U. S. Geological Survey:

Report open file series.
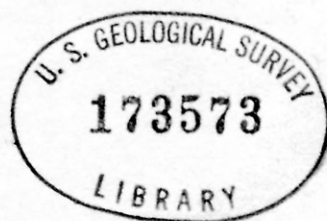
Weld – Int. 5278

UNITED STATES
DEPARTMENT OF THE INTERIOR
Geological Survey
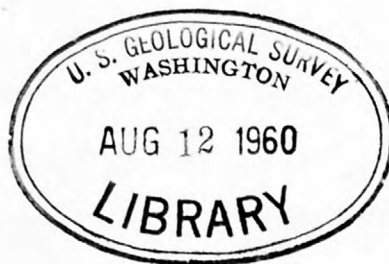Washington, D. C.

For Release AUGUST 11, 1960

GEOLOGIC REPORTS RELEASED FOR PUBLIC INSPECTION

The Geological Survey is releasing in open files the following reports. Copies are available for consultation in the Geological Survey library, 1033 GSA Bldg., Washington, D. C., and at other offices as listed:

1. Geologic map of the Lane Mountain quadrangle, California, by T. H. McCulloh. On file in the Geological Survey library, Bldg. 25, Federal Center, Denver, Colo.; 345 Middlefield Rd., Menlo Park, Calif.; 232 Appraisers Bldg., San Francisco, Calif.; 1031 Bartlett Bldg., Los Angeles, Calif.; 504 Federal Bldg., Salt Lake City, Utah.

2. Geology of the Jackson Mountains, Humboldt County, Nevada, by C. R. Willden. 120 p., 34 figs., 4 tables.

x x x

cm

U.S. Geological Survey

[Reports - Open file series]

Geology of the Jackson Mountains, Humboldt County, Nevada

by

Charles Ronald Willden, 1929-

CONTENTS

CONTENTS--Continued

CONTENTS--Continued

TABLES

ILLUSTRATIONS

ABSTRACT

The Jackson Mountains, a prominent range near the center of Humboldt County, Nevada, are of interest because the Cretaceous rocks in the range record the effects of a late Cretaceous to early Tertiary orogeny. Such an orogeny has been assumed to have effected all of the Great Basin, but the rock record is sufficiently complete to provide positive dating in only a few areas such as the Jackson Mountains.

The oldest rocks in the range are the Permian and older(?) volcanic rocks of the Happy Creek volcanic series which make up most of the northern half of the range. In a few places the Happy Creek volcanic series grades upward into undivided Permian and Triassic rocks, which consist of interbedded clastic sedimentary rocks and basic volcanic rocks, with some shaly and siliceous limestone. The Happy Creek volcanic series is also overlain by an unnamed predominantly limestone unit of Triassic age. A phyllite and slate unit of probable Triassic age is in fault contact with the Permian and Triassic undivided rocks. At several other localities the Happy Creek volcanic rocks are overlain by the early Cretaceous King Lear formation or by the Cretaceous or Tertiary Pansy Lee conglomerate, which are the two units of chief importance in dating the Cretaceous and early Tertiary orogenic events.

The King Lear formation consists of locally derived pebble and boulder conglomerate and interbedded siltstone and graywacke, and lenses of limestone.

The Pansy Lee conglomerate is a pebble conglomerate with considerable interbedded coarse-grained sandstone. The pebbles consist of chert and quartzite completely unlike rocks now exposed in the Jackson Mountains.

1

Dioritic rocks were intruded both before and after the King Lear formation was deposited. Granodioritic intrusive bodies in the range cut rocks no younger than Triassic but the granodiorite is believed to be of late Cretaceous or early Tertiary age.

Tertiary intrusive and extrusive volcanic rocks and sedimentary rocks are widely distributed along the east side and south end of the range.

The most extensive tectonic feature of the Jackson Mountains is the Deer Creek thrust, which is discontinuously exposed from Rattlesnake Canyon northeastward to the north side of Deer Creek Peak. The thrust has brought the Happy Creek volcanic series over the King Lear and Pansy Lee formations, and thus it is of late Cretaceous or early Tertiary age.

An earlier period of Cretaceous deformation is shown by a northeast-ward-plunging syncline in the King Lear formation on the southeast side of King Lear Peak.

Pre-Cretaceous deformation is shown by a tight fold in limestone of the undivided Permian and Triassic unit beneath the King Lear formation at the mouth of Rattlesnake Canyon.

The late Tertiary deformation was almost exclusively a response to vertically directed stresses, which generally produced high-angle faults rather than folds. The range has probably been uplifted principally by displacement on faults that are buried beneath the alluvium some distance to the east and west of the range.

Ore deposits in the range include some small but high-grade iron deposits, some low-grade quicksilver deposits and some small copper prospects.

