GEOLOGY OF PART OF THE KITTRIDGE SPRINGS QUADRANGLE

ELKO COUNTY, NEVADA

By

Paruhum H. Silitonga
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A Thesis submitted to the Faculty and the Board of Trustees of the Colorado School of Mines in partial fulfillment of the requirements for the degree of Master of Science (Geology).

Signed: 

Golden, Colorado

Date: December 19, 1974

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Thesis Advisor

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The Kittridge Springs quadrangle lies in Elko County, Nevada, approximately 5 miles north of the city of Elko. The Thesis Area covers the southern half of the quadrangle.

The oldest rocks exposed in the area are the Chainman and the Diamond Peak Formations which are Mississippian and Mississippian to Pennsylvanian in age. Two members in the Chainman Formation and six members in the Diamond Peak Formation can be recognized. In the Chainman Formation, sandstone is dominant; shale and conglomerate are subordinate. In the Diamond Peak Formation conglomerate is the most important; sandstone, shale and limestone are less important. The environment of deposition of these two Paleozoic formations is believed to range from shallow water or even terrestrial to deep water with turbidity currents.

Mesozoic rocks are represented by a small deposit of limestone probably of Early Triassic age.

After Triassic time the area was emergent until Early Tertiary time. In late Eocene or Early Oligocene time the area was covered in part by a lake or lakes which filled a series of connected intermontane basins or irregular depressions. At this time the Lower Member of the Humboldt
Formation, which consists of conglomerate, breccia, limestone and oil shale, was deposited. The Middle Member of the formation is mainly of volcanic clastics which indicate volcanic activity in the surrounding area. The Upper Member of the formation consists mostly of siltstone and sandstone and contains very little volcanic material. The Humboldt Formation is at least 3,000 feet thick in the area.

After the end of deposition of the Humboldt Formation in Miocene time, new volcanic activity in the area or surrounding area produced basic lavas such as basalt and hypersthene basalt.

The area was folded in Late Jurassic or Early Cretaceous time. A syncline extending from southwest to northeast in the area was cut and offset by transverse faults which formed simultaneously with the folding.

Three groups of faults can be recognized in the area. The first group are the faults which were formed before or during folding. The second group are the faults which occurred right after folding. A thrust fault in the southwest part of the area belongs to this group. The third group are the faults which occurred long after folding. In this group are included all those faults which clearly involved the Tertiary rocks indicating that they occurred in Tertiary time or later. The evidence suggests that several faults of this group are recurrent faults.
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INTRODUCTION

Location and accessibility

The Kittridge Springs quadrangle is bounded by latitudes 40°52'30" and 41°00'00" North, and longitudes 115°45'00" and 115°52'30" West. The study area covers the southern half of the quadrangle and lies between 40°52'30" and 40°56'00" North latitudes. It is located approximately 5 miles north of Elko, Nevada (figure 1). Highway 11 is located a few hundred feet to 3/4 mile from the western boundary of the area.

Two unimproved roads from Elko provide generally good access to the area. A number of jeep trails cross the study area, but a considerable part of it is accessible only by foot.

Climate and vegetation

The thesis area has an arid to semi-arid climate. During the summer months the average monthly maximum temperatures during the warmest month of July are in upper eighties in daytime and usually comfortably cool at night. Temperatures below 0°F. are common during the winter months.
Figure 1. Location of Thesis Area.
Figure 2.--Locations of places mentioned in this report.
1: Kittridge Springs quadrangle
2: Carlin, Dixie Flats, Pine Valley, Robinson Mtn. quadrangles
Average annual rainfall is 6-10 inches in the plain and 15-18 inches in the mountain area, a great part of which precipitates during July and August. Summer precipitation falls almost entirely during brief and frequently intense afternoon thundershowers. Winter precipitation falls either as rain or snow.

Wind velocities are normally moderate to strong during all seasons of the year.

The arid or semi-arid climate of the area is the most important factor controlling vegetation. The valley plains as well as the mountain areas support sparse grass, cactus and locally thick growths of bushes (cheat grass, prickly pear, sage brush, and rabbit brush). On the slopes and lower hills, particularly on soil derived from limestone, juniper trees are common.

Purpose and scope

The purpose of this study was to map the geology of the area with principal interest centering on the stratigraphy and geologic structures of the area. Therefore, the primary object of this thesis work deals with the description, subdivision, and correlation of the rock units and the structure affecting the area. Based on this study the geologic history, which is comprised of sedimentational and tectonic history, can be interpreted.
Previous investigations.

The region that includes the Kittridge Springs quadrangle was mapped in reconnaissance by Clarence King (1878) in his survey of the fortieth parallel. Roberts et al. (1958) reviewed and summarized the geology of the region. That paper is the only publication that gives an overall view of the stratigraphy and structure of the region.

Detailed studies of small areas in the region were made by Kerr (1962), Churkin and Kay (1967), Fails (1955), Lovejoy (1956, 1959), Ketner and Smith (1963) and Evans and Ketner (1971), but all these studies were made of windows in the Roberts Mountains thrust and did not describe in detail the post-orogenic rocks or Tertiary rocks such as those in the Kittridge Springs quadrangle.

The Adobe Range which is spanned by the Kittridge Springs quadrangle was examined in reconnaissance by Ketner (1970), but only the contact between Paleozoic and Tertiary rocks was mapped. Areas a few miles both north and south of the thesis area have been mapped by Smith and Ketner, but detailed maps of those areas have not yet been published. A detailed study of the Late Paleozoic rocks equivalent to those of the thesis area was made by Brew (1971) about 100 miles to the south.
Winchester (1923) described the oil shale in the Elko area. Sharp (1939) described the Tertiary Humboldt Formation in northeastern Nevada which includes the thesis area. His description of the Humboldt Formation was helpful in the present study. Van Houten (1956) briefly discussed the Cenozoic Sedimentary rocks of Nevada. Regnier (1960) made a detailed study of Cenozoic geology in the vicinity of Carlin, about 20 miles west of thesis area. Tertiary rocks were studied in some detail by Smith in an area several miles to the south of the thesis area, but the results of that work have not yet been published.

**Method of study**

Mapping was accomplished in the field on a 1:24,000 scale topographic map. The aerial photographs at a scale of approximately 1:50,000 were interpreted before and during the field work. Bearing and attitude of the bedding was measured using a Brunton compass. A number of hand specimens were collected for petrographic study in thin-section and many fossils which can be used as environment and age indicators were also collected.

All field work was accomplished during the summer of 1974.
Acknowledgements

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GEOLOGIC SETTING

From Late Cambrian until the end of Devonian time, Nevada was occupied by a broad north-trending geosyncline which had three different depositional environments. The area east of longitudes 116°-117° was generally miogeosynclinal and the area to the west was generally eugeosynclinal. In several places an assemblage which includes elements of miogeosynclinal and eugeosynclinal rocks is regarded as transitional and is believed to have been deposited between the two environments (Roberts and Lehner, 1955; Roberts et al., 1958).

The Antler orogenic belt (figure 3) which is a belt roughly along the 116°-118° meridians (Roberts et al., 1958) was the locus of intense folding and faulting that culminated in the Roberts Mountains thrust fault in Late Devonian or Early Mississippian time (Merriam and Anderson, 1942; Gilluly, 1954; Smith and Ketner, 1968; Ketner, 1970a, b). During this time the eugeosynclinal and miogeosynclinal rocks were brought into contact by telescoping along the thrust fault. The eugeosynclinal rocks were carried by the thrust fault
Figure 3. - Antler orogenic belt and flanking clastic wedges

(After Roberts et al., 1958)
A. Near the end of the Devonian, the Cordilleran geosyncline covered most of Nevada. Clastic and volcanic rocks predominated in western Nevada; carbonate rocks in central and eastern Nevada; and transitional rock types in western and west-central Nevada.

B. Orogenic movements in early Late Devonian time caused uplift, folding, and erosion in western Nevada, clastics derived from the uplift were deposited in central Nevada.

C. Folding continued into Late Devonian and Early Mississippian, along with continued uplift.

D. The Roberts Mountains thrust plate, including slivers of transitional and clastic rocks, moved eastward overriding part of the early orogenic clastics and the shelf rocks. After major thrusting, coarse clastics (M) eroded from the emergent orogenic belt were shed into eastern Nevada and deposited partly in continental and partly in marine environments, overlapping the thrust plate and shelf.

Figure 4.-- Diagrams showing inferred sequences of events during Antler orogeny in north central Nevada according to Roberts et al. (p. 2045, 1950).

++: Approximate site of Thesis Area
relatively eastward of sourtheastward over the miogeosynclinal rocks. During Mississippian and later Paleozoic time the eugeosynclinal rocks were repeatedly uplifted causing great wedges of clastics to be deposited along the flanks of the uplift (figure 3).

The eastern wedge of clastics was deposited across the thrust fault that separates the eugeosynclinal from the miogeosynclinal assemblages and is therefore called the overlap assemblage. The thesis area is located on the east side of the Antler orogenic belt and includes a thick sequence of the overlap assemblage rocks as shown in Figures 3 and 4.

