University of Nevada

Reno

Geology of the Northern Part of the Diamond Range, Eureka and White Pine Counties, Nevada

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requirements for the degree of
Master of Science in Geology

by

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Figure 1 View of the western side of the northern part of the Diamond Range; the alkali flat of Diamond Valley is at far left.

ABSTRACT

Upper Paleozoic rocks of the post-orogenic overlap assemblage are exposed throughout the northern part of the Diamond Range. The limestones, siltstones, sandstones, shales, and conglomerates are characterized by abundant chert and quartz that was reworked from eugeosynclinal rocks exposed in the source area to the west. Continental sediments of the Newark Canyon Formation were deposited during the Early Cretaceous on an erosional surface above the Carbon Ridge Formation of Permian age.

North-trending anticlines and synclines are the dominant structures in the area. The major portion of the range is an asymmetrical syncline that plunges gently to the south. Several small scale folds on the east side of the area have been overturned to the east. The rocks were deformed both prior to and following the deposition of the Newark Canyon Formation. Numerous normal faults, many of which are transverse to the trend of the folds, and a reverse fault have displaced the folded rocks.

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INTRODUCTION

The author became interested in the Diamond Range area and the Paleozoic rocks of the central Great Basin while attending geology field camp at Eureka, Nevada in the summer of 1976. At the suggestion of Dr. E. R. Larson, the author turned to a study of the northernmost portion of the Diamond Range so that the entire range would be mapped in detail. The southern and central portions had been mapped by Nolan and others (1971, 1974) and by Larson and Riva (1963) respectively. A reconnaissance map of the northern part of the Diamond Range by Dott (1954) appears to be satisfactory in some areas but questionable in others. Several alternate interpretations are presented in this study.

Location and Accessibility

The study area is located approximately 60 kilometers north of Eureka, Nevada, in eastern Eureka and western White Pine counties (Fig. 2). The area is bounded on the west by the alkali flat of Diamond Valley, on the north by Railroad Pass, on the east by Huntington Valley, and on the south by the southern edge of the Railroad Pass 15 minute quadrangle. Approximately 95 square kilometers were mapped.

Access to the area is provided by Eureka County Road 101 (a partly paved, partly gravel road) that extends north from Eureka into Diamond Valley. The area is also accessible from the east via State Highway 20 that parallels the eastern flank of the Diamond Range. Most of the canyons into the area have unimproved roads or trails that are passable with a 2-wheel drive pick-up.

Climate and Vegetation

The climate of the Diamond Range is semiarid. Afternoon thundershowers are common during the summer, but most of the 38 to 45 centimeters of annual precipitation occurs as snow during the winter months. The snow persists in small drifts near the crest of the range until late May or early June.

The mean annual temperature for the study area is approximately 7.3°C. The mean average for the month of January is -5°C and for July is 20.2°C.

The vegetation of the area is quite diverse in contrast to most of central Nevada. Pinon pine (Pinus monophylla), juniper (Juniperus utahensis), sagebrush (Artemisia tridentata), cactus (Ferocactus spp.), and several varieties of wild grasses are widespread. Mountain mahogany

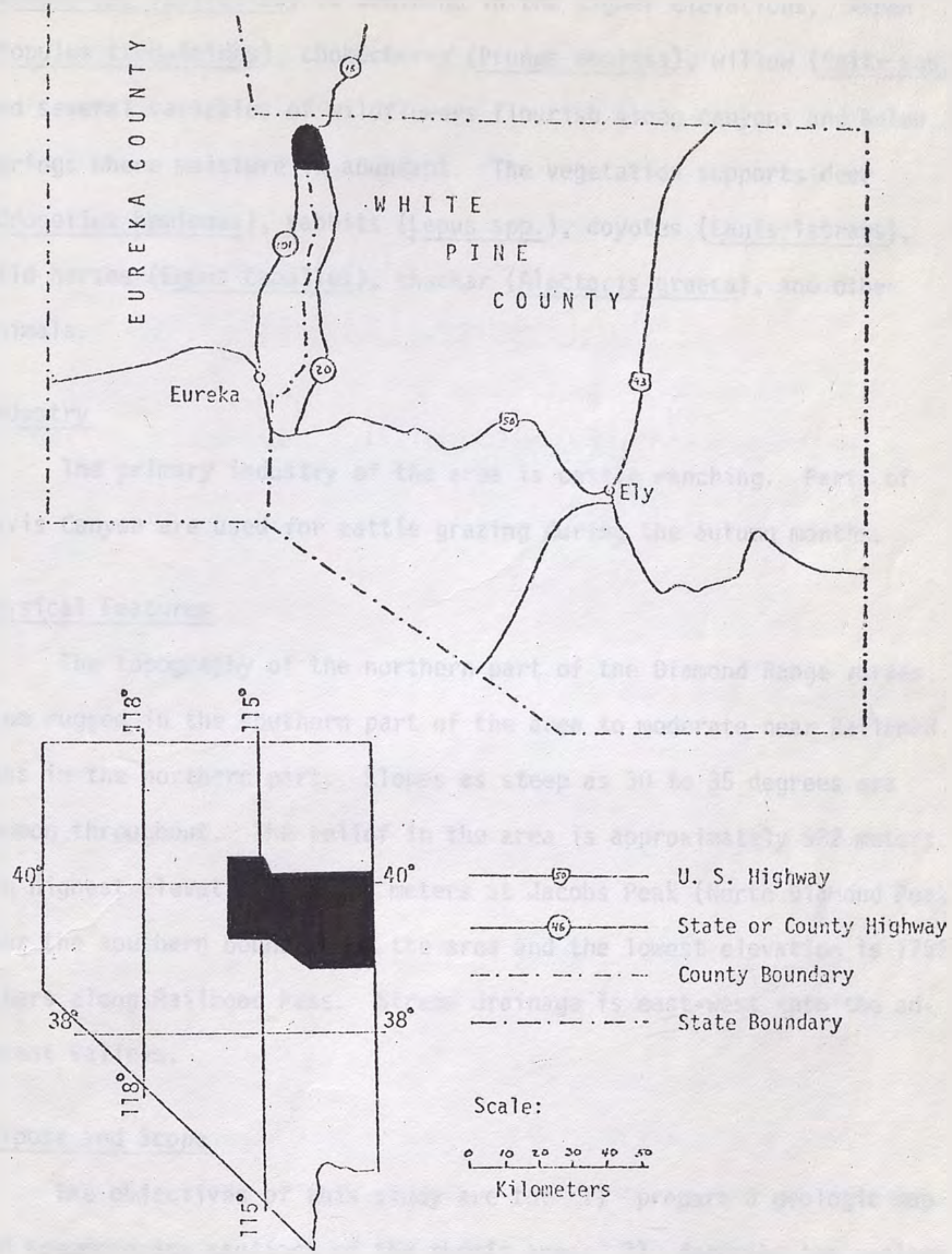

Figure 2 Index map of Nevada showing location of mapped area

(Cerocarpus ledifolius) is dominant in the higher elevations. Aspen (Populus tremuloides), chokecherry (Prunus demissa), willow (Salix spp.), and several varieties of wildflowers flourish along canyons and below springs where moisture is abundant. The vegetation supports deer (Odoceilus hemionus), rabbits (Lepus spp.), coyotes (Canis latrans), wild horses (Equus caballus), chuckar (Alectoris graeca), and other animals.

Industry

The primary industry of the area is cattle ranching. Parts of Davis Canyon are used for cattle grazing during the autumn months.

Physical Features

The topography of the northern part of the Diamond Range varies from rugged in the southern part of the area to moderate near Railroad Pass in the northern part. Slopes as steep as 30 to 35 degrees are common throughout. The relief in the area is approximately 982 meters. The highest elevation is 2734 meters at Jacobs Peak (North Diamond Peak) near the southern boundary of the area and the lowest elevation is 1752 meters along Railroad Pass. Stream drainage is east-west into the adjacent valleys.

Purpose and Scope

The objectives of this study are to: 1) prepare a geologic map and accompanying sections of the thesis area; 2) describe the geology and lithologic units; 3) present a discussion of the structure and geologic history of the area.

Method of Investigation

Field work was carried out between June and September, 1979. Geologic features were plotted on 1:20000 aerial photographs, and transferred to a topographic base map of the same scale with the aid of a Bausch and Lomb zoom transfer scope. In most cases the geologic features were walked in the field, but in some instances, they could be more accurately traced on the photos.

Stratigraphic sections were measured by the Brunton and tape method. Field descriptions of lithologic units were supplemented by binocular microscope description of hand specimens and by 35 thin sections.

Previous Work

Geologic work in the Diamond Range area dates back to 1869 when the geological exploration of the Fortieth Parallel began under the supervision of Clarence King. The first report on the Fortieth Parallel investigation was published in 1878, and included a brief description by Arnold Hague of lithologic units exposed along Railroad Canyon, the northern boundary of the area involved in this study. Hague published reports on the geology of the Eureka district in 1883 and 1892, and his reports were followed by Walcott's reports on the paleontology in 1884 and 1908. The work of King, Hague, and Walcott established new standards of detailed geologic mapping and of stratigraphic and paleontologic study for the Great Basin (Nolan and others, 1956, p. 2).

Perhaps the most significant contributions toward the geologic knowledge of the area were made during a period of increased interest by geologists of the United States Geologic Survey and the petroleum industry during the late nineteen fifties. Nolan and others revised the Paleozoic stratigraphy of the Eureka area in 1956. A more regional synthesis of the Paleozoic stratigraphy was published by Roberts and others (1958). R. H. Dott, Jr. summarized the stratigraphy of Pennsylvanian age rocks in northeastern Nevada in 1955. More recent works by Brew (1961, 1964), Stewart (1962), Brew and Gordon (1971), and Blomquist (1971) have increased greatly the understanding of Upper Paleozoic rocks in the area.

As was stated previously, Dott (1954) has mapped the northern part of the Diamond Range, but he was principally concerned with Pennsylvanian stratigraphy and his work is of a reconnaissance nature. Larson and Riva (1963) published a map of the central part of the range which was a compilation of more detailed maps by students of the Mackay School of Mines. Nolan and others (1971, 1974) mapped the southern part of the Diamond Range, including the area around Eureka.

Acknowledgements

The author is indebted to the late Dr. E. R. Larson who suggested the problem and Dr. J. Lintz who was of great assistance in the field and in the preparation of the manuscript. Both men were a source of encouragement and advice throughout graduate school. Discussions with Dr. M. J. Hibbard on igneous petrography and Dr. R. J. Watters on structural geology have been helpful. Conversations with Mr. Scott Butler have also been constructive. Additional appreciation goes to Clara Peyton for typing the manuscript.

Special thanks are extended to Mr. Milton Thompson of Diamond Valley, whose generous hospitality greatly aided the field work.

GEOLOGIC SETTING

The Diamond Range is located in the central part of the Great Basin, a region characterized by north-trending fault-bounded mountain ranges. Seventy kilometers to the south of the area, the Fish Creek Range bifurcates to form Whistler Mountain-Sulphur Spring Range to the west and the Diamond Range to the east. Physiographic evidence indicates that the Diamond Range, like most of the mountain ranges in central Nevada, has been tilted eastward (Howard, 1976, p. 54).

