

NEVADA BUREAU OF MINES

Vernon E. Scheid, Director

BULLETIN 68

GEOLOGY OF THE MOUNT VELMA QUADRANGLE, ELKO COUNTY, NEVADA

By

JOHN R. COASH

With a section on the fauna of the Sunflower Formation

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RICHARD D. HOARE



MACKAY SCHOOL OF MINES
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STATE OF NEVADA
PAUL LAXALT, *Governor*



UNIVERSITY OF NEVADA
CHARLES J. ARMSTRONG, *President*



NEVADA BUREAU OF MINES
NEVADA MINING ANALYTICAL LABORATORY
VERNON E. SCHEID, *Director*
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GEOLOGY OF THE MOUNT VELMA QUADRANGLE, ELKO COUNTY, NEVADA

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ABSTRACT

Rocks exposed in the Mount Velma quadrangle are chiefly Cenozoic volcanic rocks and several sedimentary formations which apparently belong to the "overlap assemblage" of the upper Paleozoic in north-central Nevada. Beds of volcanic and sedimentary origin of Triassic(?) Age lie between these in the south-central part of the quadrangle. In the northern part of the quadrangle, the "overlap assemblage" lies upon probable lower Paleozoic sediments belonging to the "eastern assemblage," but in one locality upon cherts of the "western assemblage." Late Cretaceous(?) intrusions were followed by uplift and erosion during the early

Cenozoic. Extensive coarse gravels underlie volcanic rocks which were extruded during at least two periods in the middle or late Cenozoic. The volcanic rocks exhibit strong folding in the northern part of the quadrangle. The folding was accompanied or followed by normal faulting. A prominent set of northwest-trending normal faults (parallel to the major basins and ranges of the region) with a strike-slip component cuts the area. Partially consolidated gravels in terraces show some effects of faulting and tilting. These are now being incised by streams well adjusted to lithology and structure.

INTRODUCTION

LOCATION

The Mount Velma quadrangle lies in the northern part of Elko County, Nevada, about 20 miles south of the Idaho-Nevada border (see fig. 1). The quadrangle is bounded by meridians $115^{\circ}30'$ and $115^{\circ}45'$, and by parallels $41^{\circ}30'$ and $41^{\circ}45'$.

The northern part of the quadrangle lies within the Humboldt National Forest. The remainder of the area is public domain, under the Taylor Grazing Act, or privately owned land, used chiefly for stock grazing. The area is accessible by paved road from Elko, Nev., and by good gravel road from Mountain Home, Idaho via Mountain City, Nev. A good gravel road, connecting with Nevada Highway 43 from Elko at the Wildhorse Reservoir, enters the quadrangle in sec. 26, T. 44 N., R. 55 E. This road crosses the northwestern corner of the quadrangle to the Gold Creek Ranger Station, which is just off the map in sec. 32, T. 45 N., R. 56 E. There is a good public camp at the ranger station. Another good gravel road crosses the southern part of the quadrangle (see fig. 1), connecting Highway 43 on the west with the road from Deeth to Jarbidge on the east.

Within the map area numerous old roads, in varying states of use and passability, may be found. Most of these are accessible by car during the summer months, but a vehicle with four-wheel drive is essential in places. Washouts are common, and rains during the early summer often make the less-used routes impassable. As the vegetation is sparse, many hillsides and ridgetops can be traveled by four-wheel drive vehicle, depending upon the underlying bedrock. Ridges composed of volcanic rocks, thick-bedded limestones, or quartzites may cause trouble due to scattered boulders on the surface, but where sandstones and shales underlie the surface, travel is usually easy. During the winter months most of the country is snowed in, and only one or two main roads may be passable.

In general outline the area is bounded by the Bruneau River on the east; by the more or less open route along creek beds of the Charleston road on the south; by the Wildhorse Basin on the west, through which Highway 43 travels; and very irregularly on the north by an area of rough mountains and steep-sided valleys. East of the Bruneau River lie the high and rugged Jarbidge Mountains. To the south, low, lava-covered hills extend all the way to Elko. On the west, the Independence and Bull Run (Centennial) Mountains rise prominently. To the north, the irregular topography passes beneath the lava plain.

PREVIOUS WORK

No previous work has been published dealing with the geology of the Mount Velma quadrangle. F. C. Schrader (1912 and 1923) published material on the Jarbidge mining district to the northeast. He does give a brief discussion of the Charleston district which lies along the eastern border of the Mount Velma quadrangle, but he quotes N. W. Sweetser and Frank Erno regarding the geology of this area, and confines his own discussion to the mining operations and the volcanic rocks of the Jarbidge district. Gianella and Prince (1944), Lincoln (1923), Vanderburg (1936), Whitehill (1875 and 1877), and York and Ferguson (1944) all mention mining districts in the area.

Reconnaissance maps of adjacent areas were published by Emmons (1910) for the area to the south and west, and by Schrader (1923) for the area to the northeast. An unpublished report of Nolan (1937) includes a geologic map of the Mountain City area. Decker (1962) has mapped the geology of the southern Bull Run (Centennial) Mountains southwest of Mountain City (see fig. 1), and both Nolan and Decker refer to an unpublished report on the geology of the Mountain City quadrangle by E. C. Stephens in the files of the

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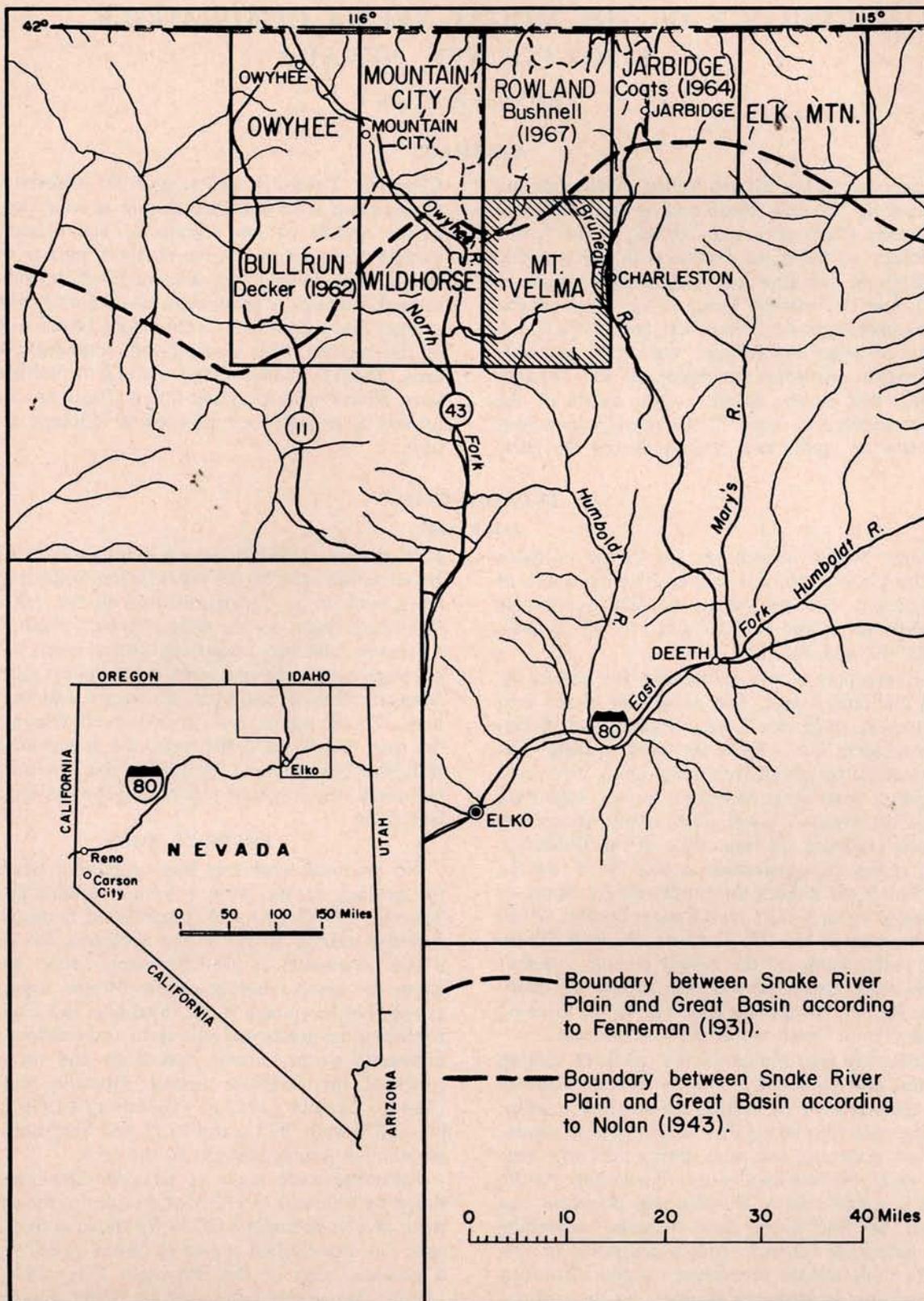


Figure 1. Map showing location of the Mount Velma and adjacent quadrangles and geographic features in the vicinity.

Anaconda Mining Co. Bushnell (1967) describes the adjacent Rowland quadrangle. Many of these and other papers on Elko County are summarized together with maps by Granger and others (1957). Robert R. Coats of the U. S. Geological Survey has mapped the Jarbidge quadrangle (Coats, 1964), and is presently mapping the adjacent Mountain City and Owyhee quadrangles (see fig. 1). The quadrangle is also covered by aerial photographs of the U. S. Soil Conservation Service.

Several reports are available on adjacent regions. Map IV of the Atlas accompanying the report of the U. S. Geological Exploration of the 40th Parallel (King, 1876) covers the region immediately to the south of the Mount Velma quadrangle. The northern boundary of this map is just south of the southern border of the Mount Velma quadrangle. The next adjacent reports cover areas over 100 miles distant from the quadrangle. These include Sharp's (1939) work in the Ruby-East Humboldt Range, Ross's (1934) report on the Wood River district and vicinity in southern Idaho, Dott's (1955) work near Elko, Lovejoy's (1959) report on Lone Mountain, and recent U. S. Geological Survey publications on other north-central Nevada areas.

FIELD WORK AND ACKNOWLEDGMENTS

The study of the Mount Velma quadrangle was undertaken originally as part of the requirement for the Ph.D. degree at Yale University. Field work was done in the summers of 1952 and 1953. The writer is indebted to the geology faculty of Yale University for making available a Hewett grant which covered the field expenses during the 1952 season. Some further work

was done in connection with the summer field camps from Bowling Green State University in 1953, 1956, 1957, and 1958. Completion of the quadrangle was made possible by support from the Nevada Bureau of Mines in the summer of 1957. Since that time continuing work on the Paleozoic fossils has been underway by Richard D. Hoare of Bowling Green State University, who is responsible for that section of this paper.

