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a variety of warm water, shallow to marginal marine, generally low energy environments. These environments were controlled by parameters including: nature of substrate, salinity, turbidity, water circulation, local wave and current energy and water depth. In middle Leonardian time the rate of carbonate production exceeded the rate of basin subsidence and a filling of the basin of deposition occurred.
APPENDIX

The appendix is composed of a series of stratigraphic sections measured during the course of this study. These and other stratigraphic sections previously published and referred to in the text are the primary data from which the conclusions of this dissertation are drawn. Figure 25 is a list of measured sections and locations. Figure 26 is a key to lithologic and biotic symbols.
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<tr>
<td>MD - MI</td>
<td>G. Pequop Mts., Elko Co., Secs. 33,34, T34N, R65E</td>
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<td>Wood Hills, Elko Co., Sec. 24, T37N, R63E</td>
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<tr>
<td>MM - MN</td>
<td>N. Pequop Mts., Elko Co., Secs. 25,36, T38N, R65E</td>
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<td>N. Schell Creek Mts., White Pine Co. Secs. 22,27,34, T25N, R65E</td>
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<td>Spruce Mtn., Elko Co., Secs. 20,29, T31N, R64E</td>
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<td>NP</td>
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Figure 25. List and location of measured Sections.
## LITHOLOGIC

- **limestone**
- **dolomite**
- **conglomerate**
- **sandstone**
- **siltstone**
- **shale**
- **nodular chert**
- **bedded chert**
- **covered**
- **tectonic breccia**
- **break in section**
- **igneous**

## BIOLOGIC

- **dasyclad algae**
- **phylloid algae**
- **Tubiphytes?**
- **encrusted grain**
- **fusulinid**
- **other foraminifera**
- **coral**
- **bryozoan**
- **brachiopod**
- **bivalve**
- **gastropod**
- **scaphopod**
- **arthropod**
- **echinoid**

## FACIES

1. **fusulinid biomicrite**
2. **dasyclad algae-mollusc biomicrite**
3. **brachiopod-bryozoan biomicrite**
4. **oid sparite**
5. **crinoid-foraminifera biosparite**
6. **biolithite**
7. **dolomite**
8. **conglomerate**
9. **bimodal sand**
10. **very fine sand**

## FAUNAL

- **Fusulinids**
  - **Triticites sp.**
  - **Schwagerina sp.**
  - **Pseudoschwagerina sp.**
  - **Parafusulina sp.**
  - **Fusulina sp.**
  - **Heritschioides sp.**
  - **Kleopatrina sp.**
  - **Lophyllidium sp.**
  - **Thysanophyllum sp.**
  - **Durhamina sp.**
  - **Caninia sp.**

---

Figure 26. Key to stratigraphic sections.
Figure 27. Section MA
Figure 23. Section MD - MI
Figure 29. Sections ME and MF.
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Figure 33. Sections ML and MV.
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Figure 37. Section MR.
Figure 38. Section MS - MT.
Figure 39. Section MU.
Figure 40. Sections MY, MZ and NP.
References


INTRODUCTION

This study has two primary purposes; first, to describe the petrology of Upper Pennsylvanian and Lower Permian strata in northeast Nevada and adjacent Utah; and second, to reconstruct the history of deposition of these strata.

Exposures of predominantly carbonate rocks were examined in an area of approximately 4,500 square miles in Elko and White Pine counties, Nevada, and Tooele County, Utah (Fig. 1). This lies within the Basin and Range Province, an area in which complicated structure and widely spaced outcrops hinder the reconstruction of depositional patterns.

Most previous stratigraphic studies in the Cordilleran miogeosyncline have been of a general nature. The works of Bissell (1960, 1962, 1964, 1970), Roberts and others (1958, 1965), Steele (1960), Stevens (1965) and Zabriskie (1970) were intended, in large part, to develop the basic stratigraphic framework of the area. Collinson (1968), Snow (1964) and Thorman (1970) concentrated on the detailed geology of particular mountain ranges or portions ranges. By utilizing these reports and incorporating new


Fraser, G., (in preparation), Geologic map of the Spruce Mountain Quadrangle, Elko County, Nevada: United States Geol. Survey Map.


Figure 1. INDEX MAP WITH LOCATION OF MEASURED SECTIONS

1 - Medicine Rge. (ma,ms,mt)
2 - N. Schell Creek Mtns (mo)
3 - Gold Hill (mo)
4 - Lone Butte-Valley Mtn (mq,mr)
5 - Spruce Mtn-S. Pequops (mh,mp)
6 - Spruce Mtn Ridge (mf,mg)
7 - S. Pequops (mj,mz)
8 - C. Pequops (md,mi,np)
9 - C. Pequops (mv)
10 - N. Pequops (mm,mn)
11 - Wood Hills (ml)
12 - Ferguson Mtn (mu)
data of a petrographic nature, this study interprets the Late Pennsylvanian and Early Permian depositional history of northeast Nevada and adjacent Utah.

Field work was conducted during the summers of 1971 and 1972 with final field checking during the summer of 1973. Twenty-two stratigraphic sections, including all or parts of the Upper Pennsylvanian and Lower Permian interval, were measured, described and sampled for study. Measured sections, presented in the Appendix, form the framework of this study. The predominantly carbonate units were described as objectively as possible using the classification of R. L. Folk (1962). Such features as bedding characteristics, color, biota, texture, composition and degree of weathering were described from outcrop. Samples were collected at horizons of significant lithic change or of noteworthy lithologic features. In the laboratory, selected specimens were examined in greater detail by slabbing, thin section, and X-ray diffraction techniques.
GEOLOGIC SETTING

Stratigraphy

"In an area the size of the one currently being considered (eastern Nevada and western Utah) and in the present state of knowledge of the strata of Pennsylvanian and Permian age, perhaps the problems concerning nomenclature, age, correlation, and conditions of sedimentation are far more numerous than are the solutions" (Bissell, 1964, p. 565). The following is a brief discussion of the stratigraphic names referred to in this study. The distribution and stratigraphic equivalence of formations are indicated on Figure 2.

Diamond Peak Formation--The Diamond Peak Formation (Nolan and others, 1956) of Mississippian and Early Pennsylvanian age consists of variegated chert pebble conglomerate, brown quartzite and minor amounts of gray limestone. Detritus composing this formation was derived from uplands of the Antler orogenic belt in central Nevada. In the Pequop Mountains the Diamond Peak Formation is approximately 1200 ft. thick (Thorman, 1970, p. 2425). The Chainman Shale conformably underlies and is laterally equivalent to the Diamond Peak Formation.
<table>
<thead>
<tr>
<th>PERMIAN</th>
<th>ELY</th>
<th>CARLIN CANYON</th>
<th>NORTHERN PEQUOP MTNS.</th>
<th>SOUTHERN PEQUOP MTNS.</th>
<th>FERGUSON MOUNTAIN</th>
<th>GOLD HILL (UTAH)</th>
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<tr>
<td>LEONARDIAN</td>
<td>LORAY FM.</td>
<td>CARLIN CANYON FM.</td>
<td>&quot;UNNAMED FM.&quot;</td>
<td>LORAY FM.</td>
<td>LORAY FM.</td>
<td>LORAY FM.</td>
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<td>WOLFCAMPIAN</td>
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<td>BEACON FLAT FM.</td>
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<td>PEQUOP FM.</td>
<td>PEQUOP FM.</td>
<td>PEQUOP FM.</td>
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<td>VIRGILIAN</td>
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<td>MISSOURIAN</td>
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**FIGURE 2. LOWER PERMIAN - PENNSYLVANIAN STRATIGRAPHY IN NORTHEAST NEVADA**
Ely Limestone—This name, as originally proposed by Lawson (1906, p. 295) and redefined by Spencer (1917, pp. 26-27), refers to thick bedded, cherty, gray limestone of Pennsylvanian and Early Permian age near Ely, Nevada. Steele (1960, p. 100) restricted the term Ely Limestone to Pennsylvanian strata and proposed the name Riepe Spring Limestone for the overlying Permian beds. Dott (1955, p. 2234), working in the Carlin Canyon and north Diamond Range areas, elevated the term to group status and proposed two new formations, the Moleen and Tomera. Bissell (1964, p. 574) included three formations (Lower Ely, Upper Ely and Hogan) in the Ely Group in Elko and White Pine counties, Nevada. In the study area the Ely Limestone varies from 0 to 2500 ft. in thickness.

Hogan Formation—Robinson (1961, pp. 103-104) proposed this formation for a 250 ft. sequence of silty, sandy limestone and calcareous siltstone in the central Pequop Mountains. At the type locality, the Hogan Formation is reported to be Middle to Late Desmoinesian.

Strathearn Formation—Dott (1955, p. 2248) proposed the name Strathearn Formation for 1,200-1,500 ft. of cross bedded, chert pebble conglomerate, silty-sandy limestone and calcareous, quartz sandstone near Carlin Canyon, Elko County. Fusulinids are abundant at the type section. The age reported by Dott is Missourian to Early Wolfcampian.
Ferguson Mountain Formation—Berge (1960, pp. 18-19) proposed this name for a thick sequence of limestone that forms most of Ferguson Mountain in Elko County. Based on fusulinids Berge considered the Ferguson Mountain Formation to contain 199 ft. of Virgilian, 1718 ft. of Wolfcampian and 268 ft. of Leonardian strata. Steele (1960, p. 101) proposed a Ferguson Springs Formation for a limestone sequence from the same area that included Missourian, Virgilian and Wolfcampian strata, but it has not been generally accepted because of the priority of Berge's work.