Central Nevada was a part of the Cordilleran Geosyncline in early and middle Paleozoic time. During this period, the region underwent steady and continuous subsidence. East-central Nevada (east of the 116th - 117th meridian) was a shallow-water miogeosynclinal (shelf) environment in which nearly 10,000 meters of dominantly carbonate with subordinate quartzite and shale were deposited. The spatial distribution of limestone on the west and dolomite on the east of the miogeosyncline is a reflection of the paleogeography during the Paleozoic. The diagenetic replacement of limestone by dolomite occurs in tidal flat areas where there is a mixing of meteoric and marine waters. (Dunham and Olson, 1978, p. 556). Miogeosynclinal sediments graded westward into a transitional zone characterized by interbedded clastic, volcanic and carbonate beds. The limited extent of the transitional zone suggests a relatively abrupt change from shelf to deep water (Stewart and Poole, 1974, p. 25). Farther west (west of the 116th-117th meridian), clastics and volcanics were deposited in a deep water eugeosynclinal (rise or ocean basin) environment. Black shales and bedded cherts were deposited in the inner part of the eugeosyncline while quartzites, volcanics and greenstones along with chert and shale were typical of the outer belt. The eugeosynclinal sequence was most likely much thicker than that of the miogeosyncline, but subsequent deformation has resulted in accelerated erosion and tectonic thinning.

The Antler Orogeny, which began in the Late Devonian, brought to an end the Cordilleran Geosyncline as it had existed during early and mid-Paleozoic time. The orogeny began with an uplift in west-central Nevada (50 to 100 kilometers to the west), approximately along the transitional zone between the eugeosynclinal and miogeosynclinal sediments. In Early Mississippian time, eugeosynclinal rocks were transported eastward over 100 kilometers along the Roberts Mountains Thrust over folded miogeosynclinal rocks. The Roberts Mountains Thrust has been attributed to gravity sliding (Churkin, 1974; Churkin and McKee, 1974; Smith and Ketner, 1968) and to eastward obduction of the eugeosynclinal rocks contemporaneous with subduction of the oceanic crust farther west. (Burchfiel and Davis, 1972, 1975; Poole and Sandberg, 1977; Shawe and others, 1978). The author concurs with Johnson (1975) who noted that the apparent absence of early orogenic clastics (pre-thrusting) precludes the possibility that the Roberts Mountains Thrust is due to gravity sliding. Eastward directed obduction or westward directed underthrusting seem more plausible.

The cherts, quartzites, and shales of the eugeosynclinal sequence exposed in the Antler Orogenic belt provided a source of clastic debris for the remainder of the Paleozoic.

STRATIGRAPHY

Introduction

Sedimentary rocks in the area consist of conglomerates, sandstones, siltstones, shales, and limestones varying in age from Mississippian to Quaternary. Most of the rocks are Upper Paleozoic in age and were deposited to the east of the Antler Orogenic Belt, an active tectonic zone in west-central Nevada. Sediments derived from the Antler Belt were termed the "Post-Orogenic Overlap Assemblage" by Roberts and others (1958, p. 2328). Rocks of the overlap assemblage are characterized by abundant detrital chert and quartz supplied by eugeosynclinal rocks.

Younger sedimentary rocks are dominated by reworked chert and quartz. Sedimentary structures suggest both fluvial and lacustrine deposition.

Sedimentary rocks are classified according to the Wentworth Grade Scale as published by Folk (1974, p. 25). Descriptions of sorting and roundness are based on tables found in Scholle (1979, p. 102-104). Bedding thicknesses are defined as follows: laminations, less than 1 centimeter; thin-bedded, 1 to 15 centimeters; thick-bedded, 15 centimeters to 1 meter; and massive greater than 1 meter.

Grain size for limestones is described using the following scheme: fine-grained, less than .0625 centimeters; medium-grained, .0625 to 2 centimeters; and coarse-grained greater than 2 centimeters.

Among the terms employed in the text, coquinite refers to a detrital limestone composed of greater than 50 percent fossil debris. An orthoquartzite is a well indurated quartzose sandstone cemented by silica.

The metric system of measurement is utilized in this study. English units with metric equivalents are given when citing authors who used the English system.

Mississippian System

Chainman Shale

The Chainman Shale was named by Spencer (1917, p. 26) for a sequence of black shales of Late Mississippian age overlying the Joana Limestone near the Chainman mine in the Ely mining district. The term was extended to the Eureka area by Nolan and others (1956, p. 59), who measured 5,000 feet (1,525 meters) of Chainman Shale at Secret Canyon, approximately 70 kilometers to the south of the study area. Three thousand nine hundred and fifty feet (1204 meters) of Chainman Shale were measured at Walters Canyon, 22 kilometers south of the study area, by Larson and Riva (1963). Dott (1954) mapped beds herein assigned to the Chainman Shale as the White Pine Shale (?); his map incorrectly shows those beds being truncated by a normal fault that parallels Fourmile Canyon, whereas they actually extend several kilometers north of the canyon.

The Chainman Shale is exposed on the west side of the area near its north end along the crest of a faulted north-trending anticline. The base of the formation is transected by a high-angle fault that parallels the crest of the anticline. The upper contact is gradational; shales, siltstones, and limestones of the Chainman Shale are interbedded with sandstones and conglomerates typical of the Diamond Peak Formation. The top of the formation is considered by the author to be the highest occurrence of dark-colored fine-grained clastics characteristic of the formation.

The Chainman Shale consists of approximately 400 meters of black shale and greenish-gray siltstone interbedded with subordinate limestone, sandstone and conglomerate. The shale and siltstone are not well exposed, usually occurring as float on the ground surface. The shale occurs as small chips (1 cm x .5 cm x .3 cm) while the siltstone forms irregular wedge-shaped fragments (approximately 3 cm x 1 cm x 1 cm). Commonly shale and siltstone intervals are covered by talus from overlying well-exposed rocks. Often the only indication of the presence of the fine-grained clastics is the grayish-brown color of the soil and the paucity of small brush and grasses on the surface.

Limestone interbeds of 1 meter or less in thickness occur throughout the formation. The rock is a dark gray to black, fine to medium-grained bituminous limestone consisting of as much as 50% abraded brachiopod and crinoid fragments. Sub-angular to sub-rounded quartz and chert sand make up 10-20% of the limestone.

Interbedded chert and quartzite pebble and cobble conglomerates and quartz and chert sandstones form resistant outcrops in contrast to the poor exposures of the shale and siltstone. The lithology of these coarse-grained clastic rocks is typical of the overlying Diamond Peak Formation.

Nolan and others (1956, p. 58) indicate a Late Mississippian age for the Chainman Shale.

Diamond Peak Formation

The "Diamond Peak Quartzite" was defined by Hague (1882, p. 28, 1883, p. 268) and described as overlying the "White Pine shale" in a synclinal structure near Diamond Peak, 35 kilometers to the south of the study area.

Hague described fine conglomerates at the base grading upwards to vitreous quartzite and green and brown "schists" and clay shale at the top. Nolan and others (1956, p. 60) proposed the name Diamond Peak Formation because of the large proportion of shale, limestone and conglomerate at the type locality. The formation is 3,525 feet (1074 meters) thick at the type locality (Brew, 1961, p. C111).

In the study area, the Diamond Peak Formation consists of approximately 925 meters of interbedded conglomerates, sandstones, limestones, and siltstones, and gradations between these rock types. The thickness of the formation is probably somewhat variable owing to the gradational contact with the underlying Chainman Shale. Conglomerate is the most distinctive lithology in the Diamond Peak Formation in the area, but siltstones and sandstones predominate. The formation is well exposed throughout the northern part of the Diamond Range, forming approximately 50% of the mapped area. The best exposures are in the southwestern part of the area, along the range front in the western one-half of Secs. 27 and 34, T.25N., R.54E., where mostly coarse clastics form steep ridges on the west limb of a north-trending syncline. The lithologies will be discussed separately because of the heterogeneous nature of the formation.

Conglomerates

The conglomerates are exposed as a series of resistant beds that stand out in marked contrast to the less resistant sandstones, siltstones, and limestones. The differential resistance is particularly noticeable on the east side of the range, where steeply dipping conglomerates alternating with finer clastics form prominent "corridors" (Fig. 3). The conglomerates are massive and void of any internal structure. Contacts with adjacent rock types, although irregular in some places, are generally planar and uniform. Channelling features such as described by Blomquist (1971) in the Buck Mountain area (approximately 40 kilometers to the southeast) were not observed in the Diamond Range.

The color of the conglomerate units varies from light gray to reddish-brown depending on the amount of hematite staining and the overall color of the clasts. Silicified conglomerates are a mottled reddish-brown to olive-green.

Conglomerate clasts consist almost entirely of pebble and cobble-sized chert and quartzite; less abundant limestone clasts are limited to the base of the formation. Chert generally predominates over quartzite, but some of the cobble conglomerates contain as much as 60% quartzite clasts. The chert is generally gray in color, but green, red and black clasts are also common. Quartzite clasts are white and black, and occasionally laminated. The majority of the clasts are pebble-sized (averaging 2 to 3 centimeters) but a few are as large as 15 centimeters across (Fig. 4). The degree of roundness increases with increasing size, from sub-rounded for pebbles to rounded for cobbles. The clasts are set in a matrix of sub-angular to sub-rounded sand and silt-sized grains of quartz and chert. Clay is present in varying proportions. The matrix of the conglomerates is compositionally and texturally similar to the Diamond Peak sandstones.

Sandstones

Diamond Peak sandstone interbeds averaging 3 to 5 meters in thickness are found throughout the formation, but are best exposed where adjacent to resistant conglomerate beds. The sandstones are fine to

Figure 3 "Corridors" formed by resistant conglomerates alternating with finer grained clastic rocks in the Diamond Peak Formation (300 meters southeast of Dora Spring, T.25N., R.55E.).

Figure 4 Quartzite and chert cobble conglomerate in the Diamond Peak Formation; clasts in this outcrop are as large as 15 centimeters across (NW1/4, NE1/4, Sec. 36, T.26N., R.54E.)

coarse-grained and are composed of sub-angular to sub-rounded grains of quartz with subordinate chert and minor accessory minerals. Pebbles and granules are common, often set in a matrix of sand with minor amounts of silt and clay. A few sandstones have been recrystallized to form well indurated orthoquartzites.

The color of the sandstone varies widely depending on the composition and minor constitutents. Light-colored sandstones indicate a predominance of quartz grains while gray and black sandstones contain as much as 40% chert. Red and tan sandstones are stained by iron oxides. The weathering of iron-oxide stained sandstones commonly results in the formation of Liesegang Rings (Fig. 5.).

Sandstones of the Diamond Peak Formation exhibit both horizontal and cross stratification. The stratification is a result of alternating chert-rich and chert-poor layers averaging 1 to 2 centimeters in thickness. Wedge-shaped and foreset varieties of cross stratification were observed. Wedge-shaped cross-beds are bounded by two converging, planar surfaces (Fig. 6). The foreset cross-beds consist of planar bottomset beds, and foreset beds that attain an inclination of 15 to 20 degrees near the top and gradually approach the attitude of the bottomset beds towards their base; topset beds have been removed by erosion. The average dip of the foreset cross bed studies was 15 to 20 degrees in the direction N90°E, indicating a west to east current flow.

In thin section,the sandstones are seen to consist of an average of 75% quartz and 25% chert. Single specimens contained as much as 95% quartz or as little as 60%. Approximately 5% of the quartz is strained. Heavy minerals are dominantly tourmaline and zircon with lesser amounts

Figure 5 Liesegang weathering of an iron-oxide stained sandstone in the Diamond Peak Formation (NE1/4, SE1/4, Sec. 36, T.26N., R.54E.).

