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Stratigraphic and Tectonic Interpretation of Oquirrh Formation, Stansbury Mountains, Utah*

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ABSTRACT.—Detailed measurement of seven stratigraphic sections within the Oquirrh Formation, Stansbury Mountains, Utah, revealed a maximum of 14,214 feet of Morrowan to Wolfcampian strata. Fusulinids were successfully used to delineate time units. Lateral lithological facies variations were seen to be extremely complex, but were simplified by fusulinid time unit delineation, making general lithologic correlation possible. Documentation of a time and structural unconformity between Oquirrh Formation and subjacent Manning Canyon Shale was obtained. The Stansbury area was seen to have constituted a marginal portion of the "Oquirrh Basin" and to have been an area of local source for sediments of Morrowan and Derryan age. Studies strongly infer that the "Oquirrh Basin" was not a repository of continuous sedimentation; but represents a series of small (areally) taphrogenic, autocannibalistic troughs and contiguous highs. Tectonic instability throughout Pennsylvanian and Lower Permian-Wolfcampian time was prevalent as indicated by diverse Oquirrh lithologies.

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Location and Accessibility

The studied area lies approximately 45 miles southwest of Salt Lake City, Utah, in the Stansbury Mountains, T. 1-5 S., R. 6-8 W., Tooele County, Utah. It includes all of the Oquirrh Formation exposed in the mountains. Oquirrh Formation crops out discontinuously along the eastern side of the range from Johnson Pass Road (Utah Hwy. 215) north to U.S. Highway 40, a distance of about 25 miles.

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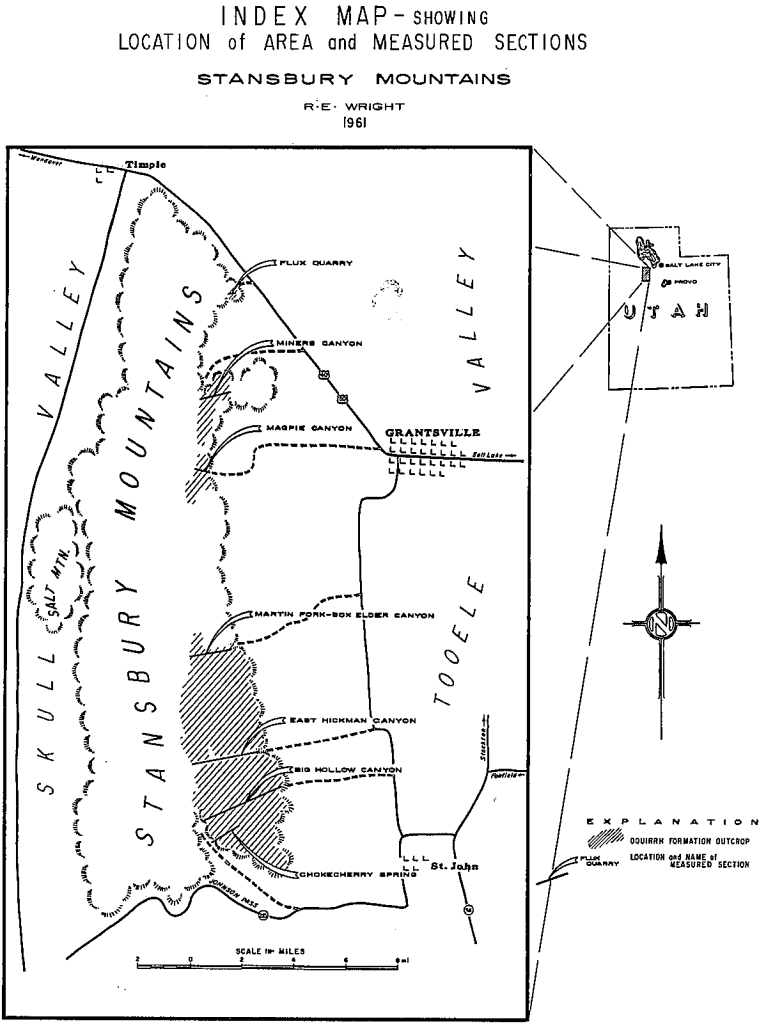

TEXT-FIGURE 1.—Index map of measured sections.

Areas of outcrop are accessible from the north by U.S. Highway 40 and from the south by Utah Highway 215. A good secondary road parallels the eastern side of the range, extending north-south, and connecting Grantsville and St. John by way of Rush Valley. This road provides access to various east-west primitive and graded dirt roads which extend into the many canyons in hills formed by the Oquirrh Formation. Immediate access to the basal Oquirrh Formation is possible only by a graded dirt road which extends north from Johnson Pass Road up Big Hollow, a north-south canyon eroded in the Manning Canyon Shale. (Text-fig. 1).

Previous Work

The name Oquirrh was first used by C. R. Keyes (1924, p. 37) to apply to a formation within the "weberian Series". Before definition of the type Oquirrh section, Nolan (1930) applied the name Oquirrh to rocks of Pennsylvanian and Permian age in the Gold Hill district of west-central Utah. When Gilluly's Professional Paper was published (1932), defining the Oquirrh Formation from its type section in the Oquirrh Mountains, the name Oquirrh had been in usage for nearly two years. Gilluly used Oquirrh to apply to the lower portion of J. E. Spurr's (1895, p. 376) "Upper Intercalated Series" at the type section, where he says the thickness of the formation is ". . . almost surely in excess of 15,000 feet."

An attempt was made by Gilluly to trace laterally certain units with hope of correlation. He found that 300-foot quartzite beds would lens out to a knife-edge within half a mile. With respect to the lensic nature of the limestones, Gilluly's opinion was that it was original (depositional) and not merely due to strike faulting. He did feel, however, that it was far less prevalent than the lensing of the quartzites.

Lambert (1941 *ms.*), deals with the major structural elements of the south and central Stansbury Range. Other than a very general treatment of Oquirrh stratigraphy, he makes little mention of Oquirrh lithology.

Some valuable concepts of age determination on the basis of fusulinids are given by Thompson, Verville, & Bissell (1950) for the area of the south-central Wasatch Mountains, Utah.

Bissell (1952), in dealing with the structure and stratigraphy of the Strawberry Valley Quadrangle, Utah, offers some explanation of tectonics influencing source and depositional areas of Oquirrh sediment in the section of that area. Fusulinids are again used by him in recognizing series within the Oquirrh Formation.

Croft (1956) mapped Morrowan, Atokan, and Desmoinesian rocks in the Northern Onaqui Mountains, a southerly extension of the Stansbury Range. Common lithologies supplemented by fusulinid data enabled him to map these time divisions of the Pennsylvanian System.

