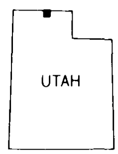
PROVISIONAL GEOLOGIC MAP OF THE LIMEKILN KNOLL QUADRANGLE, BOX ELDER COUNTY UTAH

By Brendan E. Murphy, Stanley S. Beus, and Charles G. Oviatt



UGMS Provisional maps are produced by non-UGMS geologists, often in partial fulfillment of a thesis supported by the UGMS. They often undergo a different review process and address different questions than those considered in the regular series.

UTAH GEOLOGICAL AND MINERAL SURVEY

a division of

UTAH DEPARTMENT OF NATURAL RESOURCES

MAP 79 **1985**

PROVISIONAL GEOLOGIC MAP OF THE LIMEKILN KNOLL QUADRANGLE BOX ELDER COUNTY, UTAH

by

Brendan E. Murphy [1], Stanley S. Beus [2], and Charles G. Oviatt [3]

INTRODUCTION

The Limekiln Knoll 7 1/2-minute quadrangle is located near the eastern margin of the Great Basin in north-central Utah, immediately south of the Idaho-Utah state border, and approximately 85 miles (138 km) north of Salt Lake City in Box Elder County. The dominant topographic unit, the West Hills, is a segment of the Bannock Range which extends from the Snake River Plain in southern Idaho to the Promontory Mountains north of Great Salt Lake. The West Hills are bordered on the east by the Malad River Valley and on the west by the Pocatello Valley. Both are nearly flat, fault-bounded valleys typical of the Basin and Range Physiographic Province and are covered by Lake Bonneville sediments and loess. The total relief of the Limekiln Knoll quadrangle is nearly 2,700 ft (825 m), from approximately 4,500 ft (1,375 m) above sea level at the eastern mouth of Portage Canyon to nearly 7,196 ft (2,200 m) at the summit of West Peak in the central ridges of the quadrangle.

STRATIGRAPHY

GENERAL

The Limekiln Knoll area is two structural blocks separated by the northwest-trending North Canyon fault of Beus (1968). Flat and gently west-dipping shallow-marine intertidal and supratidal detrital and carbonate strata of Middle Ordovician through Middle Pennsylvanian age underlie the area northeast of this fault. In the southwest block about 13,500 ft (4,100 m) of Middle Pennsylvanian to Early Permian age rocks are exposed and currently assigned to the Oquirrh Formation.

ORDOVICIAN SYSTEM

Swan Peak Quartzite

The oldest formation exposed in the quadrangle is the Swan Peak Quartzite of Middle Ordovician age. It is a light-gray to buff or brown quartz sandstone composed of fine- to medium-grained, well-rounded supermature quartz sand grains in a siliceous or calcareous cement. Thin to medium sandstone beds occur in some intervals and small-scale cross-beds are abundant.

The Swan Peak crops out only in the northeast corner of the quadrangle where it is exposed in the low hills on both sides of the mouth of Portage Canyon, west of Portage. Outcrops are mainly of rounded or blocky ledges of light-gray sandstone and light-gray talus slopes. A few float blocks of brown sandstone yield horizontal cylindrical trace fossils.

The exposed portion of the Swan Peak is estimated to be about 400 ft (120 m) thick; the base is not exposed. The formation is 605 ft (185 m) thick in the Malad Range five miles to the east and probably has a corresponding thickness here. The upper contact is sharp and clearly marked by the contrasting dark gray Fish Haven Dolomite which overlies the Swan Peak.

ORDOVICIAN-SILURIAN SYSTEM

Fish Haven Dolomite-Laketown Dolomite

This dolomite sequence of 1,450 ft (440 m) contains beds of Late Ordovician age (Fish Haven Dolomite) and of Silurian age (Laketown Dolomite). Because no sharp mappable contact was found within the section the two formations are mapped as one. This sequence is exposed in mile-wide segments on both sides of Portage and Middle Canyons in the northeast part of the quadrangle. The upper part of the section crops out as resistant cliffs and ledges while the lower part is less well exposed and in some places covered.

The lower 70 ft (21 m) consist of dark-gray medium-crystalline dolomite containing irregular black chert

[1] Geology Department, Bryn Mawr University
[2] Professor, Northern Arizona University
[3] Geologist, Utah Geological and Mineral Survey

nodules parallel to the bedding, typical of the Fish Haven Dolomite as recognized throughout northern Utah. The succeeding 230-ft (70-m) section has resistant light- to medium-gray dolomites that appear thick-bedded to massive in outcrop although in detail exhibit some obscure thin beds. Fossil corals of Late Ordovician age (*Streptelasma* sp.) occur in the middle of this sequence. The approximate Ordovician-Silurian boundary (and Fish Haven-Laketown contact) is placed at the top of the resistant ledges of this entire lower section of 300 ft (91 m).

The upper 1,140 ft (347 m) of the Fish Haven-Laketown section is thick-bedded to massive, fine- to coarsely-crystalline, dark and light gray dolomite that forms irregular resistant cliffs. Silurian corals, including species of *Halysites*, *Favosites* and *Syringaxon*, occur in this upper sequence. The lower part contains an abundance of black to medium-gray chert nodules. The upper part is a lighter gray dolomite in which chert is rare or absent. The upper boundary of the Fish Haven-Laketown section is placed below the first fine-grained, white-weathering dolomite typical of the overlying Water Canyon Formation.

DEVONIAN SYSTEM

Water Canyon Formation

This formation is silty to sandy dolomite, generally less resistant than the units above and below, and in some areas is extensively covered. It crops out in a thin band from Ruff Canyon northwest to the state boundary. The lower part forms a very light-gray slope, partly covered, in contrast to the darker gray of the underlying Laketown Dolomite.

Two members of the Water Canyon Formation are recognized in the quadrangle. The lower Card Member, about 280 ft (85 m) thick in Portage Canyon, is an aphanitic dolomite that is locally silty or sandy. The Card Member is thinly laminated and dark-grayish brown on a fresh surface but weathers very light gray.

The upper unit, the Grassy Flat Member, is a sandy and silty, fine-grained to aphanitic dolomite that is reddish brown or gray on weathered surfaces. It is about 275 ft (83 m) thick at Portage Canyon. Some beds of calcareous cemented quartz sandstone occur in the upper part and at the top is a 6 ft (2 m) bed of intraformational conglomerate or breccia with calcareous sandstone clasts. The upper boundary is not everywhere well exposed but, where visible, is placed below the first dark-gray ledge-forming dolomite typical of the lower Hyrum Dolomite above.

Much of the Grassy Flat Member, as here recognized, was earlier placed in the lower Hyrum Formation by Beus (1968) because it contains scattered invertebrate fossils similar to those in the Samaria Limestone Member of the lower Hyrum. Williams (1973) believed that this section (units 1-5 of the Samaria Limestone Member, Hyrum Formation, of Beus, 1968, p. 802) is more properly part of the Water Canyon Formation; his interpretation is followed here.

The total thickness of the Water Canyon Formation in the quadrangle is about 540 ft (165 m). Fossil fish from the Water Canyon Formation in the Logan quadrangle, to the east, indicate an Early Devonian age (Williams and Taylor, 1964, p. 42).

