# THE GEOLOGY OF THE NORTHERN PART OF THE ELK MOUNTAINS, ELKO COUNTY, NEVADA



by

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A THESIS

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## ABSTRACT

The Elk Mountains district is located in northern Elko County, Nevada. It constitutes a part of the boundary between the Columbia Plateau and the Basin and Range Province. The thesis area is bounded on the north by the Nevada-Idaho state line, on the south by the line separating T. 46 N. and T. 47 N., Mt. Diablo Meridian, and on the east and west by meridians 115° 00' and 115° 10' west longitude, respectively.

Cambrian and Ordovician deposits, consisting of nearly 2,000 feet of limestones and quartzites are exposed in the southeastern part of the thesis area. They have been correlated, on the basis of paleontologic evidence and lithology, with several of the formations of the Eureka district. Because rocks of this age have never been previously reported so far north in the Basin and Range Province, their occurrence in the Elk Mountains may constitute an important contribution to our understanding of the depositional and tectonic history of the region.

About 500 feet of late Miocene-early Pliocene(?) sediments occur in and near a complex structural basin adjacent to the Paleozoic rocks. The lower part of these Tertiary sediments consists of a fanglomerate, interbedded rhyolite flows, and conglomerates. These are overlain by finer conglomerates, sandstones, and shales. The latest deposits of this sequence are made up of fine, white, volcanic glass shards and are exposed not only in the basin but also along a high ridge in the central part of the area.

Volcanic rocks of early Miocene and Pliocene(?) age are widely distributed in the thesis area. The older of these rocks are, for the most part, characterized by large resorbed phenocrysts of quartz and orthoclase set in a groundmass having a trachytic texture. Where Humboldt sediments are absent, these rocks are unconformably overlain by the rhyolite flows of the younger unit. The Pliocene(?) rocks are typically flow-banded, hypohyaline, tridymite rhyolites. At least part of these rocks originated in or near the thesis area.

The rocks of the Elk Mountains, in general, have not been greatly deformed, but considerable displacement has occurred

along several north-trending normal faults and along numerous transverse faults, a condition which is typical of most of the block mountains of the Basin and Range Province.

Just beyond the southern boundary of the thesis area, Cambrian limestones have been mineralized by a granitic intrusion and mineral deposits thus formed are presently being explored. The rocks described in the thesis, however, contain no presently valuable mineral deposits.

# INTRODUCTION

## Purpose of the Study

The main objective of the present study is to investigate the rocks of the thesis area with a view towards correlating them with the rocks in better known sections of the Basin and Range Province. The correlation of these rocks is made on the basis of lithologic similarities as well as on paleontologic evidence. This is particularly true in the areas underlain by Tertiary clastic and extrusive deposits.

## Location and Accessibility

The area included in this study, as shown in Figure 1, is located in northern Elko County, Nevada. It encompasses approximately 50 square miles and lies almost entirely within the boundaries of the Humboldt Division, Humboldt National Forest. The thesis area is bounded on the north by the Nevada-Idaho state line, on the south by the line separating T. 46 N. and T. 47 N., Mt. Diablo meridian, and on the east and west by meridians 115° 00' and 115° 10' west longitude, respectively.

No all-weather roads exist in the area, but easy access may be gained during the summer months over good gravel and

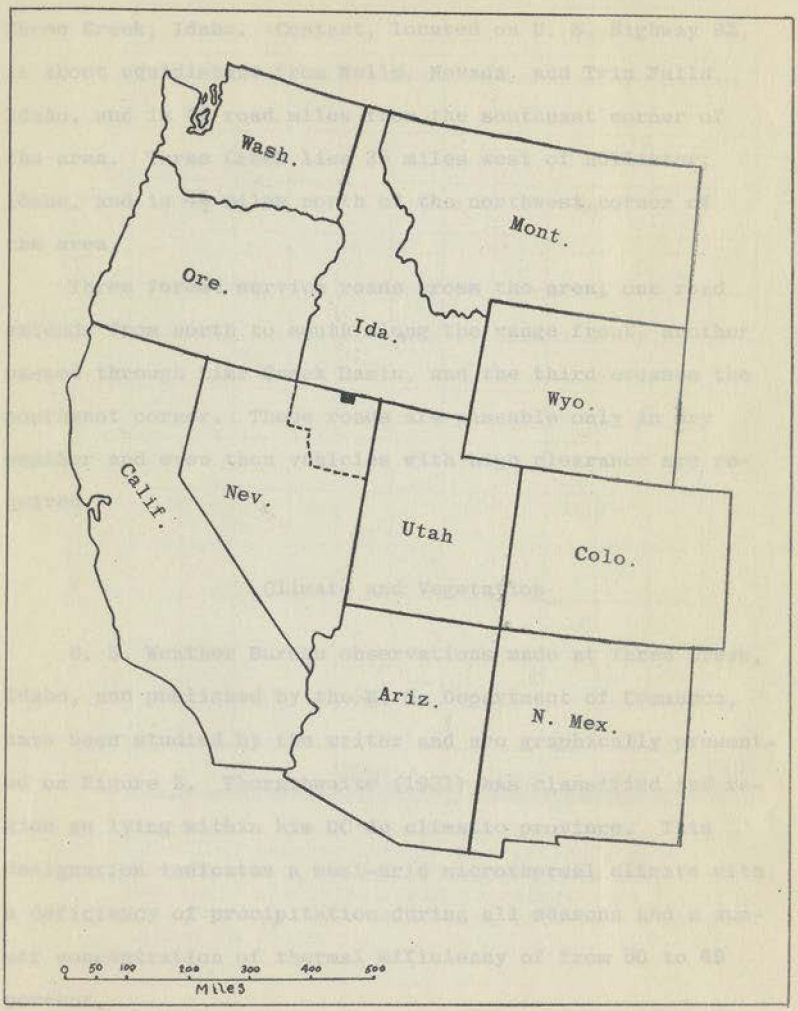


Figure 1. Map of the Western States showing the location of the thesis area (shaded) within the boundaries of Elko County, Nevada.

dirt roads from the communities of Contact, Nevada, and Three Creek, Idaho. Contact, located on U. S. Highway 93, is about equidistant from Wells, Nevada, and Twin Falls, Idaho, and is 52 road miles from the southeast corner of the area. Three Creek lies 35 miles west of Hollister, Idaho, and is $4\frac{1}{2}$ miles north of the northwest corner of the area.

Three forest service roads cross the area; one road extends from north to south along the range front, another passes through Lime Creek Basin, and the third crosses the southwest corner. These roads are passable only in dry weather and even then vehicles with high clearance are required.

## Climate and Vegetation

U. S. Weather Bureau observations made at Three Creek, Idaho, and published by the U. S. Department of Commerce, have been studied by the writer and are graphically presented on Figure 2. Thornthwaite (1931) has classified the region as lying within his DC'dc climatic province. This designation indicates a semi-arid microthermal climate with a deficiency of precipitation during all seasons and a summer concentration of thermal efficiency of from 50 to 69 percent.

By far the most common plants in the region are the common sagebrush (Artemisia tridentata) and the bud sage (Arte-

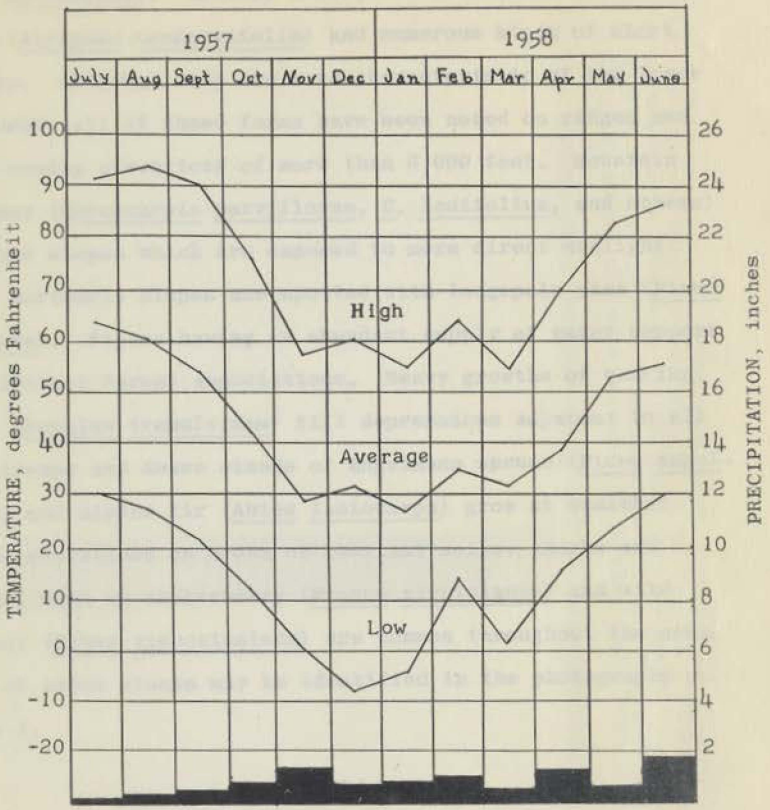


Figure 2. Graph presenting climatological data from U.S. Weather Bureau observation station, Three Creeks, Idaho, for twelve-month period immediately preceding field investigations. Curves show Fahrenheit temperatures, bars show precipitation in inches.

mesia spinescens). Closely associated with these are shadscale (Atriplex confertifolia) and numerous kinds of short grasses. Although they are more characteristic of the lower altitudes, all of these forms have been noted on ridges and peaks having elevations of more than 8,000 feet. Mountain mahogany (Cercocarpis parviflorus, C. ledifolius, and others) dominate slopes which are exposed to more direct sunlight while northerly slopes are spotted with lodgepole pine (Pinus contorta). Places having an abundant supply of water support two distinct forest associations. Heavy growths of quaking aspen (Populus tremuloides) fill depressions adjacent to all the streams and dense stands of Engelmann spruce (Picea engelmanni) and alpine fir (Abies lasiocarpa) grow at somewhat higher elevations on brown or chestnut soils. Herbs and shrubs, such as chokecherry (Prunus virginianus) and wild currant (Ribes viscosissimum) are common throughout the area. Most of these plants may be identified in the photographs on Plate 1.

## Field Work

Field data for the present study were accumulated during a seven week period in July, August, and September, 1958. Nelson B. Higgs and H. Clay Fifer, whose thesis areas adjoin that of the writer at its southern boundary, shared the field camp located near the Pyramid Tungsten, Incorporated, company mill in sec. 10, T46N, R61E.

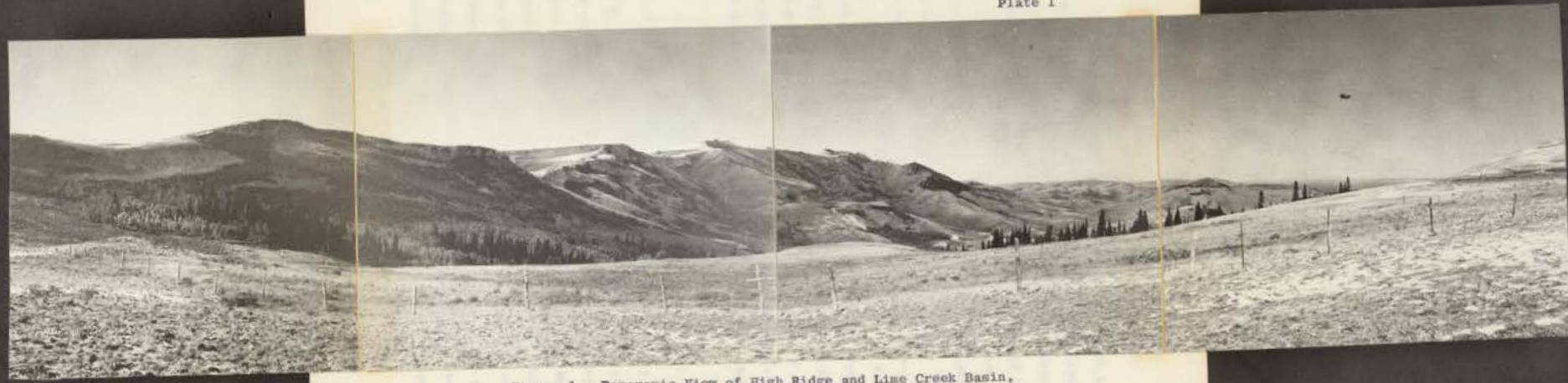

Figure 1. Panoramic View of High Ridge and Lime Creek Basin.

