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GEOLOGY OF THE SOUTHEASTERN STANSBURY MOUNTAINS AND SOUTHERN ONAQUI MOUNTAINS, TOOELE COUNTY, UTAH

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ABSTRACT

Most of the sedimentary rocks exposed in the southeastern Stansbury Mountains and southern Onaqui Mountains in Tooele County, Utah, belong to the Oquirrh Group; they are provisionally correlated with formations of the Bingham sequence originally described in the Oquirrh Mountains. Two mappable units within the Oquirrh Group, the Butterfield Peaks Formation of Middle Pennsylvanian age and the Bingham Mine(?) Formation of Late Pennsylvanian and Early Permian age, are recognized in the study areas. The Butterfield Peaks Formation in the Stansbury and Onaqui Mountains is composed chiefly of repetitive sequences of ridge-forming limestone and slope-forming sandstone. The Bingham Mine(?) Formation in the Stansbury and Onaqui Mountains, in contrast, contains mostly fine grained terrigenous clastics with intercalated limestone. In the Stansbury Mountains the Bingham Mine(?) Formation is divided into two informal members: the lower member is composed mostly of sandstone and quartzite with interbedded limestone bearing Missourian and Virgilian fossils; the upper member is Virgilian and Wolfcampian in age and contains abundant sandstone, quartzite, and limestone conglomerate.

Rocks of Atokan to early Virgilian age were deposited in shallow water, whereas the Virgilian and Wolfcampian limestone conglomerates and proximal turbidites in the Stansbury Mountains record a period of deposition in relatively deep water. By the late(?) Wolfcampian, this basin had been filled with sediment, and additional sediment had accumulated either near sea level or slightly above it.

INTRODUCTION

The Stansbury and Onaqui Mountains, located about 50 km southwest of Salt Lake City, form a continuous north-trending range in the eastern Great Basin. The range is flanked by the Cedar and Oquirrh Ranges to the west and east, respectively, with broad alluviated valleys intervening (fig. 1).

The areas mapped, which include mostly rocks of the Oquirrh Group, are shown in figure 1. The Oquirrh Group is a unit primarily of limestone and sandstone, locally up to 8,000 m thick (Roberts and others, 1965), that crops out widely in northwestern Utah in the eastern Great Basin. This unit represents a depositional episode from Pennsylvanian to Early Permian time during which sediments filled a rapidly subsiding basin on the broad Cordilleran epicontinental shelf.

There are large gaps in the knowledge of the paleogeography of the Oquirrh Basin due to uncertainty of the magnitude of Sevier (Late Mesozoic) structural dislocation of different parts of the Oquirrh Group. Reconstruction of the original geometry of the basin requires knowledge about the structure, stratigraphic thicknesses, and facies distribution of the rocks. The main purposes of this study is to describe the major sedimentary and paleoenvironmental features of middle and upper Oquirrh Group rocks in the

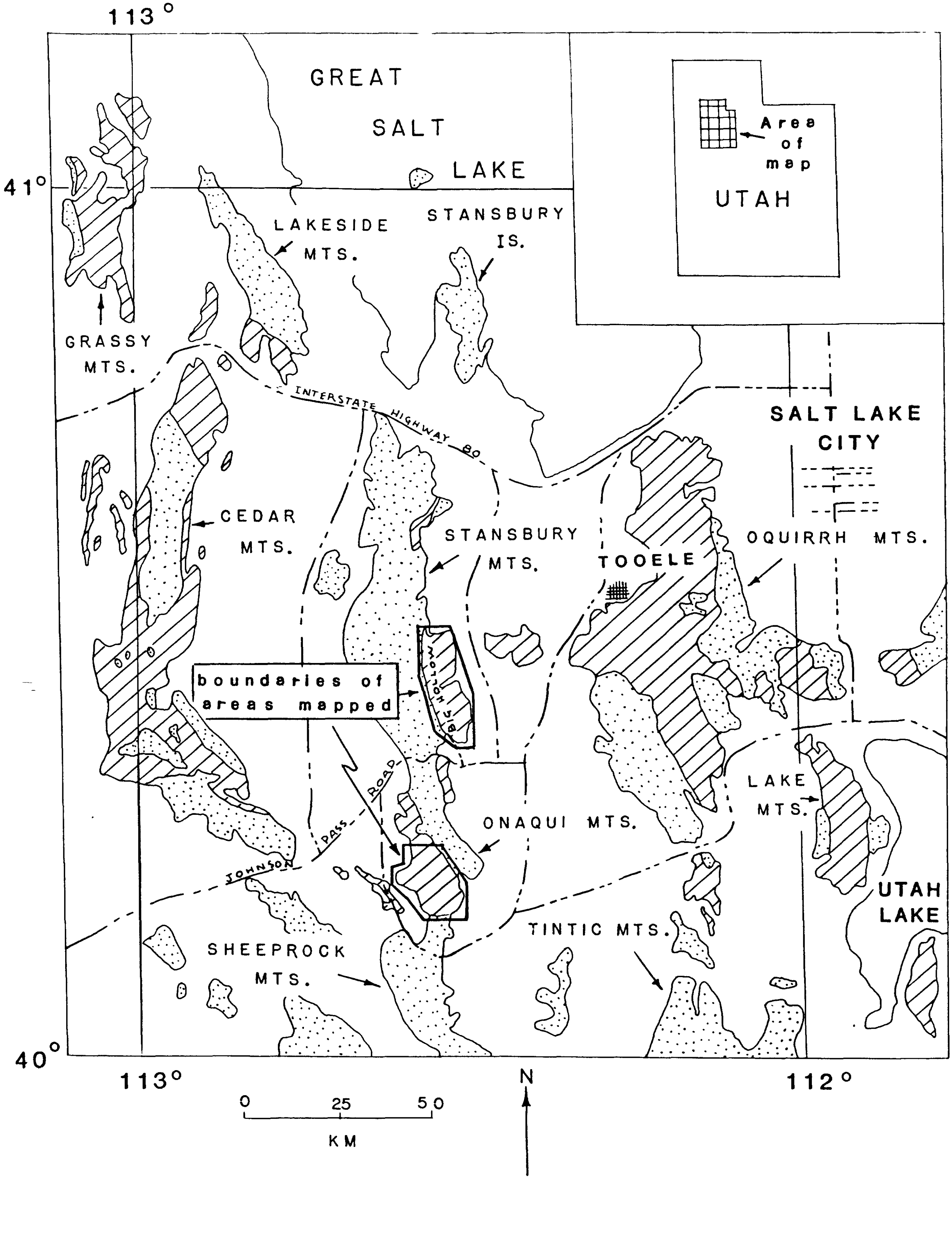

Figure 1. Location map.

Stansbury and Onaqui Mountains, and to compare these strata with correlative rocks in the type area in the Oquirrh Mountains. Another purpose is to interpret the structure of the two areas in the Stansbury and Onaqui Mountains. This report is viewed as an initial contribution toward the understanding of some of the facies and ultimately the paleogeography of the Oquirrh Basin.

STRATIGRAPHY

Rocks exposed in the areas mapped (pl. 1) consist predominantly of the middle and upper parts of the Oquirrh Group. Mississippian to Lower Triassic(?) calcareous sandstone, quartzite, and limestone, and minor amounts of Tertiary volcanic rock and Quaternary gravel that are in contact with Oquirrh rocks are described only briefly.

Great Blue Limestone

The Great Blue Limestone (Upper Mississippian) crops out along the western boundary of the area mapped in the Stansbury Mountains and at the southern boundary of the region mapped in the southern Onaqui Mountains. In both areas, the rocks typically are a medium gray- to grayish-blue-weathering, medium- to thick-bedded, nearly pure limestone with intercalated sandstone, and commonly form steep escarpments. The limestone commonly contains profuse corals, bryozoans, and other fossils in a very fine grained to micro-crystalline matrix. Dark-brown-weathering chert occurs locally in networks and stringers within limestone beds.

