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PALEOECOLOGY OF THE MANNING CANYON SHALE IN CENTRAL UTAH

by

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IN

CENTRAL UTAH

A thesis

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In partial fulfillment

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Master of Science

by

Richard W. Moyle

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CONTENTS

LIST OF ILLUSTRATIONS

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ABSTRACT

Five sections of the Upper Mississippian and Lower Pennsylvanian Manning Canyon Shale in central Utah were measured, and five additional partially exposed sections nearby were visited for comparison.

The sections range from 1000 to 2600 feet thick and average between 1500 and 1600 feet. Shale predominates throughout. Clay shales characterize the lower 600 feet of the formation and silty shales and shaly limestones typify the upper 900 to 1000 feet. Lake Mountain section is the exception in that quartzites, arkoses and subgraywackes make up about one-third of the formation. Fresh, brackish, and shallow warm marine water conditions are suggested in central Utah throughout Manning Canyon time as evidenced by typical marine fossil assemblages, pelecypod and gastropod faunas, and plant remains in the sediments.

The sponges _Talpaspongia clavata_, _Wewokella contorta_, _Wewokella solida_, and _Wewokella_ n. sp. were found in Mississippian rocks for the first time. They are present in West Canyon, Soldier Canyon and Ophir Pass.

Correlation and study of lithology demonstrate the cyclic nature of the Manning Canyon seas and reflect three regressions and two transgressions punctuated with many minor climatic and depositional changes. The formation thickens and size of the clastics increases to the east. Conclusive evidence of the Mississippian-Pennsylvanian time boundary was not found; however, it is tentatively placed above a fossiliferous limestone zone about 575 feet above the base of the formation and below a plant zone within the interbedded shales and quartzites 700 feet above the base of the formation.

INTRODUCTION

Purpose and Scope

The Manning Canyon Shale at the type locality in Manning Canyon of the Oquirrh Mountains in central Utah, and in contiguous area, bridges the Mississippian-Pennsylvanian time boundary and in addition reflects considerable variation in depositional environments.

Various geologists have mapped, measured and discussed the formation in central Utah, but a detailed study of the Soldier Canyon type section in the Oquirrh Mountains has not been reported. Nor has anyone heretofore compared the relationship of fauna and flora to the sediments, the fluctuation in salinity and depth of water, or the fluctuation between marine, brackish and non-marine water within the Manning Canyon Shale of central Utah.

The writer attempts to present data concerning the systemic boundary, and to reconstruct the sedimentary environments by means of field and laboratory evaluation of the fossils and the sediments of the formation. Also, it is a definite objective to ascertain guide fossils and correlate lithologic units from area to area.

Only a selected few complete sections were studied in detail. Partly exposed sections were visited to see if correlation could be obtained.

Locations

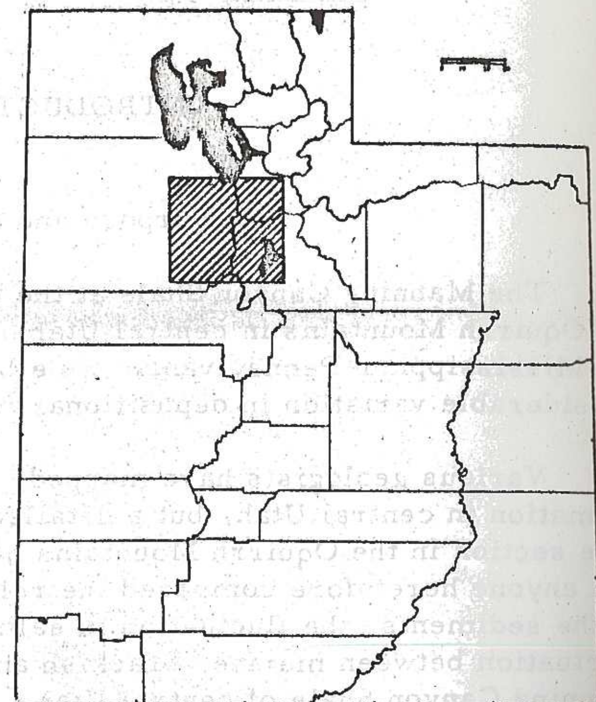
The Manning Canyon Shale crops out in many places in central Utah. Five complete sections were visited and studied along with five incompletely exposed sections (Fig. 1). Nine of the ten studied sections lie within the easternmost ranges of the Basin and Range Physiographic Province, and the remaining one lies in the westernmost part of the Wasatch Range in the Central Rocky Mountain Province.

The detailed complete sections include:

1. Soldier Canyon; (Type Section) on the north side of Soldier Canyon, about one-half mile above its mouth, Sec. 33, T. 5 S., R. 4 W., Tooele County, Utah, (BYU Loc. Nos. 11018, 11019, 11020, 11021).

Index Map

1 Soldier Canyon
2 Ophir Pass
3 Manning Canyon
4 West Canyon
5 Lake Mountain
6 Provo Canyon
7 Traverse Mountains
8 Five Mile Pass
9 Stansbury Mountains
10 Onaqui Mountains



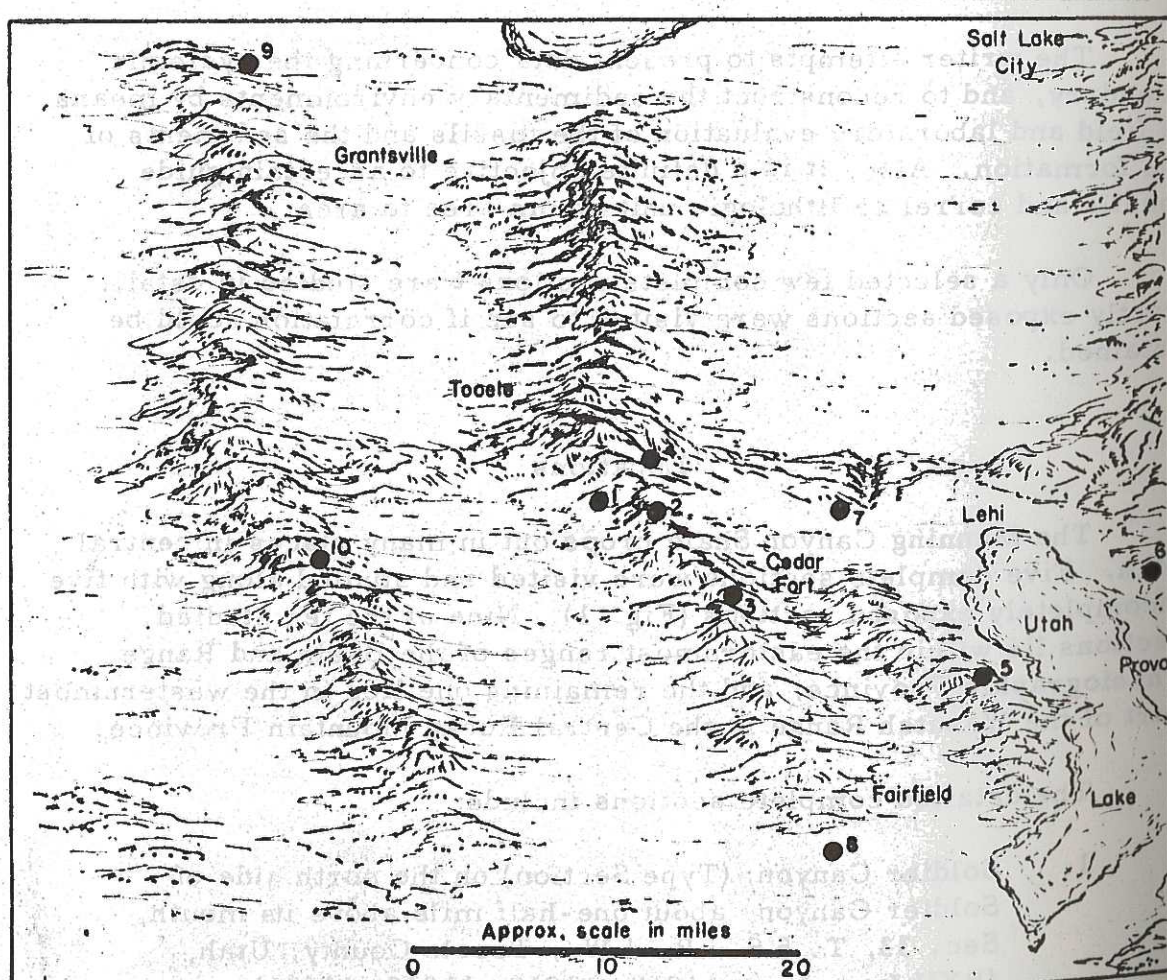


Figure 1

2. Ophir Pass; on the divide between the head of the South Fork of Soldier Canyon and the head of Ophir Canyon, Sec. 11, T. 6 S., R. 4 W., Tooele County, Utah, (BYU Loc. No. 11022).

3. Manning Canyon; (Type Locality) in Manning Canyon at the head and about one-half mile below the head, in Sec. 4, T. 6 S., R. 3 W., Utah County, Utah, (BYU Loc. Nos. 11023, 11024).

4. West Canyon; on the north side about one to one and one-fourth miles west up canyon from the mouth of Iron Canyon, Sec. 3, T. 5 S., R. 3 W., Utah County, Utah, (BYU Loc. Nos. 11005, 11025, 11026).

5. Lake Mountain; on west side of Seep Canyon north and west of spring, east side of range, Sec. 36, T. 6 S., R. 1 W., Utah County, Utah, (BYU Loc. No. 11027).

The incomplete sections observed:

6. Provo Canyon; at the head of Little Rock Canyon just east of the road, Secs. 16 and 21, T. 6 S., R. 3 E., north side of creek at Canyon Glen Camp Grounds, Secs. 4 and 5, T. 6 S., R. 3 E., and above cliffs north of the Provo City Power Plant in the mouth of Provo Canyon one-fourth S. E., Sec. 1, T. 6 S., R. 2 E., Utah County, Utah.

7. Traverse Range; measured north-south across the clay pits in center of Sec. 9, T. 5 S., R. 1 W., Utah County, Utah.

8. Five Mile Pass; on south slope of east-west trending spur, S. E. one-fourth, Sec. 2, T. 8 S., R. 3 W., Utah County, Utah.

9. Stansbury Mountain; north end of Stansbury Mountains east side in clay pit, center of Sec. 8, T. 2 S., R. 6 W., Tooele County, Utah.

10. Onaqui Mountains; north end of Onaqui Mountains north and south of the road about one-fourth to one-half mile east of Johnson Pass, Sec. 31, T. 5 S., R. 6 W., Tooele County, Utah, (BYU Loc. No. 11028).

Previous Work

Gilluly (1932, p. 31) named the Manning Canyon Shale where he observed outcrops of the formation in Manning Canyon in the southeastern part of the Oquirrh Mountains. He measured the type section of the formation in Soldier Canyon to the north and west of the Manning Canyon type locality.

Nolan (1935, pp. 32-33) described a section of the Manning Canyon Shale in the Gold Hill district of Nevada and correlated the section with that of the Oquirrh Mountains. Bissell (1935, p. 163) suggested from a fossil study in the Wasatch Mountains that the systemic boundary occurred in a ten foot limy-sandstone within the formation.

Robertson (1940, p. 70) studied the selenium percentage and content in various shale samples from the Manning Canyon Shale in Provo Canyon and Manning Canyon, Utah. Baker (1947) measured a thick section of the formation near the mouth of Provo Canyon, Utah. Bullock (1949) mapped and measured a section of the formation in the north end of the Pelican Hills on the east side of Lake Mountain and also another section on the west side of Lake Mountain.

Hebertson (1950, p. 31) attempted a correlation of the facies within the Manning Canyon Shale by means of physical and chemical sedimentary characteristics. He investigated the formation in: (1) Manning Canyon in the Oquirrh Mountains; (2) Lake Mountain, northeastern end; and (3) Provo Canyon in the Wasatch Mountains.

Calderwood (1951, pp 63-65) mapped and measured a section in the Cedar Valley Hills on the west side of Lake Mountain. Ornelas (1953) attempted to classify and evaluate the clay possibilities of the Manning Canyon Shale throughout Utah County and the adjacent areas.

McFarland (1955, pp. 11-12) mapped and measured a complete section in West Canyon in the Oquirrh Mountains. Sadlick (1955, p. 3) studied sections of the formation in: (1) Uinta Mountains, north and south flanks; (2) Wasatch Mountains, at Ogden, Salt Lake, and Provo, Utah, areas; and (3) Pisgah Hills, southwest of Logan, Utah. Young (1955) mapped an incomplete section of the formation in the southern Lakeside Mountains, Utah.

Croft (1956) mapped and measured a section in the northern Onaqui Mountains, but due to faulting in the area an accurate stratigraphic measurement could not be made. Hyatt (1956) using Ornelas' 1953 thesis as a nucleus made an additional classification and evaluation of the clay

deposits within the formation. Pitcher (1957, p. 8) mapped an incomplete section in the south and east end of the Traverse Mountains, Utah.

Field Work

Dr. Harold J. Bissell suggested the problem in the spring of 1952. The field work commenced in April of the same spring, but an interruption in August, 1952, delayed the work until the spring of 1957 when again it was commenced, being completed in June, 1958. The work consisted of detailed measuring with steel tape and sampling each rock unit in the selected stratigraphic sections.

Laboratory Work

Laboratory work included preparation and study of thin sections of the limestone and quartzites, insoluble residues of the shales, and the preparation of fossils for identification.

The writer prepared thin sections using standard procedures, and studied them with binocular and petrographic microscopes. Insoluble residues were prepared by dissolving 10 gram samples of the shales broken into pea size, in one part hydrochloric acid to one part water. These were washed, dried, weighed, and the residues determined in per cent of insoluble material.

Fossil preparation consisted of placing silicified fossiliferous limestones in one part phosphoric acid and five parts water for a controlled period of observed digestion, then carefully washing and drying the fossils. Plastic spray preserved the more fragile fossils, especially the bryozoans. Subjecting fossiliferous limestone and shale samples to heat in an electric furnace until red hot, then immersing them in cold water, caused some of the fossils to loosen from the matrix due to slaking of lime at the contact of fossil and matrix.

The color description of fresh and weathered rock surfaces conforms to that of the National Research Council rock color chart, with the exception that the color olive was excluded and different combinations of the colors green, yellow, and brown were used.

Wentworth's scale was used for grain size analysis.

A combination of Kelley (1956), and McKee and Weir (1953) terminology for bed thickness and weathering structure was used as given in the following chart:

Name	Thickness	Weathering Structure
Massive	Greater than 6 ft.	Massive
Thick	3 to 6 ft.	Blocky
Medium	1 to 3 ft.	Slabby
Thin	1 in. to 1 ft.	Flaggy
Laminae	2 mm. to 1 in.	Platy (or Shaly)
Thin Laminae	Less than 2 mm.	Papery

Fig. 2 Bed Thickness Chart

MISSISSIPPIAN SYSTEM

Great Blue Limestone

Throughout central Utah the upper member of the Great Blue Limestone crops out as a resistant ledge or cliff that can be very easily recognized from the overlying subdued slope forming Manning Canyon Shale.

The formation in the Oquirrh Mountains is exposed on the west flank of the range from Soldier Canyon on the north and west, south through Ophir Pass into the west side of Manning Canyon. On the east flank of the range it is exposed in Iron Canyon then south to just north of the town of Cedar Fort, where it is covered by alluvium.

In Lake Mountain the Great Blue Limestone is a ridge former, especially on the east side. At the mouth of Provo Canyon the ridge forming nature is again evident. This feature of the formation makes the upper contact with the basal overlying Manning Canyon Shale a recognizable stratal horizon. The complete sections in this report were measured from this contact.

The top of the upper member in the Great Blue Limestone in all areas that the present writer observed consists of medium and dark blue-gray limestone that weathers light gray, is very fine grained, and is thin to medium bedded in beds from one-half to twenty-four inches thick which weathers platy. This lithology is consistent throughout the area of study with only slight variations. In West Canyon and Soldier Canyon the weathered surface has a pink coloration. On Lake Mountain the upper member of the formation becomes cherty at the contact. In Manning Canyon, _Chonetes_ and _Archimedes_ are found along with other fossil hash very near the contact.

The Great Blue Limestone is Upper Mississippian (Girty _In_ Gilluly, 1933, p. 30) in age.

MISSISSIPPIAN-PENNSYLVANIAN SYSTEMS

Manning Canyon Shale

Gilluly (1933, p. 31) named the formation as a distinct and separate lithology. Previously Spurr (1895, p. 376) called it the "upper shale" of the Great Blue Limestone.

Gilluly named the formation from exposures in Manning Canyon, but further states, "The section measured in Soldier Canyon is believed to represent the formation better than any of the others." In the present report the writer refers to the Manning Canyon section as the "type locality" and the Soldier Canyon section as the "type section". Most of the following discussion in the report centers around observations taken in Soldier Canyon where detailed measurements and descriptions were made.

Throughout the area of study the Manning Canyon Shale, at most localities, is a valley-former. The soft and impervious nature of the shales within the formation gives rise to fertile soil covered slopes and valleys. Springs occur in the formation in West Canyon, near Ophir Pass and in Manning Canyon. Vegetation and alluvial cover makes fresh exposures scarce.

The formation consists predominantly of shale, interbedded limestone, and quartzite, with few beds of siltstone and mudstone. Arkose is present locally. The Lake Mountain locality is the only section where shales do not predominate; there quartzite, subgraywacke, and arkose are abundant and make up over one-third of the formation.

The age of the formation is uppermost Mississippian and lowermost Pennsylvanian. Previous geologic work through fossil relationships has indicated its age most likely to be Upper Chester and Lower Springer.

Thicknesses of five measured sections are as follows: Soldier Canyon, 1559 feet; Ophir Pass, 1327 feet; Manning Canyon (base faulted), 1064 feet; West Canyon (top unexposed), 1683 feet; and Lake Mountain (top unexposed), 1910 feet. Average thickness for the formation is 1500 to 1600 feet. The Soldier Canyon section is most nearly complete, is the best exposed, and represents the formation best. A correlation chart (Plate 4) shows the relationship of thickness and lithology for the formation in central Utah.

Soldier Canyon (Type section). The formation crops out on the north side of Soldier Canyon (Plate 1) which is on the north nose of the plunging Ophir Anticline approximately three to three and one-half miles east and south of Stockton, Utah. Soldier Creek has eroded across the nose of the anticline and exposed the section. It crops out at the mouth of Soldier Canyon then trends east to one-quarter to one-half mile west of the mouth of South Fork where it passes under the valley floor and is exposed intermittently to the south in South Fork Canyon on to Ophir Pass.

Of all the localities visited by the writer the exposure in Soldier Canyon presents the formation more nearly undisturbed and most completely exposed. The section was measured on the north side of the canyon about one-half mile above its mouth, Sec. 33, T. 5 S., R. 4 W., Tooele County, Utah. The writer measured the section in four segments because of local soil cover (Plate 1). The formation was divided into 32 units and sub-divided into over 120 sub-units. Three additional units in the basal part of the Oquirrh Formation were closely observed and described to familiarize the writer with the upper contact of the Manning Canyon Shale.

The Manning Canyon-Great Blue contact is taken where the platy dense dark blue-gray limestones of the upper Great Blue Limestone change to the medium gray calcareous shales in the base of the Manning Canyon Shale. The Manning Canyon-Oquirrh contact was taken at the top of the uppermost dark gray shale and the base of a sandy medium brown-gray, brown weathering limestone and calcareous brown quartzite unit.

The basal five to ten feet of the Oquirrh formation contains abundant fossils, especially the brachiopod *Spirifer*. Immediately above this basal Oquirrh unit the shaly limestones weather so as to appear as shale on some spurs in Soldier Canyon. Care should be taken by stratigraphers not to confuse this overlying 92 foot zone with the uppermost shale in the Manning Canyon Shale. Within this shaly limestone about fifty to seventy-five feet above the base occur large *Derbyia*, abundant *Echinoconchus*, *Allorisma*?, various other productids, and abundant crinoid stems which are characteristic of the Oquirrh Formation and are diagnostic enough to differentiate these two similarly appearing units.

The lithologic composition of the Manning Canyon Shale in Soldier Canyon consists of approximately the following:

Rock type	Total thickness in feet	Percentage of formation
Silty Shale	560	35.9
Clay Shale	391	25.1
Total Shale	951	61.0

Plate 1 Vertical air photo (CYO-12K-107, 1952) showing location of Soldier Canyon measured section.

Shaly Limestone	308		19.7	
Pure Limestone	220		14.2	
Sandy Limestone	10		0.6	
Total Limestone		538		34.5
Quartzite		42		2.7
Sandy Shale, Siltstone Mudstone, and other		28		1.8
Total thickness		1559		100.0

The shaly limestones are distributed throughout the entire formation while the quartzite occur in two zones, one about 600 to 800 feet above the formation base and the other about 1300 to 1350 feet above the base. The shales predominate in the basal 900 feet, but persist throughout. Also clay shales are more predominant in the basal 600 to 700 feet then silty shales become the predominant type in the top 900 to 1000 feet.

In the laboratory the shales were checked for the amount of calcium carbonate. Table 1 shows the relation of color, silt to clay, and the percentage of calcium carbonate.

The brown and red-brown shales contain the largest percentages of calcium carbonate, the light and medium gray and brown-gray shales contain lesser amounts, and the dark gray and black shales contain the least.