Arcturus Group—Lawson (1906, p. 294) used the term Arcturus to refer to an argillaceous limestone in the Robinson mining district near Ely, Nevada. Hose and Repenning (1959) applied the name Arcturus Formation to a poorly fossiliferous, calcareous sandstone with interbedded limestone and dolomite in the Confusion Range of western Utah. Bissell (1964, pp. 585, 602) described the Arcturus Formation as being poorly described. He proposed the name be elevated to group status and to include the following formations: Riepe Spring, Riepetown (Rib Hill), Pequop and Loray. With the exception of the northern Schell Creek Range and possibly the Gold Hill area, the name Arcturus Formation cannot be applied to strata considered in this study. Therefore, Bissell's proposal will be followed.
Riepe Spring Limestone—Steel (1960, p. 102) assigned the name Riepe Spring Limestone to the basal portion of the Permian limestone succession near Ely, Nevada. This massive, coral and fusulinid-bearing limestone of Wolfcampian age had previously been included as the upper 300-400 feet of the Ely Limestone. At some localities a thin chert pebble conglomerate marks the base of the formation.

Rib Hill Formation—Pennebaker (1932, p. 164) proposed the term Rib Hill Sandstone for fine grained calcareous sandstone near Ely. As Bissell (1964, p. 597) pointed out, this formation also includes considerable dolomite, siltstone and sandy limestone. Steele (1960, p. 103) noted that "Rib Hill" was previously used for a Precambrian quartzite in Wisconsin and he proposed a new name, Riepetown Sandstone. Because of its entrenchment in the literature, the possibility of confusion between the terms Riepetown and Riepe Spring, and its continued use by the U.S. Geological Survey (Hope, 1972), the name Rib Hill will be used here.

Pequop Formation—Steele (1960, p. 105) applied the name Pequop Formation to a sequence of thin-bedded, fusulinid bearing limestone, sandstone and siltstone 1,570 ft thick in the central Pequop Mountains. Robinson (1961, p. 105) pointed out that Steele's section was incomplete
MARCANTEL, Jonathan Benning, 1945-
UPPER PENNSYLVANIAN AND LOWER PERMIAN
SEDIMENTATION IN NORTHEAST NEVADA.

The Ohio State University, Ph.D., 1973
Geology

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and suggested that a nearby 3000 ft sequence be designated as the type section. Sections measured in this study in the central and southern Pequop Mountains indicate a thickness of 3000 to 3500 ft. The Pequop Formation is uppermost Wolfcampian and Leonardian in the type area.

Loray Formation—Steele (1960, pp. 106-107) designated the Loray Formation for a sequence of poorly exposed, thin bedded, yellow-tan, gypsiferous sandstone and siltstone and interbedded limestone overlying the Pequop Formation. The type section is located in Loray Wash near Montello where typically poor exposures exist.

Structure

The study area lies in the miogeosynclinal portion of the Cordilleran geosyncline (Fig. 3), an area in which thick sedimentary sequences were deposited from Late Precambrian into Early Mesozoic. A pattern of predominantly carbonate sedimentation established in the Early Paleozoic was interrupted by the Antler Orogeny (Robers and others, 1958), a period of folding and eastward thrusting which affected central Nevada from Late Devonian through Early Pennsylvanian. In response to Antler events to the west a Mississippian to Early Pennsylvanian clastic sequence was deposited, the Chainman Shale and the overlying conglomeratic Diamond Peak Formation.
FIGURE 3. STRUCTURAL SETTING
Several tens of miles to the west of the Antler belt Late Permian to Early Triassic folding and thrusting occurred, the Sonoma Orogeny (Silberling and Roberts, 1962 and Speed, 1971). This event does not appear to have affected distribution of strata in the study area.

Orogenic activity affected the eastern California and western Nevada region during the Middle Triassic to Late Cretaceous interval, i.e., the Nevadan Orogeny (Bateman, 1968) and the central Utah area during Middle Jurassic through Cretaceous, i.e., the Sevier Orogeny (Armstrong, 1968). The Nevadan Orogeny consisted of the emplacement of granitic plutons during several episodes of formation. The effects of the Sevier Orogeny are best displayed in central Utah where thick sequences of terrigenous sediments and eastward directed thrust faults are found. The terrigenous clastic sequence was derived in large part from the west in eastern Nevada and western Utah.

The study area was possibly subjected to tectonic events associated with the Sevier Orogeny. Misch (1960, pp. 33-34 and 1966, pp. 324-325) noted the occurrence of eastward directed thrust faults in the Snake Range in eastern Nevada. This led to his idea of a regional decollement thrust fault related to plutonic emplacement in the eastern Nevada and western Utah area. Roberts (1968, p. 111) related thrusting in the eastern Nevada area
to the arching of portions of eastern Nevada and glide faulting toward the Sevier belt in Utah. Armstrong and Hanson (1966, pp. 125-126) proposed that eastward thrusting in the eastern Great Basin occurred concurrently with Mesozoic metamorphism and the detachment surface was a zone of very steep metamorphic gradient. Armstrong (1968, pp. 442-444) and Birchfiel and Davis (1972, p. 113), however, concluded that Mesozoic thrusting in eastern Nevada was not related to the Sevier Orogeny, but to compressional forces to the west related to plate tectonics.

Thorman (1970, p. 2441) noted that Lower Permian strata in the central Pequop Mountains are significantly different than equivalent strata in the northern Pequop Mountains. He hypothesized that this change in facies is the result of tear faulting at the margin of two thrust plates. Although faulting of this nature may exist in the Pequop Mountains, during the course of this study no stratigraphic evidence was found that indicated the changing of original juxtaposition of lithofacies by structural displacement.

Armstrong (1972) in a prevocative paper argued that many, but not all, supposed Mesozoic thrust faults are in fact misinterpreted gravity slide features or denudation faults related to Tertiary vertical tectonics. Oligocene or Miocene to Recent block faulting is responsible for the
present basin and range topography of the study area (Roberts, 1968, p. 111). The ranges are bounded by high angle, normal faults with several thousand feet of throw. The ranges are typically broken into many separate blocks by a series of normal faults of lesser magnitude. These faults which have from a few feet to thousands of feet of throw complicate the stratigraphic sequences and make section measuring difficult.

In summary it may be stated that the eastern Nevada area underwent one or more episodes of eastward directed low angle thrusting of undetermined heave, the magnitude probably measured in miles. The effect of thrust faulting on Upper Pennsylvanian and Lower Permian strata has not been demonstrated to be significant within a single mountain range. It is conceivable, however, that the original distribution of strata between ranges could be altered considerably by such faults.
FACIES

General Statement

To facilitate an understanding of depositional history during the Late Pennsylvanian and Early Permian, sediments deposited during this time interval are divided into facies. The term facies as used in this study refers to the particular lithologic and paleontologic characteristics of a particular body of rock. The differentiation of a sedimentary sequence into facies is intended to describe the petrology in terms that reflect patterns and environments of deposition. Facies are identified on the basis of systematically applied criteria that separate them into discrete units whose nature and relationships to one another enable the reconstruction of probable depositional environments.

The following criteria, listed in order of relative importance, are used to define facies: mineralogy, texture, allochemical content. On the basis of mineralogy, lithologies can be divided into three groups: (1) limestone, (2) dolomite, and (3) siliciclastic detritus (terrigenous rocks). Texturally, limestone is divided into rock with a lime mud matrix (micrite), with spar cement (sparite), and with an organic framework (biolithite).
Terrigenous rocks are divided texturally into conglomerate, bimodal sand and very fine sand.

Limestone is further divided on the basis of allochemical content. The following allochems were found to be volumetrically important: encrusted grains, oolites, pseudoolites, pellets, intraclasts, blue-green algae, Tubiphytes?, phylloid algae, dasyclad algae, fusulinids, small foraminifera, solitary corals, fasciculate corals, massive corals, articulate brachiopods, inarticulate brachiopods, fenestrate bryozoans, ramose bryozoans, bivalves, gastropods, scaphopods, ostracodes, trilobites, crinoids, echinoids, spines and calcispheres. Table 1 is a list of the relative abundance of allochemical constituents in limestone facies.

The following facies, named for their outstanding characteristics, are defined and described.

I. Limestone

A. micrite matrix

1. fusulinid biomicrite facies
2. dasyclad algae—mollusc biomicrite facies
3. brachiopod—bryozoan biomicrite facies

B. spar cement

1. ooid sparite facies
2. crinoid—foraminifera biosparite facies

C. biolithite facies
ALLOCHEMICAL CONSTITUENTS

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<thead>
<tr>
<th>Constituent</th>
<th>Fusulinid Biomudrite</th>
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<th>Brachiopod-Echozoan Biomudrite</th>
<th>Ooid Sparite</th>
<th>Grinoid-Foraminifera Sparite</th>
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A-abundant  C-common  R-rare

Table 1. Relative abundance of allochemical constituents in limestone facies
Fusulinid Biomicrite Facies

The fusulinid biomicrite facies is characterized by abundant fusulinid foraminifera in a lime mud matrix. The following fossil groups are common accessory allochems: smaller foraminifera, articulate brachiopods, bryozoa and crinoids. Other taxa including trilobites, echinoids, gastropods, solitary corals, bivalves and encrusted grains are typically present in minor amounts. Fusulinids include species of Triticites, Schwagerina, Pseudoschwagerina, Parafusulina, Monodiexodina and Pseudofusulinella which are useful for correlation. Examples of the smaller foraminifera are Paleotextularia, Globovalvulina, Cornuspira and Climacammina. Brachiopods include Derbyia, productids and spiriferids.

Fusulinid biomicrite facies tends to be well sorted and well rounded (Fig. 4). The high degree of sorting is due both to current activity and to the fact that the same type of fusulinid is typically present in one bedding unit. Fusulinids are, of course, intrinsically well rounded and become angular only when broken. In some
4a. Photomicrograph of packed sandy fusulinid biomicrite (MG 100); Note: A=fusulinid, B=Climacolammina, C=detrital quartz; Bar=0.1mm.