Due to a decrease in thickness of the Morrowan Series in a westerly direction, to a total absence of the Series on the western flank of the Northern Onaqui Mountains, Croft suggested an unconformable relationship of the Oquirrh Formation with the underlying Manning Canyon Shale.

Teichert (1958 *ms.* p. 48-56) measured a detailed Oquirrh section in the Southern Stansbury Mountains. He found Desmoinesian to Virgilian rocks. An attempt at a more detailed breakdown was unsuccessful. Teichert did, however, find further documentation of the pre-Oquirrh unconformity mentioned by Croft.

In his study of the geology of the Stansbury Range, Rigby (1958) carried, in a similar manner, Croft's "Series" mapping northward into the Stansbury Range, again noting the Oquirrh-Manning Canyon unconformity.

Latest work on the Oquirrh Formation is a most thorough and well documented job of rock unit delineation presented by Bissell (1959, p. 93-127) on the area of the Southern Oquirrh Mountains and Five-Mile Pass Quadrangle. Bissell formally named, measured, and mapped as discrete members, rocks representing Morrowan through Virgilian ages, within the Pennsylvanian Oquirrh Formation. These members and their corresponding ages are as follows:

Pole Canyon Member	Virgilian	1,526 feet
Lewiston Peak Member	Missourian	1,409 feet
Cedar Fort Member	Desmoinesian	1,371 feet
Meadow Canyon Member	Derryan	945 feet
Hall Canyon Member	Morrowan	915 feet
	Total thickness of Pennsylvanian	6,166 feet

Attempts to carry Bissell's terminology into the Stansbury area by the writer were not successful.

Field Work

Field research was begun in April, 1959, and completed late in November.

Steel tape and Brunton Compass were used to measure detailed stratigraphic sections at critical intervals along the area of outcrop. Locations of these measured sections and their lithologic units were plotted on aerial photographs while in the field. Lithologic and paleontologic samples were collected while measuring sections and their locations marked on the aerial photographs. Intraformational units had their respective number painted upon outcrops to facilitate remeasurement or to aid in field inspection of measured sections. These numbers were painted at the base of each new unit and correspond to the unit numbers in the correlation chart (in pocket) and to samples of rocks and fossils on file at Brigham Young University.

In addition to systematic measurements made, aerial extent of the Oquirrh Formation was mapped on aerial photos and an attempt was made toward correlation of lithologic units. The detailed sections are on file in the Department of Geology, BYU.

Purpose and Scope

The Oquirrh Basin is considered to have been a single repository of continuous sedimentation throughout Pennsylvanian and possibly into the Wolfcampian. Due to transgressive overlapping of the basal Oquirrh Formation with the subjacent Manning Canyon Shale of Mississippian-Pennsylvanian age, and a relatively thinner section found here than in other areas, there is reason to believe that the Stansbury region constituted a marginal portion of the Oquirrh Basin.

The purpose of this study is to provide documentation for this hypothesis.

In addition, lateral variations of Oquirrh sediments have received only very general treatment. The nature of lateral variation and a reasonable explanation of tectonic elements which were prevalent in source and depositional areas are here described in detail.

Fusulinids and other faunal elements contained within the rocks are used to provide data for age delineation and environment of repository.

Acknowledgments

For their assistance in the preliminary stages of planning this study, I am grateful to Dr. Harold J. Bissell and Dr. J. Keith Rigby of Brigham Young University.

Dr. Bissell kindly offered his criticism of the manuscript and aided in the identification of the fusulinid fauna.

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For the inspiration and encouragement afforded by my wife, Gwen, I am truly thankful. Her parents and my own were helpful in a like manner.

STRATIGRAPHY

General Statement

Sediments comprising the surface section of the Pennsylvanian-Permian Oquirrh Formation in the Stansbury Mountains reach a maximum thickness of 14,214 feet and represent rocks ranging in age from Morrowan to Lower Wolfcampian.

At first appearance, these sediments appear to be a sequence of non-descript, alternating, massive limestones, thin, cross-bedded sandstones, and interbedded quartzites. However, detailed petrologic (field) and petrographic studies prove that extreme variation and facies changes are typical.

The limestones vary from aphanic matrix rocks to coarse-encrinites, containing abundant brachiopods, corals, bryozoans, fusulinids, and algae, reaching biostromal character; to sandy, quartz-rich limes, containing authigenic to second and possibly third cycle quartz.

Sandstones range in composition from 75 to 85 percent quartz of fine to coarse-grained size in a calcareous matrix to argillaceous and silty calcarenites which are composed of second cycle fossil detritus. Textures are predominantly finely laminated to cross-bedded, with intralaminated and bedded fossil calcarenites and quartz sands.

Least variable of the three dominant rock types are the quartzites. With little exception, all quartzites are slightly to moderately calcareous, with a content of fine-to-medium, subangular to subrounded grains composing 75 to 95 percent of the rock. Thin-sections and residues reveal semi-interlocking to interlockatory, typically quartzitic fabrics and second to possibly third cycle quartz, with many grains showing authigenic overgrowths. Dense, sandy to quartzitic limestones are commonly intercalated with the quartzites.

Supplementing these three dominant lithologies are a few light-colored, calcareous siltstones, dark to light colored limy shales, conglomerates, and diagenetic conglomerates, here difined as a rock of conglomeratic texture which is formed from an unlithified, but already deposited sediment, broken into material of conglomeratic size while yet in the process of diagenesis. Because the fabric has been reorganized, the process of diagenesis was active.

Lithologic variations are usually sharp vertically, although gradational contacts between limestones and quartzites are quite common. Lateral facies changes are of an extremely complex nature, so as to nearly prohibit any attempt at lithologic correlations other than on a very large scale.

Faunal Zonation

The following list represents at least the principal fusulinids used to delineate Series of the Pennsylvanian and Permian systems and to correlate time-units within the Oquirrh Formation. Where fusulinids were lacking, other faunal elements and lithologic similarities to previously distinguished time-units were used. Time lines were placed primarily on the basis of fusulinids. Dr. H. J. Bissell verified all fusulinid identifications.