The red-gray, red-brown, and brown shales are very calcareous (40 to 80 per cent calcium carbonate). The brown-gray, light gray, and medium gray shales are calcareous (10 to 40 per cent). The dark gray and black shales are slightly to very slightly calcareous (less than 10 per cent). Only a few of the black shales are calcareous; however, most are very carbonaceous and may in some areas be considered petroleum source rocks.

The silty shales are slightly more calcareous than the clay shales. As the color darkens to black, due to the increase in carbonaceous content in many beds, the clay content increases and the calcareous content decreases, suggesting change in depositional environment and provenance.

Of special interest in the basal half of the formation the pure limestones, fossiliferous limestones, and shaly limestones all have a one to six foot brown limestone "cap". These "caps" are evident in

Explanation of Plate 2

Figure 1 — Manning Canyon-Oquirrh contact and upper part of the Manning Canyon Shale, Soldier Canyon, Oquirrh Mountains, Utah. Viewed toward the west.

Figure 2 — Medial limestone of Manning Canyon Shale, Soldier Canyon, Oquirrh Mountains, Utah. Viewed toward the west.

Figure 3 — Great Blue-Manning Canyon contact and lower part of the Manning Canyon Shale, Soldier Canyon, Oquirrh Mountains, Utah. Viewed toward the west

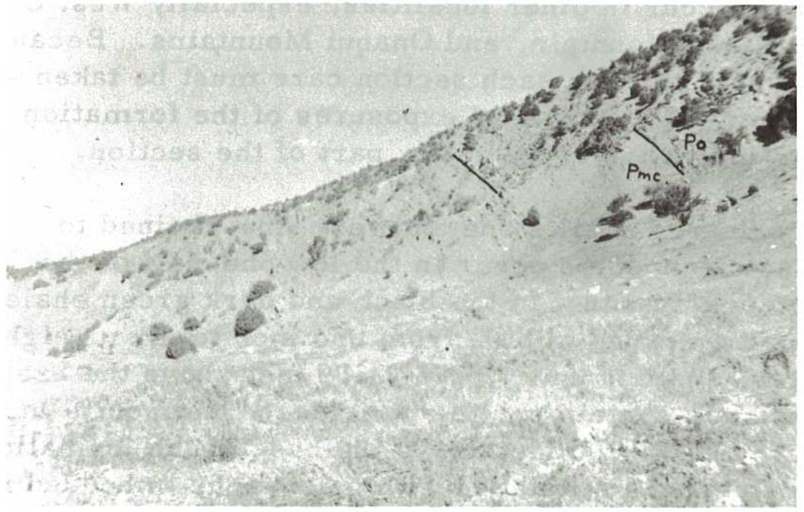


Figure 1

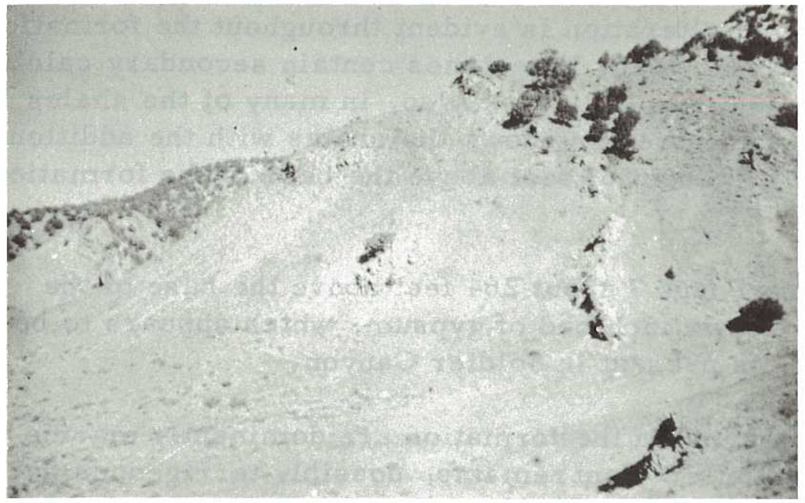


Figure 2

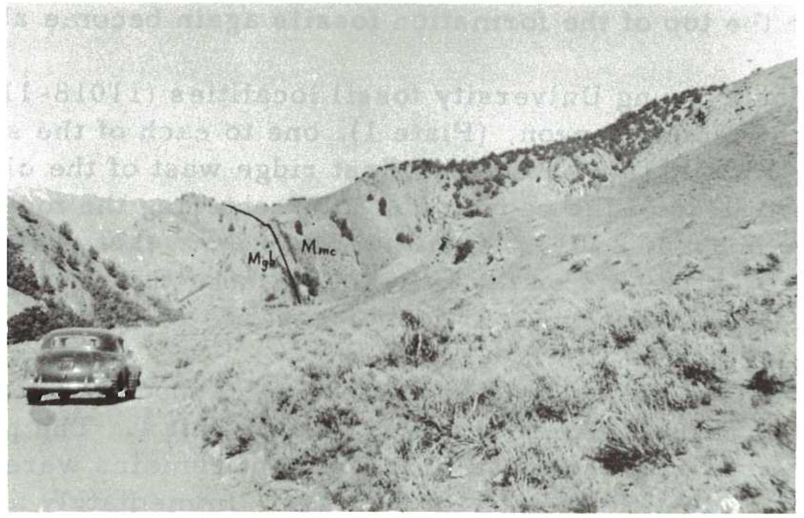


Figure 3

Soldier Canyon and occur in other localities, especially West Canyon, Manning Canyon, Lake Mountain, and Onaqui Mountains. Because of the numerous brown "caps" in each section care must be taken when correlation is attempted. In partial exposures of the formation the brown "caps" are indicative of the lower part of the section.

Siltstone, calcareous siltstone and very fine-grained to lithographic limestone nodules occur in the low one-half of the formation being more abundant in the black and dark green shales. In Soldier Canyon they range in size from one inch to six or eight inches in diameter. Within unit 7, 275 - 300 feet above the base of the formation, the nodules contain pyrite and iridescent limonite in the center. In unit 16, 640 - 700 feet above the base of the formation they are very dense calcareous siltstones with pelecypods imbedded in the outer edge.

Hydrothermal alteration is evident throughout the formation, but of minor importance. Many limestones contain secondary calcite and quartz stringers and vein fillings. Also, in many of the shales alteration takes place breaking down the shales with the addition of calcite and quartz. About 65 feet above the base of the formation this is very evident.

In the base of unit 7 about 264 feet above the base of the formation a four to six inch bed of gypsum, which appears to be a primary deposit, is present in Soldier Canyon.

The fossils found in the formation are dominantly marine invertebrates with a few plant remains, possibly terrigenous derived.

The lower 800 feet of the formation contains most of the fauna and flora. Near the top of the formation fossils again become abundant.

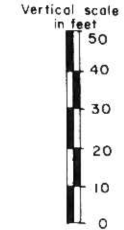
Four Brigham Young University fossil localities (11018-11021) are designated in Soldier Canyon, (Plate 1), one to each of the segments measured. The first, 11018, is on the first ridge west of the old mine tunnel on the north side of the canyon just after entering the mouth of the canyon. The second, 11019, is on the fourth spur east of the mine tunnel. The third, 11020, is on the fifth spur east of the mine tunnel, and the fourth, 11021, is on the fourth spur east of the mine tunnel.

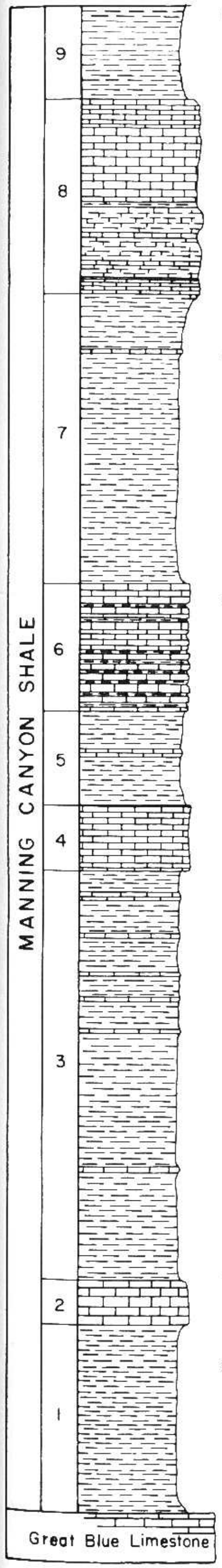
Locality 11018 contains <u>Yoldia</u>, another pelecypod genus, and plant fragments in the top fifteen to twenty feet of unit 1. The pelecypods show no evidence of being reworked, but the plant remains were so fragmented that no identification could be made. Immediately above

—Type Section of Manning Canyon Shale—

Soldier Canyon, Oquirrh Mountains, Tooele County, Utah.

Richard W. Moyle
1958





Shale, dk. gy. to blk., wthrs. med. to lt. gy. calc., silty, contains inter-bedded med. gy. very fossiliferous lms. that wthrs. lt. org.-bwn. and lt. bwn.-gy. Lms. is more abundant in top. Unit contains Spirifer, Dictyoclastus, Cleiothyridina, Fenestella, Polypora, Archimedes 2 spp., Ptylopora and crinoids.

Limestone, dk. gy., wthrs. lt. gy. throughout except med. bwn. in top 2 ft., very fine grained, thin bedded, platy and shaly, contains shale partings which become very numerous in basal 30 ft., top 6 ft. contains Acanthopecten, Spirifer, and ostracods (?).

Shale, blk. to dk. bwn. and med. gy., wthrs. blk and dk. bwn.-gy. calc. and silty in top one-half, clayey non-calc. in base. Very carbonaceous and graphitic, chippy, contains nodules with pyrite in center, fossils consist of Spirifer, Fenestella, Nucula, Amplexizaphrentis, gastropods, and crinoids (1 - 1 1/2 in. in diameter).

Limestone, dk. gy., wthrs. lt. gy. throughout with med. org.-bwn. 3 ft. top, fine grained thin and laminated bedding, platy and shaly, abundant white and yell. calcite stringers in top 3 ft.

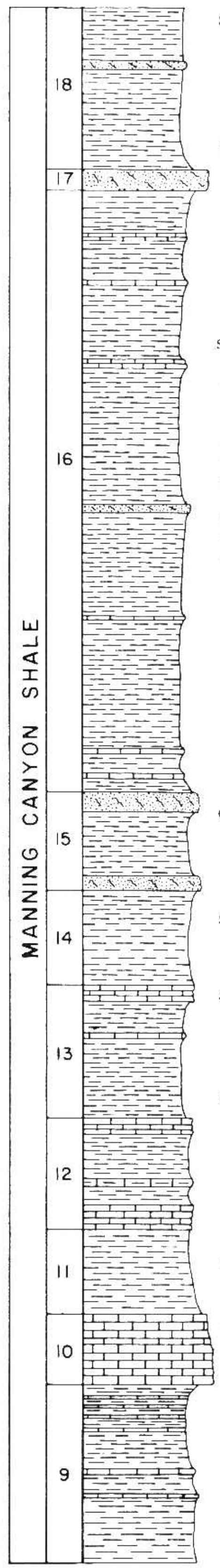
Shale, lt. to med. red-bwn. and lt. bwn. wthrs lt. bwn.-gy. and red-bwn. silty and calc. in top 10 ft., friable, calc. and clayey in basal 13 ft., contains interbedded med. gy. fine grained, yell.-bwn. wthrg. lms.

Limestone, med. gy., wthrs. lt. pink-gy., very fine grained, thin and laminated bedding, platy and shaly, ridge former, contains shale partings especially in basal 5 ft.

Shale, med. bwn.-gy. and med. bwn. becoming blk. in basal 30 ft., wthrs. med. bwn. and med. gy., calc. and silty, papery and splintery in top 15 ft., becomes calc. and clayey in middle 40 ft. of unit, carbonaceous, non-calc. and slightly silty in basal 30 to 50 ft., contains interbedded med. bwn. and med. gy. fine grained med. to lt. bwn. wthrg. lms. in beds 1-2 ft. thick that contain white calcite stringers.

Limestone, med. bl.-gy., wthrs. med. and lt. bwn.-gy., very fine grained, med. bedded, slabby, contains cherty beds in basal 6 ft., fossil hash in basal 3 ft.

Shale, lt. pink-gy. in basal 5 to 10 ft., becoming med. gy. in middle and blk. in top, wthrs. med. and lt. gy., clayey and calc., very carbonaceous in top, contains two pelecypod genera and plant fragments in top 15 to 20 ft.



Shale, blk. med. gy.-bwn. med. grn.-gy., wthrs. lt. yell.-bwn. lt. gr.-bwn. and lt. gy., calc. slightly silty, some fissile, contains interbedded med. to lt. gy., med. grained, bwn. wthrg qtzt., and med. gy.-bwn., cryst. bwn. wthrg., lms.

Quartzite, lt. gy., wthrs. med. grn., fine grained, massive, rough and pock-like surface, crossbedded, salt and pepper appearance, white quartz and yell. calcite stringers.

Shale, blk., med. bwn., med. bwn.-red., med. gy., wthrs. dk. gy., lt. pink bwn., lt. pink gy., lt. bwn.-gy., fissile, silty in top 12 ft., clayey in rest of unit, contains a few interbedded dk. gy. and blk. fine grained, med. bwn. wthrg. 1 ft. beds of lms., also a few beds of lt. to med. gy. fine grained, med. bwn. wthrg., qtzt. Some shales contain discontinuous beds, blobs, and nodules of blk. calc. siltstone, also in middle of unit pelecypods, gastropods, Cordaites ? and other plant fragments are present.

Quartzite, lt. gray, wthrs. med. bwn., med. grained, crossbedded, scintillating, rough surface, contains a blk. clay shale in middle of unit.

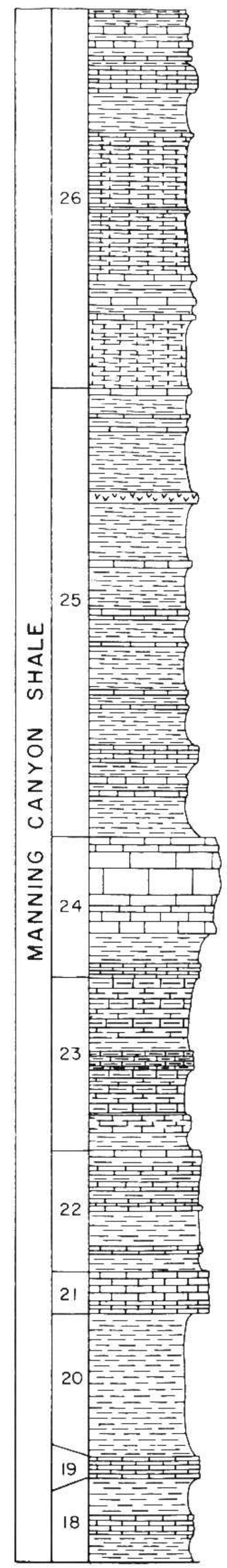
Shale, blk. wthrs. dk. gy., clayey, non-calc., contains pelecypods in basal 2 ft.

Shale, med. red-bwn., wthrs. lt. red-gy., calc., clayey in top, med. gy. calc. in basal 15 ft., contains med. gy. fine grained, med. bwn. wthrg. lms. in top 5 ft. of unit, also a few similar 1 ft. beds of lms. interbedded.

Shale, med. grn., lt. gy., grn. and yell.-gy., calc., clayey, contains med. grn., wthrs. dk. bwn. and med. org.-bwn. fine grained lms. in top and in base, also med. gy.-bl. shaly lms. in middle of unit. The lms. contain Spirifer, Nuculana, Dictyoclostus, Archimedes, Fenestella, horn corals, trilobites, crinoids, and gastropods.

Shale, med. gy. to blk., wthrs. dk. gy., very carbonaceous, clayey, non-calc., chippy.

Limestone, (medial lms.) med. gy.-bl., wthrs. med. to lt. gy., med. bwn. in top 6 to 10 ft., fine grained, med. bedded, calcite crusts on surface in middle, contains Fenestella, Polypora, Spirifer, Marginifera, Composita, Cleiothyridina, Kaskia, Griffithides, Talpaspongia, Amplexizaphrentis, crinoids, obiculod brachiopods, and ostracods.



Limestone, med. to dk. gy., wthrs. med. bwn.-gy., very fine grained, thin and laminated bedding, platy and shaly, some beds are shaly and very carbonaceous, few calcite stringers, interbedded med. gy. shale.

Igneous sill

Shale, dk. to med. gy., wthrs. med. gy. and med. to lt. bwn. calc. and silty, conts. 1-6 ft. beds of inter-bedded blk. to med. gy. fine grained lms. that wthrs. dk. to med. gy.

Limestone, blk. to dk. gy., wthrs. lt. bl.-gy., very fine grained to litho., med. to thin bedded in top 27 ft., laminated bedding in basal 3 ft. slabby and flaggy, contains 8 ft. bed of blk. carbonaceous clay shale.

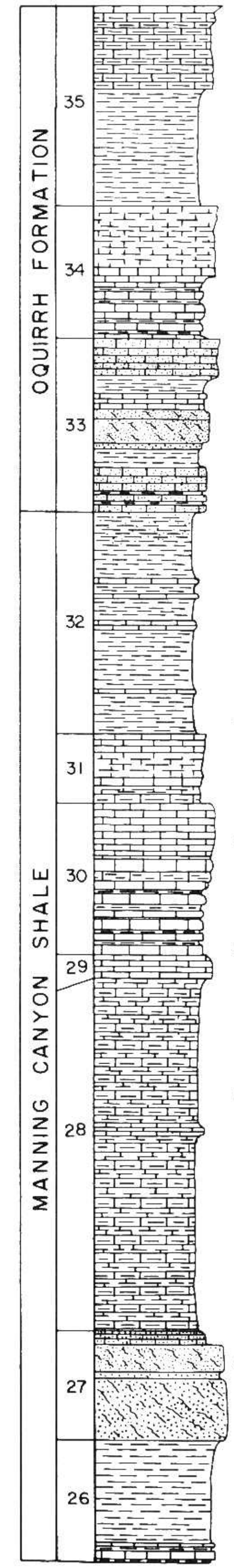
Limestone, med. gy. and med. to dk. gy.-bwn. wthrs. lt. bwn. and gy.-bwn., fine grained, thin bedded, platy and shaly, middle 11 ft. is med. gy. to blk. shale that is very fissile, calc. clayey, contains Chonetes in top 2 ft.

Shale, med. gy. and med. red-bwn. wthrs. med. gy. and med. pink-bwn., calc., friable, fissile, slightly silty, contains 5 ft. zone of dk. gy. shaly lms. in middle, fine grained laminated bedding, contains Chonetes.

Limestone, dk. gy-bl. wthrs. lt. gy-bl., fine grained, thin to thick bedded, slabby to blocky, argillaceous in part, ledge former.

Shale, blk. in base, med. red-bwn. and bwn.-gy. in top 3/4 of unit, wthrs. lt. bwn.-gy. and red-gy., calc., silty.

Limestone, med. to dk. gy., wthrs. med. gy., fine cryst., laminated and thin bedded, platy and flaggy, rough pock-like surface, calcite stringers.



Limestone, blk. to dk. gy., wthrs. med. to lt. bwn.-gy., thin bedded, platy and chippy, contains shales, becomes shale in basal 32 ft., Spirifer, Echinoconchus, Derbya, Allorisma, crinoids.

Limestone, med. gy., wthrs. lt. gy. very fine grained, laminated bedding, platy, crinoids in top 6 ft., in basal 17 ft.

Limestone, med. by., wthrs. med. to lt. bwn.-gy. also bwn., fine grained thin bed. in beds 1/4 - 12 in. thick, platy and flaggy interbedded sandy lms., shale, and calc. qtzt., contains Composita, Rhombopora, Fenestella, Spirifer, Cliothyridina, corals and crinoids.

Shale, blk. to dk. bwn.-gy., wthrs. med. bwn.-gy., silty and fine sandy, friable, calc. interbedded med. gy. and shaly lms., contains mud cracks, fucoids, Spirifer, crinoids, and other fossil hash.

Limestone, med. gy. to blk., wthrs. med. bwn.-gy., fine grained, thin and laminated bedding, platy and flaggy, shaly and sandy, Spirifer and other fossil hash, Composita (?) coquina in base.

Limestone, blk. to med. gy. wthrs. lt. gy. very fine grained, thin bedded, platy, contains brachiopod, trilobite, bryozoan, crinoid fragments, base is shaly.

Limestone, dk. gy., wthrs. med. gy., fine grained, thin bedded, flaggy, fossil hash.

Limestone, blk. to med. gy., wthrs. lt. gy. and med. bwn., very fine grained, thin and laminated bedding, very shaly and carbonaceous, contains Spirifer and other fossil hash.

Quartzite, med. gy., wthrs. lt. med. bwn. fine grained, thin bedded, argillaceous, calcareous, top 4 ft. is sandy lms.

