University of Nevada

Reno

Geology of a Portion of the Nightingale and Truckee Ranges, Washoe and Pershing Counties, Nevada

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requirements for the degree of Master of Science
in Geology

by

Vijai Narain Rai

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The thesis of Vijai Narain Rai is approved:

Thesis advisor

David B. Slemmons

Department chairman

Robert M. Gorrell

Dean, Graduate School

University of Nevada

Reno

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Abstract

The area of the investigation is underlain chiefly by metamorphosed Late Triassic and Early Jurassic rocks, a gabbroic pluton of Middle Jurassic and Early Cretaceous age, a granitic pluton of probable Cretaceous age and volcanic rocks of Early Middle to Lake Tertiary and Quaternary age. Quaternary deposits, predominantly lacustrine, occur in basinal areas.

The oldest rocks in the region consist of metasediments and sediments of Late Triassic and Early Jurassic age. These rocks are mainly slate, siltstone, mudstone, recrystallized limestone and quartzite which have been intruded by the gabbroic and granitic batholith. The sedimentary and plutonic contact is marked by hornfels, tactite and rarely by mica schists. These metasediments dip steeply and have been intensely folded and faulted. The folds are predominantly isoclinal and are more intense near the contact with the batholith.

Metamorphism, folding and faulting were first caused by the intrusion of a gabbroic rock in the Mid-Jurassic to Early Cretaceous(?), and then by the intrusion of a granitic batholith in Mid-Cretaceous time. The oldest intrusion is mainly gabbro, varying in composition near its contacts with the other rock types. The pluton is mainly granodioritic with scattered bodies of diorite in the map region. Near the Nightingale mining district aplite and pegmatite dikes are frequently observed which are partially responsible for the mineralization in the district. The major source of tungsten mineralization in the region is the granodioritic pluton.

After a period of erosion in the Late Cretaceous, Paleocene and Eocene time, volcanic activity commenced with the deposition of the Hartford Hill ash flows, welded rhyolitic tuffs, and some minor rhyolitic flows. A brief time interval separated these rhyolitic tuffs and the overlying andesitic and dacitic flows and pyroclastic volcanic rocks of the Chloropagus Formation.

The pyroclastic volcanic rocks of the Chloropagus Formation consists of welded tuffs, tuff breccia, tuff sandstone and conglomerate and are locally in excess of 1,000 feet in thickness and were deposited areally and in the depressions formed by the faulting from the earlier volcanic activity in the region.

The olivine bearing-basalt of probable Late Pliocene and Pleistocene time was subsequently deposited on these pyroclastic rocks. At the close of the volcanic eruptions, block faulting of the "Basin and Range" type displaced the flows and formed grabens and tilt block valleys and ranges.

During Late Pleistocene time, several lakes of considerable areal extent occupied these structural basins. Lake Lahontan extended over the areas presently occupied by Winnemucca and Pyramid Lakes. The lake sediments can be seen at several places in the map area up to approximately 4,400 feet in elevation indicating the height of the water and the extent of the lake during that period.

Fig 1. Photograph showing dark colored metasediments and reddish brown Hartford Hill Formation (volcanic). Photograph looking north.

INTRODUCTION

Location and Accessibility:

The area of investigation lies near the junction of Washoe, Churchill and Pershing Counties, Nevada, on the southeast border of the Winnemucca Lake Basin (fig. 1). It covers portions of Townships 23, 24, and 25 north and Ranges 23 and 24 east. U. S. Geological Survey topographic maps are available for almost the entire area.

The area is easily accessible from highways and dirt roads. It can be reached by U. S. Highway 40 and Nevada Highway 34. The southern part of the district is only about 4 miles north of Nevada Highway 34. Several gravel roads cross-cross the area. The nearest settlement is Nixon which is located at the southern end of Pyramid Lake on the Paiute Indian Reservation.

The object of this investigation:

The object of this investigation was to prepare a geologic map of the area. The metasedimentary units, although related to tungsten mineralization in the area, have never been mapped before on a proper scale. Many publications dealing with the tungsten mineralization in this area and the vicinity can be seen but none of these publications include a geologic map of the entire sedimentary units in this region.

Methods of Investigation:

The author spent several weekends during the Spring semester of 1967 and about 1-1/2 months during the Summer of 1967 mapping various rock units on a scale of 1:24,000. Enlarged topographic maps and aerial photographs from U. S. Geological Survey provided the base for the geologic map of the region. Rock contacts, dips, strikes, jointing, folds, faults