Permian System-Wolfcampian Series:
Dunbarinella hugesensis Thompson
Pseudofusulinella utahensis Thompson, Verville & Bissell
Schwagerina andresensis Thompson
Triticites cellamagnus Thompson & Bissell

Pennsylvanian System-Virgilian Series:
Triticites cullomensis Dunbar & Condra
T. kellyensis Needham
T. milleri Thompson
Waeringella bailkeyi Thompson, Verville & Bissell

Pennsylvanian System-Missourian Series:
Kansanella (Kansanella) grangerensis (Thompson, Verville & Bissell)
Triticites provoensis Thompson, Verville & Bissell
T. springvillensis Thompson, Verville & Bissell
Wedekindellina ultimata Newell & Keroher

Pennsylvanian System-Desmoinesian Series:
Eoschubertella sp.
E. mexicana Thompson
Fusulina rockymontana Roth & Skinner
Wedekindellina matura Thompson

Pennsylvanian System-Late Derryan Series:
Fusulinella acuminata Thompson

Pennsylvanian System-Early Derryan Series
Profusulinella copiosa Thompson
P. regia Thompson

Pennsylvanian System-Morrowan Series:
Millerella inflecta Thompson
M. marblensis Thompson

Chokecherry Spring Section

Rocks ranging in age from Morrowan to Early Desmoinesian were measured in this section totaling 2,306 feet. This partial section was measured and fusulinids collected to provide documentation of the Morrowan and Derryan rocks at the southern end of the Stansbury Mountains (Text-fig. 1). A complete section ranging to Missourian-Virgilian age is exposed here, but was investigated in a reconnaissance manner. A more accessible and better exposed section was measured three miles north.

Morrowan Series

A predominance of dark blue-gray to gray, silty, aphanic, skeletal-in-matrix, and biostromal limestones comprise this Series. Minor light colored, calcareous siltstones, intralaminated skeletal calcarenites and fine-to-medium

grained, subangular to rounded quartz sandstones constitute the remainder of the sediments.

Limestones form massive ledges and weather to angular, meringue-surfaced blocks from six inches to one foot in diameter. Sandstones and calcarenites weather to buff and tan, smooth, subrounded, smaller ledges, while siltstones and shales form relatively smooth slopes, littered with shaly plates of pastel shades of blue, pink, purple and gray.

Chert is present as randomly scattered blebs and nodules, constituting less than ten percent of the section. Brachiopods and bryozoans are commonly silicified. Most noticeable, particularly in thin-sections, is a high percentage of limonite stain, occurring as coatings on laminae and as pseudomorphs of limonite after pyrite.

The fusulinid genus *Millerella* is ubiquitous throughout the Series, and the contact with Derryan rocks was marked beneath unit C-13 which contains first appearance of diagnostic species of *Profusulinella.*

In addition to unidentified bryozoans, corals, productid and spiriferid brachiopods, the following fossils were identified from 837 feet of rocks assigned a Morrowan age: *Archimedes* sp., *Millerella* sp., *M. inflecta,* and *Nankinella sp.*

Derryan Series

Blue-gray to brown and tannish-gray limestones and interbedded calcareous, fine to medium-grained sandstones and quartzites are typical of this stratigraphic interval. Few bioclastic, dark blue-gray limestones are present. A light, chalky, blue-gray, variegated with maroon, calcareous, silty shale comprises 25 percent of this time-unit. Small black chert nodules and bedded chert stringers account for 35 percent of the upper 100 feet of this limy shale. With this exception, chert is a very minor constituent of the Series.

Most significant is the cross-laminated texture of sandstones, which begins in this time interval and becomes a very prominent feature in post-Derryan rocks.

Vertical gradation from limestone to quartzitic limestone, quartzite, and sandstone is strongly suggestive of cyclic deposition. This phase of the subject is dealt with in the tectonic section.

A significant difference with respect to Morrowan rocks is the noticeable decrease in amount and variation of megafossils. In addition to this, percentage of limonite coloration decreased markedly, but not to the point of being an unimportant rock component.

The Derryan-Desmoinesian boundary was placed at the base of unit C-26. This determination was based on the presence of *Eoschubertella mexicana.*

From 905 feet of Derryan rocks, in addition to unidentified bryozoans, productid and spiriferid brachiopods, the following fossils were identified: *Komia* sp., *Osagia* sp., *Profusulinella* sp., *Pseudostaffela* sp., *Eoschubertella* sp., and *Fusulina* sp.

Big Hollow—Faraday Hollow Section

A total of 14,214 feet of rocks ranging from Morrowan to questionable Wolfcampian age is exposed in this section. This represents the most complete stratigraphic record given by the Pennsylvanian-Permian Oquirrh Formation in the Stansbury Mountains.

Morrowan Series

Massive argillaceous to silty, skeletal limestones of dark gray and buff to brown color represent the 160 plus feet of Morrowan rocks. Sediments superjacent to the Manning Canyon Shale of probable Springeran age are slightly conglomeratic, with a large percentage of their constituents of dark gray to black, silty, slightly calcareous, iron-stained shales, strongly resembling reworked Manning Canyon Shale. The remainder of this thin Morrowan section contains brown and blue-gray, dense, limestones with abundant amounts of fenestrate bryozoans, brachiopods, and solitary corals, all of which have been better than 65 percent silicified. Dense chert pods, common in the darker and more dense limestones complete the accessory fraction.

In addition to the above mentioned silicified fauna, questionable forms of genus *Millerella* were identified.

Derryan Series

The Morrowan-Derryan boundary is placed with question in a covered interval, directly upon which is found *Profusulinella regia,* of unquestionable Derryan age.

Blue-gray, buff-weathering, dense, sandy, massive limestones and interbedded, fine to medium-grained quartz sandstones and calcareous quartzites typify the 1,292 feet of Derryan rocks. The limestone units contain intrabedded sandy stringers and "case-hardened" chert nodules, commonly composing up to 20 percent of the unit.

Thin-sections reveal that some limestones contain as much as 40 percent silt-size to fine-grained, subangular, detrital quartz, some grains possessing authigenic overgrowths.

Minor fractions of the section contain light-to-dark pastel shades of gray, purple, and blue, as well as black, silty, calcareous shales. These smaller shaly units form platy covered slopes beneath more massive limestones, which are upward gradations of the shales.

Algal and encrinal, skeletal-in-matrix limestones form a sizeable portion of this interval, but do not approach the biostromal nature of Morrowan carbonates.

Minor cross-laminated, sandy limestones and calcarenites, typical of Desmoinesian rocks, have their beginning in the Derryan interval.

Linoproductus sp., *Komia* sp., *Profusulinella regia, Fusulinella* (?) sp., and unidentified productid brachiopods and bryozoans were collected.

Desmoinesian Series

Light gray to dark gray, dense, aphanic, sandy, matrix limestones; light-to-dark gray skeletal-in-matrix limestones; blue-gray to light blue-gray, clastic, matrix limestones, containing silty to sandy laminae which weather in relief as buff to brown styolitic, undulatory, and regular cross-bedded laminae are most typical of this time unit.

