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SEDIMENTATION AND STRATIGRAPHY OF THE MORROWAN SERIES IN CENTRAL UTAH

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ABSTRACT

The area covered by this study of the Morrowan series of the Oquirrh formation is approximately 18 townships. The entire area is located in Utah County except the most westerly portion, which extends into Tooele County. Portions of two major physiographic provinces are included, the eastern part of the Basin and Range province and part of the south-central Wasatch Range of the Middle Rocky Mountain province.

Six sections were measured and studied. They average nearly 1,000 feet thick and are divisible into five mappable lithologic units, an upper, lower, and middle limestone lithotope separated by two sandstone lithotopes. The limestone lithotopes consist of clastic units ranging from relatively pure limestone to calcareous sandstone. The sandstone lithotopes are well sorted calcareous sandstone beds.

The sedimentary environment apparently was a rapidly sinking miogeosynclinal area in a shallow epicontinental sea. The source areas of the sediments lay to the west and north, which during sedimentation was far enough from the area of deposition to allow the material to be well sorted.

INTRODUCTION

Location

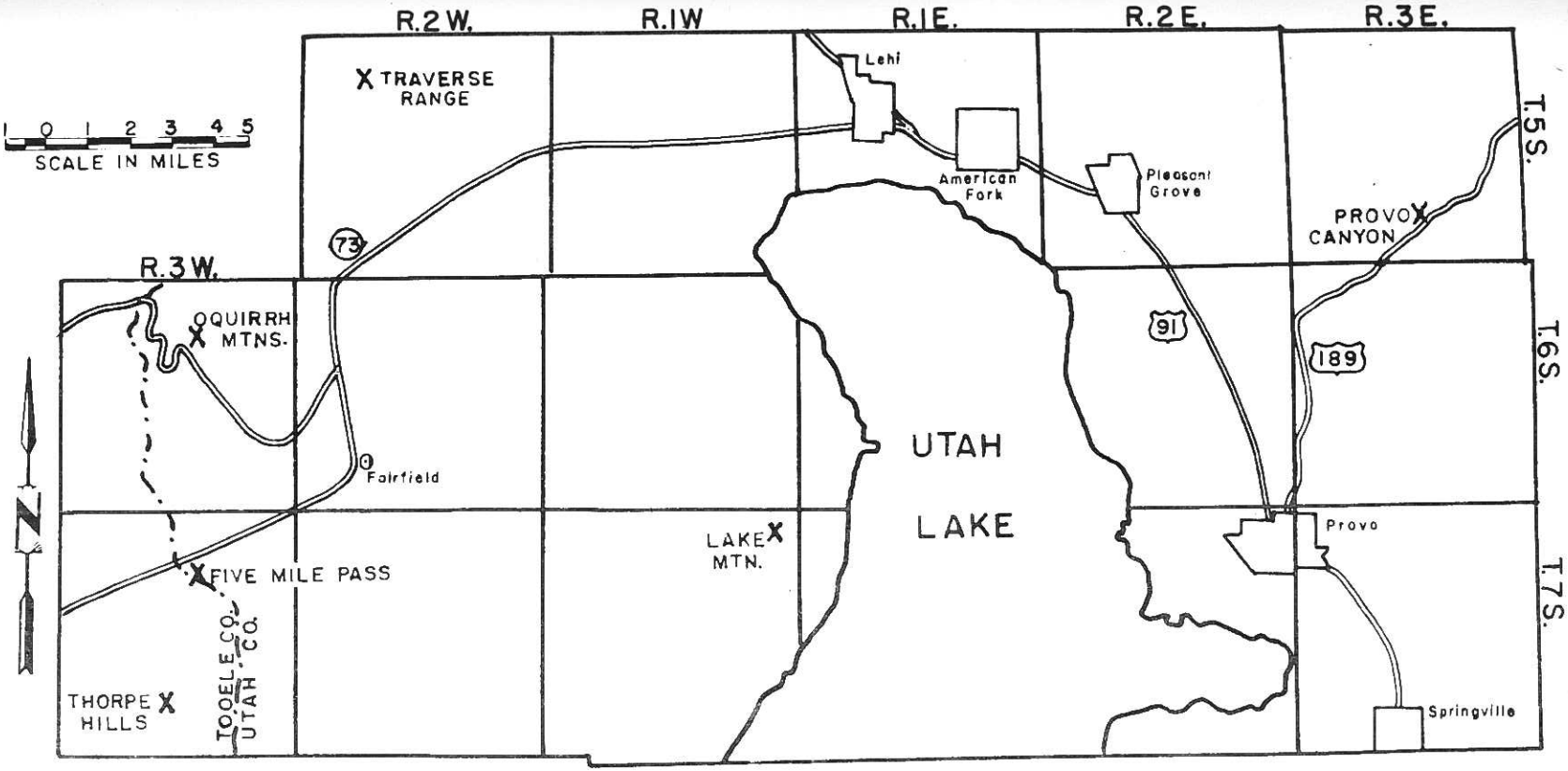
Sedimentary rocks of the Morrowan series of the Oquirrh formation outcrop at many places throughout central Utah, being particularly well exposed in the Wasatch Mountains and contiguous mountains in the Basin and Range province. For this study six stratigraphic sections were measured, sampled, and examined in detail. Five of the sections are located within Utah County: Provo Canyon section, in T. 5 S., R. 3 E.; Traverse Range section, twelve miles west of Lehi; Lake Mountain section, ten miles southwest of Lehi; Oquirrh Mountain section, five miles northwest of Fairfield; and Five Mile Pass section, five miles southwest of Fairfield. The sixth section is in Tooele County, seven miles southwest of Fairfield.

The detailed sections (fig. 1) are located as follows:

1. Provo Canyon: north side of canyon, sec. 34, T. 5 S., R. 3 E., Utah County.
2. Traverse Range: south slope, sec. 5 and 8, T. 5 S., R. 1 W., Utah County.
3. Lake Mountain: east slope, sec. 1, T. 7 S., R. 1 W., Utah County.
4. Oquirrh Mountains: south end, in Manning Canyon, sec. 10, T. 6 S., R. 3 W., Utah County.
5. Five Mile Pass: north end of Thorpe Hills, sec. 10, T. 7 S., R. 3 W., Utah County.
6. Thorpe Hills: west side, three miles south of Five Mile Pass, sec. 28, T. 7 S., R. 3 W., Tooele County.

Physiographic Location

The sections fall within two major physiographic provinces. Five are in the eastern part of the Basin and Range physiographic province,



INDEX MAP SHOWING LOCATION OF MEASURED SECTIONS

(FIG. 1)

and the sixth is in the western part of the south-central Wasatch Range of the Middle Rocky Mountain province.

Scope of Report

A few geologists have mapped and measured strata of the Oquirrh formation in connection with other work, but only three, namely, Franson (1950), Stewart (1950), and Murphy (1952), have confined their studies to a detailed examination of the Morrowan series. Franson studied the sedimentation and stratigraphy of these strata in Provo Canyon, but did not deal with correlation; and the work of Stewart and Murphy dealt principally with fossils in the Morrowan series of central Utah. Therefore, the purpose of the present report is to furnish a detailed account of the stratigraphy, sedimentary environment, and correlation of the Morrowan series of the Oquirrh formation in central Utah.

Previous Work

The Oquirrh formation was named by James Gilluly (1932) from exposures in the Oquirrh Mountains twenty miles northwest of Provo. Gilluly assigned approximately 15,000 feet of interbedded limestones, orthoquartzites, and sandstones of Pennsylvanian age to the Oquirrh formation. Previously the formation had been designated as the Upper Intercalated series by Spurr (1894), who measured and mapped it in the Mercur Mining district, twenty-five miles northwest of Provo.

Nolan (1935), in mapping the Gold Hill district of western Utah, applied Gilluly's terminology for the Pennsylvanian in that district and assigned between 5,300 and 8,000 feet of limestone and quartzite to the Oquirrh formation.

Bissell (1936) was first to apply the name Oquirrh formation to

the Pennsylvania strata of the south-central Wasatch Mountains. Later Bissell (1939) suggested that this unit, which he considered of series rank, might be subdivided on the basis of fusulinid faunas. Subsequently Thompson, Verville, and Bissell (1950) studied the fusulinid fauna of the Oquirrh formation of the south-central Wasatch Mountains, but no strata older than Atokan were determined in Provo Canyon.

Franson (1950) studied the stratigraphy of the lower 1,360 feet of the Oquirrh formation in the Provo Canyon area. He measured the complete 1,360 foot section which extends along the west base of Cascade Ridge as far north as Bridal Veil Falls and sampled each five foot stratigraphic increment.

A. A. Baker (1947) indicated that the Oquirrh formation in the south-central Wasatch Mountains is 26,000 feet thick with the lower 17,000 feet being of Morrowan to Virgilan ages, inclusive, and the upper 9,000 feet of Wolfcampian age.

Stewart (1950) studied the lower Oquirrh stratigraphy and paleontology in Provo Canyon north of Bridal Veil Falls.

Murphy and the writer (1952) measured three sections, one in Provo Canyon near Bridal Veil Falls and two in the Thorpe Hills. Murphy collected and described the invertebrate fauna from these sections, correlating the fauna of the measured sections with other faunal collections from strata of equivalent age.

Paul W. Nygreen (1955) studied in detail the stratigraphy of the lower Oquirrh formation in the Oquirrh Mountains and Logan, Utah, areas. His correlation is based primarily on his study of fusulinids. In this study he proposes the name of West Canyon limestone member to the lower limestone facies of the Oquirrh formation.

Present Work

Field work. Field work for this study began in September, 1953, and was completed in July, 1955. Sections were measured by the use of a steel tape and a brunton compass. Every distinctive rock unit in the selected stratigraphic sections was sampled.

Laboratory work. Laboratory work included preparation and study of insoluble residues and thin sections. Insoluble residues were prepared by dissolving ten grams of dried and sieved, pea-size sample at room temperature in dilute hydrochloric or acetic acid. The dilute hydrochloric acid was prepared by mixing one part concentrated acid with eight parts distilled water. The dilute acetic acid was prepared by mixing one part glacial acetic acid with five parts distilled water.

Analyses of the insoluble residues were performed to determine the percentage of authigenic quartz, detrital quartz, chert, limonite, and other minerals present in the samples.

Grain size analyses of the sandstones were made by disaggregating the sandstone with dilute hydrochloric acid and sieving. The data were grouped and plotted on histograms.

In addition to a cumulative lithofacies panel diagram prepared for the Morrowan series, cumulative lithofacies panel diagrams were compiled for each of the limestone lithotopes plus isopachous maps for each of the sandstone lithotopes.

STRATIGRAPHY

Introduction

Spurr (1894), in his description of what is now known as the Morrowan series of the Oquirrh formation, states:

> Above the upper shale belt the rocks begin to contain arenaceous layers, separated by very thick beds of pure limestone. At a distance of about 1,000 feet above the top of the shale these sandstone beds become so common as to mark the lower limit of a new lithological series, the Upper Intercalated series.

From this description it would appear that Spurr placed strata which are now known as the Morrowan series of the Oquirrh formation in the upper part of his Great Blue limestone. Gilluly (1932), in studying the rocks of the Oquirrh Mountain area, subdivided and renamed the Great Blue limestone as follows: The Great Blue limestone (restricted), the Manning Canyon shale, and the lower 1,000 feet of the Oquirrh formation (Morrowan series).

Baker (1947) described the Morrowan series as:

> . . . consisting of medium to dark gray, fine to coarse-grained, thin to thick-bedded limestone with interbedded dark gray to black shale. It forms a prominent blue gray band at the base of the Oquirrh formation. . . . The total thickness of the member is 1,245 feet.

Baker's section was measured by plane-table in the vicinity of Bridal Veil Falls in Provo Canyon.

The Morrowan rocks form an alternating slope and ledge topography. Abundant thick to massive-bedded cherty limestone beds resist weathering and stand out as a sequence of ledges and benches, whereas the slopes are formed by easily weathered, thin-bedded, argillaceous limestones.

The Morrowan series is composed predominantly of limestone that

weathers dark blue-gray. On the other hand, the Atokan (Derryan) series is comprised of interbedded sandstones, orthoquartzites, and limestones, with sandstone and orthoquartzite predominating. This gives the Atokan series a characteristic tan color, which in contrast with the dark blue-gray of the Morrowan rocks enables the upper contact of the Morrowan section to be easily distinguished, even from a distance.

All the sections studied are divisible into five distinctive lithologic units: lower, middle, and upper limestone units separated by a lower and an upper sandstone unit. The two sandstone units are single persistent beds and afford excellent key units which are especially good for relatively long distance correlation (Plate I). With the exception of the top bed of the upper limestone sequence, units within the limestone lithotopes cannot be correlated over long distances because of rapid lateral, vertical, and vertico-lateral facies changes.

General Description

The Five Mile Pass section is the most completely exposed of the sections studied and therefore will be used as the type throughout this discussion. Other sections will be discussed in relation to this Five Mile Pass standard.

For convenience of presentation, all of the rock units have been classified and grouped into five lithologic types: calcareous sandstone (greater than 50% quartz sand), arenaceous limestone (less than 50% and greater than 10% quartz sand), argillaceous limestone (greater than 10% insoluble material of clay and silt size), cherty limestone, and limestone.

The following table (Table 1) gives a complete summary (percentage

and footage) of the various rock types exposed in each measured section, listing each rock type, the cumulative footage and the percentage of the section represented by each rock type.

TABLE 1

PERCENTAGE AND FOOTAGE OF DOMINANT ROCK TYPES

Section	Thorpe Hills		Five Mile Pass		Oquirrh Mtn.		Traverse Range		Lake Mtn.		Provo Canyon	
	feet	%	feet	%	feet	%	feet	%	feet	%	feet	%
Calcareous sandstone	60	4.9	47	4.7	198	17.0	109	12.7	72	7.3	39	3.8
Arenaceous limestone	52	4.1	116	11.6	34	3.0	61	7.0	62	6.2	172	16.6
Argillaceous limestone	414	33.0	318	31.5	282	24.0	242	28.0	253	25.6	417	40.1
Cherty limestone	346	28.0	283	28.2	475	41.0	354	42.0	425	43.2	150	14.5
Limestone	369	30.0	241	24.0	173	15.0	88	10.3	173	17.7	260	25.0
Total	1241	100.	1005	100.	1162	100.	853	100.	985	100.	1038	100.

It should be noted from the cumulative panel diagram (Plate II) that the sand content reaches a maximum in the most northerly sections (Oquirrh Mountains and Traverse Range) and that the sand content in the other sections is nearly constant. The arenaceous limestone attains its greatest thickness in the Provo Canyon section.

The argillaceous limestone unit would appear to vary markedly in thickness between the different sections and to be somewhat erratic in distribution. However, by digging and working carefully in many of the covered

intervals it was found that the intervals are developed on easily weathered, thin-bedded, argillaceous limestones, and that if the argillaceous limestone outcrops are grouped with the covered intervals, this disparity in thickness disappears. The covered intervals have therefore been grouped with the argillaceous limestone in figuring percentages and thicknesses. In all of the descriptive sections (figs. 8, 9, 10, 11, 12, and 13) the covered intervals have been indicated as such, but noted as being probably argillaceous limestone units. The percentage of argillaceous limestone shows very little variation throughout all of the sections.

There is an increase in the amount of cherty limestone from the Five Mile Pass section to the Oquirrh Mountains, Traverse Range and Lake Mountain sections; then a decrease to the Provo Canyon section. Limestone development is greatest in the southern sections, Five Mile Pass, Thorpe Hills, and Lake Mountain, with considerable decrease to the north in the Oquirrh Mountains and Traverse Range.

Description of Lithotopes

Each of the sections studied can be divided into five mappable units. There is an upper, a middle, and a lower limestone unit. Each of the limestone units may have minor calcareous sandstone beds within them but nevertheless are predominantly limestone, and will hereinafter be designated as the upper, the middle, or the lower limestone lithotope. The limestone lithotopes are separted by two distinctive sandstone beds which will hereinafter be designated as the upper and lower sandstone lithotopes. All five of the units are sufficiently distinctive as to be easily recognized wherever they are well exposed (Plate I).