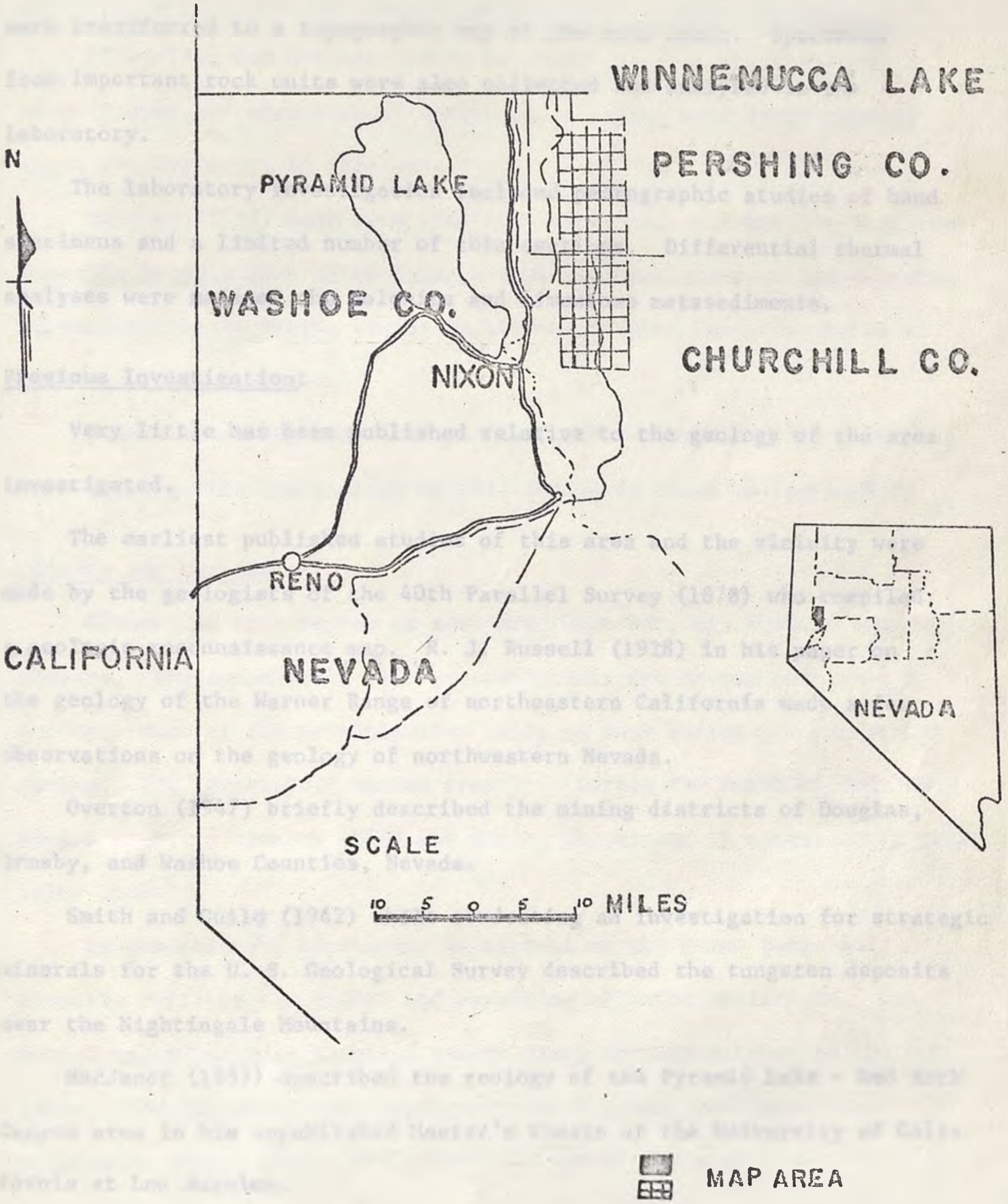

Fig. 2. Index map showing location of the map area southeast of the Winnemucca Lake.

and other structural features were located on the aerial photographs and were transferred to a topographic map of the same scale. Specimens from important rock units were also collected and analyzed in the laboratory.

The laboratory investigation included petrographic studies of hand specimens and a limited number of thin sections. Differential thermal analyses were made of the dolomite and limestone metasediments.

Previous Investigation:

Very little has been published relative to the geology of the area investigated.

The earliest published studies of this area and the vicinity were made by the geologists of the 40th Parallel Survey (1878) who compiled a geologic reconnaissance map. R. J. Russell (1928) in his paper on the geology of the Warner Range of northeastern California made a few observations on the geology of northwestern Nevada.

Overton (1947) briefly described the mining districts of Douglas, Ormsby, and Washoe Counties, Nevada.

Smith and Guild (1942) while conducting an investigation for strategic minerals for the U. S. Geological Survey described the tungsten deposits near the Nightingale Mountains.

MacJanet (1957) described the geology of the Pyramid Lake - Red Rock Canyon area in his unpublished Master's thesis at the University of California at Los Angeles.

Bonham (1962) described the aerial geology of the northern Washoe County for his Master's thesis at the University of Nevada.

An unpublished reconnaissance map of part of the area, made by Southern Pacific Railroad Company (1960-1961), is also available.

Silberling and Roberts (1962) in their paper on Pre-Tertiary stratigraphy and structure of northwestern Nevada made brief remarks about the sediments in this area.

Tingley (1963) made some scattered observations about the Tungsten deposits in this area while doing a more regional study of the tungsten mineralization in Sierra Nevada in his unpublished Master's thesis at the University of Nevada.

Beside these few scattered geologic references, no other published work dealing with the geology of this region is known to the author.

Climate and Vegetation:

Climate in this region is semi-arid with hot, dry summers and cold winters. The annual rain fall generally does not exceed more than 5 inches. Much of the precipitation falls as snow during the winter and spring. The temperature varies greatly. During the month of July and August it often exceeds 100°F and during the winter it occasionally goes below zero.

In general, the vegetation is typical of the Great Basin and directly reflects the relief and resulting climatic variations. The entire mapped area is treeless except along certain marshes in the low lands. The characteristic sagebrush, bunch grass, and associated xeroplytic desert shrubs are common throughout the area.

Drainage and Topography:

There are no permanent streams within the area, although the Truckee River flows into the Pyramid Lake area about 2-1/2 miles south of the map area.

Several large lake basins (Playas) are also present. These basins contain water especially in spring time and are invariably dry during the summer.

The maximum relief is 2,700 feet, the highest point being 6,800 feet in the northeastern part of the area and the lowest being 3,970 feet in the Winnemucca Lake basin. The average relief of the area is approximately 2,000 feet.

ACKNOWLEDGEMENTS

The author is greatly indebted to Professor E. R. Larson who supervised the thesis and visited the area on several occasions. I wish to thank Dr. A. L. Payne of the Mining Department of the Mackay School of Mines and Mr. H. F. Bonham of the Nevada Bureau of Mines for their helpful suggestions.

I also wish to thank Coleen Hull for typing the thesis. Partial financial assistance for this thesis was awarded from the Mackay School of Mines Research fund.

Fig. 3. Photograph showing isloated hill of marble butte dolomite near the south end of Pyramid Lake. Photograph looking south.

Fig. 4. Photograph showing closer view of the metasedimentary rocks in Fig. 3 of Pyramid Lake. Photograph looking northeast.

LITHOLOGIC UNITS

Sedimentary Rocks

Upper Triassic - Lower Jurassic

Mesozoic rocks in the area studied are similar to Mesozoic sediments in the other portions of western Nevada, but they show distinctive and different lithologic characteristics.

Strongly deformed Mesozoic rocks ranging in age from Triassic to Early Jurassic are exposed at several localities in northwestern Nevada. These Mesozoic rocks have been divided into two different facies, the Winnemucca and the Augusta sequences, by Silberling and Roberts (1962, p. 19). Exposures of the Augusta sequence lie generally east of those of the Winnemucca sequence, but locally the two sequences have been brought together by thrust faulting.

The Mesozoic sediments exposed in the hills southeast of Winnemucca Lake are the oldest rocks exposed in the area of investigation.

Studies of joints and bedding allowed the establishment of the proper stratigraphic sequence. The sediments in the lower part of the section are mostly siltstone, silty shale, slate with interbedded quartzite and recrystallized limestone. Some of these fine-grained clastic, terrigeneous sediments have a large amount of calcareous cement indicating a generally shallow-water marine deposition.

In the middle part of the section, the sediments tend to become more calcareous with increase in the limestone content. All the calcareous sediments are metamorphosed by the igneous activities in the region and are found as recrystallized limestone or marble. Siltstone, slaty shale and quartzite beds are still abundant. Siltstone and shale tend to become more calcareous indicating that the shallow water conditions still prevailed in the area. Few of the quartzite units are prominent, but cover wide areas. Although only 10 to 20 feet in thickness, these are traceable for miles and are very helpful in measuring and detecting faults in the area.

In the upper part, calcareous sediments become predominant, and several thick (20-30 foot) units of marble and quartzite are interbedded with calcareous slate and siltstones. Shallow water conditions seem to have prevailed during the deposition of the Mesozoic sediments in the region.

The aggregate thickness of these sedimentary and metasedimentary rock units seem to be in excess of 10,000 feet at the Nightingale Mountains. The correct thickness of these sediments is extremely difficult to determine as the dip of the beds changes very rapidly and at numerous places small scale isoclinal foldings have caused doubling of the thickness of the sedimentary strata. This folding is more frequent near the granodiorite contact causing an increase in the thickness of the calcareous sediments, which in turn increased the area of mineralization.

Several other scattered isolated localities of Mesozoic sediments have been mapped in the area. One isolated hill of these sediments, mostly dolomite, is at the southern edge of Pyramid Lake. At places these sediments are more calcareous and show no significant magnesium carbonate in the differential thermal analysis. However, their original sedimentary characteristics have been obscured by severe metamorphism.

