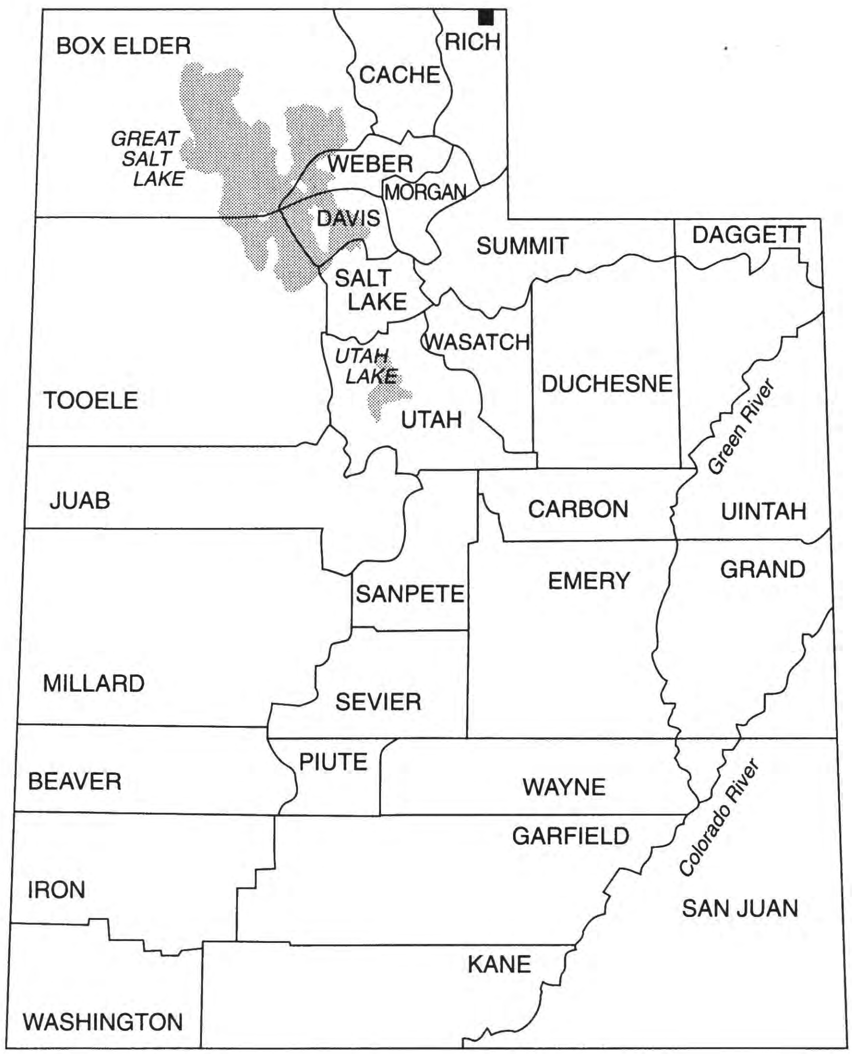
GEOLOGIC MAP OF THE SHEEPPEN CREEK QUADRANGLE, RICH COUNTY, UTAH

by
James C. Coogan



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ABSTRACT

The Sheeppen Creek and adjacent Bear Lake South quadrangles cover part of southern Bear Lake Valley, western Bear Lake Plateau, and the eastern foothills of the Bear River Range in Rich County, Utah. Geologic interest in the area has increased in the past two decades because of oil and gas discoveries in adjacent areas of the Wyoming-Idaho-Utah portion of the Cordilleran thrust belt, earthquake hazards along the eastern Bear Lake fault zone, and recreational development demands along the Bear Lake shoreline.

Triassic, Jurassic, and Eocene sedimentary rocks, Oligocene volcanic rocks, and Quaternary sediments are exposed in the Sheeppen Creek quadrangle, and a complete Triassic to Cambrian sedimentary section is known to underlie the surface exposures from outcrops and wells in adjacent areas. The Paleozoic through Jurassic miogeoclinal strata were shortened in a series of north-trending thrust faults and associated folds as part of the Cretaceous to early Eocene Sevier thrust belt. The lower Eocene Wasatch Formation consists of fluvial clastic rocks and lacustrine limestones that were deposited in a piggyback basin after main-phase folding and thrusting. An Oligocene alkaline-olivine basalt that consists of dikes, breccia, and a flow intrudes and overlies the Wasatch Formation at Black Mountain in the western part of the Sheeppen Creek quadrangle.

Principal thrust structures in Sheeppen Creek quadrangle include the Gypsum Spring décollement, folds and imbricate thrusts in the hanging wall of the Home Canyon thrust, the folded Home Canyon thrust trace, Sheep Creek anticline, the subsurface Sheep Creek thrust, North Eden and South Eden fold belts, and the subsurface Crawford thrust sheet. Folding of the Gypsum Spring décollement above the Home Canyon thrust sheet and folding of the Home Canyon thrust above Sheep Creek anticline together demonstrate that thrust faulting progressed from west to east across the area.

Mesozoic thrust structures are locally overprinted by late Cenozoic extensional faults in the adjacent Bear Lake South quadrangle. The eastern Bear Lake fault zone in the eastern Bear Lake South quadrangle is the site of several prehistoric earthquakes, and fault scarps in Quaternary sediments along the eastern lake front indicate earthquake magnitudes of 6.9 to 7.4 for individual rupture events.

Hydrocarbon exploration in this and nearby quadrangles has centered on attempts to produce gas from the Phosphoria and Dinwoody Formations of the Crawford and Sheep Creek thrust sheets based on production from the Hogback Ridge gas field located 1.5 miles (2.5 km) south of Sheeppen Creek quadrangle.

INTRODUCTION

The Sheeppen Creek and adjacent Bear Lake South quadrangles cover part of southern Bear Lake Valley, western Bear Lake Plateau, and the eastern foothills of the Bear River Range in Rich County, Utah. The present valley and plateau morphology across the two quadrangles is the result of late Cenozoic normal faulting along the Bear Lake Valley fault zone. Subsidence of Bear Lake Valley, which lies at elevations near 5,900 feet (1,800 m), is the result of relative downward displacement of the hanging wall of the eastern Bear Lake normal fault zone. Bear Lake Plateau,

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which rises above 7,000 feet (2,135 m) elevation, has been formed by relative uplift of flat-lying beds of the Eocene Wasatch Formation in the footwall of the fault zone. The flat-lying Wasatch strata have been dissected by downcutting of the North Eden and South Eden drainages commensurate with lowering of the Bear Lake Valley base level. North-northeast-trending ridges of Jurassic and Triassic strata are exposed along the lower reaches of the North Eden and South Eden drainages where the Wasatch Formation has been completely eroded.

The quadrangles lie near the center of the Wyoming salient of the Early Cretaceous through Eocene Cordilleran fold and thrust belt (Blackstone and DeBruin, 1987; Royse and others, 1975) and are underlain by the Willard, Meade-Laketown, Home Canyon, Sheep Creek, and Crawford thrust faults (figure 1). The thrust structures are locally overprinted by late Cenozoic extensional faults along the eastern Bear Lake normal fault zone. Geologic interest in the area has increased in the past two decades because of oil and gas discoveries in adjacent areas of the thrust belt, earthquake hazards along the eastern Bear Lake fault zone, and recreational development demands along the Bear Lake shoreline.

The area including the Bear Lake South and Sheeppen Creek quadrangles was originally mapped at a scale of 1:125,000 by Richardson (1941) as part of his study of the geology and mineral resources of the Randolph 30′ quadrangle. Willard (1959) mapped the surficial geology of the Bear Lake Valley in Utah. McClurg (1970) mapped part of eastern Bear Lake South and western Sheeppen Creek quadrangles at 1:24,000 scale as part of a geologic study of the North Eden Creek drainage area. Valenti (1980, 1982a, 1982b) mapped the Laketown 7.5′ quadrangle immediately south of the Bear Lake South quadrangle, and discussed oil and gas exploration in the area. Dover (1995) remapped the area during compilation of the Logan 30′ x 60′ quadrangle at a scale of 1:100,000. This report incorporates modern stratigraphic studies and data from oil and gas exploration wells to provide the first detailed description of the surface and subsurface geology of the Bear Lake South and Sheeppen Creek quadrangles. Geologic mapping for this report and the companion report on the Bear Lake South quadrangle (see Coogan, 1996) was completed in 1988 and 1989 as part of a Ph.D. dissertation (Coogan, 1992a). Please refer to Coogan (1996) for details on the geology of the Bear Lake South quadrangle.

STRATIGRAPHY

Triassic, Jurassic, Eocene, and Oligocene rocks, and Quaternary deposits are exposed in the Sheeppen Creek quadrangle. In addition, a complete Triassic to Cambrian sedimentary sequence has been drilled in the subsurface in the Meade-Laketown thrust sheet beneath Bear Lake Valley in Idaho and in the Crawford thrust sheet of eastern Bear Lake Plateau in Wyoming (Coogan, 1992a). The Paleozoic section of the Meade-Laketown thrust sheet is much thicker than the correlative sections in the Sheep Creek and Crawford thrust sheets. The thickness contrast is the result of regional east-west shortening of the Paleozoic miogeocline to shelf transition along thrust faults. This portion of the text provides detailed descriptions of the exposed stratigraphic units in Sheeppen Creek quadrangle. Subsurface stratigraphic units, shown on the structural cross sections (plate 3), are presented in the description of map units (plate 2).

Triassic

Ankareh Formation

Wood Shale Tongue (₮aw): An incomplete section of the Upper Triassic Wood Shale Tongue of the Ankareh Formation (Kummel, 1954) crops out in the northwestern Sheeppen Creek quadrangle, and directly overlies the Home Canyon thrust such that the base of the Wood Shale is not exposed. The Wood Shale Tongue is composed of bright-red to red-orange siltstone and shale that forms slopes below the more resistant Nugget Sandstone. The bright-red color distinguishes the Wood Shale from the dull-red Lanes Tongue of the Ankareh Formation, located lower in the stratigraphic section. The Wood Shale is 400 feet (120 m) thick where it was measured by Kummel (1954) north of the quadrangle at Bear Lake Hot Springs, Idaho, but approximately 570 feet (175 m) thick in the American Quasar #2-41 well (section 2, T. 14 N., R. 6 E.). The Wood Shale Tongue is separated from the overlying Nugget Sandstone by the regional J0 unconformity (Pipiringos, 1968; Pipiringos and O'Sullivan, 1978). However, the Wood Shale and Nugget Sandstone share an interfingering contact zone in outcrop northeast of Hot Springs, Idaho and in wells through the area. Thus, the J0 unconformity may not exist as a single discrete surface in the Sheeppen Creek area.

