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CONTENTS

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Contents

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Permian Stratigraphy of Northeastern Nevada and Northwestern Utah*

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ABSTRACT.—Biostratigraphic studies in the eastern Great Basin indicate an aggregate thickness of Permian sediments of 6185 feet in the Gold Hill District, 5550 feet in the Pequop Mountains, and approximately 2050 feet in the northern Leppy Range. Substantial revision of Nolan's 1935 nomenclature in the Gold Hill District and modification of the terminology used in the Pequop Mountains and Leppy Range seems desirable. At Gold Hill the strata of Nolan's "Oquirrh Formation" can better be designated by the following formational names: Ely Limestone (Springeran-Derryan), Hogan Formation (Desmoinesian), Ferguson Mountain Formation (Virgilian-Wolfcampian), Pequop and Loray formations (Leonardian), Kiabab Limestone (possibly Guadalupean) and the Plympton and Indian Canyon formations (Guadalupean). This sequence, which is correlative to Nolan's "Oquirrh Formation," is overlain by the Gerster Formation. Deposition of Permian sediments was influenced by: (1) epeirgenic uplifts, (2) retreat and advance of Permian seas, and (3) presence of three major positive areas in the eastern Great Basin. Basis for these conclusions is the existence of several regional unconformaties, presence of evaporite sequences associated with normal marine limestones, lateral variation in lithology, and lateral variations in thickness of Permian formations. Lower Permian rocks (Wolfcampian, Leonardian) are dated on the basis of contained fusulinids, but more difficulty is encountered in dating upper Permian sediments due to lack of diagnostic fossils. The Gerster Formation is dated as Capitanian because it contains a diagnostic brachiopod fauna as well as the Capitanian age fusulinids *Reichelina* and *Codonofusiella*. No Ochoan age strata are known in the Eastern Great Basin.

CONTENTS

TEXT

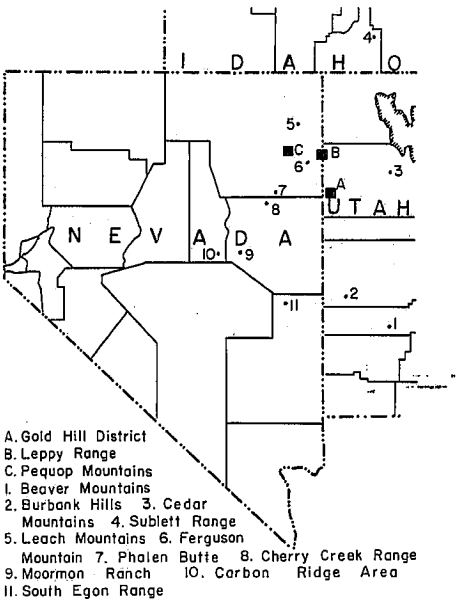
ILLUSTRATIONS

*A thesis submitted to the Faculty of the Department of Geology, Brigham Young University in partial fulfillment of the requirements for the degree Master of Arts.

INTRODUCTION

Location and Accessibility of Measured Sections

Four complete stratigraphic sections in seven traverses were measured for this study. Two of the sections are located in the Leppy range near Wendover, Utah-Nevada, one was measured in the Gold Hill Mining District, 40 miles south of Wendover, and one section is located in the Pequop Mountains, 30 miles west of Wendover (Text-fig. 1).



TEXT-FIGURE 1.—Index map showing location of investigated areas.

These sections are located as follows:

Section 1. *Leppy Range*: Traverse located five and one-half miles due north of Wendover in Section 29, T. 1 N., R. 19 W., Tooele County, Utah, and Section 22, T. 34 N., R. 70 E., Elko County, Nevada. B.Y.U. locality number 12042.

Section 2. *Leppy Range*: A traverse was made starting on the west side of A-1 Canyon and extending to the west. Increments of this traverse are in Sections 31 and 32, T. 34 N., R. 70 E. and in Sections 4 and 5, T. 33 N., R. 70 E., Elko County, Nevada. B.Y.U. locality number 12043.

Section 3. *Pequop Mountains*: One traverse was made along a spur located east of a large gravel pit excavated by the Western Pacific Railroad. This ridge is in Sections 34 and 35, T. 34 N., R. 65 E., Elko County, Nevada.

B.Y.U. locality number 12044. Another traverse was made in Indian Canyon, Section 21, T. 31 N., R. 65 E. B.Y.U. locality number 12045.

Section 4. *Gold Hill Mining District*: The upper part of the Permian section was measured in the vicinity of Gerster Gulch and Ferber Canyon, Sections 5 and 8, T. 7 S., R. 19 W., Tooele County, Utah. B.Y.U. locality number 12046. The lower part of the section was measured at Twin Peaks, Sections 12 and 13, T. 7 S., R. 19 W. B.Y.U. locality number 12047.

In addition, eleven localities were visited during the Summer of 1959 in connection with another project.

Most of the areas visited during the summer of 1959 and those areas listed above can be reached by truck or sedan on national or state highways and unimproved dirt roads. Caution should be used in visiting these areas as some of the unimproved dirt roads are impassable in inclement weather.

Purpose and Scope

Main objectives in this study of the Permian System have been to decide what nomenclature should be applied in each of the localities, the age of the formations, what correlation can be effected from place to place within this region, and what the conditions of sedimentation were during any given epoch of time. In large measure these goals and objectives have been fulfilled.

Pervious Investigations

The geology of the Gold Hill District was described by Nolan in 1935. Other geologists studied this district prior to Nolan, but their contributions deal with economic geology only. Snelson (1955 *ms.*) mapped the southern part of the Pequop Mountains and Thoreson is currently working in the northern Pequop Mountains on a graduate thesis for the University of Washington. Steele (1959 *ms.*, 1959, 1960) has made notable contributions to regional stratigraphy and related sedimentary tectonics of eastern Nevada and western Utah. Gerald B. Robinson Jr. (1961) is engaged in a mapping project and fusulinid study of the central Pequop Mountains, and Yasdan Mollazal, (1961) is studying carbonates of Ely Limestone of that area. Both studies are being done at B.Y.U. concurrently with present investigation.

Shaeffer & Anderson (1960) have published papers on the geology of the Silver Island Mountains. The Leppy Range comprises the southwestern to western segment of the Silver Island Mountains.

Field Work

Field work was done during the late summers of 1959 and 1960 and consisted of measuring Permian strata with a 100-foot steel tape and a Brunton Compass. Lithologic descriptions were recorded during the measuring procedure, utilizing note forms modified after those of Wengerd (1956, p. 42-48). The number of each unit was marked at its base with yellow paint. Samples of distinctive rock types in the unit were collected and marked with a letter indicating relative position in the unit. At least one lithologic sample was taken for every five stratigraphic feet measured. Fusulinids and other fossils were carefully collected and stratigraphically located.

Laboratory Methods

Approximately 500 thin-sections of selected samples were prepared on one inch by three inch glass slides. The majority of samples were chosen because

they are lithologically representative of the unit from which they were collected. Many of the slides were ground to show oriented fusulinids. Cellulose acetate peels and insoluble residues were made of selected samples in the petrographic investigations.

Acknowledgments

Drs. Harold J. Bissell and Lehi Hintze served in an advisory capacity during this thesis study. Dr. Bissell suggested the problem and gave the writer valuable assistance in both field work and in preparation of the manuscript.

The writer is grateful to Gerald B. Robinson, Jr. with whom the measuring and sampling of the stratigraphic section in the Pequop Mountains was accomplished. Mr. Robinson also helped in the identification of fusulinids during this study.

Field expenses were partly defrayed by a grant from the Geological Society of America.

Thanks are extended to my sister, Mrs. Lola Marie Bunker, for typing the manuscript.

STRATIGRAPHY

General Statement

Measurements of Permian strata for this study show that approximately 5500 feet of marine sediments were deposited in the Pequop Mountain area, about 5700 feet of similar materials accumulated in the vicinity of Gold Hill, 3300 to 3800 feet were deposited in the western Leppy Range area northwest of Wendover, thinning to 2300 feet six miles farther north.

Strata of these areas are divided into seven formations, one of which is Pennsylvanian-Permian, and the remainder are entirely Permian. Four of the formations are part of the Park City Group; one is new. Main rock types are limestones, dolomites, siltstones, and orthoquartzites, with shales, sandstones, bedded cherts, and evaporites occurring in lesser quantity. Three detailed columnar stratigraphic sections have been prepared to illustrate lithology and relationships in the areas investigated.

Pennsylvanian System

Ely Limesetone

Ely Limestone was named by Lawson (1906, p. 295) for thick-bedded, cherty gray limestones of the Robinson (Ruth) mining district a few miles west of Ely, Nevada. Spencer (1917, p. 26-27) redefined the formation, by placing Mississippian Chainman Shale rather than Devonian carbonates at the base, but left the upper boundary vaguely defined at the base of Arcturus Formation. Pennebaker (1932) placed the upper contact of the Ely at the base of a thick yellow silt and sand section, formerly termed Arcturus Limestone but named it Rib Hill Formation. Steele (1960, p. 100) discussed problems relating to misuse of Ely and related formations in and near the type locality, and so proposed that a reference section for this formation be designated in the Moorman Ranch section. As now properly defined, Ely Limestone is entirely Early to Medial Pennsylvanian and at the reference section (Sections 12 and 13, T. 17 N., R. 58 E. and a small portion of adjacent sections 7 and 18, T. 17 N., R. 59 E., White Pine County—not sections 7 and 8 as reported by Steele), is underlain by Early Springeran Illipah Formation (Bissell, 1960, p. 1435) and overlain by an unnamed sequence (Lane, 1960, p. 115). Robinson (1961)

has named this sequence the Hogan Formation for a sequence of Desmoinesian siltstone in the Central Pequop Mountains.

Hogan Formation

Immediately below the Medial Pennsylvanian or "sub-Strathearn" unconformity (Dott 1955, p. 225, 226) lies a sequence of yellow and tan silty limestones and calcareous siltstones of Desmoinesian age. These siltstones and limestones are present in at least three of the localities visited in 1959. The unconformity is more extensive in certain areas than in others accounting for absence of the siltstone facies. They occur in each of the sections measured for this study, however, most of these exposures of Desmoinesian rocks are restricted to an area outlined by Steele (1960, p. 92) as the Butte-Deep Creek Trough. Steele has described Desmoinesian rocks in th northern end of the Butte Mountains, Pequop Mountains, Cherry Creek Mountains, Shell Creek Range, and in the Ruth Mining District.

Steele has included these siltstones and limestones in the Ely Formation, but Lane (1960, p. 115, 116) referred to them as "unnamed", and restricted the Ely Formation to those carbonates lying stratigraphically below these siltstones and above the Chainman Shale. Robinson (1961) named this section of siltstones and limestones the Hogan Formation and designated the type section in the Pequop Mountains.

Chaetetes favosus and *Caninia torquia* are present in this formation. The writer collected *Wedekindellina* sp. (Desmoinesian) in the Leppy Range and the Pequop Mountains, and Bissell (personal communication) collected this form from the Gold Hill District.

Strathearn Formation

Dott (1955, p. 2248-2255) defined the Strathearn Formation for grayish yellow-weathering, silty limestones, calcareous quartz siltstones, and thin, commonly cross-bedded chert-pebble conglomerates. The type section is located four miles southeast of the Strathearn Cattle Company Ranch in the Humboldt Valley, Elko County, Nevada approximately ten miles west of Elko. Fusulinids are abundant in the formation at the type section and include several species of *Triticites* and *Schwagerina.* In the Elko area basal strata of the Strathearn Formation are Missourian as shown by presence of *Triticites* cf. *T. irregularis* (Staff). Higher in the section *Triticites* cf. *T. cullomensis* Dunbar and *Triticites* aff. *T. meeki* (Möller) prove presence of Virgilian rocks, and an Early Wolfcampian for the upper part of the Strathearn Formation is indicated by the presence of *Schwagerina* cf. *S. providens* Thompson & Hazzard and *Triticites* cf. *T. ventricosus* (Meek & Hayden). Pennsylvanian fusulinids only were found in the Strathearn Formation of the Leppy Range. Berge (1960) also assigned all of this formation (or its correlative, at least) at Ferguson Mountain entirely to the Upper Pennsylvanian. The Strathearn Formation is not present in the Pequop Mountains, nor in the Gold Hill Mining District.

