GEOLOGY OF THE PORTUGUESE MOUNTAIN AREA,
NYE COUNTY, NEVADA

A Thesis
Presented to the
Faculty of
San Diego State College

by
Raymond P. Waldbaum
June 1970

Approved by:

A. P. Powell
Chairman
Gary L. Peterson
June 16, 1970

James E. Shellander Jr.
TABLE OF CONTENTS

LIST OF FIGURES ........................................ vi
LIST OF PLATES .......................................... vii

Chapter

I. INTRODUCTION ......................................... 1
   GENERAL STATEMENT .................................. 1
   REGIONAL SETTING .................................. 1
   PREVIOUS WORK ...................................... 8

II. STRATIGRAPHY ....................................... 10
   GENERAL STATEMENT ................................ 10
   EUREKA QUARTZITE .................................. 10
   SIMONSON DOLOMITE ................................ 14
   GUILMETTE FORMATION ............................... 19
   PILOT SHALE ........................................ 22
   JOANA LIMESTONE ................................... 24
   CHAINMAN SHALE ..................................... 25
   WINDOUS BUTTE FORMATION ......................... 27

III. STRUCTURAL GEOLOGY ............................... 31
   REGIONAL SUMMARY .................................. 31
   FOLDS ................................................ 33
   FAULTS ............................................... 34
   UNCONFORMITIES .................................... 36
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV. GEOLOGIC HISTORY</td>
<td>37</td>
</tr>
<tr>
<td>PALEOZOIC ERA</td>
<td>37</td>
</tr>
<tr>
<td>MESOZOIC ERA</td>
<td>41</td>
</tr>
<tr>
<td>CENOZOIC ERA</td>
<td>41</td>
</tr>
<tr>
<td>REFERENCES CITED</td>
<td>43</td>
</tr>
<tr>
<td>APPENDIX</td>
<td>49</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>60</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Index Map</td>
<td>2</td>
</tr>
<tr>
<td>2.</td>
<td>Major Tectonic Elements of the Cordilleran Geosyncline</td>
<td>3</td>
</tr>
<tr>
<td>3.</td>
<td>Restored Section of Paleozoic Rocks of Central Nevada Soon After Overthrusting</td>
<td>5</td>
</tr>
<tr>
<td>4.</td>
<td>Columnar Section</td>
<td>11</td>
</tr>
<tr>
<td>Plate</td>
<td>Page</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>--------------</td>
<td></td>
</tr>
<tr>
<td>I. GeoLogic Map</td>
<td>Back Pocket</td>
<td></td>
</tr>
<tr>
<td>II. Structure Sections</td>
<td>Back Pocket</td>
<td></td>
</tr>
</tbody>
</table>
ACKNOWLEDGMENTS

I acknowledge the help of my thesis committee, Dr. Anton D. Ptacek, Dr. Gary L. Peterson, and Mr. James H. Shideler, Jr., who read and constructively criticized the manuscript.
CHAPTER I

INTRODUCTION

GENERAL STATEMENT

The mountain ranges of Nevada have been studied by numerous students and other geologists with an interest in the region. As a result most reasonably accessible area have been well studied and unmapped areas are at a premium. One such area is the Pancake Range in Nye County, eighty-three miles southwest of Ely, eighty-five miles northeast of Tonopah, and 175 miles north of Las Vegas, in east-central Nevada (Figure 1).

The portion of this range lying between 38°52' and 38°37' north latitude and 115°40' and 115°56' west longitude was mapped by the writer during the summer, 1968. The periphery of the map area is accessible by jeep trails. Altitudes vary from about 5,000 feet in the valleys to a maximum of over 9,200 feet at Portuguese Mountain. Vegetation is relatively sparse and most geologic features are well exposed.

REGIONAL SETTING

The Pancake Range is in the Cordilleran miogeosynclinal (Figure 2). In the Paleozoic Era, the area
FIGURE 1. INDEX MAP
FIGURE 2. MAJOR TECTONIC ELEMENTS OF THE CORDILLERAN GEOSYNCLINE

Modified after Eardley (1962, p. 64)
underwent accumulation of limestone and dolomite with minor amounts of shale, quartzite, and conglomerate in a shallow marine environment. The miogeosynclinal sequence has a maximum thickness which exceeds 25,000 feet (King, 1959, p. 136).

East of the Wasatch Line the Paleozoic carbonate sequence is greatly thinned and incomplete. West of the miogeosyncline is the eugeosyncline which contains an assemblage of shale, immature sandstones, chert, and volcanic rocks with maximum thicknesses exceeding 50,000 feet (Roberts et al., 1958, p. 2816).

Thrust faults with displacements of at least tens of miles have occurred between eugeosynclinal, miogeosynclinal, and shelf assemblages of Paleozoic age (Figure 3). Eugeosynclinal rocks have been thrust over miogeosynclinal rocks in western and central Nevada and miogeosynclinal rocks have been thrust over thin shelf equivalents in southern Nevada and western Utah (Armstrong, 1968, p. 431).

The oldest Precambrian rocks exposed in the geosyncline are crystalline rocks that were metamorphosed about 1.5 billion years ago. They underlie miogeosynclinal rocks in Death Valley and in the shelf sections of Utah and southern Nevada (Armstrong, 1968, p. 431). Exposures of rocks this old are rare and within most of
FIGURE 3. RESTORED SECTION OF PALEOZOIC ROCKS
OF CENTRAL NEVADA
SOON AFTER OVERTHRUSTING

After Kay and Colbert (1965, p. 271)
the geosyncline no older Precambrian rocks (more than 1.0 billion years) are exposed.

According to Armstrong (1968, p. 431) thick sections of younger Precambrian sedimentary rocks unconformably overlie the older metamorphic rocks and are unconformably overlain by the Paleozoic sequence of the Cordilleran geosyncline. However, Condie (1966, pp. 633-35) stated that Precambrian and Cambrian sequences are conformable within the northeastern Great Basin.

The Lower Cambrian stratigraphic section in the miogeosyncline consists chiefly of quartzite, argillite, and scattered deposits of dolomite. In middle and Upper Cambrian time carbonate sedimentation became more widespread resulting in deposition of complexly intertongued shale and carbonate rocks which are more dolomitic toward the top (Armstrong, 1968, p. 431).

Lower Ordovician deposits consist chiefly of limestone with minor amounts of shale succeeded by a widespread, clean, white quartzite of Middle Ordovician age. The Upper Ordovician, Silurian, and Lower Devonian miogeosynclinal sequence consists almost wholly of dolomite and Upper Devonian and later Paleozoic rocks are almost exclusively limestone (Armstrong, 1968, p. 431).

Middle Paleozoic carbonate deposits, almost
totally lacking in coarse detritus, indicate an absence of related tectonic source areas, however, tectonism significantly influenced Upper Paleozoic sedimentation in the miogeosyncline.

From Late Devonian through Permain time the rising Antler Orogenic Belt shed clastic debris into the miogeosyncline from the west. Thick Mississippian through Permian limestone sequences are interbedded with sandstone, siltstone, pebble conglomerate, and minor amounts of dolomite. In the miogeosyncline marine sedimentation continued with minor interruptions until the oceans withdrew from the eastern Great Basin in Middle Triassic time.

