High Creek
	BLACKSMITH FORMATION	Ꞓb	485(148)		Maxey (1958), High Creek
	UTE FORMATION	Ꞓu	745(227)		Maxey (1958), High Creek
	LANGSTON FORMATION	Ꞓl	360(110)		Galloway (1970), Birch Canyon
BRIGHAM GROUP	GEERTSEN CANYON(?) QUARTZITE	ꞒpꞒgc	2,549(777)		Galloway (1970), Birch Canyon
BRIGHAM GROUP	MUTUAL(?) FORMATION	pꞒm	1,800-2,300 (550-700)		Galloway (1970), Birch Canyon

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Qdn$_1$ Natural-levee deposits of the Bear River – *fine sand to clay, overbank sediments deposited during flood stage.*

Qal$_1$ Alluvial deposits of the Bear River – *fine clay to sand with some medium and coarse sand; channel deposits.*

Qac$_1$ Alluvial and colluvial deposits along axes of mountain drainages – *boulders to clay, mixed colluvial, fluvial, and alluvial-fan deposits.*

Qaf$_1$ Younger post-Lake Bonneville alluvial-fan deposits – *boulders to clay.*

Qmf$_1$ Debris-flow deposits – *surficial deposits displaced downslope as a viscous slurry flow.*

Qms$_1$ Slump and landslide deposits – *bedrock and surficial deposits displaced downslope.*

Qmc$_1$ Colluvial and slope-wash deposits – *boulders to clay mantling bedrock.*

Qaf$_2$ Older post-Lake Bonneville alluvial-fan deposits– *boulders to clay.*

Qlf$_3$ Lacustrine offshore deposits – *silt and clay deposited when Lake Bonneville stood at the Provo shoreline.*

Qlc$_3$ Lacustrine nearshore deposits – *cobbles to fine sand deposited when Lake Bonneville stood at the Provo shoreline.*

Qd$_3$ Deltaic deposits – *cobbles to fine sand deposited when Lake Bonneville stood at the Provo shoreline.*

Qaf$_3$ Alluvial-fan deposits – *boulders to clay; deposits are graded to Provo shoreline.*

Qat$_3$ Terrace deposits – *cobbles to sand deposited by streams, graded to the Provo shoreline.*

Qlf$_4$ Lacustrine offshore deposits – *fine sand, silt, and clay deposited when Lake Bonneville stood at the Bonneville shoreline.*

Qlc$_4$ Lacustrine nearshore deposits – *cobbles to sand, deposited when Lake Bonneville stood at the Bonneville shoreline.*

Qd$_4$ Deltaic deposits – *cobbles to fine sand deposited when Lake Bonneville stood at the Bonneville shoreline.*

Qll$_4$ Lagoon deposits – *sand- to clay-size sediments deposited in lagoons when Lake Bonneville stood at the Bonneville shoreline.*

Qat$_4$ Terrace deposits – *cobbles and sand deposited by streams, graded to the Bonneville shoreline.*

Qms$_4$ Slump and landslide deposits – *bedrock and surficial deposits displaced downslope; poorly developed Bonneville shoreline cut on deposits.*

Qaf$_5$ Pre-Lake Bonneville alluvial-fan deposits – *boulders to clay; only exposed in road cut.*

Qap$_5$ Pediment deposits – *boulders to clay covering flat surfaces formed primarily on the Tertiary Salt Lake Formation.*

Qnd Boulder to sand deposits of unknown origin.

Salt Lake Formation

Tslm Mink Creek Conglomerate Member – *light-gray to light-yellow tuffaceous conglomerate.*

Tslc Cache Valley Member – *light-colored tuff, limestone, sandstone, and conglomerate.*

Tslu Salt Lake Formation, undifferentiated – *poorly exposed in area north of Smithfield Canyon.*

Ml Mississippian limestone – *dark-gray limestone containing abundant brachiopods and bryozoans, part of ancient landslide mass.*

Dwc Water Canyon Formation – *lower clayey dolomite, upper sandstone and sandy dolomite.*

Sl Laketown Dolomite – *light-gray and dark-gray dolomite.*

Ofh Fish Haven Dolomite – *thick-bedded, medium-crystalline, dark-gray dolomite.*

Osp Swan Peak Formation – *olive-gray shale, quartzitic siltstone, medium-gray limestone, and dark-gray shale in lower part, gray and red-purple quartzite and gray shale in middle part; light-gray quartzite at top.*

Ogc Garden City Formation – *lower member consists of muddy limestone, crystalline limestone, and intraformational conglomerate; upper member is mostly limestone with some dolomite, and contains nodules and stringers of black chert.*

ꞒS Cambrian-Silurian units – *carbonates of Cambrian-Silurian age which are part of an ancient landslide.*

Ꞓd Cambrian(?) dolomite – *dolomite believed to be of Cambrian age.*

St. Charles Formation

Ꞓsc upper member – *thin-bedded limestone at the base followed by massive-bedded, light-gray and dark-gray dolomite.*

Ꞓwc Worm Creek Quartzite Member – *gray quartzite, light-gray sandy limestone, and coarsely crystalline, light-gray, sandy dolomite.*

Ꞓn Nounan Formation – *light-gray and medium-gray dolomite, sandy in upper part.*

Ꞓbo Bloomington Formation – *Hodges Shale at bottom is green shale and gray limestone; middle member is medium-gray and dark-gray limestone; upper member, Call's Fort Shale, is olive-brown shale and gray limestone.*

Ꞓb Blacksmith Formation – *gray dolomite in lower part, dark-bluish-gray limestone in middle, light-gray dolomite at top.*

Ꞓu Ute Formation – *alternating thin-bedded, medium-gray limestone and dusky-yellow shale; some interbedded sandstone at base.*

Ꞓl Langston Formation – *lower member, Naomi Peak Limestone, is calcareous sandstone at base and interbedded limestone and shale at top; middle member, Spence Shale, moderate-brown shale with limestone lenses at base and light-olive-gray shale at top; upper member is dark-gray dolomite with some limestone in upper part.*

ꞒZq Precambrian-Cambrian quartzite – *severely brecciated quartzite of Precambrian to Cambrian age, only located in the Crow Mountain area.*

Brigham Group

ꞒZgc Geertsen Canyon(?) Quartzite – *pink, orange, brown, purple, and gray quartzite interbedded with yellow-brown shale and yellow-brown sandstone.*

Zm Mutual(?) Formation – *pale-red-purple, grayish-orange-pink, grayish-orange, white, gray, pink, pinkish-gray, and brown quartzite containing locally abundant pebbles of quartzite and jasper; interbedded with red, green, and gray to lavender argillite; contains basalt flows.*

a/b Stacked units – *indicate thin or discontinuous cover of one unit over another unit; the cover unit is listed first and its color and pattern are shown.*

(b) Brecciated

MAP SYMBOLS

CONTACT - dashed where approximate

NORMAL FAULT - dashed where approximate; dotted where concealed; bar and ball on downthrown side; queried where existence uncertain

THRUST FAULT - dashed where approximate; dotted where concealed; sawteeth on upper plate

LOW-ANGLE NORMAL FAULT - dashed where approximate; dotted where concealed; sawteeth on upper plate

TRACE OF AXIAL SURFACE OF FOLD - dashed where approximate
- anticline
- syncline

TRACE OF LANDSLIDE SURFACE - dashed where approximate

TRACE OF SLIDE-BLOCK SURFACE - dashed where approximate

TRACE OF BONNEVILLE SHORELINE

TRACE OF PROVO SHORELINE

BEDDING
- inclined (18)
- vertical
- overturned (6)