The following tables (Tables 2, 3, and 4) give a complete summary

(percentage and footage) of the various rock types exposed in each of the limestone lithotopes in each measured section, listing the rock type, the cumulative footage, and the percentage of the lithotope represented by each rock type.

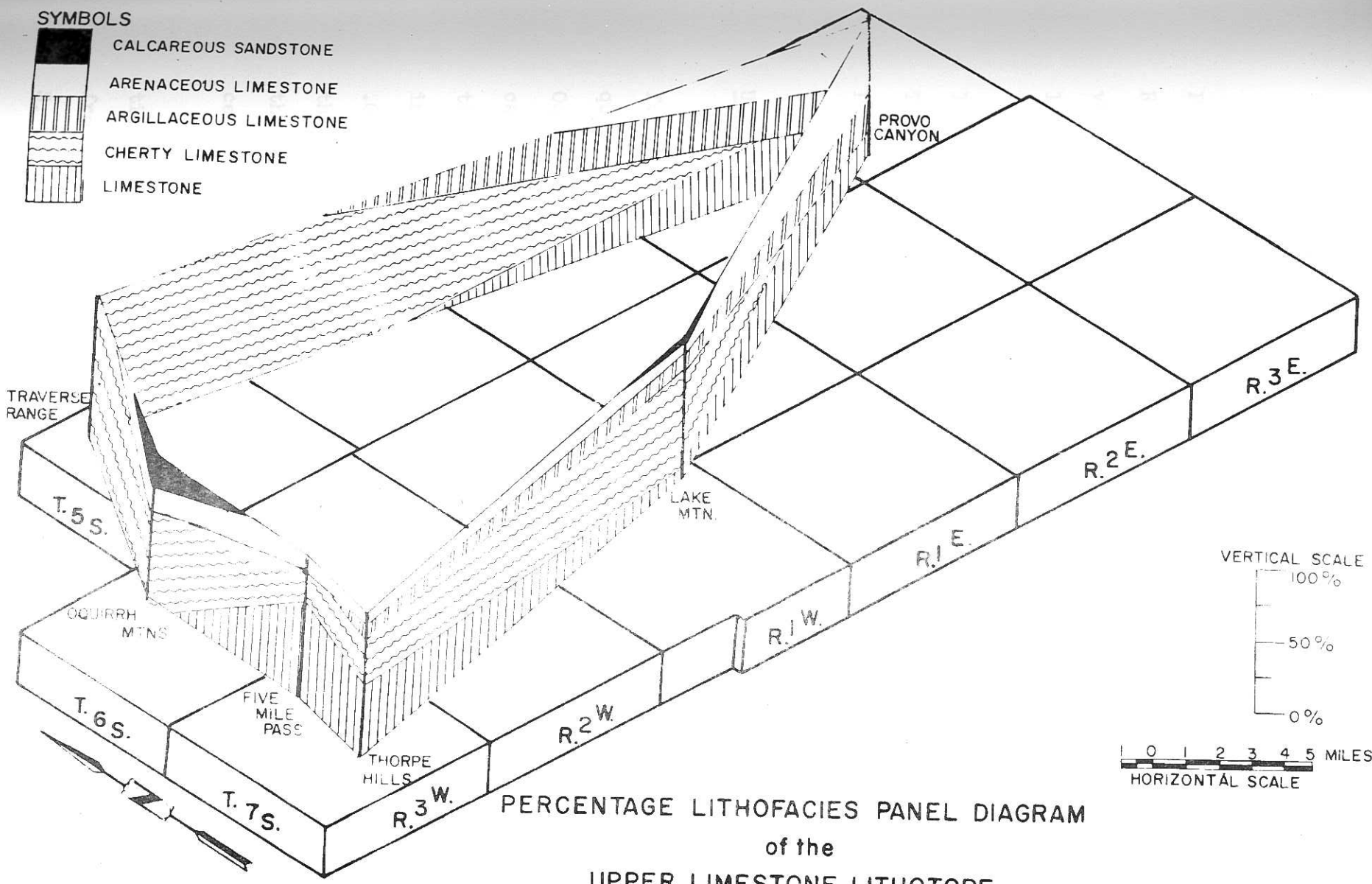
Upper Limestone Lithotope

In the Five Mile Pass section the entire upper limestone lithotope is composed of medium to thick-bedded limestones (Table 2), with only one unit each of cherty limestone and arenaceous limestone (fig. 9, part 1) occurring within the section.

TABLE 2

UPPER LIMESTONE LITHOTOPE
PERCENTAGE AND FOOTAGE OF DOMINANT ROCK TYPES

Section	Thorpe Hills		Five Mile Pass		Oquirrh Mtn.		Traverse Range		Lake Mtn.		Provo Canyon	
	feet	%	feet	%	feet	%	feet	%	feet	%	feet	%
Calcareous sandstone	0	0	0	0	33	15	0	0	7	3	0	0
Arenaceous limestone	20	7	15	12	0	0	0	0	7	3	41	46
Argillaceous limestone	10	11	0	0	24	11	0	0	30	13	26	29
Cherty limestone	95	34	20	17	157	74	26	100	181	78	0	0
Limestone	135	48	83	71	0	0	0	0	6	3	22	25
Total	261	100	118	100	214	100	26	100	231	100	89	100



PERCENTAGE LITHOFACIES PANEL DIAGRAM
of the
UPPER LIMESTONE LITHOTOPE
OQUIRRH FORMATION, MORROWAN SERIES

(fig. 2)

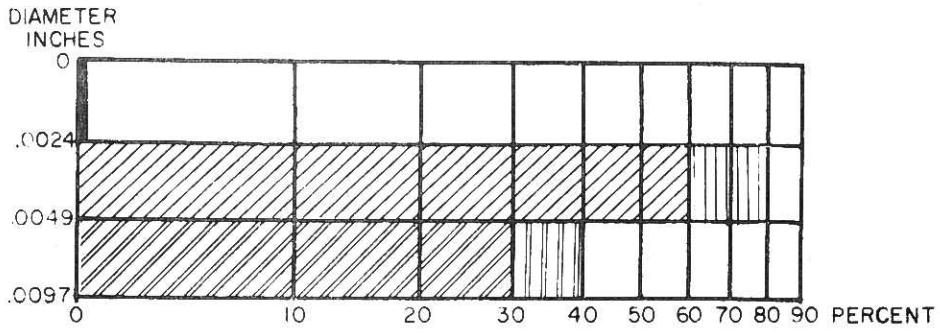
To the north and east in the Oquirrh Mountains, Lake Mountain and Provo Canyon sections the sand content increases (fig. 2). The Traverse Range section to the northeast, however, has no sand. Here the lithotope is very thin and has only two cherty limestone units comprising the complete lithotope (fig. 2).

Many of the calcareous sandstone beds where they occur in this lithotope are cross-bedded, and in a few places ripple marks were noted. This would indicate that most of the sediments during this period were deposited in very shallow seas and at times may even have been laid down as beach sands.

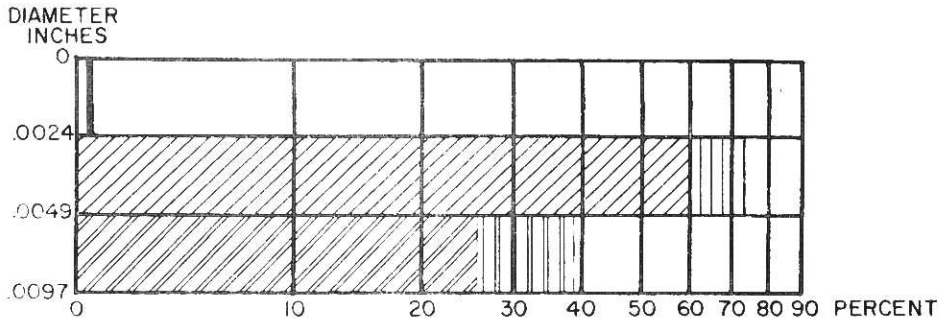
Upper Sandstone Lithotope

The upper sandstone lithotope is comprised of a single, fairly uniform, calcareous sandstone bed. Its insoluble content varies from 51% quartz sand in the Thorpe Hills and Provo Canyon sections to 98% in the Oquirrh Mountain section. Grain size analyses, obtained by dissolving the calcareous cement and then sieving, determined that 60% (Thorpe Hills section) to 78% (Oquirrh Mountain section) of the sample is greater than .0024 inches and less than .0049 inches (fig. 3); from 0% to 0.4% is less than .0024 inches; and from 30% to 40% is greater than .0049 inches and less than .0097 inches in diameter. All fragments caught on the sieves larger than .0097 inches proved to be clusters formed of grains that remained cemented together and not single grains.

The cross-bedding within the sandstone shows a preferred orientation to the south. Dip of the cross-bedding is moderately gentle, ranging from 6° to 13° from the horizontal. The direction of the dip varies from S. 22° W. to S. 5° E. The cross-bedding in the southern-most sections

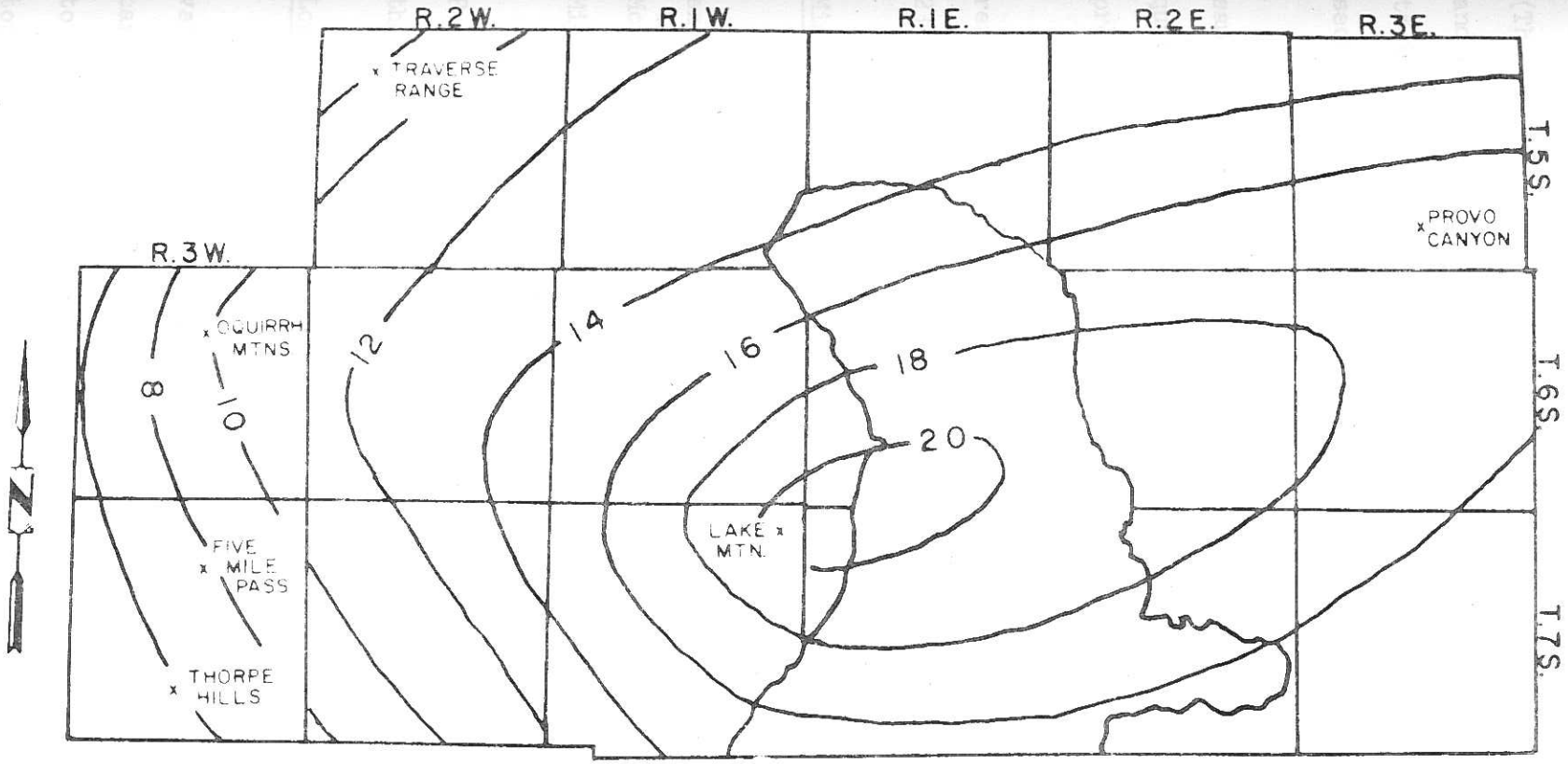


MAXIMUM & MINIMUM GRAIN SIZE CHART
of the
UPPER SANDSTONE LITHOTOPE
OQUIRRH FORMATION, MORROWAN SERIES



MAXIMUM & MINIMUM GRAIN SIZE CHART
of the
LOWER SANDSTONE LITHOTOPE
OQUIRRH FORMATION, MORROWAN SERIES

(fig. 3)



1 0 1 2 3 4 5
SCALE IN MILES

CONTOUR INTERVAL 2 FEET

ISOPACHOUS MAP
of the
UPPER SANDSTONE LITHOTOPE
OQUIRRH FORMATION, MORROWAN SERIES

(fig. 4)

(Thorpe Hills and Five Mile Pass) has longer sweeps than in the northern and eastern sections. Many of the cross-beds in the south measure from one to two feet in length, although in the Oquirrh Mountains and Provo Canyon sections the length of cross-beds is from two to seven inches.

The cementing material is essentially calcareous and after the sample had been treated in hydrochloric acid only a very fine, pure, white quartz sand remained. There is only a small amount of authigenic quartz present.

This unit represents a littoral deposit or in places may even represent a beach deposit. The thickness of the unit varies from six to 23 feet (fig. 4).

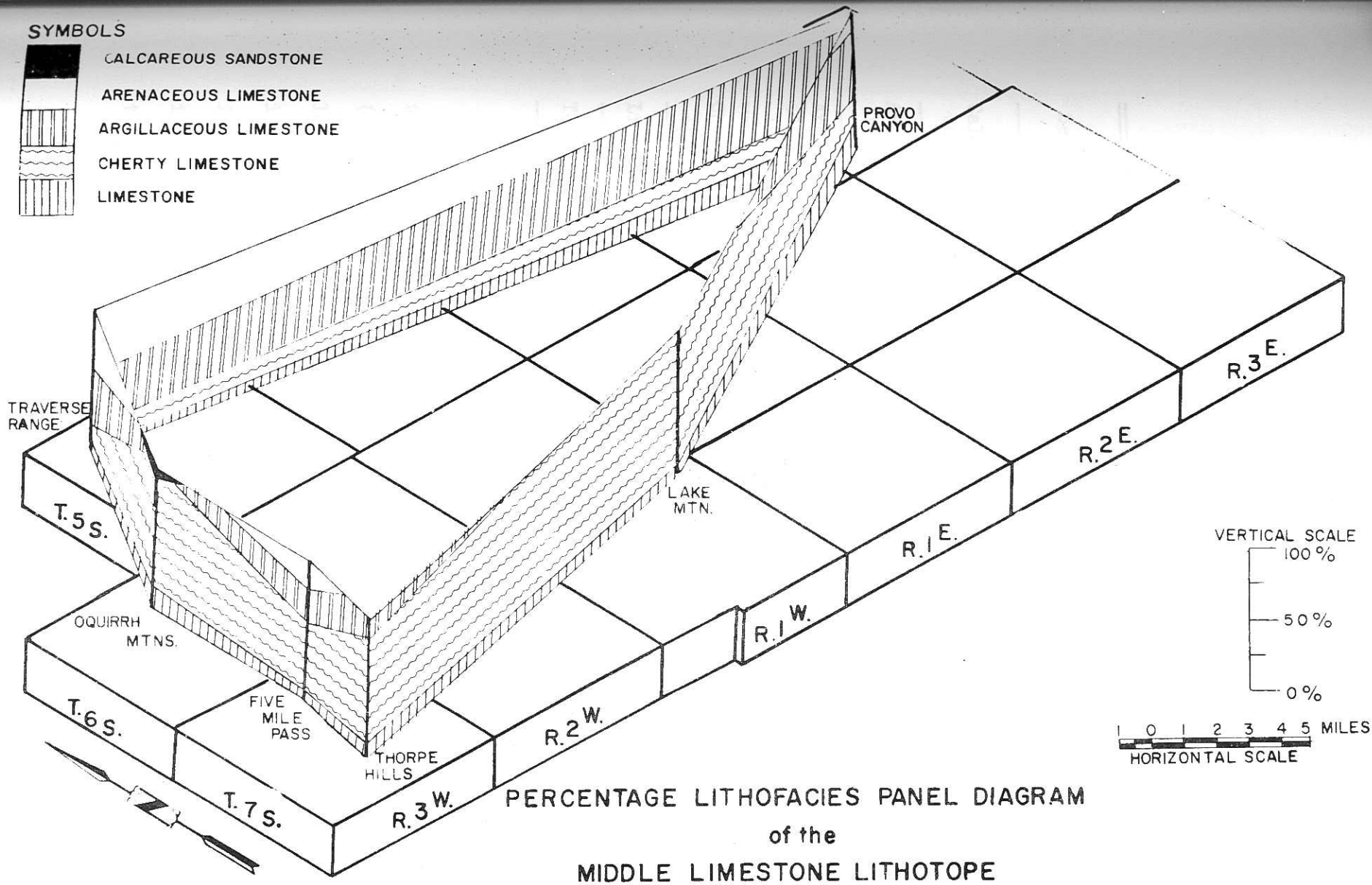
Middle Limestone Lithotope

In the Five Mile Pass section all lithic types are present with exception of the calcareous sandstone (Table 3). Only in the Oquirrh Mountain section are there any calcareous sandstone beds present in the Middle Limestone Lithotope (fig. 5).