Although quartz grains are ubiquitous throughout the series, giving quartzite qualities to a large percentage of rocks, sandstone and quartzite, as such, comprise less than 20 percent of the interval.

Limy sandstones in pastel shades of pink, purple and maroon, having a chalky or milky color are quite conspicuous, especially in the upper 66 percent of the section. These silty rocks are usually interbedded with argillaceous limestone, quartzitic limestone and quartzite.

Conglomerate, both intraformational and diagenetic, although unimportant in total percentage of rocks present, stand out as small, three to five inch resistant ledges within the limestone units.

Characteristic of Big Hollow Desmoinesian rocks is the abundance of the coral *Syringopora* sp., occurrring as partially silicified colonies within the ledges of light gray and buff quartzite limestone and calcareous quartzite.

The section is characterized by relatively smooth, even slopes occasionally interrupted by a small ledge of skeletal-in-matrix limestone less than ten inches thick, or by massive, blue-gray quartzitic limestone.

Unidentified bryozoans, solitary corals, biserial foraminifera, productid and spiriferid brachiopods were collected. In addtiion, the following fusulinids were identified: *Fusulina* sp., *F. acuminata, Eoschubertella* sp., *E. gallowayi, Fusulinella* sp., *Wedekindellina* sp. and *W. matura.*

Missourian Series

A total of 4,144 feet of sediments has been classified as Missourian rocks. The quartzitic fraction which is so characteristic of the Oquirrh Formation begins to increase in Missourian sediments. Quartzites and quartzitic limestones compose greater than 30 percent of the Missourian interval. Chert, as nodules and stringers, is only of very minor importance. A predominance of light gray and blue-gray limestones of matrix to skeletal-in-matrix character typifies the series. Interbedded and intercalated with limestones, are hard, dense, brown-gray to gray, buff-weathering, calcareous quartzites to nearly pure orthoquartzites.

Of significance in the limestones is the general subrounded nature of the detrital quartz, with all coarse-grained quartz showing well-rounded, spherical outline in thin-section.

This detrital quartz occurs most commonly as fine laminae within the limestone, and, upon weathering produces rough, buff to limonite-stained, even to cross-bedded laminations in relief on exterior surfaces of weathered rocks.

Three minor diagenetic conglomerate beds five feet thick are present at the base, at approximately the center, and at the top of the interval. The upper conglomerate is directly overlain by three to four feet of fine-grained, rounded, detrital quartz. authigenically overgrown, in a matrix of goethite and turgite.

Unidentified bryozoans, brachiopods, rugose corals and rotalid foraminifera were collected. In addition, the following fusulinids were identified: *Triticites* sp., *T. hobblensis* (?), *T. provoensis* (?), and *Schubertella mulleriedi* (?).

Virgilian Series

Virgilian rocks total 3,318 feet. A monotonous, nondescript section of silt-size to medium-grained, thin-bedded (never exceeding two feet) quartzites, intercalated with light gray and blue-gray, quartzitic, thin-bedded matrix to skeletal-in-matrix limestones compose greater than 70 percent of the series. From the Missourian boundary upward, the quartz content increases progressively, reaching a maximum in unit B-72 where, with the exception of a few minor clastic limestone beds, 1,674 feet of quartzite were measured.

Chert is common in Missourian rocks, but remains a minor (less than three percent) component.

Of subordinate mention are a few minor beds of argillaceous limestone, and two beds of cobble-size conglomerate, rich in abraded skeletals and containing fusulinids.

Exposures weather to even, rocky, buff colored slopes with only few ledges. Individual weathered fragments are dense blocks with smooth to meringue and "pox-marked" surfaces; the quartzites show one-quarter inch to one-half inch, carbonate-leached, sandy exteriors.

Virgilian age rocks contain bryozoans, productid brachiopods, algae, rugose corals and encrinal debris. *Waeringella bailkeyi* and *Triticites cullomensis* were identified from the interval.

Wolfcampian Series

A total of 480 feet of previously unrecognized Permian rocks was measured along the side of Welch Canyon roughly two miles west of St. John to Grantsville Road in sections 3 and 10, T. 5 S., R. 6 W.

Greater than 60 percent of rocks present are of quartz composition. The basal unit, (B-73) 44 feet thick, is composed of intercalated limestone and quartzite limestone in two inch to six inch beds; this is followed by 153 feet of calcareous quartzite, bearing *Triticites cellamagnus* (?) and an upper unit of 283 feet, containing limestone and quartzitic limestone, similar to B-73.

The only difference between Permian rocks and subjacent Pennsylvanian-Virgilian rocks is the fine, angular to silty nature of the quartz and darker, more argillaceous character of the sediments.

East Hickman Canyon Section

The Oquirrh Formation here contains a total of 12,220 feet of rocks of Derryan to Wolfcampian age.

Derryan Series

Thin-bedded blue-gray, fossiliferous, argillaceous limestones and pastel pink, purple and blue, limy, silty shales, containing noticeable amount of chert and up to 30 percent silt-size to medium-grained, angular to subangular quartz typify the 1,350 feet of Derryan rocks measured in this section.

Interbedded blue-gray, sandy limestones and buff-weathering, limy quartzites compose 30 percent of the section. Characteristic of the limestones are their buff-colored, sandy, frequently cross-bedded laminae which weather in relief.

Productid brachiopods compose the majority of the faunal content, and form a four foot thick biostrome in unit H-66, 785 feet above the Manning Canyon contact. Bryozoans, algae, and crinoid debris approach biostromal proportions, especially in lower half of the series. Fossils decrease and quartz content increases in the upper half.

Faunal content is composed of productid brachiopods, fenestrate bryozoans, and corals. The following forms were identified: *Profusulinella* (?) and the algae, *Komia* (?).

Desmoinesian Series

A total of 4,616 feet of rocks has been assigned a Desmoinesian age. The quartz content which began to increase in the upper half of Derryan rocks,

continued to do so in Desmoinesian time to comprise nearly 40 percent of the section.

Most characteristic are dense, light gray, buff-weathering, calcareous quartzites and quartzitic limestones; light gray and light blue-gray, aphanic, matrix limestones with varying amounts of skeletals and detrital quartz. The limestones weather as palisades between the lesser resistant quartzite rocks. Limestones predominate in the lower half of the series, while quartzites are most common in the upper half.