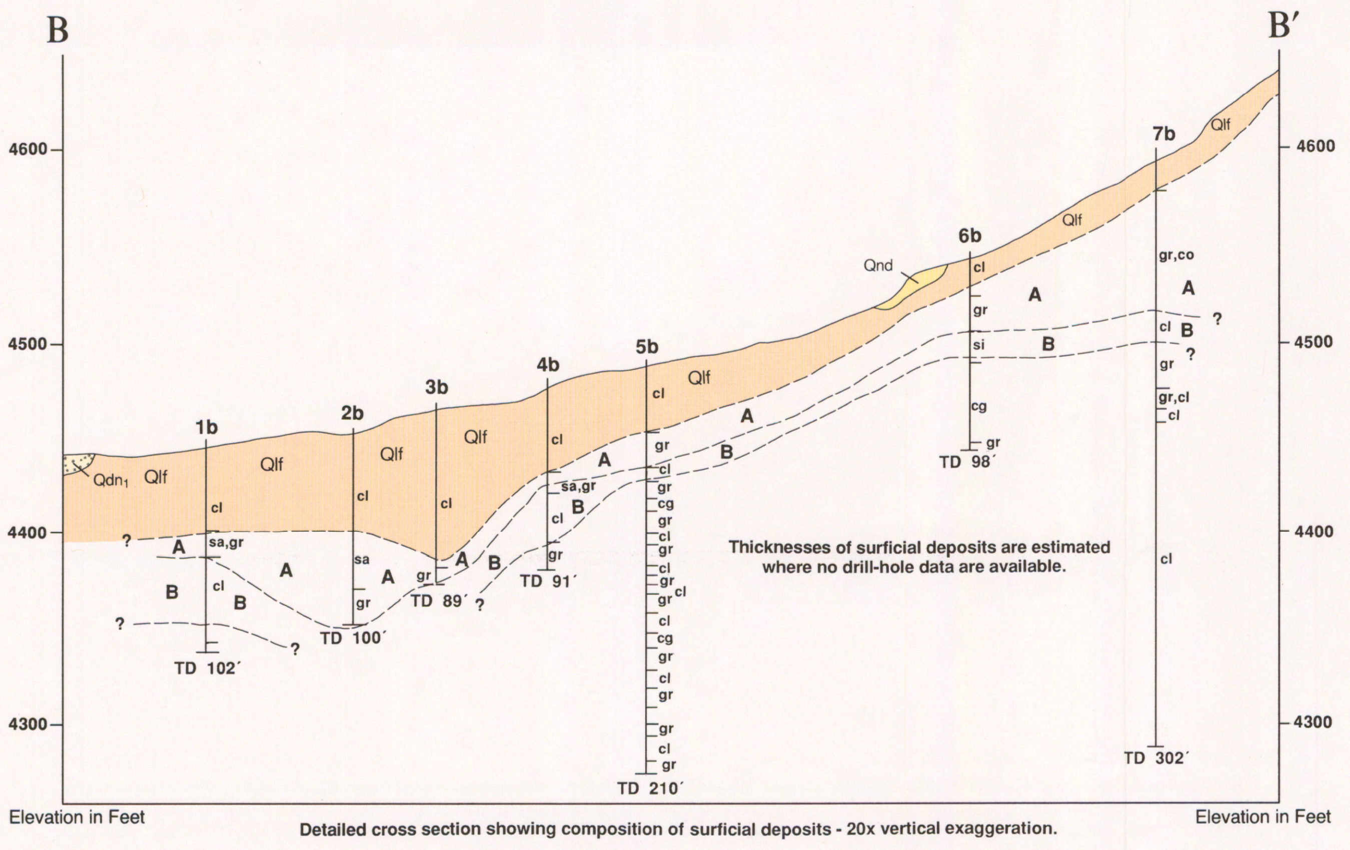
GRAVEL PIT

QUARRY

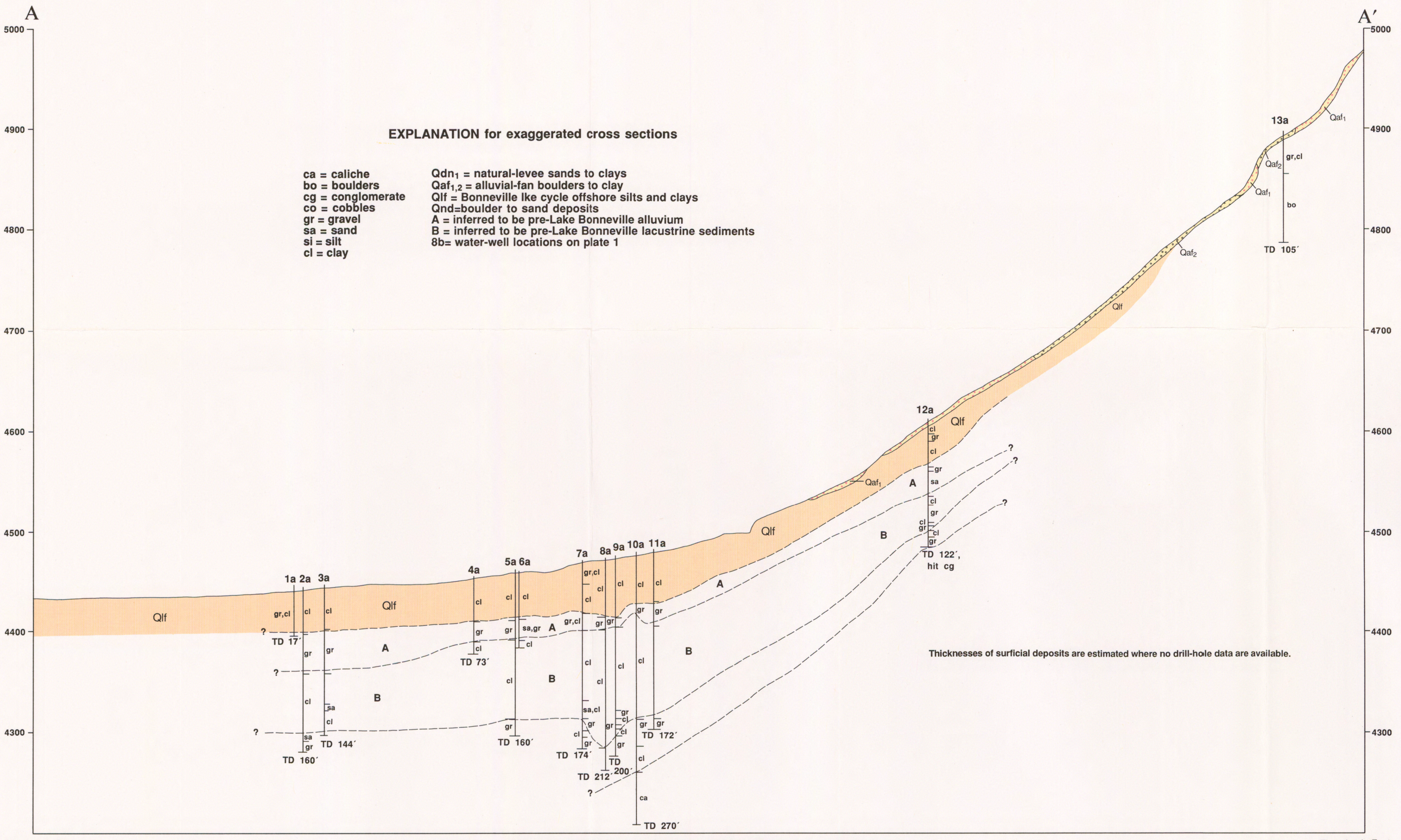
PROSPECT

WATER WELL (o 1a)

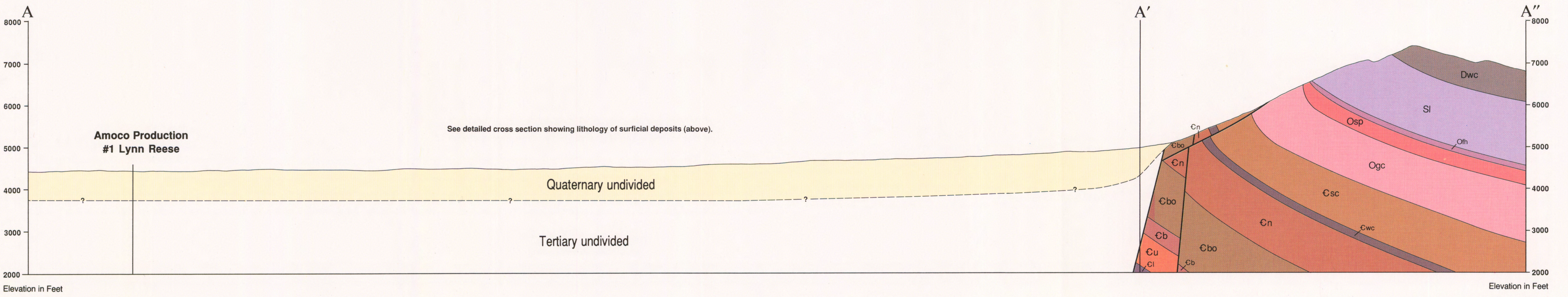
OIL AND GAS EXPLORATION WELL, DRY



Detailed cross section showing composition of surficial deposits - 20x vertical exaggeration.

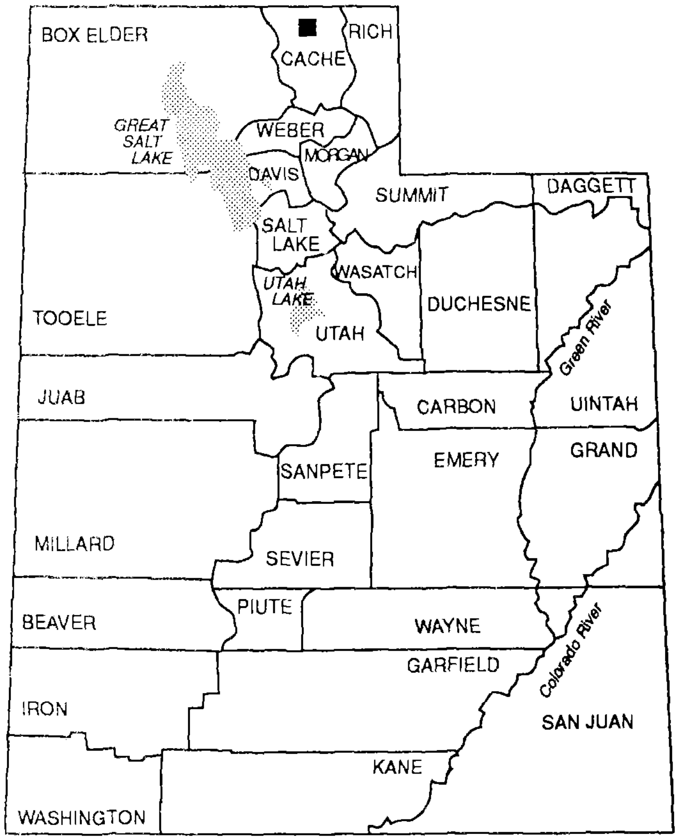


Detailed cross section showing composition of surficial deposits - 20x vertical exaggeration.



PROVISIONAL GEOLOGIC MAP OF THE SMITHFIELD QUADRANGLE, CACHE COUNTY, UTAH

by
Mike Lowe and Cheryl Leora Galloway



MAP 143 **1993**
UTAH GEOLOGICAL SURVEY
a division of
DEPARTMENT OF NATURAL RESOURCES

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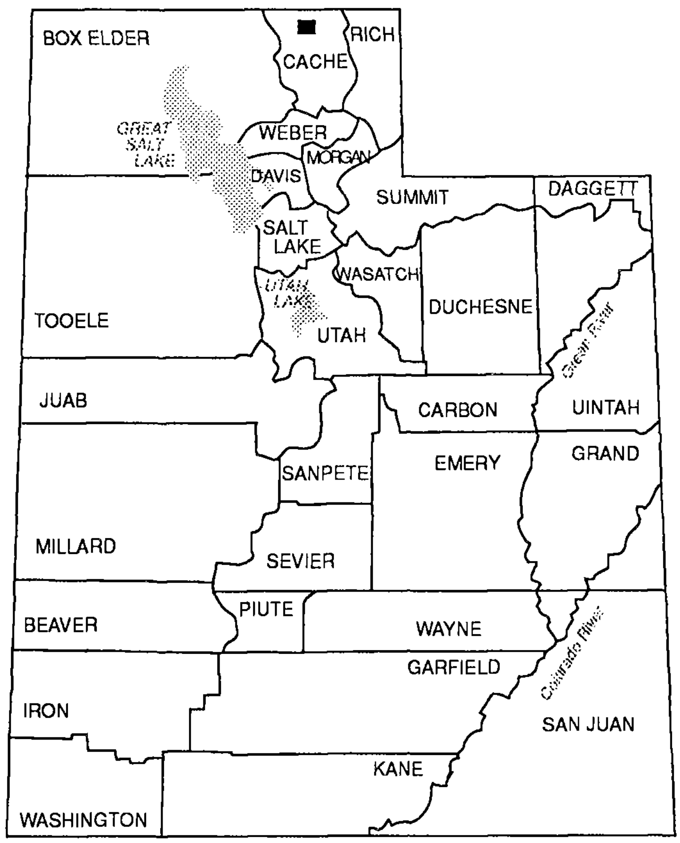

MAP 143 **1993**
UTAH GEOLOGICAL SURVEY
a division of
DEPARTMENT OF NATURAL RESOURCES

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

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PROVISIONAL GEOLOGIC MAP OF THE SMITHFIELD QUADRANGLE, CACHE COUNTY, UTAH

by Mike Lowe[1] and Cheryl Leora Galloway[2]

ABSTRACT

The Smithfield quadrangle is located on the east side of Cache Valley and the west side of the Bear River Range. Approximately 2,100 feet (640 m) of Late Precambrian rocks and about 11,500 feet (3,500 m) of Paleozoic strata are exposed in the mountains while Tertiary and Quaternary deposits, which oil-well logs indicate as several thousand feet thick in the valley, are exposed along the valley margin. The Tertiary Salt Lake Formation rests unconformably on Precambrian quartzite and Paleozoic units, and Lake Bonneville deposits overlap Cambrian rocks and the Salt Lake Formation.

The Paleozoic rocks exposed in the Bear River Range dip generally eastward, forming the west limb of the Logan Peak syncline. These beds are broken by east-dipping bedding-plane faults, and west-dipping, high- and low-angle thrust faults. During the Late Jurassic to early Tertiary Sevier orogeny, progressive local deformation successively produced the syncline and the west-dipping high-angle and low-angle thrust faults. The east-dipping bedding-plane faults are interpreted to have resulted from eastward sliding in conjunction with more extensive gliding before and during initial folding.

The East Cache fault zone is mapped along the western edge of the Bear River Range. Down-dropping of Cache Valley along the fault zone, beginning in the Tertiary, produced great topographic relief, resulting in slope instability. Large masses of soil and bedrock moved downslope, including two major pre-Quaternary landslides. A prominent west-dipping surface in the range that probably formed as a result of thrust faulting was reactivated as a westward gravity slide.

In Cache Valley, the early Quaternary was a period of pediment formation, followed by normal faulting, erosion, and alluvial-fan deposition. Cache Valley was later occupied by a pre-Bonneville-cycle lake which is tentatively correlated with the Little Valley lake cycle. The current Cache Valley landscape is dominated by the sediments and geomorphic features of the late Quaternary Bonneville lake cycle. Alluvial-fan deposition has been the principal geologic process in post-Lake Bonneville time.

Geologic hazards in the Smithfield quadrangle include flooding, landslides, debris flows, rock fall, problem soils, shallow ground water, earthquake ground shaking, surface fault rupture, and liquefaction. Bonneville lake cycle, fine-grained offshore deposits, and the Tertiary Salt Lake Formation are the primary geologic units susceptible to landsliding.

INTRODUCTION

The Smithfield 7.5' quadrangle is located about 8.6 miles (13.8 km) south of the Utah-Idaho state line in the central part of northern Utah and occupies the central portion of the eastern side of Cache Valley. The highest peak in the quadrangle lies between Dry Canyon and Hyde Park Canyon and reaches an elevation of 7,696 feet (2,347 m). The valley floor lies near 4,430 feet (1,350 m) in elevation. The area has major north-south access on U. S. Highway 91.

Previous Investigations

Galloway (1970) studied the structural geology of the eastern portion of the Smithfield quadrangle, and Lowe (1987) studied the surficial geology and geologic hazards of the quadrangle; these two M.S. theses have been combined and condensed for this map and text. Detailed investigations in the Smithfield quadrangle began with Bailey's (1927) studies of the geology of the Bear River Range and the Bear River Range fault. Williams (1948) studied the Paleozoic rocks in the area, and included a measured section of the Swan Peak Formation in Green Canyon. Ross (1951) included a description of the Garden City and Swan Peak Formations in Green Canyon. Haynie (1957) examined the Worm Creek Quartzite Member of the St. Charles Formation in Green Canyon. Williams (1958) continued his study of the stratigraphy and geologic history in Cache County. Taylor and Palmer (1981) and Taylor and others (1981) studied Cambrian and Ordovician stratigraphy and paleontology in the Bear River Range and measured a section in Green Canyon.

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[2]*Utah State University, Graduate Program*
Currently, 2011 W. 200 N. #1, Cedar City, UT 84720

There have been extensive investigations of the Salt Lake Formation in Cache Valley, which included work in the Smithfield quadrangle (Williams, 1948; Smith, 1953; Adamson 1955; Adamson and others, 1955; and Williams, 1964). Galloway (1970) redesignated the Salt Lake Group to the Salt Lake Formation. Williams (1962) studied the Bonneville lake cycle deposits in Cache Valley.

