A Detailed Stratigraphic Study of the
Battle Formation, North-Central Nevada

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science
in Geology

by

David Drowley

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Acknowledgements

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Thesis advisor

M. E. Hablau
Department chairman

Dean, Graduate School

The thesis of David Drowley is approved:

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ABSTRACT

Coarse clastic and carbonate rocks were deposited on top of the deformed Antler orogenic belt during the Pennsylvanian and Permian periods. Abrupt lateral variations in lithologic character and thickness from place to place indicate widely differing conditions of deposition over a relatively small region. The Battle Formation was deposited in this intra-mobile belt region as a result of diastrophic pulses of deformation, uplift, and erosion of local tectonic land sources.

The Battle Formation was derived from at least two principal source areas and was deposited in two, and perhaps three, small basins. Sources of sediments were probably to the east, northeast, and west of the depositional basins. Some of the conglomerates of the formation are fan-glomerates, probably related to uplifts due to faulting; others are deltaic and shallow marine conglomerates.

The Battle Formation is time transgressive locally, but this relationship cannot be demonstrated on a regional basis.
INTRODUCTION

Object of the Investigation

As originally envisioned, the purpose of this study was to define a probable source area for the Battle Formation by determining paleocurrent directions. A paucity of cross-bedding and other current directional features resulted in the abandonment of this idea. However, it was considered that a detailed description of the formation and its limitation in time and space would be worthwhile objects of investigation. Previous workers have recognized and mapped the formation at several localities, but they have only briefly related such exposures to the type locality at Antler Peak. It is hoped that this paper will yield a fuller understanding of the Battle Formation.

Location and Accessibility

The area of investigation lies in north-central Nevada, in Humboldt and Lander Counties (see Fig. 1). The area covered encompasses the Edna Mountain, Antler Peak, Osgood Mountains, and Mt. Lewis Quadrangle. U.S. Geological Survey topographic maps and geologic maps are available for the entire report area.

Much of the area is accessible from highways and dirt roads, but many localities can be reached only by foot or by helicopter. U.S. Highway Interstate 80 serves as the primary arterial for the region. Edna Mountain is directly accessible from it. The Osgood Mountains are reached by
Figure 1

Location map showing quadrangle areas involved in this study.
driving northeast from Golconda along Nevada Highway 18.
Battle Mountain (Antler Peak) is reached by dirt roads lead­
ing from Interstate 80 and Nevada Highway 8A. Mt. Lewis is
reached by dirt roads from Interstate 80 and from Nevada
Highways 21 and 8A. Valmy is perhaps the most centrally
located town with respect to exposures of the Battle Forma-
tion.

Previous Investigations

Hague and Emmons, as members of the King Survey,
carried out the first systematic investigation of the Battle
Mountain area. They mapped Paleozoic rocks as two units,
the Weber Quartzite and the Upper Coal Measures series
(Hague and Emmons, 1877, p. 666-672). In 1913, A. C. Lawson
described a series of conglomerates for which he proposed
the term "fanglomerate". In 1951, R. J. Roberts published
the first geologic map of the Antler Peak Quadrangle. As
part of the discussion which accompanied the map, he named
the Battle Formation. Roberts et al. (1958) further dis-
cussed the Battle Formation. Roberts (1964) described two
sections near Antler Peak from which he established a com-
posite type section for the Battle Formation. Dott (1966)
discussed the stratigraphic significance of the Battle
Formation in terms of regional patterns of cyclic sedimen-
tation.

Ferguson and others (1952) described a thin con-
glomerate unit, found on Edna Mountain, as the Battle Forma-
tion. Their work was really the first systematic study of
the geology of the area. Some descriptive work had been done by Hill (1915); Pardee and Jones (1919); Kerr (1940); Vanderburg (1939); and Roberts and Albritton (1943). Presently, the Edna Mountain Quadrangle is the subject of a U.S. Geological Survey investigation by R. L. Erickson and S. P. Marsh.

In the Osgood Mountains, limited studies of mineral deposits were made by Hess and Larsen (1921); Smith and Vanderburg (1932); Hardy (1941); and Bailey and Phoenix (1944). No detailed mapping was attempted until the work of Hobbs and Clabaugh (1946). Joralemon (1951) further added to the literature on mineral investigations. Detailed geologic mapping and mineral evaluation of part of the quadrangle was carried out by Cavender (1963). Detailed mapping of the Osgood Mountains Quadrangle was carried out by Hotz and Willden (1964) and by Willden (1964). Hotz and Willden first formally recognized the Battle Formation in the Osgood Mountains Quadrangle.

The first detailed description of the Mt. Lewis area was made by Arnold Hague (Hague and Emmons, 1877, p. 618-625; 631-635). Hague recognized that most of the range was made up of Paleozoic rocks, which he assigned to the Lower Coal Measures. Numerous other geologists, concerned largely with the ore deposits in the area, published reconnaissance reports: Emmons (1910); Raymond (1875); Whitehill (1877; 1879); Stuart (1909); Martin (1910); Carpenter (1910); Hill (1912); Waring (1919); Lincoln (1923); Smith and Vanderburg
(1932); Schrader (1934); Vanderburg (1939); and Gianella (1941). Gilluly and Gates (1965) were the first to systematically map the Mt. Lewis Quadrangle where they recognized the Battle Formation.

**Terminology**

Geological terms used in this thesis follow those long established by the U.S. Geological Survey for use in north-central Nevada. This is done since there appears to be no reason to change them and upset continuity in the literature. The definitions of western assemblage, eastern assemblage, transitional assemblage, and overlap assemblage are those of Roberts et al. (1958), which designate Paleozoic structural units of distinct lithologic character. The western assemblage is made up of allochthonous siliceous and volcanic eugeosynclinal rocks which were transported into north-central Nevada along the Roberts Mountains thrust. Siliceous assemblage, volcanic assemblage, western assemblage, and upper plate are wholly or partly synonymous with the western assemblage and will be used for variety as well as for structural and facies contrast. The eastern assemblage is an autochthonous miogeosynclinal carbonate facies, also regarded as the lower plate. Gradationally between the two is the parautochthonous and allochthonous transitional assemblage or facies which contains rocks characteristic of both the eastern and western assemblages. Lying above these assemblages with marked angular unconformity is the overlap assemblage, which is generally autoch-
thonous; it is here considered to be the equivalent of the Antler sequence of Roberts et al. (1958), at least within the thesis area.

Stratification and parting properties of rocks are described and classified according to the usage of McKee and Weir (1953). The Wentworth grade scale was used for separating grade classes. Thin sections were evaluated using the definitions and methods of Gilbert (1954) and Folk (1954). Other rock terms generally follow the definitions of Pettijohn (1957). Methods used in basin analysis and for the determination of paleocurrents follow those of Potter and Pettijohn (1963). Other terms will be explained at the appropriate place in the text. Geologic terms in general use are adopted without separate definition here.

**General Characteristics and Plan of Discussion**

In north-central Nevada, the Pennsylvanian system is represented predominantly by limestones of variable thickness with considerable interbedded sandstones and shales and some intercalated conglomerate. Commonly basal to the limestones are coarse conglomerates of varied lithology and thickness. These conglomerates represent the earliest post-orogenic deposition within the Antler orogenic belt in north-central Nevada. They mark the beginning of a new phase in the history of the Cordilleran geosyncline.

The Battle Formation has been recognized as belonging to this early post-orogenic phase (Roberts, 1949);
Roberts, 1951; Ferguson et al., 1952; Roberts and Lehner, 1955; Roberts et al., 1958; Hotz and Wildden, 1964; Roberts, 1964; Gilluly and Gates, 1965). Thus, it is of great importance in unraveling the structural history and paleogeography of the north-central Nevada region. This thesis attempts to detail the stratigraphy of the Battle Formation; to fix its boundaries in time and space; and to determine its origins. In the following discussion, I will first consider the regional geology in terms of stratigraphy and structure; then follow with a similar discussion of the individual mountain ranges that are pertinent. The Battle Formation is then discussed in detail by ranges; then the origin and environment of deposition of the Battle is considered.

Methods of Investigation

Four weeks were spent sampling, measuring, and describing exposures of the Battle Formation during the Summer and Fall of 1972. Four additional weekends were spent in the field during the Fall of 1972. Outcrops were located with the aid of U.S. Geological Survey geologic and topographic maps at scales of 1:24,000, 1:31,250, 1:62,500, and 1:125,000. Dips, strikes, and stratigraphic thicknesses were generally determined from field measurements. Some measurements were taken from U.S. Geological Survey maps and descriptions.
Rock specimens from scattered localities were collected and analyzed in the laboratory. Laboratory work included petrographic studies of hand specimens and a limited number of thin sections.

By using existing maps, cross sections and regional data, various interpretive maps were constructed. These include isopachous maps, a paleogeologic map and an interpretive sketch.

**Climate, Vegetation, and Topography**

The climate of north-central Nevada may be classed as arid to semi-arid. Mean annual precipitation in the valleys averages about 6 inches per year. Higher altitudes, particularly above 7,000 feet, average between 12 and 15 inches per year. Temperatures often exceed 100°F in the Summer and fall well below 0°F in the Winter. Altitudes vary within the region of this report between 4,300 feet in the Edna Mountain Quadrangle and 9,680 feet in the Mt. Lewis Quadrangle. Vegetation is generally similar to that of the Upper Sonoran association, with greasewood, sage, rabbit brush, and sparse grasses dominant. Box elder and willow are common along streams. Juniper, pinyon pine, mountain mahogany, and a few shrubs are abundant at higher elevations in some of the ranges.
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Plate I  in pocket
Plate II in pocket
In order to adequately understand the significance of the Battle Formation, it is necessary to review the regional geology of north-central Nevada. It has been recognized since the time of the Fortieth Parallel Survey that the stratigraphy and structure of Paleozoic rocks in the eastern and western parts of the state differ markedly (King, 1878, p. 247, 342). This early survey did not, however, recognize many of the major stratigraphic and structural features of the region.

Turner (1909, p. 255-256) was probably the first to recognize facies changes in Paleozoic rocks while mapping in the Silver Peak region southwest of Tonopah. Nolan (1928) was the first to point out the real significance of the differences in facies. He pointed out that volcanic and clastic rocks predominate in western Nevada and that carbonate rocks predominate in the eastern portion of the state. Nolan (1943) discussed the lithologies of the Paleozoic rocks in detail. Kirk (1933, p. 31) had recognized two distinct facies of Ordovician rocks in the Roberts Mountains. He suggested thrust faulting to explain the close proximity (only a few miles) of these facies. Kirk's suggestion was confirmed by Merriam and Anderson (1942, p. 1701-1704) when they discovered and mapped the thrust in the same area which they named the Roberts Mountains thrust fault.
Later workers have revealed that the facies changes are regional in extent and that thrust faults commonly separate the facies. The stratigraphy of north-central Nevada has been worked out in considerable detail by many geologists. The Sonoma Range Quadrangle has been mapped by Ferguson and others (1951a; 1951b); Muller and others (1951); and Ferguson and others (1952). Roberts (1951, 1964) described the geology of the Antler Peak Quadrangle; Gilluly and others that of the Mt. Lewis, Crescent Valley, Cortez, and Winnemucca Quadrangles (1965a, 1965b, 1967). Hotz and Willden (1964) mapped and described the geology of the Osgood Mountains. Willden (1964) made a geologic reconnaissance of Humboldt County. Roberts and Lehner made a similar reconnaissance study of Eureka County. Stewart and McKee of the U.S. Geological Survey have done extensive mapping during a Lander County reconnaissance study, as yet unpublished.

A general concept of facies relations has been established as a result of the extensive mapping. Four distinct lithologic assemblages have been recognized: 1) an eastern carbonate assemblage; 2) a western siliceous and volcanic assemblage; 3) a transitional assemblage; 4) an overlap assemblage.

The Eastern Assemblage

Lower Cambrian to Mississippian rocks in eastern Nevada, east of an irregular line between the 116° and 117°
meridians, are composed mostly of limestone and dolomite with minor amounts of shale and quartzite. Rocks of this assemblage were deposited in shallow mioeocynclinal seas that covered much of eastern Nevada and western Utah. A carbonate to clastic ratio of 9:1 seems to hold for the period of time involved (Roberts, 1964, p. A8). Quartzite units are commonly clean and well sorted; some, like the Eureka Quartzite, may have enormous areal extent. Shale units are generally fine-grained black siliceous shales or calcareous shales; normally without interbedded coarse clastic rocks. Limestones and dolomites tend to be rather pure carbonate rock, but may be locally shaly or sandy. At Eureka, at least 14,500 feet of this assemblage accumulated.

The Western Assemblage

West of meridians 116°-117° in central and western Nevada, predominantly clastic sedimentary rocks, chert and intercalated volcanic rocks comprise strata of early and middle Paleozoic age. These rocks were deposited in a eugeosynclinal environment far to the west of the shallow shelf seas. Rocks of this assemblage of pre-Mississippian age may have an aggregate thickness in excess of 50,000 feet. Units tend to be lenticular, thickening or thinning abruptly. Shale is estimated to make up between 20 and 40 percent of the western assemblage; sandstone and quartzite 10 to 30 percent; chert with shale partings up to 30 percent. Volcanic rocks vary from a few percent to 30 percent.
Thin, discontinuous, generally shaly or sandy limestone beds are present locally. Shale units are commonly sandy and seldom calcareous. Sandstones are generally termed graywackes, but are pure enough in places to be termed pure sandstone or orthoquartzite. Chert units range from a few inches to several hundreds of feet. These units tend to be lenticular and are separated by shale partings which also tend to be lenticular. Volcanic rocks include pyroclastics, pillow lavas and flows that accumulated mostly in a marine environment. These units are mostly lenticular. They probably formed around source centers (Gilluly and Gates, 1965, p. 7-8; Roberts, 1964, p. A7-A11; Hotz and Willden, 1964, p. 1, 2, 6; Roberts et al., 1958, p. 2813-2857).