4b. Photograph of packed fusulinid biomicrite in outcrop (MP).

Figure 4. Fusulinid biomicrite facies.
UPPER PENNSYLVANIAN AND LOWER PERMIAN
SEDIMENTATION IN NORTHEAST NEVADA

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

Jonathan Benning Marcantel, B.S., M.S.

* * * * * *

The Ohio State University
1973

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Approved by

James W. Collinson
Adviser
Department of Geology
and Mineralogy
strata a calcite spar cement is present, but in subordinate quantity to the lime mud matrix. Fusulinid biosparites are sparse in the study area. Minor amounts of detrital quartz are common in this facies in quantities less than 5% of the total grains. The fusulinid biomicrite facies tends to be grain supported rather than matrix supported, but exceptions do occur. Grain size is dependent on the original size of the fusulinids, which range from less than 1 mm to greater than 10 mm in length.

The fusulinid biomicrite facies is thin to thick bedded, light to dark gray fossiliferous limestone. Fusulinids are readily observable in some strata of this facies without use of a hand lens. A fetid odor produced by breaking a sample of this facies is not uncommon. Cross bedding is observed in some bedding units, but is commonly obscured by burrowing. Bedding units tend to be regular and laterally continuous for the extent of outcrop.

The fusulinid biomicrite facies is widespread and volumetrically important. It is found throughout the study area with the exception of in the north Schell Creek Range and the north Pequop Mountains where only a few thin beds are present. This facies is a significant component of the Riepe Spring Limestone, Ferguson Mountain Formation, Rib Hill Formation and the lower part of the Pequop Formation.
Associated with the fusulinid biomicrite facies are the brachiopod-bryozoan facies, biolithite facies, ooid sparite facies, crinoid-foraminifera biosparite facies, conglomerate facies and very fine sand facies.

Because of the biostratigraphic importance of fusulinids to Upper Paleozoic strata, the subject of their paleoecology has received considerable attention. Fusulinids are believed to have lived in an open marine shelf environment of near normal salinity (Loeblich and Tappan, 1964, p. c387). They are seldom found associated with evaporites. The presence of corals and crinoids in this facies would tend to confirm that the fusulinid biomicrite facies was deposited in an open marine environment. Cross bedding in some strata indicates that some current or wave energy was locally present. Mud matrix indicates that current or wave winnowing was not sufficient to remove fine grained material.

The use of fusulinids as water depth indicators has received considerable attention. On the basis of comparison with the modern isomorph Alveolinella, Elias (1937) theorized that fusulinids lived in water 150-180 feet deep. Stevens (1966, p. 1123) in a study of paleotopographic reconstructions in the Pennsylvanian of Colorado, concluded that fusulinids represent deposition in approximately 60-150 feet of water. Ross (1961), however, reported from
the Leonard Formation in Texas fusulinids that lived in shallow water regularly agitated by waves, possibly beach or bar features.

The association of fusulinid biomicrite with the conglomerate facies, which is believed to have, in part, a beach-bar origin, would imply that the water depths in this particular case were quite shallow, less than 10 feet as indicated by the thickness of the conglomerate sequence. However, the cross bedded fusulinids may have been transported into the site of deposition. For most of the fusulinid biomicrite facies, no absolute depth determinations are possible. Bottom conditions, as indicated by the mud matrix and burrows, were soft. The paucity of terrigenous clay and fine silt implies low turbidity.

**Dasyclad Algae-Mollusc Biomicrite Facies**

The dasyclad algae-mollusc biomicrite facies is characterized by the abundance of algae belonging to the family Dasycladaceae, a type of chlorophycophyta or green algae which is preserved in fossil form as molds with central stem and branches appearing as canals or pores (Johnson, 1963, p. 1). In thin section this facies appears as sand sized, well sorted and well rounded biomicrite or packed biomicrosparite (Fig. 5) with a minor amount of terrigenous material (less than 1 or 2%). In addition to
Figure 5. Dasyclad algal-mollusc biomicrite facies.
the dasyclad algae, mollusk remains, especially gastropods and scaphopods, commonly occur. Ostracodes, calcispheres and smaller foraminifera are also typically present. Minor accessory allochemical constituents include articulate brachiopods, fusulinids, fenestrate and ramose bryozoa, crinoids and pellets.

The dasyclad algal facies is typically thick bedded, medium gray to black, fetid and, in some cases, burrowed. Vertical, U-shaped burrows, up to 6 inches in length are similar to those described by Heckel (1972, p. 244) as being most abundant in shallow marine or marginal marine environments. This facies sometimes appears as a poorly fossiliferous micrite and must be examined closely to recognize the dasyclad algae. Except for sparsely occurring thin beds of packed, broken and abraided shell fragments interpreted as storm layers, current features are generally lacking.

Modern dasyclad algae are most abundant in shallow marine, protected, low energy, lagoonal areas (Ginsburg and others, 1972, p. 52). The available evidence indicates a similar depositional environment for the dasyclad algae-mollusc biomicrite facies. Although the original unconsolidated algal sediment was sand sized, well sorted and well rounded, these characteristics are due to the disintegration and accumulation of similar sized algal
sediments upon the death of the plant. The algae probably flourished in thick, lush algal meadows in which a limited biota lived. The occurrence of this facies was not associated with a reef or barrier, but with isolation from open marine water by distance and a low gradient bottom profile. This subject is expanded in the section on distribution of facies.

Brachiopod-Bryozoan Biomicrite Facies

The brachiopod-bryozoan biomicrite facies is characterized by the presence of brachiopods or bryozoans in a lime mud matrix. Crinoids are also typically abundant in this facies. Brachiopods and bryozoans may occur together or exclusive of each other. Brachiopods include Derbyia and undifferentiated productid and spiriferid genera. Bryozoa are fenestrate and ramose types. Common accessory allochems are crinoids, gastropods, smaller foraminifera, brachiopod spines, and pellets. Rarer taxa include fusulinids, solitary corals, inarticulate brachiopods, bivalves, scaphopods, ostracodes, trilobites and echinoids. Detrital quartz, silt and very fine sand occur in most strata of this facies and compose up to 15% of some units.

Petrographically the brachiopod-bryozoan biomicrite facies is composed of whole or broken shells in a micrite matrix (Fig. 6). Most strata have grain supported fabrics
6a. Photomicrograph of packed brachiopod-bryozoan biomicrite; Note: A = bryozoan, B = brachiopod, C = crinoid, D = silification of brachiopod shell, E = lime mud matrix, F = trilobite (MM 57); Bar = 0.1mm.

6b. Photomicrograph of sparse biomicrite; Note: A = ostracode, B = pellets (MG 2240); Bar = 0.1mm.

Figure 6. Brachiopod-bryozoan biomicrite facies.
but many do not. Very sparse biomicrites have been noted and true micrites, which contain fewer than 10% allochems, are uncommon. As noted by Zabriskie (1970), pressure solution contacts between crinoid fragments are common. Although brachiopods and bryozoa are frequently found broken, little evidence exists of strong and continuous current activity. The shelly fragments are believed to be the result of bioturbation. Cross-bedded and scoured units occur. The particle size varies widely in accordance with the fossil shell size, therefore is not a function of local energy conditions. Except for geopetal structures and occasional ripped up layers, spar cement is either very reduced in quantity or absent. Sorting by waves or currents is generally poor, as is rounding of broken grains. Some strata contain a high proportion of pellets as part of the matrix. These pellets are typically poorly defined and tend to merge with the micrite matrix.

Bedding ranges from thin to thick and color from dark to light brown-gray. The lighter shades of color tend to reflect a higher terrigenous content. The ripped-up units previously mentioned, although volumetrically minor, are observed at many horizons in this facies. The bulk of the brachiopod-bryozoan facies appears to be intensely burrowed.
Contrasting with the regular bedding of most of the brachiopod-bryozoan biomicrite facies is the occurrence of bioherms or mounds composed almost exclusively of bryozoa. These massively bedded units, usually 5 or more feet thick, are interbedded with regularly bedded brachiopod and bryozoan biomicrites. There is no evidence that these mounds were true wave resistant features. They probably represent quiet water accumulations of bryozoan communities.

The greatest textural variation in the brachiopod-bryozoan biomicrite facies occurs in the lower Pequop Formation in the Medicine Range. It is in this area that sparse biomicrites, fossiliferous micrites, sparry biomicrites and brachiopod-bryozoan biosparites are found in association with phylloid algal biolithites. Fusulinid biosparites which are otherwise uncommon may occur in association with these unusual textures.

This facies is the most widespread and volumetrically important of all carbonate facies. It occurs in significant quantity in the Riepe Spring, Ferguson Mountain and Pequop formations. Thin strata of this facies are also found in the Rib Hill Formation and Loray Formation. The brachiopod-bryozoan biomicrite facies is associated with all other facies described in this report.

The brachiopod-bryozoan biomicrite facies is believed
to have been deposited, in large part, in quiet water areas of shallow to moderate shelf depths. Terrigenous detrital influx was variable, but at times high enough to make water conditions turbid. The substrate was soft but firm and not mobile. Bryozoa and some brachiopods probably used hard parts of other animals as an attachment surface. The salinity was probably variable within narrow limits, responding to isolation from open marine conditions by low bottom profile and irregular bottom topography. Biomicrites composed of phosphatic brachiopods and ostracodes probably represent deposition in euryhaline conditions, areas subjected to periodic stream runoff and to more pronounced restriction from open marine water. The repeated occurrence of ripped up layers is believed to be the result of episodic storms that disturbed the upper few inches of otherwise static sediment.