Petrographic studies show quartz to be of questionable igneous or metamorphic origin. Grain size is usually fine and subangular in limestones, and from fine to coarse, and angular to rounded, respectively, in quartzites. Thin-sections show graded, fine, cross-laminations and insoluble residues reveal frosting of coarse, rounded grains contained therein.

Minor amounts of chert are scattered throughout the series as blebs, stringers, and nodules. In unit H-55, chert is of major importance as nodules, to six inches in diameter, surrounded by liesegang rings.

Unidentified productid brachiopods, fenestrate bryozoans, rugose corals and algae were collected. Identified were: *Syringopora* sp., *Eoschubertella* sp., *E. gallowayi* (?), *Fusulina rockymontana* (?), *F. lonsdalensis* (?) and *Pseudostaffella needhami* (?).

Missourian Series

A relatively thin Missourian section is here represented by 1,528 feet of sediments.

Detaled study reveals gray to blue-gray, light blue-gray-weathering sandy, fossiliferous, aphanic, matrix limestones; tan-gray, buff-weathering, calcareous, fine, angular-grained quartzites; intercalated sandy, matrix limestones and calcareous quartzites; and minor partially silicified, oolitic limestones.

Limestones in the lower 500 feet show "worm trails" or possible gas escape structures and mud-cracked bedding surfaces. The superjacent 60 feet of rocks are rich in primary chert (20 percent) which contains molds of crinoid stems.

Thin-section analyses reveal major amounts of limonite in the lower 700 feet, culminating in the top of unit H-31 as porous "clinker-like" rocks, composed of sedimentary limonite and 40 percent authigenically overgrown fine-grained quartz.

Approximately 40 percent of the series occurs as silt-size to medium, angular to rounded quartz grains. Roundness increases with size. The aphanic matrix limestones contain as much as 40 percent angular, silty quartz, while quartzites possess greater than 90 percent.

Faunal constituents are abundant and fusulinids occur sporadically in profusion. The coral, *Syringopora* sp. forms biostromes in the upper 600 feet of the series. In addition to this coral, unidentified fistuliporoid bryozoans, branchiopods, algae and encrinal debris were collected. *Triticites* sp. and *Triticites provoensis* were identified.

Virgilian Series

Quartzites and intercalated limestones and quartzites characterize rocks of Virgilian age. A total of 2,313 feet is contained in this measured section.

Specifically, greater than 40 percent of the series is composed of gray,

buff-weathering, calcareous quartzites, leached of carbonate in the outer one to two inches of weathered blocks. Sandy, aphanic, matrix limestones; shaly bedded, argillaceous limestones; and fine to coarse-grained clastic limestones of gray color comprise a major portion of the section.

Conspicuous as unique units and as minor interbeds are chert, encrinite, and limestone-pebble, fossiliferous conglomerates, ranging from several inches to 12 feet thick.

Lower portion of the series shows mud-cracked limestone beds and limonite stained laminae, with an abundance of limonite and turgite in unit H-25.

Detrital quartz ranges from silt-size as sandy, buff-weathering (in relief) stringers in the limestones, to medium and coarse, subrounded to rounded grains in the quartzites. Graded bedding is noticeable in thin-section, with larger grains showing signs of extenisve abrasion.

Fusulinids are most abundant in this series, both in numbers and variety, occurring in biostromal quantities and in hashy, criquina pods. Identified were *Triticites* sp., *T. cullomensis, T. kellyensis, Schubertella* sp. and *Waeringella* sp.

Wolfcampian Series

A total of 2,411 feet of sediments have been assigned a Wolfcampian age.

These rocks are primarily dark brown and gray, calcareous, argillaceous quartzites and siltstones; blue-gray and brown skeletal-in-matrix and clastic argillaceous limestones; intercalated limestones and quartzites or siltstones; and dark brown chert and limestone-pebble, skeletal conglomerates.

Quartzite properties are possessed by all rocks and approximately 50 percent of the series is quartzite or quartzose siltstone. Quartz grains range from angular, silt-size in limestones and siltstones to medium, subangular to rounded and well-abraded in quartzites. Minor amounts of quartz show authigenic overgrowths.

Limonite as cement in "swirly", undulatory laminae is most common to the basal unit of this time division.

With few exceptions, fossils are most conspicuous in conglomerates and limestones, although fusulinids occur abundantly in quartzites. Collected were unidentified productid brachiopods, bryozoans, algae, and Foraminifera. Identified were *Oketaella cheneyi, Pseudofusulinella* sp., *Schubertella* sp., *Schwagerina* sp., *Triticites* sp. and *T. cellamagnus.*

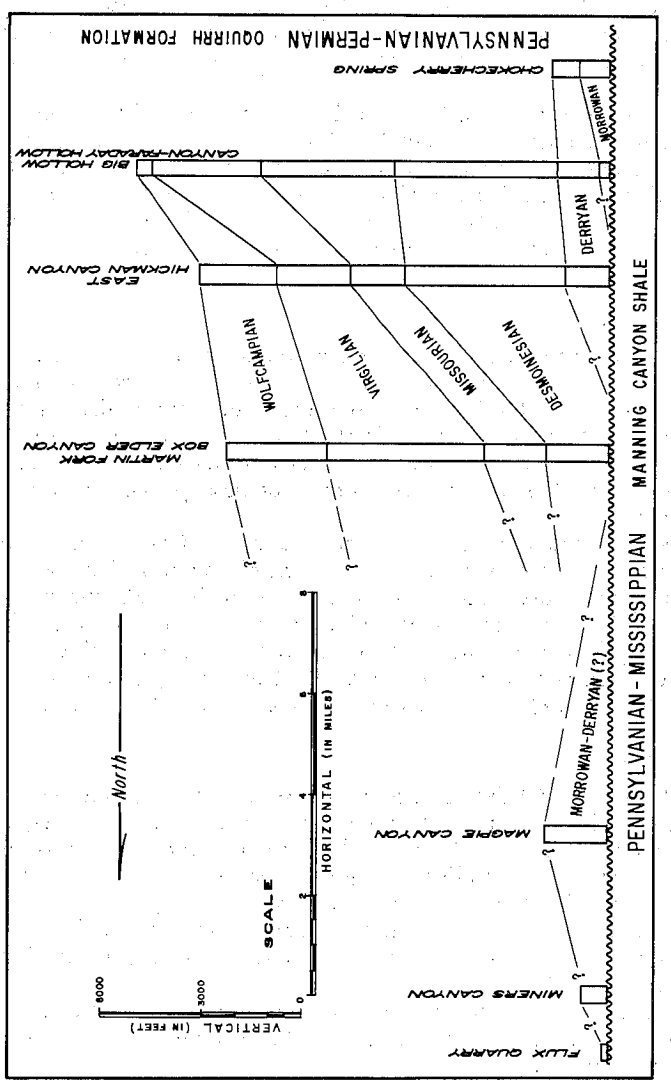
Martin Fork-Box Elder Canyon Section

Desmoinesian through Wolfcampian rocks herein contained, total 11,338 feet. The section is lacking Derryan rocks and has Desmoinesian sediments unconformably deposited upon Mississippian-Pennsylvanian Manning Canyon Shale (Text-fig. 2).

