STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES
UTAH GEOLOGICAL AND MINERAL SURVEY

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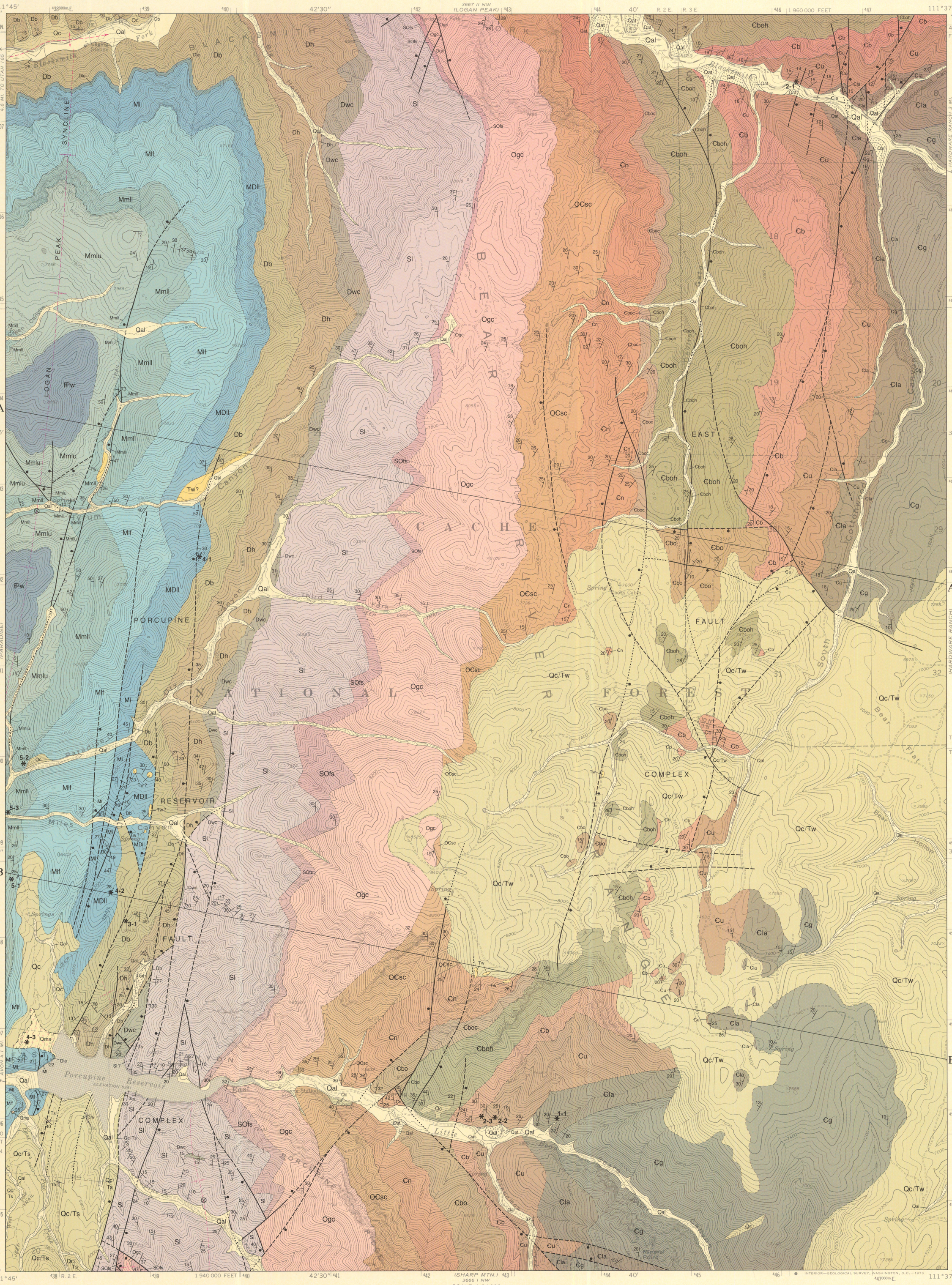
Plate 1
Utah Geological and Mineral Survey Map 113
Geologic Map of the Porcupine Reservoir Quadrangle



Base map from U.S. Geological Survey,
Porcupine Reservoir Quadrangle, 1969

SCALE 1:24 000

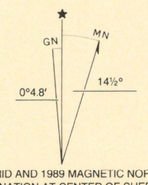
1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

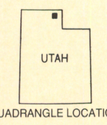
1 .5 0 1 KILOMETER

CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL

Lehi F. Hintze, Thesis Chairman
J.W. Parker, Cartographer



UTM GRID AND 1989 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET



QUADRANGLE LOCATION

GEOLOGIC MAP OF THE PORCUPINE RESERVOIR QUADRANGLE, CACHE COUNTY, UTAH

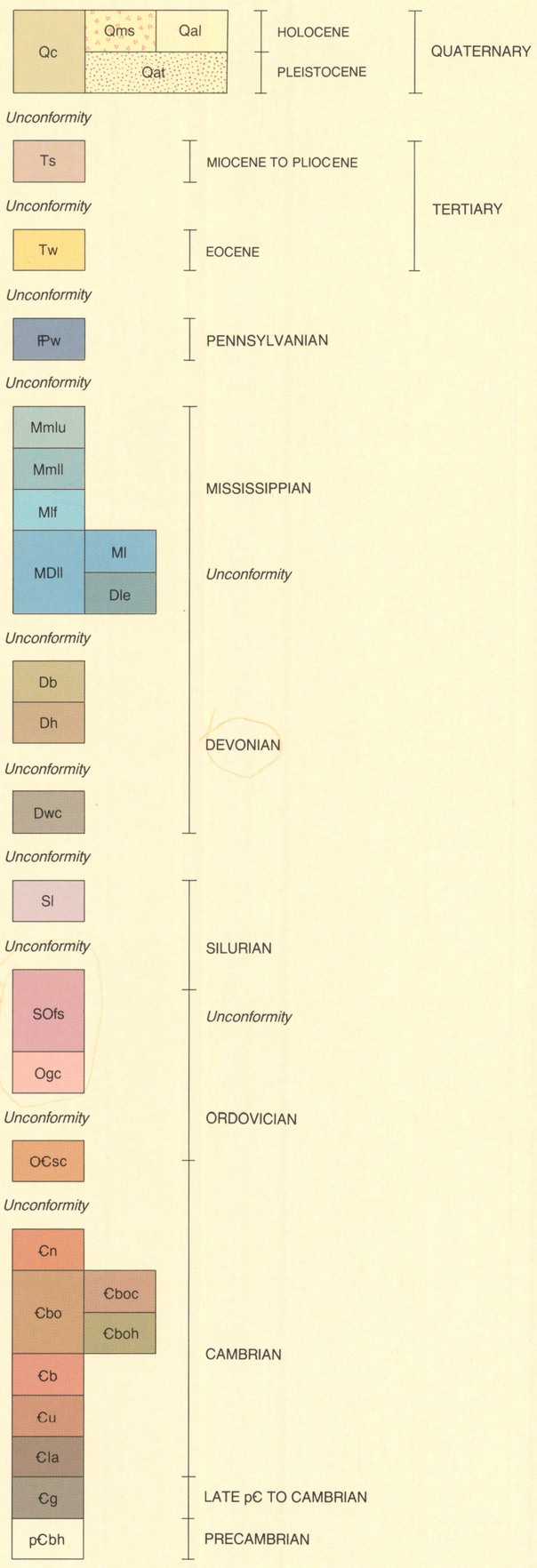
By
Lea Campbell Berry

1989

STRATIGRAPHIC COLUMN

		FORMATION	SYMBOL	THICKNESS Feet (Meters)	LITHOLOGY
QUAT.	HOLOC.	Alluvium	Qal		
		Slump and landslide deposits	Qms		
	PLEIST.	Colluvium and talus	Qc	0-40 (0-12)	
		Terrace deposits	Qat	20-50 (6-15)	
TERTIARY	MIOC./PLIOC.	Salt Lake Group	Ts	20+ (6+)	Unconformity
	EOC.	Wasatch Formation	Tw	200±(60±)	Unconformity
PENN.		Wells Formation	IPw	600-900 (180-270)	Unconformity
MISSISSIPPIAN	UPPER	Monroe Canyon Limestone	Mmlu	250-500 (75-150)	
			Mmll	500-600 (150-180)	Large solitary corals
	LOWER	Little Flat Formation	Mlf	1210 (363)	Delle Phosphatic Member
		Lodgepole Limestone	MDll, Mlo	660-690 (198-207)	Woodhurst Member; Paine Member; Cottonwood Canyon Member
		Leatham Formation	Dle	16-100 (5-30)	Unconformity
DEVONIAN	UPPER	Beirdneau Sandstone	Db	710-940 (213-282)	Upper carbonate member; Middle sandstone member; Lower carbonate member
	MIDDLE	Hyrum Dolomite	Dh	930 (279)	Samaria Limestone Member
	L.	Water Canyon Formation	Dwc	210 (63)	Unconformity; Chert
SILURIAN	MIDDLE AND UPPER	Laketown Dolomite	Sl	1240-1610 (372-483)	
	L.	Fish Haven Dolomite	SOfs	125-140 (38-42)	Chert; Unconformity
ORDOVICIAN		Swan Peak Formation		30-110 (9-33)	Unconformity
	MIDDLE	Garden City Limestone	Ogc	1160-1500 (348-450)	Chert; Intraformational conglomerate
	LOWER	St. Charles Formation	O€sc	970 (291)	Unconformity
CAMBRIAN	UPPER	Nounan Dolomite	€n	1070-1125 (321-338)	Worm Creek Quartzite; Unconformity
	MIDDLE	Bloomington Formation	€boc	190-400 (57-120)	Upper limestone member; Calls Fort Shale
			€boh	900-1100 (270-330)	Lower limestone member; Hodges Shale Member
		Blacksmith Dolomite	€b	320-480 (96-144)	
		Ute Limestone	€u	665-840 (200-252)	
		Langston Formation	€la	380-410 (114-123)	Upper member; Spence Shale; Naomi Peak Limestone Member; Lower member
	LOWER	Brigham Group: Geertsen Canyon Quartzite	€g	4200 (1260)	
PROTEROZOAN	UPPER	Brigham Group: Browns Hole Formation	p€bh	Subsurface only	

CORRELATION OF MAP UNITS



SYMBOLS

CONTACT—*Dashed where approximate or inferred.*

HIGH-ANGLE FAULT—*Dashed where approximate or inferred, dotted where covered.*

Normal fault—*Bar and ball on downthrown side.*

Strike-slip fault—*Arrows show sense of separation.*

LANDSLIDE BLOCK—*Dashed where approximate or inferred.*

STRIKE AND DIP OF BEDDING

Inclined

Vertical

Horizontal

FOLDS—*Showing trace of axial plane and plunge of axis; dashed where approximately located.*

Anticline

Syncline

*1-1 LOCATION OF PALEONTOLOGICAL SAMPLE

Qc/Tw SURFICIAL UNIT OVERLYING A BEDROCK UNIT

DESCRIPTION OF MAP UNITS

Qal Alluvium—*Sand, silt, clay, and some gravel in active streams.*

Qms Mass movement slump and landslide deposits—*Disaggregated rock and surficial deposits displaced downslope by gravity.*

Qc Colluvium and talus—*Sand, silt, and fragments to blocks of rock at the base of a cliff or steep rocky slope.*

Qat Gravel terrace deposits—*Conglomerate deposited at mouths of south-trending canyons along Blacksmith Fork and East Canyon probably during Lake Bonneville time.*

Ts Salt Lake Group—*Tuffaceous sandstone and fresh-water limestone conglomerate with quartzite clasts.*

Tw Wasatch Formation—*Basal conglomerate with limestone matrix overlain by reddish brown weathering conglomerate with quartzite clasts.*

IPw Wells Formation—*Poorly exposed sandstone with few limestone interbeds.*

Mmlu Upper unit of Monroe Canyon Limestone—*Medium to dark gray limestone, with very thin basal yellowish brown siltstone; forms ledgy slopes.*

Mmll Lower unit of Monroe Canyon Limestone—*Massive cliff-forming limestone and cherty limestone with large solitary corals.*

Mlf Little Flat Formation. Upper unit—*Quartz sandstone or siltstone with occasional beds of limestone; forms ledgy slopes.* Delle Phosphatic Member—*Basal thin-bedded shale, black chert with phosphate pellets, siltstone, and limestone.*

MDll Lodgepole Limestone and Leatham Formation, undifferentiated.