Manning Canyon Shale

The Manning Canyon Shale (Mississippian-Pennsylvanian) crops out along the western border of the area mapped in the Stansbury Mountains and along the northeastern boundary of the region mapped in the southern Onaqui Mountains. This formation is not well exposed, but it is easy to map due to its negative topographic expression. The formation consists chiefly of dusky-olive-brown siltstone, dark carbonaceous limestone, and rust-stained micaceous quartzite, and sandstone. This unit conformably overlies the Great Blue Limestone in the Stansbury Mountains and is faulted against it in the southern Onaqui Mountains (though this latter relationship occurs outside of the map boundary on pl. 1).

Oquirrh Group

Nolan (1930) first applied the name Oquirrh Formation to Pennsylvanian and Permian rocks in the Gold Hill mining district in west-central Utah, but in 1932, Gilluly applied the name to the lower part of Spurr's (1895) "Upper Intercalated Series" in the Oquirrh Mountains, which are now considered to embrace the type area. Since then, there have been several proposals to define Oquirrh stratigraphy in the Oquirrh Mountains (Bissell, 1959; Welsh and James, 1961; Tooker and Roberts, 1962, 1970; Swensen, 1975). There also have been several topical studies of the Oquirrh Group. Nygreen (1958) studied the lower portion of the type section, Wright (1961) measured Oquirrh sections in the Stansbury Mountains, and Wells (1963) conducted a study of Oquirrh quartzites from several localities. Bissell (1962) has studied the biostratigraphy of the Oquirrh Group (1952, 1959) and discussed the paleogeography of the Oquirrh Basin (1962). A doctoral dissertation by Doelling (1964) includes a description of the Oquirrh Group in the nearby Grassy and Lakeside Mountains, and one by Maurer (1970) represents a study mostly of Oquirrh Group rocks in the Cedar Range. Morris, Douglass, and Kopf (1977) published their interpretation of Oquirrh Group stratigraphy in the East Tintic Mountains.

The depositional history and the paleoenvironmental framework of some of the rocks of the Oquirrh Basin have been interpreted by Chamberlain and Clark (1973), who used trace fossils to delineate water depths, and by Larson (1976, 1978), who interpreted Late Pennsylvanian and Early Permian paleoenvironments from a study of resedimented carbonate conglomerates. Jordan (1978, 1979a) studied the regional distribution of paleoenvironments represented in upper Oquirrh rocks and has discussed the tectonic evolution of the Oquirrh Basin (Jordan, 1979b, 1979c; Jordan and Douglass, 1980); Armin (1978, 1979) and Armin and Stevens (1980) presented some findings of the work related to this study.

Type section of the Oquirrh Group

There is little agreement on the stratigraphy of the Oquirrh Group in the Oquirrh Mountains. Welsh and James (1961) proposed raising the Oquirrh Formation to group rank, subdividing it into four formations, and restricting the name to Pennsylvanian strata. Tooker and Roberts (1970) agreed that the Oquirrh deserves group status, but they have divided it differently. They have separated the Oquirrh Group rocks in the Oquirrh Mountains into three lithologically different sequences: those north of the north Oquirrh thrust in the northern Oquirrh Mountains have been designated as the Rogers Canyon sequence; those south of the Midas thrust in the central Oquirrh Mountains as the Bingham sequence; and rocks that lie between these two thrust faults as the Curry Peak sequence (Tooker and Roberts, 1970).

Swensen's (1975) proposal for redefinition of Oquirrh Group stratigraphy at the type section retained elements of the interpretations of Welsh and James (1961) and Tooker and Roberts (1970). He suggested that the name Oquirrh be restricted to Pennsylvanian strata and proposed a new formational name, Curry Peak Formation, for rocks that overlie the Oquirrh Group in the type area. He did not recognize the Curry Peak sequence of Tooker and Roberts (1970) and referred to those rocks as part of the Bingham sequence (Swensen, 1975).

Oquirrh Group in the Stansbury and Onaqui Mountains

In the Stansbury and Onaqui Mountains Oquirrh Group rocks generally are similar to the Oquirrh Group (Bingham sequence) of Tooker and Roberts (1970) in the Oquirrh Mountains. Formations of the Oquirrh Group in the Bingham sequence are: a lower clastic limestone (West Canyon Limestone), a middle unit consisting of interbedded limestone and sandstone (Butterfield Peaks Formation), and an upper unit composed mainly of sandstone and quartzite (Bingham Mine Formation).

In the study areas most attention was focused on the middle and upper parts of the Oquirrh Group, the lower Oquirrh Group being only briefly examined. Moore, Sorensen, and Armin (1978) mapped a unit in the Onaqui Mountains referred to as the lower Oquirrh Group that is of the same age as the West Canyon Limestone (Lower Pennsylvanian) in the Oquirrh Mountains. The

West Canyon Limestone in the Oquirrh Mountains is primarily limestone, while on the other hand, the lower Oquirrh Group in the Onaqui Mountains contains much more silt and sand.

The sequences of interbedded limestone and sandstone in the Stansbury and southern Onaqui Mountains are comparable in age and lithology with the Butterfield Peaks Formation in the type area of the Oquirrh Group; therefore, in this report, these rocks will be referred to as the Butterfield Peaks Formation. A time-equivalent of the Bingham Mine Formation in the Stansbury and Onaqui Mountains is moderately similar lithologically to that of the type section, although these former rocks are finer grained and contain more calcareous cement than those in the type section in the Oquirrh Mountains. They tend to form smoother more gentle slopes than the quartzites of the Bingham Mine Formation in the type area, which often form steep craggy cliffs and canyons. Here in the Stansbury and Onaqui Mountains, these rocks are provisionally correlated with those of the Bingham Mine Formation.

In the Stansbury Mountains, the Bingham Mine(?) Formation can be subdivided into two members: a lower member consisting of sandstone, quartzite, and subordinate limestone; and an upper unit composed mainly of sandstone and quartzite with intercalated limestone conglomerate. The upper member may correlate with the Curry Peak Formation of Swensen (1975), but as there is no mappable contact between this unit and the one below, due to lateral variation and poor exposure, the upper member is referred to as the upper member of the Bingham Mine(?) Formation. Rocks assigned to the Bingham Mine(?) Formation in the Onaqui Mountains are equivalent to those of the lower member in the Stansbury Mountains.

Lower Oquirrh Group

The Lower Oquirrh Group (Lower Pennsylvanian) is exposed along the northern margin of the area mapped in the southern Onaqui Mountains. This unit is in fault contact with the older Manning Canyon Shale, although the effect of this fault is unknown. The lower Oquirrh Group is composed mainly of dark dusky-blue weathering medium-bedded very fossiliferous limestone and interbedded brown- to dark-brown-weathering calcareous siltstone and sandstone. The limestone typically contains abundant crinoids, brachiopods, and corals in a bioclastic and micritic matrix. Abundant wispy sands and silt impart a light-brown-weathering appearance to the limestone and tends to mask its dominance in this unit. Sandstone and siltstone have weathered in subdued relief compared with the more resistant limestone. The lower Oquirrh Group in the southern Onaqui Mountains more closely resembles the West Canyon Limestone as described in the east Tintic Mountains (Morris and others, 1977) than the West Canyon Limestone in the Oquirrh Mountains. *Adetognathus spathus* recovered from these strata indicate a Morrowan to very early Atokan age. The Lower Oquirrh Group was not recognized in the southeastern Stansbury Mountains. Presumably, it lies beneath an overthrust there.