A detailed Cache Valley ground-water study was made by Bjorklund and McGreevy (1971). Erickson and Mortensen (1974) mapped the soils in the Cache Valley area. A reconnaissance study of the East Cache fault zone with recommendations for reducing risk from earthquakes was made by Woodward-Lundgren and Associates (Cluff and others, 1974). DeGraff (1976) mapped the Quaternary geomorphic features in the Bear River Range. Green (1977) studied the geologic hazards in Cache Valley. Rogers (1978) conducted an investigation of development sites on the Logan east bench. Liquefaction potential maps for this area have been prepared by Hill (1979) and Bay (1987). An evaluation of low-temperature geothermal potential in Cache Valley was made by deVries (1982). Swan and others (1983) studied earthquake recurrence intervals on the East Cache fault zone and trenched an area just south of Green Canyon. Christenson (1983) studied the engineering geology for land-use planning in the vicinity of Smithfield. Dover (1985) mapped the geology in the Logan 30' x 60' quadrangle. McCalpin (1986, 1989) studied surface-fault-rupture recurrence and mapped the surficial geology along the East Cache fault zone.

STRATIGRAPHY

Bedrock units of the Bear River Range represent nearly continuous deposition from late Precambrian through Devonian times. Younger Paleozoic and Mesozoic formations were presumably eroded from the area of the Smithfield quadrangle before deposition of the Tertiary Salt Lake Formation. The Salt Lake Formation is of Miocene and Pliocene age and crops out in the foothills along the eastern side of Cache Valley. The Salt Lake Formation rests unconformably on Precambrian quartzite and Paleozoic units. The valley floor and its margins are largely mantled by Quaternary sediments. They overlap Cambrian rocks along the mountain front in the southern one-fourth of the quadrangle, and overlap the Salt Lake Formation in the remainder of the quadrangle.

Precambrian System

Mutual(?) Formation (Zm)

The oldest strata exposed in the Smithfield quadrangle are herein tentatively mapped as the Mutual(?) Formation, based on correlation with part of the Precambrian-Cambrian section northeast of Huntsville, Utah (Crittenden and others, 1971). Galloway (1970) designated only the top 336 feet (102 m) of these strata as Mutual Formation; underlying rocks were designated simply as Precambrian quartzite. However, the designation of the entire sequence as Mutual(?) Formation is supported by recent geologic mapping by Brummer and McCalpin (1990) in the adjacent Richmond quadrangle to the north, where the Mutual Formation has a total thickness of about 3,000 feet (914 m). This matches well with Crittenden and others (1971), who show the Mutual Formation thickening northward from about 1,200 feet in the Huntsville area to about 3,000 feet (365-914 m) near Pocatello. Alternatively, Dover (1985) considers the lower portion of Galloway's (1970) Precambrian quartzite unit, which contains basalt flows, to be part of the Precambrian Browns Hole Formation, and the upper portion of Galloway's (1970) Precambrian quartzite and Mutual Formation to be Geertsen Canyon Quartzite. We do not concur with Dover (1985) however, and the Browns Hole Formation, a thin unit which separates the Mutual Formation from the Geertsen Canyon Quartzite in the Huntsville area (Crittenden and others, 1971), is not recognized in the Smithfield quadrangle.

The lower portion of the Mutual(?) Formation in the vicinity of Birch and Smithfield Canyons is predominantly quartzite that is white to grayish orange and that weathers moderate yellowish brown. Above the westernmost thrust fault in Dry Canyon and Birch Canyon, the lower portion of the Mutual(?) Formation contains basalt flows. In Dry Canyon, the lower basalt flow crops out on the north side of the canyon at the contact with the down-dropped Salt Lake Formation. The exposed thickness of basalt is 10 to 20 feet (3-6 m). The upper flow, also 10 to 20 feet (3-6 m) thick, lies about 100 feet (30 m) higher in the section and is clearly interbedded with the quartzite. A basalt flow is also present on the north side of Birch Canyon near the top of the ridge. The exposed thickness is only a few feet. The quartzite, stratigraphically above the flow in Birch Canyon, is white, gray, pink, and brown. It contains abundant pebbles in many places, and red, green, and gray to lavender argillite is interbedded with the quartzite.

The upper 336 feet (102 m) of the Mutual(?) Formation in Birch Canyon consists mostly of quartzite that is pinkish gray, grayish orange pink, and pale red purple. The purple quartzite is quite distinctive. Pebbles of white, pink, and gray quartzite, as well as jasper, are relatively abundant in the upper portion of the Mutual(?) Formation, but the quartzite does not contain feldspar.

The exposed thickness of the Mutual(?) Formation may be 1,800 to 2,300 feet (550-700 m); however, this estimate is uncertain because of intense folding and thrust faulting. The upper contact with the overlying Geertsen Canyon(?) Quartzite seems to be conformable.

Precambrian-Cambrian System

Geertsen Canyon(?) Quartzite (€Zgc)

The Geertsen Canyon(?) Quartzite was mapped as the Brigham Formation in the Smithfield quadrangle by Williams (1948) and by Galloway (1970); however, Williams did not recognize separate underlying units of Precambrian age. This report will use the nomenclature of Crittenden and others (1971), and the name Geertsen Canyon(?) Quartzite is here applied. The Geertsen Canyon Quartzite in the Huntsville area overlies the Browns Hole Formation. There seems to be no counterpart to the Browns Hole Formation in the Smithfield quadrangle. The Geertsen Canyon Quartzite is assigned a Precambrian and Early Cambrian age (Crittenden and others, 1971).

The Geertsen Canyon(?) Quartzite in the Smithfield quadrangle is 2,549 feet (777 m) thick on the ridge between Birch and Smithfield Canyons where exposures are excellent. It consists mostly of quartzite that is pink, orange, brown, purple, and gray. The Geertsen Canyon(?) Quartzite contains abundant particles of limonite, thus much of the quartzite is yellow brown on weathered surfaces. Yellow-brown shale and some yellow-brown sandstone are interbedded with the quartzite. Interbedded shale is especially abundant near the top of the formation. Flakes of muscovite are common in shale and sandstone in the upper part of the Geertsen Canyon(?) Quartzite, which also contains notable amounts of feldspar particles in places. Biotite flakes are rarely present. The Geertsen Canyon(?) Quartzite in the Smithfield quadrangle is gradational upward into the Langston Formation.

Precambrian-Cambrian Quartzite (€Zq)

Brecciated quartzite of Precambrian to Cambrian age is exposed at three locations north of Smithfield Canyon, south and east of Crow Mountain. The quartzite is light brown, reddish brown, and white. The Tertiary Salt Lake Formation overlaps the quartzite, which may be part of a landslide which was displaced westward from the Bear River Range to the east.

Cambrian System

Langston Formation (€l)

The Langston Formation is 360 feet (110 m) thick on the ridge between Birch and Smithfield Canyons, where it contains three members. The basal Naomi Peak Limestone Member, 33 feet (10 m) thick, consists of interbedded light-gray to medium-dark-gray, very finely crystalline limestone and shale, with quartz and muscovite sand. Light-gray to pale-yellowish-brown, very fine-grained calcareous sandstone is present in the lower 17 feet (5.2 m) of this member.

The Spence Shale Member, 120 feet (36.6 m) thick, consists of light-olive-gray shale, a medium-brown shale, and a lower third with limestone lenses.

The upper member, 207 feet (63 m) thick, is mostly medium- to dark-gray dolomite which is very fine to medium crystalline and medium to thick bedded. The lower 19 feet (5.8 m) of the upper member is medium-dark- to dark-gray, thinly laminated to thin-bedded limestone. This limestone is fossiliferous and contains silt and quartz sand.

The Langston conformably overlies the Geertsen Canyon(?) Quartzite as shown by a gradual change upward from detrital to carbonate rock. It also seems to be conformable with the overlying Ute Formation. The Langston Formation is of Middle Cambrian age (Albertan Stage) (Maxey, 1958).

Ute Formation (€u)

The Ute Formation was not measured in the Smithfield quadrangle; however, the basal part of the Ute is shale and forms a covered slope in contrast to the dolomite ledges of the Langston below. The upper contact, in Hyde Park Canyon, was placed at the top of a massive-bedded unit of white limestone, 5 to 10 feet (1.5-3 m) thick. Dolomite of the Blacksmith Formation occurs above the massive-bedded, white limestone.

Maxey (1958) measured the Ute Formation at High Creek, approximately 8 miles (13 km) northeast of the Smithfield quadrangle. At that location, it consists of alternating thin-bedded, medium-gray limestone and dusky-yellow shale except for the basal part, which is interbedded sandstone and limestone. The total thickness at High Creek is 745 feet (227 m). The Ute Formation seems to be conformable with the Langston Formation below and the Blacksmith Formation above. The Ute Formation is of Middle Cambrian age (Albertan Stage) (Maxey, 1958).

Blacksmith Formation (€b)

In the Smithfield quadrangle, the Blacksmith Formation is mostly light- to medium-gray dolomite with some limestone. The dolomite weathers light gray and the weathered surface is characterized by a sandy aspect. The Blacksmith Formation was measured by Maxey (1958) at High Creek, where it is 485 feet (148 m) thick and seems to be conformable with the Ute Formation below and the Bloomington Formation above.

Fossils have not been found in the Blacksmith Formation; however, the overlying Bloomington Formation is of Middle Cambrian age. Therefore, the Blacksmith is also considered to be of Middle Cambrian age (Albertan Stage) (Maxey, 1958).

Bloomington Formation (€bo)

The Bloomington Formation of the Smithfield quadrangle is well exposed on the first ridge south of Hyde Park Canyon. There, the section consists of three successively younger members as follows: (1) yellow-green shale and gray limestone, the Hodges Shale Member, (2) medium-gray and dark-gray limestone, and (3) interbedded olive-brown shale and gray limestone, the Calls Fort Shale Member. South of Beef Hollow, the upper part of the Bloomington Formation contains some dolomite. The estimated thickness of the Bloomington Formation at Hyde Park Canyon is 1,500 feet (457 m). The Bloomington Formation is intensely deformed near the mountain front.

The Bloomington Formation of the Smithfield quadrangle is similar to a section at High Creek, measured by Maxey (1958), where it seems to be conformable with the underlying Blacksmith and the overlying Nounan Formations. The Bloomington Formation is of late Middle Cambrian age (Albertan Stage) (Maxey, 1958).

Nounan Formation (€n)

In the Smithfield quadrangle, the Nounan Formation consists of light-gray and medium-gray dolomite, which weathers light gray. Limestone is not present in the upper part of the formation as reported by Maxey (1941) at High Creek. The upper part of the Nounan Formation is sandy and grades into the overlying Worm Creek Quartzite Member of the St. Charles Formation. A distinctive bed of coarse-crystalline white dolomite, 5 to 20 feet (1.5-6 m) thick, occurs within 20 feet (6 m) of the top of the formation.

Maxey (1941) recognized a lower dolomite and an upper limestone in the Nounan Formation at High Creek, where the total thickness was 1,125 feet (343 m). It is evidently conformable with the underlying Bloomington Formation and is gradational with the overlying Worm Creek Quartzite Member of the St. Charles Formation. The Nounan Formation is of Late Cambrian age (Croixian Stage) (Williams, 1948).

St. Charles Formation

Worm Creek Quartzite Member (€wc) – The basal Worm Creek Quartzite Member of the St. Charles Formation was measured by Haynie (1957) in Green Canyon, in the southern part of the Smithfield quadrangle. At this location he recognized five successively younger units in the Worm Creek: (1) gray quartzite, 6 feet (1.8 m) thick; (2) light-gray, sandy limestone, 4 feet (1.2 m) thick; (3) gray quartzite, 1 foot (0.3 m) thick; (4) light-gray, sandy dolomite, 80 feet (24 m) thick; and (5) coarse-crystalline, light-gray, sandy dolomite, 29 feet (9 m) thick. The Worm Creek is gradational with the underlying Nounan Formation. In Green Canyon, it is 120 feet (37 m) thick. The Worm Creek Quartzite Member of the St. Charles Formation is of Late Cambrian age (Croixian Stage) (Williams, 1948).

Upper member (€sc) – The upper member of the St. Charles Formation consists of thin-bedded limestone at the base followed by massive-bedded, light-gray and dark-gray dolomite. The limestone is about 10 feet (3 m) thick at Green Canyon and thickens northward. It is not found south of Green Canyon, probably because of structural thinning. The upper member is gradational with the underlying Worm Creek Quartzite Member and seems to be unconformable with the overlying Garden City Formation of Ordovician age.

Maxey (1941) reported a total thickness of 1,015 feet (309 m) for the St. Charles at High Creek. If the thickness given by Haynie (1957) for the Worm Creek in Green Canyon is accepted, the upper member is about 900 feet (274 m) thick in the Smithfield quadrangle. The upper member of the St. Charles Formation is of Late Cambrian age (Croixian Stage) (Williams, 1948).