Ml Lodgepole Limestone. Woodhurst Member—*Medium to dark gray limestone cyclically interbedded with calcisiltite or calcareous mudstone; abundant megascopic fossils.* Paine Member—*Medium to dark gray limestone, thin-bedded; contains black chert nodules, lenses and beds.* Cottonwood Canyon Member—*Fine-grained sandstone.*

Dle Leatham Formation—*Light gray to yellowish brown thin-bedded siltstone and gray limestone; abundant pellets of limonite near base; forms slopes.*

Db Beirdneau Sandstone. Upper carbonate member—*Interbedded dolomite and limestone capped by resistant blocky bed of limestone known as the "contact ledge".* Middle sandstone member—*Dolomitic and calcitic siltstone, sandstone, and quartzite, with minor white chert; thin-to medium-bedded.* Lower carbonate member—*Light to medium gray yellowish orange and brown limestone and dolomite; varying amounts of quartz sand and silt; thin-to thick-bedded.*

Dh Hyrum Dolomite. Upper unit—*Light to dark gray dolomite, dolomitic limestone and limestone; brecciation and deformation of beds common; fetid; few quartzite beds.* Samaria Limestone Member—*Basal thin-to medium-bedded dolomite, silty dolomite, and limestone, multicolored; ledge-forming.*

Dwc Water Canyon Formation. Grassy Flat Member—*Multicolored dolomitic siltstone interbedded with dolomite; grades up into dark gary limestone.* Card Member—*Light brownish gray boundstone, weathers very light gray; thin-bedded.*

Sl Laketown Dolomite—*Light to medium gray dolomite, white to medium gray chert near base and top; forms massive vertical cliffs; thin-to-thick-bedded.*

SOfs Fish Haven Dolomite and Swan Peak Formation, undifferentiated. Fish Haven Dolomite—*Dark gray dolomite, thick-to very thick-bedded; scattered chert nodules and lenses; forms cliffs.* Swan Peak Formation—*Gray shale interbedded with multicolored quartzite and sandstone, laminated to thin-bedded; limey dolomite common at base; poorly exposed.*

Ogc Garden City Limestone—*Thin-to medium-bedded blue-gray crystalline and fossiliferous limestone, intraformational conglomerate and limey mudstone, with silty interbeds and lenses, dolomite and black chert near top.*

O€sc St. Charles Formation. Upper dolomite and limestone unit—*Cliff-forming, banded light and dark gray dolomite with thin sections of thin-bedded limestone and calcisiltite.* Worm Creek Quartzite—*Thin bed of fine-grained quartzite overlain by dolomite.*

€n Nounan Dolomite—*Light to dark gray dolomite, fine to coarsely crystalline; sections of dark gray limestone and dolomitic sandstone near top.*

€bo Bloomington Formation, undifferentiated.

€boc Upper limestone and Calls Fort Shale Members of Bloomington Formation—*Olive-brown shale overlain by blue-gray limestone.*

€boh Lower limestone and Hodges Shale Members of Bloomington Formation—*Interbedded limestone and shale overlain by blue-gray limestone; forms ledgy slopes.*

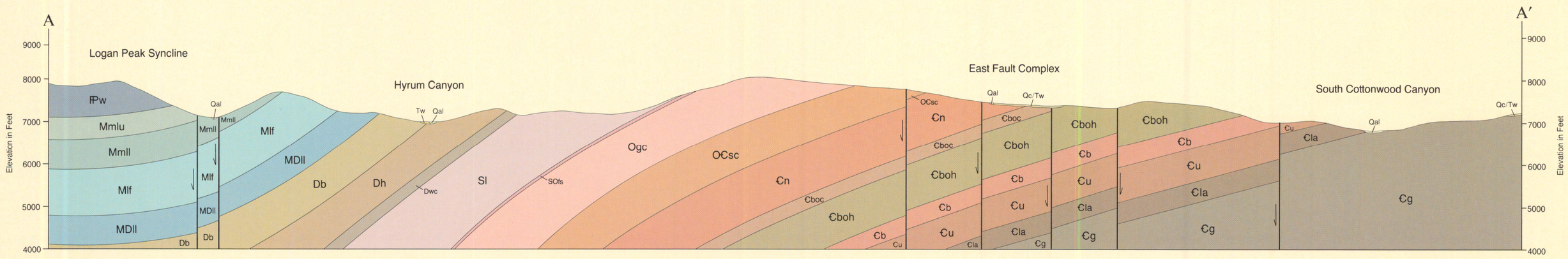
€b Blacksmith Dolomite—*Cliff-forming, medium-bedded to massive dolomite, light to medium gray.*

€u Ute Limestone—*Thin-bedded blue-gray limestone and olive-brown shale; reddish brown weathering; thin-bedded silty limestone at base.*

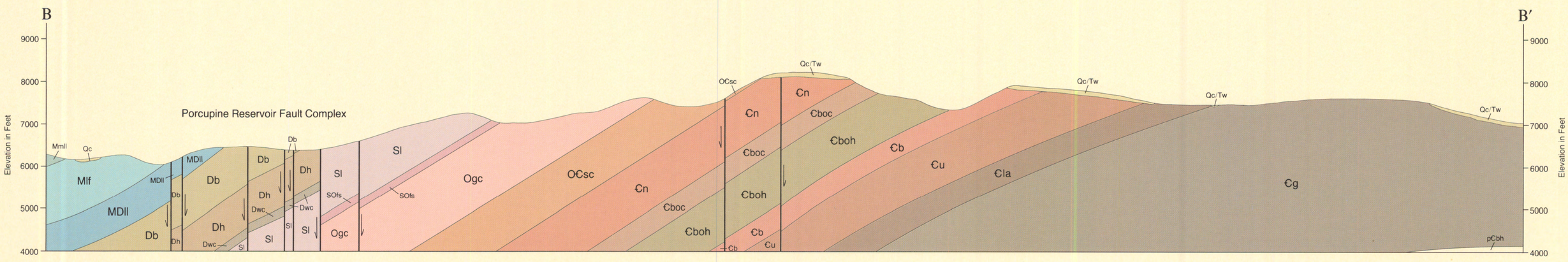
€la Langston Formation. Upper member—*Light to dark blue-gray dolomite and dark gray limestone; reddish brown weathering.* Spence Shale Member—*Light olive-brown to dusky yellow shale.* Naomi Peak Limestone Member—*Thin-bedded, blue-gray limestone.* Lower member—*Interbedded dolomite and limestone as found in upper member.*

€g Geertsen Canyon Quartzite—*Thick-bedded to massive light gray to brown quartzite; some pebble conglomerate.*

p€bh Browns Hole Formation—*Quartzite, volcanic rocks, and shale; on cross section only.*



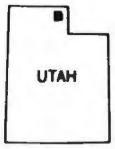
Note: Paris Thrust lies 10,000-15,000 feet below surface (Dover, 1985).



GEOLOGY OF THE PORCUPINE RESERVOIR QUADRANGLE CACHE COUNTY, UTAH

by

Lea Campbell Berry



UTAH GEOLOGICAL AND MINERAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES
MAP 113 **1989**

UTAH GEOLOGICAL AND MINERAL SURVEY

606 Black Hawk Way
Salt Lake City, Utah 84108-1280

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GEOLOGY OF THE PORCUPINE RESERVOIR QUADRANGLE CACHE COUNTY, UTAH

by

Lea Campbell Berry[1]

ABSTRACT

The Porcupine Reservoir quadrangle contains one of the most complete and best exposed sections of Paleozoic rocks in the Bear River Range, totalling 14,000 feet (4267 m) of marine strata. Thicknesses of marine strata mapped include, by age, Precambrian-Cambrian basal quartzite, 2900 feet (884 m) thick; Cambrian, 4610-5220 feet (1405-1590 m) thick; Ordovician, 1400-1650 feet (426-503 m) thick; Silurian, 1240-1610 feet (378-490 m) thick; Devonian, 2190-2280 feet (667-695 m) thick; Mississippian, 2600-2900 feet (792-884 m) thick; and Pennsylvanian, 600-900 feet (183-274 m) thick. Nonmarine sediments unconformably overlie the Precambrian and Paleozoic sediments and include conglomerate, siltstone, and sandstone of Eocene age, 0-200 feet (0-61 m) thick; sediments of Miocene and Pliocene age, 0-20 feet (0-6 m) thick; Quaternary terrace deposits, 20-50 feet (6-15 m) thick; colluvium and talus, 30+ feet (9+ m) thick; and alluvium.

Proterozoic and Paleozoic strata, part of the Bear River Range and Cache allochthon, are gently folded in the Logan Peak syncline, with minor folds complicating the limbs. Northeast- and northwest-trending normal faults, cut by north-trending normal faults, suggest an intermediate phase of faulting between Mesozoic folding and late Cenozoic basin-and-range faulting.

Hyrum Dolomite and Beirdneau Sandstone are possible reservoir rocks for gas. Other commodities with possible economic interest include phosphate pellets from the Little Flat Formation, calcium carbonate, pure silica, and water.

Quaternary and Tertiary units slid on underlying Devonian and Mississippian Formations to form a landslide, 1300 feet (396 m) long and 1500 feet (457 m) wide, north of Porcupine Reservoir in 1983-1984. The reservoir was not damaged.

[1] Graduate, Department of Geology, Brigham Young University, Provo, Utah.

INTRODUCTION

The Porcupine Reservoir quadrangle area is in the southern Bear River Range of northern Utah approximately 4 miles (6.4 km) east of the town of Paradise. The Bear River Range is included in the Middle Rocky Mountain physiographic province. Maximum relief in the area is about 3300 feet (1005 m); altitudes range up to 8529 feet (2600 m) near the head of Miles Canyon. Blacksmith Fork Canyon, in the northern part of the Porcupine Reservoir quadrangle, is known for its complete and well-exposed Paleozoic section and has been a mecca for stratigraphers for over 100 years (Walcott, 1908a,b; Deiss, 1938; Williams and Maxey, 1941). Geologic maps of the area are outdated and of small scale, therefore an updated map and better delineation of Paleozoic stratigraphy and structure of the Porcupine Reservoir quadrangle are the emphasis of this study.

The geology of the Porcupine Reservoir quadrangle was investigated by Williams (1948) as part of his study of the Logan 30-minute quadrangle. Dover (1985) also produced a map of the Logan 30-minute quadrangle from a study of aerial photographs. Stratigraphic studies of many individual formations have been published by Williams and Maxey (1941), Richardson (1941), Williams (1948, 1971, 1973), Ross (1949), Holland (1952), Dutro and Sando (1963), Sando (1967), Rigo (1968), Sandberg and Gutschick (1969), VanDorston (1970), Oriel and Armstrong (1971), Palmer (1971), Crittenden (1972), Sando, Dutro and others (1976), Sandberg and Poole (1977), Sandberg and Gutschick (1979), Gutschick and others (1980), Sandberg and others (1981), Taylor and others (1981), Taylor and Landing (1982). In addition, several Utah State University students including Mecham (1947), Haynie (1957), Hafen (1961), Budge (1966), Eliason (1969), Gardiner (1974), Wakely (1975), Buterbaugh (1982), and Deputy (1984) have unpublished theses that feature aspects of stratigraphy of the area.