The lithology and fossil record of the lower Oquirrh Group in the southern Onaqui Mountains indicate that most of this unit accumulated under shallow-marine conditions. The relative abundance of terrigenous material in the lower Oquirrh Group in the southern Onaqui Mountains as compared to the age-equivalent West Canyon Limestone in the Oquirrh Mountains rules out an eastern source for the silt and sand. Bissell (1962) cites the presence of the Western Utah Highland on the west side of the Oquirrh Basin as one possible source of siliceous material, however, relatively pure limestone in the Cedar Mountain of Morrowan age (Maurer, 1970) suggests that not much terrigenous material could have been supplied from a positive area to the west. Therefore, a northern and (or) southern accessway to supply silicate detritus during this time is indicated. The case for this seems to be valid even when considering the enormous amount of eastward movement and attenuation of decollement thrust sheets in the Sevier orogenic belt that has been postulated (Roberts and others, 1965; Armstrong, 1968).

Butterfield Peaks Formation

The Butterfield Peaks Formation is exposed in the southern Onaqui Mountains where it is in fault contact with the Great Blue Limestone, Manning Canyon Shale, the Lower Oquirrh Group, and the Bingham Mine(?) Formation (pl. 1). Folding and poor exposure preclude an estimate of the thickness of this unit in the Onaqui Mountains.

In the Stansbury Mountains the Butterfield Peaks Formation is in fault contact with the older Manning Canyon Shale to the west. Because of the discontinuity at the base, the total thickness of the Butterfield Peaks Formation cannot be measured. Reconstruction from cross sections yields a thickness of approximately 1,850 m near Chokecherry Spring, where this formation attains its maximum thickness in the Stansbury Mountains. For comparison, one reference section of the Butterfield Peaks Formation in the type area is 2,764 m (9,072 ft) thick (Tooker and Roberts, 1970). The formation thins northward in the Stansbury Mountains and finally wedges out where the unit strikes into a fault separating it from the Manning Canyon Shale.

Lithology

Although there are many rock types in the Butterfield Peaks Formation, the general aspect is that of monotonously interbedded ledge-forming limestone and slope-forming sandstone and siltstone (fig. 2). Massive biostromal limestone sequences are more prevalent near the contact with the older Manning Canyon Shale, and interbedded quartzite, sandstone, and siltstone sequences are thicker toward the top of the unit. Interbedding of limestone and sandstone is most noticeable in the upper half of the Butterfield Peaks Formation. The base of the formation is poorly exposed in the Stansbury Mountains.

A convenient way to describe the different lithologies in this formation is to treat the siliceous clastics as one group and the limestone sequences as another. Quartzite and calcareous sandstone and siltstone are the most voluminous rock types, comprising an estimated 50 to 75 percent of the formation. These rocks typically are light grayish yellow on fresh surfaces, weathering yellowish gray or light grayish brown, and are composed of very well sorted, silt- to medium sand-sized quartz and feldspar grains.

Siliceous sequences generally are 10 to 30 m thick, but range in thickness from less than 1 to 80 m. These units are primarily medium and thick bedded, but laminated units and beds up to 2 m thick are not uncommon. Cross-stratification, horizontal lamination, and scouring at the bases of some

Figure 2. Typical exposure of the Butterfield Peaks Formation showing ledge-forming limestone interbedded with less resistant sandstone and quartzite. View is to south from the southern Onaqui Mountains.

beds have been observed in some thin- to medium-bedded sandstones. Tabular-planar lens- and wedge-shaped crosslaminated sets, generally 5 to 20 cm thick, and low-angle (<10°) crossbeds are common; high-angle (>10°) avalanche-type crossbeds are less common. Herringbone cross-stratification was rarely observed. In crossbedded zones, bedding contacts commonly are wavy and show local scoured surfaces. Medium- to thick-bedded sandstones have few, if any, discernible sedimentary structures and generally are barren of fossils. Bedding contacts generally are planar.

Limestone sequences are interbedded with the siliciclastics. From a distance, the massive limestones appear dusky bluish gray, and they form clifflike exposures. The limestone sequences generally are 2 to 20 m thick but range from less than 1 to 60 m. They are composed of a variety of limestone types which commonly occur in a rhythmical vertical sequence. Intervals up to 6 m thick of laminated to thin-bedded crossbedded sandy calcarenite and interbedded sandstone commonly are present at the tops and bottoms of limestone sequences (fig. 3) and commonly grade vertically into cross-stratified sandstone and quartzite. Thin wavy sand wisps within the calcarenites are characteristic of this interval and serve to accentuate crossbedding and laminations. Very coarse grained calcarenite with randomly oriented tabular lime-mud chips up to 3 cm in length commonly occurs in this lithology (fig. 4).

The central parts of the limestone sequences, commonly sandwiched between crossbedded sandy calcarenite, typically are thin- to thick-bedded wackestone and packstone with lesser mudstone and grainstone. Most of these lithologies are mediuum to dark gray on fresh surfaces, weathering medium gray to bluish gray, or dark gray. Medium- to thick-bedded wackestone and packstone, 0.3 to 1.0 m thick, commonly contain crinoid debris, solitary rugose corals, Syringopora, and gastropods in a micritic matrix. Light-purplish-gray- to pale-reddish-purple-weathering platy micritic limestone beds, 5 to 30 cm in thickness, commonly contain abundant lacy and ramose bryozoans, thin-shelled brachiopods, and crinoid parts.

Intercalated with the sandstone and limestone of the Butterfield Peaks Formation is light-grayish-purple-, pale-reddish-purple-, and pale-pink-weathering, laminated to very thin bedded argillaceous limestone occurring in sequences up to 30 m thick, although averaging less than 15 m. These rocks are unfossiliferous and are poorly exposed. Similar variegated, pale-reddish-purple- and pink-weathering medium-bedded sparsely fossiliferous limestones are present near the base of the Butterfield Peaks Formation south of Stradley Springs in the Stansbury Mountains.

Age and correlation

At present there is some disagreement as to the age of the lowest part of the Butterfield Peaks Formation in the Stansbury Mountains. Wright (1961) reported 255 m (837 ft) of Morrowan strata in one of his measured sections in the Stansbury Mountains. The writer, however, collected fusulinids and brachiopods of Desmoinesian and Atokan age (loc. nos. 6, 7, 8, 9 in the Stansbury Mountains, pl. 1, table 1) very near the base of the Butterfield Peaks Formation in the vicinity of Wright's (1961) measured section. This implies that an interval of Morrowan strata, if present, is much thinner than suggested by Wright (1961).

A.

B.

Figure 3. Crossbedded limestone of the Butterfield Peaks Formation in the southern Onaqui Mountains. A- Alternating, crossbedded sandstone and calcarenite. B- Crossbedded calcarenite. Note high angle of crossbeds in lower photograph (27° to 28°).

Figure 4. Bioclastic and intraclastic grainstone and packstone, and laminated sandstone of the Butterfield Peaks Formation in the Stansbury Mountains. Note scoured bedding contacts (marked with dashed line).