In Mesozoic time these rocks were folded on a giant scale (Roberts et al., 1958; Brew, 1971; Ketner and Smith, 1974) and they were deeply eroded in Cretaceous and Tertiary times. Early in Tertiary time the region was partly occupied by a widespread lake which gradually filled with detrital, sediments. In Middle Tertiary time volcanoes erupted and the region was broken by high-angle faults.
STRATIGRAPHY

The Kittridge Springs quadrangle is in the region where eugeosynclinal rocks were thrust over miogeosynclinal rocks on the Roberts Mountain thrust fault, and during Mississippian and later Paleozoic time were repeatedly uplifted. The resulting clastics deposited along the east flank of the uplift. In the thesis area, therefore, are primary synorogenic deposits laid down in a large marine trough. The Tertiary rocks, partly lacustrine and partly volcanic or volcanic-associated, were deposited in small non-marine basins.

Generalized columnar sections of the formations are shown in Figures 6, 11, and 18. Thicknesses were measured on the map. Lithology and sequence were based on field observations in many places where exposures permit.

Paleozoic rocks

Chainman Formation

The Chainman Formation was first called the Chainman Shale by Spencer (1917) as one part of the White Pine Shale of Hague (1883). Because of abundant nonshaly lithic types
in this rock unit in Eureka County, Brew (1971) preferred to call it the Chainman Formation. Brew (1961) has stated before that in Eureka and White Pine Counties, the Chainman Shale and the Diamond Peak Formation are differentiated on the basis of the relative proportions of conglomerate, sandstone and siltstone. Smith and Ketner (1968) distinguished the Chainman Shale from the Diamond Peak Formation in the Carlin and Pinon Range Area by the dominance of shale and sandstone in the first formation and the dominance of sandstone and conglomerate in the second one. Ketner (1970) used the name Chainman Shale for the Mississippian rock unit which consists of sandstone and siliceous shale in the Adobe Range. This Chainman Shale is called Chainman Formation by the present author in the thesis area because shale was found to comprise only a small part of the rock unit. The Chainman Formation can be divided into two members: Conglomerate Member and Sandstone and Shale Member.

**Conglomerate Member**

The Conglomerate Member crops out in Secs. 15, 16, 17, 19 and 20 T.35N, R.55E. The color is gray. It weathers to pale gray or olive gray and locally to reddish brown. Generally the beds are massive but a very few have layers of 4 inches to 3 feet in thickness. The member is composed of pebbles of white to gray quartzite, siltstone, and pale-
Figure 5. - Conglomerate Member of the Chainman Formation (Sec. 16, T. 35 N, R. 55 E). The angular pebbles are chert and the rounded ones are quartzite. The pen is 6 inches long.
green, dark and dark-gray chert in a matrix of partly silicified sandstone and sandy mud. The pebbles are mostly 1/2 - 2 inches in diameter and very rarely up to 4 inches. The pebbles generally touch each other. The quartzite and the siltstone pebbles are rounded whereas the cherts are always angular (Figure 5). The angularity of the cherts associated with rounded quartzite and the approximately equant shapes of the pebbles are characteristic of this member and can be used to differentiate it from conglomerate in the Diamond Peak Formation.

From the outcrops in Sec. 16, T.35N, R.55E, it is estimated that this member is at least 440 feet thick in the thesis area.

**Sandstone and Shale Member**

**Sandstone:** The sandstone crops out in a southwest-northeast trending belt in the central part of the area. The sandstone is commonly gray or dark gray and rarely also dark brown. It weathers to light gray and pale olive and forms irregular fragments and large flakes 1/2-1 inch thick and 2-6 inches in diameter. Individual strata are 4 inches to 1 foot thick.

In thin sections the grains of the sandstone are seen to be fine to coarse, subangular to rounded, equigranular to disk or rod shaped, poor to moderately sorted, of low
porosity, and compact. The composition is variable. Quartz ranges between 10-50%, Chert, 20-35%; rock fragments consisting of shale, siltstone and sandstone range between 10-40%; silica and clay cement can be up to 15%. Traces of plagioclase, muscovite, pyroxene, zircon and rutile are also observed. The matrix generally forms between 10-20% of the rock. The sandstone, therefore, can be classified as subfeldspathic lithic wacke (Williams, Turner and Gilbert, 1954).

Locally the sandstone grades into pebbly sandstone, conglomeratic sandstone or into siltstone. The sandstone also is interbedded with shale, siltstone, and minor amounts of lenticular conglomerate. The siltstone is gray to reddish brown and weathers to a light gray. It is commonly silica-cemented and faintly cross-laminated. Some of the siltstone contains casts of fossils (brachiopods?) and very rarely shows ripple marks. The few conglomerates present in this member occur in lenses as much as 3-6 feet thick and hundreds of feet long. These lenses are gray-weathering and consist of silica-cemented pebbles and cobbles of chert and quartzite.

Shale: The shale occurs as a thick lens or lenses within the sandstone. It is gray to dark greenish gray, weathering to gray or pale gray. It is generally poorly exposed and forms irregular fragments 1/5 inch thick and 1/2-1 inch in diameter. A thin section shows that the shale contains about
10% of very fine, angular to rounded and equigranular to rod shaped quartz grains and about 2% of limonite cement.

The shale commonly grades to siltstone and sandstone. Siltstone in the shale is gray, cross laminated, and weathers to pale gray. Sandstone in the shale unit is the same color as the siltstone, is fine to medium grained, and is composed of chert and quartz particles. Individual lenses of the siltstone and sandstone are 1/2-4 inches thick.

The maximum thickness of the shale unit in Sec. 19, T. 35 N, R. 55 E, is estimated to be about 360 feet. The unit can be traced about one mile.

The thickness of the Sandstone and Shale Member is estimated from its attitude and map exposure to range from 260 to 880 feet.

The age of the Chainman Formation in the neighbouring Pinon Range according to Smith and Ketner (1968), is Mississippian. This age is the same as the age of the Chainman Shale described by Nolan et al. (1956) in the Eureka district and the same formation described by Brew (1971) in the Diamond Peak Area, Eureka County, Nevada.

No strong indicator of environment of deposition has been found in the Chainman Formation. The brachiopods in some beds suggest shallow water marine conditions. However,
Figure 6. Generalized columnar section of the Chainman Formation

MISSISSIPPIAN

CONglomerate Member

0-440'

Gray to greenish-gray shale and siliceous shale with some siltstone and fine-grained sandstone.

SANDSTONE AND SHALE MEMBER

260'-880'

0-360'

Fine to medium grained, bedded sandstone intercalated with siltstone, shale, coarse and pebbly sandstone.

Conglomerate composed of angular-chert and rounded quartzite pebbles. Generally massive, partly bedded.
the few poorly developed graded beds and sandstone inter-
bedded with shale and siltstone suggest that part of the
Formation may have been deposited by turbidity currents in
a fairly deep water environment (bathyal?).

Diamond Peak Formation

The Diamond Peak Formation was originally named Diamond
Peak Quartzite by Hague (1883) for exposures near Eureka,
Nevada. It was divided into 8 informal members by Brew (1971)
in the type locality. This proposed division of the Formation
is not applicable in the thesis area owing to lateral changes
in lithology.

The Diamond Peak Formation covers almost one half of
the thesis area. Here, it can be divided into 6 members in-
formally designated A, B, C, D, E, and F. Four members are
recognized in the lower plate of a thrust fault which occurs
in the southwest part of the area and two different members
are recognized in the upper plate.

Member A

Member A is the lowermost member of the Diamond Peak
Formation in the lower thrust plate. This member covers
all of the central and northeastern part of the area. It
is characterized by massive conglomerates interbedded with
similar thin to thick bedded conglomerates. The massive
conglomerate beds are as much as 30 feet thick but the
bedded conglomerates are only 4 inches to 3 feet thick.
The conglomerates are gray, weathering dark gray and brownish gray. Member A occupies all the highest relief of the area and is characterized by a rough surface. The clasts consist of light-gray quartzite, light to dark gray, light-green, reddish-brown and dark-brown chert, light-gray quartz sandstone and very rare light-gray arkose and siltstone. Most pebbles are between 1/2-2 1/2 inches in diameter, and cobbles are as much as 10 inches in maximum diameter. A few quartzite boulders up to 15 inches in diameter were observed. The quartzite clasts are subrounded to rounded whereas the chert clasts are subangular to subrounded. The matrix is medium to coarse-grained sandstone of the same composition as the pebbles and cobbles. Generally the matrix is siliceous and in places shows abundant limonite stains.

In all the conglomerate, no graded bedding, preferred clast elongation, or imbrication has been observed. The conglomerate often grades to conglomeratic sandstone, sandstone, siltstone, and shale, all of which are commonly laminated, cross laminated, or cross bedded.

In a thin section the sandstone grains are seen to be coarse, subangular to rounded, equigranular to disk or rod shaped, and moderate to poorly sorted. The matrix is about 15% of the rock. The grains are: quartz +20%, chert +35%,
rock fragments +35%. These consist of shale +15%, siltstone +10%, sandstone +10%, and a trace of plagioclase. Cements are clay material +6%, limonite +4%. This sandstone can be classified as subfeldspathic lithic wacke also.

The thickness of the Member A is estimated in Secs. 6, 7 and 8, T. 35N, R. 55 E, to be at least 6,600 feet.