Pennsylvanian-Permian Systems

Ferguson Mountain Formation

Berge (1960, p. 18-19) named the Ferguson Mountain Formation for a thick sequence of carbonates which overlies the Strathearn Formation or Strathearn-equivalent strata. Type section is at Ferguson Mountain in Sections 21 and 22, T. 30 N., R. 69 E., Elko County, Nevada. This section shall be referred to frequently since it is located in the approximate central part of the

area under consideration in the present paper. Berge describes the Ferguson Mountain Formation as an approximate but not exact time-rock formation. On his columnar stratigraphic section Berge places the lower boundary of this formation several hundred feet below the Pennsylvanian-Permian time boundary, and the upper limit at the base of a distinctive coral biostrome. Berge reports primitive forms of the fusulinid *Parafusulina* (Early Leonardian) 269 feet below this coral biostrome thus making the Ferguson Mountain Formation time-transgressive. Berge assigned a total thickness of 1986 feet to the formation of which 1718 feet was reported to be Wolfcampian and the remaining 268 feet Leonardian. On the columnar section however, he shows the formation to be 2185 feet thick of which 268 feet obviously is Leonardian, 1718 feet Wolfcampian, but the lower 199 feet is Virgilian. This disparity between Berge's columnar section and text discussion seemingly resulted when changes were made in the columnar section due to additional fusulinid data, but were not made in the text. That is, the pages of the text were off the press before the section was completed and evidently were not corrected in light of additional paleontologic data. Correct thickness of 2185 feet should be noted for Ferguson Mountain Formation.

Distribution... The Ferguson Mountain Formation has been measured for this study in the Pequop Mountains, the Leppy Range, and in the Gold Hill District. In addition, this formation was measured during the summer of 1959 in the Cherry Creek Range north of Ely, and in the Leach Mountains near Montello, Nevada. Several field excursions were made to the type area with Mr. John S. Berge and Mr. Lyle M. Slade. The areal extent of the Ferguson Mountain Formation is shown in Text-fig. 2 and covers an area similar to that shown by Steele (1960, p. 104) for Ferguson Springs Formation.

Lithology.—In the Gold Hill Mining District the Ferguson Mountain Formation consists primarily of normal marine limestones. White and light gray sparry criquinas and sparry limestones, which weather to light gray or light tan, are abundant throughout the section, but are especially numerous in the lower one-fourth of the formation. Skeletal limestones, fusulinid coquinites, and detrital limestones are also common rock types of the formation at this locality. Thin-section studies show that foraminiferal tests compose nearly 90 percent of some of these skeletal limestones. Other rock types in the Ferguson Mountain Formation are dark gray and brown-gray to light gray matrix limestones which weather yellow-brown or brown-gray. Similarly, all gradations between a matrix limestone and skeletal and detrital limestones are present. The lower 100 feet of the Ferguson Mountain Formation at this locality contains from five to ten percent bedded and nodular chert. No chert is found in the succeeding 925 feet, from three to ten percent bedded and nodular black and brown chert is present in the next 500 feet, but no chert is present in the upper 175 feet of the formation.

The detrital quartz content of each thin section was determined by using a Spencer binocular microscope equipped with an attachment containing two polarizing discs which, in essence, gives the same results as the crossed nicols of the petrographic microscope. Of the 70 slides studied from the formation in this area detrital quartz content does not exceed ten percent of the sample; a few contain five to ten percent of this material, but the average lies nearer three and one-half percent.

The Leppy Range has rock types which are approximately similar, but are

somewhat more detrital in nature. In A-1 Canyon several units contain sediments which should be classed as skeletal or bioclastic limestones due to the high percentage of fusulinid tests, bryozoan fragments, and crinoid stems, but there are few of the Foraminifera which are so characteristic of the Ferguson Mountain Formation in the Gold Hill Mining District. Five and one-half miles north of Wendover the section is decidedly more clastic and Foraminifera are sparse to absent. Fusuline coquinites are relatively abundant, but this should not be considered unusual since fusulinids clearly flourished in areas where silt content of the sediments was fairly high. Highest detrital quartz content of this formation at Gold Hill is ten percent, but in the Leppy Range highest content of this material was found to be approximately 55 percent and averaged 12 percent. At A-1 Canyon approximately 50 to 60 percent of the section is dolomites, but five miles to the north only about 15 percent of the formation is of this rock type.

Black and brown nodules of chert are found primarily at the base and at the top of the Leppy Range section but do not exceed three percent of the rock volume.

Light gray and dark blue-gray matrix, skeletal, and detrital limestones make up nearly all of the Ferguson Mountain Formation in the Pequop Mountains. These limestones are generally finer grained than those of the Gold Hill and Leppy Range areas, and the percentage of detrital quartz is also lower. Quartz content does not exceed three percent, judging from examination of numerous thin-sections. Chert content of these sediments is amazingly high in comparison with the other sections, but this is true only of those sediments at the base of the formation. The lower 160 feet contain from 20 to 30 percent gray and brown nodular chert and red and gray bedded chert. Remainder of the formation contains up to two percent nodular chert which is sparsely distributed throughout the strata.

A conglomerate unit 60 feet thick which weathers into a prominent cliff, occurs 160 feet above the Ferguson Mountain Formation-Unnamed Siltstone contact. Most discrete quartzite pebbles contained in this conglomerate are between one-fourth inch and two inches in diameter, and are well sorted but are sub-angular in shape.

Thickness.—Ferguson Mountain Formation is 1715 feet thick in the Gold Hill Mining District, thins to 800 feet at A-1 Canyon, to 753 feet five and one-half miles north of Wendover, and is only about 245 feet thick in the Pequop Mountains. Berge (1960, columnar stratigraphic section) assigns 2185 feet to the type section of the Ferguson Mountain Formation in the Toana Range, which is 40 miles southeast of Central Pequop Mountains.

Age and Correlation.—As noted above, Berge placed the base of this formation at the type locality, several hundred feet below the Pennsylvanian-Permian boundary, and the upper contact at a coral biostrome which lies above the Wolfcampian-Leonardian boundary; thus, the Ferguson Mountain Formation consists of Virgilian, Wolfcampian, and Early Leonardian rocks at Ferguson Mountain.

In the Pequop Mountains Late Wolfcampian rocks rest disconformably upon Desmoinesian strata. Study of the fusulinids indicates that only part of the Ferguson Mountain Formation (approximately 245 feet thick) is present, and is Late Wolfcampian at this locality. A coral biostrome, similar to that found at Ferguson Mountain, is present at the upper boundary of the formation. The

first occurrence of *Parafusulina,* however, is approximately 250 feet above this biostrome and the formation is therefore no younger than Wolfcampian.

In the Gold Hill District Virgilian species of the genus *Triticites* occur in lower units of the Ferguson Mountain Formation. The upper boundary has been placed at a unit containing an abundance of the corals *Corwenia* and *Syringopora.* No species of *Parafusulina* were found below this biostrome of corals and the formation has been assigned an age ranging from at least Virgilian to Late Wolfcampian.

In the Leppy Range the formation is entirely of Wolfcampian age. Although Virgilian sediments are present they have been assigned to the Strathearn Formation. At A-1 Canyon several units in stratigraphic succession contain coral biostromes of *Corwenia.* First occurrence of *Corwenia* is associated with numerous echinoid spines and together with characteristic lithic changes is taken as the upper boundary of the Ferguson Mountain Formation. *Parafusulina* with observable cuniculi were found at the top of this unit, but none were found below this bed. Five miles to the north the coral biostromes were not found, but fusulinids are still abundant in the formation.

Pequop Formation

Steele (1960, p. 106) named the Pequop Formation for a sequence of thin-bedded fusuline-bearing limestones and siltstones which he indicated as being one and one-half miles north of the Jasper railroad tunnel in the Pequop Mountains, Elko County, Nevada. Map location of this stratigraphic section is given as Section 3, T. 33 N., R. 65 E. The position of this measured section appears to be in error because such a location would place the section in an area of complicated faulting and folding, and generally poor outcrop. Furthermore, little if any of the Pequop Formation is exposed at that locality. Seemingly, the section may have been measured along a spur located directly east of a large gravel pit excavated by the Western Pacific Railroad. This east-west trending spur is one of the most prominent in the area and is relatively unaffected by faulting. Location of this ridge is in sections 31 and 32, T. 34 N., R. 70 E. and sections 4 and 5, T. 33 N., R. 70 E. No ridge nearer the Jasper tunnel has a good section of the Pequop Formation.

Lower Moorman Ranch Member.—Steele (1960) has divided the Pequop Formation into three members. The lower carbonates have been assigned to the Lower Moorman Ranch since they have lithologic and faunal similarities to the light colored carbonates of the Moorman Ranch area in the Butte Mountains, White Pine County, Nevada.

Summit Springs Evaporite Member.—When Standard of California-Continental Oil companies drilled their Summit Springs Unit No. 1 well (NW. ¼ NW. ¼, Sec. 30, T. 20 N., R. 60 E., White Pine County, Nevada) they penetrated two thick sequences of evaporites. Steele arbitrarily dated the lower of these two as Medial Leonardian on the basis of *Schubertella melonica,* Dunbar & Skinner, (according to Steele, an Early Leonardian form) in subjacent beds and occurence of *Parafusulina shaksgamensis* Reichel (Late Leonardian according to Steele) in overlying strata. He correlated this evaporite sequence with a thin, yellow gypsiferous appearing siltstone which is present between Upper Leonardian and Lower Leonardian sediments of the Moorman Ranch area.

Upper Moorman Ranch Member.—This member includes that part of the

Pequop Formation which lies stratigraphically above the Summit Springs Evaporite Member and below the Loray Formation.

Distribution.—Thick sequences of the Pequop Formation are exposed in each of the three areas under consideration. This formation is also present at Ferguson Mountian but the upper part is faulted out and Pequop sediments are in fault contact with the Plympton Formation. During the summer of 1959, sections of the Pequop Formation were examined at Cherry Creek Range, Leach Mountains, and Moorman Ranch in southern Butte Mountains. Steele (1960, p. 104, 106) states that outcrops of the Pequop Formation are distributed over 18,000 square miles in northeastern Nevada and northwestern Utah. Excellent outcrops of the Pequop Formation with easily recognized members are exposed in the Gold Hill District and thus the eastern outcrop of the formation must now be extended. Areal extent of the formation as now known (Text-fig. 2) suggests that the formation may cover as much as 23,000 square miles. Further investigations may reveal that the Pequop Formation is present in other localities.

Lithology.—At its type locality the Pequop Formation consists of thin-bedded fusuline-bearing silty-sandy limestones and calcareous siltstones which weather to a red-brown color. This characteristic color of weathered rocks commonly makes identification easy; even at considerable distance from outcrop. In the lower one-half of the formation encrinites are interbedded with fusulinid coquinites and silty-sandy limestones.

Chert content varies from zero to ten perecent, but averages slightly over two and one-half percent. Detrital quartz content varies from a few to ninety percent, and averages approximately 14 percent of the bulk of the rock.

In the Gold Hill District the Lower Moorman Ranch Member of Pequop Formation consists of blue-gray fine-crystalline to bioclastic limestones. Thin-bedded silty and sandy limestones similar to those of the Pequop Mountains occur predominantly in the lower units of the member. Some calcareous dolomites are present, but are in the minority. Silt and sand content varies from nothing to forty percent with an average of approximately three percent. Most of the silt and sand is restricted to the lower 200 feet of the member. No chert is found on the lower 230 feet but some of the upper units contain as much as 30 percent. Average chert content for this member is approximately six and one-half percent.

Interbedded white and light yellow gypsum (now altered to alabaster) with numerous black styolites and light gray dolomite make up the Summit Springs Evaporite Member. Narrow igneous dikes have baked the gypsum of initial deposition to a hard white and light yellow alabaster. Studies of insoluble residues show that the alabaster has a high calcite content. Cool dilute (1:7) hydrochloric acid will dissolve approximately 40 percent of the rock, leaving a flocculent white residue of gypsum. No chert and not more than one percent of detrital quartz are found in the member.

Upper Moorman Ranch Member consists of interbedded dolomites, limestones, and orthoquartzites which weather to a rusty red-brown and light gray-brown color. Black and brown nodular chert averages five percent.

At A-1 Canyon near Wendover the lower one-half of the formation consists of blue-gray and gray-brown thin-bedded silty limestones which weather red-brown. This part of the section contains abundant fusulinid coquinites, several biostromes of the coral *Corwenia,* numerous echinoid spines, and some brachiopods, bryozoans, and gastropods. Less abundant forms are textularid Foraminifera and the trilobite *Ameura* sp. The upper one-half of the forma-

tion consists of resistant red-brown orthoquartzites interbedded with thin light gray dolomites both of which weather to a slightly darker shade of the same color. Fossils are rare in this sequence.

The measured section five and one-half miles north of Wendover is similar in lithology to the upper one-half of the formation exposed at A-1 Canyon. This is not intended to mean a correlation of time-parallel units. Rather, the northern section was nearer the Northeast Nevada High positive area in northern Nevada and Utah and so received more silt and sand than the area farther south. No fusulinids and few other fossils were found in this part of the section. Little chert occurs, and the average detrital quartz content of the rock is approximately 80 percent.