Special thanks are due to Chester R. Longwell of Yale University and the U. S. Geological Survey, who has been advisor on the work and who has contributed to the solution of many problems, and to Kent Bushnell of Yale University and the Standard Oil Co. of Calif., who assisted greatly in the field and in later consultation. Thanks are also due to other members of the staff at Yale University who have given advice; to numerous local residents, especially Jerry Horton and M. Richard King, the rangers at the Gold Creek ranger station; to Robert R. Coats, James Gilluly, Preston Hotz, Thomas B. Nolan, and Ralph J. Roberts of the U. S. Geological Survey for advice on adjacent areas in northern Nevada; to Helen Duncan and her associates at the U. S. National Museum for assistance in fossil identification; to E. R. W. Neale of the Canadian Geological Survey, Willard H. Parsons of Wayne State University, and M. S. Lougheed of Bowling Green State University for assistance with thin sections of the igneous rocks; to Joseph Lintz of the Mackay School of Mines, University of Nevada; to Nancy Cobble, Alice Schwarz, Dale Courtney, Michael Werner, and the writer's wife, Emily, all of whom assisted in the preparation of the manuscript; and to all who permitted quotations which are acknowledged in the paper.

GEOGRAPHY

The Mount Velma quadrangle is considered by the Forest Service (Roy Kuehner, oral communication, 1952) to lie in the intermountain semidesert country. The Humboldt National Forest is a watershed and grazing area rather than a timbered country. There is little timber, other than scattered aspen patches, except at higher altitudes in surrounding mountain ranges. The dominant vegetation is the bunchgrass and sagebrush association. Almost without exception in the Mount Velma area, the hilltops are bare and bedrock is exposed. However, most outcrops tend to blend into the brown grass and brush.

The climate of the area is generally similar to that of the surrounding region. Summer days are warm and generally dry, but the nights are cold and frost is not uncommon. The winters are long; snow begins to

accumulate at higher altitudes in October, and remains in protected spots during most of the summer. Precipitation is slightly greater than in either the lava plateau to the north or the basin-and-range country to the south. Springs are fairly abundant and several streams are permanent.

Thus, under proper management, the country can support large numbers of grazing stock. Most of the stock is brought in for the summer grazing only, and is moved to the south during the winter months. However, small ranches are able to grow sufficient feed crops along the main streams to keep small herds during the winter. Mining operations are second in importance, although this has not always been the case. The mining history of the area is discussed in a later section of the paper.

GEOMORPHOLOGY

The Mount Velma quadrangle lies on the northern limit of the Basin and Range province as defined by Fenneman (1931) (see fig. 1). However, it would seem that Nolan (1943) was more nearly correct for

this area when he arbitrarily placed the northern boundary of the Basin and Range province along the Nevada-Idaho boundary, for the flat-lying lavas of the adjacent lava plain do lie some 10 miles to the north, just south

of the Idaho border. Volcanic rocks are present over much of the quadrangle, but these rocks are broken by faults in a pattern very similar to that of the Basin and Range province. Although the normal faulting, which is the cause of typical basin-and-range topography, is present, the upthrown blocks here have not been lifted as high as in many of the ranges to the south; the border faults are more numerous, thus tending to reduce the topographic effect as compared to a single great border escarpment; and the effects of the additional complexities of structure and lithology tend to obscure the basin-and-range topography.

The major feature of the quadrangle is a northwest-trending uplifted block. A series of steps, parallel to the general trend, occur on both sides of the central part of the block. Mount Velma itself (also known locally as Haystack Mountain and shown thus on the map) lies in the central and highest part of the block (see pl. 1). A steep escarpment with maximum relief of 1,600 feet (in less than half a mile) borders the block on the southwestern side; the relief is less on the northeastern side. Strong headward erosion by the streams on the steep west face seems to be pushing the divide eastward. The Haystack Mountain block is composed primarily of steeply dipping sedimentary rocks which strike southwestward, diagonally across the block; folded volcanic rocks occur north of Thompson Creek. Mount Ichabod, south of Haystack Mountain, is composed mainly of quartzite, and is an uplifted block with faults on both sides.

The relief in the quadrangle is not as great as in adjacent areas. Haystack Mountain has an altitude of 8,200 feet, while the Copper, Independence, and Jarbidge Mountains rise to 10,000 feet and more. Bench marks record altitudes of 6,331 feet in the northwestern part of the quadrangle, 6,320 in the southwestern part, and 6,118 to 5,719 feet along the Bruneau River in the eastern part.

Two major drainage systems meet along a very irregular divide in the region. The general outlines of the main streams appear in figure 1. Of the south-flowing system, only the North Fork of the Humboldt River and a major tributary, Beaver Creek, which drains the southern part of the Mount Velma quadrangle, are of interest. Both are part of the interior drainage system of the northern Great Basin.

Beaver Creek heads in the south-central part of the Mount Velma quadrangle (see pl. 1). The stream flows entirely in volcanic rocks, at least within the quadrangle. The West Fork of Beaver Creek is especially interesting as an illustration of fault control. The headward part of the creek from sec. 21, T. 43 N., R. 56 E. southward to the P. Elia ranch runs parallel to a mapped fault 1.5 miles to the northeast and to a dissected fault scarp about 2 miles to the southwest, and so appears to follow another member of the set.

The north-flowing streams head well to the south of the drainage limits of these south-flowing streams. The

Bruneau River, which forms a natural boundary close to the eastern part of the Mount Velma (Haystack Mountain) block, heads some 15 miles south of the northern limit of the North Fork and Beaver Creek. The East Fork of the Owyhee River heads in a low divide in the Wildhorse Basin, very close to the southwestern corner of the Mount Velma quadrangle. A major tributary of the East Fork of the Owyhee River, Penrod Creek, flows southwestward across the northwestern corner of the Mount Velma quadrangle.

The area is highly dissected. Drainage patterns vary locally, as rock structure and lithology effectively control the stream courses. Fault control of the stream courses is astonishingly dominant. The example of Beaver Creek has already been cited. Other examples would include the course and changes of course of Hay Meadow Creek and the positions of some of its tributaries, especially on the east side; the stream which is a tributary to Dolly Creek on the eastern side of the north end of Haystack Mountain; the abrupt change of course of Gold Creek near Fuzzie Spring; and the position of Rosebud and Cornwall Creeks.

Lithologic boundaries also serve as stream controls. Coleman and Hammond Canyons, in the northwestern part of the quadrangle, serve as prime examples, following closely the borders of a small stock. The upper part of Thompson Creek, a tributary to Hay Meadow Creek northwest of Haystack Mountain, follows the boundary between volcanic and sedimentary rocks. The upper part of Williams Creek, which heads opposite the north fork of Thompson Creek, follows the upturned, folded volcanic layers.

Thus, it is apparent that the streams of the area are well adjusted to lithology and structure. This adjustment is almost certainly postvolcanic. Only major streams such as the Bruneau, Humboldt, and Owyhee Rivers could have survived the outpouring of lavas and pyroclastics during the mid-Cenozoic. Even if these streams were antecedent, evidence points to a northern source for prevolcanic gravels, which would necessitate considerable rearrangement of the present stream pattern for reconstruction of the earlier pattern. Fenneman (1931, p. 234) states that the Snake River across southern Idaho is a consequent stream, although antecedent elsewhere to several structural and topographic features. The north-flowing drainage system in this area is tributary to the Snake River.

The implication is still present that much of the faulting and other disturbance in the area is not extremely recent, as considerable time would be required to achieve this remarkable adjustment. However, all of the valleys are V-shaped, indicating a youthful stage of development. Locally some streams meander a bit, as does Penrod Creek just west of the quadrangle, and small flood plain deposits are evident. In addition, it is apparent that much of the volcanic cover on the uplifted blocks has been removed by erosion. Yet there is also the possibility that some of the valleys are partially

filled and are now being eroded again. And the lower course of Gold Creek appears to be along an extremely recent fault scarp.

There is no evidence of glaciation within the mapped area. The valley fill, such as the partially cemented gravel which is incised 3 to 6 feet in places along Hay

Meadow Creek, might be related to proglacial drainage, or to slight changes in elevation during recent times. The fill nowhere shows direct signs of glaciation.

Ground-water solution in limestone has been slightly active in the area. Solution pits may be seen on the hill in sec. 35, T. 45 N., R. 55 E. *

Table 1. Stratigraphic section for the Mount Velma quadrangle and vicinity.

Age	Formation	Thickness (feet)	Description	
Cenozoic	Alluvium	0-135	Unconsolidated stream gravels	
	Terrace gravels	0-60+	Partially consolidated stream gravels	
	Volcanic rocks	3,500±	Rhyolitic tuffs and flows	gray upper member
				white lower member
Prevolcanic gravels	0-75	Irregular gravels, with chert, quartzite, and granite pebbles to boulders		
Tr.(?)	Triassic(?) Formation	1,000-4,000±	Thin-bedded, yellow volcanic(?) ash, with chert and limestone	
Permian	Poorman Peak Formation	3,100±	Black mudstones and dark cherts, with crinoidal limestones and fine conglomerates	
	Hammond Canyon Formation	1,960-2,500±	Thin-bedded limestones, with interbedded chert laminae	
	Sunflower Formation	Upper sandstone member	1,460-2,000±	Fine-grained, micaceous sandstone and siltstone, with thin silty limestones; basal ash bed
		Middle limestone member	296-530	Clastic limestone, gray, locally very fossiliferous (crinoidal)
		Lower conglomerate member	100-1,910	Quartzite- and chert-pebble conglomerate, with beds of quartzitic and friable sandstone
Lower(?) Paleozoic	Tennessee Mountain Formation		Interbedded limestone and shale, partially metamorphosed	
	Prospect Mt. (?) Quartzite	960-3,000	Light-brown to gray, bedded quartzite with schistose partings	

DESCRIPTIVE GEOLOGY

SEDIMENTARY ROCKS

The following quotation from the abstract of the paper by Roberts and others (1958) will serve as a framework for the descriptive material:

"Eastern Nevada differs greatly in stratigraphy and structural history from the western part. In eastern Nevada . . . the Paleozoic rocks from Middle Cambrian to Upper Mississippian are mostly limestone and dolomite with minor amounts of shale and quartzite. In central and western Nevada the correlative strata are predominantly clastic sedimentary rocks and chert, with intercalated volcanic rocks and pyroclastics. . . The

eastern assemblage is miogeosynclinal, the western, eugeosynclinal. The two have been brought into contact by telescoping along a thrust fault of great magnitude—the Roberts Mountains thrust—which carried the western assemblage relatively eastward or southeastward over the eastern assemblage . . . in Late Devonian or Early Mississippian time (Antler Orogeny). From an emerged area . . . coarse clastic rocks were deposited both eastward and westward; these grade laterally into finer sediments and limestone of normal marine facies. In the orogenic belt the sediments that were deposited on the deformed strata . . . are designated the

overlap assemblage. Orogenic movements continued along the belt in Pennsylvanian and Permian time, and throughout the Mesozoic, probably into Cretaceous time, causing further deformation of the previously folded and thrust-faulted rocks and of the sediments of the overlap assemblage as well."