Coarse clastic rocks are found interbedded, locally, with rocks of the western assemblage. Such units, of Late Devonian age, have been mapped in the Sulphur Springs Range by Carlisle and Nelson (1957). Limestone and chert conglomerate, chert, black shale and quartzite may reflect early pre-thrust orogenic activity.

The Transitional Assemblage

Units above and below the Roberts Mountains thrust can generally be sharply distinguished, but a transitional facies is recognized at Battle Mountain, Edna Mountain, the Osgood Mountains, the Sonoma Range, and the northern Shoshone Range (Hotz and Willden, 1955, p. 1652). This assem-
blage is regarded as parautochthonous (Roberts et al., 1958, p. 2813, 2826-2829).

Clastic, volcanic, and carbonate rocks characterize the transitional assemblage. Less than 40 percent are carbonate rocks. Most of the clastics are shale or sandy shale; coarse clastics are rare. Chert and siliceous shale are less abundant than in the western assemblage. Fine-grained tuffs and tuffaceous shales constitute most of the volcanic material. Units of this assemblage probably reflect the oscillatory nature of the eugeosynclinal-miogeosynclinal boundary (Roberts, 1964, p. A9).

The presence of transitional strata in the Osgood Mountains, Edna Mountain, the Sonoma Range and elsewhere indicates that the source of the Roberts Mountains thrust further to the west.

The Overlap Assemblage

A north-trending positive area was developed in central Nevada beginning with Late Devonian orogenic movements (Nolan, 1928, p. 161). A belt of rugged highlands, the Antler orogenic belt, was formed between the 116° and 118° meridians. Intense folding and faulting within this belt culminated in the Early Mississippian Roberts Mountains thrust (Roberts et al., 1958, p. 2813, 2838).

Orogenic movements continued into Early Pennsylvanian time with extensive deposition of coarse clastics in central and eastern Nevada. The clastic rocks grade later-
ally into finer sedimentary rocks east of the Antler orogenic belt. These clastics interfinger with the normal marine strata. Within the orogenic belt the clastic rocks and associated lenticular limestones overlap folded and faulted strata of the western, transitional, and eastern assemblages that were involved in the orogeny. Roberts and Lehner (1955, p. 1661) named this post-orogenic facies the overlap assemblage.

North-central Nevada was partly emergent during the remainder of the Paleozoic. Sediments of this age were probably deposited in straits and embayments as indicated by the thin, lenticular units which vary abruptly along the strike of the orogenic belt.

Thick clastic and volcanic accumulations in a marine environment in northwestern Nevada point to a westward migration of the eugeosynclinal environment during the late Paleozoic. These rocks were piled up on the western margin of the Antler orogenic belt during the Late Permian Sonoma orogeny (Golconda thrust) (Roberts, 1964, p. A9).
The overlap assemblage is represented by the Antler sequence, which includes the Battle Formation, the Highway Limestone, the Antler Peak Limestone, the Adam Peak Formation, the Etchart Limestone, the Edna Mountain Formation, and the Brock Canyon Formation. The transitional assemblage is represented by the Osgood Mountains Quartzite, the Preble Formation, the Paradise Valley Chert, the Harmony Formation, and the Comus Formation. The Scott Canyon, Valmy, and Gough's Canyon Formations, the Elder Sandstone, and the Slaven Chert represent the western assemblage. Units of the eastern assemblage are the Prospect Mountain Quartzite, Pioche Shale, El Dorado Dolomite, Shwin Formation, Eureka Quartzite, Hanson Creek Formation, Roberts Mountains Limestone, undifferentiated Devonian Limestones and the Pilot Shale.

Units of the Havallah sequence, deposited in western Nevada and moved eastward along the Golconda thrust, include the Pumpernickel and Havallah Formations. Mesozoic (?) strata of the China Mountain Formation were laid down following a Late Permian uplift. Major thrust faults or gravity slides have superimposed the western assemblage upon the transitional and eastern assemblages. Units of the overlap assemblage are in depositional and thrust contact with underlying formations of the western, transitional,
and eastern assemblages. Figure 2 summarizes and correlates the Paleozoic units found within the thesis area.

The Stratigraphy of the Osgood Mountains

Eleven Paleozoic formations are represented in the Osgood Mountains Quadrangle. Units of the western assemblage include the Valmy, Gough's Canyon, and the Farrel Canyon Formations. Members of the transitional assemblage include the Osgood Mountain Quartzite, the Preble Formation, Paradise Valley chert, Harmony Formation, and the Comus Formation. The Battle Formation, Adam Peak Formation, and the Etchart Limestone comprise the overlap assemblage. No formations belonging to the eastern assemblage have been recognized in the Osgood Mountains. Many of the stratigraphic units are only found in structural contact with one another. The Valmy Formation was probably brought into the area along the Roberts Mountains thrust. The Gough's Canyon and Farrel Canyon Formations were most likely brought into the area during the Sonoma orogeny (Golconda thrust).

Ferguson and others (1952) named the Osgood Mountains Quartzite for exposures at the southern end of the Osgood Mountains in the Golconda Quadrangle. In the Osgood Mountains, the formation has been divided into two separate units: the Osgood Mountains Quartzite member and the Twin Canyon member. The formation consists of well-sorted, uniform, fine to medium grained quartzite. It is medium to thick bedded; cross bedding is common. Quartz grains are subrounded to rounded and are generally well sorted. Pebbly
Figure 2  Correlation Chart (after Gilluly and Gates)
layers, as much as a few inches thick, are occasionally found. Quartz grains make up more than 90 percent of the quartzite. Other primary constituents include the heavy detrital minerals zircon, sphene, and most commonly, tourmaline. These accessory minerals tend to be rounded. Hematite, in the matrix, occasionally lends a distinctive reddish purple to the quartzite. The Twin Canyon member contains more silty and shaly material than the rest of the formation. Cross bedding is not common. The accessory minerals are the same as in the rest of the formation. The base of the Osgood Mountain Quartzite is not exposed; the upper part of the formation is gradational into the overlying Preble Formation. An estimated 5,000 feet of the formation is exposed. No fossils have been found in the formation. Thickness and position beneath the Preble Formation (of Middle Cambrian age) suggests an Early to Middle Cambrian age for the Osgood Mountain Quartzite (Hotz and Willden, 1964, p. 6-10).

The Preble Formation was named by Ferguson and others (1952). It consists of an estimated 6,000 feet of limestone, phyllitic shale, and quartzite (R. L. Erickson, 1972, oral communication). Isoclinal folding and minor faulting may have duplicated the section in some places. The Preble is predominantly shale, but includes quartzite beds in its lower part. The middle and upper part of the formation consists of interbedded phyllitic shale and limestone. No accessory minerals have been determined for the
Preble Formation. Fossil evidence indicates a Middle and Late Cambrian age for the formation (Hotz and Willden, 1964, p. 10-13).

The Paradise Valley chert was first recognized by Hotz and Willden (1964). This late Cambrian formation is exposed only in the Hot Springs Range. It consists predominantly of chert, but it also contains minor amounts of siliceous shale and limestone. The chert is well but extensively fractured. Shale occurs as partings or as thin beds. Limestone occurs in small lenses and thin beds in which Late Cambrian fossils have been found. Total thickness of the Paradise Valley chert is between 300 and 500 feet. Relations with the older Preble Formation are unknown since the two formations are not in structural contact. The Paradise Valley chert is in depositional contact with the overlying Harmony Formation, but exposures are not good enough to establish whether the contact is conformable or not. Heavy minerals present include zircon, blue and green tourmaline, abundant monazite, xenotime, ilmenite, rutile, magnetite, and hematite (Hotz and Willden, 1964, p. 13-14).

Ferguson and others (1951) named the Harmony Formation for exposures in the Sonoma Range. The Harmony Formation is composed predominantly of feldspathic sandstones, with some interbedded shales, minor amounts of pebble conglomerate, and clastic limestone. The light brown to olive green sandstone is very distinctive. Sand grains are medium to coarse, composed of quartz, feldspar, and muscovite.
Graded bedding is common; no cross bedding has been found. Most specimens are poorly sorted and most of the grains are subangular to subrounded. Heavy minerals include apatite, sphene, ilmenite, tourmaline, epidote, magnetite, and rutile. Thickness of the formation has been estimated to be more than 4,000 feet. The top of the formation is not exposed. Fossil evidence indicates a Late Cambrian age for the formation (Hotz and Willden, 1964, p. 14-19).

The Comus Formation was defined by Ferguson and others (1952) from exposures on Edna Mountain. It is largely an alternating sequence of dolomite, limestone, and shale with subordinate amounts of chert, siltstone, and tuffaceous material. Sandstone and quartzite are conspicuously absent. All contacts with other Paleozoic formations are fault contacts. Its stratigraphic position is based on fossils ranging in age from Early to Middle Ordovician. The exposed thickness is on the order of 3,200 to 4,600 feet. Accessory minerals are notably absent (Hotz and Willden, 1964, p. 20-21).

The Valmy Formation is exposed only at two localities in the Osgood Mountains Quadrangle, one on the east side of the Hot Springs Range and the other on the east side of the Osgood Mountains. The formation consists mainly of chert and siliceous shale, some quartzite, and minor amounts of volcanic rock. The chert is light gray to black; thin bedded to massive. The siliceous shale commonly occurs as partings between chert layers, but may be found in beds as
much as two feet thick. The quartzite is light colored, vitreous and pure with grains that are rounded to well rounded and well sorted. Quartz grains make up 95 percent or more of the quartzite with quartzite fragments making up most of the rest of the rock. The grain size ranges from 0.1 mm to 1 mm with an average of about 0.5 mm. No chert fragments have been observed in the rock. Minor accessory minerals include apatite, zircon, and a little mica. Neither the top nor the base of the formation is seen in the quadrangle, but exposures have an estimated thickness of nearly 2,000 feet. Only Early Ordovician fossils have been found in the Valmy Formation in this area. The strata exposed appear to be correlative with the lower part of the type section in the Antler Peak Quadrangle (Hotz and Willden, 1964, p. 22-23).

Hotz and Willden (1964, p. 24) named the Gough's Canyon Formation for exposures in the Osgood Mountains. The formation lies on the upper plate of a thrust and is overlapped by a higher thrust. Its stratigraphic relationships with other Paleozoic formations is unknown. Most of the formation is composed of altered volcanic rocks (60%) and coarse grained fossiliferous limestones. Calcareous shale, siliceous shale, and chert are of lesser importance making up the other 10 percent of the rock. Minor accessory minerals include fine-grained sphene, magnetite, and apatite. The formation is complexly folded but may be more than 5,000 feet thick. Fossil evidence establishes the
Gough's Canyon Formation as Early to early Late Mississippian (Hotz and Willden, 1964, p. 24-28).

In the Osgood Mountains, the Battle Formation is predominantly a poorly bedded boulder conglomerate. At some places the upper part is composed of pebble conglomerate, coarse sandstone, and interbedded white fine-grained limestone, with minor amounts of red shale and sandstone. Blocks, boulders, and pebbles were derived principally from the Osgood Mountains Quartzite. Thickness of the formation ranges from less than 100 feet to more than 400 feet. The age of the formation is Middle Pennsylvanian or younger. (Hotz and Willden, 1964, p. 29-30). This formation will be discussed in greater detail later.

The Etchart Limestone was named by Hotz and Willden (1964, p. 30). It is predominantly limestone and sandy limestone, some interbedded dolomite, calcareous shale, and lenticular beds of pebble conglomerate. The thickness and lithology is widely variable. The formation is from 250 feet to 300 feet thick at the south end of the range and may exceed 1,000 feet at the north end. The Etchart Limestone has been assigned an age range from Des Moinesian to Virgilian or Wolfcampian. It is correlative with the Highway Limestone and the Antler Peak Limestone. The Etchart appears to be the temporal equivalent of the Battle, at least locally. Two or three miles east of the northeast corner of the quadrangle, the formation may exceed 2,000 feet in thickness. The relations of this formation to the
Battle will be discussed in greater detail later (Hotz and Willden, 1964, p. 30-36).

The Adam Peak Formation was named by Hotz and Willden (1964, p. 36). It is made up chiefly of shale, siltstone, dolomitic sandstone, chert, and limestone. Minor accessory minerals include subrounded zircon, and less commonly, green tourmaline. The formation lies in thrust contact with the Harmony and Battle Formations, the Osgood Mountains Quartzite, and the Etchart Limestone. Locally, the Adam Peak rests with apparent conformity on the Battle Formation. Total thickness of the formation is approximately 2,100 feet. Faunal evidence assigns a Late Pennsylvanian to Early Permian age. The Adam Peak Formation is contemporaneous with part of the Etchart Limestone in the Osgood Mountains and the Antler Peak Limestone of the Antler Peak Quadrangle (Hotz and Willden, 1964, p. 36-38). Possible relations of this formation to the Battle Formation will be discussed in a later chapter.

The Pennsylvanian and Permian age Farrel Canyon Formation was named by Hotz and Willden (1964, p. 38). The formation is not well exposed; the lithology and thickness are poorly known. It consists largely of interbedded sandstone, chert, shale, siltstone, and some volcanic flow rocks and pyroclastics. Individual units are variable and lenticular. Feldspar constitutes between 30 and 55 percent of the sandstones. Accessory minerals total less than a percent of the sandstones; they are mostly well rounded zircon, some
clear and some pink, grains of magnetite and tourmaline. Neither the top nor the bottom of the formation is exposed. The Farrel Canyon Formation is in fault contact with all formations upon which it rests. It is estimated to be between 3,000 and 4,000 feet thick. No fossils have been found within the formation. It has been assigned a tentative Pennsylvanian (?) to Permian (?) age on the basis of lithology, which is similar to that of the Pumpernickel and Havallah Formations of the Sonoma Range (Hotz and Willden, 1964, p. 38-40).