Desmoinesian Series

A partial (?) section is represented by 1,937 feet of rocks in angular unconformity with subjacent Manning Canyon Shale.

Discrete blue-gray and gray, skeletal-in-aphanic matrix limestones; interbedded shaly limestones in pastel shades of purple, pink, blue and green; and interbedded tan-grey buff-weathering quartzites; limy, cross-bedded sand-



TEXT-FIGURE 2.—Diagramatic interpretation of the Oquirrh Formation-Manning Canyon unconformity.

stones, and sandy, blue-gray matrix limestones characterize Desmoinesian rocks.

Total quartz content is greater than 40 percent and shows a noticeable increase from bottom to top of section. Quartz grains are ubiquitous, constituting up to 40 percent of the limestones. In such cases, grains are present in buff-colored, sandy stringers and cross-bedded laminae, which weather in relief on blue-gray, meringue surface of limestones. Grain size ranges from silt-size to coarse, with roundness increasing with size, from subangular to rounded.

Chert is present as scattered blebs and nodules within more argillaceous limestones. Limonite is prevalent in lower units as cement in sandy laminae.

Most abundant fossils collected were productid and spiriferid brachiopods. In addition, unidentified brachiopods, corals, bryozoans, and algae were noted. Identified were *Eoschubertella* (?), *Fusulina rockymontana, Fusulinella acuminata* (?), *Millerella* (?), *Paramillerella* (?), *Profusulinella* (?) and *Staffella* (?).

Missourian Series

This unit, containing 1,782 feet of rocks, is characterized by a predominance of blue-gray, gray and brown, silty to sandy, skeletal-in-matrix limestones and shaly, thin-bedded pastel pink and purple shaly limestones and limy shales, occurring primarily in the lower two thirds of the section. Upper third is typified by massive units of calcareous sandstones and quartzites which, with quartz fraction of the limestones, compose greater than 45 percent of the series.

Chert is present in minor amount, and silicification of skeletals is evident from thin-section analyses. Petrographic studies show a prevalence of angular, fine-grained quartz in limestones with medium-sized, subrounded grains dominant in sandstones and quartzites in cross-bedded fabrics.

Unidentified spiriferid brachiopods, bryozoans, encrinal debris and algae were noted. In addition, *Archimedes* sp., *Caninia* sp., *Oketaella lensensis* (?), *Pseudostaffella* (?) and *Wedekindellina ultimata* (?) were collected.

Virgilian Series

A total of 4,602 feet of rocks was assigned a Virgilian age. Greater than 50 percent of this total is composed of quartzites and siltstones, not to mention the quartz content of gray and dark gray, sandy, skeletal-in-matrix limestones. Intercalated bedding of gray limestones and tan, buff-weathering quartzites typifies this Pennsylvanian interval.

Of significance is the presence of opal throughout unit M-32a, and nature of quartz-rich stringers which weather in relief upon gray, meringue-weathered limestone surfaces.

Identified were *Schubertella* (?), *Triticites* sp., *T. cullomensis* (?) and *T. milleri* (?). Unidentified fossils collected were algae, bryozoans, brachiopods and crinoid debris.

Wolfcampian Series

Thickest section of Permian rocks in the Stansbury Range, totaling 3,016 feet was measured in this section.

Cherty, hashy, conglomerate pods, contained within dark-gray and brown, dense, sandy limestones distinguish rocks of Wolfcampian age.

Completing the series are minor brown and gray calcareous quartzites, brown, dense, limy siltstones and minor intercalated limestones and quartzites.

"Worm trails" or possibly gas escape structures and mud-cracked bedding surfaces appear approximately 200 feet below top of the section.

Unique in occurrence is a brown and gray, aphanic, matrix limestone, unit M-44, containing petroliferous styolites, badly fractured and "shot" through with calcite veinlets.

Fusulinids are abundant locally, usually appearing in cherty, conglomeratic, fossil hashes and encrinites, in part silicified. Collected were *Schubertella* sp., *Schwagerina* sp. and *Triticites* sp. In addition, unidentified algae, brachiopods, and bryozoans were noted.

Magpie Canyon Section

Rocks of Pennsylvanian age, totaling 1,389 feet are questionably assigned a Morrowan-Derryan age. An absence of fusulinids makes a more accurate assignment impossible. Lithologic and faunal similarities to known Morrowan-Derryan age rocks in the Stansbury section are sole substantiating criteria for this decision.

Basal units are blue-gray, meringue-weathering, thin-bedded, argillaceous, cherty limestones. Limonite appears as cement in sandy laminae and as finely laminated pseudomorphs after pyrite. Fossils vary in kinds and numbers, appearing in relief on weathered surfaces due to partial or complete silicification. Quartz content is variable, but increases in stratigraphically younger rocks, occurring as silt-size to fine, angular grains in dense, aphanic, matrix of limestones, and as fine-to-medium-grains in buff- and rusty-brown-weathering, cross-laminated sandstones and quartzites in the top of the section.

Chert, as bedded nodules and blebs, forms an appreciable amount of the section.

Fossils form biostromal ledges, especially in the lower 1000 feet. Productid brachiopods are abundant and ubiquitous. Bryozoans, corals, and crinoid debris and the following fossils were identified: *Archimedes* sp., *Dictyoclostus* sp., *Linoproductus* sp. and a very questionable *Eoschubertella.*

Miners Canyon Section

This section is placed in the Morrowan-Derryan series, on lithologic similarities and available faunal data.

A total of 816 feet of sediments is characterized by dark colored, gray, blue-gray and brown-gray, thin-bedded, argillaceous, cherty, fossiliferous limestones. These hard, dense, aphanic rocks form the lower 500 feet of the section. Abundant productid and spiriferid brachiopods contained in them form distinct beds to a maximum of four feet.

At 70 feet above the Manning Canyon Shale contact, six inches of diagenetic conglomerate occur within a blue-gray, aphanic, cherty limestone. Roughly 150 feet above this horizon, six inches of purple and black chert and pebble conglomerate appear. Throughout the section, minor conglomeratic beds were noted.