Jurassic

Nugget Sandstone (Jn)

The Lower Jurassic Nugget Sandstone (Veatch, 1907; Pipiringos, 1968) is exposed in northwestern Sheeppen Creek quadrangle in the hanging wall of the Home Canyon thrust and the core of Sheep Creek anticline. The unit is medium- to fine-grained, well-rounded, quartz sandstone that occurs in thick to medium cross-bedded sets. Most of the Nugget Sandstone is friable and distinctively red-orange in color, however the upper 100 to 200 feet (30 to 60 m) of the Nugget is often well-indurated, white sandstone. The white sandstone appears to be the result of bleaching by removal and/or reduction of the iron oxide cements found in the red-orange sandstone. The white sandstone is limited to the uppermost part of the Nugget Sandstone. This stratigraphically restricted diagenesis probably occurred before folding and faulting. The Nugget is approximately 1,300 feet (400 m) thick in both the American Quasar #2-41 and #12-1 Eden State Federal wells (sections 2 and 12 respectively, T. 14 N., R. 6 E.). The upper contact of the Nugget Sandstone is overlain by interbedded, red and yellow sandstone and red shale at the base of the Gypsum Spring Member of the Twin Creek Limestone. The regional J1 unconformity (Pipiringos, 1968; Pipiringos and O'Sullivan, 1978) lies along the contact at the base of the lowest, nonresistant, red shale of the Gypsum Spring Member.

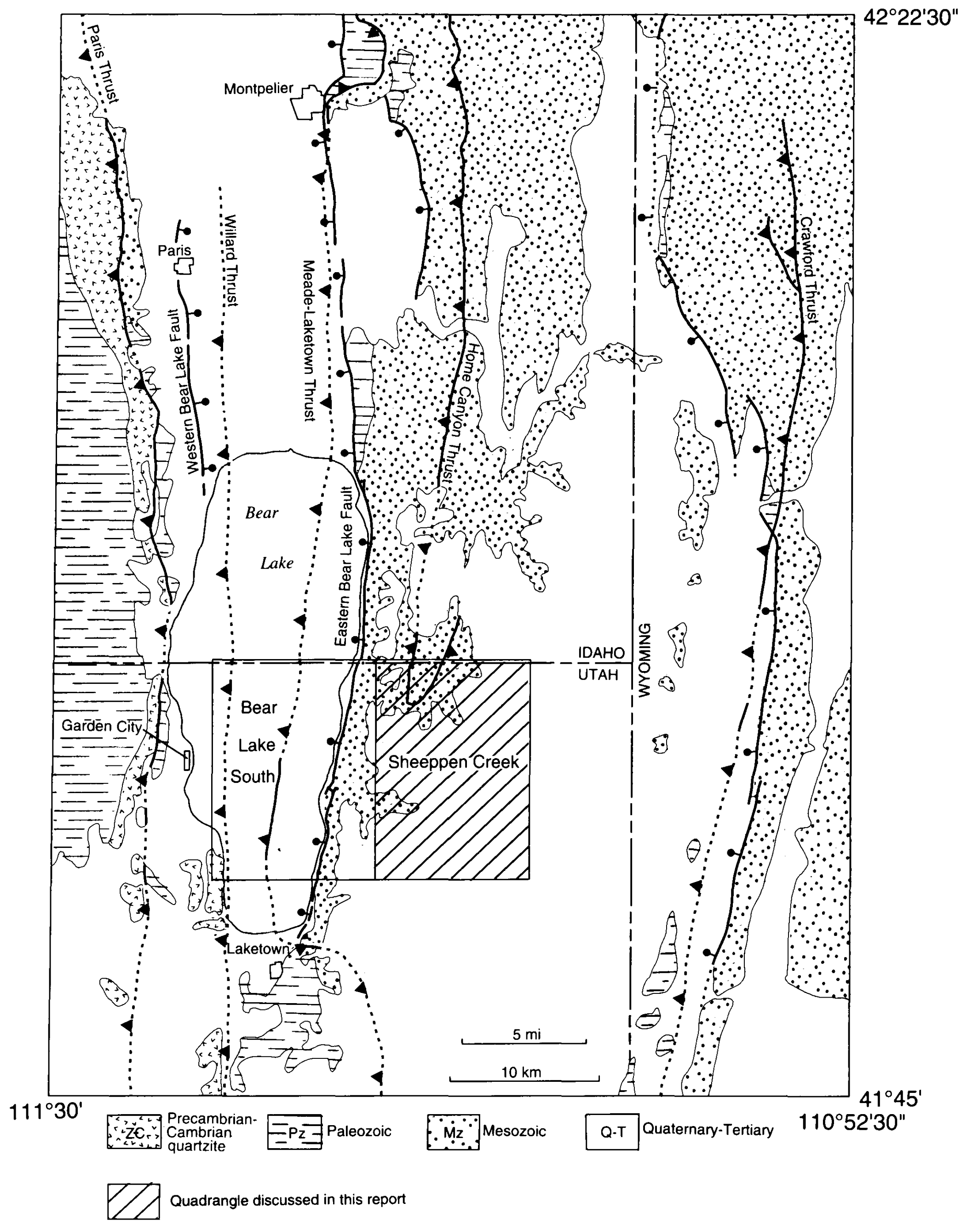

Figure 1. *Geologic index map for the Bear Lake South and Sheeppen Creek quadrangles.*

Twin Creek Limestone

Gypsum Spring Member (Jtg): The Middle Jurassic Gypsum Spring Member of the Twin Creek Limestone (Imlay, 1967) is exposed along the limbs of Indian Creek syncline and Sheep Creek anticline. The Gypsum Spring Member consists of red shale, siltstone, and sandstone; yellow sandstone; light-gray, gray-brown, and dark-gray dolomite and brecciated dolomite. Anhydrite was noted in all sample logs from wells that penetrated the Gypsum Spring Member, but it is not exposed in outcrop. The Gypsum Spring Member is 350 feet (105 m) thick on the east limb of Indian Creek syncline on the north side of North Eden Canyon, but it is tectonically thickened elsewhere. The Gypsum Spring Member has a well-defined internal stratigraphy throughout the map area despite structural complications associated with the member, which is an important décollement horizon throughout the region (Coogan and Boyer, 1985). A thin, yellow to orange sandstone lies approximately 25 feet (8 m) above the base of the member. Two of the thicker dolomite beds are useful for mapping the structural deformation of the Gypsum Spring in the study area. The lower dolomite bed lies about 100 feet (30 m) above the base of the Gypsum Spring Member and consists of light-gray to white weathering, light-gray-brown dolomite that is thinly laminated and locally brecciated. The upper dolomite bed consists of gray weathering, dark-gray, pervasively brecciated dolomite that contains many small, calcite-spar-filled vugs, and has a fetid odor when fractured. The main décollement horizon in the Gypsum Spring Member (Gypsum Spring décollement) lies between the two dolomite beds, although multiple décollement horizons exist within the member. The upper contact of the Gypsum Spring Member is the regional J2 unconformity (Pipiringos, 1968; Pipiringos and O'Sullivan, 1978) and is at the base of a ledge where resistant, gray grainstones of the Sliderock Member lie above nonresistant, red shales of the Gypsum Spring Member.

Sliderock Member (Jts): The Middle Jurassic Sliderock Member of the Twin Creek Limestone (Imlay, 1967) forms resistant ridges and ledges along the flanks of Indian Creek syncline, in the fold belt in South Eden Canyon, and in the east flank of Sheep Creek anticline in the North Eden Creek drainage in the Sheeppen Creek quadrangle. The Sliderock Member is approximately 500 feet (150 m) thick in surface exposures, but it thins to 250 to 300 feet (75 to 90 m) in wells immediately east of the quadrangle. The lower half of the member consists of gray, resistant, sandy, lime packstone to grainstone with pelecypod and crinoid fragments, dominantly from *Gryphaea* and *Pentacrinus*. The upper half of the member consists of lime packstone, wackestone, and micrite. The upper part of the member is less resistant and has more pervasive cleavage than the lower part. Cleavage intensity appears to be related to grain size and clay content, with closely spaced cleavage in clay-rich micrites and widely spaced cleavage and bedding-normal stylolites in lime grainstones. The contact with the overlying Rich Member is lithologically gradational between the packstones and wackestones of the Sliderock Member and the micrites of the Rich Member.

Rich Member (Jtr): The Middle Jurassic Rich Member of the Twin Creek Limestone (Imlay, 1967) is exposed in the northern Indian Creek syncline, the South Eden Canyon fold belt, and along the east flank of Sheep Creek anticline in the North Eden Creek drainage in the Sheeppen Creek quadrangle. The member consists of massively bedded, gray to light-gray, lime micrite with pervasive pencil cleavage at a high angle to bedding. The upper contact is placed at the base of a red-brown shale zone in the overlying Boundary Ridge Member. The Rich Member has undergone a large amount of internal structural thickening and attenuation throughout the area. The Rich Member is 730 feet (220 m) thick on the east flank of Sheep Creek anticline in the northern part of the Sheeppen Creek quadrangle and thins eastward to 550 to 600 feet (165 to 180 m) thick in wells immediately east of the quadrangle.

Boundary Ridge Member (Jtb): The Middle Jurassic Boundary Ridge Member of the Twin Creek Limestone (Imlay, 1967) is exposed in the Sheeppen Creek quadrangle along the South Eden Canyon fold belt and along the east flank of Sheep Creek anticline in the North Eden Creek drainage. The Boundary Ridge Member consists of two red-brown shale zones that are separated by a massive, gray to dark-gray, oolitic limestone. The upper shale is capped by a thin, oolitic limestone that is overlain by micrite beds of the Watton Canyon Member. The member is easily recognized on aerial photographs by two parallel vegetation bands in the shale zones. The Boundary Ridge Member is 265 to 300 feet (80 to 90 m) thick in North Eden Canyon.

Watton Canyon Member (Jtw): The Middle Jurassic Watton Canyon Member of the Twin Creek Formation (Imlay, 1967) is exposed in the South Eden fold belt and along the east flank of Sheep Creek anticline in the North Eden Creek drainage in the Sheeppen Creek quadrangle. The member consists of resistant, medium-bedded, gray to dark-gray micrite and oolitic wackestone and packstone. The Watton Canyon Member has a distinctive rectangular weathering pattern that is caused by parting planes along bedding-plane stylolites and along spaced cleavage and stylolites normal to bedding. The Watton Canyon Member is 800 feet (245 m) thick in North Eden Canyon. The upper contact is placed at the top of the uppermost, resistant micrite bed, beneath a less-resistant zone marked by vegetation in micrite beds of the Leeds Creek Member.