UNIT NO.	FT ABOVE BASE	COLOR	WT AFTER ACID	PER CENT OF SOLUBLE MATTER	FIELD CARB. CLASSIF.	SILT & CLAY CONTENT
33	1594	DK-MD GY	7.72	22.8	C	S
33	1573	MD GY	8.99	10.1	C	S
32	1558	DK-MD GY	8.72	12.8	C	S
32	1532	MD GY	7.63	23.7	VC	CL
32	1514	MD BWN-GY	8.02	19.8	C	CL
32	1511	MD BWN-GY	7.79	22.1	C	SS
32	1501	LT-MD GY	7.79	20.2	C	S
31	1488	DK GY	7.56	24.4	C	S
26	1209	LT BWN-GY	5.43	45.7	VC	CL
26	1192	MD BWN-GY	7.62	23.8	C	SS
26	1182	LT GY	6.25	37.5	C	SS
26	1166	LT GY	4.43	55.7	VC	CL
25	1159	LT BWN-GY	5.50	45.0	VC	SS
25	1155	LT BWN-GY	4.94	50.6	VC	CL
25	1143	LT BWN-GY	5.04	49.6	VC	CL
25	1125	MD BWN-GY	5.13	48.7	VC	SS
25	1110	DK-MD GY	6.44	35.6	C	SS
25	1090	MD BWN-GY	5.40	46.0	VC	S
25	1074	DK GY	5.68	43.2	VC	S
25	1054	LT-MD GY	6.00	40.0	VC	CL
24	1014	BLK	10.01	NONE	NC	CL
23	1000	MD BWN-GY	5.04	49.6	VC	S
18	868	MD BWN	8.16	18.4	C	SS
18	818	DK GY	9.73	2.7	VSC	CL
18	802	MD GY	10.03	NONE	NC	SS
16	795	MD GY-BWN	10.00	NONE	NC	SS
16	784	BLK	10.02	NONE	NC	SS
16	771	MD BWN	9.58	4.2	VSC	S
16	747	MD RED-BWN	1.71	82.9	VC	SS
16	737	BLK	9.39	6.0	SC	CL
16	716	MD BWN-GY	9.04	9.6	SC	CL
16	715	MD RED-BWN	8.81	11.9	C	SS
16	714	DK GY	9.93	0.7	VSC	CL
16	710	DK GY & BWN	10.01	NONE	NC	CL
16	705	MD BWN	9.99	0.1	VSC	S
16	676	DK GY	10.00	NONE	NC	CL
16	640	DK GY	10.00	NONE	NC	CL
16	630	MD GY	10.10	NONE	NC	CL
15	625	MD BWN-GY	10.00	NONE	VSC	SS
15	621	MD GY	9.96	0.4	VSC	CL
15	607	LT-MD GY	10.01	NONE	VSC	CL
14	577	DK GY	10.08	NONE	VSC	CL
13	572	MD BWN-GY	9.19	8.1	SC	SS
13	555	MD RED-BWN	5.61	43.9	VC	SS
13	540	MD BWN	8.10	19.0	C	S
12	526	MD GY	8.60	14.0	C	SS
12	524	DK GY	10.03	NONE	SC	SS
12	521	LT-MD GY	10.00	NONE	SC	SS
12	515	MD GY	10.02	NONE	VSC	SS
11	507	DK GY	9.99	0.1	NC	S
11	484	DK GY	10.00	NONE	NC	CL
9	439	MD GY	9.30	7.0	SC	CL
9	422	MD BWN-GY	10.07	NONE	VSC	SS
9	402	DK GY	10.02	NONE	NC	CL
9	392	DK GY	10.00	NONE	NC	SS
7	331	MD GY	9.99	0.1	VSC	SS
7	319	MD GY	10.20	NONE	NC	CL
7	309	MD GY	9.70	3.0	VSC	CL
7	302	DK GY	10.01	NONE	NC	SS
7	288	DK GY	9.96	0.4	NC	SS
7	274	MD GY	9.67	3.3	VSC	CL
5	210	MD RED-BWN	7.59	24.1	C	SS
5	203	LT BWN-GY	4.50	55.0	VC	SS
3	175	LT BWN	3.57	64.3	VC	CL
3	139	DK GY	9.97	0.3	VSC	CL
3	137	LT BWN	3.89	61.1	VC	S
3	132	LT BWN-GY	3.86	61.4	VC	SS
3	112	BLK	10.10	NONE	NC	CL
3	93	MD GY	10.30	NONE	NC	SS
3	83	DK GY	10.00	NONE	NC	SS
3	75	MD BWN-GY	9.10	9.0	SC	SS
3	67	BLK	9.86	1.4	VSC	CL
1	50	BLK	8.30	17.0	SC	SS
1	46	DK GY	6.70	32.0	C	SS
1	42	MD GY	7.80	22.0	C	SS
1	38	LT GY	4.80	52.0	VC	CL

Note:

10 gram samples and 1:1 Hydrochloric acid were used.
Soluble material includes $CaCO_3$, $MgCO_3$ and other solubles.
VC: Very calcareous, 40-80 per cent
C: Calcareous, 10-40 per cent
SC: Slightly calcareous, 5-10 per cent
VSC: Very slightly calcareous, less than 5 per cent
NC: Non calcareous
CL: Clayey, 100 per cent clay size
S: Silty, more than 25 per cent silt size
SS: Slightly silty, less than about 25 per cent silt size

Table 1. Color, particle size, and soluble material of the shales in Soldier Canyon, Oquirrh Mountains, Utah.

this pelecypod zone, crinoid stems and a broken brachiopod hash comprise the basal three feet of limestone in Unit 2. Directly above in the base of unit 3 generically unrecognizable pelecypod fragments are present, but are absent five feet above. In the top of unit 4, which occurs 200 feet above the base of the formation, is a two inch bed of faecal-pellet limestone.

Locality 11019 is the most fossiliferous in Soldier Canyon. In the top twenty feet of unit 7 Spirifer, Composita, Amplexizaphrentis, Marginifera, Cleiothyridina, Dictyoclostus, Yoldia, Fenestella, and Nucula are well preserved in the shales and whole specimens weather out. In unit 7, 323 feet above the base of the formation, directly under a one foot bed of brown limestone, is a six to eight foot bed of large crinoid stems that are one to one-half inch in diameter.

In the top of unit 8, directly under the dark gray, brown weathering limestone is a six foot zone within the shaly limestone where large Acanthopecten (?) are abundant especially in the top six inches. A few Spirifer sp. and a few scattered ostracods (?) are mixed with the Acanthopecten (?).

The most fossiliferous shale and limestone units in the formation are 9 and 10. Within the shale bryozoans and brachiopods are abundant. Composita, Spirifer, Cleiothyridina, and Dictyoclostus are by far the most abundant brachiopods; Archimedes oquirrhensis, Archimedes owenanus, Fenestella are the most abundant bryozoans. Polypora debilis, Ptylopora, Marginifera, and Nuculana are present also in the shale. Mr. Lloyd Burkle (personal communication) stated that Archimedes owenanus is a mid-continent upper Osagean and lower Meramecian form. In Soldier Canyon this species occurs stratigraphically higher in upper Chesterian. The fenestellid bryozoans are abundant in the lower part of the shale in unit 9 and Archimedes becomes abundant in the top three to ten feet.

Unit 10 is a marker bed because of its fossil content. Local writers have designated this limestone as the medial limestone in the formation and have attempted correlation on this bed. In Soldier Canyon the bed varies from fifteen to twenty-three feet thick. The limestone contains Spirifer, Composita, Amplexizaphrentis, Orbiculoidea, Kaskia, Griffithides (?), Fenestella, Polypora, Talpaspongia calavata, abundant crinoid stems, and a few ostracods. Archimedes does not appear in the limestone, but in the shales and interbedded limestones above in unit 12 they occur and show their highest appearance in the formation at about 525 feet above the base of the formation. Fenestella and Polypora continue on up to the top of the formation, but in less abundance.

Talpaspongia occurs in less abundance than in the West Canyon area but does occur in the basal three to six feet of unit 10. This sponge appears to be a good guide fossil, but was found only in Soldier Canyon, Ophir Pass, and West Canyon by the writer. In thin section a few poorly preserved endothyrids (?) were observed in this medial limestone, but were unidentifiable.

Nuculana, Caneyella, Yoldia, and Nucula (?) become abundant in the shale zone above unit 10 in Units 12, 14, and 16. A zone of fragmented plants occurs in unit 16 about 708 feet above the base of the formation. According to Mr. Gilbert Greene (personal communication) the only recognizable fragments were those of Cordaites (?). The plants occur in a very silty, brown hard shale. Their fine details seem to be destroyed by weathering. Leaves, seeds, and pods were evident, but the abundant flora found in Lake Mountain was not observed in this section.

Locality 11020 contains Chonetes chesterensis. Only a few specimens were found in the shaly limestones at the top of unit 22 and the base of unit 23.

Locality 11021 is in the top 500 feet of the section and fewer fossils were found than in the lower two-thirds of the formation. Near the middle of unit 28 a dark gray-brown weathering limestone contains a few Spirifer and crinoid hash. The Spirifer are partially replaced by silica and were too fragile to be etched.

A very fine fossil hash is present in the basal two feet of unit 29. Brachiopod and trilobite fragments are the most abundant. Upon thin section study no microfossils were encountered. Unit 30 contains a few Spirifer, Composita, Dictyoclastus, Kaskia, crinoid and bryozoan fragments. A one-foot bed of brachiopod coquina, probably Composita, occurs a few feet above the fossiliferous limestone of unit 30. Throughout the top fifty feet of the formation Spirifer sp. and crinoids appear to be the most abundant fossils. They are intermixed with fossil hash.

Fossils found in Soldier Canyon are as follows:

Buxtonia semicircularis ? (Sutton and Wagner)
Cleiothyridina orbicularis ? (McChesney)
Cleiothyridina sp.
Chonetes chesterensis (Weller)
Composita subquadrata (Hall)
Composita sp.
Derbyia sp.

Dictyoclostus sp.
Linoproductus ovatus (Hall)
Marginifera lasallensis ? (Worthen)
Marginifera sp.
Orbiculoidea sp.
Pinna sp. (?)
Spirifer cameratus ? (Morton)
Spirifer occidentalis (Girty)
Spirifer opimus (Hall)
Spirifer rockymontanus (Marcou)
Spirifer sp.
Acanthopecten sp.
Aviculopecten sp.
Caneyella richardsoni (Girty)
Edmondia sp. (?)
Nucula croneisi (Schenck)
Nucula sp.
Nuculana bellistriata ? (Stevens)
Nuculina sp.
Yoldia glabia (Beede and Rogers)
Yoldia sp.
Stegocoelia turritella (Hall)
Griffithides sp. (?)
Kaskia chesterensis (Weller and Weller)
Archimedes oquirrhensis (Condra and Elias)
Archimedes owenanus (Hall)
Fenestella sp.
Polypora debilis (Elias)
Ptylopora sp.
Talpaspongia clayata (King)
Amplexizaphrentis sp.
Endothyra sp.
Ostracods
Crinoid columnals
Other gastropods
Cordiates (?) fragments, seeds and pods

Ophir Pass: The Ophir Pass section is located about four miles to the south and east of the Soldier Canyon section on the divide between the head of the South Fork of Soldier Canyon and the head of Ophir Canyon, in Sec. 11, T. 6 S., R. 4 W., Tooele County, Utah. The base was taken at the top of the steeply east dipping Great Blue Limestone about 2000 to 3000 feet west of the log cabin located 200 to 300 feet down from the divide in Ophir Canyon. The section was then taped east to the upper contact of the Manning Canyon Shale.

On the pass the complete section is exposed with the lower and upper contact distinct. The lower part up to the fossiliferous limestone (unit 6) was covered with a thin soil so digging for samples was necessary. The upper part of the section is well exposed.

Lateral changes in the Ophir Pass section occur in three zones as follows: first, in a limestone near the base (unit 2) where the lithology changes from fine grained cherty limestone with a fine fossil hash in Soldier Canyon to a fine grained limestone containing intraformational sub-angular conglomerate with pebbles, one-fourth inch by one-half inch in diameter, in the base, along with abundant crinoids, and a few corals and brachiopods. The argillaceous content increases, but the color remains about the same. Second, the quartzite beds (units 8 and 10) increase in thickness but remain about the same in texture and lithology, except for the addition of more argillaceous material. The same quartzite zone in Soldier Canyon does not contain beds over six to eight feet thick, while in Ophir Pass the quartzite thickness is about seventy feet. The third zone of interest occurs 350 feet from the top of the formation where the quartzite and calcareous quartzite of Soldier Canyon (unit 27) becomes more calcareous in Ophir Pass. The color, grain size, and weathered surface remain the same, but the calcium carbonate percentage increases. This same unit (unit 14) in Ophir Pass might be termed a sandy limestone.

The measured thickness of the formation at Ophir Pass is 1347 feet. This thickness is about 200 feet thinner than at Soldier Canyon. The thinning probably is due to possible error in measurement of the dip in the beds, rather than lateral thinning in the formation.

Fossils are common in the limestone and calcarous shale beds. One Brigham Young University locality 11022 was designated in Ophir Pass. Within the Ophir Pass section Spirifer, Composita, and crinoids are most abundant, pelecypods and bryozoans common, and a few trilobites, corals, and sponges are present.

The sponges are of special interest. The zone of Talpaspongia clavata occurs in a three to four foot bed about 3 feet above the base of the fossiliferous limestone (unit 6, medial limestone). The sponges were replaced and weathered, but are characteristically the same shape and weather a light-medium orange-brown color.

The Wewokella zone immediately underlying the Talpaspongia zone in West Canyon was not evident or the specimens were covered in Ophir Pass. A higher zone of Wewokella was discovered in a five foot, black, very fine grained limestone about 200 feet stratigraphically higher in the section. This is at 796 feet above the base of the formation. The limestone directly overlies the large quartzite bed in the section. Only one good complete specimen was found although the limestone bed was examined laterally for some distance.

Shales in Ophir Pass are covered and more poorly exposed than in Soldier Canyon, which probably accounts for the lack of the abundant pelecypod and bryozoan faunas, rather than lateral faunal changes within the section.

The Chonetes zone so evident in Soldier Canyon could not be recognized in this section. The Archimedes zones (Ophir Pass units 5 and 7) immediately above and below the fossiliferous limestone (unit 6 medial limestone) were not as evident; however, they are present.

The fauna collected (BYU loc. 11022) includes:

- Avonia sp. (?)
- Cleiothyridina sp.
- Composita subquadrata (Hall)
- Composita sp.
- Dictyoclostus sp.
- Spirifer opimus (Hall)
- Spirifer sp.
- Nucula sp.
- Yoldia sp.
- Archimedes oquirrhensis (Condra and Elias)
- Fenestella sp.
- Polypora sp.
- Talpaspongia clavata (King)
- Wewokella n. sp.
- Amplexizaphrentis sp.
- Trilobite fragments
- Crinoid stems and fragments
- Other pelecypods

Manning Canyon (Type Locality). The formation in Manning Canyon crops out discontinuously from the head of the canyon southeast to about one mile above the old townsite of Manning. A section aggregating 1064 feet was measured in three parts at the head and about one-half mile below the head of Manning Canyon in SW1/4 Sec. 4, T. 6 S., R. 3 W., Utah County, Utah. This is located about six and one-half miles southeast of Soldier Canyon. Two Brigham Young University fossil localities, 11023 and 11024, were designated in the canyon.

The basal 410 feet of the section was measured east from the steeply dipping Great Blue Limestone starting where the road leaves the old railroad bed. The basal part is exposed in the road cut. A possible fault exists in the base of the Manning Canyon Shale at this point as evidenced by the difference in strike between the Great Blue Limestone and the Manning Canyon Shale. The average strike in the Great Blue Limestone is about N. 20 W. while the limestones and quartzites in the basal part of the Manning Canyon Shale strike N. 50 W. The Great Blue Limestone over rides 200 to 300 feet of the base of the Manning Canyon Shale. Down the canyon from this measured basal unit black shales occur which could possibly be the basal black shales found in Soldier Canyon, but due to the displacement within the base a measured segment could not be attached to the section.

The middle 390 foot segment of the section was measured across the shallow valley directly east and north of the main road across Mercur Pass. This part of the section except for a few limestones and quartzites was covered, especially in the lower part, making dips and strikes difficult to obtain.

The top 255 feet of the formation was measured on the small east-west ridge about one-fourth to one-half mile north of the Mercur Pass road. The Oquirrh-Manning Canyon contact is similar to the one found in Soldier Canyon in that the pink-gray and purple-gray shales in the Manning Canyon Shale are overlain by basal sandy medium gray, brown weathering limestones of the Oquirrh Formation.

Lithology in Manning Canyon varies little from the sections to the north in Ophir Pass and Soldier Canyon except in the basal part. Quartzites are present about 120 to 150 feet above the base of the measured section, whereas in Soldier Canyon a silty shale occurs at about the same stratigraphic position. A lateral change in lithology occurs in Manning Canyon within the quartzite 570 feet above the base of the measured section. The quartzite is very argillaceous and fine grained which varies from the clean quartzites in Soldier Canyon and Ophir Pass. This quartzite contains Archimedes mcfarlani and Kaskia. The quartzite is calcareous enough that the fossils can be etched.

The remainder of the formation is similar to the type section. The limestone of unit 18 in Manning Canyon is more distinctly jointed and stylolites are present. These structures were not found in the equivalent units in West Canyon (15), Ophir Pass (12), and Soldier Canyon (24).

The top shale unit in Manning Canyon has a pink and purple coloration not evident in other localities. The basal black shales and limestones of units 1 and 2 in Soldier Canyon and Ophir Pass and the overlying shaly limestones of units 4 and 6 are not exposed in Manning Canyon. This is possibly due to faulting in the base of the formation. The medial limestone, unit 10 in Soldier Canyon, might also be faulted and unexposed in Manning Canyon. However, the brown-gray, brown weathering fossiliferous limestone and shale of unit 7 in Manning Canyon contains the same fauna as unit 12 in Soldier Canyon which there overlies the medial limestone. In Manning Canyon unit 6 could possibly be the medial limestone although no sponges were found.

The fossils found in the basal part of the section in Manning Canyon (Loc. 11023) consist predominantly of Composita, Spirifer, and crinoids, with Archimedes oquirrhensis, Fenestella, corals and trilobite fragments present. They are found in the limestones and shales of units 6 and 7, 325 to 390 feet above the base of the formation.

In the upper 600 feet of the section, Loc. 11024, and argillaceous quartzite, unit 10, about 570 feet above the base of the formation contains Archimedes mcfarlani, Kaskia, sp. fenestellid bryozoans, and fragments of crinoids and brachiopods. This bed contains the only Archimedes mcfarlani found during the study.

The limestones of unit 12 are fossiliferous in the base containing abundant Spirifer, a few pelecypods and other broken fossil hash. About 70 feet from the top of the formation, in the base of unit 22, a zone of Spirifer, and crinoids with fossil hash, is present. Only a few pelecypod fragments were found throughout the shales. Also, no plants were found in the section.

The fossils found in Manning Canyon are:

- Archimedes oquirrhensis (Condra and Elias)
- Archimedes mcfarlani (Condra and Elias)
- Polypora sp.
- Kaskia sp.
- Fenestella sp.
- Spirifer sp.
- Composita sp.
- Cleiothyridina sp.
- Dictyoclostus sp.
- Corals
- Crinoids

West Canyon: The formation is exposed on the north plunging nose of the Long Ridge Anticline. The section was measured south to north from the north slope of Iron Canyon to the north slope of West Canyon

about one to one and one-fourth miles up Iron Canyon from its mouth in Farmers Flat, Sec. 3, T. 5 S., R. 3 W., Utah County, Utah. The base of the formation is exposed in Iron Canyon and the overlying limestone and quartzite form the main ridge between Iron and West Canyons. The upper shales of the formation form the main valley of West Canyon.

A complete section of 1683 feet was measured in two parts. The lower 1283 feet was measured on the north slope of Iron Canyon. The upper 400 feet is largely covered and the interval was measured in West Canyon about one-fourth to one-half mile northwest from Farmers Flat.

The Great Blue-Manning Canyon contact is taken where the gray and blue-gray, light-gray weathering thin bedded, platy limestones are overlain by light pink-gray and black shales. The contact of the Manning Canyon Shale with the Oquirrh Formation was covered in the area, and an arbitrary boundary was selected. The writer walked the formation laterally to the head of West Canyon but no exposures of the upper part or contact were found.

The section is about eight miles east of the type section in Soldier Canyon and is appreciably thicker. The medial limestone, Unit 6 in West Canyon, thickens to 98 feet and all the other units appear thickened. The lithology appears similar to the other three sections in the Oquirrh Mountains. The brown "capped" limestones are evident and thus correlation was effected.

The writer measured 1282 feet of section plus an estimated additional 400 feet at the top for a total thickness of 1682 feet. McFarland (1955, p. 12) reports a measured thickness of 2495 feet in Iron and West Canyons. Realizing the 800 feet difference the writer rechecked the thickness and feels the discrepancy may have been in the long shallow dip slope measurements of McFarland's units 62 to 66 (McFarland, 1955, p. 7). Although the formation thickens to the east it is considered that the true thickness is between 1600 and 1700 feet.

Fossil assemblages are similar to the Soldier Canyon faunas, however two sponge zones were found. According to Professor J. K. Rigby (personal communication) these sponges are the first found in the West in Mississippian rocks. Professor H. J. Bissell and the writer found a zone of Talpaspongia clavata in a 12 foot zone in the medial limestone about 682 to 694 feet above the base of the formation.