The iron occurs in veins that cut the Happy Creek volcanic series or as replacement bodies near the contact between diorite and the Happy Creek volcanics. Bleached volcanic rocks that are cut by numerous closely spaced joints with a film of hematite in the volcanic rock on either side of the joints suggest that the iron of the iron deposits has been derived from the Happy Creek volcanic rocks. The diorite intrusives may have provided heat and solutions to mobilize the iron of the volcanic rocks.

INTRODUCTION

The Jackson Mountains in Humboldt County, Nevada are one of only
3 areas in Nevada where Cretaceous rocks are found to record the late
Mesozoic and early Tertiary orogenic history of the region. The area
is of great interest to the structural geologist for this reason.
The range also has considerable interest for the petrologist, because
the dioritic intrusive rocks may have been derived from or had their
composition controlled to some degree by the Permian or older volcanic
rocks, which are the predominant rock type of the range. Economically
the range is interesting because of important iron and quicksilver
deposits. In spite of its interesting geological problems, the area
remained virtually a terra incognita until the summer of 1956 when I
began to map the range as part of a cooperative reconnaissance mapping
project of Humboldt County between the U. S. Geological Survey and the
Nevada Bureau of Mines.

Location and accessibility

The Jackson Mountains lie between longitudes 118°15' W. and 118°45' W.
and extend about 7½ miles south of the 41st parallel and about 3 miles
north of 41°30' N. The location of the range with respect to other
geographic features in Humboldt County is shown in figure 1. This re-
port deals only with that part of the range north of the 41st parallel.

The region is sparsely populated. Settlements are limited to the
small village of Jungo at the southeast end of the range, the smaller
settlement of Sulphur southwest of the range, and a mining camp at the
Iron King mine in the north-central part of the range. There are several
ranches along the east side of the range, one at Quinn River Crossing
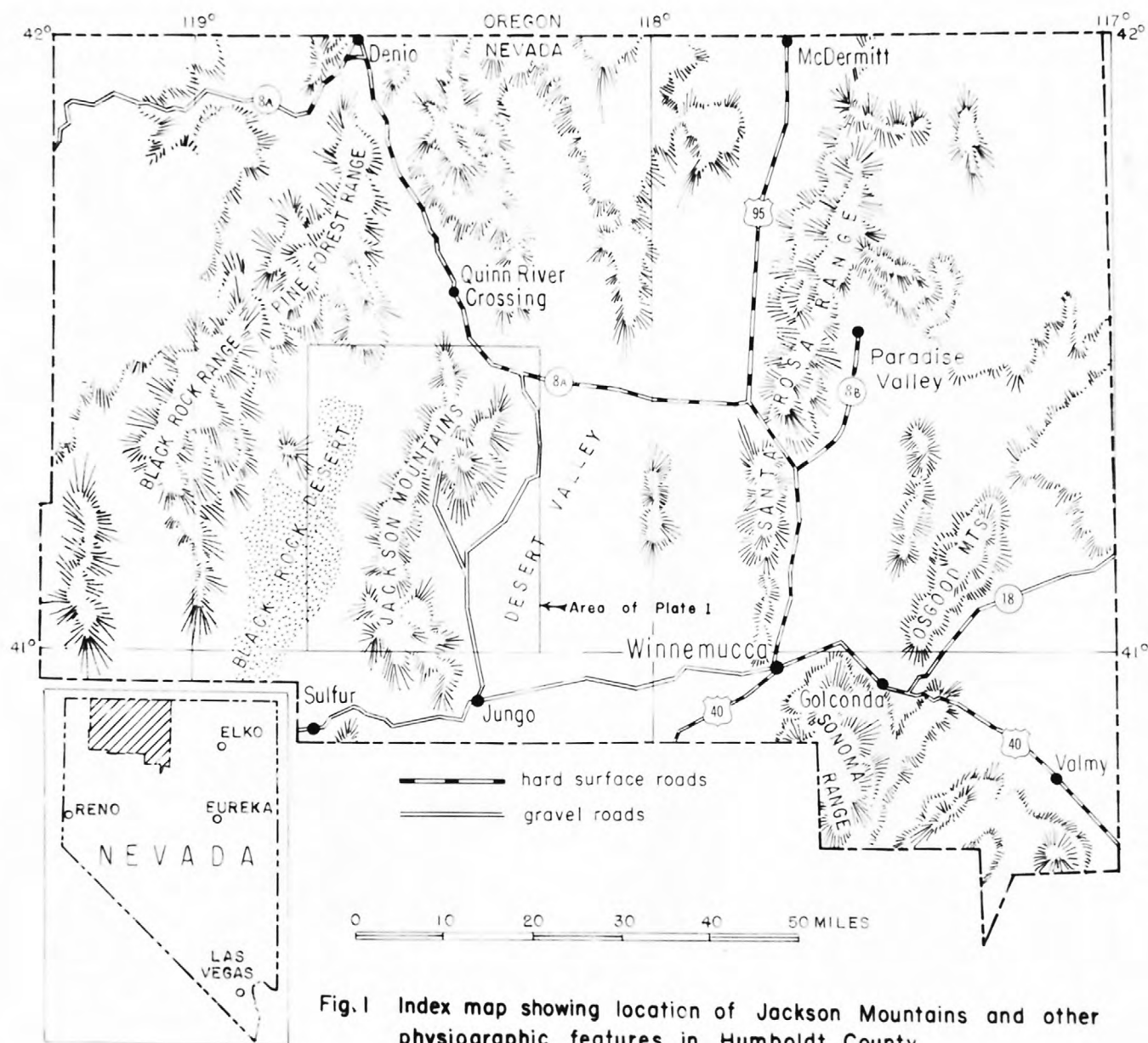
Fig. 1 Index map showing location of Jackson Mountains and other physiographic features in Humboldt County