In the Truckee Range in the southeastern part of the area, these metasediments can be observed at several localities beneath volcanic rocks and lake sediments. These metasediments are dolomite, slaty shales, siltstones, mudstones and recrystallized limestone and quartzite units, like those in localities in the Nightingale Mountains with which they are correlated.

That all the sediments in the area have undergone some degree of metamorphism is clearly evident from petrographic examination of rock samples. Shaly rocks, where metamorphosed near an igneous body, grade into siliceous hornfels and, very rarely, mica schists. This metamorphism is shown by the minerals in the siliceous hornfels and mica schists. The metamorphic minerals are more common near the contact metamorphic zone where garnet, epidote, hornblende, scheelite and Powellite are present in the metasedimentary sequence. However, beyond the zone of intense metamorphism the shale and siltstone are slaty, and limestone and sandstone units have been crystallized. The metamorphic minerals mentioned above are probably formed largely from materials introduced by the solutions that caused the metamorphism.

At the intrusive contact with the granodiorite intrusion tactite has developed in the sediments. Tactite is the common name applied to the rocks containing tungsten deposits in this area. They may be defined as metamorphic rocks of complex mineralogy, formed by the contact metamorphism of limestone, dolomite, or other soluble rocks into which foreign matter from an intruding magma has been intruded by hot solutions or gases. It does not include the enclosing zone of Wollastonite, tremolite and calcite (Hess, 1919, p. 378).

The sequence of metamorphism is thought to be as follows:

1) formation of the marble zone; 2) formation of light silicate zone; 3) formation of the dark silicate zone. Kerr (1946, p. 55) has referred

to the first step as marmorization, to the second as initial replacement and to the third as advanced replacement. The advanced replacement or silicate zone is commonly referred to as tactite. Near the contact, calcareous sediments, besides being intruded by large granodioritic mass, have also been intruded by more or less flat lying aplite dikes, which cut both the granodiorite and sediments near the Nightingale Mine. These aplite dikes are also responsible for the tungsten mineralization in the area. Sandstone near the contact with the igneous bodies has been completely metamorphosed to quartzite and in thin section show crystallized quartz, hypersthene, magnetite and scheelite minerals.

Correlation of the Mesozoic Sediments.

The correlation of the Mesozoic rocks from one section to another in the northwestern Nevada is extremely difficult due to great diversity in their lithologies and general scarcity of the fossils. Silberling and Roberts (1962) attempted to correlate units from different areas, the result being the recognition of the Winnemucca and Augusta sequences. Correlation of the metasedimentary units at the Nightingale Range to these scattered localities is attempted here.

The Triassic rocks that typify the Winnemucca Sequence underlie parts of the Humboldt Range and the western parts of the Sonoma Range quadrangle where they crop out in northern Stillwater Range, East Range, Tobin Range, Sonoma Range, hills northwest of Winnemucca, and the Nightingale Mountains near the dry Winnemucca Lake. All these Triassic sediments are very diversified in lithology and except at a few places are generally unfossiliferous. At these localities the Winnemucca group is divisible into six formations in ascending order: The Prida, Natchez Pass, Grass Valley, Dunn Glen, Winnemucca and Raspberry formations. (Silberling and Roberts, 1962, p. 20.)

The Prida and Natchez Pass formations are largely carbonate sequences that thicken westward to a maximum of about 3,000 feet. The overlying sediments, for the most part, are fine grained terrigeneous clastic sediments indicating a shallow water deposition (Silberling and Roberts, 1962, p. 20). However, the sediments in the area of investigation at the lower part are mostly slate, siltstone and shale with recrystallized and lenticular limestone and become more calcareous in the upper part. These sediments are in general, lithologically identical to the Upper Triassic Grass Valley, Winnemucca and Raspberry formations. These localities which aggregate more than 8,000 feet in thickness are mainly shale, mudstone, sandstone, and siltstone, with little carbonate rocks. (Silberling and Roberts, 1962, p. 20.) Several attempts to collect fossils from the area of investigation were made. Only one fossil pelecypoda Monotis subcircularis (Gabbs) was found which was common in the Noric Stage of the Triassic System. This fossil and the similarity to the Winnemucca, Raspberry, and Grass Valley formations suggested a correlation of these units.

The base of the sediments near the Winnemucca Lake is not observed in this area. However, in the localities nearby where Koipato and Winnemucca sequences contact is exposed, it has been observed to be unconformable. The time represented by this unconformity represents most of the early and mid-Triassic time (Silberling and Roberts, 1962, p. 20). Extensive erosion was prevalent during that period and in the Tobin Range to the east, the entire Koipato was removed before deposition of the Winnemucca sequence.

A columnar section (Plate 2 in pocket) shows the relation of the sediments in the Nightingale and Truckee Ranges to several other localities. They clearly demonstrate a very diversified lithology and unique structural history. On the basis of its unique lithology these sediments at the Nightingale Mountains might be assigned a new formational name. However, no new name has been applied to these sedimentary units because of their limited areal extent.

These sediments are part of a very diversified Triassic and Early Jurassic Sea. The distribution of Triassic rocks in the general region indicate a southward to eastward transgression of the sea. The calcareous units of the lower Winnemucca sequence constantly thin northeast and eastward in the Humboldt, East Range, and Sonoma Range indicating a shoreline to the east and southeast. On the basis of some ammonites, brachiopods and pelecypods, the Grass Valley formation has been assigned a Late Triassic Age (Silberling and Roberts, 1962, p. 23). The metasediments at the Nightingale Mountains on the basis of lithologic similarity and Montis subcircularis (Gabbs) can be said to be of Late Triassic or Early Jurassic(?) age, and probably equivalent to the Grass Valley.

IGNEOUS ROCKS

Middle Jurassic - Middle Cretaceous

Most of the Nightingale and Truckee Range, except at places having metasediments, is underlain by intrusive gabbroic and granodioritic rocks of batholithic dimension, and some minor bodies of diorite, and a few dikes of aplites in the tungsten mineralized area. The northern part of the map region is predominantly granodioritic while the extensive volcanic and gabbroic plutonic rocks cover the southern and the central part of the map region.

Middle Jurassic - Early Cretaceous

Gabbroic Rocks

In the south central and central part of the map region, several bodies of gabbroic rock types are recognized. The dark colored, medium to coarse grained rocks in thin section have predominantly labradorite 55-60%, Augite 20%, and biotite 5%. Accessory minerals are olivine, hornblende, hypersthene, and iron oxide. The majority of the gabbro bodies in the area have approximately the same mineralogical composition.

The contact of gabbroic rocks and the granodiorite is poorly exposed, but the field evidences suggest that the gabbroic rocks have been mapped in several other localities in northwestern Nevada. Speed and Page (1964) studied gabbroic rocks in West Humboldt, Stillwater and Clan Alpine Ranges and a Potassium-Argon date on primary biotite suggested an age of $(150 \pm 3) \times 10^6$ years. The gabbroic intrusion in the area is probably related to the same basic intrusive period. As these intrusives are older than the granodiorite the gabbroic intrusives are probably Mid-Jurassic to Early Cretaceous(?).

Middle Cretaceous

Granodiorite and related igneous rocks.