South Fork of Lime Creek begins in clump of aspen in center of first photo. Note nivation feature in upper center of second photo. Red Point, elev. 8,828 feet, is in upper left of third photo, with Quartzite Butte in upper left of last photo. View is NW to NE from the southern boundary of the area at approximately 8,000 feet above sea level.

Field maps were first made with transparent overlays on aerial photographs. Information was later transferred to a simple planimetric map and finally to a contour map which was prepared by the writer from U. S. Army base maps.

Early in September, Dr. Walter L. Youngquist and Dr. Ewart M. Baldwin, of the University of Oregon, arrived in the area, and, in the company of Mr. Higgs, Mr. Fifer, and the writer, they made a field check of the area.

The more detailed mapping was done in the sedimentary rocks which are confined to the area east and south of Red Point. (Place names referred to in the thesis are shown on the geologic map on Plate 2). A reconnaissance was made in the surrounding district to determine the relationship of the areal structure to that of the region as a whole.

## Previous Work

Immediately south of the area, in the N½, T. 46 N., R. 61 E., lies a granitic stock which has an area of about two and one-half square miles. This stock has intruded the sediments of the two southernmost peaks of the Elk Mountains, Red Elephant and White Elephant Buttes, and was probably responsible for the mineralization of the surrounding rocks. The mineralization and the mining activities in the district were studied by Schrader (1912). His report was based on a half-day reconnaissance of the district and on information gathered

through conversations with local miners. His cursory examination of the sediments led Schrader to believe that the Cambro-Ordovician rocks of the Elk Mountains were like those at Contact and "appear to belong to the upper Carboniferous portion of the Eureka region section," (Schrader, 1912, p. 106). A summary of Schrader's findings was presented by Granger, et al. (1957).

During the summer of 1955, Dr. Youngquist, and Dr. L. R. Laudon, of the University of Wisconsin, visited the area and found fossil trilobites in the flaggy limestones along Lime Creek, (Youngquist, oral communication). In a report on the results of certain drilling operations in the Snake River Plains, north of the thesis area, Youngquist and Kiilsgaard (1951) briefly mention the occurrence of Paleozoic rocks in the Elk Mountains.

No other reference has been made to the rocks of this district.

## GEOMORPHOLOGY

The Elk Mountains lie on the boundary between the two physiographic provinces known as the Basin and Range Province and the Columbia Plateau. A high northeasterly-trending ridge traverses the thesis area and forms a natural division line between sectors which are typical of each of these provinces. Southeast of the ridge is a sector which, for the most part, consists of Paleozoic limestones and quartzites and Cenozoic fluviatile and lacustrine deposits. Here, as elsewhere throughout the Basin and Range Province, normal faulting has produced block mountains having steep slopes. Three such mountains in this section are Quartzite Butte, Pearson Mountain (new name),[1] and Copper Mountain. Together with three other peaks, described by Higgs (1959) and Fifer (1959), they make up the whole of the Elk Mountains. The major streams of this sector, Lime Creek, North Creek, Hawes Creek, and Chimney Creek flow eastward into Wilson Creek. They form the western part of the dendritic

[1]Knowing of no name which has ever been applied to this mountain, the writer proposes that it be called "Pearson Mountain" in honor of Mr. Gilbert A. Pearson, manager of the Pyramid Tungsten, Incorporated operations in the Elk Mountains, and for thirty years a prospector and miner in Idaho and Washington.

pattern of the larger, southward-flowing stream and owe their origin to numerous springs and to melting snow which remains until late August in depressions along the high ridge. All of Chimney Creek and the upper reaches of Hawes, North, and Lime Creeks may be classified as consequent streams because their courses are determined by irregularities in the surfaces of the land. Hawes, North, and Lime Creeks become subsequent streams, however, as they progress eastward following the strike of less resistant formations and flowing around more resistant rocks.

The physiography of the eastern half of the thesis area is illustrated in the photos on Plates 1, 3 and 4.

In the sector north and west of the dividing ridge, extrusive igneous rocks predominate and form a southerly extension of the Columbia Plateau. These rocks dip gently to the northwest over a distance of many miles, thus providing an unobstructed view of the Snake River Plains which lie in that direction. The streams in this sector flow down the dip slope of the underlying rocks and are all consequent streams which have developed dendritic patterns. At higher elevations all the streams except Deadwood Creek are ephemeral. They become perennial streams farther down the slope where they are reinforced by small springs. Throughout most of this sector the valleys have broad, "V"-shaped cross-profiles and a relief of several hundred feet.

PANORAMA FROM QUARTZITE BUTTE

Plate 3

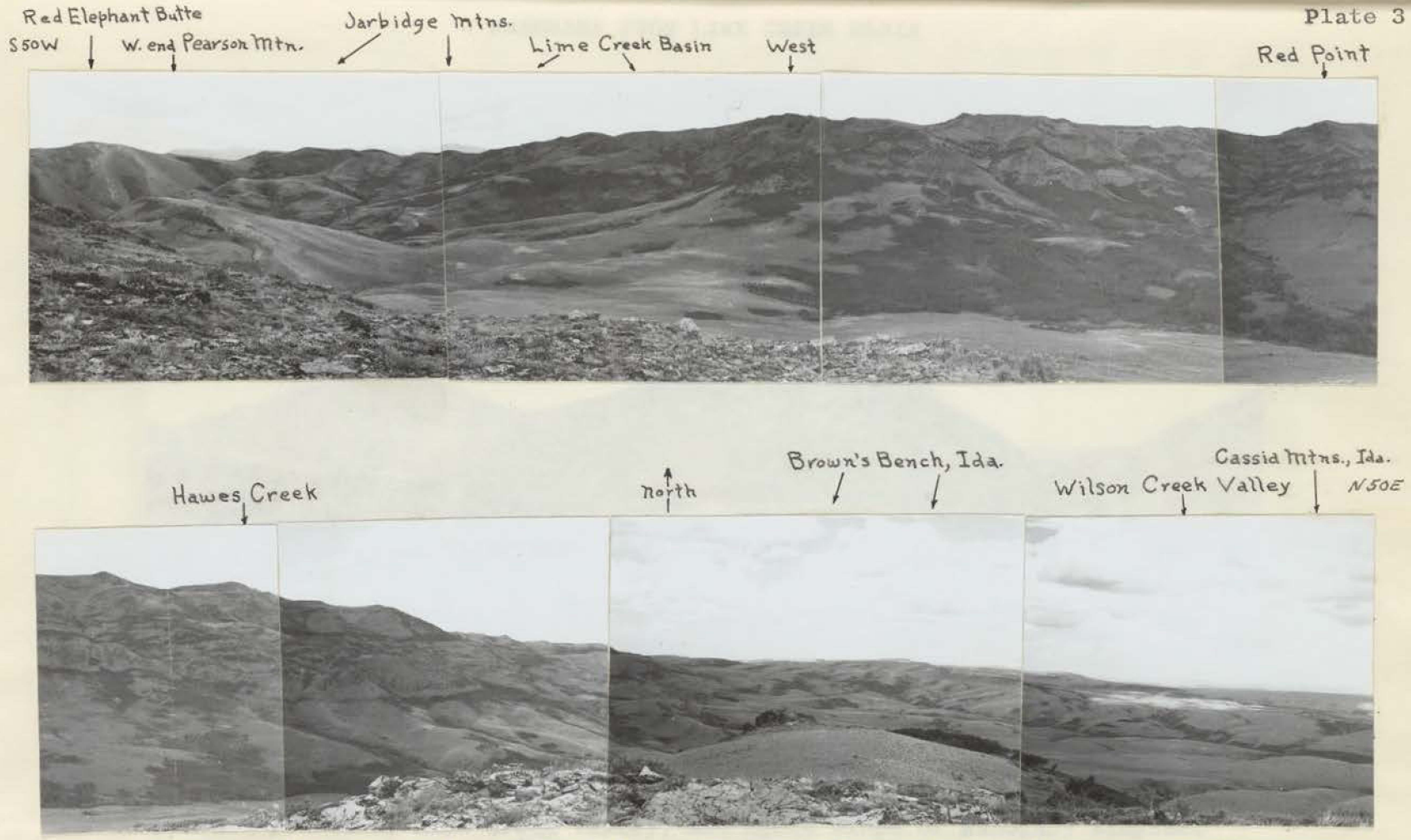


Figure 1. Panoramic View of High Ridge, Lime Creek Basin, and Wilson Creek Valley.

Horizontal lineations of vegetation in the face of the high ridge show fault-traces. Photos from top of Quartzite Butte, the surface of which may be seen in the foreground. Directions and important physiographic features are shown above the photos.

PANORAMA FROM LIME CREEK BASIN

Plate 4

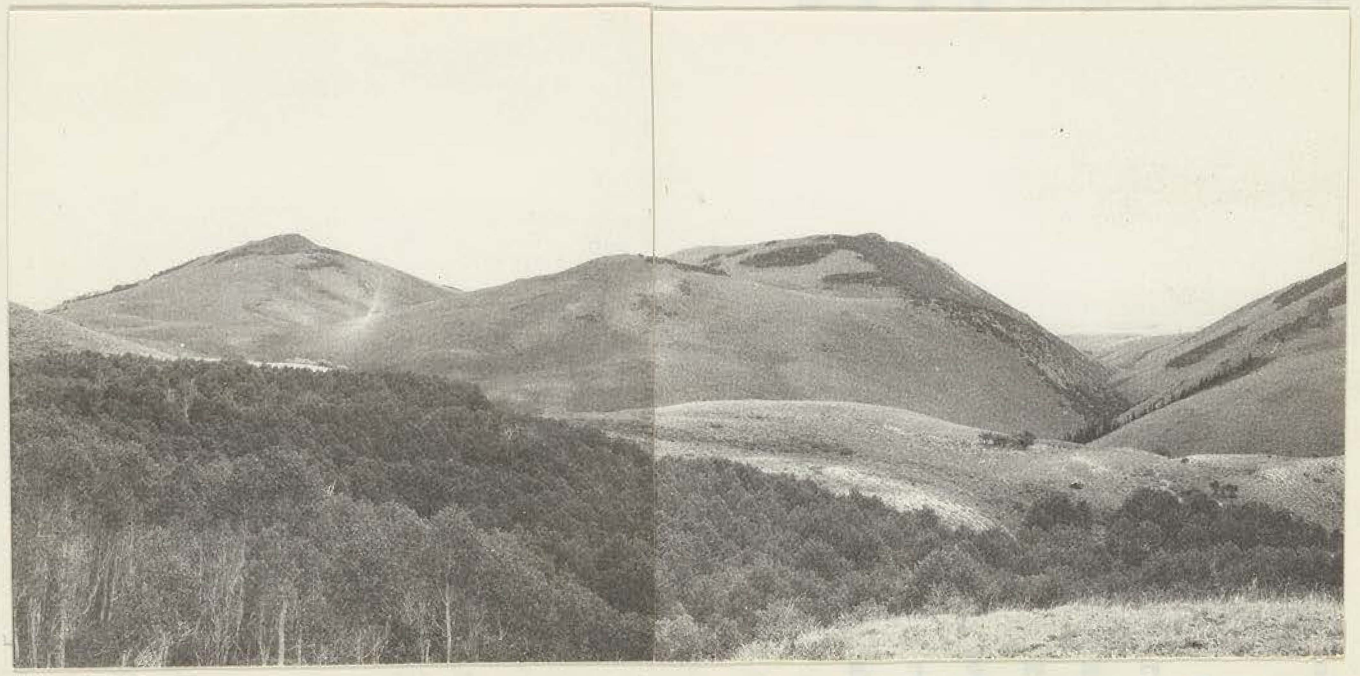

**Figure 1. Panorama From Lime Creek Basin.**

Features are, from left to right, Quartzite Butte, North Creek valley, Pearson Mountain, Lime Creek valley, and north slope of Mahogany Elephant Butte. View is due east from near the head of North Fork of Lime Creek. Light-colored Humboldt formation underlies fore and middle ground.