Figure 6 Wedge-shaped cross-beds in a sandstone of the Diamond Peak Formation. Field of view is approximately 1 meter across (SW1/4, Sec. 23, T.25N., R.54E.).

of rutile and epidote. Tourmaline, rutile, and epidote occur as sub-rounded to sub-angular grains; zircon is usually rounded to well-rounded.

Sandstones are most commonly cemented by silica in the form of a microcrystalline matrix or as quartz overgrowths that form in optical continuity with the original grain (Fig. 7). Calcite is the cementing agent of a few beds, usually in association with the etching or corrosion of chert and quartz grains.

Limestones

Limestone beds 1 to 2 meters in thickness are found throughout the Diamond Peak, but overall comprise less than one percent of the formation. The thick-bedded to massive limestones are generally medium to dark gray in color and medium to coarse-grained, weathering to light or medium gray. Fossils and clastic debris are generally absent, although a few beds contain sparse gastropods, brachiopods, and crinoids.

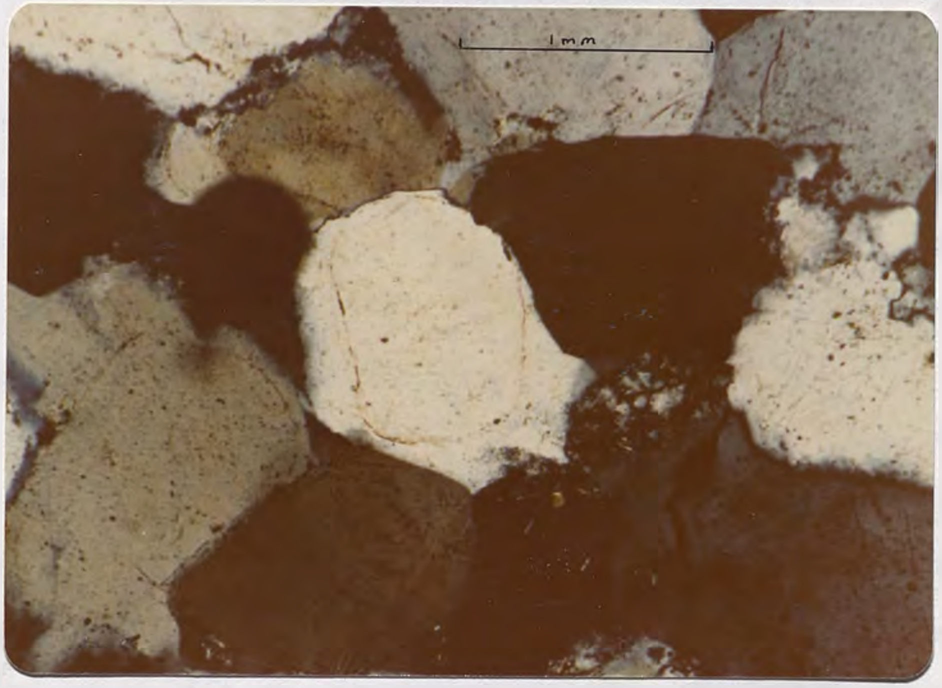

Figure 7 Quartz sandstone in the Diamond Peak Formation cemented by secondary overgrowths of detrital quartz grains.

Siltstones

Poorly exposed maroon, reddish-brown, and green siltstones occur throughout the Diamond Peak Formation in the area, but are especially prominent in the upper part of the formation on the west side of the range. An upper siltstone member was distinguished from a lower conglomerate member by Dott (1954). Bedding planes are usually wavy with individual beds varying from a few centimeters to nearly a meter in thickness. Ripple marks and micro-cross-laminations are common. Ripple marks are characterized by an average ripple width of 2 centimeters and a ripple height of .5 centimeters with the steep side inclined to the east. The N10°W trend of the ripples indicates a N80°E current direction.

The siltstones are commonly interbedded with thin-bedded, fine-grained sandstones and pebbly siltstones. The pebbly siltstones contain numerous elongate, rip-up clasts of fine-sandstone and siltstone that were most likely derived from adjacent beds.

In thin section, the siltstones are composed of angular to subangular quartz silt in a sericitic matrix. Quartz grains are commonly rimmed by translucent hematite. Petrographic work performed by Brew (1964) determined that the color of the siltstones is a function of the amount of iron minerals, with red siltstones containing 7 to 8 times as much opaque iron minerals as the green siltstones.

The contact between the Diamond Peak Formation and the overlying Ely Limestone is gradational. Within a stratigraphic interval of 50 meters, chert and quartzite pebble conglomerates and red siltstones and sandstones characteristic of the Diamond Peak Formation are interbedded with thick-bedded limestones and pebbly limestones characteristic of the Ely Limestone. The dominant lithology in this interval is a few beds contain sparse gastropods, brachiopods, and crinoids.

Figure 7. Quartz sandstone in the Diamond Peak Formation cemented by secondary overgrowths of detrital quartz grains.

siltstone of the Diamond Peak; limestones are subordinate, and no more than 1 meter thick. The contact was placed at the highest occurrence of red siltstone in the section because above this horizon limestone is the dominant lithologic type and below this horizon quartzose rocks predominate. Near the contact the red siltstone of the Diamond Peak becomes increasingly calcareous and the limestone contains an increasing amount of red ferruginous material (Fig. 8).

The Diamond Peak Formation is mostly of Late Mississippian age but may include beds of Early Pennsylvanian age in the upper part (Dott, 1955, p. 2268).

Figure 8 Red, calcareous siltstones interbedded with gray limestones in the upper part of the Diamond Peak Formation (E1/2, NE1/4, Sec. 26, T.25N., R.54E.).

Pennsylvanian System

Ely Limestone

The name "Ely limestone" was proposed by Lawson (1906, p. 225) for thick-bedded cherty limestones that are exposed in the Robinson mining district, 100 kilometers southeast of the study area. The unit was redefined by Spencer (1917, p. 27-28) for beds of Pennsylvanian age lying between the Chainman Shale and the Arcturus Formation in the Ely mining district. The usage of the term was extended to the Eureka area by Nolan and others (1956, p. 61-63). These beds were initially mapped in the Eureka area by Hague (1883, p. 268-270; 1892, p. 85-91) as part of his "Lower Coal Measures limestone." Dott (1955, p. 2234) elevated the Ely to group status in the Elko-Carlin area (80 kilometers to the north), defining the Moleen (lower limestone) and Tomera (upper conglomerate and limestone) formations, and extended this division to parts of central Nevada, including the northern part of the Diamond Range.

The Moleen and Tomera formations as defined by Dott are somewhat obscure in the study area. While there is a decrease in nodular chert and an increase in terrigenous material upwards in the section, this change is gradual and is not defined by a traceable lithologic horizon. The Ely Limestone (formational status) is recognized in this paper because distinctive lithologic characteristics of the Moleen and Tomera formations are absent in the Diamond Range.

Prominent ledges alternating with covered intervals characterize the Ely Limestone in the study area as well as throughout central Nevada. The formation is well exposed in the area, occurring in a continuous outcrop band near the crest of the range, and in three isolated outcrops in the northern part of the area. The best exposures are between Davis and Fivemile canyons on the west side of the range, where 552 meters were measured.

The ledge-forming limestone is light to dark gray, and weathers light gray to brown. Individual ledges are commonly 2 to 10 meters in thickness with distinct stratification planes varying from a few centimeters to more than a meter. Numerous small caverns are prominent in the larger ledges near the base of the formation. The limestone is fine to coarse-grained and is largely detrital, although a few beds appear to be mostly non-detrital. Terrigenous quartz and chert sand and silt is present in varying quantities throughout the limestone, making up as much as 30% of some beds in the upper half of the formation. Lenses of subangular to sub-rounded red, green, and gray chert pebbles, commonly 1 to 2 centimeters in thickness, are present in otherwise homogeneous limestones (Fig. 9). Carbonate and silica detritus is set in a fine-grained calcareous matrix that lacks any evidence of recrystallization. Well to poorly preserved fossils and fossil fragments are abundant. Crinoids and brachiopods are common throughout the formation, usually as abraded or disarticulated fragments. Bryozoa, fusulinids, and corals are less prominent.

A distinctive characteristic of the ledge-forming limestone is secondary chert layers and nodules that are parallel to bedding (Fig. 10). Chert is most commonly black on the interior surface and brown or tan on the exterior. Chert layers averaging 5 centimeters in thickness are prominent near the base of the formation. Rhythmically spaced layers make-up as much as 40% of some outcrops, giving the rock a distinctive

Figure 9 Lenses of detrital chert pebbles in a thick-bedded portion of the Ely Limestone (500 meters north of hill 7768, T.25N., R.55E.).

Figure 10 Chert layers and nodules contained in thick-bedded portions of the Ely Limestone. Note the alternating thin-bedded limestone (NE1/4, Sec. 12, T.25N., R.54E.).

striped appearance. Irregularly shaped chert nodules averaging 10 centimeters are common throughout the formation. A three-dimensional view of chert nodules provided by bedding plane surfaces indicates that the nodules are essentially "tire-shaped," reaching diameters of up to 1 meter. The preservation of identical fossil fragments in the chert and the limestone points to a replacement or secondary origin for the chert. This concurs with the majority opinion of sedimentologists on the origin of nodular chert (Pettijohn, 1975, p. 474; Krauskopf, 1967, p. 170).

The slope-forming intervals are underlain by thin-bedded, light to dark gray fossiliferous limestones that commonly contain abundant terrigenous sand and silt. The weathering of these beds yields a light pink to tan, platy float.

A few thin beds (1 to 2 meters thick) of reddish-brown pebble conglomerate are interbedded with limestone in the upper 300 meters of the formation. The conglomerate consists of sub-angular to sub-rounded clasts of red, green, gray, and black chert, and white and gray quartzite set in a quartz-sandy and calcareous matrix. A unique sequence of cobble and pebble conglomerates interbedded with pebbly sandstones is found near the top of the formation, approximately 1 kilometer southeast of Jacobs Peak (NE1/4, NE1/4, Sec. 36, T.25N., R.54E.). In this outcrop, conglomerate clasts are composed of tan laminated sandstone and red argillite (?), in addition to chert and quartzite. Interbedded pebbly sandstones are cross-bedded, with some cross-beds attaining an inclination of 30 degrees to the east. This sequence is less than 7 meters thick, and is not traceable for more than 10 meters.

The colonial coral Chaetetes occurs in a zone less than 1 meter thick, approximately 350 meters above the base of the formation. The widespread occurrence and restricted range of the Chaetetes faunizone suggests time-stratigraphic significance (Dott, 1955, p. 1246).

The Ely is of Springeran through Lower Atokan age (Dott, 1955, p. 2264) and is disconformably overlain by the Carbon Ridge Formation. The contact is usually covered over an interval of less than 10 meters, and is drawn at the highest occurrence of gray ledge-forming limestone typical of the Ely.

Permian System

Carbon Ridge Formation

A sequence of very poorly exposed brown siltstones alternating with limestones and coquinites disconformably overlies the Ely Limestone. These beds were mapped as "Undifferentiated Permian" by Dott (1954) in the northern part of the Diamond Range, and as informal "Unit A" by Larson and Riva (1963) in the central part of the range. Riva (1957, p. 13) assigned this sequence to the Late Wolfcampian on the basis of the fusulinid fauna, and correlated it with the Carbon Ridge Formation in the Eureka area because of lithologic similarity and identical stratigraphic position. The present author has visited the type locality of the Carbon Ridge Formation, and accepts the correlation of Riva.