The writer found a zone of the sponges Wewokella contorta and Wewokella solida. These sponges weather out of the shales in unit 5 approximately 600 feet above the base of the formation. At present the Wewokella zone was found only at this one locality in central Utah.

Three Brigham Young University localities 11005, 11025, 11026 were designated in West Canyon. Locality 11005 is the Talpaspongia zone, 11025 is the Wewokella zone, and 11026 is designated as a general locality for fossils in West Canyon. The shale of unit 5 contains Wewokella, and also has thin beds of fossiliferous limestone containing abundant bryozoans and brachiopods. Archimedes oquirrhensis, Fenestella, Polypora, Dictyoclostus, Composita, Spirifer, Cleiothyridina, Kaskia, corals, and crinoid stems are present. The top of unit 4, 550 to 570 feet above the base of the formation contains abundant Spirifer, Composita, Polypora, Rhombopora ?, Fenestella, Dictyoclostus, corals, trilobites and crinoids.

The quartzites and shales of units 10 and 11, 870 to 1000 feet above the base of the formation, contain plant fragments and a few pelecypod fragments. The plants were so fragmented and poorly preserved that generic identification was impossible.

Fossils present in West Canyon include:

Locality 11005
- Talpaspongia clavata (King)

Locality 11025
- Wewokella contorta (King)
- Wewokella solida (Girty)

Locality 11026
- Cleiothyridina sp.
- Composita subquadrata (Hall)
- Composita sp.
- Dictyoclostus sp.
- Spirifer opimus (Hall)
- Spirifer sp.
- Kaskia sp.
- Archimedes oquirrhensis (Condra and Elias)
- Fenestella sp.
- Polypora sp.
- Rhombopora sp. (?)
- Yoldia sp.
- Nucula sp.

- Horn corals
- Gastropods
- Other pelecypods
- Crinoids

Lake Mountain: On the east flank of Lake Mountain a 1910 foot section of the Manning Canyon Shale was measured, east to west, on the west side of Seep Canyon 1000-2000 feet, north and west of the spring, Sec. 36, T. 6 S., R. 1 W., Utah County, Utah. The section is about 25 miles south-east of Soldier Canyon.

The Great Blue-Manning Canyon contact on Lake Mountain is at the top of a dark gray, light gray-weathering cherty limestone, where it is overlain by medium gray shales that become variegated above the base. The contact of the Manning Canyon Shale with the Oquirrh Formation is not readily located, but was taken beneath the dominant medium gray, brown weathering quartzite.

The lithology differs from other areas in that quartzites, subgraywackes and arkoses become more abundant than in any of the other sections. The lithologic summary is as follows:

Rock Type	Thickness in feet	Percentage
Shales	1231	64.5
Quartzites, arkoses and graywackes	600	31.4
Limestones	79	4.1
Total	1910	100.0

The section is thicker and the clastics are coarser grained. Limestones are less common and comprise only five per cent of the formation.

Large nodules 8 to 12 inches in diameter are present in the basal shale, unit 1, and consist of calcareous siltstone. Possible repetition may occur in the lower quartzite units on Lake Mountain especially in units 4, 6 and 7. Bullock (1949) suggests numerous faults and repetition of the beds occur on the east side of Lake Mountain. However, in the section measured no fault evidence or repetition was observed. Also, the section is 1910 to 2000 feet thick on the east side of Lake Mountain as compared to Bullock's (1949, p. 18) measurement of 1419 feet on the east and Calderwood's (1951, pp. 63-65) measurement of 1130 feet on the west side. The increase in the thickness of the section further suggests repetition.

The Brigham Young University fossil locality 11027 is designated in the section; however, the invertebrate fossils are rare. A plant fauna is abundant and well preserved. The few pelecypods found in the shaly siltstone of the upper part of unit 6, 1154 feet above the base of the formation, are poorly preserved.

Plants are in the light yellow-brown and yellow-gray shales of unit 13, 1588 to 1602 feet above the base. The same flora was found to the south about one to one and one-fourth miles in the Overcross clay pits located in the NE 1/4, SW 1/4, Sec. 1, T. 7 S., R. 1 W., Utah County, Utah. Also to the north end of Lake Mountain in the Powell Pit located SE 1/4, NE 1/4, Sec. 3, T. 6 S., R. 1 W., Utah County, Utah. The different genera were consistant throughout the three localities. The plants were not broken or fragmented as in other areas where they have been found. Alethopteris sp. and Neuropteris sp. appear to be most abundant genera.

Fossils collected from Lake Mountain are:

Flora:
- Alethopteris sp.
- Asterophyllites, 2 spp.
- Cordaites sp. fragments
- Calamites sp.
- Eremopteris missouriensis
- Eremopteris sp.
- Neuropteris 3 or 4 spp.
- Sphenopteris 2 spp.
- Other seeds, pods and nuts (?)

Fauna:
- Pelecypods
- Gastropods
- Crinoids

Provo Canyon. The Manning Canyon Shale was visited and observed at three localities in Provo Canyon. The first is above the Great Blue Limestone cliffs north of the Provo City Power Plant in the mouth of Provo Canyon, and the second is on the north side of the Provo River at Canyon Glen Camp Grounds, also south and across the highway. The third is east of the road at the head of Little Rock Canyon and also to the south at the head of Rock Canyon.

At the mouth of Provo Canyon the basal black shales in the formation are exposed, but no correlation of the upper part of these shales with the black shales at Canyon Glen Camp Grounds is positive because of numerous faults in the north slope of Provo Canyon.

At Canyon Glen Camp Grounds the section consists of black shales and fossiliferous limestones. They appear similar to shales and fossiliferous limestones in the lower part of the section, possibly near the black shales and medial limestone of Soldier Canyon units 7 and 12, 250 to 550 feet above the base of the formation. The upper medium and light gray shales and limestones of the formation are exposed in the south slope of Provo Canyon, across the highway at Canyon Glen Camp Grounds.

The third location is the same area in which Baker (1947) measured 2600 feet of the formation. The section is so poorly exposed that no measurements were attempted. At the head of Little Rock Canyon a unit of quartzite occurs in the base of the formation and contains plant trunks and stems. The trunks show round stem scars. The fossils are poorly preserved, but appear to be one of the lepidodendrons, possibly Lepidodendron sp.

Traverse Mountain. The Manning Canyon Shale is exposed north of the Lehi-Cedar Fort highway on the south slope of Traverse Mountain. Only one location was visited where a partial section of the formation is exposed in the clay pits. The formation on Traverse Mountain is faulted and covered so that only in the clay pits is it exposed. Shale, quartzite, and limestone were observed which possibly compare to the middle part of the section. This is evidenced by the plant flora. The plants occur in a very light gray clay shale. South in Lake Mountain the shales occur in a more brown and yellow shale containing silt. The plants in the Traverse Mountain occurring in the clay shales suggest possible transportation, but no fragmentation of leaves and stems is evident.

The fossils found in the Traverse Mountain are:

- Cordaites 2 spp. (?)
- Eremopteris sp.
- Neuropteris sp.
- Leaf fragments, thorns, spores (?), and seed pods
- Pelecypod fragments
- Gastropods
- Crinoids

Five Mile Pass. The Manning Canyon Shale forms the low subdued slope that forms Five Mile Pass. The section appears faulted. Two localities were visited. One locality occurs on the southern tip of the

Oquirrh Mountain about one to two miles north of the highway in Five Mile Pass, approximately on the Utah-Tooele County line. Variegated shales of red, yellow and gray shades containing pelecypod, gastropod and crinoid fragments were observed in the clay pits at this locality. Also, in this area plant fragments occur in the green-gray fine grained quartzite. From the occurrence of plants in quartzites the exposed partial section probably is in the middle to upper part of the formation.

The other locality visited in the Five Mile Pass area is located about eight miles south of the pass and about five miles east of Topliff, Utah. Only the uppermost 50 to 100 feet of the formation is exposed with a fault contact at the base. However good sedimentary contact with the overlying basal Oquirrh Formation is exposed in this area. The limestones and shales are sandy and appear very similar to the upper two units in the formation at Soldier Canyon (units 31 and 32). Fossil hash containing brachiopod fragments and crinoids occurs in the limestones and pelecypod fragments occur in the shales at this locality.

Stansbury Mountain. One short, faulted, partial section was visited in the northernmost end on the east flank of the range. The shale exposed in the clay pits is variegated green and brown-gray with some black. A few *Spirifer* sp., productid brachiopods, corals, crinoids and bryozoans were collected from the shale and the fossiliferous brown limestone that forms the west wall of the pit. The fossils were too poorly preserved for identification. The partial section observed probably occurs in the lower part of the formation.

Onaqui Mountains. A section in Johnson Pass in the northern end of the Onaqui Mountains was ivsited. The section appeared too faulted for measurement, but with further walking out of key beds possibly a section could be obtained. The section is predominately shale with quartzite and shaly limestone common in the lower one-half of the formation. Pure white quartzite occurs midway in the section with green and brown-green shales. Medium gray, brown-weathering limestones and brown and gray shales characterize the top of the formation.

Brigham Young University fossil locality 11028 was designated in this area. Pelecypods were observed to be abundant in the upper shale units with few occurring in the shaly limestones in the lower one-half of the formation. No fossil plants were found.

Fossils collected in the shales and limestones in the Onaqui Mountains include:

- *Cleiothyridina* sp.
- *Dictyoclostus* sp.
- *Composita* sp.
- *Spirifer* sp.
- *Amplexizaphrentis* sp.
- *Nucula* sp.
- *Fenestella* sp.
- Crinoids
- Gastropods
- Pelecypod fragments

CONCLUSIONS

Correlation and Age

Correlation throughout central Utah within the Manning Canyon Shale is evident by means of key lithologic units. Four sections in the Oquirrh Mountains, one in the Onaqui Mountains and one in Provo Canyon appear to correlate well by means of these beds and fossil zones.

The first zone is in the black shales in the basal 200 feet of the formation. The second zone consists of the overlying shaly limestone, fossiliferous limestones, and fossiliferous shales. This zone is about 200 to 550 feet above the base of the formation and contains the medial limestone near the top of the zone. The third lithologic zone occurs in the silty shales and interbedded quartzites in Soldier Canyon about 550 to 900 feet above the base of the formation. This third zone contains more and thicker quartzite beds as it is correlated to the east. The fourth zone consists of carbonaceous non fossiliferous pure and shaly limestones containing interbedded calcareous shales. The zone is about 900 to 1050 feet above the base of the formation. The fifth and top lithologic zone in the formation is predominantly gray and brown-gray shale with a few thin beds of limestone. Near the top it becomes sandy and more calcareous. Midway in this top zone a calcareous quartzite can be correlated in Soldier Canyon, Manning Canyon and Ophir Pass. This quartzite is not as evident in Lake Mountain, West Canyon, Onaqui Mountains nor in Provo Canyon.

Individual lithologic and fossil zones also helped in the correlation of the sections throughout central Utah.

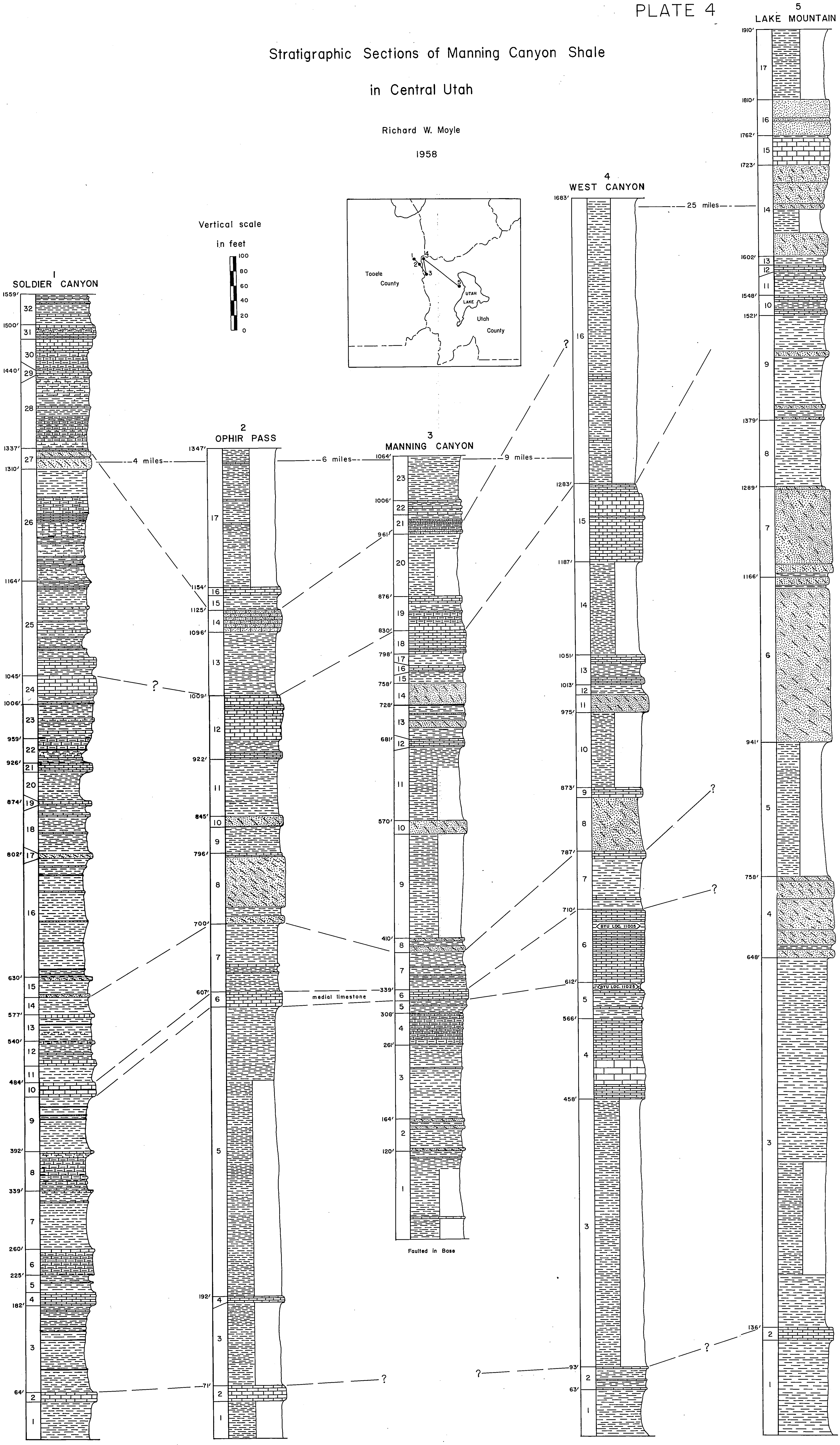
The fossiliferous medial limestone unit is evident in Soldier Canyon, Ophir Pass, Manning Canyon, West Canyon (Plate 4) and is helpful in determining the lower part of the section. The fauna is not too different in this limestone than in the overlying and underlying units, however the abundance of fossils and the presence of *Talpaspongia clavata* in the basal part of this medial limestone makes it a good unit for correlation. The shale with interbedded limestone, overlying and underlying this medial limestone also help to correlated this limestone with comparable facies. Abundant bryozoans, especially *Archimedes* and *Fenestella*, the brachiopds *Composita* and *Spirifer*, and crinoid stems help to correlate these shales which in turn help designate the medial limestone in West Canyon, Ophir Pass and Manning Canyon.

PLATE 4

Stratigraphic Sections of Manning Canyon Shale in Central Utah

Richard W. Moyle

1958



Plants are good fossils for correlation in the middle and upper part of the formation within the sections measured in central Utah. The plants on Traverse Mountain may be an exception because they seem to appear stratigraphically higher in the section.

The brown "capped" limestones in the lower part of the formation appear to be helpful to correlate. However, because of their abundance in each section, care should be taken when using them individually to correlate.

The limestone of unit 24 in Soldier Canyon, along with its equivalent units in Ophir Pass (12), West Canyon (15), and Manning Canyon (18), can be used to correlate the upper part of the formation. A limestone with similar appearance in Provo Canyon might also be correlated with this unit.

Correlation with the major transgressions and regressions of the Manning Canyon sea is evident (Plate 5), especially in the sections in the Oquirrh Mountains. The Lake Mountain and Onaqui Mountain sections correlated partially using the lithologic cyclic nature of the formation.

Due to temporal transgression, the Maning Canyon Shale has been mapped by most geologic workers as Mississippian-Pennsylvanian. A few geologists working throughout central Utah have suggested differentiating Mississippian and Pennsylvanian rocks of the Manning Canyon Shale at the top of the predominate fossiliferous dark gray-blue limestone, termed the "medial limestone," that occurs about 450 feet above the base of the formation. Others suggest the time boundary occurs 200 to 330 feet higher in the formation at the zone of the arkosic and graywacke quartzites.

Elias (1956, p. 71) suggests that a similar controversy occurs relative to the Caney Shale throughout Oklahoma and that it might be solved somewhat by a practical lithologic differentiation. He worked with the Caney Shale in the northern and southern Arbuckle Mountains and states the differentiation between the two ages in the shale occurs between, ". . . the dark gray or black, more or less bituminous shale, with large to very large limestone and small phosphatic concretions below, to gray, non-bituminous hale with medium-size ferruginous, brownish to reddish concretions above."

It is impracticable to use such a lithologic change alone in the shales to differentiate time within the Manning Canyon Shale in central Utah. However a local differentiation based on the shale color change and the bituminous content of the shales and limestones might possibly be observed in the type section in Soldier Canyon (Plate 3). The time change liekly occurs in a zone between 1050 to 1150 feet above the base of the formation in the basal part of unit 25 or just above the dark gray and dark brown limestone of unit 24. Below unit 24 in the section the shales are predominantly black, dark gray and dark brown, very carbonaceous and contain zones of abundant calcareous siltstone nodules and concretions. Above unit 24 in the section the shales are medium and light gray, medium and light brown-gray, and are slightly carbonaceous.

The quartzites and sandy limestones above unit 24 conform closer to the overlying sandstones, quartzites, and limestones of the Oquirrh Formation than to the underlying quartzites, siltstones and limestone of the typical Manning Canyon Shale.

The paleontologic change between the faunas of the Mississippian and Pennsylvanian age throughout central Utah is not abrupt or conspicuous. The fauna change seems to occur without a profound break and may be transitional in all of the areas studied in this report. The writer feels that if a break is apparent in the fauna, it occurs in the Soldier Canyon section above unit 12, 550 feet above the base of the formation. The abundant fauna typified by Archimedes, Composita, Amplexizaphrentis, and Talpaspongia found in the formation below unit 12 disappears above the unit. Chonetes chesterensis occurs above this suggested break, but disappears about 1000 feet above the base of the formation in the top of unit 23. Dictyoclostus, Spirifer, Cleiothyridina, Derbya, and other brachiopods seem to carry thoughout the entire formation.

A distinct difference in lithology occurs directly above unit 12 in Soldier Canyon. The sediments show near shore to terrestrial conditions. The abundance of plants within the formation also occur in this overlying zone. The plants and the quartzites of this zone (units 14 to 18) in Soldier Canyon suggest a time break at this point, marked by a change in sedimentary conditions. The changes likely occurred in provenance and environment of sedimentation, but may have been more gradual than abrupt. The writer realizes that the time boundary is suggested near the close of a regression and not at the customary beginning of a transgression. The plants resemble Pennsylvanian forms thus suggesting the time boundary be arbitrarily drawn below the plant zone in unit 16; however, these plants might well be Upper Mississippian in age.

The Mississippian-Pennsylvanian time boundary may be arbitrarily drawn in the Ophir Pass, Manning Canyon, and West Canyon sections at about the same stratigraphic position as in Soldier Canyon. The time boundary in Ophir Pass occurs above the

medial limestone unit 6 in the silty shales and quartzites of units 7 and 8 (Plate 4). Plants were not found in these units in this locality. In Manning Canyon the boundary might be placed in the shales and quartzites of units 7 to 10. The boundary in West Canyon may occur above the medial limestone of unit 6 in the shales and quartzites in units 8 to 10. Plant fragments occur in unit 11 within the West Canyon section (Plate 4).

Environment of Sedimentation

The environment of the shales as suggested by fossils, varying amount of silt and clay, varying amount of organic material and iron, and the calcareous content suggests both near-shore and shallow epineritic to shallow infraneritic conditions of deposition.

Sediments were possibly deposited on an unstable shelf directly adjacent to the deeper zones of the geosyncline. Calcareous content suggests a tidal flat environment for the brown and brown-gray shales. The brown color is probably due to oxidation of iron during deposition suggesting oxidating shallow near-shore conditions. Some of the silty and sandy shales are calcareous. The warmth of the water in the shallow near-shore conditions may be the cause of calcium carbonate in these sediments.

Abundance of organic material suggests deposition farther from shore or under slightly reducing conditions for the black shales. However, Hager (1928, p. 936) notes that "Black muds are deposited in estuaries, lagoons, and enclosed parts of the sea, where the water is relatively quiet and wave action is slight, or also in depression on the continental shelf where there is little current." The same type of origin might explain some of the black shales within the formation.

In summary of the different shales in the Manning Canyon Shale, two different vertical sequences exist in the section. The vertical lithologic change can probably be taken for lateral shift near-shore to deeper marine conditions. The first sequence consists of a change from near-shore to deeper marine, sandy shales, silty shales, clay shales, calcareous clay shales. The second sequence consists of calcareous sandy shales, calcareous silty shales, clay shales, and calcareous clay shales.