Cherty limestone is thickest in the southern sections (Five Mile Pass, Thorpe Hills, and Lake Mountain) and exhibits a marked decrease to the east and north (fig. 5).

Lower Sandstone Lithotope

The lower sandstone lithotope is composed of a single bed which varies from an arenaceous limestone in the Provo Canyon section to a calcareous sandstone in the Oquirrh Mountain section, and contains from 33% to 96% of quartz, respectively. The Lake Mountain lower sandstone lithotope is 95% insoluble, the Traverse Range 74%, the Five Mile Pass 64% and the Thorpe Hills lower sandstone lithotope 61%.



PERCENTAGE LITHOFACIES PANEL DIAGRAM
of the
MIDDLE LIMESTONE LITHOTOPE
OQUIRRH FORMATION, MORROWAN SERIES

(fig. 5)

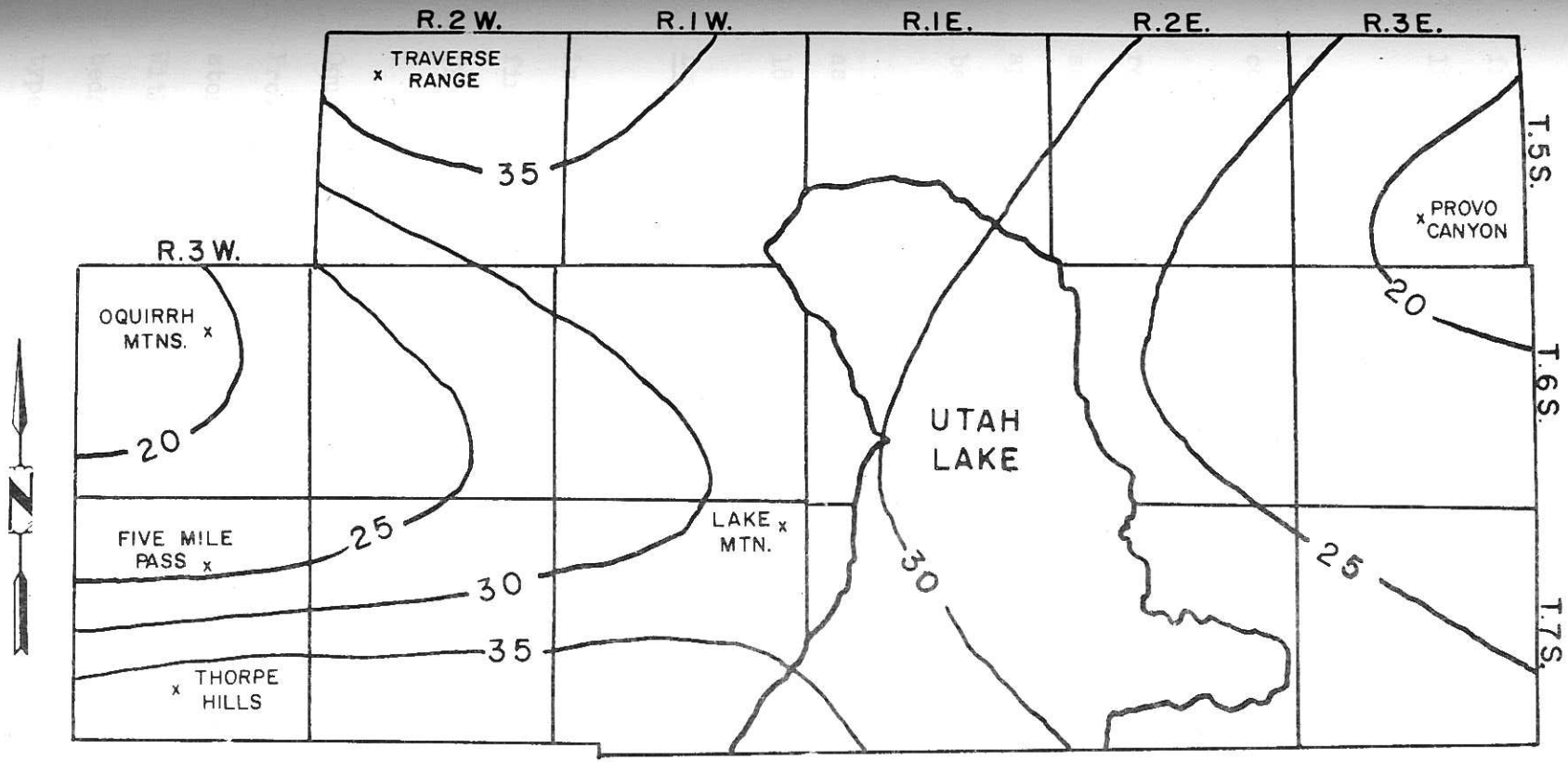
TABLE 3

MIDDLE LIMESTONE LITHOTOPE
PERCENTAGE AND FOOTAGE OF DOMINANT ROCK TYPES

Section	Thorpe Hills		Five Mile Pass		Oquirrh Mtn.		Traverse Range		Lake Mtn.		Provo Canyon	
	feet	%	feet	%	feet	%	feet	%	feet	%	feet	%
Calcareous sandstone	0	0	0	0	4	2	0	0	0	0	0	0
Arenaceous limestone	0	0	21	19	0	0	57	42	0	0	4	3
Argillaceous limestone	10	12	31	27	0	0	56	41	0	0	90	57
Cherty limestone	69	80	55	47	150	88	18	13	78	92	22	14
Limestone	7	8	8	7	16	10	5	4	7	8	42	26
Total	86	100	115	100	170	100	136	100	85	100	158	100

Grain size analyses, obtained by dissolving the calcareous cement, followed by sieving, shows from 60% (Oquirrh Mountain section) to 74% (Thorpe Hills section) of the sample being greater than .0024 inches and less than .0049 inches (fig. 3). From 0.4% to 0.6% was less than .0024 inches and from 26% to 39% is greater than .0049 inches and less than .0097 inches in diameter. All fragments caught on the sieves larger than .0097 inches were, as before, clusters formed of grains that remained cemented together and not single grains.

The cross-bedding within the sandstone exhibits a preferred orientation to the south. The dip is moderately gentle, ranging from 8° to 17°



1 0 1 2 3 4 5
SCALE IN MILES

CONTOUR INTERVAL 5 FEET

ISOPACHOUS MAP
of the
LOWER SANDSTONE LITHOTOPE
OQUIRRH FORMATION, MORROWAN SERIES

(fig. 6)

from the horizontal. The direction of dip varies from S. 18° W. to S. 12° E.

The cementing material is essentially calcareous throughout, and contains only a very small amount of authigenic quartz. All of the samples could be disaggregated by treating in hydrochloric acid.

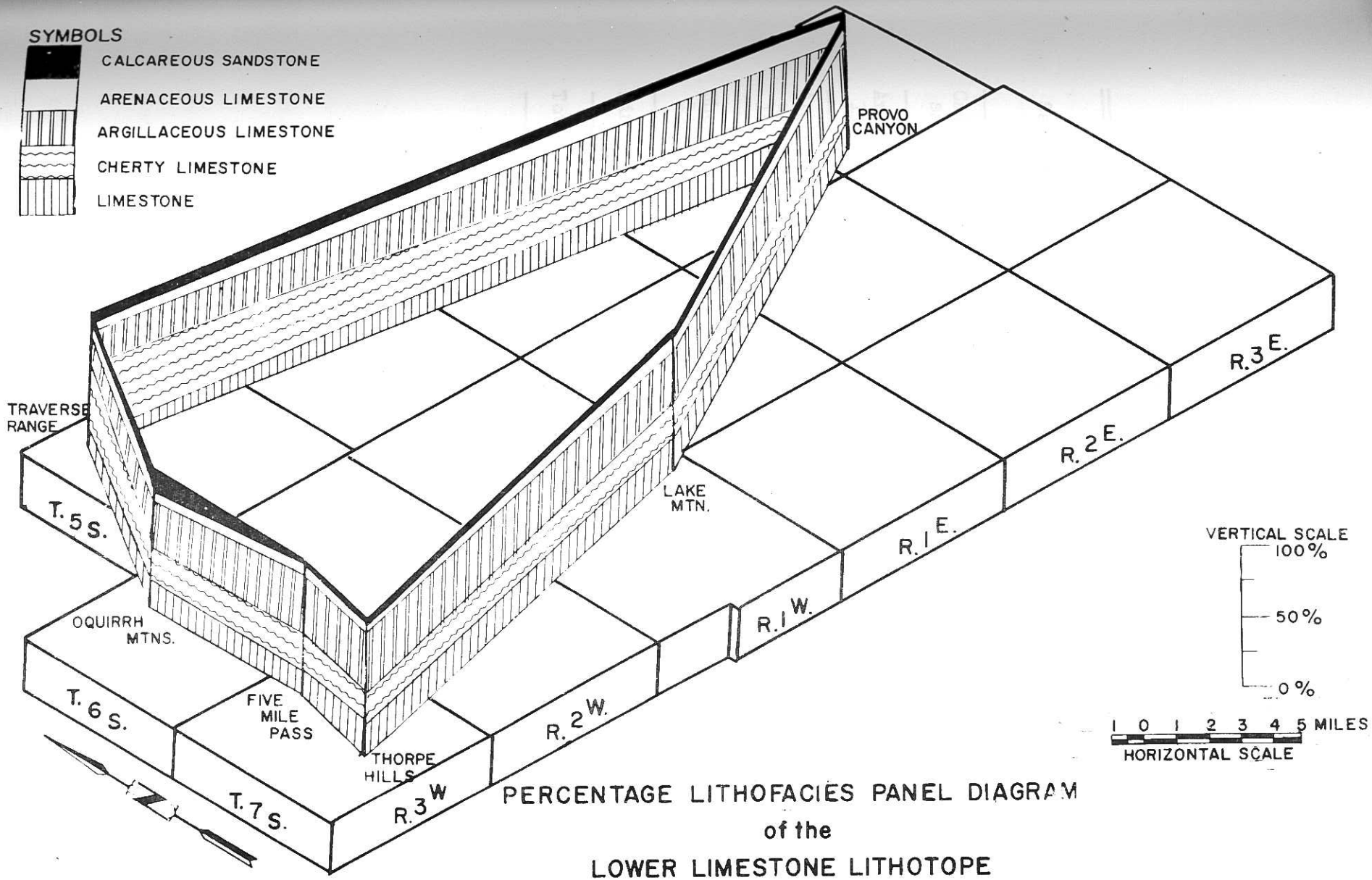
The sandstone bed has a peculiar weathering habit which makes it readily recognizable in the field. In all localities studied, the lower sandstone breaks down partially by exfoliation, having a distinct rounded appearance in contrast to the blocky weathering habit of the contiguous beds.

This unit is also a littoral or beach type deposit much the same as the upper sandstone lithotope. The thickness of the unit varies from 18 feet in the Oquirrh Mountains to 37 feet in the Thorpe Hills (fig. 6).

Lower Limestone Lithotope

The lower limestone lithotope has all five rock types represented in each section. Calcareous sandstone appears in all six sections for the first time, the more northerly sections having the greater percentage (Table 4).

Calcareous sandstone is fairly evenly distributed with only the Oquirrh Mountain section having any considerable amount (fig. 7). The Provo Canyon section contains the most arenaceous limestone and the limestones within the other sections are about of the same aggregate thickness. With the exception of the Traverse Range section the argillaceous limestone beds comprise a greater percentage of the lithotope than any other rock type. The southern and eastern sections have the least percentage of cherty limestone, and, conversely, the greatest content of pure limestone.



PERCENTAGE LITHOFACIES PANEL DIAGRAM
of the
LOWER LIMESTONE LITHOTOPE
OQUIRRH FORMATION, MORROWAN SERIES

(fig. 7)

TABLE 4

LOWER LIMESTONE LITHOTOPE
PERCENTAGE AND FOOTAGE OF DOMINANT ROCK TYPES

Section	Thorpe Hills		Five Mile Pass		Oquirrh Mtn.		Traverse Range		Lake Mtn.		Provo Canyon	
	feet	%	feet	%	feet	%	feet	%	feet	%	feet	%
Calcareous sandstone	33	3	17	2	124	17	62	9	11	2	26	3
Arenaceous limestone	32	4	81	11	34	5	4	1	55	9	108	14
Argillaceous limestone	382	45	287	39	258	35	186	29	223	36	302	40
Cherty limestone	182	22	208	28	168	22	310	48	166	27	128	17
Limestone	226	26	151	20	157	21	83	13	160	26	196	26
Total	845	100	744	100	741	100	645	100	615	100	760	100

CONCLUSIONS

All evidence obtained in this study, including field and laboratory research, indicates that the sediments of the Morrowan series in central Utah were deposited in the neritic marine zone. Furthermore, the evidence (cross-bedding, ripple marks, and abundance of life) strongly suggests that at times the water was less than 120 feet deep (epineritic), but at other times it likely was as much as 600 feet deep (infraneritic).

The sediments are nearly all clastic. Even the limestones that contain less than 10% insoluble material show ample evidence of reworking. In thin section the grains are seen to be cemented by secondary calcite and not an intergrowth of calcite crystals formed by exsolution (crystalloblastic).

Quarts in the sediments is almost entirely comprised of clastic grains, with only a very small percentage occurring as authigenic growths. The detrital grains are very fine sand to silt size with minor amounts of clay size particles (Wentworth's scale).

The abundance of cross-bedding and clastic constituents, the great thickness, and occasional ripple marks would seem to indicate that the sediments of this series (Morrowan) in the area studied were most likely deposited in a rapidly subsiding geosynclinal area and in shallow seas where they were subject to considerable current and wave action. It would appear that the source area was to the north and west, and probably not far removed from the depositional site.

A. J. Eardley (1939) noted that a positive area existed at times in northern Utah in the vicinity of Antelope Island. He states that this area

was positive during the Proterozoic, most of the Paleozoic, and during part of the Mesozoic. Eardley has designated this area the Northern Utah Highland. John C. Young (1955), in his work on the Southern Lakeside Mountains, gave further documentary evidence of this positive area.

Croft (1956) studied and mapped the northern Onaqui Mountains to the west of the region in which the writer worked, and found that the Morrowan series thins westerly to 85 to 120 feet near Johnson's Pass and disappears entirely a few miles to the west.

H. J. Bissell* showed the writer an isopachous map of the Pennsylvanian system he was in the process of preparing and on which he had indicated a highland area extending along the west side of the Onaqui and Stansbury Mountains.