The Carbon Ridge Formation was proposed by Nolan and others (1956, p. 64) for dominantly calcareous rocks of Wolfcampian age that are exposed south and east of Eureka. Many of the beds assigned to the Carbon Ridge Formation were initially mapped by Hague (1883, p. 270; 1892, p. 93-95) as part of his "Coal Measures limestone" of Carboniferous age.

Nolan and others (1956, p. 65) report 1,750 feet (533 meters) of the formation at Carbon Ridge, 65 kilometers to the south of the study area.

The Carbon Ridge Formation is exposed in the southeastern and central parts of the area, forming the crest of the range for a distance of three kilometers. The bare, grassy slopes of the formation are distinctive, and can be recognized from a distance (Fig. 11). A thickness of 427 meters was measured by the author in the southern part of the area; 1,350 feet (411 meters) were measured by Larson and Riva (1963) a few kilometers to the south.

Two members were identified at the measured section on the basis of lithologic and faunal characteristics. Poor exposures elsewhere in the formation prohibited the mapping of the two members. The lower member consists of 110 meters of dark-gray to brown thin-bedded siltstone. The siltstone is characteristically poorly exposed, usually occurring as

Figure 11 View looking northeast towards hill 8602, near the central part of the area. The barren slopes of the Carbon Ridge Formation above the ledge-forming Ely Limestone.

light-brown platy float with fragments averaging 2 to 4 centimeters in thickness. Worm trails and small brachiopods are abundant. Some beds are finely laminated, with individual laminations varying from 2 to 10 millimeters. Secondary black chert in the form of nodules and beds is distinctive near the top of the unit. In thin section, the rock consists of sub-angular to angular quartz silt in a fine-grained matrix of sericite and calcite. Fine laminations are the result of slight changes in texture or in the amount of quartz silt present.

The upper member consists of thin-bedded brown siltstone typical of the lower member interbedded with thick-bedded to massive limestone and coquinite. The limestone and coquinite form small ledges (1 to 2 meters thick) in contrast to the poor exposures of the siltstone. Secondary black chert is abundant in this member. The fine to coarse-grained bituminous limestone is medium to dark-gray, and weathers to light gray. Sub-angular to sub-rounded quartz and chert sand and silt is present throughout the member, making up as much as 30% of some beds. Sub-rounded pebbles and granules of red, green, and gray chert are present in minor amounts in limestone beds near the top of the formation. In thin section, the limestone consists of dominantly angular to sub-angular detrital fossil fragments in a fine-grained calcareous matrix. Rounded sand-sized grains of reworked quartz siltstone make-up less than 5% of the limestone.

Fossil content in the upper member is highly variable, with individual beds ranging from unfossiliferous to highly fossiliferous coquinites. The limestone contains crinoids, brachiopods, bryozoa, and fusulinids. The coquinites are commonly composed of crinoid stems (as large as 1 centimeter) and brachiopod shells, with fewer bryozoa and fusulinids.

One of the most striking features of the Carbon Ridge Formation is secondary black chert beds and nodules. The chert occurs in both members, but is more abundant in the upper member. Chert nodules average 20 centimeters x 10 centimeters, whereas chert beds often attain thicknesses of 70 centimeters or more. Both forms of chert are bordered by a 1 to 2 centimeter zone of slightly calcareous material, indicating incomplete replacement of the limestone by the chert. The border zone of the chert beds consists of partially replaced coquinites. The author believes that the coquinites were selectively replaced by the chert because of their high initial permeability.

The abundant and diverse fusulinid fauna in the Carbon Ridge Formation has drawn a great deal of attention from paleontologists. Henbest (in Nolan and others, 1956, p. 65-66) has identified four faunal zones from the Carbon Ridge Formation in the Eureka area. The first is characterized by cylindrical or cigar-shaped species of Triticites such as T. irregularis (Staff), T. ohioensis, T. oryziformis Newell, and T. plicatulus Merchant and Keroher. The second and third zones are characterized by Pseudoschwagerina and Schwagerina, respectively. Pseudoschwagerina fauna were found to be more abundant in the western exposures and the Schwagerina fauna in the eastern exposures; locally, the two faunas interfinger. Henbest's highest zone, the Parafusulina zone, was found only in the southern Diamond Mountains. Nolan and others (1956, p. 66) reported that although the lowest or Triticites zone was suggestive of a Pennsylvanian age for the base of the formation, the associated fauna was more indicative of a Permian age. They concluded that the fauna indicated a Wolfcampian age for the bulk of the formation, and possibly a Leonardian age for the upper part. In the Diamond Range, Dott (1955, p. 2271) and Riva (1957, p. 13) have assigned this sequence to the Wolfcampian.

Garden Valley Formation

Interbedded conglomerates, pebbly sandstones and fusuline-bearing limestones are in fault contact with the Diamond Peak Formation near the western edge of the study area. In the Central Diamond Range, Larson and Riva (1963) correlated this sequence with the Garden Valley Formation of Permian age on the basis of faunal and lithologic similarities. The author concurs with Larson and Riva (1963) and the correlation is accepted in this paper.

The Garden Valley Formation was named by Nolan and others (1956, p. 67-68) for exposures on the west slope of the Sulphur Spring Range, 35 kilometers southwest of the study area. Nolan and others (1956, p. 67-68) recognized four members within the Garden Valley Formation: 1) a basal limestone and sandstone member; 2) one made up of conglomerate, sandstone, and shale; 3) a resistant siliceous conglomerate; and 4) a sequence of purple and red shales and conglomerates. The sequence in the Diamond Range is correlated with the lower two members of the formation at the type locality.

Limestone is the dominant lithology in the study area. The limestones are generally light to medium gray and fine to medium-grained, weathering to light gray or brown. Most are thick-bedded to massive, but thin-bedded limestones are also present. Sub-angular chert and quartz sand is usually present in amounts greater than 5%. Sub-angular to sub-rounded chert and quartzite pebbles are common in a few beds, either in discrete lenses or distributed throughout the rock. The limestone as a whole is poorly fossilferous, but crinoid, fusulinid, and brachiopod fragments comprise as much as 30% of individual beds. Small, brown chert nodules (less than 10 centimeters thick) are rare.

Massive and structureless conglomerate interbeds are generally over 10 meters in thickness. The color of the conglomerate varies from light gray to light red depending on the amount of hematite staining. The conglomerates are composed of sub-angular to rounded pebbles (averaging 1 to 3 centimeters in diameter) of light-colored chert and quartzite. Some beds are composed largely of well-rounded cobbles. Pebbly sandstones contain anywhere from 50 to a few percent pebbles. The matrix is composed of fine to medium-grained, sub-angular to subrounded quartz sand, with varying amounts of silt. Silica is the cementing agent.

Rocks as far away as 100 meters from the fault contact with the Diamond Peak Formation have been strongly recrystallized and silicified. The granular texture of some of the conglomerates has been obscured by recrystallization. The limestones near the fault are commonly silicified, or strongly recrystallized and cut by irregular calcite veinlets. Near Davis Canyon silicified beds show prominent Liesegang rings.

The exact thickness of the Garden Valley Formation in the study area is indeterminable due to spotty exposures and concealed structure, but it is probably greater than 500 meters.

Larson and Riva (1963) considered the Garden Valley Formation as defined to be Leonardian in age on the basis of Parafusulina and associated fauna. Dott (1955, p. 2272) suggested a Leonardian or Wolfcampian age based on Pseudofusulina sp. and Schwagerina or Parafusulina collected from the study area. Both Parafusulina and Pseudoschwagerina were identified at the type locality by Nolan and others (1956, p. 68), who consider the formation to be Wolfcampian or Leonardian at the base and possibly as young as Triassic near the top. It is possible that the Garden Valley Formation in the study area is correlative with the Carbon Ridge Formation of Wolfcampian age exposed near the crest of the range, but it seems more likely, owing to substantial lithologic differences, that the Garden Valley Formation is slightly younger.

Cretaceous System

Newark Canyon Formation

Lying with angular discordance above the Carbon Ridge Formation in the central and northern parts of the Diamond Range is a sequence of sandstones, siltstones, conglomerates, and limestones. These rocks were mapped by Larson and Riva (1963) as informal "Unit G" of presumed Guadalupian age in the central part of the range, and as undifferentiated limestone and siltstone of Permian age by Dott (1954) in the northern part of the range.

Noting the absence of angular unconformities in the Permian section in the Diamond Range area, Larson (in Langenheim and Larson, 1973, p. 21) tentatively correlated "Unit G" with the Newark Canyon Formation of Early Cretaceous age. Similar designations were made by Stewart and Carlson (1976) and Hose and Blake (1976, p. 16). The correlation of Larson is accepted in this paper because of the similar lithologic characteristics and stratigraphic position of "Unit G" and the Newark Canyon Formation.

The Newark Canyon Formation was defined by Nolan and others (1956, p. 68) for a heterogeneous assemblage of fresh-water limestones and clastic rocks of Early Cretaceous age that are exposed at the type locality, 50 kilometers to the south of the study area. The Newark Canyon Formation rests unconformably on Paleozoic Formations ranging in age from Ordovician to Permian; the unconformity is angular in most places.

The Newark Canyon Formation is exposed in the southeastern part of the study area where it forms the core of an asymmetrical syncline that parallels the crest of the Diamond Range. The contact with the underlying Carbon Ridge Formation is an angular unconformity with a discordance of up to 25 degrees; the degree of discordance of the contact is obscured by poor exposures. The formation is 142 meters thick at the measured section and consists of a basal 67 meters of interbedded sandstone and conglomerate and an upper 75 meters of siltstone with minor conglomerate. The upper part of the formation has been eroded.

The lower member forms a prominent ridge on the west limb of the syncline near the southern boundary of the area. The unit consists of light gray or tan laminated sandstone alternating with tan chert and quartzite pebble conglomerate. The sandstones, which are moderately to well sorted, are composed of sub-angular to sub-rounded grains of fine to medium-grained quartz and chert. Calcite and silica act as cementing agents. Limonite staining is ubiquitous. The basal sandstone contains silicified fusulinids that have been reworked from Paleozoic rocks, most likely from the Carbon Ridge Formation. In thin section, the sandstones contain trace amounts of microcline and plagioclase, suggesting a partial granitic source. The conglomerates are composed of angular to rounded clasts of white quartzite and green, gray, and red chert set in a fine-grained matrix of sub-angular to sub-rounded quartz and chert. In general, the quartzite clasts have a slightly higher degree of roundness than the chert clasts. This occurs as a result of the tendency of chert to fracture and split during transport (Folk, 1974, p. 81). Most pebbles are 1.5 centimeters or less in the maximum direction, but a few are as much as 4 centimeters long. The conglomerates are massive and void of any channelling features.

The upper member consists of poorly exposed reddish-brown quartz siltstone with thin interbeds of chert pebble conglomerate. The conglomerate is composed of pebbles of green and red chert set in a fine sand or silty matrix; most pebbles are less than 1 centimeter in diameter. The weathering of the upper siltstone unit produces a deep red soil (Fig. 12)

Figure 12 Typical poor exposures and red color of the upper part of the Newark Canyon Formation. Slopes in the background are underlain by the Carbon Ridge Formation. View is looking south toward measured section d-d'.

that is characteristic of the Newark Canyon Formation in the Eureka area (Nolan and others, 1956, p. 69).