The sedimentary rocks in the Mount Velma quadrangle include a wide variety of lithologic types that range in age from lower Paleozoic(?) to Cenozoic (see table 1). Coats (1964, p. 5) indicates the presence of probable Precambrian rocks along Copper Creek in the northeastern part of the quadrangle. The sedimentary rocks are fairly well exposed, although they do not stand out in bold relief as is common in many of the Great Basin ranges to the south. However, a large part of the area is covered by volcanic rocks which obscure the underlying sedimentary rocks. Furthermore, the sedimentary rocks, often together with the overlying volcanic rocks, are very complexly faulted and folded, so that even where the sedimentary rocks are exposed it is extremely difficult to find anything resembling a complete section of any given formation. To add to the difficulties, fossils are very rare in the rocks of this area. Only a few limestone beds within one formation (Sunflower Formation) contain abundant fossils. Many of the specimens obtained are so crushed or distorted as to make positive identification impossible. Finally, few of the fossils found and identified are useful for positive age determination.

As has been pointed out, very little work has been done in this region, therefore, any correlations made of sedimentary sections must be over long distances. The combination of varying lithologies, complex structure, and lack of fossils makes positive correlations with sections such as those at Battle Mountain, Eureka, or the Wood River area impossible without detailed studies of the intervening country. Correlation is made with Bushnell's (1967) section in the adjacent Rowland quadrangle wherever possible, but there are only a few such correlations possible as the parts of the total section exposed in the two quadrangles differ greatly. Some suggestions are made regarding correlation with Decker's (1962) section in the Bull Run quadrangle. Robert Coats of the U. S. Geological Survey has recently mapped the Jarbidge quadrangle (Coats, 1964) and is currently mapping the Mountain City and Owyhee quadrangles, and it seems advisable to leave to him the correlations to be made through this intervening area. Dott's (1955, 1958) work on the Pennsylvanian near Carlin and Elko provides further possibilities for correlation of part of the section.

Several new formation names are proposed. Except for the Sunflower Formation, these are meant to be provisional, and are given only for the sake of clarity in the present paper. The writer feels that if future work provides correlation with established sections, then the local names may be abandoned. If not, then some of

these will need further definition before becoming permanent.

The color designations used in the descriptions which follow are based upon the Rock Color Chart, published and distributed by the National Research Council (1948). The number in parentheses after each color designation is that given in the chart, which is based upon the Munsell color system. The grain-size designations used in the descriptions are those indicated in the Suggested Classification of Detrital Particles of the Committee on Sedimentation, National Research Council (1942).

Prospect Mountain(?) Quartzite

Thick sections of quartzite have been described by Coats (1964) in the Jarbidge quadrangle, and by Bushnell (1967) in the Rowland quadrangle, and in both cases have been provisionally correlated with the basal Cambrian Prospect Mountain Quartzite of eastern and central Nevada. That correlation is accepted for outcrops of the same unit in the northeastern part of the Mount Velma quadrangle, and for other quartzite outcrops elsewhere in the quadrangle on the basis of lithologic similarity and stratigraphic position.

The Prospect Mountain(?) Quartzite near the St. Elmo mine strikes N. 5° W. and dips about 20° W. The exposure measures 620 feet, but the section is not complete; Bushnell (1967) describes 2,000 to 3,000 feet in the southern part of the Rowland quadrangle. The quartzite is light brown (5 YR 6/4) to very light gray (N 8). The beds range from one-quarter inch to 10 feet in thickness; they are nearly pure quartz and have an even, sugary texture. The weathered surface is generally some shade of gray, locally tinged with brown. Many of the bedding surfaces have a lustrous appearance, and some beds are separated by thin schistose partings. The rock apparently was originally a very pure quartz sandstone with shale partings, and has undergone low-grade metamorphism. No fossils have been found in the formation. The quartzite is an excellent cliff maker, being extremely hard and resistant to weathering. The bedding and partings make small cliffs and benches, the height of the cliff depending upon the thickness of the quartzite bed.

Near the St. Elmo mine, a schist bed, about 340 feet thick, occurs as an interbed in the quartzite. The schist is gray olive green (5 GY 3/2) to grayish olive (10 Y 4/2). Small pyrite cubes are abundant in the weathered rock.

Similar schist interbeds are found in the northeastern part of the quadrangle in the southern end of the Copper Mountains. Here the quartzite and schist are apparently unconformably overlain by beds of Early Mississippian Age. The quartzite exposed on Mount Ichabod and Mason Mountain is more massive, and there are few schistose partings. On Mount Ichabod, the prospect Mountain(?) Quartzite is unconformably

overlain by the Sunflower Formation. No overlying beds were observed on Mason Mountain. The base of the Prospect Mountain(?) Quartzite is not exposed in the Mount Velma quadrangle.

Paleozoic Chert and Shale

On the southeastern slope of Cornwall Mountain in sec. 3, T. 44 N., R. 56 E., the Sunflower Formation rests unconformably upon a small body of chert and shale. The beds are gray brown (5 YR 3/2), and show slight metamorphism. About 200 feet of section is exposed in a slide area near the foot of the slope. There are no fossils present, but their lithology suggests that they belong to the western assemblage of lower Paleozoic rocks (Roberts and others, 1958, p. 2854).

Similar chert and shale have been noted by R. J. Roberts (oral communication, 1957) northwest of Mountain City, Nev., where they form part of an allochthonous block in thrust contact with carbonate rocks of the eastern assemblage; as this is the sole thrust of the western assemblage, it is presumed that the thrust is the northward extension of the Roberts Mountains thrust. The chert and shale unit on Cornwall Mountain is in normal fault contact with the Prospect Mountain(?) Quartzite on the east, and therefore, it cannot be proved that it rests on a thrust fault. No other explanation has been suggested to account for the western assemblage rocks in this area.

Tennessee Mountain Formation

The Tennessee Mountain Formation was provisionally defined by the author (unpublished Ph.D. thesis, Yale University, 1954) in reference to a thick sequence of highly deformed, interbedded limestone and argillaceous rocks on the southwest flank of Tennessee Mountain in the southwest part of the Rowland quadrangle. The formation has been further defined by Bushnell (1967) in connection with the mapping of the Rowland quadrangle. Bushnell assigns the formation to the Cambrian or Ordovician systems and points out similarities with other rocks belonging to the eastern assemblage, lower Paleozoic rocks. The formation does not crop out in the Mount Velma quadrangle, but is mentioned here as it will be discussed later (see Geologic History and Structure).

Paleozoic Rocks, Undifferentiated

Rocks of Paleozoic age are found in the northeastern corner of the Mount Velma quadrangle, southeast of the Copper Mountains. Time has not permitted detailed mapping of this area which seems more closely allied to the area eastward, so these rocks are mapped simply as Paleozoic, undifferentiated. However, the Hammond Canyon and Sunflower Formations are known to be present. Also, a collection by Coats (written communication) from sec. 11, T. 44 N., R. 57 E. contained Late Mississippian (Meramec) conodonts according to W. H. Hass (written communication, 1958).

Sunflower Formation

The Sunflower Formation is here defined and named for the Sunflower Reservoir which lies at the southern extremity of Sunflower Flat, a large open basin in the southwestern corner of the Rowland quadrangle. The best exposures are in the line of hills extending eastward from Jenkins Peaks, in the southeastern corner of the Mountain City quadrangle, along the southern border of the Rowland quadrangle as far as the valley of Big Bend Creek and southward into the Mount Velma quadrangle. The beds dip very steeply, and commonly are vertical or overturned. The rocks at either end of this line of hills are considerably disturbed, but elsewhere the beds are offset only by minor cross faults. The strike is generally slightly north of west. The oldest beds lie on the northern side of the hills. A total thickness of nearly 4,000 feet was measured at this locality. The thickness is generally less at other places.

Other exposures of the Sunflower Formation are seen on Cornwall Mountain in secs. 3 and 10, T. 44 N., R. 56 E.; along the southern side of Penrod Creek and Hay Meadow Creek in sec. 25, T. 44 N., R. 55 E.; in several small patches east and north of Cornwall Mountain; in the hills and slopes between Cornwall Mountain and the Gold Creek Ranger Station; and on the slopes north of the Ranger Station; and on the northern part of Mount Ichabod in secs. 14, 23, and 24, T. 43 N., R. 56 E. The Cornwall Mountain exposure is the best after those at the Sunflower Reservoir.

The formation varies a great deal in thickness, but the lithology is fairly constant over the area. The formation is divided into three members: a lower conglomerate, a middle limestone, and an upper sandstone. Correlation of the members within the area is made on the basis of fossils, lithology, and stratigraphic position in the sequence.

Lower conglomerate member

The basal member of the Sunflower Formation is quartzite- and chert-pebble conglomerate for the most part, but also includes beds of quartzitic or friable sandstone. (The term quartzite, or quartzitic, is used here to indicate rocks composed of quartz fragments, so tightly packed or cemented that the rock breaks across the grains rather than around the grains.) Two sections were measured in the hills south of the Sunflower Reservoir.

The following section was measured across the hill southeast of the Sunflower Reservoir, in sec. 36, T. 45 N., R. 55 E. (extending into the Rowland quadrangle):

	Thickness of unit (feet)	Total feet to base
Conglomerate, partly covered.....	200	1,910
Conglomerate, coarse, quartzitic.....	820	1,710
Conglomerate(?), covered.....	160	890
Conglomerate, quartzitic.....	80	730
Conglomerate and sandstone, partly covered..	320	650
Sandstone, with local interbeds of quartzitic conglomerate.....	330	330

The base of the section is covered, but the bottom of the sandstone bed at the bottom of the exposure is probably within 20 feet of the base. The thickness given is a minimum.

The rocks characteristically weather brownish gray (5 YR 4/1) or grayish red (10 R 5/2). Also helpful in the field is the distinction in the lichen growth on the rock surface. The conglomerate beds are commonly covered with a black lichen while the overlying limestones bear a lichen that is red or sometimes yellow; bedded cherts higher in the section, which also weather dark red, have yellow or gray lichen. On a fresh surface, the sandstone beds are light brown (5 YR 6/5); the more quartzitic sandstones and fine conglomerates range from grayish orange (10 YR 7/4) to yellowish gray (5 YR 7/2); and coarser conglomerates have a matrix similar to the latter, but the enclosed pebbles and cobbles vary considerably in color from medium dark gray (N 4) to very light gray (N 8) for the quartzites and from brownish gray (5 YR 4/1) to grayish red (10 R 4/2) for the chert.