The environment of the limestones appears to have been shallow marine to open marine. The fossil fauna suggests epineritic clear water to shallow infraneritic clear water. The dense, hard, very fine grained to finely crystalline limestones devoid of fossils suggest the outer edge of the shelf to a deeper marine lithotope. Fossiliferous limestones are present in the lower one-half and in the top of the formation, while the lithographic limestones are in the middle and upper part of the formation in central Utah.

Quartzites near the middle of the section at Soldier Canyon, Ophir Pass and West Canyon suggest that these sediments were washed into the geosyncline at a faster rate than the basin was sinking or that stabilization was occurring. This is evident from the reworked character of the sand grains, from cross-bedded and from the well-sorted subangular and subrounded grains. The reworked character of the sand grains is evident also on Lake Mountain.

The quartzite beds on Lake Mountain appear to retain the same thickness laterally. No evidence of channeling or lensing was evident, so possibly the sands were deposited as a blanket sediment in shallow sea conditions.

Current action during deposition of the shales and limestones was very slight. Fossils occur neither broken nor fragmented. Of special interest testifying to quiet bottom conditions is the Archimedes and Fenestella zone in Soldier Canyon about 400 to 525 feet above the base of the formation. Within this zone very fragile spiral fronds are well preserved in place and are unbroken.

Samples of quartzite from the basal Oquirrh Formation in central Utah, especially in Soldier Canyon, show an increased argillaceous content and less rounding of the grains. This suggests a faster subsiding basin at the close of Manning Canyon and the beginning of Oquirrh time.

Some of the sediments, especially sands, laid down in the formation were possibly of a terrestrial environment because of the presence of land plant fragments. Also, according to Bissell (personal communication) the formation locally contains a few thin coal beds.

The cyclic nature of the formation and the terrestrial fossils (possibly 2 to 3 zones) suggest that the strand line of the Manning Canyon sea migrated back and forth several times, and that transgression-regression occurred.

Cyclic Sedimentation. From the detailed study of the type section of the formation in Soldier Canyon cyclic sedimentation is evident.

The cyclic sedimentary nature of the Manning Canyon Shale was believed by previous writers to be due to local diastrophic control, which consists of a combination of gradual sinking of the geosyncline and a gradual rising of the surrounding land masses.

Throughout central Utah the cyclic nature of the formation is best evidenced in plotting the different lithologies of the measured sections, then outlining the cyclic transgressions and regressions of the shallow Manning Canyon sea (Plate 5). Two transgressions and three regressions are evidenced in both lithologic and fossil changes.

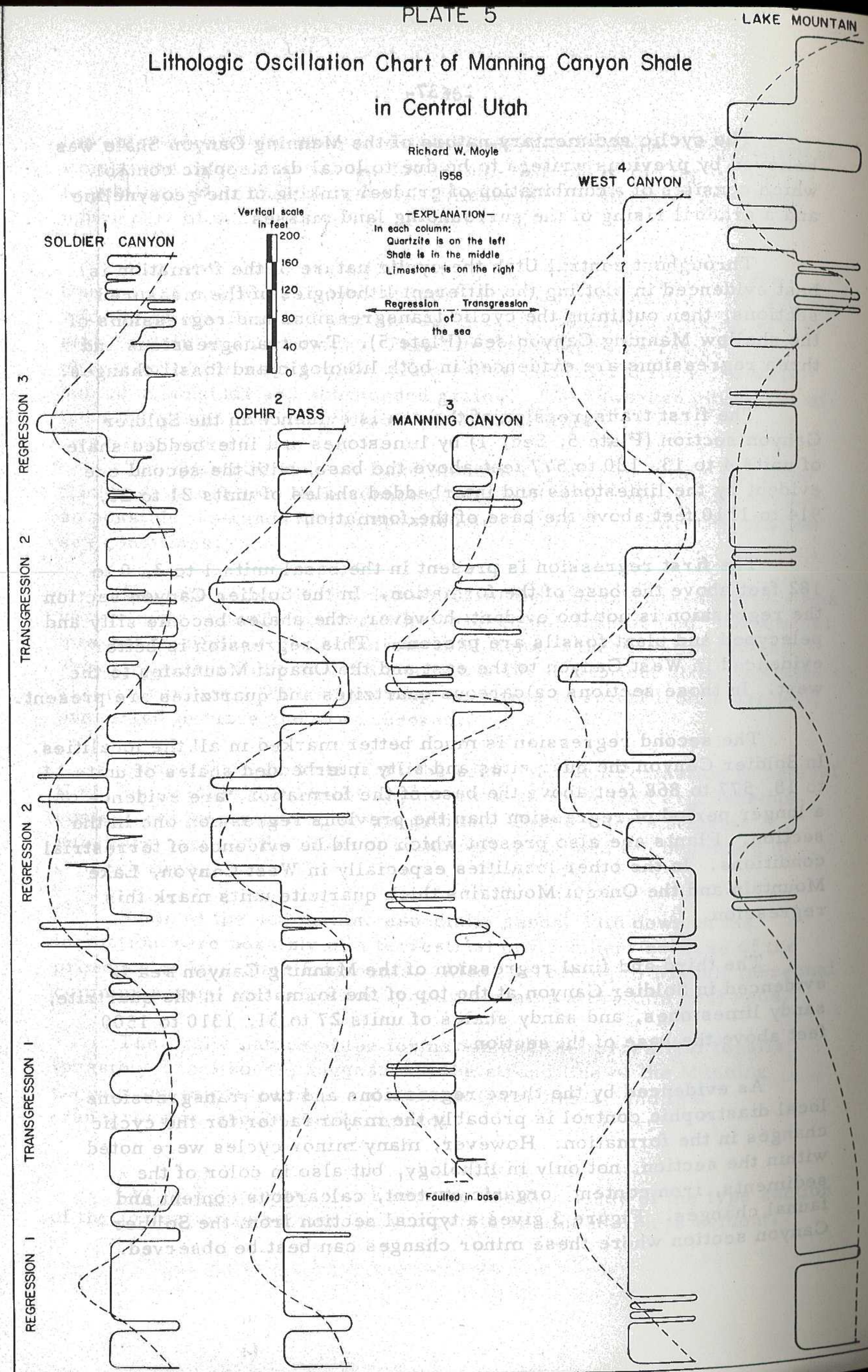
The first transgression of the sea is evidence in the Soldier Canyon section (Plate 5, Sec. 1) by limestones and interbedded shale of units 4 to 13, 180 to 577 feet above the base, with the second one evident by the limestones and interbedded shales of units 21 to 26, 914 to 1310 feet above the base of the formation.

The first regression is present in the basal units 1 to 3, 0 to 182 feet above the base of the formation. In the Soldier Canyon section the regression is not too evident; however, the shales become silty and pelecypod and plant fossils are present. This regression is better evidenced in West Canyon to the east and the Onaqui Mountains to the west. In those sections calcareous quartzites and quartzites are present.

The second regression is much better marked in all the localities. In Soldier Canyon the quartzites and silty interbedded shales of units 14 to 18, 577 to 868 feet above the base of the formation, are evidence of a longer period of regression than the previous regression one in the section. Plants are also present which could be evidence of terrestrial conditions. In the other localities especially in West Canyon, Lake Mountain and the Onaqui Mountains thick quartzite units mark this regression.

The third and final regression of the Manning Canyon sea is evidenced in Soldier Canyon at the top of the formation in the quartzite, sandy limestones, and sandy shales of units 27 to 31, 1310 to 1500 feet above the base of the section.

As evidenced by the three regressions and two transgressions local diastrophic control is probably the major factor for the cyclic changes in the formation. However, many minor cycles were noted within the section, not only in lithology, but also in color of the sediments, iron content, organic content, calcareous content and faunal changes. Figure 3 gives a typical section from the Soldier Canyon section where these minor changes can best be observed.



Also the minor cyclic changes in the formation are evident in the fossils (Figure 5). It is unreasonable to explain each of these minor changes as a separate diastrophic movement within the depositional basin. Climate may be a determining factor. Glaciation during the Upper Mississippian to Middle Permian possibly had some influence and should not completely be overlooked.

Wheeler (1957, p. 1985) states, "The persistent belief that late Paleozoic glaciation was confined to the Permian has influenced some to favor the diastrophic interpretation." Yet, in noting Permian glaciation studies of different men, they have dated tillites as early as the lower part of middle Carboniferous time. Also, as Wheeler (1957, p. 1998) states if ". . . others are correct in their belief that eustatic sea level fluctuation is the primary factor in sedimentation control, glaciation can be reasonably regarded as the most likely cause of fluctuation." He further states that glaciation constitutes an important factor in cyclothemic genesis.

The cyclic nature of the Upper Mississippian sediments in central Utah is evidently not as observable as in the Illinois Basin and other locations in the eastern United States, but during this present study, the sediments in the Manning Canyon Shale show a definie cyclic nature. With more detailed work in central Utah with the Upper Mississippian sediments a eustatic change in the sea due to glaciation might become more evident.

Source Area. The varying thickness of the formation observed eastward from the Gold Hills through the Onaqui Mountains, Stansbury Mountains, Oquirrh Mountains, Lake Mountain, and Provo Canyon demonstrates thickening towards the east. Thickness varies from about 500 feet in the Gold Hills to 2600 feet in Provo Canyon. Also the size and amount of clastic sediments increases towards the east.

Black and brown carbonaceous shales in the base of the formation indicate that at least some of the sediments were derived from a source area containing a thick layer of mature soil. This area probably was to the east of the Mississippian Cordilleran miogeosyncline or a positive craton in or near it. The Colorado Mountains uplift was in its initial stage and sediments shed from its west slope into this geosyncline which were transported by ocean currents over wide areas.

Lake Mountain area, however, because of the thick beds of sandstone and quartzite suggests two possible areas from which sediments could be derived. First, the sediments could have been derived from the east as suggested by eastward thickening of the section and eastward increasing clastic size. Second, the sediments could derive from

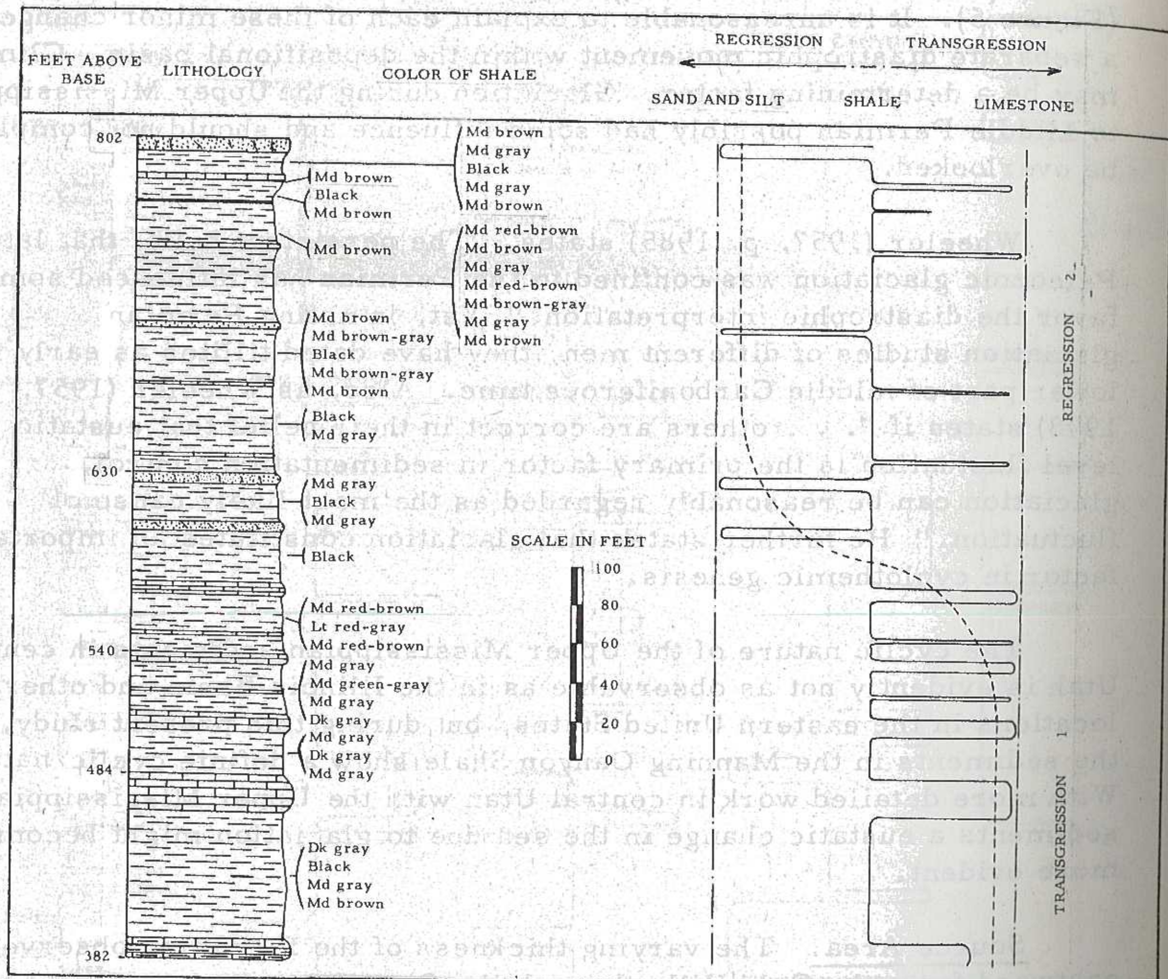


Figure 3. Cyclic patterns in Manning Canyon Shale, Oquirrh Mountains, Utah.

pre-existing sediments of lower and middle Paleozoic sediments exposed in a small emergent high along part of western Utah as evident from a preliminary isopach map of Mississippian rocks prepared by Bissell (personal communication). Less than 500 feet of sediments represent the total Mississippian rocks in the area of this emergent high. In the San Francisco Mining district Upper Mississippian and Lower Pennsylvanian sediments are missing. This suggests either an area of non-deposition or an emergent area subject to erosion. Of the two suggestions there is no evidence of the latter, but both suggest an emergent local high from which sediments could have been derived.

Also, a source area to the north and west of central Utah should be considered a strong possibility. In this area the Antler orogeny, a late Mississippian and early Pennsylvanian disturbance, caused an uplift that could evidently have supplied sediments which were transported to the east and south into central Utah. Dott (1955, pp. 2222-23) reports the Tonka Formation (Mississippian-Pennsylvanian) of eastern Nevada consists of coarse conglomerates and quartzites which pass vertico-laterally into shales.

The coarse clastics intertonguing eastward with the black shales of the Upper Mississippian and the Lower Pennsylvanian limestones in central Utah prove this western source for at least some of the sediments. However, in Lake Mountain the abundance of coarser clastics that are sub-rounded and sub-angular suggest a much closer source area. This favors the second supposition above, namely that sediments likely were derived from the pre-existing Paleozoic sediments exposed in a small emergent high along part of western Utah. (Figure 4).

Another possible source area is to the south in southern Utah and northern Arizona. Nolan (1943, p. 155) states that "Over much of southern Nevada and the adjoining parts of southern California Upper Mississippian beds appear to be missing." Noble (1922) suggests that similar conditions prevail in the Grand Canyon region.

Figure 4 shows the thickness of the Manning Canyon Shale in central Utah and the thickness of correlative formations in the contiguous area. The thickness in turn suggests the four source areas of sediments in the Upper Mississippian and Lower Pennsylvanian time.

Paleoecology

The paleoecology has not been discussed for each unit and sub-unit of the formation. In this report six major zones, where one lithology predominates, and a few other minor zones of special interest are discussed.

The basal 50 feet of predominantly black shale in the formation contains abundant pelecypods and plant fragments which suggest shallow lagoonal conditions close to shore where the plant fragments could have washed in without undue maceration, or were aquatic types which lived in that environment. The presence of pelecypods suggests

Explanation of Figure 4

References to numbered localities

1 Agatston 1957
2 Unterman and Unterman 1944
3 Sadlick 1955
4 Unterman and Unterman 1944
5 Williams 1948-A
6 Peace 1956
7 Peace 1956
8 Olson 1956
9 Moyle 1958 (this report)
10 Baker 1947
11 Bissell 1950
12 Moyle 1958 (this report)
13 Bissell 1950
14 Moyle 1958 (section visited during present study)
15 Rigby and Bissell (personal communication)
16 Dott 1955
17 Bissell (personal communication)
18 Nolan 1935
19 Youngquist 1951
20 Ogden 1951
21 Nolan 1943
22 Bissell (personal communication)
23 Weller 1948
24 Westgate and Knopf 1932
25 Bissell (personal communication)
26 Nolan 1943 and Weller 1948

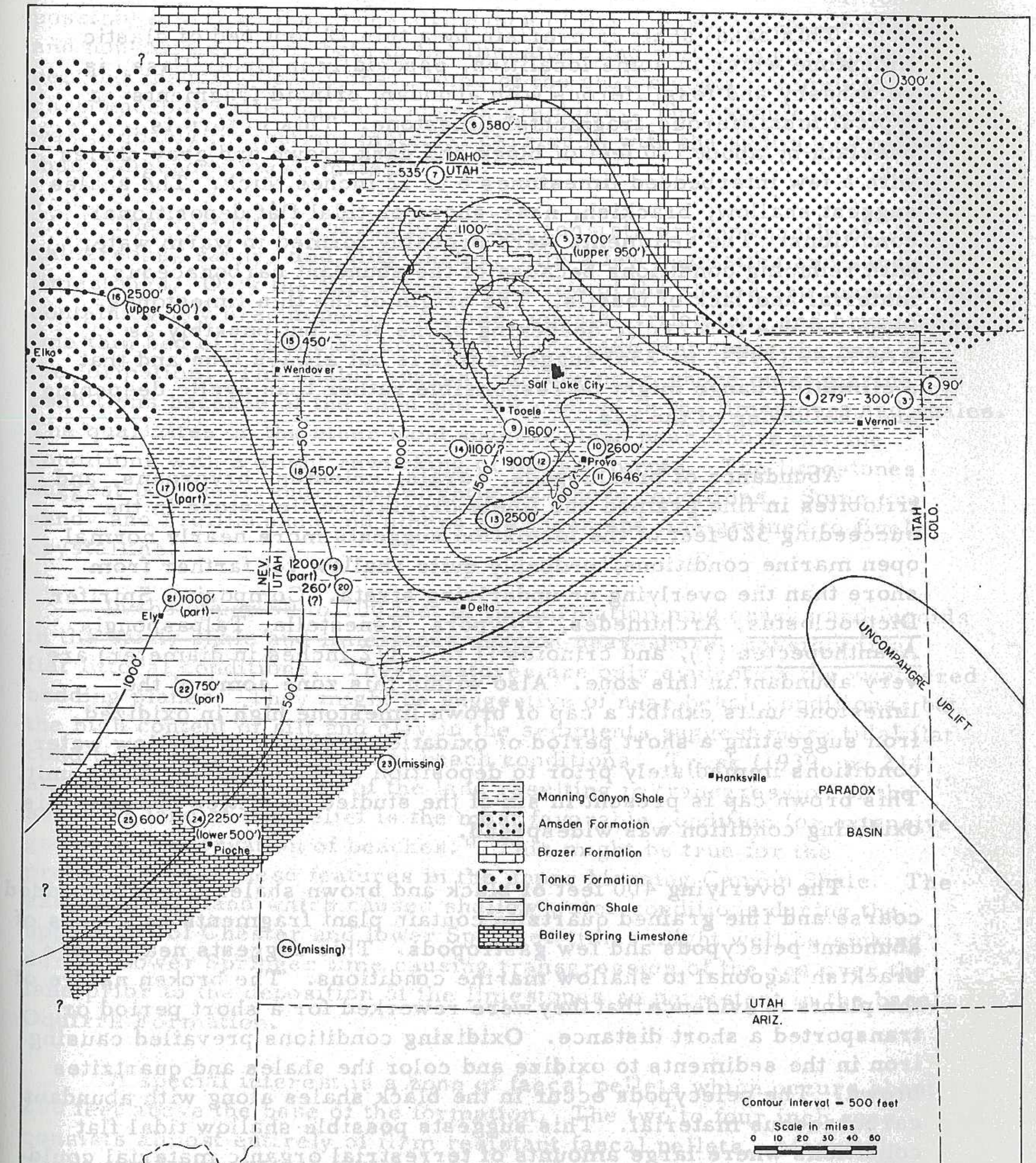


Figure 4. Isopachous map of Manning Canyon Shale and correlative formations in central Utah and eastern Nevada.

the water was probably brackish, slightly aerated, yet somewhat turbid. The fauna shows no evidence of being washed into the area.

This basal shale is overlain by a thin 12 foot bed of clastic limestone which in some localities, especially in Ophir Pass, is very hashy and fossiliferous with abundant crinoid fragments--a typical fossiliferous-fragmental limestone. This in turn is overlain by about 110 feet of black and dark brown and gray shales with a few interbedded limestones 6 to 12 inches thick. The shales suggest shallow, brackish, near-shore or tidal flat depositional conditions. The sediments were probably formed in warm water with reducing conditions because of the abundant carbonaceous material and lack of fossils. The origin of the thin limestones might be due to a cyclic deepening of the sea, but possibly as Bruchner (1953, p. 236) suggests this is not always true and that a climatic change might be responsible rather than cyclic deepening and shallowing of the sea.