During Jurassic time the area of thick sedimentation shifted eastward and the Cordillera was uplifted and deformed, becoming a source area which shed sediments eastward toward the Colorado Plateau through Cretaceous and Paleocene time. As a result there is a hiatus between Paleozoic deposits of the Cordilleran geosyncline and the overlying Tertiary deposits.

Tertiary rocks of the eastern Great Basin are divisible into three groups. The oldest group consists of lacustrine and fluviatile nonvolcanic continental sedimentary rocks of Paleocene and Eocene age. The middle group consists chiefly of ignimbrites of Latest
Eocene, Oligocene, and Early Miocene age. This sequence is associated with the major deformation of the region that faulted and tilted older Cenozoic rocks (Van Houten, 1956, p. 2801). The youngest group consists of a heterogenous sequence of sedimentary and volcanic rocks deposited during the development of Basin and Range structure. Tertiary volcanic rocks in the Pancake Range belong to the second group.

Throughout the Great Basin the unconformity between Paleozoic and Tertiary rocks predates the major high angle faulting which uplifted the north-south trending ranges, forming the fundamental topographic pattern of the region (Armstrong, 1968, p. 434).

In the Great Basin as a whole there is a disconformity between Paleozoic and Tertiary rocks. The angularity of the unconformity is commonly less than five degrees however locally the unconformity is distinctly angular (Cook, 1965, p. 54). This is the case in the Pancake Range.

PREVIOUS WORK

Previous work in the area includes that of Cook (1960), Brogan (1968, unpublished San Diego State College Master thesis), Dreessen (1969, unpublished San Diego State College Master thesis), and the San Diego State
College field geology class of summer 1967 who mapped in an area immediately to the north.
CHAPTER II

STRATIGRAPHY

GENERAL STATEMENT

Rocks of Ordovician, Devonian, Mississippian, and Tertiary ages are exposed in the Portuguese Mountain area of the Pancake Range (Figure 4). The oldest unit in the area is the Eureka Quartzite, of Ordovician age. The Simonson Dolomite, of Devonian age, is the next youngest and it is overlain by the Guilmette Formation, also of Devonian age. Overlying the Devonian sequence are the Pilot Shale, the Joana Limestone, and the Chainman Shale, all of Mississippian age. Middle Tertiary ignimbrites overlie the Paleozoic sedimentary rocks with distinct angular unconformity.

EUREKA QUARTZITE

The Eureka Quartzite was named by Hague (1883, p. 262) for exposures in the Eureka District of Nevada, however Hague failed to designate a type locality. Kirk (1933, p. 30) designated, as a type locality, an exposure of Eureka Quartzite on Lone Mountain, eighteen miles northwest of Eureka. Kirk was able to distinguish three members: (1) basal seventy-five feet of quartz
<table>
<thead>
<tr>
<th>System</th>
<th>Series</th>
<th>Formation</th>
<th>Thickness(ft)</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>TERTIARY</td>
<td>Oligocene</td>
<td>Windows Butte</td>
<td>2350</td>
<td>White to brown moderately welded tuffs, thickly bedded, resistant, of probable nuee ardente origin.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>unconformity,</td>
</tr>
<tr>
<td>MISSISSIPPIAN</td>
<td>Upper</td>
<td>Chairman</td>
<td>520</td>
<td>Olive-gray sandy fissile shale, with crinoid columnals.</td>
</tr>
<tr>
<td></td>
<td>Lower</td>
<td>Osage L.s.</td>
<td>47</td>
<td>contact not exposed</td>
</tr>
<tr>
<td>DEVONIAN</td>
<td>Upper</td>
<td>Pilot</td>
<td>1400</td>
<td>Thickly bedded, gray, fine grained, unfossiliferous limestone.</td>
</tr>
<tr>
<td></td>
<td>Devonian</td>
<td>Guinnette</td>
<td>1300+</td>
<td>contact not exposed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Gray, platy, calcareous shale.</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>Simonsen</td>
<td>150</td>
<td>Light-gray, fine grained, thickly bedded limestone and dolomitic limestone, chert pebble conglomerate near top. With <em>Atrypa</em> cf. <em>A. montanensis</em>, <em>Leiorynchus walcotti</em>, <em>Martinia nevadensis</em>, <em>Cyathophyllum</em> sp., and &quot;spaghetti&quot;.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>321</td>
<td>Interbedded finely laminated fine grained dolomite,&quot;spaghetti&quot; rock, mottled dolomite with <em>Spirifer pinyoensis</em>, <em>Cyrtospirifer</em> (?) sp. <em>Tabulephyllum</em> sp., unidentified ramose bryozoans.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>80</td>
<td>Fine grained dolomite pseudobrecia.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>300</td>
<td>Interbedded &quot;spaghetti&quot; rock, pseudobrecia.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cross-bedded, light gray sandstone.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fine, grained, dense, vitreous quartzite.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>base not exposed</td>
</tr>
</tbody>
</table>

**FIGURE 4. COLUMNAR SECTION**

scale: 1 in. = 500 ft.
sandy dolomite and brownish cross-bedded sandstone, (2) 150 feet of dense, vitreous, white quartzite, (3) uppermost zero to three feet of dolomitic sandstones. Webb (1956, p. 13) restricted the Eureka, at the type locality, to 181 feet of relatively pure, brownish, cross-bedded quartz sandstone and the overlying dense, white quartzites.

Middle Ordovician quartzites occur in eastern Nevada and western Utah in a linear belt whose western boundary passes approximately through Warm Springs and Eureka and whose eastern boundary passes through Las Vegas and Provo (Hintze, 1960, p. 59). The members of the Eureka Quartzite established at Lone Mountain are readily traced throughout most of this linear belt. The whole quartzite sequence can be correlated from Cortez, Nevada southward to Hot Creek, Nevada in the western part of the miogeosyncline. Webb (1958, p. 2343) reported 450 feet of Eureka Quartzite on the west flank of Roberts Creek Mountain, in the Roberts Mountains, and stated that the unit thins southward. Roberts and others (1958, p. 2830) reported 350 feet of Eureka at Cortez and Webb (1956, p. 52) reported only 132 feet in the Arrow Canyon Range.

Maximum thicknesses of Eureka Quartzite are exposed between the White Pine Range and the Thomas
Range, in the central part of the miogeosyncline. Kellog (1963, p. 685) reported 621 feet on the southern Egan Range. Webb (1956, pp. 34-69) reported 448 feet in the Lund region, 451 feet in the southern Snake Range, 467 feet at the Desert Range Experiment Station, 535 feet in Smooth Canyon and a maximum thickness of 590 in the Thomas Range. The greatest thickness reported east of the Thomas Range is 200 feet in the Tintic District, representing drastic thinning to the east (Kirk, 1933, p. 39).

The Eureka Quartzite of Lone Mountain and its time-rock correlatives throughout the Great Basin are bracketed in age by the overlying and underlying strata. At the type locality the Eureka conformably overlies the Copenhagen Formation which is no younger than Middle Trenton. Lying disconformably on the highest Eureka and equivalents are Upper Ordovician dolomites of Richmond age (Webb, 1958, p. 2368). Thus the Eureka has an age of Middle and Upper Trenton and possibly Lower Cincinnatian. Kirk (1933, p. 43) suggested a possible age correlation of the Eureka Quartzite of the Great Basin with the Harding Sandstone in Colorado.