The Structure of the Osgood Mountains Quadrangle

The principal structural trends of the Osgood Mountains and the Hot Springs Range closely parallel the trend of the ranges. Bedding of sedimentary rocks, the axes of folds, and the major thrust and high angle reverse faults in the southern and central parts of the Osgood Mountains have a predominant strike of about N. 50° E. The strikes of the main structural elements is virtually north-south at the north end of the range. The main structural features of the Hot Springs Range are folds in the Harmony Formation. Trends of the fold axes shift from north-south in the southern part of the range to slightly east of north at the north end of the range. Folds and thrust plates provide the dominant pre-Pennsylvanian structural elements in both ranges.

A broad anticline in the Osgood Mountain Quartzite and the Preble Formation is revealed in the central and
south-central parts of the Osgood range. Toward the north end of the range the anticline is concealed beneath younger thrust plates and unconformably overlying rocks of Pennsylvanian age. The surface of the fold axis is sinuous and tends to be west of the range crest in the south (See plates I and II). There is marked drag folding in beds of the Osgood Mountain Quartzite which are exposed along the limbs of the anticline. The axial planes of the folds are inclined along the corresponding limbs of the major fold. 

Strata of Paleozoic age, younger than the Osgood and the Preble are often steeply tilted and tightly folded. However, no well defined anticlines or synclines have been found in these units. Much of the folding in these formations is related to thrust faults (Hotz and Willden, 1964, p. 69).

Development of the major anticline took place during deformation prior to the deposition of the Battle Formation and the Etchart Limestone. The Osgood Mountain Quartzite, the Preble Formation, and possibly some younger formations were folded and eroded; then strata of Pennsylvanian age were deposited on the Osgood Mountain Quartzite and the Preble Formation. Minor infolding of the quartzite and Pennsylvanian limestones at a few places may be evidence of post-Pennsylvanian deformation (Hotz and Willden, 1964, p. 70).

Along the west side of the Osgood Mountains, Cambrian, Mississippian, Pennsylvanian, and Permian strata have
been thrust over one another in an imbricate pattern. Thrust faults are also exposed along the crest and eastern side of the range. These thrusts involve Cambrian, Ordovician, Pennsylvanian, and Permian rocks. Only two pre-Pennsylvanian plates have been recognized in the Osgood Mountains. The earliest of the thrusts carried the Valmy Formation into the area. The base of the thrust is concealed in the Osgood Mountains, but the movement of the thrust is believed to have coincided with the Roberts Mountains thrusting of Late Devonian to Early Mississippian age. The Twin Canyon thrust, exposed on the east side of the range, is pre-Middle Pennsylvanian because it is overlapped by the Battle Formation in sec. 3, T. 37 N., R. 41 E. The thrust changes to a high angle reverse fault in a northerly direction. The Osgood Mountain Quartzite makes up the upper plate or hanging wall. It overrides the Preble Formation to the south and the Twin Canyon member to the north (See plate I). Displacement along the fault is not accurately known, but it must be at least a few thousand feet to account for the superposition of the Osgood Mountain Quartzite. The thrust fault appears to have developed along the attenuated common limb of an assymetrical syncline and anticline. The southwest limb of the anticline was thrust over the syncline, probably as a result of fracturing and continuing compressional deformation (Hotz and Willden, 1964, p. 70).

Other thrust faults are common in the Osgood Mountains. Most appear to be of an imbricate nature. All of
them were developed as a result of post-Pennsylvanian deformation, since they involve a variety of Pennsylvanian and Permian strata as well as earlier formations. These thrusts are probably related to the Golconda thrust of the Sonoma orogeny or to Mesozoic thrusting. Late Paleozoic formations below the thrust have only been moderately folded locally. Some have been tilted without marked folding. Most of the deformation of these Late Paleozoic formations has resulted from Tertiary high angle faulting. There are some sections, particularly of the Battle Formation, that appear to be involved in bedding plane thrusts along the basal contact. The age and amount of displacement along these thrusts is uncertain (Hotz and Willden, 1964, p. 70-74, 81-82).

The Stratigraphy of the Edna Mountain Quadrangle

Nine formations representing three distinct structural and lithologic assemblages are found on Edna Mountain. Structurally lowest of the Paleozoic formations are units of the transitional assemblage including the Osgood Mountain Quartzite, the Preble, and Comus Formations. Overlapping these units, with angular unconformity, is the Antler sequence including the Battle Formation, the Highway Limestone, the Antler Peak Limestone, and the Edna Mountain Formation. Late Paleozoic western assemblage formations, the Pumpernickel and Havallah Formations, structurally overlie the overlap assemblage. No formations belonging to either the lower Paleozoic western assemblage or to the
eastern assemblage have been recognized within the Edna Mountain Quadrangle.

The oldest formation recognized in the area is the Cambrian (?) Osgood Mountain Quartzite. It is a massive light-brown quartzite, generally fine-grained, locally cross-bedded. There are a few layers with small white quartz pebbles. Micaceous partings are commonly found along the bedding planes. A few thin beds of siliceous brown slate have been found. The amount of mica increases upward in the formation, resulting in bands of quartz-mica schist. The Osgood Mountain Quartzite generally has moderate easterly dips, but locally it has steep westerly dips. No fossils have been found within the formation, but it must be Late Precambrian or Lower Cambrian in age since it lies conformably below the Middle Cambrian Preble Formation. The Osgood Mountain has been correlated with the Prospect Mountain Quartzite of the Eureka and Pioche districts, and the northern Shoshone Range. It is estimated to be at least 5,000 feet thick; the base is not exposed (Ferguson, Muller, and Roberts, 1952; Roberts, et al., 1958, p. 2821, 2826).

Gradationally above the Osgood Mountain is the Middle Cambrian Preble Formation. The formation was named by Ferguson et al. (1952) for exposures near the northern end of the quadrangle. It consists of a gray to light purple, tan, silvery, green, and maroon phyllite and shale with limestone lenses. These lenses range from a few hun-
dred feet to more than a mile long in the lower part of the section. There are occasional red and green chert bands and a little argillite locally. Quartz-mica schist and quartzite are found near the base of the section. The formation may exceed 12,000 feet in thickness (Ferguson et al., 1952), but more likely is on the order of 6,000 feet thick, with perhaps the entire section repeated due to isoclinal folding, thrusting, and Basin and Range faulting (R. L. Erickson, 1972, oral communication). Some early Late Cambrian fossils from the formation have been reported (Roberts et al., 1958, p. 2827; Ferguson et al., 1952).

The Comus Formation structurally, and perhaps stratigraphically, overlies the Preble Formation. On Edna Mountain the contact is a high angle fault; in the Osgood Mountains the contact has been obscured by alluvium. The formation is chiefly interbedded shale, in part siliceous, and chert, with some dark, impure limestone and dolomite and brown, fine-grained quartzite. In many places, the shale is more properly described as a slate. Graptolites from the Comus are of Early and Middle Ordovician age. The type section, near Comus siding in the Edna Mountain Quadrangle, is about 3,000 feet thick. The Comus is equivalent to the lower and middle members of the Valmy Formation in the Antler Peak Quadrangle (Ferguson et al., 1952; Roberts et al., 1958, p. 2831).

The Battle Formation of Middle Pennsylvanian age overlies the Preble Formation with marked angular uncon-
formity. The contact appears to be depositional. The formation is a thin, lenticular conglomerate that varies from 20 to 100 feet thick. It consists of thin to thick bedded coarse, unsorted quartzite and chert conglomerate. The Battle intertongues with the Highway Limestone which is considered to be the equivalent of the upper part of the Battle Formation at the type section near Antler Peak (Roberts et al., 1958, 2841, 2842; Ferguson et al., 1952; Roberts, 1964, p. A31). The Battle Formation at Edna Mountain will be discussed in greater detail in a later chapter.

Ferguson et al. (1952) recognized the Highway Limestone at exposures on Edna Mountain. It is a massive light gray limestone; in places it is cherty near the base. Thin pebbly and sandy layers are found throughout. The limestone contains some conglomerate. Toward the south the formation tends to get coarser, with conglomerate being the preponderant member. The conglomerate is massive, with brown, angular chert and quartzite pebbles in a limy matrix. The Highway interfingers with the Battle Formation locally; at other localities, it rests directly on the Preble Formation. Further to the west on Edna Mountain, the Highway is missing. Fusulinids found in the Highway Limestone are of Atokan age. The type section is about 200 feet thick. The formation is correlative with the upper part of the Ely Limestone of eastern Nevada (Ferguson et al., 1952; Roberts et al., 1958, p. 2842).
The Antler Peak Limestone rests disconformably upon the Highway Limestone on the northeastern side of Edna Mountain, and it rests with angular unconformity on the Preble Formation farther to the west. It consists of gray and tan, fine to medium grained, thin bedded to massive dolomitic limestone. A basal conglomerate, up to 30 feet thick, contains pebbles of Highway Limestone. Limestone beds have sandy layers and pebbly layers chert and vitreous quartzite. Locally, there are chert lenses and nodules. The upper part of the formation has numerous shaly beds. Fusulinids, brachiopods, conodonts, and other faunas indicate a Late Pennsylvanian to Early Permian age for the Antler Peak. The formation does not exceed 200 feet in thickness and it is missing in places. The Antler Peak Limestone is wholly or partly correlative with the Brock Canyon Formation of the northern Shoshone Range, the Strathhearn Formation of Carlin Canyon, the Garden Valley and Carbon Ridge Formations of the Eureka district, and the Havallah Formation (Ferguson et al., 1952; Roberts et al., 1958, p. 2843; Gilluly and Gates, 1965, plate 3).

The Edna Mountain Formation rests on the Antler Peak Limestone, and the Highway Limestone with erosional unconformity. Locally, it rests with angular unconformity on the Preble Formation. Fossils of Wordian age have been found in the Edna Mountain Formation. It is considered to be the equivalent of the Gerster Formation at Gold Hill, Utah. The Edna Mountain consists of fine-grained sandstone and quart-
zite with a few beds of slate, limestone, calcareous sandstone, and dolomitic sandstone. The quartzite grades locally into a fine-grained grit which is rarely micaceous. There are a few feet of conglomerate beds at the base and scattered at higher intervals in the section. The basal conglomerates are not generally more than two feet thick. Pebbles are derived from the Preble and from itself. The formation is about 250 feet thick (Ferguson et al., 1952; Roberts et al., 1958, p. 2843-2844).

The Pumpernickel Formation of Pennsylvanian (?) age rests in thrust contact upon the Preble Formation and the Antler sequence. It is composed of dark chert and dark siliceous argillite with intercalated greenstones, with subordinate metavolcanics, conglomerate, and quartzitic sandstone. Intense folding, thrusting, and normal faulting have rendered thickness measurements virtually impossible. The presence of the overlying Havallah Formation and the proximity of the type section in the Sonoma Range suggest a thickness of 5,000 to 6,000 feet. Conodonts of Desmoinean age or younger have been found in the Pumpernickel. The formation may be at least partly correlative with several formations including the Chainman Shale, the Diamond Peak Formation, and the Ely Limestone of the Eureka district; the Tonka Formation and the Ely Group of Carlin Canyon (Roberts et al., 1958, p. 2847-2848; Ferguson et al., 1952; Roberts, 1964, p. A44; Gilluly and Gates, 1965, plate 3).
The uppermost Paleozoic unit on Edna Mountain is the Havallah Formation. It consists of dark gray dense limestone with interbeds of dark chert, tan sandstone and light tan slate. The sandstone tends to be quartzitic and calcareous; the beds are platy to massive. The thickness of the formation probably does not exceed 500 feet in the quadrangle, where the Havallah occurs only as erosional remnants. The remnants probably correspond to the lower part of the Jory member in the Antler Peak Quadrangle. Fusulinids indicate an age range from Atokan to Leonardian at Battle Mountain (Ferguson et al., 1952; Roberts et al., 1958, p. 2848-2849; Roberts, 1964, p. A48-A49).

The Structure of the Edna Mountain Quadrangle

Compression during the Antler orogeny resulted in development of a large anticline in the area presently occupied by the Osgood Mountains. The Osgood Mountain Quartzite forms the core of the structure, the axis of which passes through the northwestern portion of the Edna Mountain Quadrangle. Generally the overlying Preble Formation has eastward dips, except for small fold areas or places where isoclinal folding and overturning to the east are evident. The Preble sits on the east limb of the Osgood Mountains anticline. The Comus Formation may or may not be part of the same fold structure. Its contact with the underlying Preble has been obscured by high-angle faulting and alluvium. It represents a sharp facies contrast, with discordant dips relative to the Preble, but that could be due,
at least in part to the normal faulting and in part to a post-Cambrian hiatus. There is no evidence that the Twin Canyon thrust of the Osgood Mountains is present in the Edna Mountain Quadrangle, but the probable duplication of the Preble Formation suggests that it might be. There is no other evidence of pre-Battle folding, thrusting, or normal faulting in the quadrangle.

The formations of the Antler sequence were deposited under widely differing conditions over a relatively small area. The rocks exhibit abrupt lateral variations in lithologic character and thickness from place to place. There is abundant evidence of local hiatus between the formations, indicating local warping and uplift.

During the Sonoma orogeny, the overturned beds of the Pumpernickel and Havallah Formations were thrust into the area. The folds of these formations generally have a northward trend and vary greatly in intensity. Formations of the overlap assemblage that lie beneath the thrust plate are only locally folded and are generally little disturbed (Ferguson et al., 1952).

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**Stratigraphy of the Antler Peak Quadrangle (Battle Mountain)**

Eight Paleozoic formations, dissected by a variety of Tertiary plutons and wrapped in a mantle of Quaternary alluvium, comprise the stratigraphic sequence within the Antler Peak Quadrangle. Rocks of the upper plate of the Golconda thrust, the overlap assemblage, the western and
transitional assemblages are found on Battle Mountain. No
units of the eastern assemblage have been recognized within
the Antler Peak Quadrangle. All stratigraphic units are
structurally above the Roberts Mountains thrust. The west­
er assemblage is represented by the Scott Canyon and Valmy
Formations; the Harmony Formation is the only transitional
facies unit exposed; the Antler sequence is comprised of
the Battle Formation, Antler Peak Limestone, and the Edna
Mountain Formation; the Havallah and Pumpernickel Formations
make up the upper plate of the Golconda thrust (Havallah
sequence).