As they flow out onto the plateau to the northwest, the streams cut deeply into the rhyolites and are contained in narrow, steep-sided canyons.

The entire area is characterized by rather high local relief. The lowest point, approximately 6,180 feet above sea level, is located in the NW¼ sec. 1, T. 47 N., R. 60 E. Red Point, in the NW¼ sec. 15, T. 47 N., R. 61 E., is the highest peak in the Elk Mountains and has an elevation of 8,828 feet. Although the total relief in the area exceeds 2,600 feet, the relief in any one locality probably is not greater than 2,000 feet.

# STRATIGRAPHY

## General Statement

A wide variety of rock types and depositional environments are represented within the thesis area. Three large stratigraphic units are delineated on the basis of lithologic features, age, and distribution within the area.

The oldest unit exposed is one of Paleozoic sediments consisting of Cambrian and Ordovician limestones and quartzites. These rocks occur only in the southeast quarter of the area and form the main mass of Pearson Mountain, Copper Mountain, and Quartzite Butte. A detailed discussion of the various formations which make up this unit will be presented in later paragraphs.

Immediately overlying the Paleozoic sediments is a sequence of Tertiary lacustrine and fluviatile deposits and interbedded extrusive igneous rocks. These deposits are best exposed in Lime Creek Basin, but they also occur north and east of Quartzite Butte and in a depression along the high central ridge. The rocks of this sequence are lithologically identical to those designated by Sharp (1939) as being typical of the Humboldt formation, deposited during late Miocene time.

Aside from small portions covered with alluvium and colluvium, all of the remaining area is underlain by extru-

sive igneous rocks of various lithologies. These rocks were extruded during Miocene and early Pliocene(?) time. In the Jarbidge mining district, less than 10 miles away, they were designated by Schrader (1912) as "Old Rhyolite" and "Young Rhyolite".[2]

Quaternary alluvial deposits occupy the broader portions of the stream valleys and a thin mantle of fragmental material covers the higher parts of the mountains. The origin of these deposits and their relation to the structure and climate of the area will be discussed later in the thesis.

The lithologic character, depositional sequence, and thickness of the Paleozoic and Cenozoic sediments are diagrammatically represented in the generalized columnar section presented on Plate 5.

[2] Although these units have not been named in accordance with the rules of stratigraphic nomenclature, the writer, for convenience, will retain the names used by Schrader.

## CAMBRIAN SYSTEM

### General Statement

The occurrence of Late Cambrian rocks in the thesis area is of particular interest because they have never before been found so far north in the Basin and Range Province. According to A. R. Palmer[3] of the U. S. Geological Survey, the most northerly exposures of sediments of this age previously discovered are located in the Cherry Creek, Nevada section. These lie approximately 140 miles due south from the Elk Mountains.

Most of the sedimentary rocks in the thesis area are assigned to the Cambrian system. Their distribution is shown on the geologic map presented on Plate 2. These deposits are made up of shale, quartzite and thin-bedded marine limestones with silty or shaly partings. Although most of these strata are unfossiliferous, some beds yield many fossil trilobites and a few fragmentary brachiopods. From these fossil remains, and from certain lithological characteristics, it is concluded that the rocks of this sequence were deposited during Middle and Late Cambrian time. The writer believes that three Cambrian formations are present here.

[3]Letter to Dr. Lehi Hintze, Brigham Young University, 1959.

Paleogeographic maps by Schuchert (1955) and Eardley (1951) suggest that similar environments of deposition obtained in both the Eureka, Nevada district and the thesis area during most of Middle and Late Cambrian time. The general lithology of the two sections, which corresponds fairly well, although major lithological differences occur in the upper part of the Trempealeauan rocks, seems to substantiate this view. For these reasons, and because the writer believes that the naming of formations should be restricted to formal geologic publications, the formational nomenclature used by Nolan, et al. (1956) at Eureka is adopted for the Cambrian rocks of the thesis area.

## Hamburg Limestone

Distribution and thickness: Outcrops of the Hamburg limestone, within the area mapped, are restricted to the lower south slope of Pearson Mountain and to parts of Mahogany Elephant Butte. That part of the section on Pearson Mountain is probably the most nearly complete, however. Because it is obscured by talus slopes, the position of the upper contact is only approximated. The base of the Hamburg limestone is not exposed in the thesis area.

A section of the Hamburg beds was measured from a point on the south slope of Pearson Mountain to the bed of Lime Creek, thence eastward along Lime Creek to the place where

the stream crosses the range front fault and southward up the northeast slope of Mahogany Elephant Butte. The strata which are exposed on Pearson Mountain and in Lime Creek, have northward dips ranging from 8 to 40 degrees. On Mahogany Elephant Butte, however, severe folding and associated faulting makes accurate measurement of the strata difficult. The Cambrian rocks in that place are, accordingly, referred to on the geologic map, (Pl. 2), as "undifferentiated limestones". Higgs (1959) discusses the rocks in the more southerly mountain and relates their deformation to nearby igneous activity and block-faulting. The outcrops on Pearson Mountain have an aggregate thickness of 220 feet and those on Mahogany Elephant nearly 100 feet. Thus, the total thickness of Hamburg limestone exposed here approximates 320 feet.

Lithology: The higher portion of this unit consists chiefly of dense, dark-gray to blue siliceous limestone strata which range from 1 to 7 inches in thickness. A few thin beds of gray chert occur at irregular intervals in the outcrops which form ragged cliffs along the lower south slope of Pearson Mountain. These massive, cliff-forming beds are illustrated on Plate 6, Figure 1. Destructional analysis of a specimen taken from the upper part of the outcrop indicates that these rocks contain 16 percent of material that is insoluble in hydrochloric acid. Under the microscope the insoluble material appears to be sili-

Plate 6



Figure 1. Outcrop of Hamburg Limestone.

This outcrop, typical of the upper part of the Hamburg, occurs on the south slope of Pearson Mountain.



Figure 2. Photomicrograph of Hamburg Limestone.

This photo shows the intimate association of chalcedony (light and dark material) in a fine-grained groundmass of grey carbonates.
(crossed nicols, X ca. 100)

ceous. A thin-section of the same rock was examined under the petrographic microscope (Pl. 6, Fig. 2). The intimate association of chalcedony and calcium carbonate suggests either that they were precipitated simultaneously or that the chalcedony was introduced during diagenesis.

Below the cliffs, in the bed of Lime Creek, occur scattered outcrops of lighter-gray, regularly-bedded limestones in layers ranging from three-fourths of an inch to two inches in thickness. A particularly good exposure of a part of these beds is located in the south bank of Lime Creek at the place where it crosses the range front fault. Here they form a straight-sided cliff about 30 feet high and display the regular bedding and thin, silty partings which are characteristic of all the outcrops of this unit.

Field identification: Although the lower, light-grey limestones of this formation are not significantly different from many other Cambrian rocks in the Great Basin, the massive, siliceous beds which overlie them are diagnostic of the Hamburg. This seems to be true, not only in the thesis area, but in the Eureka district as well. According to Nolan et al., (1956) silica is "especially abundant" in the rocks which are immediately below the Dunderberg shale.

Age and correlation: Because the beds here assigned to the Hamburg limestone failed to yield recognizable fossils, correlation must necessarily be made on the strength of its stratigraphic position with relation to overlying beds of

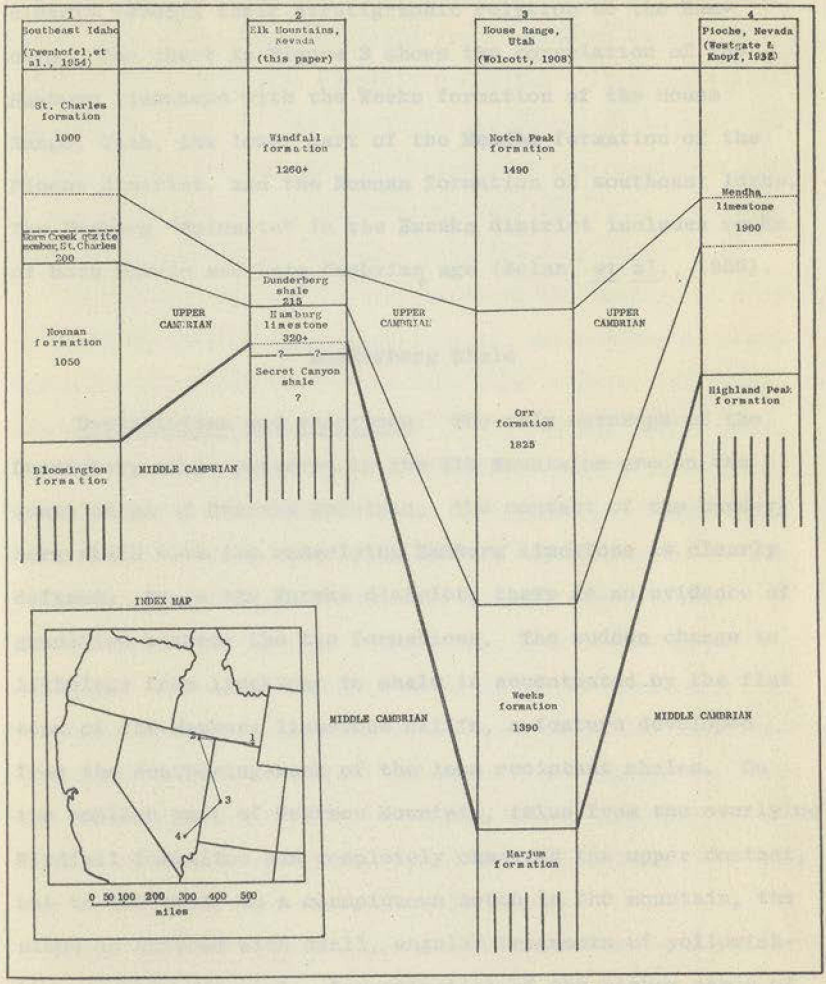


Figure 3. Correlation Chart For Cambrian Rocks.

The chart above shows relative age and thickness of the Cambrian strata in the Elk Mountains and in three well-known regions in the Basin and Range Province.

known age and on the basis of lithology. The presence of the overlying Dunderberg shale and Windfall formation clearly reveals their stratigraphic relation to the Hamburg. The chart in Figure 3 shows the correlation of the Hamburg limestone with the Weeks formation of the House Range, Utah, the lower part of the Mendha formation of the Pioche district, and the Nounan formation of southeast Idaho. The Hamburg "dolomite" in the Eureka district includes rocks of both Middle and Late Cambrian age (Nolan, et al., 1956).