The Eureka is present in a thrust plate in the north central part of the Portuguese Mountain area. A thickness of 300 feet was measured although neither top
nor bottom was exposed. In the study area the Eureka consists of thickly bedded, yellowish brown weathering, dense, vitreous quartzite. It is composed of well-sorted, subrounded quartz grains indurated with silica cement. This sequence of Eureka is probably equivalent to the middle member of Kirk (1933, p. 30).

**SIMONSON DOLOMITE**

The Simonson Dolomite was named by Nolan (1935, p. 19) for exposures in the Deep Creek Mountains southwest of Gold Hill, Utah. In his description of the Simonson, Nolan (1935, p. 19) wrote "The most striking feature is the very general presence of a fine lamina- tion, caused chiefly by variations in the amount of darker pigment present in the laminae and to a much less degree by variations in the grain size."

Osmond (1954, pp. 1931-54), working in the Ely area, distinguished four well-developed members in the Simonson Dolomite:

1. The basla member consisting of cliff forming homogenous, buff, coarse-grained, recrystallized dolomite.

2. The "Lower Alternating Member" consisting of alternating layers of very fine-grained dolomite and fine- to medium-grained dark gray dolomite.
3. The "Brown Cliff Member" consisting of a cliff-forming, thickly-bedded, fetid, brown dolomite characterized by its homogeneity and biostromal nature with a fauna including stromatoporoids, tabular corals, bryozoans, small gastropods, and *Stringocephalus*.

4. The uppermost member, the "Upper Alternating Member," which is similar to the Lower Alternating Member, however is more thickly bedded and less distinctly laminated.

Exposures of Simonson Dolomite occur east of Eureka and north of Hiko in east central Nevada and in westernmost Utah. The Simonson is thin along the Utah-Nevada boundary and thickens into the Confusion and Roberts Mountains Basins. Osmond (1954, p. 1948) stated that the Simonson Dolomite represents the shoreward facies of part of the Nevada Limestone of central Nevada. Westward and northwestward this rock unit passes into a predominantly clastic section and eastward it disappears.

Kellog (1963, p. 685) reported 1,061 feet of Simonson in the southern Egan Range. Langenheim and others (1960, p. 67) reported an increase in thickness of the Simonson from 1,127 feet at Gold Hill to 1,575 feet in the Cherry Creek Mountains but only 883 feet on Ward Mountain. Sharp (1942, p. 663) reported 1,900 feet of Simonson at Pearl Peak in the Ruby Mountains with
Stringocephalus 660 feet below the top. The Nevada Formation at Lone Mountain is dolomitic and the Stringocephalus zone occurs near the top. Nolan (1935, p. 19) described 963 feet of Simonson on the north side of Sevy Canyon. Other Middle Devonian dolomites and limestones occur throughout most of the Great Basin and they are generally referred to the Nevada Formation, however occasionally they are assigned local formation names. At Gold Hill three Middle Devonian formations have an aggregate thickness of 2,650 feet. In the San Francisco District, Utah, there are 1,500 feet of Middle Devonian carbonate rocks, and at Pioche, Nevada, approximately 3,000 feet (Nolan, 1943, p. 153). Thinner sections are found along the eastern border of the Great Basin. The correlative Jefferson Dolomite has a thickness of 1,200 feet in northeastern Utah, 185 feet in the Oquirrh Range, and 150 feet in the Cottonwood District (Nolan, 1943, p. 153).

The Simonson Dolomite is correlative with the upper members of the Nevada Formation east of Eureka and with the upper part of the Union Member and the Telegraph Canyon Member of the Nevada Formation in the Sulphur Springs Range. These correlative contain elements of the Stringocephalus, Helolites, Martinia kirki, and Spirifer pinyonensis faunal zones which are considered
Middle Devonian (Kellog, 1963, p. 698; Merriam, 1940, pp. 53-59; Cooper and others, 1942, p. 1773).

In the Portuguese Mountain area the Simonson Dolomite crops out in steep slopes with the overlying Guilmette Formation at the top. No complete Simonson section is exposed in the area. The basal Oxyoke Sandstone Member crops out as a dip slope in the north central part of the study area. This member consists of approximately eighty feet of brownish gray weathering, light gray, cross-bedded sandstone composed of approximately 40 percent quartz, 35 percent feldspar, 10 percent clay minerals, and 15 percent hematite, well indurated with silica cement.

The portion of the Simonson Dolomite overlying the basal member comprised approximately 1,900 feet of alternating mottled and finely laminated dolomite, dolomite pseudobreccia, and "spaghetti rock" in which three units are recognized. The lowermost unit consists of 321 feet of interbedded spaghetti rock and pseudobreccia. The spaghetti rock is a tannish gray weathering, gray, fine-grained calcitic dolomite containing gently curved, unbranched rods 2 to 3 mm. (0.1 inch) in diameter. These are presumed to be bryozoans and are similar to those referred to as Thamnopora (Osmond, 1954, p. 1950). The breccia is composed of
gray, fine grained, calcitic dolomite fragments in a matrix of tannish gray, fine-grained calcitic dolomite. The fragments are slightly less calcitic than the matrix and vary in maximum dimension from about 1 to 20 mm, the average being about 8 mm. This is judged to be a pseudobreccia of the type discussed by Osmond (1956, pp. 34-35) in which the clastic texture is caused by metasomatism failing to reach completion, rather than a true sedimentary breccia.

The middle unit in the Simonson Dolomite in the study area consists of 150 feet of pseudobreccia of the type discussed above. The uppermost unit is variable in lithology and thickness across the Portuguese Mountain area. In the north central part of the area it consists of finely laminated, fine-grained brown and tannish gray dolomite to which the term "Zebra rock" is applied. The zebra rock has a maximum measured thickness of 287 feet, however the base is not exposed. In the southern part of the area, including Portuguese Mountain, the uppermost unit consists of massive, coarse-grained, grayish brown, calcitic dolomite, thickly bedded spaghetti rock, and three to five foot-thick interbeds of zebra rock and mottled dolomite with an exposed thickness of over 1,300 feet. This unit contained a poorly preserved, silicified fauna including the brachiopods *Spirifer pinyonensis*. 
and Cyrtospirifer (?) sp., the coral Tabulophyllum sp. and unidentified bryozoans.

The mottled dolomite in the Simonson consists of irregular masses of white crystalline dolomite in a matrix of dark, finer-grained dolomite. The white masses are 0.5 to 1.5 inches wide and one to several inches long. This mottled dolomite is similar to the "Mackarel dolomite" described by Sharp (1942, p. 662) in the lower part of the Nevada Formation of the Ruby Mountains, Nevada. It is also similar to the "Roiled dolomite" described by Osmond (1956, p. 38) in the Simonson of the Ely area. Osmond (1956, p. 38) attributed the roiled type of dolomite to two factors: "These are alternating laminae of two varieties of carbonate sediment with contrasting colors and intrastratal soft rock deformation referred to as rolling." These factors combine to create an intermingling of irregular bodies of the two types of sediment. In the cases studied they are both dolomite.

GUIMETTE FORMATION

The Guilmette Formation was named by Nolan (1935, p. 20) for exposures in Sevy Canyon on the west side of the Deep Creek Mountains in the Gold Hill District, Utah. At the type locality "The Guilmette Formation is composed
chiefly of dolomite but contains also some thick limestone beds and several lenticular sandstones" (Nolan, 1935, p. 20). The rocks of the type area constitute a distinctly dolomitic facies in contrast to the predominance of limestone in the Guilmette Formation throughout most of the Great Basin (Langenheim and others, 1960, p. 67). The Guilmette occurs in an area of east central Nevada extending north approximately to Gold Hill, west to Eureka, south to Lund, and east to the Utah line, thickening toward the south. The Guilmette is 888 feet thick at the type locality (Nolan, 1935, p. 21). It thickens to about 1,600 feet in the Cherry Creek Mountains and consists of interbedded fine-grained gray limestone and nodular argillaceous limestone with interbeds of sandstone and calcareous siltstone.