The Scott Canyon Formation, of late Early or early
Middle (?) Cambrian age, was named by Roberts (1951). It
consists of dark-gray to black chert, shale, and argillite
with intercalated greenstone flows, pillow lavas, and pyro­
clastics. Minor amounts of sandstone, quartzite, and lime­
stone are also present. Total thickness of the formation
is estimated to be more than 5,000 feet. This western
assemblage formation is exposed only in the Antler Peak
Quadrangle. The Scott Canyon Formation probably represents
a volcanic island-arc environment. It was brought into the
area along the upper plate of the Roberts Mountains thrust
fault. Heavy minerals are not in notable abundance.
Archeocyathids, sponges, algae, and some trilobites have
served to render the Cambrian age assignment. The forma­
tion may be correlative, in part, with both the Osgood
Mountains Quartzite and the Preble Formation (Roberts, 1951;
Fossil evidence has established a Late Cambrian age for the Harmony Formation. The formation was named by Ferguson and others (1951); it belongs to the transitional assemblage. The Harmony is made up of interbedded sandstone, feldspathic sandstone, arkose, granule and pebbly sandstone, shale, calcareous shale, and limestone. Sandstone constitutes about 70 percent of the formation; limestone 2 percent or less; shale makes up the remainder. Rocks of the Harmony Formation are generally not resistant to erosion. The formation is estimated to be about 3,000 feet thick. According to Roberts and Arnold (1952), the Harmony Formation is allochthonous and it appears to have been thrust eastward at least 30 miles. Average compositional values for the sandstones of the formation include 60 to 80 percent quartz, 10 to 20 percent feldspar, 2 to 5 percent mica, matrix and cement 20 to 30 percent. Of the feldspars, about 55 percent is orthoclase, 33 percent plagioclase, and 12 percent microcline. The only accessory minerals reported are muscovite and biotite, in roughly equal proportion. The Harmony Formation was probably deposited in a relatively deep water environment following rapid transport over a short distance, possibly by density currents (Roberts, 1964, p. A25).

The Ordovician Valmy Formation was named and described by Roberts (1949, 1951, 1964) from exposures in the
Antler Peak Quadrangle. This western assemblage unit has been subdivided into three members, with an aggregate thickness on the order of 8,500 feet. The lower member consists of interbedded shale, quartzite, chert, and greenstone. The greenstone includes pillow and massive lavas and pyroclastic rocks. The middle member is made up of interbedded shale, quartzite, and chert with intercalated greenstone. The greenstones are mainly breccias, which grade laterally into tuffs. The upper member is composed of interbedded shale and chert with thin quartzite beds and minor greenstone. The quartzite of the Valmy Formation exhibits a seriate texture which is very distinct. Grains show a fairly large size range, with larger grains generally scattered in a matrix of medium sized grains. Grains range in size from 0.1 mm to 1 mm. Only minor accessory minerals have been found in quartzites of the Valmy Formation, totaling less than 0.1 percent of the rock. Well-rounded grains of tourmaline and zircon constitute the only accessory minerals. On the basis of graptolites, the formation has been assigned an Early and Middle Ordovician age; it is considered to be the equivalent of the Vinini Formation of the Roberts Mountains and elsewhere. The Valmy Formation may have been deposited in a volcanic archipelago environment similar to the one inferred for the Scott Canyon Formation. Density currents may have been a significant depositional factor (Roberts, 1964, p. A17-A22; Roberts et al., 1958, p. 2832).
Roberts (1951; 1964) named and described the Battle Formation from exposures in the Antler Peak Quadrangle. He divided the formation into three members consisting of reddish-brown to dark-red conglomerate with interbedded sandstone, shale, and thin limestone beds. In this area, the Battle represents the basal unit of the overlap assemblage. It has been assigned a Middle Pennsylvanian age and it is considered to be the equivalent of the upper part of the Ely Limestone of eastern Nevada (Roberts, 1958; 1964). The formation will be discussed in much greater detail later.

Disconformably overlying the Battle Formation is the Late Pennsylvanian and Early Permian Antler Peak Limestone. The formation was named by Roberts (1951). The Antler Peak Limestone has been subdivided into 12 units, A through O, having a total thickness of 625 feet at the type section on Antler Peak. The top of the formation is an erosional surface. Near Copper Basin, in sections 21 and 28, T. 32 N., R. 44 E., the lower units A-F are absent. The formation consists largely of medium to dark grey limestone and shaly limestone, with subordinate shale. Some of the limestone beds contain sand and pebbles of chert and quartzite, probably derived from the same source as the clastic material of the Battle Formation. Faunal evidence indicates that the limestone was deposited in a marine shallow water environment. The formation has been assigned a middle Missourian to early Wolfcampian age (Roberts, 1964, p. A32-A36; Roberts et al., 1958, p. 2843).
The youngest unit of the overlap assemblage in the Antler Peak Quadrangle is the Edna Mountain Formation. The formation was named by Ferguson and others (1952) for exposures on Edna Mountain. It is mostly interbedded limy shale, limestone, sandstone, and chert conglomerate. The Edna Mountain Formation rests upon the Antler Peak limestone with erosional unconformity. Thickness of the formation is estimated to be about 200 feet. The Edna Mountain Formation is regarded as Guadalupian in age and is considered to be correlative with part of the Phosphoria and Gerster Formations of the Rocky Mountains and western Utah (Roberts et al., 1958, p. 2843-2844; Roberts, 1964, p. A36-A37).

Structurally overlying the Battle Formation, Antler Peak Limestone, and the Edna Mountain Formation, is the Pumpernickel Formation of the Late Paleozoic western assemblage. The Pumpernickel is made up of shale, chert, and greenstone with some limestone, sandstone, and pebbly conglomerate. The base of the formation is not exposed. Known exposures are estimated to have a thickness of at least 5,000 feet. Isoclinal folding, distinctive western lithology and other evidence indicates that the Pumpernickel Formation was thrust into the Antler Peak area from the west during the Sonoma orogeny. Conodonts found in the Pumpernickel indicate a Middle Pennsylvanian or younger age assignment. The formation may be correlative, at least in part, with the Battle Formation and the Ely limestone (Roberts, 1964, p. A37-A44; Gilluly, 1965).
The Havallah Formation was first described by Ferguson and others (1952). It rests with possible disconformity on the Pumpernickel Formation. The formation has been divided into three members composed of interbedded sandstone, quartzite, shale, limestone, and chert. Total thickness of the formation has been estimated to be 10,000 feet by Ferguson and others (1952), but Roberts (1964, p. A45-A48) has measured sections having a total thickness of only 4,500 feet. The Havallah was deposited in a eugeosynclinal environment. Many of the sandstones of the lower part of the formation may have been deposited from density currents. The Havallah Formation was brought into the quadrangle by the Golconda thrust during the Sonoma orogeny. The Havallah may be the partial equivalent of several formations including the Battle Formation, Highway Limestone, Antler Peak Limestone, the Etchart Limestone, and the Brock Canyon Formation (Roberts, 1964, p. A45-A49; Gilluly, 1965).

The Structure of Battle Mountain

The present structure of the Galena Range is made up of three principal blocks, separated by thrust faults, that have been warped into a domal configuration by Mesozoic and Tertiary intrusions. These blocks are the Valmy and Scott Canyon block which includes Cambrian and Ordovician rocks of the western assemblage; the Dewitt block, which is made up of the Harmony Formation of the transitional assemblage and the Golconda block, which includes late Paleozoic
rocks of the Pumpernickel and Havallah Formations. The Antler block, a later structural feature unrelated to thrust faulting, has been broadly warped along a northwest trending axis and has been cut by high angle faults. See plate I.

The Valmy Formation and the Scott Canyon Formation of the block bearing their names, are in thrust contact with one another. At most places, this relationship is covered by the Dewitt block. Regional relationships, minor thrusts, local folding and crushing demonstrate that this structural block is allochthonous. The thrust plate is inferred to have moved into the Battle Mountain area along the Roberts Mountains thrust, which is not exposed here (Roberts, 1964, p. A79).

The major structure in the Valmy block is a complexly faulted anticlinal fold. The fold axis trends southward with a plunge of about 30°. There may be another southward plunging anticline on the north side of North Peak. A southward plunging syncline may underlie North Peak and the peak to the south (see plate I). Three eastward dipping thrust faults cut the Valmy Formation. The dip is probably the result of post-thrust folding and tilting. Although numerous Tertiary faults cut the Valmy and Scott Canyon blocks, only one pre-Tertiary high-angle fault has been recognized. This fault cuts across the nose of the major anticline in the Valmy Formation (see plate I). The basal contact of the Battle Formation in sec. 19, T. 32 N., R. 43 E., is not displaced by the fault. A pre-Atokan age for the
fault is inferred (Roberts, 1964, p. A79-A80).

Major folds within the Scott Canyon block have not been discerned. Abundant minor folds suggest that the formation has been highly folded and overturned. Minor folds are commonly overturned toward the east. No pre-Tertiary normal faults have been recognized as cutting the Scott canyon block (Roberts, 1964, p. A81).

Structurally above the Valmy and Scott Canyon blocks is the Dewitt block. The Harmony Formation is the sole unit represented in the block. It was thrust into the area along the Roberts Mountains thrust. The block appears to have a broad assymmetric anticlinal structure. The fold axis strikes N 20° W., roughly coincident with the Antler anticline. Oversteepening or overturning toward the east is suggested by numerous minor folds whose western limbs dip gently and whose eastern limbs dip steeply. The main structural feature of the Dewitt block may be an overturned syncline (see plate I). No pre-Atokan normal faults have been recognized within the Dewitt block (Roberts, 1964, p. A81-A82).

The Antler block includes all the units of the Antler sequence: the Battle Formation, Antler Peak limestone, and the Edna Mountain Formation. The block is principally exposed along a diagonally northwest trend that extends across the range and an area east of Copper Basin (see plate I). The Antler block rests unconformably upon the older blocks and it was not disturbed by the same com-
pressional forces. Formations of the Antler sequence have been folded into a northwest trending anticline. Rocks of the western limb dip to the west or southwest at 10° to 40°; the eastern limb generally dips at 10° to 30° northeast (see plate I). Most normal faults that cut the Battle Formation are late Eocene or post-Eocene in age and have not been traced far into the underlying formations. Many of these faults, particularly near the top of the range have had the effect of widening the outcrop and duplicating units of the Antler sequence. A reverse fault, near the head of Trenton Canyon has served to narrow the outcrop. Few sections of the formation are undisturbed enough to allow measurement with complete confidence. The Antler anticline may have a southward plunge, but there is no concrete evidence to support it (Roberts, 1964, p. A81-A83).

Folded strata of the Pumpernickel and Havallah Formations make up the Golconda block, which was thrust into the area during the Sonoma orogeny. Both of these formations have been folded and sheared along faults. In a south to north direction the block is in structural contact with the Dewitt, Antler, Valmy, and Antler blocks upon which it rests. Folds in this block are north striking, assymetrical to overturned anticlines and synclines. Only the sole thrust (the Golconda thrust) has been recognized in this block. This thrust and later high angle faults have served to disturb, at least locally, the Battle Formation and the Antler Peak Limestone (see plate I) (Roberts, 1964,
The Stratigraphy of the Mt. Lewis Quadrangle

Sixteen formations of Paleozoic age are exposed within the Mt. Lewis Quadrangle and vicinity. Eight of the formations belong to the eastern assemblage including the Prospect Mountain Quartzite, the El Dorado Dolomite, the Shwin Formation, the Eureka Quartzite, the Hanson Creek Formation, the Roberts Mountain Limestone, some unnamed Devonian Limestone, and the Pilot Shale. These units all belong to the lower plate of the Roberts thrust. Western assemblage formations of the upper plate include the Valmy Formation, the Elder Sandstone, and the Slaven Chert. Also part of the upper plate is the Harmony Formation of the transitional assemblage. The overlap assemblage is represented by two facies, the Antler Peak facies and the Cortez Mountains facies which include the Battle Formation, and the Antler Peak Limestone in the former and the Brock Canyon Formation in the latter. The Havallah Formation is the lone representative of the Late Paleozoic western assemblage. It was brought into the area during the Sonoma orogeny.

One small, three hundred foot thick exposure of the Prospect Mountain Quartzite constitutes the oldest unit in the area. The formation was named by Hague (1892) for exposures in the Eureka district. The rock is made up of fairly well-rounded quartz grains, some feldspar, and in some places, a few flakes of muscovite. Quartz is predomi-
nant, although some beds contain considerable feldspar. Most of the quartz grains average 0.5 mm or less in diameter, although some granules may be as much as 3 or 4 mm across. No fossils have been found within the formation. Correlation has been based tentatively on lithologic similarity with the upper Prospect Mountain of the Eureka district, although a similarity with the Osgood Mountain Quartzite also exists. A few beds resemble a transition between the Prospect Mountain Quartzite and the Pioche Shale of the Eureka and Pioche districts (Gilluly and Gates, 1965, p. 10).

The Eldorado Dolomite was named by Hague (1892) for exposures in the Eureka mining district. The formation is made up almost entirely of highly broken and irregularly bedded dolomite. The dolomite is coarsely granular and largely recrystallized, with an average grain size of probably 1 mm. Thickness of the formation is roughly 500 feet; the base is not exposed. The Eldorado is unfossiliferous and has been dated by lithology and structural position (Gilluly and Gates, 1965, p. 10-11).