Hyrum Dolomite

The Hyrum Dolomite is about 810 ft (247 m) thick in the quadrangle and is mainly dark-gray dolomite and limestone that form resistant ledges and cliffs. Dark-gray fossiliferous limestone and dolomitic limestone of the Samaria Limestone Member comprise the lower 335 ft (102 m). The type section of the member, which is at the state line on the north boundary of the quadrangle, is expressed as three resistant cliffs or ledges of skeletal fossiliferous limestone separated by less resistant beds of silty dolomitic limestone generally lacking in megafossils. The Middle-Upper Devonian boundary occurs within the Samaria Limestone as indicated by the occurrence of the brachiopods *Ambothyris utahensis* Beus and *Rensselandia cloudi* Frost and Langenheim (late Middle Devonian) in the lower limestone cliffs and *Desquamatia oneidensis* (Beus) and *Allanella engelmanni* (Meek) (early Late Devonian) in the middle and upper limestone cliffs of the member (Beus, 1965; Beus, 1968; Williams, 1973).

The upper part of the Hyrum Dolomite, above the Samaria Limestone, is dark to light gray finely crystalline dolomite, mostly thin to medium bedded, that forms ledges and slopes. Chert nodules occur in a few beds and a 13 ft (4 m) quartz sandstone bed occurs in the lower half of this unit. The uppermost 245 ft (75 m) of the Hyrum Dolomite is ledge-forming limestone separated by weaker interbeds of dolomitic limy sandstone. This sequence forms a prominent cliff in the middle of the Devonian section. The upper boundary of the Hyrum is placed at the top of this cliff-forming limestone and beneath the first sequence of medium- to light-gray dolomite and limy dolomitic sandstone of the Beirdneau Sandstone.

Beirdneau Sandstone

The Beirdneau is a dolomite and dolomitic to calcareous quartz sandstone unit exposed as a band up to 1/2 mile wide from the north side of Ruff Canyon to the northern boundary of the quadrangle. It is 990 ft (302 m) thick at the state line (Beus, 1968, p. 791). The formation is predominantly medium to light gray dolomite in the lower third of the section. The middle part of the section is mainly quartz sandstone and dolomitic quartz sandstone, and the upper third is light gray silty dolomite. A 60 ft (18 m) quartz sandstone forms a prominent ledge near the middle of the formation. The upper part of the Beirdneau has a few resistant dolomite ledges but is generally less resistant than the lower two-thirds of the section. The upper boundary is placed beneath the lowest prominent cliffs of thin-bedded cherty limestone of the overlying Lodgepole Limestone which contrasts sharply with the slope-forming dolomite at the top of the Beirdneau.

No fossils have been found in the Beirdneau in this area. It is bounded by rocks of Late Devonian age beneath and Early Mississippian age above and is considered to be of Late Devonian age.

MISSISSIPPIAN SYSTEM

Lodgepole Limestone

The Lodgepole Limestone is the lowest of four Mississippian formations which together make up 2,600 ft (790 m) of section in the quadrangle. The Lodgepole is one of the most prominent rock units in outcrop because of the persistent 50-ft (15-m) cliff at the base. The formation crops out in a thin band from Limekiln Hollow north to the state line in the north-central part of the quadrangle.

Four distinct subunits are recognized in the Lodgepole primarily on the basis of topographic expression. The basal subunit is a resistant cliff-forming sequence of thin-bedded mudstone to wackestone. It contains abundant black chert nodules up to 3 in (8 cm) thick parallel to the bedding. The second subunit is a slope-forming light-gray lime grainstone in beds 2-4 in (5-10 cm) thick. This subunit is about 134 ft (40 m) thick. The third subunit is a medium-gray, resistant, skeletal grainstone with abundant crinoid plates. It is about 115 ft (35 m) thick and forms irregular cliffs and ledges. The uppermost subunit is a light-gray crinoidal grainstone and packstone containing 0.4 in (1 cm) lenses of black chert. It forms partially covered slopes above the ledges of subunit 3 and is about 39 ft (12 m) thick. The total Lodgepole Limestone unit is a little over 400 ft (122 m) thick at the state line.

Marine invertebrate fossils are abundant in the unit and include brachiopods, corals, crinoids, bryozoans, trilobites, gastropods and ostracods. The fossils indicate an Early Mississippian age (Kinderhookian and early Osagian) for the formation. The top of the Lodgepole Limestone is placed at the top of the highest gray limestone beds below the covered slope containing brown-weathering siltstone chips of the Humbug Formation.

Humbug Formation

The Humbug Formation occurs as a smooth slope above the cliffs and ledges of the underlying Lodgepole Limestone. It consists of fine-grained calcareous sandstone or siltstone, commonly brown weathering, and a few thin beds of dark gray limestone. The thickness at the state line is 978 ft (298 m) in the two small outcrop areas at the north end of the quadrangle. The top of the Humbug is clearly marked by the first appearance of resistant dark-gray limestone ledges of the overlying Great Blue Limestone.

No diagnostic fossils were recovered from the Humbug within the quadrangle. It is considered to be the correlative of the Little Flat Formation of southeastern Idaho which is late Early to early Late Mississippian (Osagian to Meramecian) age (Sando and others, 1976).

Great Blue Limestone

In general, the Great Blue Limestone is predominantly a medium- to dark-blue-gray limestone exposed as blocky ledges and irregular cliffs separated by slope-forming shales. Many beds are either skeletal wackestone or packstone, with individual beds up to 30 percent fossil fragments, dominantly crinoid plates in a dark-gray lime mud matrix. Brown to dark gray chert nodules up to 2 in (5 cm) thick are locally abundant in the limestone. Within the Limestone Knoll quadrangle, the Great Blue Limestone crops out only in a 1/2-square-mile area at the state line, but the outcrop band extends continuously for 8 miles to the north into southern Idaho. Abundant marine invertebrate fossils from the unit include brachiopods, corals, crinoids, bryozoans, trilobites, gastropods, ostracods and endothyrids. Key species among these indicate an age of Late Mississippian (Meramecian and Chesterian) for the Great Blue (Beus, 1968, p. 794).

MISSISSIPPIAN-PENNSYLVANIAN SYSTEM

Manning Canyon Formation

This unit is the least well exposed formation of the Paleozoic section within the quadrangle. A thin wedge at the state line forms a smooth, sagebrush-covered slope mantled with loose blocks of yellow-brown sandstone. Four rock types are recognized in the Manning Canyon unit: black shale, green to brown shale, yellow-brown quartz sandstone, and yellowish-weathering skeletal limestone. Exposures are not adequate to determine the relative thickness of each lithology, but at better exposed sections in northern Utah the formation is about half shale, and the other half limestone, sandstone and siltstone. The Manning Canyon is 300 ft (91 m) thick at the state line. The top is a sharp boundary marked by the basal limestone ledges of the Oquirrh Formation.

Fossils from the Manning Canyon Formation were obtained near the stream bed in North Canyon, Idaho, about 300 yards north of the state line. The collections include the brachiopods *Inflatia* sp., *Rhipidomella nevadensis* Girty, and *Reticulariina spinosa* Norwood and Pratten which indicate a Late Mississippian (Chesterian) age for the formation. Fossil evidence from elsewhere in northern Utah indicates that the Mississippian-Pennsylvanian boundary is probably somewhere within the formation.

PENNSYLVANIAN-PERMIAN SYSTEM

Oquirrh Formation

All of the rocks found in the southwestern structural block are assigned to the Oquirrh Formation which has been subdivided into six informal units ranging in age from early Middle Pennsylvanian to Early Permian. The combined thickness of these units in the Limekiln Knoll quadrangle probably exceeds 14,900 ft (4,500 m).