Field work for this study was completed in the summers of 1983-1985 with David Berry as field assistant. Numerous outcrops, which allowed measurement of attitudes shown on the map, were exposed in Hyrum Canyon, Paradise Dry Canyon, Third Canyon, and roadcuts in the Bear Flat area during excavation of the Mountain Fuel pipeline. Many of these outcrops, along with others, were also buried with the pipes in 1985.

STRATIGRAPHY

Blacksmith Fork Canyon provides easy access to excellent exposures of late Precambrian-Cambrian Geertsen Canyon Quartzite to Devonian Beirdneau Sandstone, generally with only minor structural complications except for extensive faulting in the Cambrian Langston Formation (plate 1). Very thick sequences of marine carbonates and clastics composing these formations were deposited in the Cordilleran miogeosyncline (Armstrong, 1968; Hintze, 1973). The end of the miogeosyncline in this area in Late Devonian time is reflected by the regional unconformity at the base of the Devonian Leatham Formation (Hintze, 1973; Sandberg and Gutschick, 1979). Mississippian rocks were deposited during two major marine transgressions (Poole and Sandberg, 1977), and the Oquirrh Basin also developed during this period followed by Pennsylvanian Wells Formation deposition along the basin flanks. Precambrian to Pennsylvanian strata were later thrust eastward as part of the Cache allochthon or upper plate of the Paris thrust (Crittenden, 1972). Various Quaternary units unconformably overlie continental Tertiary formations and, together, these Cenozoic deposits unconformably overlie Proterozoic and Paleozoic strata.

Stratigraphers specializing in paleoenvironmental interpretation have coined member names for many of the formational units in this area based on exceptional exposures of a single stratigraphic section. Some of these units are too thin to show at the scale of the map and, in most cases, it has not been possible to map them because poor exposures do not allow them to be traced.

PRECAMBRIAN AND CAMBRIAN

Browns Hole Formation (Precambrian)

The Browns Hole Formation, composed of quartzite and some volcanic rocks, lies below the Geertsen Canyon Quartzite (cross-section B-B', plate 2) (Crittenden and others, 1971) but is not exposed at the surface in this quadrangle.

Geertsen Canyon Quartzite (Late Precambrian to Cambrian)

The oldest rocks exposed in this quadrangle are assigned to the Geertsen Canyon Quartzite of the Brigham Group, following Crittenden and others (1971). The base of the formation is not exposed in this quadrangle, however, the formation is 4200 feet (1280 m) thick in the type section 5 miles (8 km) north of Huntsville, Utah (Crittenden and others, 1971). The quartzite is reddish brown, brown, pink, and greenish brown with light gray and shades of brown being most common on fresh surfaces. Grain sizes range from fine to very coarse; lenses and beds of pebble conglomerate, along with scattered pebbles, are common in the lower portion of the exposed section (SE corner of the quadrangle). Bedding is thick to massive and small-scale crossbeds are common. Exposures on slopes are typically expressed as blocky outcrops and as scattered rubble on relatively horizontal surfaces.

> In the upper few hundred feet *Scolithus* is common in greenish brown beds. At the top of the formation, shale partings separate thin beds of quartzite. This "shaly" facies grades into the sandy limestone and dolomite beds of the overlying Langston without indication of hiatus (Williams, 1948).

Oriel and Armstrong (1971) indicated that the top of the Brigham Group in southeast Idaho transgresses eastward, resulting in progressively younger ages toward the east. A paucity of fossils has made unequivocal age assignments difficult; Crittenden and others (1971) assigned the formation an Early (?) Cambrian and Precambrian age at Huntsville, Utah, and Oriel and Armstrong (1971) and Palmer (1971) supported an early Middle Cambrian and older age assignment in the Bear River Range.

Langston Formation (Cambrian)

A type section of the Langston Formation, 380 feet (115.8 m) thick, in South Cottonwood Canyon (type section was originally designated in Blacksmith Fork Canyon by Walcott, 1908b, and later amended and clarified by Williams and Maxey, 1941) consists of a middle limestone member between upper and lower dolomite members. Limestone and shale (Naomi Peak Limestone Member and Spence Shale Member) intertongue near the base of the formation in the East Canyon section, 413 feet (125.8 m) thick (Rigo, 1968). Members were not mapped separately because of limited exposures and cover.

The dolomite is medium bluish gray to very light gray, medium to coarsely crystalline and medium to thick bedded. Conspicuous subrounded dark bluish-gray grains, possibly chert, are commonly scattered through the medium-bluish-gray dolomite. Weathered outcrops are generally rounded and inconspicuous, grainy in texture, and moderate to dark reddish brown, which effectively distinguishes them from other dolomites in the area.

The Naomi Peak Limestone Member is a thin-bedded lime mudstone, medium to dark bluish-gray on fresh and weathered surfaces. The upper Langston Formation limestone is thin to medium-bedded mudstone to packstone, medium to dark gray on fresh and weathered surfaces, with abundant oolites, pisolites, intraformational conglomerates, and shale partings. Occasional thin (1-2 feet; .3-.6 m) beds of shale are intercalated with the upper limestone beds. The shale is micaceous, thinly laminated and light olive brown to dusky yellow.

The gradational basal contact is placed at the base of the first limestone bed above the Geertsen Canyon Quartzite. The Langston Formation accumulated mostly in upper peritidal and inner carbonate shelf environments; its shales were deposited in outer and inner clastic shelf environments (Buterbaugh, 1982; as determined for sections including East Canyon and Blacksmith Fork Canyon).Fossils recovered include *Glossopleura* sp. (fossil location 1-1 shown on plate 1) identified by Dr. Lehi Hintze during a field inspection (September 22, 1984). This form is assigned to the *Glossopleura* zone of the Middle Cambrian.

Ute Limestone (Cambrian)

Thin-bedded limestone and shale of the Ute Limestone conformably overlie the Langston Formation and underlie the Blacksmith Dolomite. Blacksmith Fork Canyon was selected as the type locality in 1908 by Walcott. The Ute Limestone thickens from 665 feet (202 m) in the Left Fork of Blacksmith Fork Canyon (Williams, 1948) to 840 feet (256 m) in East Canyon, as measured by Rigo (1968). The limestone ranges from lime mudstone to grainstone with rare pisolites and abundant intraformational breccia and oolites, commonly stained reddish brown on both fresh and weathered surfaces. Fresh surfaces of limestone are medium to dark bluish gray. Thin-bedded silty limestone weathering moderate reddish brown and associated with a soil of the same color is common at the base of the formation. Pisolitic and oolitic wackestones to packstones frequently overlie this basal bed.

Interbedded shale is light olive brown to dusky yellow, micaceous and thinly laminated, similar to shale in the Langston Formation. Although shale is restricted to the lower part of the formation, slightly coarser terrigenous clastics are common in upper beds. Bedding surfaces of the limestone vary from planar, smooth and rounded to dimpled and rough to undulatory, separated by silt laminae of light brown, light orangish brown, reddish brown or moderate red to pink.

The Ute Limestone is slightly less resistant than the Langston and considerably less resistant than the Blacksmith Dolomite; however, its limestone beds frequently form ledges. The lower contact is drawn at the base of the first limestone above the Langston dolomite beds. The Ute and Langston intertongue in the East Canyon section but the contact is conformable elsewhere. A few sinkholes in the Ute are found in the area between East Canyon and Bear Flat.

A north-trending shoal, separating a deep-water shelf to the west from a shallow shelf and lagoon to the east, was the site of deposition for sediments of the Ute Limestone, as determined from sections including Blacksmith Fork Canyon (Deputy, 1984).

The following fossils were collected from the Ute Limestone and identified by R.A. Robison (trilobites), A.J. Rowell (brachiopods), and J.K. Rigby (sponges):

Fossil sample and location 2-1 shown on plate 1	
Ehmaniella sp.	group 1
Fossil sample and location 2-2 shown on plate 1	
Prototreta attenuata (Meek)	
Linnarssonia ophirensis (Walcott)	
Acrothele sp.	
Lingulella sp.	group 2
Eoorthid gen and sp. indet.	
Cambrotrophia sp.	
Alistokare sp.	
Fossil sample and location 2-3 shown on plate 1	
Protospongia fenestrata (Salter)	group 3
Bathyuriscus sp.	
Elrathina sp.	
Kootenia burgessensis (Resser)	
Onymagnostus seminula (Whitehouse)	group 4
Peronopsis fallax (Linnarsson)	
Semisphaerocephalus sp.	
Zacanthoides sp.	
ptychopariid, n. gen. and n. sp.?	

The *Ehmaniella* sp. coquina is representative of the *Ehmaniella* zone; the second group of fossils represents brachiopods; and the third group, a sponge, is associated with the fourth group of fossils, a trilobite assemblage, representing the *Ptychagnostus gibbus* zone. A Middle Cambrian age is assigned to the Ute Limestone.

Blacksmith Dolomite (Cambrian)

The cliff-forming, medium to thick-bedded and massive dolomite of the Blacksmith Dolomite contrasts sharply with the weaker overlying and underlying shaly formations. Walcott named Blacksmith Fork Canyon as the type locality for Blacksmith Limestone in 1908. This formation varies in thickness from 325 feet (99 m) north of the quadrangle in the Left Fork of Blacksmith Fork Canyon (Williams, 1948) to 477 feet (145 m) in East Canyon (Rigo, 1968).

The dolomite is dominantly light to very light gray and medium gray on fresh and weathered surfaces and fine to coarsely crystalline with common occurrences of oolites and boundstone. Surfaces of weathered outcrops vary from grainy with a "sugary" appearance to relatively smooth where laminated as a boundstone. Small-scale crossbeds occur throughout the formation, and a thin limestone bed is typically found a few feet below the upper contact. The lower contact is placed at the base of the first dolomite bed above the limestone of the Ute. This contact is slightly gradational in East Canyon, but unconformable elsewhere.

Blacksmith Dolomite accumulated in marine environments including supratidal, intertidal, open and restricted platform, and shoal facies, determined from sections in northernmost Utah and southeast Idaho (Zelazek, 1981). No fossils were found in this formation, but small irregular calcite blebs that weather in relief are abundant and interpreted as recrystallized trace fossils. A late Middle Cambrian age is assigned to the Blacksmith Dolomite (Palmer, 1971).

Bloomington Formation (Cambrian)

The Bloomington Formation strongly resembles the Ute Limestone and, without the intervening Blacksmith Dolomite, the two would be difficult to differentiate. The Bloomington can be divided into four members, a lower shale (Hodges Shale) 400-500 feet (122-152 m) thick, lower limestone 500-600 feet (152-183 m) thick, upper shale (Calls Fort) 150-250 feet (46-76 m) thick, and upper limestone 40-150 feet (12-45 m) thick (Williams, 1948). The Calls Fort Shale and the upper limestone are combined and mapped as a unit, but extensive cover and faulting inhibit delineation of the lower members. All members are easily distinguished in Blacksmith Fork Canyon but undergo facies changes to the south where carbonates thicken and shales thin. Dolomitization of the upper portion of the upper limestone is also pervasive toward East Canyon. A faulted section of the Bloomington is 482 feet (147 m) thick in East Canyon (Rigo, 1968), but the complete formation ranges between 1200-1400 feet (365-427 m) thick throughout the rest of the quadrangle. This formation forms ledges and slopes.

Holdges Shale Member consists of interbedded limestone and light olive-brown to dusky-yellow shale that alternates with thinner sections of strictly shale. The Calls Fort Shale Member is also a light olive-brown to dusky-yellow shale but contains less limestone.

Lower and upper limestones are medium to dark-bluish-gray lime mudstones to packstones, thinly bedded, occasionally oolitic, and locally contain thin silty interbeds in varied light shades of brown, pink, red, and orange. A dolomite bed intertongues in the upper half of the lower limestone member and thickens toward East Canyon. The top of the lower limestone member is marked by a distinctive sequence, including a bed two feet (.6 m) thick of black chert, overlain by a 4- to 15-foot-thick (1.2-4.5 m) bed of white-weathering dolomite boundstone which, in turn, is overlain by a thicker sequence of crossbedded oolitic lime mudstone to packstone. The upper limestone member contains an intraformational conglomerate that exhibits a "jigsaw puzzle" pattern on bedding surfaces. These marker beds, along with the members, satisfactorily distinguish this formation from the Ute Limestone.