In the type locality, Brew (1971) reported that the Diamond Peak Formation underlies the Chainman Formation with gradational contact. He believed, however, that the Diamond Peak Formation in many places interfingers with the Chainman Formation. Hague (1883), Nolan and others (1956), Stewart (1962) found that the two formations are in intertonguing relationship. In the thesis area the Chainman Formation does not crop out in the north-northwest (northwest limb of the syncline). This may indicate that the Chainman Formation is wedging out and the Diamond Peak Formation becomes thicker in those directions. If this interpretation is correct, then, the member or at least the lower part of it should be the same age as the Chainman Formation, i.e. Mississippian.
Figure 7. The massive conglomerate in Member A of the Diamond Peak Formation in Sec. 1, T. 35 N, R. 54 E. The pebbles are mainly chert and quartzite. The hammer is one foot long.

Figure 8. Bedded conglomerate in Member A of the Diamond Peak Formation in Sec. 8, T. 35, N, R. 55 E about 30 feet thick, showing large-scale cross bedding.
Figure 9. A photomicrograph of sandstone in Member A of the Diamond Peak Formation. (Thin section PHS, 25 A) ch: chert; q: quartz; sh: shale; s: siltstone; ss: sandstone. (Plain light)
Member B

Member B is conformable above the Chainman Formation but is of different lithology from the Member A. It is found in the southwest part of the area. This member consists of a series of prominent ledge-forming conglomerates overlain by interbedded sandstone and siltstone with sparse shale. The thick and very thick bedded conglomerates are for the most part gray or pale gray, weathering gray and brownish gray. They are composed of pebbles and cobbles of light-gray quartzite and gray, dark, greenish and brownish chert, all in a matrix of siliceous medium-grained sandstone. The overlying sandstone and siltstone are gray on fresh exposure and weather to olive gray. Commonly the beds have internal laminations 2 inches to 1 foot thick. The sandstone generally grades to siltstone and siliceous shale.

In thin sections, the sandstones show that the grains are fine to coarse, subangular to rounded, equigranular to, disk or rod shaped, poor to moderately sorted, and compact. The matrix forms between 20-25% of the rock. The grains consist of: quartz 20% to 35%, chert 25% to 35%, rock fragments, 20% to 25% and there are traces of muscovite, orthoclase, plagioclase and zircon. Cements are: clay, 3-5%, silica 7-13% and limonite 2-9%.
The thickness of this member in Sec. 35, T. 35 N, R. 54 E is estimated to be about 750 feet. The member is believed to be in the same stratigraphic position as Member A, therefore, its age also is Mississippian. The differences in lithology may indicate that they were deposited in different environments. The rapid change in lithology between these two members within a very short distance according to Ketner (personal communication) can be explained by assuming that the Member B originally was deposited farther to the south and has been thrust north to its present position. The same situation actually was found by Brew (1961) in Eureka and White Pine Counties where a thrust has brought siltstone, sandstone and conglomerate of the Diamond Peak Formation over siltstone, sandstone and shale of the Chainman Formation. However, during field work no strong evidence of a thrust between Member B and the Chainman Formation was found.

Member C

This member has been found in the southwest of the area and also in Secs. 10 and 15, T. 35 N, R. 55 E. The lower part of this member consists of black, grayish-black, grayish-green shale or silty shale. It weathers to slightly brownish or dark-yellowish brown. Some beds are siliceous and some are calcareous. Limestone occurs in lenses as much as 1/2-1 inch thick and several tens of feet long. There are
many brachiopods, corals, crinoid columnals, and bryozoans. The shale grades upward to limy shale, shaly limestone and finally to limestone with several beds of sandstone at the top. All beds are dark: black, grayish-black and dark-yellow, weathering to slightly gray brown or yellowish brown. The upper beds are fossiliferous as is the shale underneath. The individual strata of the limestone are between 2 inches and 1 foot thick.

In thin sections of the calcareous sandstone the grains are seen to be medium, subangular to rounded, equigranular to rod shaped, moderately sorted, having low porosity, and compact. The grains consist of quartz about 30%, chert about 15%, rock fragments about 10%, plagioclase about 2%, orthoclase 1% and there is a trace of pyroxene. Cements are: carbonate about 25%, clay about 15% and limonite about 2%.

The thickness of the Member C in Sec. 35, T. 35 N, R. 54 E, is about 400 feet. It is conformable above Member B.

From the same black shale as found in this member, Dott (1955) found in a quarry on Highway 11, 5 miles northwest of Elko the fossils which according to Gordon and Duncan (1962) are of Mississippian age.
Member D

Member D is the youngest part of the Diamond Peak Formation recognized in the lower thrust plate. It is conformable above Member C with a gradational contact between them. The lowest part of this Member consists of dark, gray-dark, bluish-gray and gray limestone interbedded with sandy limestone, calcareous siltstone, calcareous sandstone and calcareous pebbly sandstone. All beds are fossiliferous locally. The fauna consists of brachiopods, crinoid columnals, colonial or solitary corals, especially horn-corals. Limestone beds are between 2-10 inches thick. The siltstone and sandstone are laminated and some are cross laminated. The pebbly sandstone consists of dark-greenish and dark-reddish chert pebbles and very rare gray quartzite pebbles. All pebbles are subangular to subrounded and between 3/4-1 1/2 inches in diameter. The pebbles are so sparse they generally do not touch each other.

In the middle part of the member sandstone becomes predominant but is interbedded with siltstone, shale, limestone and conglomerate. The sandstone is fine-grained, gray-greenish or yellowish brown, weathers to gray brown or pale gray. Some beds are cross laminated but most have layers between 8 inches and 3 feet thick. The siltstone and shale are also gray greenish or gray brown, weathering
to pale gray or olive gray. The limestone is gray and bluish gray. The conglomerate consists of pebbles and cobbles mostly of quartzite, and green and dark chert in a fine sandstone matrix. The color of the conglomerate is also gray, weathering to pale gray. Individual beds are as much as 6 feet thick.

In thin section of the calcareous sandstones carbonate cements are seen to form between 30% to 40% of the rock. The grains are fine to medium, subangular to rounded,

Figure 10: Calcereous pebbly sandstone intercalated with calcareous sandstone in Member D of Diamond Peak Formation in Sec. 35, T. 35 N, R. 54 E. The pebbles are chert and quartzite. The pen is 5 1/2 inches long.
equigranular to rod shaped, poor to moderately sorted, porous to slightly porous, friable to compact. The grains are: quartz 20-35%, chert 10-15%, rock fragments (shale and siltstone) 5-10%, bioclastics replaced by carbonate 2-20%, ooliths 0-3%, plagioclase up to 1%, opaque iron ore up to 1% and there is a trace of microcline.

The limestone in a thin section shows oolitic texture with bioclastics replaced by carbonate. It contains quartz grains about 7%, chert about 7%, and rock fragments about 2%.

In the upper part of the member, sandstone and siltstone are almost equal in amount and together are subordinate to the conglomerate. Shale and limestone are scarce.

The thickness of Member D is estimated in Sec. 35 T. 35 N, R. 54 E to be about 245 feet.

**Member E**

The Member E is a rock unit recognized only in the upper thrust plate. It consists mainly of conglomerate beds, 2 inches to 3 feet thick, interbedded with siltstone, silicified sandstone, and pebbly sandstone. The conglomerate is gray or yellowish gray and weathers in part to olive gray. It consists of pebbles and cobbles of quartzite, quartz sandstone and dark-gray to reddish or greenish chert in a matrix of siliceous sandstone that in places shows abundant limonite stains. The pebbles mostly are approximately equant
and well rounded. Most are about 1/2 inch in diameter, but rarely cobbles are about 3 inches in diameter. The conglomerate in this member is commonly cross bedded. Most of the sandstone and the siltstone are thinly laminated, but some have layers between 4 inches and 20 inches thick. They are gray-white, yellowish-brown colored and weather to reddish brown. Some of the sandstone beds are composed almost entirely (95% or more) of quartz but most contain a large proportion of chert grains. The siltstone carries some brachiopods and some crinoid fragments.

In a thin section of the sandstone, the grains are seen to be coarse, subangular to subrounded, disk to rod shaped, poorly sorted, slightly porous, and compact. The matrix comprises about 12% of the rock. The grains are: quartz and quartzite about 12%, chert 45%, rock fragments consisting of shale 25% and siltstone 13%. Clay cement forms about 5% of the rock. The sandstone also can be classified as subfeldspathic lithic wacke.

The thickness of the member is difficult to estimate owing to its complex structures. However, it is at least 660 feet thick in the map area (in Sec. 23, T. 35 N, R. 54 E).

**Member F**

This member is characterized by brownish-purple, reddish conglomerate alternating with brownish-purple and reddish
or dark-brown sandstone and conglomeratic sandstone. The lower and top parts of the Member may be called "red beds" because of their intense red color characteristic of red beds elsewhere. The conglomerate consists of pebbles and cobbles of dark, black and reddish-brown chert having a maximum diameter of 4 inches, in a matrix of siliceous, poorly sorted sandstone. The beds are between 10 inches and 6 feet thick. The conglomerate is interstratified with brownish-purple, very dusky red-purple, poorly sorted sandstone, conglomeratic sandstone and siltstone. In the lower part of the member, the sandstone is also interstratified with bluish-gray limestone lenses. The sandstone generally is cross bedded and the siltstone is cross laminated.