Unit 1. The best exposures of Unit 1 are on the south-facing slopes along Left Hand Fork about 1.3 mi (2 km) from its juncture with Middle Canyon. Lithologically, this unit comprises a monotonous sequence of intercalated thin- to medium-bedded, 6-18 in (15-45 cm), medium- to dark-gray, silty limestones and thin-bedded, 4-8 in (10-20 cm), medium- to dark-brown, fine-grained calcareous sandstones. Nodules and 4-8 in (10-20 cm) layers of black chert, a minor component of this unit, are common in the lower part.

Unit 1 has few outcrops, occurring in a terrain of rounded hilltops with few isolated outcrop ledges (probably slumps) and scattered talus slopes. However, good outcrops occur at minor fault scarps, where 13-20 ft (4-6 m) ledges expose sequences of alternating limestone and calcareous sandstone. The limestones are fine grained, massive and silty. The silt is mixed thoroughly within the limestone and is not concentrated as laminae or lenticules. Typically, the silt is quartz, though fine skeletal fragments constitute a small proportion of the silt material. Bioturbation is extensive in many of the limestone layers and is seen as small pelloid-shaped depressions affecting as much as 40 percent of the rock volume. Differential erosion of the burrows accentuates these depressions into light-gray "ovoids" or ellipses, with long axes less than 0.4 in (1 cm) in length, against a normally weathered, medium-gray limestone background. This bioturbation is rarely visible on freshly broken rock surfaces. Unlike the limestone beds in overlying Oquirrh units, Unit 1 has a conspicuous lack of medium- to coarse-grained bioclastic limestone beds.

The interbedded sandstones are fine-grained, massive, calcareous quartzites, generally medium to light brown. Locally, they exhibit fine laminations and cross laminations. In the lowest parts of the unit, 2-4 in (5-10 cm) layers of black chert have replaced or cemented the sandstone beds, especially near the North Canyon fault. It is not known if the presence of this chert is a result of processes at or shortly after the time of deposition of the sediments, or a result of circulating groundwater associated with the nearby North Canyon fault. The interbedded limestones in this part of the unit do not appear to be altered in any way.

Fusulinids from three localities have been identified as *Pseudostaffella* sp. and *Triticites* sp., as well as a schwagerinid, and were assigned ages ranging from early Middle Pennsylvanian to Late Pennsylvanian (Missourian) by R. C. Douglass (personal communication, 1983). Stratigraphic contacts with adjacent Pennsylvanian units are not exposed in this area, but the oldest unit south of the fault along Portage Canyon (Unit 2) contains fusulinids of a Late Pennsylvanian (Virgilian) age. The lithology of Unit 1 suggests that they must have been deposited in oxygenated, shallow waters that sustained an extensive community of burrowing organisms. Local laminations and cross laminations in many of the limestone and sandstone beds further suggest that the rocks were deposited in water affected slightly by tide or wave. The deposition of thin layers of fine-grained sandstone indicates a cyclical influx of detrital material deposited in a quiet marine environment, as suggested by their fine-grained texture and the well-sorted, sheetlike nature of the individual sandstone layers.

Unit 2. This unit is exposed on the east and west limbs of a broad syncline plunging gently south in the central region of the quadrangle. The base of the unit is not exposed as the sequence has been truncated by normal faults to the north, south, west, and east. Quaternary Lake Bonneville sediments cover an unknown amount of Unit 2 to the east, thus the 2,450 ft (747 m) of Unit 2 measured in the study area is the minimum thickness.

Unit 2 includes intercalated, medium- to thick-bedded, 2-4 ft (0.6-1.2 m) medium brown to dark gray, micritic and fine- to coarse-grained bioclastic limestones and medium- to thick-bedded, 2-4 ft (0.6-1.2 m), medium brown to dark gray, fine- to medium-grained, quartzose to subarkosic, calcareous sandstones. Bioturbation is present in many of the limestone and sandstone beds. Several 3-5 ft (0.9-1.5 m) massive beds of limestone conglomerate occur throughout the unit and are more common in the lowermost 500 ft (150 m) of the exposed sequence.

In the lower half of the unit, many of the limestone beds occur as 1 ft (0.3 m) rounded ledges that form subdued ridges along hillslopes underlain by Unit 2. These thick-bedded, medium- to dark-gray, massive limestones weather light to medium gray, and locally appear light purple or pink. The weathered surfaces commonly show fine laminae of quartz silt as well as fine- to coarse-grained skeletal fragments. The fine- to coarse-grained bioclastic limestones contain skeletal fragments dominated by echinoderms and bryozoans and are micrite supported (packstone) to grain supported (grainstone).

In the upper half of the unit, the limestone beds are identified by the presence of localized talus slopes of fine- to coarse-grained bioclastic limestones and bioturbated silty limestones similar to those in the lower half of the unit. This talus weathers to a light to medium gray and locally to a light purple or pink. Intercalated with these limestones are thick 2-4 ft (0.6-1.2 m) medium-brown to dark-gray massive beds of calcareous sandstone. These sandstones have undergone more intense leaching and are less erosion resistant than the limestones. They do not form ledges in any part of the unit, they do normally display small, rounded float blocks of partially leached sandstone between the talus slopes of the limestone beds. Commonly, these sandstone float blocks have a thin, leached outer layer and an unweathered calcareous core. Partial exposures of the calcareous sandstone subunits adjoin the tops and bottoms of the limestone beds which form rounded ledges. Here the sandstone beds are seen to be massive, fine to medium grained, quartzose to subarkosic, and calcareous.

Throughout Unit 2, and especially common in the lowermost 500 ft (150 m), are 3-5 ft (0.9-1.5 m) dark gray, massive beds of limestone conglomerate. These beds form isolated, rounded ledges less than 2 ft (0.6 m) high and appear as resistant to erosion as the bioclastic and silty limestone beds. The clasts, both micritic and bioclastic, contain minor amounts of quartz silt. They are subrounded to subangular and are imbedded in a matrix of poorly sorted micrite and quartz silt. The skeletal material in the clasts has not been identified, and the provenance of the clasts is unknown but possibly they are derived from an intraformational source since the clasts resemble limestone beds of Units 1 and 2. The conglomeratic limestones do not appear to be confined to channel areas but, because of the extensive, sheetlike nature of the deposits, appear to have formed on an extensive flat marine basin.

Fusulinids from locality III have been identified as *Triticites* sp. and *Pseudofusulinella* sp. and were assigned a Late Pennsylvanian (Virgilian) age by R. C. Douglass (personal communication, 1983). The upper limit of Unit 2 is mapped as a conformable contact at the base of the first bed of nodular chert-bearing calcareous sandstone of Unit 3. The thick, massive beds of limestone conglomerate and poorly sorted bioclastic packstones found in this unit suggest turbulent transport of sediment into a quiet and undisturbed marine environment. Deposition probably occurred at the base of a submarine topographic slope, the materials coming in via turbidity currents and debris flows.

Unit 3. These strata are exposed as the youngest sequence of rocks in the core of a broad, gently plunging syncline in the east-central part of the Limekiln Knoll quadrangle. It underlies the highest ridges in the area (6,500- 7,100 ft) and is recognized on aerial photographs by the presence of extensive 30 x 100 ft (9x30 m) talus slopes. The best exposures of Unit 3 are along the ridges just north of the Ruff Canyon jeep trail in the east-central part of the study area.