Bedding within the conglomerate member is well defined in all but the coarsest strata, and individual beds in the area south of Sunflower Reservoir can be traced for as much as half a mile with little change in grain size, sorting, or roundness. Crossbedding or lenticular beds are not present. In some beds the size sorting is exceptionally good, especially in two or three thick beds composed almost entirely of very small pebbles. Almost all pebbles are well rounded. Elongate or flattened grains or pebbles tend to lie parallel with the bedding planes.

Near the base of the section sandstone beds are the most abundant. In each bed grains vary slightly in size, sorting, roundness, and composition. One of the sandstone layers very near the base of the section may be considered as typical of the sandstones. It consists of well-sorted, subrounded, medium sand grains which are about 95 percent white (N 9) quartz. The sandstones are exceptionally clean, and, following Gilbert (Williams and others, 1954, pp. 289-290), would be called an arenite. The grains in many of the beds are more angular, especially in some of the pebble conglomerates.

The pebble conglomerates, many of which are quartzitic, contain a large percentage of chert. In these beds there is generally a sand matrix, fine-grained and subangular. Embedded in this matrix, but commonly so tightly packed that there is very little matrix, are rounded pebbles of chert and quartzite. Little cementing is seen in the thin sections, nor do the sand grains and the pebbles show any secondary quartz enlargement. The grains do not show straining either. In the coarsest beds in the upper part of the section, cobbles as large as 8 by 5 by 3½ inches are found in beds up to 20 feet thick.

In the east wall of the valley between the two hills in the southeastern corner of sec. 36, T. 45 N., R. 55 E., an exposure in the ditch cut shows a filled channel

about 2 feet wide and a few inches deep in the conglomerate beds. The channel now stands on edge as the beds here are nearly vertical, but the channel shows that bottom of the beds lie to the north. This channel is the only direct evidence of top and bottom found in this member.

The other section was measured in the hills south of the Sunflower Flat and Reservoir, across the northern side of 7260 hill, in sec. 35, T. 45 N., R. 55 E., in the Rowland quadrangle. Here the lower part of the section is concealed, but the top of the member is well exposed, and the contact with the overlying limestone lies in a thin transition zone. The maximum thickness measured here was 1,985 feet.

The basal conglomerate member is much thinner at other localities. At the bend in Hay Meadow Creek, south of Island Mountain, in the NE¼ sec. 24, T. 44 N., R. 55 E., only about 100 feet of the member are present. The top of the member is beautifully exposed here and is seen to be gradational with the overlying limestone. Fine pebble conglomerate beds interfinger with thin clastic limestone beds for about 40 feet stratigraphically.

The basal conglomerate of the Sunflower Formation at the Sunflower Reservoir in the Rowland quadrangle appears to lie unconformably upon the Tennessee Mountain Formation. No material from the latter formation is seen in the lower part of the conglomerate. The roundness of the pebbles suggests that the material was brought in from a considerable distance. The excellent sorting and even stratification, plus the lack of crossbedding, point to deposition in a body of standing water. However, the presence of even one small channel, plus the coarseness of some of the material indicates that the shoreline was not far distant, and points to its fluctuation. The great variation in thickness might suggest that the sea bottom was quite irregular, with local basins of deposition in which great thicknesses accumulated. A marine origin is postulated on the basis of marine fossils in the overlying interbedded limestones.

The conglomerate does not correspond with any of the three genetic categories of Krynine (Pettijohn, 1949, p. 242) for high-quartz sandstones, in that while there is detrital chert, there is little secondary quartz growth. The beds fit somewhat better into Pettijohn's oligomictic gravels, which are described as the product of marine transgression over a surface of low relief (Pettijohn, 1949, p. 208).

The conglomerate contains two distinct types of material—rounded pebbles of chert and quartzite, and subrounded to subangular sand grains of pure quartz. The sand grains and some of the quartzite pebbles were derived locally from outcrops of quartzites, such as the Prospect Mountain(?) Quartzite, which are exposed in so many parts of the region today. The chert and dark quartzite pebbles were apparently derived from the western assemblage, upper plate rocks which once covered much of the area (see Roberts and others, 1958,

fig. 4); for example, the Valmy-like quartzites that crop out in the belt between Mountain City and Rowland (Roberts, oral communication, 1957).

There are two facies of the conglomerate member which deserve special mention. On the southeastern side of Cornwall Mountain the conglomerate is well exposed in a series of small cliffs and benches. The fragments include many subangular to subrounded pieces of limestone, up to 10 cm in diameter. Older limestones from which these could have been derived are presently known only to the north and west of this area. Here on Cornwall Mountain, the conglomerate lies unconformably on the western assemblage Paleozoic chert and shale.

On the northern slope of Mount Ichabod the Sunflower Formation is exposed along the crest of the ridge. At the extreme northern end of the ridge, the conglomerate member is of normal character, but as it is traced southward it changes rather abruptly. Within less than a mile massive outcrops are seen in which the fragments are chiefly large (12 to 20 cm), angular to subangular pieces of the underlying Prospect Mountain(?) Quartzite (see fig. 2). Here the member is entirely quartzitic.

Within another half mile, this facies changes again to well-rounded cobbles of quartzite which are embedded in the base of the overlying limestones (see fig. 3). Here is a remarkable exposure of the onlap of the conglomerate onto the quartzite, and of the limestone over the conglomerate onto the quartzite.

Thus the conglomerate was deposited in a basin, bordered on the southeast by an island of the quartzite and on the northwest by a high area which was apparently the chief source of sediment.

Fossils appear to be extremely rare in the conglomerate member. One unidentifiable external mold of a gastropod is the only specimen collected. From the general configuration it appears to be a Lower Paleozoic form which has been reworked into the conglomerate member. The conglomerate member is assumed to be only slightly older than the overlying limestone into which it grades.

Middle limestone member

Lying conformably above the basal conglomerate member of the Sunflower Formation is a series of limestone beds. These beds are best exposed at the type section across the hill 7260 in sec. 35, T. 45 N., R. 55



Figure 2. Photograph on Mount Ichabod, showing quartzite breccia in conglomerate of the Sunflower Formation.



Figure 3. Photograph on Mount Ichabod, showing limestone member of the Sunflower Formation lying unconformably on Prospect Mountain (?) Quartzite, with quartzite cobbles at the contact.

E., in the southwestern corner of the Rowland quadrangle and the northwestern corner of the Mount Velma quadrangle. Both the top and bottom of the limestone member can be located fairly accurately. The following section was measured at this location:

	Thickness of unit (feet)	Total feet to base
Limestone, speckled appearance due to crinoid stem and brachiopod fragments in the gray limestone, coarse-grained.....	38	531
Limestone, many small crinoids, partly covered.....	154	493
Limestone, almost entirely covered.....	96	339
Limestone, containing fusulinids.....	1	243
Limestone, many small crinoids.....	12	242
Limestone, fusulinids and abundant corals.....	1	230
Limestone, many small crinoids and brachiopod fragments.....	32	229
Limestone, fusulinids and abundant corals.....	1	197
Limestone, thick-bedded, barren.....	34	196
Limestone, colonial corals.....	2	162
Limestone, thick-bedded, barren.....	160	160

The lithology of the limestone beds varies somewhat, but in general, clastic limestone predominates throughout most of the sections. Locally, some beds are crystalline, but even these contain some detrital quartz (at

least 20 percent in insoluble residues). Insoluble residues for most samples show 30 to 50 percent insoluble material, mostly finely divided silica. Magnesium is present in some of the beds. Locally there is some slight degree of metamorphism. Thin sections show irregular amounts of silt-size quartz particles, minor amounts of fine to medium sand-size particles, and traces of detrital magnetite with a very noticeable metallic luster, with many calcite grains, broken and irregular. Locally, the beds are crinoidal limestone; in thin section these beds appear identical with those described by the diagram in Williams and others (1954; fig. 115b, p. 342). The edges of the grains of calcite forming the fossil fragments are indefinite and irregular, and have been welded together in a microstylitic boundary. In other beds, the grains are commonly cemented with a calcite cement (not in optical continuity with the calcite grains), or they may be separated by the silt-size quartz grains embedded in a calcite cement.

The section at Hay Meadow Creek measures 296 feet from the top of the upper lens of conglomerate to the top of the exposed section of limestone. The fossils here, commonly crinoids, are disarticulated, although there are preserved some 3- to 4-inch crinoid stems.

Most of the beds could be called calcarenites, but some of the fossils are fairly well preserved and the beds including these larger fragments would fall into the calcirudites. On a fresh surface the limestones are a medium-dark gray (N 4), but where sandy they tend to weather a dusky yellow (5 Y 6/4). The gradational contact with the underlying conglomerate member at Hay Meadow Creek has been mentioned. It is also seen at the north end of Cornwall Mountain, and at the north end of Jenkins Peaks (Rowland quadrangle).

The fragments making up the limestone are probably allogenic, as suggested by the disarticulated fossils, size sorting, and association with the underlying conglomerate and overlying calcareous sandstones and siltstones and sandy limestones.

Locally, as on the northern part of Mount Ichabod, the underlying conglomerate is missing and the limestone lies directly on older rocks (Prospect Mountain(?) Quartzite). Both small and large cobbles of the quartzite are embedded in the base of the limestone, which is overlain conformably by the upper sandstone member of the Sunflower Formation.

Discussion of fauna (Richard D. Hoare)

Most of the collections from the Sunflower Formation have been made from the limestone member. A few specimens have been found in the upper sandstone member. The following list comprises forms collected from the limestone member at the type locality and at other exposures in the area:

- Schwagerina* cf. *S. sublettensis* Thompson, Dodge, & Youngquist
- Pseudofusulinella nevadensis* Hoare
- Pseudofusulinella symmetrica* Hoare
- Triticites* cf. *T. meeki* (Möller)
- ?*Bartramella* sp.
- Pseudofusulina sunflowerensis* Hoare
- ?*Endothyra* sp.
- Textularia* sp.
- ?*Climacammina* sp.
- Endothyranella* sp.
- Rhombotrypella* sp.
- Sulcoretopora* sp.
- Penniretipora* sp.
- Fistulipora* sp.
- Polypora* sp.
- Rhabdomeson* sp.
- Fenestella* sp.
- ?*Hexagonella* sp.
- Stenoporoid and rhomboporoid spp.
- Cladochonus nevadensis* Hoare
- Cornwallatia tabularia* Hoare
- Bayhaium vallum* Hoare
- Caninia* cf. *C. trojana* Easton
- Caninia elkoensis* Hoare
- Caninia goldcreekensis* Hoare
- Caninia* sp.
- Acaciapora duncanai* Hoare
- Bradyphyllum gracilium* Hoare

Solitary corals indet.