Leeds Creek Member (Jtl): The Middle Jurassic Leeds Creek Member of the Twin Creek Formation (Imlay, 1967) is exposed in the Sheeppen Creek quadrangle in a series of tight folds in the North Eden Creek drainage and in the eastern part of the South Eden Canyon fold belt. The Leeds Creek Member consists of massive, gray micrite that weathers very light gray. The Leeds Creek Member has a penetrative, bedding-normal, pencil cleavage and is easily weathered to form extensive, light-gray soil zones. Thin silt laminae define bedding in otherwise massive outcrops. The Leeds Creek Member is about 1,550 feet (475 m) thick along North Eden Creek. The upper contact is transitional from wackestone and packstone beds, composed mostly of *Gryphaea* and *Pentacrinus* fragments, in the upper 200 feet (60 m) of the Leeds Creek Member to *Gryphaea* and *Pentacrinus* grainstones and sandstone beds of the overlying Giraffe Creek Member.

Giraffe Creek Member (Jtgc): The Middle Jurassic Giraffe Creek Member of the Twin Creek Limestone (Imlay, 1967) is exposed in tight folds along North and South Eden Creeks in the center of the Sheeppen Creek quadrangle. The Giraffe Creek Member is composed of light-gray, greenish-gray, and pinkish-gray, calcareous sandstone and gray, lime grainstone. Grainstones are dominantly composed of *Gryphaea* and *Pentacrinus* fragments. The sandstone is mainly light gray and locally glauconitic in the lower part of the member, and changes to pinkish gray in the upper part of the member where it is transitional with less calcareous, red sandstone beds of the overlying Preuss Redbeds. The Giraffe Creek Member is about 300 feet (90 m) thick in North Eden and South Eden Canyons.

Preuss Redbeds (Jp)

The lower part of the Middle Jurassic Preuss Redbeds (Imlay, 1952) is exposed in the cores of tightly folded synclines along North and South Eden Creeks in the center of the Sheeppen Creek quadrangle. Only a few hundred feet of nonresistant, red sandstone and shale of the basal Preuss Redbeds are exposed in the synclines. Salt is present near the base of the Preuss Redbeds in wells throughout the thrust belt (Coogan and Yonkee, 1985), but is not exposed at the surface in the map area. The Preuss Redbeds unit is overlain with angular unconformity by the Eocene Wasatch Formation.

Tertiary

Wasatch Formation

Gently dipping strata of the Eocene Wasatch Formation overlie a regional angular unconformity above highly folded Paleozoic and Mesozoic rocks in the Bear Lake South and Sheeppen Creek quadrangles. The age of the Tertiary strata of Bear Lake Plateau has been a matter of disagreement between workers in Utah and Idaho. Oriel and Platt (1980) mapped the Tertiary strata in the Bear Lake North and Pegram Creek quadrangles, Idaho as Miocene-Pliocene Salt Lake Formation, whereas Richardson (1941), McClurg (1970), and Valenti (1982a) mapped the same strata as Eocene Wasatch Formation in adjacent areas of Utah. The Tertiary strata in Idaho were dated as Miocene-Pliocene by a single collection of *Lepidorae* teeth from tuffaceous conglomerates in a gravel pit in the northwestern corner of Bear Lake Plateau in the Pegram Creek quadrangle, Idaho (Oriel and Tracey, 1970). Subsequent mapping (Coogan, 1992a, 1992b) demonstrated that these tuffaceous conglomerates overlie redbeds of the Wasatch Formation mapped by Richardson (1941), McClurg (1970), Valenti (1982a), and Dover (1995). The Wasatch redbeds are also overlain and truncated by the Oligocene basalt of Black Mountain in the Sheeppen Creek quadrangle. The only local biostratigraphic control within the Wasatch Formation is from Eocene gastropods in limestones reported by H.P. Buchheim (Loma Linda University, verbal communication, October, 1989) in the vicinity of the southeast corner of the Sheeppen Creek quadrangle. The Wasatch Formation is divided into three informal members in the Sheeppen Creek quadrangle: (1) the quartzite conglomerate member; (2) the limestone member; and (3) the main body. The sedimentology, depositional setting, and tectonic significance of the Wasatch Formation of Bear Lake Plateau are discussed by Coogan (1992b). A measured section from the Sheeppen Creek quadrangle is included in the appendix in this report.

Quartzite Conglomerate Member (Twq): Gray conglomerate beds dominated by well-rounded cobbles of white and gray quartzite locally overlie the basal Wasatch unconformity along the North Eden and South Eden drainages in Sheeppen Creek quadrangle. These distinctive conglomerates are informally designated as the quartzite conglomerate member of the Wasatch Formation to distinguish them from the more poorly sorted, red and orange conglomerates of the main body of the Wasatch Formation. The quartzite conglomerate member is correlated, east and north of the Sheeppen Creek quadrangle, to similar exposures along the Wyoming border (Coogan, 1992b). The quartzite conglomerate member is 0 to 100 feet (0 to 30 m) thick. The upper contact is marked by an abrupt change to red and orange-red sandstone, mudstone, and conglomerate of the main body of the Wasatch Formation.

Limestone Member (Twl): Eocene limestones are mapped informally as the limestone member of the Wasatch Formation in this report following the usage of Dover (1995). The limestone member of the Wasatch Formation consists of the oncolitic limestone, algal limestone, and limestone conglomerate. Oncolites within the limestone are generally 0.5 to 1.5 inches (1.3 to 3.8 cm) in diameter with nuclei of granule-sized chert, quartz, and carbonate grains that are surrounded by concentrically zoned carbonate layers. Laminated limestone and limestone, flat-pebble conglomerate in the limestone member resemble algal-mat structures. Limestone conglomerate beds are made up of coated and non-coated pebbles in a micritic and/or sparry limestone or calcareous sandstone matrix. A light-gray siltstone bed forms the base of the limestone member along the South Eden Canyon measured section (appendix). At least two major and many smaller tongues of the limestone member terminate eastward in central and western Sheeppen Creek quadrangle, where they interfinger with the main body of the Wasatch Formation. The limestone member map unit therefore contains a significant amount of the red mudstone, sandstone and conglomerate lithologies in the quadrangle along its eastward transition with the main body of the Wasatch Formation. The limestone member thickens southwestward to a maximum preserved thickness of 400 feet (120 m) in southeastern Bear Lake South quadrangle.

Limestone beds in the Wasatch Formation were mapped as the Cowley Canyon Member of the Wasatch Formation by McClurg (1970) in Sheeppen Creek quadrangle, based on its lithologic similarity to the type section of the Cowley Canyon Member south of Logan Canyon, Utah, 17 miles (27 km) southwest of the quadrangle (see Williams, 1948). Direct stratigraphic or biostratigraphic correlation to the Cowley Canyon type section is tenuous and is not justified at this time. The localized distribution of the limestone and its intertonguing relations with the main body of the Wasatch Formation indicate that the Cowley Canyon and Bear Lake Plateau limestone beds may have been deposited in separate local basins at different times (compare Oaks and Runnells, 1992; and Coogan, 1992a, 1992b).

Main Body (Tw): The main body of the Wasatch Formation consists of poorly exposed, red and red-orange mudstone, sandstone, and minor conglomerate. Mudstone comprises approximately 85 percent of the main body along the eastern boundary of the Sheeppen Creek quadrangle, where it is interbedded with laterally discontinuous, channel sandstone beds and conglomeratic sandstone beds. Conglomerate beds in the main body are locally well developed near the headwaters of South Eden Creek. The main body is up to 700 feet (210 m) thick beneath Black Mountain and up to 600 feet (180 m) thick beneath the plateau surface of eastern Sheeppen Creek quadrangle. The main body interfingers westward with the limestone member of the Wasatch Formation.

Basalt of Black Mountain

Basalt Dikes (Tbd): Dikes of alkaline-olivine basalt crop out on the east and west sides of the Black Mountain summit. The basalt is bluish-black, aphanitic, with small (≤0.8 inch [2 mm]), green, olivine phenocrysts, and locally developed vesicles. X-ray diffraction analysis by McClurg (1970), and microscopic and microprobe analyses by Puchy (1981) identified the main constituents of the basalt as olivine, plagioclase feldspar (labradorite to bytownite), pyroxene (augite), and magnetite. Puchy (1981) reported a limited occurrence of natrolite (zeolite mineral) fill in basalt vesicles. Potassium-Argon (K-Ar) whole-rock dating of a sample from the eastern dike yielded an Oligocene age of 28.8 ± 1.7 Ma (section 14, T. 14 N., R. 6 E.; table 1). The dikes are parallel to and separated by a linear breccia zone (Tbb) that trends N. 35°E. Columnar joints within the dikes are oriented at high angles to the breccia zone, with the mean of west-plunging column axes oriented N. 30°W., 29°, and the mean of east-plunging column axes oriented S. 44°E., 39° (30 measurements each). The column orientations indicate that the dikes formed along the walls of the fissure-like, breccia-filled conduit.

Table 1.
Basalt of Black Mountain Potassium-Argon Whole Rock Age Determination (sample location section 14, T. 14 N., R. 6 E.)

Argon Analyses	**^{40*}Ar, ppm** .001549 .001445 .001686	**^{40*}Ar/Total ^{40}Ar** 0.416 0.368 0.425	**Ave. ^{40*}Ar, ppm** 0.001567
Potassium Analyses	**%K** 0.774 0.775	**Ave. %K** 0.775	**^{40}K, ppm** 0.924
Ratio	$\frac{^{40*}Ar}{^{40}K} = 0.001688$		
Constants Used	$\lambda_\beta = 4.962 \times 10^{-10}$/year $(\lambda_e + \lambda'_e) = 0.581 \times 10^{-10}$/year ^{40}K/K = 1.193×10^{-4} g/g		
Age Equation	$AGE = \frac{1}{\lambda_\beta + (\lambda_e + \lambda'_e)} \ln\left[\frac{\lambda_\beta + (\lambda_e + \lambda'_e)}{(\lambda_e + \lambda'_e)} \times \frac{^{40*}Ar}{^{40}K} + 1\right]$		
Age	28.8 ± 1.7 Ma		

Analyses performed by Geochron Laboratories, Cambridge Massachusetts, on March 6, 1989.
NOTES: *^{40*}Ar = radiogenic ^{40}Ar, Ma = millions of years*

Basaltic Breccia (Tbb): A linear breccia zone oriented approximately N. 35°E. separates the basalt dikes (Tbd) at the summit of Black Mountain. The breccia contains randomly oriented blocks of bluish-black, aphanitic, alkaline-olivine basalt and blocks of white, partially silicified limestone. The breccia matrix is white, finely crystalline calcite; silica, and zeolite. The silicified limestone contains preserved oncolites, which suggests that the limestone was derived from the limestone member of the Wasatch Formation which lies immediately beneath the summit of Black Mountain. Alternatively, the silicified limestone could be derived from the collapse of a stratigraphically higher and presently eroded interval of the Wasatch Formation that was near the level of extrusion. The breccia is interpreted as fill material in the fissure conduit for the basalt at Black Mountain.