Thickness.—At Gold Hill the Pequop Formation is about 2,000 feet thick. The lower 850 feet is the Lower Moorman Ranch Member, overlain by 250 feet of white evaporites comprising the Summit Springs Member, and the remaining 900 feet is the Upper Moorman Ranch Member. In the Leppy Range the formation is 850 feet thick at A-1 Canyon and 625 feet thick five miles farther north. In Central Pequop Mountains at the newly-designated reference section (Robinson, 1961), Pequop Formation is 2,650 feet thick. Steele (1960, p. 106) assigns 1,570 feet to the formation at what he considered the type locality, but subsequent measurements made by Robinson (1961) and measurements made at several different localities in the Pequop Mountains for this study show that the actual thickness of the formation is considerably greater.

Age.—In the Pequop Mountains the lower 250 feet of the Pequop Formation is Late Wolfcampian. In the Gold Hill District and in the Leppy Range the formation is entirely Leonardian.

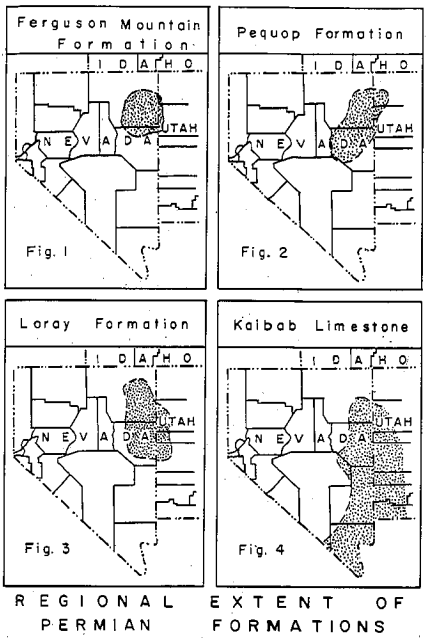
Loray Formation

Steele (1960, p. 106) named a series of yellow-tan gypsiferous siltstones and thin bioclastic limestones the Loray Formation. The type section is located at the head of Loray Wash in the Southern Pacific Railroad cut on the southwest side of Montello Valley (SW ¼, NE. ¼, Section 28, T. 38 N., R. 68 E., Elko County, Nevada). In the Gold Hill District and in the Pequop Mountains the Loray Formation overlies the Pequop Formation and is overlain by the Kaibab Limestone.

Distribution.—In addition to sections mentioned above this formation was also measured in the Cherry Creek Range and the Leach Mountains, a few miles northwest of the type locality. Steele (1960, p. 107) identified the Loray Formation at Ferguson Mountain and in the Butte Mountains. He believes that the upper 300 to 400 feet of Hose & Repenning's Arcturus formation in the Confusion Range constitutes sediments of this formation. Sediments of this sequence were not definitely identfied in either of the stratigraphic sections measured in the Leppy Range. Known outcrops of the formation occur over an area of approximately 19,000 square miles in northeastern Nevada and northewestern Utah.

Lithology.—In the Pequop Mountains Loray Formation is composed of thin-bedded, yellow-tan and red-brown silty bioclastic limestones. Chert content averages about two percent and silt content averages about eight perecent.

In the Gold Hill District only low outcrops of Loray Formation are found, and these are best seen beneath massive ledge-forming Kaibab Limestone. These outcrops show that the lower 100 feet of the formation is composed of thin-bedded silty and sandy limestones. Good exposures of the upper 100 feet were found. Twenty-five miles to the northwest at Ferguson Mountain, however,



TEXT-FIGURE 2.—Regional extent of Permian formations.

excellent exposures of gypsum occur immediately beneath the Kaibab Limestone. Chert content of the Loray is about three percent and the detrital quartz averages about four percent. Loray Formation was not recognized in the Leppy Range. The writer interprets this as non-deposition, because apparent blended contact relations between Pequop and Indian Canyon formations typify the area.

Thickness.—At Gold Hill the Loray Formation is approximately 200 feet thick, in the Pequop Mountains it is 256 feet thick, and sediments similar in lithology and outcrop pattern to the Loray Formation are 59 feet thick at A-1 Canyon near Wendover. The writer could not identify these latter sediments with certainty, but believes that they are the siltstones of the Loray Formation. The formation is absent five and one-half miles north of Wendover.

Age and Correlation.—Steele considers the Loray Formation to be equivalent to the upper dolomite and anhydrite section drilled in Standard of California-Continental's Summit Springs #1 Unit, and he dates this sequence as Lower Guadalupian on the basis of stratigraphic position and faunal control in adjacent strata. Dunbar, *et al.,* (1960) assign the overlying formation, the Kaibab Limestone to the Upper Leonardian. If this is correct, then the Loray Formation must also be Leonardian. At least the upper part of the Loray Formation at Ferguson Mountain does consist of anhydrite. This may also be true of the formation in the Gold Hill District. The Loray Formation can be correlated with the upper 300 to 400 feet of the Arcturus Formation in the Confusion Range. In southwestern Utah and southeastern Nevada sediments of this same age and stratigraphic position are included in the Toroweap Formation.

Park City Group

On the basis of regional stratigraphic studies McKelvey, *et al.*, (1956, p. 2834-2840) recommended that new nomenclature be given to designate the Park City Formation of the northern and central Wasatch Mountains and equivalent strata in the phosphate field of Colorado, Wyoming, Montana, Idaho, Nevada, and Utah. The name Phosphoria Formation was retained for the mudstone, chert, and phosphorite sequence, and strata of dominantly carbonate lithology were referred to the Park City Formation. Hose & Repenning (1959, p. 2178) used the term Park City Group in the Confusion Range of west-central Utah in referring to a sequence of dominantly carbonate strata which are considered essentially equivalent to the Park City Formation of the Wasatch Mountains. They divided the Park City Group of the Confusion Range into three formations, which are, in ascending order, Kaibab Limestone, Plympton Formation, and Gerster Formation. As it now stands, geologists of the U.S. Geological Survey use the name Park City Group in the eastern Great Basin, and apply the name Park City Formation in parts of Rocky Mountain area. Seemingly, one would suppose that if this nomenclature is followed, then formations of their group rank would be correlative with members of the formation's rank, in part at least.

Kaibab Limestone

Darton (1910, p. 21, 28-30) named the Kaibab Limestone from the Kaibab Plateau (located on the north side of the Grand Canyon, Arizona). Though the Kaibab Plateau is the type locality for the Kaibab Limestone no detailed sections were measured and no type section was designated.

Noble (1927, p. 41) designated Kaibab Gulch, which lies about six miles north of the Utah-Arizona border and eight miles southwest of the abandoned settlement of Paria, Utah, as the type section.

Distribution.—The Kaibab Sea deposited sediments over a large area in northern Arizona, southern and northwestern Utah, southern and northeastern Nevada and part of southern California (Text-fig. 2). Excellent outcrops of the Kaibab Limestone were measured in the Pequop Mountains and in the Gold Hill District. Kaibab Limestone may also be present at A-1 Canyon in the Leppy Range where approximately 61 feet of strata overlying the Pequop Formation are, in a few respects, lithologically similar to the Kaibab Limestone of the Gold Hill District and the Pequop Mountains. The similarity is more striking when thin-sections of the three areas are compared. Tentatively the Kaibab Limestone is included in the section at A-1 Canyon, but five miles to the north of A-1 Canyon, this formation apparently is absent. Absence of Kaibab Limestone at this locality is interpreted as non-deposition of the formation in this thinner Permian section.

In addition, Kaibab Limestone was measured at Phalen Butte, and in the South Egan Range. Berge (1960, p. 30) described the formation in the Ferguson Mountain area. Recognition of Kaibab Limestone at Ferguson Mountain and in the Pequop Mountains indicates that the margin of this formation is farther to the west in northeastern Nevada than was formerly supposed.

Lithology.—Light gray fine-crystalline to bioclastic limestones and dolomites comprise massive beds of Kaibab Limestone. At Indian Canyon in the Pequop Mountains the formation consists primarily of massive bioclastic limestones. Encrinites comprise the dominant rock type although some of the bioclastic

limestones are composed of brachiopods and brachiopod "tailings" or "fossil hash." Upper beds of the formation are composed of interbedded dolomitic limestones and calcareous dolomites. Chert content varies from one to twelve percent and averages five percent of the rock volume. Less than one percent detrital quartz is found in the formation at this locality.

Near Gold Hill the formation is lithologically similar to the same sequence in the Pequop Mountains except that the upper 50 feet is comprised entirely of fine- to coarse-crystalline dolomite. The possibility is strong that this part of the sequence should be referred to the Grandeur Member of the Park City sequence of western Utah, but at present this dolomite unit has been included in the Kaibab Limestone because it is the upper part of a prominant cliff, most of which is limestone and, except for chemical composition, the limestones and dolomites are lithologically similar. Certain nomenclatural problems would result, because Grandeur Member belongs to Park City Formation, and Park City is termed Group in western Utah (Hose & Repenning, 1959). Exposures at A-1 Canyon resemble the Kaibab Formation lithologically and are in the same stratigraphic position. Instead of massive cliffs of the Kaibab, as seen in the Gold Hill District, however, the exposures at A-1 Canyon form low ledges. Kaibab Limestone was not deposited in the northern Leppy Range. Kaibab Sea was transgressive in a northerly direction, but apparently did not extend as far as present northern Leppy Range.

Thickness.—The Kaibab Limestone is 223 feet thick in the Gold Hill District and 402 feet thick in the Pequop Mountains. Possible Kaibab sediments are 61 feet thick at A-1 Canyon, but are entirely absent five and one-half miles north of Wendover. Berge (1960, p. 30) reports a thickness of approximately 420 feet at Ferguson Mountain.

Age and Correlation.—Exact age of the Kaibab Limestone is difficult to determine. Darton (1910, p. 30) states that Kaibab Limestone contains an abundant fauna of Pennsylvanian age. King (1930, p. 9, fig. 1) illustrates the Kaibab as being Late Leonardian and Early Wordian. Steele (1960, p. 107) considers it to range in age from Early Guadalupean to Early-late Guadalupean.

For this study the Leonardian-Guadalupean boundary has been placed, with question, at the base of the Kaibab Limestone though this boundary may well fall higher in the section. The time boundary has been placed at this point because deposition of the underlying Loray Formation represents a withdrawal of the seas from the area, and the Kaibab Limestone indicates that an inundation took place during ensuing transgression. This may represent withdrawal of seas during late Leonardian and advance of the Kaibab seas during Late Leonardian-Early Wordian. The brachiopod fauna of the three areas investigated is poor and no attempt has been made to date the formation at these localities.

Stratigraphic position and lithologic character of this fromation in northeastern Nevada and northwestern Utah indicate that it is equivalent, in part at least, to Kaibab Limestone identified in the Confusion Range. Hose & Repenning (1959, p. 2180) correlate the Kaibab Limestone of the Confusion Range with the formation at its type locality. If transgression from south to north did occur, then apparently Kaibab Limestone records temporal transgression, and it seemingly is younger in western to northwestern Utah and adjacent Nevada, than at its type locality.

Plympton Formation

Hose & Repenning (1959, p. 2181) named the Plympton Formation for a sequence of dolomitie rocks overlying the Kaibab Limestone in the Confusion Range in west-central Utah. This same sequence had earlier been referred to as the Phosphoria Formation by Newell (1948). Hose & Repenning however, considered this term inappropriate because of the marked lithologic difference between these rocks and those of the type Phosphoria Formation in southeastern Idaho, and renamed the formation for a stratigraphic section they measured on Plympton Rigde (approximately 22 miles north of U.S. Highway 6). The lower 219 feet of this assemblage in the Pequop Mountains consists of phosphatic bedded chert. A similar unit of chert, 197 feet thick, occurs in the Gold Hill District but is underlain by 173 feet of finely crystalline dolomites of the Plympton Formation. There is a strong possibility that this sequence represents a southward-pointing tongue, possibly equivalent to the Meade Peak Phosphatic Shale Member of the Phosphoria Formation. The Meade Peak Member is well exposed in the Cedar Mountains, 50 miles to the northeast of the Gold Hill District, and in the Leach Mountains, 75 miles to the north-northwest. Present studies have not advanced to the point where definite correlation can be made between the Meade Peak Member in Idaho and northern Utah and the phosphatic cherts of the Gold Hill-Pequop area. Difficulty in nomenclature is encountered if this chert is designated as the Meade Peak Member since at Gold Hill this would involve a section of dolomite of Plympton Formation overlain by Meade Peak phosphatic cherts which in turn would be overlain by dolomites of the Plympton Formation. Such a sequence would also involve mixing terminology of the Park City Group with terminology of the Phosphoria Formation. One solution would be to propose a new formal member name for this phosphatic chert unit in the Gold Hill and Pequop Mountains area, and suggest correlation with Meade Peak Member of Phosphoria Formation. Sufficient detailed work has not been done to justify this, however.