Although only a limited number of thin sections of the granodioritic batholith were studied, in general, these granodioritic rocks are light-colored, medium to coarse grained, and composed of about 60 to 65 percent plagioclase, 15-20 percent potash feldspar, 10-20 percent quartz and 5-10 percent mafic minerals. Major plagioclase on the basis of extinction angles seems to be andesine type, whereas the potash feldspar is mostly orthoclase with some microcline and perthite. Anhedral quartz crystals are common with oscillatory zoning indicating that it was formed in a silicate melt. This rock type has very little variation in the map area in texture and chemical composition. Chemical analyses of some granodioritic rock, from adjacent localities have been made by the United States Geological Survey (unpublished information) and are shown in Table 1. These granodioritic samples were collected from Shawave, Trinity, Granite, Antelope, and Selenite Ranges and the isotopic age determination indicates the probable age of these granodiorites of the order of 85-94±5 million years, or Mid-Cretaceous. The batholith in the area mapped is related to the same general granodioritic intrusion in these regions and is probably of the same age.

Besides granodiorite, some other igneous rocks of more or less similar lithology are found in scattered localities. Small outcrops of these rocks are found in Sections 29 and 34 of T. 25 N., R. 24 E. They are medium grained and with less potash feldspars. Plagioclase, mostly oligoclase and andesine constitute about 70 percent of the rock and quartz about 10 percent, potash feldspars 10 percent and mafic minerals, biotite, hornblende, magnetite and hematite the other 10 percent. Hence, this rock is

Table 1

		Shawave Rg.	Trinity Rg.	Trinity Rg.
		40°01'N-119°04'W	40°23'N-118°31'W	40°04'N-118°48'W
		T-944	T-946	T-961
K-Ar age	biotite	87.2± 2.6	93.7± 2.8	91.2± 2.7
"	hornblende	90.2± 9.0	89.6± 9.0	91.9± 9.2
Rapid Rock Analyses - U.S.G.S.	SiO_2	67.9	62.1	63.9
	Al_2O_3	16.2	17.5	17.8
	Fe_2O_3	1.2	17.	1.8
	FeO	1.5	3.0	2.1
	MgO	1.1	2.3	1.2
	CaO	3.5	5.4	4.6
	Na_2O	3.7	3.8	4.4
	K_2O	3.2	2.2	2.2
	H_2O^+	.78	.79	.88
	H_2O^-	.14	.12	.12
	TiO_2	.40	.65	.56
	P_2O_5	.12	.22	.21
	MnO	.08	.09	.08
	CO_2	.08	.09	.08
		100.	100.	100.

U.S.G.S. Unpublished information

Table 1 (contd)

Granite Rg.	Antelope Rg.	Selenite Rg.
40°43'N-119°20'W	40°48'N-118°27'W	40°26'N-119°16'W
T-975	T-1010	T-1047
91.2 ± 2.7	92.0 ± 2.8	91.3 ± 2.7
91.9 ± 9.2	95.2 ± 9.5	93.9 ± 9.4
67.8	63.0	
16.1	16.8	
1.6	1.8	Analyses not yet received.
1.8	2.7	
1.4	2.3	
3.5	5.2	
3.9	4.0	
2.6	2.3	
.49	.66	
.04	.15	
.48	.64	
.15	.20	
.07	.12	
.05	.05	
100.	100.	
Intrudes probable Late Paleozoic metasediments and volcanics.		

Fig. 5. Photograph showing dipping metasedimentary stratas in Secs. 21, and 22, T. 25 N., R. 24 E. Photograph looking northwest.

Fig. 6. Photograph showing Hartford Hill Formation rhyolite tuff exposed next to Canyon in Sec. 23, T. 25 N., R. 24 E.

classified as diorite, as the potash feldspars make up less than eight percent of the total feldspars.

Some aplite and pegmatite dikes can also be observed in the map area. These are more predominant near the Nightingale Mine where major tungsten mineralization has occured. These light colored rocks develop from the residual solutions of the magmas that produce the plutons they transect and hence are composed of minerals that crystallized last in the interstices of the parent bodies.

VOLCANIC ROCKS

Early Miocene

Hartford Hill Formation

The lowest volcanic rock sequence is exposed east of the Nache Peak near the Winnemucca Lake. This moderately thick sequence of welded ash flow tuffs, tuffaceous fluviolacustrine deposits and some minor flows are yellowish to cream colored and are resting unconformably on the Triassic metasediments. These rocks have been considerably deformed and pronounced jointing and faulting can be observed in these rocks. Prior to erosion, this rock unit must have covered a greater portion of the map area, but today it is limited only to several scattered hilltops and is preserved beneath the overlying Chloropagus Formation and the olivine bearing basalt at the Nache Peak. These ashflows and tuffaceous sediments show moderate stratification and bedding.

In thin sections, these rocks are seen to have fragments of quartz, potash feldspars, and iron minerals scattered in a principally silicic ground mass.

Occasionally, large fragments of pumice can also be observed in the Hartford Hill Formation. These pyroclastic rocks were deposited areally and in standing bodies of water.

This sequence of rhyolitic rocks is correlated with the Hartford Hill Formation of Miocene Age (Axelrod) on the basis of a very similar lithology and similar stratigraphic position.

Late Miocene-Pliocene

Chloropagus Formation

The second and lithologically more diversified sequence of volcanic rocks is lying disconformably over the rhyolitic tuffs and ashflows. This sequence of volcanic rock which is more than a thousand feet thick at the Nache Peak extends throughout the area east of Nixon, and in the central part of the map area, it consists of a series of flow breccias, welded tuff, some diatomite, tuffaceous sandstone and conglomerate intercalated with dacite and andesitic flows.

In the lower part of the section, these pyroclastic materials are more predominant and are interbedded with flows mostly of andesitic and dacitic nature. In thin section, these volcanic lava flows are fine-grained, with andesine and K-feldspars predominating the groundmass and crystals. In accessories the predominant minerals are Augite, biotite, hornblende, and iron oxide. Dacite flows have quartz, K-feldspars and plagioclase crystals scattered in the groundmass or cryptocrystalline matrix of K-feldspars and plagioclase.

Tuffs in this sequence vary in thickness from place to place. They are tuff breccia, tuff sandstone and tuff conglomerate and indicate deposition in the standing body of water. Tuff sandstone and conglomerate might have been deposited aerially on land, and later eroded and deposited in small water bodies occupying fault basins. Miocene or Early Middle Tertiary faulting in the region probably created several small standing bodies of water in the region in which these later pyroclastic materials were deposited. The thickness of these pyroclastic and andesitic flows is in excess of 1,000 feet near the Nache Peak region. However, west of the Nightingale Mine the thickness of the pyroclastic rocks is approximately 500 feet.

Pliocene - Pleistocene

Olivine basalt

In the upper part of this sequence near the Nache Peak and east of Nixon, thick series of basaltic lava flows can be observed. These fine grained, inequigranular, dark colored basalts have glassy to cryptocrystalline matrix, with fragments of plagioclase mostly labradorite being in excess of 60 percent, K-feldspars are less than 10 percent, olivine from 5 to 20 percent. Accessories constitute magnetite, hematite, hypersthene, biotite, augite, and hornblende. On the basis of the varied presence of olivine, this basalt is classified from olivine-bearing to olivine basalt. This olivine-bearing basalt is in excess of 500 feet in thickness at the Nache Peak region and east of Nixon.