In the southern Egan Range the Guilmette varies in thickness from 1,250 to 1,900 feet (Kellogg, 1963, p. 685). On Ward Mountain at Willow about 2,500 feet of Guilmette are exposed (Langenheim and others, 1960, p. 68).

South of Lund the West Range Limestone is said to be a facies equivalent to the uppermost Guilmette Formation (Langenheim and others, 1960, p. 68). The lower part of the Guilmette is lithologically and stratigraphically correlative with the Meister Member of
the Devils Gate Limestone which is considered to be Middle to Upper Devonian (Senican) (Kellog, 1963, p. 700).

The Guilmette Formation is exposed in discontinuous outcrops throughout most of the Portuguese Mountain area. Most commonly it forms the upper portions of cliffs and steep dip slopes inclined to the east. The contact with the underlying Simonson Dolomite was placed below the first massive cliff-forming limestone unit which commonly coincided with the first appearance of stromotoporids. The presence of "spaghetti" is continuous into the Guilmette. The brachiopods *Atrypa* (?) sp., *A. cf. A. montanensis*, *Leiorhynchus walcotti*, *Martinia nevadensis*, the coral *Cyathophyllum* sp., an unidentified gastropod, and unidentified bryozoans were collected from the Guilmette.

In the study area the Guilmette consists most typically of resistant, fine-grained, blueish gray to light brown weathering, light gray, massive limestone with thick interbeds of fine-grained, gray dolomite. Near fault zones it is intensely fractured and the fractures are filled with sparry calcite. Calcite rhombs nearly one foot long were collected from fault zones in the Guilmette. A lens of green chert pebble conglomerate, probably derived from the Vinini Formation to the west, is present in the Guilmette in the north central part of
the study area. A maximum of 1,400 feet of Guilmette was measured about four miles northeast of Portuguese Mountain, however the top is not exposed.

PILOT SHALE

Several formational names have been suggested for rocks of Mississippian age in the Great Basin. The term White Pine Shale was proposed by Hague (1883, pp. 266-268) for Mississippian rocks in the White Pine District, Nevada. Spencer (1917, p. 26) divided White Pine correlatives in the Ely District into three formations, in ascending order: Pilot Shale, Joana Limestone, and Chainman Shale. Easton and others (1953, p. 149) recognized "... The utility of Spencer's formations" but stated that "... It is preferable to call them members because it seems impossible to differentiate the Pilot Shale from the Chainman Shale in localities where the intervening Joana Limestone is absent." For this reason they suggest that three members be recognized in the White Pine Shale: the Pilot Shale Member, the Joana Limestone Member, and the Chainman Shale Member. This suggestion did not gain wide acceptance and the Pilot, Joana, and Chainman are generally considered separate formations today.

The Pilot Shale was named by Spencer (1917, p. 26)
for exposures at Pilot Knob in the western part of the Ely Quadrangle. Spencer (1917, p. 26) described the Pilot Shale as "... Made up of soft, highly carbonaceous shales, varying in color from drab to nearly black," and reported a maximum thickness of 400 feet at the type locality. The Pilot Shale typically forms relatively nonresistant benches between cliffs of Guilmette Formation and Joana Limestone. The Pilot is reportedly absent in the Gold Hill, Cherry Creek, Lund, and Cave Valley areas, in the Arrow Canyon Range, Mormon Mountains, and the Duckwater area (Langenheim and others, 1960, p. 71). Rock types at this stratigraphic level vary greatly between localities. As a result there is confusion concerning the character of the Pilot and its age has not been established with certainty. Nolan and others (1956, p. 52) reported that the Pilot Shale ranges in thickness from 315 to 1,000 feet at localities in eastern Nevada. The Pilot is correlative with the lower part of the White Pine Shale and with the Bristol Pass Limestone and is tentatively assigned to the Late Kinderhook (Langenheim and others, 1960, p. 73).

The Pilot consists of fissile calcareous shale with interbedded siltstone and limestone. The limestones are thicker in the lower part and the contact with the underlying Guilmette Formation is considered to be at
the top of the last massive limestone of the Guilmette. The contact with the overlying Joana Limestone is well defined at most localities (Clark and Becker, 1960, p. 1663), however in the Portuguese Mountain area this contact is not exposed. In the Portuguese Mountain area the Pilot Shale consists of about fifty feet of platy, tannish gray weathering, gray, calcareous shale with neither the base nor the top exposed.

JOANA LIMESTONE

The Joana Limestone was named by Spencer (1917, p. 26) for the type locality at the Joana Mine, on the south side of Robinson Canyon in the Ely District. At the type area the Joana consists of "... Massive uniformly bluish-gray beds which in a few places contain nodules of chert," with a maximum thickness of 400 feet near Pilot Knob (Spencer, 1917, p. 26). The Joana occurs in most of the mountain ranges in east central Nevada. Exposures are known as far west as the Pancake Range, as far east as the Utah line, as far north as the Ruby Mountains, and as far south as Sunnyside. It thins over the Ely Arch in the vicinity of Ely and it also thins westward toward the Antler Orogenic Belt. It thickens southward and a maximum 980 feet is present in the Pioche Basin in the vicinity of Sunnyside and Pioche (Langenheim,
Near Eureka the Joana is coarse-grained and clastic with thicknesses varying from 84 to 135 feet (Nolan and others, 1956, p. 55). The Joana thins and pinches out a short distance northwest of Eureka (Roberts and others, 1958, p. 2838). In the southern Egan Range the Joana Limestone consists of 670 to 705 feet of medium gray, thinly to thickly bedded limestone, crinoidal in part (Kellogg, 1963, p. 703). The Joana is correlative with the middle part of the White Pine Shale and with the Peers Spring Formation and is assigned to the Osage (Langenheim, 1960, p. 73).

In the Portuguese Mountain area the Joana Limestone consists of 147 feet of light brown to light gray weathering, medium gray, fine grained, unfossiliferous limestone. It protrudes through the alluvium of Little Smokey Valley in the northwest part of the area and neither its top nor bottom is exposed.

CHAINMAN SHALE

The Chainman Shale was named by Spencer (1917, p. 26) for exposures at the Chainman Mine, near Lane. At the type locality it consists of soft, fissile, clay shales grading locally into sandy shale (Spencer, 1917, p. 26).

The Chainman is a clastic wedge deposit shed
toward the east from the Antler Orogenic Belt. It occurs in "... A broad belt covering the eastern half of Nevada and the western one-fifth of Utah" (Sadlick, 1960, p. 86). The belt extends northward to the Idaho state line and southward into Death Valley, California. The Chairman thickens westward from a minimum of about 1,800 feet in the Confusion Range to about 7,600 feet in the Diamond Range (Sadlick, 1960, p. 81). Sadlick and Schaeffer (1959, p. 1786) distinguished four facies in the Chairman. In ascending order they are: (1) a lower clastic facies which rests unconformably on folded older rocks and thins northward from 530 feet at Pioche, Nevada to 215 feet in the Confusion Range, (2) a carbonate facies which thickens eastward, (3) a shale sequence which thickens northward, and (4) an eastward thinning clastic facies.