The lower conformable contact is placed at the base of the first shale above the Blacksmith Dolomite (Williams, 1948). This contact is gradational in East Canyon. Numerous sinkholes are found in the Bloomington Formation between East Canyon and Bear Flat. Lower intertidal to shallow subtidal environments are suggested by M.E. Taylor (written communication to C.G. Oviatt, Dec. 12, 1984) for deposition of this formation. I did not find fossils in this formation, but faunas have been collected by previous workers. A Middle Cambrian age is assigned to the Bloomington Formation (Palmer, 1971).

Nounan Dolomite (Cambrian)

Thin- to medium-bedded dolomite and limestone of the Nounan Dolomite conformably overlie and disconformably underlie adjacent formations (Williams, 1948). Thickness of the formation ranges from 1070 feet (326 m) in Blacksmith Fork Canyon (Gardiner, 1974) to approximately 1125 feet (343 m) in East Canyon. Gardiner's (1974) subdivision of the Nounan into three members was not followed in this report due to lack of distinctive lithologies in the lower and middle members. The upper member, based on the appearance of terrigenous material and limestone, is lithologically distinct, although thin in this quadrangle, and was not mapped separately.

Two types of dolomite make up the Nounan Dolomite; the most common type is fine to medium grained, medium light to medium dark gray, weathering light to medium gray, with common occurrences of bioturbation and ghosts of relict grains. Shapes of relict grains resemble intraclasts, bioclasts, ooids, oncolites and pellets. Outcrops are usually low, rounded and often isolated, with a rough irregular surface. However, in Blacksmith Fork Canyon the base of the formation composed of this lithologic type is an irregular cliff former.

The second and less abundant type of dolomite is light gray to white, weathering light gray, and ranges from a very finely crystalline laminated boundstone to a medium to very coarsely crystalline dolomite. The lighter color and cliff-forming topographic expression of this dolomite contrast sharply with the dominant darker dolomite. Both dolomite types are interbedded throughout the Nounan Dolomite.

A limestone sequence, approximately 30 feet (9.1 m) below the upper contact, is 15 to 25 feet (4.5-7.6 m) thick (Gardiner, 1974). It is thin bedded, medium brownish gray to dark gray, weathering medium gray. Lithology ranges from a lime mudstone to packstone with abundant oolites and Bromella n. sp. trilobite skeletal debris and common silty interbeds.

Near the contact with the overlying Worm Creek Quartzite Member of the St. Charles Formation, a bed of dolomitized oolitic to oncolitic wackestone is overlain by a dolomitic sandstone and dolomite sequence weathering reddish to yellowish brown and containing quartz and feldspar sand grains (Gardiner, 1974). Total thickness of the sandstone and dolomite sequence ranges considerably throughout the quadrangle, reaching a maximum of approximately 75 feet (23 m) south of the switchbacks on the west side of Devils Gate Canyon.

The lower conformable contact was placed at the base of the first dolomite above the upper limestone member of the Bloomington Formation. Where dolomitization has penetrated the upper Bloomington, relict textures of the rock are generally preserved and make the contact distinguishable. Numerous sinkholes in the Nounan Dolomite are found in the area between East Canyon and Bear Flat. Shallow subtidal and intertidal environments were suggested by Gardiner (1974) for the deposition of the Nounan Dolomite.

Fossils recovered from the limestone beds of the upper Nounan (collection site located in Logan Peak quadrangle, south of Utah Highway 101 and directly south of the abutment of the second dam in Blacksmith Fork Canyon, approximately 30 feet (9 m) below the upper contact) include *Bromella* n. sp. of the *Prehousia* zone identified by A.R. Palmer (January 28, 1985). Williams (1948) and M.E. Taylor (written communication to C.G. Oviatt, December 19, 1984) assign a Middle to Late Cambrian age to the formation.

ORDOVICIAN AND SILURIAN

St. Charles Formation (Cambrian-Ordovician)

The St. Charles Formation is divided into a basal quartzite unit, the Worm Creek Quartzite Member, 60 feet (18.3 m) thick in East Canyon (Rigo, 1968), and an upper massive cliff-forming dolomite and limestone unit. A formational thickness of approximately 972 feet (296 m) measured in East Canyon (Hafen, 1961) is representative of the quadrangle. The Worm Creek Quartzite is too thin to map separately.

The Worm Creek Quartzite Member contains a bed three feet (.9 m) thick of quartzite overlain by finely crystalline dolomite, light to medium gray, weathering gray to yellowish brown, and thin to medium bedded. The quartzite is very fine to medium grained, pale yellow to yellowish brown, weathering from light to yellowish brown to shades of red, pink and purple.

The upper unit is characterized by banded light and dark gray dolomite in layers approximately 10 to 30 feet (3-9 m) thick. Thin sections of limestone are occasionally interbedded with the dolomite, most notably above the Worm Creek Quartzite. The light dolomite is fine to medium crystalline, medium to thick bedded with gray chert nodules and stringers. Bold cliffs in East Canyon are formed by this dolomite. The dark dolomite is medium to coarsely crystalline, medium to thick bedded, commonly bioturbated and mottled with small white calcareous blebs and veins that are more resistant to weathering. The weathered surface of this dolomite frequently appears grainy and massive. It has a fetid odor when broken.

Two distinctive beds, a dark gray oncolitic dolomite overlain by a thin white-weathering, dark-bluish-gray lime wackestone, mark the upper part of the upper dolomite and limestone unit. The limestone is laminated to thin bedded, light to medium gray, weathering medium to dark gray, and ranges from lime mudstone to packstone with common light brown weathering calcisiltite interbeds. This limestone strongly resembles some Ute, Bloomington, and Garden City limestones and forms slopes. A few sinkholes in the St. Charles Formation were found in the area between East Canyon and Bear Flat.

The lower disconformable(?) (Williams, 1948) contact is placed at the base of the first quartzite bed of the Worm Creek Quartzite Member above the Nounan Dolomite. Sediments of the St. Charles Formation were deposited in shallow water peritidal environments (M.E. Taylor, written communication to C.G. Oviatt, 1984; and Wakeley, 1975, sections in Preston and Soda Springs quadrangles, southeast Idaho). Molluscs were recovered from the upper dolomite unit. Previous workers have collected trilobites and brachiopods (M.E. Taylor, written communication to C.G. Oviatt, 1984; Williams and Maxey, 1941; Taylor and Landing, 1982). A Late Cambrian to Early Ordovician age has been assigned to the St. Charles Formation, and the Cambrian-Ordovician boundary is approximately 45 feet (13.7 m) below the top of the formation in Blacksmith Fork Canyon (Taylor and Landing, 1982).

Garden City Limestone (Ordovician)

The Garden City Limestone is composed dominantly of interbedded crystalline and fossiliferous limestone, intraformational conglomerate, lime mudstone and muddy limestone with silty interbeds and lenses. Dolomitic limestone and dolomite, including nodules, stringers, and beds of black chert, form the upper part of the formation. The limestone is thin to medium bedded, ranges from mudstone to grainstone, medium to dark bluish gray, weathers light to medium bluish gray with abundant mudcracks. Tan to red silty interbeds and lenses commonly weather in relief and are often deformed. The dolomite is fine to medium crystalline, and medium gray, weathering light to medium gray. The black chert weathers light brownish orange and forms nodules in limestone beds at its lowest occurrence, increasing to stringers and beds up section. Thicker bedded sections of limestone form ledges between remaining slope-forming sequences. Measured thicknesses of the formation are reported by Ross (1949) as 1160 feet (354 m) in Blacksmith Fork Canyon, increasing to 1500 feet (457 m) in the Sharp Mountain quadrangle directly south (Hafen, 1961).

The lower disconformable contact (Taylor and others, 1981; Taylor and Landing, 1982) is placed at the base of a quartz arenite bed in East Canyon and at the base of a dolomitic siltstone in Hyrum Canyon that overlies the pisolitic dolomite and white-weathering limestone beds of the St. Charles upper dolomite unit.

Ross (1949) interpreted the Garden City Limestone as a shallow marine deposit: trilobites, gastropods, crinoids, nautiloids and brachiopods were observed in the formation. Ross (1949) collected numerous taxa and established faunal zones based primarily on trilobites from numerous northern Utah sections including one in Blacksmith Fork Canyon. The Garden City Limestone is Early to Middle Ordovician.

Swan Peak Formation (Ordovician)

The Swan Peak Formation thins from 105 feet (32 m) in Blacksmith Fork Canyon (Ross, 1949) to 30 feet (9 m) in East Canyon (Francis, 1972) and is completely absent east and south of the quadrangle. In this quadrangle, only the lowest of three members recognized by Francis is represented; mid-Paleozoic erosion was apparently responsible for removal of the upper two quartzite members (Williams, 1948). Surface expression is poor. Slabs of rock two to four inches (7-14 cm) thick are sparsely scattered on slopes of the formation between limited subcrop exposures.

Interbedded shale is medium gray to greenish gray and alternates in 1- to 3-inch (3.5-10.6 cm) beds with thin to laminated quartzite and sandstone. The quartzite is very fine grained and light yellowish gray, gray to reddish orange, weathering shades of yellow, pink to purple to orange. The sandstone and quartzite are similar colors, excepting light yellowish gray, and the fresh surfaces of both are frequently finely streaked in more than one shade. The sandstone is fine to very fine grained and ranges from quartz arenite to quartz wackestone.

Feeding burrows or "fucoid traces" throughout most quartzite beds are abundant (VanDorston, 1970). The limy dolomite, most common at the base of the formation, is finely crystalline, medium to dark brownish gray, and weathers medium to dark gray to yellowish brown.

The conformable and gradational basal contact (Williams, 1948) is placed at the base of the lowest quartzite or sandstone bed above the Garden City Limestone. Shallow shelf and shore-face environments were suggested as the sites of deposition by VanDorston (1970) and Francis (1972) from sections including Blacksmith Fork Canyon and East Canyon.

A single brachiopod specimen, *Orthambonites* sp., was recovered during this study. Detail studies (Ross, 1949; Van Dorston, 1970; Francis, 1972) have produced varied collections. The Swan Peak Formation is Middle Ordovician in age (Williams, 1948; Ross, 1949).

Fish Haven Dolomite (Ordovician to Silurian)

Conspicuous dark gray cliffs form isolated vertical projections at most exposures of the Fish Haven Dolomite. The formation is 140 feet (43 m) thick in Blacksmith Fork Canyon (Mecham, 1973) and thins to 125 feet (38 m) south of East Canyon (Hafen, 1961). The dolomite is thick to very thick bedded, fine to coarsely crystalline, usually dark gray on both fresh and weathered surfaces, but occasionally medium gray as found on Porcupine Ridge (plate 1). Although relict textures are largely obscured, crinoidal bioclasts locally comprise up to 20 or 30 percent of the rock, and medium gray chert occurs in some beds as scattered nodules and lenses, comprising up to 10 percent of the rock. Well preserved specimens of corals are common. Surfaces of outcrops are typically rough and irregular; with a granular texture if coarsely crystalline.

The unconformable basal contact (Williams, 1948) is placed at the base of the thick dolomite overlying the thinly bedded quartzite, sandstone and shale of the Swan Peak Formation. Rich (1981) suggested an open marine shelf environment for deposition of the Fish Haven Dolomite from sections in the Logan area. Crinoidal bioclasts and corals, including *Halysites* sp., were recovered from this formation. The Fish Haven is assigned a Late Ordovician (Latest Edenian) to Early Silurian age by Leatham (1985) on the basis of conodont studies.