about 2 miles north of the range, and 2 along the west side.

Jungo and Sulphur are on State Highway 49, a graded gravel road that extends eastward to Winnemucca a distance of 35 miles from Jungo. A graded gravel road, maintained by A. and B. Mining Company, connects the Iron King mine with Jungo, which is on the Western Pacific Railroad and is the shipping point for the iron mines in the range. Most of the ranches are connected by county-maintained gravel roads. Several of these gravel roads extend northward to State Highway 8A, a paved road, and these provide the best access to the range. Most of the interior of the range and the west side south of Jackson Creek are accessible by rather poor dirt roads.

Physical features

The Jackson Mountains are one of the prominent ranges of northwestern Nevada. King Lear Peak, which rises to 8,910 feet, is a conspicuous landmark visible for many miles. Much of the north part of the range is over 8,000 feet high and some summits rise to over 9,000 feet. Desert Valley on the east side of the range lies at 4,000 to 4,100 feet elevation and the Black Rock Desert on the west lies at about 4,000 feet. Low relief and subdued topography characterize the southern third of the range, whereas the northern two-thirds is characterized by rugged topography and high relief. Shore features of the Pleistocene Lake Lahontan, especially wave-cut terraces, spits, and bars, are abundant along both flanks of the range especially at the north end and surrounding the low detached hills on the southeast side of the range.

The high north part of the range is drained by 4 perennial streams: Trout Creek which flows south, Bottle Creek which flows east, Happy

6

Creek which flows north, and Jackson Creek which flows west. Inter-
mittent streams occupy most of the other large canyons. Springs are
numerous, a notable one being the excellent limestone spring at the
mouth of the unnamed canyon between Elbow and Alaska Canyons.

Vegetation consists mainly of sagebrush and other desert shrubs
but junipers are abundant throughout the range, cottonwood and aspen
grow in the canyon bottoms, and aspen are found in protected places
at higher elevations in the north part of the range. The several
ranches in the area graze cattle throughout the range.

Climate

The Jackson Mountains are in an area of semi-arid climate. Most
of the precipitation occurs from October to June with approximately
equal amounts each month. The summer months are dry with no precipita-
tion other than sporadic thunder showers. The winter temperatures are
mild except at the higher elevations, and the summer temperatures are
high but not unpleasantly hot except at low elevations in the valleys
on either side of the range.

There are no climatological stations in the range but the data
from 5 stations in the surrounding area are summarized in the accompanying
tables.

Table 1.--Average precipitation (in inches) at points near area

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Elev. in feet
Denio[1]	.64	2.06	.76	.47	.51	2.14	.18	.27	.02	.28	.90	.42	8.65	4,185
Kings River Valley[1]	.43	1.53	1.18	1.10	.10	2.85	.15	.32	Trace	.13	.19	.23	8.21	4,240
Leonard Creek Ranch[1]	.43	1.94	1.23	.84	.24	2.60	.08	.24	.12	.19	.11	.09	8.11	4,225
Orovada[2]	1.14	1.14	1.04	1.25	1.51	1.21	.26	.11	.40	1.05	.96	1.21	11.28	4,300
Winnemucca[3]	.96	1.01	.86	.83	.84	.79	.31	.18	.34	.79	.84	1.00	8.75	4,299

[1] Figures for 1958 only

[2] Long term mean for period 1931-1955

[3] Long term mean for period 1921-1950

8

Table 2.--Average temperatures for 1958 in degrees Fahrenheit at points near area

	Annual Average	Average Maximum	Month of Maximum	Average Minimum	Month of Minimum	Extreme Temp.	Maximum Month	Extreme Temp.	Minimum Month
Denio	50.2	71.2	August	32.6	January	103	July	-3	November
Kings River Valley	-----	73.4	do	31.1	do	101	August	-5	do
Leonard Creek Ranch	53.4	76.5	do	32.8	do	101	July	6	do
Orovada	-----	75.2	do	33.4	do	100	August	-----	-----
Winnemucca	49.8	72.7	do	31.6	do	100	August	2	November

Data from U. S. Weather Bureau, 1959, Climotological data, Nevada, annual summary 1958, v. 73, no. 13.