Unit 3 is a sequence of alternating subunits of dark gray to light brown, finely laminated silty limestone, grading upward to 3-4 ft (0.9- 1.2 m) thick, rounded, ledge-forming, medium-gray, coarse-grained and bioclastic limestone; medium- to dark-brown, fine- to medium-grained, quartzose to subarkosic calcareous sandstone; and massively bedded, partially silicified, fine- to medium-grained, nodular chert-bearing, calcareous sandstone. Thinly bedded 2-10 in (5-25 cm) layers of black chert are intermittent throughout the unit and are more abundant at the top.

The limestone subunits are dark gray, finely laminated and silty at the base of the unit where they are distinguishable as discrete 10 x 12 x 16 in (25x30x40 cm), slightly weathered and subrounded float blocks of silty limestone. These limestones may contain up to 50 percent of fine quartz sand, locally forming 0.04 in (1 mm) erosion resistant tan laminae and cross laminations.

In the middle and upper parts of the unit, very thick (greater than 7 ft, 2.2 m), medium- to coarse-grained bioclastic limestone beds form ledges. These beds contain detrital quartz in places, and are both matrix supported (microsparite packstone) and grain supported (grainstone). The limestone ledges weather medium- to light-gray, and generally have a vuggy texture due to the differential weathering of the micritic matrix. In thin section, bryozoan, brachiopod, pelecypod and echinoderm fragments are identifiable. In addition, large numbers of fusulinids are present. Specimens include *Pseudofusulina* sp. and *Triticites* sp. and were assigned an Early Permian (Wolfcampian) age by R. C. Douglass (personal communication, 1983). Interbedded with these limestone are thick sequences of massively bedded 1-2 ft (0.3-0.6 m), fine- to medium-grained, partly silicified and nodular chert-bearing calcareous sandstones and medium- to dark-brown, fine- to medium-grained, quartzose and subarkosic, calcareous sandstones.

The latter of these two lithologies forms well exposed outcrops on the tops of many ridges and along some gullies. Beds usually form angular ledges about 3-6 ft (1-2 m) high and display partings every 3-4 in (7-10 cm), probably due to very thin argillaceous laminae within the subunit. Extensive talus slopes of this calcareous sandstone are exposed even though there are few good exposures of this subunit. The sandstone blocks are uniformly rectangular and measure approximately 4 x 4 x 6 in (10x10x15 cm), they weather rusty orange, red and brown, and are extensively leached of their carbonate content. Minor proportions of these talus slopes (less than 10 percent) are partially leached, silty and bioclastic limestone blocks derived from adjacent limestone beds.

The other sandstone subunit in Unit 3 is not well exposed in any outcrop but is commonly found in large, massive float blocks throughout the sequence. These large blocks are partially silicified, nodular chert-bearing, calcareous sandstones. They typically contain about 3 percent dark, heavy mineral grains. Weathered surfaces are pink to orange and have a bumpy texture due to the differential weathering of the chert nodules.

Black chert beds of two to ten inches (5.25 cm) are common in Unit 3. In the lower parts of the sequence, they are thin, 1-3 in (3-8 cm) layers separating the silty limestone layers from adjacent beds of silty limestone. Toward the top of the unit they are much thicker, more abundant, and found interspersed among all of the differing subunits: the silicified sandstones, silty limestones, quartzose to subarkosic sandstones, and bioclastic limestones. The thinner cherty layers in the lower portion of the sequence are commonly found as float blocks attached to remnants of silty limestone beds; the thicker chert layers in the upper part of the unit are observed in well-exposed, small outcrops as discrete beds among the other subunits. The total thickness of Unit 3 is 4,000 ft (1,220 m). The top of the unit was mapped at the top of the final occurrence of the nodular chert-bearing sandstone subunit. This stratigraphic contact is conformable.

The lithology of Unit 3 further documents subsidence and infilling of a sedimentary basin, a period of relatively constant sedimentation on the basin floor. The interbedded limestones, most of which contain broken and abraded skeletal material of unknown origin, may be the result of episodic turbidity currents and debris flows of carbonate sediments. The lack of bioturbation or any sedimentary structures within the unit suggest that Unit 3 rocks were deposited in a marine environment subjected to little wave- or tide-induced agitation.

Unit 4. The best exposures of Unit 4 are located on the west limb of the south-plunging anticline to the south and west of Broad Canyon, in the southern half of the Limekiln Knoll quadrangle. The sequence consists of a uniform series of medium brown, finely laminated and partly silicified quartz siltstones, with local pods and stringers of medium- to dark-brown chert. The unit rarely crops out, but float, consisting of thin slabs broken perpendicular to bedding, is very characteristic. These float chips weather brown, pale red and orange. Dark gray, coarse-grained bioclastic limestones, and medium-gray silty limestones are present but are not common occurrences in this unit. The bioclastic limestone beds that are present form low, rounded ledges present only near the base of the unit and containing no identifiable fossil fragments except for some local stringer beds containing large Permian(?) fusulinids. Typically, these fusulinids are mud-supported by a micritic matrix (packstone).

The silty limestone beds, a minor subunit throughout Unit 4, contain laminae, and cross laminations locally, of quartz silt that weathers tan. The limestone itself is medium gray and weathers light gray. Throughout the unit 3-4 in (8-10 cm) dark brown to black chert layers are common. These typically form massive slabs of float measuring approximately 3 x 4 x 6 in (8x10x15 cm), and generally weathering black. Unit 4 is 1,450 ft (442 m) thick. A marker bed of dark gray, bioclastic limestone containing large fusulinids marks the base of the overlying Unit 5.

Unit 4 was deposited in quiet waters that allowed accumulation of hemipelagic sediment and very fine detrital material derived from nearby sources. The lack of limestone conglomerate suggests that tectonism, perhaps responsible for earlier turbidity currents and debris flows, was not active during this time.

Unit 5. This unit is exposed on the limbs of several south-plunging open folds in the southern part of the quadrangle. The basal subunit of this sequence is a series of interbedded dark gray, micritic limestones and dark gray coarsely crystalline bioclastic limestones approximately 130 ft (40 m) thick. Both are relatively free of quartz sand and silt, and weather to form light-blue to gray float blocks. A small percentage of both display thin laminae of quartz silt.

Above this basal sequence, calcareous siltstones similar to those in Unit 4, but with a slightly lower percentage of layered brown chert, persist for more than 400 ft (120 m). These are included in Unit 5 because of the decidedly different nature of the unit's basal limestones from those limestones encountered in Unit 4.

Ledge-forming limestones occur in the upper two-thirds of Unit 5. They range from medium- and dark-gray, coarsely crystalline and bioclastic, to medium and dark brown silty limestones. Included within them are 3 in (8 cm) discontinuous layers and nodules of dark brown to black chert, and 2-4 in (5-10 cm) interbeds of medium to dark brown calcareous sandstone which is less weather resistant. The ledges in this sequence weather light to medium gray and are characteristically parted into slabs 8-20 in (20-50 cm) thick, due to weathering of the less erosion resistant interbeds of calcareous sandstone.