Abundance of brachiopods, corals, crinoids, bryozoans, and trilobites in fine grained and finely crystalline limestone in the succeeding 320 feet of the formation suggests more nearly normal open marine conditions, probably quite shallow yet farther from shore than the overlying or underlying strata. Composita, Spirifer, Dictyoclostus, Archimedes, Polypora, Fenestella, Talpaspongia, Acanthopecten (?), and crinoids (1 to 1 1/2 inches in diameter) are very abundant in this zone. Also within this zone some of the limestone units exhibit a cap of brown limestone high in oxidized iron suggesting a short period of oxidation probably in shallow water conditions immediately prior to deposition of the overlying shale unit. This brown cap is present in six of the studied localities showing this oxidizing condition was widespread.

The overlying 400 feet of black and brown shales and interbedded coarse and fine grained quartzite contain plant fragments and zones of abundant pelecypods and few gastropods. This suggests near-shore brackish lagoonal to shallow marine conditions. The broken nature of the plants is evidence that they were reworked for a short period or transported a short distance. Oxidizing conditions prevailed causing iron in the sediments to oxidize and color the shales and quartzites brown. The pelecypods occur in the black shales along with abundant carbonaceous material. This suggests possible shallow tidal flat conditions where large amounts of terrestrial organic material could be washed in and concentrated.

The next overlying 200 feet of interbedded fine grained to finely crystalline limestone and calcareous shale contains thin beds of

Chonetes, and Spirifer. The limestones which contain fossils suggest shallow normal marine conditions, whereas the non-fossiliferous limestones and shales suggest shallow near-shore marine conditions, possibly in a tidal flat. The abundance of black carbonaceous material and non-oxidized iron both in the limestone and shale support non-aerated reducing conditions. Some of the shales contain so much carbonaceous material as to appear graphitic. The organic content was probably terrestrial material carried in with the sediments rather than indigenous fossil material.

The top 500 feet of the formation consists predominantly of calcareous, sandy, and silty shales, with a few quartzites and sandy limestones. Only the limestones and a few of the shales are fossiliferous, containing few brachiopods, crinoids, corals, trilobites, and bryozoans. One thin bed of brachiopod coquina occurs 1486 feet above the base of the formation. The shales suggest shallow near-shore quiet marine conditions because of the sand and silt content in the limestones and shales. The quartzites on the other hand suggest clean near-shore marine conditions with a slight reworking of the sediments. The limestones suggest both near-shore and slightly off-shore conditions. Some are sandy and argillaceous and others are clean and fine grained to finely crystalline.

In the upper 50 to 100 feet of the formation mud cracks and fucoids in the sandy shale and limestones suggest near-shore, possibly tidal flat littoral conditions. These features are only evident on the weathered bedding planes. They might be suggestive of near beach conditions, but the high content of silt and clay in the sediments suggest more tidal flat conditions rather than normal beach conditions. Trask (1939, p. 214) states, "Gradual sinking of the land resulting in transgression of the sea over land of low relief is the most favorable condition for extensive geologic preservation of beaches." This might be true for the preservation of these features in the upper Manning Canyon Shale. The eastward highland which caused shallow water conditions during the upper part of Chester and lower Springer times might well be sinking during Lower Springer time causing transgression of the sea over the land prior to the deposition of the limestones so persistent in the basal Oquirrh Formation.

Of special interest is a zone of faecal pellets which occurs about 200 feet above the base of the formation. The two to four inch zone consists almost entirely of firm resistant faecal pellets. Moore (In Trask, 1939, p. 516) concluded that for some areas such pellets owe their origin to detritus eaters perhaps one of the pelecypods or holothurians.

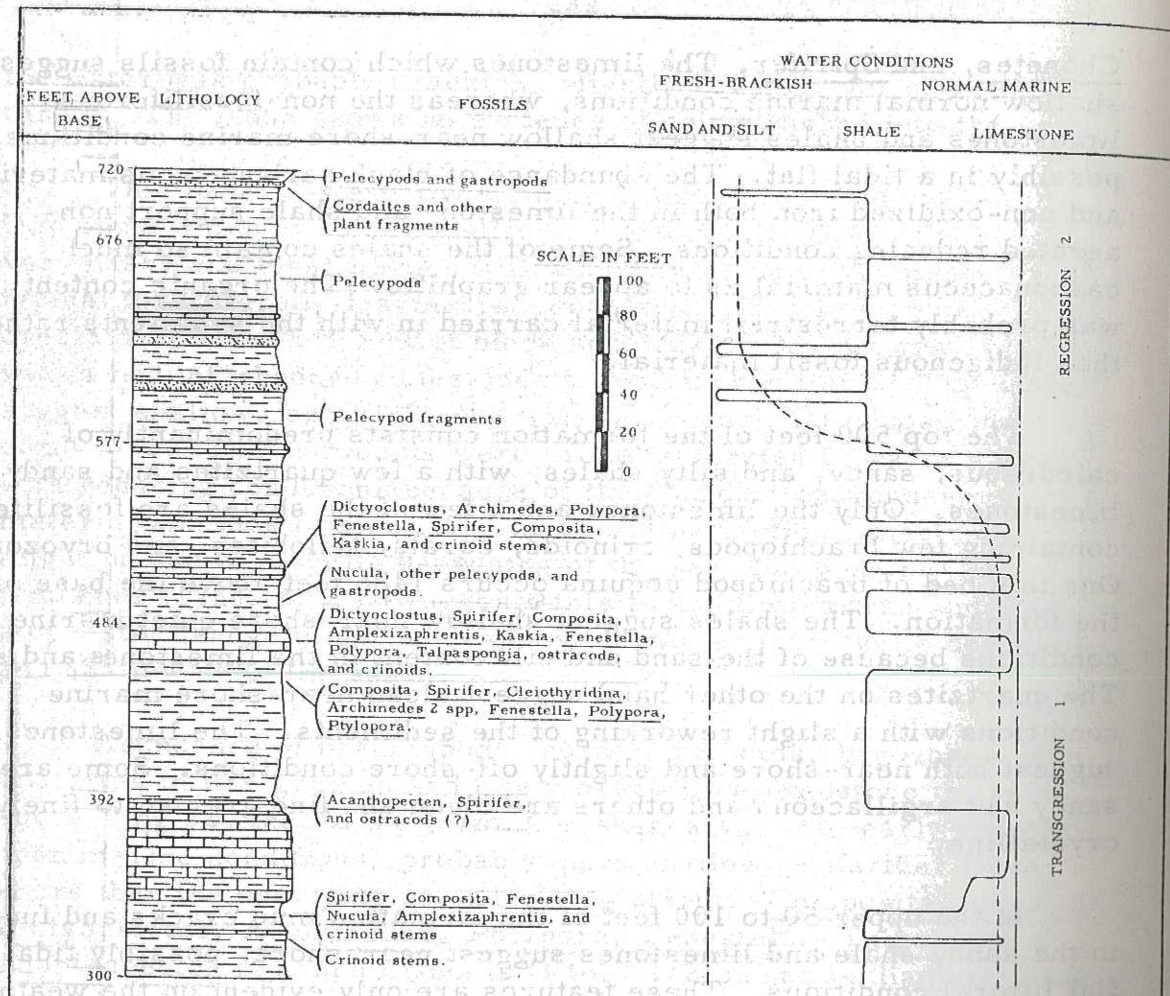


Figure 5. Fossil-sediment facies patterns in Manning Canyon Shale, Soldier Canyon, Oquirrh Mountains, Utah.

Fossils are associated throughout the formation with certain sedimentary facies. Figure 5 gives a typical fossil-sediment facies pattern in the Soldier Canyon section and also gives the possible salinity of the water in which the fossils lived.

Brachiopods, corals, bryozoans, trilobites and crinoids characterize normal epineritic marine conditions. However, in some sediments within the formation, some bryozoans, brachiopods, and crinoids, are directly associated with silty shales and seem to be indigenous of that environment. No evidence of current reworking or fragmenting the fossils is present.

Pelecypods and gastropods suggest brackish water conditions. In Soldier Canyon they are commonly found in the dark gray and brown shales. Some, however, are associated directly with Spirifer and crinoids which suggests more normal marine environment for some of the pelecypods because the crinoids and brachiopods show no evidence of being transported.

The plants are found in silty shales, fine grained quartzites, and in one locality in pure clay shale. The shales and quartzites vary from ash gray, light yellow-brown for the shales to brown-green, green, and green-gray for the quartzites. The plants suggest very near-shore to terrestrial conditions. In Lake Mountain and Traverse Mountain the fossils have been found in clay and silt shales and are well preserved. In West Canyon, Five Mile Pass, Soldier Canyon, and Provo Canyon they are found in the quartzites and very silty shale and also show evidence of being reworked by currents.

APPENDIX

Measured Sections

Soldier Canyon. A composite section was measured in four parts (Plate 1) on the north side of Soldier Canyon about one-half mile above the mouth, Sec. 33, T. 5 S., R. 4 W., Tooele County, Utah.

The base of the measured section was taken at the top of the Great Blue Limestone cliff where it is overlain by a medium gray shale which is light pink-gray in the base and becomes black in the top. The basal 260 feet of the shale up to the top of unit 6 was measured and described on the north-south trending spur about 200 to 300 feet west of the first mine tunnel on the north side of the road after entering the canyon.

The dark gray-brown weathering limestone in the top of unit 6 served as a key bed to identify the same unit four spurs to the east on a lower more subdued spur where the next 542 feet of the section were measured and described.

Because of the alluvial cover on the fourth spur the next 243 feet were measured and described on the next spur east or the fifth spur east of the mine tunnel.

Due to faults and folds in the upper part of the section on the fifth spur, the top 514 feet of the Manning Canyon Shale and about 140 feet of the basal Oquirrh Formation were measured and described on the next spur west or the fourth spur east of the mine tunnel.

The prominent quartzite bed (unit 17) was the key bed which effected offsetting measurement of the section to the fifth spur, and the dominant limestone in the top of unit 24 was the key bed along which offset of the section back to the fourth spur was accomplished.

The contact of the Manning Canyon Shale and the Oquirrh Formation was taken where the shales and the shaly limestones change upward to sandy limestones and calcareous quartzites (base of unit 33). These medium gray, brown weathering sandy limestones and calcareous quartzites should not be mistaken as the 27 foot calcareous quartzite of unit 27 because above unit 27 the shales are similar to the typical Manning Canyon Shales whereas the shaly limestones and limestones as well as the fossil fauna above unit 33 resemble the basal Oquirrh Formation.

The writer felt that inasmuch as a general description of the Soldier Canyon section is given on Plate 3 it would be repetitious to include in the appendix the detailed emended type section of the Manning Canyon Shale in Soldier Canyon. The detailed section is placed on file with the Geology Department of the Brigham Young University at Provo, Utah, and is available on request.

Manning Canyon. A composite section was measured in three parts at the head and about one-half mile below the head of Manning Canyon, SW 1/4, Sec. 4, T. 6 S., R. 3 W., Utah County, Utah.

The basal 410 feet of the measured section was taken at the top of the Great Blue Limestone on the first large bend in the road about one-half mile down Manning Canyon from the head, where the Great Blue Limestone is steeply east-dipping along the old railroad bed. The middle 390 feet was measured across the valley directly east and north of the main road across Mercur Pass. The upper 255 feet was measured on the small east-west ridge about one-fourth to one-half mile north of the Mercur Pass road.

The quartzite beds in unit 8 were used as markers to connect the basal and middle segments of the section. A dark gray-blue limestone of unit 18 was a marker bed to connect the middle and the upper parts of the section.

The Oquirrh-Manning Canyon contact was taken at the top of the pink-gray and purple-gray shales in the top of the Manning Canyon Shale, and the overlying sandy medium gray, brown weathering limestone containing fossil hash, cross-bedding, and crinoid stems (?). This upper contact is very similar to the one found in Soldier Canyon.

Pennsylvanian

Oquirrh Formation

Unit No.	Description	Thickness in feet	Feet Above Base
24	Limestone: Dark gray, weathers light gray and light gray with pink tinge in basal 12 ft., lithographic to finely crystalline, thin bedded in beds 1 to 10 in. thick in the top 14 ft. and 1/2 to 2 in. thick in the base, weathers platy with laminae on		

Unit. No.	Description	Thickness in feet	Feet Above Base
	weathered surface in the top 14 ft., contains bryozoans (?) or crinoid (?) fragments, marker bed.	26	
	Limestone: Dark gray and medium gray, weathers light brown-gray with local mottling of light red-brown and light orange brown, fine grained, thin bedded in beds 4 to 12 in. thick, contains fossil hash	4	
	Total thickness measured of Oquirrh Fm.	30	

<u>Mississippian-Pennsylvanian</u>

Manning Canyon Shale

23	Shale (Calcareous): Dark brown-gray and medium red-brown, weathers medium purple-gray and pink-brown, contains light yellow-brown and medium orange-brown in the base, silty, calcareous. Contains a few dark gray limestones that weather medium yellow-brown and light orange-brown, very fine grained, argillaceous, beds 1/2 to 6 in. thick. Limestones become more abundant in the basal 20 ft. making up about 50 to 60 per cent of the sediments	58	1064
22	Limestone: Dark gray, weathers medium and light brown, very fine grained, thick bedded in bed 3 ft. thick, contains a few vertical white calcite stringers 1/4 in. thick . . .	3	1006
	Shale: Dark gray, weathers to medium brown-gray soil slope, calcareous, slightly silty	6	1003
	Limestone: Dark gray in basal 3 ft. becoming medium gray in the top,		

Unit No.	Description	Thickness in feet	Feet Above Base
	weathers medium and light brown-gray, also medium brown, very fine grained to finely crystalline, thin bedded in beds 2 to 12 in. thick, shaly in middle 4 ft., contains brachiopods and crinoids in basal 3 ft. with a finely broken fossil hash in the top	10	997
21	Shale: Medium gray, weathers to light brown-gray soil slope, sandy, calcareous	6	987
	Limestone: (Sandy) Medium gray-brown, weathers medium yellow-brown, fine grained, thin bedded in beds 1/2 to 2 in. thick, weathers flaggy . . .	4	981
	Shale: Medium gray, weathers to medium brown-gray soil slope, silty, calcareous	11	977
	Limestone: (Sandy) Medium gray, weathers dark and light brown mottled, fine grained, thin bedded in beds 6 to 12 in. thick, contains small amount of mica, weathers blocky and slabby with pock-like surface	5	966
20	Shale: (Covered) Dark and medium gray, weathers to medium gray fine grained sandy soil slope, calcareous, contains fine quartz sand which makes up about 20 per cent of the shale . . .	85	961
19	Limestone: Medium red-gray in basal 3 ft. becoming medium gray in middle 4 ft. and medium brown in top 3 ft., weathers light and medium orange and pink brown, very fine grained, thin bedded in beds 1/2 to 2 in. thick, weathers platy	10	876

Unit No.	Description	Thickness in feet	Feet Above Base
	Shale: (Calcareous) Black and dark gray, weathers to medium gray fine grained soil slope containing a few chips, very calcareous and carbonaceous	10	866
	Limestone: (Shaly) Medium brown-gray in basal 8 ft. becoming medium gray in top, weathers medium yellow-brown and light orange-brown, fine grained, laminated bedding in beds 1/4 to 1 in. thick, weathers very platy	26	856
18	Limestone: Dark gray, weathers medium and light blue-gray, very fine grained to lithographic, thin bedded in beds 2 to 10 in. thick, weathers blocky and slabby due to good parallel jointing, laminae on weathered surface, wavy beds containing styolites about 10 ft. from base in a 10 in. bed	21	830
	Limestone: Dark gray and black, weathers dark gray, fine grained, thin bedded in beds 1 to 6 in. thick, weathers with rough and irregular surface, contains few styolites in top 2 in.	3	809
	Limestone: Dark gray, weathers light-medium blue-gray, very fine grained to lithographic, thin bedded in beds 1/2 to 4 in. thick, weathers flaggy, contains a few very thin calcite stringers	8	806
17	Shale: Dark green and dark green-gray, weathers medium green-gray and medium green-brown chip covered soil slope, clayey, slightly calcareous	16	798
16	Limestone: Dark gray, weathers medium blue-gray, very fine grained,		

Unit No.	Description	Thickness in feet	Feet Above Base
	thin bedded in beds 1 to 12 in. thick, weathers flaggy, contains numerous horizontal and vertical white calcite stringers 1/8 to 1 1/2 in. thick, styolites displace calcite stringers	8	782
15	Shale: Dark green and green-black, weathers medium green and medium green-gray, silty, non-calcareous, contains abundant chips in the soil slope	16	774
14	Quartzite: Medium brown-gray, weathers light medium brown-gray with a green tinge, very fine grained, thin to thick bedded in beds 2 in. to 8 ft. thick, average thickness 2 to 12 in., weathers slabby with scintillating surface, medium red-brown iron splotches present in a few zones on the weathered surface	30	758
13	Shale: Dark green and green-black, weathers to medium and light green-brown chip covered soil slope, silty, locally very carbonaceous, contains interbedded quartzite in beds 1 to 10 ft. thick, dark green becoming medium-brown-green on the weathered surface, fine grained	47	728
12	Limestone: Dark-medium brown-gray in basal 8 ft. becoming dark gray in top, weathers medium brown, fine grained, thin bedded in beds 2 to 12 in. thick, weathers flaggy and blocky, contains white calcite stringers 1/4 to 1/2 in. thick, very fossiliferous and hashy, brachiopods and pelecypods predominate	11	681
11	Shale: Dark gray and black, weathers to light brown-gray and medium gray		

Unit No.	Description	Thickness in feet	Feet Above Base
	chip covered soil slope, silty, non-calcareous, contains few interbedded black-brown weathering limestone beds 6 to 12 in. thick with abundant fenestellid bryozoans	100	670
10	Quartzite: (Argillaceous) Light gray, weathers light brown-gray in the top 4 ft. becoming dark gray, medium gray weathering in the underlying 6 ft. The next underlying 2 ft. is medium red-gray that weathers dark red-gray and light pink-gray, the basal 6 ft. is light-medium gray, weathers light and medium yellow-brown contains argillaceous spots and blobs which cause the weathered surface to be pock-like, blobs are medium yellow and medium brown about 1/8 in. by 1/2 in. Unit is very fine grained, very dense and hard, weathers to subrounded blocks, contains Archimedes, Kaskia, crinoids and brachiopod fragments	18	570
9	Shale: (Covered) Medium green, dark green, medium green-brown, medium brown-gray and black, weathers to medium brown and light brown-gray soil slope containing chips, silty and some clayey, non-calcareous, darker shales very carbonaceous. Base contains brown shales, middle contains green shales, and top is black. Middle green shales contain 4 to 6 in. black siltstone nodules that weather light brown . .	42	552
8	Quartzite: Dark gray, weathers medium green-brown and medium green-gray, fine grained, top 2 ft. massive, basal 2 ft. thin bedded in beds 1 to 2 in. thick, weathers flaggy, scintillating surface. .	4	410

Unit No.	Description	Thickness in feet	Feet Above Base
	Shale: Medium gray, weathers to light brown-gray very chippy slope, silty, non-calcareous	6	406
	Quartzite: Dark gray, weathers medium green-brown and light green-gray, fine grained, thin to medium bedded in beds 4 to 24 in. thick, weathers slabby, scintillating surface, contains few white quartz veins . . .	9	400
7	Shale: Medium brown-gray and medium gray, weathers to light brown-gray soil slope containing fine shale chips, calcareous and slightly silty, contains interbedded limestones which are dark gray and medium brown-gray, which weather light and medium orange-brown, fine grained, beds 6 to 12 in. thick, very fossiliferous containing Composita, Spirifer, Archimedes, Fenestella, corals, crinoids, and trilobites.	52	391
6	Limestone: Dark blue-gray, weathers light brown-gray, very fine grained, basal 2 ft. thin bedded in beds 1/2 to 2 in. thick, overlying 12 ft. laminated bedding 1/16 to 1/2 in. thick, weathers platy and flaggy, contains a few white calcite stringers 1/16 to 1/2 in. thick.	14	339
5	Shale: Medium red-gray, weathers to light pink-gray fine grained soil slope, calcareous, slightly silty	7	325
	Limestone: Light gray-brown, weathers mottled light brown and light gray, very fine grained, laminated bedding in beds 1/4 to 1 in. thick, weathers platy . .	1	318
	Shale: (Calcareous) Light gray, weathers about the same, very calcareous, slightly silty	9	317

Unit No.	Description	Thickness in feet	Feet Above Base
4	Limestone: Medium and dark brown, weathers medium orange-brown, fine grained to finely crystalline, thin bedded in beds 1/2 to 4 in. thick, weathers platy, contains few calcite stringers	1	308
	Limestone: (Shaly) Dark blue-gray, weathers light brown-gray, very fine grained, basal 3 ft. massive, upper 3 ft. laminated bedding in beds 1/4 to 1 in. thick, weathers platy, few vertical white calcite stringers 1/8 to 1/2 in. thick	6	307
	Limestone: (Shaly) Same as overlying 6 ft. except more shaly, thinner bedding, and no calcite stringers	12	301
	Limestone: Medium brown, weathers medium pink-brown, lithographic in bed 1 ft. thick	1	289
	Limestone: (Shaly) Dark medium gray, weathers light gray, fine grained, thin bedded in beds 1/2 to 12 in. thick, weathers slabby and flaggy	25	288
	Limestone: Medium brown, weathers light brown, lithographic, thin bedded in beds 1 to 2 in. thick, weathers flaggy	2	263
3	Shale: Medium gray and medium pink-gray, weathers to very light gray and light pink-gray fine grained soil slope, slightly silty and calcareous.	26	261
	Limestone: (Siliceous) Black and dark gray, weathers dark brown-gray, fine grained, weathers slabby	1	235
	Shale: Top 22 ft. light brown-gray, weathers medium brown gray with fine chips in the soil slope, clayey, pink in top.		