## Dunderberg Shale

Distribution and thickness: The only outcrops of the Dunderberg shale observed in the Elk Mountains are on the south slope of Pearson Mountain. The contact of the Dunderberg shale with the underlying Hamburg limestone is clearly defined. As in the Eureka district, there is no evidence of gradation between the two formations. The sudden change in lithology from limestone to shale is accentuated by the flat tops of the Hamburg limestone cliffs, a feature developed from the weathering-back of the less resistant shales. On the eastern part of Pearson Mountain, talus from the overlying Windfall formation has completely obscured the upper contact, but to the west, in a conspicuous notch in the mountain, the slope is covered with small, angular fragments of yellowish-brown, shaly material. Investigation of the higher parts of

the slope at this place revealed the presence of two 3-foot beds of massive limestone conformably overlying the Dunderberg shale. The overlying limestones are considered to be the lowermost strata of the Windfall formation. Although faulting in this locality has displaced and contorted some of the strata, an effort was made to arrive at a reasonable estimate of the thickness of the Dunderberg shale and it is concluded that this formation is not more than 215 feet thick.

Lithology: In the Eureka district, the Dunderberg shale is characterized by approximately equal thicknesses of shale and zones of interbedded shale with thin, nodular and lenticular limestones (Nolan, et al., 1956). In the thesis area, however, this formation is predominantly shale with only one 15-foot band of interbedded shale and limestone occurring at the top of the section. The lower 200 feet appear to be composed entirely of yellowish-brown, fissile shales which weather to small, angular flakes. The gray limestones in the upper 15 feet of the unit occur in layers ranging in thickness from one-half inch to one inch which are interbedded with bands of shale of equal thickness. The shales are somewhat darker-brown in color than those below, but this is thought to be due to the protection from weathering afforded them by the more resistant limestone layers.

Age and correlation: It is noteworthy that no fossils were found in these exposures of the Dunderberg shale while all other known outcrops of this formation contain a most

abundant fauna. Trilobite carapaces, which are so abundant in equivalent beds at Eureka, may have escaped notice in the thesis area. This seems highly unlikely, however, because the outcrops were very closely examined. Even in the absence of fossil evidence, these beds may be correlated with the Dunderberg shale with reasonable certainty. The overlying Windfall formation, conformable on the Dunderberg, contains several species of trilobites which were considered by Mr. A. R. Palmer to be mostly of Trempealeauan and partly of latest Franconian age.

The Dunderberg shale of the Elk Mountains, therefore, is correlated with the Orr formation of the House Range, Utah, the middle part of the Mendha formation in the Pioche district, and the lowermost beds of the St. Charles formation, including the Worm Creek quartzite member, in southeast Idaho.

## Windfall Formation

According to Wilmarth (1938), the Pogonip limestone was originally defined by King (1876, U. S. Geol. Expl. 40th Par. Atlas, Map IV), and included all beds between the Prospect Mountain quartzite (Lower Cambrian) and the Eureka quartzite (Middle Ordovician). These beds were redefined by Hague (1883, U.S.G.S. 3rd Ann. Rept., p. 253-263) as comprising 2,700 feet of limestones, the unit being overlain by the Eureka quartzite and underlain by the beds now called the

Dunderberg shale. It was later suggested by Walcott (1923, Smithsonian Misc. Coll., vol. 67, No. 8, p. 466-467, 475) that the lower 1,500 feet of the Pogonip contained a "Lower Ozarkian" fauna and he, accordingly, proposed the name "Goodwin formation" for the lower unit. Neither the "Goodwin formation" nor the "Ozarkian System", to which it was referred, were officially recognized, however, and for many years the name "Pogonip limestone" was used in the manner prescribed by Hague.

Recent work by Nolan, et al., (1956) has shown that in the Eureka district the lower part of Walcott's "Goodwin formation", bearing a later Franconian and Trempealeauan fauna, may be mapped as a separate unit. For this unit, they proposed the name "Windfall formation". Within the Windfall formation at Eureka, two distinct lithologies were recognized: (1) a lower member called the Catlin, consisting of alternating massive limestones and thinner, sandy or silty limestones underlain by beds containing much laminated chert, and (2) an upper sequence of uniformly thin-layered, platy and sandy limestones, the Bullwhacker member. The Windfall formation in the Eureka district is about 650 feet thick and at Cherry Creek, Nevada, equivalent beds are nearly 1200 feet thick. In the thesis area, beds of Windfall age may have attained a much greater thickness. Field relationships indicate that perhaps as much as 800 feet of these beds may have been cut out by faulting on Quartzite Butte.

Catlin member: The lowermost strata assigned to the Catlin member are two 3-foot beds of massive, blue, finely-crystalline limestone. These beds, separated by a thin shale parting, form the base of a prominent ledge just above the Dunderberg shale. The upper part of the outcrop is 30 feet thick and consists of thin-bedded, flaggy, gray limestones and interbedded tan, shaly layers. No fossils were found in these beds. Approximately 100 feet higher up the slope, however, several specimens of trilobites were collected from a small outcrop of flaggy limestone strata similar to those below. This outcrop is characterized not only by the presence of trilobite carapaces but also by two 8-inch bands of fine, bluish-black, fissile shale which occur near the middle of the exposure. The top of the Catlin member is considered here to be marked by a small outcrop of more massive limestone beds which range from 2 inches to 3 inches in thickness.

Bullwhacker member: The Bullwhacker member of the Windfall formation is better exposed in the thesis area than any of the other Cambrian units. All known outcrops of this member occur on Pearson Mountain and Quartzite Butte. At the former locality they form cliffs and "chimneys" which in places are nearly 200 feet high, (Pl. 7). On Quartzite Butte only the higher beds of the sequence are exposed though the lower portion is thought to exist there under a thin soil cover. The areal distribution of the Bullwhacker member is shown on the geologic map, (Pl. 2).

Plate 7



Figure 1. Pinnacles in the Windfall Formation.

View of an outcrop in the west end of Pearson Mtn., looking due west up North Fork of Lime Creek.



Figure 2. Fractured and Contorted Limestone.

Strata of the Bullwhacker mbr. in the fault-zone along North Fork of Lime Creek. View is east, with Pearson Mtn. in the background.

In the Eureka district, Nolan, et al., (1956) state that the member has an essentially constant thickness of 400 feet. In the thesis area, on the other hand, the exposed Late Cambrian beds occurring above the Catlin member appear to be nearly 1,100 feet thick. Because of the nature of the faulting on Quartzite Butte, the writer considers this estimated thickness to be rather conservative.

Three excellent exposures of the lower strata of the Bullwhacker member are on the south side of Pearson Mountain. The largest outcrop, high on the east end of the mountain, is 390 feet thick and is lithologically very much like the entire member as it was described by Nolan, et al., (1956) in its occurrence at Eureka. The lower part of the outcrop consists predominantly of dark gray, finely-crystalline, flaggy limestone strata interbedded with thin, pinkish, silty layers. Higher in the cliffs, shaly intercalations appear between the beds of limestone and weather to a brilliant orange-red color. These strata grade upward into a tan or brownish-colored sequence which is more characteristic of the Bullwhacker member. As at Eureka, many beds contain abundant trilobite and brachiopod remains.

Less extensive exposures of this part of the member also occur on both sides of the notch in Pearson Mountain, (Pl. 7, Figs. 1 and 2), which is about a mile west of the outcrop just described. It is notable that, although the strata in the more westerly outcrops correspond in general lithology

to those in the eastern exposure, they contain a fauna which is not only more diversified but which is also better preserved.

On the top of Pearson Mountain, conformably overlying the cliffs which resemble the typical Bullwhacker member at Eureka, is a 280-foot sequence of very thin, laminated, light to medium-gray, siliceous limestone beds. Individual layers, ranging from one-sixteenth of an inch to one-fourth of an inch in thickness, weather out as flat, angular plates and form a talus slope beneath steep cliffs like those described earlier. Although yellowish-tan, silty partings occur between many of these limestone layers, they are so thin that they are relatively insignificant. They do, however, impart their color to most of the outcrop. The beds of this unit were probably overlain by more massive, sandy limestones, fragments of which are to be found scattered about on the top of Pearson Mountain. No organic remains were observed in any of the strata which, at this place, lie above the typical Bullwhacker member.

Displaced and sharply folded strata, silicified zones, breccias, and steeply inclined beds like those shown in Plate 8, prove that faulting has taken place along a line trending north-northeast from the notch in Pearson Mountain to, and perhaps beyond, the summit of Quartzite Butte. The descriptions presented in the foregoing paragraphs have dealt for the most part with the deposits which lie east of this normal fault. On the north and northwest slopes of

VERTICALLY INCLINED STRATA

Plate 8



Figure 1. Vertical Beds of the Windfall Formation.

These strata, located on the northwestern flank of Pearson Mountain, have been steeply tilted by faulting. The fault zone, just to the left of the photo, trends NNE to Quartzite Butte. View is NNE. Note the very thin laminae of limestone at the point of the rock-hammer.

Quartzite Butte, however, is a sequence of beds, the lithology of which differs considerably from that of the other Cambrian rocks.

The lowest member of this sequence is a massive, fine-textured, yellowish-gray quartzite having an exposed thickness of approximately 90 feet. Its base is nowhere exposed, but field relationships suggest that this member lies directly above the sandy limestone whose remnants are found on the top of Pearson Mountain. The quartzite crops out in a nearly continuous, curving line which extends northeastward from a point above the large stand of spruce and fir trees on the northwest side of the mountain toward the place where Hawes Creek crosses the range front fault. Although no fossils were found in the quartzite itself, the limestones above it have yielded trilobite remains of Trempealeauan age.

The strata which overlie the quartzite are, for the most part, made up of mottled, light and dark gray, siliceous limestone strata ranging in thickness from three-fourths of an inch to 2 inches. Their undulatory bedding surfaces are covered with elongate concretions and flattened stringers of dark gray chert, (Pl. 9, Fig. 1). Many fragments of trilobites and phosphatic brachiopods are found both on the bedding surfaces and throughout the mottled limestone strata, (Pl. 9, Fig. 2). Ripplemarks, such as those shown in Plate 10, Figure 1, are common in higher parts of the sequence. The spaces between the limestone layers are filled with loose silt

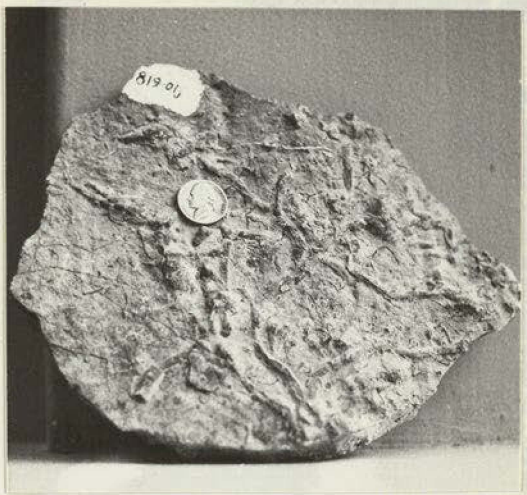


Figure 1. Specimen of Upper Windfall Limestone.

Specimen from Quartzite Butte showing nodules and stringers of chert on the bedding surface.

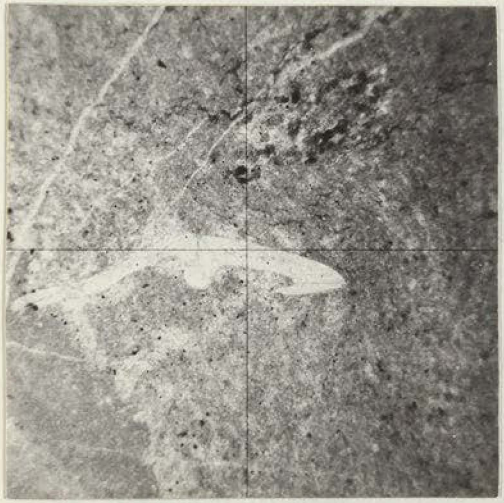

Figure 2. Photomicrograph of Thin-section.

Slide is from the specimen illustrated in Fig. 1, above. Note enclosed thoracic segment of trilobite.

Plane light, (X ca. 25)

Plate 10



Figure 1. Cast of Ripple-marks.

These features are abundant in the late Trempealeau limestones on Quartzite Butte and suggest shallow-water deposition.