Rocks of the Shwin Formation were named and described by Gilluly and Gates (1965, p. 11-14). The formation is made up of chloritic argillite, metadolerite, greenstone, chloritic phyllite, black limey slate, mottled shaly limestone, limey mudstone, and calc-phyllite. Complex folding and faulting have rendered the stratigraphic succession uncertain. All contacts with other formations are faults. It appears that the more calcareous and muddy sediments are
higher in the section. Total thickness of the formation is estimated at 1,500 to 2,000 feet. A Middle Cambrian age has been determined on the basis of agnostid trilobites (Gilluly and Gates, 1965, p. 11-14).

Unconformably above the Eldorado is the Eureka Quartzite of Hague (1883, p. 253, 262). It consists of homogeneous, massive bedded, moderately well-sorted medium sand-sized rock with some coarse and silt-sized grains. Grains, approximately 0.5 mm are readily visible, but the rock, being a true quartzite, breaks across them. The original quartz grains appear to be well-rounded. Accessory minerals, such as tourmaline, zircon, kyanite, apatite, staurolite, magnetite, brown hornblende, and biotite, make up less than one percent of the rock. The formation, based on regional evidence, is considered to be Middle Ordovician. It is similar in mineral composition and grain shape to the Valmy Formation and probably had the same source. It is better sorted however. (Gilluly and Gates, 1965, p. 15-16).

Merriam (1940, p. 10-13) named the Hanson Creek Formation for exposures on Pete Hanson Creek in the Roberts Mountains. The formation is seen only in windows in the northern Shoshone Range. It consists of massive limestone and dolomite of Middle and Upper Ordovician age. The total exposed thickness is from 600 to 700 feet. The dolomites are rather coarse with an average grain size of about 1 mm. The limestones tend to aphanitic and thin-bedded with shaly partings. Contacts with formations above and below appear
Gilluly and Gates (1965, p. 17) modified the name Roberts Mountain Formation of Merriam (1940, p. 11-14) to the Roberts Mountain Limestone because of the dominant limestone lithology of the formation in the northern Shoshone Range. No beds analogous to the basal chert described by Merriam (1940, p. 12; Nolan et al., 1956, p. 36-37) at the type locality have been recognized. However, the basal beds appear to be concordant with the underlying Hanson Creek. Most of the Roberts Mountain Limestone consists of dark, thin-bedded, platy, carbonaceous limestone. Some is shaly and calcareous. Total thickness probably does not exceed 1,000 feet. A Lower Silurian (Niagaran) age has been assigned to the formation (Gilluly and Gates, 1965, p. 17-19).

No formal recognition has been accorded some Devonian limestones which are found in the Mt. Lewis Quadrangle. Faunal evidence indicates a Devonian age for the limestones, but owing to the fact that the mass is dissected by numerous faults and that its boundaries are all faulted no subdivision has been attempted. The strata are regarded as the equivalent of the Nevada Limestone as used by Hague (1892, p. 70-84). The rock is virtually all limestone with almost no megascopically identifiable siliceous constituents or dolomite; the bedding ranges from medium to thick. Most of the limestone is aphanitic or fine-grained. A few beds are coarsely crystalline. Thickness of the formation is esti-
The Pilot Shale was named by Spencer (1917, p. 26) from exposures in the Ely district. It is considered to be the equivalent of the lower White Pine Shale as defined by Hague (1892, p. 68-69). The base and the top of the formation are faulted. The formation is 300 to 400 feet thick, which is similar to the thickness in the Eureka district. Rocks of the formation are mostly limy shale. There are some thin limestones and conspicuous micaceous parting planes. Conodonts from the formation in this area are of upper Devonian age. No characteristically Mississippian fauna has been recognized from the Pilot Shale in the Mt. Lewis Quadrangle (Gilluly and Gates, 1965, p. 21-22).

The oldest unit of the upper plate recognized in the northern Shoshone Range is the Harmony Formation of Late Cambrian age. The Harmony is composed of arkose and arkosic siltstone. Grain sizes vary from fine conglomerate to coarse sand to silt. Grains are angular to subrounded with low sphericity; the sorting is poor. Fine grained material is abundant even in the coarser beds. The coarser sandstones are made up of 50 to 70 percent quartz, 10 to 20 percent K-feldspar, 10 to 15 percent albite, as much as 2 percent partially chloritized biotite, and 3 percent calcite and clay matrix. Accessory minerals include apatite, sphene, zircon, tourmaline, and rutile. No fossils have been found in the formation in the Mt. Lewis Quadrangle, but correlation
has been made with lithologically similar fossiliferous beds in the Hot Springs Range by Hotz and Willden (1964, p. 19; Roberts et al., 1958, p. 2827). (Gilluly and Gates, 1965, p. 22-23).

At least 12,000 feet and perhaps more than 25,000 feet of the Valmy Formation have been recognized in the northern Shoshone Range. Thrusting and facies changes have made it impossible to determine any accurate thickness. The quartzites and quartz sandstones are very pure. Grains are moderately to poorly sorted, ranging from coarse sand size to silt size. The silt size particles predominate. Coarser grains are highly spherical and stand out from the finer grains which are subangular to subrounded. Small authigenic outgrowths, in optical continuity with the central grain, cement many of the rocks so that they break across the grains. The large spherical grains commonly do not break and stand out on the fractured surface. The heavy minerals zircon, green and brown tourmaline, biotite, hornblende, and augite are present along with sparse grains of chalcedony. Cherts within the formation are composed chiefly of very fine silt-sized quartz in a siliceous matrix. The mineral content of the chert is very closely similar to the quartzites of the formation. The chert contains the tests of radiolaria, organic material of an undetermined nature, and some sericite. Current bedding is common in the Valmy. The entire Ordovician System appears to be represented by the Valmy Formation in the northern Shoshone Range (Gilluly
The Elder Formation was named and described by Gilluly and Gates (1965, p. 35-36). It lies above, and in fault contact with, the Valmy Formation. The formation has been assigned a Llandovery age, but it may span the entire Silurian. It has a thickness of between 2,000 and 4,000 feet of fine grained sandstone. Much of it is silty, with subordinate interbeds of siltstone, sandy siliceous tuffite shale, and thin, platy chert. There is also some cherty shale, and a little quartzite. Much of the sandstone is notably feldspathic; some is a true arkose. Some of the sandstone is crossbedded and some is ripple marked. The sandstone and siltstone are composed of 70 to 80 percent quartz, 15 to 20 percent potassium feldspar, 5 percent muscovite and minor albite. The chert of the Elder Sandstone contains as much as 20 percent sericite and 10 percent potassium feldspar. This is in sharp contrast to the very pure silica of the cherts in the Valmy Formation (Gilluly and Gates, 1965, p. 35-36). This formation belongs to the upper plate of the Roberts thrust.

Gilluly and Gates (1965, p. 37) named the Slaven Chert. This upper plate formation consists largely of black chert, generally in nodular beds only a few feet thick. The rock is generally composed of about 85 percent quartz of very fine to silt size, about 10 percent iron oxides and organic matter, and nearly 5 percent sericite. Dark carbonaceous shale forms partings between chert layers, but
may be as much as 4 to 10 feet thick. Some sections contain limy, brown-weathering sandstone beds, from a few inches to a few feet thick. The sandstones are very poorly sorted and contain angular to subrounded fragments of chert, shale, greenstone, and limestone as much as 2 mm in diameter. Such fragments constitute 25 percent of the sandstones; silt to coarse sand size quartz grains make up 55 percent; a finely crystalline carbonate matrix constitutes the rest. Some of the sandstones could be termed graywackes. The larger quartz grains are well rounded; the smaller grains are angular. Feldspathic sandstone and limestone constitutes the remainder of the formation. The formation has a thickness between 2,000 and 4,000 feet. The base of the formation is in fault contact with older rocks; therefore its depositional base is unknown. Fossils from the Slaven Chert have been assigned a Middle and Upper (?) Devonian age (Gilluly and Gates, 1965, p. 37-42).

The Battle Formation marks the base of the overlap assemblage in the Mt. Lewis Quadrangle. It has been termed the Battle Conglomerate in the northern Shoshone Range (Gilluly and Gates, 1965, p. 43). The formation is mostly a coarse conglomerate, although locally there are some sandstones, marls, and mudstones. The formation rests on the Valmy Formation in both depositional and thrust contact. Thickness varies from 50 to about 400 feet. No fossils have been found in the Battle Conglomerate, but a Middle to Late Pennsylvanian age has been inferred on the bases of position
and lithology (Gilluly and Gates, 1965, p. 43-44). The Battle Conglomerate will be discussed in greater detail in a later section.

Disconformably overlying the Battle Conglomerate is the Antler Peak Limestone. The contact with the Battle appears to be both gradational and conformable, but a time gap has been inferred to intervene between them, like the one that has been recorded at Antler Peak (Roberts, 1964, p. A32). There is no faunal evidence for the stratigraphic gap at Mt. Lewis; it is therefore possible that the Battle Conglomerate may be Late Pennsylvanian. The Antler Peak Limestone is almost entirely a light gray limestone, with beds ranging from a few inches to 5 feet in thickness. Locally, some irregular chert nodules are found in the limestone. There are a few shaly beds and some of limy sandstone. The limestones vary from coarsely granular to almost aphanitic. The exposures are generally small and highly deformed and the formation has not been subdivided within the Mt. Lewis Quadrangle. The Antler Peak Limestone is estimated to be 700 feet thick. The top is an erosional surface. The formation has been assigned a Late Pennsylvanian to Early Permian age (Gilluly and Gates, 1965, p. 45-47).

The Brock Canyon Formation was named by Gilluly and Gates (1965, p. 44) for exposures in the Cortez Mountains. The thickness of the formation is estimated at 1,200 to 1,500 feet. It consists of dolomite, conglomerate, sandstone, and limestone and it has been subdivided into three
members. The base of the formation is in fault contact with the Valmy Formation, but the displacement is believed to be very small. The Brock Canyon is not in contact with any other formations of the overlap assemblage. The dolomite is dense and fine grained, occurring in beds 2 to 12 feet thick. The total thickness of the dolomite member may be as much as 240 feet. The middle member is made up of conglomerate and sandstone that has a thickness of at least 400 feet. The conglomerate is much finer than the Battle Conglomerate, seldom having pebbles more than 3 or 4 inches in diameter. The pebbles are of chert, quartzite, quartz, and sandstone. They are generally well rounded. The matrix is of sand, silt, and finely comminuted rock fragments. Many of the pebbles appear to have come from the Valmy Formation. Interbedded carbonaceous shales have yielded poorly preserved plant fossils. The upper member is a shaly limestone with considerable sandstone interbeds. This unit may be as much as 600 feet thick. The Brock Canyon may be partly correlative with the upper Battle Conglomerate, but most likely it is wholly correlative with the Antler Peak Limestone (Gilluly and Gates, 1965, p. 44-45).

Calcareous mudstone is the only rock type of the Havallah Formation that is exposed in the northern Shoshone Range. The mudstone is carbonaceous, almost an argillite. These rocks have been correlated with the type section in the Tobin Range on the basis of lithology, algae, and worm tracks. The Havallah was probably thrust into the area
during the Sonoma orogeny. Bedding is so obscure that thickness determinations can only be guessed. Perhaps 1,000 feet of the formation are present. Although no diagnostic fossils have been found, it is assumed that the formation is equivalent in age to similar rocks in the Antler Peak Quadrangle (Atokan to Leonardian?). (Gilluly and Gates, 1965, p. 47-48).

The Structure of the Mt. Lewis Quadrangle

At least four different ages of orogenic deformation are recorded in the structure of the northern Shoshone Range. The first two episodes involved great folds and thrusts of Paleozoic and Early Mesozoic age. The last two episodes involved normal faulting and tilting of Tertiary or younger age and are not considered here.

The first deformational episode took place between Early Mississippian and Early Pennsylvanian time. The Roberts Mountains thrust and the Trout Creek transcurrent fault formed at this time. Considerable folding took place both above and below the thrust zone. Several subsidiary thrusts, higher in the section, were also involved in the folding. More than 19 faults wrenched the upper plate (see plate I). These structures were produced during the Antler orogeny. The most prominent folds are asymmetric to isoclinal antiforms and synforms that have been overturned toward the east. These fold structures have been further deformed by concurrent and subsequent thrusting of an imbricate nature. These rocks have been little disturbed by
metamorphism. Thrusting probably took place at a depth of at least several thousand feet (Gilluly and Gates, 1965, p. 2). The Roberts thrust is highly faulted and has a relief of at least 10,000 feet.

An overturned segment of the Roberts thrust on the north is separated from an openly folded segment to the south by the Trout Creek transcurrent fault. The structures along both sides of the fault appear to be highly independent of one another (Gilluly and Gates, 1965, p. 2, 112-115).

The lower plate of the Roberts Mountains thrust is also highly deformed. Owing to patchy exposures, little can be inferred regarding the structure of the lower plate (Gilluly and Gates, 1965, p. 2). There are no strata of the overlap assemblage assignable to the Battle Conglomerate or the Antler Peak Limestone that are known to be in depositional contact with rocks of the lower or upper plates that resided in the Mt. Lewis Quadrangle at the close of the Antler orogeny.

Thrust faulting probably of comparable complexity to the Roberts Mountains thrust, took place during the Lewis orogeny. This orogeny is considered to be equivalent to the Sonoma orogeny. It involves formations of the western and overlap assemblages including the Valmy, Battle, Antler Peak, and the China Mountain (?) of Triassic age. A single thrust mass from this orogeny extends across the exposed edges of four or five lower thrusts, which are related to the Roberts thrust. Small outliers of this
thrust mass (the Whiskey Canyon thrust) occur over an area several miles beyond the main thrust sheet. Faults related to the Lewis orogeny are somewhat folded, but not nearly as deformed as the plates related to the Roberts Mountains thrust. The actual age of the Lewis orogeny within the Mt. Lewis Quadrangle cannot be dated more precisely than post-Early Triassic (?) and prior to the intrusion of early Tertiary stocks. Regional evidence, the presence of the Havallah Formation and the China Mountain (?) Formation, suggests a Triassic age for the deformation (Gilluly and Gates, 1965, p. 2, 123-125).
THE BATTLE FORMATION

The Battle Formation was named and described by Roberts (1951) from exposures in the Antler Peak Quadrangle (Fig. 3). The formation is the basal unit of the overlap assemblage. It underlies parts of Battle Mountain, its type locality, the northern Shoshone Range, and the Edna and Osgood mountains. Widely differing conditions of deposition, over a relatively small area, are indicated by rather abrupt lateral variations in lithologic character and thickness (Roberts et al., 1958, p. 2841). The Battle rests on formation of Cambrian (?) to Ordovician age belonging to the overthrust western and transitional assemblages. Fragments of rock, locally derived from these underlying formations, constitute the Battle Formation.