**Ooid Sparite Facies**

The ooid sparite facies is characterized by the presence of oval, sand-sized carbonate grains set in a calcite spar or microspar cement. Two types of grains compose the bulk of the allochems of this facies--oolites (superficial oolites) and biogenically encrusted grains. Accessory grains, which are volumetrically minor, include intraclasts, pellets, ostracodes and gastropods. Other less common allochemical constituents are lithoclasts,
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dasyclad algae, fusulinids, small foraminifera, articulate brachiopods, bryozoa, crinoids and echinoids. Minor amounts, less than 5% of very fine to fine quartz sand and very coarse quartz silt are present in some strata.

True oolites, although present, are typically subordinate in number to superficial oolites. Oolites contain nuclei of detrital quartz, pellets, or fossil fragments. The most common fossil nuclei are gastropod fragments. Superficial oolites and oolites range in size from fine to medium sand. Grains are well sorted and typically well rounded. Minor amounts of admixed micrite matrix is commonly present and a few samples contained more micrite than spar or microspar.

Biogenically encrusted grains are subspherical, often embayed, encrustations about a nucleus (Fig. 7). Length of the long axis of the grain usually ranges from 1.5-2.5 mm with some exceptionally large ones up to 5 mm. The short axis in thin section of most specimens varies from 0.5 to 0.9% of the length of the long axis. Grains are usually well sorted and very well rounded. The encrusting organism(s) are attached initially to a hard nuculeus, usually identifiable as a fossil fragment, quartz or other terrigenous grain, or a carbonate pellet. Fossil nuclei include fragments of ostracodes, trilobites, brachiopods, brachiopod spines, bryozoa, crinoids, echinoids,
Encrusted grain (MA 2001); Note organic encrustations about a hard nucleus, in this case gastropod fragments; Bar = 0.1mm.

Encrusting nubecularid foraminifera (MA 2001); Bar = 0.1mm.

Figure 7. Photomicrographs of encrusted grain biosparite
fusulinids and smaller foraminifera, green algae, gastropods and unidentified mollusk fragments. Silt and very fine sand size detritus are often incorporated into the encrusting layers. The selection of nuclear material seems to be fortuitous and on a material available basis rather than selective. The condition of the nucleus may or may not be altered. If it is altered it is by micritization or recrystalization. Encrustations are in the form of irregularly concentric laminae of micrite that may or may not preserve identifiable organic structures. Encrusting nubecularid foraminifera are most commonly identified.

Twenhofel (1919, pp. 351-352) named the form genus Osagia for algal-like concentric bodies found in the Lower Permian of Kansas and Oklahoma. The term was also used by later workers for foraminiferal encrusted grains and algal foraminifera consortia. Henbest (1963, p. 36) emended the term Osagia to include only those grains composed primarily of Girvanella (blue-green algae) encrustations. In the specimens studied, well developed foraminiferal structures are present but readily identifiable Girvanella structures are not. The absence of Girvanella may be the result of later micritization or diagenesis. Irregular borings similar to those described as algal? boring in "Osagid" grains by Toomey (1969,
p. 1327) are present and tend to obscure and micritize other organic structures. Because these grains cannot be definitely identified as Osagia as emended by Henbest, the term encrusted grain is used.

In addition to the borings and micritization already discussed, these grains often display a reddish or greenish color, a distinctive change from the gray hues of the surrounding matrix. Henbest (1963, pp. 10-16) reported similar features in other encrusted grains. He related this to the presence of magnesium in amounts greater than 2% in the shell wall of encrusting foraminifera and subsequent diagenesis in an oxidizing zone. The concentration of iron in the encrusted grains is a noteworthy and commonly observed feature.

In outcrop, the ooid sparite facies is thin to medium bedded and light olive gray to medium gray. Cross bedding is present in some strata and obscured by burrowing in others. Because lenses or bar-like accumulations are poorly developed or absent, this facies probably has a blanket or sheet-like geometry. Small scale scour features are observed in some sections. The ooid sparite facies is poorly exposed except where mound-like accumulations have been noted.

Mounds associated with this facies occur in the Brush Creek area of the southern Pequop Mountains (Fig. 8). These structures vary in size from 15 to 40 feet in
8a. Photograph of mounds in outcrop

8b. Photomicrograph of micritized carbonate granules associated with mounds (MH-4621c); Bar = 1.0 mm.

Figure 8. Carbonate mounds in the Pequop Formation
diameter and from 4 to 10 feet high. Relief in comparison to adjacent beds is up to 5 feet. The mounds are easily detectable in the field and represent a distinctive departure from the typical horizontal bedding. The mounds are composed of superficial oosparite with dasyclad algae, fusulinids and rare red algae.

The ooid sparite facies is a widespread, but volumetrically small rock type. It is found throughout the study area and is especially well developed in the southern Pequop Mountains. Oolites and biogenically encrusted grains do not generally occur in the same bedding unit, but do occur with each other. The thick ooid sparites in the southern Pequop Mountains are predominantly superficial oosparite. This facies is found primarily in the upper Pequop Formation and the Loray Formation.

Algal-foraminifera consortia similar to the encrusted grain biosparite have been recently reported from tidal channels in oolite shoals in the Bahamas (Buchanan and others, 1972, p. 606). Water depths averaged 7 feet and surface current velocities averaged as high as 0.6 knots. Although evidence is insufficient to conclude that the encrusted grains formed in an identical environment, it is believed that the mechanism of formation was probably similar. The uniform size of these foraminiferal encrusted
grains is a function of the wave energy present in the depositional environment. The ambient wave energy not only caused sorting, but also provided a limiting factor for the optimum size development of the grains.

Ball (1967, pp. 573-577) described from the Bahamas a type of sand body referred to as "platform interior sand blankets" that possesses many attributes in common with the oosparite including: texture, internal structures, composition, geometry and depositional setting. Ball's platform interior sand body is found in shallow, moderately agitated water on the Bahaman platform interior and is not associated with any nearby break in slope or deep marine area. Fairbridge (1967) has noted that modern oolites are found about the latitudes of 25°N. and S. and at a water temperature range of 20°-30° C.

In summary, the ooid sparite facies is interpreted to have been deposited in an agitated, shoal water environment subjected to moderate, but not strong, washing and winnowing by marine currents. The general lack of well developed oolites with many concentric laminae; the lack of lens or bar-like bodies; and the widespread occurrence of admixed lime mud and microsparite indicate that this facies was, in general, not formed in an area continuously subjected to high energy waves or currents, but rather an area subjected to moderate energy conditions. The substrate was composed of mobile sand size material that became
locally stabilized. Turbidity was variable, a function of the local energy conditions and availability of mud.

Crinoid-Foraminifera Biosparite Facies

The crinoid-foraminifera biosparite facies is defined by the presence of crinoids and foraminifera in a calcite spar cement. This facies is a distinctive textural departure from the bulk of biogenic limestone considered in this study which has a lime mud matrix. The most abundant grains in this facies are the characterizing allochems, crinoids and small foraminifera. The foraminifera belong mostly to the family Nubeculariidae. Some strata of this facies are composed almost exclusively of crinoid debris. Tubiphytes? is a common accessory grain in certain beds of this facies. Other common accessory allochemical constituents are intraclasts, pellets and fusulinids. Many less common accessory grains are also present; these include red algae, corals, articulate brachiopods, brachiopod spines, bryozoans, bivalves, gastropods, trilobites, echinoids and quartz sand. Because much of the fossil material is fragmented, identification of many grains is difficult.

Texturally the crinoid-foraminifera biosparite facies is typically a packed fragmental biosparite (Fig. 9). Some lime mud matrix may be present in minor amounts, but most samples from this facies are well washed. Sorting, a
Figure 9. Crinoid-foraminifera biosparite facies (MS 168);
Note: A = porcellaneous foram, B = crinoid, C = abraided fusulinid, D = spar cement; Bar = 0.1mm.
function of the diversity of taxa, is variable, ranging from good to poor. Fossil grains are not abraided enough to overcome the original differences in size. Pressure solution features are common, especially in crinoid grains. Euhedral quartz overgrowths are common. Although this diagenetic feature occurs in other facies, it is nowhere else as prevalent as in the crinoid-foraminifera biosparite facies.

On outcrop, the crinoid-foraminifera biosparite facies is typically thin to thick bedded with small scale current features and local scour surfaces. No scours deeper than 2 feet were observed. Burrows are common and tend to obscure or obliterate primary bedding features. The limestone is medium gray and emits a fetid odor when broken. This odor is especially common in crinoid fragment biosparite.

The crinoid-foraminifera biosparite facies is found in most of the study area, but is not as volumetrically important as many other carbonate facies. It occurs most commonly in the Riepe Spring Formation, the Pequop Formation, and, to a lesser extent, the Rib Hill Formation and Ferguson Mountain Formation. This facies is associated closely with the conglomerate facies, the fusulinid facies and the biolithite facies. In many respects, the crinoid-foraminifera biosparite facies can be considered a higher
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energy equivalent of the biolithite and fusulinid biomicrite facies.

The broken and abraded nature of the grains and the lack of mud matrix indicate that the crinoid-foraminifera biosparite facies was deposited in moderate to high energy conditions. Deposition was in the form of sand sheets or sand waves rather than discrete channels as witnessed by the absence of significant scours. The diverse biota implies normal marine salinities. Deposition, therefore, was in or adjacent to open water. Bottom conditions were firm, but locally mobile. There is no indication of prolonged mobility as in the ooid sparite facies. Turbidity was uniformly low.

**Biolithite Facies**

Into the biolithite facies are placed limestones made of organic structures growing in place and forming a coherent resistant mass during growth. This facies includes organic structures found in growth position, not debris derived from such structures. Organically bound sediment which could be classified as biolithite, but is specifically excluded from the biolithite facies as defined here is dolomite stromatolite placed in the dolomite facies.