Cambrian(?) Dolomite (€d)

On the north side of Hyde Park Canyon, severely brecciated dolomite believed to be of Cambrian age rests on a west-dipping surface. This west-dipping surface is described more fully later in the text. The dolomite is medium gray, contains gray chert, and the brecciated fragments are cemented by calcite. This unit resembles dolomite of the St. Charles Formation or dolomite near the top of the Garden City Formation.

Cambrian-Silurian Rocks (€S)

The Cambrian-Silurian unit is part of a pre-Quaternary landslide south of Beef Hollow, which is described in the Pre-Quaternary Landslide section below. It consists of a mass of limestone and dark-gray and light-gray dolomite which is stratigraphically complex.

Ordovician System

Garden City Formation (Ogc)

Ross (1951) divided the Garden City Formation, 1,405 feet (428 m) thick, into two members: (1) lower limestone characterized by intraformational conglomerate, and (2) upper cherty limestone. The lower member is 1,039 feet (317 m) thick in Green Canyon and consists of intraformational conglomerate, muddy limestone, and crystalline limestone. The upper member, 366 feet (112 m) thick in Green Canyon, is divided into two parts: (1) lower dark-gray limestone with black chert, and (2) upper limestone or dolomite with a decreasing amount of black chert toward the top. The uppermost part of the Garden City Formation is dolomite between Green and Logan Canyons and in places north of Green Canyon. The members of the Garden City Formation, recognized by Ross, are present throughout the Smithfield quadrangle.

The Garden City Formation seems to rest disconformably on the St. Charles Formation; it is conformable with the overlying Swan Peak Formation. The Garden City Formation is of Early and Middle Ordovician age (Canadian and Champlainian Stages) (Ross, 1951).

Swan Peak Formation (Osp)

The Swan Peak Formation in Green Canyon may be divided into four successively younger units as follows: (1) lower unit, 226 feet (69 m) thick, which consists of olive-gray shale and quartzitic siltstone in the lower part, medium-gray limestone and dark-gray shale in the middle part, and a covered interval; (2) gray quartzite and shale, 24 feet (7 m) thick; (3) red-purple quartzite and shale, 39 feet (12 m) thick; and (4) light-gray quartzite which weathers pinkish and yellowish gray, 111 feet (34 m) thick. The total thickness in Green Canyon is 401 feet (122 m).

The Swan Peak Formation thins southward for stratigraphic reasons. There are also marked changes in thickness along the outcrop between Green Canyon and Logan Canyon. On the north side of Logan Canyon, the Swan Peak Formation is 283 feet (86 m) thick. Most of this reduction in thickness is at the expense of the basal unit characterized by shale and is attributed to obscure bedding-plane faults.

The Swan Peak Formation is conformable with the underlying Garden City Formation; however, the overlying Fish Haven Dolomite seems to rest unconformably on the Swan Peak Formation (Ross, 1951). In places, detailed evidence indicates a structural relationship between the Swan Peak and Fish Haven rocks. On the north side of Green Canyon, a thin layer of breccia of the Fish Haven Dolomite rests on a sandstone bed at the top of the Swan Peak Formation. On the south side of Green Canyon, large calcite crystals are present at the base of the Fish Haven. Evidently this brecciation and recrystallization of the lowermost part of the Fish Haven Dolomite occurred as it slid over the Swan Peak Formation. The Swan Peak Formation is Middle Ordovician in age (Champlainian Stage) (Ross, 1951).

Fish Haven Dolomite (Ofh)

Williams (1948) described the Fish Haven Dolomite of the Smithfield quadrangle as a thick-bedded, medium-crystalline, dark-gray dolomite. In Green Canyon, it is about 140 feet (43 m) thick as defined by Williams.

The Fish Haven Dolomite thins toward the mountain front, probably as a result of bedding-plane faulting. Where not disturbed, it rests unconformably on the Swan Peak Formation. This hiatus represents part of Middle and Late Ordovician time. The Fish Haven Dolomite is conformable with the overlying Laketown Dolomite of Ordovician and Silurian age. The Fish Haven Dolomite is regarded as late Ordovician in age (Cincinnatian Stage) (Williams, 1948).

Silurian System

Laketown Dolomite (Sl)

Budge (1966) measured the Laketown Dolomite in Logan Canyon and recognized four successively younger members: (1) medium-dark-gray dolomite, 297 feet (91 m) thick, (2) medium-dark-gray and dark-gray dolomite, 550 feet (168 m) thick, (3) medium-gray dolomite, 417 feet (127 m) thick, and (4) dark-gray dolomite, 195 feet (59 m) thick. The total thickness is 1,459 feet (445 m).

The Laketown Dolomite is conformable with the underlying Fish Haven Dolomite. It seems to be unconformable with the overlying Water Canyon Formation of Devonian age. Williams (1948) regarded the Laketown Dolomite as being of Silurian age; however, Budge (1966) assigned the lower part to the Late Ordovician and the remainder to Early and Middle Silurian.

Devonian System

Water Canyon Formation (Dwc)

Taylor (1963) recognized two members in the Water Canyon Formation: (1) the lower Card Member, and (2) the upper Grassy Flat Member. The Card Member, 251 feet (76.5 m) thick in Logan Canyon, is clayey dolomite with intraformational breccia, and weathers light gray. The Grassy Flat Member, 355 feet (108 m) thick in Logan Canyon, consists mostly of calcareous sandstone, sandy dolomite, intraformational breccia, and clayey dolomite. The lowermost part of this member contains plant remains and abundant fish fragments. The total thickness of the Water Canyon Formation, measured by Taylor 1.7 miles (2.7 km) east of the mouth of Logan Canyon, is 606 feet (185 m).

The Water Canyon Formation crops out only at the southeast corner of the Smithfield quadrangle, where both members are present. The Water Canyon Formation lies disconformably on the Silurian Laketown Dolomite and is conformable with the overlying "Jefferson Formation" of Taylor (1963). An Early Devonian age for the Water Canyon Formation is suggested by the fish fauna (Branson and Mehl, 1931).

Mississippian System

Mississippian Limestone (Ml)

Mississippian limestone is part of a pre-Quaternary landslide remnant south of Beef Hollow. The limestone is dark gray and petroliferous, and it contains nodules and stringers of gray chert, abundant brachiopods and bryozoans, and a few gastropods and corals. The most common fossil is a small brachiopod which resembles *Composita*. The fossil assemblage indicates a Mississippian age.

Tertiary System

Undifferentiated Salt Lake Formation (Tslu)

The Salt Lake Formation is poorly exposed east of Crow Mountain, making it difficult to distinguish the members. This area is mapped as undifferentiated Salt Lake Formation. The soil is similar to soil formed on the Cache Valley Member on the west side of Cache Valley, indicating the possible presence of the tuffaceous Cache Valley Member.

Two informal members of the Salt Lake Formation are recognized in the Smithfield quadrangle: (1) a lower tuffaceous sandstone, probably representing the Cache Valley Member, and (2) an overlying conglomerate of the Mink Creek Member.

Cache Valley Member (Tslc) – Light-gray, tuffaceous sandstone of the Cache Valley Member crops out in two small exposures, one of which is about 0.2 mile (0.3 km) south of Dry Canyon. The other small outcrop is found west of Crow Mountain near the northern boundary of the Smithfield quadrangle. This member also contains tuff, limestone, and conglomerate north of the quadrangle. The sandstone appears discordant with the overlying conglomerate of the Mink Creek Member suggesting that an unconformity may exist between the two units.

Mink Creek Conglomerate Member (Tslm) – The Mink Creek Conglomerate Member crops out in the foothills along the mountain front and contains pebbles, cobbles, and boulders of many rock types. The matrix of sand and silt is tuffaceous and light gray to light yellow. The conglomerate is cemented by calcium carbonate. South of Smithfield Canyon, it consists mostly of pebbles and cobbles of limestone, dolomite, and chert. Essentially no quartzite is present, although the conglomerate overlaps quartzite between Hyde Park and Smithfield Canyons. North of Smithfield Canyon, near the mountains, boulders and cobbles of quartzite, limestone, and dolomite are present. The particle size decreases westward. Along the mountain front, the contact between the Mink Creek Conglomerate Member of the Salt Lake Formation and the underlying Paleozoic rocks is an angular unconformity.

Quaternary System

The Quaternary sediments exposed at the surface in the Smithfield quadrangle consist of lacustrine, alluvial, and mass-movement deposits. Measured sections and sieve analyses of the unconsolidated Quaternary deposits can be found in Lowe (1987). Map units underlying thin surficial units, which are less than approximately 10 feet (3.3 m) thick, are shown where possible. Thin units, with the exception of non-designated units (boulder accumulations) such as colluvium over bedrock, were not mapped above the Bonneville shoreline, however.

Bonneville lake cycle refers to both the transgressive and regressive phases of the last deep-lake cycle in the Bonneville basin (32,000 to 10,000 years ago [Currey and Oviatt, 1985]). Bonneville deposits refer to those sediments deposited during the transgressive phase of Lake Bonneville and to sediments deposited when the lake level was controlled by the Zenda threshold in south-central Idaho. Provo deposits refer to those sediments deposited when the lake level was controlled by a lower threshold at Red Rock Pass, and to those sediments deposited during the climatically controlled regression from the Provo shoreline.

Number subscripts for map-unit symbols refer to the relative age (youngest period of deposition) of the deposits. Age classification of Quaternary map units and corresponding number subscripts are: pre-Lake Bonneville deposits (5), Bonneville deposits (4), Provo deposits (3), older Holocene deposits (2), and younger Holocene deposits (1). Older and younger Holocene map units indicate relative ages based on geomorphic and stratigraphic relationships, not specific age ranges based on age dates.

Pre-Lake Bonneville Deposits

Alluvial-fan deposits (Qaf_5) – Pre-Lake Bonneville alluvial-fan deposits are exposed in a road cut, which is too small to be mapped, but is shown with an arrow on plate 1, in section 12, T. 12 N., R. 1 E. At this location normal faults offset the unit with the east side down. These sediments were probably deposited as alluvial fans and had morphologies similar to younger Holocene alluvial-fan deposits. Grain sizes range from small boulders (4 x 8 x 5 inches [10 x 20 x 13 cm]) to clay with mostly cobble-size clasts. Clasts are poorly sorted, angular to subrounded, and the deposit is poorly bedded with some imbrication of pebbles. Total thickness of the pre-Lake Bonneville alluvial-fan deposits is at least 19 feet (5.8 m) at the road cut. Although not exposed at this site, the alluvial-fan unit is probably underlain by older Quaternary units and the Tertiary Salt Lake Formation. Bonneville lake cycle deposits overlie the pre-Lake Bonneville alluvial-fan deposits.

Pediment deposits (Qap_5) – Pre-Lake Bonneville pediment deposits occur along the mountain front from north of Green Canyon to Hyde Park Canyon. Other deposits were mapped north of Smithfield Canyon. Pediment sediments were deposited as alluvium and alluvial fans on relatively flat surfaces which slope at low angles toward the valley. The pediments formed primarily on the easily erodible, Tertiary Salt Lake Formation. Grain size of these deposits ranges from boulders to silt and clay. The central areas of the pediments are covered with a fine sand, silt, and clay deposit which may represent an eolian cover. At the pediment edges and in other erosional areas, pebbles, cobbles, and boulders are the predominant grain size. Exposures in gullies less than 5 feet (1.5 m) deep reveal coarser material at depth, indicating that the fine-grained cover is very thin. The coarse material is poorly sorted and clasts are subangular to rounded.

Bedrock outcrops along the south edge of the pediment located just north of Mahogany Hollow are about 20 feet (6 m) below the top of the pediment deposits. Seismic data, collected at a station on the pediment surface near the outcrops using a single-channel seismograph, verify that this is the thickness of the pediment deposits. These deposits are underlain by the Tertiary Salt Lake Formation and are, in some areas, overlain by Bonneville deposits and younger Quaternary alluvial-fan deposits.

Non-Designated Units (Qnd)

Non-designated units have two distinct morphologies and vary in age. The first type occurs in the valley northwest of Smithfield, and between Logan and North Logan. It consists of low mounds of poorly sorted sand and gravel which are covered at the edges by Provo offshore silt and clay. Clasts are subangular to subrounded. These sediments may have been deposited on pre-Lake Bonneville highs around which lake sediments were later deposited. The preferred explanation is that the mounds represent subaqueous debris flows from deltas immediately east of the outcrops. Deposition would have taken place late in the Provo shoreline stage of the Bonneville lake cycle.

The second type of non-designated unit was previously described by Galloway (1970) as "boulder deposits." In the area east of Hyde Park, these boulder accumulations are the result of erosion from nearby steep slopes created by faulting or Bonneville lake cycle shoreline erosion. The clasts consist of small to large, subangular to subrounded, limestone, dolomite, and quartzite boulders. The boulder deposits are probably underlain by pre-Lake Bonneville pediment deposits, but the underlying units are not exposed. The boulders are residual lag deposits which accumulated as finer grained matrix materials were eroded and transported away from the steep slopes by lacustrine, colluvial, and fluvial processes (Lowe and Eagan, 1988).