A definite increase in quartz is readily seen in upper half of the section. Rocks are more sandy, lighter in color and exhibit delicate, intricate, cross-bedded patterns and transulatory ripple marks. Grain size of quartz ranges from predominately angular, silt-size to minor, subrounded and medium.

Productid and spiriferid brachiopods, fenestrate bryozoans, algae, corals and encrinal debris constitute faunal elements.

Flux Quarry Section

Northermost exposure of the Oquirrh Formation in the Stansbury Mountains includes 228 feet of gray, cherty, aphanic matrix limestone and interbedded buff-weathering, calcareous quartzite, occurring in one inch to one foot beds. A central unit of the same lithology occurs as thin, fissile, shaly limestone and limy shale, weathering to shaly fragments less than five mm in size.

A peculiar, minute scale cross-bedding, resembling spillitic pillow lavas is common to the gray, aphanic limestone.

This section is assigned a Lower Pennsylvanian age because of its immediate superjacent relationship with Manning Canyon Shale and its lithologic likeness to rocks in the Miners Canyon Section.

CORRELATION AND LATERAL LITHOLOGIC VARIATIONS WITHIN TIME LIMITS

With few exceptions, extreme lateral facies variation discourages any attempt at pure lithologic correlations within the Oquirrh Formation. Megascopic fossils, likewise, offer little aid in such endeavors. Fusulinids alone, were the key to the series delineation and correlation, demonstrated on Chart 1 (in pocket).

The 14,000 feet of sediment included in the Oquirrh Formation contain rocks representing essentially continuous deposition from Morrowan through Wolfcampian. Furthermore, this stratigraphic sequence is divided into series, each of which has easily defined lithology.

Morrowan rocks are most susceptible to lithologic correlation, because of the biostromal nature of some limestones. Presence of appreciable amounts of limonite is ubiquitous within the series, occurring as accessory cement and as pseudomorphs after pyrite. Dark, "euxinic-color" of sediments, conspicuous cherty beds and silicification of faunal constituents are characteristic of the predominance of skeletal-in-matrix limestones assigned a Morrowan age. Little variation from these features was noted from south to north.

Consistency of lithology is not attributed to time of deposition, but rather to environment and source material. Fusulinids document an unconformity with subjacent Pennsylvanian-Mississippian Manning Canyon Shale. As in the East Hickman Canyon section, basal Derryan rocks in contact with Manning Canyon Shale show comparable lithology to Lower Morrowan rocks, while the same conclusion can be made of Lower Desmoinesian rocks of the Martin Fork-Box Elder Canyon section.

Correlation of paleontologically documented rocks with fusulinid barren rocks of the Magpie, Miners and Flux Quarry sections is done primarily on the basis of lithologic similarities.

An increase in quartz content, causing lithology to shift toward lighter colored sandstones, quartzites and silty, pastel, blue, pink, maroon and purple, calcareous shales, characterizes rocks of Derryan age. Limestones are abundant. Cross-bedded sandstones and quartzites, with cross-laminated calcarenites are typical, but not laterally mappable.

After the Desmoinesian, lateral facies variation increased. A four foot thick bed of light gray to white quartzitic limestone was seen to disappear

within 50 yards, grading into a gray-buff-weathering quartzite, and this in turn, into limy shales and shaly limestones. Massive quartzite units, several tens of feet thick vanished from one canyon wall to another, in less than one-tenth of a mile. Within parallel bedding planes (top and bottom) massive, resistant ledge formers change from quartzites to skeletal-in-matrix limestones in relatively short distances, commonly less than 50 feet.

Most apparent in the Desmoinesian rocks is a marked increase in quartz content over strata of Derryan age. Lighter colored sandstones and quartzites typify the Desmoinesian Series. Limestones are still present, but are quite sandy and quartzitic. Laterally, the quartz content of the Desmoinesian Series increases from 20 percent in the Big Hollow Canyon-Faraday Hollow Section to 40 percent in the East Hickman Canyon and Martin Fork-Box Elder Canyon Sections. Diagenetic conglomerates, common to the Big Hollow Section are not present in sections to the North. A decrease in faunal abundance and diversity of kinds is noticeable in the East Hickman and Big Hollow Sections, while Desmoinesian rocks of the Martin Fork Section show abundance of fossils in numbers and kinds. *Chaetetes favosus,* common to Lower Desmoinesian strata to the east in the Oquirrh Mountains, is absent in the Stansbury Mountains.

Missourian rocks vary conspicuously from one section to another. The Big Hollow Section is typified by three units which consist of interbedded and intercalated quartzite and quartzitic limestone "sandwiched" by thin-bedded, maroon, pink, purple and blue-gray, fossiliferous limestones. In the East Hickman Section, only 1,528 feet of sediments appear, showing a thinning of 2,600 feet. Lithology in East Hickman resembles the central one-third of the Big Hollow Section. The section at Martin Fork-Box Elder Canyon remains thin, but lithologically, is different from both southern sections. Sandy limestones and sandy, argillaceous limestones are predominant rock types, with calcareous quartzites and limy sandstones dominant only in the upper third of the section. While fusulinids occur in appreciable amounts throughout the Missourian, the Martin Fork Section has abundant large corals, brachiopods and crinoidal debris, uncommon in southern sections.

As in the Desmoinesian age rocks, quartz content increases from south to north, ranging from 30 percent in Big Hollow to greater than 45 percent in Martin Fork.

Apparent continuity of deposition prevailed into Permian time, however lithologic changes are noted. Sediments are dark brown, argillaceous, conglomeratic and cherty.

In no instance was any discrete unit traceable or recognizable as the same entity from one measured section to another, regardless of its stratigraphic age.

TECTONICS AND SEDIMENTATION

General Statement

A variety of tectonic elements is reflected by sediments comprising the Oquirrh Formation as studied in the Stansbury Mountains.

As suggested by Croft (1956), Teichert (1958 *ms.*) and Rigby (1958), the Stansbury Mountains do constitute a marginal portion of the "Oquirrh Basin". Meticulous study of rocks superjacent to the Pennsylvanian-Mississippian Manning Canyon Shale and analyses and identification of faunal elements reveal a marked time, as well as structural unconformity of the Oquirrh Formation with subjacent Manning Canyon Shale (Text-fig. 2).