These highland areas appear to have been the source of much of the sediments deposited in the Oquirrh basin. However, an additional provenance, perhaps to the north, might possibly have furnished additional sediments to this repository, at least during part of Pennsylvanian time.

In the lower limestone lithotope there is an abundance of argillaceous and arenaceous limestone. This lower unit was also the unit which Murphy (1952) found to be the most fossiliferous. In each of the limestone units where Murphy collected bryozoans, the writer found the insoluble content to be less than 10%. This would suggest that this unit may have been deposited in very shallow seas where light and the aeration of water was sufficient for abundant life. Further, the great amounts of argillaceous and arenaceous limestone beds would indicate it to be close enough to the source area that there were yet periods in which quantities of detritus

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*Personal communication, February 4, 1956.

were being carried by the currents. The great number of cherty units in the northern sections would seem to indicate that silica was transported from the north and may have been brought by currents into this area from a volcanic archipelago which lay to the west, and which, according to Eardley (1951), was possibly a source of much of the chert in the miogeosyncline.

The lower sandstone lithotope is a well sorted, cross-bedded sandstone and would indicate a period of structural stability during which sufficient time elapsed for reworking of the upper part of the lower limestone lithotope and a concentrating of the sand into a very uniform bed. It will be noted (fig. 6) that there is only a 15 foot variation in thickness over the complete area. There seems to have been a very shallow, broad trough extending north-south through the Traverse Range and Lake Mountain area where the sediments are slightly thicker.

In the middle limestone lithotope the southern sections received much less argillaceous and arenaceous material than the northern sections, but a relative increase in chert content. The source area of the argillaceous and arenaceous material must have become less active or the transporting currents were not as strong as they were during deposition of the lower lithotopes. Currents carrying silica may have been very important at this time and/or the amount of volcanic-derived silica being deposited in the water increased.

The upper sandstone lithotope is composed of a single bed of well sorted, cross-bedded, calcareous sandstone and indicates the occurrence of another period of structural stability. As with the lower sandstone lithotope, there was sufficient time for the reworking and deposition of the upper sandstone as a very uniform unit covering the entire area. The thickest part is in the vicinity of Lake Mountain where it reaches a

thickness of 20 feet (fig. 4).

The upper limestone lithotope is composed of cherty as well as pure limestone in the western section, but in the eastern sections contains the greater amount of detrital material. The more active source area during the deposition of this lithotope seems to have been to the north, indicating a period of structural activity in that area. The currents carrying the silica deposited a greater amount in the western part of the area than in the eastern part.

The sedimentary environment of the Morrowan series of the Oquirrh formation in Central Utah may be summed up as a rapidly sinking miogeosynclinal area in a shallow epicontinental sea. The source area lay to the west and north, and during this time was either low enough or sufficiently removed from the area of deposition to allow the material to be well sorted.

STRATIGRAPHIC COLUMN OF THE FIVE MILE PASS AREA
OQUIRRH FORMATION, MORROWAN SERIES
SEC. 10, T. 7S., R. 3W. UTAH COUNTY, UTAH

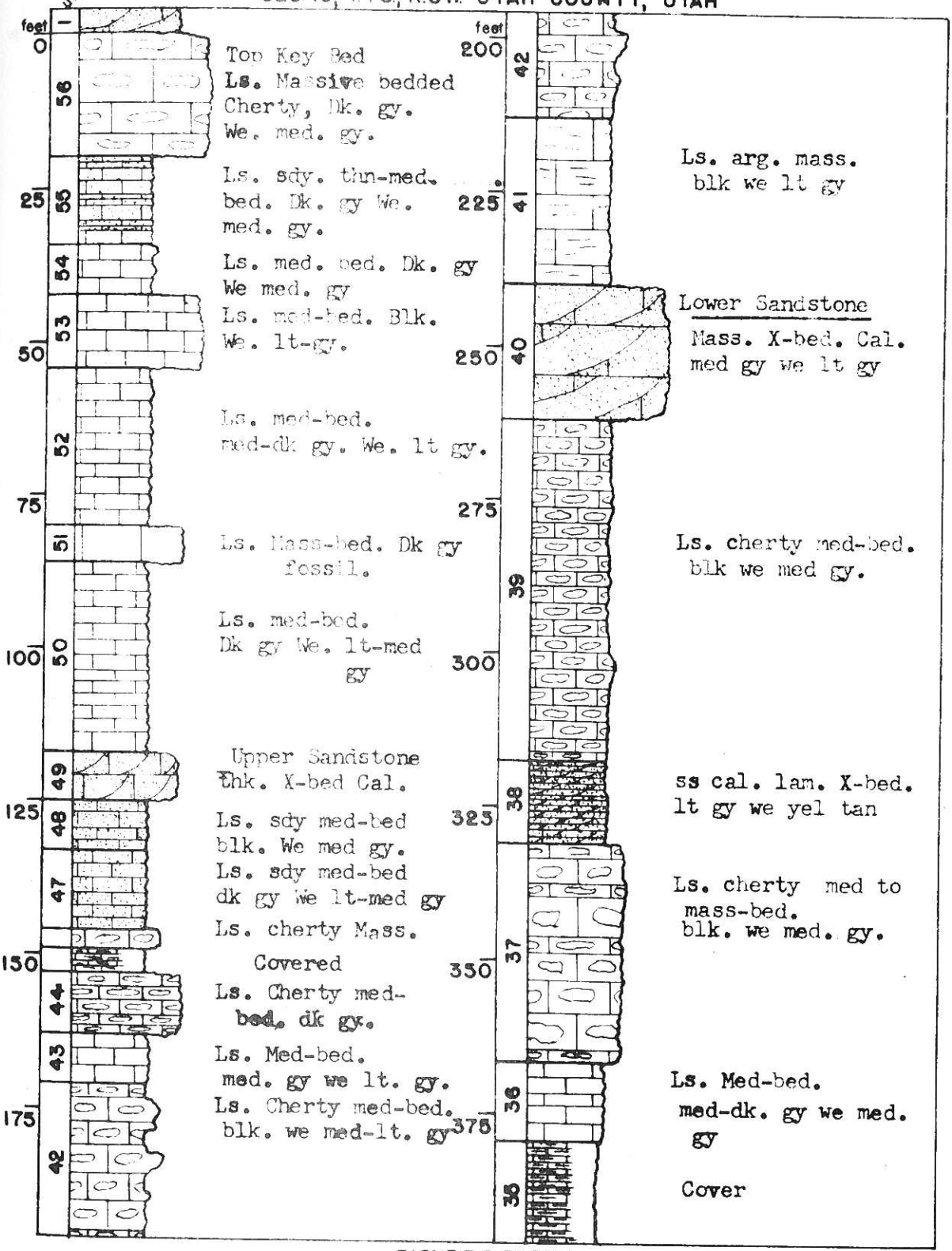


FIGURE 8, PART 1

FIGURE 8, PART 2

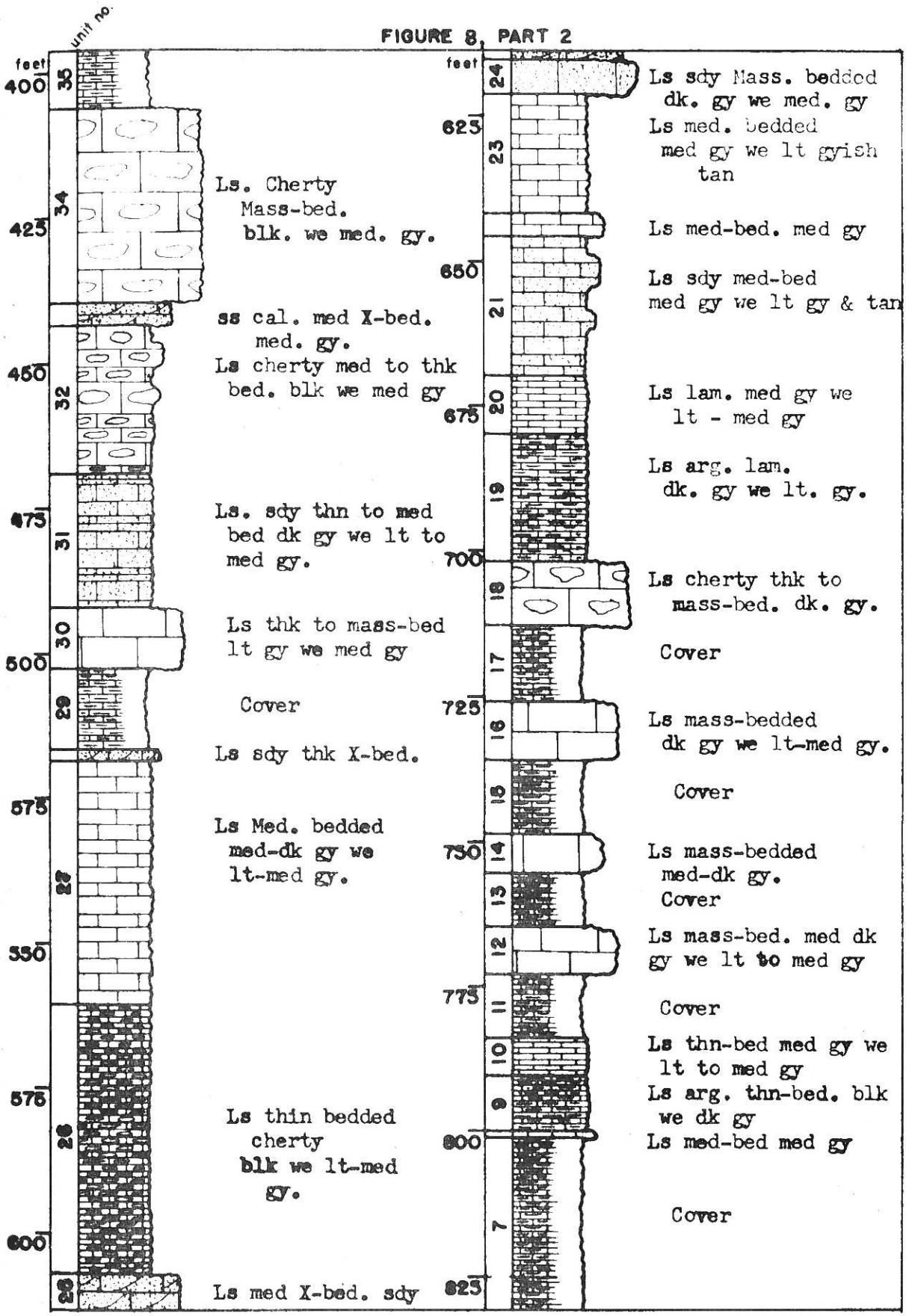
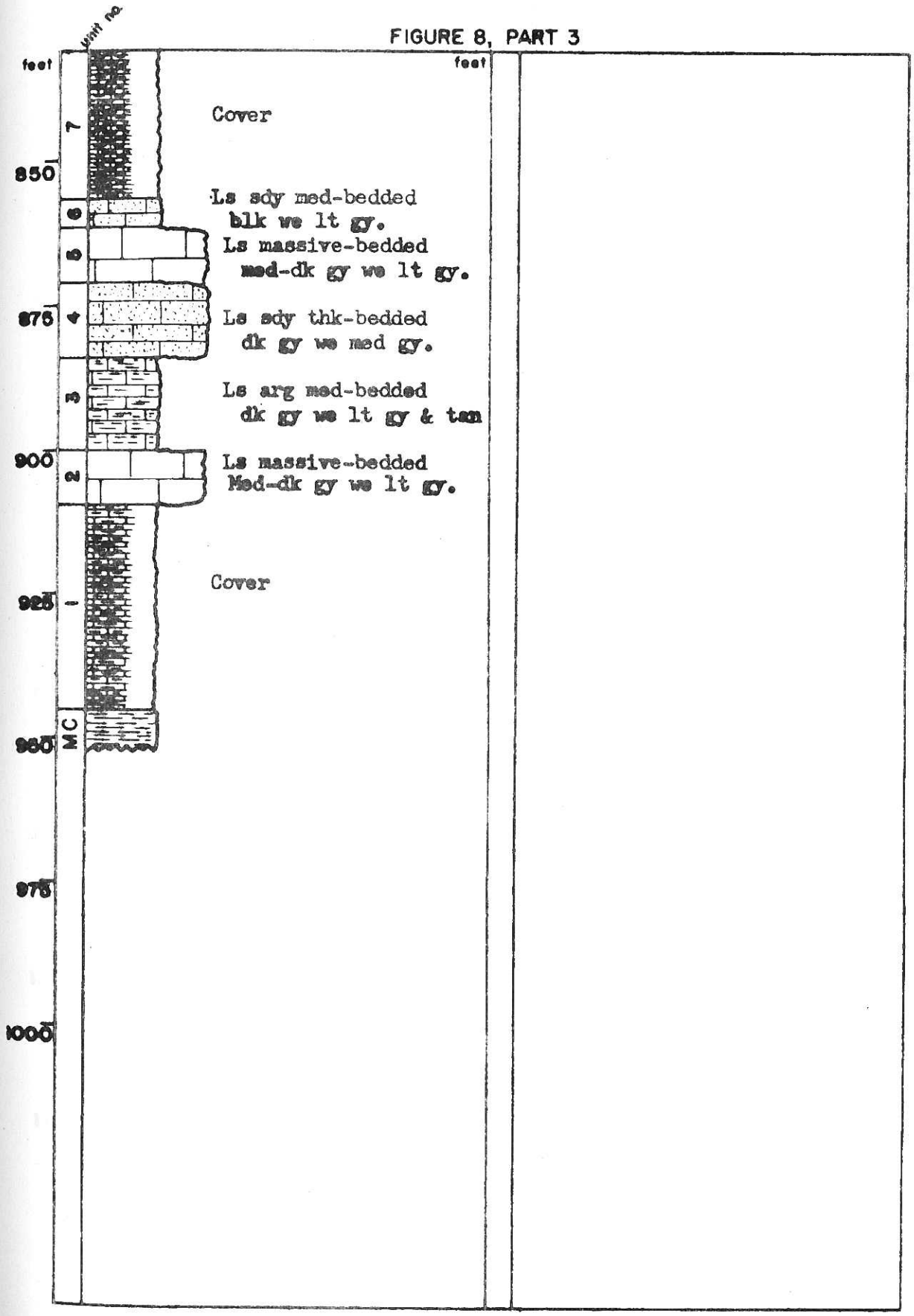