Field and laboratory work

This report is based on field work which commenced in May 1956 and continued intermittently through the summer totaling just over 2 months, 2 weeks in the spring of 1957, 2 weeks in the fall of 1957, and 1 week in the spring of 1958. My experience mapping the remainder of Humboldt County, which required an additional 10 months field work, was of immense value in identifying the rock units in the Jackson Mountains, and without this experience the mapping of the range would have required much more time. F. R. Shawe, during part of 1956, and D. H. Whitebread, in the spring of 1957, capably assisted with the mapping.

Army Map Service photographs at a scale of approximately 1:60,000 were used as a mapping base and the geology was later transferred, when base maps became available, to the Army Map Service multiplex compilation sheets at a scale of 1:62,250. This transfer, which required about a month, was accomplished largely by inspection but a Salzman projector was used for some of the alluvial contacts. The stratigraphic sections were measured by means of Brunton tape traverses.

The laboratory work occupied about 4 months time and consisted of petrographic study of thin-sections and stained rocks, microscopic and X-ray identification of minerals, and sample preparation.

Acknowledgments

I am indebted to numerous residents of the area and mine operators for helpful information and assistance. Among them C. J. Rowe, mine superintendent and W. G. Austin, President, both of A. and B. Mining Co., and Ray R. Whiting, Jr. of Humboldt Metals Co. deserve especial

thanks. W. J. O'Toole and H. V. W. Donohoo, the latter now with Texas Gulf Sulfur Co., contributed much helpful information through discussions.

I am deeply indebted to the staff of the School of Mineral Sciences at Stanford University for much helpful assistance in particular to K. B. Krauskopf, R. R. Compton, and G. A. Thompson for many stimulating and helpful discussions of numerous problems concerning geologic interpretations and report preparation.

My colleagues on the U. S. Geological Survey have also provided a great deal of assistance. D. R. Mabey has contributed much helpful gravity data. R. E. Wallace and N. J. Silberling visited me in the field and by their stimulating discussion contributed materially to my understanding of the geology of the area. H. T. Morris has critically read the manuscript and his helpful suggestions have greatly improved the report.

Previous work

The earliest reference to the geology of the Jackson Mountains is found in the reports of the Fortieth Parallel Survey, although the range was not referred to by name. King (1878, p. 565, 601, 648) described the volcanic rocks along the west side of the range north of the Kamma Mountains and Hague and Emmons (1877, p. 789-790) briefly described the geology of the southern part of the range. Russell was the next worker to mention the area in his monograph on Lake Lahontan. He described a fault along the west side of the Jackson Mountains and briefly mentioned the vegetation and physiography of the area (Russell, 1885, p. 27, 38). These references to the range are so brief and indefinite as to be of no real use in understanding the geology.

11

Useful statements about the geology of the range or parts of it did not appear until the U. S. Geological Survey began the examination of mining districts in the area. The first such examination was that of the Red Butte district, which is on the west side of the range about 7 miles north of the south boundary of the map, by Ransome in 1908. His report (1909, p. 27-30) gives a brief, but good, general account of the geology of the southwest part of the range. Roberts' report (1940) on the Bottle Creek quicksilver district gives an excellent description of the geology of an area in the northeast part of the range.

During the second World War the U. S. Geological Survey and the U. S. Bureau of Mines examined and sampled the quicksilver deposits in the Bottle Creek district as part of a statewide investigation of quicksilver deposits. The two publications resulting from this work (Bailey and Phoenix, 1944, p. 80-90; Benson, 1956, p. 19-24, 38-40, 42-49) contain much helpful information about the mines but say little about the geology of the range.

The iron deposits were similarly examined in 1954 by F. R. Shawe, R. G. Reeves, and V. E. Kral (in press) as a cooperative program of the U. S. Geological Survey and the Nevada Bureau of Mines.

The range and mining districts are also mentioned in publications by Hill (1912, p. 213-214), Schrader, Stone, and Sanford (1917, p. 190-199), Lincoln (1923, p. 98-99, 102), Vanderburg (1938, p. 17, 41-42), and Gianella (1941, p. 52, 57); but these are essentially catalogues of mining districts or mineral occurrences and provide little or no geologic information.