Table 1. Summary of the ages of fossils recovered from the Butterfield Peaks Formation in the Stansbury and Onaqui Mountains
[Locality numbers are keyed to location points on plate 1. All fossils were identified by Dr. C. H. Stevens unless otherwise indicated]

Locality number	Sample number	Location: Township	Location: Range	Location: Section	Taxa	Age
					Stansbury Mountains	
1	77-AF-9	5 S.	6 W.	7	*Fusulinella* sp.	Atokan
2	77-AF-18	4 S.	7 W.	-	*Beedeina* ? sp.	Desmoinesian?
3	77-AF-21	4 S.	7 W.	-	*Beedeina* ? sp.	Desmoinesian?
4	77-AF-35	5 S.	6 W.	6	*Pseudofusulinella* sp. *Triticites* sp.	Early Missourian?
5	77-AF-45	5 S.	6 W.	16	*Pseudofusulinella* sp. *Triticites* sp.	Early Missourian?
6	77-AF-87	5 S.	6 W.	17	*Fusulinella* sp.	Atokan
7	77-AF-88	5 S.	6 W.	17	*Mesolobus* cf. *M. euampygus* (Girty)	Desmoinesian
8	78-AF-8	5 S.	6 W	20	*Mesolobus* sp.	Middle Pennsylvanian
9	Seq 5-6	5 S.	6 W.	18	*Fusulinella* sp.	Atokan
10	Seq 6-6	4 S.	7 W.	-	*Beedeina* sp.	Desmoinesian
					Onaqui Mountains	
1	77-AF-13	7 S.	6 W.	29	*Beedeina* sp.	Desmoinesian
2	77-AF-14	7 S.	6 W.	7	*Beedeina* sp.	Desmoinesian
3	77-AF-15	7 S.	6 W.	19	*Beedeina* sp.	Desmoinesian
4	77-AF-16	7 S.	6 W.	32	*Beedeina* sp.	Desmoinesian
5	77-AF-62	7 S.	6 W.	19	*Beedeina* sp.	Desmoinesian
6	77-AF-65	7 S.	6 W.	18	*Beedeina* sp.	Desmoinesian
7	77-AF-68	7 S.	6 W.	18	*Beedeina* sp.	Desmoinesian
8	77-AF-71	7 S.	6 W.	29	*Beedeina* sp.	Desmoinesian
9	77-AF-72	7 S.	6 W.	29	*Beedeina* sp.	Desmoinesian
10	77-AF-73	7 S.	7 W.	12	*Fusulinella* sp.	Atokan
11	Seq 2-8	7 S.	6 W.	29	*Beedeina* sp.	Desmoinesian?
12	f13673*	7 S.	6 W.	6	*Beedeina* sp.	Desmoinesian
13	f13674*	7 S.	7 W.	12	*Beedeina* sp.	Desmoinesian
14	f13681*	7 S.	6 W.	7	*Beedeina* sp.	Desmoinesian
15	f24545*	7 S.	6 W.	8	*Beedeina* sp.	Desmoinesian

*U.S. Geological Survey Foraminifera catalogue number.

Fusulinids collected from beds slightly below the upper contact of the Butterfield Peaks Formation (loc. nos. 4, 5, Stansbury Mountains, pl. 1, table 1) are of probable early Missourian age. Fossil locality number 2 (table 1), also near the upper contact, probably is late Desmoinesian in age, so the Desmoinesian-Missourian boundary presumably is located a few meters below the top of the Butterfield Peaks Formation. No Missourian fossils were collected from the Butterfield Peaks Formation in the Onaqui Mountains, but a very thin interval of unfossiliferous early Missourian strata may be present there. The age of the Butterfield Peaks Formation in the two areas of study is considered to be Atokan to very early Missourian.

The Butterfield Peaks Formation in the Oquirrh Mountains is considered to be Atokan and Desmoinesian in age (Tooker and Roberts, 1970). The uppermost 72 m (235 ft) of the reference section has not yielded fossils, but fusulinids referable to the genus Triticites, of probable Missourian age, were found about 3 m (10 ft) above the base of the overlying Bingham Mine Formation (Tooker and Roberts, 1970). In light of the occurrence of an early Missourian interval at the top of the Butterfield Peaks Formation in the Stansbury Mountains, it is postulated that a very thin interval of early Missourian strata occurs at the reference section of the Butterfield Peaks Formation in the Oquirrh Mountains. Correlation of the Oquirrh Group in the Stansbury Mountains and southern Onaqui Mountains, and surrounding localities is shown in plate 2.

Depositional environment

The two major rock types of the Butterfield Peaks Formation, sandstone and limestone, reflect at least two fundamentally different environments of deposition. Field observations indicate that the characterisitic repetition of interbedded sandstone and limestone is suggestive of episodes of transgression and regression. Interpretation of the mode of deposition of the thick sandstone that overlies and underlies the relatively thin limestone intervals in the Butterfield Peaks Formation is a major problem due to the few and ambiguous sedimentary structures and the paucity of fossils.

The limestone, on the other hand, contains abundant paleoenvironmental indicators. Commonly there are several types of limestone in any one limestone sequence, and the criteria used to distinguish them also allow interpretation of their depositional environments. Furthermore, many limestone intervals have a similar vertical arrangement of the different lithologies that make up each interval. A typical succession consists of a lower commonly crossbedded sandstone overlain by sandy grainstone and bioclastic sandstone, that is in turn overlain by limestone containing very shallow water faunas in the lower part and shelf faunas in the middle. This sequence commonly is repeated in reverse order upward to another sandstone unit. The sandy grainstone and bioclastic sandstone at the bottom and top of many typical limestone sequences commonly contain rounded abraded bioclasts interlaminated with sandstone and siltstone. Interbedded with this lithology are bioclastic and intraclastic packstone and grainstone. These well-washed sediments, generally lacking a micrite matrix, suggest deposition in a high-energy environment. Laminated sandy and silty grainstone and bioclastic sandstone and siltstone may represent deposition on a wave-washed beach, and the associated intraclastic, shelly packstone and grainstone may have accumulated in channels where tidal flow was concentrated.

Micritic limestone containing a euryhaline shallow-marine faunal assemblage commonly is in close vertical association with sandy grainstone and intraclastic packstone and grainstone discussed previously. These rocks contain common ostracodes, a few types of foraminifera, and local gastropods; this euryhaline faunal assemblage generally indicates adverse environmental conditions, particularly large variations in salinity. The evidence indicates that this lithology resulted from deposition in a shallow coastal embayment, or perhaps a protected area shoreward of a bar or shoals.

The central interval of strata of many limestone sequences commonly is wackestone and packstone containing a large population of brachiopods, pelmatozoans, and bryozoans, as well as locally abundant fasciculate and horn corals, several types of foraminifera, and algae. Relatively common articulated fossils and abundant micrite matrix suggest that the fauna is in place and that the water was not very agitated. The presence of suspension feeders, such as, bryozoans, pelmatozoans, and corals, which cannot endure prolonged turbidity (Heckel, 1972), also indicate a quiet, yet oxygenated, environment. A stable hospitable normal-marine environment enabled development of a relatively diverse biotic community.

Locally common fusulinids tend to occur in the middle of the limestone sequences. Besides being invaluable biostratigraphic markers, they also have been used in paleobathymetric studies. They lived in normal marine waters greater than 13 m in depth (Stevens, 1969) and probably ranged to depths greater than 50 m (Stevens, 1966). As the writer found no evidence in the Butterfield Peaks Formation in either the Stansbury or Onaqui Mountains to suggest that water depths exceeded those in which fusulinids presumably lived, it seems reasonable to surmise that water depths never were much greater than 50 m during deposition of the Butterfield Peaks Formation and that at most times it was considerably less. Thus it is postulated that the fusulinid zones represent maximum marine inundation.

In general, the environments represented by the different limestone types range from shoreline at the tops and bottoms of the limestone sequences, to shallow open marine in the middle. Therefore, the limestone sequences apparently record transgressive-regressive episodes. Considering the shallowing trend away from the middle of the limestone sequences, it seems unlikely that the sand was deposited in water deeper than that in which the limestone accumulated. It could be argued that carbonate development was the result of decreased terrigenous influx, which in turn was caused by the wearing down of the provenance region(s), but there is no apparent sedimentological evidence of this, such as fining upward sequences; it seems more probable in this case that the sand was environmentally restricted to shallow water or subaerial environments where high-energy conditions necessary to transport it existed.