The Newark Canyon Formation has been assigned to the Lower Cretaceous (Nolan and others, 1956, p. 70) on the basis of terrestrial plants, fossil fish, and fresh-water gastropods collected in the Eureka area. Indigenous fossils were not observed from the formation in the study area; it is assumed that the Lower Cretaceous age of the formation applies to the northern part of the Diamond Range.

Tertiary System

Fluvial and Lacustrine Sediments

Variegated sediments of probable Tertiary age are poorly exposed along Railroad Pass, forming a thin veneer above the underlying Diamond Peak Formation (Fig. 13). The sediments consist of light-gray, tan, red, and dark-gray sandstone and pebbly sandstone interbedded with conglomerate. The sandstone is composed of greater than 95 percent sub-angular to angular quartz, and less than 1 percent each of chert, feldspar, and hornblende(?). The grains are weakly cemented by calcium carbonate, and in some beds set in a fine-grained volcanic ash matrix. The conglomerate contains sub-angular to sub-rounded pebbles of chert and quartzite in a quartz-sandy matrix.

The presence of hornblende (?), feldspar, and volcanic ash indicates that the Tertiary sediments were derived, at least in part, from volcanic rocks. Cross-bedding, fine-laminations, and cut-and-fill structures suggest both fluvial and lacustrine deposition (Fig. 14).

Figure 13 View to the west showing the variegated Tertiary sediments. The Railroad Pass road is at far right (SW1/4, NE1/4, Sec. 30, T.26N., R.55E.).

Figure 14 Cross-bedding in this outcrop gives evidence for a fluvial origin for this part of the Tertiary sequence. Cross-beds dip approximately 15 degrees to the east (SW1/4, NE1/4, Sec. 30, T.26N., R.55E.).

Quaternary System

Sedimentary rocks of Quaternary age are divided into older and younger alluvium on the basis of texture and overall form. The two types are distinguishable both in the field and on aerial photos.

Older Alluvium

Prominent terraces surrounding Diamond Valley represent the shoreline of Pleistocene Lake Diamond. Lake Diamond was one of several lakes that dotted the Great Basin during the Pleistocene Epoch when the climate was cooler and the rate of precipitation was considerably higher. Field examination by Hubbs and Miller (1948, p. 34-35) showed that valleys to the west drained into Diamond Valley through Devils Gate (55 kilometers to the south) and filled the lake to a maximum depth of 130 feet (40 meters). The outlet of the lake was at Railroad Pass where it emptied into the south fork of the Humboldt River.

Lake terraces are present along the western boundary of the area and are mapped as older alluvium. The best exposures of older alluvium are near the mouth of Fourmile Canyon where terraces have been dissected by intermittent streams. The older alluvium is composed of alternating fine and coarse gravel beds that are weakly cemented by calcium carbonate. The coarser beds, which are generally 1 meter or more in thickness, consist of well-rounded cobbles of conglomerate, sandstone, and quartzite in a matrix of sub-rounded to rounded pebbles of conglomerate, sandstone, quartzite and limestone. The finer gravel beds are very well sorted and are composed of sub-rounded to rounded pebbles of sandstone, quartzite and limestone. Contacts between the beds are generally planar, although somewhat irregular. The high degree of textural maturity of the older alluvium indicates a high-energy beach-type environment of deposition.

Younger Alluvium

Younger alluvium is not widespread in the northern part of the Diamond Range. The lack of development can be attributed to the narrow and steep-sided canyons that commonly contain intermittent streams that cut down to the bedrock surface. The best exposures, however, are on the east side of the area where the mountain front gradually slopes into Huntington Valley. Younger alluvium is composed of angular to sub-angular silt and sand, and sub-angular to sub-rounded gravel; all rock types exposed in the area are represented in the alluvium.

IGNEOUS ROCKS

Two small granodiorite stocks and an andesite dike intrude the Paleozoic rocks. The classification of the igneous rocks is based on a system by Travis (1955, p. 12). Textural and structural descriptions are patterned after Jackson (1970, pp. 255-273). Grain size is described as follows: aphanitic, crystals are not visible to the unaided eye; fine-grained, crystals are visible but less than 1 millimeter in diameter; medium grained, 1 to 5 millimeters; and coarse-grained greater than 5 millimeters.

Granodiorite Stocks

A small granodiorite stock intrudes rocks of the Ely Limestone and the Diamond Peak Formation at Jacobs Peak(North Diamond Peak) along the crest of the range (Fig. 15). The prominence of Jacobs Peak (rising over 100 meters above the crest of the range) reflects the good exposures and resistance of the granodiorite to erosion. Sub-parallel joints with an approximate attitude of N25°E 50°W give the rock a "bedded appearance."

Megascopically, the granodiorite is light gray to white and fine to medium-grained. White to light gray orthoclase and plagioclase, and colorless quartz phenocrysts are dominant. Dark green to black pseudo-hexagonal biotite crystals as long as 8 millimeters across are common, usually weathering to a distinctive golden brown. Subhedral crystals of black hornblende are rare.

In thin section, the rock is a hypidiomorphic-granular hornblende-biotite granodiorite, consisting of 55% plagioclase (An 34-44), 20% quartz, 10% orthoclase, 10% biotite, and 5% hornblende. Plagioclase

Figure 15 View looking east towards the granodiorite stock at Jacobs Peak. Black meta-siltstones of the Diamond Peak Formation are in the foreground.

crystals are elongate and subhedral to euhedral. Albite and combined carlsbad-albite twins are common; pericline and baveno twins are less prominent. Most of the plagioclase is normally zoned from a calcic core to a sodic rim. Quartz and orthoclase are anhedral and inequigranular. Biotite occurs as subhedral to euhedral tabular crystals. Hornblende is usually anhedral and irregularly shaped. Trace amounts of sphene, zircon, apatite, hematite, and calcite are present.

Parts of the granodiorite stock are transected by small aplite dikelets, commonly no more than a few centimeters in width. The light gray, fine-grained aplite is composed dominantly of quartz and alkali feldspar, with only a trace amount of biotite. According to Williams and others (1954, p. 16), "Aplites develop from residual solutions of the magmas that produce the plutons they transect, and hence are composed chiefly of the minerals that crystallized last." The post-grandiorite age of the aplite is suggested by field relationships and thin section observation (Fig. 16). Small, isolated outcrops of quartzose material near the center of the pluton are most likely genetically related to the aplite.

Two groups have dated the stock by lead-alpha ratios in zircon, and two different ages have resulted. Sterns (in Roberts and others, 1966, p. 48) gives an age of 30 ± 10 million years; Roberts (in Adair and Stringham, 1960, p. 231) gives an age of 45 ± 10 million years. On the basis of these determinations, the stock is most likely Eocene or Oligocene.

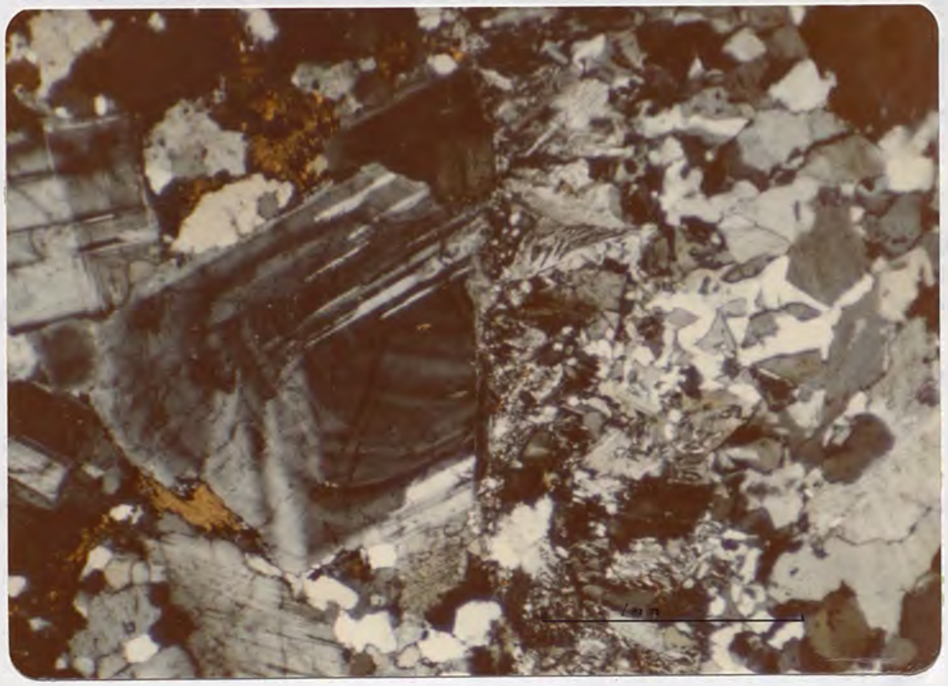

Figure 16 Photomicrograph of an aplite dikelet (right) transecting the granodiorite. Note the sheared plagioclase grain at the contact. (Sample collected in SE1/4, SW1/4, Sec. 25, T.25N., R.54E.)

A granodiorite stock also intrudes rocks of the Diamond Peak Formation near Fivemile Canyon. The granodiorite is very poorly exposed, usually occurring as scattered cobbles or boulders on the surface. The effects of weathering and limonite staining are pervasive in marked contrast to the granodiorite at Jacobs Peak.

The stock is composed of light gray to brown, fine to medium-grained hornblende biotite granodiorite. It is both compositionally and texturally identical to the granodiorite at Jacobs Peak, and is most likely contemporaneous.

Andesite Dike

An olive-green, propylitized, biotite-hornblende andesite intrudes rocks of the Diamond Peak Formation in the northeast quarter of section three, north of Fourmile Canyon. The andesite appears to be at least partially discordant with the sedimentary rocks, and is therefore termed a dike. The poorly exposed dike can be traced for over 400 meters, with an observable thickness varying from 5 to 20 meters.

In hand specimen, the andesite consists of 35% plagioclase, 10% hornblende, 5% biotite, and 50% fine-grained, olive-green matrix. Tan-colored altered phenocrysts of plagioclase are the most distinctive characteristic of the rock. Subhedral to euhedral black biotite and hornblende are also partially altered. On the weathered surface, alternating 5 millimeter bands of olive-green and tan are conspicuous.

The pervasive nature of the propylitic alteration is clearly visible in thin section. Practically all of the rock is at least partially replaced by intergrowths of calcite and chlorite. Plagioclase phenocrysts are completely replaced; hornblende and biotite crystals are usually only partially replaced. Trace amounts of apatite and quartz are also present.

The andesite dike is probably contemporaneous with andesite dikes and flows of Oligocene age in the Eureka area.

Contact — Metamorphic Rocks

The effects of contact metamorphism are extensive around both granodiorite stocks, but are most pervasive near Jacobs Peak where limestones have been strongly recrystallized.

Within 30 meters of the granodiorite at Jacobs Peak, the Ely Limestone has been recrystallized to a coarse-grained white marble with accessory garnet (grossularite - andradite) and chrysocolla. The garnets are red and dark green and commonly as large as 1 centimeter in diameter; some phases of the marble are essentially composed of "garnet-rock," or large masses of garnets weakly cemented by calcite. The presence of light-blue chrysocolla along fractures and dispersed throughout the marble has drawn a great deal of attention from prospectors in the past. According to ranchers in Diamond Valley, the numerous small prospect pits in the marble were dug during the 1950's, apparently without significant production.