Kellog (1963, p. 703) reported a maximum thickness of 1,001 feet for the Chairman in the southern Egan Range. There it is composed of a lower portion of medium brown to gray varicolored mudstone and platy shale and an upper portion of black, fissile shale that becomes olive gray toward the top.

The Chairman Shale is exposed in the northwest part of the Portuguese Mountain area in the east limb of a syncline bordering Little Smokey Valley. Here it
consists of about 520 feet of reddish brown to tan weathering, olive gray, sandy, fissile shale. The lower contact with the Joana Limestone is concealed beneath alluvium and the upper part of the Chainman is overlain with angular unconformity by younger Tertiary volcanic rocks.

WINDOUS BUTTE FORMATION

The Portuguese Mountain area is in the Great Basin Ignimbrite Province which extends from Winnemucca, Nevada south nearly to Las Vegas and from central Utah west to Death Valley (Cook, 1960, p. 134). Most of the ignimbrites in the Great Basin are in the rhyodacitic composition range and are composed chiefly of welded tuffs. They range in thickness from zero to 2,000 feet and some have areal extents of up to 10,000 square miles.

Cook's (1960, p. 134) usage of the term ignimbrite is adopted by the writer. It means "... A nonsorted pyroclastic deposit of probable Pelean or nuee ardente origin." The term nuee ardente is used in accordance with Cook (1960) and Dolgoff (1963) who use it to designate "... Any eruptive phenomenon involving a turbulent gas cloud and/or pyroclastic flow" (Dolgoff, 1963, p. 877).

A nuee ardente is a volcanic phenomenon
intermediate between an explosive pyroclastic eruption in which magma is disrupted by sudden and violent expansion of gases, and a lava flow in which dissolved gases escape without disrupting the magma. According to most authors a nueé ardente is characterized by a fiery, turbulent, expanding gas cloud containing glass shards, crystals, drops of magma, and lithic fragments ripped from the fissure or group of fissures producing the eruption.

The characteristics of Great Basin ignimbrites supports the nueé ardente theory of origin. Their vast aerial extent indicates great mobility, their pyroclastic textures indicate expanding gases, and their welding precludes simple air-fall origin.

Approximately two-thirds of the Portuguese Mountain area is covered with ignimbrites. Cook (1965, p. 15) assigned these rocks to the Windous Butte Formation and estimated that thickness of the Formation does not exceed 2,000 feet in the Pancake Range. The Windous Butte in the Grant Range has a K-A age of 34 million years (Oligocene)(Cook, 1960, p. 139).

The writer was able to distinguish sixteen units within the volcanic sequence and they are considered to be members of the Windous Butte Formation. They are most commonly exposed individually or, at best, in a
succession of two or three units. Consequently stratigraphic relations have been determined for only seven of the units. Petrographic descriptions of these units appear in Appendix.

Typically the ignimbrites in the study area are light colored, moderately welded, acidic tuffs. They are assigned rock names according to the ratio of alkali feldspar to plagioclase. Ignimbrites in which alkali feldspar constitutes less than one-third of the total feldspar are called dacite. Ones in which alkali feldspar constitutes one-third to two-thirds of the total feldspar are called rhyodacite. The name rhyolite is applied to ignimbrites in which alkali feldspar constitutes more than two-thirds of the total feldspar.

Most of the ignimbrites in the Portuguese Mountain area are in the rhyodacitic to dacitic composition range and are composed of approximately 40 percent crystals and 60 percent vitric groundmass and vitroclastic fragments. The minerals occurring most commonly as phenocrysts are plagioclase, quartz, sanidine, and biotite. Occurring in lesser amounts are orthopyroxene, clinopyroxene, zircon, and magnetite. Although some of the members depart widely from the mean mineral composition of the Windous Butte Formation as a whole, most of the members tend to have approximately the same
proportion of minerals occurring as phenocrysts. The following mineralogical composition is typical of the Windous Butte as exposed in the study area: plagioclase, 35 percent; quartz, 30 percent; sanidine, 16 percent; biotite, 16 percent; and minor accessory minerals, 3 percent. The plagioclase in most of the units is zoned and twinned and has a mean composition of approximately An_{11}. The quartz grains are large and angular and form the most prominent phenocrysts. The sanidine occurs as subhedral grains. The biotite is molded by welding and compaction and in most members is partially altered. The groundmass contains compressed glass shards and lithic fragments.
The Portuguese Mountain area is situated in the Basin and Range Province which is characterized by north-south trending ranges, separated by broad valleys. The ranges have complex internal structures of Mesozoic and Tertiary age including folds, some of which are overturned, overthrusts, and high-angle faults. The range fronts have formed along several parallel faults of late Tertiary age producing a series of en echelon scarps. The ranges consist of tilted fault blocks which are commonly broken into smaller parallel blocks, upthrown on the same side and tilted in the same direction as the ranges as a whole. This creates a step like profile which may continue below the valleys. The deepest part of the valleys are parallel and adjacent to the highest part of the ranges.

A structural feature characteristic of many ranges in east central Nevada is low-angle faulting emplacing younger rocks over older. The age and origin of these faults are a subject of controversy at the present time. Misch (1960, pp. 37-39) visualized a
Mesozoic (probably early Cretaceous) deformation in the Great Basin as being due to decollement thrusting in which Paleozoic rocks overrode the basement. Within the Great Basin there is a trend toward upward increasing structural simplicity in Paleozoic rocks above a major decollement. The reverse relationship is said to hold for Paleozoic rocks below a decollement (Misch, 1960, p. 38). Harris (1959, pp. 2646, 2649) suggested that uplift of the Sevier Arch created major folds which developed into belts of structural weakness and by means of late Tertiary gravity faulting caused younger rocks to be emplaced over older in the Great Basin. Younger over older thrusting has also been attributed to a combination of decollement and gravity faulting occurring from Jurassic through late Tertiary time (Moores and others, 1968, p. 1718).

Block faulting, uplifting the present ranges, is visualized as the final phase of Great Basin deformation. The theories which have been advanced to explain the block faulting of the ranges of the province in late Tertiary time fall into two categories: (1) theories based on regional tension, and (2) theories based on regional compression. The Great Basin is, at the present time, a topographic high, having risen approximately 3,000 feet since Oligocene time (Osmond, 1960, p. 261).
Tension arising from this epeirogeny may have resulted in adjustment by high-angle faulting, producing the ranges. Longwell (1950, p. 432) attributed this Tertiary deformation to the collapse of an arch following transfer to the surface of subcrustal igneous material, causing compressional forces in the crust.

FOLDS

The dominant structural feature of the Portuguese Mountain area is a south plunging syncline indicated by outcrops of the Simonson Dolomite and Guilmette Formation dipping toward the east in the western part of the area and west dipping Guilmette Formation in the east part of the area (Plate II). The Devonian rocks are exposed in discontinuous blocks as the overlying Tertiary volcanic rocks have been only partially removed by erosion. Due to the thick cover of volcanic rocks the axis of the syncline cannot be precisely located.

The distribution of Devonian rocks which is suggestive of a syncline may also be due to a younger over older thrust. Field relationships do not preclude either hypothesis. Minor folding has been superposed on the broad synclinal structure.