In thin sections, the sandstone shows the same texture as the sandstone in the previous member. The grains are fine to coarse, subangular to rounded, equigranular to rod shaped, poorly sorted, slightly porous, and compact. The matrix forms 12-20% of the rock. The grains are: quartz and quartzite 35% to 38%; chert 30%, and rock fragments consisting of shale 10% to 15%, siltstone 3-5%, and sandstone 4-5%. There is trace of muscovite. Cements are clay about 5% and limonite 10-15%. This sandstone also can be classified as a subfeldspathic lithic wacke.
In the middle of the member, a gray conglomerate occurs which contains coarse cobbles of quartzite and gray to dark chert up to 10 inches in diameter. This conglomerate is also interstratified with gray sandstone which is composed of quartz and green chert particles.

Member F is easy to recognize owing to the red-brown or yellowish-brown soil that generally covers it. The thickness of this member is at least 450 feet in the map area (Sec. 34, T. 35 N, R. 54 E).

Member F lithically resembles Member F of the Diamond Peak Formation of Brew (1971), especially in the purple and brown color of the sandstone and conglomerate, except for the absence of limestone phenoplastic conglomerate in the thesis area. If these two members are correlative the age of the Member F in the thesis area must be Late Mississippian as is Member F of the Diamond Peak Formation in the type locality. Member F in the thesis area also resembles the Tonka Formation of Dott (1955) as both units include red beds. According to Dott (1955) and Gordon and Duncan (1962) the Tonka Formation is Late Mississippian to Early Pennsylvanian. Quite possibly Member F is younger than any of the other members.

Provenance and environment of deposition

The Diamond Peak Formation in the thesis area becomes thicker toward the north-northwest part of the area. The
pebbles of the conglomerate are coarser and seem to be less well sorted. These facts suggest that the north-northwest part of the area was closer to the provenance.

The generally rounded pebbles of quartzite in comparison with the generally more angular pebbles of chert might indicate that the source of the quartzite was farther away than the source of the chert, or that the chert is more easily broken. The sandstone which is commonly interbedded with the conglomerate probably was derived from the same terrane as the source of the conglomerate because it contains a large amount of chert and quartzite particles. No metamorphic or igneous clasts have been observed in the Diamond Peak Formation of the thesis area. The most likely provenance terrane therefore seems to be the early Paleozoic formations of the upper plate of the Roberts Mountains thrust for these are largely of quartzite and chert identical to the clasts of the Diamond Peak Formation.

There are no strong environment indicators in this formation. The cross laminated or cross bedded siltstone, sandstone and conglomerate and the fauna of Members D and E suggest a shallow water marine environment.

The red beds in Member F together with the cross laminated and cross bedded sandstone may indicate terrestrial and/or shallow water which periodically has been exposed to weathering processes.
The fossiliferous dark shale and limestone in Member C may have been deposited in a calm and perhaps quite clear marine environment, probably below wave base.

The bedding and textures of the sandstone which grades to siltstone and shale in Member B might represent a turbidite deposit deposited in a deep water environment. The transportation of gravel-size material far out into the basin producing conglomerate like that found in Member B is quite difficult to explain. Brew (1971), however, has found the same situation in the type locality of the Diamond Peak Formation in Eureka County. He believed that the pebbles may have been dislodged from coalescing deltas at the edge of the basin and carried into deeper water by subaqueous slides probably in the same manner as those described by Kay (1957) concerning Paleozoic deformation and deposition in Nevada and Utah.

The large-scale crossbedding in conglomerate of Member A might indicate strong currents (Brew, 1971). The poor sorting of the sandstone and conglomerate indicates rapid deposition. These two conditions can be found near shore, probably in a deltaic environment. The environment of the massive conglomerate is more difficult to explain. The absence of cross bedding, definite channeling, or small scale scours preclude river deposition. The dominance of pebbles, cobbles
and even boulders in the conglomerate and the lack of stratiﬁcation, graded bedding, preferred clasts elongation, and imbrication suggests classification as disorganized conglomerate which, according to Walker and Mutti (1973), is a kind of conglomerate that has been deposited by turbidity currents. So probably part of the Member A has been deposited in relatively deep water. Probably well-bedded conglomerates produced by strong currents in a deltaic environment occasionally slid into deeper water when the delta became overloaded. The massive conglomerates could have been formed in this way.
Figure 11. Generalized columnar section of the Diamond Peak Formation.
Mesozoic Rocks

In Sec. 16, T. 35 N, R. 55 E, there is an exposure of yellowish-brown limestone intercalated with yellowish-brown calcareous sandstone and conglomeratic sandstone. This rock unit may be in fault contact with the Chainman Formation and is unconformable under the Tertiary rocks. The internal sequence and the thickness of this rock unit cannot be determined owing to small and poor exposures.

No fossils have been found to indicate the age of the rock, but lithologically it is similar to the Triassic limestone in a quadrangle 20 miles northeast of the thesis area which was mapped by Ketner. Comparison was made by making a short trip to that Triassic limestone during the visit of Ketner to the thesis area. The age of the limestone discussed above is, therefore, believed to be Triassic (Ketner, pers. comm., 1974).

Tertiary Rocks

Humboldt Formation

The name, Humboldt Formation, was originally applied by King (1878) to a group of Tertiary rocks exposed along the Humboldt River in Elko County, Nevada. Sharp (1939) redefined the Humboldt Formation and proposed the Tertiary rocks in the vicinity of Elko and the Ruby-East Humboldt
Range in Elko County as the type locality. Van Houten (1956) considered the Humboldt Formation equivalent only to his vitric tuff unit of Nevada. The lower member of the Humboldt Formation whose age is Late Miocene according to Sharp (1939) is, in fact, lithologically the same as what Van Houten called the Eastern Sedimentary Sequences of Nevada. The age of that unit, according to Van Houten, is Oligocene. Decker (1962) has used the Humboldt Formation for the vitric tuff unit in the Bull Run quadrangle, Elko County, about 70 miles north of the thesis area. Knight (1953) named the Tertiary limestone, conglomerate and basalt lava flow in the Carlin Canyon Area as Humboldt Formation.

Regnier (1960) has introduced new formation names for the Tertiary rocks in the vicinity of Carlin, which is located about 20 miles west of Elko. He avoided using the term, Humboldt Formation, because of the different lithologic character of the Tertiary rock he investigated and also because he doubted the age assigned by Sharp for the Humboldt Formation.

In the present report the name Humboldt Formation is used simply because the lithologic descriptions and divisions of the Formation proposed by Sharp can be followed in the thesis area as shown in Table I. The age of each member, however, has to be modified as a result of more recent dating
### Comparison of the Humboldt Formation as described by Sharp with the Humboldt Formation of this paper

<table>
<thead>
<tr>
<th>SHARP (1939)</th>
<th>Humboldt Formation</th>
<th>Lithology</th>
<th>Basalt flow, lahar and volcanic breccia</th>
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</thead>
<tbody>
<tr>
<td>Member</td>
<td>Pyroxene andesite, olivine-pyroxene basalt, flows, breccia and associated tuff</td>
<td>Mudstone, shale, siltstone and fine conglomerate</td>
<td>UPPER</td>
</tr>
<tr>
<td>Member</td>
<td>Rhyolitic tuff and ash</td>
<td>Shale, oil shale, limestone, sandstone, conglomerate, fanglomerate and breccia</td>
<td>LOWER</td>
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<table>
<thead>
<tr>
<th>Member</th>
<th>Humboldt Formation</th>
<th>Lithology</th>
<th>Siltstone, sandstone and conglomerate</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Vitric tuff, ignimbrite</td>
<td>MIDDLE</td>
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<thead>
<tr>
<th>Member</th>
<th>Humboldt Formation</th>
<th>Lithology</th>
<th>Oil shale, chert and limestone nodules, conglomerate, fanglomerate and breccia</th>
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<th>Member</th>
<th>Humboldt Formation</th>
<th>Lithology</th>
<th>Carboniferous Rocks</th>
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<td></td>
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<td>Coniferous Rocks</td>
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TABLE II:
Comparison of Tertiary Stratigraphy of the thesis area to Tertiary Stratigraphy of east half of Carlin, Dixie Flats, Pine Valley and Robinson Mountain quadrangles.