Basalt Flow (Tbf): A lobe of bluish-black, aphanitic, alkaline-olivine basalt that extends down the west side of Black Mountain between 7,420 and 7,600 feet (2,261.6 and 2,316.5 m) elevation is interpreted as the remnant of a basalt flow that lies stratigraphically above the limestone member and main body of the Wasatch Formation. D.W. Fiesinger (written communication, 1993) provided a K-Ar age of 31.1 ± 1.9 Ma on the flow. The basalt lobe is composed of broken and randomly oriented columns in floaty outcrop. The contact between the basalt and the underlying Wasatch Formation is obscured by colluvium, but it appears to have a low westward slope. The lobate outcrop pattern of the basalt, the low slope at the base of the basalt, and the lack of a landslide scarp up slope from the basalt indicate that it is not a Quaternary mass-wasting deposit like the basalt-clast landslide deposits on the south and east sides of Black Mountain.

Quaternary

The Quaternary system is represented by a variety of alluvial and mass-wasting surficial deposits. Descriptions of these deposits are presented in order of relative age, oldest to youngest.

Older Alluvial-Fan Deposits (Qaf_2)

Older alluvial-fan deposits are present in North and South Eden Canyons; the toes of these fans are cut by low-level (modern) alluvium (Qal). On the north side of South Eden Canyon, the fan overlies the Leeds Creek Member of the Twin Creek Limestone. These unconsolidated deposits are composed of rounded cobbles and pebbles that are probably derived from Wasatch Formation conglomerates, and angular, pebble- and cobble-sized clasts derived from the Twin Creek Limestone that are set in a light-gray, fine-grained matrix. A smaller alluvial-fan deposit is preserved on a spur of the north wall of North Eden Canyon west of the former site of upper North Eden reservoir. The older alluvial-fan deposits lie at elevations between 6,200 and 6,480 feet (1,889.8 and 1,975.1 m) in South Eden Canyon, and between 6,100 and 6,250 feet (1,859.3 and 1,905.0 m) in North Eden Canyon, and were probably deposited during a highstand of Bear Lake, possibly during deposition of the older deltaic deposits (Qd_2) at the mouths of North and South Eden Canyons in the Bear Lake South quadrangle. If co-deposition is correct, the age of the older fans is probably middle late Pleistocene (see Coogan, 1996). The older alluvial-fan deposits vary from 0 to approximately 200 feet (0 to 60 m) thick.

Alluvium (Qa)

Alluvium consists of unconsolidated gravel, sand, silt, and clay present in low areas above the modern drainage profiles of North Eden and South Eden Creeks, and their major tributaries. Given this setting, these deposits are probably older than the Holocene low-level alluvium (Qal). Other areas of general alluvium (Qa) are mapped in the eastern reach of Little Creek, and in Current Creek south of North Eden Canyon. These two areas of general alluvium (Qa) are not adjacent to low-level alluvium (Qal), and might be the same age and/or older than low-level alluvium. The alluvium (Qa) is Holocene and possibly older in age, and is 0 to 10 feet (0 to 3 m) thick.

Landslides and Slumps (Qms)

Landslides are mapped on the north, south, and east sides of Black Mountain in the Sheeppen Creek quadrangle. The landslide deposits on the south side of Black Mountain are composed primarily of angular basalt blocks with little matrix material. A series of landslide scarps with up to 80 feet (24 m) of relief form a south wall to the Black Mountain summit. Landslide deposits on the north and east sides of Black Mountain contain large, angular, basalt clasts with smaller, rounded clasts and fine-grained matrix derived from the Wasatch Formation. Other small landslides and slumps, derived from the Wasatch Formation, were mapped near the heads of Little and Currant Creeks, along South Eden Canyon, and near the upper reaches of North Eden Canyon in the Sheeppen Creek quadrangle. Landslides and slumps are Holocene and probably Pleistocene in age. Landslide and slump deposits are generally less than 100 feet (30 m) thick, but may be as thick as 250 feet (75 m) on the flank of Black Mountain.

Talus (Qmt)

Talus deposits are composed of unconsolidated, matrix-free, angular, pebble- to boulder-sized debris. These deposits are only present in the northwest corner of the quadrangle. Talus is Holocene and possibly older in age, and is generally less than 10 feet (3 m) thick.

Colluvium (Qmc)

Colluvium consists of unconsolidated and largely unstratified, mostly angular, silt- to boulder-sized debris that is present along the sides of major drainages and on the flanks of Black Mountain. Colluvial deposits also lie immediately down slope from bedded outcrops of the Wasatch Formation along and between North Eden and South Eden Canyons. A colluvial apron containing angular, basalt fragments blankets the lower slopes of Black Mountain. Large areas of colluvium containing micrite shards and pencils overlie the Leeds Creek Member of the Twin Creek Formation in North Eden and South Eden Canyons. Colluvium apparently grades into and is cut by low-level alluvium (Qal), and is therefore Holocene and possibly older in age. Colluvial deposits are generally 0 to 20 feet (0 to 6 m) thick.

Younger Alluvial-Fan Deposits (Qaf_1)

Unconsolidated, crudely stratified, poorly sorted, clay- to boulder-sized material forms fan-shaped deposits at the mouths of small tributary drainages to North Eden and South Eden Creeks. These deposits grade laterally into low-level alluvium (Qal) and are therefore Holocene in age (see Coogan, 1996). These younger fan deposits are 0 to 40 feet (0 to 12 m) thick.

Low-Level Alluvium (Qal)

Low-level alluvium consists of unconsolidated deposits of gravel, sand, and mud that lie in the valley bottoms of North Eden Canyon, South Eden Canyon, North Fork Sixmile Creek, Rabbit Creek, and their tributaries. Drainage profiles are graded to or slightly above modern Bear Lake levels, so the deposits are later Holocene in age (see Coogan, 1996). The grain size and mineral constituents of alluvium in North Eden Canyon were reported by McClurg (1970). These alluvial deposits are generally less than 15 feet (5 m) thick.

STRUCTURE

Introduction

The Sheeppen Creek quadrangle is located in the center of the Wyoming salient of the Cordilleran fold and thrust belt which developed in Cretaceous to early Tertiary time. The principal thrust faults that controlled the early structural development of the area include: (1) the Willard thrust fault, located in the subsurface of the western Bear Lake South quadrangle; (2) the Meade-Laketown thrust fault, located beneath Bear Lake in the Bear Lake South quadrangle; (3) the Home Canyon thrust, which crops out in the northern Sheeppen Creek quadrangle; (4) imbricate thrust faults exposed in southeastern Bear Lake South quadrangle; (5) the Sheep Creek thrust, which has been drilled beneath the Sheeppen Creek quadrangle; and (6) the Gypsum Spring décollement, which crops out in South Eden Canyon in Bear Lake South quadrangle. Folds in the map area are generally related to thrust faulting. The eastern Bear Lake fault zone transects the earlier formed thrust faults and folds along the Bear Lake shorefront in eastern Bear Lake South quadrangle. Refer to Coogan (1996) for descriptions of structural features in the Bear Lake South quadrangle, and to Coogan (1992a) for details on the structural geology of the area.

Thrust Faults

Home Canyon Thrust Fault

The Home Canyon thrust was originally mapped 4 miles (7 km) north of Sheeppen Creek quadrangle by Oriel and Platt (1980) where it is locally obscured by overlying Tertiary strata.

Previous mapping within the Sheeppen Creek quadrangle by Richardson (1941), McClurg (1970), or Dover (1995) did not delineate this thrust fault. The Home Canyon thrust places the Wood Shale Tongue of the Ankareh Formation on the upper Nugget Sandstone along the west flank of Sheep Creek anticline at the north edge of the Sheeppen Creek quadrangle. The Home Canyon thrust is folded about the crest of Sheep Creek anticline along the north wall of North Eden Canyon where it places the lower and middle Nugget Sandstone on the uppermost Nugget Sandstone. The thrust was penetrated along the anticline crest by the American Quasar #12-1 Eden State well (section 12, T. 14 N., R. 6 E.) where the Nugget Sandstone overlies the Gypsum Spring Member of the Twin Creek Limestone at 720 feet (219 m) depth (cross section A′-A″). The Home Canyon thrust was also penetrated by the #2-41 Eden State well (section 2, T. 14 N., R. 6 E.)(cross section A′-A″). The Home Canyon thrust dips eastward on the east limb of Sheep Creek anticline where it places the upper Nugget Sandstone over the Gypsum Spring Member on the south side of North Eden Canyon, and where it lies entirely within a décollement zone in the Gypsum Spring Member on the north side of the Canyon.

Sheep Creek Thrust Fault (not exposed)

The Sheep Creek thrust is a blind thrust beneath Sheep Creek anticline and the fold belt in the Twin Creek Limestone exposed along North Eden and South Eden canyons in the Sheeppen Creek quadrangle. The Sheep Creek thrust was penetrated by the American Quasar #2-41 Eden State well (section 2, T. 14 N., R. 6 E.) where the thrust places overturned Nugget Sandstone on the east limb of Sheep Creek anticline over upright Gypsum Spring Member at a depth of 16,688 feet (5,086.5 m) (cross section A′-A″). The shortening of the Paleozoic through Nugget Sandstone section along the Sheep Creek thrust at depth is transferred eastward along the Gypsum Spring décollement to the fold shortening of the Twin Creek Limestone that is expressed at the surface in the North Eden and South Eden fold belts.