In thin section, the coarse-grained marble consists of 90% calcite, 5% garnet, 5% chrysocolla, and trace amounts of quartz and hematite (Fig. 17). The calcite is 1 to 3 millimeters in diameter and equidimensional in shape. Subhedral to euhedral garnet crystals averaging .2 to .4 millimeters are commonly zoned, and occur as individual crystals and intergrown masses. Chrysocolla is interstitial between the framework grains.

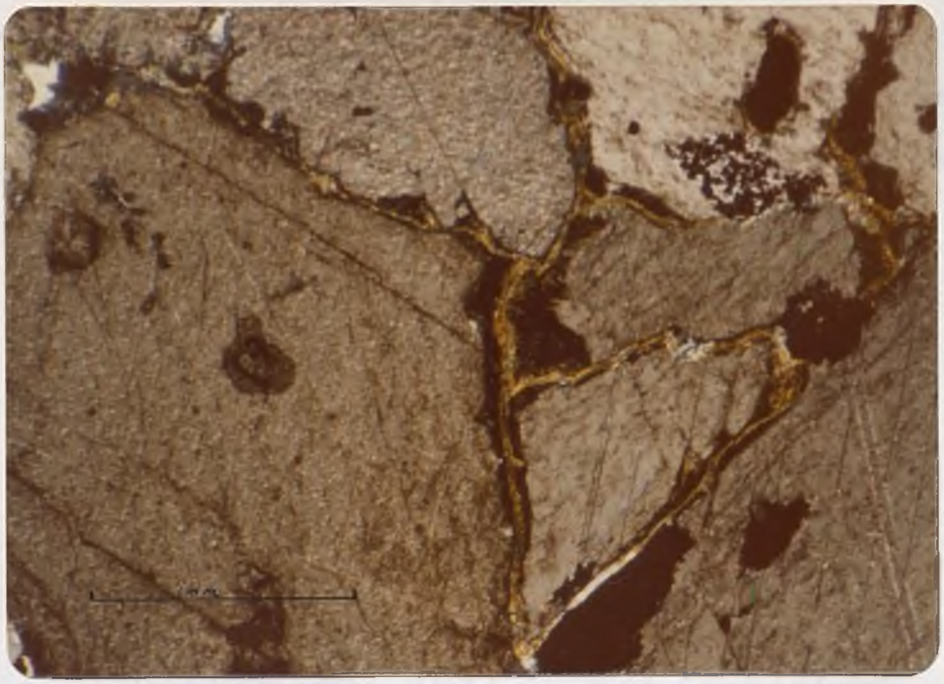

Figure 17. Photomicrograph of the coarse-grained marble. Note the interstitial chrysocolla between crystals of calcite. The dark-colored grains in the upper right-hand corner are garnets. (Sample collected in NE1/4, SW1/4, Sec. 25, T.25N., R.54E.)

Fine-grained marble is found as far away as 130 meters from the contact. In thin section, the marble is composed of 90% calcite, 5% tabular-shaped, subhedral wollastonite, and 5% percent anhedral diopside. The wollastonite - diopside - calcite assemblage is typical of marbles formed at high temperatures (Williams and others, 1954, p. 190). Cherts interbedded with the limestone have been recrystallized to quartzite.

Clastic rocks of the Diamond Peak Formation near the contact have been less noticeably affected, resulting in an obliteration of the granular texture and a reduction of the hematite to magnetite.

Siltstones and sandstones within 50 to 75 meters of the stock near Fivemile Canyon have been recrystallized to form resistant beds that stand out above the poorly exposed grandiorite. Meta-siltstones are black, fine-grained, and massive. The clastic texture of the red to green meta-sandstones has been obscured by recrystallization.

STRUCTURAL GEOLOGY

Structural Setting

Basin-and-Range structure precludes the possibility of correlating structural features or delineating fold systems over a regional area, but generalizations can be made.

The Diamond Range lies in a zone characterized by broad, north-trending folds in Paleozoic rocks. To the east of the study area (including the southern Ruby Mountains, Buck Mountain-Bald Mountain area, and the Butte Mountains) the folds are typically open and gentle, with average dips less than 40 degrees (Sharp, 1942; Rigby, 1960; Douglass, 1960). In the western part of the zone, including the Diamond Range-Pinon Range area, the rocks are more intensely deformed into tighter and sometimes overturned folds (Nolan and others, 1971, 1974; Larson and Riva, 1963; Ketner and Smith, 1974; Smith and Ketner, 1977). The folded rocks are offset by high-angle and thrust faults of varying trends.

Introduction

The rocks of the northern part of the Diamond Range have been moderately deformed by folding and faulting. The north-trending folds were likely the result of east-west directed compression that began as early as the late Paleozoic and continued into the late Mesozoic. The angular unconformity at the base of the Newark Canyon Formation indicates deformation prior to the Early Cretaceous; the folding of the Newark Canyon Formation was the result of a younger period of deformation.

Younger high-angle faults, including one reverse fault, have displaced the folded rocks.

Folds

The major fold in the area is a north-trending asymmetrical syncline that parallels the crest of the range. The Paleozoic and Mesozoic rocks are folded about the north-trending axis which plunges 10 to 15 degrees to the south. The description of the geometry of the fold is somewhat generalized due to the poor exposures of the Carbon Ridge and Newark Canyon Formations. The average dip of the western limb of the syncline is less than 45 degrees east, but locally, beds at the top of the Ely Limestone are nearly vertical (Fig. 18). The eastern limb maintains a dip of less than 45 degrees west in the southern part of the area but becomes much steeper to the north where it is affected by disharmonic and small-scale folding.

Numerous small-scale folds that plunge gently to the south-southeast were mapped on the east side of the range. Most of the small scale folds are upright, but three are conspicuously overturned to the east. The easternmost of this series of overturned folds is a tightly folded

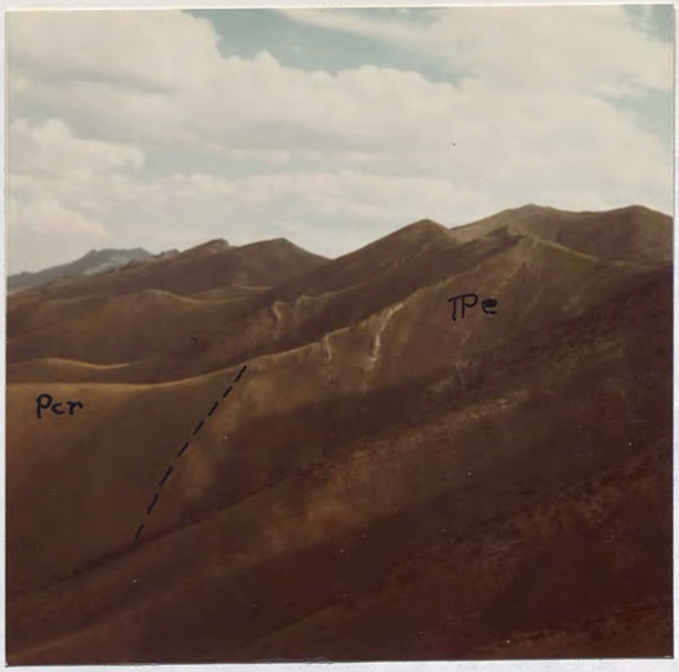

Figure 18 View looking south at exposures of the Ely Limestone in the western limb of the major syncline, near the southern boundary of the area. Note the increase in dip from right to left (west to east) and the slight disharmonic folding in the upper part of the Ely Limestone. The Carbon Ridge Formation is exposed at left. (E1/2, Sec. 36, T.25N., R.54E.)

anticline within the Diamond Peak Formation. Along most of its trend the hinge is not exposed, and the nature of the fold is uncertain. However, in the northern exposures of the fold, upright beds dipping less than 10 degrees west can be traced to where they become overturned and dip steeply to the west. The transition from upright to overturned beds occurs within an interval of 10 meters (Fig. 19)

Approximately 1 kilometer west of the overturned anticline is a disharmonically folded, partly overturned asymmetrical syncline in the Ely Limestone (Fig. 20). The syncline is bordered on the west by an anticline that is overturned to the east in its southern exposures, but upright to the north.

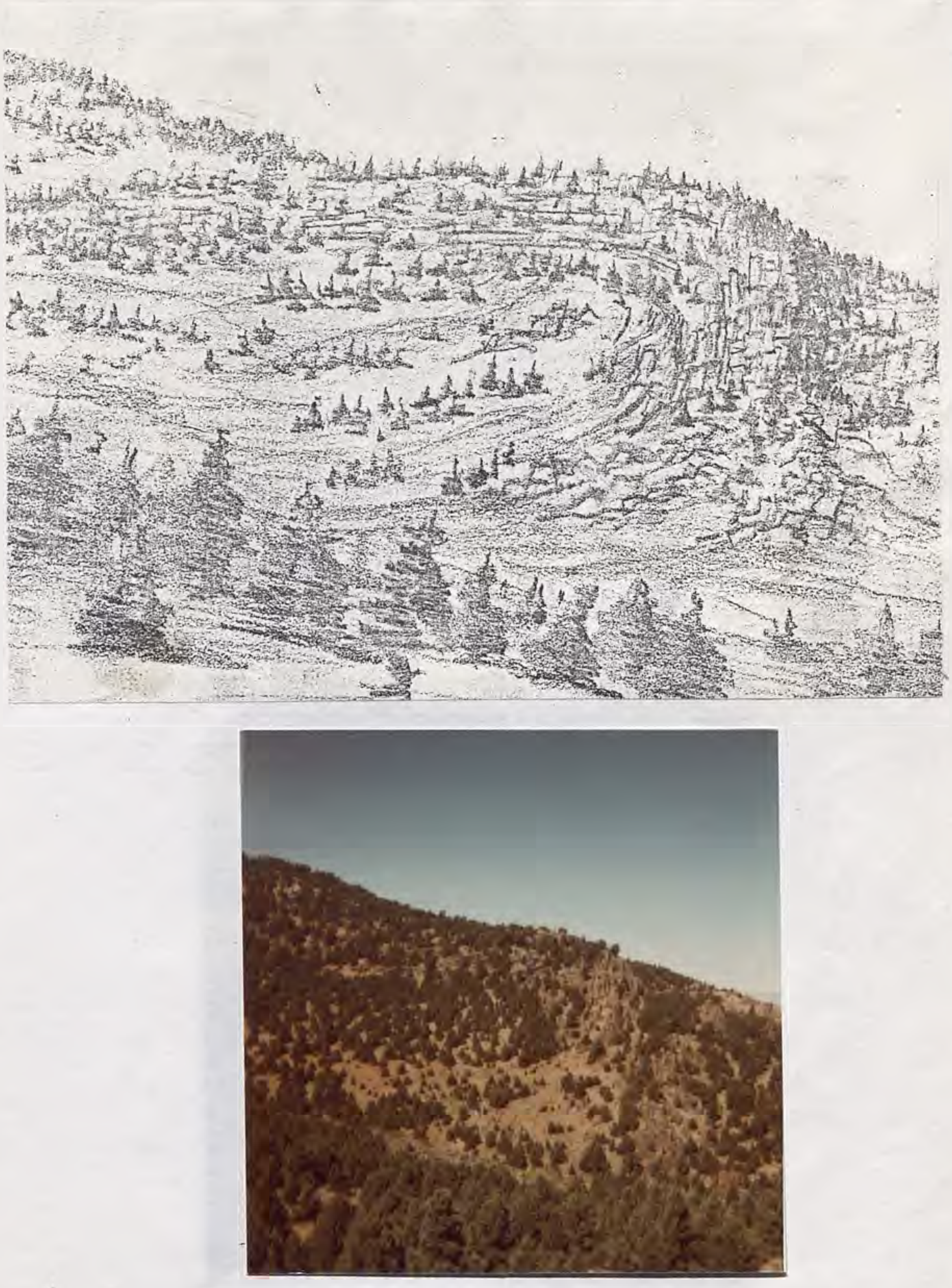

Figure 19 View looking north at a tightly folded, overturned anticline in the Diamond Peak Formation. Beds to the right (east) are overturned, and dip steeply to the west. (1.2 kilometers north-northeast of hill 7025, T.25N., R.55E.)