Sandstone with low-angle lens- and wedge-shaped crosslaminated sets occur just above and below the limestone sequences, and discontinous parallel laminae appear throughout the section. Most of the beds, however, seemingly are structureless. In addition, all of the sandstone and quartzite is composed of well-sorted mineralogically mature detritus which serves to impart a massive character to the beds. Many of the seemingly massive beds may contain diagnostic sedimentary structures which might be shown by X-radiograph analysis. Alternatively, massiveness may reflect intense biogenic churning, or it may be a primary feature of sublittoral sheet sands that are formed by rapid deposition from suspension that occurs during unusual storm or flood conditions (Goldring and Bridges, 1973). These sheets can be laterally persistent with beds generally 5 to 70 cm thick, but ranging up to 2 m thick (Goldring and Bridges, 1973).

Some of the characteristics of the sand are not dissimilar to those of eolian material; the sands are well sorted and their grain size closely corresponds with typical modern eolian deposits (Reineck and Singh, 1973, p. 210). Wright (1961) also reported frosted, pitted quartz in rocks from a section of probable Lower(?) to Middle Pennsylvanian sediments in the Stansbury Mountains. Large-scale avalanche-type crossbed sets that are distinctive of many wind deposits were not seen; parallel laminations are much more common. The lack of crossbedding, however, does not rule out the possibility that some of the sand is of eolian origin; horizontally bedded eolian sand sheets that are developed by rapid deposition have been described by Glennie (1970). Red staining of strata, typical of many subaerially deposited beds, is not obvious in the Butterfield Peaks Formation, but this may be due to the lack of iron oxide.

It seems reasonable to postulate that the sandstone in the Butterfield Peaks Formation accumulated in shallow marine and subaerial environments with contemporanous formation of limestone in more offshore marine waters. A similar phenomenon is occurring today along the North African Mediterranean coastline (Caulet, 1973).

Bingham Mine(?) Formation

This formation is typified by very thick sequences of grayish-yellow- and orangish-brown-weathering thin- to medium-bedded sandstone, siltstone, and quartzite, which contain intercalated medium-gray- and bluish-gray-weathering, fossiliferous limestone, and dark- to light-gray-weathering limestone conglomerate. This unit can be subdivided into two lithologically distinct members in the Stansbury Mountains that were not mapped due to lateral variation and poor exposure. The lower member consists of thick monotonous sequences of grayish-yellow to orangish-brown calcareous sandstone and siltstone to vitreous quartzite with interbedded limestone becoming less common toward the top; the upper member consists chiefly of sandstone and quartzite with common carbonate conglomerate interbeds. The lower member is present in both the Stansbury and Onaqui Mountains, but the upper member is present only in the Stansbury Mountains. The thickness of this formation in the Stansbury Mountains, estimated from cross sections, is about 3,500 m.

Lower member

In the Onaqui Mountains, the Bingham Mine(?) Formation is exposed on a dissected ridge west of the main ridge of the southern Onaqui Range (pl. 1). This unit extends eastward to Burnt Canyon and Dry Canyon, where the contact with the underlying Butterfield Peaks Formation, although covered, probably is a low-angle fault. The thickness of this unit cannot be estimated because it is poorly exposed, folded, and neither the top nor base is exposed.

The contact between the Bingham Mine(?) Formation and the underlying Butterfield Peaks Formation in the Stansbury Mountains apparently is conformable and is placed at the top of the highest interbedded limestone in the interbedded limestone and sandstone sequence of the Butterfield Peaks Formation. There is no single limestone sequence that is recognized everywhere at the top of the underlying Butterfield Peaks Formation, although a distinctive vertical lithologic change generally can be detected along a laterally persistent horizon. For contrast, in one reference section in the Oquirrh Mountains, Tooker and Roberts (1970) mark the lower boundary of the Bingham Mine Formation at the base of the prominent Jordan limestone marker unit, which is not present in either the Stansbury or Onaqui Mountains. In the Stansbury Mountains the Bingham Mine(?) Formation is in fault contact with the older Manning Canyon Shale, and is covered by Tertiary volcanic rocks at the northern part of the area mapped and by Quaternary alluvium to the south. A very rough estimation of the thickness of this member, based on cross section reconstructions, is about 1,500 m.

Calcareous sandstone and siltstone, and vitreous quartzite are the major rock types in the lower member. Grayish-yellow calcareous sandstone and siltstone comprise most of the siliceous clastic rocks, especially in the lower half of the lower member. Dense, vitreous quartzites increase in proportion upward in the section. These rock types underlie many smooth talus-covered slopes that appear moderate yellowish brown and dark yellowish orange from a distance (fig. 5). Sandstone, siltstone, and quartzite form sequences ranging up to 80 m in thickness. These lithologies occur in laminations and beds up to 1 m in thickness; beds generally are 5 to 30 cm thick. Wedge- and tabular-planar-shaped crossbed sets commonly are intercalated within parallel-bedded sandstones. Fossils are rare in these siliceous clastic rocks.

Petrographically, most quartzites, sandstones, and siltstones are texturally and mineralogically mature, consisting of subangular well-sorted grains ranging from 0.02 to 0.20 mm in diameter, composed dominantly of quartz and subordinate microcline, orthoclase, plagioclase, and accessory minerals. The cement generally is calcite. The vitreous quartzites are mineralogically similar, but they are more densely packed and have primarily a siliceous cement.

Interbeds of light-gray-, pale-grayish-purple-, and brownish-gray-weathering thin- to medium-bedded fossiliferous micritic limestone, calcarenite, and sandy or silty limestone are common, especially near the base of the lower member. Sequences generally are 1 to 10 m thick, but some range up to 25 m thick. Beds are laminated to 1 m thick. Bedding contacts are planar, but wavy wispy sand and argillaceous partings within beds are ubiquitous features. More pure limestones commonly contain syringoporoid and solitary rugose corals, bryozoans, brachiopods, and crinoid fragments. Fusulinids locally are profuse and are most abundant in silty limestone. Zoophycos(?) assemblage trace fossils, which have been observed on bedding surfaces of flaggy-weathering limey siltstone and silty limestone, are most abundant near the top of the lower member.

Upper member

The upper member of the Bingham Mine(?) Formation is exposed in a belt parallel to, and east of, the lower member in the Stansbury Mountains. A very rough estimate of the thickness of the upper member of the Bingham Mine(?) Formation is approximately 2,000 m, based on reconstructions from cross

Figure 5. Lower member of the Bingham Mine(?) Formation. Smooth-weathering slopes on the right side of the photo are characteristic of the Bingham Mine(?) Formation in the southern Onaqui Mountains. View is westward across Dry Canyon.

sections. It is composed of quartzite, sandstone, and siltstone with subordinate limestone conglomerate and limestone. Sandstone and quartzite are yellowish-gray and moderate orangish-pink weathering and are light gray to grayish brown on fresh surfaces. They are medium bedded and very fine to medium grained. Sequences ranging up to 100 m in thickness contain beds 5 to 70 cm thick, averaging 20 cm. All gradations between vitreous quartzite and the more porous and weathered calcareous sandstone are present in the upper member. Fossils generally are rare in these rocks, although casts of fusulinids "pockmark" surfaces of some quartzites near the exposed top of the upper member.