Distribution.—The formation is well exposed in the Gold Hill District and in the Pequop Mountains, is present at A-1 Canyon in the Leppy Range, but is entirely missing five miles farther north. Berge (1960, p. 32) and Steele (1960, p. 109) reported the formation in the Ferguson Mountain area. During the summer of 1959 the formation was measured at Phalen Butte, and observed in the Butte Mountains.

Lithology.—Fine-to coarse-crystalline dolomites comprise the greater part of the Plympton Formation. These light gray dolomites contain "ghosts" or relics of crinoid columnals and brachiopods which are more easily seen in thin-section. Chert is abundant throughout the formation and occurs both in nodular and bedded form. The lower 219 feet of this sequence in the Pequop Mountains consists of phosphatic bedded chert. A similar unit of phosphatic chert, 197 feet thick, occurs at Gold Hill but is underlain by 173 feet of fine-crystalline dolomites of the Plympton formation. When the rock is broken a phosphatic odor is readily detected.

Thickness.—In the Gold Hill District Plympton Formation is 930 feet thick, in Pequop Mountains it is 539 feet thick, at A-1 Canyon there is 105 feet, but five and one-half miles north of Wendover the formation is absent. Hose & Repenning report a thickness of 690 feet from the type area, Steele reports 983 feet from the Butte Mountains, and 238 feet were measured by Berge in the Ferguson Mountain area.

Age and Correlation.—Stratigraphic position indicates that the Plympton Formation possibly is Guadalupean. Recently Dunbar, *et al.,* (1960, p. 1763-1805) show its age as Early Wordian. Since fossils are rare or poorly preserved in this dolomite sequence no attempt has been made to date the formation on the basis of faunal content. Stratigraphic position and lithologic similarity indicate that the formation is correlative with the type section in the Confusion Range.

Indian Canyon Formation (new name)

Indian Canyon Formation is herein proposed for a sequence of cherty, sandy and silty dolomites, dolomitic orthoquartzites, and dolomitic siltstones. The type section is located at Indian Canyon in the Pequop Mountains (Section 21, T. 31 N., R. 65 E.) The type section was measured one-half mile north of the road which bisects Indian Canyon and the base of each measured unit was marked with a number, using yellow paint.

Steele (1960, p. 109) identified this sequence, but referred it to the Phosphoria Formation. Except for high chert content of the sediments at Indian Canyon, however, there is little lithologic similarity between this sequence and the Phosphoria Formation. At the type section of the Phosphoria Formation the sequence consists of dark chert, phosphatic and carbonaceous mudstone, phosphorite, cherty mudstone, and minor amounts of dark carbonate rock; light colored carbonate rocks are either absent or present only in local lenses, and sandstone is entirely absent. In the section at Indian Canyon there is a high percentage of light colored carbonate rocks, siltstones, and orthoquartzites. Phosphorite and phosphatic mudstones are absent in the Indian Canyon Formation, but are present in this development in basal part of Plympton Formation. This latter formation, however, is approximately 380 feet stratigraphically below Indian Canyon Formation. Seemingly Steele had this assemblage in mind in referring some of the strata to Phosphoria Formation; it is the writer's interpretation that Phosphoria Formation does not extend this far south in Nevada.

Distribution.—The Indian Canyon Formation (Text-fig.3) was measured in the Pequop Mountains, in the Gold Hill District, and in the Leppy Range. During the summer of 1959 the section was also measured at Phalen Butte. Steele (1960, p. 109) states that, "The Phosphoria Formation has been identified in the central portion of the Butte Mountains where it measures 48 feet in thickness."

Lithology.—At the type section the Indian Canyon Formation consists of thin-bedded calcareous siltstones, dolomites, orthoquartzites, and bedded cherts. The orthoquartzites and siltstones generally weather to a red-brown color and give the formation a characteristic hue in all three measured sections. Dolomite weathers light gray, and bedded chert is black. Nodular chert is abundant throughout most of the section and varies from about 1 or 2 percent in a few of the units to about 60 percent. Nodular chert is brown or black in most of the formation, but several of the lower units contain white chert rosettes which are approximately one inch in diameter.

In the Gold Hill District and in the Leppy Range the formation contains fewer orthoquartzites and bedded cherts, and contains some silty limestones. At these two localities algal felts are associated with the calcareous siltstones and silty limestones.

Thickness.—At the type locality the Indian Canyon Formation is 710 feet thick, in the Gold Hill District it is about 475 feet thick, and in the Leppy Range total thickness is 400 feet.

Age and Correlation.—Strata of the Indian Canyon Formation are time equiva-

lent, in part at least, to some units of the Phosphoria Formation, and the formation is Guadalupean (Wordian). Steele (1960, p. 109) dates the "Phosphoria" Formation of the Pequop, Butte, and Leach Mountains as Late Wordian to Early Capitanian on the basis of faunal dating and stratigraphic position. The present writer did not find diagnostic fossils, however. Baker, *et al.* (1960, Fig. 1) refers the Gerster to the Late Wordian and Capitanian, and the Plympton Formation to the Wordian; because Indian Canyon Formation lies between these two, it is Wordian.

Gerster Formation

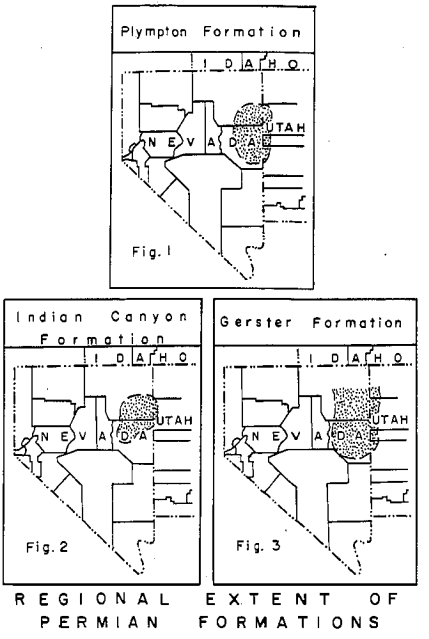
Nolan (1935, p. 39) named the Gerster Formation for a sequence of brownish-gray thin-bedded sandy and shaly limestones which weathers yellow-brown. This exceptionally fossiliferous formation was named for strata which crops out on the south side of Gerster Gulch, nine miles west of the Gold Hill District. At this locality and in the Pequop Mountains the Gerster Formation is unconformably overlain by Triassic strata, probably the Thaynes Limestone. Because of faulting and overlap of Bonneville sediments the top of the formation is not exposed in the Leppy Range.

Distribution.—Gerster Formation (Text-fig. 3) was measured in the Pequop Mountains, the Leppy Range, and in the Gold Hill District. During the summer of 1959 the formation was studied in the Butte Mountains, at Phalen Butte, and in the Currie Hills six miles southeast of Currie, Elko County, Nevada. Hose & Repenning (1959) have reported the formation from the Confusion Range of west-central Utah.

Lithology.—At the type locality and in the Pequop Mountains Gerster Formation is composed of yellow-brown, medium-gray, and red-brown fine-bioclastic to crystalline limestones which weather to a yellow-brown or red-brown. At these two localities the formation contains abundant brachiopods and bryozoans. Nolan (1935, p. 39) stated, "These beds are richly fossiliferous in all the exposures seen," and he further added, "These beds are sharply set off from the underlying sandstones and dolomites of the Oquirrh formation by their lithology and especially by their abundant fossil content, which was the basis for mapping the contact between the two." Chert content varies from two to ten percent and averages about four percent. Thin-section and insoluble residue studies show that detrital quartz content exceeds two percent of the total bulk of the carbonate. As has been noted in previous pages, Oquirrh Formation is absent in western Utah; rather, Indian Canyon, Plympton, Kaibab, Loray, Pequop, Ferguson Mountain, and Ely formations underly Gerster Formation in descending stratigraphic order in the Gold Hill District and contiguous areas.

Brown-gray and blue-gray silty and sandy limestones which weather gray and olive-gray, are the predominant rock types in the Leppy Range. A few thin yellow-brown and red-brown siltstone units are interbedded with the limestones. Detrital quartz content varies from about 15 to 55 percent with an average of 30 percent. Brachiopods are not numerous at this locality, but fusulinids, bryozoans, and algae comprise the greater part of the fauna. Most of the measured units contain no chert, and where present in the unit it does not exceed two percent.

Thickness.—Nolan (1935, p. 40) reported that the Gerster Formtaion is approximately 600 feet thick at the type section. Accurate measurements are difficult to obtain because of faulting which disrupts the basal units of this formation. Measurements for this study were made at the head of Gerster



TEXT-FIGURE 3.—Regional extent of Permian formations.

Gulch (approximately one mile west of the type section) where faulting is not present. A total thickness of 423 feet was obtained at this locality. In the Leppy Range. The Gerster Formation is at least 200 feet thick, top not exposed, and in the Pequop Mountains there are about 310 feet of Gerster sediments.

Age and Correlation—Hose & Repenning (1959, p. 2181) have recognized the Gerster Formation in the Confusion Range and have correlated it with the Franson Member (facies) of the Park City-Phosphoria assemblage. The formation carries an excellent brachiopod fauna and, with these fossils, has been correlated with certain other formations in the west. Approximately the lower one-fifth of Gerster Formation has been called Early Wordian by the Permian Subcommittee of the National Research Council's Committee on Stratigraphy with the greater part of the Formation being Late Wordian and Capitanian. Presence of the fusulinid genera *Reichelina* and *Codonofusiella* indicate a Capitanian age for the upper 100 feet at least of the measured section in Leppy Range. Dunbar, *et al.*, (1960, p. 1782) states that the ". . . Gerster Formation appears to be a westward extension of the upper part of the Franson Member of the Park City Formation and has yielded abundant brachiopods which Gordon regards as Upper Guadalupean (Capitanian)."

Triassic System

Thaynes Limestone

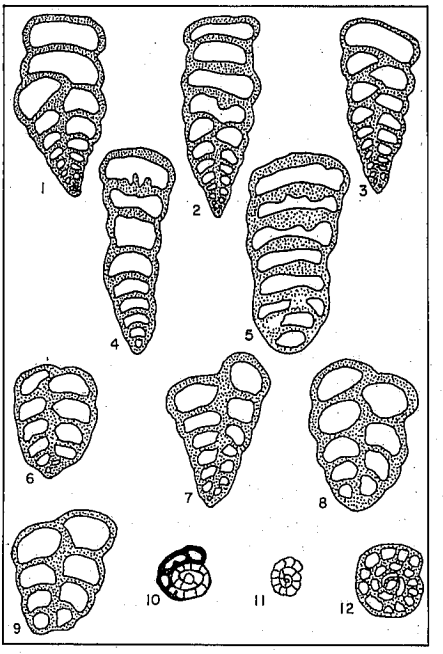
Thin-bedded red-brown and yellow-brown silty limestones of the Triassic Thaynes Limestone unconformably overlie the Gerster Formation in the Gold Hill District and in the Pequop Mountains. No Triassic sediments were found in the Leppy Range. The cephalopod *Meekoceras* sp. occurs in a unit about 20 feet above the base of the formation in the Pequop Mountains and approxi-

mately 30 feet above the Permian-Triassic boundary in the Gold Hill District. A sharp contact exists between the light yellow-brown, fine-crystalline limestones of the Gerster Formation, and the darker yellow-brown and red-brown silty limestones of the Thaynes Limestone. This lithologic break is also accompanied by a change in fauna. The Gerster Formation contains abundant brachiopods and bryozoans whereas the Triassic sediments contain cephalopods and gastropods.

FOSSILS

Ferguson Mountain Formation

Fusulinids are the most abundant fossils in this formation. Species of *Schwagerina, Paraschwagerina, Dunbarinella, Triticites* have been identified in the present study. Foraminifera (Text-fig. 4) are found in all three measured



TEXT-FIGURE 4.—Figs. 1-3 *Cribostomum* spp. (x 15); 4-5 *Climacammina* spp. (x 15); 6-9 *Paleotextularia* spp. (x 50); 10-12 *Endothyra* spp. (x 50).

sections, but are especially numerous at Twin Peaks in the Gold Hill District. Genera identified are *Paleotextularia, Climacammina, Cribrostomum,* and various forms of *Endothyra. Permodiscus* has been found in strata of the Ferguson Mountain Formation in this area. Other types of Foraminifera are present in the formation, but were too poorly preserved for generic assignment. Genera of brachiopods in the section include *Juresania, Composita,* and *Dictyoclostus.* Crinoid columnals are distributed throughout Permian sections at all areas studied, but are especially numerous in the lower units of the Ferguson Mountain Formation at Gold Hill. Lioclemid, fenestrate, and rhomboporid

bryozoans, rugose corals, various forms of algae, and echinoid spines are found in the formation, but are not as abundant as above mentioned fossils. *Syringopora* sp. is abundant in the upper one-half of the Ferguson Mountain Formation at Gold Hill, but occurs less frequently in the Leppy Range and in the Pequop Mountains.