Areas of thin veneers of boulders covering steep slopes underlain by the Tertiary Salt Lake Formation are also mapped as non-designated units (second type) on the north sides of Smithfield and Birch Canyons. The source for the boulders may have been the Salt Lake Formation or pre-Lake Bonneville pediments which were subsequently eroded from the area. No boulders of the size found in these deposits were noted in exposures of Salt Lake Formation outcrops in the Smithfield quadrangle, but Adamson (1955) described coarse-grained Salt Lake Formation lithologies farther north in the Cub River region. Galloway (1970) suggests that the deposit on the north side of Birch Canyon consists of boulders of Swan Peak Quartzite weathered from an erosional remnant of a slide mass. The slide mass may have moved along the west-dipping structural surface which is described later in this report.

Bonneville Deposits

Offshore deposits (Qlf_4) – Bonneville offshore deposits form a discontinuous north-south-trending band of low erosional mounds between elevations of about 4,800 and 5,040 feet (1,464 and 1,537 m) around which current drainage channels flow. Bonneville offshore deposits accumulated in beds of alternating grain size, possibly reflecting seasonal variations in lacustrine processes as sediments settled into the deeper waters of Lake Bonneville. Grain sizes range from medium sand to clay with the finer grained sediments predominant. This unit is locally at least 27 feet (8 m) thick; however, maximum thickness is not known, as underlying units are not exposed. The Bonneville offshore deposits are underlain by pre-Lake Bonneville units and overlain by Provo nearshore deposits and Holocene subaerial deposits.

Nearshore deposits (Qlc_4) – Bonneville nearshore sediments form a north-south-trending discontinuous band of deposits between elevations of 5,130 and 4,840 feet (1,563 and 1,476 m). Morphologically, these deposits form wave-built platforms, spits, and bars. Grain sizes range from cobbles to fine sand, with grain size generally decreasing as distance from the shoreline increases. Individual beds within these deposits are well sorted, and clasts are subangular to well rounded. The thickness of an exposure just south of Dry Canyon is 6.83 feet (2.08 m), but the maximum thickness of the deposit is not known. No cross bedding was noted in this exposure, but the unit was well bedded with some pebble imbrication. Bonneville nearshore deposits are underlain by pre-Lake Bonneville deposits (inferred) and, in some areas, are overlain by Provo nearshore and deltaic deposits and by younger Holocene alluvial-fan deposits.

Lagoon deposits (Qll_4) – Lagoon deposits form flat areas behind Bonneville-shoreline-level offshore bars. Grain sizes range from medium sand to clay with the finer grain sizes predominant. The sediments are well sorted and weakly stratified. Although not exposed, pre-Lake Bonneville units probably underlie the Bonneville lagoon deposits.

Deltaic deposits (Qd_4) – Bonneville deltaic deposits are found where Birch Creek and Summit Creek have jointly built a delta which dips gently to the west. Grain size varies from cobbles to coarse sand. The deltaic sediments are well sorted with subangular to well-rounded clasts. The deposit is well stratified. Individual beds are 3 to 30 inches (7.6-76 cm) thick. Total thickness of the deposit is unknown, but a gravel pit between Smithfield and Birch Canyons exposed 34 feet (10.4 m) of deltaic sediment. The Bonneville deltaic deposits are underlain by the Mink Creek Conglomerate Member of the Salt Lake Formation, outcrops of which are found in the slopes of the drainage where Birch Creek has cut into the delta. There are no overlying deposits.

Terrace deposits (Qat_4) – Bonneville terrace deposits are present along the north side of Birch Creek and along the north and south sides of Summit Creek. The terrace deposits are alluvial sediments deposited by streams graded to the Bonneville shoreline. Birch Creek and Summit Creek have since incised these deposits, forming the terraces. Grain sizes range from cobbles to clay with cobbles and coarse sand predominant. Individual beds within the terrace deposits are well sorted and clasts are angular to rounded. Coarser grained units are well bedded, but not cross bedded, and have some pebble imbrication. Finer grained units occur in lenses and are well laminated. Total thickness is unknown, but 33.5 feet (10.2 m) of the unit was exposed on the south side of Summit Creek. The Bonneville terrace deposits are inferred to be underlain by pre-Lake Bonneville alluvium and colluvium, and they are overlain locally by younger Holocene alluvial-fan deposits.

Slump and landslide deposits (Qms_4) – Landslide deposits which formed when Lake Bonneville was at the Bonneville shoreline are located in sections 23 and 25, T. 13 N., R. 1 E. The landslides in section 25 appear to be rock slumps (Varnes, 1978) within the Tertiary Salt Lake Formation. The landslide in section 23 is an earth slump (Varnes, 1978) in Bonneville offshore deposits and their cap of Bonneville nearshore gravels. The landslides have poorly developed arcuate head scarps and hummocky slide masses. Depositional characteristics are the same as for the materials from which the landslides originated except sedimentary structures are commonly deformed by the landsliding. One exposure in the northern landslide in the SW ¼ NW ¼ SW ¼ section 25, T. 13 N., R. 1 E. is 30 feet (9.2 m) thick. Salt Lake Formation boulders from the landslide mass also are partially buried by Bonneville nearshore deposits and a poorly developed Bonneville shoreline crossing the northern landslide in section 25 was noted on aerial photographs.

Provo Deposits

Offshore deposits (Qlf_3) – Provo offshore deposits form the flat floor of Cache Valley except where they are overlain by post-Lake Bonneville alluvial-fan deposits. These deposits are predominantly fine-grained sediments which settled out of suspension in deep-water areas when Lake Bonneville stood at the Provo shoreline. Grain sizes range from fine sand to clay with clay predominant. The deposits are well sorted. Sedimentary structures were not observed; however, Feth and others (1966) observed well-stratified, cyclically bedded sediments in similar deposits elsewhere in the Lake Bonneville basin. Thickness varies from nothing at the basin margins to 90 feet (27 m) nearer the valley center at the western edge of the quadrangle. Average thickness, estimated from drill-hole data, is 60 feet (18 m) in the western portion of the quadrangle. Drill-hole data indicate that Provo offshore deposits are underlain in most areas by Bonneville offshore deposits and pre-Lake Bonneville alluvial and alluvial-fan deposits. The contact between Bonneville offshore deposits and Provo offshore deposits could not be determined from water-well logs, so Qlf on the cross sections (plate 2) represents the entire Bonneville lake cycle.

Nearshore deposits (Qlc_3) – Provo nearshore deposits form gentle slopes dipping at low angles from the Provo shoreline toward the valley floor. The nearshore deposits also form bars and shoreline embankments along the Provo shoreline. Grain sizes range from cobbles to fine sand with some silt and clay in lenses. Individual beds within the deposits are well sorted, and the clasts are subangular to rounded. Deposits are well stratified and the silt and clay lenses are well laminated. Thickness of beds is variable, but an exposure in the old Hyde Park landfill measured 10.7 feet (3.3 m). The Provo nearshore deposits are underlain by Bonneville offshore deposits and are overlain, in some areas, by post-Lake Bonneville alluvial-fan deposits. The nearshore deposits have been covered by later deposits in most areas. Much of the evidence for the Provo shoreline in the Smithfield quadrangle was destroyed during the construction of the Logan, Hyde Park, and Smithfield Canal, which was built at the approximate elevation of the Provo shoreline.

In Hyde Park, thin Provo nearshore deposits overlie pre-Lake Bonneville alluvial-fan deposits. Large boulders in the alluvial-fan deposits encountered in foundation excavations indicate the thin nature of the nearshore deposits. The Provo nearshore deposits are overlain in some areas by post-Lake Bonneville alluvial fans.

Deltaic deposits (Qd_3) – Provo deltaic deposits are found at the mouths of Smithfield, Hyde Park, and Logan Canyons where they form triangular-shaped landforms with surfaces that slope at low angles toward the valley. These sediments were deposited by streams flowing into Lake Bonneville when it stood at the Provo shoreline. Grain sizes range from cobbles to fine sand with some silt and clay lenses. Deposits are well sorted and well stratified with some cross beds and imbricated pebbles. Clasts are subangular to subrounded. Individual beds range in thickness from 4 to 18 inches (10 to 45 cm). Maximum thickness of the unit is not known, but 10.5 feet (3.2 m) of Provo deltaic deposits were exposed in the north part of Logan. The Provo deltaic deposits are underlain by Bonneville nearshore and offshore deposits, and are overlain in some areas by post-Lake Bonneville alluvial-fan deposits.

Terrace deposits (Qat_3) – Provo terrace deposits, which are found near the mouth of Smithfield Canyon, are alluvial sediments deposited when Summit Creek was graded to the Provo shoreline. No vertical exposures were found in this unit, but depositional characteristics should be similar to Bonneville terrace deposits. It is inferred from the Bonneville terrace deposits that grain sizes range from cobbles to coarse sand with some silt and clay in lenses. The deposits are well sorted, and the clasts are subangular to subrounded. Total thickness is unknown because of the lack of exposures. These deposits are underlain by Bonneville deltaic deposits, and are overlain in some areas by post-Lake Bonneville alluvial-fan deposits.

Alluvial-fan deposits (Qaf_3) – Provo alluvial-fan deposits slope toward the valley at low angles, are concave-upward in longitudinal direction, and convex-upward in cross section. These are alluvial-fan deposits which were graded to the Provo shoreline. Grain sizes range from large cobbles to clay, sorting is fair to poor, and clasts are angular to rounded. Deposits just west of the mouth of Green Canyon are 4.8 feet (1.5 m) thick. Provo alluvial-fan deposits are underlain by Bonneville nearshore and offshore deposits and are overlain by older and younger Holocene alluvial-fan deposits.

Thin Provo alluvial-fan deposits that overlie Bonneville offshore deposits occur northwest of the mouth of Green Canyon. This unit represents an alluvial fan or fan delta which was graded to the Provo shoreline and formed a thin cap over Bonneville offshore sediments. Grain sizes range from boulders to clay, sorting is poor, and the clasts are angular to subrounded. The offshore deposits contain flow rolls and other soft-sediment deformation, which may indicate that an earthquake occurred when the sediments were still wet.

Older Holocene Deposits

Alluvial-fan deposits (Qaf_2) – Post-Lake Bonneville, older Holocene alluvial-fan deposits have upper surfaces that are steepest at the apex and decrease in slope downstream. Grain sizes range from cobbles to medium sand with some silt and clay in lenses. The deposits are poorly to moderately sorted, and the clasts are subangular to rounded. Deposits are stratified with some pebble imbrication, and grain size coarsens downward slightly. Maximum thickness of this unit is not known, but 4.8 feet (1.5 m) of these deposits were exposed in a foundation excavation near the mouth of Green Canyon. The older Holocene alluvial-fan sediments are underlain by Provo deltaic and offshore sediments and are overlain in some areas by younger Holocene alluvial-fan deposits.

Younger Holocene Deposits

Natural-levee deposits (Qdn_1) – Post-Lake Bonneville, younger Holocene natural-levee deposits are located along the banks of the Bear River. These are overbank sediments deposited by the Bear River during flood stages, forming a natural levee. The deposits are thickest near the channel bank and create a slight slope away from the river. Grain sizes range from very fine sand to clay with a minor amount of fine and medium sand. The deposits are very well sorted. Because no vertical exposures were available, the maximum thickness of the unit and types of sedimentary structures in the deposits are unknown. The natural-levee sediments are underlain by Provo offshore deposits.

Alluvial deposits (Qal_1) – Post-Lake Bonneville, younger Holocene alluvial deposits form the floodplain of the Bear River. Grain sizes range from very fine sand to clay with a minor amount of fine to coarse sand. The deposit is well sorted. No vertical exposures in this unit were available, so sedimentary structures and unit thickness are unknown. These deposits are underlain by, and are incised into, Provo offshore deposits.

Alluvial and colluvial deposits (Qac_1) – Post-Lake Bonneville, younger Holocene alluvial and colluvial deposits fill the valley bottoms of the incised drainages of Dry Hollow and Green, Hyde Park, Dry, Birch, and Smithfield Canyons. These deposits were formed by a combination of alluvial and mass-wasting processes (landslide, debris flow, colluvium, slope wash, etc.). Grain sizes range from cobbles to clay. The deposits are moderate to poorly sorted, and clasts are subangular to subrounded. No vertical exposures in this unit were measured, so sedimentary structures and maximum unit thickness are unknown. Younger Holocene alluvial and colluvial deposits are underlain by older Quaternary deposits and bedrock, and they are overlain in some areas by younger Holocene alluvial fans.