Presence of limestone conglomerate distinguishes the upper member from the lower. Limestone conglomerate typically occurs in 5- to 15-m-thick vertical associations with thin beds of ripple-stratified, laminated, and graded calcareous sandstone, sandy bioclastic packstone, and grainstone. The limestone conglomerate is both matrix and framework supported, with a preponderance of the latter. Most striking are matrix-supported medium- to dark-gray-weathering massive medium- to thick-bedded poorly sorted limestone conglomerate (fig. 6). Beds generally are 30-50 cm thick, ranging up to 1.5 m in thickness. Clasts of light-gray and pale-reddish-purple unfossiliferous limestone and silty limestone, medium-gray sandy limestone, and light-yellowish-gray quartzite occur in a dominant lithology of micrite or calcarenite. The clasts are subrounded to lenticular and rarely tabular, averaging 3 to 10 cm in maximum diameter, but ranging from small pebble size up to 30 cm. Clasts comprise 5 to 60 percent of the matrix-supported beds. Disarticulated fossil fragments and fusulinids are abundant constituents of some of the rocks.

Limestone conglomerate beds less than 20 cm thick generally are framework supported, medium to dark gray weathering, poorly sorted, weakly to fairly well graded, and composed of limestone, quartzite, and chert pebbles in a bioclastic packstone matrix.

Thin beds of medium- to dark-gray, medium-grained to pebble-size, weakly to fairly well sorted, graded, fossiliferous packstones are in close vertical association with the limestone conglomerate. These beds, ranging from 10 to 15 cm in thickness, show bedding contacts that mostly are parallel and planar. Some shallow scours, however, were observed. Rare instances of reverse to normal grading were noted, and some such beds form the bottom unit (division A) of Bouma turbidite sequences (Bouma, 1962). Thin- to medium-bedded silty and sandy microcrystalline limestone and calcareous siltstone locally display parallel and wavy laminae and crosslaminae, ball and pillow structure, and rare flame structure (fig. 6).

Fossils in the upper member generally are confined to the limestone conglomerate and thin graded bioclastic beds; undoubtedly they are transported. Nereites assemblage trace fossils (Seilacher, 1964) are present in the upper member, being especially conspicuous in flaggy silty limestones.

Exposures are increasingly poor toward the top of the upper member, but the talus indicates that quartzite and sandstone are the dominant rock types.

The base of this member is arbitrarily placed at the base of a 4-m-thick limestone conglomerate sequence located just to the west of the small patch of

A.

B.

Figure 6. Limestone in the upper member of the Bingham Mine(?) Formation in the Stansbury Mountains near Mud Springs. A- An overturned, crudely graded bed containing clasts of limestone, silty and sandy limestone, quartzite and fossil fragments in a micritic and skeletal matrix. Some clasts and fossils are silicified. B- A sequence of laminated, sandy limestone (lsl), silty limestone with load and flame structures (sl), and a thin, graded, bioclastic bed (b).

Tertiary volcanic rocks in the Stansbury Mountains. This bed, which is faulted at one locality, can be traced for about 200 m and probably pinches out underneath talus. It serves as a convenient local marker because it is stratigraphically the lowest exposed limestone conglomerate. The lowest exposed limestone conglomerate, north and south of this locality, is approximately on strike with this marker bed; an approximate boundary of the base of this member is shown on plate 1. Younger rocks contain an increasing proportion of intercalated limestone conglomerate.

Correct placement of the top of this member is now uncertain. An ammonite identified as belonging to the Early Triassic genus Meekoceras was recovered from strata near the bedrock-alluvium contact near the overturned syncline in the northeast part of the mapped area (Jordan and Allmendinger, 1979). These beds formerly were considered part of the Oquirrh Formation (Wright, 1961). However, Meekoceras occurs at the base of the Thaynes Formation that overlies the Triassic Dinwoody Formation in southern Idaho, and typically it occurs low in the Thaynes Formation in the Wasatch Mountains. The unit above the Oquirrh Group is provisionally identified by Jordan and Allmendinger (1979) as the Kirkman Limestone of Permian age, but no attempt was made to subdivide the package of Permian and Triassic(?) rocks that overlie the Oquirrh Group in the Stansbury Mountains. The contact between the Oquirrh Group and post-Oquirrh rocks is approximate (pl. 1) due to its poor exposure and gradational nature. Tentatively, it is placed between the thin beds composed of medium- to coarse-sand-size graded bioclastic material of the Oquirrh Group, and oncolite-bearing limestone of the Kirkman Limestone.

Age and correlation

The Bingham Mine(?) Formation in the Stansbury Mountains is considered to be Missourian to Wolfcampian in age. The age of the lower member is regarded as Missourian and Virgilian (table 2). The upper member was deposited during Virgilian and Wolfcampian time (table 2).

In the southern Onaqui Mountains, the Bingham Mine(?) Formation is of Late Pennsylvanian age (table 2) and is correlative with the lower member in the Stansbury Mountains. Fossils younger than Virgilian have not been found in the Onaqui Mountains; it is likely that they have been stripped away by erosion.

The Bingham Mine(?) Formation in both areas of study is here regarded as provisionally correlative with the type Bingham Mine Formation of the Oquirrh Group in the Oquirrh Mountains (Tooker and Roberts, 1970). Alternatively, it may be that the lower and upper members of the Bingham Mine(?) Formation in the Stansbury and Onaqui Mountains are correlative with the Bingham Mine Formation and Curry Peak Formation, respectively, of Swensen (1975) (fig. 5). The "best" correlation of the Upper Pennsylvanian and Lower Permian Oquirrh Group rocks in the Stansbury and Onaqui Mountains awaits a consensus on the most suitable stratigraphic system for the type Oquirrh Group.

Depositional environment

The depositional environment of the lower member is difficult to determine because of the poor exposure and the predominance of thick sequences of commonly featureless siliceous clastic rocks. Sandstone, siltstone, and

Table 2. Summary of the ages of fusulinids from the Bingham Mine(?) Formation in the Stansbury and Onaqui Mountains
[Locality numbers are keyed to location points on plate 1]

Locality number	Sample number	Location			Fusulinids	Age
		Township	Range	Section		
Stansbury Mountains						
11	77-AF-19	4 S.	6 W.	19	*Triticites* sp.	Late Pennsylvanian
12	77-AF-20	4 S.	6 W.	20	*Pseudofusulinella* sp.	Late Pennsylvanian
13	77-AF-25	4 S.	6 W.	30	*Triticites* sp.	Virgilian(?)
14	77-AF-30	4 S.	6 W.	29	*Pseudofusulinella* sp. *Triticites* sp.	Virgilian or Wolfcampian
15	77-AF-36	5 S.	6 W.	5	*Triticites* sp.	Late Pennsylvanian
16	77-AF-40	5 S.	6 W.	5	*Triticites* sp.	Late Pennsylvanian or Early Permian
17	77-AF-42	5 S.	6 W.	4	*Triticites*? sp.	Late Pennsylvanian or Early Permian
18	77-AF-46	4 S.	6 W.	28	*Schwagerina* sp.	Wolfcampian
19	77-AF-48	4 S.	6 W.	29	*Triticites* sp. *Schwagerina*? sp.	Wolfcampian
20	77-AF-51	4 S.	6 W.	19	*Pseudofusulinella* sp. *Triticites* sp.	Virgilian(?)
21	77-AF-55	4 S.	6 W.	19	*Triticites* sp.	Virgilian
22	77-AF-80	5 S.	6 W.	4	*Pseudofusulinella* sp.	Late Pennsylvanian Early Permian
23	77-AF-82	5 S.	6 W.	4	*Triticites*? sp.	Late Pennsylvanian
24	78-AF-7	4 S.	6 W.	30	*Triticites* sp.	Virgilian(?)
25	78-AF-16	5 S.	6 W.	16	*Pseudofusulinella* sp. *Triticites* sp.	Late Pennsylvanian or Early Permian
26	78-AF-22	4 S.	6 W.	19	*Pseudofusulinella* sp. *Triticites* sp.	Missourian(?)
27	78-AF-23	4 S.	6 W.	31	*Pseudofusulinella* sp. *Triticites*? sp.	Missourian(?)
Onaqui Mountains						
16	77-AF-1	7 S.	6 W.	29	*Kansanella* sp.	Missourian
17	77-AF-12	7 S.	6 W.	19	*Triticites* sp.	Missourian
18	77-AF-56	7 S.	7 W.	36	*Triticites* sp.	Virgilian(?)
19	77-AF-57	7 S.	7 W.	36	*Triticites* sp.	Virgilian(?)
20	77-AF-58	7 S.	6 W.	31	*Triticites* sp.	Late Pennsylvanian
21	77-AF-59	7 S.	6 W.	31	*Triticites* sp.	Virgilian(?)
22	77-AF-61	7 S.	6 W.	30	*Triticites* sp.	Late Pennsylvanian
23	13671*	7 S.	7 W.	13	*Triticites* sp.	Late Pennsylvanian
24	24544*	7 S.	6 W.	19	*Triticites* sp.	Late Pennsylvanian
25	13682*	7 S.	7 W.	26	*Triticites* sp.	Late Pennsylvanian
26	13672*	7 S.	6 W.	30	*Triticites* sp.	Virgilian
27	13683*	7 S.	7 W.	36	*Triticites* sp. *Pseudofusulinella* sp.	Late Pennsylvanian
28	24543*	7 S.	6 W.	31	*Triticites* sp.	Late Pennsylvanian