Gypsum Spring Décollement

Anhydrite beds in the Gypsum Spring Member of the Twin Creek Limestone form important local décollement horizons throughout the thrust belt (Coogan and Boyer, 1985). The Gypsum Spring décollement in the eastern Bear Lake South quadrangle forms the footwall décollement zone for the imbricate thrusts in South Eden Canyon and along the lakefront slope to the south, as well as the upper décollement, or "roof thrust" (Boyer and Elliott, 1982), to the eastern imbricate thrust and folds in South Eden Canyon. In Bear Lake South quadrangle, the décollement is best exposed immediately north of South Eden Canyon, where it underlies Indian Creek syncline. The approximate position of the décollement is delineated by tight folding in the upper dolomite bed (bed "D" in plate 1) of the Gypsum Spring Member that is disharmonic with respect to folds in the underlying Nugget Sandstone. In the Sheeppen Creek quadrangle, the Gypsum Spring décollement forms the frontal décollement zone of the Home Canyon thrust, the footwall décollement of the blind Sheep Creek thrust, and it underlies the tight folds in the Twin Creek Limestone in the North Eden and South Eden fold belts. Folding of the Gypsum Spring décollement by underlying structures of the Home Canyon and Sheep Creek thrust sheets is consistent with a general sequence of thrusting getting younger to the east across the map area.

Crawford Thrust Fault (not exposed)

West-dipping Cambrian through Jurassic rocks of the Crawford thrust sheet underlie Sheeppen Creek quadrangle. The west dip of the thrust sheet reflects folding above the principal footwall ramp of the Crawford thrust, along which the thrust cuts obliquely across Cambrian through Jurassic strata. The location of the ramp beneath Sheeppen Creek quadrangle (plate 3) is constrained by well control and seismic reflection data.

Folds

Indian Creek Syncline

Indian Creek syncline is a gently north-plunging fold in the Twin Creek Limestone that lies along the boundary between Bear Lake South and Sheeppen Creek quadrangles north of South Eden Canyon. The syncline is underlain southward by the Gypsum Spring décollement. Indian Creek syncline is an asymmetric syncline with west limb dips up to 80 degrees east and very shallow east limb dips. Along the west limb of the syncline, the moderately to steeply east-dipping Sliderock Member is decoupled from the overturned, west-dipping Nugget Sandstone by a general zone of disharmonic folding and detachment in the Gypsum Spring Member, rather than by a single discrete décollement surface.

Sheep Creek Anticline

Sheep Creek anticline is exposed in northern Sheeppen Creek quadrangle. It is an asymmetric, east-vergent anticline with 35 to 45 degree southwest dips in the Nugget Sandstone on the west fold limb and up to 77 degree east dips in the Twin Creek Limestone of the east limb. The east limb is overturned in the subsurface with dips as low as 25 degrees west. Sheep Creek anticline is cored by anhydrite of the upper part of the Mississippian-Pennsylvanian Amsden Formation in the subsurface. The anticline is isoclinally folded at the Amsden level, which indicates that the fold core formed by hinge collapse along low shear strength anhydrite zones. Sheep Creek anticline plunges 15° S. 25°W. in the subsurface, and it therefore probably underlies the overturned folds in the Twin Creek Limestone in South Eden Canyon near the western edge of Sheeppen Creek quadrangle.

The steep and overturned east limb and the high structural relief of Sheep Creek anticline indicate that it formed as a fault-propagation fold (Mitra, 1990; Suppe and Medwedeff, 1990) along the tip of the Sheep Creek thrust, and was later translated eastward onto the Gypsum Spring décollement after breakthrough across the east limb or frontal synclinal hinge beneath the anticline. Hinge collapse in the Amsden anhydrites probably accompanied the initial folding.

North Eden Fold Belt

The North Eden fold belt is comprised of folds in the upper Twin Creek Limestone east of Sheep Creek anticline in northern Sheeppen Creek quadrangle. The westernmost fold sets are south-plunging S-folds developed in the Watton Canyon (Jtw) and Leeds Creek (Jtl) members west of the South Fork of North Eden Creek. The southwestern S-fold is a monocline pair and the northeastern S-fold is an anticline-syncline pair, both of which originate in the upper part of the Watton Canyon Member. The S-folds have a top-to-west shear sense, consistent with parasitic, flexural-slip folding during growth of Sheep Creek anticline. A syncline-anticline pair in the Leeds Creek and Giraffe Creek (Jtgc) members east of South Fork is probably related to folding above the Gypsum Spring décollement that developed during slip along the Sheep Creek blind thrust. The syncline is isoclinal, with the overturned west limb and steep east limb both dipping about 75 degrees west. The syncline is cored by the lowermost, salt-bearing part of the Preuss Redbeds. The isoclinal syncline probably developed by hinge collapse along the Preuss salt horizon, which formed an upper décollement to Twin Creek folding throughout the region (Coogan and Yonkee, 1985).

South Eden Fold Belt

This fold belt in the Twin Creek Limestone is best exposed along the north side of South Eden Canyon in Sheeppen Creek quadrangle. The westernmost folds consist of two inverted anticline-syncline pairs in the Gypsum Spring, Sliderock, Rich and Watton Canyon Members that comprise the 0.5-mile-wide (8 km), recumbent limb of an overturned synform. The well control in cross-section B-B' (plate 3) indicates that the synform lies in the hanging wall of the Home Canyon thrust. In addition, the synform has a top-to-east shear sense, possibly as the result of fault-parallel shear immediately beneath a large-displacement, east-directed thrust fault. This was probably the Meade-Laketown thrust (figure 1), which has subsequently been eroded as well as displaced westward along the eastern Bear Lake normal fault zone (Coogan, 1996, plate 3).

The eastern folds are two upright, anticline-syncline pairs in the Leeds Creek and Giraffe Creek Members, and the lower part of the Preuss Redbeds near the former site of South Eden Reservoir. Like the folds along trend in North Eden Canyon, they are probably related to folding above the Gypsum Spring décollement that developed during slip along the Sheep Creek blind thrust.

Hogback Ridge Anticline and Syncline

Hogback Ridge anticline and syncline are subsurface structures along the trend of Hogback Ridge gas field (cross section B′-B″), which was explored by three wells immediately south of Sheeppen Creek quadrangle (Walker, 1982). Like Sheep Creek anticline, Hogback Ridge anticline probably originated as a fault-propagation fold cored by the Mississippian-Pennsylvanian Amsden Formation. The Hogback Ridge structures might continue northward into the central Sheeppen Creek quadrangle beneath Plateau syncline, but there are not sufficient data to continue it to cross section A′-A″.

Plateau Syncline

Plateau syncline is a subtle fold in Eocene Wasatch strata that trends roughly north-south through the eastern half of Sheeppen Creek quadrangle. Both limbs of the syncline locally dip up to 9 degrees. The subtle surface syncline overlies a more pronounced subsurface syncline in Mesozoic strata that was mapped by Walker (1982, figure 5) along the northeast side of the Hogback Ridge structure at the south edge of the quadrangle. Plateau syncline and associated minor folds may have developed during minor, Eocene uplift above the western part of the Crawford thrust ramp, and along the Hogback Ridge structure in southern Sheeppen Creek quadrangle.

ECONOMIC GEOLOGY

Oil and Gas

The Wyoming-Idaho-Utah portion of the Cordilleran thrust belt was the site of extensive oil and gas exploration, which culminated in the discovery of 27 oil and gas fields from 1975 to 1982 (Kluth and Lamerson, 1988). At present, economic production is limited to 24 fields on the southern Absaroka thrust sheet, where hanging wall anticlines in Mesozoic and Paleozoic reservoir rocks are juxtaposed against footwall Cretaceous source rocks (Lamerson, 1982; Warner, 1982).

The Sheeppen Creek quadrangle became an exploration target following the October, 1977 discovery of Hogback Ridge field, a subsurface anticline located in section 20, T. 13 N., R. 7 E. on the hanging wall of the Crawford thrust, 1.5 miles (2.5 km) south of the quadrangle. Hogback Ridge field produced a total of 5.8 billion cubic feet (164 million cubic meters) of dominantly methane and nitrogen gas from fractured carbonate reservoir intervals in the Dinwoody Formation (Triassic) until depletion and abandonment in 1981 (Walker, 1982). Two of the three offset wells to the field yielded gas shows in Triassic and Permian intervals without commercial flows. Fourteen other wells were drilled to test Triassic and Permian reservoirs of the Crawford and Sheep Creek thrust sheets in the Sheeppen Creek and adjacent quadrangles (Clem and Brown, 1985; Coogan, 1992a). Of these, the Marathon 0.1 #1-15 South Eden Canyon well (section 15, T. 13 N., R. 6 E.), 1,800 feet (550 m) south of Bear Lake South quadrangle, reported three minor gas shows on drill-stem tests in imbricated Triassic rocks beneath the Sheep Creek thrust sheet; and the American Quasar #14-44 Nebeker well (section 14, T. 14 N., R. 7 E.) 4,000 feet (1,200 m) east of Sheeppen Creek quadrangle (plate 3, cross section A′-A″) reported minor gas on a drill-stem test in the Dinwoody Formation of the Crawford thrust sheet. No shows were reported in the two wells drilled in the Sheeppen Creek quadrangle (#2-41 Eden and #12-1 Eden wells) in the Sheep Creek thrust sheet. No exploration wells have been drilled in Bear Lake South quadrangle, and no hydrocarbon shows were reported from four wells drilled through Triassic and Paleozoic rocks of the Meade thrust and the Paris thrust footwall in Bear Lake Valley, Idaho.

The main limitation for the traditional hydrocarbon plays in the area appears to be the timing of anticlinal traps with regard to source rock thermal maturation. Marine Cretaceous rocks, which are the source for hydrocarbon accumulations in the Absaroka thrust sheet, are absent in the footwall of thrust sheets in the Sheeppen Creek quadrangle and other quadrangles adjacent to the Bear Lake South quadrangle. The presumed source rock for all reported hydrocarbon shows in the area are phosphatic shales of the Permian Phosphoria Formation. The lack of complex hydrocarbons in Hogback Ridge gas analyses indicates that hydrocarbon generation from Phosphoria source rocks may have been limited to a very mature phase of residual dry gas generation near the time of structural entrapment. Peak Phosphoria hydrocarbon generation and expulsion probably preceded thrust sheet emplacement and associated folding in this part of the thrust belt (Warner, 1982; Valenti, 1987), and probably coincided with initial burial of the area beneath the foreland basin clastic wedge in early Cretaceous time (Aronson and Elliott, 1985). However, Mississippian rocks of the Meade-Laketown thrust sheet exposed near Laketown, Utah have relatively low conodont alteration indices of 1.5 to 2 (Sando and others, 1981), and Phosphoria samples from the Meade hanging wall near Soda Springs, Idaho also have low thermal maturities (Desborough and others, 1988), which indicate that upper Paleozoic rocks of the Meade-Laketown thrust sheet may not have been as deeply buried prior to thrusting and folding as rocks of the Crawford and Absaroka thrust sheets to the east, and they may be capable of further hydrocarbon generation. Thus, areas of the Meade-Laketown thrust sheet beneath Bear Lake Valley remain prospective for hydrocarbon generation.