These volcanic rocks have been correlated with the Chloropagus Formation on the basis of the general lithologic similarities and similar stratigraphic position. At its type section in the middle foot hills of the Hot Springs Mountains, the Chloropagus Formation of Pliocene to Pleistocene age consists of basalt, andesite, tuffaceous sandstone, shale, breccias, agglomerates (Axelrod, 1956). The section described here closely resembles the Chloropagus Formation in lithology and is correlated with it.

In brief, volcanic rocks of diverse lithology are abundant in the region. However, these volcanic rocks become more predominant in the southern part of the map region. These rocks are the result of volcanic activity that culminated in the Early Middle Tertiary and has continued up to the Pleistocene time with some brief intervals. These intervals are marked by disconformities in the volcanic sequence. Pyroclastic rocks in these sequences were deposited areally to subareally. Several small bodies of water probably existed in the region, largely the result of normal faulting and other structural disturbances which accompanied these volcanic eruptions.

QUATERNARY DEPOSITS

Several types of the quaternary deposits have been grouped into one single unit on the geologic map of the region. These quaternary sediments include eolian, lacustrine, playa, stream, talus and landslide deposits.

Eolian sand deposits are quite common near the Winnemucca Lake and several other small basins. Fluviolacustrine deposits are the most predominant type in these basins. Large Pleistocene lakes occupied all the basins in the map region. Well developed shorelines features of these lakes can be seen every where in the map area up to and below the elevation of approximately 4,400 feet. These shoreline lacustrine deposits consist predominantly of silts and clays, but locally sand and gravel deposits of the lake can also be seen. In the interior part of these basins these lake deposits become more clayey and silty.

During the pluvial pleistocene periods Lake Lahontan occupied all the basins in the map region and were all interconnected. Winnemucca Lake at its southern end was connected with Pyramid Lake. All the Pleistocene lakes dried up leaving a remnant in the form of the present day Pyramid Lake.

Although no geophysical work is available for the amount of the surficial deposits in the dry Winnemucca Lake, it is believed that these deposits will exceed more than 1,000 feet in thickness on the western side of the lake. This lake represents a tilted fault basin, the eastern side of the lake being unfaulted. Elsewhere, in smaller basins, the thickness of surficial deposits probably does not exceed 500 feet.

Small alluvial fans, talus, slope wash and landslide deposits can be seen at several places in the map region. These types of quaternary deposits are characteristic and represented everywhere in the western part of the State. They are indirectly related to the Basin and Range topography of the State.

STRUCTURE:

The area of investigation contains several sequences of complex folding and faulting. The earliest folding and faulting disturbances resulted in the deformation of the Mesozoic Sedimentary rocks. The strike of these beds is in general N. 30-45° W. and the dip between 75° E. - 75° W. However, at several places due to isoclinal and very tight folding, deviation from this prevailing attitude can be noticed. Folding in the Mesozoic sediments is very tight and on a very small scale at numerous places. It seems reasonable to relate the deformation of these sediments to the emplacement of intrusive bodies.

There are two main phases of igneous activity in the map region. First, the igneous activity related with gabbroic rock type which probably started in Mid-Jurassic period which caused general uplift, folding and faulting in the map area. Gabbroic igneous activity in several adjacent areas in northwestern Nevada is related to the Mesozoic thrust faulting and folding (Speed, 1964). The basic igneous activity on the basis of Potassium-Argon age dating near Lovelock seems to have occurred in Mid-Jurassic Early Cretaceous(?) period.

After the initial phase of basic igneous activity, the second and more pronounced phase of igneous activity marked by the intrusion of a batholith of granodiorite, caused very conspicuous folding, faulting and jointing in the area.

This granodioritic igneous activity seems to have taken place in Late Mesozoic period (Mid-Cretaceous) on the basis of Potassium-Argon age dating by U.S.Geological Survey (unpublished information). The tectonic deformation of these Mesozoic sediments is thus intimately related to this igneous intrusion and in my opinion is a combination of vertical uplift and compressional folding.

The relationship of structural deformation to this igneous activity becomes more and more evident at places where the granodioritic igneous bodies are exposed near the sediments. This close relationship of the folding to the granodioritic intrusion can be noted everywhere in the area where igneous bodies are exposed, or are very close beneath the surface. The folding ranges from asymmetrical to isoclinal, overturned. At some places drag folding is very pronounced. At several places near the fold axes a pronounced lineation is expressed by the elongation of the mineral grains in the direction of the fold axes. Boudinage has developed parallel to the direction of fold axes and indicates the direction of the tectonic transport. Overturned folds are quite conspicuous in the middle of the area. At several places the relationship of bedding to the cleavage was studied, which very clearly indicates the overturning of the beds.

Besides being very intensely folded, these Mesozoic sediments were also subjected to faulting at the time of plutonic activity. The contact of the granitic body and the sedimentary rock in the northern part seems to be of normal type without any faulting. However, the contact near the Nightingale Mine seems to be tectonic contact bounded by a high angle normal fault. The contact of sedimentary rocks with the granitic body abruptly becomes more vertical and the xenoliths which were so prevalent in the northern side disappear abruptly near the Nightingale Mine. The granodiorite intrusion (forming an excellent pediment surface in the central part of the area) has been pushed upward in relation to the sedimentary rocks. This fault probably is related to the granodioritic igneous activity in the region. Some isoclinal and drag folding near the Nightingale Mine are also evident and are probably associated with this fault.

Triassic sediments, besides being intensely folded and faulted, are also strongly jointed. The majority of the joints are in three main directions: 1) Parallel to the bedding; 2) Normal to both bedding and linear structures; 3) At an angle approximately 45° to the prevailing strike. Besides these three main joint systems, several (about three) other less important joint patterns intersect the rocks. These joints are the result of igneous and volcanic activities in the region.

The third period of deformation in the form of tilting and faulting culminated somewhere in the Middle Tertiary after the deposition of the Hartford Hill Formation, and subsequently tilting and faulting of the sedimentary and volcanic sediments. This volcanic activity was marked by the deposition of Hartford Hill Formation. These pyroclastic rocks which are mostly rhyolitic and tuffs are exposed in the hills on the western side of the Nache Peak. This period of deformation is inferred on the basis of more pronounced tilting and structural deformation in the Hartford Hill Formation than in the overlying Chloropagus Formation.

This deformation caused extensive tilting, jointing and normal faulting in the region. The structural basins thus formed in this area were the site of deposition of more than a thousand feet of tuffs, breccia, conglomerate, fluvo-lacustrine sediments and andesitic and dacitic lava flows, which are the Chloropagus Formation. This deposition took place some time during the Late Miocene and Early Pliocene.

The Chloropagus Formation is in direct contact with the Triassic-Jurassic metasediments near Nache Peak and the adjoining area. The Hartford Hill Formation is in an area near the southeastern edge of Winnemucca Lake where it is underlain by the metasediments. The contact between Hartford Hill and the Chloropagus Formation is a high angle fault.

This unusual occurrence can be explained by a reversal in the movement of the Chloropagus - Hartford Hill fault. The Hartford Hill formation is a downthrown block formed in Pre-Chloropagus time. After a period of erosion during Late Miocene the Hartford Hill eroded awayfrom the upthrown block and subsequently the Chloropagus Formation was deposited on the eroded surface. Later, due to change in the stress conditions movement on the fault was reversed and the western side or the fault with the Hartford Hill Formation moved up and subsequently the Chloropagus formation was eroded from the upthrown block bringing Hartford Hill Formation into contact with Chloropagus Formation. Fig. 7 is a generalized diagram showing the movement on Hartford Hill Chloropagus fault.