The most abundant and widespread organic framework sediment is coral biolithite consisting of several genera of fasciculate and massive forms. Solitary corals are
also occasionally found associated with the biolithite facies, but are not framework builders. The following genera of fasciculate and massive corals have been identified by C. H. Stevens (personal communication): Heritschioides, Thysanophyllum, Durhamina, Lithostrotionella, Kleopatrina, Orionastraea and Syringopora. Few fossil grains are found within the biolithite bedding unit. The most common of these are crinoids, oncolites of blue-green algae and small foraminifera. Encrusting Tubiphytes? encrusting bryozoa and red algae are also observed, but less commonly. Adjacent bedding units may contain a varied biota including foraminifera, crinoids, echinoids, gastropods, bryozoa, brachiopods, dasyclad algae, trilobites and ostracodes.

Texturally coral biolithite consists of a framework of coral in growth position with intercoralline space filled with lime mud, sparse fossil grains and minor detrital quartz silt and very fine sand. Beds of horizontal, overturned, and broken coral biolithite are found intimately associated with coral in growth position. Irregularly distributed spar-filled areas are common. These are primarily a result of sheltering by rigid organic framework rather than winnowing by currents.

As areally isolated subfacies of the biolithite facies is found in the Medicine Range. This is phylloid algal
biolithite which contains abundant encrustations of Tubiphytes. Fasciculate corals, ostracodes and encrusting foraminifera are common constituents with calcispheres and gastropods among the less common accessory grains. Associated with phylloid biolithite, but in separate beds are fusulinid biomicrite and brachiopod-bryozoan biomicrite.

The phylloid algae appear as branching plates of sparry calcite in a lime mud matrix (Fig. 10). The individual plates are approximately 1 mm in diameter and several cm or more in length. The spar is in the form of a mosaic of crystals whose size decreases toward the plate edges. Because of the recrystallization of the algal blades, it is difficult to identify them with any certainty, but the absence of micrite filled pores and the presence of poorly preserved cellular structure in some specimens indicate these are red algae, possibly similar to Archaeolithophyllum.

Tubiphytes are identified by their porcelaneous, fine shell texture, their encrusting habit, presence of spar filled areas, and their characteristic layered appearance (Fig. 11). Internal irregular cylinders which are characteristic of the genus, Maslov (1956, pp. 82-84) as cited by Toomey (1969, p. 1323), were not observed.
10a. Photograph of polished slab (MA 648); Note: A = branching phylloid algal plates, B = Tubiphytes? which appear white in reflected light, C = internal sediment; Bar = 5cm.

10b. Photomicrograph of phylloid algal plate (MA 216); Note increase in crystal size of calcite spar away from plate margin and encrusting Tubiphytes? which appears dark in transmitted light; Bar = 0.1mm.

Figure 10. Phylloid algal biolithite.
Figure 11. *Tubiphytes*? (MA 216); Note spar-filled circular cavities and layered appearance; Bar = 0.1mm.
The biolithite facies is commonly light to medium gray and thin to thick bedded. Both coral and phylloid algal biolithites occur as irregularly bedded units that thicken and thin in outcrop. Thicknesses are seldom greater than 3 feet and no massive units have been observed. Phylloid algal biolithite is less continuous than coral biolithite and can be termed biohermal.

Phylloid algal biolithite has only been observed in the lower Pequop Formation of the Medicine Range. Scattered plates of phylloid algae are, however, observed in thin section from other areas and other stratigraphic units. Coral biolithite occurs throughout the study area with the exception of the Wood Hills and northern Pequop Mountains. It is found in the Riepe Spring Formation, the Ferguson Mountain Formation and the lower Pequop Formation. The biolithite facies is not as important volumetrically as many other facies. It is most closely associated with the fusulinid biomicrite facies, conglomerate facies and, to a lesser extent, the brachiopod-bryozoan biomicrite facies.

In a paleoecological study Wells (1957) concluded that most rugose corals lived in open marine water less than 150 feet deep with a temperature between 16-21° C. The water was non-turbid and well oxygenated. Stevens (1966), in a study of Lower Permian paleoecology in east-
central Nevada, agreed with Wells and further specified depths of 10-30 m for his coral community (coral biolithite). The highly varied biota associated with coral biolithite and the lack of terrigenous mud support the interpretation that the corals lived in an open marine, non-turbid environment. The presence of overturned and broken corals would indicate; however, that these animals lived in shallow enough water to be episodically subjected to moderately strong wave energy. Furthermore the intimate association of coral with blue-green algal balls, which form by rolling around in the upper photic zone, implies a shallow water origin.

The coral biolithite cannot be termed a reef facies in the sense that it represents a massive, wave resistant structure adjacent to deep water. To the contrary, this subfacies consists of relatively thin biostromal accumulations that normally grew in a shallow water, low energy, shelf-like environment that was only occasionally subjected to moderate to high energy conditions, probably the result of storm generated waves and not deep ocean swells.

In a study of phylloid algal mounds in the mid-continent region, Heckel and Cocke (1969, pp. 1066-1067) concluded the mounds possibly began on local high areas in warm, shallow marine water. Shallowness of water in conjunction with the baffling effect of the algal growth
reduced water movement and allowed micrite deposition. The lack of a diverse or abundant biota associated with phylloid algal biolithite implies some restriction in water circulation perhaps caused by the baffling effect of a thick, lush algal growth.

**Dolomite Facies**

The dolomite facies is defined by the presence of 50% or more dolomite in the rock. This facies can be divided into replacement dolomite and penecontemporaneous dolomite. Replacement dolomite consists of limestone which has been dolomitized. Relict limestone textures and residual calcite are frequently observable. Unaltered shell fragments and dolomitized oolites are common constituent particles in this type of dolomite (Fig. 12).

Penecontemporaneous dolomite contains few or no relict limestone textures, is generally fine grained (usually 10 u or less), may show stromatolitic laminations (Fig. 12), and commonly has a clotted texture. Mud cracks are present and fossils are normally sparse. When fossil material is present, it consists of ostracodes or gastropods and algal? stromatolites. Molds of gypsum crystals have been found in penecontemporaneous dolomite.

The dolomite facies occurs throughout the area and locally is volumetrically important. Although it is found principally in the Riepe Spring and Loray formations, it
12a. Photomicrograph of replacement dolomite (ME 384); Note dolomitized oolites with detrital quartz nuclei; Bar = 0.1mm.

12b. Photograph of penecontemporaneous dolomite (MA 2147). Algal? stromatolite; Scale in cm.

Figure 12. Dolomite facies.
also occurs in the Rib Hill, Pequop and Ferguson Mountain formations. The dolomite facies is light to dark gray. Bedding in penecontemporaneous dolomite tends to be thin or laminated. In replacement dolomite the bedding of the original limestone is preserved. Dolomite is associated with the conglomerate facies, ostracode and gastropod biomicrite of the brachiopod-bryozoan biomicrite facies, the ooid sparite facies, very fine sand facies and especially the bimodal sand facies. In the Loray Formation, the dolomite facies is interbedded with chert.

Dolomite similar to the penecontemporaneous dolomite has been reported forming in modern areas of carbonate production in supratidal and upper littoral areas (Shinn and others, 1965; Illing and others, 1965). The penecontemporaneous dolomite subfacies probably formed in similar environments. It is noteworthy that replacement dolomite is usually closely associated with the penecontemporaneous dolomite. This implies that the dolomitized limestones were both geographically and temporally related to penecontemporaneous dolomite.

**Conglomerate Facies**

The most distinctive rock type in the study area is the conglomerate facies which occurs in the Spruce Mountain, southern Pequop Mountains and Valley Mountain area. The conglomerates, along with associated limestone, dolomite
FIELDS OF STUDY

Major Field: Geology

Studies in carbonate petrology. Professor C. G. Kendall

Studies in stratigraphy. Professor J. W. Collinson
and sandstone, are of Late Pennsylvanian and Wolfcampian age. Hope (1972) first reported the presence of these conglomerate beds and assigned them to the Riepe Spring Formation on the basis of age and position in stratigraphic sequence.

The conglomerate crops out as resistant, brownish-tan weathering units (Fig. 13) interbedded with medium gray limestone, light gray dolomite and brown sandstone. Individual conglomerate units range in thickness from a few inches to approximately 40 feet. Most bedding units are approximately 5 feet or less. As noted by Hope (1972) the conglomeratic sequence is thickest in the Spruce Mountain Ridge area and thins southward toward Spruce Mountain. Thinning also occurs eastward toward the southern Pequop Mountains, northeastward toward the central Pequop Mountains, northward toward the Wood Hills and southwestward toward Valley Mountain.

The conglomerate can be divided into two distinctive types on the basis of texture, sedimentary structure and composition. Type 1 conglomerate is composed of angular chert clasts and rounded limestone clasts in a lime mud matrix with varying amounts of calcite cement. The chert clasts, which range in size from a few millimeters to greater than 8 inches in diameter, are usually light to dark gray; many have relict fossil textures. A silicified
13a. Photograph of Type 1 conglomerate in outcrop (MF); Note angularity of grains; Scale = 6 inches.

13b. Photograph of Type 2 conglomerate in outcrop (MF); Note well developed planar cross bedding.

Figure 13. Conglomerate facies.
specimen of the coral Caninia was identified by C. H. Stevens from a fragment of Type 1 conglomerate. In addition to being angular, chert clasts tend to be elongate with the long axis more than 5 times the length of the minimum axis. The limestone clasts are medium gray biomicrite with poorly preserved crinoid and brachiopod fragments. In general appearance they resemble the underlying Ely Limestone. Limestone clasts range from a few millimeters to greater than 1 foot in diameter. Because of the softness of limestone, these clasts tend to be well rounded.