Laketown Dolomite (Silurian)

Massive vertical cliffs expose the thick section of Laketown Dolomite, which measures 1610 feet (490.7 m) in Blacksmith Fork Canyon (Budge, 1966) but thins to 1240 feet (377.9 m) in the Sharp Mountain quadrangle directly to the south (Hafen, 1961). Light to medium-gray dolomite is most common, although weathered and fresh surfaces range from very light to dark gray. The dolomite is very fine to medium crystalline, thin to thick bedded, infrequently laminated and commonly bioturbated and mottled light and medium to dark gray. Gray chert, 5 to 10 feet (1.5-3 m) thick, marks the upper Laketown and a 5 to 10-foot-thick (1.5-3 m) bed rich in 2 to 3-inch (7-10.5 cm) brachiopods is found in the middle of the formation. White to medium-gray chert lenses, layers, and nodules comprise from 20 to 50 percent of the light to medium-gray dolomite host in the lower 100 feet (30 m) of the Laketown, making it conspicuously chertier than the Fish Haven.

For field mapping purposes the lower disconformable contact (Leatham, 1985) is placed above the upper darker gray dolomite of the Fish Haven, which commonly weathers to granular rubble in this quadrangle. Lighter gray chert-rich Laketown Dolomite beds lie above the contact. Neritic and littoral marine environments were proposed by Budge (1966) for the deposition of the Laketown Dolomite. Pentamerid brachiopods, solitary corals, and algae were recovered from this formation. Budge (1966) collected fossil annelids, cephalopods, coelenterates, crinoids, and algae. The Laketown Dolomite is Early to Late Silurian in age (Leatham, 1985).

DEVONIAN

Water Canyon Formation (Devonian)

The red, purple, white and gray rocks of the Water Canyon Formation are some of the most colorful and least resistant in the quadrangle. Williams and Taylor (1964) measured 245 feet (74.6 m) of this formation in Blacksmith Fork Canyon; however, Williams (1971, 1973) later declared the upper intraformational breccia ledges to be part of the Hyrum Dolomite, decreasing the thickness of the Water Canyon Formation to approximately 208 feet (63 m).

Two members, named by Williams and Taylor (1964) as the lower Card Member (93 feet; 28.3 m thick) and upper Grassy Flat Member (115 feet; 35 m), make up the formation. Neither member was separately mapped because of poor exposures and thin units. The Card Member consists of thin to laminated beds of white or very light-gray-weathering, light brownish-gray boundstone. The Grassy Flat Member is a sequence of interbedded dolomitic siltstone and finely crystalline dolomite which grade upsection into medium and coarsely crystalline limestone. Very thin beds of dolomitic siltstone range from purplish red to gray to shades of brown and yellow on both weathered and fresh surfaces, and chips are typically found as scattered float on slopes. Thin- to medium-bedded dolomite is white to light gray and weathers reddish brown or light yellowish or brownish gray. The limestone is medium to dark gray on fresh and weathered surfaces, changing to reddish or orangish brown or light to moderate red on fresh and weathered surfaces where beds are contorted and contain intraformational breccia. Mudcracks and laminations are common throughout the formation.

The disconformable lower contact (Williams, 1948) is placed at the base of the slope-forming, thinly bedded, white-weathering boundstone that overlies the darker, massive, cliff-forming dolomite of the Laketown.

Although an unequivocal marine or fresh water origin for the Water Canyon Formation has not been determined, Williams and Taylor (1964) favor a shallow marine neritic to littoral zone environment for deposition.

I did not find any fossils in this formation, but Denison's studies (1952, 1958) have identified important fish and other faunal elements. The Water Canyon Formation is Early Devonian in age (Denison, 1958; Williams, 1948).

Hyrum Dolomite (Devonian)

Ledge-forming dolomite, dolomitic limestone, limestone and minor quartzite overlie the basal Samaria Limestone Member of the Hyrum Dolomite. In Blacksmith Fork Canyon, the complete Hyrum Dolomite is 932 feet (284 m) thick and the Samaria Limestone Member is 134 feet (40.8 m) thick (Williams, 1971; Eliason, 1969). The formation is extensively faulted in the southern half of the quadrangle. The Samaria Limestone Member was not mapped separately because of poor exposure and cover.

The Samaria Limestone Member, dominantly medium to dark gray on fresh weathered surfaces, is thin- to medium-bedded dolomite, silty dolomite and limestone. The basal part of the member is three rounded limestone ledges that are either medium to coarsely crystalline carbonates or multicolored (shades of yellow, pink, orange, brown and light to dark gray) intraformational breccias whose clasts and matrix are composed of lime mudstone that is typically laminated. A very thin bed of very fine-grained dolomitic sandstone lies above the ledges.

A marked increase in quartz sand content and grain size toward the south is apparent in the dolomite, dolomitic limestone, limestone and quartzite overlying the Samaria Limestone Member. The carbonates range from laminated to thick bedded, light gray to dark gray on fresh and weathered surfaces, and very fine to coarsely crystalline. The dark gray dolomite usually has a fetid odor when freshly broken and crumbles to sand-size particles where deeply weathered. A terrigenous component, silt in northern sections and sand in southern sections, is common in some beds. Brecciation, contortions and deformation of the carbonates is also common. A striking and characteristic dolomite lithology, occurring as either entire beds or lenses throughout the formation, is a breccia composed of dark-gray clasts in a nearly white calcite matrix. The quartzitic to dolomitic sandstone beds are very fine to medium grained, laminated to medium bedded and light gray to light yellowish gray, weathering light gray to yellowish brown. The number of sandstone beds doubles from two in the Blacksmith Fork Canyon to four in southern sections, allowing for some uncertainty caused by extensive faulting. The lower disconformable contact is placed at the base of three rounded limestone ledges that overlie the lighter Water Canyon sediments.

A basin near the edge of the miogeosyncline was the site of accumulation of the Hyrum Dolomite. The sandstone beds were deposited in a shallow near-shore environment (Williams, 1971). Brachiopods, corals and conodonts are among the fauna recovered from the Samaria Limestone Member by Williams (1971) and Eliason (1969) during extensive collecting of the entire formation. No fossils were discovered during this study.

The Samaria Limestone Member is of Middle Devonian age and the top of the Beirdneau Sandstone is Middle Famennian, uppermost Devonian (Williams, 1971; Sandberg and Poole, 1977). No fossils have been recovered between the top of the Samaria Limestone Member of the Hyrum Dolomite and the top of the Beirdneau Sandstone. Therefore, Frasnian and earliest Famennian times (upper to uppermost Devonian) are represented in the barren interval (Williams, 1971).

Beirdneau Sandstone (Devonian)

The entire Beirdneau Sandstone is clearly exposed in Blacksmith Fork Canyon but elsewhere is covered, poorly exposed, or extensively faulted, making it difficult to map members separately. The formation in Blacksmith Fork Canyon is 1087 feet (331 m) thick in the far northwest corner of the quadrangle, but it thins depositionally to 937 feet (286 m) thick eastward at the forks of the canyon in Section 3, T 10 N, R 2 E (Williams, 1971). Mullens and Izett (1964) reported a maximum thickness of 710 feet (216 m) in the Paradise quadrangle, directly to the west. Williams (1971) divided the formation into a middle sandstone member between upper and lower carbonate members.

The dolomitic and calcitic siltstone, sandstone and quartzite of the middle sandstone member are light to medium gray, light yellowish gray, pink to red, and yellowish to orangish brown on fresh and weathered surfaces. Bedding is thin to medium with abundant laminations, and grain size ranges from very fine to coarse. Distinctive lenses and beds of white chert are interbedded near the top of this member. Sandstone grades from quartz arenite to quartz mudstone with a dolomitic or calcitic matrix. The sandstone of the northern sections becomes quartzite to the south. Crossbeds, ripple marks, and mudcracks are common. One bed of note in this member is a quartz wackestone with a "tapioca pudding" texture. The well-rounded, fine grains of clear quartz are surrounded by a white calcitic matrix. Dolomite and limestone, the dominant lithologies of the lower and upper carbonate members, are thin to thick bedded, very fine to coarsely crystalline, light to medium gray, light yellowish gray, light to moderate yellowish orange to yellowish brown, and weather to the same colors, excluding light yellowish gray. If not crystalline, the carbonates are usually mudstone. Mudcracks and ripple marks are common and intraformational conglomerate, breccia, and contorted beds are found in some places. Grains of quartz sand and silt are found in varying percentages within the carbonates. The upper carbonate member is capped by a resistant 25-foot-thick (7.6 m) blocky bed of limestone, interbedded with arenaceous calcitic dolomite that is locally known as the "contact ledge." The formation forms scattered ledges and cliffs in steep canyons but in areas of less relief forms rounded, smoother slopes.

The lower gradational contact is placed at the base of the thin-bedded, arenaceous, carbonate sequence underlain by the Hyrum Dolomite and is marked by a color change from the gray Hyrum Dolomite to the earthy yellowish orange-brown Beirdneau Sandstone. The sediments of the Beirdneau were deposited in a very shallow sea and were occasionally exposed and subjected to tidal currents, according to Williams (1971).

Brachiopods (fossil location 3-1, plate 1) were collected during this study and by Williams (1971) from the top of the formation, and indicate that the section is Lower Famennian (uppermost Devonian). The "contact ledge" was described as

Middle Famennian (uppermost Devonian) by Sandberg and Poole (1977) from conodont collections. Frasnian and Middle Famennian times (upper to uppermost Devonian) are represented in the Hyrum Dolomite, above the Samaria Limestone Member, and in the Beirdneau Sandstone.

Leatham Formation (Devonian)

The Leatham Formation forms a slope, usually covered with either vegetation or talus from the overlying Lodgepole Limestone, between the "contact ledge" of the Beirdneau Sandstone and the lower cliff of the Lodgepole Limestone. The Leatham Formation is 85 feet (25.9 m) thick at its type locality in Leatham Hollow, north of Blacksmith Fork Canyon in the adjoining Logan Peak quadrangle (Holland, 1952; Sandberg and Poole, 1977). The formation thins under an erosional unconformity and is only 16 feet (4.8 m) thick immediately south of the Porcupine Dam (plate 1) (Sandberg and Gutschick, 1979). Here the Leatham also overlies a major regional unconformity (Sandberg and Gutschick, 1979). In contrast, Mullens and Izett (1964) reported a conformable Leatham-Lodgepole contact along parts of Blacksmith Fork Canyon in the Paradise quadrangle, directly to the west, where the Leatham reaches a thickness of 100 feet (30.5 m). Exposures in this quadrangle are usually limited to small chips of siltstone scattered in soil, except immediately north of Porcupine Reservoir where a roadcut exposes a thin, eroded section.

The Leatham Formation is composed of laminated to thin-bedded, light-gray to light yellowish-brown siltstone and medium-gray limestone. Siltstone dominates the lithology and locally is slightly to very calcareous. Near the base of the formation, the siltstone contains abundant pellets of limonite, forming a distinctive marker bed. The limestone ranges from lime mudstone to wackestone and is slightly more resistant than the siltstone. A few thin beds of calcareous sandstone are interbedded in the lower part of the Leatham.

The basal unconformable contact (Sandberg and Gutschick, 1979) is drawn at the base of the siltstone, limestone, and sandstone sequence that overlies the limestone beds of the "contact ledge" at the top of the Beirdneau Sandstone.

The lower Leatham sediments were deposited on the continental shelf and slope, and the upper sediments were accumulated in very shallow water environments including mudflats, offshore bars, and lagoons (Sandberg and Gutschick, 1979). An offshore open marine environment produced many of the limestone units (Sandberg and Gutschick, 1979). The age of the Leatham Formation is Late Devonian, determined by conodont studies by Sandberg and Poole (1977) and Sandberg and Gutschick (1979). Fossils were not recovered during this study.