The dominant structural feature of the area to the north is an eastward-overturned, south plunging
syncline involving rocks of Mississippian through Permian age (Brogan, unpublished M.S. thesis, San Diego State College, p. 50). The synclines mapped by Brogan and the writer both plunge south and may be the same structure however their common axial plane trace is displaced by approximately five miles of left-lateral movement. South of the study area rocks of Ordovician through Devonian age are exposed in an eastward-inclined fault block which appears to be part of the west limb of the syncline to the north (Dreessen, 1969, personal comm.).

In the northwest part of the study area an overturned sequence of Joana Limestone and Chainman Shale is exposed. It appears to be part of the west limb of an eastward-overturned syncline which has been faulted into the study area by displacement in a right-lateral sense relative to the area to the north.

FAULTS

The southern boundary of the Portuguese Mountain area is delimited by a high-angle fault inclined toward the north. At the northern boundary of the area the axis of the major syncline is displaced approximately five miles in a left-lateral sense by the action of Faults A and B (Plate I). Right-lateral displacement of
approximately three miles occurred on Fault A. Left-lateral displacement of approximately eight miles occurred on Fault B. The net effect of these movements was a five mile separation of the northern and southern portions of the syncline and movement to the west of the intervening block. A high-angle normal fault separates the west front of the range from Little Smokey Valley with its trace marked by a zone of jasperoid alteration. Faulting is not suggested along the east front of the range bounding Railroad Valley.

In the north central part to the Portuguese Mountain area the Eureka Quartzite has overridden the Guilmette Formation, providing evidence of older over younger thrusting in the Pancake Range. Older over younger thrusting is reported by Misch (1960, pp. 23, 38) in the Schell Creek Range, northern Snake Range, northern Egan Range, and east Humbolt Range and in these areas the deformed Paleozoic rocks rest on an exposed decollement thrust.

In the west limb of the major syncline the Devonian sequence is partially repeated several times by north-south trending high-angle faults. This set of faults offsets and truncates a set of older northeast to east-west trending faults in the Devonian rocks throughout much of the area. Minor faults are common in the
Palaeozoic carbonate and Tertiary volcanic terrain.

UNCONFORMITIES

No unconformities are known to be present in the Palaeozoic section in the study area. In the area there is an angular unconformity between the Palaeozoic and Tertiary rocks. The angularity of the unconformity is greatest in the northwest part of the area where Chainman Shale with near-vertical dips is overlain by volcanic rocks with a maximum dip of $12^\circ$ to the east. Within the major syncline Tertiary volcanic rocks are also folded and the angularity of the unconformity does not exceed $10^\circ$. 
Exposures of Paleozoic rocks in the Portuguese Mountain area are limited to the Ordovician, Devonian, and Mississippian systems. However the study area, in conjunction with adjoining areas to the north and south, provides a record of Paleozoic sedimentation from Ordovician through Permian time.

During Cambrian time the miogeosyncline subsided and a maximum of 8,000 feet of carbonate rocks, sandstone, and shale were deposited in it (Osmond, 1960, p. 254). This sequence thins abruptly east of the Wasatch Line and becomes more cherty and argillaceous toward the west. Deposits of Middle Cambrian through Upper Mississippian age are divisible into a predominantly carbonate miogeosynclinal facies in western Utah and eastern Nevada and a thicker volcanic and cherty eugeosynclinal facies in central and western Nevada.

In Ordovician time the western facies accumulated up to 25,000 feet of black graptolitic shales, thick sandstones similar to the Eureka Quartzite, bedded chert, and volcanic rocks, i.e., Vinnini Formation (Osmond,
During early Ordovician time the miogeosyncline was subsiding slowly and contained a shallow sea in which the Eureka was deposited. Middle and Upper Trenton transgressions of this sea developed the Eureka Quartzite across beveled formations from central Utah to central Nevada. The source of the fine and even grained, pure quartz Eureka is said to be emerged Swan Peak Sandstone on the cratonal edge (Webb, 1958, pp. 2372-2376). Kirk (1933, p. 42) stated that the widespread occurrence of cross-bedding and ripple marks and the lack of fossils in the Eureka are suggestive of shallow water and emergent conditions. The Eureka may represent reworking, under shallow water conditions, of an already relatively pure quartz sandstone by a shifting strand line.

Deposition of an eastern and western facies continued through Silurian time however deposits of this age are thinner at many localities than those of other periods. The Silurian section is not exposed in the study area, however to the south dolomite of the Laketown Formation is exposed.

The varied dolomites of the Simonson Formation comprise the next youngest unit in the Portuguese Mountain area and reflect a continuation of carbonate deposition in the eastern facies through Devonian time.
Work by Moore (1929) and Elias (1937) has established certain Paleozoic fossils as indicators of water depth, water temperature, bottom material, and current intensity. Their conclusions were used by the writer in interpreting fossil material. The Simonson fauna is representative of a warm, shallow sea. The Guilmette Formation also contains a warm, shallow water fauna, indicating that the rate of deposition in the miogeosyncline was in close accord with the rate of subsidence. Gray and green chert pebble lenses in the Guilmette of the Portuguese Mountain area indicate a beginning of deformation in the Antler Orogenic Belt to the west.

The Antler Orogenic Belt rose to considerable height during Mississippian time and was deeply eroded. Clastic material eroded from the orogenic belt was deposited in the eastern and western facies as well as in small basins within the belt. The western facies deposits of Mississippian age include chert, immature sandstones, conglomerates, pyroclastic rocks and andesitic flows. In the eastern assemblage shales predominate with minor limestone and chert pebble conglomerate. The Lower Mississippian Pilot Shale occurs in the study area and represents the change from carbonate to predominantly clastic deposition in the miogeosyncline. The overlying Joana Limestone, also of
Lower Mississippian age, represents a temporary return to carbonate deposition. The Joana is unfossiliferous in the study area, however at other localities in eastern Nevada it contains abundant crinoid columnals. Stalked crinoids lived only at depths sufficient to avoid destructive agitation by waves. Presence of abundant short sections of columnals and absence of complete dorsal cups in the Joana indicates that waves or currents were sufficiently strong to disarticulate crinoids after death.

The Middle Mississippian Chainman Shale represents a resumption of clastic wedge deposition in the miogeosyncline in response to the continuing deformation and uplift of the Antler Orogenic Belt. North of the study area the Chainman contains chert pebbles like those in the Guilmette in the study area. Similar pebbles are present in abundance in the Scotty Wash Quartzite (Upper Mississippian), Diamond Peak Quartzite (Upper Mississippian), and Ely Limestone (Upper Mississippian to Lower Pennsylvanian) north of the study area (Brogan, 1968, oral commun.). These pebbles can be matched lithologically with the Vinnini Formation (Ordovician) to the west. The presence of these pebbles in some, but not all, formations of Devonian through Pennsylvanian age indicates that the Antler Orogenic Belt
was rising in pulses and shedding coarse debris intermittently.

MESOZOIC ERA

Locally in the western miogeosyncline marine sedimentation was continuous through Triassic or earliest Jurassic time. In Jurassic time the western miogeosyncline was uplifted and became a source area, shedding sediments onto the eastern edge of the miogeosyncline and the Colorado Plateau during Jurassic and earliest Cretaceous time. In Early Cretaceous time the eastern miogeosyncline was uplifted (Sevier Orogenic Belt) and became a source area shedding sediments eastward into the Rocky Mountain geosyncline (Armstrong, 1968, p. 432). By latest Cretaceous time deformation had ceased in the Sevier Orogenic belt and the Laramide Orogeny had begun to the east. In the Pancake Range a phase of deformation post-dates the Paleozoic sequence and pre-dates the Tertiary volcanic rocks however the specific age of deformation is not known.