After the deposition of these fluvo-lacustrine sediments an unusually quiet period existed in this region; this is indicated by the presence of a slight unconformity between the conglomeratic fluvo-lacustrine deposits and the overlying olivine basalt. This erosional surface is, however, not very conspicuous and is overlain by a thick sequence of volcanic rocks at Nache Peak. The source for these volcanic rocks may have been somewhere close to the Nache Peak region. No age dating of these volcanic eruptions is known to the author but on the basis of petrologic similarity to the dated basaltic flows in the nearby areas described by MacJanet and Bonham, this activity must have commenced some time during the Upper Pliocene or Pleistocene times. This volcanic activity and subsequent faulting caused tilting of the entire rock units

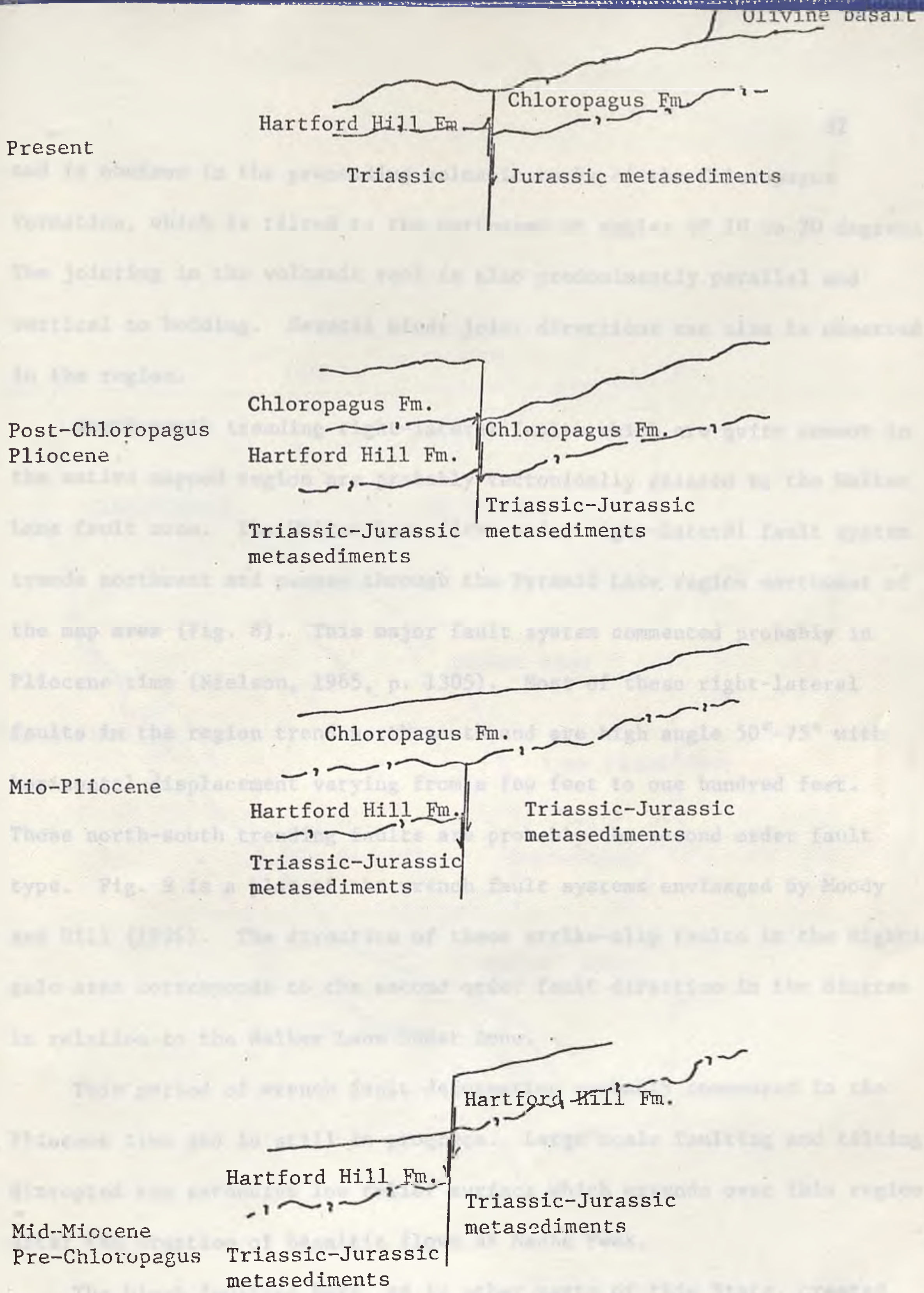

Fig. 7. Diagrammetic sketch showing the movement on the Hartford Hill - Chloropagus fault.

and is obvious in the preceeding volcanic rocks of the Chloropagus Formation, which is tilted to the northwest at angles of 10 to 20 degrees. The jointing in the volcanic rock is also predominantly parallel and vertical to bedding. Several minor joint directions can also be observed in the region.

North-south trending right-lateral faults which are quite common in the entire mapped region are probably tectonically related to the Walker Lane fault zone. The Walker Lane first-order right-lateral fault system trends northwest and passes through the Pyramid Lake region northwest of the map area (Fig. 8). This major fault system commenced probably in Pliocene time (Nielson, 1965, p. 1305). Most of these right-lateral faults in the region trend north-south and are high angle 50°-75° with horizontal displacement varying from a few feet to one hundred feet. These north-south trending faults are probably the second order fault type. Fig. 9 is a plan of the wrench fault systems envisaged by Moody and Hill (1956). The direction of these strike-slip faults in the Nightingale area corresponds to the second order fault direction in the diagram in relation to the Walker Lane Shear Zone.

This period of wrench fault deformation probably commenced in the Pliocene time and is still in progress. Large scale faulting and tilting disrupted the extensive low relief surface which extends over this region after the eruption of basaltic flows at Nache Peak.

The block faulting here, as in other parts of this State, created major boundary faults with rather large dip slip movements in other areas. The downthrown blocks are occupied mostly by valleys, and lakes like the Winnemucca and the Pyramid; the upthrown blocks are represented by high mountains.