- Brachythyryna* cf. *B. fritschi* (Schellwien)
- Brachythyryna* aff. *B. rectangulus* (Kutorga)
- Brachythyryna* cf. *B. uralicus* (Tschernyschew)
- Brachythyryna* cf. *B. salteri* (Tschernyschew)
- Spiriferella drascheri*? (Toula)
- Neospirifer* sp.
- ?*Phricodothyris* sp.
- ?*Cleiothyridina* sp.
- Avonia* sp.
- Linoproductus* spp.
- ?*Antiquatonia* sp.
- Reticulatia* cf. *R. huecoensis* King
- Kochiproductus* cf. *K. porrectus* (Kutorga)
- Kochiproductus* sp.
- ?*Quadrochonetes* sp.
- Crinoid columnals
- Echnoid spines

The fusulinids and corals, of all the fauna, have been studied in the most detail (Hoare, 1963, 1964, 1966). Species of *Pseudofusulinella*, *P. nevadensis* and *P. symmetrica*, and of *Pseudofusulina*, *P. sunflowerensis*, are present. Species of *Pseudofusulina* are known only from the Permian (Thompson, 1948). *Pseudofusulinella*, although more commonly Permian, has been described from the Upper Pennsylvanian (Thompson and others, 1958). Specimens referable to *Schwagerina sublettensis*, which was originally described from the Permian of the Sublett Range, Idaho (Thompson and others, 1958), are present. One specimen is questionably referred to the genus *Bartramella*, which has been reported from the Pennsylvanian Ely Limestone in Nevada (Verville and others, 1956) and from the Permian of the Sublett Range, Idaho (Thompson and others, 1958).

The corals contain several forms which indicate a Permian Age. One species of *Caninia*, *C. cf. C. trojana* Easton (1960) was described from the Permian in White Pine County and the Spring Mountains, Nevada (Easton, 1960). The genus *Bradyphyllum*, represented by *B. gracilium*, has been reported elsewhere from the Middle Carboniferous of China and from the Heath and Cameron Creek Formations (Lower Pennsylvanian-Lower Permian) in Montana. *Cornwallatia tabularia* and *Bayhaium vallum* are colonial tabulate corals of restricted stratigraphic and geographic occurrence in the limestone member. *Bayhaium* has been reported from the Permian McCloud Limestone in California.

The bryozoans, although not studied in great detail, have a Pennsylvania-Permian appearance. *Rhombotrypella* has been described from the Pennsylvanian portion of the Oquirrh Formation in Utah (Condra and Elias, 1944) and is known from the Permian in Russia.

There has been less preservation of the brachiopods than other forms. Enough partial specimens have been found, however, to make some tentative identification. *Kochiproductus* cf. *K. porrectus* (Kutorga) has been described from the Permian Coyote Butte Formation in

central Oregon by Cooper (1957), as has *Spiriferella draschei* (Toula) among other forms. Most of the spiriferoids are similar to those described from the "Schwagerina" limestone of Russia by Tschernyschew (1902), although similarities with forms in the faunas of Greenland described by Dunbar (1955) are present.

On the basis of the fauna collected, the Sunflower Formation is thought to be lowermost Permian (Wolfcampian) in age. The fauna is dissimilar to those of the Permian in the southwestern United States and appears to have Asiatic affinities.

Upper sandstone member

Conformable above the middle limestone member of the Sunflower Formation are up to 1,400 feet of fine-grained sandstone, micaceous siltstone, thin beds of silty limestone, and at least one bed of volcanic ash near the base. All of the beds are clastic, and many are calcareous. Bryozoa, brachiopod, and pelecypod molds are poorly preserved in the ash bed. Brachiopod spines are found in one of the thin silty limestones, and carbon films which may have been plant stems are found in one thick bed of sandstone.

A fairly complete exposure on the south flank of the hill in section 35, south of Sunflower Flat, permits listing of the following measured section, although the upper part of the section is covered:

	Thickness of unit (feet)	Total feet to base
Siltstone and sandstone, covered.....	900+	1,332+
Siltstone, dark-gray.....	18	432
Sandstone and siltstone, light-brown.....	156	414
Limestone, thin-bedded, gray.....	78	258
Sandstone and siltstone, brown, partly covered.....	150	180
Volcanic ash, pale-red.....	30	30

Other sections are found along the southern side of Hay Meadow and Penrod Creeks southwest of Island Mountain, and on the southern shoulder of Cornwall Mountain. Although faulting is present, this latter exposure is probably the best.

The ash bed in the type section consists of very fine-grained, angular, mostly silt-size particles. Some silt-size quartz fragments are mixed in the finer matrix. The material is siliceous, and may be a trachyte. The fossils are best seen in a small outcrop on the east side of the hill in sec. 31, T. 45 N., R. 56 E. The following fossil identifications were made by Mackenzie Gordon of the U.S. Geological Survey (written communication, 1954):

- Branching bryozoan indet.
- Rhynchonellid brachiopod indet.
- Ambocoeloid brachiopod indet.
- Pelecypod indet.

The fossils apparently resemble late Paleozoic forms, although not even a tentative age determination could be made.

The sandy and silty beds appear chiefly as rubble on weathered surfaces. They are subgraywackes with thin

chert lenses. The limestone is silty and slightly micaceous. The top of the section is not exposed, and a fault seems to cut the rocks, bringing in bedded quartzite and chert of the Hammond Canyon Formation.

At Hay Meadow Creek, about 2,000 feet of section are poorly exposed. Carbonaceous streaks suggestive of plant stems are fairly common in the lower part of the section. The lower part of this section is siltstone, but the upper part seems to be chiefly limestone or silty limestone. Both the top and bottom of this exposure are faulted, and there may be other faults within the section.

The section on the south shoulder of Cornwall Mountain is similar to the others in general aspect, and the exposures are somewhat better, but the section is so faulted that measurements are not accurate. Estimated thickness of the member at this location is 1,450 feet. The sandstone rests conformably on the limestone member and is conformably overlain by the Hammond Canyon Formation. The basal pale-red ash bed is present, but unfossiliferous. Limestones appear to be more numerous and, higher in the section, contain sandy lenses. The contact occurs just about at the fence marking the National Forest boundary along the section line between secs. 3 and 10, T. 44 N., R. 56 E.

Hammond Canyon Formation

The Hammond Canyon Formation is provisionally defined and named for Hammond Canyon in the northwestern part of the Mount Velma quadrangle. The formation crops out along the northeastern side of the canyon, on the hills to the north and northwest, on the hill north of Fuzzie Spring, and on the hills west and south of Coleman Canyon. Other exposures are along the eastern side of the creek in sec. 26, T. 44 N., R. 55 E.; on the southern end of Cornwall Mountain in secs. 10 and 11, T. 44 N., R. 56 E.; and in secs. 33 and 34, T. 44 N., R. 56 E. It is also exposed along Seventysix Creek, just off the eastern edge of the map.

In sec. 2, T. 44 N., R. 55 E., south of Warm Creek, 816 feet of section are exposed in sequence, apparently near the base of the formation. Probably more than 1,000 feet of section are exposed to the southeast, stratigraphically above the lower portion measured, but structural complications and lack of fossils prevent measurement of any detailed section. About 1,960 feet of section were measured on the southern end of Cornwall Mountain, but several faults complicate the measurements.

The formation is composed of thin-bedded limestones, interbedded with cherty limestones, and siltstones (see fig. 4). Thin-bedded layers of alternating cherty limestone and limestone are most common. These limestones contain some very fine clastics, but generally no fossil fragments. Weathered surfaces commonly show differential weathering of the cherty layers, which appear on casual observation as small sand lenses in the limestone. Closer inspection reveals small pits where



Figure 4. Example of limestone and chert of the Hammond Canyon Formation.

the calcareous material has weathered out. The cherty layers weather a light brown (5 YR 7/4) and the calcareous layers a medium light gray (N 6), but the fresh surface of both is grayish black (N 2). Upon application of hydrochloric acid to the weathered surface, only the gray layers effervesce, but on the fresh surface both effervesce freely. The beds are from ½ to 1½ inches in thickness, but commonly there are laminations within the beds.

The limestones are only slightly thicker than the alternating cherty and noncherty beds. They are more crystalline, and contain little clastic material. They are medium dark gray (N 4). These limestones often contain fossil fragments. Spines, probably from brachiopods, are rather common. The siltstones are generally fissile, and are a pale red (5 R 6/2), weathering to a light brown (5 YR 7/4).

The Hammond Canyon Formation has undergone contact metamorphism in the vicinity of the intrusion at Hammond and Coleman Canyons. At the outcrop, the altered rock appears to be a light-gray (N 7), fine-grained, dense, crystalline quartzite, which weathers white (N 9), and occurs in 1- to 2-inch beds containing laminations. In thin section the rock is hornfelsic

and shows very tightly packed, silt- to sand-size quartz grains, with considerable development of anadalousite(?). No other minerals appear to be present.

The age of the Hammond Canyon Formation is not definitely known. Lying in two small fault blocks on the ridge in sec. 2, T. 44 N., R. 55 E., is a dark-gray (N 3) limestone, which contains coarsely silicified fossils. The limestone in thin section is seen to be composed of large fragments of calcite and of very fine-grained calcite, separated by smaller fragments of calcite and quartz. According to M. Gordon, Jr. (written communication, 1954), the fossils are so crushed and distorted that they cannot be identified as to genus. Most of the fossils appear to belong to one species of brachiopod, with a pair of dental lamellae in the ventral valve, possibly a compositoid. Some small gastropods are also recognizable. Also present in one sample (USGS Locality 16387) of this same dark limestone are poorly preserved and apparently altered specimens of conodonts of the genus *Gondolella* (W. H. Hass, written communication, 1957). *Gondolella* ranges from the Pennsylvanian (Des Moines) into the Middle Triassic. According to Hass, these specimens of *Gondolella* are distinctly linguiform and in this respect resemble those

from the Upper Paleozoic. Hass states, however, that as yet too few conodont faunas from post-Pennsylvanian formations are known, and, therefore, no very precise age determination or correlation can be made.

No detailed work was done on the exposures of the Hammond Canyon Formation on Seventysix Creek, but some samples were collected. One sample contained a number of fusulinids, which have been identified by R. D. Hoare (oral communication, 1950) as belonging to the genus *Triticites*. The position of the sample in the section is not known.

The Hammond Canyon Formation is conformable upon the upper sandstone member of the Sunflower Formation near the southern end of Cornwall Mountain. In other places the base of the formation is either covered or faulted. The Hammond Canyon Formation is conformably overlain by the Poorman Peak Formation. This contact is well exposed east of Poorman Spring near the northwest corner of the quadrangle.

On the basis of the above data, the Hammond Canyon Formation is tentatively assigned a Permian Age; final definition of this formation is deferred, pending further work.