Unit No.	Description	Thickness in feet	Feet Above Base
	Middle 35 ft. medium brown-gray, weathers light brown-gray, contains abundant carbonaceous material, graphitic, contains a few interbedded 1 to 4 in. beds of medium gray-brown, dark brown weathering fine grained quartzite. Basal 13 ft. light brown in base becoming black in top 3 to 4 ft., very silty, weathers to fine grained soil slope	70	234
2	Quartzite: Medium brown-gray, weathers medium yellow-brown, fine grained, thin bedded in bed 1/2 to 8 in. thick, weathers flaggy.	3	164
	Shale: Medium brown-gray, weathers light brown-gray and medium brown, silty, weathers to chippy soil slope, contains few pelecypod fragments also a very few 1 to 2 in. beds of dark gray siltstone.	5	161
	Quartzite: Medium brown-gray, weathers medium yellow-brown, fine grained, thin bedded in beds 1/2 to 6 in. thick, weathers platy and flaggy . .	5	156
	Shale: Medium gray and medium brown-gray, weathers to light brown-gray soil slope, slightly silty	27	151
	Quartzite: Medium brown-gray, weathers light brown-gray, fine grained, laminated bedding in beds 1/2 to 1 in. thick, weathers platy	4	124
1	Shale: Medium gray, weathers light gray and light brown, very fissile and friable, clayey, weathers to fine grained soft soil slope	9	120

Unit No.	Description	Thickness in feet	Feet Above Base
	Limestone: (Argillaceous) Medium gray, weathers medium yellow-brown, fine grained, contains light brown argillaceous partings, thin bedded in beds 2 to 4 in., weathers to rounded slabs	1	111
	Shale: (Covered) Dark and medium gray, weathers medium gray and light yellow-gray, silty, the top 25 ft. is very chippy while the underlying 15 to 20 ft. weathers in splinter-like chips, contains few interbedded medium and light gray, medium brown weathering, fine grained quartzite beds 6 to 18 in. thick	80	110
	Limestone: Medium brown, weathers medium orange-brown, very fine grained, massive, few white calcite stringers	2	30
	Shale: (Covered) Black and medium gray in weathered slope, slightly silty, non-calcareous	28	28

Fault (?) contact

Great Blue Limestone (top)

Limestone: Medium blue-gray, weathers light gray, very fine grained, thin bedded in beds 1 to 12 in. thick, weathers flaggy and platy, cliff former.

Ophir Pass. The Ophir Pass section is located on the east-west trending divide between the head of the South Fork of Soldier Canyon and the head of Ophir Canyon in Sec. 11, T. 6 S., R. 4 W., Tooele County, Utah. The Manning Canyon Shale forms the divide. The Great Blue Limestone forms the ridge west of the divide and the Oquirrh Formation forms the ridge east of the divide.

The Great Blue-Manning Canyon contact is at the top of the steeply east dipping medium gray, light gray weathering limestone slope about 2000 to 3000 feet west of the log cabin which is located 200 to 300 feet down the canyon from the head of Ophir Canyon.

The Manning Canyon-Oquirrh contact was taken where the medium gray shales and interbedded limestones in the upper part of the Manning Canyon Shale are overlain by the sandy medium gray, brown weathering limestones of the basal Oquirrh Formation.

Conformable contact

Mississippian and Pennsylvanian

Manning Canyon Shale

Unit No.	Description	Thickness in feet	Feet Above Base
17	Shale (Covered): Medium gray, weathers to light brown-gray soil slope, calcareous and silty, contains interbedded medium gray, medium brown-gray weathering, fine grained limestone in beds 6 to 24 in. thick . .	193	1347
16	Limestone: Medium gray-brown, weathers light and medium brown, fine grained, sandy, thin bedded in beds 4 to 12 in. thick, weathers slabby, contains white calcite stringers, also calcite coating on weathered surface	10	1154
15	Shale (Covered): Medium gray, weathers to light and medium gray and medium brown soil slope, calcareous and silty.	19	1144
14	Limestone (Arenaceous) Light-medium gray, weathers light brown, fine grained, thin bedded in beds 2 to 12 in. thick, weathers slabby, very sandy on weathered surface	29	1125
13	Shale (Covered): Medium gray, weathers to medium gray soil slope, silty and calcareous	87	1096

Unit No.	Description	Thickness in feet	Feet Above Base
12	Limestone: Medium brown-gray, weathers light to medium yellow brown, fine grained, laminated and thin bedded in beds 1/4 to 1 1/2 in. thick, weathers platy	12	1009
	Limestone: Dark gray, weathers light blue-gray in the top 5 feet, dark-medium blue-gray in the basal 37 feet, fine grained, thin bedded in beds 1 to 4 in. thick, weathers platy and flaggy, contains vertical white calcite stringers in the basal 20 to 30 feet	49	997
	Shale: Black, weathers to medium gray fine grained soil slope, calcareous and clayey	16	948
	Limestone: Dark gray, weathers light gray, very fine grained, laminated and thin bedded in beds 1/4 to 4 in. thick, weathers slabby and rounded	10	932
11	Shale: Black, weathers to medium gray to black very fine grained soil slope, clayey becoming slightly silty locally, calcareous in top few feet	77	922
10	Quartzite: Medium gray, weathers medium gray and medium red-brown in base becoming medium yellow-brown in top 2 ft., fine to medium grained, thin bedded in beds 2 to 12 in. thick, weathers slabby, crossbedded, scintillating on weathered surface in the basal one half of the unit	14	845
9	Shale: Dark green, dark green-gray and medium gray, weathers to medium green-brown and green-gray chippy soil slope, silty and sandy, calcareous in basal few feet, contains a few interbedded medium gray, medium brown weathering, fine grained quartzite beds, 1 to 3 ft. thick.	35	831

Unit No.	Description	Thickness in feet	Feet Above Base
8	Limestone: Black, weathers dark to medium blue-gray, fine grained, thin bedded in beds 2 to 6 in. thick, weathers slabby, contains Wewokella n. sp.	5	796
	Quartzite: Dark green-gray in the basal 10 ft. becoming medium gray and light gray in the middle 50 ft. and medium gray in the top 10 ft., weathers medium and dark brown, very fine grained, dense and hard, thin and medium bedded in beds 1 in. to 3 ft. thick, weathers flaggy and slabby, contains cross-bedding locally	69	791
	Shale: Dark green-gray, and green-black, weathers to medium green-gray and medium brown soil slope, slightly silty	12	722
	Quartzite: Medium gray and medium green-gray, weathers medium brown and light brown, fine grained, thin bedded in beds 1 to 8 in. thick, weathers flaggy	10	710
7	Shale: Medium gray and medium brown-gray, weathers to light and medium brown-gray fine grained soil slope, sandy and silty especially in top	55	700
	Limestone: Medium brown-gray, weathers light brown, fine grained to finely crystalline, thin bedded in beds 1/2 to 1 in. thick, weathers flaggy, contains a few Spirifer, bryozoan and crinoid fragments	3	645
	Shale: Medium brown-gray, weathers to light brown-gray soil slope, calcareous and slightly silty	8	642

Unit No.	Description	Thickness in feet	Feet Above Base
	Limestone (Argillaceous): Medium brown-gray, weathers light brown-gray, fine grained, thin bedded in beds 1/2 to 2 in. thick, very argillaceous, weathers flaggy, contains Dictyoclostus, Spirifer, Fenestella, Archimedes, trilobite fragments, and crinoid stems	1	634
	Shale: Black and dark green-gray, weathers to medium greenish brown-gray soil slope containing a few chips, clayey, calcareous and fossiliferous in basal 5 to 10 feet containing Archimedes, Nucula, Composita, Spirifer, and crinoids . .	26	633
6	Limestone: Dark to medium gray and medium brown-gray, weathers light and medium brown-gray, fine grained, thin bedded in beds 1/2 to 12 in. thick, weathers flaggy, very fossiliferous, contains, Dictyoclostus, Spirifer, Fenestella, Polypora, Amplexizaphrentis, Talpaspongia, Composita, trilobite and crinoid fragments	21	607
5	Shale: Medium gray in basal 100 ft. becoming black and dark green-gray in the middle of the unit and medium gray to medium brown in the top 150 ft., weathers to dark gray and medium green-brown chippy soil slope, calcareous and clayey in base becoming clayey and non-calcareous in the middle of the unit and silty in the top 100 to 150 ft., contains black siltstone nodules about 1 to 3 in. in diameter .	394	586
4	Limestone: Dark and medium blue-gray, weathers light gray and light brown, fine grained, thin bedded,		

Unit No.	Description	Thickness in feet	Feet Above Base
	cross-bedded and irregular bedded in beds 1/2 to 3 in. thick, weathers flaggy, sandy in top, contains white calcite stringers, hashy in basal one half	6	192
3	Shale (Covered): Medium gray, weathers to light gray and light brown-gray, fine grained soil slope .	115	186
2	Limestone: Medium blue-gray in base becoming medium and light brown-gray in top, weathers medium and light gray with some brown, medium and coarse grained in basal 5 ft., fine grained throughout the rest of the unit, medium bedded in beds 1 to 1 1/2 ft. thick, weathers slabby and blocky, contains intraformational limestone pebble conglomerate in the basal 5 ft., arenaceous in the top 5 to 10 ft., contains brachiopod, coral, pelecypod, and crinoid fragments . .	21	71
1	Shale: Medium to dark gray with medium brown partings, weathers light pink-gray in base and light gray in the upper 45 ft., slightly calcareous and slightly silty.	50	50

Conformable contact

Mississippian

Great Blue Limestone (top)

Limestone: Medium gray, weathers light gray and light pink-gray, very fine grained, thin bedded in beds 1/2 to 2 in. thick, weathers flaggy and platy, contains black chert and fossil hash.

West Canyon: The formation was measured in two segments. The lower 1283 feet was on the north slope of Iron Canyon about one to one and one-fourth miles up the canyon from the mouth. The upper 400 foot interval was measured in West Canyon about one-fourth to one-half mile northwest of Farmers Flat. Both of these localities occur on the north plunging nose of the Long Ridge Anticline, Sec. 3, T. 5 S., R. 3 W., Utah County, Utah.

The Great Blue-Manning Canyon contact is exposed in Iron Canyon on the north side of the stream bed where the medium gray, light gray weathering platy limestones are overlain by black shales. The Manning Canyon-Oquirrh contact is arbitrary because the upper 400 feet of the formation is covered.

Conformable contact (covered)

Mississippian-Pennsylvanian

Manning Canyon Shale

Unit No.	Description	Thickness in feet	Feet Above Base
16	Shale (Covered): Medium gray, weathers to light gray and light brown-gray soil slope, contains interbedded medium gray limestone that weathers medium and light gray to medium and light brown	400	1683
15	Limestone: Medium brown and medium brown-gray, weathers light brown and light orange-brown, fine grained, laminated bedding 1/4 to 1 in. thick, weathers platy	13	1283
	Limestone: Medium and light gray, weathers very light gray, fine grained, laminated and thin bedded in beds 1/4 to 2 in. thick, weathers platy	31	1270
	Limestone: Dark gray to black, weathers dark gray, very fine grained, thin bedded in beds 2 to 6 in. thick, weathers flaggy, contains a few white calcite stringers 1/2 in. thick.	3	1239

Unit No.	Description	Thickness in feet	Feet Above Base
	Limestone: Dark gray, weathers light gray, fine grained to lithographic, thin bedded in beds 1 to 12 in. thick, weathers flaggy and slabby, contains a few white calcite stringers	58	1236
14	Shale (Covered): Black and dark green, weathers to medium brown-green and medium green-gray soil slope, silty, non-calcareous, contains a few beds of dark green, fine grained quartzite that weathers medium brown-green . . .	127	1178
13	Limestone: Dark gray, weathers light gray, very fine grained to lithographic, laminated and thin bedded in beds 1/2 to 3 in. thick, very argillaceous in basal 3 ft., weathers platy, contains a few white calcite stringers 1/2 to 1 in. thick	10	1051
	Shale: Black to dark green, weathers dark and medium green-gray chippy soil slope, silty, contains a few siltstone nodules 1 to 1 1/2 in. in diameter . .	18	1041
	Limestone: Dark-medium gray, weathers dark gray, fine grained, laminated bedding in beds 1/8 to 1/4 in. thick, weathers platy, contains a few horizontal and vertical white calcite stringers	10	1023
12	Shale: Dark brown and medium green-gray, weathers to medium and light green-brown soil slope, silty and slightly calcareous.	14	1013
11	Quartzite: Dark and medium gray-green, weathers medium brown-green and green-gray, thin bedded in beds 1 to 12 in. thick, weathers slabby, contains plant fragments	24	999

Unit No.	Description	Thickness in feet	Feet Above Base
10	Shale (Covered in base): Black and dark green, weathers to medium brown-green and medium green-gray soil slope with fine chips, slightly silty. .	102	975
9	Limestone: Black, weathers dark gray with medium orange-brown stains on surface, very fine grained to finely crystalline, thin bedded in beds 1/2 to 12 in. thick, weathers flaggy	13	873
8	Quartzite: Light gray, weathers light gray, fine grained to finely crystalline, scintillating, thin bedded in beds 6 to 24 in. thick, weathers slabby	22	860
	Quartzite: Light gray, medium green-gray, medium gray and dark gray, weathers medium brown-gray, medium brown-green and medium brown, medium and fine grained, medium bedded in beds 1 to 2 ft. thick becoming thin bedded in the top 15 ft., cross-bedded, weathers slabby and blocky .	51	838
7	Limestone (Sandy and argillaceous): Medium gray and medium blue-gray, weathers to light blue-gray and light to medium brown, very fine grained to finely crystalline, thin bedded in beds 1 to 6 in. thick, weathers flaggy and rounded due to argillaceous content. .	9	787
	Shale: Dark brown and dark gray becoming black in basal 15 ft., weathers to medium brown-gray soil slope, slightly silty, calcareous in upper one half, contains a few thin beds of medium-brown-gray quartzite that weathers medium brown, pelecypod fragments occur in the basal one half.	68	778

Unit No.	Description	Thickness in feet	Feet Above Base
6	Limestone: Dark medium gray becomes medium brown in top 2 to 4 in., weathers light gray, very fine grainted, thin bedded in beds 2 to 6 in. thick, contains *Dictyoclostus*, brachiopod spines, and other fossil hash	2	710
	Limestone: Medium to light brown, weathers light brown with pink and yellow tinge, fine grained, thin bedded in beds 1 to 4 in. thick, weathers flaggy and platy, contains crinoids, horn corals, and brachiopod fragments	6	708
	Limestone: Dark and medium gray, weathers light gray and light brown-gray, fine grained to lithographic, thin and medium bedded in beds 1 to 24 in. thick, contains *Dictyoclostus*, *Composita*, *Cleiothyridina*, *Spirifer*, *Fenestella*, *Polypora*, *Talpaspongia*, horn corals, and crinoids. About 4 ft. above the base of the sub-unit occurs a 1 ft. bed of intraformational limestone pebble conglomerate, the pebbles are angular and 1/4 to 1/2 in. in diameter. . . .	25	702
	Limestone: Medium gray, weathers light gray, fine grained, thin bedded in beds 6 to 12 in. thick, weathers flaggy, contains *Dictyoclostus*, *Spirifer*, *Fenestella*, and crinoids.	65	677
5	Shale: Black and dark brown-gray, weathers to medium brown-gray soil slope, contains a few black siltstone nodules, silty and calcareous, interbedded medium brown fine grained fossiliferous limestones that weather dark and medium brown occur in beds 6 to 24 in. thick. The shales contain		

Unit No.	Description	Thickness in feet	Feet Above Base
	Wewokella 2 spp. and the limestones contain Archimedes, Fenestella, Polypora, Rhombopora (?), Kaskia, Spirifer, Dictyoclostus, Composita, horn corals, crinoids, a few pelecypods	46	612
4	Limestone: Medium brown, weathers medium orange-brown, fine grained, thin bedded in beds 2 to 6 in. thick, weathers flaggy, vertical white calcite stringers 1/2 to 1 in. thick, contains Dictyoclostus and other fossil fragments.	2	566
	Limestone: Dark gray becomes medium red-gray in top 10 ft., weathers medium gray becomes light pink-gray in top 50 ft., fine grained to lithographic, thin bedded in basal 20 ft. becomes massive in middle 32 ft., and thin bedded in top 53 ft., weathers flaggy and slabby, contains white calcite stringers in the middle of the sub-unit and becomes fossiliferous in the top 10 ft., brachiopod fragments and crinoids are abundant in the fossiliferous part . .	106	564
3	Shale (Covered): Dark gray in base becomes light gray in top, weathers to light gray and light red-gray soil slope, contains black siltstone nodules and pelecypod fragments	365	458
2	Shale: Black and dark brown, weathers to medium brown-gray soil slope, calcareous and slightly silty, contains interbedded medium brown, fine grained, medium orange-brown weathering limestone in beds 6 to 24 in. thick	30	93

Unit No.	Description	Thickness in feet	Feet Above Base
1	Shale: Medium red-gray in basal 6 ft. becomes black in top, weathers to medium brown-gray soil slope, silty, slightly calcareous, contains black calcareous siltstone nodules in basal one-half	63	63

Conformable contact

Mississippian

Great Blue Limestone (top)

Limestone: Dark gray, weathers light gray and light brown gray, fine grained, thin bedded in beds 1 to 12 in. thick, weathers flaggy and platy, ledge former.

Lake Mountain: A 1910 foot section on the east flank of Lake Mountain was measured east to west, on the west side of Seep Canyon about 1000 to 2000 feet north and west of the spring, Sec. 36, T. 6 S., R. 1 W., Utah County, Utah.

The Great Blue-Manning Canyon contact is taken where the dark gray, light gray weathering, cherty limestone are overlain by medium gray shales. The Manning Canyon-Oquirrh contact is not readily located because of soil cover. The contact was arbitrarily taken beneath the dominant medium gray, medium brown weathering quartzite of the Oquirrh Formation.