The Battle consists primarily of coarse red to brown quartzite, chert, and sandstone conglomerate with minor amounts of interbedded sandstone, shale, and limestone. The thickness of the Battle varies widely; it has a maximum thickness of 730 feet at the type locality in the Antler Peak Quadrangle; at Edna Mountain, it ranges from 20 to 100 feet thick; in the Osgood Mountains, it ranges from 60 to 400 feet in thickness; and in the northern Shoshone Range from 100 to 400 feet thick. Faunas from the middle and upper members at the type section provide an Atokan (early Middle Pennsylvanian) age assignment. The Battle is divisible into three members only within portions of the Antler Peak Quadrangle. Plant fragments have been found in
Between the black lines: the type section of the upper member (258 ft.) of the Battle Formation. The Antler Peak Limestone overlies the upper member of the Battle.

Above the black line: the type section of the middle member (74 ft.) and the lower member (398 ft.) of the Battle Formation. Below the line: Harmony Formation.
the lower beds at Antler Peak, where the conglomerates may have been deposited under terrestrial conditions.

A facies of the Battle Formation, the Highway Limestone, is found only on Edna Mountain. This 200 foot thick unit is comparable to the middle and upper members of the Battle at Antler Peak.

The Battle is considered to be the equivalent of the upper part of the Ely Limestone (Lawson, 1906, p. 295; Spencer, 1917, p. 27) and the Bird Spring Formation (Longwell and Dunbar, 1936, p. 1204). It is also equivalent to the upper part of the Moleen Formation and the lower Tomera Formation (Dott, 1955, p. 2234). See Figure 3 for a correlation chart for the Battle Formation.

Lawson (1913, p. 328) termed the Battle Formation to be a "fan-glomerate". Other geologists consider the Battle to be a mixture of terrestrial and marine conglomerates formed in an archipelago characterized by numerous bays and straits (Roberts et al., 1958, p. 2852; Hotz and Willden, 1964, p. 81; Roberts, 1964, p. A31; Gilluly and Gates, 1965, p. 47).

The Osgood Mountains Quadrangle

The Battle Formation is exposed in the central and south-central parts of the Osgood Mountains. It rests unconformably on the Osgood Mountain Quartzite in most places, and on the Preble Formation locally. The formation is generally overlain by the Etchart Limestone and the Adam Peak Formation, although on the east side of the range it occurs
as gently dipping to flat lying erosional remnants. Only a few erosional remnants are found west of the crest of the range. In sec. 26, T. 38 N., R. 41 E., and in sec. 4, T. 37 N., R. 41 E. the Battle Formation pinches out rapidly westward where the Etchart Limestone rests directly on the Osgood Mountains Quartzite.

In this range the Battle Formation is predominantly a poorly bedded boulder conglomerate (Fig. 4). At many places, the basal two or three feet of the formation are composed of angular fragments of randomly oriented quartzite in a sandy and shaly matrix. The angular fragments are few and as much as several feet in diameter where the underlying quartzite is thick bedded or massive. The fragments are abundant and not much more than a foot in greatest dimension where the quartzite is thin bedded. This basal zone grades upward into poorly bedded boulder conglomerate with no apparent break. The conglomerate is made up almost exclusively of fragments of Osgood Mountain Quartzite, with only a few small fragments of chert. The quartzite fragments range from small pebbles about one-fourth inch in diameter to rare blocks 10 feet or more in diameter; generally the clasts are of boulder size. Most commonly, the clasts are firmly cemented in a quartzite matrix. Fragments in such a rock may be extremely difficult, if not impossible, to distinguish from the matrix which has the same color and texture. At some places, the matrix is dark reddish-brown to dark purple sand and shale. At some localities the
Typical conglomerate of the Battle Formation in the Osgood Mountains Quadrangle. Figure 4
upper part of the formation is composed of pebble conglomerate, some coarse grained sandstone, and some interbedded white limestone in beds less than ten feet thick. The limestones generally contain some sandy and pebbly material. Minor amounts of interbedded red shale and sandstone have been found (Hotz and Willden, 1964, p. 29).

Where the beds have been steeply tilted, the contact with the underlying rocks appears to be faulted, but the faulting appears to be along the bedding plane. North of Hogshead Canyon for a distance of nearly two miles, the contact of the Battle Formation and the Osgood Mountains Quartzite is nearly parallel with the contact of the Battle Formation and the overlying Etchart Limestone. Along this strike the Battle exhibits only minor changes in thickness due to minor channeling of the underlying quartzite. Minor channeling may be seen at a few other scattered localities.

At most places where the Battle Formation is exposed in this quadrangle only a coarse boulder conglomerate is present. But at some localities the lithology of the formation gradually changes upward from coarse boulder conglomerate to pebble conglomerate with interbedded sandstone, shale, calcareous shale, and limestone. Such a gradual upward change is similar to that observed at the type locality at Antler Peak. At most localities in the Osgood Mountains limestones rest directly on the Cambrian rocks. In some places there are patches of coarse grained conglomerate beneath the limestone; the base of the limestone commonly
contains lenticular beds of coarse-grained quartzite conglomerate and pebble conglomerate. At Lone Butte, in sec. 34, T. 37 N., R. 41 E., there is a boulder conglomerate approximately 60 feet thick which is overlain by limestone which has thin interbeds of quartzite pebble conglomerate in its basal part.

Original lenticularity and faulting have resulted in considerable variation in the thickness of the Battle Formation. The maximum thickness exposed is about 400 feet. At most places it does not exceed 100 feet (Hotz and Willden, 1964, p. 30). Thickness relationships are somewhat obscure, but they indicate a westward thinning of the Battle in the Osgood Mountains (Fig. 7). The Battle wedges out to the west underneath the Etchart Limestone.

In the Osgood Mountains, the Battle Formation is overlain by limestones of Middle Pennsylvanian (Atokan or younger) age. It appears to intertongue with these limestones to the west. The limestones contain bryozoan, coral, and brachiopod genera including Rhombotrypella, Fenestella, Polypora, Archimedes, Cystodictya, Rhambdomeson, and Ascopora. In places, the Battle is beneath limestones of Late Pennsylvanian age, probably contemporaneous with the Antler Peak Limestone. Some conglomerate of the Battle Formation may be as young as Late Pennsylvanian. In SE 1/4 sec. 17, T. 37 N., R. 41 E., some thin beds of limestone, interbedded with coarse conglomerate, contain Late Pennsylvanian fusulinids belonging to the genera Climacammina,
Bradyina, Tetraxis, and Triticites (Hotz and Willden, 1964, p. 30, 33, 35).

Hotz and Willden (1964) believe that while it is possible that some of the Battle Formation is of terrestrial origin, much of it is certainly of marine origin. In the Osgood Mountains, conglomerates of the Battle Formation interfinger at many places with marine limestones. The Battle was probably derived from a nearby rugged terrain that lay to the east of the present range. The Battle and its equivalents in the Osgood Mountains may have been deposited in an environment of many bays and straits, as in an archipelago (Hotz and Willden, 1964, p. 38, 81).

The Edna Mountain Quadrangle

Within this quadrangle, the Battle Formation is exposed only in small discontinuous outcrops along the northeastern and extreme northern portions of Edna Mountain (see plate I). The scattered exposures are distributed in a northwesterly direction for a distance exceeding five miles. In an east-west direction, the maximum spread of the outcrop is approximately one mile. The best exposures are on a prominent point in sec. 33, T. 36 N., R. 41 E. (see appendix II); in the SW 1/4, sec. 3, T. 35 N., R. 41 E.; in NW 1/4, sec. 14, T. 35 N., R. 41 E. Other poorly exposed to moderately well-exposed outcrops of the Battle Formation are to be found in the same general area. At almost all of the localities, the Battle Formation is overlain
by the Highway Limestone with which it intertongues (sec. 3, T. 35 N., R. 41 E.). The Battle varies in thickness from approximately 20 feet to 100 feet. The Battle Formations appear to thin toward the west (Fig. 7). Much of the thinning may be attributed to erosion and, possibly, to thrust faulting. There are no conglomeratic exposures that are lithologically referable to the type section at Antler Peak.

Wherever it is seen, the Battle tends to be a very thick bedded to massive boulder, cobble, and pebble conglomerate (Fig. 5). Locally, there are small limy or sandy lenses. The conglomerates grade laterally and vertically into calcareous shale, limestone, and a conglomerate composed of chert and quartzite grit. The formation tends to be resistant to weathering, although many of its exposures are not prominent. Beds dip gently to moderately at 5° to 30° in either a westerly or southeasterly direction.

In the northern and central exposures on Edna Mountain, the Battle Formation consists of pebbles, cobbles and boulders of pink, white, and grey quartzite in a siliceous matrix; there are minor limestone, sandstone, and shale lenses near the base of the formation. More southerly exposures of the formation are composed of coarse boulder, cobble, and pebble conglomerate having rounded to subangular clasts of chert and vitreous quartzite in a quartzite matrix. The formation is thick bedded to massive and unsorted or very poorly sorted. A massive quartzite boulder conglomerate is exposed in sec. 3, T. 35 N., R. 41 E.; it
Figure 5. Thrust fault marked by black line. The Cambrian Preble Formation is below the fault plane; the Battle Formation (the dark beds to the right of center) and the Highway Limestone (the lighter beds in the center and upper left) are above the fault plane.
contains well rounded quartzite boulders, in a poorly sorted quartzite matrix of sand and pebbles. The section is repeated with limestone intervening.

The thickness distribution of the formation is somewhat irregular, although on average, it appears to become thinner toward the southeast, with an accompanying increase in chert content. The northernmost exposures on Edna Mountain have very little chert (sec. 33, T. 36 N., R. 41 E.); those in sec. 3, T. 35 N., R. 41 E. may have as much as 25 percent chert clasts; the southernmost exposures in sec. 14, T. 35 N., R. 41 E. may contain as much as 67 percent chert clasts. The proportion of quartzite clasts increases in the opposite direction. Some quartzite clasts, to the south, are dark grey like the Valmy.

Thin section studies reveal a quartzite and chert framework that constitutes 85-95 percent of the conglomerate. Quartzite clasts make up 30-90 percent of the framework. The chert percentage of the framework varies from 10 to 70 percent. Particles are poorly sorted, subangular to rounded and they vary in size from 2 mm to more than 31.2 cm. The chert tends to be more angular than the quartzite and chert clasts generally do not exceed 2.5 cm.

The matrix varies from 5-15 percent of the rock. Quartz comprises between 85 and 25 percent of the matrix; quartzite varies from 15 to 2 percent; chert ranges from 3 to 5 percent. Particles in the matrix vary from angular to rounded; they are poorly sorted and range in size from 0.05
mm to 1 mm. Some pebbles have been physically deformed. The cement is silica with trace amounts of iron oxide. Cement may constitute up to 70 percent of the matrix. There appears to have been an addition or redistribution of silica cement during diagenesis, with some recrystallization of quartz in veins.

At Edna Mountain, the Battle Formation rests with marked angular unconformity upon the Middle and Upper Cambrian Preble Formation. Unlike the Battle in other quadrangles, the formation on Edna Mountain does not generally reflect the lithology of the underlying formation. Only one locality was visited where phyllites of the underlying Preble Formation were found to be incorporated into the conglomerate (sec. 14, T. 35 N., R. 41 E.). These rare clasts were angular and did not exceed about 1 cm in length.

Erickson and Marsh (1971) have mapped thrust faults at the base of the Battle and Highway Formations. The thrusting was inferred from the truncation of Battle and Highway beds resting with angular discordance on the Preble Formation (Fig. 6). Displacement along the thrust faults must have been small, probably much less than a mile. The faulting may have affected the thickness of the Battle, but probably only slightly. Battle Formation of similar thickness and erratic distribution may be seen at Lone Butte and other localities in the Osgood Mountains to the north and west.
Figure 6. Typical conglomerate of the Battle Formation on Edna Mtn.
The Battle Formation has been assigned a Middle Pennsylvanian (Atokan) age on the basis of Ascopora and other fauna of the Chaetetes-Profusulinella zone (Hotz and Willden, 1964, p. 33-34; Dott, 1966, p. 76). The Highway contains a fauna similar to that collected about 400 feet above the base of the Battle at its type locality. The Highway, and thus the Battle at Edna Mountain, are regarded as equivalent to the middle and upper parts of the Battle Formation at Antler Peak (Roberts, 1964, p. A31).

The Antler Peak Quadrangle

Within this quadrangle, the Battle crops out in an erosional remnant in Copper Basin, in fault slivers in Rocky and Trenton Canyons, and in a belt as much as a mile wide extending northwesterly. At the type section east of Antler Peak, the Battle Formation has a total thickness of 730 feet. The type section is a composite measured from two localities: Section A, measured 500 feet southeast of Antler Peak and Section B, measured due east from 1/4 corner between secs. 3 and 4, T. 31 N., R. 43 E. For a detailed description, see Appendix I. The type section has been divided into the lower, middle, and upper members.