FIGURE 8, PART 3



STRATIGRAPHIC COLUMN OF THE THORPE HILLS AREA

OQUIRRH FORMATION, MORROWAN SERIES

SEC. 28, T. 7 S., R. 3 W. TOOELE COUNTY, UTAH

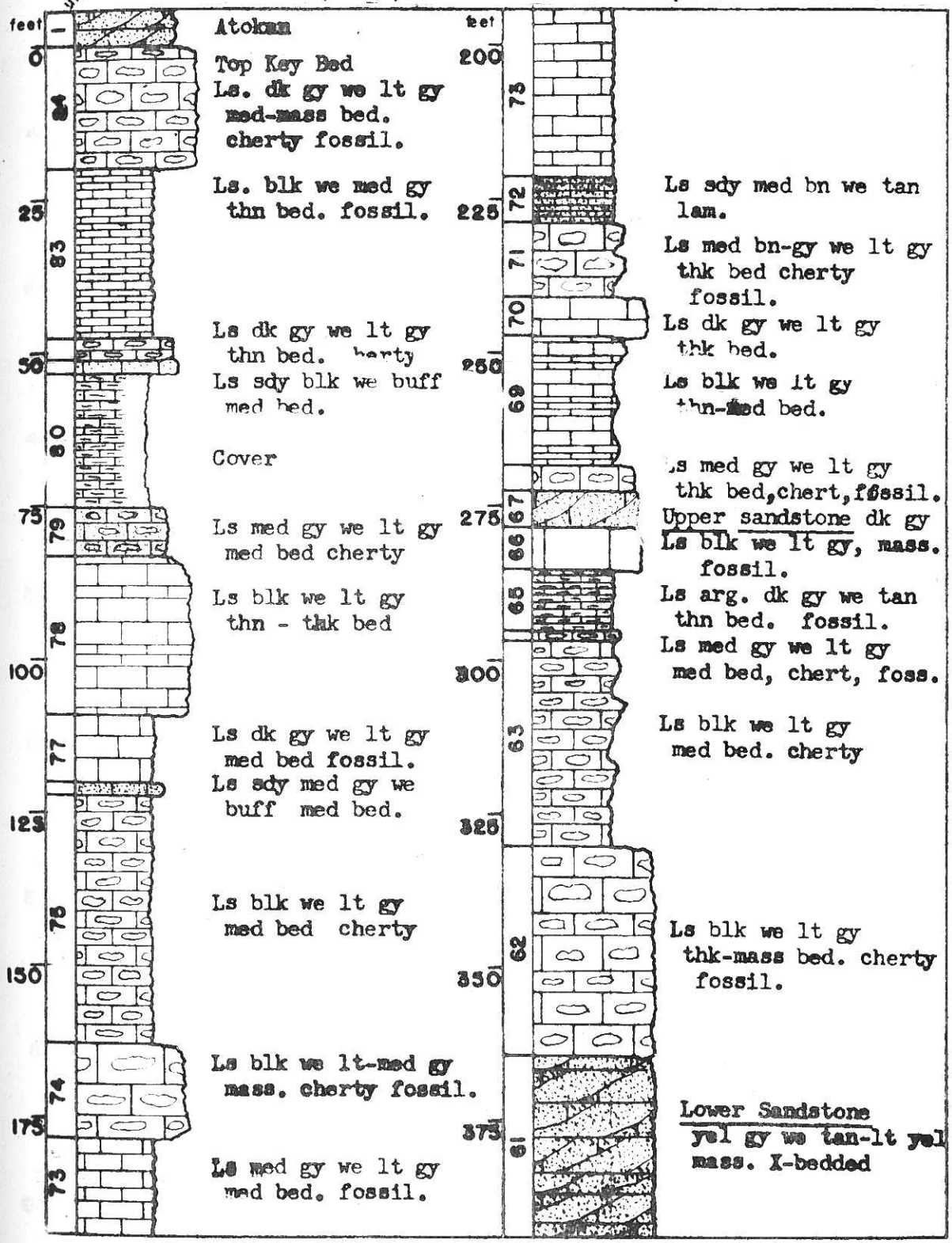


FIGURE 9, PART I

FIGURE 9, PART 2

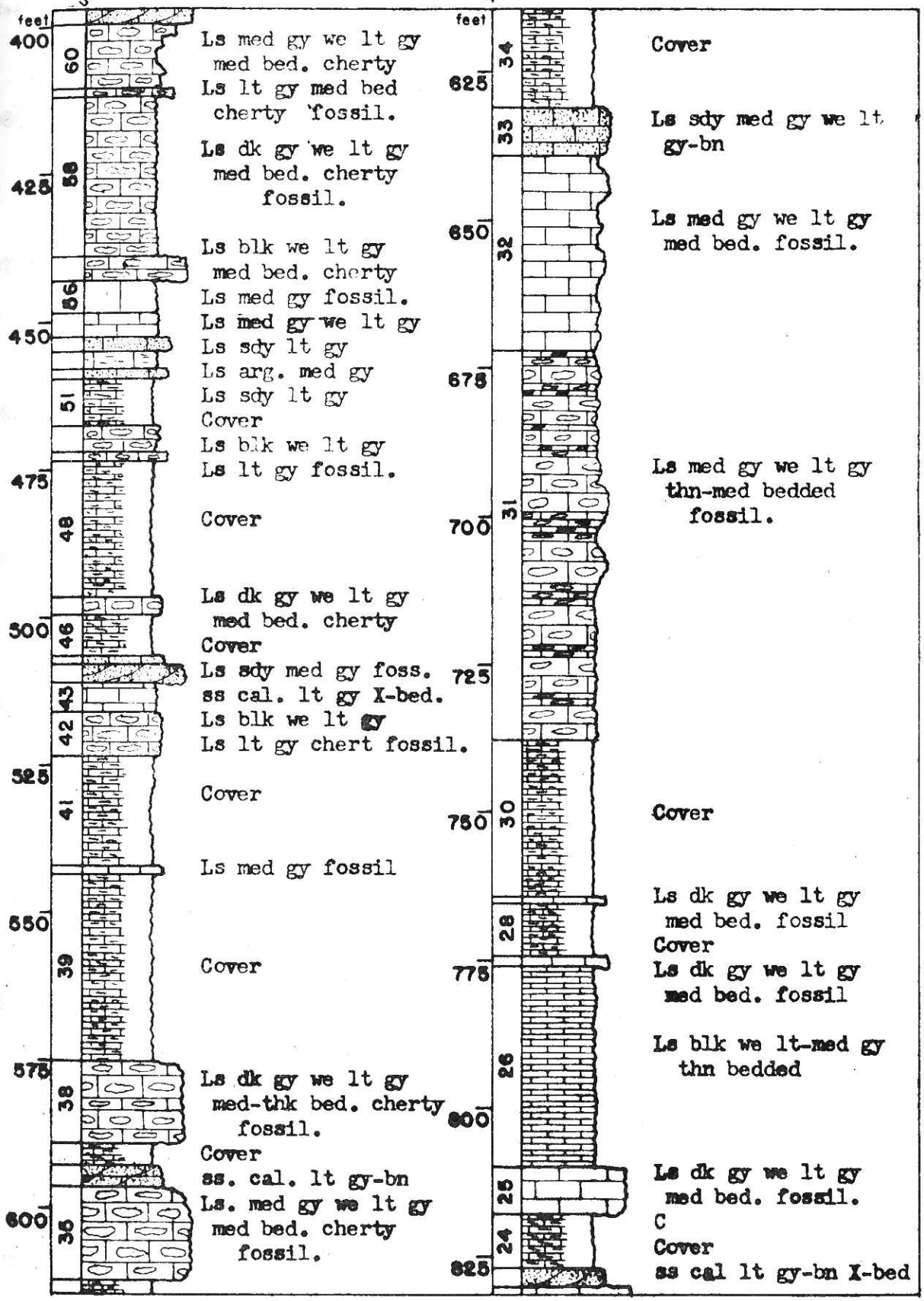
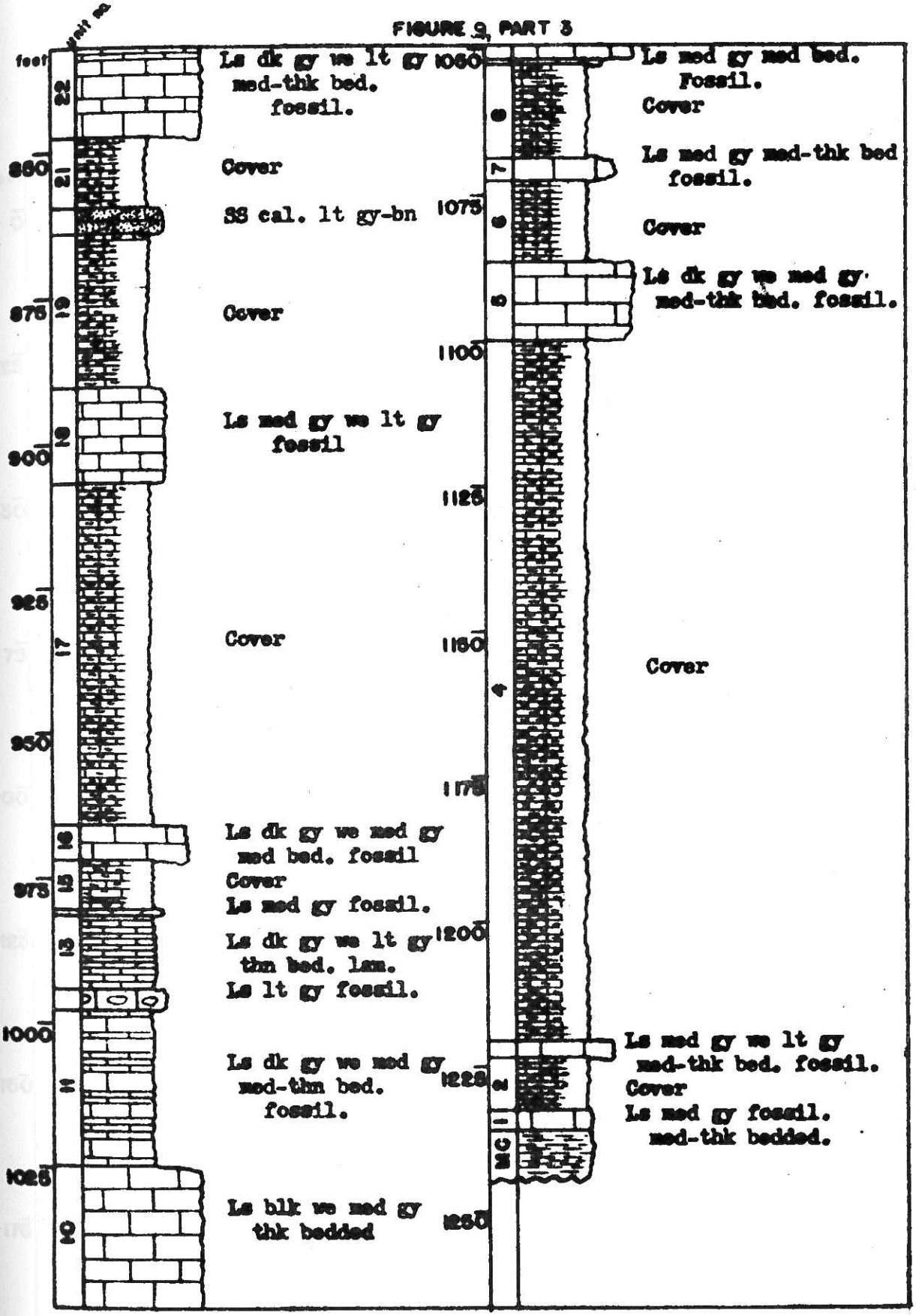


FIGURE 9, PART 3



STRATIGRAPHIC COLUMN OF THE OQUIRRH MOUNTAIN AREA
OQUIRRH FORMATION, MORROWAN SERIES
SEC. 10 T. 6 S. R. 3 W. UTAH COUNTY, UTAH