MISSISSIPPIAN (OSAGEAN AND MERAMECIAN) AND PENNSYLVANIAN

Stratigraphic Terminology

Terminology in the Bear River Range for Mississippian stratigraphic units above the Lodgepole Limestone is problematic, a condition that will continue until a comprehensive comparative study of Mississippian sections in northern Utah and southern Idaho is undertaken. Nomenclature is presently drawn from two separate areas, the Chesterfield Range of southeast Idaho and the Oquirrh and East Tintic Mountains of north-central Utah. Usage of the term Brazer Limestone and its three members (A, B, and C) was widespread until Sando and others (1959) restricted the original term Brazer Dolomite to the Crawford Mountains of northern Utah. Deseret Limestone, Humbug Formation, and Great Blue Limestone are terms derived from the Oquirrh-East Tintic Mountains and have been used in several Utah State University theses involving the Bear River Range and by Oviatt (1986) in the Honeyville quadrangle of the Wasatch Mountains to the west.

Sandberg and Gutschick (1979) used "Little Flat Formation equivalent" and "Monroe Canyon Limestone equivalent," derived from southern Idaho, for the same sequence of rocks in a section adjacent to the Porcupine Dam (plate 1) in this quadrangle. Figure 1 compares these sets of terminology and their age relationships. The author, in accordance with Sandberg and Gutschick (1979), believes the terminology from southern Idaho (Little Flat Formation and Monroe Canyon Limestone) best represents and simplifies the Mississippian stratigraphic nomenclature in this quadrangle and is more similar lithologically when compared to type section descriptions. This report will show the preferred nomenclature on the map and will indicate equivalent units used previously in the text.

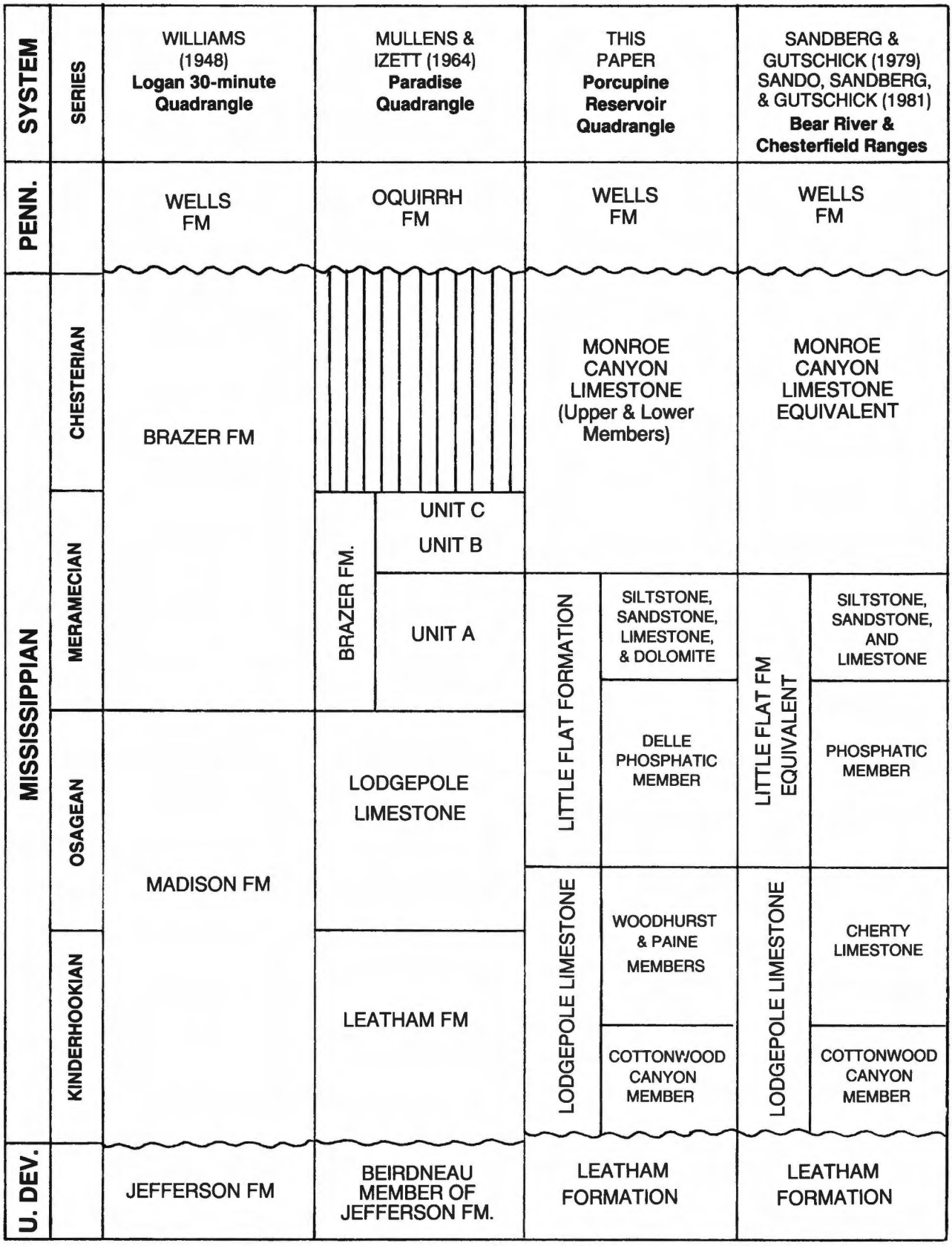
Lodgepole Limestone (Mississippian)

The Lodgepole Limestone is easily recognized on steep slopes, such as in Blacksmith Fork Canyon, by vertical upper and lower cliffs, locally known as the lower and upper Chinese Walls, separated by an intermediate slope. The formation is 690 feet (210.3 m) thick in Blacksmith Fork Canyon as measured by Mullens and Izett (1964) in the Paradise quadrangle, directly to the west, and 660 feet (201 m) thick just south of the Porcupine Reservoir in East Canyon (Sandberg and Gutschick, 1979).

Three members, Cottonwood Canyon, Paine, and Woodhurst, are recognized in Montana by Sando and Dutro (1974) and in Stansbury Island, northern Utah, by Sandberg and Gutschick (1979). The basal Cottonwood Canyon Member contains black shale, sandstone, and limestone north of Blacksmith Fork Canyon in Leatham Hollow (Sandberg and Gutschick, 1969). However, the Cottonwood Canyon Member in this quadrangle is very thin (about 25 feet or 7.6 m thick measured south of Porcupine Dam, plate 1; Sandberg and Gutschick, 1969) and is represented by a few beds of fine-grained sandstone. Members were not mapped separately due to extensive cover.

The Lodgepole Limestone is medium to dark gray on fresh and weathered surfaces, is locally chert rich, and is thin bedded with abundant megascopic fossils. It ranges from mudstone to packstone. Lenses and beds of coarse-grained limestone are more resistant than the fine-grained limestone. The Paine

Figure 1. *Mississippian comparative nomenclature chart.*



Member, although thin bedded, appears massive and contains up to 30 percent of dark gray or black chert nodules, lenses and ½ to 2-inch (1.7-7 cm) beds that often weather light yellow brown. This section is less fossiliferous than the overlying Woodhurst section.

The Woodhurst Member is cyclically bedded alternating ¼ to 3-inch (.9-10.6 cm) interbeds of light-yellow-brown calcisiltite or calcareous mudstone with gray limestone that is often tinted brown. The Woodhurst Member contains dolomitized beds and is capped by a persistent 10-foot-thick (3 m) bed of light-gray crystalline dolomite. Beds containing intraformational breccia and oolites are rare, while laminations are common throughout the formation.

The basal disconformable contact (Sandberg and Gutschick, 1979) is placed at the base of the chert-rich limestone overlying the dominantly siltstone sequence of the Leatham Formation. Open marine sandstone, foreslope limestone, and shallow slope to foreland basin limestone and calcisiltite, respectively, form the Cottonwood Canyon, Paine, and Woodhurst Members of the Lodgepole Limestone (Gutschick and others, 1980).

Gastropods, corals, brachiopods, crinoids and bryozoans are well preserved in the Lodgepole Limestone. Zonal identifications are given in terms of the coral zonation of Sando and Bamber (1985). Fossils collected during this study were identified by W.J. Sando and include:

Fossil sample and location (4-1) shown on plate 1, probably Coral zone I
- brachiopods, undet.
- Euomphalacean gastropods, undet.
- *Lophophyllum?* sp.
- *Amplexus* sp.

Fossil sample and location (4-2) shown on plate 1
- Euomphalacean gastropods, undet.
- (these fossils suggest the Paine Member)

Fossil sample and location (4-3) shown on plate 1, Coral zone II
- Euomphalacean gastropods, undet.
- *Vesiculophyllum* sp.
- *Sychnoelasma* sp.
- (these fossils are common in the Woodhurst Member)

Conodonts were studied by Sandberg and Gutschick (1969), and Newman (1980) and Holland (1952) completed general faunal descriptions. An Early Mississippian age (Kinderhookian and Osagean) was assigned to the Lodgepole Limestone (Sandberg and Gutschick, 1969).

Little Flat Formation (Mississippian)

This formation measures 1206 feet (367.6) thick in Blacksmith Fork Canyon (Member A of Brazer Limestone of Mullens and Izett, 1964, fig. 2) and is dominantly quartz sandstone or siltstone, with occasional beds of limestone or dolomite and a phosphatic zone at the base. Exposure is usually poor or covered in the quadrangle. The basal Delle Phosphatic Member consists of 30 to 50 feet (9.1-15.2 m) (Sandberg and Gutschick,1979) of black phosphatic chert, brown shale, siltstone and dark gray limestone. Often found as small, blocky chips in soil, the black chert breaks with a hackly fracture and is frequently dotted with rounded,white ⅛ to 1/16-inch (.4-.2 cm) diameter phosphate pellets or bloom. Thinly laminated shale to mudstone or claystone ranges from brown to brownish gray and is usually covered, but occasionally it is seen as a concentration of very small platy chips. The siltstone and limestone are similar to the overlying rocks.

The overlying sandstone, siltstone, limestone, and dolomite form the remainder of the Little Flat Formation. The fine- to very fine-grained sandstone to siltstone is thin to thick bedded and light yellow to gray to yellowish orange. It weathers orangish, yellowish, or grayish brown. The framework is mainly rounded quartz grains with minor feldspar and a silty, siliceous matrix that is infrequently calcareous. Limestone, more abundant in the upper half of the formation, and dolomite, forming a few beds only in the lower part of the formation, together comprise less than one-eighth of the formation. The limestone is dark gray to black, weathering medium to dark gray, thin to thick bedded, and occasionally bioclastic, fetid, and cherty. The sand component in the upper limestone beds is reflected by a sandy weathering surface, closely resembling the surfaces of the interbedded sandstones and siltstones. The dolomite is fine to medium crystalline and light gray on fresh and weathered surfaces. The formation forms slopes with ledges of both sandstone and limestone.

The contact with the Lodgepole Limestone is conformable. The Delle Phosphatic Member was deposited in a starved basin receiving dominantly fine-grained, terrigenous sediments, an abrupt change from the shelf environment depositing carbonates of the Lodgepole Limestone (Sando and others, 1976). The rest of the beds comprising the upper part of the Little Flat Formation are shallow water, open-marine deposits (Sando, 1967).

Coral and conodont zones have been studied by Dutro and Sando (1963) and Sandberg and Gutschick (1979). The Delle Phosphatic Member is Early Osagean to Early Meramecian in age and the age of the remainder of the Little Flat Formation is Early to Middle Meramecian (Sandberg and Gutschick, 1979).

Monroe Canyon Limestone (Mississippian)

A siltstone unit 6 feet (1.8 m) thick separates two thick limestone sequences that make up the Monroe Canyon Limestone in the Bear River Range. The lower limestone, 500-650 feet (152-198 m) thick, is a massive cliff former and is well exposed in Hyrum and Paradise Dry Canyons (plate 1). The upper limestone, 250-500 feet (76-152 m) thick, forms ledgy slopes and, like the middle shale-siltstone, is poorly exposed. This formation was measured by Mullens and Izett (1963) in Blacksmith Fork Canyon in the adjacent Paradise quadrangle where they called it Member B and C of the Brazer Limestone.