EXPLANATION

Quaternary

Tertiary and Quaternary

Tertiary intrusives

Mesozoic or early Tertiary intrusives

Mesozoic

Paleozoic

25   0   25   50 Miles

Modified from color proof of Tectonic
Map of the United States, 1960 edition
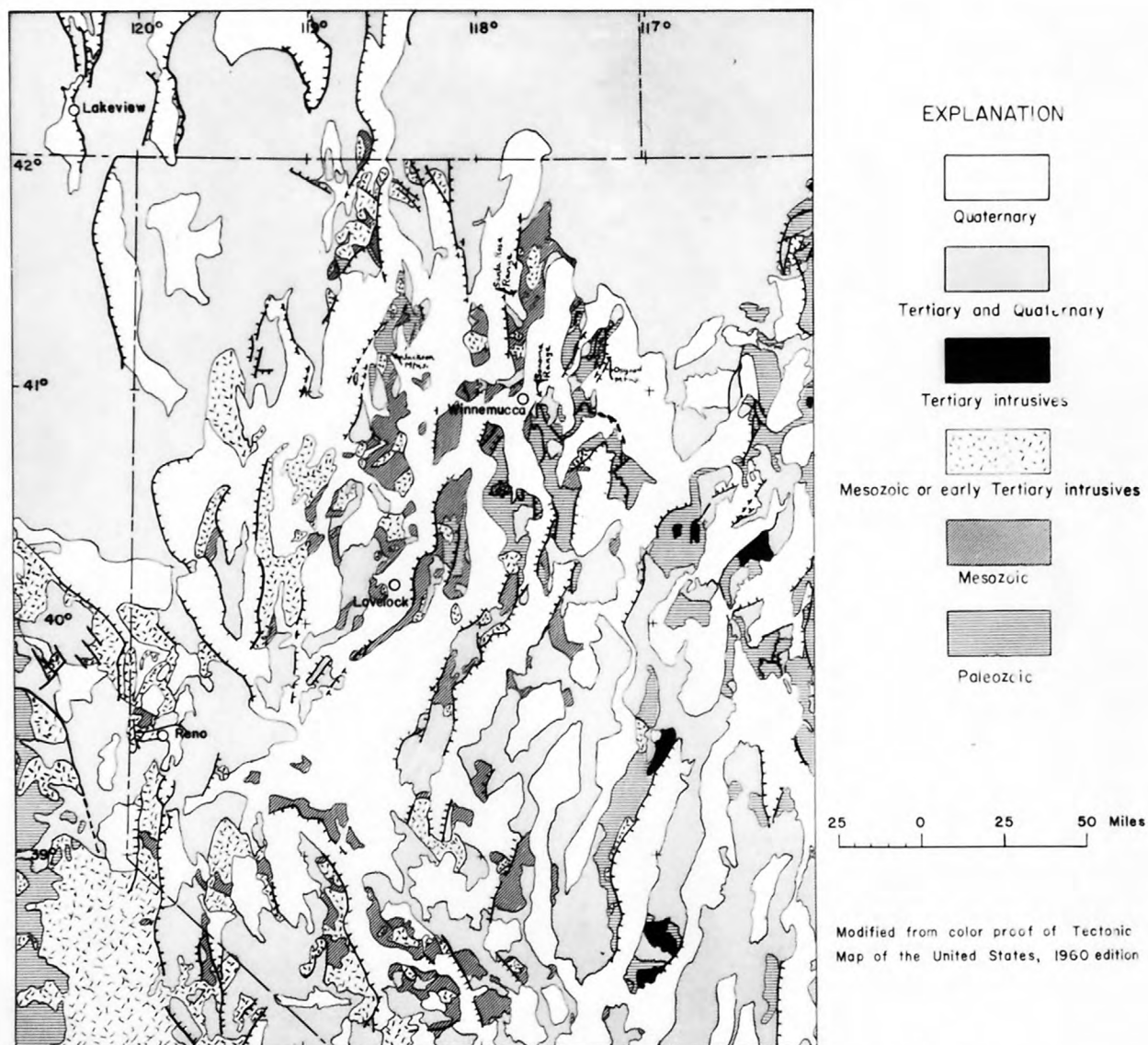
Fig. 2   General geology of northwestern Nevada and parts of adjacent states showing regional structural and stratigraphic setting of the Jackson Mountains

PERMIAN OR OLDER ROCKS

Happy Creek volcanic series

The Happy Creek volcanic series, named for exposures along Happy
Creek in the north part of the range, is the only unit assigned a
Permian or older age. The Happy Creek is by far the most extensive
unit in the range. It extends from one end of the range to the other
and has been recognized in the south end of the Kings River Range and
in the Pine Forest Range (Willden, 1960, shown as unnamed andesitic
and basaltic volcanic unit of Permian age).