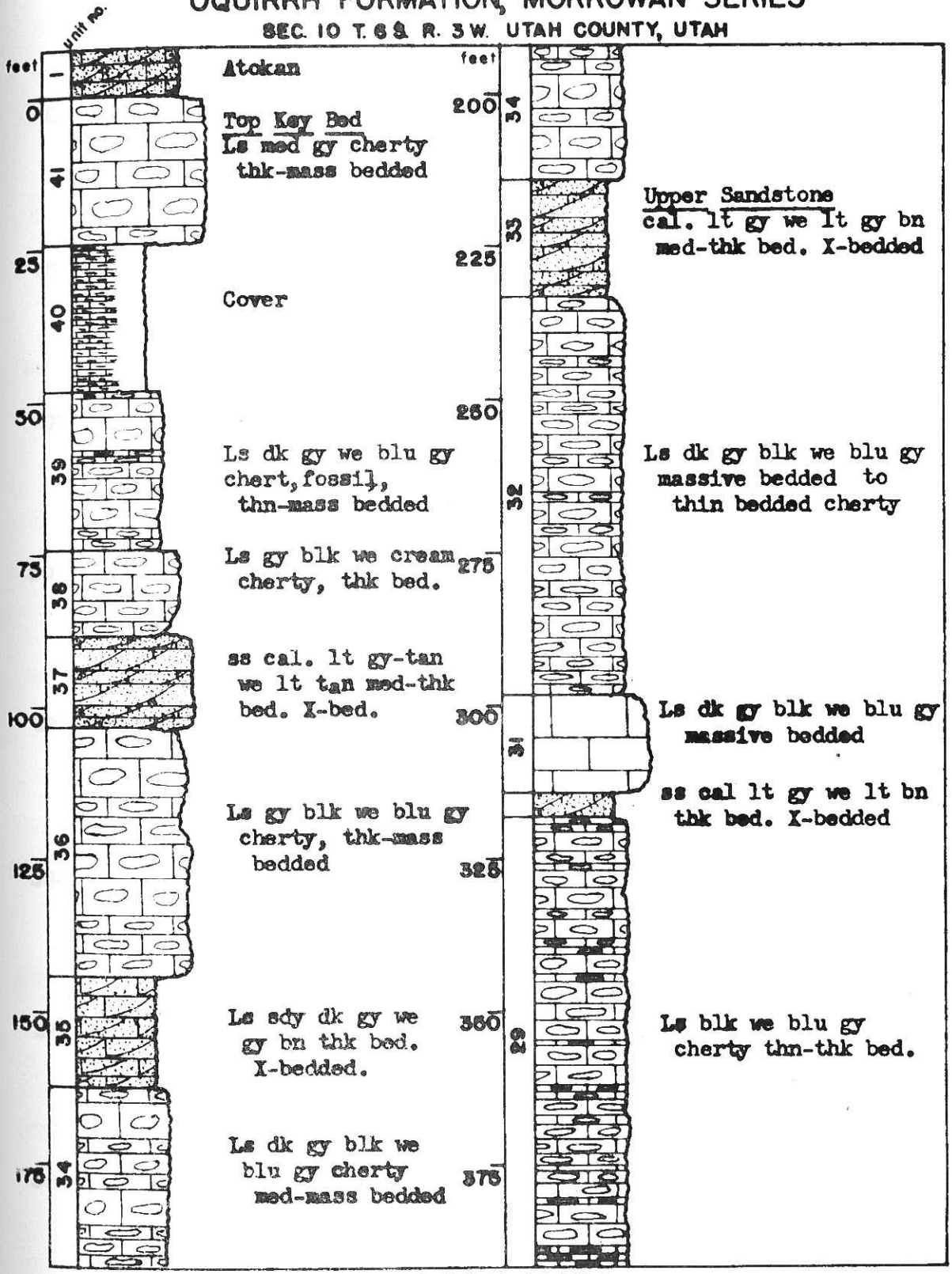


FIGURE 10, PART 1

FIGURE 10, PART 2

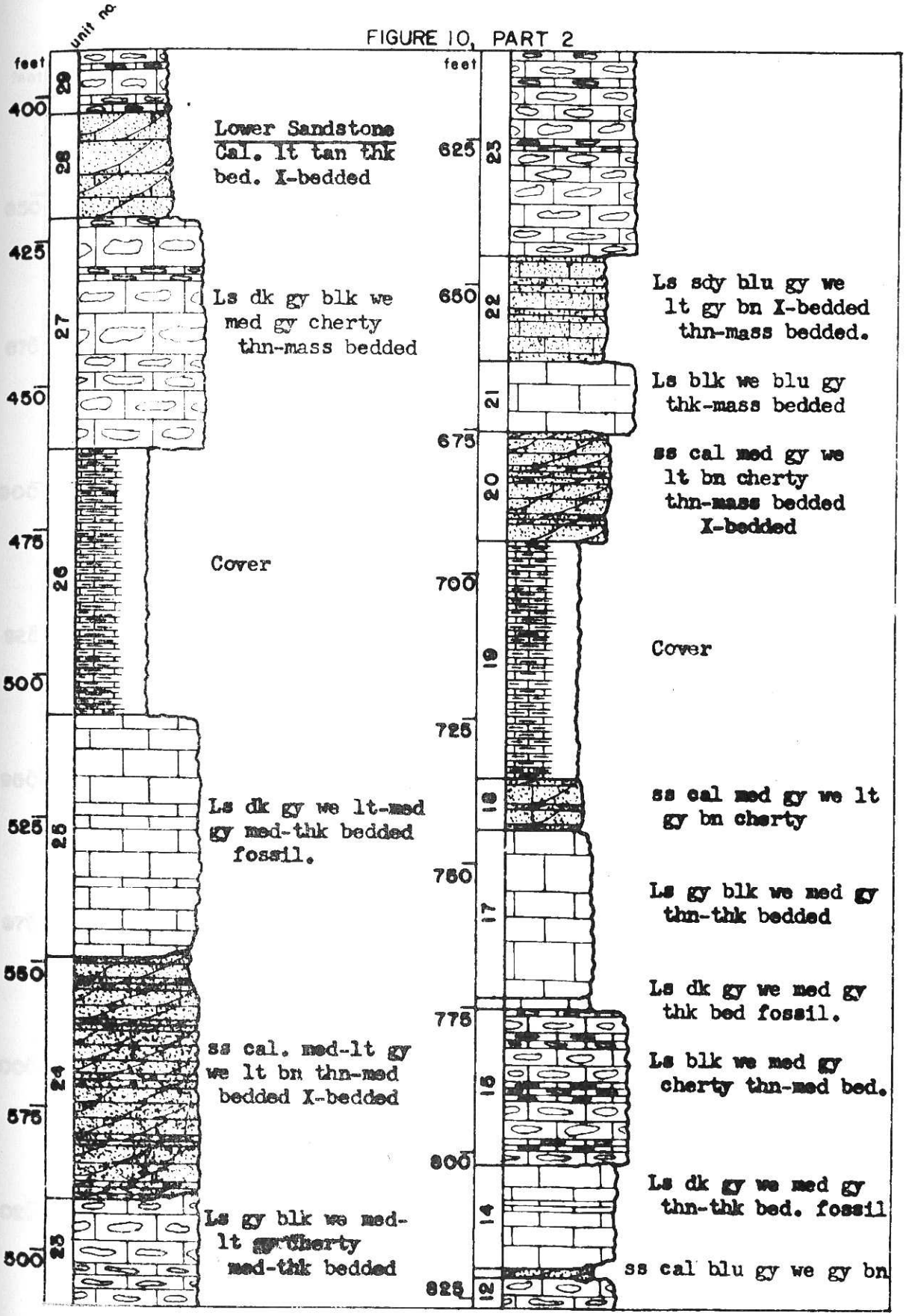
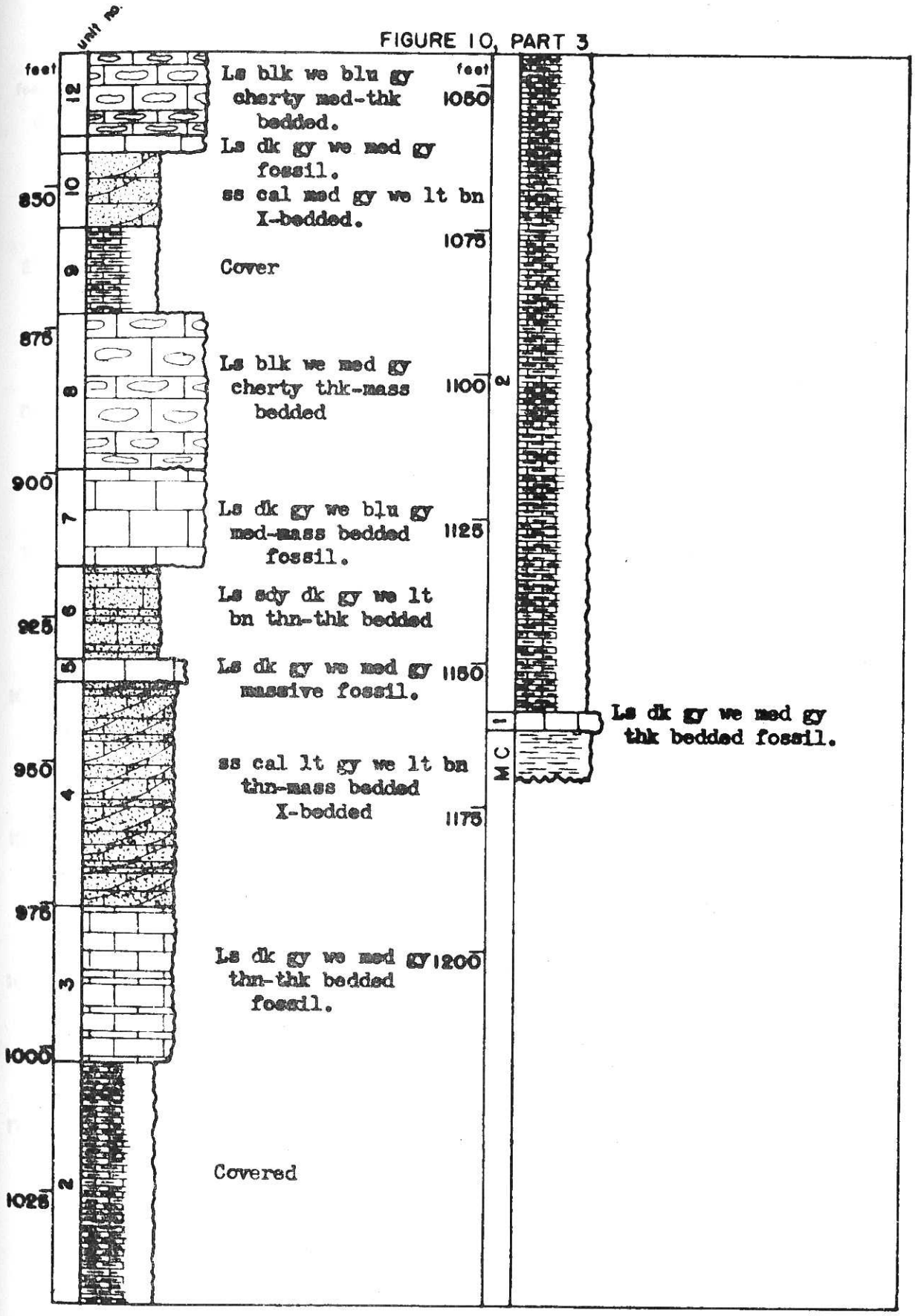


FIGURE 10, PART 3



STRATIGRAPHIC COLUMN OF THE LAKE MOUNTAIN AREA
OQUIRRH FORMATION, MORROWAN SERIES
SEC. 1, T. 7 S., R. 1 W., UTAH COUNTY, UTAH

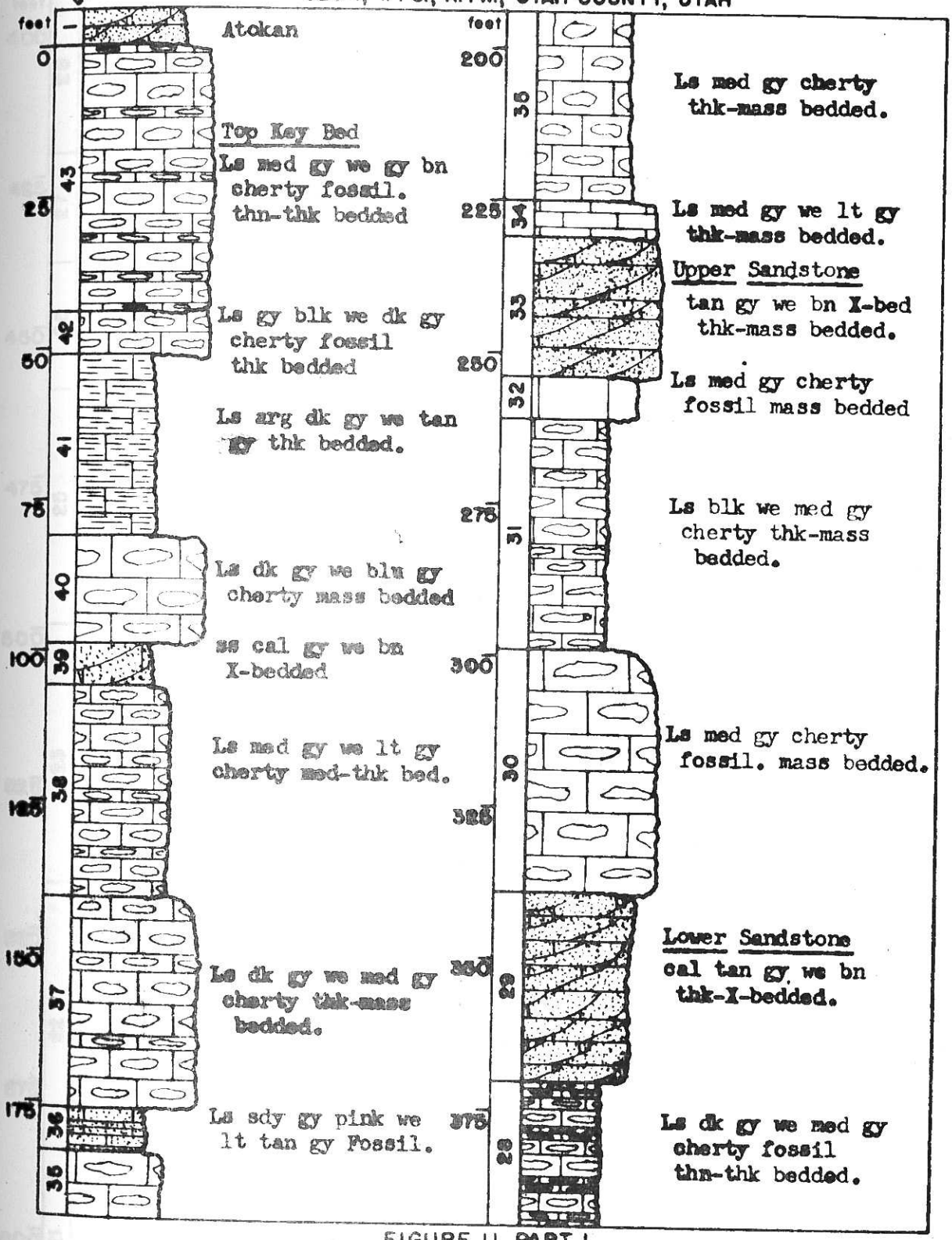


FIGURE 11, PART 1

FIGURE 11, PART 2

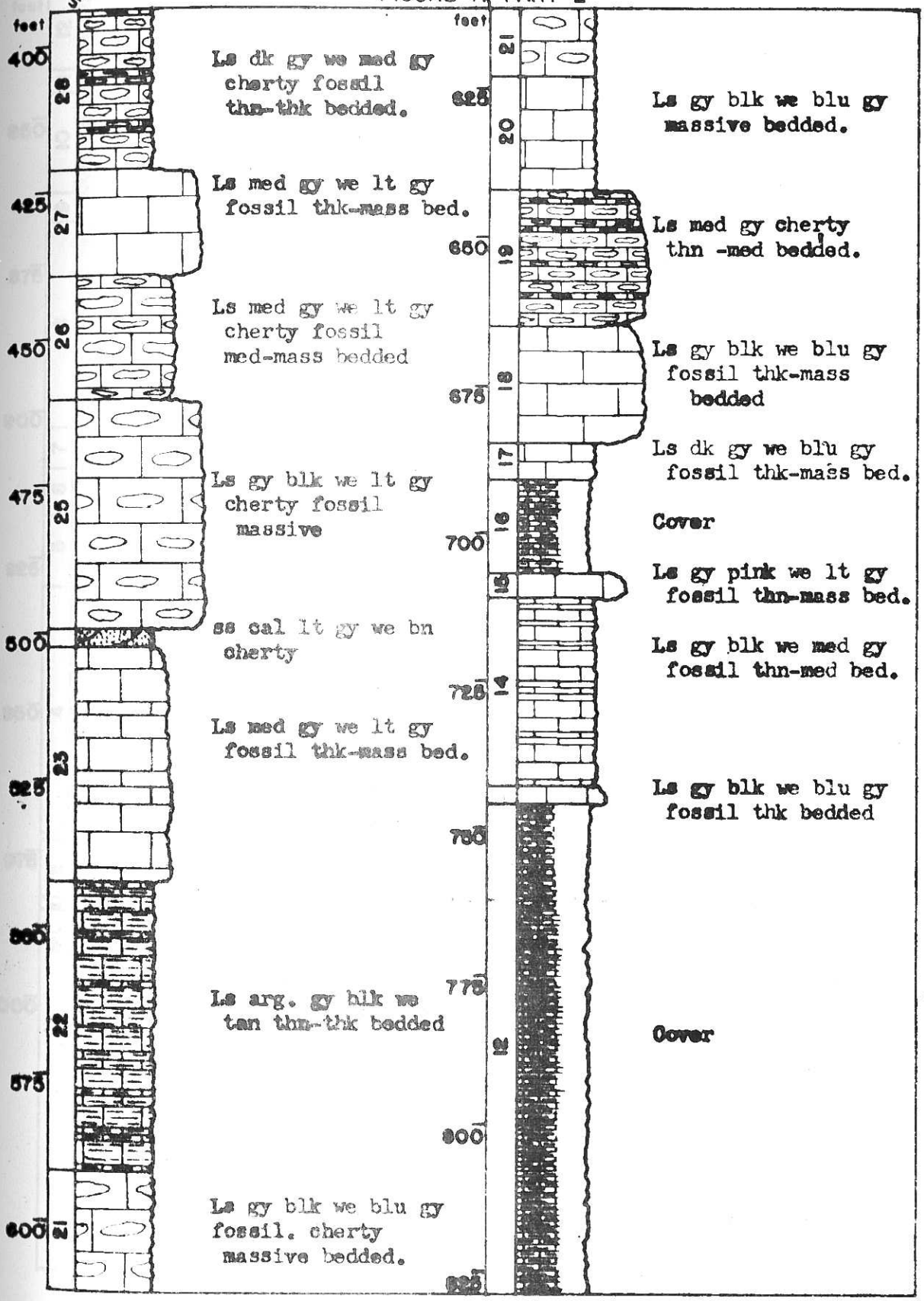
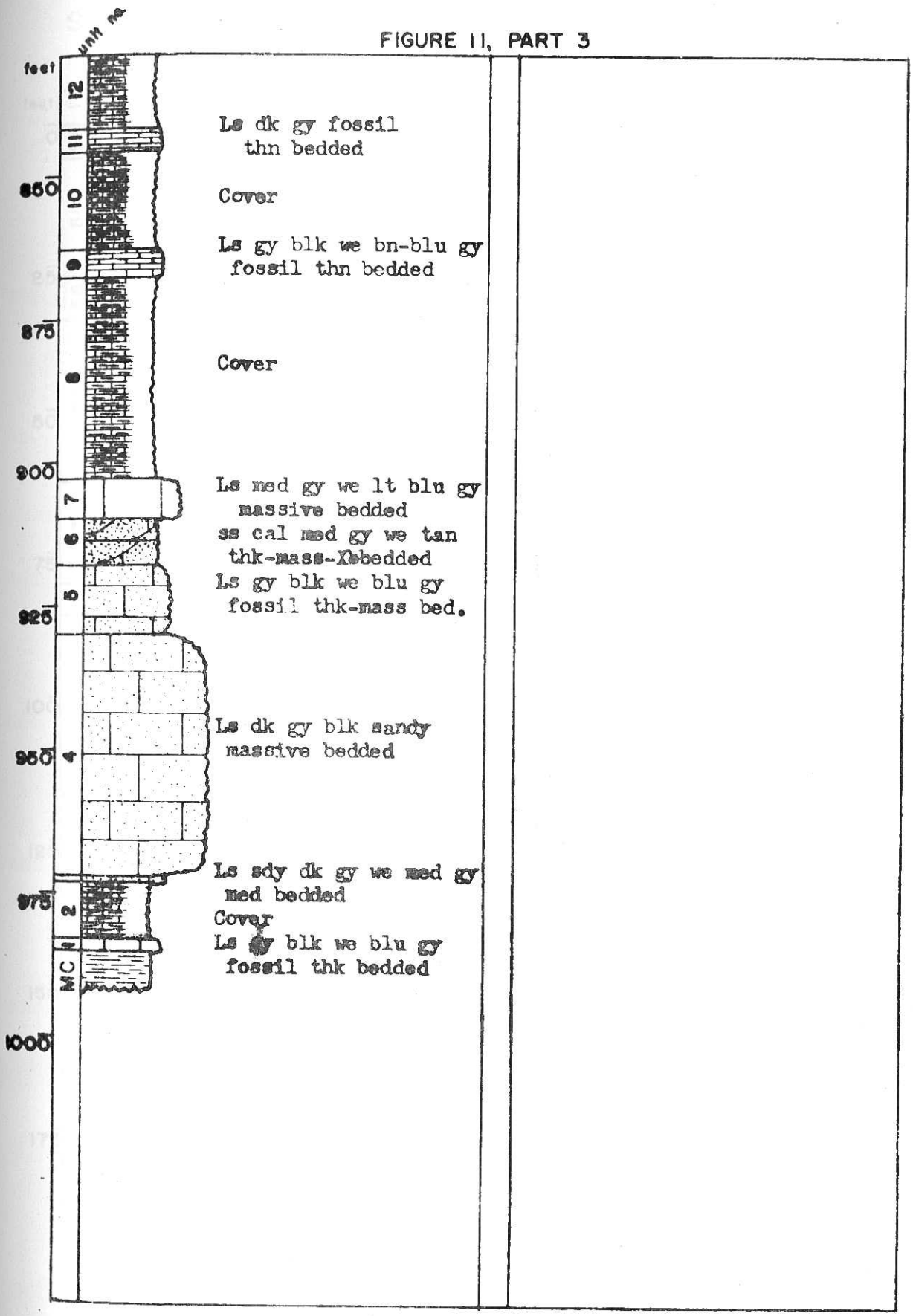