<table>
<thead>
<tr>
<th>Age</th>
<th>Rock unit</th>
<th>This paper (1974)</th>
<th>Member</th>
<th>Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miocene?</td>
<td>Basalt</td>
<td>Basalt lava flow, lahar and volcanic breccia</td>
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<tr>
<td>Miocene</td>
<td>Tuffaceous sedimentary rocks and ash: siltstone, sandstone and conglomerate</td>
<td>Siltstone, sandstone and conglomerate</td>
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<tr>
<td>Oligocene</td>
<td>Predominantly lava flows</td>
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<td>Ash-flow tuff</td>
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<td>Tuffaceous sedimentary rocks and ash</td>
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<td></td>
<td>Ash-flow tuff and tuffaceous sedimentary rocks interlayered</td>
<td>Vitric tuff, ignimbrite and chert</td>
<td>Middle</td>
<td>Humboldt</td>
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<tr>
<td>Age</td>
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<td>Eocene</td>
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<td>Non-cherty limestone</td>
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<td>Chert and limestone</td>
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<td>Limestone with chert</td>
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<td>Limestone and limestone-</td>
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<td>Conglomerate and sand-</td>
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<td>stone and breccia</td>
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of the rocks. So in this report the age assigned to each member is based on correlation with the Tertiary stratigraphy of the east half of the Carlin, Dixie Flats, Pine Valley, and Robinson Mountain quadrangles mapped by Smith and Ketner (1972) which is located only about 9 miles southwest of the thesis area. The ages of some of the rock units in the quadrangles mentioned above have been determined by K-Ar dating in 1971. The Elko Oil Shale which has been used as the key horizon for correlation between these two areas is believed to be the same age throughout northeastern Nevada (Winchester, 1923; Sharp, 1939; Van Houten, 1956; Ketner, 1970). This correlation is shown in Table II.

So, in the thesis area the three members of the Humboldt Formation of Sharp (1939) are present.

**Lower Member**

The Lower Member of the Humboldt Formation can be divided into 5 rock units.

*Conglomerate and sandstone unit:* This rock unit is unconformable above the Chainman Formation. It consists of about 480 feet (in Sec. 25, T. 35 N, R. 54 E) of interbedded white, yellow and red sandstone and Paleozoic-pebble conglomerate. The conglomerate is similar in appearance to the Diamond Peak Formation. It is composed of subrounded to rounded pebbles and cobbles of chert, quartzite, and conglomerate, which have been derived from Paleozoic conglomerate,
in a matrix of sand. The maximum diameter of the cobbles is 5 inches, but, most of the pebbles have diameters of 1-2 inches. The conglomerate generally shows cross bedding, scour and fill, and channel features. The conglomerate beds and lenses can be up to 24 feet thick. The sandstones are fine grained and are composed of quartz, chert and feldspar. They are thinly bedded and cross laminated.

This rock unit is lithically similar to the Rand Ranch Formation in Carlin Area (Regnier, 1960) which is of Oligocene age. However, based on comparison with the closer neighbouring area mapped by Smith and Ketner (1972) as mentioned before, this rock unit must be of Eocene age.

The sedimentary features indicate that this unit is a stream or alluvial deposit.

Breccia unit: In Sec. 20, T. 35 N, R. 55 E, there is an outcrop of light purple to reddish-brown breccia, consisting of angular fragments of light-gray quartzite, dark and reddish-brown chert, igneous rocks, and Paleozoic conglomerate, 1 inch to 1 foot in diameter with a tuff sandstone matrix. The base of the breccia is not exposed, the maximum thickness is about 40 feet. It is unconformable overlain by middle member of the Humboldt Formation.

A thin section of the matrix shows hypocrystalline, porphyritic-vitric texture. The ground mass, about 82% of
Figure 12. Breccia in Lower Member of Humboldt Formation, crops out in Sec. 20, T. 35 N, R. 55 E. The pebbles mainly are quartzite and chert, the matrix is tuff sandstone.

The rock, consists of vitreous glass. The grains of the matrix which are medium to coarse, consist of: quartz 5%, sanidine 5%, plagioclase (albite) 2%, biotite 5% and magnetite (alteration of biotite) 1%. The matrix, therefore can be called as vitric tuff.

A thin section of a sandy shale pebble in the breccia shows it to consist of about 67% argillaceous material. The grains are fine, subangular to subrounded, disk or rod shaped, and consist of: quartz and quartzite 18%, chert 12%, muscovite 1%, and a trace of plagioclase, microcline, diopside,
hypersthenes, epidote, hematite and limonite. This shale may have been derived from shale of the Chainman Formation.

The breccia may be in the same stratigraphic position as the Conglomerate and Sandstone unit, overlying the Chainman Formation from which most of its fragments were derived. The age of the breccia, therefore, may be Eocene the same as the age of the Conglomerate and Sandstone unit. This rock unit might be the equivalent of the Eastern Conglomerate which consists of reddish-brown conglomerate and breccia of Eocene age described by Van Houten (1956) in eastern Nevada.

The breccia may have developed as a talus deposit containing blocks or fragments of several types of rocks.

**Limestone with chert nodules unit**: Conformable above the conglomerate and sandstone unit, fresh-water limestone crops out at a number of localities. In most places, however, it lies directly on Paleozoic or Mesozoic rocks. The limestone is white, light-brown or cream colored. It is chalky to dense and finely crystalline. The beds range from a fraction of an inch thick to a few feet thick. Some of the limestone is silicified and shows stromatolitic features.

In two thin sections, the limestone is seen to consist of about 85% carbonate including a small percentage which has replaced bioclastics. It contains about 15% of grains
which are fine, angular and rod shaped and consist of: quartz 2-5%; biotite (partly chloritized) 2-5%; plagioclase (albite) 2-10% and sanidine 0-2%.

The limestone contains a great number of irregular black, gray, brown, and white nodules of chert ranging from an inch to a foot in diameter. It contains also many shells of fresh water gastropods and pelecypods. In many places the limestone is interbedded with pale-green, reddish-brown, yellowish-gray shale, siltstone, sandstone, conglomeratic sandstone and conglomerate, all in beds an inch to a few feet thick.

The maximum thickness of this unit is about 700 feet (Sec. 19, T. 35 N, R. 54 E). The presence of the fresh water fauna in this rock unit indicates that the environment of deposition was nonmarine, probably in a lake environment. The presence of the stromatolitic feature indicates that the water was sometimes shallow and probably even periodically was emergent as shown by the presence of the reddish-brown siltstone, sandstone and conglomerate. During deposition of the limestone there was volcanic activity, perhaps quite far from the area, which has produced the low percentage of volcanic materials in the limestone. The source of the silica for the formation of the chert nodules in the limestone may have been derived from volcanic material produced by those volcanoes.
Chert and limestone unit: In Sec. 25, T. 35 N, R. 54 E, and Sec. 30, T. 35 N, R. 55 E, the limestone with chert nodules unit, discussed above, passes upward into a unit in which the chert becomes predominant and the limestone becomes subordinate. The chert is dark-brown and white, white-gray or creamed colored. All beds are silicified and irregularly bedded. The maximum thickness of this unit is estimated in Sec. 25, T. 35 N, R. 54 E and Sec. 30, T. 35 N, R. 55 E., to be about 400 feet. It is believed that this unit developed only locally at the top of the limestone with chert nodule unit.

The abundance of chert in this rock unit could have been caused by an increase in the silica supply after deposition of the limestone with chert nodules unit described before. The origin of bedded cherts can be simply by accumulation of siliceous organic matter as found in the Schoonover Formation described by Fagan (1962) in the northern Independence Range, Elko County. However, the chert also can be deposited by direct precipitation of opaline silica supplied by volcanic activity (Krauskopf, 1959). The origin of Ordovician bedded chert of Cordilleran eugeosynclinal in Nevada and Idaho has been interpreted by Ketner (1969) to be the result of direct precipitation of quartz.
The origin of chert in the chert and limestone unit probably is due to an increase in volcanic activity after deposition of the limestone with chert nodules unit. The increase in silica supply relative to the carbonate supply resulted in a more siliceous deposit.

The limestone with chert nodules unit and the chert and limestone units can be correlated with the Eocene cherty limestone unit of east half of the Carlin, Dixie Flats, Pine Valley and Robinson Mountain quadrangles, Elko and Eureka County mapped by Smith and Ketner (1972). These stratigraphically similar units are under the oil shale unit.

**Oil shale:** In many places, the limestone with chert nodules unit is conformably overlain by thin-bedded or laminated, dark brown, petroliferous, organic shale (oil shale). A single group of similar beds is seldom over a few feet thick. The oil shale is interbedded with laminated grayish-yellow siltstone, brownish-silty shale, greenish-gray claystone, dark-gray siliceous shale, brownish-yellow dolomite, gray tuffaceous mudstone, and sandstone all in beds of one to two feet thick. The oil shale quickly disintegrates on exposure to air so in most outcrops it is represented by loose pieces of brown to dark shale which weather to white, gray-white or pale-gray color. This oil shale contains some bituminous matter. The siltstone or silty shale,
Figure 13. Oil Shale intercalated by silty shale in Lower Member of Humboldt Formation in Sec. 19, T. 35 N, R. 55 E.

generally contains abundant plant fossils and the shale or claystone contains abundant fossil ostracos and snails.
The maximum thickness of this unit estimated in Sec. 31, T. 35 N, R. 55 E, is only about 330 feet. The Elko Oil Shale which crops out about 6 miles south of the thesis area has been correlated with the Eocene Green River Formation of Southwestern Wyoming, northeastern Utah and northwestern Colorado by Winchester (1923). Sharp (1939) has grouped this oil shale with the Lower Member of the Humboldt Formation of Miocene age based on a number of plant fossils found in the oil shale. Van Houten (1956) believed that the age of the oil shale is Eocene or Oligocene as suggested by the age of the fossil snails found in the rocks. This age was confirmed later by K-Ar dating on biotite from tuff found in upper part of the oil shale which indicate the age of 38.6 ± 0.8 m.y. (McKee et al., 1971).