The base of the Happy Creek volcanic series is not exposed and the
internal stratigraphy is poorly known. A tuff and breccia unit probably
in excess of 1,500 feet thick (see fig. 3) is present within the for-
mation along Happy Creek and on King Lear Peak. At both localities
the tuff and breccia unit is part of the upper plate of an extensive
thrust, so that its exact stratigraphic position is not known. Much
thinner tuff units are present elsewhere but they are not laterally
continuous and have not been useful in deciphering the stratigraphy
of the formation or the internal structure of the range.

The Happy Creek volcanic series grades upward into an unnamed
unit assigned a Permian and Triassic age. This gradation begins with
the appearance of pillow lavas, then shaly and cherty beds separating
volcanic units, which are usually pillow lavas but include fragmental
volcanics and non-fragmental flow units, and then graywacke, pebble
conglomerate, and limestone interbedded with flow units. The contact
on the map is somewhat arbitrary but is generally located on a coarse
graywacke composed of volcanic debris above which the section is

Figure 3.--Happy Creek volcanic series in the headwaters of Happy Creek.
Rocks in center foreground consist of interlayered tuffs, agglomerates,
and graywackes

1 inch
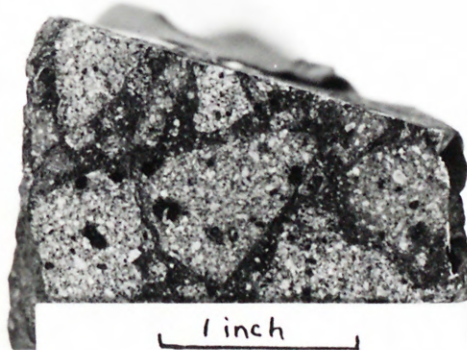
Figure 4.--Specimen of andesite flow-breccia from Happy Creek volcanic
series

predominantly non-volcanic clastic rocks. Fragmental volcanic rocks occur lower in the section and at some localities it is quite possible that the contact has been placed on a fragmental volcanic rock (breccia) rather than the graywacke.

The thickness of the formation is unknown because the base is not exposed and the internal stratigraphy is uncertain. A thickness on the order of 20,000 feet is not unreasonable, and is indeed required by the outcrop widths unless the formation is tightly folded or much repeated by faults, neither of which have been noted in the younger rocks.

The rocks of the Happy Creek volcanic series are preponderantly volcanic rocks but graywackes are found at places associated with tuffs. The rocks are principally of andesitic composition with basaltic rocks in a distant second place and trachytic to dacitic rocks of infrequent occurrence. Rhyolitic rocks have not been observed.

The andesites, which are commonly flow-breccias, are generally light-gray to dark reddish gray aphanitic to porphyritic rocks. The porphyritic rocks usually have an aphanitic matrix and small phenocrysts; the plagioclase phenocrysts are rarely longer than 2 mm and the mafic phenocrysts, which are either clear, nearly colorless augite or chlorite relicts of pyroxene, seldom exceed 5 mm in longest dimension. A typical andesite flow-breccia is shown in figure 4 and a thin section of a similar rock is shown in figure 5. The andesites contain from about 60 to 80 percent plagioclase, which is usually considerably altered to sericite and clay and, in some specimens, epidote and clino-zoisite, 10 to 20 percent pyroxene which is altered to chlorite in most specimens but is quite fresh in some, 5 to 10 percent black-opaque minerals, 5 to 20 percent microcryptocrystalline material between

17
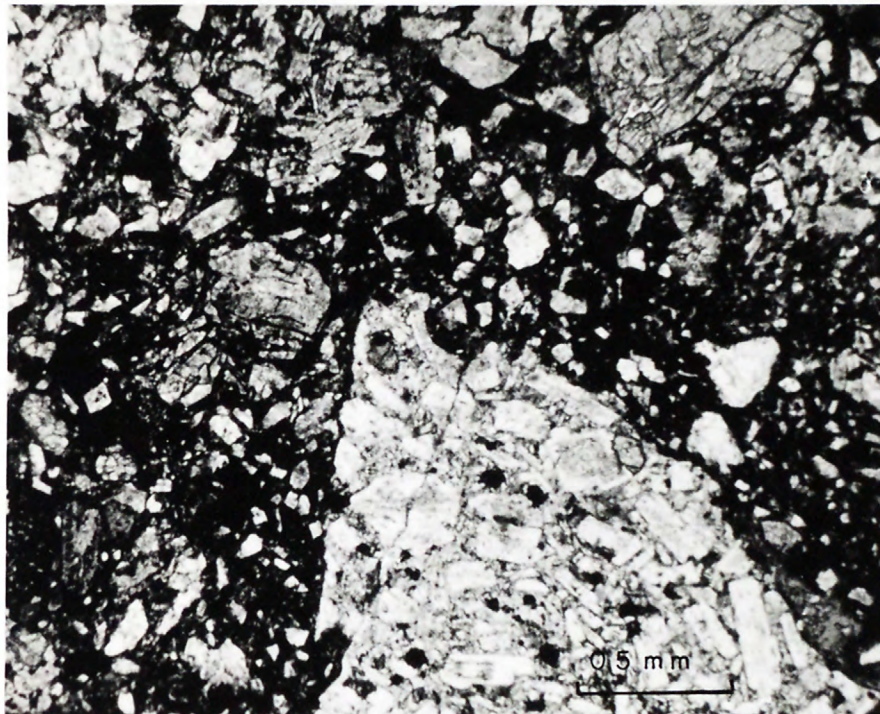
Figure 5.--Photomicrograph of flow-breccia of Happy Creek volcanic series