CENOZOIC ERA

Laramide deformation was most intense during Paleocene and Lower Eocene time and had ceased by the Middle Eocene. Thus, orogeny moved eastward across the
miogeosyncline through time. Following deposition of the early Tertiary sediments volcanic activity began in the Great Basin Ignimbrite Province, producing an extensive blanket of pyroclastic rocks over the region. These rocks were deposited unconformably on deformed older rocks with high relief. The ignimbrites may represent transfer to the surface of a comparable thickness of magma, causing some faulting during volcanism. However, the major phase of Tertiary deformation which created the present Basin and Range structure and topography post-dates the ignimbrite sequence.
REFERENCES CITED
REFERENCES CITED


and Schaeffer, F. E., 1959, Dating of an Antler Orogenic phase (Middle Mississippian) in western Utah (Abs.): Geol. Soc. America Bull., v. 70, no. 8, p. 1786.


PETROGRAPHIC DESCRIPTIONS OF MEMBERS WITHIN THE WINDOUS BUTTE FORMATION

Members of Known Stratigraphic Position

**Member Tv₁**

Partially welded rhyodacitic crystal vitric tuff. Light gray on fresh surface, weathers gray, moderately resistant, 100+ feet thick, forms cliffs and dip slopes in east central part of study area. In thin section: crystals 40%, fresh, subhedral, elongate crystals aligned. Plagioclase (45%, An₁₈, up to 0.10 in., twinned, zoned), sanidine (30%, 0.08 in., resorbed, with inclusions of plagioclase), quartz (25%, 0.08 to 0.25 in., deeply embayed, shattered, fractures and embayments filled with partially devitrified glass), biotite (10%, up to 0.08 in., deep reddish brown to greenish brown), trace hypersthene and magnetite. Groundmass 60%, largely devitrified, with lenticular vitroclastic fragments up to 0.5 in.

**Member Tv₂**

Welded dacitic vitric crystal tuff. Gray on fresh surface, weathers dark gray, relatively large aerial extent in east central part of study area,
resistant, 15 feet thick. In thin section: crystals 30%, fresh, subhedral, shattered. Plagioclase (50%, An_{12}, 0.03 to 0.1 in., twinned, zoned, shattered, slightly embayed), quartz (20%, 0.05 in., shattered, deeply embayed), sanidine (15%, 0.05 to 0.1 in., slightly embayed), biotite (15%, 0.1 in., light brown to light green). Groundmass 70%, partially devitrified, with compressed vitric fragments.

**Member Tv_{3}**

Slightly welded rhyodacitic crystal vitric tuff. Light maroon of fresh surface weathers tannish gray to light brown, hard and resistant, approximately 50 feet thick, forms ridges and cliffs in east-central and northeast part of study area. In thin section: crystals 50%, poorly aligned, subhedral, fresh, resorbed. Sanidine (35%, 0.03 to 0.10 in., subhedral, resorbed edges, with inclusions of devitrified glass, biotite and plagioclase in larger crystals), plagioclase (30%, An_{15}, 0.02 to 0.05 in., twinned and zoned, occurs as phenocrysts and inclusions in sanidine, subhedral, resorbed edges), quartz (20%, 0.05 to 0.30 in., euhedral to subhedral, resorbed, fractured), biotite (10%, 0.07 in., green and brown, partially altered to chlorite, as phenocrysts and inclusions in sanidine). Groundmass,
50%, largely devitrified.

Member Tv₄

Partially welded rhyodacitic crystal vitric tuff. Medium gray on fresh surface, weathers brownish gray, crops out in east-central part of study area as lens with maximum thickness of approximately 15 feet. In thin section: crystals 50%, fresh, anhedral to subhedral. Quartz (50%, 0.05 to 0.20 in., embayed, as inclusions in glass shards and pumice), plagioclase (20%, An₄, 0.08 in., twinned, zoned, larger crystals embayed), sanidine (15%, 0.05 in., embayed), biotite (15%, 0.05 to 0.10 in., dark brown). Groundmass 50% glassy, largely devitrified, with vitroclastic fragments to 0.50 in.

Member Tv₅a

Partially welded rhyodacitic vitric crystal tuff. Light chocolate brown of fresh surface, weathers medium to dark brown, approximately 400 feet thick, forms hills throughout the northern one-half of the study area. In thin section: crystals 40%, fresh, euohedral to subhedral. Quartz (45%, 0.01 to 0.15 in., some large crystals deeply embayed and/or shattered), plagioclase (25%, An₈, 0.03 to 0.1 in., zoned, twinned, larger crystals intensely shattered), sanidine (15%, 0.04 in., euohedral to subhedral), biotite (15%, 0.03 to 0.10 in., reddish brown to
greenish brown). Groundmass glassy, largely devitrified into radially arranged crystallites.

**Member Tv₅ᵇ**

Welded rhyodacitic crystal vitric tuff. White to light gray on fresh surface, weathers dark brown, approximately 150 feet thick, forms resistant hill tops overlying member Tv₅ᵃ in southeastern part of study area. In this section: crystals 50%, subhedral to anhedral, intensely fractured. Quartz (40%, 0.03 to 0.15 in., shattered, larger crystals slightly embayed), plagioclase (30%, 0.03 to 0.05 in., zoned, twinned, shattered, cavities filled with glass), sanidine (25%, 0.03 to 0.1 in.), biotite (5%, 0.04 in., light brown, altering to chlorite). Groundmass white, glassy, largely devitrified.

**Member Tv₆**

Welded rhyodacitic crystal vitric tuff. Light gray to light tan on fresh surface, weathers light pinkish-gray, moderately resistant, approximately 150 feet thick, forms ridges and dip slopes on the east central part of the study area. In this section: crystals 50%, subhedral, fresh, embayed. Quartz (45%, 0.04 to 0.15 in., anhedral to subhedral, embayed, as
phenocrysts and inclusions in vitroclastic particles), plagioclase (25%, $\text{An}_{12}$, up to 0.10 in., zoned, twinned, embayed), sanidine (20%, up to 0.10 in., with inclusions of quartz), biotite (10%, 0.01 to 0.10 in., reddish brown to very dark brown, some longer grains bent). Trace magnetite. Groundmass largely devitrified into radial-fiberous crystallites, with vitroclastic fragments up to 0.40 in.

**Member Tv 7**

Welded quartz porphyry. Yellowish tan on fresh and weathered surfaces, soft and friable, approximately 20 feet thick, occurs as pods in northwest part of study area. In thin section: crystals 40%, subhedral, fresh, segregated into bands in groundmass. Quartz (70%, subhedral, resorbed, 0.05 to 0.10 in., larger crystals slightly fractured), sanidine (10%, 0.07 in., subhedral, larger crystals slightly resorbed), plagioclase (10%, twinned, zoned, 0.05 in.), biotite (10%, dark reddish brown, 0.05 in.). Groundmass glassy with pumice fragments 0.25 to 1.0 in., lithic fragments 0.15 in.