The lower member, 398 feet thick, is a medium to thick bedded conglomerate, characteristically medium to deep red, except where metamorphosed. Rock fragments are poorly sorted, ranging from boulder to granule size in a sandy to silty matrix of iron oxide and calcite cement. Clasts are made up of sandstone, quartzite, chert, lime-
stone, greenstone, and jasper. Fragments are subangular, but may be sub-rounded to well-rounded. Locally, near the base of the lower member, unidentified plant fragments have been found. Rarely, current bedding and torrential bedding is found in the lower part of the formation. Such features are normally confined to a single bed or group of beds; probably indicating minor variation in depositional conditions. Toward the top of the lower member, beds exhibit better sorting and are more uniform. There are fewer boulder beds than in the basal part of the lower member. Cobble and pebble conglomerate beds and sandstone predominate. Some shaly beds are present (Roberts, 1964A, p. A28; 1964B, p. B8).

Pebble and granule conglomerate, interbedded with sandstone, shale, calcareous shale, and limestone, comprise the bulk of the middle member. The conglomerates and sandstones are generally better sorted and a lighter red than those of the lower member. Limestone beds grade into calcareous sandstone and shale along the strike. Most of the fossils found are from this member, which is 74 feet thick (Roberts, 1964A, p. A28-A29; 1964B, p. B8).

Two hundred and fifty eight feet of interbedded fine sandstones, pebble conglomerate, shale, and calcareous shale make up the upper member. The sandstones are commonly coarse grained. Pebble conglomerates are composed mainly of subangular to rounded quartzite, chert, and jasper pebbles. Shaly layers, which comprise most of the upper member, con-
tain limestone lenses. Only a few fossils have been found (Roberts, 1964A, p. A28-A29; 1964B, p. B8).

The Battle Formation rests with angular unconformity on rocks of the Valmy and Harmony Formations. Over most of the quadrangle, the Battle dips gently westward. East of Copper Basin however, it dips moderately eastward. The units upon which it rests were highly folded and thrust faulted prior to the deposition of the Battle Formation. The lower beds of the Battle strongly reflect the immediately underlying rocks.

Where the Battle Formation rests on the Harmony Formation, a large proportion of boulders of Harmony sandstone is found in a matrix of sand grains also derived from the Harmony Formation. Pebbles of greenstone, quartzite, chert, and jasper are assumed to have come from the Scott Canyon and Valmy Formations. The source of reddish and yellowish limestone pebbles is uncertain. A similar relationship may be noted where the Battle overlies the Valmy Formation—the basal beds contain chert and quartzite pebbles derived directly from the Valmy. A greater proportion of chert and quartzite pebbles is to be found in the middle member. Conglomerate beds of the upper member are comprised almost entirely of quartzite and chert. Locally, the upper member contains gray crystalline limestone pebbles which are lithologically similar to limestones that are interbedded in the Battle Formation. These facts indicate that the sources of rocks other than quartzite and chert
were either eroded away as time went on, or that they were gradually covered up by overlapping conglomerate beds (Roberts, 1964A, p. A29-A30).

Originally the thickness of the Battle Formation was probably highly variable. The deepest part of the basin of accumulation was in the vicinity of the type section, near the head of Cow Canyon. From that point the formation appears to thin to the northwest and north. This is probably due to either non-deposition or to erosion prior to the deposition of the overlying units. Thinning must have been mainly in the lower members, which appear to end successively northwestward, perhaps due to overlap along a seaward sloping land area (Roberts, 1964A, p. A30). In the area of the Marigold Mine the Battle Formation is only 50 to 200 feet thick.

The thickness of the Battle Formation is variable, but in general it appears to thicken in a southerly or southwesterly direction (Fig. 7). The formation is thickest where marine beds have been recorded within the section. According to Roberts (1964, p. A33), the base of the overlying Antler Peak Formation is stratigraphically much younger at Antler Peak than it is at Copper Basin to the northeast.

Contact metamorphism and hydrothermal alteration have obscured the lithology of the formation in the vicinity of Copper Basin. Here, the Battle is composed mostly of pebble and granule conglomerate with a few cobble beds,
Isopachous maps of the Battle Formation.

Figure 7
interlayered with sandstone. It is well-stratified and medium to thick bedded. Clasts are subangular to subrounded and are embedded in a sandy matrix. Most of the cobbles, pebbles, and granules were derived from the chert and quartzites of the Valmy and Scott Canyon Formations, while some sandstone and argillite was derived from the underlying Harmony Formation. The formation is about 150 feet thick in this area (Roberts, 1964A, p. A28, A30).

A minimum thickness of 570 feet has been estimated for the Battle Formation in the vicinity of Copper Canyon, where three members are also recognized. These members probably correspond with those of the type section, but cannot be precisely correlated owing to contact metamorphism and hydrothermal alteration. The basal member is a chloritic conglomerate, 120 feet thick, which probably was altered from a calcareous conglomerate. The middle member is made up of 150 feet of calcareous and siliceous hornfels. Three hundred feet of interbedded quartzite conglomerate, quartzite, and siliceous hornfels constitute the upper member.

Fauna from the Battle Formation within the Antler Peak Quadrangle include Climacococina sp., Endothyra sp., Bradyina sp., Tetraxis sp., Fusulinella sp., Chaetetes sp., and a Hydrozoan (?). An Atokan age has been assigned to the Battle Formation on the basis of this assemblage. Units of similar age based on faunal evidence include the Highway Limestone (Ferguson and others, 1952); the upper Ely Lime-
stone (Spencer, 1917); the upper Moleen and lower Tomera
Formations (Dott, 1955); and the Bird Spring Formation (Longwell and Dunbar, 1936).

A. C. Lawson (1913) was the first to extrapolate the origin and environment of deposition for the Battle Formation. He considered that the Battle was a remnant of an ancient alluvial fan which was composed of angular fragments of the underlying rock. It was his belief that the term conglomerate did not adequately convey the "mode of the deposit and the climatic conditions which determined that mode" (Lawson, 1913, p. 329). In order to adequately describe the inferred genetic relationship of the Battle Formation to what he believed to be its modern analogue, Lawson coined the term "fanglomerate". His definition states "... I must first make clear that it is not intended to include the finer sediments on the lower flanks of alluvial fans, but only the coarser deposits in the upper parts. ... In many alluvial fans the constituent blocks are of extraordinary size near the apex, and sporadic blocks several feet in diameter are by no means uncommon far down the slope where the average size of the fragments may be less than an inch. ... Apart from its interest as a type of sedimentary rock the fanglomerate of Battle Mountain is significant of the existence of conditions in the far past similar to those which prevail in the Great Basin today. Those conditions are bold relief and aridity. ... Bold relief is the immediate result of acute diastrophism (Lawson, 1913, p. 328-332)."
Roberts (1964A, p. A30-A31) disagrees sharply with Lawson's concept of source and environment. He infers from Lawson's descriptions that Lawson visited localities only in the Copper Basin area where the Battle Formation does not have limestone beds. At Copper Basin the Battle consists of medium- to thick-bedded conglomerate made up of subangular to rounded chert, sandstone, and some limestone cobbles and pebbles in a silicified sandy matrix. The conglomerate is generally well bedded. Crossbedding, channeling, and similar features are rare.

Certain features of the basal part of the Battle Formation are similar to deposits in modern alluvial fans. The basal member shows poor sorting and some crossbedding (Fig. 8), current bedding, channeling, and abrupt changes in lithology. If one examines the formation on a regional basis however, a different impression results. The middle and upper parts of the Battle contain a large number of marine beds. It seems likely, therefore, that both marine and terrestrial conditions obtained during the deposition of the Battle Formation.

Rock fragments are mostly subangular to subrounded in the lower beds. Such features as channeling, current bedding, and crossbedding are present locally, but they are characteristic of only a few beds. On average, bedding is uniform and tends to be gradational without abrupt changes. Sorting is poor in the lowest beds, which were probably deposited by streams of high competence adjacent to a rugged
Left: SW dipping tabular crossbed in the Battle Formation of the Antler Peak Quadrangle. Such features are rare.

Figure 8

Above: typical conglomerate of the Battle Formation in the Antler Peak Quadrangle.
upland. Stratigraphically upward, the sorting becomes fair to good, suggesting gradually diminishing relief in the source area (Roberts, 1964A, p. A31).

Unweathered rock carried by the streams attests to rapid erosion and transport. The coarseness and angularity of the material and the relative fragility of some of the sandstone, limestone, and greenstone clasts indicates that the source area was rather close. Iron oxide cement in part of the conglomerate indicates that the climate was probably hot and humid with seasonal rainfall (Roberts, 1964A, p. A31; Krynine, 1938). These conglomerates exhibit some of the features of sedimentary rocks related to faulting (Longwell, 1937, p. 440). Roberts (1964) believes that the conglomerate was deposited on a delta plain during flood periods by streams of great carrying power. The basin in which the Battle Formation was deposited oscillated from subaerial to estuarine or marine conditions caused by crustal instability.

The Mount Lewis Quadrangle

Gilluly and Gates (1965) recognized the Battle Conglomerate as the equivalent of the Battle Formation at Antler Peak. They felt that the local name for the formation should reflect the predominantly conglomeratic nature of the deposit. Other authors have regarded strata of similar age at other localities to be Battle Formation despite the strongly predominant conglomeratic aspect of these deposits (Hotz and Willden, 1964; Ferguson et al., 1952).
In view of this, I propose that the name Battle Conglomerate be abandoned in the Mt. Lewis Quadrangle and that the name Battle Formation be adopted.

Outcrops of the Battle Formation are few and scattered in the northern Shoshone Range where most are only small erosional remnants. All exposures of the formation are above the plane of the Whiskey Canyon thrust, although not necessarily in contact with it. The Battle is a ledge forming unit that does not have an imposing topographic expression. Only two complete sections are exposed within the quadrangle. The thickest section, approximately 400 feet, lies in sec. 1, T. 29 N., R. 45 E. on the northern spur of Mt. Lewis. Another section, probably not exceeding 150 feet in thickness, is exposed along the west flank of Mt. Lewis, in secs. 10 & 11, T. 29 N., R. 45 E. The depositional base of the formation is seen at only one other locality (NE 1/4, sec. 1, T. 29 N., R. 45 E.). All other exposures of the Battle occur as erosional remnants in fault contact with younger and older rocks.

Wherever the basal contact of the Battle is depositional, the formation rests upon the Valmy Formation. The contact is a smooth but obvious unconformity with a discordance of 5 to 10 degrees. Coarse fragments of the underlying Valmy Formation are incorporated into the lower Battle. This supports the idea of a depositional contact. The Valmy Formation, however, was clearly transported into the quadrangle along the Whiskey Canyon thrust. At Having-
don Peak (sec. 10, T. 29 N., R. 46 E.) and at Bens Peak (sec. 30, T. 30 N., R. 46 E.), the Battle Formation rests in thrust contact upon Valmy Formation which is the lower plate of the Whiskey Canyon fault. Gilluly and Gates (1965, p. 124) regard the thrust at the base of the Battle (Havinddon Peak fault) as slightly younger than the Whiskey Canyon thrust.

Usually the formation is a light grey to tan, light brown and grayish orange weathering, cobble and pebble conglomerate, with occasional sandstone beds. Near the head of Horse Canyon, in secs. 10, 11, T. 29 N., R. 45 E., some mudstones and mottled red and grey marls ranging from 4 to 10 feet thick have been found. Boulders, cobbles, and pebbles range from more than 31 cm to less than one centimeter in length. Most clasts are well rounded and range between 5 centimeters and 16 centimeters in diameter, and consist of chert, quartz, quartzite, and subordinate argillite in a finer matrix of quartz, subordinate feldspar and rock fragments. The matrix is generally composed of angular to subrounded particles ranging from sand to small pebbles. Silty and shaly material comprise a negligible fraction of the rock. The conglomerate is submature.

The bedding in the Battle ranges from medium to massive, with occasional current bedding and lensing. Bedding tends to be somewhat irregular, due to weathering, erosion, or minor channeling. The conglomerate appears to be rather uniformly coarse, although it does get a little
bit finer toward the top, locally developing a shaly matrix. Sorting ranges from poor or absent to excellent. Some small pebble layers are strongly unimodal and may occasionally occur as imbrications. Cross beds are very rare, although one excellent exposure shows numerous current bedding features (Fig. 9). Other current directional features, such as flute casts, sole markings, fossils, and striations, were not found. Conglomerate layers of the formation are generally separated by irregular sandy or gritty layers which range from a few inches to a few feet thick.

The Battle Formation varies in thickness from about 50 feet to approximately 400 feet. The variable thickness may be attributed to deposition on an irregular surface. The top of the formation is somewhat abrupt, but it gives way to the Antler Peak Limestone without evidence of unconformity (Gilluly and Gates, 1965, p. 43).

Correlation of the Battle Formation of the northern Shoshone Range with the type section at Antler Peak is based on lithologic similarity and the apparent conformity with the overlying Antler Peak Limestone. The apparent conformity of the Battle with the Antler Peak in the Mt. Lewis Quadrangle suggests that the Battle Formation may be as young as Upper Pennsylvanian. However, there may be an obscure unconformity, similar to the one at Antler Peak, that separates the two formations. No fossils have been found yet in the Battle at Mt. Lewis (Gilluly and Gates, 1965, p. 44).
Current bedding in the Battle Formation, sec. 1, T. 29 N., R. 45 E., Mount Lewis Quadrangle. Exposure about 45 feet thick.

Typical conglomerate from the Battle Formation of the Mount Lewis Quadrangle.
Other Upper Paleozoic Conglomerates

Conglomerates, sandstones, quartzites, and carbonate rocks temporally equivalent to or younger than the type section of the Battle Formation at Antler Peak have been recognized at several localities in northern and central Nevada. These include the Tallman Conglomerate of the Sonoma Range (Ferguson et al., 1951; Willden, 1964; Gilluly, 1967); the Moleen and Tomera Formations of Carlin Canyon, Pine Valley, Elko, and the northern Diamond Range (Dott, 1955; Smith and Ketner, 1972); the Brock Canyon Formation of the Cortez Mountains (Gilluly and Gates, 1965; Gilluly and Masursky, 1965; Muffler, 1964); an unnamed overlap sequence in the Simpson Park Range (McKee, 1968); the Wildcat Peak Formation of the Toquima Range and its probable equivalent in the Toiyabe Range (Kay, 1965; Means, 1962; Washburn, 1968; McKee, 1973); the Garden Valley Formation of the Sulphur Springs Range (Nolan et al., 1956; Roberts et al., 1964); the Carbon Ridge Formation of the Eureka district (Nolan et al., 1956; Steele, 1960; Roberts et al., 1964); the Sunflower Formation of the Rowland and Mt. Velma Quadrangles (Coash and Hoare, 1967; Bushnell, 1967).