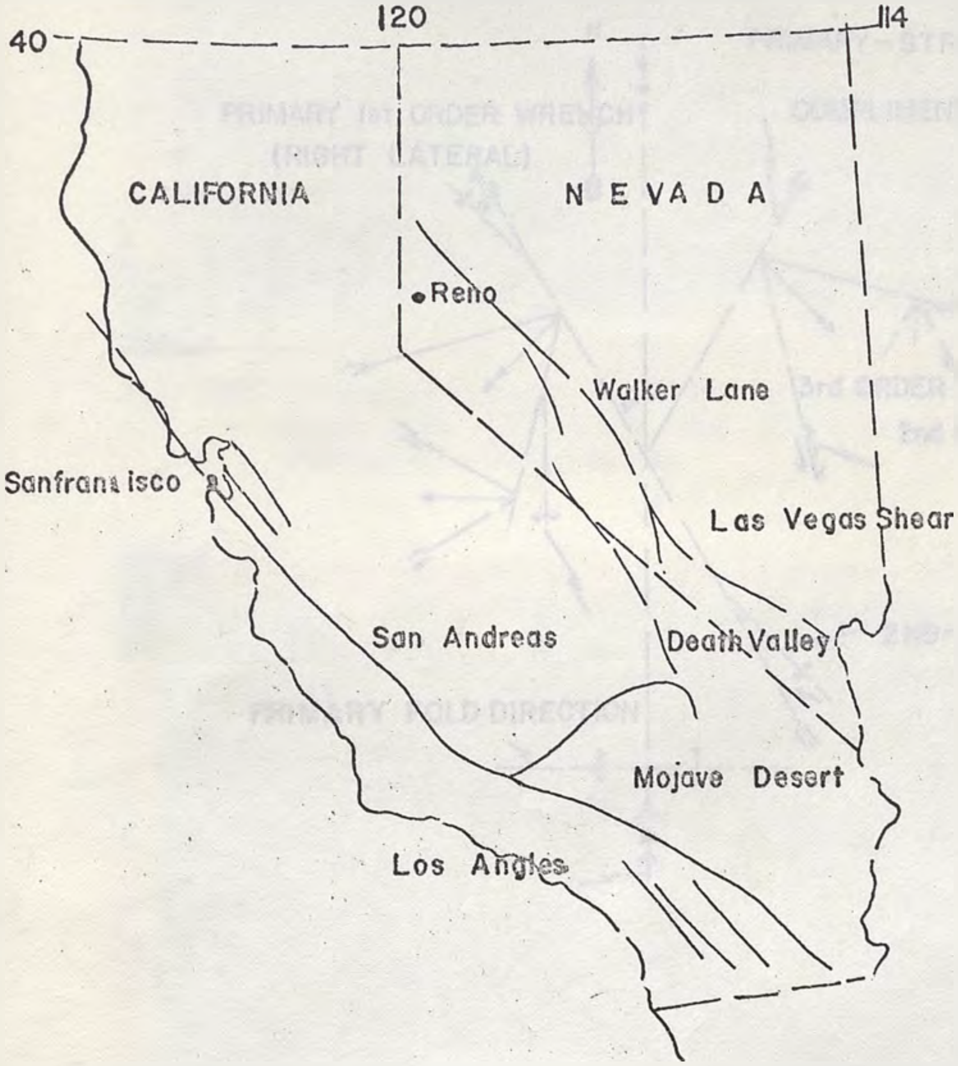

Fig. 8. Map showing location of major strike slip faults in California, and Nevada (Nielson, R.L., 1965, Geol. Soc. America Bull. v. 76, p. 1301-1308).

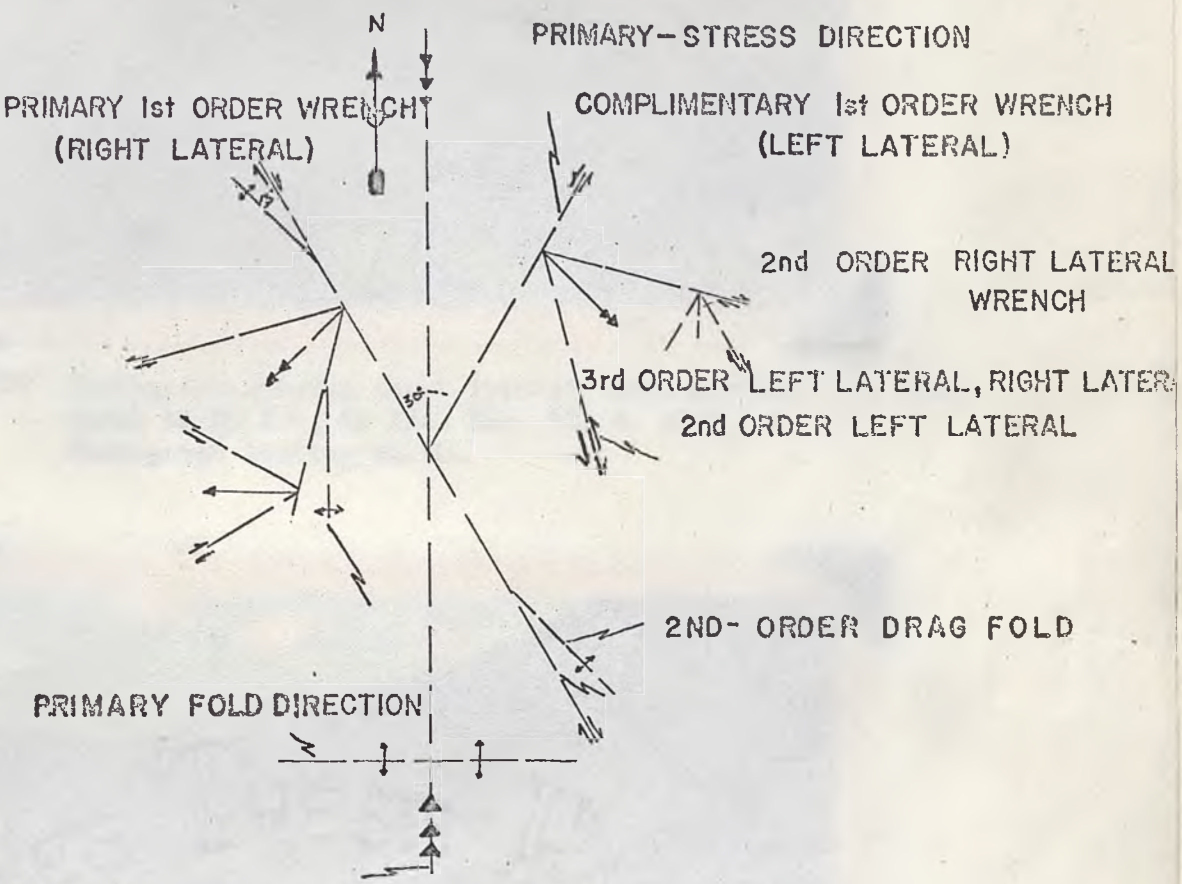

Fig. 9. Plan of Wrench System (world-wide system of strike slip faults) envisaged by J. D. Moody and M. J. Hill, 1956 (Bull. Geol. Soc. America, 67).

Fig. 10. Photograph showing right lateral fault movement and drag-folds in NW 1/4, SE 1/4, Sec. 22, T. 25 N., R. 24 E. Photograph looking north.

Fig. 11. Photograph showing right lateral strike slip movement in NW 1/4, SE 1/4, Sec. 22, T. 25 N., R. 24 E. Photograph looking north.

Thus, tectonically Cenozoic deformation is very important. In the area of investigation both the Cretaceous and the Cenozoic deformation are very conspicuous and their effects are pronounced. All the mineralization in the area is directly related to these orogenic movements and associated igneous activity. Present topography and internal drainage is the result of the Cenozoic movements creating north-south trending mountains and valleys throughout Nevada.

Fig. 12. Photograph showing plunging syncline in NW 1/4, SE 1/4 Sec. 21, T. 25 N., R. 24 E. Photograph looking northeast.

Fig. 13. Overturned isoclinal and drag folds 200 feet east of Fig. 12. Photograph looking northwest.