Interbedded with these massive ledges of limestone are heavily eroded areas 6-12 ft (1.8-3.6 m) thick. Float consists of small, extensively leached, red quartzose sandstone chips typically containing 1/4 in (8 mm) layers of dark brown to black chert. A uniform sequence of these interbedded limestones and sandstones continues upward for about 900 ft (275 m), where the first massive, crossbedded, calcareous orthoquartzite of Unit 6 is encountered. Fusulinids from the base of this sequence have been identified as *Pseudoschwagerina* sp., a peculiar form of *Triticites*(?) sp., and a fairly advanced *Schwagerina* sp., and were assigned an age of Early Permian (Late Wolfcampian) by R. C. Douglass (personal communication, 1983). Unit 5 is 1,400 ft (427 m) thick. The stratigraphic contact with the overlying Unit 6 is conformable.

The alternating sequences of rocks deposited in both Units 5 and 6 document the final stages of the infilling of the Oquirrh Basin. They indicate slight transgressive and regressive intervals, or they may represent local variations in sediment accumulation due to shoaling. The bioclastic limestones containing gastropods and fusulinids are indicative of an oxygenated outer shelf environment, and the locally crossbedded sandstones and siltstones reflect shallow subtidal deposits of detrital material.

Unit 6. The youngest Oquirrh Formation unit in the Limekiln Knoll quadrangle is exposed on the outermost limbs of a south-plunging anticline in the southwest corner of the map, and in the core of a south-plunging syncline in the southeast part. The top of it lies beneath a major unconformity throughout the study area. The best outcrops of the unit are exposed on the western limb of the anticline in the southwest corner of the map. Here, the sequence consists of many prominent ledges of bioclastic, sandy limestone beds and intercalated, highly eroded beds of calcareous sandstone.

The basal subunits of this member are two 12-ft-thick (3.6 m) beds of white to buff crossbedded sandstone weathering tan to brick red. They are well sorted, medium-grained, massively crossbedded, and orthoquartzitic beds, lithified with a calcareous cement. Separating these two basal orthoquartzites, and intercalated with the ledge-forming limestones higher up the section are 10 ft (3 m) beds of highly eroded calcareous sandstone. This subunit is rarely well exposed. Typically, wide areas of leached, tan to light brown sandstone float occur between the limestone beds. These float chips contain medium-sized quartz grains, less than 3 percent heavy mineral grains and, in some instances, 3 in (8 cm) brown chert layers. Only in rare cases can calcareous cement be detected, as most of the float chips have been thoroughly leached.

The limestones of Unit 6 are 8-12 ft (2.4-3.6 m) thick. They are similar to those limestones exposed in Unit 5 in that they range from medium- and dark-gray, coarsely crystalline and bioclastic, to medium- and dark-brown sandy limestones. Interbeds of 2-4 in (5-10 cm) less weather resistant, calcareous sandstone characteristically part these limestones into slabs 8-20 in (20-50 cm) thick. Blue-gray chert is a diagnostic characteristic of the limestones in Unit 6 occurring as discontinuous layers and irregularly shaped nodules throughout the limestones, and it is not encountered anywhere else in the Oquirrh Formation in the Limekiln Knoll quadrangle.

Beneath the major unconformity at all three exposures in the Limekiln Knoll quadrangle is a medium- to dark-gray, coarsely bioclastic and sandy limestone. The bed is a bioclastic packstone with a sandy and micritic matrix containing about 70 percent skeletal fragments, including Permian(?) fusulinids and large 1 in (3 cm) gastropods. All of the bioclastic material in this limestone bed has been replaced by white, sparry calcite. Unit 6 has a maximum thickness of about 1,650 ft (500 m).

TERTIARY SYSTEM

Salt Lake Formation

A single, large outcrop of unconsolidated interbedded tuffs and tuffaceous conglomerates, apparently the Tertiary Salt Lake Formation, is found on the south-facing slopes of the ridges north of Middle Canyon and unconformably overlies Unit 1 of the Oquirrh Formation. The conglomerates are grayish white and consist of subangular clasts of orthoquartzite, dolomite and limestone, usually less than 6 x 4 x 4 in (15x10x10cm), set in a matrix of tuffaceous sand and silt. The interbedded tuffs are buff to light tan, fine- to medium-grained, and locally are crossbedded. The grayish white color of the Salt Lake Formation is clearly observed on aerial photographs, and its presence can be confirmed by digging generally less than 1 ft (0.3 m) into the soil horizon above it.

QUATERNARY SYSTEM

The Quaternary alluvial, colluvial, and lacustrine sediments are subdivided into six map units. Where possible, the ages of the units are inferred relative to the Lake Bonneville chronology and terminology in current usage by Currey and others (1984). An arm of Lake Bonneville occupied the Malad River Valley in the eastern part of the map area and controlled late Quaternary sedimentation and landform development in Malad Valley and in the major canyons draining the east flank of the West Hills.

Lacustrine gravel was deposited in the shore zone in favorable localities in the eastern part of the map area. Undifferentiated lacustrine/alluvial units are mapped both in areas where the two kinds of deposits intertongue or are gradational and in areas where they cannot be spatially distinguished at a scale of 1:24,000. The thickness of the Lake Bonneville sediments is variable and has not been measured.

A pre-Bonneville soil developed in fine-grained eolian or colluvial deposits is poorly exposed on the north side of a deeply incised stream approximately 2000 feet west of Portage Cemetary in the NW1/4 SW1/4 sec. 1, T. 14 N., R. 4 W. The soil profile is cumulic and consists of about 14 feet of oxidized (5 YR 4/4), slightly sticky, sandy clay loam with calcium carbonate distributed throughout and concentrated as weak calcic horizons at several levels in the profile. This degree of soil development, particularly the oxidation, is much greater than post-Bonneville soil development in this area.

The Bonneville Shoreline is poorly developed on the Limekiln Knoll quadrangle, but occurs at altitudes between 5160-5180 ft (1573-1579 m; Currey, 1982). The crest of a beach ridge at the Provo Shoreline south of the mouth of Middle Canyon has an altitude of 4780 ft (1457 m). Prominent deltas were deposited in Lake Bonneville during the Provo stage at the mouths of Middle Canyon, Portage Canyon, and Ruff Canyon on the quadrangle. Similar Provo-stage deltas were deposited at the mouths of Broad Canyon and Johnson Canyon east of the map area. Alluvial terraces (represented by Qla_1) in the canyons are graded to the surfaces of the Provo deltas and are inset into the older transgressive Bonneville lacustrine/alluvial units (Qla_2).

Undifferentiated alluvial and colluvial deposits of Bonneville and pre-Bonneville (?) age (Qac_2) form isolated sloping terrace remnants or "shoulders" along the valley margins in the bottoms of the major canyons above the Bonneville Shoreline. The deposits were probably produced during periods when the base levels of the major trunk streams in the West Hills were considerably higher, as controlled by lake level, and by increased hillslope activity during the effectively moister climate of Bonneville and pre-Bonneville time. Alluvial and colluvial deposits of Provo age and younger (Qac_1) are mapped along the floors of the major canyons. Undifferentiated alluvium and colluvium covers the floor of Whites Valley.

STRUCTURE

The rocks of the Limekiln Knoll quadrangle have been folded and faulted. Two major structural domains are separated by the North Canyon fault, a normal fault that trends N. 30-50 degrees W. in the northeastern part of the quadrangle. Lower Paleozoic rocks exposed northeast of the fault are simply tilted; Upper Paleozoic rocks southwest of the fault are folded into anticlines and synclines.