FIGURE 11, PART 3



STRATIGRAPHIC COLUMN OF THE TRAVERSE RANGE AREA
OQUIRRH FORMATION, MORROWAN SERIES
SEC. 5 & 8, T. 5S., R. 1W. UTAH COUNTY, UTAH

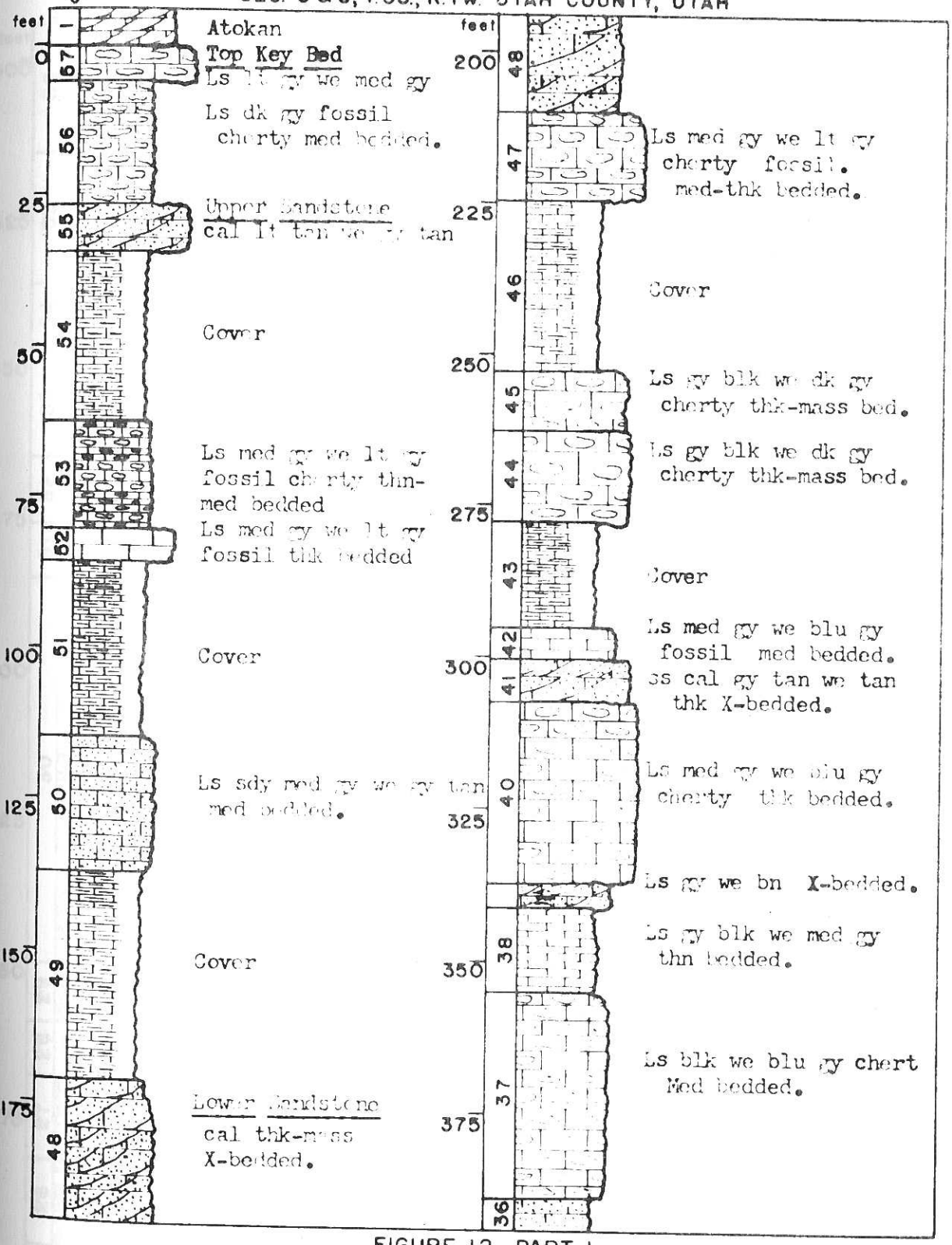


FIGURE 12, PART I

FIGURE 12, PART 2

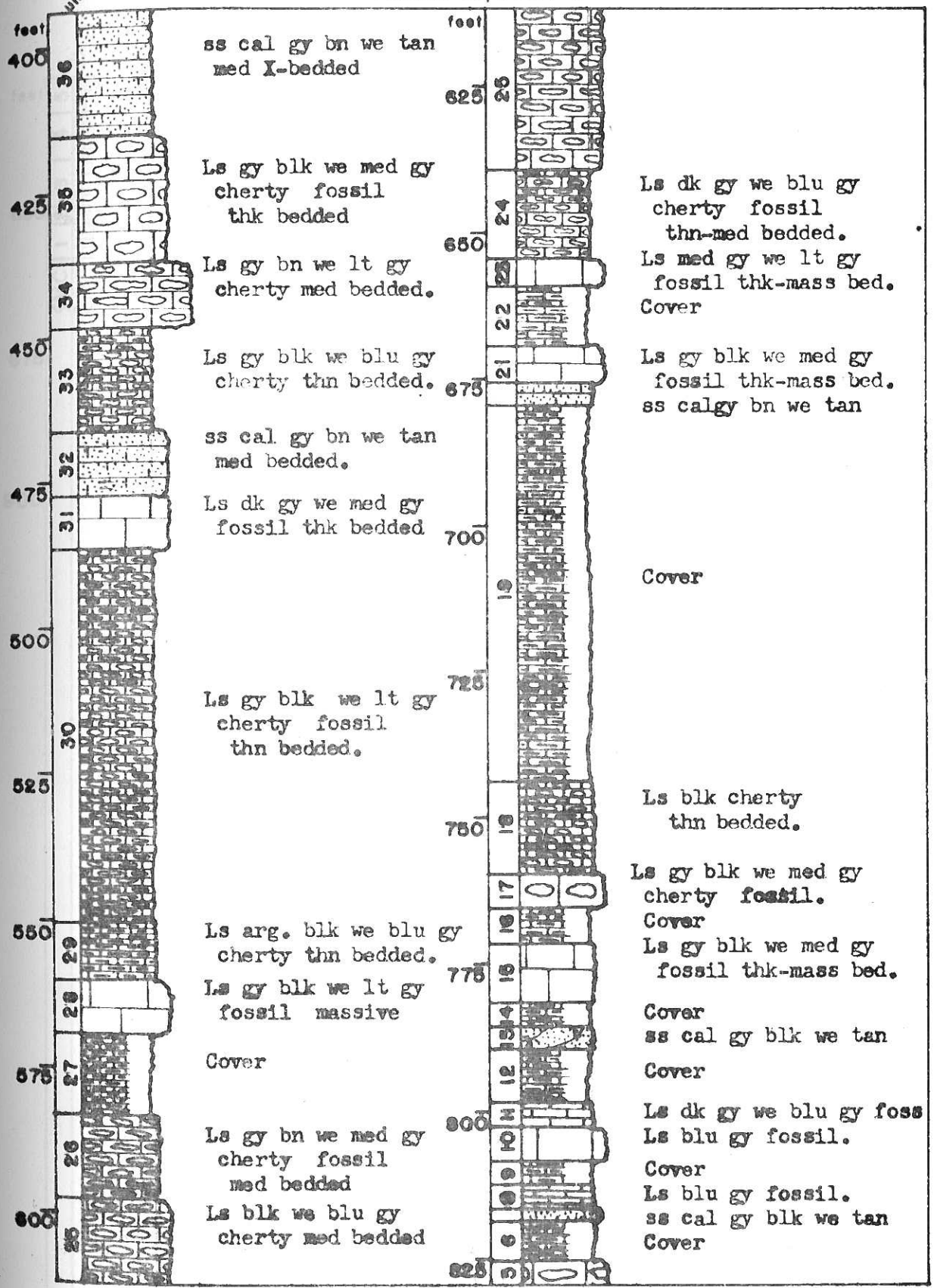
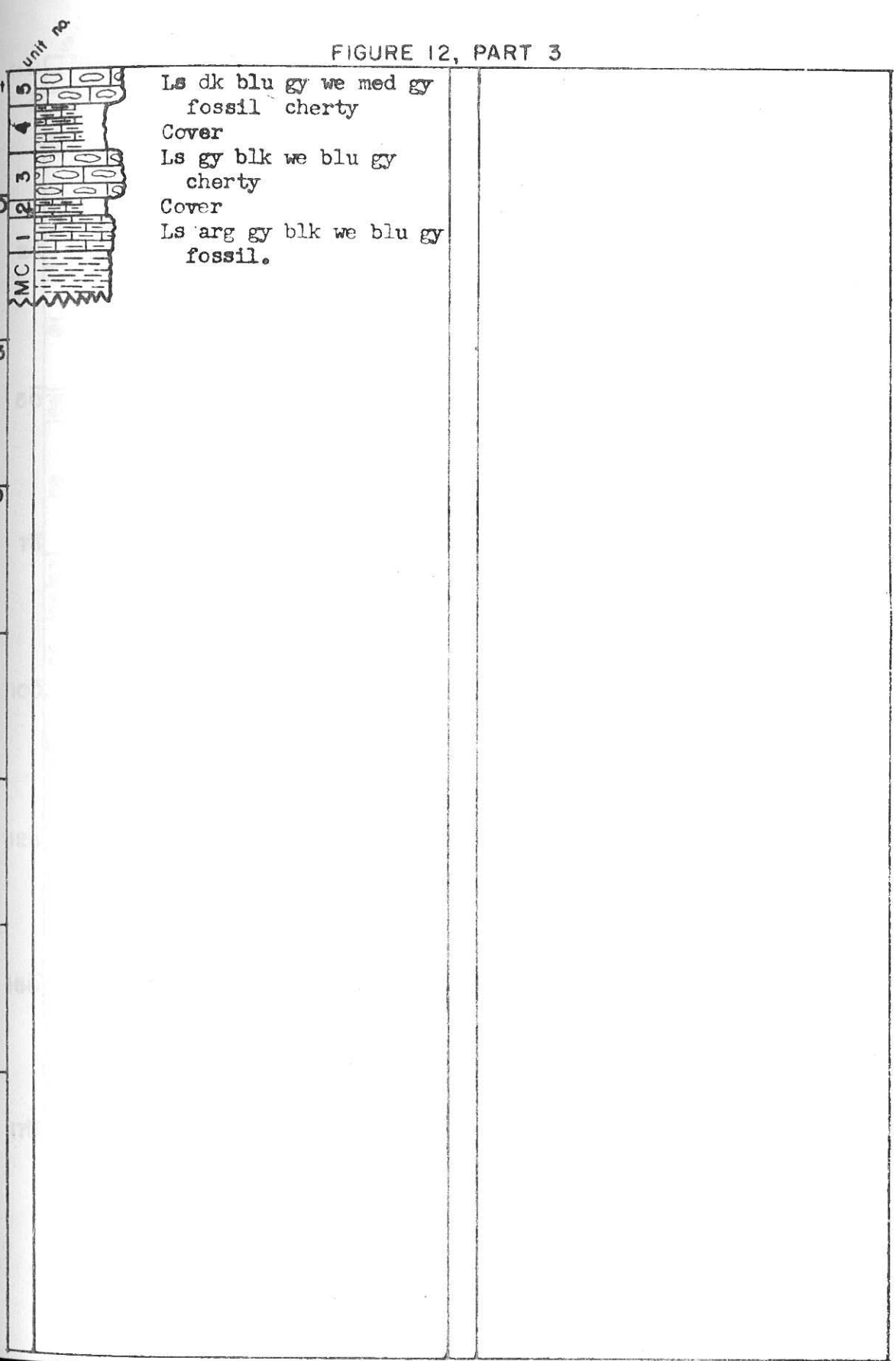


FIGURE 12, PART 3



STRATIGRAPHIC COLUMN OF THE PROVO CANYON AREA
OQUIRRH FORMATION, MORROWAN SERIES
SEC. 34, T. 5 S., R. 3 E., UTAH COUNTY, UTAH