Alluvial-fan deposits (Qaf_1) – Post-Lake Bonneville, younger Holocene alluvial-fan deposits are found at the mouths of most canyons and gullies in the Smithfield quadrangle, including the Summit Creek alluvial fan which stretches across the quadrangle to the Bear River. These deposits are composed of alluvial and debris-flow sediments. The younger Holocene alluvial fans dip toward the valley at low angles, are concave in longitudinal section, and are convex in cross section. Grain sizes range from large boulders to clay. Sorting is fair to poor and clasts are angular to subrounded. The deposits are poorly to moderately bedded with some pebble imbrication. The thickest exposure of this unit is 5.6 feet (1.7 m). Younger Holocene alluvial fans are underlain by older Quaternary deposits and bedrock.

Debris-flow deposits (Qmf_1) – Post-Lake Bonneville, younger Holocene debris-flow deposits derived from colluvium forming on the Salt Lake Formation are found on the south sides of Dry and Hyde Park Canyons. Debris flows are sediment/water mixtures which move downslope as a viscous slurry flow (Pierson and Costa, 1987). These poorly sorted deposits are small and thin with hummocky surfaces. Grain sizes range from coarse sand to clay, with clay predominant. Sedimentary structures and unit thickness are not known as no vertical exposures were available. The debris-flow deposits are underlain by the Mink Creek Conglomerate Member of the Salt Lake Formation and colluvium.

Colluvial and slope-wash deposits (Qmc_1) - Post-Lake Bonneville, younger Holocene colluvial deposits form a thin veneer over the Salt Lake Formation. Grain sizes range from cobbles to clay. The deposits are poorly sorted and the clasts are subangular to rounded. These deposits are commonly thicker in swales than on noses of ridges. The colluvial deposits are overlain in some areas by post-Lake Bonneville, younger Holocene alluvial-fan deposits, but in some areas may be pre-Lake Bonneville in age. Very thin layers of colluvium mantling slopes over bedrock units were not mapped.

Slump and landslide deposits (Qms_1) – Post-Lake Bonneville, younger Holocene landslide deposits are found in Smithfield Canyon and on the mountain front between Dry and Birch Canyons. Three of the landslides are debris slides in colluvium formed on the underlying Mink Creek Conglomerate Member of the Salt Lake Formation. They have arcuate head scarps, but have not completely failed. When they fail, they will probably mobilize into debris flows and form deposits similar to the post-Lake Bonneville, younger Holocene debris-flow deposits described previously.

A large landslide near White Horse Village in Smithfield Canyon appears to be a complex slump in the Mink Creek Conglomerate Member of the Salt Lake Formation. This landslide has formed a series of flat areas below the arcuate scarp at its crown. This landslide is above the Bonneville shoreline terrace in Smithfield Canyon, so a relative age could not be determined. The head scarp appears to be relatively unweathered. The internal structures within the landslide are jumbled, as seen in road cuts below White Horse Village. The landslide near White Horse Village is more than 15 feet (4.6 m) thick as determined from road cuts in the landslide. The deposits are underlain by the Salt Lake Formation.

STRUCTURE

Folds

Logan Peak Syncline

The western flank of the Logan Peak syncline forms a structurally complex zone in the mountains of the eastern part of the Smithfield quadrangle. The axis of the syncline, located 1.5 to 4 miles (2.4-6.4 km) east of the quadrangle boundary, trends north-northeast. In the southeastern part of the Smithfield quadrangle, rocks of Cambrian to Devonian age generally strike N. 15° E. and dip 20° to 40° E. Near the mountain front, the dip increases to 60° to 80° E. In places, especially near thrust faults, the bedding dips more steeply and is overturned to the east. In the northeastern part of the quadrangle, north of Hyde Park Canyon, rocks of Precambrian-Cambrian age strike about N. 15° E. and dip 50° to 70° E. A gradual steepening in dip is evident toward the mountain front.

Minor Folds

Folds are present in the Precambrian quartzite between Hyde Park Canyon and the north edge of the quadrangle. On the north side of Birch Canyon in succession from west to east are a small syncline, a small anticline, a larger syncline, and a larger anticline. Southward, in Dry Canyon, the larger anticline is displaced by a thrust fault. Small, tight folds are common within the less competent rock units of the eastern part of the Smithfield quadrangle. These are especially evident in the Bloomington Formation.

Thrust Faults

Bedding-Plane Faults

Bedding-plane thrust faults are found in the St. Charles and Garden City Formations in Green Canyon, where related faults diverge upward from a lower fault that is concordant with the east-dipping underlying beds and discordant with the overlying beds. A notable, east-dipping, bedding-plane fault crosses Green Canyon about 1 mile (1.6 km) east of the mountain front, just above the St. Charles-Garden City contact. On the south side of the canyon, beds below the fault dip east more steeply than beds above the fault. In places, beds below the fault are clearly truncated by the fault, whereas overlying beds are concordant with the fault.

Another bedding-plane fault occurs in the upper part of the Garden City Formation, on the south side of Green Canyon, about 2 miles (3.2 km) east of the mountain front. Beds above and below this fault seem to diverge, the fault dips to the east at a low angle and is parallel to the beds above.

High-Angle Thrust Faults

High-angle thrust faults are those that dip more than 45 degrees. A major high-angle thrust fault extends from the southern boundary of the quadrangle northward to Hyde Park Canyon. It strikes north-northeast, dips about 75° W., and is well exposed 0.2 miles (0.3 km) south of Green Canyon. The displacement on this fault is about 1,100 feet (335 m) at a location 0.4 mile (0.6 km) south of Green Canyon, where the lower part of the Nounan Formation has been thrust over the Worm Creek Quartzite Member of the St. Charles Formation so that the Bloomington-Nounan contact is within 50 feet (15 m) of the base of the St. Charles Formation. In places, masses of brecciated white dolomite mark the trace of the fault, and the fault surface is exposed where the breccia has been eroded. Slickensided surfaces are present on the fault surface as well as in the brecciated white dolomite. Limonite is present along and near the fault for about 1 mile (1.6 km) north of Green Canyon. On the south side of Mahogany Hollow, the high-angle thrust fault extends under a pre-Quaternary slide block. Locally, the thrust fault coincides with the slide block surface.

Between Mahogany Hollow and Dry Hollow, east of the slide block, the Bloomington Formation on the west is thrust up next to the Nounan Formation. Thus, in Bogus Hollow, a wedge of thin-bedded limestone of the Bloomington Formation is caught between the thrust fault on the east and the slide-block surface on the west. A similar situation exists on the ridge north of Bogus Hollow.

A separate high-angle thrust fault, in the Langston Formation, extends northward from Hyde Park Canyon for about 1 mile (1.6 km). Another high-angle thrust fault is present in Hyde Park Canyon near the eastern boundary of the quadrangle. This fault is within the Bloomington Formation and the displacement is small. South of Hyde Park Canyon, the dip decreases and the fault is classified as a low-angle thrust fault.

Low-Angle Thrust Faults

Low-angle thrust faults are those that dip less than 45 degrees, usually 20 to 30 degrees. An important low-angle thrust fault was recognized on the north side of Logan Canyon near the mountain front by Peterson (1936). This west-dipping fault extends into the Smithfield quadrangle at least as far north as Dry Canyon and strikes about N. 15° E. south of Green Canyon, the displacement is 150 to 300 feet (46-91 m) eastward; north of Green Canyon, it ranges from a few feet to perhaps as much as 800 feet (244 m) eastward.

Another low-angle thrust fault extends for 1 mile (1.6 km) between Dry Hollow and Hyde Park Canyon near the base of the mountain. In Hyde Park Canyon this fault dips about 25°W. On the northern side of Hyde Park Canyon, it displaces the nearly vertical Ute-Blacksmith contact eastward by about 20 feet (6 m). Northward, the fault disappears within the Blacksmith Formation.

Two nearly parallel low-angle thrust faults involving Precambrian rocks extend from Hyde Park Canyon to the northern boundary of the quadrangle. These faults strike about due north and dip 20° to 30° W. In Birch Canyon, displacement on the eastern fault is at least 800 feet (244 m).

Interpretation of Thrust Faults

The three kinds of thrust faults found in the Smithfield quadrangle probably reflect progressive deformation during the Late Jurassic to early Tertiary Sevier orogeny. The east-dipping bedding-plane faults are interpreted to have formed at an early stage of the Sevier orogeny. They may have resulted from eastward sliding in conjunction with more extensive gliding before and during initial folding. The gliding might have involved the mass between the east-dipping Willard thrust fault on the west, and the west-dipping Paris-Woodruff thrust faults on the east. Such faulting may account for the drastic thinning of the Swan Peak Formation and Fish Haven Dolomite along the mountain front between Green and Logan Canyons as well as the breccia between these formations in Green Canyon and elsewhere. The steep east dip of the beds beneath the bedding-plane faults, compared with the beds above, suggests emplacement of the overriding mass after moderate folding of the beds beneath.

The high-angle thrust faults, on the eastern limb of the anticline located immediately west of the Logan Peak syncline, formed generally after the bedding-plane faults. These thrust faults dip west and formed by stretching of the steeply dipping beds on the eastern flank of the rising anticline.

Low-angle thrust faults, which involve relatively greater horizontal displacement, probably formed during extreme steepening and overturning of the eastern limb of the anticline inferred to exist west of the Logan Peak syncline. In at least one case, a low-angle thrust fault must offset a major, high-angle thrust fault that formed earlier (plate 2, A'-A").

West-Dipping Structural Surface

A prominent west-dipping structural surface is exposed on the north side of Hyde Park Canyon and extends northward at least to the quadrangle boundary. It was reported in City Creek, 2 miles (3.2 km) north of the quadrangle boundary, by Bailey (1927). This surface truncates the Mutual (?) Formation and is west of the zone of folds and thrust faults previously described. In the Smithfield quadrangle, the surface strikes N. 10° W. to about N. 10° E., and dips 20° to 30° W., with an average of 22° W. On the north side of Hyde Park Canyon, severely brecciated dolomite rests on the west-dipping surface. Conglomerate of the Salt Lake Formation was deposited on the breccia. Similar conglomerate rests on the west-dipping surface elsewhere in the Smithfield quadrangle.

The most likely interpretation of the surface is that it represents a thrust fault along which later backsliding occurred because of removal of support due to down dropping of Cache Valley by normal faulting. The surface was largely cleared by sliding and erosion; later, conglomerate of the Salt Lake Formation was deposited. Normal faulting may have taken place along this surface after deposition of the Salt Lake Formation; therefore, the contact between the Salt Lake Formation and older bedrock units is shown as a low-angle normal fault on plate 1. Galloway (1970) interprets the quartzite boulder deposit on the north side of Birch Canyon to be a remnant of a slide mass of the Swan Peak Formation. This boulder deposit is at a low elevation between masses of carbonate rock of Cambrian age located at Crow Mountain north of Smithfield Canyon, and on the north side of Hyde Park Canyon. The anomalous location of the quartzite may be evidence of sliding of independent masses on a previously formed west-dipping surface.

Features similar to the west-dipping surface of the Smithfield quadrangle are found at other places in Utah. In the Paradise quadrangle, on the west flank of the Bear River Range about 8 ½ miles (14 km) south of the Smithfield quadrangle, Mississippian rocks rest on Devonian and older Mississippian rocks along a surface which dips 20° to 40° W. (Mullens and Izett, 1964, plate 1). Mullens and Izett interpreted this feature as a gravity fault; however, they also stated that it could be a thrust fault with younger rocks over older ones. Hanson (1949) interpreted two features, which dip 25° W. and separate Paleozoic units on the west side of the Malad Range in Utah, as low-angle gravity faults.

Normal Faults

The Mink Creek Conglomerate Member of the Salt Lake Formation overlaps Precambrian and Paleozoic rocks along the mountain front in the central and northern parts of the Smithfield quadrangle. This conglomerate may be downfaulted against older rocks of the Bear River Range along the pre-existing structural surface that dips west approximately 20 to 30 degrees. In the southern part of the quadrangle, where a major normal fault approaches the base of the mountain, the conglomerate is probably downfaulted, but field relations are obscured by Lake Bonneville deposits. The great thickness of the lower part of the Salt Lake Formation in the northeastern part of Cache Valley is indicative of relative down dropping of the valley contemporaneous with deposition.

The normal faults probably dip steeply toward the valley, however, with the exception of an antithetic fault exposed in a road cut, actual fault surfaces are not exposed. The westward concavity of the East Cache fault zone in the southern part of the quadrangle strongly suggests a westward dip. Westphal and Lange (1966) attributed some aftershocks of a 1962 earthquake that had its epicenter in the Bear River Range to two east-dipping surfaces; however, the same data might indicate parallel west-dipping faults to the east.

East Cache Fault Zone

Normal faults of the East Cache fault zone within the Smithfield quadrangle trend northward along the eastern side of Cache Valley. They displace latest Pleistocene and Holocene basin-fill deposits. The valley is inferred to have dropped relative to the Bear River Range in most instances, but a road cut east of Hyde Park indicates that the east side (mountains) dropped relative to the west side at that location. No post-Lake Bonneville fault scarps were identified north of Green Canyon. This could mean that the East Cache fault zone is segmented and that the northern portion of the quadrangle has not had a surface-faulting event as recently as the southern portion of the quadrangle. The East Cache fault zone is discussed below in detail from south to north.