Building Materials

Sand and Gravel

Possible sources of well-rounded sand and gravel are poorly consolidated gravel beds in the Wasatch Formation. Colluvial aprons and alluvial fans locally contain poorly sorted, angular gravel adjacent to Nugget Sandstone outcrops in North Eden and South Eden Canyons.

Road Metal

Most gravel roads across Bear Lake Plateau and the eastern shore of Bear Lake are paved with limestone road metal from various members of the Twin Creek Limestone. Colluvial aprons adjacent to Twin Creek outcrops and highly cleaved and fractured outcrops are easily quarried sources of road metal. The Watton Canyon Member of the Twin Creek Limestone is presently quarried for road metal in the southwestern corner of section 26, T. 14 N., R. 6 E. on the south side of South Eden Canyon.

Riprap and Fill

Riprap and fill material for civil engineering purposes are plentiful in talus, alluvial-fan, and some colluvial deposits adjacent to Nugget Sandstone outcrops in North Eden Canyon. Two quarries in highly weathered Nugget outcrops in the center of section 2, T. 14 N., R. 6 E. were used for fill material for upper North Eden reservoir dam. A third quarry near the Nugget - Gypsum Spring contact in SE¼NE¼ section 3, T. 14 N., R. 6 E. was used for the lower North Eden reservoir dam.

Building and Paving Stone

Friable intervals of the Nugget Sandstone that exhibit clean parting planes along cross bedding have been historically quarried along western Bear Lake Plateau immediately north of the Sheeppen Creek quadrangle. Quarries in the Pegram Creek quadrangle, Idaho were the source of Nugget Sandstone building stone for the Mormon tabernacle in Paris, Idaho (Kaliser, 1972). Sandstone of similar quality is exposed in the upper part of the Nugget Sandstone in South Eden Canyon, adjacent to lower North Eden Reservoir in North Eden Canyon, and north of the American Quasar #2-41 well near the Idaho border. Elsewhere, particularly along the lakefront ridge in northeastern Bear Lake South quadrangle, the Nugget Sandstone is highly indurated and intensely fractured quartzite.

Cement Rock

Elemental analysis for cement-rock quality was performed on a sample from the Rich Member of the Twin Creek Limestone collected on the north side of South Eden Canyon (NE¼ SW¼SE¼ section 27, T. 14 N., R. 6 E.) in the Sheeppen Creek quadrangle (table 2). This sample contains too much silica to be used as cement rock (J.K. King, verbal communication, July, 1993). The Twin Creek Limestone is mined for cement rock in northern Utah at Devils Slide in Morgan County, about 65 miles (105 km) to the southwest. It is possible that unsampled intervals of the Twin Creek Limestone might contain suitable cement rock in the Sheeppen Creek quadrangle.

WATER

Surface Water

Surface water was impounded for irrigation and livestock along North Eden Creek in lower and upper North Eden reservoirs, and South Eden Creek reservoir prior to failure of the dams during flooding on April 20, 1980. The South Eden Creek reservoir was rebuilt, but remains unfilled due to lack of a spillway (Utah Division of Water Rights, 1980; D.K. Marble, written communication to J.K. King, February 24, 1993).

Table 2.
Cement Rock Elemental Analysis, Rich Member of Twin Creek Limestone (sample location section 27, T. 14 N., R. 6E.)

Element	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	Na_2O	P_2O_5	SiO_2	TiO_2	S	Ba	Cr	LOI	Total
Percent	5.04	39.00	2.48	1.36	1.94	0.06	0.32	<0.01	19.30	0.34	0.07	<0.01	<0.01	31.15	100.99

Analyses performed by Bondar-Clegg, August 18, 1989
NOTES: *LOI = Lost On Ignition*

Ground Water

Shallow aquifers in Sheeppen Creek quadrangle are limited to permeable intervals of the Wasatch Formation on Bear Lake Plateau. Springs issue from the Wasatch Formation where permeable sandstone, conglomerate, and fractured limestone aquifers intersect drainages down gradient from major recharge areas. Springs in eastern Sheeppen Creek quadrangle, such as those at the headwaters of North Eden and South Eden Creeks, most commonly discharge where conglomerates with abundant clast-contact fractures overlie impermeable, red shale zones in the main body of the Wasatch Formation. Many springs in southwestern Sheeppen Creek and southeastern Bear Lake South quadrangle discharge near the contact between the limestone member and the overlying main body of the Wasatch Formation. These springs include Cottonwood and associated springs along Cottonwood Creek, the spring along the northern head of Little Creek, a spring in eastern South Eden Canyon, and springs in the east and middle branches of the South Fork of South Eden Creek. The springs result from downward infiltration of water through the main body of the Wasatch Formation to fractured aquifers that are underlain by impermeable zones in the limestone member. Most of these springs discharge from a fractured, oncolitic limestone at the top of the limestone member.

The size of springs in the Wasatch Formation is a function of the size of the recharge area(s) for individual springs. The largest recharge area for the Wasatch aquifers is along Lake Ridge, the crest of which rises to 7,200 feet (2,194.6 m) elevation immediately east of Sheeppen Creek quadrangle. The largest perennial springs lie immediately west of Lake Ridge near the trough of Plateau syncline, where gently west-dipping Wasatch aquifers intersect drainages at elevations below 6,800 feet (2,072.6 m). These springs include the headwaters of North Eden Creek, Rabbit Spring near the head of Rabbit Creek, Sheeppen Spring and associated springs near the head of Sheeppen Creek, and springs along the east side of the North Fork of Sixmile Creek. The springs are down structural and hydrologic gradient from outcrops of the aquifers in the Lake Ridge recharge area. The Lake Ridge recharge area probably also contributes to springs at the headwaters of South Eden Creek by ground-water transport across the divide between the headwaters of Sheeppen and Rabbit Creeks.

A second recharge area for Wasatch aquifers surrounds Black Mountain in western Sheeppen Creek quadrangle. The Black Mountain area recharges small, perennial and intermittent springs at the headwaters of Black Mountain Creek, Little Creek, Currant Creek, and the South Fork of North Eden Creek, as well as springs along the north side of South Eden Canyon. Small perennial and intermittent springs along Cottonwood Creek in southeastern Bear Lake South quadrangle and southwesternmost Sheeppen Creek quadrangle are down dip from a recharge area along the lakefront ridge in southeastern Bear Lake South quadrangle. The lakefront recharge area, and a recharge area along the drainage and groundwater divide at the southern edge of Sheeppen Creek quadrangle, supply small, perennial and intermittent springs along the middle and east branches of the South Fork of South Eden Creek.

GEOLOGIC HAZARDS

Earthquakes

The eastern Bear Lake fault zone has been the site of Pleistocene and Holocene surface rupture (McCalpin, 1990) and is thought to be the locus of an estimated magnitude 6 earthquake in 1884 (Pechmann and others, 1992). Fault scarps that cut Holocene alluvial fans, colluvium, and deltaic sediments are continuous along the east shore of Bear Lake in the adjacent Bear Lake South quadrangle. McCalpin (1990) estimated paleoearthquake recurrence and magnitudes from trenches across two Quaternary fault scarps on North Eden delta, with minimum recurrence intervals of 9,100 to 10,100 years and 500 to 2,500 years respectively, and minimum magnitudes of 6.9, 7.1, and 7.4 for different faulting events across the scarps. Although there is no evidence for Holocene faulting in the Sheeppen Creek quadrangle, ground shaking from earthquakes generated along faults in the Bear Lake South quadrangle could damage ranch facilities and earthen dams on the North Eden and South Eden drainages, and induce landsliding or slumping. Individual slip events in the past 4,600 to 2,100 years produced throws of 18 and 8.5 feet (5.6 and 2.6 m) across the western scarp of the eastern Bear Lake fault zone in the Bear Lake South quadrangle (McCalpin, 1990).

A magnitude 4.8 earthquake and a large magnitude 4.3 aftershock occurred on November 19, 1988 beneath the Bear River Range near the Utah-Idaho border, approximately 3 miles (5 km) west of the Bear Lake South quadrangle (Pechmann and others, 1992). This earthquake can be explained by slip at depth on the eastern Bear Lake normal fault zone (see Coogan, 1996).

Flooding

Upper North Eden, lower North Eden, and South Eden dams failed due to overtopping associated with apparent heavy run-off on April 20, 1980 (Utah Division of Water Rights, May, 1980). The combined capacity of the North Eden dams was 571 acre-feet (704,043 cubic meters) and the release washed out the canyon road and covered 60 acres of farmland with rocks and debris. The North Eden dams have not been rebuilt. The reported release from South Eden dam was 47 acre-feet (57,951 cubic meters), with no reported downstream damage. The South Eden dam has subsequently been rebuilt to a height of 20 feet (6.1 m), but it is not operational pending construction of a spillway to regulate the hydraulic height to 17 feet (5.1 m) (D.K. Marble, written communication to J.K. King, February 24, 1993).

Other Hazards

None of the slides, slumps, or talus deposits mapped are near habitation, so they do not constitute a major hazard to existing development. No problem soils are known (Campbell and Lacey, 1982).

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APPENDIX

MEASURED SECTION OF THE WASATCH FORMATION AT SOUTH EDEN CANYON, SHEEPPEN CREEK QUADRANGLE

A section of the Wasatch Formation was measured in NE¼ of section 26, NW¼ of section 25, and the S½ of section 24, T. 14 N., R. 6 E., Rich County, Utah by J.C. Coogan on November 4, 1988 using the tape and compass method. Three informal members of the Wasatch Formation are described in the section: the main body, limestone member, and quartzite conglomerate member. The limestone member consists of an upper tongue of oncolitic limestone and a lower unit that includes a variety of interbedded lithologies including limestone conglomerate, calcareous sandstone, reddish-orange mudstone, and gray mudstone.

Top of section is the crest of hill in NW¼SE¼ of section 24.