Poorman Peak Formation

The Poorman Peak Formation is provisionally defined and named for Poorman Peak at the western boundary of the Mount Velma quadrangle, in secs. 11 and 14, T. 44 N., R. 55 E. The formation is exposed in the area north of Poorman Peak, especially from the Jenkins Peaks road eastward, across the ridges lying off the quadrangle to the northwest of Poorman Peak, to the contact with the Hammond Canyon Formation. A section was measured in secs. 10 and 11, T. 44 N., R. 55 E. as follows (thicknesses are approximate):

	Thickness of unit (feet)	Total feet to base
Limestone, crinoidal, with fine conglomerate and sandstone lenses.....	180	3,860
Shale, black.....	240	3,680
Limestone, sandy.....	30	3,440
Shale, green, fossiliferous.....	60	3,410
Limestone, coarse, sandy.....	70	3,350
Limestone and black shale, alternating.....	690	3,280
Chert, black.....	70	2,590
Shale, black.....	1,130	2,520
Chert, black.....	15	1,390
Shale, black.....	300	1,375
Chert, black (at Poorman Spring).....	60	1,075
Limestone, dark-gray, fossiliferous.....	15	1,015
Shale and chert, black, alternating.....	1,000	1,000

The formation, as exposed here, is cut by faults, especially at the top, so that a true thickness is not shown. A more complete section probably is present across the broad crescentic band between Cornwall Pass and Haystack Mountain, but this outcrop is also faulted.

Very small crinoid stems and stem fragments are characteristic of the limestones, which are classed as calcarenites. At least one bed of ash occurs, which contains molds of fossils with the upper limestones. Above

the limestone at Poorman Peak is a coarse, impure sandstone, up to 60 feet thick locally, which appears to contain volcanic material. In thin sections the sandstone is seen to consist of quartz and much sericitized feldspar, with some muscovite (probably secondary), some calcite, and a little specular hematite. W. H. Parsons of Wayne State University suggests (written communication, 1954) that this might be a feldspathic sediment, sericitized and recrystallized during deformation, so that the clastic structure is not readily apparent.

Both the cherts and mudstones contain small amounts (generally less than 10 percent) of detrital quartz, sub-angular and of fine sand or silt size. The sandstones are not as quartz-rich as those of the upper member of the Sunflower Formation, but tend more toward a sub-graywacke, although they are not as dark in color. The grains are generally subangular, and fine sand or silt-size material predominates. Colors in the sandstones range from light-gray orange (19 YR 7/4) to pale-yellowish brown (10 YR 6/2).

The Poorman Peak Formation lies conformably on the Hammond Canyon Formation east of Poorman Spring, and also south of Cornwall Mountain. The formation is overlain by Triassic(?) rocks, apparently with little or no discordance.

The following fossils have been collected from the ash and limestones of this formation. Identification is by R. D. Hoare (oral communication, 1960).

Fenestrellina sp.
Lophophyllidium? sp.
Juresania? sp.
Antiquatonia sp.
Marginifera? sp.
Linoproductus sp.
Neochonetes sp.
Spiriferina? sp.
Astartella cf. *A. concentrica* (Conrad)
Limipecten sp.

These would indicate a Late Pennsylvanian and/or Permian Age.

One sample from these limestones, taken just off the western edge of the quadrangle northwest of Poorman Peak, yielded the following conodonts, identified by W. H. Hass (written communication, 1957):

Gnathodus sp. A
Gnathodus sp. B
Gnathodus spp. fragments
Neoprioniodus sp.
 Fragments of blade-like and bar-like conodonts

According to Hass, these would suggest that the rocks could be of Late Mississippian Age. On the basis of the above, the Poorman Peak Formation is tentatively assigned a Permian Age, even though the apparent age discrepancy with the conodonts has not been resolved. Final definition of this formation is deferred, pending further work.

Triassic(?) Undifferentiated

Rocks believed to be of Triassic Age are exposed along the Charleston road which traverses the southern part of the quadrangle. William L. Stokes of the University of Utah reports (written communication, 1953):

"There are definite Triassic rocks along the road which connects 43 with Charleston. I have located these on my [field] map in sec. 30, T. 43 N., R. 57 E. The rock is mainly thin-bedded, yellowish, limy siltstone. I found positive *Lingula* remains, and several small cephalopods. The *Lingula* is extremely common in other Triassic localities in northeastern Nevada. These are not positive proof, but when taken with the lithologic similarity to definite fossil-bearing Triassic near Montello and Jakes Canyon (areas several miles to the east) they appear to be Triassic beyond reasonable doubt."

Rocks similar in lithology to those in question crop out over large areas in the Mount Velma quadrangle, both northeast and northwest of Mount Ichabod and on Mount Velma. The rocks are folded and faulted, and no complete section is exposed. Certainly there are several hundred and perhaps several thousand feet of Triassic(?) beds in the area.

The rocks are primarily the "yellow siltstones" mentioned by Stokes. However, under the microscope some of these (which are extremely fine grained) appear to be tuff, probably water laid. Some of the darker beds are also of volcanic origin and show flow structure.

This same area is described by D. L. Clark (1957, pp. 2204-2205) as his Beaver Creek section. Fossil evidence cited by Clark was similar to that reported by Stokes. Clark (personal communication) reports that ". . . this section was troublesome because the lithology was different from other Triassic sections and because this was one of the few sections from which I was unable to get good Triassic conodonts."

The author has been unable to find any fossils in these or in similar rocks elsewhere in the quadrangle. The Triassic(?) lies conformably or with slight local unconformity on the Poorman Peak Formation, and is overlain unconformably by Cenozoic volcanic rocks. No definition of these rocks is attempted, pending further investigation.

Prevolcanic Gravels

Gravel beds representing materials eroded prior to extrusion of the volcanic rocks are found in many parts of the quadrangle, and are mapped locally as a separate unit. The most significant outcrops of these beds follow a nearly continuous line from just north and west of the summit of Cornwall Pass, southward across the pass, paralleling the curved outcrop pattern of the Poorman Peak Formation to the east and back to the west again, crossing the divide north of Haystack Mountain in the southwestern corner of sec. 23, T. 44 N., R. 56 E. Other outcrops are found in the down-dropped block

just west of Haystack Mountain; south of Island Mountain along Penrod Creek, although these may be mixed with more recent material as are the gravels in the basin north of Island Mountain; along Thompson Creek; at the stream junction east of Haystack Mountain in the corner of sec. 31, T. 44 N., R. 57 E.; and probably along the East Fork of the Owyhee River near Mountain City.

The beds vary a great deal in thickness and lithology; at places they are entirely lacking beneath the volcanic rocks, while at other places they are apparently as much as 50 to 75 feet thick. The pebbles, cobbles, and boulders in the beds are chiefly quartzite. At the top of the divide north of Mount Velma, at an altitude of about 7,500 feet, two extremely large boulders are seen in a thick deposit of the gravels. The largest, composed of a dark quartzite, shot through with quartz veins, measures approximately 13 by 21 feet. The other, about 6 by 11 feet, is composed of granite. Both of these boulders, as well as most of the others in these beds, are well rounded.

In the outcrop along Annie Creek (too small to show on pl. 1), both light and dark quartzite pebbles, ranging in size from coarse sand to medium-size pebbles, are found embedded in a volcanic matrix. No limestone pebbles are found in the gravels although the volcanic rocks lie upon limestones at several places. Apparently the climate or the stream action was such that only the durable quartzites could survive.

Many of the pebbles in the gravels are a medium-blue-gray (5 B 5/1) color, and are similar to quartzite cropping out near Rowland. The granitic pebbles are similar to the rock found on Tennessee Mountain. Thus it seems that the source area for the gravels was to the north.

The gravel beds, as well as the underlying sedimentary and overlying volcanic rocks, are tilted, folded, and faulted. They were eroded after the emplacement of the intrusive bodies and prior to the extrusion of the volcanic rocks.

Terrace Gravels

Along Martin Creek and locally along Hay Meadow Creek are exposed fairly well-sorted, compacted and partially cemented gravels with well-rounded, medium-size pebbles, chiefly of quartzite. These gravels form terraces that rest on the volcanic and older rocks, well above the present streams. The gravel beds dip as much as 40° westward in the area east of Gold Creek, and are cut by faults. The east wall of Gold Creek valley, just north of its junction with Martin Creek, is a fault scarp in the gravel beds. Along Hay Meadow Creek, these gravels are incised by the stream.

Alluvium

Very recent alluvium, consisting chiefly of gravels difficult to distinguish from the pre-existing gravel beds, from which it is in part derived, is found along most streams in the area.

IGNEOUS ROCKS

Intrusive Rocks

A small body of igneous rock intrudes the sedimentary rocks of the Hammond Canyon Formation in the adjacent corners of secs. 1, 2, 11, and 12, T. 44 N., R. 55 E., between Coleman and Hammond Canyons. The igneous rock crops out over an area of slightly less than 1 square mile, and thus might appropriately be termed a small stock or boss.

The rock is a very pale orange (10 YR 8/2) on the fresh surface, but weathers to a very light brown (5 YR 6/4). It is composed chiefly of light-colored plagioclase with some quartz and orthoclase. The grain size averages 2 to 3 mm. In many samples the plagioclase is approximately equal in amount to the orthoclase.

In thin section, the plagioclase shows a tendency toward euhedral outlines, and also exhibits normal and oscillatory zoning. Slight strain shadows are present in the quartz. The orthoclase is kaolinized. It appears to surround and locally penetrate the plagioclase; the plagioclase within the orthoclase has albitic rims. The biotite is somewhat bleached, showing incipient chloritization and muscovitization. Some magnetite is associated with the biotite. Accessory zircon(?), sphene, allanite(?), and some micropertite are also present. The rock can be classified as a quartz monzonite (E. R. W. Neale, written communication, 1954).

Along the west side of Coleman Canyon, a dark, fine-grained igneous rock is found. It weathers medium gray (N 4), but the fresh surface appears medium dark gray (N 5), although it is composed of both darker and lighter grains. In thin section the chief minerals are zoned plagioclases, more sodic than those of the quartz monzonite; subhedral to euhedral biotite, intergrown with the plagioclase; and zoned hornblende, anhedral to subhedral, occurring as nuclei within the biotite, as does the plagioclase. Neale suggests that this is a hornblende-biotite andesite, and adds that the groundmass is similar to that of flows. However, the rock in Coleman Canyon is more likely a mesocratic border facies of the quartz monzonite boss.

The sedimentary rock on all sides of the intrusive has been metamorphosed; the metamorphosed belt is only a narrow border on the east side, but is almost half a mile in width on the north and west. The country rock is mostly thin-bedded siliceous rock of the Hammond Canyon Formation, now altered to a hornfels, and showing slight epidotization. Some oxidized magnetite is present, and some gold occurs where small areas of limestone are present at the contact on both sides of the stock.