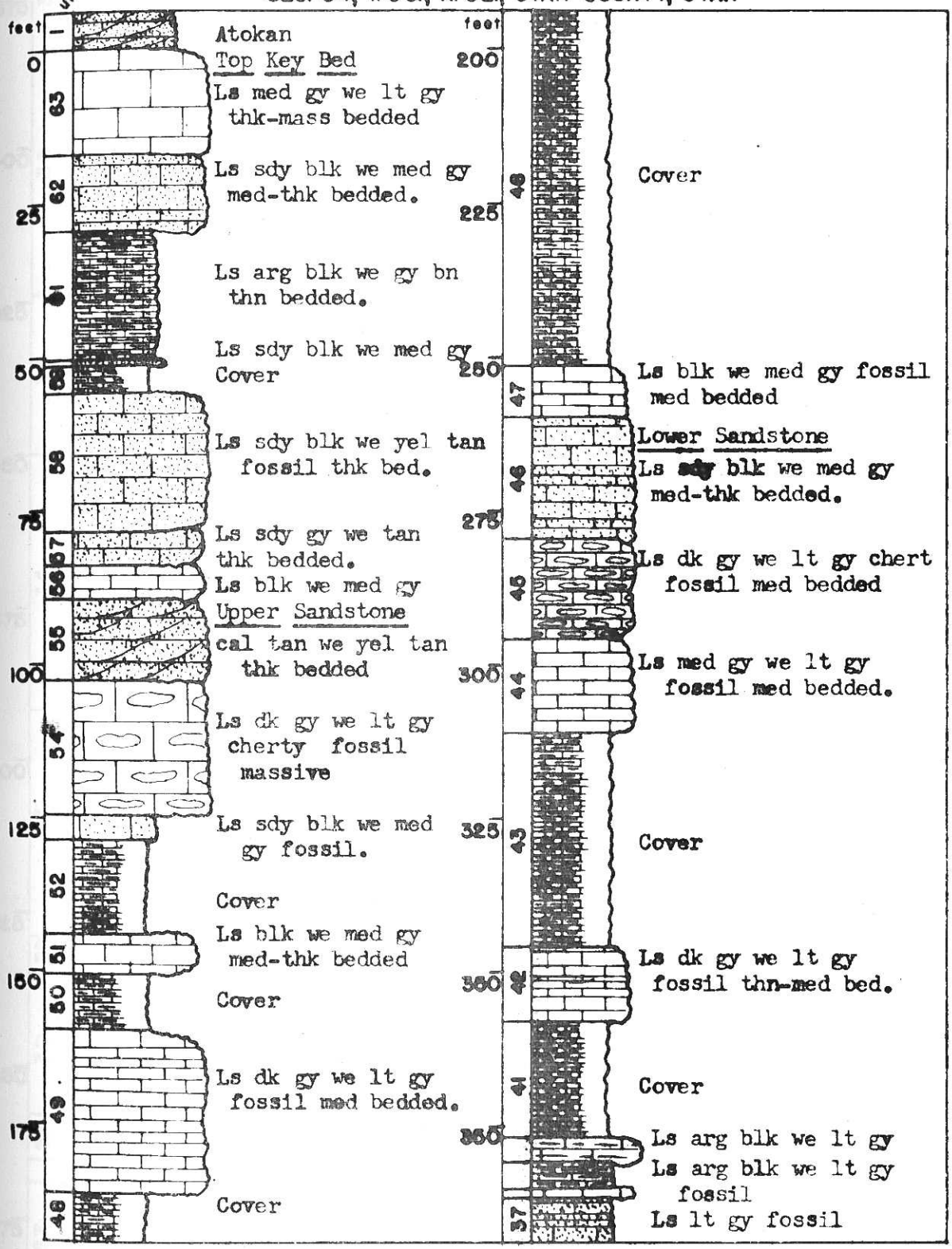


FIGURE 13, PART I

FIGURE 13 PART 2

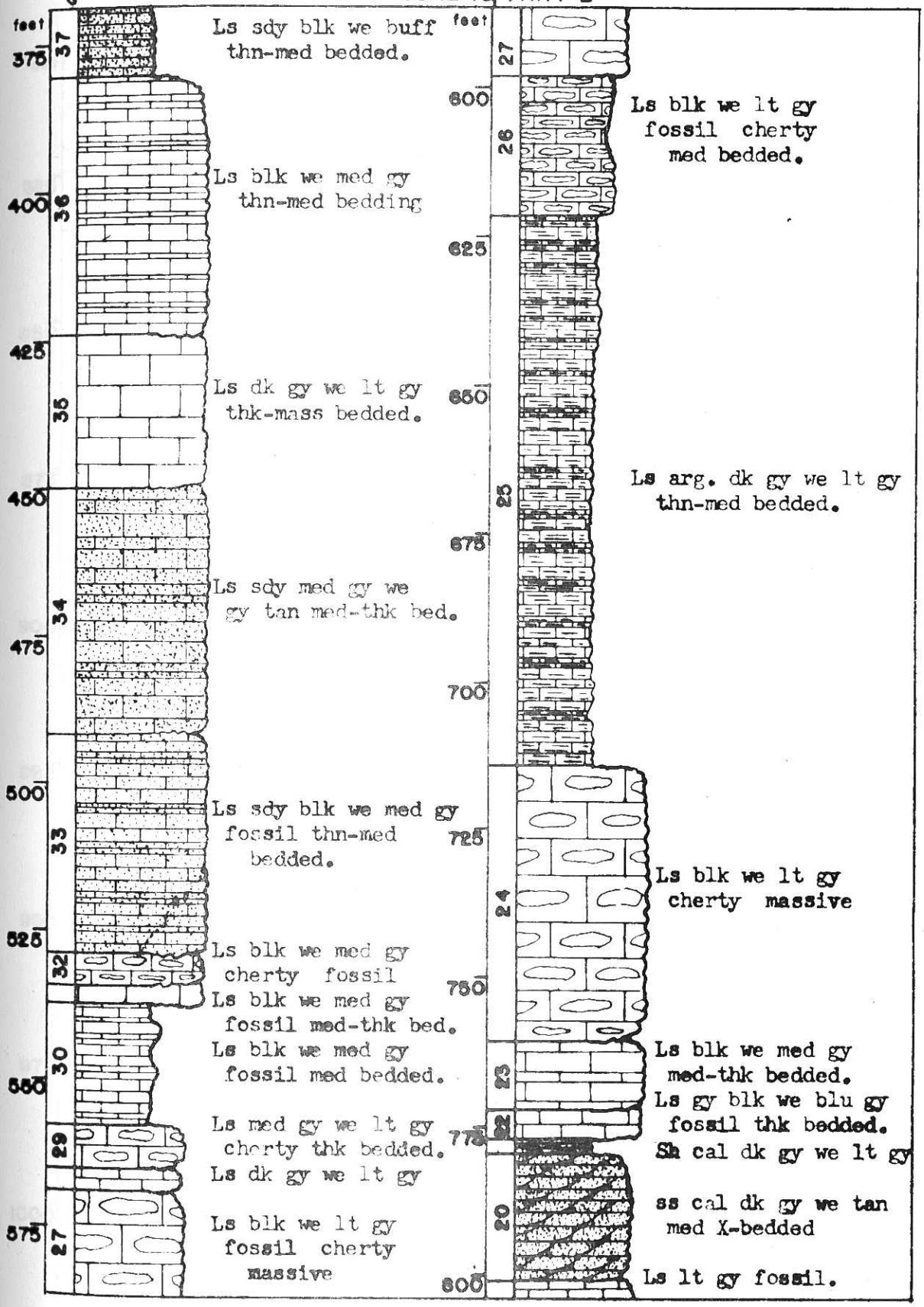
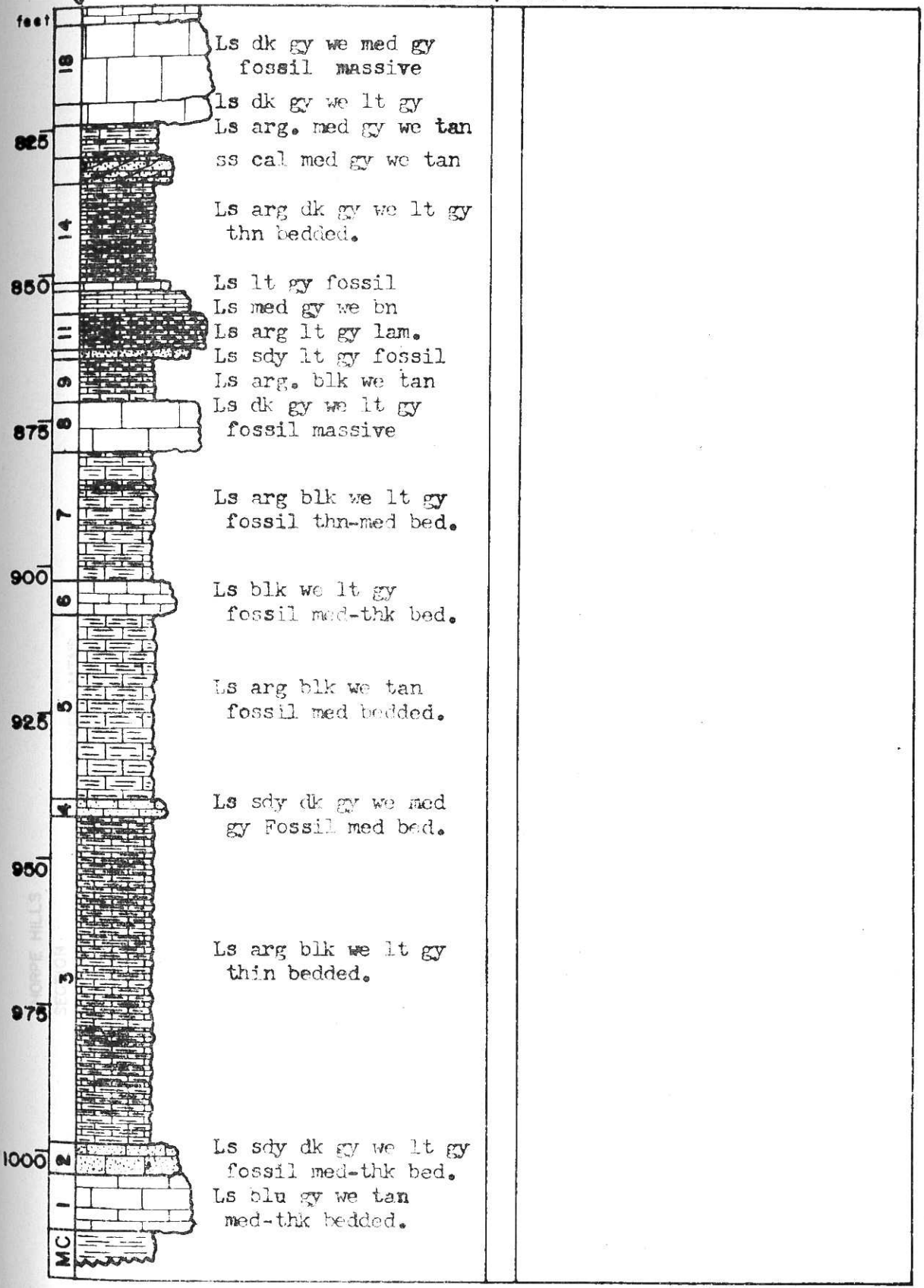
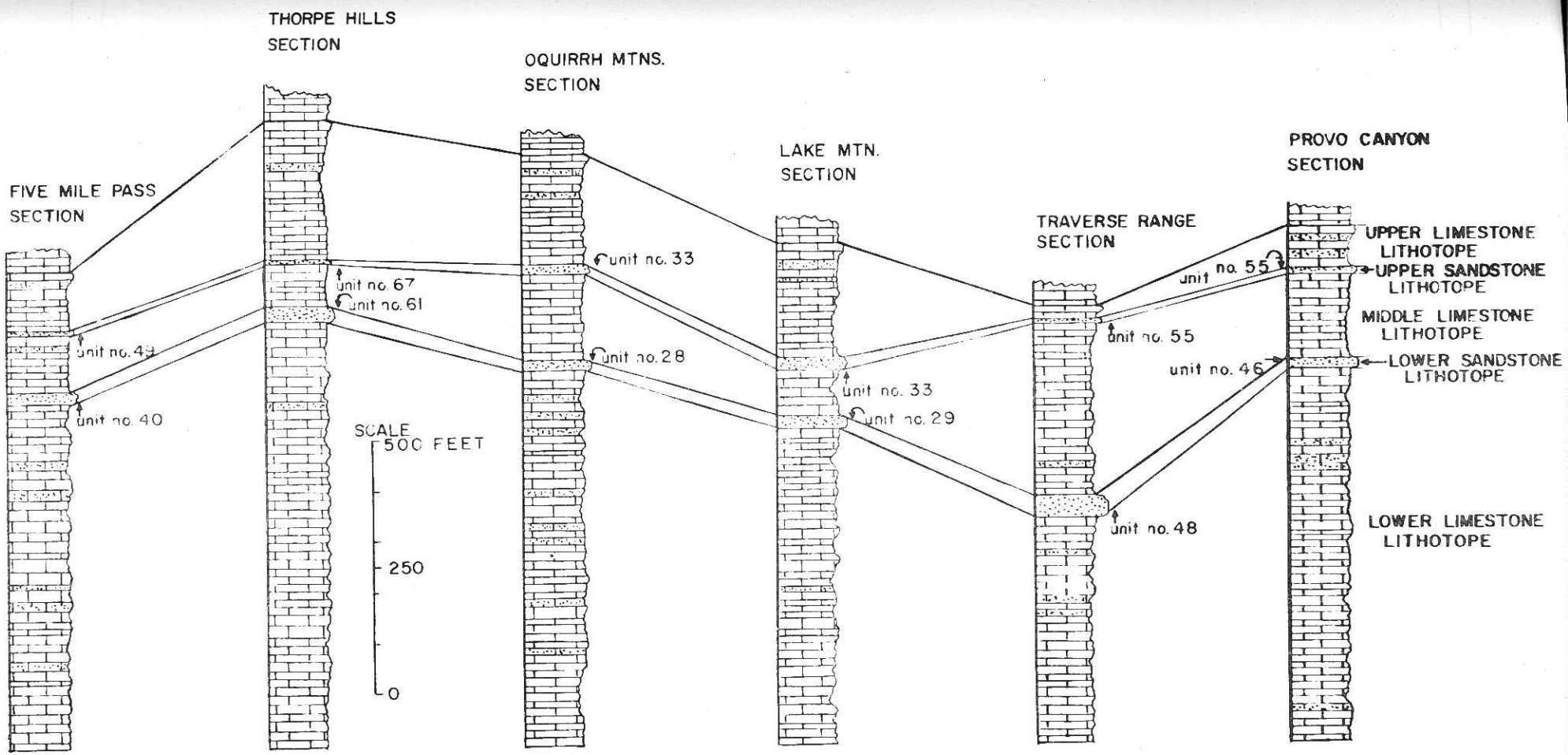


FIGURE 13, PART 3





GENERALIZED DIAGRAMMATIC STRATIGRAPHIC SECTIONS OF THE MORROWAN SERIES

(Plate I)

SYMBOLS

COVER

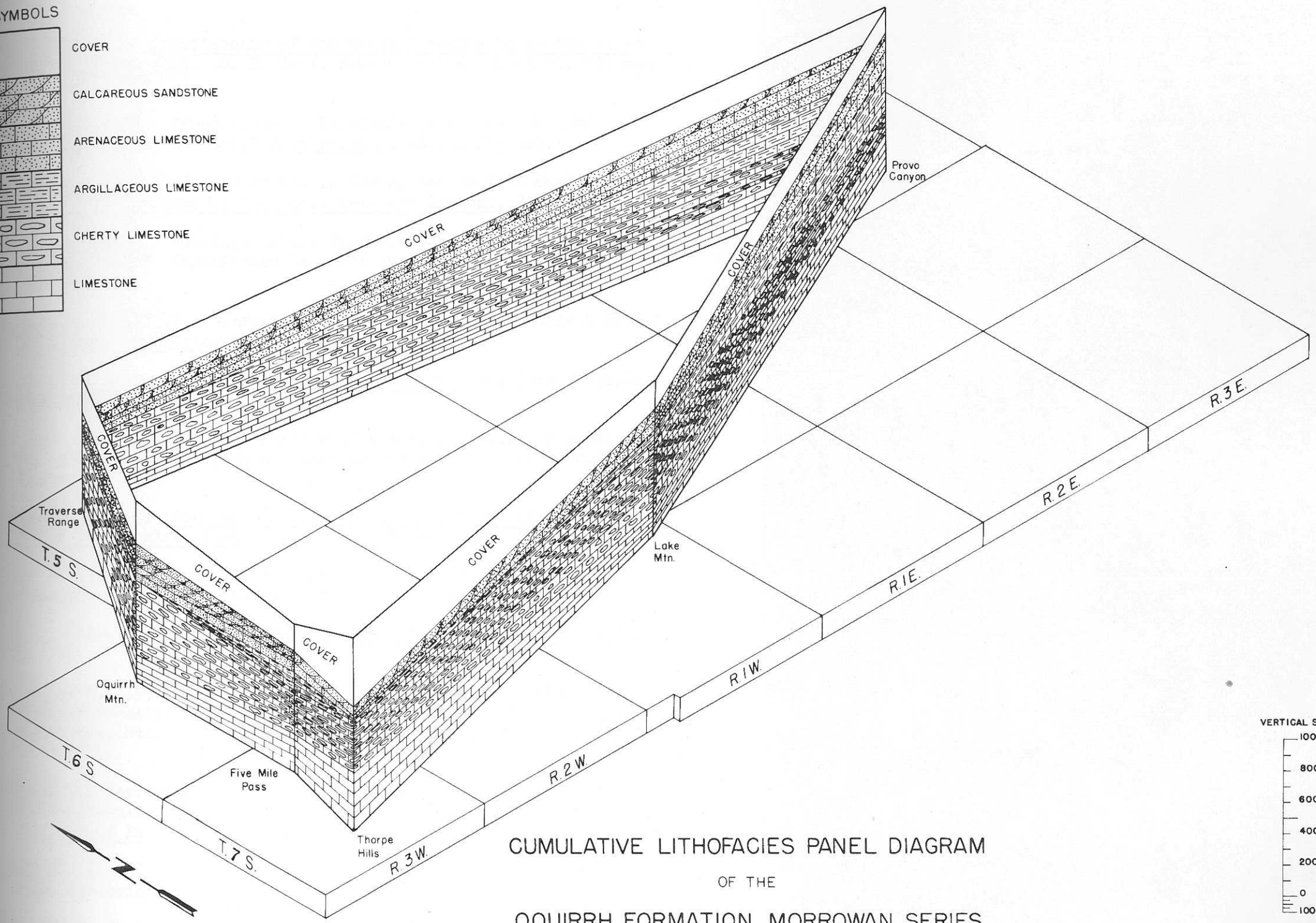
CALCAREOUS SANDSTONE

ARENACEOUS LIMESTONE

ARGILLACEOUS LIMESTONE

CHERTY LIMESTONE

LIMESTONE



CUMULATIVE LITHOFACIES PANEL DIAGRAM

OF THE

OQUIRRH FORMATION, MORROWAN SERIES

IN CENTRAL UTAH

VERTICAL SCALE

1000 FEET

800

600

400

200

0

100

0 1 2 3 4 5 6 MILES

HORIZONTAL SCALE

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