The upper and lower limestone is thin to massively bedded, fetid, and medium to dark gray on fresh and weathered surfaces, but locally it may be brownish gray and ranges from

mudstone to packstone. Some limestone is fine to medium crystalline. In places the limestone contains chert, intraformational conglomerate, oolites, crinoidal bioclasts and, most notably, large solitary corals. The nodular, lensoidal, and bedded chert is medium gray to black, comprising up to 20 percent of the host limestone, and is most abundant at the top of the lower limestone.

The middle siltstone is laminated to thin bedded and ranges from dark yellowish orange to yellowish brown, in sharp contrast to the dark gray limestone.

The lower gradational contact is placed at the base of the dominantly limestone sequence, above the sandstone-limestone beds of the Little Flat Formation. The Monroe Canyon Limestone was deposited in a shallow-water, open marine environment.

Fossils recovered during this study and identified by W.J. Sando, with coral zonation in terms of Sando and Bamber (1985) include:

Fossil sample and location 5-1 shown on plate 1, Coral zone IV

Gigantoproductoid brachiopods, undet.
Faberophyllum sp.
(these fossils suggest Monroe Canyon Limestone)

Fossil sample and location 5-2 shown on plate 1, Coral zone IV

Faberophyllum sp.
Acrocyathus? sp.
(these fossils suggest lower Monroe Canyon Limestone)

Fossil sample and location 5-3 shown on plate 1, Coral zone IV

Faberophyllum sp.
Bellophontacean gastropods, undet.
Clisiophyllum? sp
(these fossils suggest lower Monroe Canyon Limestone)

Dutro and Sando (1963) studied faunal zones based on corals and gastropods in southeast Idaho. In the Bear River Range and Wellsville Mountains, faunal zones based on corals, brachiopods, pelecypods, and cephalopods were discussed by Sweide (1977). The formation is Late Meramecian to Chesterian in age (Sando, 1967).

Wells Formation (Pennsylvanian)

The Wells Formation caps two divides along the western edge of the quadrangle (plate 1). Both exposures of the interbedded sandstone and limestone are largely covered with vegetation. Mullens and Izett (1963) measured a 385-foot (117.3 m) partial section of the formation in SE ¼, Section 30, T 10 N, R 2 E, a northwest-facing slope of the Hyrum-Paradise Dry Canyons divide, and reported a maximum thickness of 600 feet (182.8 m) for the Paradise quadrangle (located directly west of this quadrangle). A section approximately 900 feet (274 m) thick is exposed on the divide between Blacksmith Fork and Hyrum Canyons (plate 1) in this quadrangle.

Sandstone comprises three-quarters of the Wells Formation and limestone the remaining one-quarter (Mullens and Izett, 1963). The sandstone is very fine to medium grained, light gray to grayish brown, and weathers orangish to grayish brown. It is composed dominantly of quartz grains with either a silty siliceous or calcareous matrix. Laminated to thin-bedded float of both sandstone and limestone dominates in this quadrangle, but Mullens and Izett (1963) also reported thick-bedded units and cyclic interbedding of the sandstone and limestone.

The limestone is light to medium gray on fresh and weathered surfaces, is locally bioclastic and conglomeratic, and ranges from mudstone to packstone. Mullens and Izett (1963) correlated this part of the Wells Formation by lithology with the "sandy Oquirrh" that contains fossils of Middle Pennsylvanian age (Nygreen, 1958). No fossils were found during this study.

The unconformable contact between the Wells Formation and the Monroe Canyon Limestone is placed at the base of the interbedded sandstone and limestone, above the coral-bearing, dark-gray limestone (Mullens and Izett, 1963).

In the Paradise quadrangle, the upper limestone of the Monroe Canyon Limestone thins under an unconformity from 600 feet (183 m) thick at Hyrum Canyon to 200 feet (61 m) thick at McKenzie Mountain, located southwest of Porcupine Reservoir (plate 1) (Mullens and Izett, 1963). This unconformity, of Early Pennsylvanian age, also accounts for the absence of Lower Pennsylvanian rocks in the area (Mullens and Izett,1963).

Faunal studies have been completed by Nygreen (1958). A shallow water marine shelf, on which the limestone and sandstone of the Wells Formation were deposited, flanked the Oquirrh basin, which was centered in northwest Utah where deeper facies sediments accumulated (Jordan and Douglas, 1980).

TERTIARY

Wasatch Formation (Eocene)

The Wasatch Formation unconformably covers lower Paleozoic rocks in the southeastern part of the quadrangle. The formation is about 200 feet (61 m) thick (cross-section B-B', plate 2) and is divided into an upper and lower conglomerate. Williams (1948) identified the lower conglomerate as the Cowley Canyon Member and measured an 83-foot (25.3 m) section for this member. He reported an average thickness of 300 feet (91 m) for the entire Wasatch Formation in the Logan 30-minute quadrangle. The Wasatch and its usual colluvial cover are typically heavily vegetated. Poor exposures inhibit accurate measurement of thicknesses.

The widespread upper conglomerate weathers to a characteristic red soil with scattered rounded cobbles and pebbles of white Brigham Quartzite. The lower conglomerate occurs as a few, small, scabby outcrops. It unconformably overlies Cambrian formations along the north rim of East Canyon (plate 1)

and Devonian and Mississippian rocks in fault blocks along the ridge north of Miles Canyon and in Hyrum and Green Canyons. Identification of the conglomerate in these fault blocks is queried on the map because exposures are too limited for a definitive assignment to either the Wasatch Formation or the Salt Lake Group. The matrix of the lower conglomerate is light gray, pink, orangish pink or reddish orange lime mudstone to lime wackestone with or without angular grains and granules of limestone, black chert and quartzite. The well-rounded clasts average 3 to 5 inches (10.6-17.7 cm) but range from ½ inch to 1.5 feet (1.7-63.7cm) in diameter and are composed of locally derived limestone, quartzite and sandstone. Many limestone and sandstone clasts were derived from local Devonian and Mississippian formations.

Fossil gastropods, leaves, fish scales and bones were recovered from the conglomerates by Veatch (1907), Richardson (1941), and Williams (1948). The conglomerates of the Wasatch were laid down as continental deposits over deformed Paleozoic and Mesozoic beds in northeast Utah and the basal limestone conglomerate accumulated in a shallow lake (Williams, 1948). The Wasatch Formation is of Eocene age (Richardson, 1941; Williams, 1948).

Salt Lake Group (Miocene and Pliocene)

Patchy exposures of the Salt Lake Group are largely limited to fault-controlled valleys north and south of the Porcupine Reservoir, but road cuts reveal thin, incomplete sections. Outcrops of tuffaceous sandstone and limestone extend around the northern perimeter of the Porcupine Reservoir and also south of the reservoir, beyond the southwest corner of the quadrangle. Isolated exposures along the northern edge of Porcupine Reservoir are each only a few feet wide and are not shown on the map. Approximately 20 feet (6 m) is the maximum exposed thickness of the Salt Lake Group in this quadrangle although Adamson, Hardy and Williams (1955) reported thicknesses of at least 2000 feet (609 m) in southern Cache Valley. Poor exposures and incomplete and faulted sections prohibit accurate determinations of thickness and the use of subdivisions within the group. The Salt Lake Group overlies Silurian and Devonian rocks with angular discordance.

Laminated to thin-bedded tuffaceous sandstone is the most common lithology. It is light gray to very pale brown on fresh and weathered surfaces, fine grained, and poorly indurated. The limestone is a porous, very light-gray to light-pinkish-brown calcareous mudstone. It is locally brecciated and includes clasts from underlying Paleozoic formations such as the Beirdneau Formation.

The tuffaceous sediments and limestone of the Salt Lake Group accumulated in and around fresh-water lakes and fluviatile environments and are of Miocene and Pliocene ages (Mansfield, 1920; Adamson, Hardy and Williams, 1955; Danzl, 1982). Fossil gastropods, ostracodes, and molluscs are listed in reports by Adamson, Hardy and Williams (1955), Yen (1947), and Swain (1947).

QUATERNARY

Terrace Deposits (Quaternary)

Quaternary terrace gravel was deposited at the mouths of north-south-trending canyons and ravines along Blacksmith Fork and East Canyons, most probably during Lake Bonneville time when gradients of the canyon streams were shallower. The terraces are conspicuous on aerial photographs and lie at altitudes of approximately 5360 to 5500 feet (1633-1676 m) in Blacksmith Fork Canyon (plate 1) and 5600 to 5720 feet (1706-1743 m) in East Canyon. Exposed thicknesses along roadcuts range from approximately 20 to 50 feet (6-15.2 m).

The matrix of the conglomerate is light-yellow to very light-gray to light-brown calcareous mudstone to wackestone. The angular to subrounded clasts are dominantly derived from the directly underlying formation, average 2 to 3 inches (7-10.6 cm), but range from ¼-inch (.8 cm) granules to 1-foot (42.5 cm) cobbles. Clast size appears to increase toward the canyon walls where boulders are occasionally found. Bedding is thin to thick and often discontinuous or nonexistent. Soil profiles disconformably overlie the conglomerate.

Colluvium and Talus (Quaternary)

Colluvium ranges from silt, sand, and fragments to blocks of rock that are deposited by rain wash or gravity and mantle underlying formations. Talus, included on this map with colluvium, is an accumulation of loose broken rock at the base of cliffs or steep mountain faces, most notably Blacksmith Fork Canyon. Accumulations of colluvium, up to 30 or 40 feet (9-12 m) thick, overlie the Wasatch Formation and Paleozoic formations in the southeastern quarter of the quadrangle. The colluvium is usually tinted the characteristic reddish brown of the Wasatch where it overlies that formation.

Alluvium (Quaternary)

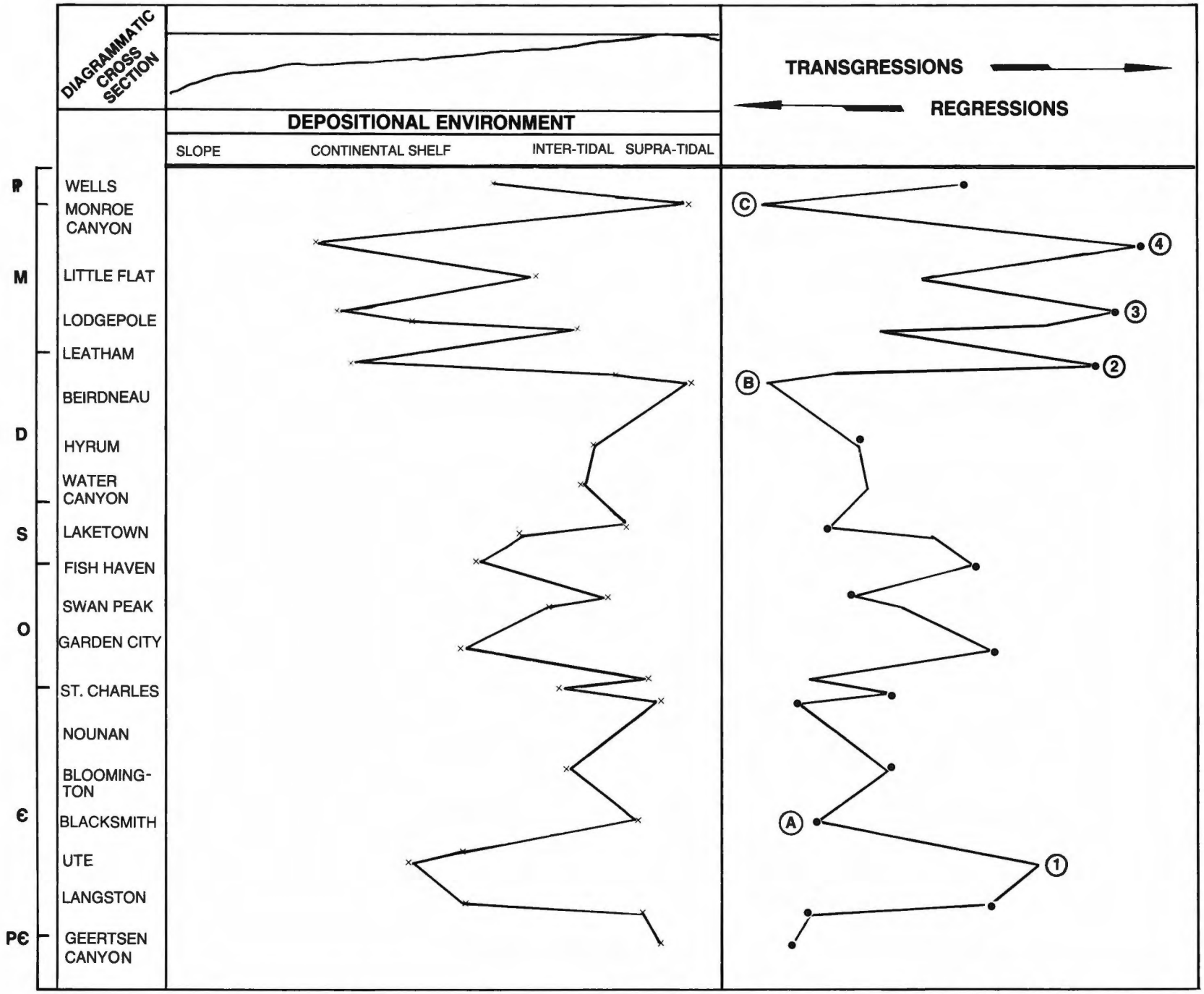
Alluvium consists mainly of sand, silt, and clay, with some gravel, and is grayish or reddish to yellowish brown. It occupies the present floodplains of active streams.