Figure 20 View looking south at an asymmetrical syncline in the Ely Limestone. (1 kilometer west-northwest of hill 7025, T.25N., R.55E.)

On the west side of the area, a north-trending syncline bounded on the east by an anticline can be traced for over 9 kilometers. The two folds plunge very gently to the north. The beds to the west of the synclinal axis dip an average of 30 degrees to the east, and those to the east dip an average of 70 degrees to the west. Siltstones near the axis of the fold between Davis and Box Springs Canyon have been folded disharmonically above the more competent conglomerate beds.

The anticline that borders the syncline on the east is upright, but highly asymmetrical. The beds to the east of the axis dip an average of 25 to 30 degrees to the east, in contrast to beds on the west that dip approximately 70 degrees west (Fig. 21).

Figure 21 View looking south at an asymmetrical anticline in the Diamond Peak Formation on the west side of the area. (Secs. 23, 26, 35, T.25N., R.54E.).

Faults

Reverse Fault

A high-angle, west-dipping fault, which places Permian beds (here called the Garden Valley Formation) against older rocks, is exposed intermittently for over 35 kilometers along the western flank of the Diamond Range. The relative movement along the fault has been a matter of disagreement by previous workers. Nolan and others (1974) consider the fault to be a normal, Basin-and-Range type fault which may have been active in recent time. Larson and Riva (1973) contend that the fault is a reverse fault, the compressional nature of which is indicated by extreme elongation of chert pebbles and fusulinids contained in the Permian beds.

In the study area the fault has an approximate attitude of N-S60°W, although both the strike and dip seem to be somewhat variable. The fault is exposed continuously for over 6 kilometers; a small, isolated segment is also present near Fourmile Canyon. The abrupt change in slope, and the contrast in weathering colors of the juxtaposed Diamond Peak and Garden Valley Formations define the fault contact in the field (Fig. 22). Although slickensided surfaces suggest a reverse movement on the fault in the area, conclusive evidence as to the relative displacement is lacking. Nevertheless, the author favors the reverse-fault interpretation proposed by Larson and Riva (1963), and based on compressive distortion of contained clasts in the Garden Valley Formation. The distorted clasts were observed by the author in the central part of the Diamond Range. Displacement along the fault is on the order of several hundred meters.

Figure 22 View looking north at the west-dipping reverse fault. The Garden Valley Formation is in the hanging wall of the fault (left); the Diamond Peak Formation is in the footwall. The Davis Canyon road trends across the photo in the background. (W1/4, Sec. 27, T.25N., R.54E.).

Normal Faults

Numerous normal faults were mapped within the area, and a few of them show displacement of 100 meters or more. The dominant trend of the faults is east-northeast, or transverse to the fold direction. A few are oblique to this trend.

The most prominent fault in the area is an east-west trending normal fault that transects the axis of the major syncline, near Fourmile Canyon (Fig. 23). The lateral extent of the fold is uncertain, but it can be traced for at least two kilometers. The topographic expression of the fault indicates a dip of approximately 50 to 60 degrees to the north. The hanging wall of the fault has been down-dropped at least 100 meters.

Figure 23 View looking east along the trend of the fault that parallels Fourmile Canyon. The left side (hanging wall) of the fault has been down-dropped.

A northeast trending fault has offset the Diamond Peak/Ely Limestone contact near Dora Spring on the east side of the area. The fault can be traced for approximately one kilometer, but apparently dies out east of the Carbon Ridge/Ely Limestone contact. Displacement along the fault is approximately 200 meters.

A high-angle fault is coincident with the north-trending anticline on the west side of the area. The displacement along this fault varies from near zero south of Fivemile Canyon to more than 500 meters to the north of Fourmile Canyon.

Two converging faults in the northern part of the area near Railroad Pass may have considerable displacement, but absence of marker beds precludes the estimation of the offset. Numerous other faults were mapped in the area, most with small displacement.

High-angle Basin-and-Range faults bound the Diamond Range but are not exposed within the area.

GEOLOGIC HISTORY

The Antler Orogeny and associated uplift radically changed the depositional pattern from one of carbonate deposition during the early and middle Paleozoic to one of dominantly clastic deposition during the late Paleozoic. The Upper Paleozoic rocks in the area were deposited in a subsiding basin to the east of the Antler source area. The basin received clastic debris from cherts, quartzites, and other eugeosynclinal rocks exposed in the Antler belt.

The oldest rocks in the area are assigned to the Chainman Shale of Late Mississippian age. The fine-grained texture and dark color of the shales and siltstones suggest deposition in a calm, anaerobic environment. Coarse-grained clastics of the Diamond Peak Formation interbedded with the shales and siltstones of the Chainman Shale indicate alternating periods of uplift and quiescence in the source area. At times the source area must have attained substantial relief to transport cobbles that are abundant in some conglomerate beds. Sedimentary structures in the area support regional evidence that the predominant current direction during Late Mississippian time was west to east, but they are not conclusive as to the depth of water in which the Chainman-Diamond Peak sequence was deposited. Channelling features and indigenous shallow marine fauna in other areas, however, are evidence for a shallow marine to marginal non-marine environment of deposition (Wilson and Laule, 1979, p. 86; Blomquist, 1971, p. 38).

The gradational contact between the Diamond Peak Formation and the Ely Limestone suggests a gradual decrease in the amount of clastic debris supplied to the basin in latest Mississippian and earliest

Pennsylvanian time. Fragmented fossils and abundant detrital quartz in the Ely Limestone are likely the result of shallow water deposition characterized by considerable wave and current action (Dott, 1958, p. 11). Renewed uplift in the Antler belt during Latest Ely (Atokan) time is reflected in the increasing amount of detrital chert and quartz in the upper part of the Ely Limestone.

At the end of Ely time, regional uplift resulted in the partial emergence of the area. A period of erosion that accompanied the uplift partially removed the Ely Limestone in the central part of the Diamond Range and completely removed the formation to the south of Eureka.

A return to marine conditions occurred during the Early Permian, and the deposition of the Carbon Ridge Formation. Abundant detrital material and abraded fossils in the formation are indicative of agitated, shallow water deposition. Farther west, sediments of the Garden Valley Formation were intermittently receiving coarse clastic debris from the Antler belt. Renewed uplift and erosion in the study area began as early as Late Permian time, and continued into the Mesozoic.

East-west directed compression and associated folding began sometime following the deposition of the Permian rocks, possibly as early as Late Permian time. Extensive deformation occurred prior to the Early Cretaceous, and the deposition of the Newark Canyon Formation in freshwater lakes on the Carbon Ridge Formation. A renewed period of folding is responsible for the deformation of the Newark Canyon Formation. It seems likely that the Newark Canyon sediments were not only laid down near the end of a period of intense deformation, but were also affected by the closing stages of this deformation, which was completed by

Eocene time. (Nolan, 1962, p. 28). Faulting in the area most likely post-dated the final phase of folding.

The scarcity of Early Tertiary rocks indicates that uplift and erosion continued into the Cenozoic. Tertiary volcanism began in the area during the Eocene or Oligocene with the deposition of rhyolite flows and tuffs. Many of these rocks were reworked and redeposited by streams and lakes. Intrusive igneous activity was most likely contemporaneous or slightly younger than the deposition of the volcanic rocks.

Basin-and-Range faulting and associated erosion began in the Miocene, and continues today. Triangular fault scarps document the presence of a borderline fault on the west side of the range, but the existence of a corresponding fault on the east side is less obvious. Quaternary alluvium is widespread near the flanks of the mountains. Recent streams continue to transport material from the mountains to the adjacent valleys.

NW$\frac{1}{4}$ Sec. 23 T25N. R.54 E.

Section of the upper part of the Diamond Peak Formation measured along a-a'

	Thickness (meters)	
	Unit	To Base
Ely Limestone: Alternately thin and thick-bedded limestones		
Diamond Peak Formation:		
Siltstone, dark red and grayish-green, sandy, calcareous near the top of the unit, thin to thick-bedded, weathers reddish-brown. Interbedded with sandstone, tan, calcareous, and 1 meter beds of limestone, medium gray to brown, medium to coarse-grained, contains red and green ferruginous material	29.3	114.9
Orthoquartzite, red to brown, laminated	2.9	85.6
Conglomerate, reddish-brown to olive-green; composed of sub-rounded pebbles of green and gray chert and white quartzite, sandy matrix, silicified	2.7	82.7
Siltstone, dark red and grayish-green	15.3	80.0
Conglomerate, light brown; composed of sub-rounded pebbles of green and gray chert, sandy matrix; thin (less than 10 centimeters) interbeds of sandstone, tan, laminated	2.9	64.7
Covered; float indicates dark-red siltstone	26.3	61.8
Sandstone, medium gray, medium-grained, poorly exposed; composed of sub-rounded grains of quartz and chert; minor sub-rounded pebbles of chert and quartzite; limonite blebs; laminated	3.9	35.5
Covered; float indicates dark-red siltstone, black orthoquartzite, and light brown chert pebble conglomerate	27.5	31.6
Orthoquartzite, light brown	1.1	4.1
Sandstone, light gray, medium-grained, poorly exposed; composed of sub-rounded grains of quartz and chert; faintly laminated	2	3
Sandstone, light brown, medium-grained; composed of sub-rounded to rounded grains of quartz and chert; minor sub-rounded pebbles of chert	1	1
Siltstones, sandstones, conglomerates, and limestones approx.	810	

Section of Ely Limestone measured along b-b'