The colonial coral *Corwenia* sp. is found in all three sections at or near the top of the formation. Some geologists believe this biostrome occurs at the Wolfcampian-Leonardian time boundary. However, Berge (1960, p. 20) has found Leonardian fusulinids 268 feet below a *Corwenia* biostrome at Ferguson Mountain, and diagnostic Late Wolfcampian fusulinids occur 250 feet above a *Corwenia* biostrome in the Pequop Mountains. In the Leppy Range species of *Parafusulina* occur a few feet above a biostrome of *Corwenia,* but several beds containing this coral were found higher in the measured section. Furthermore, the writer noted at least three biostromes of *Corwenia* at Ferguson Mountain. *Corwenia* then, does not indicate precisely the Wolfcampian-Leonardian boundary but may serve as a useful clue to approximate position of this boundary after which fusulinids can be used to determine where it occurs.

Pequop Formation

Fusuline coquinites are common to the Pequop Formation, and abundant tests of these organisms are found throughout the section in most areas. Fusulinid genera of these areas include *Schwagerina, Pseudoschwagerina,* and *Parafusulina.* Encrinites are abundant in the lower half of the formation at Gold Hill, in the lower half of the Leppy Range section, and are abundant throughout the section in the Pequop Mountains. *Syringopora, Corwenia,* the trilobite *Ameura,* rugose corals, brachiopods, echinoid spines and ambulacral plates, lioclemid bryozoans, algae, foraminifers, and gastropods also occur in the formation. With the exception of *Ameura,* these fossils are common, but play a minor role to occurrence of fusuline coquinites.

Loray Formation

No fusulinids were found in this formation. This sequence is evaporitic, in part at least, and no diagnostic fossils were found. Brachiopod fragments, crinoid stems, some bryozoans, and algae were found in this bioclastic limestones.

Kaibab Limestone

The formation contains abundant crinoid columnals, almost to the exclusion of other fossil types, although some brachiopod fragments and bryozoans occur with the crinoids.

Plympton Formation

Occasional criniod columnals, brachiopods, and bryozoans are found in the dolomites of the Plympton Formation, but these are usually poorly preserved. No attempt was made to identify them.

Indian Canyon Formation

Large algal felts are numerous in the carbonates and calcareous sandstones of this sequence. These fossils are approximately one centimeter in diameter in most cases though some measure nearly two centimeters. In thin section they

have about the same configuration as a fingerprint with ridges and grooves being visible. In the silty and sandy limestones of the formation usually only the gross outline of the algae can be seen.

Gerster Formation

Brachiopods dominate the fauna of the Gerster Formation in its type locality and in the Pequop Mountains. These include *Punctospirifer kentuckyensis* (Shumard), *Composita subtilita* (Hall), *Composita mira* (Girty), *Muirwoodia multistriatus* (Meek), *Horrodonia subhorrida* (Meek) and *Lissochonetes* sp. One pelecypod, *Aviculopecten* sp. was found. Fenestrate bryozoans and crinoid columnals are abundant in the formation. Microscopic examination of thin-sections show that algae is a major constituent of the rock in numerous places. In the Leppy Range the abundant brachiopod fauna, for which the Gerster Formation is well known elsewhere, is not present. The fauna of this area consists of a few brachiopods, lioclemid bryozoans, algae, gastropods, and fusulinids. Fusulinids include the genera *Parafusulina, Codonofusiella,* and *Reichelina.* To the writer's knowledge this is the first reported occurence of these fusulinid genera from the Gerster in the eastern Great Basin.

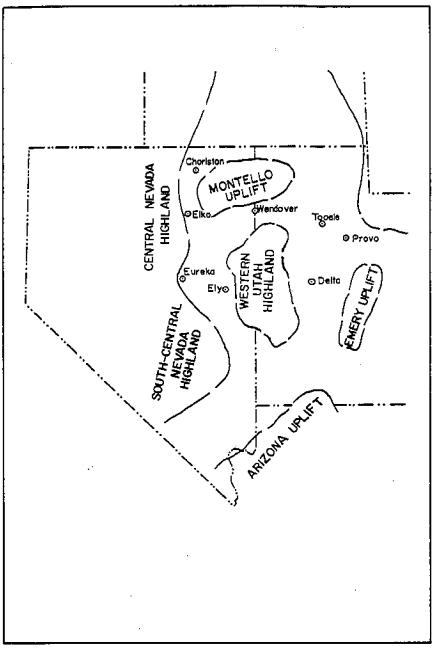
Summary

The fauna of these Permian formations indicates that the seas of this period were rather shallow. Some dolomites and some orthoquartzites contain no fossils but it is probable that these units were also deposited in shallow water.

Fusulinids of the Ferguson Mountain and Pequop formations provide an excellent basis for age determination. In addition the fusulinids found in the Gerster Formation near Wendover date the upper part of the formation as Capitanian.

SOURCE OF SEDIMENTS

Three major positive areas contributed sediments to the depocenter during Permian time (Bissell, 1960, p. 1429, 1430; Steele, 1960, p. 92). The area investigated was bounded on the west, north, and east by these highlands. Positive areas during Medial and Late Pennsylvanian and Early Permian time were designated by Bissell (1960) as Central Nevada Highland, Montello Uplift, and Western Utah Highland (Text-fig. 5). For Medial Permian the positive areas he designated are the Nevada-Idaho Highland, (highlands occupying areas both to the west and to the north of the measured sections), and the Western Utah Highland (Text-fig. 6). Steele refers to these three areas as the Antler Orogenic Belt, the Northeast Nevada High, and the West-Central Utah Highlands (Text-fig.7). A negative feature which is bounded by these three areas has been designated by Steele as the Butte-Deep Creek Trough. It is in this trough that the thicker and more continuous sections of Permian strata are found. Epeirigenic uplift caused a marked regional unconformity in the eastern Great Basin (Dott, 1955, p. 2255; Steele, 1960, p. 94). In many areas Wolfcampian strata rest upon Derryan (Atokan) or Desmoinesian sediments. All are marine, however, and normally a blended disconformity it evidenced. In the Butte-Deep Creek Trough, sedimentation was more continuous and the period of non-deposition was shorter, but the unconformity is clearly defined. Age determinations based on study of the fusulinid fauna show that in the Pequop Mountains Late Wolfcampian strata rest unconformably upon Desmoinesian



TEXT-FIGURE 5.—Medial and Late Pennsylvanian and Early Permian positive areas (after Bissell, 1960, p. 1429).

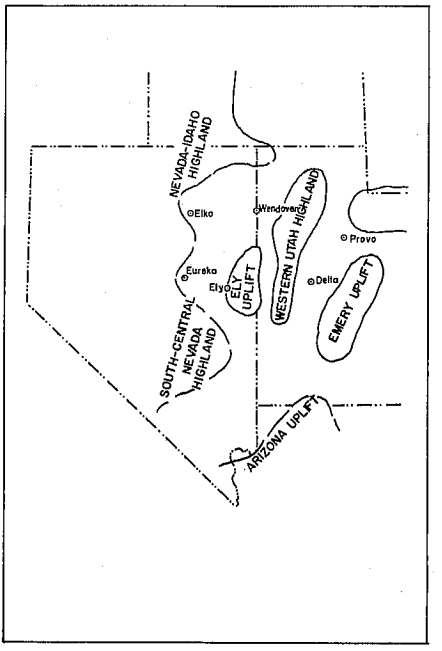
strata, and at Gold Hill and in the Leppy Range Virgilian rocks overlie Desmoinesian strata.

Wolfcampian Epoch

Marine limestones containing abundant crinoid stems and silty-sandy limestones were deposited in the Gold Hill District during Early Wolfcampian. The Western Utah Highland shed clastics westward to the Gold Hill District. In the Leppy Range silty-sandy limestones and some calcareous siltstones were deposited and the higher silt and sand content of the Wolfcampian strata in this area suggests that the Montello Uplift was strongly positive at this time. No Early Wolfcampian sediments were deposited in the area now including Pequop Mountains. Essentially the same conditions existed during Medial Wolfcampian as had existed during the earlier part of the epoch. Medial Wolfcampian sediments of the Gold Hill District are slightly more clastic in nature and contain abundant fusulinid coquinites. This may reflect a more positive nature of the Western Utah Highland. Steele (1959 b, p. 97) indicates an eastern source of sediments in the Gold Hill District on the basis of crossbedding and thinning of sandy units to the west.

During Late Wolfcampian normal marine sediments containing fusulinid coquinites and encrinites were deposited in that part of the trough, now occupied by Pequop Mountains. Not since the Desmoinesian had sedimentation taken place in this area. Conglomerates are abundant throughout the section and suggest that the Central Nevada Highland was strongly positive during this time. Except for an increased abundance of colonial corals little change in

lithology is noted in the Gold Hill District. In the Leppy Range dolomites are abundant at A-1 Canyon and probably are the result of a restricted environment.



TEXT-FIGURE 6.—Medial Permian positive areas (after Bissell, 1960, p. 1430).

Leonardian Epoch

It is strongly suggested that sediments of all three measured sections record continuous deposition during Late Wolfcampian and Early Leonardian. All three of the positive elements were active. An increase in silt and sand content is observed in the Gold Hill District and in the Pequop Mountains and thin units of conglomerate are found in the Lower Leonardian of the Leppy Range.

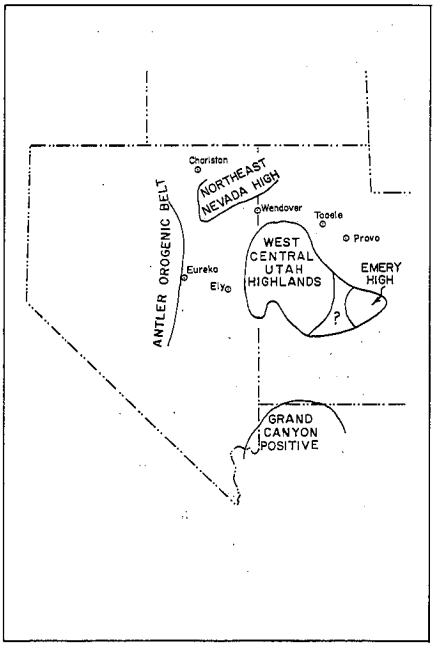
Retreat of the sea in Medial Leonardian time created physical environments in the Gold Hill District which were favorable for the deposition of gypsum and dolomites. In the Pequop Mountains and in the Leppy Range sedimentation was essentially comparable to Early Leonardian. Bissell (1960, p. 1430) shows that the Montello Uplift had shifted northward during this time and was joined to the western positive area to form the Nevada-Idaho Highland. Steele (1959, p. 141) also discussed the northward shift of the axis of Butte-Deep Creek Trough. In the Pequop Mountains most of the Late Leonardian section consists of normal marine sediments, but the upper 200 feet (Loray Formation) consists of siltstones and silty limestones, both of which contain a small percentage of evaporites. At Gold Hill the upper part of the Loray Formation is covered with debris from the prominent cliffs of the Kaibab Linestone, but 25 miles to the northwest the upper Loray Formation is composed of gypsum.

These evaporitic sequences indicate that shallowing of the seas took place at this time. The Loray Formation is not present in the Leppy Range.