Landslide Deposits

Varicolored gray, cream, and white tuffaceous clays of the Tertiary Salt Lake Group form hummocky mounds at the toe of the landslide on the northwest side of Porcupine Reservoir; these blocked the road north of the reservoir during the spring and summer of 1984.

DEPOSITIONAL PATTERNS

Figure 2 charts the sequence of depositional environments from the Cambrian Geertsen Canyon Quartzite to the Pennsylvanian Wells Formation in this quadrangle. A history, including four major marine transgressions (numbered) and three major regressions (lettered), can be derived from the sequence of environments.



1. = MAJOR MARINE TRANSGRESSIONS
(A) = MAJOR MARINE REGRESSIONS

Figure 2. History of transgressions and regressions derived from the sequence of depositional environments.

Number one represents the continuation of the west to east (Oriel and Armstrong, 1971) transgression from deposition of the basal Precambrian and Cambrian quartzite, the Geertsen Canyon Quartzite, to deposition of the overlying Cambrian carbonates. Regression A marks the beginning of a series of minor regressions and transgressions that extend through the Silurian period. The minor transgressions are often represented by quartz sandstones such as those found in the Worm Creek Quartzite Member of the St. Charles Formation, at the base of the Garden City Limestone, and in the Swan Peak Formation.

An abundance of terrigenous clastics in Devonian formations reflect their shallow marine depositional environments which were occasionally exposed as a result of tectonic unrest. The breakup of the miogeosynclinal depositional pattern and the major unconformity at the base of the Leatham Formation is shown by regression B. Transgression 2 records the deposition of the basal sediments of the Leatham Formation and marine inundation following the Late Devonian tectonic upheaval.

During transgressions 3 and 4, respectively, the Lodgepole Limestone and the quartz sandstone and sandy limestone beds of the Little Flat Formation spread eastward. The regressive carbonate bank of Poole and Sandberg (1977) is recorded by the thick chert-rich limestone sequence of the Monroe Canyon Limestone. Regression C reflects the major unconformity between the Monroe Canyon Limestone and the Wells Formation.

In the Porcupine Reservoir quadrangle all of the Cambrian formations thicken toward the south, and Ordovician, Silurian, and Devonian formations and the Mississippian Lodgepole Limestone thicken toward the north. I believe the Devonian formations thin to the south in this quadrangle, even though the sections in East Canyon are faulted and cannot be accurately measured. Williams (1948) and Mullens and Izett (1964) concur with this idea.

The thicker sequences of rock (southern Cambrian sections and northern Ordovician, Silurian, Devonian, and Mississippian Lodgepole Limestone sections) were probably closer to either a source area or depositional center or "basin." Therefore, the source area or depositional center probably shifted from south to north after the Cambrian period.

STRUCTURE

This quadrangle is part of the Cache allochthon of the Wyoming-Utah overthrust belt. The structure of this portion of the allochthon is relatively simple and the Paris—Willard thrust lies between 10,000 and 15,000 feet (3048-4572 m) below the surface (Dover, 1985). Proterozoic and Paleozoic strata were warped by major and minor folds related to Mesozoic Sevier thrusting and, along with Tertiary and Quaternary units, are cut by Tertiary and Quaternary normal faults.

FOLDS

The largest structural feature in the quadrangle is the Logan Peak syncline (plate 1) that trends northward through the Logan 30-minute quadrangle (Williams, 1948). Rocks on the east limb of this fold dip westward approximately 10° near the eastern boundary of the quadrangle. Dip increases to 50° near the axis of the syncline on the west side of the quadrangle (cross-section A-A', plate 2). Dips on the west limb range from 5° to 25° from east to west in the adjacent Paradise quadrangle (Mullens and Izett, 1963). The syncline is asymmetric in the northwest corner of the area mapped (plate 1), with strata dipping more gently on the west limb. The axial plane of the syncline is inclined to the east.

Minor folds, an anticline plunging to the east in Blacksmith Fork Canyon, and a syncline trending north on Porcupine Ridge (plate 1) complicate the limbs of the Logan Peak syncline. The anticline in Blacksmith Fork Canyon may represent a culmination of the axis of the Logan Peak syncline. The syncline on Porcupine Ridge, together with the minor anticline in the southwest corner of the area, may be a drag fold associated and contemporaneous with the Logan Peak syncline. Smaller folds (usually anticlines and synclines) and flexures are common especially north and south of the reservoir in the southwest corner of the quadrangle. These range from a few feet to 1000 feet (304 m) in width and length and usually have a northerly or east-west trend. Included in this group of folds is the small syncline north of the Porcupine Reservoir (plate 1) which is crosscut by a north-trending fault, suggesting that this fold predates basin and range faulting.

FAULTS

The greatest concentration of faults within the quadrangle occurs in the southwest corner and in the eastern third of the area mapped. These areas will be referred to as the Porcupine Reservoir fault complex and East fault complex, respectively. Most of the faults are normal and high angle with a northwest-northeast-, or north-south-trend which reflects the structural pattern of the adjacent Basin and Range Province. However, a number of faults trend east-west in the East fault complex. No direct evidence was found in the field to indicate relative movement of the faults, therefore the terms used are based on apparent movement. Most of the faults were mapped to justify juxtaposed stratigraphic units, and aerial photographs were used to verify and define the fault trends.

In the Porcupine Reservoir fault complex, two sets of step faults form a graben on the divide between Paradise Dry and Miles Canyons. Minor faults modify the graben south of Miles Canyon. Relative movements of faults south of the reservoir are difficult to determine because of the monolithic nature of the Laketown Dolomite. A reverse fault, one of the few found in the quadrangle, dips 68° west with a vertical stratigraphic displacement of less than 10 feet (3 m) and cuts the Lodgepole Limestone on the Porcupine Reservoir dam abutments. Apparent vertical displacement by faults in this complex is generally small; individual fault blocks are generally displaced less than 800 feet (243 m).

Much of the area in the East fault complex is covered by colluvium, so faults are probably more extensive than shown on the map. Faults that are dashed across colluvium in this area (plate 1) reflect lineaments traced on aerial photographs. Individual fault blocks generally have an apparent vertical displacement of less than 1200 feet (365 m). Some east-trending faults in this complex may be tear faults related to thrusting (Armstrong and Oriel, 1965), but direct evidence is lacking, therefore, normal faults are used to explain displacements.

Northeast- and northwest-trending faults cut each other approximately the same number of times in this quadrangle, which suggests they are contemporaneous. North-south faults generally cut northwest-and northeast-trending faults in this area and may reflect a change in the stress field between the episodes of faulting as determined by strain ellipsoid studies (Verbeek and Grout, 1986). Northeast- and northwest-oriented faults suggest an intermediate phase of faulting between the Sevier orogeny and later basin-and-range faulting (north-south-oriented faults). North-south-trending faults dissect rocks of the Salt Lake Group and, therefore, are at least as young as Pliocene in age.

Abundant lineaments, evident on aerial photographs, are drawn as faults on Dover's (1985) map of the Logan 30 x 60 quadrangle; however, field inspections failed to show any offset on most such features within this portion of the Bear River Range. They probably represent joint patterns.

ECONOMIC DEPOSITS

Various companies have leased and explored for petroleum and natural gas in this quadrangle in response to region-wide interest in the Overthrust Belt but, at present, active exploration has ceased.

Sando and others (1981) report conodont CAI values of 3 to 3.5 from Mississippian potential source rocks sampled at Porcupine Reservoir (plate 1) and Blacksmith Fork Canyon. These values indicate hydrocarbons are in an early post-mature state and suggest that production would be limited to gas (Sando and others, 1981). The upper tongue of the basal Cottonwood Canyon Member of the Lodgepole Limestone, present directly north of the quadrangle (Sando and others, 1981) along with the Delle Phosphatic Member of the Little Flat Formation are potential source rocks. Traps and reservoirs may have formed by fault contact of these source rocks with potential reservoir rocks such as coarse-grained Beirdneau Sandstone or fractured Hyrum Dolomite in the Porcupine Reservoir fault complex (plate 1).

Other commodities with possible economic interest include: (1) phosphates, found as pellets in chert in the Delle Phosphatic Member at the base of the Little Flat Formation, average less than 4 percent P_2O_5 as determined by Mullens and Izett (1964); (2) calcium carbonate, a lime source for cement from the Monroe Canyon Limestone, Lodgepole Limestone, Ute Limestone, and Bloomington Formation; (3) pure silica, extracted from the Geertsen Canyon Quartzite; and (4) water. In the Bear Flat area (plate 1), numerous ranch owners have developed springs for cabin use. The springs are usually fault-controlled and occur in the Bloomington Formation, Nounan Dolomite, St. Charles Formation, and Garden City Limestone. Cattlemen use the limited number of springs found elsewhere in Silurian, Devonian, and Mississippian formations. Hyrum City pipes water from a faulted zone in the Garden City Limestone to generate power from their municipal hydroelectric plant in Blacksmith Fork Canyon.

GEOLOGIC HAZARDS

The landslide mapped in Section 17, T 9 N, R 2 E (plate 1), involves Quaternary colluvium and underlying Tertiary Salt Lake Group (Qc/Ts), that in turn overlies Devonian and Mississippian formations. The latest slow and creeping movement of the Quaternary and Tertiary units over the Paleozoic units occurred during the exceptionally wet spring of 1984, with substantial movement also observed in 1983. The overall dimensions of the landslide are 1500 feet (457 m) wide and 1300 feet (396 m) long. Renewed movement of the landslide is possible especially during wet seasons; this could be a hazard, especially if the slide moves into the reservoir and displaces water over the spillway.

A small landslide mapped southwest of the reservoir involves Quaternary alluvium and colluvium that has slipped on underlying Mississippian units.

There is potential for future activity along Quaternary faults which could result in further movement of the strata previously involved. A potential hazard exists if activity is renewed along the fault which dissects the northern dam abutment (Ml).

Numerous sinkholes have been found in the area between East Canyon and Bear Flat. These sinkholes occur in the Ute Limestone, Bloomington Formation, Nounan Dolomite, and St. Charles Formation.

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