The Lower Paleozoic rocks northeast of the North Canyon fault uniformly dip 20-35 degrees to the west and strike N. 10-20 degrees W. Dips less than 20 degrees are present in exposures along the east margin of the West Hills. Normal faults of small displacement also occur and generally strike nearly north and are downthrown to the east.

The structure southwest of the North Canyon fault is more complex. A large amplitude anticline and syncline pair strike slightly west of north (N. 5-15 degrees W.) and parallel the range. The anticline is located in the southwestern part of the quadrangle and is structurally separated from the eastward-lying syncline by subparallel faults. Both folds are broad, open structures with limbs dipping 30-40 degrees and nearly vertical axial planes. These folds plunge southward about 15 degrees.

The dips on the flanks of these folds are highly variable and indicate that smaller folds are superimposed, prominently along the east flank of the mountain range. The axial planes of these smaller folds strike nearly parallel to the larger folds but dip steeply east or west. They are illustrated on the cross-section, figure B-B'.

Two types of faults are exposed in the Limekiln Knoll quadrangle: north-trending, short, high-angle reverse faults and longer, through-going high-angle normal faults. The pattern of these faults, along with the pattern of the smaller folds, suggest that the rocks located southwest of the North Canyon fault comprise the upper plate of a block that has moved east. A regional decollement is inferred at depth below the Oquirrh Formation and southwest of the North Canyon fault. The decollement is not exposed on the quadrangle, but it is exposed to the northwest (Coward, 1979; Smith, 1982).

An alternative interpretation by Platt (1977) of the high-angle, normal North Canyon fault, where it extends northwards into Idaho, shows it as the steepened edge of a thrust fault beneath a decollement. The subsurface geometry of the blocks on either side of the fault would be nearly the same with either interpretation.

It is difficult to locate and identify the short faults, and the relative movement that has taken place along them, due to the monotonous stratigraphy and the poor quality of exposures. They may be recognized by 1) 30-50 ft (10-15 m) thick, steeply inclined areas of white, sparry calcite veins and gashes that cross-cut bedding at oblique angles, 2) steeply inclined areas of lush vegetation on otherwise dry, barren hillsides, indicating above-average porosity and groundwater migration, 3) low, rounded fault scarps, and 4) abrupt changes in the orientation of axial plane cleavage. The short faults have a close relationship with many of the small-scale folds, either following planes of weakness developed during the earlier small-scale folding or as reverse faults developing synchronously with the folding. The stratigraphic throw is difficult to quantify, but vertical displacement is inferred because 1) no single fault cuts out all of any one member of the Oquirrh Formation, and 2) those faults that cut stratigraphic boundaries produce small horizontal displacements at those contacts. Many of these faults are truncated by the longer faults. Thus, the smaller faults, and the associated small-scale folds which were the result of regional compressional stresses, antedate the long faults which were activated in a subsequent regional tensional stress regime.

The through-going, high-angle normal faults can generally be recognized by indirect evidence: 1) long, straight, and broad alluvium-filled canyons and gullies, 2) abrupt stratigraphic discontinuities across short horizontal distances, and 3) abrupt changes in the orientation of axial plane cleavage. The long faults cut all other tectonic features and are thus inferred to be most recent in origin.

GEOLOGIC HISTORY

The geologic history of the Limekiln Knoll quadrangle is as follows:

1. Deposition of the Lower Paleozoic units in a miogeosynclinal environment, followed by development in Upper Paleozoic time of a basin in which the Oquirrh Formation was deposited.

2. Rapid sedimentation in the Oquirrh Basin from the Middle Pennsylvanian to at least Early Permian, with thinner marginal facies sediments being deposited in the area of Limekiln Knoll and much thicker, basinal facies sediments being deposited at some distance west of the quadrangle.

3. At some time between the Late Permian and Late Miocene, but before the onset of Basin and Range normal faulting, a relatively flat decollement surface formed at some depth beneath the Oquirrh Formation and enabled considerable west to east translation of Oquirrh Formation strata.

4. During thrusting, several broad folds developed as a result of the thrust sheet bending over irregularities (pitches and flats) in the decollement surface (or formed as a result of bending on a Basin and Range listric normal North Canyon fault much later) along with the short faults and smaller folds.

5. The Tertiary (Miocene-Pliocene) Salt Lake Formation overlies the Basin and Range North Canyon fault, so some of the normal faulting occurred prior to the late Miocene. There is no evidence that the Salt Lake Formation has been tilted in the Limekiln Knoll quadrangle. The extent of Basin and Range faulting since late Miocene time is unknown.

6. The long, through-going, high-angle normal faults present in the Limekiln Knoll quadrangle appear to be the most recent in origin, but the normal faulting may be the most recent movement along high-angle tear faults along which strike slip motion occurred during thrust faulting.

ECONOMIC GEOLOGY

The economic resources of the Limekiln Knoll quadrangle are limited. No mines, quarries or prospects for metallic or non-metallic mineralization are present. Plentiful sand and gravel is present in the Quaternary Lake Bonneville Formation suitable for a variety of construction purposes. Some of the Oquirrh units might be useful as a source of crushed stone or borrow materials. Exploration for petroleum would be speculative; the geology and characteristics of rocks beneath the inferred thrust fault, southwest of the North Canyon fault, are unknown.

REFERENCES

Beus, S. S., 1963, Geology of the Blue Spring Hills, Utah-Idaho: Ph. D. dissertation, Univ. of California, Los Angeles, 282 p.

Beus, S. S., 1965, Devonian faunule from the Jefferson Formation, central Blue Spring Hills, Utah-Idaho: Journal Paleontology, v. 39, no. 1, p. 21-30.

Beus, S. S., 1968, Paleozoic stratigraphy of Samaria Mountain, Utah-Idaho: American Association Petroleum Geologists Bulletin, v. 52, no. 5, p. 782-808.

Coward, R. I., 1979, Geology of the Buist quadrangle, southeastern Idaho: M. S. thesis, Bryn Mawr College, Bryn Mawr, PA, 30 p.

Currey, D. R., 1982, Lake Bonneville: Selected features of relevance to neotectonic analysis: U. S. Geological Survey Open-File Report 82-1070, 30 p.

Currey, D. R., Oviatt, C. G., and Czarnomski, J. E., 1984, Late Quaternary geology of Lake Bonneville and Lake Waring: Utah Geological Association Publication 13, 1984 Field Conference, p. 227-237.

Murphy, B. E., 1983, Geology of the Limekiln Knoll quadrangle, north-central Utah: M. A. thesis, Bryn Mawr College, Bryn Mawr, PA, 53 p.

Platt, L. E., 1977, Geologic map of the Ireland Springs-Samaria area, southeastern Idaho and northern Utah: U.S. Geological Survey Map MF-890.

Sando, W. J., Dutro, J. T., Jr., Sandberg, C. A., and Mamet, B. L., 1976, Revision of Mississippian stratigraphy, eastern Idaho and northeastern Utah: U. S. Geological Survey Journal of Research, v. 4, no. 4, p. 467-479.

Smith, R. B., 1982, Geologic map of the Strevell 15-minute quadrangle, Cassia County, Idaho: U. S. Geological Survey Miscellaneous Investigations Map I-1403.

Williams, J. S., 1973, Fossil distribution across the Middle-Upper Devonian boundary, Portage and Logan Canyons, north central Utah: Geol. Soc. Am. Bull., v. 84, no. 5, p. 1699-1703.