Figure 2. Late Windfall Strata on Quartzite Butte.

Irregular bedding surfaces and sandy intercalations characterize this outcrop on the northwestern flank of the mountain. View is slightly east of north.

and sand which weather rapidly. Consequently, the brittle limestones, locally 340 feet thick, can form only low cliffs such as shown in Plate 10, Figure 2.

So far as the writer is able to judge from available literature, no late Trempealeauan quartzite has heretofore been found in the Great Basin. It is notable, however, that the quartzite in the Elk Mountains, although perhaps much thinner, is lithologically similar to the early Trempealeauan Work Creek quartzite member of the St. Charles formation of southeastern Idaho and northern Utah, (Richardson, 1913, Mansfield, 1927). Furthermore, the beds which overlie the quartzite in the thesis area bear a striking resemblance to the uppermost strata of the St. Charles formation in their occurrence at Blacksmith Fork Canyon, Utah, (Walcott, 1908). These beds are believed to be represented south of the thesis area by the sandy and cherty facies of the Chokecherry dolomite of the Gold Hill district, Utah, (Nolan, 1930, 1934).

With these considerations in mind, it is concluded that the environments in which the sediments of the St. Charles formation were deposited rise in the geologic scale of time as they are traced westward and northward. Coupled with the opinion of Nolan, et al., (1956) that the typical Bullwhacker limestone environment rises in the time scale as it is traced southwestward into the Antelope Range, these views seem to provide the foundation for an hypothesis upon which to base the place of origin of the land mass that is known to have

risen in central Nevada during Early Ordovician time. The writer believes that this same land mass probably extended northward through Idaho and may have been the source of the conglomerates, quartzites and "slates" comprising the Ramshorn formation of Ross (1934), in south-central Idaho. The precise geographical boundaries of this land mass, however, could only be found from subsurface investigations, yet to be made beneath the lavas of the Snake River Plains.

Age and correlation: Numerous trilobites were collected in the Windfall formation of the Elk Mountains and the best of these were sent to Dr. Lehi Hintze, Brigham Young University, Provo, Utah. Although the specimens were not too well preserved, Dr. Hintze suggested (personal communication, 1958) a probable late Middle to early Late Cambrian age for the collection, but because he was not especially familiar with the fauna he proposed that the collection be forwarded to Mr. A. R. Palmer, of the U. S. Geological Survey, for more specific identification. Mr. Palmer's subsequent report shows that "although none of the trilobites can be identified closely, collections (from the western and northern localities) contain Late Cambrian trilobites" ... and that "collections (from the eastern locality), although containing indeterminate trilobites, may be the oldest. The pinkish cast to the surfaces (on which they are found) is more typical of the lower Windfall equivalents". Field relationships, as interpreted by the writer, can neither verify nor refute

an older age for the eastern collections. Future investigations may help to clarify this matter.

According to Mr. Palmer "these trilobites represent the northernmost known Cambrian beds west of the Wasatch Range and extend the geographic distribution of Windfall-like rocks nearly 100 miles farther north than previously known. Notes on each specimen follows:

EN-1 Olenid cf. Plicatolina, but with large pygidium.

EN-2 saukiid - indicating this collection to be Trempealeau in age.

EN-3, 5, 6 - trilobites not determinable.

818-03NS, A-C - All specimens seem to be of an indeterminate olenid, perhaps the same as that on EN-1, with a large pygidium.

CuM-1 - thorax of a Eurekia?? - perhaps Trempealeau age.

K-3 - pygidium of a Eurekia or closely related trilobite - Trempealeau age.

WL-7 - trilobites are indeterminate, but the cheek of one looks olenid in aspect.

EF-4, 7, 9 - indeterminate trilobites."

The numbers on the specimens represent the writer's collection numbers; EN and 818-03NS specimens are from the east side of the notch in Pearson Mountain, WL-7, is from the west limb of that mountain, EF is from the east flank of Pearson Mountain, CuM-1 was found on Copper Mountain, and K-3 was collected on Quartzite Butte. Another trilobite cranidium, which

was well-preserved, was collected on Quartzite Butte and tentatively identified by the writer as Iddingsia cf. I. similis (Walcott).

The foregoing paleontologic evidence and field relationships show that in the Elk Mountains all of the beds occurring between the Dunderberg shale and the unconformably overlying Eureka quartzite are of late Late Cambrian (Trempealeau) age. They are equivalent to part of the Notch Peak limestone in the House Range, Utah, the upper part of the Mendha formation in the Pioche district, and the youngest beds of the St. Charles formation in southeast Idaho.

## ORDOVICIAN SYSTEM

### General Statement

Within the thesis area, deposits of Ordovician age are represented only by the Eureka quartzite which unconformably overlies the Late Cambrian deposits of the Windfall formation. Geologists who have studied the unconformity as it occurs below the Eureka in other areas have postulated that a barrier or "welt" rose in central Nevada during Early or Middle Ordovician time. This barrier presumably trended about north-south through the Cordilleran geosyncline, separating it into two separate seaways which received, on the west, predominantly clastic material, and on the east, mainly carbonate deposits.

In the region east of Eureka, Nevada an unconformity below the quartzite is less apparent than in other places, such as at Cortez, Nevada where the Eureka quartzite rests on the Hamburg dolomite, and in the Roberts Mountains where it is underlain by the Goodwin limestone of Early Ordovician age. The unconformity in the Elk Mountains represents a period of erosion or non-deposition intermediate in magnitude between that at Cortez and that in the Roberts Mountains. These relationships seem to further substantiate the "rising welt" theory and may even provide a connection between the Eureka

quartzite and the sediments of the Ramshorn formation and the Kinnikinic quartzite of south-central Idaho, all of which may have been deposited in a transgressing sea during Early and Middle Ordovician time. The writer is aware of the fact that a great deal of time and space are involved in such postulations, but in the light of available data believes that a physical connection between the Early Ordovician deposits of Idaho and the Eureka quartzite is probable.

## Eureka Quartzite

Distribution and thickness: The Eureka quartzite, like the Late Cambrian deposits upon which it rests, has never before been found so far north in the Basin and Range Province. Although the outcrops of this unit are restricted to a small area on the north end of Quartzite Butte, they are large enough to display characteristic features and to clearly reveal their relationship to the underlying strata, (Pl. 11). Because of faulting and fracturing, it is not possible to obtain accurate measurements of the thickness of the unit, but its maximum exposure is thought to be not in excess of 250 feet.

Lithology: Two distinct lithologies seem to characterize the Eureka quartzite outcrops in the Elk Mountains. The lower 100 feet or so of those massive blocks which appear to be in place consists of cross-laminated, yellowish-white, and mottled reddish-brown to red quartzite. Individual quartz grains in

Plate 11



Figure 1. Unconformity on Quartzite Butte.

Shown above is the contact between the Eureka quartzite and the Windfall fm. The dashed line indicates the dip of Cambrian beds. View is southward.

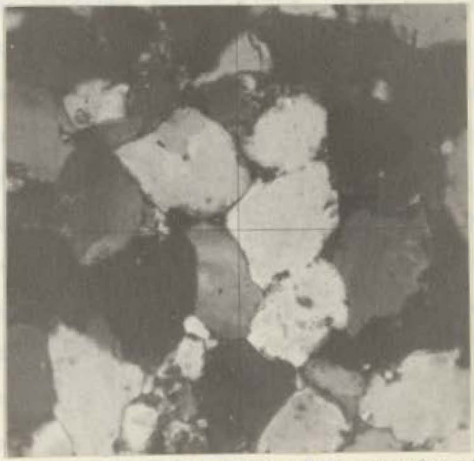

Figure 2. Photomicrograph of Eureka Quartzite.

Subrounded grains of quartz sand now appear angular because of cementing silica filling the interstices, developing interlocking texture. (crossed-nicols; X ca. 100).

the rather porous red laminae are perhaps a little more angular than the subrounded grains of the lighter-colored layers. Within the yellowish layers are commonly found small, irregular strings and splotches of red material which were apparently detached from subjacent laminae during diagenesis. The cross-bedded lower unit displays many of the features of a shoreline sand-dune deposit. Kirk (1933) also suggests that the Eureka quartzite may have been essentially a continental deposit, subjected to only partial and intermittent marine transgression.

The upper portion of the Eureka quartzite in this area is made up of pure, white, fine-grained, clastic quartz particles. No bedding is apparent in this unit which weathers into great angular blocks, many of which are to be found scattered about the adjacent valley floor. Thin-section analysis reveals that constituents of this part of the Eureka quartzite are subrounded quartz grains of even size (1/8-1/4 mm) which have been cemented by secondary silica. As is shown in the photomicrograph in Plate 11, Figure 2, the cementing silica was deposited in optical continuity with the enclosed grains. No heavy minerals were observed in the thin-sections examined although an occasional thin streak of brown iron oxide was noted. The extreme purity and massive nature of the upper unit suggest that it is probably a stable shelf deposit or that it may have been deposited in a sea that was slowly transgressive.

Field identification: The Eureka quartzite presents no problem in field identification where the lower unit is exposed. Its reddish coloration and distinct cross-bedding, both easily seen on weathered surfaces, readily differentiate this quartzite from all other quartzites which are known to occur in the central and northern parts of the Great Basin.

Age and correlation: The Eureka quartzite of the Elk Mountains, like all other known exposures of this formation, has yielded no fossils. Correlation is made on the basis of its lithology and its unconformable stratigraphic position above the Late Cambrian Windfall formation. Because of the absence of organic remains within the Eureka quartzite itself, the age of the formation has necessarily been determined from adjacent beds or from deposits which are considered to be facies of the Eureka. Cooper and Kay (Twenhofel, et al., 1954) believe this unit to be of at least middle or late Trenton age and in their opinion it is correlative with no other unit in the region, except for the Kinnikinic quartzite of south-central Idaho, which may, in fact, be somewhat older.

## TERTIARY SYSTEM

### General Statement

Sedimentary rocks of Tertiary age are widely distributed in the region surrounding the Elk Mountains. The lithology of these rocks, their structural relationships, and fossil evidence indicate that they are of continental origin and were probably deposited under lacustrine and fluviatile conditions. In many instances, beds of such deposits may be traced for several miles. Sharp (1939) estimates that they attain a thickness of 5,800 feet near Elko, Nevada. In his report, Sharp refers these strata to the "Humboldt formation" of King (1878) and assigns to them a Late Miocene and, in part, an Early Pliocene age. In the section described by Sharp, southwest of Elko, the Humboldt formation is made up of from 60 to 75 percent sandstone, shale, mudstone, and siltstone, 10 to 15 percent conglomerate, and lesser quantities of limestone, ash and tuff, fanglomerate, and breccia.

Rather extensive deposits which resemble certain elements of the Humboldt formation occur in the thesis area. Their distribution, lithology, probable origin, and relation to the Humboldt formation in its type section will be discussed in the paragraphs which follow.

### Humboldt Formation

Distribution and thickness: Rocks which are herein assigned to the Humboldt formation, unconformably overlying sub-

jacent strata, are well-exposed throughout Lime Creek Basin, along the rim of the high ridge sector, and in Wilson Creek valley just east of the range front fault. Although the greatest thickness observed in any one continuous section is 208 feet, field relationships suggest that as much as 500 feet of these sediments and their interbedded rhyolite flows may be present within the thesis area.

Lithology: In the section near Elko, the Humboldt formation has been divided into three members: (1) a lower member, consisting of shale, limestone, sandstone and conglomerate, (2) a middle member, with ash and tuff predominating, and (3) an upper member of fine conglomerate, sandstone, mudstone, siltstone, and shale beds. The basal part of the section in the thesis area is characterized by the presence of fanglomerate material which is exposed in a branch of the North Fork of Lime Creek at the base of Copper Mountain. This fanglomerate lies unconformably upon the Late Cambrian limestones of the Windfall formation. It consists of sharply angular fragments of limestone, quartzite, and shaly limestone which range from a few inches to as much as 7 feet in length. The matrix is very fine and is made up of the same material as the large fragments. The deposit is loosely consolidated and in many places has slumped into the stream which passes through it.