	Thickness (meters)	
	Unit	To Base
Carbon Ridge Formation: Poorly exposed siltstones, limestones, and coquinites		
Disconformity		
Ely Limestone:		
Covered	23.3	552.3
Limestone, medium gray, coarse-grained, thick-bedded; pebbles and small cobbles of chert	1.3	529
Limestone, medium gray to brown, fine-grained, weathers tan, thin-bedded, poorly exposed	1.7	527.7
Covered	9.0	526
Limestone, medium gray to brown, medium to coarse-grained, thick-bedded; chert nodules	15.1	517.0
Covered	5.3	501.9
Conglomerate, medium gray to brown, calcareous; consists of sub-rounded pebbles of red and green chert in a matrix of sub-angular to sub-rounded quartz and chert sand	1.8	496.6
Limestone, medium gray, medium to coarse-grained, alternately thin and thick-bedded	13.2	494.8
Limestone, dark gray, fine-grained, weathers tan, thin-bedded; abundant bryozoa	13.6	481.6
Limestone, medium gray, medium to coarse-grained, thin-bedded to massive; lenses of sub-rounded chert pebbles; silicified horn corals in upper 5 meters	27.2	468
Limestone, dark gray, fine to medium-grained, thin to thick-bedded; bryozoa and horn corals; 5 centimeter chert layers	2.5	440.5
Covered	14.8	438.3
Limestone, medium gray to brown, fine-grained; minor sub-rounded chert pebbles	2.2	423.5
Limestone, light gray, medium-grained, massive; chert nodules 1 meter in diameter and 15 centimeters in thickness; abundant silicified brachiopods and corals in upper half	14.6	421.3
Coquinite, medium gray, medium to coarse-grained; abundant bryozoa, crinoid, and brachiopod fragments; 5 centimeter thick chert nodules	2.2	406.7
Limestone, light gray, medium-grained; lenses of quartz sand and silt; 8 centimeter thick chert nodules	5.6	404.5
Covered	8.8	398.9
Limestone, medium gray, alternately fine and medium-grained; fine fossil debris; cliff former	6.6	390.1
Limestone, dark gray, fine-grained; weathers tan, thin-bedded; poorly exposed	9.8	383.5

Ely Limestone (Continued)

	Thickness (meters)	
	Unit	To Base
Limestone, dark gray, fine-grained; lenses of quartz and chert sand are 5 centimeters thick and 10 centimeters apart; abundant crinoid and brachiopod fragments; silicified corals and brachiopods in upper .5 meter	5.0	373.7
Covered	1.8	368.7
Limestone, light gray, medium-grained; abundant well preserved bryozoa at the base of the unit; chert nodules average 1 meter in diameter and 30 centimeters in thickness	1.6	366.9
Covered	4.7	365.3
Limestone, medium gray, fine-grained, thick-bedded; thin lenses of sub-rounded chert pebbles	9.8	360.6
Limestone, medium gray, medium to coarse-grained, weathers tan, thin-bedded; abundant brachiopods, fusulinids, and crinoids; minor quartz sand	6.6	350.8
Limestone, medium gray, coarse-grained; highly fossiliferous, abundant chert nodules. Contains <u>Chaetetes</u> in the upper .5 meter	9.0	344.2
Limestone, medium gray, medium to coarse-grained, massive; lenses of quartz and chert detritus (2 centimeters thick); a 30 centimeter thick chert pebble conglomerate occurs 13.3 meters above the base of the unit	22.7	335.2
Covered	9.5	312.5
Conglomerate, tan, calcareous; consists of sub-rounded to rounded pebbles of red and gray chert, and white and gray quartzite. Matrix consists of coarse-grained, sub-rounded quartz and chert.	2.0	303
Limestone, medium to dark gray, medium-grained, minor sub-rounded chert pebbles; chert nodules; small cliff former	5.5	301
Limestone, light gray, fine-grained, weathers tan; interbedded with limestone, medium gray, fine-grained, fine fossil fragments; sequence is poorly exposed	4.3	295.5
Limestone, medium to dark gray, fine to medium-grained; 5 centimeter black chert layers	4.1	291.2
Limestone, medium gray, medium-grained, weathers tan, thick-bedded; minor chert nodules	3.0	287.1
Limestone, dark gray, fine-grained, thick-bedded, bituminous odor; silicified horn corals and crinoids; 10 centimeter chert nodules; sequence is poorly exposed	8.1	284.1

Ely Limestone (Continued)

	Thickness (meters)	
	Unit	To Base
Covered	10.6	276.0
Limestone, light to dark gray, medium-grained, laminated in places; well preserved crinoids near the top of the unit; minor chert nodules	16.2	265.4
Conglomerate, light brown, calcareous; consists of sub-angular to sub-rounded pebbles of chert and quartzite; sandy matrix. This is the first conglomerate bed above the base of the formation along the line of section	1.3	249.2
Limestone, light to medium gray, medium-grained; alternating with limestone, medium-gray to tan, medium-grained, laminated; minor 5 centimeter thick chert nodules; silicified brachiopods near the top of the unit	17.1	247.9
Limestone, dark gray, fine-grained, massive; 5 to 7 centimeter thick chert layers are commonly 5 centimeters apart. Alternating with coquinite, light gray to tan, medium-grained; abundant brachiopod and crinoid fragments; 7 centimeter thick chert nodules	28.1	230.8
Covered	5.5	202.7
Limestone, medium-gray, fine-grained, thick bedded, faintly laminated in places; abundant crinoid and brachiopod fragments; minor sub-rounded quartz and chert sand; 5 centimeter chert nodules near the top of the unit	9.3	197.2
Covered	8.4	198.9
Coquinite, medium-gray, coarse-grained: composed of mostly crinoid and brachiopod fragments; minor black chert layers as thick as 8 centimeters	3.6	179.5
Limestone, medium-gray, fine to medium-grained; 10 to 15% of the rock is composed of sub-rounded pebbles and coarse sand-sized grains of chert and quartz; unit is poorly exposed; 5 centimeter chert layers are prominent near the base; abundant brachiopods, crinoids, and fusulinids	33.3	175.9
Covered	4.6	142.5
Limestone, medium-gray, medium-grained, massive; chert nodules vary in thickness from 5 to 20 centimeters	29.5	138
Limestone, medium to dark-gray, fine-grained, massive; abundant 5 centimeter thick chert nodules	4.2	108.5

Ely Limestone (Continued)

	Thickness (meters) Unit	To Base
Covered	5.6	104.3
Limestone, medium-gray, fine to medium-grained, thick-bedded; abundant brachiopod and crinoid fragments. Alternating with limestone medium-gray to tan, fine-grained, thin-bedded	11.3	98.7
Covered	1.1	87.4
Limestone, medium-gray, medium to coarse-grained; abundant corals, brachiopods, and crinoids; chert nodules up to 15 centimeters thick	32.5	86.3
Limestone, medium-gray, fine-grained, rhythmically spaced chert layers (5 centimeters thick)	6.0	53.8
Covered	6.0	47.8
Limestone, medium-gray, medium to coarse-grained; abundant brachiopod fragments; thin sandy lenses	2.4	41.8
Covered	7.2	39.4
Limestone, tan, fine to medium-grained, thick-bedded, fine quartz sand	1.2	32.2
Limestone, light to medium-gray, medium-grained, massive, minor 5 centimeter thick chert nodules	6.3	31
Covered	16.4	24.7
Limestone, light-gray, fine to medium-grained; rounded outcrops	.3	8.3
Covered	7.0	8.0
Limestone, medium-gray with minor amounts of red and green ferruginous material, fine-grained; abundant chert nodules (2 to 4 centimeters thick)	1.0	1.0

Diamond Peak Formation: siltstones, sandstones, conglomerates, and limestones.

Section of Carbon Ridge Formation measured along c-c'

	Thickness (meters)	
	Unit	To Base
Newark Canyon Formation: siltstones, sandstones, and conglomerates		
Angular Unconformity		
Carbon Ridge Formation:		
Covered	12.2	427.2
Limestone, medium gray, medium-grained, weathers light gray: poorly exposed, abundant crinoid, bryozoa, fusulinid, and brachiopod fragments; some beds contain sub-rounded chert pebbles. Thin beds of brown siltstone	72.5	415.0
Limestone, medium gray, medium to coarse-grained; weathers light gray, poorly exposed, sparsely fossiliferous, crinoids and bryozoa fragments in some beds; sub-angular to sub-rounded chert and quartz sand make up 10 to 30% of the limestone. Thin beds of brown siltstone	64.2	342.5
Siltstone, medium brown to dark gray, calcareous, thin-bedded; weathers light brown, poorly exposed. Interbedded with limestone, medium gray, medium to coarse-grained; crinoid fragments; sub-angular to sub-rounded chert makes up 5 to 10% of the limestone.	19.2	278.3
Covered; float indicates siltstone and limestone. Siltstone is medium brown, calcareous; forms light brown platy float. Limestone is medium gray; medium-grained; bryozoa, crinoid, and fusulinids fragments; minor sub-angular to sub-rounded chert sand.	52.2	259.1
Siltstone, alternately medium gray and brown, calcareous, thin-bedded; weathers light brown. Interbedded with 1 meter beds of limestone, medium to dark gray, medium-grained, weathers light brown; crinoid, fusulinid, and bryozoa fragments; minor sub-angular to sub-rounded green and red chert sand. Thin-bedded black chert	20.0	206.9
Covered; float consists of 2 to 4 centimeter-thick fragments of light brown calcareous siltstone	22.9	186.9
Siltstone, medium gray to brown, calcareous, thin-bedded, weathers light brown. Interbedded with limestone, medium gray, fine to medium-grained and coquinite medium gray, coarse-grained, thick-bedded; abundant fusulinid and brachiopod fragments. Crinoid stems as large as 1 centimeter in diameter. Thin-bedded black chert	41.2	163.0

Carbon Ridge Formation (Continued)

	Thickness (meters) Unit	Thickness (meters) To Base
Siltstone, medium gray to brown, calcareous, thin-bedded; some beds are finely laminated (2 to 4 millimeters); weathers light brown. Interbedded black cherts average 30 centimeters in thickness near the base and 60 centimeters in thickness near the top of the unit.	11.4	121.8
Coquinite, dark gray, medium to coarse-grained; bituminous; weathers light gray; composed of crinoid stems	.6	110.4
Siltstone, dark gray to brown; some beds are slightly calcareous; thin-bedded, weathers light brown; poorly exposed; forms platy float (2 to 4 centimeters thick): abundant worm trails and small brachiopods. Upper 4 meters contain black chert beds (30 to 50 centimeters thick) and nodules (20 centimeters x 10 centimeters): chert beds and nodules are commonly rimmed by partially silicified limestones.	109.8	109.8

Disconformity

Ely Limestone: Alternately thick and thin-bedded limestones

Section of Newark Canyon Formation measured along d-d'

Newark Canyon Formation:

Upper part eroded

		Thickness (meters) Unit	To Base
Siltstone, pale red to tan, sandy, calcareous, poorly exposed; contains 1 meter interbeds of red conglomerate; conglomerate contains sub-rounded pebbles of green and red chert and white quartzite	approx.	75.0	141.9
Sandstone, light brown to light gray, medium-grained; well sorted, calcareous; mostly sub-angular grains of quartz; interbedded with thin red siltstones		11.6	66.9
Sandstone, tan, fine to medium-grained, sub-angular grains of quartz and chert, moderately sorted, calcareous, laminated		12.5	55.3
Conglomerate, tan; composed of sub-angular pebbles of white quartzite and green, gray, and red chert, fine-grained matrix; abundant limonite staining		15.0	42.8
Sandstone, light gray, medium-grained, weathers white to light gray; composed of sub-rounded grains of quartz and chert; laminated		5.9	27.8
Covered		2.5	21.9
Siltstone, pale red, sandy		1.5	19.4
Conglomerate, light brown; composed of angular pebbles of white quartzite and green and gray chert, fine-grained matrix, calcareous; interbedded with light-gray quartzite, fine-grained; weathers white.		6.7	17.9
Sandstone, light gray, fine-grained; composed of sub-rounded grains of quartz and chert, well sorted, laminated.		5.0	11.2
Sandstone, light gray to brown, medium-grained; sub-angular grains of quartz and chert, moderately sorted, calcareous.		6.2	6.2

Angular Unconformity

Carbon Ridge Formation: Poorly exposed limestones, siltstones, and coquinites.

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