**Members of Unknown Stratigraphic Position**

**Member Tv 8**

Welded dacitic crystal vitric tuff. Grayish
brown on fresh surface, weathers tan to grayish brown, approximately 50 feet thick, forms low hill in north-central part of study area. In thin section: crystals 50%, fresh, euhedral to subhedral, largely resorbed, fractured. Plagioclase (40%, An<sub>10</sub>, 0.20 in., twinned, zoned, deeply embayed, some large crystals shattered), quartz (25%, 0.10 to 0.15 in., shattered and resorbed, embayments filled with partially devitrified glass, some grains with thick halos of same devitrified glass), sanidine (20%, 0.03 to 0.07 in., embayed, with vitroclastic inclusions), biotite (15%, 0.03 to 0.08 in., brown to greenish brown, altering to chlorite). Groundmass glassy, partially devitrified, with lithic fragments up to 0.25 in.

**Member Tv<sub>9</sub>**

Slightly welded dacitic vitric crystal tuff. Purplish gray on fresh surface, weathers brownish gray to maroon, hard and resistant, approximately 50 feet thick, forms small hill in north-central part of study area. In thin section: crystals 30%, partially altered, shattered, euhedral to subhedral. Plagioclase (60%, An<sub>8</sub>, 0.03 to 0.10 in., zoned, twinned, high fractured, with inclusions of biotite), biotite (25%, 0.01 to 0.02 in., reddish brown to green, resorbed, fractured,
altering to chlorite), quartz (15%, 0.08 in., fractured, resorbed), trace magnetite. Groundmass glassy, largely devitrified, altering.

**Member Tvd12**

Unwelded dacitic crystal tuff. Medium gray on fresh surface, weathers chocolate brown, approximately 100 feet thick, forms moderately steep ridges at two localities in the northeast part of the study area. In thin section: crystals 30%, euhedral to subhedral, fresh. Plagioclase (75%, An8, 0.03 to 0.08 in., as intergrowths of euhedral to subhedral crystals, twinned, zoned, resorbed, cavities filled with glass), clinopyroxene (15%, 0.1 in., anhedral, resorbed, cavities filled with glass and groundmass), hypersthene (10%, 0.07 in., resorbed, cavities filled with glass). Groundmass gray microcrystalline plagioclase, with opaque crystallites and vitric clasts 0.05 to 0.1 in.

**Member Tvd13**

Welded rhyolitic crystal vitric tuff. Light maroon on fresh surface, weathers darker maroon, approximately 100 feet thick, soft and nonresistant, forms gentle slopes in east-central part of study area. In thin section: crystal 70%, subhedral to anhedral,
parallel alignment of elongate grains, fresh, resorbed. Quartz (50%, 0.03 to 0.10 in., unfractured, deeply embayed, cavities filled with glass), sanidine (30%, 0.1 in.), plagioclase (15%, An3, 0.02 to 0.1 in., zoned, twinned, larger grains shattered), biotite (5%, 0.05 in., brown, largely altered. Groundmass vitroclastic, pumice fragments molded around crystals.

**Member Tv14**

Alternating thin beds of gray, green, white, and red tuffs, moderately resistant, approximately 250 feet thick, cliffy outcrops form northeast front of range, most thinly bedded volcanic unit in study area.

**Member Tv15**

Welded rhyodacitic crystal tuff. Dark gray on fresh surface with gray lithic fragments, weathers light chocolate brown, approximately 150 feet thick, forms resistant outcrops in northern part of study area. In thin section: crystals 20%, quartz (45%, 0.08 to 0.15 in., resorbed, larger crystals shattered), plagioclase (30%, An25, 0.03 to 0.15 in., zoned, twinned, slightly resorbed), sanidine (15%, 0.05 in., subhedral, very slightly resorbed), clinopyroxene (5%, 0.03 in.). Groundmass microcrystalline with vitroclastic fragments to 0.25 in.
Member Tv\textsubscript{17}

Welded vitric biotite porphyry. Maroon on fresh surface weathers reddish tan. Moderately resistant, 400 feet plus thick, forms low hills in south-central part of study area. In thin section: crystals 10\%, biotite (100\%, 0.1 in., altered). Groundmass glassy with laminations of elongate glass shards and rectangular vitroelastic fragments.

Member Tv\textsubscript{18}

Welded rhyodacitic vitric crystal tuff. Mottled fresh surface, white bodies 0.5 to 1.0 in. in maroon matrix, weathers light reddish tan, moderately resistant, crops out in west front of range south of Portuguese Mountain, no bedding apparent, thickness unknown. In thin section: crystals 20\%, moderately fresh, euhedral to anhedral, oriented. Plagioclase (50\%, 0.03 to 0.1 in., some larger crystals embayed, twinned, zoned), sanidine (25\%, 0.1 in., subhedral, embayed), biotite (25\%, 0.03 in., dark green to dark brown, altered, strongly aligned). Groundmass glassy, alternating laminae of devitrified and undeitrified glass, with vitroelastic fragments up to 1.0 in.
Member T\textsubscript{V20}

Slightly welded crystal vitric tuff. Tannish white on fresh surface, weathers very light tan, weathered surface appears "pock marked" due to weathering out of phenocrysts, moderately resistant ridge former in southeast part of study area. In thin section: crystals 65\%, well sorted, subhedral to anhedral, feldspars with dusty alteration coating. Plagioclase (40\%, 0.07 in., zoned, altering to clay), quartz (60\%, 0.07 to 0.1 in., embayed), trace magnetite, zircon. Groundmass 35, glassy, with vitric clasts, 0.1 in.
ABSTRACT
ABSTRACT

Approximately 4,300 feet of Ordovician, Devonian, and Mississippian rocks crop out in the Portuguese Mountain area of the Pancake Range. The Ordovician is represented by mature sandstones, the Devonian by carbonate rocks, and the Mississippian by clastic rocks with minor carbonates. Most of the contacts between formations are not exposed.

The structure of most of the area is interpreted as a gently folded syncline. This structure is inferred from outcrops of Devonian rocks which dip east in the western part of the area and dip west in the eastern part of the area. An alternative explanation is that the Devonian rocks have been emplaced by younger over older thrusting. Field relationships do not preclude either hypothesis. In the west limb of the suggested syncline the section is repeated by high-angle faulting. In the northwest part of the area rocks of Mississippian age are exposed in a possible eastward-overturned syncline which is thought to be related to a similar fold known in the area to the north. The Ordovician quartzite is exposed above a Devonian limestone in a fault block in the central part of the area as a result of older over younger thrusting.
The area was in the Cordilleran miogeosyncline during Paleozoic time. Carbonate deposition was predominant through the Devonian. In Mississippian time the Antler Orogenic Belt, to the west of the Portuguese Mountain area, shed a clastic wedge eastward into the miogeosyncline. Sedimentation is known to have continuous locally in the Great Basin through Triassic or earliest Jurassic time, however in the Portuguese Mountain area no Paleozoic rocks younger than Mississippian are exposed. A Mesozoic deformation folded the Paleozoic rocks in the area.

In Oligocene time the area received deposits of pyroclastic rocks, primarily welded rhyodacitic to dacitic tuffs of nueé ardente origin. A late Tertiary deformation produced the north-south trending ranges which now characterize the Basin and Range Province.
GEOLOGY OF THE PORTUGUESE MOUNTAIN AREA, NYE COUNTY, NEVADA

WALDBAUM 1970