Southern quadrangle boundary to Green Canyon – Post-Lake Bonneville fault scarps with the west side down are mapped south of Green Canyon. The scarps offset a post-Provo shoreline terrace in Logan Canyon and are covered at most other locations by post-Lake Bonneville, younger Holocene alluvial fans. In the southern part of the quadrangle the normal fault is about 1,000 feet (305 m) from the mountain front but converges with the mountain front just south of Green Canyon.

Green Canyon To Beef Hollow – No fault scarps were identified in this area of the quadrangle. The location of the fault zone is inferred from topography. Lineaments on air photos suggest a zone of faults in the vicinity of Beef Hollow.

Beef Hollow to Hyde Park Canyon – No fault scarps were identified in this area, but a normal fault with the east side down was mapped in the SW¼ SW¼ NW ¼ section 12, T. 12 N., R. 1 E. where offset beds of pre-Lake Bonneville alluvial-fan deposits were exposed in a road cut. A zone of normal faults with the west side down is inferred, based on topography and air photo lineaments, where pre-Lake Bonneville pediments have been offset near the western edge of the Salt Lake Formation. A normal fault with the west side down is also inferred, based on topography, along the western edge of the Paleozoic rocks.

Hyde Park Canyon to northern quadrangle boundary – No fault scarps were identified in this area of the quadrangle. A zone of normal faults, with the west side down, has been inferred, based on topography and air photo lineaments, along the west side of the contact between the Salt Lake Formation and Quaternary unconsolidated sediments. A normal fault with the east side down is inferred, based on topography, along the eastern edge of Round and Long Hills. Round and Long Hills are interpreted to be separated from Tertiary rocks to the east by a graben.

Pre-Quaternary Landslides

Green Canyon to Sysnath Hollow

Erosional remnants of a major landslide are scattered along the mountain front between Green Canyon and Sysnath Hollow. They consist of blocks of Cambrian-Silurian rock, Swan Peak Formation, Fish Haven Dolomite, and Mississippian limestone. The largest remnant of the slide extends from about 0.9 miles (1.5 km) north of Green Canyon to Beef Hollow. The mass is stratigraphically complex and was mapped as a Cambrian-Silurian unit. It is about 1,600 feet (488 m) long in the north-south direction and from 800 to 1,400 feet (244-427 m) wide in the east-west direction.

The extensive erosion of the slide mass, notably in Beef and Reeder Hollows, suggests a pre-Quaternary age for the sliding. The Salt Lake Formation overlaps blocks of quartzite and limestone, which may be part of the slide mass, between Reeder and Sysnath Hollows.

Two landslide remnants are present near the top of the ridge, both north and south of Beef Hollow. Beds exposed directly beneath these masses seem to have been dragged by sliding of the overlying masses, and they dip less steeply eastward than those a short distance away.

Round Hill and Long Hill

Round Hill and Long Hill, between lower Hyde Park and Dry Canyons, may be parts of a slide from the mountain front immediately to the east. They consist of conglomerate of the Salt Lake Formation which is isolated from an extensive outcrop of the same formation to the east by Quaternary deposits. A topographic re-entrant is present in the mountain front east of Round and Long Hills. The Cache Valley Member of the Salt Lake Formation, which crops out northeast of Long Hill and which must underlie both Round Hill and Long Hill, could have facilitated sliding. If sliding took place, it was before the formation of the Bonneville shoreline which cuts both Round Hill and Long Hill. The preferred explanation for Round Hill and Long Hill is that they represent a horst, bounded on the west by a west-dipping normal fault, and on the east by an east-dipping normal fault.

Crow Mountain

Crow Mountain, northeast of Smithfield near the north boundary of the quadrangle, is composed of severely brecciated dolomite and limestone which resemble the upper part of the St. Charles Formation and the Garden City Formation, respectively. The Salt Lake Formation overlaps the brecciated limestone on the east side of Crow Mountain.

The anomalous location of the dolomite and limestone of Crow Mountain, as well as the disoriented masses of brecciated quartzite to the east, resulted from westward landsliding on the flank of the Bear River Range. The carbonate rock and quartzite of Crow Mountain could have moved downslope from an area about 3 miles (5 km) to the east, where a brecciated mass of the St. Charles and Garden City Formations rests on a prominent west-dipping surface in the Richmond quadrangle. The brecciated quartzite, which crops out between Crow Mountain and the Bear River Range, could have come from the area of Precambrian and Cambrian quartzite that extends along the base of the Bear River Range. A broad re-entrant along the mountain front, evidenced by subdued ridges north and south of Smithfield Canyon, seems to represent the site of a large landslide.

The slide probably moved over unconsolidated and water-saturated sediments of the lower member of the Salt Lake Formation. Under these circumstances, according to Hubbert and Rubey (1959), a large mass of rock could be transported a considerable distance down a surface of low slope. The sudden load would be supported mostly by water in a sedimentary unit that is not highly permeable. A less likely interpretation involves westward sliding of the carbonate rock of Crow Mountain over previously brecciated Precambrian-Cambrian quartzite.

Slide Blocks

A slide block is an intact mass of rock that has moved downslope a relatively short distance. The trace of the slide-block surface is usually concave, with the result that the length along the mountain front is about twice the width. Three slide blocks are present between Green Canyon and Dry Hollow, south of Hyde Park Canyon. A mass of brecciated dolomite, which rests on the prominent west-dipping surface just north of Hyde Park Canyon, is also mapped as a slide block. Another slide block, mapped in the Ute Formation east of the brecciated dolomite, is unusual because of its straight trace which extends northward from Hyde Park Canyon.

The largest of the five slide blocks extends from Mahogany Hollow to Dry Hollow. It is 3,600 feet (1,097 m) long, 1,200 to 1,600 feet (366-488 m) wide, and involves the Bloomington Formation, the Nounan Formation, and the Worm Creek Quartzite Member of the St. Charles Formation. At the southern end, the Bloomington-Nounan contact on the slide block is offset only about 100 feet (30.5 m) westward, but along the northern end, the slide block moved about 1,000 feet (305 m) westward.

The slide blocks formed later than the pre-Quaternary landslides, and in the two southernmost slide blocks the weight added by pre-Quaternary landslides may have activated the slide blocks. The larger slide block, between Mahogany and Dry Hollows, may have been controlled by the west-dipping, high-angle thrust fault near its eastern side.

GEOLOGIC HISTORY

Pre-Quaternary Structural Events

The earliest structural event recognized in the Smithfield quadrangle is the folding and related faulting of the Precambrian and Paleozoic rocks along the front of the Bear River Range. These compressional events are classified as part of the Sevier orogenic phase by Hintze (1979). There, east-dipping beds form the western limb of the Logan Peak syncline. Eastward movement on the bedding-plane faults probably occurred before and during initial folding. As folding progressed, the beds steepened on the eastern flank of a major anticline and high-angle, west-dipping thrust faults formed. Folding in the Bear River Range probably occurred within the interval that extends from late Jurassic time (Armstrong and Cressman, 1963) to early Tertiary time. A major anticline, and perhaps other folds, possibly formed just west of the Bear River Range.

The latest Sevier event in the Smithfield quadrangle was eastward movement on west-dipping, low-angle thrust faults. Deformation of this type is to be expected with greater steepening and local overturning of the beds along the eastern side of Cache Valley on the eastern limb of a major anticline. Deformation characterized by crustal shortening ended in the vicinity of the Bear River Range by the time of deposition of the Eocene Wasatch Formation, which does not crop out in the quadrangle but was encountered at depth in an oil well in the western portion of the quadrangle.

Normal faulting followed the folding and thrust faulting of the Sevier orogeny. The Wasatch Formation was deposited on a surface of relatively low relief and is presumed to be of middle Eocene age. The Salt Lake Formation, which overlies the Wasatch Formation, seems to have accumulated during downfaulting of major valleys. The Salt Lake Formation ranges in age from late Eocene or early Oligocene to Pliocene. Thus, normal faulting may have began as early as Eocene time and continues to the present.

The relative downdropping of Cache Valley produced great topographic relief along the western side of the Bear River Range, resulting in slope instability. As a consequence, large masses moved down the west-dipping surface. Two major landslides seem to have moved over the lower member of the Salt Lake Formation and to have been covered by conglomerate of the upper member. Slide blocks, with relatively little movement, evidently formed after emplacement of the large landslides. Accelerated erosion of the mountains, east of the normal faults, resulted in the deposition of the upper conglomerate member of the Salt Lake Formation.

Quaternary Geologic History

Early Quaternary time was a period of pediment formation. These pediments have been offset by at least one episode of valley-side-down normal faulting, creating two levels of pediment surfaces in the central portion of the quadrangle, between Beef Hollow and Hyde Park Canyon.

Three major lacustrine cycles have been identified in the Bonneville basin (Scott and others, 1983; Oviatt and others, 1987), only two of which left deposits in the Smithfield quadrangle. The oldest lacustrine cycle, which occurred sometime between 90,000 and 150,000 years ago, is called the Little Valley lake cycle (Scott and others, 1983). The next oldest, which occurred sometime between 40,000 and 80,000 years ago (Oviatt and others, 1987), is called the Cutler Dam lake cycle. No deposits of the Cutler Dam lake cycle have been identified in the Smithfield quadrangle. The youngest lacustrine episode is called the Bonneville lake cycle (Scott and others, 1983), which began about 32,000 years ago and ended about 10,000 years ago (Currey and Oviatt, 1985). Interlacustrine cycles when the lakes were either small or nonexistent are correlated with sequences of subaerial deposits and soils (Morrison, 1965).

Pre-Little Valley lake cycle sediments were deposited in Cache Valley; the evidence for this is found in logs of some deeper water wells in the valley below the stratigraphic sequences labelled B (plate 2). Cache Valley was then occupied by a pre-Bonneville lake, which is tentatively correlated with the Little Valley lake cycle. Evidence for this lake cycle is also found in logs of some deeper water wells in the valley and is shown in the stratigraphic sequences labelled as B on plate 2. These deposits are up to 80 feet (24.4 m) thick (cross-section A-A') but are not exposed at the surface in the Smithfield quadrangle.

Post-Little Valley lake cycle alluvial and alluvial-fan sediments were deposited next in Cache Valley. Evidence for these deposits is found in the deeper water wells and in a road cut in section 12, T. 12 N., R. 1 E. With the onset of the Bonneville lake cycle, lacustrine sediments were once again deposited in Cache Valley. Although the floor of Cache Valley has areas which are below 4,500 feet (1,373 m) in elevation, no shorelines or shoreline deposits corresponding to the Stansbury shoreline have been identified. The Stansbury shoreline, which was cut about 23,000 years ago during the transgressive phase of Lake Bonneville, has been mapped in other areas within the Bonneville basin at about 4,500 feet (1,373 m) in elevation (Currey and Oviatt, 1985). This may indicate that the threshold between Cache Valley and the Great Salt Lake basin was, at that time, higher than the Stansbury shoreline.

Two levels of Bonneville shoreline bars are found at an approximate elevation of 5,130 feet (1563 m), just south of the mouth of Dry Canyon. The lower bar may be an earlier transgressive deposit reflecting a stillstand just before the lake reached the Zenda threshold. Soft-sediment deformation in fine-grained Bonneville offshore sediments near the mouth of Green Canyon may indicate an earthquake event occurring when, or shortly after, Lake Bonneville stood at the Bonneville shoreline. Feth and others (1966) have attributed similar soft-sediment deformation in the Ogden area to earthquakes.

Provo shoreline features have been identified north of Summit Creek at elevations of approximately 4,800 feet (1,464 m). The shoreline was probably also cut at this elevation in other locations in the quadrangle, but construction of the Logan, Hyde Park, and Smithfield Canal disturbed those shoreline features which have not been covered by post-Lake Bonneville alluvial fans. Post-Provo nearshore and deltaic features found along the eastern margins of Provo deltas formed by the Logan River and Summit Creek at elevations of about 4,680 feet (1,426 m) indicate that a stillstand during the regression from the Provo shoreline occurred at this elevation.

Post-Lake Bonneville time is represented primarily by alluvial-fan deposition. Two different ages of alluvial fans have been identified, based on stratigraphic and geomorphic relationships, in the Summit Creek and Green Canyon areas of the Smithfield quadrangle, but it should be recognized that alluvial-fan deposition was probably constantly occurring during post-Lake Bonneville time. Post-Lake Bonneville normal faulting has occurred at least once in the Smithfield quadrangle. These faults offset post-Provo shoreline terraces in the Logan 7.5' quadrangle but are largely buried by post-Lake Bonneville alluvial fans in the Smithfield quadrangle (Swan and others, 1983).