Source of Sediments

Text-fig. 2 is the writer's interpretation of the Oquirrh-Manning Canyon unconformity. Unquestionable Morrowan rocks are seen to be resting upon Manning Canyon Shale of Springeran (?) age in Chokecherry Spring Section. Progressing northward, within three miles, Derryan sediments are superjacent to Springeran (?) rocks, and within three and one-half miles, Desmoinesian strata assume the same relationship, at Martin Fork-Box Elder Section. It would appear that a simple transgressive overlap exists to this point, however roughly eight miles north, rocks of questionable Morrowan-Derryan age again occupy a superjacent position to the Manning Canyon Shale. It is proposed that the high in the vicinity of Martin Fork-Box Elder Canyon represents a subaqueous or very low subaerial welt which served as source of much detritus, particularly fine-grained, angular quartz and argillaceous material contained in Morrowan-Derryan rocks to the north and south.

Recognition of dark shales and conglomerates in basal Oquirrh strata strongly suggests that the Manning Canyon surface underwent some erosion and served as a local source for these lowest sediments. Thin-section analyses reveal an ubiquitous occurrence of pyritic laminae, now limonite pseudomorphs, in basal rocks. According to Huber & Garrels (1953), iron is insoluable in a basic solution and is precipitated within a few hours after acidic river water contacts basic sea water. This precipitation would occur close to shore, further substantiating the Stansbury area as one of local source.

Residues and thin-sections reveal two distinct quartz types: (1) silt-size to fine, angular to subangular grains, showing distinct borders and sharp extinction: (2) medium-to-coarse, subrounded-to- rounded grains, having crenulated borders and showing pronounced undulatory extinction. According to Krynine (1941) quartz of this nature depicts an igneous or sedimentary origin, and a metamorphic origin, respectively. Labile constituents are nonexistant. Sources of igneous and metamorphic quartz, free from unstables could possibly have been from islands within the Salt Lake, the Farmington complex, the Cottonwood area or the Uintas.

The Northeast Nevada High and the West Central Utah High of Steele (1959 *ms.*) probably supplied sediment to the Stansbury repository.

It is difficult to find a single source capable of supplying 14,000 feet of diverse lithologies. Due to evidence offered of a local welt of source within the Stansbury repository, and the second to possibly third cycle well-rounded quartz and fossil detritus, the writer rather believes that the Stansbury area is typical of Pennsylvanian tectonics, characterized by subqueous welts and furrows, various short lived positive areas, and typical autocannibalistic sedimentation in taphrogenic and autogeosynclinal repositories (Steel, 1959 *ms.*).

Transporting Media

With few exceptions, Oquirrh lithologies and textures indicate that mode of transport was by strong current action in relatively shallow water, probably well within the neritic zone. Detrital fraction of basal strata was probably deposited in large part, by streams flowing eastward from the Stansbury High. Documentation of this could be obtained by cross-bedding studies, particularly in the Magpie and Miners Canyon Sections, as well as in Derryan and Desmoinesian rocks.

Minor amounts of sediment may possibly have been deposited by strong

winds into a littoral environ as indicated by cross-bedding in Miners Canyon section. Fine-grained quartz, pitted and frosted, occurring in delicate cross-bedded fabrics suggests eolian conditions.

Depositional Environment

Sediments examined show sedimentary conditions ranging from moderately deep, calm, euxinic seas, to rapidly oscillating littoral environments.

Little change in depositional tectonics is evident from Morrowan age rocks to those of Derryan age. Fine silty material, derived from weathered Manning Canyon Shale surface was carried into calm, neritic seas. Dark-colored, argillaceous, cherty limestones, with appreciable amounts of sedimentary pyrite denote an euxinic environ, prevailing during basal Oquirrh sedimentation. Copious and diverse faunal elements range throughout Late Morrowan and Derryan time as water depth decreased and currents increased.

Species of the coral *Chaetetes,* common to rocks of Derryan and Desmoinesian age in other Oquirrh sections do not appear in the Stansbury area. Due to the absence of this colonial coral, usually occurring in biostromal quantities, (Bissell, 1959, p. 108), it is reasonable to assume that marked instability of depositional area prevailed in Late Derryan and throughout Desmoinesian time. Supporting this assumption is the unique occurrence of diagenetic conglomerate and mud-cracked beds, observed in Desmoinesian rocks.

Cross-bedded sandstones, containing second cycle fossil detritus are suggestive of instability, leading to cannibalism of previously lithified sediment. Thin-sections reveal a conspicuous amount of subrounded to rounded skeletal fragments as discrete grains in the laminae of cross-bedded sandstones in rocks, predominantly of Desmoinesian age.

From Desmoinesian to Late Virgilian time faunal elements increased (especially fusulinids) and sediments became sequences of intercalated limestones and quartzites, interrupted by somewhat regular intervals of pastel-colored, limy shales and shaly limestones, approximating a cyclic depositional pattern. Water was apparently of epineritic depth as vast quantities of predominantly fine to medium, subrounded quartz accumulated in warm, turbulant, calcareous seas (Revelle & Fairbridge, 1957). Rhythmic fluctuations of source and depositional area produced thousands of feet of intercalated quartzitic limestones and calcareous quartzites.

Periods of intermittant stability gave rise to growth of *Syringopora* sp., copious fusulinid faunas, extra large caninid corals, crinoids, productid and spiriferid brachiopods, the latter four seen in Martin Fork-Box Elder Canyon Missourian strata. These more stable interims were followed by transgressing seas, producing limy shales and shaly limestones.

Beginning in Late Virgilian, increased unrest of source and repository provided for the accumulation of many thin, cherty conglomerates and conglomeratic pods and lenses, contained in dark brown, silty limestones and calcareous, silt-size-grained quartzites. Silicification of faunal elements, particularly fusulinids, is pronounced in Wolfcampian rocks and chert becomes a noticeable rock constituent as in Lower Pennsylvanian strata.

In summary, it can be said that general instability of source and depositional areas of Oquirrh strata in the Stansbury area is suggested by Oquirrh stratigraphy.

CONCLUSIONS

1. The use of fusulinids as a means of time delineation of Pennsylvanian-Permian stratigraphy is successfully accomplished.
2. Irrefutable documentation of an angular unconformity between the Oquirrh Formation and subjacent Manning Canyon Shale is provided.
3. A local source area for Lower Pennsylvanian deposition is shown.
4. The Stansbury area is seen to constitute a marginal portion of the "Oquirrh Basin", and inferrence is made that the "Oquirrh Basin" was not a continuous repository of sedimentation, but a series of areally small, taphrogenic, autocannibalistic troughs and contiguous highs.
5. Tectonic instability throughout Pennsylvanian and Permian Early Wolfcampian is suggested by more than 14,000 feet of diverse Oquirrh lithologies.

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