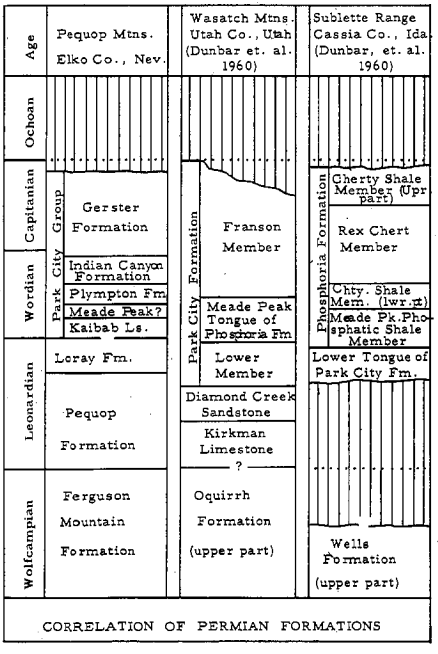
Guadalupean Epoch

Wordian

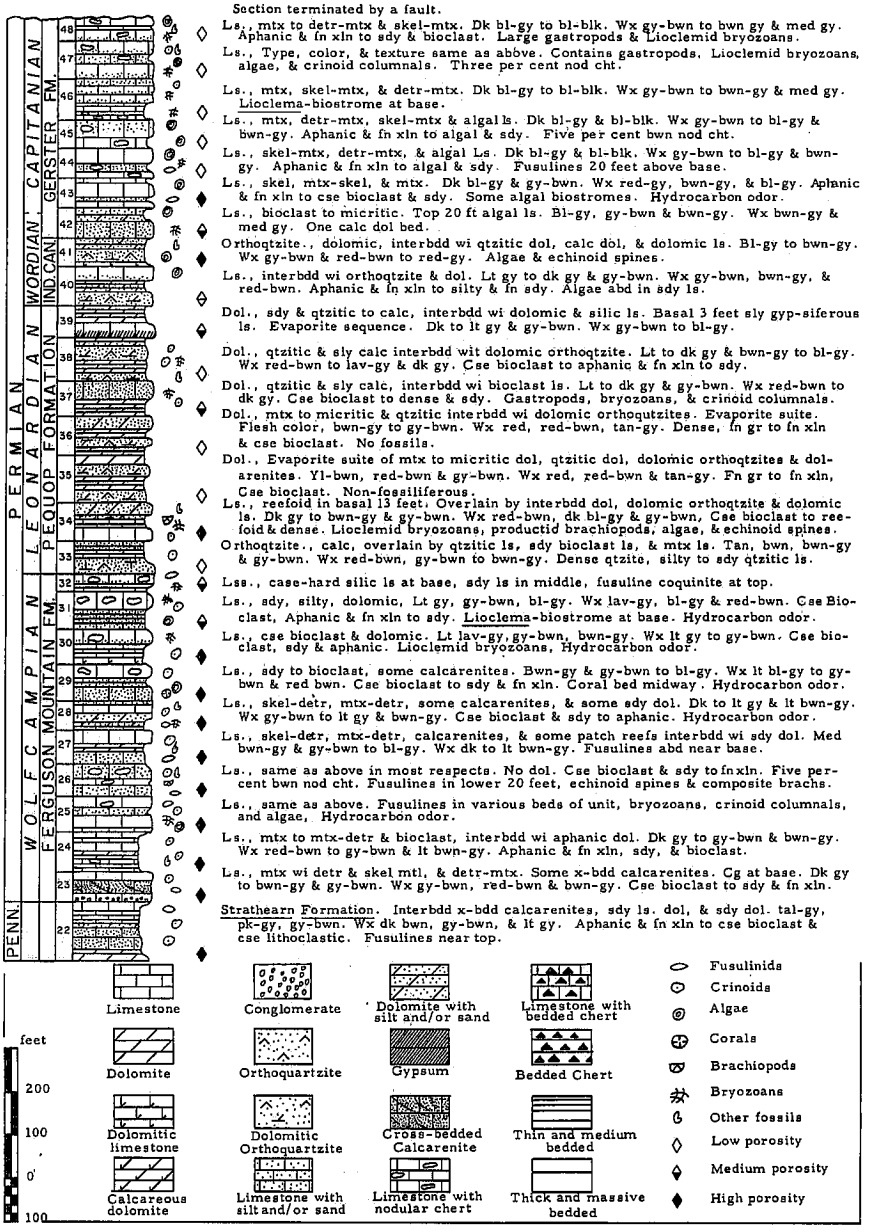
Normal marine sediments of the Kaibab Limestone overlie the evaporites of the Loray Formation. Possibly the Loray Formation represents evaporites formed during shallowing of seas in Late Leonardian, and the Kaibab Limestone, possibly Early Wordian in this area, represents inundation by a northerly transgressing sea. As previously mentioned the Leonardian-Guadalupean boundary likely is not at the same stratigraphic position relative to formation boundaries, but for this study the boundary is placed (with question) at the Loray-Kaibab contact. Kaibab Limestone is well exposed in the Gold Hill District and in the Pequop Mountains may be a thin wedge at A-1 Canyon near Wendover, and is absent five and one-half miles north of Wendover. Kaibab Limestone is overlain by phosphatic cherts (possibly a unit correlatable with the Meade Peak Phosphatic Shale Member of the Phosphoria Formation) in the Gold Hill District and in the Pequop Mountains. This would indicate that the Phosphoria Seas had some influence on sedimentation in these areas. Dolomites of the Plympton-Indian Canyon formations indicate that the area was covered by warm shallow seas during this time interval. Several authors have commented that some dolomite likely was a product of epeiric seas. It has also been noted that certain dolomites were probably deposited in partially restricted or restricted basins. Pettijohn (1949, p. 317) states, "Dolomites are so commonly



TEXT-FIGURE 7.—Tectonic index map (after Steele, 1960, p. 92).



TEXT-FIGURE 8.—Correlation of Permian formations.



TEXT-FIGURE 9.—Columnar stratigraphic section of the Leppy Hills area, Tooele and Elko counties, Utah-Nevada.

associated with silt and gypsum beds, that apparently the high salinity and the conditions responsible for the salinity, promote dolomitization."

Wordian-Capitanian

Normal marine limestones were deposited in this area during Late Wordian and Early Capitanian. Limestones of the Gerster Formation contain abundant brachiopods in the Gold Hill District and in the Pequop Mountains. In the Leppy Range the formation contains abundant silt and sand and indicates that the Nevada-Idaho Highland (Bissell, 1960, p. 1430) was active during Capitanian. Gerster Formation represents the last Permian deposition in the area. Triassic sediments containing the cephalopod *Meekoceras* unconformably overlie strata of the Gerster Formation.

APPENDIX

Crystal Size

In discussion of lithology the following parameters were used: Aphanic (0.01 mm), fine-crystalline (0.01-0.25 mm), medium-crystalline (0.25-1.0 mm), and coarse-crystalline >1.0 mm).

Limestone Terminology

When discussing the types of limestone the following terms were used: matrix limestone: Composed almost entirely of fine-textured (crystalline and/or grained) material, particularly if variable; some may be aphanic, but if so possibly the term micrite applies. Matrix-with-detrital or matrix-with-skeletal: Most of the rock consists of matrix material but also contains from 10 to 30 percent detrital or clastic skeletal material. Detrital-matrix or skeletal-matrix: Contains from 30 to 50 percent detrital or skeletal material. Matrix with-detrital or matrix with-skeletal: Most of the rock consists of matrix material but this material is less than 90 percent. Detrital or skeletal: Detrital or skeletal materials exceed 90 percent. Other terminology has been used in describing some limestones and other rock types, but these are self explanatory. Correlations are shown (Text-fig.8) and lithologies are explained (Text-fig.9-11).

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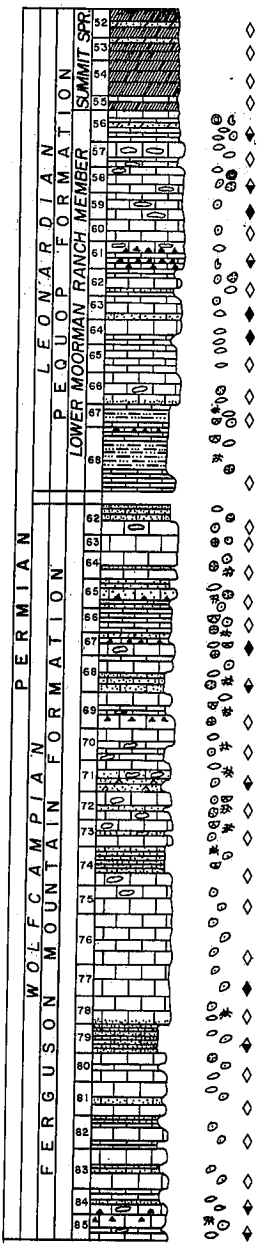


Alabaster, calc; & thn bds of gyp, calc, & silty dol. Wh, & med bl-gy.

Alabaster, calc; calc & silty dol. Lt gy & lt gy-bwn. Wx wh & dk bl-gy.

Alabaster, calc. Wh & lt gy. Wx same. Aphanic to fn xln, sly silty.

Alabaster, & mtx ls. Wh & lt bl-gy. Wx wh, lt gy, & bwn-gy. Aphanic & fn xln.

Ls., mtx & mtx-wi-skel; & silty dol. Dk gy-bl, bwn, & gy. Fn & med xln, silty & fn sdy. Abd fusulines, Syringopora sp., rugose corals, & algae.

Ls., mtx, mtx-wi-skel, & mtx-wi-detr mtl. Dk gy & red gy. Wx dk bl-gy. Med xln.

Ls., mtx & mtx-wi-skel. & skel-wi-detr mtl. Dk bl-gy & olv-gy. Wx dk bl-gy. Med xln. Abd fusulines at base.

Ls., mtx, mtx-wi-detr & skel-detr. Yl-gy, bwn, & lt bl-gy, Wx bwn, & lt bl-gy.

Ls., mtx & mtx-wi-skel mtl. Lt gy & yl-gy. Wx dk bl-gy & bwn. Fn & med xln.

Ls., mtx & mtx-wi-skel mtl; interbdd wi blk bdd cht. Dk gy, purp-gy & blk. Wx lt orange-gy, gy & blk.

Ls., mtx & mtx-wi-skel to mtx-skel ls. Some mtx-wi-detr mtl. Upper 5 feet cirquina. Red & gy & dk bl-gy. Wx bl-gy. Fn & med xln, silty & fn sdy. Abd calcite veins.

Ls., mtx, mtx-wi-skel, & mtx-wi-detr to detr-mtx. Orange-gy, red-gy, & bl-gy.

Ls., mtx, mtx-wi-skel mtl. Red-gy & bl-gy. Wx lt & med gy, & bl-gy. Med xln.

Ls., mtx, & mtx-wi-skel. Lt & med gy. Wx dk bl-gy & gy-bwn. Fn & med xln.

Ls., mtx & mtx-wi-skel to skel-mtx, some mtx wi detr. Bl-gy. Wx lt gy & dk bl-gy. Med & cse xln.

Siltst, calc; & mtx-wi-skel to skel ls. Olv-gy, bwn-gy & dk bl-gy. Wx bwn-gy & bwn.

Ls., mtx, mtx-wi-skel to mtx-skel; siltst; & bdd cht in ls. Olv-gy, purp-gy & blk. Wx lt bwn & purp-gy. Fn xln & silty, Corwenia sp. & Syringopora sp. (Section above measured in vicinity of Gerster Gulch & Ferber Canyon. Section below measured at Twin Peaks.

Ls., mtx & mtx-wi-skel to mtx-skel, some mtx-wi-detr mtl. Lt gy & dk olv-gy. Wx lt gy-bwn & dk gy-bl. Fn to med xln, silty in some beds. Syringopora sp.

Ls., mtx & mtx-wi-skel to skel. Dk bl-gy & olv-gy. Wx bwn-gy, bl-gy & yl-bwn.

Ls., mtx-wi-skel to mtx-skel, some mtx-wi-detr mtl. Med dk-gy & dk gy-bl.

Ls., mtx-wi-skel to skel, & mtx-wi-detr. Dk gy-bl & olv-gy. Wx bwn, red-bwn & lt gy. Fn & med xln, silty & fn sdy. Five per cent bdd & nod cht.

Ls., mtx-wi-skel to skel. Med gy-bl & med bwn-gy. Wx bwn, yl-bwn, & bl-gy.

Ls., mtx-wi-skel to skel & mtx-wi-detr. Med to cse xln & cse bioclast, silty.

Ls., mtx-wi-skel to mtx-skel, & detr-mtx. Med-bwn-gy & dk gy-bl. Wx bwn & bwn-gy. Med to cse xln & med bioclast, silty & fn sdy.

Ls., mtx-wi-skel to mtx-skel, & mtx-wi-detr. Some bdd cht in ls. Dk gy, olv-gy & lt tan-bwn. Wx yl-bwn, med bl-gy & lt bwn-gy. Fn to med xln, bioclast, silty & sdy.

Ls., mtx, mtx-wi-skel, & mtx-wi-detr mtl. Dk bl-gy & dk olv-gy. Wx lt yl-bwn, lt bwn & bl-gy. Fn to med xln & silty.

Ls., mtx-wi-skel to skel & mtx-wi-detr. Lower one-half orthoqtzite. Dk gy-bl to dk olv gy & blk. Wx red-bwn, lt yl-bwn, & med bl-gy. Fn to cse xln, silty & sdy.

Ls., mtx-wi-skel & mtx-wi-detr. Olv-bwn & bwn-gy. Wx lt tan-gy, gy-bwn & dk bl. Fn to med xln, silty.

Ls., mtx & detr-mtx, Olv-gy & dk gy-bl. Wx lt yl-bwn, red-bwn & med bl-gy. Fn & med xln. Silty & fn ss.

Ls., mtx, skel-mtx, & detr-mtx. Bl-gy & olv-gy. Wx gy-bwn. Fn to med xln, silty.

Ls., mtx, contains sml amt evaporitic mtl. Olv-gy & bl-gy. Wx gy-bwn & bl-gy. Fn to med xln.

Ls., same as above. Lower 10 feet skel ls. Crinoid columnals.

Ls., lower 35 feet mtx, upper part mtx-skel & skel. Wh to lt gy & lt to med bl-gy. Wx lt tan & med bl-gy. Fn to med xln & cse bioclast.

Ls., mtx-wi-skel to mtx-skel & detr-mtx. Olv-gy & med bl-gy. Wx med bwn-gy. Fn to med xln, silty & fn sdy.