Based on the presence of many fresh-water faunas as reported by several authors it is undoubted that the Oil Shale has been deposited in a lake environment. Based on plant remains Axelrod (1957) concluded that the climate in Early Tertiary time was temperate, cooler (25°C) and more moist than at present.

Middle Member

The Middle Member of the Humboldt Formation is characterized by thick sequences of vitric tuff, which is interbedded with lenses of ignimbrite and chert. This member is
separated from the Lower Member by erosional or slightly angular unconformities.

**Vitric tuff unit**: The most extensive and widely exposed sequence of Tertiary sedimentary rocks in the thesis area is the vitric tuff unit, which is composed of lapilli tuff, pumiceous tuff and tuffaceous sandstone. The lapilli tuff consists of angular fragments of rhyolite and dacite, between 1/2 and 2 1/2 inches in diameter embedded in a matrix of fine to medium tuff sandstone consisting of quartz, biotite, feldspar and glass. The lapilli tuff is generally massive. The pumiceous tuff is generally massive, but in places contains beds 3-6 feet thick. It consists of light-gray, reddish-gray and yellowish-gray tuff sandstone which includes fragments of pumice and other volcanic rocks, 1/2-3 inches in diameter. The lapilli tuff and the pumiceous tuff are interbedded with white, gray-white, soft and friable, thin-bedded or laminated tuffaceous sandstone which consists of quartz, biotite, feldspar and glass fragments. Individual layers are 1 inch to 1 foot thick. Most beds are cross laminated and few show ripple marks.

The thickness of this unit is estimated in Sec. 36, T. 35 N, R. 54 E to be 1,100 feet. In thin sections, the tuff sandstone is seen to consist of angular to subangular pyroclastics in a matrix of glass and microlites. The grains
Figure 14. Vitric tuff of Middle Member of Humboldt Formation, showing massive lapilli tuff with laminated tuffaceous sandstone in Sec. 14, T. 35 N, R. 55 E.
lt: lapilli tuff
ts: tuffaceous sandstone

Figure 15. Photomicrograph of a thin section of vitric tuff. (Thin section: PHS. 171), taken from Sec. 15, T. 35 N, R. 55 E.
q: quartzite; s: sanidine; ab: albite; b: biotite; g: glass; m: magnetite. The matrix is glass shards (plain light)
are composed of: quartz, 2-7%; sanidine, 5-7%; plagioclase, (albite-oligoclase), 1-10%; biotite (partly sericitized), 0-10%; opaque iron ore, 2-3%; rock fragments (volcanics), 2-3%. The glass ground mass ranges from 25% to 84% of the rock and microlites from 0% to 35%.

Due to an abundance of vitric material in this rock unit, Van Houten (1956) named it the Vitric Tuff Unit for the first time, which name also is used informally in this report.

The interbeds of white vitric tuff found in this unit show laminations, cross laminations and ripple marks which indicate that the rock unit probably was deposited in a dynamic aqueous or eolian condition. Part of the massive lapilli tuff probably is ash-flow tuff as shown by the general poor sorting, as where lapilli 1/2 to 2 1/2 inches in diameter are mixed with sand size material. The angularity and poorly sorted of the grains in a matrix of glass shards as shown by the photomicrograph of a vitric tuff in Figure 15, according to Epis (personal communication, 1974) are also characteristics of the ash flow.

The age of the Middle Member of the Humboldt Formation according to Sharp (1939) is Late Miocene. Van Houten (1956) thought that the age of the Vitric Tuff in Nevada is Late Miocene to Pliocene. However, dating by K-Ar on sanidine and on biotite by McKee et al. (1971) from ash-flow tuff
above the oil shale give ages of \( 33.2 \pm 0.7 \) m.y. and \( 34.9 \pm 0.7 \) m.y. respectively which indicate an Oligocene age. Based on this data, the age of the vitric tuff unit in the thesis area is believed to be Oligocene.

**Ignimbrite:** Several small masses of ignimbrite are found in Secs. 14, 15, T. 35 N, R. 55 E, interbedded or as lenses within the vitric tuff. They are gray-white or purple-white in color, weathering to light gray or gray-white. They show almost horizontal sheeting. The maximum thickness of the massive ignimbrite including some vitric tuff beds in it is about 80 feet and hundreds of feet long.

In the thin sections, the ignimbrite shows that it consists of 72% to 81% glass shard as matrix and about 19%-28% fine to coarse grains that are angular to subangular, disk to rod shaped, and composed of: quartz, 7-10%; sanidine 5-7%; plagioclase (albite-oligoclase), 2-5%; brown biotite (partly altered to magnetite), 4-5%; and opaque iron ore, 0-1%. Some of the glass particles evidently are firmly welded and are molded or bent around the crystals. The ignimbrite can be called rhyolitic tuff.

The occurrence of the ignimbrite is believed to result from rapid, thick deposition of hot ash flows (Smith, 1960). The absence of the ignimbrite in the western part of the area may be because it is farther from the center of the volcanism. So, the source of the vitric tuff, or more
certainly the ignimbrite, must have come from active volcanoes east of the area.

Figure 16. Photomicrograph of a thin section of the ignimbrite from Sec. 15, T. 35 N, R. 55 E (Thin Section: PHS. 142), showing moderately welded and eutaxitic fabric.

q: quartz; ab: albite; s: sanidine; b: biotite; g: glass shards (plain light).

The ignimbrite in the area is probably equivalent to the abundant ignimbrite in Central Nevada, however, no attempt to correlate them has been made.

Chert: Local beds or lenses of chert were found in several places within the vitric tuff. The maximum thickness of individual chert beds is 8 inches. It is of various colors: yellow, pink, green, gray, blue and white. Banded
textures (alteration of dark and light color) are common. The maximum thickness of the chert lenses that have been observed is only about 20 feet.

The occurrence of this chert may be due to alteration of vitric tuff or ash during and soon after deposition. Under certain conditions, the silica released by the vitric tuff could have accumulated as chert (Van Houten, 1956).

**Upper Member**

The Upper Member of the Humboldt Formation consists of massive or cross bedded siltstone interstratified with layers of conglomerate, sandstone or shale. The siltstone is gray, weathering yellowish gray, friable and soft. Scour and fill channels are common features. The conglomerate consists of subrounded to rounded pebbles of quartzite, gray to green chert, Paleozoic conglomerate, limestone, sandstone, tuff sandstone and fragments of ignimbrite, generally between 1/2-1 inch in diameter, very rarely blocks 1 foot in diameter. This conglomerate is generally cross bedded, and not well indurated. The sandstone is yellowish-gray, weathering gray to dark gray. It is cross bedded, very poorly sorted, friable and soft. It consists of particles of quartz, biotite, feldspar, and some glassy materials and is fine to coarse grained. The mudstone and shale are gray or light green.
The thickness of this Member in Sec. 34 and 35, T. 35 N, R. 55 E, is about 350 feet. The age of the Upper Member of the Humboldt Formation according to Sharp (1939) is Pliocene. However, this member can be lithically correlated with Miocene tuffaceous sedimentary rocks and ash shown by Smith and Ketner (1971) on the geologic map of the East Half of the Carlin, Dixie Flats, Pine Valley and Robinson Mountain

![Image of geological formation with a hammer and chisel.]

**Figure 17.** Upper Member of the Humboldt Formation in Sec. 34, T. 35 N, R. 55 E, showing scour and fill, laminated and cross laminated siltstone. The pebbles are quartzite, chert, paleozoic conglomerate, limestone and ignimbrite.
quadrangles, Elko and Eureka Counties which, as had been stated before, is located only about 9 miles southwest of the thesis area.

The deposition of this member must have been by stream as shown by scour and fill bedding features and cross lamination in siltstone.

This member probably is separated from the Middle Member by an erosional surface or unconformity. The conglomerate of this member contains pebbles of tuff sandstone and fragments of ignimbrite which probably were derived from the Middle Member. The bedding attitudes in this member seem to be gentler than those found in the older member.

**Basalt Lava Flow**

In Sec. 25, T. 35 N, R. 54 E, a basalt lava flow rests unconformably on the Humboldt Formation. It is about 75 feet thick and about 1 mile long. It is dark colored and weathered to dark reddish or rusty red. It is fine grained at the top and bottom surface but becomes coarser toward the middle of the lava body. The top surface is vesicular with some vugs that have been filled with quartz. The lava is jointed in many directions and in several localities shows sheeting features.

In two thin sections, the basalt shows a holocrystalline, porphyritic-aphanitic texture. The phenocrysts are fine to
Figure 18.- Generalized columnar section of the Humboldt Formation.
Figure 19. Photomicrograph of a thin section of the basalt from Sec. 25, T. 35 N, R. 54 E (Thin section: PHS. 22) l: labradorite; a: augite; the groundmass consists of microlites of plagioclase and pyroxene (plain light).