Conformable contact (covered)

Mississippian-Pennsylvanian

Manning Canyon Shale

Unit No.	Description	Thickness in feet	Feet Above Base
17	Shale (Covered): Medium gray, weathers to light gray and light		

Unit No.	Description	Thickness in feet	Feet Above Base
	brown-gray soil slope, silty, slightly calcareous in base	100	1910
16	Quartzite (Argillaceous): Medium to light gray, weathers light gray, medium gray, and medium brown-gray, fine grained becomes medium grained in base and very fine grained in top, thin bedded in beds 2 to 12 in. thick, cross-bedded especially in upper one-half, weathers slabby and blocky	25	1810
	Quartzite: Medium brown, weathers dark brown, fine to medium grained, thin bedded in beds 4 to 12 in. thick, argillaceous, weathers slabby	3	1785
	Sandstone: Medium gray, becomes medium red-gray in top, weathers medium to dark gray and dark red-gray, medium grained, thin bedded in beds 2 to 12 in. thick, weathers slabby, arkosic in middle 10 ft., feldspar makes up about 30 to 40 per cent of the rock	20	1782
15	Shale: Variegated medium gray and medium brown, weathers light gray and light brown-gray, calcareous, and silty	2	1762
	Limestone: Dark gray to dark blue-gray, weathers light brown-gray and light gray, very fine grained, thin and medium bedded in beds 2 to 24 in. thick, weathers slabby with rough surface, contains a few white calcite stringers	37	1760
14	Quartzite: Light gray, weathers light pink-gray and light brown-gray, very fine grained, medium bedded in beds		

Unit No.	Description	Thickness in feet	Feet Above Base
	1 to 3 ft., weathers slabby and rounded, scintillating in base	23	1723
	Quartzite: Medium gray and dark gray, weathers medium and light brown-gray with a green tinge, very fine grained, thin bedded in beds 1/2 to 6 in. thick, weathers flaggy, cross-bedded . . .	29	1700
	Quartzite: Medium gray and light gray mottled, weathers dark brown and medium gray, fine grained, thin bedded in beds 2 to 6 in. thick, weathers flaggy, cross-bedded	7	1671
	Shale (Covered): Medium gray and medium green-gray, weathers to medium and light yellow-brown and medium brown-gray, silty, contains interbedded medium gray and light gray fine grained, medium brown weathering quartzite beds 6 to 12 in. thick	32	1664
	Quartzite: Medium and light gray, weathers medium brown, medium gray and black, fine grained, thin bedded in beds 2 to 12 in. thick, weathers slabby and rounded, contains medium brown argillaceous specks in top one-half and discontinuous brown argillaceous laminae banding in basal one-half . .	30	1632
13	Shale: Medium green-gray, light gray, and light yellow-brown, weathers to light and medium brown soil slope, well foliated, clayey, slightly calcareous, locally slightly silty, contains a few interbedded calcareous siltstone beds 1/2 to 2 in. thick, *Alethopteris*, *Neuropteris*, *Cordaites*, and other plant fragments occur in the light yellow-brown shales	14	1602

Unit No.	Description	Thickness in feet	Feet Above Base
12	Limestone: Medium gray, weathers light and medium gray, very fine grained, thin bedded in beds 1/2 to 2 in. thick, weathers slabby and blocky, contains white calcite stringers	8	1588
11	Shale: Medium gray, weathers to light gray and light pink-gray soil slope, calcareous, slightly silty, contains a 2 ft. bed of dark gray, fine grained, medium gray weathering limestone that has laminated bedding in beds 1/2 in. thick	32	1580
10	Limestone: Medium and dark blue-gray, weathers light gray, very fine grained, thin bedded in beds 6 to 12 in. thick, weathers flaggy and platy . . .	9	1548
	Shale: Variegated medium yellow, medium brown-yellow, medium green-brown, medium red-gray, and light gray, weathers to light yellow-brown and light brown-gray soil slope, slightly calcareous	12	1539
	Limestone: Dark gray, weathers light gray, very fine grained, thin bedded in beds 4 to 6 in. thick, weathers platy and flaggy, contains very thin white calcite stringers	6	1527
9	Shale: Variegated medium and light yellow-brown, medium and light red-gray, very light gray, and light yellow-gray, weathers to light yellow-brown, and medium brown soil slope	48	1521
	Quartzite: Medium gray-brown, weathers light brown and medium brown-gray, fine grained, thin bedded in beds 6 to 12 in. thick, weathers flaggy.	9	1473

Unit No.	Description	Thickness in feet	Feet Above Base
	Shale: Dark green, medium green-brown, and green-black, weathers to medium green-brown soil slope, contains fine grained dark green quartzite and siltstone beds 1/2 to 2 in. thick, pelecypod fragments occur especially in the basal 20 to 30 ft..	65	1464
	Quartzite: Medium gray and medium red-gray becomes medium green-gray in top 1 ft., weathers light gray and light pink gray, fine grained to finely crystalline, medium bedded in beds 1 to 2 ft. thick, scintillating, contains medium brown argillaceous partings . .	6	1399
	Shale: Medium green and medium green-gray, weathers about the same, silty, contains pelecypods in basal 1 to 2 ft.	10	1393
	Quartzite: Medium gray, weathers light and medium brown, very fine grained, thin bedded in beds 4 to 12 in. thick, weathers flaggy.	4	1383
8	Shale: Dark green to black, weathers to medium green-brown soil slope, wilty, contains a few pelecypod fragments.	90	1379
7	Quartzite: Light and medium gray, weathers light brown and light gray, fine to medium grained, thin and medium bedded in beds 2 to 36 in. thick, weathers slabby and blocky, becomes more argillaceous in top 5 ft. and in basal 13 ft., also in the top and the base the unit is darker brown	118	1289

Unit No.	Description	Thickness in feet	Feet Above Base
	Shale: Black, weathers to medium gray soil slope containing fine chips, silty, and non-calcareous	5	1171
6	Quartzite: Medium gray-brown, weathers light gray-brown, fine grained, medium bedded in beds 2 to 4 ft. thick, cross-bedded in base, weathers blocky, ledge former	12	1166
	Shale: Black, weathers dark gray, silty, contains abundant pelecypod fragments	2	1154
	Quartzite: Light gray, medium gray, and light brown-gray, weathers medium brown, medium and dark red-brown, and light brown-gray, fine and medium grained, medium bedded to massive, weathers blocky and rounded, scintillating	211	1152
5	Shale (Covered): Black to medium green-gray, weathers to medium and light green-brown soil slope containing fine chips	183	941
4	Quartzite: White to light gray, weathers light gray, medium and dark red-brown, and light to dark brown, fine to medium grained becomes very coarse grained in basal 3 ft. of sub-unit, thin to thick bedded in beds 1 to 4 in. thick in the base to 4 to 6 ft. thick in top, weathers slabby and blocky, scintillating, ledge former in basal 20 ft., cross-bedded throughout	92	758
	Shale: Black, weathers to medium gray chippy soil slope, slightly silty, non-calcareous	6	666
	Quartzite: Light to medium gray, weathers light and medium brown and		

Unit No.	Description	Thickness in feet	Feet Above Base
	brown-gray, fine grained, thin and medium bedded in beds 6 to 24 in. thick, weathers slabby	12	660
3	Shale: Light brown in basal 20 ft., medium red-gray in overlying 52 ft., and black in top 430 ft., weathers to medium gray and medium brown-gray soil slope, clayey, slightly calcareous in basal 75 ft.	502	648
2	Limestone: Dark gray, weathers medium gray, fine grained, thin bedded in beds 1 to 4 in. thick, weathers platy	17	146
1	Shale: Variegated light yellow, dark yellow-brown, light and medium yellow-gray, light gray, and medium and light red-gray, weathers to light gray and light red-gray fine grained soil slope, calcareous, silty; contains siltstone and chert nodules that are light yellow and light yellow-gray, 1 to 2 ft. in diameter	129	129

Conformable contact

<u>Mississippian</u>

Great Blue Limestone (top)

Limestone: Medium and dark gray, weathers light gray, fine grained, thin bedded in beds 1 to 12 in. thick, weathers platy and flaggy, contains discontinuous black and gray chert beds.

Explanation of Plate 6

Figure 1 — Fine grained quartzite from unit 17 in Soldier Canyon, Oquirrh Mountains, Utah; 800 feet above the base of the formation, magnified 20 times, plain light.

Figure 2 — Fucoidal sandy limestone from the top of unit 32 in Soldier Canyon, Oquirrh Mountains, Utah; 1540 feet above the base of the formation, magnified 10 times, plain light.

Figure 3 — Fine grained calcareous quartzite from the top of unit 27 in Soldier Canyon, Oquirrh Mountains, Utah; 1335 feet above the base of the formation, magnified 20 times, plain light.

Figure 4 — Fine grained sandy limestone from unit 29 in Soldier Canyon, Oquirrh Mountains, Utah; 1435 feet above the base of the formation, magnified 20 times, plain light.

Figure 5 — Medium grained arkosic sandstone from the base of unit 16 in Lake Mountain, Utah; 1770 feet above the base of the formation, magnified 5 times, plain light.

Figure 6 — Cross-bedded sandy limestone from the top of the formation in Five Mile Pass, Utah; megascopically the cross-beds are evident only on the weathered surface, magnified 5 times, plain light.

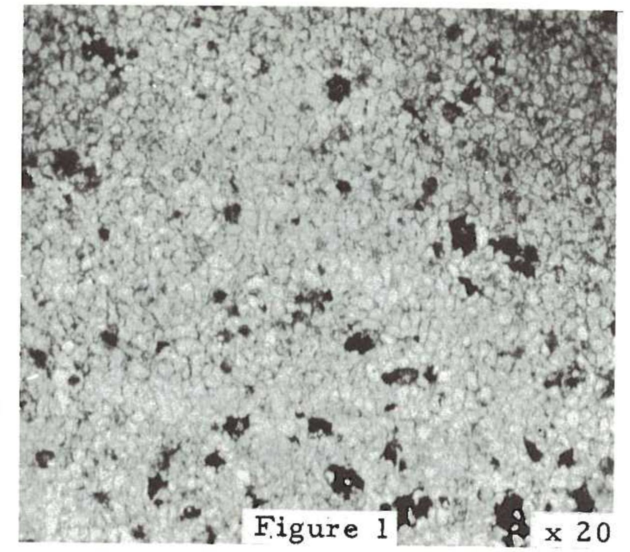


Figure 1 x 20

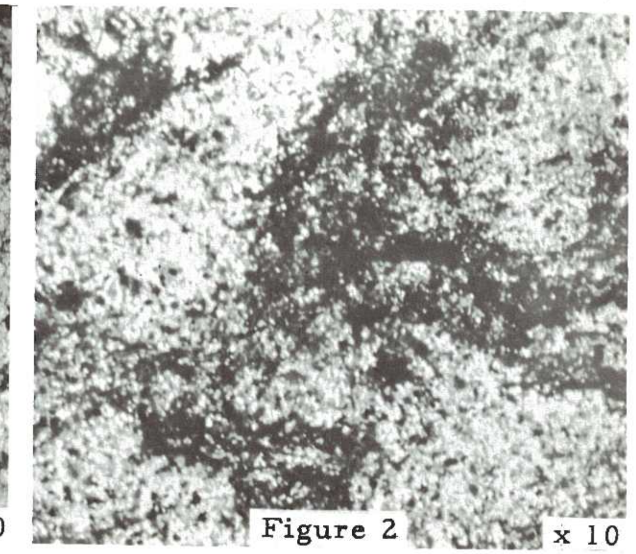
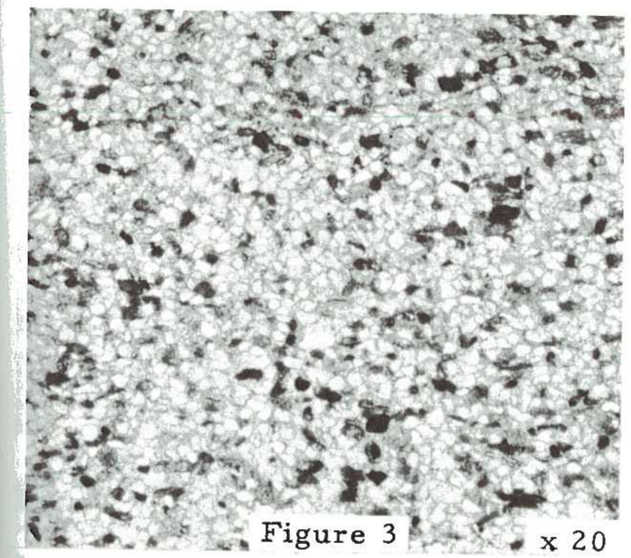


Figure 2 x 10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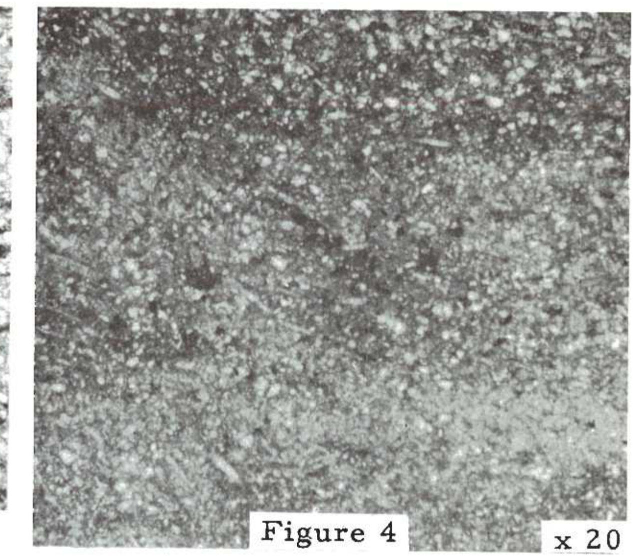
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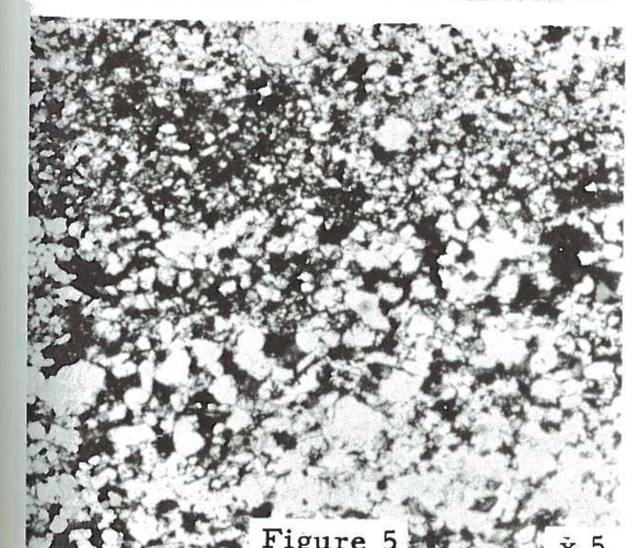


Figure 5 x 5

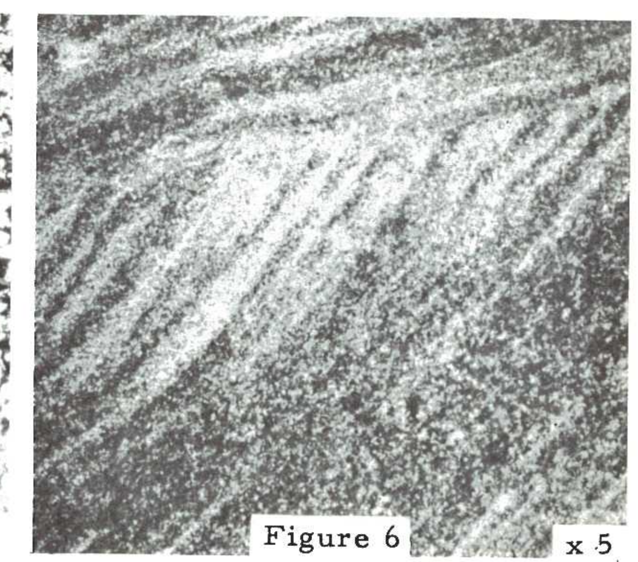


Figure 6 x 5

Explanation of Plate 7

Figure 1 Fragmental argillaceous limestone from the top of unit 7 in West Canyon, Oquirrh Mountains, Utah; 785 feet above the base of the formation, magnified 5 times, plain light.

Figure 2 Crinoidal limestone from unit 2 in Ophir Pass, Oquirrh Mountains, Utah; 60 feet above the base of the formation, magnified 10 times, plain light.

Figure 3 Hashy fossiliferous limestone from unit 32 in Soldier Canyon, Oquirrh Mountains, Utah; 1513 feet above the base of the formation, magnified 20 times, plain light.

Figure 4 Fossiliferous limestone from unit 10, medial limestone, in Soldier Canyon, Oquirrh Mountains, Utah; 480 feet above the base of the formation, magnified 10 times, plain light.

Figure 5 Brachiopod coquina from unit 31 in Soldier Canyon, Oquirrh Mountains, Utah; 1485 feet above the base of the formation, magnified 10 times, plain light.

Figure 6 Faecal pellet limestone from top of unit 4 in Soldier Canyon, Oquirrh Mountains, Utah; 200 feet above the base of the formation, magnified 5 times, plain light.

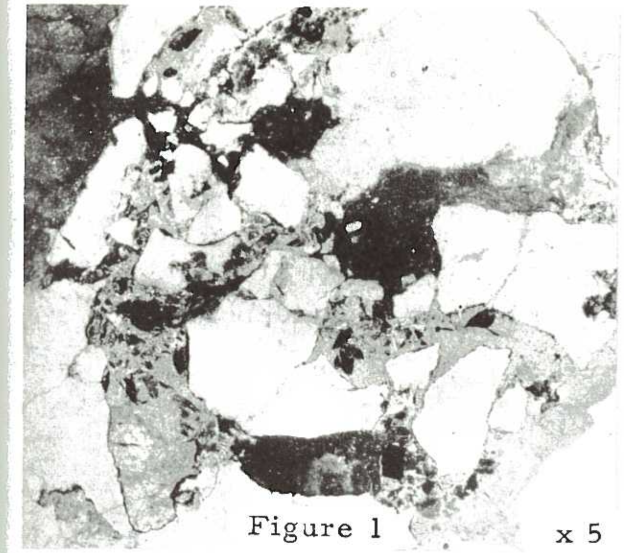


Figure 1 x 5

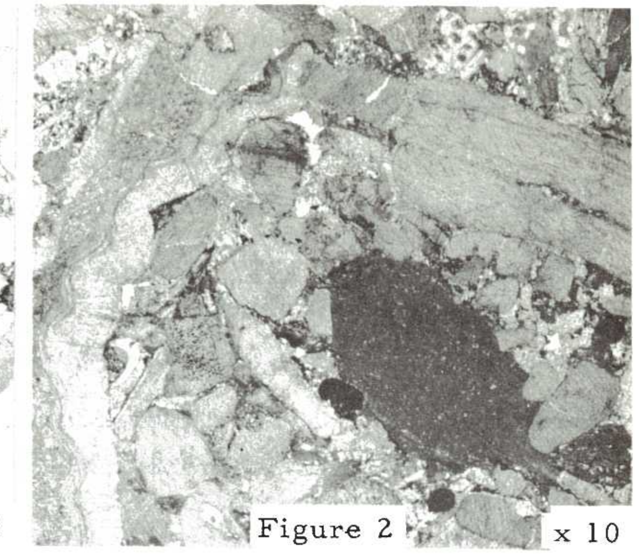
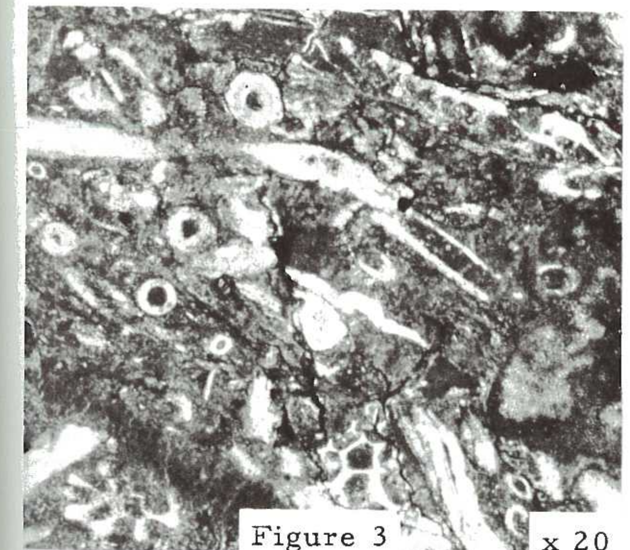


Figure 2 x 10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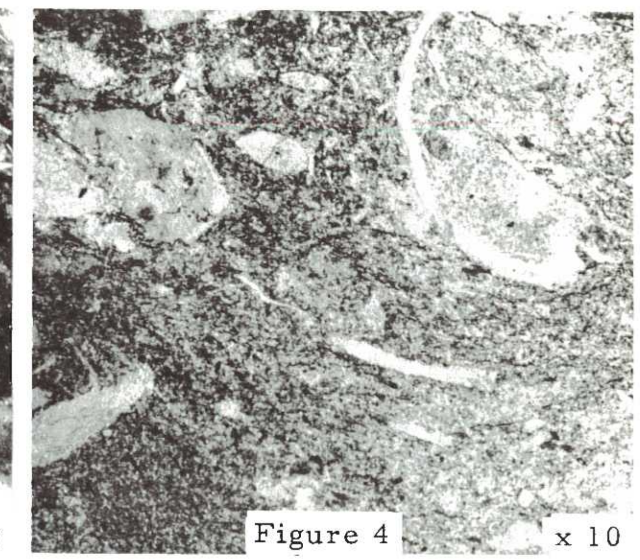
Figure 4 x 10

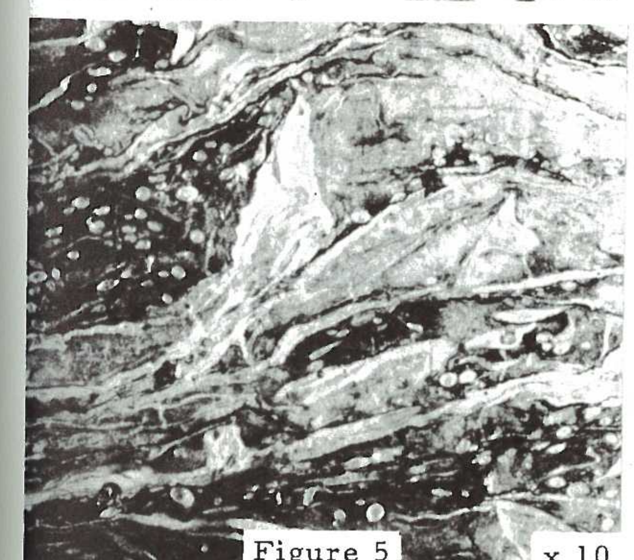
Figure 5 x 10

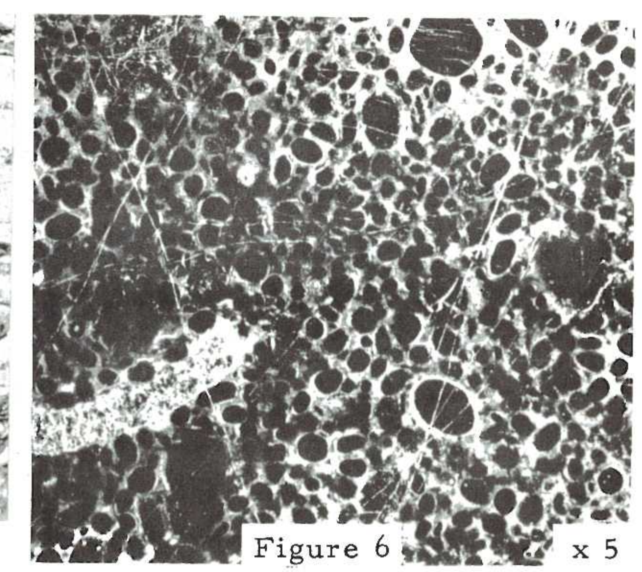
Figure 6 x 5

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