grains and in a few specimens about 5 percent brown-bordered olivine
grains[1].

The plagioclase is generally unzoned but some specimens show faint
zoning. The unzoned plagioclase is albitized and the zoned plagioclase
has an average composition from sodic andesine to sodic labradorite.
The albitization of the plagioclase and the clinozoisite, epidote, and
chlorite in these rocks are probably products of the low-grade regional
metamorphism that has effected most of the pre-Cretaceous rocks in nor-
thern Nevada. The metamorphic minerals in these rocks and the few speci-
mens of andesine and labradorite show that the Happy Creek volcanic
series was not originally a soda rich (spilitic) suite of rocks; however,
I have no specimens of the pillow lavas and these may be spilites.

The basalts are generally strongly altered but relict pyroxene
phenocrysts can be recognized in a chlorite and serpentine matrix. A
few specimens contain scattered plagioclase phenocrysts altered to
clinozoisite, calcite, and white mica.

The trachytes contain scattered plagioclase phenocrysts in a matrix
of crudely oriented lath-like sanidine grains. The plagioclase is gen-
erally so altered to clay and white mica that its composition can not
be determined and clay is extensively developed in the matrix.

Dacitic rocks have been recognized only as flow-breccias. These
rocks contain abundant plagioclase, minor quartz, and in some specimens
biotite in a microcryptocrystalline matrix. The plagioclase shows

---

[1] Where percentages for mineral constituents of a rock are not
given the most abundant mineral is listed first with the following
minerals in order of decreasing abundance.

19

faint zoning and is usually partially altered to clay; its composition
is usually near sodic andesine.

The Happy Creek volcanic rocks have been the host rock for at least
part of the iron deposits of the range. Figure 6 shows a breccia of
andesite cemented with hematitic chert that contains about 45 percent
iron.

The age of the Happy Creek volcanic series is not definitely known
because it lacks fossils, but it appears to grade upward into a unit
that contains Permian fossils. Thus it can be assigned a Permian or
older age.

The uncertain age of the formation makes correlation with rocks
in surrounding areas difficult. A possible correlative unit might be
the Koipato formation, which has long been supposed to be of Permian
age. The Koipato formation, however is dominantly of rhyolitic composi-
tion and recent work in the Humboldt Range has shown that at least the
upper part of the Koipato is of Triassic age (Roberts and others, 1958,
p. 2849; and Wallace and others, 1959). Another possible correlation
is with the basic volcanic rocks found in the Pablo formation in the
Toyabe Range (Ferguson and Cathcart, 1954), but this is a rather distant
area with few or no data in the intervening area to support such a cor-
relation. Perhaps the best correlation is with the basic volcanic for-
mation of Mississippian age in the Osgood Mountains named the Goughs
Canyon formation by P. E. Hotz and myself in a report in preparation.
It is unlikely that the Happy Creek volcanic series correlates with
any of the older Paleozoic basic volcanic rocks because the older vol-
canic rocks are associated with shale and chert both of which are lack-
ing in the Happy Creek.

20

Figure 6.--Breccia of andesite from the Happy Creek volcanic series with a hematitic jasper cement

21

PERMIAN AND TRIASSIC ROCKS UNDIVIDED

A single unnamed unit of probable Permian and Triassic age is present along the west side of the range at the south boundary of the map, through the central part of the range south of Post Creek, along the east front of the range from the south end of Trout Creek Spur to the northeast side of Buff Peak, and along the west front from just south of Jackson Creek to just east of Buckbrush Spring.

This unnamed unit overlies the Happy Creek volcanic series with a gradational contact. The rocks of the unit, which have all been metamorphosed, consisted originally of a lower part of interbedded graywacke, basic volcanic rocks, silty cherty shale, pebble conglomerate, and some silty and siliceous limestone, grading upward into an upper part of predominantly shale with thin chert, limestone, and dolomite beds (see fig. 7). Secondary cleavage has been formed in most of these rocks, the shale beds are phyllitic and in places schistose, the chert and limestone are recrystallized, and stretched pebbles in the conglomerates show the effect of dynamic metamorphism (see fig. 8a and fig. 8b). The upper predominantly shale unit just south of the area of plate 1 grades upward into a unit consisting of thick carbonate beds with interbedded phyllitic shale and considerable thin cherty beds. This carbonate unit is probably equivalent to the unnamed Triassic limestone shown on the west front of the range in the vicinity of McGill and Alaska Canyons.