Immediately above the fanglomerate lies a unit composed of red, ashy material thought to represent an early phase of nearby volcanic activity which was probably responsible for

Plate 12



Figure 1. Prominent Outcrop of the Humboldt Formation.

This exposure occurs near the head of North Fork of Lime Creek. Strata consist of conglomerate, sandstone, and shale. View is looking north.

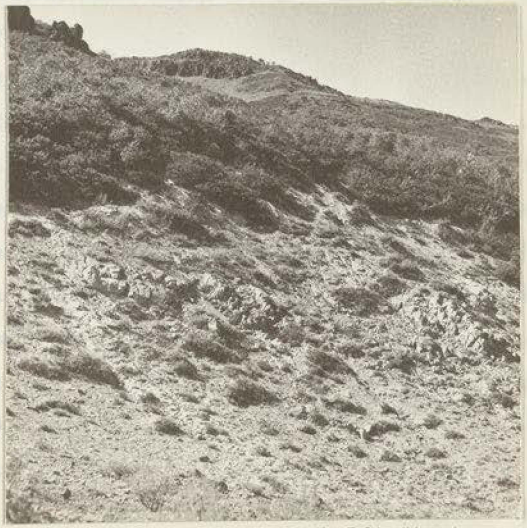

Figure 2. Glassy Humboldt Strata

An exposure at the base of the cliff on the middle branch of Hawes Creek. View is toward the northwest.

the emplacement of the next higher unit, a sequence of dark green and pink rhyolite flows. The lower, dark green rocks were studied in thin-section but they so closely resemble the typical Old Rhyolite deposits that a separate microscopic description here would seem redundant when it is considered that the Old Rhyolite is treated in some detail in the part of this paper which deals with igneous rocks.

The best exposure of Humboldt sediments in the Elk Mountains is located in the face of the cliffs on the southwest side of Lime Creek Basin, (Pl. 12, Fig. 1). This outcrop is about 300 feet wide and more than 200 feet thick. Its location and conspicuous light color make this sequence of beds easily visible from any high point in the southeast sector. Beds of conglomerate, sandstone, and greenish mudstone make up the major portion of the outcrop, although some sandy shale is present. The basal member of the sequence is a large-cobble conglomerate. The subangular cobbles consisting primarily of limestone, rhyolite, and granite fragments, are imbedded in a matrix of medium to coarse sand. The shape of the cobbles and their northwesterly direction of preferred orientation suggest that they were not transported far and probably originated on the flanks of the granitic intrusion which lies approximately two miles to the southeast. This conglomerate is best exposed on a hillside 500 yards south of the prominent Humboldt exposure illustrated in Plate 12, Figure 1.

Intervals of repeated and relatively rapid uplift of the granitic portion of the Elk Mountains are inferred from the

beds of pebble and granule conglomerate, sandstone, and siltstone which overlie the coarser conglomerate just described. The materials of the overlying beds are essentially the same as those in the basal conglomerate, but they become progressively finer and more quartzose near the top of the exposure.

The latest deposits of the Humboldt formation are exposed along the base of the cliffs west of Quartzite Butte (Pl. 12, Fig. 2), and high on the rim south of Red Point. The outcrop found in the latter place, at an elevation of 8,425 feet, more than 1,000 feet above comparable Humboldt beds in the adjacent valley, clearly indicates the magnitude of post-Miocene faulting in the area. The well-bedded strata which make up this unit are characterized by their white color. The beds, composed entirely of clear glass shards which are loose and friable, disintegrate rapidly where exposed to weathering.

Minor outcrops of various units of the Humboldt formation occur throughout Lime Creek Basin and in the valley of Wilson Creek. The surface of most of those areas is covered with gray soil and pebbles or fragments of Humboldt sediments. Higgs (1959) and Fifer (1959) describe similar Humboldt deposits which lie to the south and southeast of the thesis area and provide a physical connection with the more extensive deposits found elsewhere in the region.

Age and correlation: Aside from a few fragments of petrified wood, the exposures of the Humboldt formation with-

in the Elk Mountains have yielded no organic remains. Because of the proximity of known Humboldt deposits near Contact, Nevada and the striking lithologic similarity to the Humboldt in its type locality, the writer believes that correlation of these deposits can be made even in the absence of paleontologic evidence. Sharp (1939) presents what appears to be conclusive data which show the Humboldt formation to be of late Miocene, and in part, perhaps of early Pliocene age.

## IGNEOUS ROCKS

### General Statement

Much of the thesis area is covered by extrusive igneous rocks which seem to have been erupted after the intrusion of the granitic stock that is located south of Red Elephant and White Elephant Buttes. Many of the flows underlie or are interbedded with the Humboldt sediments which were derived from the Paleozoic rocks and from the granitic mass itself. It is concluded, therefore, that the earliest extrusions were probably not contemporaneous with, but closely followed, the emplacement of the granite.

Following the deposition of the Humboldt formation, a great volume of rhyolite and volcanic ejecta covered the district. Much of this material originated either in or very near to the thesis area and spread westward and northward toward the Jarbidge Mountains and the Snake River Plains.

Schrader (1912, p. 35), in his report on the mining operations of the region, has recognized that the rhyolites "were erupted in at least two distinct periods". He, accordingly, described them as "Old Rhyolite" and "Young Rhyolite". To avoid confusion, these names will also be used in the paragraphs which follow.

### Old Rhyolite

Distribution and thickness: Much of the area north of Hawes Creek, some of the high ridge sector, and part of the

valley of Deadwood Creek, is underlain by rocks of the Old Rhyolite series. Most of these rocks weather rapidly and form rounded hills or, where capped by more resistant, younger flows, slope gently to the neighboring streams. In Lime Creek Basin, however, a few flows are interbedded with the lower strata of the Humboldt formation while others unconformably overlie eroded Paleozoic rocks. In these exposures, the rhyolites form the conspicuous ridges west of Copper Mountain and Pearson Mountain.

In the Jarbidge Mountains, 10 miles west of the thesis area, rocks which are identical to these, have been assigned a thickness of nearly 6,000 feet, (Schrader, 1912, p. 36). A reconnaissance of that area shows that such a thickness is not unreasonable. North of Hawes Creek and east of Red Point, where the best exposures of these rocks are found, complex faulting of lithologically similar strata makes an accurate estimate of thickness impossible. Outcrops of Old Rhyolite have been noted at an elevation of about 8,700 feet near Red Point and at approximately 7,200 feet in the nearby valley of Deadwood Creek. If faulting is absent in the intervening area, as it appears to be, then the Old Rhyolite here attains a thickness of about 1,500 feet.

Lithology: By far the greater majority of the Old Rhyolite outcrops in the thesis area are composed of massive layers of tan, yellowish, pink, or gray flow material. The photograph which is presented on Plate 13, Figure 1, illustrates a typical exposure of such material. The tan and yellow

Plate 13

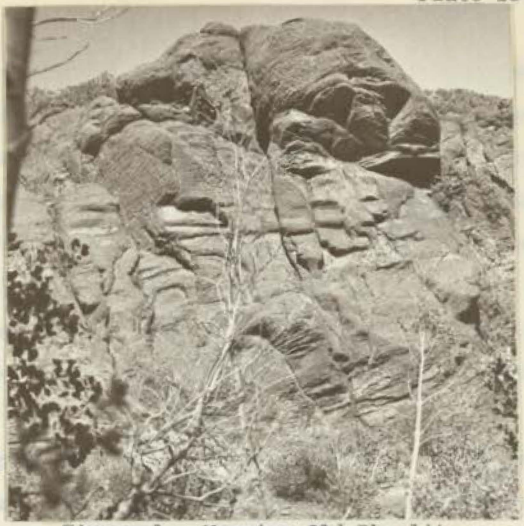

Figure 1. Massive Old Rhyolite.

This typical exposure of Old Rhyolite occurs in the north bank of Hawes Creek on the upthrown side of an E-W fault. View is northward.



Figure 2. Photomicrograph of Old Rhyolite.

The long, dark, crystals are biotite. Light areas are quartz and orthoclase with microlitic inclusions. (plain light; X ca. 100)

varieties are characterized by a very fine-grained groundmass which encloses numerous resorbed phenocrysts of quartz, orthoclase, and plagioclase. On their weathered surfaces, these rocks tend to become crumbly, breaking up into small, angular fragments usually not more than one-fourth of an inch in their greatest dimension. This peculiar habit causes the rock to appear coarse-grained and when viewed at a distance of 10 feet or more, it may readily be mistaken for granite.

Extending northeastward across Lime Creek Basin are several exposures of dense, pink rhyolite which form distinct ridges whose steep outward faces display rough columnar jointing. Although somewhat coarser than in the varieties just described, the groundmass of this rock exhibits a finely-crystalline texture. Phenocrysts are also contained in this unit but here they are considerably smaller, usually not more than 2 mm. long. The rock weathers into rough blocks ranging from 6 to 10 inches across, which accumulate at the base of the outcrops.

A rather extensive outcrop of gray, vesicular material occurs along the road in the vicinity of Chimney Creek. The major portion of this rock consists of thin, glassy flakes or scales which enclose large phenocrysts of orthoclase and plagioclase feldspar; the orthoclase is much altered to kaolinite. The rock appears to have been formed from a highly mobile, frothy material which transported within it the earlier-formed phenocrysts.

Petrology: Several different specimens of Old Rhyolite were examined in thin-section. Except for the presence of iron oxides, particularly hematite and limonite in the pink and tan varieties, all of the rocks seem to have about the same composition. In the Jarbidge Mountains, the rocks of the Old Rhyolite series have been mineralized by numerous dikes. They constitute there the country rock from which notable quantities of gold have been extracted. Because of their economic importance Schrader (1912, p. 39-40) examined them closely. Schrader's description of the Old Rhyolite rocks is as follows:

> "Under the microscope the groundmass is seen to range from microcrystalline through cryptocrystalline to glassy. Much of it is streaked or banded with flow structure. Some unindividualized glassy base is nearly always present, forming by far the greater part of some slides, and much of it is devitrified. The groundmass is usually microlitic or contains some rods of feldspar, quartz, augite, and other greenish dark bisilicates, presumably biotite and hornblende, with which in some sections it is heavily charged. These minerals usually lie parallel with the flow structure but in some slides are disposed in axiolitic, radial, or spherulitic structure. Locally these spherulites constitute the principal part of the groundmass. In some slides portions of the groundmass are microgranophyric or micropegmatitic and portions contain lithophysae or small vesicles lined with quartz and feldspars.
>
> The phenocrysts are mainly quartz, orthoclase, and plagioclase, with here and there a little biotite, hornblende, and augite. The feldspars usually show crystalline outline, the quartzes are in general rounded or globular and penetrated more or less by sinuous embayments of the groundmass. In some slides, however, both the feldspar and the quartz occur also

in angular fragments that have seemingly resulted from flow breccia and give the slide a clastic or brecciated appearance. The feldspar and quartz, like the other phenocrysts, are irregularly distributed throughout the slide, singly and also in groups of rough circular or triangular outline in which the crystals and fragments aggregate 30 or 40 in number.

Both the feldspar and the quartz contain glassy inclusions which in places are so plentiful as to form netlike intergrowths with the host mineral. They also contain as small inclusions earlier feldspars, bisilicates, and the accessory minerals including magnetite. Some quartzes and feldspars exhibit frayed or corroded borders. The feldspar as a rule is mostly kaolinized or altered to a kaolinitic substance and to muscovite or sericite, and some is altered beyond identification. The feldspar is principally orthoclase, but microperthite and albite are present in some slides. The orthoclase occurs mainly in tabular and rectangular crystals and some in Carlsbad twins. Plagioclase on the whole is only sparingly present. It occurs mainly in rectangular crystals and is mostly oligoclase. Some of it, however, gives optical tests corresponding to andesine-labradorite.