Coarse grains consisting of: plagioclase (labradorite), 25-30%; augite, 14-16%, opaque iron ore, 2%, and trace of hornblende. The ground mass consists of microlites of plagioclase and pyroxene that range between 52% and 59% of the rock. The basalt probably is equivalent to the Miocene Basalt above the tuffaceous sedimentary rocks and ash unit shown in the geologic map of the area about 9 miles southwest of the thesis area by Smith and Ketner (1972) as shown in Table II.
Lahar and Volcanic Breccia

In several localities the vitric tuff unit of Middle Member of Humboldt Formation is unconformably overlain by irregular deposits consisting mainly of a chaotic mixture of large and small fragments of pyroclastic debris from 1/4 inch to 3 feet in diameter. Lesser components are igneous rock, sandstone, quartzite, chert and conglomerate and all are embedded in a matrix of mud, vitric lapilli, and ash with fragments of pumice. The matrix is about 60% of the rock. There are a few laminated tuff sandstones. The pyroclastics and the igneous rocks are all basaltic in composition. The lahar, in places grades to volcanic breccia where angular fragments of pyroclastics are dominant and because there is very little matrix the rock fragments touch each other. The color of the rock fragments of the breccia is dark brown or dark gray weathering to gray or gray brown.

Thin sections of the fragments of the volcanic rocks in the breccia show that they have at least two kinds of textures: holocrystalline, porphyritic-aphanitic and hypocrystalline, porphyritic-vitroaphanitic. All are vesicular. Phenocrysts are fine to coarse and are composed of: plagioclase (labradorite), about 50%; hypersthene, 5-10%; magnetite, 2-5%. Ground mass consists of: aphanitic or microlites of pyroxene and plagioclase, 0-34%; glass, 0-37%;
Figure 20. Volcanic Breccia in Sec. 14, T. 35 N, R. 55 E. Most boulders are basalt and a few are quartzite and chert.

Figure 21. Photomicrograph of vesicular-hypersthene basalt flow found as a boulder in the volcanic breccia in Sec. 30, T. 35 N, R. 55 E (Thin section: PHS. 20A). l: labradorite; h: hypersthene; m: magnetite. The groundmass is glass with some vesicles partly filled with hematite (plain light).
vesicles filled with hematite, 1%. The volcanic rocks, therefore, can be classed as vesicular hypersthene basalt flow.

The boulders of vesicular hypersthene basalt flow probably are a product of other volcanoes which were active in the surrounding area after deposition of the Humboldt Formation. The volcanic rocks derived from these volcanoes may have mixed during transport with fragments of older rocks such as quartzite, chert, tuff sandstone, and lapilli tuff with pumice. The last two evidently were derived from the vitric tuff unit of the Humboldt Formation.

This rock unit probably is the same age as the Miocene basalt lava flow discussed before. In the neighbouring region, especially in the area mapped by Smith and Ketner (1972), there was only one period of basalt production after the Oligocene. Since the Lahar and Volcanic Breccia is unconformable above the Oligocene vitric tuff of the Humboldt Formation, then it is probable that its age is Miocene or younger.

**Quaternary Rocks**

Four lithologic units of Quaternary age were mapped in the thesis area.

**Fanglomerate**

This unit consists of angular and subangular cobbles and pebbles, chiefly of quartzite, chert, silt and clay. This
fanglomerate covers the contact of the Paleozoic rocks with the Humboldt Formation in Sec. 25, T. 35 N, R. 54 E. The thickness of the Fanglomerate may be tens of feet.

**Terrace Alluvium**

This alluvium covers the surfaces of terraces tens to hundreds of feet above the present stream level. The thickness of this unit is probably as much as 60 feet.

**Colluvium**

A veneer of talus and landslide deposits mixed with alluvium obscure the bedrocks in the northwest part of the thesis area and in several other localities.

**Stream Alluvium**

Stream alluvium consists of younger deposits of sand and gravel along modern stream courses and at the bottom of several valleys. The maximum thickness of the alluvium probably is tens of feet.
There were three major stages of deformation in the area. They are: (1). Folding and high-angle faulting probably in late Jurassic or Early Cretaceous time. (2). Reverse faulting that followed the folding, and (3). Block faulting that occurred later in Tertiary to Quaternary time.

**Fold**

The pre-Tertiary rocks clearly have been affected by at least one period of folding, as shown by the presence of a syncline axis in Diamond Peak and Chainman Formations extending from southwest to northeast in the thesis area. In general the syncline is asymmetric, northwest limb steeper than the southeast limb. The strata on the northwest limb dip to the southeast at angles between 20° to 50°, whereas the strata on the southeast limb generally dip to the northwest at angles between 10° and 30°.

The contour diagram in Figure 22, which is based on 340 attitudes measured in the Diamond Peak and Chainman Formations, shows the asymmetry of the syncline. The diagram also shows that the syncline plunges 4°S, in a S 35° W direction.
Figure 22. - Contour diagram, poles to Diamond Peak and Chainman beddings. Plotted on lower hemisphere, equal area net.

Contour interval: 2\%, lowest contour: 1\%

α: fold axis: $35^\circ W + 4^\circ S$
This syncline is a portion of the Adobe syncline which according to Ketner and Smith (1974) is of Late Jurassic or Early Cretaceous age. According to them, the Adobe syncline extends all along the entire length of the Adobe Range (Figure 2) and continues to the Cortez Mountains about 50 miles southwest of the area. They reported that the syncline is partly isoclinal, partly overturned in the north but becomes more open to the south. The thesis area is in the more open part.

The syncline axes shown in the geological map of the area (Plate 1) may represent one long syncline which originally extended from southwest of the area to northeast of it, and later was cut and offset by a number of transverse faults. Alternatively each of the short segments are different syncline axes, which have been developed independently in each block separated by transverse faults. In the first case, horizontal movement along the transverse faults must correspond to the horizontal displacement of the fold axes. In many places, however, as in Secs. 7, 8, and 9, T. 35 N. R. 55 E, the separations shown by the fold axis seem to be too great to be the result of such small transverse faults. Therefore, it is more probable that the transverse faults existed before or were formed during the folding. In this case the discontinuity of the fold axes can be explained as the result of differential advance of adjoining segments of the fold arc (Figure 23).
No folds in Tertiary rocks have been found. This may be either because of the obscurity of the attitudes especially in the Tertiary massive tuff or because they have not yet been folded. Probably the second possibility is the case as pointed out by Sharp (1939). The Tertiary rocks have been uplifted, tilted and slightly warped, but not folded.

Faults

The faults in the area generally do not show up clearly on the ground. Most of the high-angle faults have been identified by studying aerial photographs. In the field, one or several of the following features have been used as criteria to ascertain the presence of the faults or confirm those seen on the photographs.

(1) Offset of contact between rock units
(2) Repetition of the rock units
(3) Abrupt changes in attitude of bedding
(4) Abrupt termination of folds and faults
(5) Nearly straight valleys that cross the structures obliquely or that appear to offset other valleys
(6) Lines of springs
(7) Linear zones of alteration, strong cementation or discoloration

Three episodes of faulting can be recognized:

(1) Faulting before or during the folding
(2) Faulting shortly after folding

(3) Faulting long after the folding (younger faults)

Faulting before or during folding

There are two sets of these: (1) The older faults which trend nearly parallel to the fold axis and which have been truncated by transverse faults as found in Secs. 13, 24, T. 35 N, R. 54 E, and Secs. 7, 8, 19, T. 35 N, R. 55 E (all strike N 10°-45°E); and (2) The transverse faults which intersect the fold axis and strike N 10°-45° W.

No fault surface well enough exposed to permit measurement of dip has been found. The straight linearity of the traces of most of these older faults as they cross topography suggest a generally steep dip.

The faults that are almost parallel to the fold axes and are generally the oldest faults in the area, probably are compressional reverse faults that preceded or accompanied the folding. However, it is possible also that they are high angle tensional faults that resulted from block faulting before folding. According to Nolan (1943) an episode of uplift occurred in the Great Basin Area, from Permian to Late Mesozoic time which produced many block faults.

The transverse faults which may be classified also as tear faults probably developed simultaneously with folding due to the same compressional stress that caused the folding.
Figure 23: Schematic block diagram showing the occurrence of tear faults as suggested by Keiner [pers.comm., 1974]
By assuming these faults to be tear faults it can be explained that the discontinuity of the fold axes in the area is mainly due to differential advance of adjoining segments of the fold arc producing unequal development of folds in each of the segments or blocks, as shown schematically in Figure 23.

Faulting right after folding

There are two important kinds of faults that occurred probably right after folding and resulted from a continuation of compressional stress that produced the Adobe syncline (Ketner, 1970, Ketner and Smith, 1974). These kinds of faults commonly occur during the maximum development (towards the end) of an orogeny according to Osmond (1960). The two kinds of faults are high-angle reverse faults and low-angle thrust faults.

High-angle reverse fault

A high-angle reverse fault is located at the crest of the Adobe Range and can be traced for about 2 miles in Secs. 12, 13, T. 35 N, R. 54 E, and Sec. 7, T. 35 N, R. 55 E. It strikes N 40°-45° E. On aerial photographs this fault is revealed by a strong and straight lineament. In the field the fault is shown by discontinuous depressions, abrupt changes in attitude of bedding, a linear zone of alteration or discoloration, and abrupt termination of fold axes and faults against it.
No dip on this fault that can be measured in the field, but, again the straight linearity of the fault suggests a steep dip.