Unit Number	Thickness in feet	Description
Limstone member (upper tongue)		
1	22	Limestone, white to light-gray, massively bedded, with oncolites and coated grains in micritic matrix; local horizontally laminated, algal(?) structures.
Total limestone member (upper tongue): 22 feet (7 m) Incomplete, top of section is crest of hill.		
Main Body		
6	99	Covered slope of reddish-orange soil.
5	21	Mudstone; reddish-orange, poorly exposed in clayey, reddish-orange soil.
4	14	Sandstone; light-gray to pinkish-gray, trough-cross-stratified in 1-foot (30.5 cm) beds; some chert pebbles along base of beds.
3	92	Mudstone and minor sandstone; reddish-orange mudstone in trenches dug along poorly exposed slope; minor, lenticular, sandstone bodies about 1-foot (30.5 cm) thick crop out on adjacent slopes.
2	7	Sandstone; light-gray, medium to coarse, quartz and chert grains, trough cross stratified.
1	7	Mudstone; red-orange.
Total main body: 240 feet (73 m)		
Limestone Member		
12	9	Limestone conglomerate; light-gray conglomerate composed of well-rounded, gray to white quartzite, orange sandstone, and gray limestone cobbles and pebbles, with coated, pebble-sized, chert clasts in a fining upward sequence; limestone clasts are derived from the Twin Creek Limestone, sandstone clasts are derived from the Nugget Sandstone.
11	12	Mudstone; reddish-orange, poorly exposed in red, clayey soil.
10	4	Sandstone; light-gray, calcareous, medium-grained, horizontally laminated; forms small cliff.
9	43	Mudstone; reddish-orange, exposed by trenching; forms a bench of reddish-orange, clayey soil.
8	2	Silty sandstone; as unit 6.

Unit Number	Thickness (feet)	Description
7	1	Mudstone; reddish-orange in clayey soil.
6	9	Silty sandstone; pink, calcareous, horizontally laminated; poorly exposed in floaty outcrop.
5	16	Mudstone; reddish-orange, poorly exposed in red, clayey soil.
4	10	Limestone conglomerate and calcareous sandstone, interbedded; light-gray conglomerate composed of 0.2 to 0.8-inch (0.5 to 2 cm) in diameter, coated grains, oncolites, and chert granules in a course, calcareous, sandstone matrix; interbedded with light-gray to pink, coarse- to medium-grained, calcareous sandstone.
3	35	Gray-brown soil zone with gray, mudstone float.
2	39	Mudstone; mainly gray to light-gray, silty mudstone as small, floaty outcrop in gullies and trenches over highly covered interval; some pink-weathering soil zones.
1	29	Mudstone; gray to light-gray; contains some slightly calcareous siltstone; poorly exposed in gullies and trenches; forms small bench to east of section line.
Total limestone member: 209 feet (64 m)		
Quartzite conglomerate member		
9	2	Sandstone; trough cross stratified, gray, coarse- to medium-grained, with chert pebbles near base.
8	4	Conglomerate and sandstone, interbedded; trough cross stratified, as unit 6.
7	6	Sandstone; trough cross stratified, gray, coarse- to medium-grained.
6	10	Conglomerate and sandstone, interbedded; sandstone is light-gray, coarse-grained with black and gray chert pebbles at base of 1 to 2-foot (30.5 to 60 cm) thick, lenticular, trough cross-stratified beds; conglomerate is massive and contains well-rounded, quartzite pebbles and cobbles, and black and gray chert pebbles.
5	8	Conglomerate; massive, tan and gray, poorly exposed, mainly composed of well-rounded, quartzite cobbles, and black and gray chert pebbles in coarse sandstone matrix.
4	8	Trough cross-stratified conglomerate; gray, coarsens upward from subangular to subrounded, gray and black, chert-pebble conglomerate to gray to white, well-rounded, quartzite, pebble and cobble conglomerate.
3	5	Conglomerate; massive, tan and gray, with bimodal clast composition of gray to white, well-rounded, quartzite pebbles and cobbles, and subangular to subrounded, gray and black, chert pebbles as in unit 1; discontinuous lenticular outcrops of sandstone as in unit 2 adjacent to line of setion.
2	2	Sandstone; trough cross stratified, light-gray, poorly sorted, quartz sandstone in a discontinuous, lenticular outcrop; black and gray chert pebbles along scoured base; encased in massive gravel.
1	8	Conglomerate; massive, tan and gray, with bimodal clast composition of gray to white, well-rounded, quartzite pebbles and cobbles (1.2 to 3.15 inches [3 to 8 cm] in diameter), and gray and black, subangular to subrounded, chert pebbles; one limestone cobble derived from the underlying Twin Creek Limestone; matrix is poorly sorted, coarse-grained sandstone.

Unit Number	Thickness (feet)	Description
Total quartzite conglomerate member: 53 feet (16 m)		
Total Wasatch Formation: 524 feet (160 m)		
Angular Unconformity		
Twin Creek Limestone, Leeds Creek Member		

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Base map from the U. S. Geological Survey
Sheeppen Creek 7.5' Quadrangle, 1986

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Lori J. Douglas, Cartographer

14°5'
250 mils

1997 MAGNETIC DECLINATION
AT CENTER OF SHEET

UTAH
QUADRANGLE LOCATION

GEOLOGIC MAP OF THE SHEEPPEN CREEK QUADRANGLE, CACHE COUNTY, UTAH

by

James C. Coogan

1997

The Miscellaneous Publication Maps provide an outlet for authors who are not Utah Geological Survey staff. Not all aspects of this publication have been reviewed by the UGS.

DESCRIPTION OF MAP UNITS

Qa — Alluvium - *Gravel, sand, silt, and clay located above major streams (probably older than Qal) and at isolated locations in other drainage age uncertain*

Qal — Low-level alluvium - *Gravel, sand, and mud in valley bottoms of major streams.*

Qaf₁ — Younger alluvial-fan deposits - *Poorly sorted, clay- to boulder-sized material in crudely stratified, fan-shaped deposits.*

Qaf₂ — Older alluvial-fan deposits - *Rounded cobbles and pebbles from Wasatch Formation conglomerate, and angular pebbles and cobbles of Twin Creek Limestone in a fine-grained matrix.*

Qmc — Colluvium - *Angular, silt- to boulder-sized material from nearby outcrops.*

Qms — Landslides and slumps - *Angular blocks of basalt around Black Mountain, including some material from the Wasatch Formation; other deposits are largely derived from the Wasatch Formation.*

Qmt — Talus - *Matrix-free, angular, pebble- to boulder-sized debris.*

Basalt of Black Mountain

Tbf — Basalt flow - *Black, aphanitic, alkali-olivine basalt in a lobate exposure.*

Tbb — Basaltic breccia - *Breccia of black basalt and some white, partially silicified, oncolitic limestone from the Wasatch Formation in a white matrix of crystalline calcite, silica, and zeolite; exposure is linear.*

Tbd — Basalt dikes - *Black, aphanitic, alkali-olivine basalt with small (<0.8 inch [2 mm]) olivine phenocrysts; age about 29 million years.*

Wasatch Formation

Tw — Main body - *Poorly exposed red mudstone, and lesser sandstone and conglomerate.*

Twl — Limestone member - *Oncolitic and algal limestone, limestone flat-pebble conglomerate, and light-gray siltstone; interfingers with the main body such that this limestone map unit contains significant main-body lithologies in easternmost exposures.*

Twq — Quartzite conglomerate member - *Gray conglomerate with well-rounded cobbles of white and gray quartzite.*

Jp — Preuss Redbeds - *Only basal part exposed; red, non-resistant sandstone and shale, with salt in subsurface.*

Twin Creek Limestone

Jtgc — Giraffe Creek Member - *Light-, greenish-, and pinkish-gray, calcareous sandstone and gray, lime grainstone composed of fossil fragments.*

Jtl — Leeds Creek Member - *Gray, non-resistant, massive micrite with pervasive pencil cleavage; upper portion is fossiliferous, lime wackestone and packstone that grades into overlying Giraffe Creek Member.*

Jtw — Watton Canyon Member - *Gray, resistant, medium-bedded micrite and oolitic, lime wackestone and packstone with distinctive rectangular weathering pattern derived from spaced cleavage.*

Jtb — Boundary Ridge Member - *Lower and upper red-brown shales separated by massive, gray, oolitic limestone; capped by thin, oolitic limestone.*

Jtr — Rich Member - *Massive, micritic limestone with pervasive pencil cleavage; has undergone extensive structural thickening and thinning.*

Jts — Sliderock Member - *Upper half is lime packstone, wackestone, and micrite, grading up into the Rich Member; lower half is gray, resistant, sandy, lime packstone and grainstone with fossil fragments.*

Jtg — Gypsum Spring Member - *Red shale, siltstone, and sandstone; yellow sandstone; gray, dolomite and brecciated dolomite; anhydrite in subsurface.*

Jn — Nugget Sandstone - *Reddish-orange, friable, medium- to fine- grained, quartz sandstone; capping by white, well-indurated sandstone is common.*

Ankareh Formation

Ŧaw — Wood Shale Tongue - *Not completely exposed; exposures are bright-red siltstone and shale.*

CROSS SECTIONS ONLY
For units west of this quadrangle see Bear Lake South quadrangle (Coogan,1996)

Q — Quaternary undivided

Transitional Shelf Sequence - rocks of the Home Canyon thrust sheet; same as Inner Shelf Sequence for Jurassic through Mississippian rocks.

D — Devonian undivided - *Probably includes Leatham Formation (where present), Beirdneau Formation, Hyrum Dolomite, and Water Canyon Formation, or Three Forks and Jefferson Formations.*

Sl — Laketown Dolomite - *Thick-bedded dolomite.*

O — Ordovician undivided - *Probably includes Fish Haven Dolomite, Swan Peak Formation (where present), and Garden City Limestone.*

C — Cambrian undivided - *As depicted, probably includes Upper Cambrian rocks, St. Charles and Nounan Formations.*

Inner Shelf Sequence - rocks of the Sheep Creek, Crawford, Absaroka, and other thrust sheets exposed east of the Bear Lake Plateau.