Ls., detr-mtx, Olv-gy, bwn-gy & dk bl-gy. Wx yl-bwn & bwn-gy. Med & cse xln & fn sdy & silty.

Ls., mtx, mtx-wi-skel & skel-mtx. Dk bl-gy. Wx yl-bwn & dk bl-gy. Fn to med xln.

Ls., mtx & mtx-wi-skel. Med gy & lt olv gy. Wx lt yl-bwn & olv-gy. Fn & med xln, silty to fn sdy.

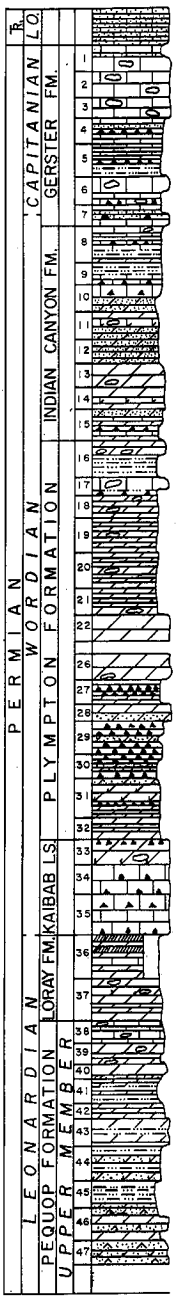
Ls., same as above. Olv-gy & dk bl-gy. Wx yl-bwn & med bl-gy. Fn & med xln, silty & fn sdy.

Ls., mtx, mtx-wi-skel, & detr-mtx. Lt & med gy, & med bl-gy. Wx yl-bwn & med bl-gy. Med & cse xln, silty & fn sdy.

Ls., mtx & mtx-wi-skel, mtx-skel at base & contains some bdd cht, mtx-wi-detr mtl. Lt gy, med gy, & med bl-gy. Med & cse xln, silty & fn sdy.

Ls., mtx, mtx-wi-skel, some bdd cht in upper lss. Med bl-gy & med gy.

TEXT-FIGURE 10.—Columnar stratigraphic section of the Gold Hill District, Tooele County, Utah.



Thaynes Limestone. Ls., mtx-wi-detr & skel mtl. Bwn to red-bwn. Wx bwn to red-bwn. Fn to med xln, silty & fn xln. Abd Meekoceras abt. 20 feet above base.

Ls., mtx & mtx-wi-skel, & mtx-wi-detr mtl. Gy, yl-bwn & pk-bwn. Wx yl-bwn, lt pk-bwn & lt gy. Fn to med xln. Five percent gy & bwn nod cht. Abd brachiopods.

Ls., mtx-wi-skel to mtx-skel, Dk gy & bwn-gy. Wx lt bl-gy, & med yl-bwn. Med & cse xln & cse bioclast. Abd brachiopods, bryozoans & crinoid columnals.

Ls., mtx & mtx-wi-skel. Gy & gy-bwn. Wx med gy & dk bl-gy. Med & cse xln.

Ls., lithographic, mtx, mtx-wi-detr silt; some bdd cht. Wh, lt yl-bwn & gy. Wx wh, red-bwn & lt gy. Lithographic to med xln, silty. No fossils.

Siltst., calc; bdd cht; & mtx-detr ls. Purp, wh, & gy-bwn. Wx lt bwn, wh, & red-bwn. Med xln, silty. Some brachiopods & bryozoans.

Ls., mtx-wi-skel, mtx-wi-detr to mtx-detr; bdd cht in one ls bed. Wh & lt yl, lt gy-bl. Wx med to dk red-bwn & lt gy. Med xln, silty & fn sdy. Few Fossils.

Ls., mtx-wi-skel & mtx-wi-detr; calc siltstone, & bdd cht in ls. Lt gy-bwn, pk & gy. Wx pk, lt gy & dk gy-bwn. Med & cse xln, silty, few fossils.

Ls., mtx & mtx-wi-skel to mtx-skel; calc siltst; & bdd cht in ls. Bwn, gy-bwn, & dk gy to blk. Wx lt gwn-gy, med gy-bwn & dk bl-gy. Med to cse xln, silty.

Siltst., sly calc; & silty ls wi bdd cht. Lt gy & yl-bwn. Wx lt gy, dk pk, & yl-bwn.

Ls., mtx-wi-skel & mtx-wi-detr; lower one-half silty dolomite. Lt gy & lt gy-bwn. Wx dk gy. Med xln, silty.

Dol., silty & calc; dolomic & silty mtx & mtx wi detr ls. Med bl-gy & pk-gy. Wx gy-bwn & bwn. Med xln, silty.

Dol., calc wi some silt. Med yl-bwn & dk bl-gy. Wx lt gy-bwn & med gy. Med to cse xln. silty.

Dol., calc. Bwn-gy & dk gy. Wx lt gy to bwn. Med to cse xln. Ten percent nod cht.

Dol., calc. & dolomic ls. Same color & texture as above.

Dol., some calc & some silty; lithographic & mtx ls; Some bdd cht. Dk bl-gy & bwn-gy. Wx yl-bwn & lt gy. Lithographic & fn to med xln.

Siltst., calc; & mtx-wi-skel ls. Lt bwn, bwn-gy & gy. Wx dk bwn & med bl-gy. Fn & med xln & silty.

Ls., mtx-wi-skel; calc siltst; & bdd cht in ls. Yl-bwn & bwn-gy. Wx bl-gy & yl-bwn.

Dol., sly cald & sly silty. Lt yl-bwn & med bl-gy. Wx lt gy & gy-bwn. Fn & med xln.

Dol., calc & silty. Dk bwn-gy & yl-gy. Wx & dk gy-bwn. Med xln, silty. Five per cent gy, bwn, & wh nod cht. No fossils.

Dol., calc. Gy, bwn-gy & gy-bwn. Wx med gy & gy-bwn. Med xln, Five per cent case hard ls. No fossils.

Dol., calc. Same color & texture as above. Ten per cent bwn & gy nod cht.

Dol., calc. Gy & gy-bwn. Wx bwn & lt gy. Med to cse xln. Five per cent bwn nod cht. No fossils. Strong hydrocarbon odor.

182 feet omitted.

Dol., calc. Olv, olv-bwn & dk gy. Wx lt bwn & lt bwn-gy. Three percent bwn nod cht.

Cht., bdd in upper one-half. Lower one-half dol. Dk & bwn-gy. Wx bwn, yl-bwn, & lt gy. Aphanic cht & fn xln dol.

Dol., calc & silty. Bwn-gy to bwn-olv. Wx lt gy & med bl-gy. Fn xln, silty & sdy.

Cht., & thin bds of silty dol. Some siltst (not shown). Cht is bwn & blk & wx same. siltst is yl-bwn & wx dk bwn. Dol is yl-bwn & wx med gy. Aphanic & med xln.

Cht., bdd; & siliceous dol. Cht blk & bwn, dol bwn & yl-bwn. Fn xln, silty.

Dol., calc & sly silty. Some wh & lt gy nod cht. Dol lt bwn-gy & yl-bwn. Wx lt gy & lt yl-bwn. Aphanic cht & fn to med xln & silty dol. No fossils.

Dol., same texture & color as above.

Dol., calc; bdd cht upper 10 feet. Olv-gy. Wx lt gy & yl-bwn. Med & cse xln. Contains crinoid columnals.

Ls., mtx-wi-skel. Some bdd cht. Lt to med gy. Wx wh to med gy. Med to cse xln & cse bioclast. Crinoid debris.

Ls., same as above. Upper one-half contains 35 per cent bdd cht, lower one-half 20 per cent.

Gypsum? interbdd wi dol. Outcrop covered but exposures at Ferguson Mtn are of gypsum, and this type lithology may also be present at Gold Hill. Lower one-half dol & ls. Some low outcrops in lower part.

Dol., sly calc, Dk bwn-gy. Wx lt bwn & olv-gy. Med xln.

Ls., mtx & mtx-wi-detr. Dk gy & bwn-gy. Wx yl-bwn & bwn. Med & fn xln, silty.

Dol., mtx & mtx-wi-detr. Dk bwn-gy to olv-gy. Wx lt to med gy. Med xln, silty.

Dol., mtx, sly silty. Dk gy, bwn gy & olv. Wx lt gy & bwn. Fn to med xln, silty.

Siltst., & calc silty dol. Lt bwn & dk bl-gy. Wx yl, gy, & bwn.

Dol., sly calc. Dk bl-gy & lt yl-bwn. Wx gy-bl, wh, gy, & yl-bwn, Med xln, silty.

Dol., sly calc & silty; & calc siltst. Dk gy, yl-bwn, med-gy. Wx dk yl-bwn & lt-gy.

Dol., calc & silty; & calc siltst. Dk olv-gy & lt to med yl-bwn. Wx dk yl-bwn & dk bl-gy. Med & cse xln, silty.

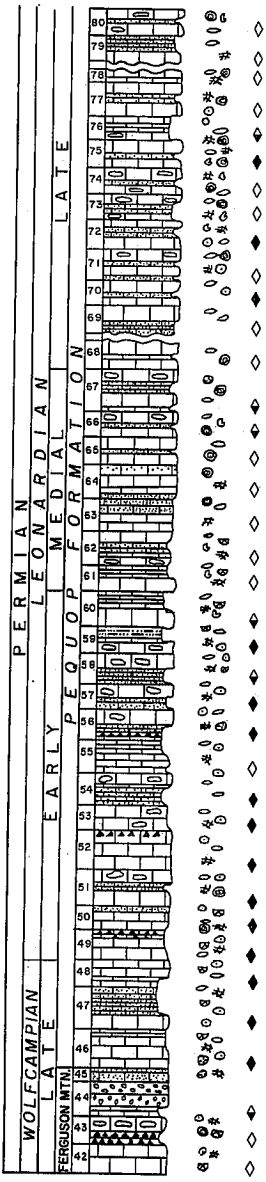
Siltst., lower 5 feet calc & silty dol. Wh, yl, & dk bl-gy. Wx yl-bwn, wh, & bl-gy. Fn xln, silty & fn sdy.

Dol., interbdd wi orthoqtzite. Lt yl-bwn & dk bl-gy. Wx lt & med gy, & yl-bwn. Fn & med xln, silty & fn sdy. No cht. No fossils.

Orthoqtzite, & calc, silty dol. Lt yl-bwn & dk bl-gy. Wx bwn & lt gy. Med xln.

328 feet omitted.

TEXT-FIGURE 10.—Continued.



Ls., mtx, mtx-wi-skel, & mtx-wi-detr. Gy, dk gy-bl & mar. Wx lt bl-gy & red-bwn.

Ls., mtx, mtx-wi-skel, & detr-mtx. Dk gy-bl, mar & gy. Wx dk bl-gy & bwn.

Fault

Ls., mtx, mtx-wi-skel, & mtx-wi-detr. Badly brecciated. Gy & red-gy. Wx yl-bwn & gy.

Ls., mtx, mtx-wi-skel & mtx-wi-detr. Med gy-bl & red-gy. Wx yl-bwn & med bl-gy. Fn to med xln, silty.

Ls., mtx & mtx-wi-skel to mtx-skel ls. Aphanic, fn to med xln, silty & fn sdy.

Ls., mtx-wi-skel, & mtx-wi-detr to mtx-detr ls. Dk gy-bl to blk & lt tan-gy. Wx bwn & med bl-gy to yl.

Ls., mtx, mtx-wi-skel to skel, & mtx-wi-detr to detr-mtx. Med gy, red-gy & lt bwn.

Ls., mtx, mtx-wi-skel to mtx-skel, & mtx-wi-detr. Dk gy-bl, olv-gy & lt gy-bwn. Wx med bl-gy, mar-gy & bwn. Fn to med xln, silty. Abd fusulines & gastropods.

Ls., mtx, mtx-wi-skel to skel, & detr-mtx. Dk olv-gy, dk bl-gy & lt red-gy.

Ls., skel-mtx & mtx-skel. Med bl-gy, med gy & gy-bwn. Wx bwn, yl-bwn & olv-gy. Fn to med xln.

Ls., mtx, mtx-wi-skel, & mtx-wi-detr. Abd fusulines, some bryozoans & crinoids.

Ls., mtx, mtx-wi-skel & mtx-wi-detr. Red-gy & dk gy. Wx lt bl-gy, yl-bwn & red-bwn

Fault

Ls., mtx & mtx-wi-detr. Dk gy, dk bl-gy & bwn-gy. Wx bwn & dk bl-gy to blk.

Ls., mtx, mtx-wi-skel, mtx-wi-detr. Dk olv-gy, red, dk bl-gy. Wx red-gy, bwn & dk bl-gy. Fn to med xln, silty & fn sdy. Fusulines, bryozoans, algae & a coral biostrome near top of unit.