The deeply-colored quartz grains constituting the "fish eye" quartz under the microscope show clear, with the coloring matter restricted to the fractures and the periphery of the phenocrysts. The coloring is therefore not indigenous, nor was it incorporated in the quartz at the time of crystallization, as in smoky quartz, but is due to secondary foreign ferric oxide.

In the portions of the district containing the more highly altered rocks, where devitrification and silicification have been more extensive, some feldspars and quartzes are more or less surrounded by a fringe or aureole of secondary silica and adularia, which locally as replacing minerals deeply penetrate the feldspar, particularly the plagioclase. In these rocks there is more or less pyrite and marcasite ranging from macroscopic crystals down to small grains and fine dust.

The biotite occurs sparingly in small plates and foils, and is mostly altered to chlorite. In a few slides biotite, magnetite, and hornblende seem to have resulted by alteration of augite. The augite, which is of rare occurrence, forms small yellowish-brown crystals.

Magnetite, zircon, and apatite occur as accessory minerals.

Secondary minerals besides the pyrite and marcasite, are sericite, chlorite, hematite, limonite, kaolinite, epidote, hyalite, opaline chalcedony, quartz, adularia, and a little calcite.

Many of the altered rocks are traversed by small macroscopic and microscopic veinlets of adularia, quartz, and yellowish chalcedonic or opaline silica, ranging down to less than one-eighth of an inch in width. In some veinlets the filling seems to be exclusively adularia. The veinlets are usually closed, but some are bipartite and composed of two sets or sheets of adularia crystals, one set frozen end on to either wall with the opposite ends butting and interlocking with those of the other set. More generally, however, the veinlet is composed of a single set of crystals, each of which extends, usually, from wall to wall."

The photomicrograph on Plate 13, Figure 2, illustrates many of the above features. The thin-section is from an exposure at the base of the Humboldt formation and is believed to be typical of the Old Rhyolite series.

Age and correlation: Schrader (1912) assigns a Miocene(?) age to the Old Rhyolites of the Jarbidge district. South of the thesis area, these rocks have been found by Fifer (1959), and from outcrops in the vicinity of the Pyramid Tungsten, Incorporated property, they may be followed through Elkhorn Ridge and Canyon Creek to the southeast flank of the Jarbidge Mountains where they form the main mass of the Crater Range. Because in Lime Creek these rocks underlie and are interbedded with the lower strata of the Humboldt formation, their age may be ascertained with considerable precision. Accordingly, the

Old Rhyolite is found to be not older than early Miocene, and probably not younger than late Miocene.

## Young Rhyolite

Distribution and thickness: The first phases of volcanic activity occurring after the extrusion of the Old Rhyolite are represented by deposits of white, glassy materials which comprise the uppermost strata of the Humboldt formation. The eruption of these finely-divided pyroclastics preceded the outpourings of rhyolitic lava, ash, and pitchstone which now cover not only the northwestern part of the thesis area but much of the adjacent region as well. Young Rhyolite flows constitute nearly all of the cliff on the west side of Lime Creek Basin and much of the underlying rock in Wilson Creek Valley. The high ridge is almost completely capped by the latest flows of the sequence, but by far the greatest volume of Young Rhyolite has been poured out upon the surface of the northwestern part of the thesis area.

The thickness of the Young Rhyolite differs from place to place because of the uneven surface upon which it lies. Nearly 1,000 feet of these rocks occur in the cliff near Lime Creek Basin. Greater thicknesses exist along Canyon Creek, at a place 2 miles south of the southwest corner of the thesis area. It therefore seems reasonable that, in the northwestern part of the thesis area, this unit may be as much as 1,200 to 1,400 feet thick, (Pl. 14).

Plate 14



Figure 1. View from the West Boundary of the Thesis area.

This photograph reveals the nature of the terrain in the western half of the area. Pliocene(?) rhyolites underly most of the area between the camera and the horizon. The two peaks on the right are beyond the southern boundary. The view is up the dip-slope; the horizon is about 6 miles away.

Lithology: Many rock types are represented in the Young Rhyolite of the Elk Mountains. They range from dark, reddish, massive flows which in places exceed 100 feet in thickness, through purplish or lavender, platy strata, gray, fine-grained dike rock, ash, pumice and scoria, to spherulitic pitchstone and obsidian. Although the greater part of the series is made up of platy materials, a significant quantity of the rocks consists of pitchstone and scoria which crops out along the high ridge near vents which apparently were the source of much of the rock material. Most of the pitchstone contains spherulites of tridymite and orthoclase which in most cases do not exceed 2 inches of diameter, (Pl. 15, Fig. 1). Similar rocks are described by Fifer (1959) from an outcrop below Elkhorn Ridge, about 3 miles south of the thesis area. In that exposure many of the spherulites exceed 6 inches in diameter.

Petrology: The writer's laboratory examination of the rocks of the Young Rhyolite series is in general agreement with the findings of Schrader (1912, p. 44-45) who reports that:

> "under the microscope (the lithoidal rock) is seen to consist essentially of a brownish to greenish gray, semi-opaque felsitic glass, with spherulitic and axiolitic structure, most of which is not resolvable with the lightest-power objective. This groundmass, however, is uniformly interrupted, to the amount of about one-third the area of the slide, by crudely circular areas of tridymite in its characteristic forms, which seems to be also plentifully present throughout the groundmass. The rock contains as small crystals, or rather fragments of crystals, a little orthoclase, a very little plagioclase which gives tests corresponding to oligoclase, a little biotite, altered hornblende seemingly derived from augite, a very little quartz, and considerable hematite, which is especially prominent about the peripheries of the tridymite areas .....
>
> A black rock of vitreous lustre resembling pitchstone (was seen to consist) of dark-gray microlitic

Plate 15

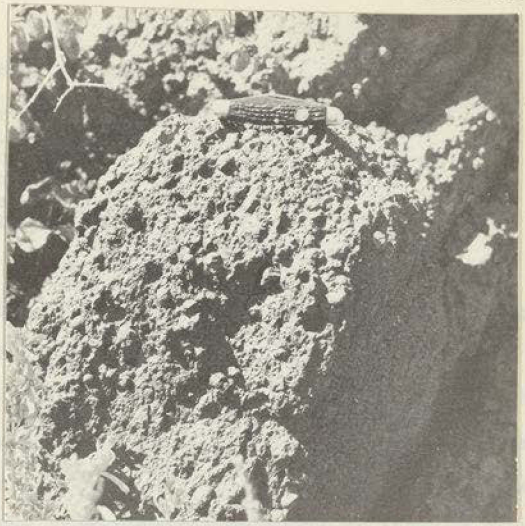

Figure 1. Spherulitic Phase of Young Rhyolite.

Rocks of this kind occur in many places along the high ridge west of Lime Creek Basin.



Figure 2. Photomicrograph of Flow-banded Young Rhyolite.

A specimen showing excellent fluidal structure. Fragments of orthoclase, tridymite, and augite are scattered throughout the glassy groundmass.

(crossed-nicols; X ca. 25)

> glass, charged with feldspathic and augitic(?) microlites, the whole showing-----fluidal banding, with subordinate areas of spherulitic structures. Resting in the groundmass are a few small crystals, or fragments of crystals, of orthoclase, sanidine, a little biotite and augite, the latter mostly altered to hornblende, and a little plagioclase (oligoclase-andesine). Magnetite, hematite and limonite are also present."

A thin-section of flow-banded Young Rhyolite is illustrated in Plate 15, Figure 2.

Age and correlation: Rocks which are similar to the Young Rhyolite of the Elk Mountains district are of common occurrence throughout most of southern Idaho and northern Nevada. Kirkham (1931) describes rocks of similar composition from southwestern Idaho which were apparently derived from fissures and craters occurring along the Snake River. For these lavas he proposes the name "Owyhee rhyolite", (not to be confused with the "Owyhee basalt" of southeastern Oregon) and assigns to them a late Miocene or early Pliocene(?) age. In the thesis area, Young Rhyolite rocks unconformably overlie the late Miocene-early Pliocene(?) Humboldt formation, indicating that they are also of late Miocene or early Pliocene age. Approximately 15 miles northeast of the Elk Mountains, just west of Rogerson, Idaho, is a conspicuous volcanic crater. This volcano and others which dot the Snake River Plains north and west of the Jarbidge Mountains may have provided a common source for the Owyhee rhyolite of Kirkham and part of the Young Rhyolite of the Elk Mountains region.

## QUATERNARY SYSTEM

Deposits of Quarternary age are represented in the thesis area by colluvium, gravel, and alluvium which fill depressions along the streams. Most of Lime Creek Basin is covered by a mantle of gray soil containing numerous pebbles of limestone and quartzite, materials which have been derived from the disintegration of underlying Humboldt sediments. In the area northwest of Copper Mountain, recent landsliding of the Humboldt formation has been responsible for the accumulation of a large quantity of colluvium, which now supports a dense growth of quaking aspen and gives rise to the several large springs that provide Lime Creek with a continuous water supply.

Many huge boulders of quartzite may be seen near Hawes Creek where they have fallen from the north slope of Quartzite Butte. More debris of this kind is scattered over the surface of Wilson Creek Valley, east of the range front.

All of the mountain peaks and high ridges are covered by a thin mantle of sharply angular fragments of limestone or rhyolite. The nature of this material is clearly shown in Plates 1, 3 and 8. These deposits and the talus slopes on Pearson Mountain are to be expected in a dry region where mechanical disintegration of the rocks is more pronounced than chemical decomposition.

## STRUCTURAL GEOLOGY

### General Statement

As has been stated elsewhere in this paper, the Elk Mountains district is located on the boundary between the Basin and Range Province and the Snake River Plains, a subdivision of the Columbia Plateau. Geologic structures which are characteristic of both of these physiological regions occur in the thesis area. Basin and Range structures are peculiar to the southeast and high ridge sectors. The slightly dipping, relatively undisturbed strata typical of the Plateau country underlie the northwestern part of the area.

### Folds

On the geologic map (Pl. 2) only a few representative strike and dip symbols are shown in the western half of the thesis area. Slight undulations occur in the rocks there and modify the gentle (3 to 7 degree) northwesterly regional dip, but it is apparent that these rocks have not been subjected to intense deformation. The writer believes that the slight local changes in the dip of the rocks of this sector may be due to irregularities in the surface of the underlying rock and/or to continued movement along pre-existing faults in the Paleozoic rocks during regional uplift.

In the southeast and high ridge secors, on the other hand, certain strata of both sedimentary and volcanic rocks have been intensely deformed. In every instance, however, sharply-folded beds are associated with adjacent faults (Pl. 16). The Cambrian rocks in Pearson Mountain and Quartzite Butte are slightly arched and constitute a part of a northward plunging anticlinal fold.

## Faults

The southeast and high ridge sectors of the thesis area are characterized by fault-block mountains, bounded on one or both sides by northward-trending normal faults. The geologic map which accompanies this paper shows many of these faults, but it should be noted that minor faults, having a throw of less than 100 feet, are not shown because they nowhere appear to be related to notable topographic features or to conspicuous changes in outcrop patterns. Omission of these minor faults also serves to avoid confusion in the interpretation of the important geologic structures.

The oldest and probably the greatest of the faults in the area is the range front fault. It separates Pearson Mountain, Quartzite Butte, and Old Rhyolite deposits from the rocks of Wilson Creek Valley. Outcrops of highly resistant silicified limestone, such as is shown in Plate 17, Figure 1, occur along the east side of the range and clearly delineate the zone of faulting.

DRAG FOLDS IN CAMBRIAN LIMESTONE

Plate 16



Figure 1. Sharply Folded and Metamorphosed Limestone Strata.