The intrusion apparently followed an old line of weakness, along which movement has reoccurred since emplacement of the stock. The age of the intrusive is uncertain. Nolan (1943, p. 163) states that stocks of quartz monzonite or related rocks were probably emplaced during the Cretaceous period in the province,

but that the exact dates and extent of the intrusions are not known. He states further that many of the intrusive granitic rocks in central or eastern Nevada have been assigned to the Cretaceous period, but that there is little direct evidence as to their age. Although evidence from adjacent regions points toward the Cretaceous as the time of emplacement, there is no evidence locally to oppose either an earlier or a later date. The stock is tentatively assigned to the Cretaceous.

Volcanic Rocks

A succession of rhyolitic tuffs and flows is found over most of the region. These rocks have been considerably deformed in the Mount Velma quadrangle, and therefore description of the prevolcanic surface is difficult, as are attempts to study a complete section of the layers. The best exposure of this volcanic sequence probably is in the southwestern part of the quadrangle. Table Mountain (sec 13, T. 43 N., R. 55 E.) is believed to contain the highest exposed beds in the series, while the basal beds are thought to be indicated by a group of white tuffaceous beds at a road junction in sec. 10, T. 42 N., R. 55 E., just off the map to the west.

One section of volcanic rocks is well exposed between Cornwall Mountain and Martin Creek, standing in hogbacks with the dip slope to the west. A thickness of about 3,500 feet is estimated, but there may be some repetition due to faulting. This locality must have been a topographic basin at the time of deposition of the volcanic beds, as their thickness is greater than that elsewhere in the area. The beds are preserved due to downfolding into a large syncline, the axis of which lies south of Little Island Mountain. The volcanic rocks are cut by many normal faults, and blocks are tilted by differential movement along bordering faults.

No complete sections have been studied, but the section in general can be divided into two units. The lower unit is white rhyolitic tuff, very fine-grained, and containing interlocking glass shards. Minerals recognized include a little plagioclase, a little quartz, a little sanidine(?), and less than 1 percent ferromagnesian minerals. There is considerable alteration to clay. The glasses have a refractive index ranging from 1.50 to 1.51. In the northern part of the quadrangle the basal unit is more commonly a yellowish-gray crystal tuff. The glassy groundmass shows typical shards, locally devitrified, and contains small cavities encrusted with fine crystals. The groundmass is somewhat altered to chlorite.

Between the lower and upper units much petrified wood is found.

The upper unit is a gray porphyritic rhyolite. Minerals include quartz, plagioclase, sanidine(?), and devitrified glass. One sub-unit is a grayish-red welded tuff, in thin section resembling fig. 50C of Williams and

others (1954). A few crystal fragments, mostly quartz, are in a groundmass that shows flow lines. Shards of glass are squeezed and flattened, apparently while still hot, giving the rock a delicate lamination (W. H. Parsons, written communication, 1954). Other beds include a reddish-brown, fine-grained crystal tuff. It contains well-sorted fragments of quartz, orthoclase, and rock fragments, all in a reddish, almost opaque hematite-stained groundmass of glass. Parsons (written communication, 1954) states that it probably fell as a dust.

Another layer is a pale green crystal tuff in which the groundmass shows many shards of glass, with considerable devitrification. The crystal fragments are largely plagioclase and biotite, and a few pieces of felsitic rock fragments are present. A thin section of this specimen closely resembles fig. 48B in Williams and others (1954). A specimen from the area south of

Penrod Creek is a pinkish-gray, vitric tuff, of andesitic or slightly more silicic composition (Neale, written communication, 1954). Other samples include a light brownish-gray biotite-hornblende andesite and a light greenish-gray quartz latite. Rounding of phenocrysts and embayment by the groundmass in the latter two samples may suggest consolidation from lava rather than pyroclastic origin.

As seen from these brief descriptions, the composition of the volcanic rocks varies a great deal, but tends to be mostly acidic. Similar rocks in the region have been designated by Schrader (1912, 1923) as "young rhyolites" (Pliocene). The present work of R. R. Coats of the U. S. Geological Survey includes a thorough study of the volcanic rocks of the region, so any correlation and naming of these rocks is deferred, pending completion of his work.

GEOLOGIC HISTORY AND STRUCTURE

The earliest deformation known in the area preceded the deposition of the conglomerate member of the Sunflower Formation. At the sluice gate at the east end of the Sunflower Reservoir, the conglomerate lies unconformably upon tilted beds of the Tennessee Mountain Formation. The complex tight folding, minor faulting, and metamorphism exhibited in the Tennessee Mountain Formation in the Rowland quadrangle are, however, not found in the overlying Sunflower Formation, which apparently represents the "overlap assemblage" (Roberts and others, 1958) of the Sunflower Formation upon the early Paleozoic "eastern assemblage" as represented here by the Tennessee Mountain Formation.

At Mount Ichabod, the Sunflower Formation rests unconformably upon the Prospect Mountain(?) Quartzite (which is older than the Tennessee Mountain Formation but still is part of the "eastern assemblage"). However, on the southeastern slope of Cornwall Mountain, the Sunflower Formation rests unconformably upon dark cherts, which, according to Roberts (oral communication, 1957) are typical of the "western assemblage" of the lower Paleozoic. The thrust which presumably brought these cherts into the area from the west is concealed in the Mount Velma quadrangle, but crops out in the adjacent Mountain City and Rowland quadrangles. There was evidently considerable volcanic activity in the region as ash beds are found, increasing in number and accompanying the fine conglomerate lenses toward the top of the Poorman Peak Formation. The abundant chert might also indicate volcanic activity.

Following at least some slight erosion locally, the Triassic(?) siltstone was deposited, with much volcanic activity.

The next known event in the area was the intrusion of the quartz monzonite stock. Whether the intrusion caused a new line of weakness or whether it came in along an old one is not known, but it does lie in the major fault zone of the area at present. Some contact

metamorphism and deformation accompanied the intrusion, particularly as evidenced in the Hammond Canyon Formation (but note that at least part of the deformation of this formation was penecontemporaneous). The intrusion is tentatively dated as Late Cretaceous although there is no local evidence for such an age.

Uplift and erosion followed during the early Cenozoic. The surface initially must have had considerable relief, as deposits of gravel were formed which contain some huge boulders, all well rounded. Two periods of volcanic extrusion occurred during the middle or late Cenozoic, with sufficient time between the periods for a large forest to grow.

After extrusion of the volcanic rocks, major faulting began. The principal faults are northwest-trending parallel to the west face of Haystack Mountain, a scarp of the Mount Velma fault. If the northeastern block of the Mount Velma fault were active (perhaps with some strike-slip movement,) this might account for the facts that folding occurs in the volcanic rocks in this block only, that a set of northeast-trending normal faults are almost entirely restricted to this block, and that the only major reverse fault identified in the area also lies in this block.

The syncline in the north-central part of the quadrangle is a major feature of the area's structure, involving both the volcanic rocks and the underlying sedimentary rocks. The steep westward plunge (85°) is probably due in part to the tilting of this northeast block of the Mount Velma fault. The reverse fault, seen at the mine at the head of Rosebud Creek, probably developed with the folding; here the quartzite found on Rosebud Mountain is thrust southward over the limestone of the Sunflower Formation. Nearly all of the northeast-trending normal faults in this northeast block are cut by northwest-trending normal faults paralleling the Mount Velma fault.

The Mount Velma fault has formed a scarp almost 1,500 feet high along the west face of Haystack Mountain. Total displacement on the fault probably exceeds 3,000 feet. North and south of Haystack Mountain, the fault consists of several parallel faults.

Erosion accompanied and followed the deformation. Many valleys and some local basins, particularly the one formed along the synclinal axis, were filled with coarse gravels. Apparently movement on the Mount Velma fault continued until quite recently, as these

gravels are steeply tilted toward the west also. This late movement was accompanied by small, north-trending normal faults, most of which are too small to be shown on the map, although the one along the lower part of Gold Creek is quite obvious. This fault cuts the tilted gravels, and the scarp produced is only slightly eroded. Many of these small faults are steep faults, downthrown on the west side.

The present streams, while still youthful, are well adjusted to structure and to lithologic boundaries.

ECONOMIC GEOLOGY

MINING HISTORY

The northwestern part of the Mount Velma quadrangle is known in the early mining literature as the Island Mountain district. The district derives its name from the prominent hill, still known as Island Mountain, which lies south of the junction of Gold Creek and Martin Creek. The area was settled as early as 1867 when Hugh Martin first occupied a squatter's claim along what is now called Martin Creek. His homestead was located a short distance upstream from the present Gold Creek Ranger Station. A large part of the local history of the area is recorded (Rohwer, 1940) from the memory of Hugh Martin, Jr., who was still living in Mountain City in 1958.

However, it was not until August of 1873 that Manual Penrod (or E. Penrod) and two partners, C. Rousells and W. Newton, discovered placer gold in the gravel deposits north of Island Mountain. Additional exploration proved the claims to be well worth working. Some of the deposits produced as high as \$700 per ton in gold (Whitehill, 1873-74). The claims were worked continuously until 1902, the greatest production coming between 1895 and 1898.

Sluicing methods were used, and a number of Chinese were employed with rockers. Recoveries as high as \$2.50 per pan and as much as \$30 per day with rockers were recorded (Vanderburg, 1936, p. 74). However, the severe winters caused great hardship for the operators. Travel to Elko, the nearest supply center, was virtually impossible for long periods of time during the winter months, and equipment could be moved only in the summer. The dry summers caused a shortage of water for proper working of the mines, and much effort and money were expended in attempts to bring water in from neighboring sources. In 1895 some 11 miles of ditch were built from Martin Canyon to the head of Coleman Canyon. Five miles of ditch and 2,500 feet of pipe were used to bring water from the Owyhee River. One company even proposed to bring water from the Bruneau River, some 25 miles to the east at an estimated cost of \$75,000. The Sunflower Reservoir was built to impound water for operation of hydraulic giants. But with all this effort, only enough water was available, even during good summers, for about six months of operation each year. Lack of water was one

of the main reasons for eventual abandonment of many of the claims.

A town known as Gold Creek grew up in the area around the junction of Martin Creek and Gold Creek. At its most populous the town is estimated to have contained some two to three thousand persons. It was complete with hotel, saloons, and stores. A commissary and post office were located at Williams Cabin, now a deserted stone building, east of Little Island Mountain. About 1902 the main building, known as the Waldron block, was moved to Mountain City where it served for many years as the hotel, and only a concrete slab along the main road south of the Ranger Station remains to mark the site of the town of Gold Creek. The mining industry dwindled thereafter, and the area has since been used chiefly for summer grazing of cattle and sheep (Rohwer, 1940).