*U.S. Geological Survey Foraminifera catalogue number.

quartzite beds in the lower member commonly show internal lamination and crosslamination with erosive contacts with underlying crossbedded sets, but most beds are megascopically structureless.

The massive nature of the sandstone may be a primary feature of these rocks. Goldring and Bridges (1973) described sheets of massive sandstone that are formed in shallow sublittoral environments as a result of rapid deposition during storms, floods, tides, and tsunamis, and even by turbidity currents. Alternatively, bioturbation may have obliterated original sedimentary structures.

Intercalated limestones within the lower member of the Bingham Mine(?) Formation contain abundant echinoderms, brachiopods, bryozoans, corals, and minor gastropods and phylloid algae. Fusulinids are more abundant in the lower member of the Bingham Mine(?) Formation than in the Butterfield Peaks Formation. Communities of organisms that are known or inferred to require normal marine shallow-shelf conditions, and also those that probably inhabited more restricted environments, are present in strata of the lower member, suggesting that sea level was fluctuating during this time, or, alternatively, that these are the result of the creation and destruction of restricting bars.

The upper part of the lower member was deposited in deeper marine water. Much of it probably was deposited below wave base as indicated by the Zoophycos trace fossil assemblage (Seilacher, 1978) and the clastic rocks that generally are finer grained.

The first appearance of limestone conglomerate at the base of the upper member records the development of relatively steep submarine slopes. Coarsely bioclastic packstones containing moderately sorted fragments of bryozoans, echinoderms, brachiopods, fusulinids, and lithoclasts are enveloped by unfossiliferous beds and are in close vertical association with turbidite and submarine debris-flow sequences, suggesting that fossils were transported from shallower waters. A dominantly westward inclination of ripple cross-laminae (T. E. Jordan, pers. commun., 1979) may suggest transport in that direction.

Larson (1976, 1978), who studied Late Pennsylvanian and Early Permian resedimented conglomerate in Oquirrh Group exposures east of the Stansbury Mountains, suggested that deposition probably took place in break-in-slope and upper-distal-slope environments.

Post-Oquirrh Group Rocks

Undifferentiated Triassic(?) and Permian sedimentary rocks

These rocks are exposed in the northeastern part of the area mapped in the Stansbury Mountains. The lower part of this undivided unit consists mainly of siliceous clastics with intercalated limestone, some of which contain abundant silt and sand, and are locally cherty or fossiliferous. The sandstone, siltstone, and quartzite are yellowish brown to brown on fresh surfaces, weathering light brown to light orangish tan. These thin to thick beds typically lack internal sedimentary structures.

The proportion of thin- to thick-bedded fossiliferous limestone, most of which is medium to dark gray and weathers medium gray, increases upwards in this sequence. Recumbent folding of strata near the uppermost exposures in this sequence can be recognized by the outcrop pattern produced by thick-bedded fossiliferous recrystallized limestone.

Most of the post-Oquirrh Permian and Triassic(?) rocks in the Stansbury Mountains are of shallow marine origin, indicating that shallow-water conditions were restored to this area by late(?) Wolfcampian time. The presence of algal oncolites in limestone at the base of this unit is suggestive of deposition in the low intertidal to subtidal environment (Heckel, 1972).

Tertiary volcanic rocks

Volcanic flows and water-laid tuff crop out in only a few small patches within the area mapped in the Stansbury Mountains. Dark-purplish-brown hornblende latite comprises most of the flow rocks; white tuffaceous beds are associated with them. These rocks unconformably overlie all older rocks.

Undifferentiated Quaternary alluvium

The majority of the undifferentiated Quaternary alluvial deposits are unconsolidated gravels surrounding the base of the Stansbury and Onaqui Mountains. Dissected alluvial fans are well exposed at the south end of Big Hollow and in East Hickman Canyon.

STRUCTURE

Introduction

Principal deformation of eastern Great Basin miogeoclinal rocks occurred during the Sevier Orogeny. At that time, thick eastward-directed thrust sheets were stacked along the ancient miogeoclinal-cratonal boundary in the general region of this study (see Roberts and others, 1965; Armstrong, 1968). The continuity of the geology shows that rocks of the Stansbury and Onaqui Mountains lie within one major tectonic sheet, the upper plate of the inferred Tintic Valley thrust fault (Roberts and others, 1965; Morris and others, 1977). Cenozoic Basin-and-Range faulting has resulted in exposure of parts of this large allochthon.

Stansbury Mountains

The major structural feature of the Oquirrh Group rocks in the southeastern Stansbury Mountains is a marked angular discordance between the Oquirrh Group and the older Manning Canyon Shale, which is well exhibited on aerial photographs and also is suggested by projection of bedding attitudes. This contact has been interpreted as a depositional unconformity (Rigby, 1958; Wright, 1961) and a thrust fault (Tooker and Roberts, 1971; Sorensen and Moore, 1978). Morrowan strata reportedly lie at the base of the Oquirrh Group from the southernmost exposures of this unit to where these rocks wedge out at Stradley Spring; north of where they wedge out, Atokan rocks overlie the Manning Canyon Shale. Atokan rocks similarly wedge out north of Hickman Pass (Wright, 1961). Rigby (1958) and Wright (1961) reported that these relationships were produced by transgressive onlap. They cited the presence of dark shales and conglomerates in the basal Oquirrh Group (in unspecified locations) as sedimentological evidence for onlap. Although the writer recognized conglomerates near the base of the Oquirrh Group in the Stansbury Mountains, field relationships and petrographic evidence indicate that clasts in the conglomerate are intraformational, rather than the remains of eroded older rocks.

The writer favors a thrust fault interpretation for this discordance. Rigby (1958) mapped the Broad Canyon thrust fault from the northern tip of the Stansbury Range to the patch of Tertiary volcanic rocks just north of the area of this study. Tooker and Roberts (1971) and Moore and Sorensen (1979) inferred that this fault continues southward under 10 km of volcanic rock cover and then forms the contact between the Oquirrh Group and the Manning Canyon Shale. Sorensen and Moore (1978) concurred and described this fault as an imbrication within the upper plate of the Tintic Valley thrust fault. The minimum amount of stratigraphic displacement is about 1,000 m at the northern end of the area mapped for this study.