Ls., mtx & mtx-wi-skel. Dk olv-gy & dk bl-gy to blk. Wx bwn & dk bl-gy. Fn to med xln, silty.

Ls., mtx-wi-skel, & mtx-wi-detr. Blk, dk bl-gy & bwn-gy. Wx bwn, yl-bwn & dk bl-gy.

Ls., mtx, mtx-wi-skel, & mtx-wi-detr. Blk & dk olv-gy. Wx dk bl-gy & bwn. Aphanic fn xln & silty.

Ls., mtx, mtx-wi-skel to skel-mtx, & mtx-wi-detr. Olv-gy, red-gy & blk. Wx lt bl-gy, & yl-bwn. Aphanic, fn xln & silty.

Ls., mtx, mtx-wi-skel & mtx-wi-detr. Olv-gy, bl-gy, bwn-gy & blk. Wx bwn, yl-bwn, & bl-gy. Fn & med xln. silty & fn sdy.

Ls., mtx, mtx-wi-skel to skel-mtx. Gy, olv-gy & blk. Fusulines abd upper one-half.

Ls., mtx-wi-skel to skel, & mtx-wi-detr. Dk bl-gy, blk, & lt bwn-gy. Wx bwn, yl-bwn & dk bl-gy. Med xln, silty. Numerous gastropods lower one-third.

Siltst., calc, & mtx-wi-skel to mtx-skel ls. Gy & lt gy-bwn. Wx bwn & dk bl-gy.

Ls., mtx-wi-skel to mtx-skel & mtx-wi-detr. Dk bl-gy & med bwn-gy. Wx bwn, red-bwn, & dk bl-gy. Med & fn xln, silty. Brachiopods, bryozoans, & fusulines.

Ls, mtx-wi-skel to skel, & detr-mtx. Fn to cse xln & cse bioclast, silty & fn sdy.

Ls., mtx-wi-skel to skel, mtx-wi-detr & some bdd cht. Lt gy, bwn-gy & med bl-gy. Wx bwn & dk bl-gy. Cse xln, cse bioclast, & silty.

Ls., mtx & mtx-wi-skel. Dk gy & dk olv-gy. Wx med bl-gy & bwn. Fn & med xln. Crinoid columnals, fusulines, & bryozoans.

Ls., mtx-wi-skel to skel, & mtx-wi-detr. Gy, bwn-gy & purp-gy. Wx bl-gy, bwn & mar-gy. Fn xln, cse bioclast & silty. Criquinites & fusuline coquinites.

Ls., mtx-skel & skel. Lt to med bl-gy, gy, & olv-gy. Wx-gy, med bl-gy & bwn.

Ls., skel-mtx to skel; some bdd cht. Lt & med gy to olv-gy. Wx med bl-gy & tan to bwn. Cse xln & cse bioclast.

Ls., skel-mtx to mtx-skel. Dk bl-gy to blk, lt bwn-gy. Wx tan-gy, dk bl-gy & bwn. Cse xln, Criquinite.

Ls., lower two-thirds skel-mtx to skel; upper one-third silic & silty.

Ls., mtx-wi-skel, skel-mtx & mtx-wi-detr. Lt bwn-gy, gy, & bl-gy. Wx yl-bwn, bwn-gy & bl-gy. Fn to cse xln.

Ls., mtx, mtx-wi-skel, & skel-mtx. Med bwn-gy, lt & dk gy. Wx lt & med bwn & med bl-gy. Fn to cse xln.

Ls., mtx-wi-skel, mtx-wi-detr, & detr-mtx. Gy, bl-gy & gy-bwn. Wx bl-gy, bwn-gy, & mar-gy. Fn to med xln, silty & fn sdy. Corwenia sp.

Ls., mtx, mtx-wi-skel, & skel-mtx. Med bl-gy & tan-gy. Wx med & dk bl-gy. Med & cse xln. abd fusulines, corals, gastropods & crinoid columnals.

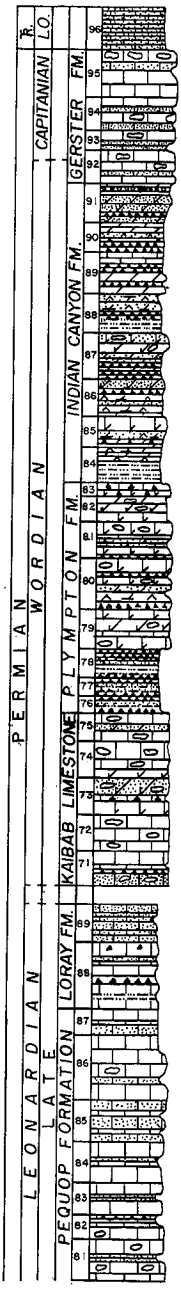
Ls., mtx & mtx-wi-detr to detr-mtx. Med & cse xln, silty & fn sdy.

Cg., qtzite pebbles; & mtx & mtx-wi-skel ls. Gr-gy, lt gy & gy-bwn. Wx gy & dk tan-gy. Aphanic & fn xln & fn to very cse detr. Colonial corals in ls beds.

Ls., mtx, mtx-wi-skel, & mtx-wi-detr. Bdd cht at base. Red-gy, gr-gy, tan-gy & bl-gy. Wx bwn, 61-bwn, & dk bl-gy. Aphanic & fn xln, silty.

Ls., mtx, & mtx-wi-skel. Blk, dk bl-gy & med gy. Wx yl-bwn & med & dk bl-gy.

TEXT-FIGURE 11.—Columnar stratigraphic section of the Pequop Mountains area, Elko County, Nevada.



Unit 96--Thaynes Limestone. Ls., mtx wi detr & skel mtl. Bwn to red-bwn. Wx bwn to red-bwn & blk. Fn to med xln, silty & fn sdy. Abd Meekoceras sp.

Ls., mtx-wi-skel & detr mtl, & skel-mtx. Lt. pk, tan, & mar. Wx lt yl, lt mar, & lt tan-gy. Fn to med xln & silty. Three to ten per cent nod cht & case-hard silic ls in upper beds. Productid & spiriferid brachiopods, lioclemid bryozoans.

Ls., mtx-wi-detr & mtx-wi-skel, mtx-skel, & skel. Lt yl-tan, lt red-tan, & lt mar in upper beds. Productid & spiriferid brachiopods, lioclemid bryozoans.

Ls., mtx-wi-detr & skel mtl, Some brachiopod coquinites & lioclemic bryozoans.

Ls., same as above. Lt tan-gy, lt to med bwn-gy. Wx lt bwn & tan-gy. Fn to cse xln, silty & sdy. Brachiopod coquinites, abd crinoid stems & bryozoans.

Dol., calc, silty & sdy, interbdd wi bdd cht. Five foot cg bed near top. Bdd cht. some nod cht & small cht rosettes. No fossils.

Cht., bdd & nod, interbdd wi orthoqtzite & silic dol. Olv-gy & lt tan-gy. Wx lt gy to lt bwn-gy & yl-tan. Aphanic & fn xln, qtzitic & silty.

Cht., bdd & nod, interbdd wi deter & skel ls & dol. Olv-gy, lt tan-gy & gy. Wx lt bwn-gy & yl-tan. Aphanic, fn xln, qtzitic & silty.

Sltst., subfria, interbdd wi dolomic orthoqtzite & bdd cht. Lt gy, lt yl, bwn-gy, & red-bwn. Wx lt yl, lt gy & lt red-bwn. Silty & fn sdy, qtzitic, fn to med xln.

Cht., interbdd wi silty calc dol & silty dolomic ls. Lt to med bwn & bwn-gy. Wx lt to med bwn-gy & gy-bwn. Aphanic, fn xln, qtzitic, silty & fn sdy.

Dol., silty & calc, interbdd wi dolomic orthoqtzite & bdd cht. Lt gy to gy-gr & lt bwn-gy. Wx lt tan, red-bwn, & blk. Silty & fn sdy, fn to med xln, Cht rosettes.

Orthoqtzite., dolomic; dolomic ls; & dol containing bdd cht. Lt gy to bwn-gy. Wx lt gy, med bwn & blk. Fn & med xln, qtzitic, silty & fn sdy. Abd cht rosettes.

Siltst., dolomic; dolomic orthoqtzite & some calc dol. Olv-gy, lt tan & mar-gy. Wx bwn, gy-gr & red-tan. Fn xln, silty & fn sdy.

Ls., dolomic, contains 20 per cent bdd & nod cht. Lt to med gy. Wx lt gy & red-bwn.

Ls., dolomic & calc dol. Lt gy, lt yl & med gy-bwn. Wx lt gy, bwn-gy & lt yl. Fn to med xln, silty, fn sdy. Some wh cht rosettes.

Ls., dolomic, interbdd wi orthoqtzite & bdd cht. Bwn-gy to olv-gy & olv-bwn. Wx lt gy, red-bwn & olv-gy. Aphanic & fn to med xln, silty. Echinoid spines.

Ls., dolomic; silty dol, dolomic orthoqtzite & bdd cht. Bwn-gy, purp-gy, & lt-gy. Wx lt gy, bwn & red-bwn. Fn to med xln, cse silty & fn sdy. Hydrocarbon odor.

Ls., dolomic, mtx, mtx-wi-skel & wi-detr; some calc dol. Lt yl-tan, tan-gy & mar. Wx lt gy, yl & mar-gy. Med to cse xln, silty & fn sdy.

Cht., phosphatic, wi some siltst. Dk gy, dk bwn, & blk. Wx same wi phosphate wh & bl. strong phosphatic odor when broken.

Cht., and siltstone, same as above but cht contains more phosphate.

Cht., and siltstone, same as above.

Ls., mtx, mtx-wi-skel, mtx-wi-detr, mtx-skel, & skel-mtx; Sdy dol & calc dol. Lt gy-ben, gr-gy & yl-bwn. Wx lt yl-gy, bwn-gy, & mar. Aphanic & fn xln, bioclast.

Ls., mtx & some skel. interbdd wi calc dol. Gy-bwn to lt gy & wh. Wx-gy-bwn to lt gy & wh. Fn to med xln & bioclast.

Ls., mtx & mtx-wi-skel mtl; silty calc dol, & ls containing bdd cht. Bwn, gy-bwn to lt tan. Wx lt gy-bwn to bwn-gy & gy. Fn xln to cse bioclast, silty & fn sdy.

Ls., mtx, mtx-wi-skel to skel. Bwn, gy-bwn to bwn-gy. Wx bwn, bwn-gy, & red-bwn. Aphanic & fn to cse xln & bioclast. Red-bwn nod cht lower one-half. Fetid odor.

Ls., mtx, mtx-wi-detr, & mtx-wi-skel to skel. Some bdd cht. Gy bwn to bwn-gy. Wx lt tan, bl-gy & bwn. Aphanic, fn to cse xln, bioclastic & silty.

Ls., mtx-wi-detr, detr-mtx, & mtx-detr. Lt bl-gy, gy & gy-tan. Wx lt bl & yl-gy. Fn xln, silty & fn sdy. No cht.

Ls., mtx-wi-detr silt & fn ss; calc siltst, & bdd cht. Lt bl-gy, lt tan & yl. Wx same. Aphanic, fn & med xln, med bioclast, silty & fn sdy.

Ls., mtx, mtx-wi-detr silt & fn ss, mtx-wi-skel to skel-mtx. Lt bl-gy, med gy & lt gy. Wx same wi some yl-gy. Fn xln, silty & fn sdy.

Ls., mtx, mtx-wi-skel to mtx-skl (some encrinites), & mtx-wi-detr. Lt bl-gy, gy & lt tan. Wx same. Aphanic to fn & med xln, med bioclast, silty & fn sdy.

Ls., mtx-wi-detr silt & fn ss, some mtx-wi-skel. Lt bl-gy, gy, lt pk & yl. Wx med bl-gy, dk gy, & lt pk. Aphanic & fn xln to silty.

Ls., mostly mtx, some mtx-wi-detr silt & fn ss, & some mtx-wi-skel. Lt bl-gy to med gy & dk gy. Wx lt bl-gy to lt gy. Aphanic & fn xln to silty & fn sdy. No cht.

Ls., mtx, mtx-wi-detr, & mtx-wi-skel mtl. Some cse bioclastic encrinites. Lt bl-gy to med gy & dk gy. Wx lt bl-gy. Aphanic & fn xln to silty & fn sdy.

Ls., mtx, mtx-wi-skel, mtx-skel, mtx-wi-detr, & detr-mtx. Bdd cht at top of unit. Dk gy, bwn-gy, mar & red-gy. Wx bl-gy to gy-bl, & mar. Aphanic, fn to med xln.

Ls., mtx, mtx-wi-skel, & mtx-wi-detr mtl. Dk gy, bwn-gy, & lt yl-tan. Wx lt to med gy, bl-gy, & lt yl-tan. Aphanic, fn & med xln, & cse bioclast.

TEXT-FIGURE. 11.—Continued.

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