Williams, J. S., and M. E. Taylor, 1964, The Lower Devonian Water Canyon Formation of northern Utah: Wyoming University, Dept of Geology, Contribuions to Geology, v. 3, no. 2, p. 38-53.

UTAH GEOLOGICAL AND MINERAL SURVEY

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

THE UTAH GEOLOGICAL AND MINERAL SURVEY is one of eight divisions in the Utah Department of Natural Resources. The UGMS inventories the geologic resources of Utah (including metallic, nonmetallic, energy, and ground-water sources); identifies the state's geologic and topographic hazards (including seismic, landslide, mudflow, lake level fluctuations, rockfalls, adverse soil conditions, high groundwater); maps geology and studies the rock formations and their structural habitat; provides and disseminates educational materials concerning the geology of Utah; and provides information to decisionmakers at local, state, and federal levels.

THE UGMS is organized into five programs. Administration provides support to the programs. The Economic Geology Program undertakes studies to map mining districts, to monitor the brines of the Great Salt Lake, to identify coal, geothermal, uranium, petroleum and industrial minerals resources, and to develop computerized resource data bases. The Applied Geology Program responds to requests from local and state governmental entities for site investigations of critical facilities, documents, responds to and seeks to understand geologic hazards, and compiles geologic hazards information. The Geologic Mapping Program maps the bedrock and surficial geology of the state at a regional scale by county and at a more detailed scale by quadrangle.

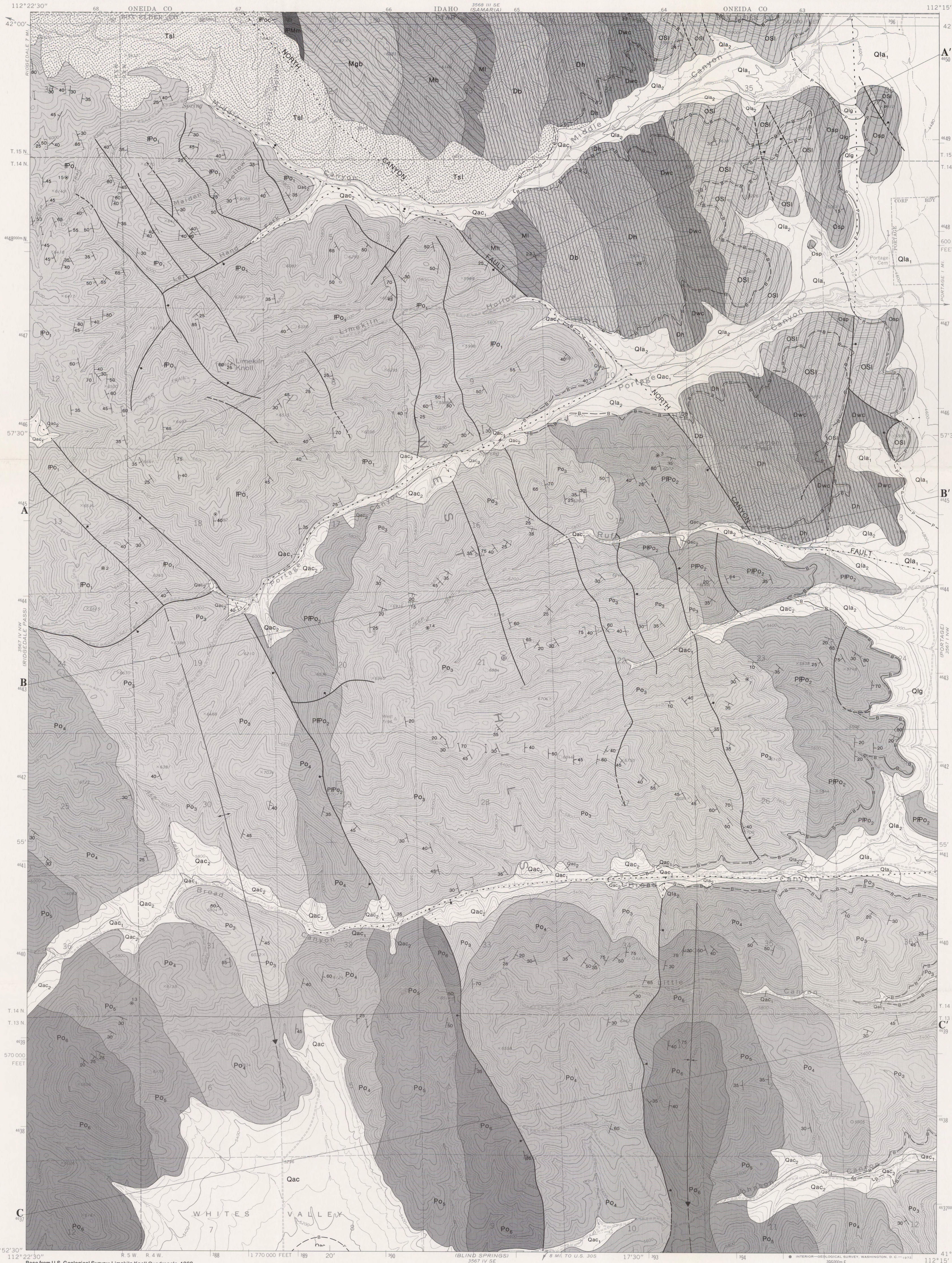
THE INFORMATION PROGRAM distributes publications, and answers inquiries from the public and manages the UGMS library. The UGMS Library is open to the public and contains many reference works on Utah geology and many unpublished documents about Utah geology by UGMS staff and others. The UGMS has begun several computer data bases with information on mineral and energy resources, geologic hazards, and bibliographic references. Most files are not available by direct access but can be obtained through the library.

THE UGMS PUBLISHES the results of its investigations in the form of maps, reports, and compilations of data that are accessible to the public. For future information on UGMS publications, contact the UGMS Sales Office, 606 Black Hawk Way, Salt Lake City, Utah 84108-1280.

UTAH GEOLOGICAL AND MINERAL SURVEY
UTAH DEPARTMENT OF NATURAL RESOURCES
in cooperation with
THE UNITED STATES GEOLOGICAL SURVEY

Published and sold by
UTAH GEOLOGICAL AND MINERAL SURVEY
Genevieve Atwood, Director
606 Black Hawk Way
Salt Lake City, Utah 84108

Plate 1
Utah Geological and Mineral Survey Map 79
Provisional Geologic Map of the Limekiln Knoll Quadrangle



Base from U.S. Geological Survey: Limekiln Knoll Quadrangle, 1968

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL

Field mapping by authors in 1984
Thesis advisor: Lucian Platt, Bryn Mawr College
K. D. Brown, Cartographer

UTM GRID AND 1968 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

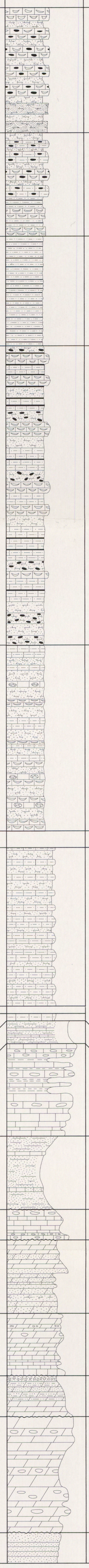
PROVISIONAL GEOLOGIC MAP OF THE LIMEKILN KNOLL QUADRANGLE, BOX ELDER COUNTY, UTAH

by
Brendan E. Murphy [1],
Stanley S. Beus [2], and Charles G. Oviatt [3]
[1] Geology Department, Bryn Mawr College, [2] Professor, Northern Arizona University,
[3] Geologist, Utah Geological and Mineral Survey