Type 1 conglomerate exhibits crude low angle cross bedding and generally sharp basal contacts. The cross beds are in poorly defined sets, several inches thick that dip irregularly at only a few degrees. Reliable directional data from crude, low angle cross bedding is very difficult to obtain and to interpret. Although basal contacts are sharply defined, definite scour surfaces are not always present. Basal scours do occur, however, especially in the Spruce Mountain Ridge area where channels up to 4 feet into the underlying limestone is present.

Sorting of chert and limestone clasts is typically poor with a mixing of sand, granule, pebble and cobble sizes in a bedding unit, but some units are moderately sorted. Although fining upwards sequences occur, most
sequences display no pronounced systematic variation in grain size.

Interbedded with Type 1 conglomerate is medium gray biomicrite, very cherty medium gray biomicrite, medium gray to brown sandy and pebbly limestone, medium gray dolomite and brownish gray calcareous quartz sandstone. The limestone contains crinoid, fusulinid, brachiopod and mollusk remains. Sandstone and sandy limestone are sometimes cross bedded and exhibit other small scale current features.

Most Type 1 conglomerate can be traced laterally for several hundred feet; however, units thicken and thin. It is believed that the conglomerate units lense out or are replaced by contiguous conglomerate sequences.

Type 2 conglomerate differs from Type 1 conglomerate in containing a wider variety of clasts, possessing greater textural maturity, and displaying well developed current features (Fig. 14). The following types of clasts are present in Type 2 conglomerate: light to dark gray chert, green chert of several hues, reddish-brown chert of several hues, black chert, medium grained white sandstone, light colored quartzite and medium gray limestone. Clasts tend to be subrounded to well rounded and equidimensional. Sorting is moderate to good. Well developed high angle cross beds are typical of Type 2
14a. Photograph of polished slab of Type 2 conglomerate (MF 753): Note rounding of larger grains; Bar = 1cm.

14b. Photomicrograph of Type 2 conglomerate (MF 683); Note: A = chert pebbles, B = sandstone pebbles, C = dolomite cement; Bar = 0.1mm.

Figure 14. Conglomerate facies - Type 2 conglomerate.
conglomerate with some dips as much as 30°. Interbedded with conglomerate units are sandstone, pebbly and sandy limestone, light gray dolomite, highly fossiliferous limestone with crinoids, bryozoans, fusulinids and smaller foraminifera, corals and brachiopods.

Type 2 conglomerate tends to have a gradational rather than a sharp lower contact and exhibits a wider range in thickness than Type 1 conglomerate. Thinning of beds occurs and units are believed to be lenticular. In Valley Mountain and the southernmost Pequop Mountains where the conglomerate is much thinner, some Type 2 conglomerate can be seen pinching out from a thickness of 4 or 5 feet within 100 feet of outcrop.

Admixed with chert and limestone clasts are quartz sand and broken and abraided shell fragments. Sand and silt sized chert and limestone grains also may be present, but in minor quantities. The cementing agents are silica, saddle dolomite and calcite spar. The following fossil fragments have been identified from Type 2 conglomerate: corals, fusulinids and smaller foraminifera, brachiopods, bryozoans, echinoids and especially crinoids.

Throughout the area where the conglomerate facies occurs, Type 1 conglomerate underlies Type 2 conglomerate with little or no intermixing. The lower conglomerate is believed to be derived from erosion of Ely Limestone or possibly Riepe Spring Limestone to the north. Both the
gray chert and biomicrite clasts appear identical to lithologies found in the Ely Limestone. The detrital coral *Caninia* recovered from Type 1 conglomerate is believed to be reworked from the Ely Limestone. The most convenient and logical source for the exotic clasts occurring in the overlying Type 2 conglomerate is the Mississippian-Early Pennsylvanian Diamond Peak Formation which underlies the Ely Formation. Immediately to the north, in the area of the central and northern Pequop Mountains, the Diamond Peak Formation was exposed by a Late Pennsylvanian-Early Permian unconformity (Thorman 1970). The only other source of the exotic pebbles lies to the west along the Antler Orogenic Belt where western assemblage rocks of Ordovician age (Valmy and Vinini formations) occur (Roberts and others, 1958). Because the Diamond Peak Formation was in part derived from western assemblage rocks, this is the ultimate source for the variegated chert pebbles.

Interbedded marine limestone and marine fossils within the matrix indicate that the conglomerate facies was deposited in a marine or near shore marine environment. The general absence of a clay size matrix and the paucity in many instances of silt and even very fine sand material; the rounding and breakage of chert, sandstone and limestone clasts; the presence of broken and abraided
fossil material; the presence of a coarse spar cement and the presence of granule, pebble and cobble sized clasts indicate that wave or current energy in the area of deposition was high.

The conglomerate facies is believed to have been deposited in a nearshore shallow water environment in response to uplift of the source area to the north. Coarse detritus was shed in pulses from highlands and deposited in the adjacent sea. In the case of Type 1 conglomerate little or no marine reworking occurred and the conglomerate remained texturally immature. Continued erosion of the source area exposed older and more varied rocks to the north. After transport to the basin of deposition, prolonged winnowing by marine agents sorted and rounded clasts of Type 2 conglomerate and formed them into a series of nearshore bars, shoals and beaches. Figure 15 is an idealized depositional model for both Type 1 and Type 2 conglomerates.

**Bimodal Sand Facies**

The bimodal sand facies is characterized by two grain size populations: very fine and medium sand or fine and coarse sand. Detrital quartz makes up 75% to 95% of the grains. Accessory minerals include orthoclase, plagioclase, chert and carbonate sand. Grains are subangular to round; the larger grains are generally better rounded (Fig. 16).
FIGURE 15. Depositional Model For Conglomerate Facies
Figure 16. Photomicrograph of bimodal sand facies (MO 1650).
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Sorting within a mode is typically good. The cementing agent is calcite, dolomite or a combination of these two. Shell material and poorly preserved relict fossils including crinoids, ostracodes, brachiopods and molluscs are present, but sparse.

This facies is best developed in the southern and southeastern portions of the study area, the northern Schell Creek Range and Gold Hill area. The bimodal sand facies is apparently restricted to the Loray Formation.

The bimodal sand facies varies from reddish-brown to brown-gray. Units are thin bedded and commonly display small scale planar cross beds. The grain size has been noted to coarsen upward in many sequences. The bimodal sand facies is closely associated with the dolomite facies. Strata of bimodal sand up to 15 feet are typically interbedded with penecontemporaneous and replacement dolomite.

The bimodality of terrigenous sand which defines this facies is believed to be the result of two concurrently active modes of transport in the depositional environment. The intimate association with the dolomite facies which is believed to have a history of subaerial exposure implies that the bimodal sand facies may have been influenced by aeolian processes. Deposition of the bimodal sand facies is interpreted to be in a subaerial to
Very shallow marine environment.

Very Fine Sand Facies

The very fine sand facies is volumetrically the most important and, because of poor exposure, the least known of all facies recognized. Petrographically it can be characterized as a calcareous or sometimes dolomitic very fine sandstone to coarse siltstone composed primarily of terrigenous detritus. Although quartz is most common, feldspar and chert particles are locally prominent. Zircon, unidentified "heavy minerals" and mica are minor, but widespread accessory grains. Thin sandy limestone is interbedded with the very fine sand facies. This limestone may contain a varied fauna consisting of fusulinids, crinoids and brachiopods. The sandstone and siltstone may contain sparse to abundant fusulinids, bivalves, crinoids, inarticulate and articulate brachiopods, bryozoans and ostracodes. Usually, however, fossils are sparse or absent. Trace fossils, especially structures resembling Zoophycus, are abundant at some horizons. The most widespread and common fossils are bivalves, phosphatic brachiopods (especially Orbiculoidea?) and trace fossils.

The very fine sand facies is typically reddish-brown, light brown or light gray. It is generally thin bedded with current features such as low angle cross beds and ripples preserved. Local silicification and thin cherty
units are present. This facies is the most poorly exposed of all those studied. It is slope forming and usually covered with shrubs, grass and a poorly developed regolith. The Rib Hill Formation is composed almost entirely of this facies. The very fine sand facies also occurs in all other formations in this study.

The very fine sand facies was, at least in part, deposited in a normal marine environment. This is indicated by the presence of a stenohaline fauna in some beds of this facies. Other beds are characterized by burrowing bivalves, phosphatic brachiopods and trace fossils and may well have originated in a marginal marine environment or perhaps a very shallow brackish water environment. From this study the only conclusion that can be reached with certainty is that the fine detrital facies represents a period of terrigenous influx into a previously carbonate-forming environment. This influx seems to have gradually dominated the carbonate production. After the period of substantial detrital influx ceased, limestone production once again became established.

Summary of Depositional Environments

Upper Pennsylvanian and Lower Permian carbonate and terrigenous sediments in northeast Nevada and adjacent Utah accumulated in a rapidly subsiding basin in a variety of shallow marine and marginal marine environments.
Environmental differences are the result of the interaction of a varied number of physical, chemical and biological parameters. In dealing with ancient rocks the exact nature and relative importance of the parameters which controlled the nature of the sediments forming at that time are always highly speculative. Interpretation of depositional environments in this study are further complicated by the fact that such features as massive, wave resistant reefs and true deep water basins do not occur. The transition from deep water, reef, shallow marine to subaerial zones provides the classic picture of a depositional model. This does not exist in the study area.

With these limitations in mind, the petrographic facies that can be recognized are thought to be the result of the interaction of the following environmental parameters: wave and current energy, water depth, salinity, turbidity and nature of substrate. The facies are also a function of mineralogy. Table 2 summarizes the relationship between facies and environmental parameters. These parameters can be determined or inferred from petrographic data, comparison of grain types or biotic group with modern equivalents, and by association with facies which are better understood.
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X-major, x-minor

Table 2. Summary of depositional environments.
Despite the apparent complexity and constant change from one facies to another, a simplified pattern of deposition can be determined. Facies can be classified into the following depositional environments: subaerial, shoal, lagoonal, open marine and organic buildup. Subaerial facies exhibit evidence of at least temporary exposure. The term shoal refers to areas of very shallow water that experience periodic or episodic events of high energy. Lagoon refers to a shallow marine environment having restricted connection to the sea. Open marine facies were deposited in neritic environments without restriction of water circulation. The term organic buildup includes biohermal and biostromal organic frameworks, similar to modern day patch reefs. Figure 17 summarizes the grouping of facies into depositional environments.