ECONOMIC GEOLOGY

Sand and gravel have been the most economically important mineral commodity in the Smithfield quadrangle. Gravel deposited in Pleistocene Lake Bonneville along the eastern edge of Cache Valley has been extensively exploited. Gravel pits, most of them operational, are found in deltaic deposits graded to the Provo shoreline near the mouth of Logan, Green, Hyde Park, and Smithfield Canyons; in deltaic deposits graded to the Bonneville shoreline near the mouth of Birch Canyon; in Bonneville nearshore deposits near the mouth of Dry Canyon; and in Provo nearshore deposits just east of the city of Hyde Park. The best gravel occurs in places where wave action reworked Tertiary conglomerates (Mink Creek Conglomerate Member of the Salt Lake Formation) or alluvial sediments.

Clay deposits have been mined commercially near Smithfield, and near the mouths of Logan and Hyde Park Canyons. The clay was used primarily to make bricks.

A prospect pit for silver and lead is located in the NE¼ NE¼ section 25, T. 12 N., R. 1 E., in the Garden City Formation. A prospect pit for titanium and vanadium is located in unsurveyed N ¼ SW¼ section 30, T. 13 N., R. 2 E., in the Mink Creek Conglomerate Member of the Salt Lake Formation. No further information is available on this mineral occurrence. There is also low-grade mineralization (copper, lead, silver) in the Cambrian rocks along the northeast edge of the quadrangle.

Building stone has been quarried on a small scale at several locations in Green Canyon. Quartzite, some of which was used in the construction of the Logan Mormon Temple, was quarried in the SW¼ SW¼ section 17, T. 12 N., R. 2 E., from the Swan Peak Formation. Limestone was quarried in the NW¼ NE¼ section 19, T. 12 N., R. 2 E., from the Garden City Formation.

One petroleum well was drilled in the Smithfield quadrangle in the NW¼ SW¼ section 17, T. 12 N., R. 1 E. The well, which reached a depth of 8,159 feet (2,487 m), was dry and was abandoned. This well provides information concerning the thickness of Quaternary and Tertiary deposits in Cache Valley. The Tertiary Wasatch Formation was encountered at a depth of 7,395 feet (2,254 m) and the Ordovician Swan Peak Formation was encountered at a depth of 7,750 feet (2,362 m).

GEOLOGIC HAZARDS

Geologic hazards affecting the Smithfield quadrangle include flooding, landslides (flows, slides, and falls), problem soils, shallow ground water, and seismic hazards. Geologic hazards are considered here on a quadrangle-wide scale; site-specific investigations should be conducted prior to development in potentially hazardous areas.

Flooding

In the Smithfield quadrangle, floods occur in response to cloudburst storms or rapid spring snowmelt and runoff. One of the largest historical cloudburst-generated floods in the Smithfield quadrangle occurred along Summit Creek on June 6 and 7, 1964, when over 2 inches (5.1 cm) of rain in 24 hours was recorded at Logan, Utah (Butler and Marsell, 1972). Storm-related floods also occurred in 1980, 1981, (Utah Division of Comprehensive Emergency Management, 1981) and 1983.

Seasonal flooding related to snowmelt and runoff has also been documented along local streams. Snowmelt flooding occurred during the spring of 1983 with damage including the destruction of several bridges and general scour and undercutting of embankments, culverts, bridges, and roads (Christenson, 1983). Snowmelt flooding also occurred in Cache Valley during the springs of 1985 and 1986. Potential 100-year floodplains in the Smithfield quadrangle are shown on Federal Insurance Administration Flood Hazard Boundary Maps and Flood Insurance Rate Maps (Federal Insurance Administration, 1980, 1981, 1986a, and 1986b).

Landslides

Landslides are classified after Varnes (1978). The term landslide includes flows, slides, and rock falls.

Flows

Debris flows are the most common type of flow in the Smithfield quadrangle. Debris flows are viscous slurry flows (Pierson and Costa, 1987) containing 20 to 80 percent particles which are coarser than sand (Costa and Baker, 1981). All younger Holocene alluvial fans in the Smithfield quadrangle should be considered debris-flow hazard areas unless site-specific investigations indicate otherwise. Incision of streams and construction of retention structures and canals can modify the areas at risk. Debris flows have occurred in colluvium deposits associated with the Salt Lake Formation; these deposits are shown on plate 1.

Debris flows containing more than 50 percent water are called debris floods (Wieczorek and others, 1983). Debris floods from Dry Creek in the spring of 1983 reached the Logan, Hyde Park, and Smithfield Canal (south of 300 South Street in Smithfield), although most of the coarser debris was dropped before entering the canal (Christenson, 1983).

Earth flows occur in material that is predominantly fine grained. This type of flow would likely be associated with any slumps occurring in Bonneville offshore deposits.

Slides

Slides in the Smithfield quadrangle include rock slumps, earth slumps, debris slumps, and debris slides. They occur primarily in the Salt Lake Formation, in colluvium formed on the Salt Lake Formation, and in Bonneville offshore sediments. Steeper slopes in these formations appear to be more susceptible to failure. Site-specific investigations should be conducted prior to approval of any development located in areas underlain by the these formations where the slopes are steep (> 30 percent).

Rock slumps – Rock slumps were mapped in section 25, T. 13 N., R. 1 E., and section 18, T. 13 N., R. 2 E., all of which are in the Salt Lake Formation. The rock slump on which White Horse Village has been built is a complex slump which has formed a series of flat areas.

Earth slumps – An earth slump, primarily involving Bonneville offshore sediments, was mapped in the SE ¼ NE¼ section 23, T. 13 N., R. 1 E. Alluvial deposits possibly related to the Provo shoreline appear at the toe of the slide in an undeformed terrace indicating that the slump may have occurred prior to Lake Bonneville's retreat from the Provo shoreline about 13,500 years ago (Christenson, 1983).

Debris slides – Debris slides have been mapped near the north boundary of the Smithfield quadrangle in the N ½ of section 18, T. 13 N., R. 2 E., and in the SE¼ NW¼ SW¼ section 25, T. 13 N., R. 1 E. These debris slides have formed in the thin colluvium covering the Salt Lake Formation.

Rock Falls

Several areas of potential rock-fall hazard were identified in the Smithfield quadrangle; however, it should not be inferred that all rock-fall hazard areas have been identified. Areas of potential rock-fall hazard were noted below an outcrop of the St. Charles Formation near the center of section 25, T. 12 N., R. 1 E., below an outcrop of the Bloomington Formation in the SE ¼ NW ¼ SE ¼ section 24, T. 12 N., R. 1 E., below Salt Lake Formation outcrops above the north side of the Hyde Park Canyon drainage, and below brecciated outcrops of Salt Lake Formation in the rock-slump mass in the SE ¼ SW ¼ SW ¼ section 25, T. 13 N., R. 1 E. Site-specific rock-fall studies should be completed prior to any development below steep slopes containing bedrock outcrops or perched boulders. Rock-fall hazards are likely to be greatest during earthquakes.

Problem Soils

Problems related to soils in the Smithfield quadrangle are most likely to occur in soils containing clays with a moderate to high shrink-swell potential. Erickson and Mortensen (1974) mapped several soils in the Smithfield quadrangle with a high shrink-swell potential, and these soils are primarily found in offshore silts and clays near the valley center. No documented problems with collapsible soils were noted during the course of this investigation. Detrimental effects caused by construction on problem soils are best avoided by conducting soils and foundation studies prior to development.

Shallow Ground Water

Shallow ground water has been mapped by Bjorklund and McGreevy (1971); however, due to wet cycles the water table could be higher than in 1966 when they collected their data. The principal zone of shallow ground-water occurrence is in the vicinity of, and west of, springs and flowing wells in the western portion of the Smithfield quadrangle.

Seismic Hazards

The Smithfield quadrangle is in a seismically active area. The principal zone of surface faulting in the Smithfield quadrangle is the East Cache fault zone, but not all earthquake hazards in the quadrangle can be attributed to movement along this fault zone. The largest earthquake recorded in the area occurred on August 30, 1962. The epicenter of the Richter magnitude 5.7 earthquake was in the Bear River Range about 9 miles (14.5 km) northeast of Richmond, Utah, in southern Idaho (Arabasz and others, 1979). Because of its magnitude and proximity to populated areas, this earthquake is the most damaging in Utah history (Christenson, 1983). Other earthquakes of Richter magnitude 4.0 or greater, in the Cache Valley area, occurred in 1923 and 1964.

Ground Shaking

Ground shaking is produced by propagation of large-amplitude seismic waves at the earth's surface. The largest magnitude events are likely to accompany surface-faulting events on Quaternary faults such as the Wasatch and East Cache fault zones. Part of the East Cache fault zone lies within the Smithfield quadrangle, and therefore surface faulting along this fault zone probably represents the greatest ground-shaking hazard within the Smithfield quadrangle. The ground-shaking hazard is greatest for sites underlain by thick, fine-grained silts and clay because they amplify ground motion, in some cases by as much as a factor of ten (Hays and King, 1984).

Swan and others (1983) estimate that the last two surface-faulting events on the East Cache fault zone in the Logan area had an approximate magnitude of M_S 6.8. Additional data indicate that surface-faulting events associated with earthquakes in the magnitude range of M_S 6.5 to M_S 7.2 have occurred repeatedly along the East Cache fault zone at Logan, Utah (Swan and others, 1983).

The best way to manage the ground-shaking hazard, which affects virtually the entire Smithfield quadrangle, is to construct buildings which are resistant to ground-shaking damage. Although few epicenters have been located along mapped traces of the East Cache fault zone since 1850, geologic evidence (Swan and others, 1983) indicates that this fault zone is capable of generating earthquakes much larger than any that have occurred during historical time (Christenson, 1983). For these reasons, the area is in Uniform Building Code seismic zone 3, in which earthquakes of modified Mercalli intensity VIII and higher may occur and cause damage (Christenson, 1983). All future construction should conform to Unified Building Code standards for seismic zone 3 with monitoring by regulatory agencies as recommended by the Utah Seismic Safety Advisory Council (1979) for their seismic zone U-4 (Christenson, 1983).

Surface-Fault Rupture

Swan and others (1983) have concluded that two surface-faulting events have occurred along the East Cache fault zone east of Logan since Lake Bonneville receded from the Bonneville shoreline between 15,000 and 14,000 years ago. The first event occurred prior to 13,500 years before present, and had a net vertical tectonic displacement of 4.4 feet (1.35 m) (Swan and others, 1983). Evidence for this event is a 9.8 to 11.5 foot-high (3 to 3.5 m) scarp near the mouth of Logan Canyon (Swan and others, 1983).

The most recent event, which had a net vertical tectonic displacement of 4.6 feet (1.4 m), postdates the recession of the lake below the Provo shoreline (about 13,500 years before present). Extensive burial of the scarp by alluvial fans suggests that this event occurred prior to about 6,000 to 8,000 years before present (Swan and others, 1983). Thermoluminescence dating of colluvial deposits suggests that the most recent event occurred between 6,000 and 8,900 years before present (McCalpin, 1989). Swan and others (1983) calculated the average recurrence, based on the two events described above, to be 7,250 years plus or minus 250 years. McCalpin (1989) calculated the average recurrence interval to be 6,800 years. The fact that it has been 6,000 to 8,900 years since the last surface-faulting event, and that the average recurrence interval is approximately 6,800 years, implies that considerable strain may have accumulated on the more active segment of the East Cache fault zone (southern portion of the Smithfield quadrangle) since its last large earthquake (McCalpin, 1989).

The most likely areas for surface-fault rupture to occur in the future are along areas of previous (prehistorical) fault rupture (Christenson, 1983). McCalpin (1989) and this report have indicated some areas with definite fault scarps. Cluff and others (1974) used aerial photographs to map lineaments which may be indicative of zones of past surface faulting. It is recommended that construction in these areas be preceded by site-specific trenching studies, and that no building be constructed across zones of deformation caused by previous surface-faulting earthquakes.

Liquefaction

Earthquake ground shaking can cause saturated sandy soils to liquefy, resulting in loss of bearing strength or ground failure. Hill (1979) prepared a liquefaction potential map for Cache Valley using William's (1962) geologic map and Bjorklund and McGreevy's (1971) depth to ground water map. A much more comprehensive study concerning liquefaction potential in Cache County has been completed (Bay, 1987). Liquefaction potential throughout most of the quadrangle is rated as low, but along the Bear River the liquefaction potential is rated as moderate to high (Bay, 1987).

Earthquake-Generated Landslides

No earthquake-generated landslide studies have been completed for the Smithfield quadrangle. Those areas showing evidence of past landsliding will likely be susceptible to future landsliding during seismic events. Site-specific studies in these areas should aid in avoiding hazards from earthquake-generated mass movements.

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