Jtc — Twin Creek Limestone - *Mostly limestone, with some shale; siltstone, sandstone, dolomite, and anhydrite-bearing member at base (Gypsum Spring).*

Jn — Nugget Formation - *Sandstone.*

Ŧaht — Wood Shale Tongue of the Ankareh Formation, Higham Grit, Timothy Sandstone and Portneuf Limestone Members of the Thaynes Formation, and Lanes Tongue of the Ankareh Formation - *Mixture of shale, siltstone, sandstone, and limestone.*

Ŧt — Thaynes Formation - *Shale and limestone.*

Ŧtw — Woodside and Dinwoody Formations - *Shale and siltstone.*

PIPM — Phosphoria, Wells, and Amsden Formations - *Limestone, chert, phosphatic shale, and sandstone.*

Mm — Madison Group - Includes Mission Canyon Formation (= Brazer Dolomite) and Lodgepole Limestone - *Thick-bedded dolomite and limestone.*

Dd — Darby Formation - *Shale, sandstone, and dolomite; sometimes called the Three Forks and Jefferson Formations in the Cordilleran fold and thrust belt.*

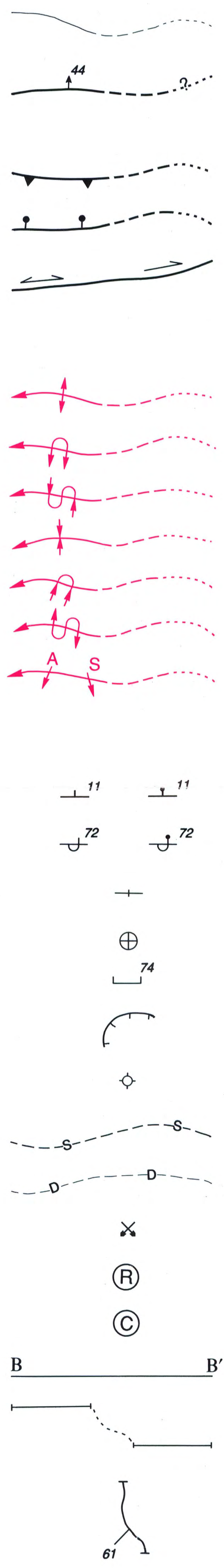
Ob — Bighorn Dolomite - *Thick-bedded dolomite.*

Ꞓg — Gallatin Limestone and Gros Ventre Formation - *Thin-bedded, silty limestone, oolitic limestone, and shale.*

Ꞓf — Flathead Sandstone - *Arkosic sandstone.*

pꞒx — Crystalline basement rocks - *Precambrian*

MAP AND CROSS SECTON SYMBOLS



Contact - *dashed where approximately located; dotted where concealed*

Fault - *dashed where approximately located; dotted where concealed; queried where uncertain; arrow shows dip*

Thrust - *sawteeth on upper plate*

Normal - *ball and bar on downthrown side*

Arrows on cross section show relative motion. *Double-headed arrows indicate separate slip episodes with opposite slip directions*

Folds - *dashed where approximately located or inferred; dotted where concealed; arrow shows plunge direction where known*

Anticline

Overturned Anticline

Synformal (inverted) Anticline

Syncline

Overturned Syncline

Antiformal (inverted) Syncline

Monocline - *showing anticlinal bend, A; showing synclinal bend, S*

Strike and Dip of Bedding - *in structurally complex areas ball used when top of bedding is known*

Inclined; *symbol on right used where top of bed can be distinguished*

Overturned; *symbol on right used where top of bed can be distinguished*

Vertical

Horizontal

Strike and Dip of Cleavage

Landslide Scarp

Dry Hole

Ancient Shoreline

"D" marker of Gypsum Spring Member of Twin Creek Limestone

Gravel Quarry

Radiometric Sample Locality

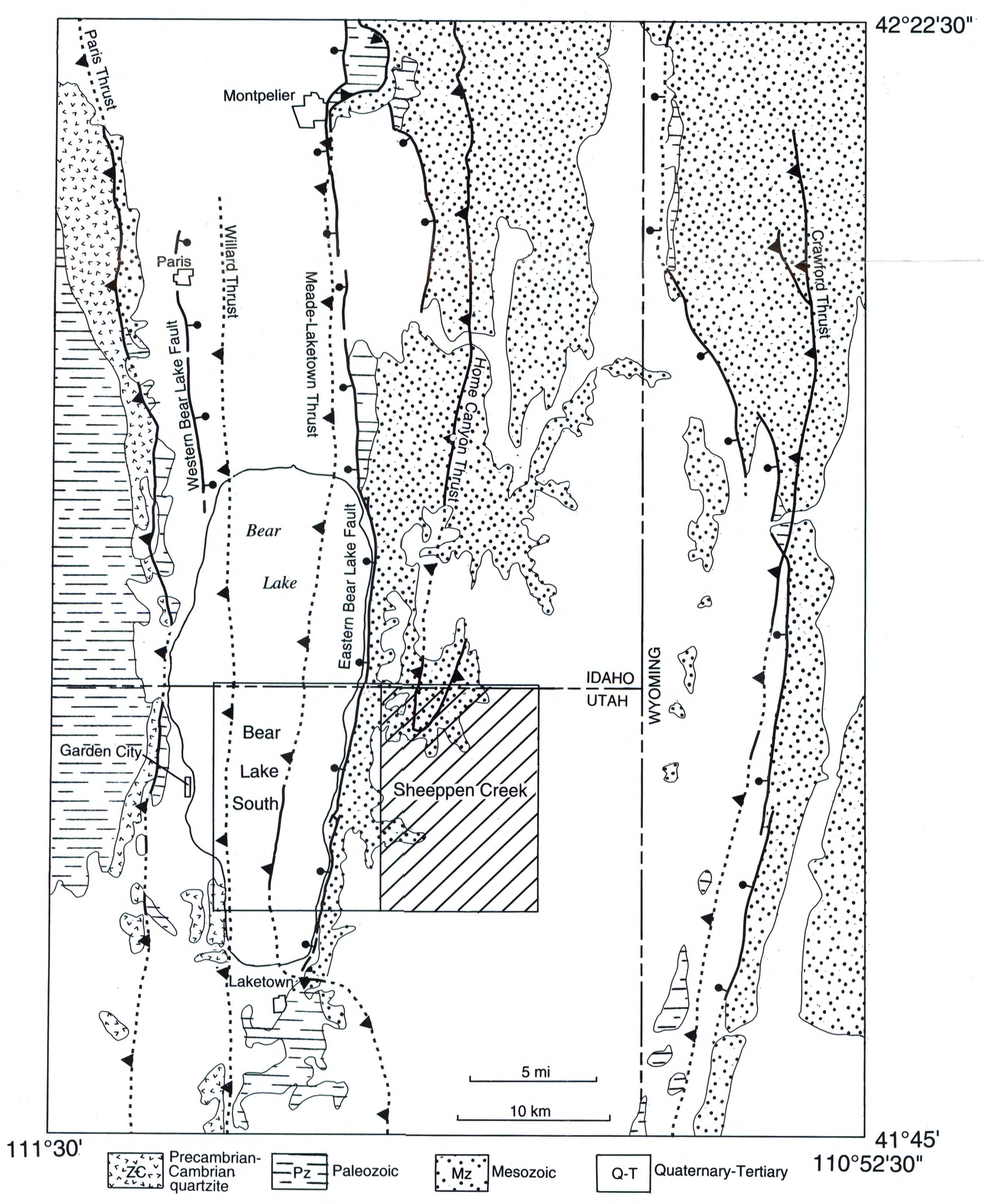
Chemical Sample Locality

Line of Cross Section

Line of Measured Section - *dashes shown where offset*

Drill hole on cross section showing bore-path deviation and dip from dip meter survey

INDEX MAP



CORRELATION OF MAP UNITS

(*indicates exposure in the Sheeppen Creek quadrangle)

Holocene / Pleistocene (Quaternary): Qal*, Qaf₁*, Qdma, Qlsg₁, Qmc*, Qmt*, Qms*, Qa*, Qd₁, Qlf, Qlsg₂, Qaf₂*, Qd₂

unconformity

Oligocene (Tertiary): Tbf*, Tbb*, Tbd*

Eocene (Tertiary): Tw*, Twl*, Twq*

regional angular unconformity

Middle (Jurassic): Jp*, Jtgc*, Jtl*, Jtw*, Jtb*, Jtr*, Jts*

J2 unconformity

Jtg*

J1 unconformity

Lower (Jurassic): Jn*

J0 unconformity

Upper (Triassic): Ŧaw*, Ŧh

unconformity

Lower (Triassic): Ŧti, Ŧtp, Ŧal

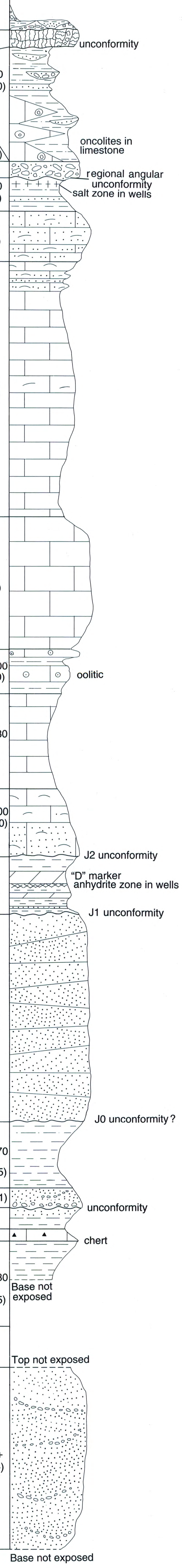
Intervening section missing in quadrangle due to displacement on Willard and Bear Lake faults.

Middle / Lower (Cambrian): Ꞓgc

STRATIGRAPHIC COLUMN

(*indicates exposure in the Sheeppen Creek quadrangle)

Time Stratigraphic Units		Formation and Members		Symbol	Thickness feet (meters)	Lithology
Quaternary		Surfical deposits		Q*	0-50 (0-15)	
Tertiary	Olig.	Basalt of Black Mountain		Tbf*, Tbb*, Tbd*	0-40 (0-12)	unconformity
Tertiary	Eocene	Wasatch Formation	Main body	Tw*	0-700 (0-210)	
			Limestone member	Twl*	0-400 (0-120)	oncolites in limestone
			Quartzite Conglomerate Member	Twq*	0-100 (0-30)	regional angular unconformity
Jurassic	Middle	Preuss Redbeds		Jp*	0-200 (0-60)	salt zone in wells
		Twin Creek Limestone	Giraffe Creek Member	Jtgc*	300 (100)	
			Leeds Creek Member	Jtl	1550 (475)	
			Watton Canyon Member	Jtw*	800 (245)	
			Boundary Ridge Member	Jtb*	265-300 (80-90)	oolitic
			Rich Member	Jtr*	550-730 (165-220)	
			Sliderock Member	Jts*	250-500 (75-150)	J2 unconformity
			Gypsum Spring Member	Jtg	350 (105)	"D" marker; anhydrite zone in wells; J1 unconformity
	Lower	Nugget Sandstone		Jn*	1300 (400)	J0 unconformity ?
Triassic	Upper	Ankareh Formation	Wood Shale Tongue	Ŧaw*	400-570 (120-175)	
		Higham Grit		Ŧh	135 (41)	unconformity
	Lower	Thaynes Formation	Timothy Sandstone	Ŧti	125 (38)	
			Portneuf Limestone	Ŧtp	65 (20)	chert
		Ankareh Formation	Lanes Tongue	Ŧal	508-580 (155-175)	Base not exposed
Intervening Lower Triassic through Cambrian rocks not exposed in quadrangles. See cross sections.						Top not exposed
Cambrian	Middle / Lower	Geertsen Canyon Quartzite		Ꞓgc	1200+ (365+)	Base not exposed



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