North of East Hickman Canyon, strata of the Oquirrh Group generally are overturned, perhaps the result of eastward shear along the Broad Canyon fault. Most beds strike north-northwest, except in the easternmost exposures where folding(?) has disrupted this pattern (pl. 1). South of East Hickman Canyon, beds are right side up near the base of the group, with progressively younger beds to the east steepening and overturning (pl. 1). The eastward steepening and overturning, and the folding of the rocks is thought to be the result of increased proximity to the leading edge of the Tintic Valley thrust fault, a structural feature that, based on the discordance of structural trends and juxtaposed sedimentary facies, lies between the Stansbury Range and South Mountain, located about 3 km to the east of the area mapped.

Except for the Broad Canyon thrust fault, only relatively minor faulting is detectable within the boundaries of this study. Small faults recognized by offset of limestone beds show displacement on the order of a few meters to tens of meters. Most of these faults are oriented east-west, suggesting that they are small wrench faults related to the forces that folded and overturned the rocks in the Stansbury Mountains.

Near East Hickman Canyon, a nearly vertical fault striking N. 25° W. is traceable for about 1.5 km and locally forms the contact between the Butterfield Peaks Formation and the Bingham Mine(?) Formation. The east block is relatively downthrown with unknown, but probably minor, displacement. Movement on this fault postdates overturning and folding.

Onaqui Mountains

Oquirrh Group rocks are bounded on the south by the Onaqui tear fault that extends through the saddle at Rock Canyon Spring (pl. 1). This fault, which is interpreted to be the southern boundary of the Stansbury Mountain-Cedar Range structural block (Sorensen and Moore, 1978), may extend more than 75 km to the west. There are distinctly different structural styles on opposite sides of this fault; the northward-dipping homoclinal sequence to the south is complexly faulted whereas strata to the north are gently folded and strike north-northwest. The Oquirrh Group, which dominates in the southern Onaqui Mountains, does not crop out in the Sheeprock Mountains, the range that continues southward across the Onaqui tear fault.

The Butterfield Peaks Formation terminates northward along the East Faust thrust fault where it comprises the leading edge of this fault and overlies Manning Canyon Shale and Lower Pennsylvanian Oquirrh rocks. Upper-plate rocks are deformed and brecciated within a few tens of meters of the fault trace, and beds of the Manning Canyon Shale locally are overturned near the contact. The East Faust thrust fault apparently is steeply dipping to the west, at least near the surface. This fault, like the Broad Canyon fault, may be an imbricate structure within the upper plate of the Tintic Valley thrust (Sorensen and Moore, 1978) because the similarity of age-equivalent Oquirrh Group facies in the Stansbury Range and the southern Onaqui Mountains suggests that movement on the East Faust thrust is much less than that on a first-order Sevier decollement thrust, such as the Charleston-Nebo thrust (Roberts and others, 1965), and less than that on the Tintic Valley thrust. In addition, it may be a southerly continuation of the inferred Skull Valley thrust fault (pl. 1) (Sorensen and Moore, 1978). A conservative estimate of the stratigraphic displacement is about 1,000 m, but it could be much greater.

A discontinuity between the Butterfield Peaks Formation and the Bingham Mine(?) Formation is suggested by discordant bedding attitudes in the vicinity of Dry Canyon and Burnt Canyon (pl. 1). Many outcrops near the inferred contact between these two formations are brecciated, suggesting that the angular discordance was caused by faulting. Fossil data show that displacement is not required, so the apparent discontinuity is regarded as a low-angle thrust(?) fault with minor movement, perhaps on the order of tens to a few hundred meters. This fault, here named the Dry Canyon fault, is similar to the subparallel East Faust thrust. The trace of this fault indicates that it strikes north-northwest and dips about 15^{o} to the west. Only a few other faults, probably with minor displacement, were identified within the boundaries of the areas of study.

Middle and Upper Pennsylvanian strata in the area mapped in the Onaqui Mountains are warped into gentle north-northwest-trending discontinuous folds. Most folds appear symmetrical, but a few have slightly steeper east flanks. The average maximum dips on the flanks of folds is about 50^{o}. The gentle folds in the Onaqui Mountains may be superimposed upon a broadly arched structure, perhaps a southerly continuation of the Stansbury anticline, presumably formed during Sevier overthrusting (Tooker and Roberts, 1971). The anticline dies out to the south, probably because much of the crustal movement was taken up along the Onaqui tear fault.

GEOLOGIC HISTORY

The two areas studied both lie within the Oquirrh Basin in which thick sequences of sediments were deposited during the Late Carboniferous and Permian time (Bissell, 1962; Chamberlain and Clark, 1973). The paleogeography of this sedimentary basin is not yet agreed upon due to differences in estimation of the magnitude of Late Mesozoic thrusting which has resulted in displaced facies of the basin. Roberts and others (1965) and Stevens (1977) proposed that the Oquirrh Basin originally was elongate with an east-west orientation, extending from central and northeast Nevada to the Utah-Wyoming shelf, whereas Bissell (1962) showed it as extending north-south. Jordan (1979c) has postulated that the axis of the basin had a northwesterly trend throughout most of its existence.

Predominantly shallow water carbonate deposition on the Cordilleran geocline continued from the Early Paleozoic through Early Pennsylvanian time, but then large volumes of siliceous clastics with interbedded limestone sequences were laid down. The Butterfield Peaks Formation in the Stansbury and Onaqui Mountains, of Middle Pennsylvanian age, was deposited in extremely shallow-shelf conditions; sands migrated along the oscillating margins of the transgressive and regressive seas, and shelf carbonates accumulated in the shallow marine environments. Similar Middle Pennsylvanian rocks in the Oquirrh Mountains, Tintic Mountains, Cedar Mountains, and Grassy Mountains suggest that the topography was virtually flat. The great thickness of the Butterfield Peaks Formation in the Stansbury and Onaqui Mountains apparently is due to pronounced subsidence at a rate roughly equal to that of sediment accumulation.

The dominance of siliceous clastic sedimentation that commenced in the late Desmoinesian became even more pronounced in the Missourian. Thick sequences of mature siliceous detrital material characterize the main body of the Upper Pennsylvanian Bingham Mine(?) Formation. Sand and intercalated carbonate continued to accumulate in fairly shallow waters throughout most of the Missourian, but Virgilian and early Wolfcampian time was typified by relatively rapid subsidence. A thick section of sandstone with intercalated resedimented limestone conglomerate and proximal turbidites was laid down during this last pulse of Oquirrh Basin downwarping.

By late(?) Wolfcampian time, the Oquirrh Basin had been filled so that shallow-marine conditions prevailed. Relatively thin sequences of post-Wolfcampian-Permian and Triassic(?) rocks also were deposited in shallow water.

The Late Mesozoic Sevier orogenic uplift in central Nevada caused large sheets containing thick rock sequences to pull apart and move eastward by gravity sliding (Roberts and others, 1965; Tooker and Roberts, 1971). These sheets piled up as they rode up on each other in the area now occupied by the eastern Great Basin (Roberts and others, 1965). Movement on the Broad Canyon thrust fault in Big Hollow, and the East Faust and Dry Canyon thrust faults in the Onaqui Mountains probably was concomitant with the juxtaposition of the Stansbury-Cedar Range structural block and other major blocks to the east and is a reflection of this telescoping (Sorensen and Moore, 1978). Folding, overturning, and minor wrench faulting in this area probably also occurred during this time. Cenozoic Basin-and-Range faulting and subsequent erosion have resulted in exposures of the rocks as they are presently distributed.

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