Fig. 14. Photograph showing the limestone and granodiorite contact near the Nightingale Mine near Nache Peak.

Fig. 15. Granodiorite and metasediments contact in the northern part of map region. Xenoliths of metasediments in granodiorite near the contact. Photo looking northwest.

Economic Geology:

Tungsten: Part of the area had rich tungsten deposits. During World War II, due to the high prices of tungsten, most of the minerals had been mined. There were three different localities where tungsten mineralization had taken place. The biggest one was near the Nightingale Mine in the middle of the map area, the second a small group at the northern end of the district, and a third, higher grade claim at the north eastern part of the map area. About 15,000 tons of tungsten ore have been mined from this area (Smith and Guild, 1942).

The main ore at these mines is granular, crystalline and layered tactite. Scheelite crystals as long as an inch have been observed in the area (Smith and Guild, 1942). The layering in tactite is probably reflective of the original bedding of the sediments.

The scheelite is abundant only in tactite, which is formed from limestone that has been altered at the granodiorite contact. However, some parts of the scheelite body is richer than others, perhaps because of structural features. Possibly some large structural feature, such as curves in the bed, or in contact, for example - permitted the mineralizing solutions to circulate with special freedom in some places and consequently content of WO_3 in the tactite bodies is from 0.50 to 11%.

In short, the origin of tungsten mineralization at the contact can be described as follows. The association of tungsten deposits with contact zones is the result of hot magma and emanating hot solution and gases given off from the magma and reacting with the carbonate host rock. Since tungsten minerals are noted to form at very high temperature and pressure, one can infer that mineralizing solution did not move very far from the source magma. Hence, the most favorable place for the tungsten mineralization is the contact zone itself which is nearer to the source magma. However, most tungsten mineralization is associated with carbonate deposits (Tingley, 1963). Thus, the presence of a suitable host rock such as limestone or dolomite also seems to be a controlling factor in affecting the mineralization. However, presence of suitable host rock and intruding magma do not assure tungsten mineralization as the structure of the beds plays a very important role in the tungsten mineralization. Most of the steep contact, vertical or near vertical, in the area, seems to have tungsten mineralization. The most probable explanation could be that vertical contact facilitated movement of hot mineralizing solutions and gases. Other local structural features which control the localization of tungsten deposits are listed as follows (Tingley, 1963):

1) Irregularities of the contact, particularly projections of limestone into the igneous body.

2) Areas where the contact forms an angle with the strike of the bedding of the intruded rock.

3) Folding or areas of dip change in the intruded rock.

4) Fracturing along the contact.

5) Presence of aplite dikes and/or quartz veins.

6) Pre-mineral faulting, producing areas accessible to mineralization.

The solutions that are an essential agent of the mineralization probably rose from a deeper source and their route was controlled by the structure of the rocks in the contact zone and their most intense mineralizing effects are localized in the chemically susceptible limestone, (Smith and Guild, 1942, p. 47). The tungsten introduced by these solutions was deposited almost entirely in the metamorphosed parts of the limestone, forming the ore bodies; in only a few places is there scheelite in the granodiorite and none was seen in the dikes.

Geologic History of the Area:

The geologic history of this region and surrounding area of northwestern Nevada indicates a succession of very complex tectonic and depositional history.

The Antler Orogeny in the Late Devonian-Early Mississippian periods brought to an end the Cordilleran geosyncline in Nevada as it has existed during early Paleozoic time (Roberts and Silberline, 1962). The deposition within this belt during the remainder of the Paleozoic time was in relatively shallow marine embayment. However, west of this belt, in northwestern Nevada and California, eugeosynclinal sedimentation presisted until it was abruptly terminated in mid or late Permian time by the Sonoma Orogeny.

From late Permian until Jurassic time the area affected by these earlier orogenic movements were relatively free of any strong crustal deformation and a nearly continuous succession of generally marine, shallow water and volcanic sediments were deposited. Thus, following the Sonoma Orogeny in this region and western Nevada, volcanism was resumed, and persisted until Mid-Triassic time. This resulted in the deposition of the Koipato sequence over the folded and thrusted Havallah sequence and the deposition of the Diablo sequence over the Antler Orogenic belt further south. Emergence and nondeposition followed, after which the Triassic seas advanced eastward and southeastward across western Nevada. However, due to local disturbances throughout middle and late Triassic time and probably early Jurassic time the Antler Orogenic belt was a local source of clastic sediments both east and west of this belt. These Mesozoic deposits are generally fine-grained terrigeneous sediments deposited in the shelf region of the Lower and Middle Mesozoic Seas in the western Nevada. From the fine-grained clastic and non-clastic limestone and dolomite found in the area studied, it can be inferred that they were also deposited in shallow marine seas on the shelf region of an early Mesozoic geosyncline. This shallow sea at that time extended in most of the western Nevada and California (Silberling and Roberts, 1962). However, the beginning of the Jurassic Period grought a regression of this Mesozoic sea from western Nevada. This view was advocated by Silberling and Roberts (1962). The middle and upper Triassic rocks of most of the western Nevada were deposited near the eastern margin of the sea which transgressed over this area from the west. This shallow sea at that time extended in most of the western Nevada and California.

During the later part of the Jurassic period these rocks were uplifted, folded, faulted during periods of two igneous activities, and subjected to subareal erosion in the area. The first igneous activity which started in Mid-Jurassic-Early Cretaceous(?) period caused general uplift, folding and faulting of the Mesozoic sediments and the second which culminated in Mid-Cretaceous in the form of a hugh batholith caused very tight folding and faulting. Field observations indicate a very close relationship to this tight folding and faulting with that of the granodioritic intrusion.

During the Early Tertiary time these metasedimentary and plutonic rocks were undergoing very active erosion. However, probably due to external drainage, which formerly existed in this region, none of these Early Tertiary sediments were being deposited locally.

During Early Miocene time sequences of volcanic rocks were deposited. This volcanic activity was accompanied by tilting and faulting in the area, which created local basins where pyroclastic rocks were accumulated.

After a brief interval volcanic activity commenced again in the region in the Late Miocene time and thick series of pyroclastic rocks were deposited.

The volcanic activity with a brief interruption continued until the later part of the Pliocene and Pleistocene which is indicated by thick series of basaltic flows at the Nache Peak and the adjoining area.

Shortly after the final eruption of volcanic activity or even contemporaneously with the final volcanism block faulting commenced in the entire Basin and Range Province which affected this region. This block faulting produced horsts, grabens, block mountains and basins. These normal faults thus are located at the Boundary between the mountains and the valleys in the map area. This block faulting brought very significant changes to the existing geomorphic phenomena. External drainage which existed during most of the Early and Middle Tertiary Period were destroyed and thick series of lacustrine sediments accumulated in the valleys. This phenomena is still in operation today. High mountains are being eroded away and the adjoining valleys are receiving large quantities of sediments because of the destruction of external drainage from the region. Right-lateral faults of the Walker Lane fault zone of second order relative to the Walker Lane Shear are seen in the area. This right-lateral slippage probably commenced in Pliocene time, and still is evident at certain areas nearby. During the Quaternary Period most of the valleys were occupied by lakes which covered extensively the State of Nevada. The shoreline of Lake Lahontan which occupied northwestern Nevada maintained an elevation of 4,400 feet in much of the region.

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