The question of the importance of tides in the study area is not readily answerable. It is entirely possible that sediments included in certain facies formed in an intertidal environment. These would include some stromatolites of the dolomite facies, packed and abraded bio­micrites and biosparites interbedded in the brachiopod-bryozoan biomicrite facies and possibly strata included in the ooid sparite facies. To call such sediments intertidal would imply deposition in an environment subjected to diurnal or semidiurnal flooding and exposure. Because
DEPOSITIONAL ENVIRONMENTS

SUBAERIAL  SHOAL  LAGOONAL  ORGANIC BUILD-UP  OPEN MARINE

SEA LEVEL

FACIES

DOLOMITE  OOID SPARITE  BRACHIOPOD - BRY.  BIOLITHITE  FUSULINID BIOMICRITE  BIOMICRITE
BIOMODAL SAND  CRINOID-FORAM  BIOMICRITE  DASYCLAD ALGAE -
BIOSPARITE  CONGLOMERATE  MOLLUSC BIOMICRITE

VERY FINE SAND

FIGURE 17. UPPER PENN.-LOWER PERMIAN DEPOSITIONAL ENVIRONMENTS IN NORTHEAST NEVADA
the same results can be caused by episodic or long term periodic events, it is believed that the term intertidal should be avoided.

The medium to dark shades of gray and the fetid odor of much of the carbonate rocks; the general absence of well developed oolites, intraclasts or highly abraded grains; and the preponderence of a lime mud matrix suggest that the bulk of Upper Pennsylvanian and Lower Permian carbonate sediments formed in a low energy, reducing environment generally protected from winnowing currents. In the southern Pequop Mountains, where extensive oosparites do occur, the ooids tend to be poorly developed, typically consisting of a single micrite coating. True moderate to high energy conditions apparently existed for a significant time only where the conglomerate facies is present or where well developed oolites or biosparites are found.

There are three lines of evidence which indicate that Upper Pennsylvanian and Lower Permian sedimentation is of a warm water character: (1) petrographic evidence, (2) faunal evidence, (3) paleomagnetic evidence. Jaanusson (1973, p. 13) theorized that petrographic criteria could be used to distinguish warm water carbonates from carbonates forming in temperate climates. He cited the presence of accretionary type grains and the
presence of aragonite in areas of present day warm water carbonate production. These are not found in modern temperate carbonate environments. The botryoidal grains, oolites and superficial oolites of the ooid grain subfacies are of this character.

Stehli (1964) related the character and diversity of faunas, especially brachiopod faunas, to paleoclimatic zones. He pointed out that faunal diversity is greatest at low latitudes and decreases in the direction of higher latitudes. According to Stehli, Permian brachiopod diversity in the Nevada-West Texas area is high and therefore of a warm water character. Although some of Stehli's conclusions as to the position of the paleoequator in the Permian have been questioned (see discussions in Nairn, 1964) his data from the western U.S. appear valid. McElhinny (1973, p. 202) cited recent paleomagnetic data which place the Permian equator very near the northeast Nevada area.

In summary, carbonate facies appear to have formed in a broad, shallow warm water environment somewhat analogous to the interior of the Grand Bahama Banks and Florida Bay which are within the 60 ft contour and contain broad areas only several feet dep (Cloud, 1962 and Scholl, 1966). Currents and tidal flow are restricted by the broad, shallow areas which in some localities contain a series of
anastomosing, low relief mounds. Water circulation is locally inhibited causing different degrees of restriction or isolation from the open marine milieu. Varied biotic communities have become established as a result of this restriction and the attendant changes in environmental parameters such as salinity and ambient water energy. The majority of ancient carbonates in this study are interpreted as having formed in an analogous environment. As will be pointed out, isolation from open marine conditions became increasingly important as the rate of carbonate production exceeded the rate of basin subsidence during Leonardian time.
DEPOSITIONAL HISTORY

Distribution of Facies

From the discussion included in the description of individual facies, it is apparent that most formations contain a variety of facies. Certain facies are more typical of a particular formation. The conglomerate facies is found only within the Riepe Spring Formation and the Rib Hill Formation is composed of the very fine sand facies and minor interbeds of other facies. The Pequop Formation can be divided into a lower unit characterized by the fusulinid biomicrite and biolithite facies and an upper unit characterized by the dasyclad algae-mollusc biomicrite, brachiopod-bryozoan biomicrite and ooid sparite facies. The bimodal sand and dolomite facies are best developed in the Loray Formation.

Figure 17 is a series of isopach maps of Upper Pennsylvanian, Wolfcampian and Leonardian strata. These maps are based on faunal data, both published and collected during this study. Fusulinids and corals provide the diagnostic age determinations (Appendix). Upper Pennsylvanian strata are absent or very thin north of the Spruce Mountain Ridge-Jasper Tunnel area in the Pequop Mountains and thin southward from the southern Pequop-Spruce Mountain Ridge area.
FIGURE 18. Isopach maps of Virgilian (A), Wolfcampian (B), and Leonardian (C) strata. Section code same as figure 1 and appendix.
Wolfcampian strata also thin greatly north of the Spruce Mountain Ridge-Jasper Tunnel area. A slight thinning towards the southern margin of the study area is also indicated. Leonardian strata are equally thick over most of the study area, but thin toward the southern margin.

Figure 19 is an isopach map of the conglomerate found in the Riepe Spring Formation as defined by Hope (1972). The Upper Pennsylvanian-Lower Permian conglomerate extends from the Wendover area on the east to at least as far west as the Secret Pass area of the Ruby Mountains. The greatest thickness is located in the Spruce Mountain Ridge area where the conglomerate is greater than 200 feet thick. An erosional unconformity genetically linked to the conglomerate is found in the northern part of the study area. This subject will be more fully developed in the section entitled "Structural Control of Facies."

Figure 20 is a diagrammatic cross section which illustrates vertical and lateral changes in depositional environment and thicknesses of strata. Of particular interest is the abrupt change in the nature of Upper Pennsylvanian and Wolfcampian strata in the northern part of Spruce Mountain Ridge and at Jasper Tunnel. Note the thick occurrence of the conglomerate facies immediately to the south of this area and the drastic thinning of equivalent and slightly younger strata to the north.
FIGURE 19. Isopach map of conglomerate facies
Data from Secret Pass, Toana Range and Wendover area by C.H. Stevens (personal comm.)

Section code as in figure I
KEY TO DEPOSITIONAL ENVIRONMENTS
(IN ORDER OF VOLUMETRIC IMPORTANCE)

1. SUBAERIAL
2. SHOAL
3. LAGOONAL
4. OPEN MARINE & ORGANIC BUILD-UP

FIGURE 20. DIAGRAMMATIC CROSS SECTION ILLUSTRATING MAJOR PATTERNS IN CHANGES OF DEPOSITIONAL ENVIRONMENT
Farther to the south a major facies change in all formations occurs as does a thinning of Upper Pennsylvanian and Lower Permian sediments. In the northern area the limestone of the Pequop Formation is replaced by equivalent sandy strata.

In an east-west direction a dramatic facies change occurs in uppermost Pennsylvanian and Wolfcampian strata. The conglomerate facies thins to the west and is completely absent east-southeast of the Spruce Mountain and southern Pequop Mountains area. The very fine sand facies, which is well developed in the central and western area, is equivalent to various limestone facies in the Ferguson Mountain area.

**Structural Control of Facies**

From the evidence gathered, it appears that the nature and distribution of facies are in part structurally controlled. Immediately north of the Spruce Mountain Ridge and southern Pequop Mountains, the following changes occur (Fig. 21): (1) approximately 2,000 ft of Upper Pennsylvanian and Wolfcampian strata thin to 300 ft; (2) the conglomerate facies which is most fully developed at Spruce Mountain Ridge and in the southern Pequop Mountains is absent except for a thin (15-30 ft) conglomerate that continues northward to the area of U.S. 40 (Fig. 19); (3) Pennsylvanian strata are truncated in the
FIGURE 21. North-south cross section through study area.
central and northern Pequop Mountains by an unconformity resulting in the loss of an additional 1,500 ft of stratigraphic section; and (4) facies of the Pequop Formation continue unchanged across the Jasper Tunnel area but are replaced by a poorly fossiliferous, terrigenous sequence in the northern Pequop Mountains.

The variation in distribution of facies is best explained by postulating a period of uplift in an area adjacent to a rapidly subsiding basin (Fig. 22). A zone of Late Pennsylvanian-Early Permian faulting or flexure trending east-west through the Jasper Tunnel area and the northern part of Spruce Mountain Ridge separated the uplifted area to the north from a basin of deposition to the south (Fig. 23). Chert and limestone pebbles were derived from the north primarily from the Ely Limestone. As erosion continued the Diamond Peak Formation furnished variegated chert, sandstone and sand grains which were originally transported from the Antler Orogenic Belt to the west during the Mississippian. The variegated chert pebbles are well rounded, unless broken, and represent second generation detritus. During Wolfcampian time, active uplift ceased, eliminating the source for coarse detritus. Subsidence in the southern area continued throughout most of Wolfcampian time and the fine detrital sediments of the Rib Hill Formation were deposited. During
FIGURE 22. Late Pennsylvanian–Early Permian tectonism in the Pequop mountain area.
KEY

- UPPER PENN.-WOLFCAMPION UPLIFTED AREA
- LEONARDIAN POSTIMENT

NUMBERS DENOTE MEASURED SECTIONS AS IN FIG. 1

FIGURE 23. UPPER PENN.-LOWER PERMIAN TECTONIC FRAMEWORK
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this time several areas including the central and northern Pequops, the Ancestral Rockies to the east and the ancestral Antler Orogenic Belt to the west may have provided the terrigenous detritus of the Rib Hill Formation. During latest Wolfcampian and Leonardian time regional subsidence occurred and the influx of fine terrigenous detritus into the study area was greatly reduced. Limestones of the fusulinid biomicrite facies along with minor coral biolithite were the initial deposits of the Pequop Formation.