This outcrop of Windfall beds occurs near the south bank of the South Fork of Lime Creek, adjacent to a major fault zone. Note the two sets of fractures and the differential weathering of hard and soft laminae. View is toward the southeast.

Plate 17



Figure 1. Range Front Fault Zone.

The trace of the fault is marked by this ridge of silicified limestone which extends around the east end of Pearson Mountain.



Figure 2. Faulted Area on Top of Quartzite Butte.

Silicified, thin-bedded limestone cropping out on the south end of the mountain. View is southeast, with the top of the peak at the left.

After making a survey of available literature, the writer has concluded that as much as 16,000 feet of Paleozoic, 7,500 feet of Mesozoic, and 2,000 feet of Cenozoic rocks may have been eroded from the top of Pearson Mountain. When these thicknesses are added to the 1,300 feet of Cambrian rocks remaining in the mountain, it appears that the range front fault has a total stratigraphic displacement of more than 20,000 feet at the place where it is crossed by Lime Creek, and perhaps even more near the south end of Mahogany Elephant Butte.

Two other major faults are located on the west side of Lime Creek Basin. Although offset in some places by cross-faulting, they extend from points north of Hawes Creek southward beyond the limits of the thesis area. Red Point, the highest peak in the Elk Mountains with an elevation of 8,828 feet, attests to the magnitude of these two faults, the combined stratigraphic throw of which is believed to be about 2,000 feet in surface rocks and probably much more at depth.

Lesser faults, having throws of from 200 to 500 feet, exist in the southern part of Lime Creek Basin, on Copper Mountain, and on the west side of Pearson Mountain and Quartzite Butte, (Pl. 17, Fig. 2). Some of these faults are directly related to the granitic intrusion south of Red Elephant White Elephant Buttes, while others are cross-faults or "tear" faults associated with incompetent rocks found in the high ridge sector and on Quartzite Butte.

The faulting in the Elk Mountains district appears to be of the same nature as that which produced most of the block-mountains in the Basin and Range Province. A discussion of the many theories which have been advanced to account for the origin of the unique structures of the Province would be too lengthy for presentation here. Osmond (1958), after making an extensive study of the region, suggests that:

> "The tectonic evolution of the Province depicts a broad region of subsidence being transformed through several progressive stages into a positive area. Igneous activity and compressional deformation reached a maximum during upper Mesozoic and lower Cenozoic. In a typical orogenic cycle this maximum of intensity is followed by a rising of the belt, slacking of stresses and adjustment of blocks of the crust along previously developed faults parallel to the compressional axes.
>
> It is possible that following the maximum of compression, the Province has risen slightly and displacement of the blocks has occurred along the abundant pre-existing faults and folds. Individual blocks have tilted (rotated) with the ranges rising and the valleys sinking on a regionally rising crust. This has happened to the relatively brittle fractured crust while compressional folding was taking place along the Pacific Coast and in the Rocky Mountains on either side of the Basin and Range Province."

## GEOLOGIC HISTORY

A period of continuous deposition, represented by 1,800 feet of Middle and Upper Cambrian strata, constitutes the earliest recognizable phase of the geologic history of the Elk Mountains. The epicontinental sea in which these sediments were deposited seems to have persisted throughout this period. The presence of the Dunderberg shale, however, indicates a deepening of the sea in the vicinity of the thesis area during early Dresbach time. The quartzite and nodular, cherty and sandy limestones in the upper portion of the Windfall formation indicate that uplift of the area occurred in Late Cambrian and Early Ordovician time.

The angular unconformity between strata of the Windfall formation and the Eureka quartzite (Pl. 11) suggests that uplift and erosion continued until Middle Ordovician time when the sea once again encroached upon the land, reworking part of the continental deposits of the lower Eureka quartzite and depositing them again as the white, massive upper unit of that formation. Although the Eureka quartzite is the youngest Paleozoic rock exposed in the Elk Mountains the writer believes that several thousand feet of younger strata may have been deposited in the area but have since been removed by erosion or lie concealed beneath the Tertiary deposits.

Although no outcrops of Late Paleozoic, Mesozoic, or Early Tertiary rocks occur within the thesis area, several thousand feet of tan and greenish shales and dark limestones crop out about 15 miles to the southeast. After a rather cursory examination of some of the fossils contained in these rocks the writer has concluded that they are probably Triassic in age. No effort was made to determine the areal extent of these deposits, but it is apparent that these Triassic(?) rocks were deposited in a miogeosynclinal environment and probably once covered the thesis area.

During Late Mesozoic and Early Cenozoic time the region is believed to have stood above sea level where it was subjected to compressional deformation. Northward-trending folds and zones of weakness were probably formed at this time and these may have provided points of access for the numerous granitic stocks which, according to Lindgren (1915), Ferguson (1929), and Kerr (1946), were intruded in eastern Nevada and western Utah during a time not earlier than Eocene. The rocks in White Elephant and Red Elephant Buttes, adjacent to the southern boundary of the thesis area, have been uplifted, metamorphosed, and mineralized by such a granitic stock.

Outcrops of Humboldt sediments at elevations of 7,700 feet south of Copper Mountain, and 8,425 feet in the high ridge sector near Red Point, indicate that movement along faults in those localities has occurred since early Pliocene time.

## ECONOMIC GEOLOGY

### Metallic Minerals

Several metallic minerals have been found near the granitic stock just south of the thesis area; accordingly, numerous prospects have been excavated on Pearson Mountain and Copper Mountain. So far as the writer could discover, none of these prospects shows appreciable mineralization. One excavation on Copper Mountain has exposed a quartz vein about 14 inches wide which contains noticeable quantities of chrysocolla. This hydrous copper silicate is commonly found associated with other secondary minerals of copper in the upper part of copper veins (Dana, 1932, p. 686). For this reason, the writer believes that greater, and perhaps workable, quantities of copper minerals may occur at depth in this place.

### Petroleum

The Paleozoic rocks of the Elk Mountains have been investigated by several oil companies during the past few years. No oil shows are known from the Paleozoic section here, and no very obvious source or reservoir rocks are exposed. However, more attractive stratigraphic sections may lie preserved in the adjacent valleys.

Near Carlin, Nevada, the shales of the Humboldt formation have yielded some oil by distillation (Granger, et al., 1957). Laboratory examinations of shaly Humboldt strata from the thesis area, however, indicate that they contain no appreciable quantities of hydrocarbons.

## Non-Metallic Deposits

Igneous rocks and stream gravels in the Elk Mountains provide an abundant supply of road metal and the Cambrian limestones could be used for agricultural purposes. There is no demand for such commodities in the immediate vicinity, however, and the great distances over which they must be transported to possible markets prohibits their economical exploitation.

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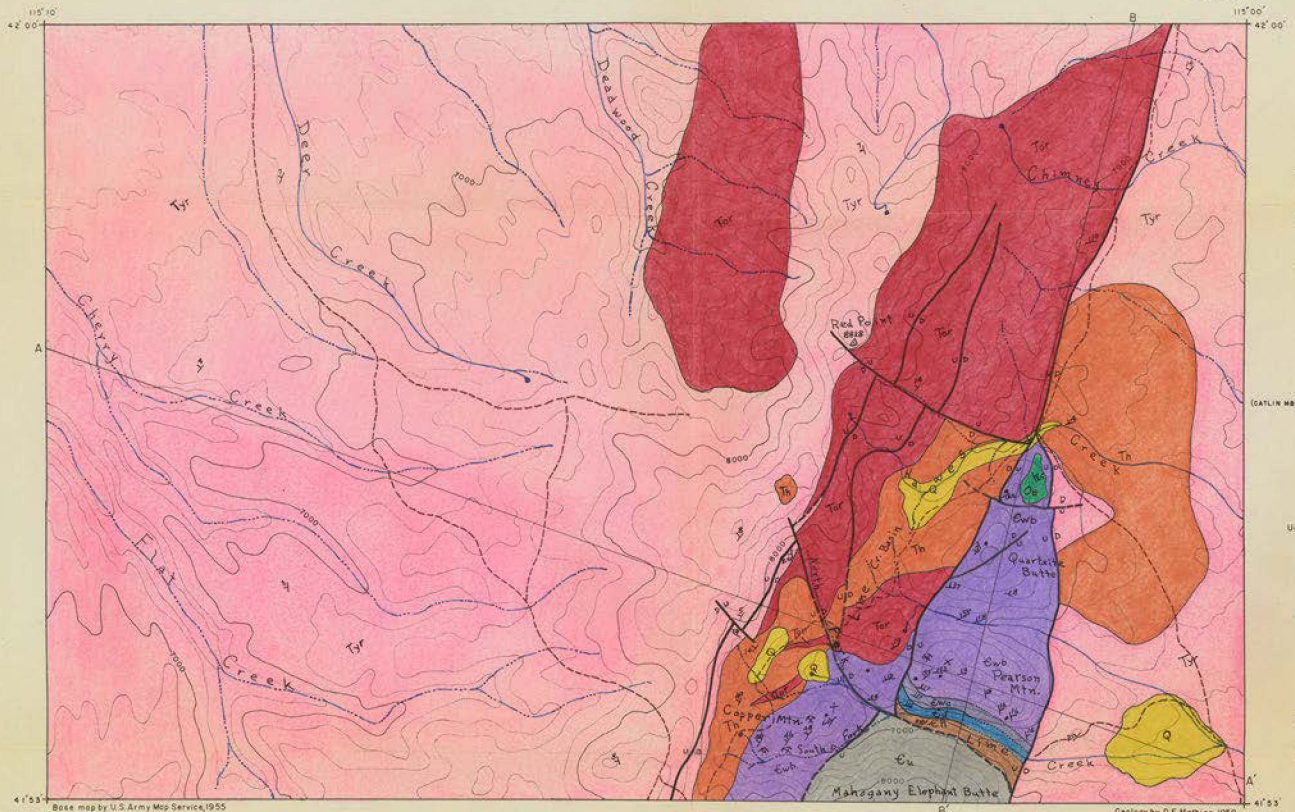
Typed by Jeanne R. Mathias

Figure 1. Idealized columnar section of the exposed sedimentary rocks of the Elk Mountains, Nevada, showing sequence of deposition and lithological characteristics. The lithologic symbols used correspond to those approved by the U. S. Geological Survey.

Plate 5

Plate 2




Base map by U.S. Army Map Service, 1955

Geology by D.E. Mathias, 1959

LEGEND

QUATERNARY

Q — Alluvium, colluvium

TERTIARY

Tyr — Young Rhyolite series

Th — Humboldt formation

Tor — Old Rhyolite series

ORDOVICIAN

Ou — Eureka quartzite

CAMBRIAN

Cwb, Cwc — Windfall formation (CATLIN MBR.-Cwc, BULLWHACKER MBR.-Cwb)

Cd — Dunderberg shale

Ch — Hamburg limestone

Cu — Undifferentiated limestones

SYMBOLS

Dip and strike of beds

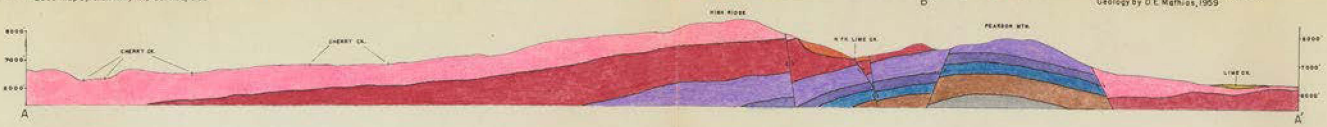
Vertical beds

Mine or prospect

Formation contact (dotted where inferred)

Fault (dashed where inferred)

Fossil locality







# GEOLOGIC MAP AND CROSS-SECTIONS of the NORTHERN PART OF THE ELK MOUNTAINS, ELKO COUNTY, NEVADA.

Scale = 1:40,000

0 1 2 MILES

Contour interval 200 feet

DATUM IS MEAN SEA LEVEL