All of the above named formations are notably conglomeratic. Some are fossiliferous and are demonstrably the temporal equivalents of the Battle Formation at Antler Peak and elsewhere. None of these formations are assignable to the Battle Formation for two reasons: 1) they do not underlie the Antler Peak Limestone or the Etchart Lime-
stone; 2) many of these formations are isolated structurally and stratigraphically.

**Regional Sedimentary Patterns**

Orogenic and epeiorogenic activity controlled deposition in north-central and eastern Nevada during the Pennsylvanian and Permian periods. The distribution of positive and negative features are illustrated by the isopachous maps (Figures 10, 7). The principal features, which are indicated on the maps, did not exist throughout the upper Paleozoic, but they did govern sedimentation in varying degrees. The varied thicknesses and diversity of facies in the overlap assemblage, as well as unconformities of different duration, indicate an unstable environment in the Antler orogenic belt. This belt was both positive and negative with respect to sea level. Most sedimentation was confined to areas along the flanks of the Antler belt--to the east and to the west--in rather deep, elongate troughs.

Two regional unconformities are recognized, one is immediately below the Battle Formation and the other is immediately above it. These stratigraphic breaks make it impossible to evaluate the role erosion has played in altering regional sedimentary patterns as interpreted by isopach maps. Erosion must have altered seaways, basins, and positive areas as they are presently interpreted. Thrust faulting has had a similar effect.
Figure 10

Isopachous and lithofacies map of the Pennsylvanian System in Nevada.
Origin and Environment of the Battle Formation

Conglomerates of the Battle Formation may be classed as 'extraformational' and as epiclastic rudites according to the scheme of Pettijohn (1949, p. 196). Of the epiclastic rudites, only oligomictic and polymictic conglomerates are recognized in the Battle. Oligomictic conglomerates are those of simple composition; usually of only one stable, rather well sorted rock type (Pettijohn, 1949, p. 196). They are usually marine gravels related to a transgressing sea (Krumbein and Sloss, 1963, p. 164). Polymictic conglomerates are those composed of several poorly sorted metastable and stable rock fragments (Pettijohn, 1949, p. 196). These are primarily ancient alluvial or river gravels and fanglomerates. Some polymict conglomerates may be poorly sorted but lithologically homogeneous. Conglomerates of this type were derived from special source areas and deposited under conditions of rapid burial without complete sorting. They commonly form clastic wedges and were derived from tectonically active areas under conditions of fluvial transport (Krumbein and Sloss, 1963, p. 164).

Sedimentation during the time of deposition of the Battle Formation took place in a varied environment. Local basins and uplifts prevailed along the foundering axis of the Antler orogenic belt. Both positive and negative areas were locally emergent during the Pennsylvanian and Permian periods. More continuous sedimentation occurred in deposi-
tional basins to the east and west of the orogenic belt.

The varied sources and depositional environments of the Battle Formation are readily discerned at the different localities where the formation is exposed. Differences in lithology, coarseness, age, formational facies, and thickness indicates that there were at least two distinct facies of the Battle (Fig. 11). A western facies is characterized by an overwhelming proportion of coarse quartzite conglomerate; an eastern facies typically has beds of mixed lithology which were developed in several environments. Cross bedding in the western facies is absent; but is sometimes found in the eastern facies. The conglomerates of these two facies are not believed to have been continuous. Sediments were derived from the east, northeast, and west. The overall pattern of deposition of the Battle Formation was the result of intermittent tectonism and, perhaps, eustatic changes (Dott, 1966, p. 81).

Faunal differences might ordinarily indicate a time-transgressive relationship between various areas of deposition of a formation. This cannot be demonstrated for the Battle Formation on a regional basis because of a lack of evidence for mixing of the Battle facies.

The Osgood Mountains Quadrangle

The uniform lithology, coarseness, poor sorting, and wedge shape of the formation indicate a nearby eastern source for the Battle Formation in the Osgood Mountains.
Interpretive sketch showing depositional relationships of the Battle Formation.
The formation, which is derived from the Osgood Mountain Quartzite, has the characteristics of a conglomerate related to faulting. Where was the inferred eastern source of the Battle? No exposures of the Osgood Mountain Quartzite are known from east of the range; but a possible source may have been the hanging block of the Twin Canyon thrust which had a westward direction of movement. Hotz and Willden (1964, p. 70) suggest that several thousand feet of displacement would be required to explain the offset. This would provide an adequate source for several hundred feet of conglomerate.

A transgressive sea, marked by conglomerates with limestone lenses and better sorting and rounding of clasts covered the Battle Formation and brought its sedimentary cycle to a close.

The Edna Mountain Quadrangle

The Battle Formation of Edna Mountain may have had the same source as the Battle in the Osgood Mountains. The bulk of the formation is made up of fragments of the Osgood Mountain Quartzite. If the quartzite was from the Osgood Mountains, it may have been shed down the backslope of the hanging block of the Twin Canyon thrust. Longwell (1937, p. 434-437) has described such a relationship in the Virgin Mountains of southern Nevada.

The lenticular outcrops of the Battle may be the remnants of ancient distributaries that carried coarse alluvial gravels into a quiet, shallow marine environment.
The lenticularity may also be explained by dissection of an alluvial fan prior to or during the encroachment of the sea. Certainly, the area to the west on Edna Mountain was eroded during later emergence leaving no record of the Battle Formation or the Highway Limestone.

The chert may have come from two sources: the Preble Formation, and the Comus Formation. Both formations could indicate a local source, while the Preble may also indicate a western source. Chert is not common in the Preble, so it seems an unlikely source; but it is common in the Comus Formation. In sec. 14, 15, T. 35 N., R. 41 E., the overlying Highway Limestone tends to be a gritty conglomerate and coarse sandstone while limestone is characteristic elsewhere. The Battle at this locality contains much more chert than elsewhere. This suggests a local emergent area on this portion of Edna Mountain which could have provided a source of chert. Exposures of the Comus Formation are less than half a mile from the chert bearing conglomerates and sandstones of the Battle Formation and Highway Limestone.

Thrust faults may have affected the thickness and present distribution of the Battle Formation, but it does not affect the interpretation of probable source areas.

The Antler Peak Quadrangle

Field work by this writer supports the ideas of Roberts (1964, p. A31) concerning the origin and environment
of deposition of the Battle Formation. The formation was deposited in both a lateritic terrestrial environment and a deltaic to shallow marine environment. Some of the massive conglomerates of the formation are perhaps properly termed fanglomerates, but no evidence was found to support the idea of an arid environment as advanced by Lawson (1913, p. 332).

Source rocks for the Battle Formation at Battle Mountain are the Valmy, Scott Canyon, and Harmony Formations. Clasts of quartzite, chert, greenstone, and jasper were derived from the Valmy and Scott Canyon Formations. Sandstone and limestone came from the Harmony Formation. Some of the limestone may have been introduced from the Scott Canyon or as a result of sedimentary cannibalism.

A lack of sufficient current directional data prevents a quantitative determination of current direction. The geometry of the formation and the increasing proportion of quartzite and chert clasts higher in the section suggests a northeasterly or northerly source area.

The Mount Lewis Quadrangle

The Battle Formation in the northern Shoshone Range was transported into the area from the west, possibly from the vicinity of the Reese River Valley. Deposition of the formation took place in a terrestrial environment, perhaps on an alluvial fan developed by aggrading streams. The source area of the Battle may have been the same for Mt.
Lewis as it was for the Antler Peak Quadrangle.

Chert, quartzite, and sandstone clasts came from the underlying Valmy Formation. Feldspar in the rocks could have been derived from either the Harmony Formation or from the Elder Sandstone. The Harmony appears to be the most likely source because it was brought into the northern Shoshone Range along with the Valmy and Battle Formations as part of the upper plate of the Whiskey Canyon thrust. The source of the argillite in the Battle is uncertain. It may have come from either the upper plate Scott Canyon Formation of the Antler Peak area or from the lower plate Shwin Formation of the Mount Lewis Quadrangle. The Scott Canyon Formation is more likely because it is intimately associated with the formations transported into the northern Shoshone Range by the Whiskey Canyon thrust.
BIBLIOGRAPHY


APPENDIX I

Stratigraphic Section
Battle Formation
Composite Section from Antler Peak
(Secs. 28, 33, T. 32 N., R. 43 E.)

Section from Roberts (1964, p. A29), designated the type section for the Battle Formation.

Pennsylvanian:

Antler Peak Limestone: (Not described.)

Pennsylvanian:

Battle Formation: Upper member, measured 500 feet SE of Antler Peak

10. Shale, siltstone, fine sandstone; red, thin bedded. Shale layers average one-eighth to one-fourth inch thick. Upper beds are red, yellow, and brown calcareous shale. 140 feet

9. Conglomerate, light brick red. Pebbles chiefly chert, quartzite, and some limestone in a coarse sandy matrix. 98

8. Sandstone, pebbly sandstone, shale, and limy shale. Sandstone, light to dark reddish brown grading into yellow sandstone at top, thin to medium bedded, containing limy nodules and layers. Shale and limy shale, gray to yellowish, thin bedded. 20

Total thickness, upper member 258

Middle and lower members measured due E from 1/4 cor. between secs. 3 and 4, T. 31 N., R. 43 E.

Break in section.

7. Limestone, light gray with abundant fossil fragments including crinoid stems, brachiopods, and gastropods. 6
6. Conglomerate, siliceous shale, and sandstone. Siliceous shale, red, green, and gray, locally calcareous. Conglomerate, generally leached gray; massive to thick bedded. Sandstone, red, fine to coarse, in beds 2 to 24 inches thick; thin bedded near top. Sandstone grades laterally into siliceous shale, and pebbly sandstone into conglomerate.

5. Limestone, reddish gray, mottled red brown in places in medium to thick beds with wavy bedding; grades into reddish yellow shale and sandstone at base and top; contains Productus, Fusulinella, and Chaetetes.

Total thickness, middle member

4. Conglomerate and sandstone. Conglomerate, reddish brown, medium to thick bedded; pebbles and cobble chiefly gray, red, and brown chert, some quartzite; well bedded for the most part; generally good sorting. Sandstone, pale to dark reddish brown, generally thin to medium bedded; locally calcareous. Sandstone and conglomerate interfinger along the strike.

3. Conglomerate, reddish brown, thick bedded. Cobble, pebbles, and boulders of gray, green, brown, and white chert, quartzite, and sandstone. In places contains sandy partings and layers of thin bedded reddish brown and green sandstone. Generally well bedded, but not well sorted.

2. Conglomerate and sandstone. Conglomerate boulders, cobbles, and pebbles of sandstone, limestone, greenstone, chert, and quartzite. Boulders up to 3 feet in diameter, commonly angular, poorly sorted. Matrix pebbly sandstone; cement calcareous, ferruginous, and argillaceous; lenticular bedding; in places calcareous, shaly. Sandstone, reddish brown, generally well bedded; locally shows torrential cross bedding.
1. Conglomerate, medium to dark reddish brown, thick bedded to massive. Conglomerate contains boulders, cobbles, and pebbles of sandstone, quartzite, chert, limestone, and greenstone. Boulders up to 3 feet in diameter, commonly angular to subangular. Torrential cross bedding common; sorting poor except in pebble conglomerate. Matrix is reddish brown sandstone with calcareous, ferruginous, and argillaceous cement; locally contains plant fragments.

Total thickness, lower member 398 feet

Unconformity.

Base, folded strata of the Harmony Formation.

Total thickness, Battle Formation 730 feet
APPENDIX II

Stratigraphic Section

Battle Formation

North Side of Edna Mountain

(Sec. 33, T. 36 N., R. 41 E.)

Pennsylvanian:

Battle Formation:

4. Conglomerate, medium grey, grayish orange and light to dark brown, coarse grained, moderately to poorly sorted, massive; composed predominantly of subangular to subrounded quartzite pebbles and cobbles; occasional subangular chert clasts; minor irregular quartzitic sandstone and pebbly sandstone interbeds; sparse matrix of quartzose sandstone with some calcareous sandstone near the top; siliceous cement; unfossiliferous. Base gradational. 9 feet

3. Conglomerate, dark brown to maroon or gray, coarse grained, massive, poorly sorted; subangular to well rounded quartzite pebbles, cobbles and boulders; framework constitutes the bulk of the rock. Subangular to well rounded cobbles and pebbles predominate near the top; pebbles and cobbles grade downward into coarse, subangular to subrounded quartzite cobbles. The lowest portion of the section is mostly a coarse quartzite cobb conglomerate with occasional quartzite boulders; unsorted; some granule and pebble conglomerate lenses; matrix of quartzose sand and small quartzite pebbles; chert clasts rare; silicified. Strata cut by numerous quartz veins striking N 25° W, N 75° W, and N 60° E. Base obscured by talus. 55 feet

Break in section.
2. Sandstone, siltstone, shale, olive brown to brown; sandstone medium grained quartzose, well sorted, siliceous cement; grades into a light brown to pink, slightly calcareous shale above and olive brown to brown, moderately fractured siltstone below; medium to thick bedded; unfossiliferous. Base concealed.  

1. Conglomerate, maroon to brown, coarse to gritty, massive; subangular to subrounded quartzite pebbles in a quartzose sandstone matrix; fair sorting; unfossiliferous. Base of these beds, and therefore of the formation, is not exposed.

Cambrian:

Preble Formation: (Not described.)