UTAH
QUADRANGLE LOCATION

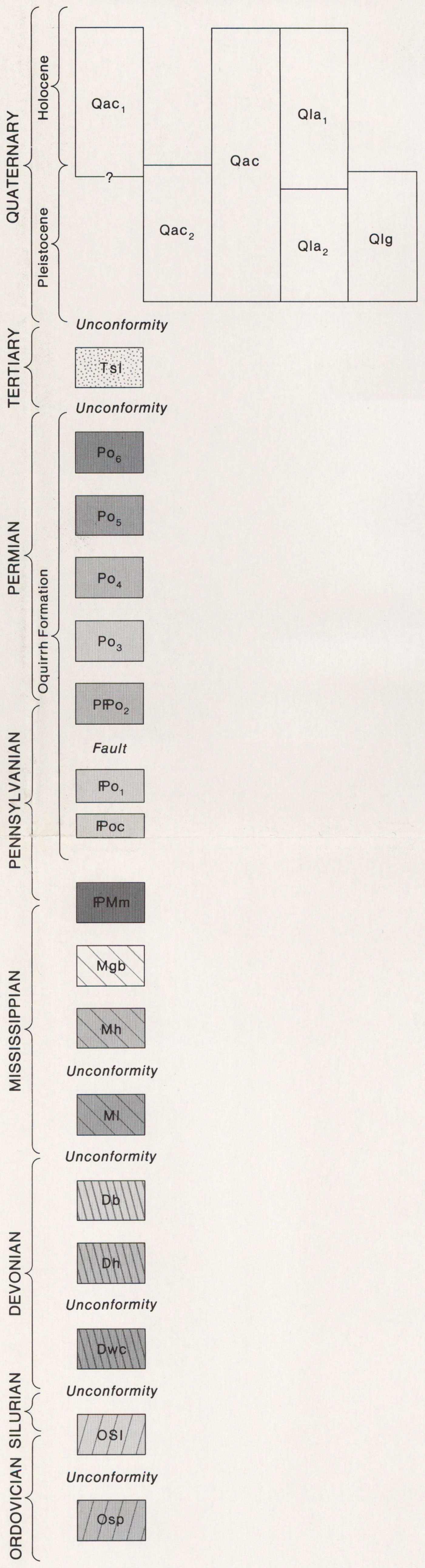
1985

UTAH GEOLOGICAL AND MINERAL SURVEY
UTAH DEPARTMENT OF NATURAL RESOURCES
in cooperation with
THE UNITED STATES GEOLOGICAL SURVEY



FORMATION		SYMBOL	LITHOLOGY	THICKNESS feet (meters)
OQUIRRH FORMATION	Unit 6	Po$_6$		1650 (503)
	Unit 5	Po$_5$		1400 (427)
	Unit 4	Po$_4$		1450 (442)
	Unit 3	Po$_3$		4000 (1220)
	Unit 2	PIPo$_2$		2450 (747)
	Unit 1	IPo$_1$		2200 (671)
		IPoc		
Manning Canyon Fm.		IPMm		300 (91)
Great Blue Limestone		Mgb		1220 (372)
Humbug Formation		Mh		980 (299)
Lodgepole Limestone		Ml		400 (122)
Beirdneau Sandstone		Db		990 (302)
Hyrum Dolomite		Dh		820 (250)
Water Canyon Formation		Dwc		540 (165)
Laketown-Fish Haven Dolomite		OSl		1540 (470)
Swan Peak Quartzite		Osp		400+ (122+)

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Qac$_1$ *Stream alluvium and slope wash along major streams and mouths of tributaries.*

Qac$_2$ *Older slope wash and stream alluvium underlying dissected terrace remnants.*

Qac *Stream alluvium, alluvial fans, and slope wash in Whites Valley.*

Qla$_1$ *Lacustrine sand and gravel and intertonguing alluvial deposits of Provo and post-Provo age.*

Qla$_2$ *Lacustrine sand and gravel and intertonguing alluvial deposits above lacustrine shore-zone gravel.*

Qlg *Lacustrine shore-zone gravels.*

Tsl *Unconsolidated, interbedded buff to light tan tuffs and tuffaceous conglomerates, grayish-white.*

Po$_6$ *Interbedded cherty gray limestone and tan to red quartzose sandstone with two massive crossbedded calcareous orthoquartzite ledges near the base.*

Po$_5$ *Interbedded ledgy limestone, soft calcareous sandstone and cherty siltstone.*

Po$_4$ *Cherty brown, finely laminated siltstone.*

Po$_3$ *Thick-bedded brown quartzose to subarkosic sandstone and medium- to thick-bedded silty and bioclastic limestone.*

PIPo$_2$ *Bioclastic thick-bedded gray limestone and thick-bedded brown to gray calcareous sandstone.*

IPo$_1$ / IPoc *Interbedded silty limestone and calcareous sandstone. Poc represents similar beds at the lower part of this sequence in the autochthonous block northeast of the North Canyon fault.*

IPMm Manning Canyon Formation—*Poorly exposed black shale, green to brown shale, yellow-brown quartz sandstone, and yellowish-weathering skeletal limestone.*

Mgb Great Blue Limestone—*Medium- to dark-gray ledgy and cliffy limestone separated by slope-forming shales. The limestones are locally cherty and fossiliferous.*

Mh Humbug Formation—*Slope-forming fine-grained calcareous sandstone or siltstone and a few thin beds of dark gray limestone.*

Ml Lodgepole Limestone—*Predominantly dark limestone containing abundant black chert nodules with a prominent persistent basal cliff in outcrop, 50 feet thick. Contains abundant marine fossils.*

Db Beirdneau Sandstone—Light- to medium-gray dolomite and calcareous quartz sandstone. The medial quartz sandstone is more resistant than the upper and lower dolomites and forms a prominent ledge.

Dh Hyrum Dolomite—*Dark-gray dolomite and limestone that form resistant ledges and cliffs.*

Dwc Water Canyon Formation—*Consists of a lower Card member of locally sandy or silty light-gray-weathering aphanitic dolomite and an upper Grassy Flat member of reddish-brown to gray-weathering fine-grained to aphanitic dolomite.*

OSl Laketown-Fish Haven Dolomite—*Thick sequence of dark-and light-gray dolomite that forms irregular resistant cliffs. The lower 300 feet of the 1450-ft unit are believed to be Ordovician in age. Locally fossiliferous.*

Osp Swan Peak Quartzite—*Light-gray to buff or brown quartz sandstone only partially exposed on the quadrangle.*

CONTACT
Dotted where covered

FAULT
Dashed where location inferred; dotted where covered; bar and ball on downthrown side

STRIKE AND DIP OF BEDDING
45
Inclined
Vertical
Horizontal

STRIKE AND DIP OF CLEAVAGE
30
Inclined
Vertical

TRACE OF AXIAL SURFACE OF FOLD
Anticline
Syncline

Location of Paleontological sample

Trace of Bonneville shoreline dashed where inferred

Trace of Provo shoreline dashed where inferred