Low-angle reverse faults (thrust faults)

These faults are located in Secs. 14, 23, 26, 27 and 34, T. 35 N, R. 54 E. The evidence of these faults in the field is the truncation of overlying and underlying beds along a contact that generally follows the contours and the presence of many low angle slickensides. Where the base of the thrust plate is exposed as in several places in Secs. 27 and 34, T. 35 N, R. 54 E, it is usually marked by a very pronounced breccia zone at least 5 feet thick. In Sec. 34, T. 35 N, R. 54 E, where the Member F of the Diamond Peak Formation characterized by the red beds is believed to be thrust over Member D of the same formation, breccia grades upward into undisturbed red beds.

The syncline in the vicinity of this thrust fault is asymmetric where the northwest flank is steeper than the southeast one. This indicates that the compression force that produced the fold as well as the thrust fault mostly came from the northwest. It is logical, therefore, to conclude that the thrust fault is dipping to the northwest and that the movement of the upper plate was from northwest to southeast. The minimum distance of transport must have been
1 1/2 miles - the width of the upper plate in this and the neighbouring quadrangle to the west

Faulting long after folding (younger faults)

In this group are included all the faults that clearly have affected the Tertiary rocks. They strike generally in all directions: N 30°-45° W, N 20°-40° E, almost N - S and almost E - W.

The range fault in the northwest of the area which strikes N 25°-35° E and extends from Sec. 1 to Sec. 22, T. 35 N, R. 54 E, (more than 4 miles) belongs to this group.
The presence of this fault is shown almost entirely by physiographic evidence: (1) The front of the mountain range is straight and in several places cuts the rock structure, (2) The range rises abruptly from the waste-filled valley, (3) The absence of branches of the major valley cutting through the range, (4) A landslide along the range front, (5) Triangular facets aligned along the mountain front on interstream areas, and (6) The presence of several scarplets. All these features are the most common evidences of block faulting in the Basin and Range Province according to Nolan (1943). Moreover, according to Sharp (1939), actually many of the mountain ranges in the Elko Area are bounded on one or both sides by faults which separate the pre-Miocene rocks of the mountain blocks from the Miocene basin deposits. According to him also, generally the fault planes have basinward steep dips and the faults are normal. This is probably true especially for the fault just described.

The other important faults of this group are the faults located in Secs. 25 and 26, T. 35 N, R. 54 E. All these faults have affected both the Tertiary and Paleozoic rocks. The straight linearity of these faults indicates that they are high angle faults and probably are normal faults as the result of the block-faulting that widely occurred not only in Elko Area (Sharp, 1939; Kay, 1952, 1960 and Kerr, 1962)
but in all parts of the Basin and Range Province (Nolan, 1943).

Figure 25. Faults in Secs. 25 and 26, T. 35 N, R. 54 E.
View looking toward west.
Mcs: Chainman Formation, sandstone and shale member
PMdb: Diamond Peak Formation, Member B
Thc: Humboldt Formation, Lower Member, conglomerate
Thcl: Humboldt Formation, Lower Member, chert and limestone
Tht: Humboldt Formation, Middle Member, vitric tuff
Tlf: Basalt lava flow
Qf: Fanglomericate

One fault in Sec. 25, T. 35 N, R. 54 E, has offset the late Tertiary lava flow for about 200 feet. This indicates that the age of the fault is Late Tertiary or even younger, but apparently the fault has offset the Paleozoic rocks more than the younger rocks as shown in Figure 27 and in Plate 1. This evidence suggests that the fault was active before Late
Tertiary time. Another example is the fault along the Kitt-ridge Springs extending from Sec. 7 to 20, T. 35 N, R. 55 E. This fault is truncated by a high-angle reverse fault related to the folding and is therefore probably a pre-Tertiary fault. However, the same fault has affected also the Tertiary lime-
stone in Sec. 17 and 20, T. 35 N, R. 55 E. This evidence suggests that some older faults became active again in Ter-
tiary or Quaternary; in other words, some of the younger

Figure 26. High angle normal fault in Sec. 19, T. 35 N, R. 55 E. View looking toward N 45° W. 
Mcc: Chainman Formation, Conglomerate member 
Thl: Humboldt Formation, Lower Member, limestone 
Qc: Colluvium
faults are recurrent faults. The same conclusion also has been made by Osmond (1960).
Figure 27: Simplified geologic map to show geologic structures of the area.

[Simplified from Plate 1]
GEOLOGIC HISTORY

The thesis area is in the region where eugeosynclinal rocks were thrust over miogeosynclinal rocks on the Roberts Mountains thrust fault in Latest Devonian or Early Mississippian time during Antler orogeny (Roberts et al., 1958). During Mississippian and later Paleozoic time the eugeosynclinal rocks were repeatedly uplifted causing a great wedge of clastics to be deposited along the flanks of the uplift. At that time the thesis area, located east of the orogenic belt, became a subsiding basin elongated in a northeast-southwest direction. Into this basin, beginning in Early Mississippian time, were transported poorly sorted silt, clay, sand and lesser amounts of gravel derived from the provenance terrane to the west which apparently was elevated as the basin subsided. It was at this time that the Chainman Formation was deposited.

In later Mississippian time the tectonic activity in the Antler orogenic belt became more intensive so that a greater proportion of pebbles and cobbles were transported into the basin. At this time the Diamond Peak Formation began to be deposited. These formations probably were deposited as deltas. Generally, coarser material was deposited
immediately at the mouth of the entering stream and finer material was deposited around the margins of the deltas. Occasionally there were slides of debris as the deltas became overloaded and oversteepened. Many of these slides probably developed into turbidity currents which carried coarse debris into the domains where finer sediments were normally deposited. Member A of the Diamond Peak Formation evidently was deposited close to the source of detritus. The upper part of the Chainman Formation and Members B-E of the Diamond Peak were deposited farther from the main source of detritus but they include tongues of conglomerate that extend from Member A.

Members B, C, and D of the Diamond Peak Formation are probably contemporaneous with Member A but their lesser thickness and finer grain suggests they were deposited farther from the source of detritus or to one side of the main deposit, perhaps between two deltas where coarse detritus was deposited only occasionally. In modern alluvial fans and marine deltas the main site of deposition is constantly changing from one side of the fan or delta to the other. In addition, the supply of detritus may have changed because of renewed uplift in the source area from time to time.

Because Members E and F of the Diamond Peak are on thrust faults their relation to the other members is unknown.
Member E contains marine fossils but the red beds of Member F and the lack of marine fossils suggest that it was de-
posited above the water line. If so, it may be the youngest
part of the formation, perhaps deposited as the basin began
to emerge. According to Dott (1955) emergence in the region
began in Middle Pennsylvanian time.

There is no record in the thesis area of deposition in
later Pennsylvanian or Permian time. Either the area was
entirely emergent and all detritus was removed from the re-
gion or subsequent erosion has removed all deposits of that
time interval.

In Early Triassic the area was submerged again by shallow,
clean, and calm water in which the Triassic limestone was
deposited.

In Late Jurassic or Early Cretaceous time the area was
folded and faulted. At the end of the folding the high-angle
and low-angle reverse faults occurred due to continuation
of the compression forces. The forces that caused the fold-
ing and the reverse faults probably were aligned in a north-
west-southeast direction, and the tectonic transport by the
thrust faults was to the southeast.

After the Early Triassic time the area was probably
emergent until the present. During the early part of the
emergent interval all erosional debris was removed from the
region, but beginning in Tertiary time the debris was de-
posited locally.

In Late Eocene or Early Oligocene time, the area was
covered in part by a lake or lakes which filled a series of
connected intermontane basins or irregular depressions. At
that time, limestone, chert, and the oil shale were deposited.
In the meantime or shortly before, along the river courses
and on its flood plains, conglomerate was deposited. Along
small scarps of the mountains, breccias were deposited. All
of these deposits form the Lower Member of the Humboldt For-
mation.

Later, in Oligocene time, the lakes dried up or filled
up. The greater part of deposition took place along the
river courses and on the floor plains of moderately large
streams. Contemporaneously volcanism in the surrounding
area supplied large quantities of fine to coarse pyroclastic
materials to the area. These deposits formed the Middle
Member of the Humboldt Formation. At that time the center
of the volcanisms was closer to the eastern part of the area.

In the early part of Miocene time, the volcanism nearly
ceased and sedimentation occurred mainly along the river
courses and flood plains also. This material which formed
the Upper Member of the Humboldt Formation was a mixture
of the older rocks eroded by the rivers.
In later Miocene time and probably early Pliocene time, another period of volcanism was active in the area or in the surrounding area. This volcanism erupted basic materials which produced the basalt lava flow, lahar, and volcanic breccia. At this time the center of the volcanism seems to have been located close to the western part of the area as indicated by the presence of the lava flow there.

From Miocene to Quaternary time the area periodically has been subjected to regional uplift producing tensional force which caused block-faulting, and which reactivated some of the older faults. This process is still active as shown by small scarps in parts of the area.
SELECTED BIBLIOGRAPHY


GEOLOGIC CROSS SECTIONS OF THE KITTRIDGE SPRINGS QUADRANGLE ELKO COUNTY, NEVADA

By
Parshen H. Stithaga
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(For explanation see Plate 2)