In the area of the northern Schell Creek Mountains, the Medicine Range and Gold Hill another change in facies and sediment thickness occurs. This change can also be related to underlying structural control. The following changes in sediment character have been noted (Fig. 21): (1) Wolfcampian and Leonardian sediments, which are thicker than 5,500 ft in the southern Pequop Mountains, Spruce Mountain Ridge and probably the Ferguson Mountain area where much of the Pequop Formation has been eroded (Berge, 1960), thin to less than 3,000 ft in the northern Schell Creek Mountains; (2) a marked facies change occurs in Leonardian sediments in the same area, from a sequence composed essentially of the fusulinid biomicrite, brachiopod-bryozoan biomicrite, dasyclad algae-mollusc biomicrite and ooid sparite facies in the north to the
bimodal sand and dolomite facies in the south; (3) the phylloid algae biolithite subfacies is found in significant quantity only in the Medicine Range; (4) the crinoid-foraminifera biosparite facies is found in Leonardian rocks in significant quantity only in the Medicine Range and to limited extent in the northern Schell Creek Mountains; and (5) most Leonardian strata in the Gold Hill area is composed of the dolomite and bimodal sand facies.

This variation in thickness and facies is best explained by postulating the presence of an east-west trending posiment which effected sedimentation during Leonardian and possibly Wolfcampian time (Fig. 23). During Leonardian time, this area which included Gold Hill, the northern Schell Creek Mountains and the Medicine Range was topographically higher than the area to the north and at times was slightly above sea level. There is no evidence that any sediment was derived from this area. The positive area subsided at a slower rate than the area to the north resulting in a thinner stratigraphic sequence.

Because this study did not include areas farther to the south the southward extent of this posiment is unknown. However, the sediments described from the Butte Mountains and Moorman Ranch area by Zabriskie (1970) and
Stevens (1965) include some deposits of a marginal marine nature, such as dolomite and dolomitic sandstone.

The hypothetical structural elements which influenced Late Pennsylvanian and Early Permian sedimentation both appear to be east-west trending. Because only the north flank of the posiment in the southern portion of the study area can be observed, it is perhaps premature to state this. However, major changes of facies and thickness, as noted, do occur from north to south implying an east-west trending feature of unknown width. This east-west trending structural grain is at right angles to the present major structural features of the area; the north-south geosynclinal trend that became established in the Late Precambrian and the north-northeast trending Antler Orogenic Belt of Late Devonian to Early Pennsylvanian age. The Sonoma Belt to the west of Late Permian to Early Triassic age and the Sevier Belt to the east of Late Mesozoic age also trend north-northeast (Fig. 3).

The only major east-west trending structural feature known in the area is the Cortez-Uinta Axis, a positive feature that has been episodically active at least as far back as Ordovician time (Roberts and others, 1965, pp. 1928-1929). Significantly this feature passes through the study area and can be traced from the Uinta Mountains in Utah to the east to the Antler Orogenic Belt to the west.
During Late Devonian time the Cortez-Uinta Axis was involved in local sharp uplift, faulting, erosion and the deposition of coarse and fine grained clastics, the Stansbury Disturbance in Utah. It is entirely possible that the observed change in sediment character and thickness in the Spruce Mountain Ridge and Jasper Tunnel area reflect a rejuvenation of the Cortez-Uinta Axis during Late Pennsylvanian and Wolfcampian time.

In the vicinity of Carlin Canyon in western Elko County, approximately 50 miles west of the Lone Butte section (Fig. 1), exists a Late Pennsylvanian to Early Permian sequence much like the conglomerate facies of this study. The Strathearn Formation of Dott (1955, p. 2248) consists of 1,200-1,500 ft of chert pebble conglomerate and silty and sandy limestone. Dott considered the age of this unit to be Missourian to Early Wolfcampian. Bissell (1967), however, believes the Strathearn Formation to be Late Pennsylvanian only.

Because of gross lithologic similarities, equivalent thicknesses, age and proximity of the conglomerate facies to the Strathearn Formation, a case can be made for equating the two sequences. Hope (1972) has preferred, however, the use of the term Riepe Spring Formation for what is referred to in this study as the conglomerate facies and associated limestone facies of Late
Pennsylvania and Wolfcampian age. It seems reasonable that the conglomerate facies should be referred to the Strathearn Formation or, if it can be shown that the two sequences are genetically or lithologically distinct, to be given a unique name.

Depositional Concinnity

Dott (1955, p. 2255) and Steele (1960, p. 93) called attention to a widespread unconformity present in the eastern Nevada area, the sub-Strathearn unconformity of Dott. The rocks below the unconformity range in age from Upper Desmoinesian to Atokan and above the unconformity from Lower Missourian to Wolfcampian (Steele, 1960). This unconformity is apparently present throughout the study area, with the possible exception of the Spruce Mountain Ridge-Southern Pequop area which received thick Late Pennsylvanian sedimentation.

From the data presented it is believed that the depositional history of Upper Pennsylvanian and Lower Permian strata can be conveniently divided into 5 episodes (Fig. 24).

Episode 1—Late Pennsylvanian to Early Wolfcampian During Episode 1, the central Pequop area was uplifted and became a source for coarse detritus which accumulated in the Spruce Mountain, Valley Mountain, southern Pequop
FIGURE 24. EPISODES IN THE DEPOSITIONAL HISTORY OF UPPER PENN.-LOWER PERMIAN STRATA NORTHEAST NEVADA
Mountain areas included in the study, as well as the Secret Pass area to the west and the central Toana Mountains and the Wendover vicinity to the east. During this time, the fusulinid biomicrite facies was being deposited in the Ferguson Mountain and Gold Hill areas. In areas to the south, thin poorly exposed sediments of the dolomite facies were forming.

Episode 2—Mid to Late Wolfcampian

Mid to Late Wolfcampian sediments are dominated by the very fine sand facies of the Rib Hill Formation in the Medicine Range, the Spruce Mountain area, the southern Pequop Mountains and to a lesser extent in the northern Schell Creek Range. Thin beds of the crinoid-foraminifera biosparite facies occur at the base of the Rib Hill Formation. To the west at Lone Butte, the very fine sand facies is interbedded with brachiopod-bryozoan biomicrite facies and minor strata of the ooid sparite facies. To the east at Ferguson Mountain the fusulinid biomicrite facies continued to be deposited. Thus Episode 2, in large part, reflects a period of detrital influx into a basin of carbonate deposition.

Episode 3—Latest Wolfcampian to Early Leonardian

Episode 3 occurs with the widespread distribution of the fusulinid biomicrite facies usually initially accompanied by residual beds of the fine detrital facies.
Brachiopod-bryozoan biomicrite facies, crinoid-foraminifera biosparite facies and thin coral biolithite also occur. During this time in the Medicine Range in addition to the above listed facies, phylloid algae biolithite mounds encrusted with *Tubiphytes*? were forming. In the northern Schell Creek Mountains, thin coral biolithite is overlain by bimodal sandstone and dolomite. Episode 3, therefore, reflects the reestablishment of carbonate production throughout the study area. The lower Pequop Formation was deposited during this episode.

**Episode 4—Middle Leonardian**

Middle Leonardian strata reflect the general shallowing of the basin of deposition and the gradual loss of the fusulinid biomicrite facies. In the area of the southern Pequop Mountains, widespread ooid sparite facies is found. To the north in the central Pequop Mountains, thick dasyclad algae-mollusc biomicrite facies occurs. To the south in the northern Schell Creek Range, this sequence is replaced by the bimodal sand and dolomite facies. In the Medicine Range, the brachiopod-bryozoan biomicrite facies occurs along with some beds of the ooid sparite facies, the dolomite facies, and especially the very fine sand facies. This episode resulted in the deposition of the upper Pequop Formation.
Episode 5 - Late Leonardian

Episode 5 is the final filling of the basin of deposition or the culmination of the long regressive phase that ends with the transgressive Kaibab Limestone. This episode is represented by the Loray Formation, a unit containing the very fine sand facies, thin ostracode and brachiopod biomicrite of the brachiopod-bryozoan biomicrite facies, the dolomite facies, thin units of the ooid sparite facies, the biomodal sand facies and bedded cherts.
CONCLUSIONS

During the Late Pennsylvanian and Early Permian, the nature of sedimentation in northeast Nevada was partially controlled by structure. Late Pennsylvanian and Early Wolfcampian uplift occurred in the central Pequop Mountains mainly north of the Jasper Tunnel and north of Spruce Mountain Ridge. This uplifted area underwent erosion which exposed strata as old as the Late Mississippian-Early Pennsylvanian Diamond Peak Formation. The coarse detritus derived form the uplifted area accumulated in nearshore marine or marginal marine environments immediately to the south of the area of uplift.

During Leonardian and possibly Wolfcampian time, sediment thicknesses and facies were controlled by a posiment located in the southern part of the study area including the northern Schell Creek Mountains, the Gold Hill area and the Medicine Range. The Lower Permian sedimentary sequence thins onto the posiment and assumes a "supratidal" character.

Carbonate and terrigenous sediments are divided into a series of facies which vary through time and space. The facies are believed to have formed or accumulated in