Little attention was paid to quartz mining in the early days, although some claims were filed. At least two discoveries date from about 1875, one of which assayed at \$500 per ton in gold. Claims on Rosebud Mountain and at the head of Rosebud Creek, which date from the 1890's, are still being worked, though for lead and silver now. However, much prospecting was done throughout the years, and prospect pits, shafts, and tunnels dot the hillsides. Much work was done in and around the intrusive body lying between Hammond and Coleman Canyons. The Hammond Exploration Co. built a small amalgamating mill in 1917, and continued work for several years (Lincoln, 1923).

In the late 1940's the St. Elmo mine was opened about one half mile east of Cornwall Mountain. Extensive shafts and tunnels were opened in quartz veins, and some large-scale building was begun on the site. However, the operation was abandoned in 1950. The claim has been filed on again, but there is no active work.

The above workings were in search of gold. More recently there has been much prospecting in the area for tungsten and for uranium. Several prospects of the latter have been located in the surrounding area, but none in the Mount Velma quadrangle.

One other mining district lies partly within the boundaries of the Mount Velma quadrangle. This is the Charleston district, chiefly a site of placer mining, which

developed at approximately the same time as the Island Mountain district. The Charleston district lies in the northeastern part of the quadrangle, along the Bruneau River and Seventysix Creek. The town of Charleston is abandoned. Further information on the district can be found in Lincoln (1923), Schrader (1912 and 1923), and Vanderburg (1936).

MINERAL DEPOSITS

The mineral deposits in the Mount Velma quadrangle can be separated into three groups: placer gold deposits at Island Mountain and at Charleston, replacement deposits in Coleman and Hammond Canyons, and vein deposits on the eastern and northern flanks of Cornwall Mountain.

The placer deposits at Charleston have been described by Schrader (1923, pp. 78-83). Those at Island Mountain occur in the gravels deposited in a basin just north of the mountain. Three streams—Gold Creek and the streams from Coleman and Hammond Canyons—enter the basin from the north. Gold Creek has supplied material from the hills just off the northern edge of the quadrangle. The streams from Coleman and Hammond Canyons supply material from the intrusive and its bordering rocks. However, most of the gravels resemble the prevolcanic gravels and must have been derived from reworking of those beds. Gold is known to occur in Coleman and Hammond Canyons, and in the Rowland district to the north from which some of the materials of the prevolcanic gravels were presumably derived.

The small intrusive body between Coleman and Hammond Canyons apparently caused some replacement in the wall limestones, and some gold was deposited. These deposits were worked for some time, but apparently neither the size of the intrusion nor the conditions established in the limestones were sufficient to cause much mineralization, as the yield of the operations was small.

Some gold has been found in vein deposits associated with the faults on the eastern and northern flanks of Cornwall Mountain. The St. Elmo mine is in an upraised block of the Prospect Mountain(?) Quartzite, bordered on all sides by normal faults, and cut through by numerous minor faults. The main tunnel, now caved is apparently along a northwest-trending normal fault. The Mink mine at the head of Rosebud Creek (thought to be the deposit mentioned by early writers as lying in Hope Gulch) lies at the junction of some small north-trending normal faults, a northeast-trending normal fault, and an east-trending reverse fault.

The replacement deposits associated with the stock between Coleman and Hammond Canyons are probably Late Cretaceous, but may possibly be early Cenozoic. The mineralization of the fault zones is certainly postvolcanic, as all of the faults apparently cut volcanic rocks. It is possible that some of these veins also may have been associated with the earlier deposits around the stock. The placer deposits are postvolcanic in age, although some of the materials were derived from prevolcanic gravels.

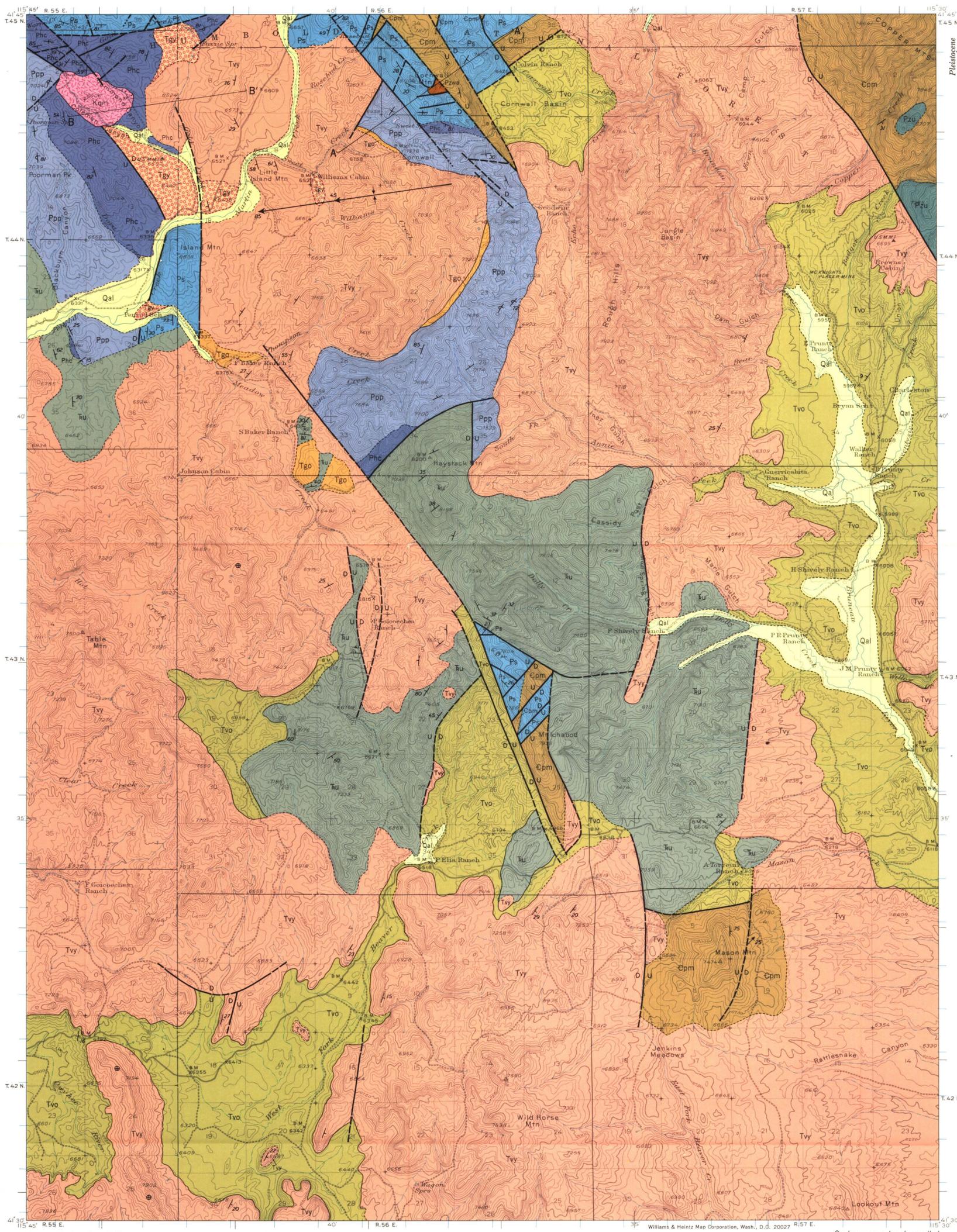
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- EXPLANATION**
- Qal**
Alluvium
Unconsolidated stream gravels
 - Tg**
Post-volcanic gravel
Partially consolidated terrace gravels
 - Tvy**
Younger volcanic rocks
Gray, porphyritic rhyolite; with interbeds of reddish-brown crystal tuff
 - Tvo**
Older volcanic rocks
Light gray to white rhyolitic tuff
 - Tgo**
Pre-volcanic gravel
Coarse gravels
 - Kqm**
Quartz Monzonite
 - Tu**
Triassic(?) rocks, undifferentiated
Thin-bedded, yellowish limy siltstones
 - Ppp**
Poorman Peak Formation
Crinoidal calcarenites, interbedded with black cherts and dark mudstones
 - Phc**
Hammond Canyon Formation
Thin-bedded limestones interbedded with cherty limestones and siltstones
 - Pz**
Upper Paleozoic(?) rocks, undifferentiated
Chiefly limestones
 - Ps**
Sunflower Formation
Basal quartzitic conglomerate; middle clastic fossiliferous limestone; upper fine-grained sandstone interbedded with silty limestones and an ash bed.
 - Pzwa**
Western assemblage(?) rocks, undifferentiated
Gray-brown chert and shale
 - Cpm**
Prospect Mountain(?) quartzite
Light brown to gray quartzite, with thin schistose partings.

Pleistocene and Recent
QUATERNARY

TERTIARY

CRETACEOUS(?)

PERMIAN

PALEOZOIC

LOWER PALEOZOIC(?)

LOWER CAMBRIAN

CONTACT
Dashed where approximately located or inferred; dotted where concealed

High-angle fault
Normal, reverse, or strike slip. Dashed where approximately located or inferred; dotted where concealed; queried where doubtful. U, upthrown side; D, downthrown side

Syncline

Strike and dip of beds

Strike and dip of overturned beds

Strike of vertical beds

Horizontal beds

Topographic base from U.S. Geological Survey 15' Quadrangle

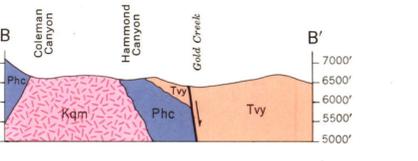
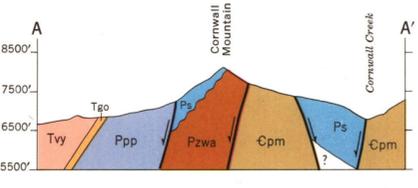
SCALE 1:62,500

Geology mapped and compiled in 1952-1957



VERTICAL SCALE 1 in = 3000 ft

HORIZONTAL SCALE 1:62,500



**GEOLOGIC MAP OF THE MOUNT VELMA QUADRANGLE,
ELKO COUNTY, NEVADA**

By John R. Coash
1967

The Mackay School of Mines is the educational, research, and public service center for the mineral industry of Nevada. It is one of several colleges of the University of Nevada. The School consists of three divisions: the academic division, composed of the departments of instruction; the Nevada Bureau of Mines; and the Nevada Mining Analytical Laboratory.

The Nevada Bureau of Mines and the Nevada Mining Analytical Laboratory, as public service divisions of the Mackay School of Mines, assist in the development and utilization of Nevada's mineral resources. They identify, analyze, and evaluate minerals, rocks, and ores found in Nevada; conduct field studies on Nevada geology and mineral deposits, including oil and gas; pursue research in mineral beneficiation, extractive metallurgy, and economic problems connected with the mineral industry of Nevada; and publish reports and maps pertaining to Nevada's geology and mineral resources.

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