The thickness of the Permian-Triassic unit is uncertain owing to possible structural complexities but an estimate on the order of 3,000 to 5,000 feet seems reasonable.

The Permian and Triassic age of the unit is based on 2 collections

Figure 7.--Outcrop of thin-bedded chert and phyllite of the undivided
Permian and Triassic unit exposed at the mouth of Bottle Creek

Figure 8a.—Stretched-pebble conglomerate from the lower part of the undivided Permian and Triassic unit at the south end of Trout Creek Spur showing pronounced elongation of pebbles. Scale is in inches
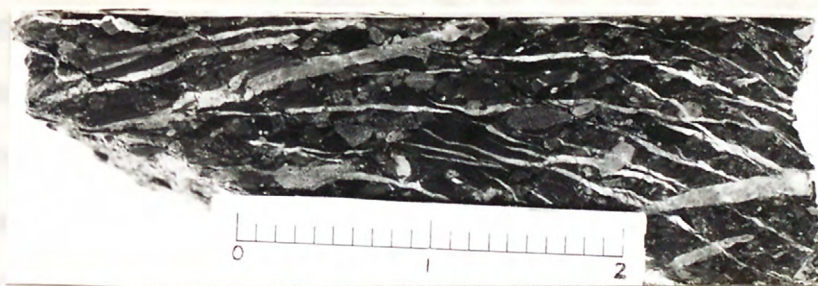
Figure 8b.—Stretched-pebble conglomerate showing flattening of pebbles. Scale is in inches

Fig. 9   Correlation of the Permian and Triassic rocks of the Jackson Mountains and nearby areas

rocks in nearby areas. These units are a predominantly limestone section exposed on the west side of the range and a metamorphosed fine-grained clastic unit, herein designated phyllite, exposed in the southeast part of the range. The two units are not in contact within the map area but from a study of somewhat similar rocks in the Pine Forest Range to the northwest it is reasonably sure that the limestone is the older of the two.

Unnamed limestone

The limestone unit is exposed on the west side of the range from just south of Elbow Canyon southward to about a mile and a half south of Alaska Canyon, and in a small area on the west side of the north end of the range. The limestone rests on the Happy Creek volcanic series at the north end of the range and south of Elbow Canyon, but in the vicinity of Alaska Canyon the limestone rests on the undivided Triassic and Permian rocks although this contact was not observed. No upper contact of the limestone is exposed in the Jackson Mountains but in the Pine Forest Range a similar limestone unit is overlain by a phyllite, slate, and fine-grained quartzite unit.

The maximum thickness of the limestone in the Jackson Mountains is between 1,000 to 1,500 feet. The thickness of the similar limestone in the Pine Forest Range is 1,700 feet.

The following four members can be recognized in the limestone unit at its exposure in the Jackson Mountains and are especially well-developed in the limestone unit in the Pine Forest Range: 1) a thin basal unit of dark-gray carbonaceous and sandy limestone, overlain by 2) a thick unit (about 500 feet) of calcareous siltstone, overlain by 3) a somewhat

27

thinner unit of buff to dark-gray crystalline limestone interbedded with black argillite, overlain by 4) a thick section of buff to gray crystalline limestone and limestone-pebble conglomerate with occasional shale and mudstone beds. Chert-pebble conglomerate occurs in the lower part of the section in the Pine Forest Range.

The section in the Pine Forest Range has also yielded one collection of poorly preserved fossils that N. J. Silberling has assigned an early Mesozoic age, possibly Late or late Middle Triassic (written communication, Dec. 1956).

Without precise dating and with only a general knowledge of the stratigraphy absolute correlations are not possible, but the limestone unit probably correlates best with the Natchez Pass formation exposed in the East range (Ferguson, Muller, and Roberts, 1951). The suggested correlations are shown on figure 9.

Unnamed phyllite

The unnamed phyllite unit is exposed in several small isolated areas in the southeast part of the range and on some low hills about 3 miles southeast of Roberts Ranch.

The unit consists mainly of light-gray to light greenish gray phyllite but also includes slate and fine-grained quartzite, and hornfels near the diorite intrusive on the low hills southeast of Roberts Ranch. Characteristically, the unit lacks coarse-grained rocks. The coarsest-grained rocks in it are fine- to medium-grained quartzites.

The unit has too restricted an occurrence within the map area to warrant an estimate of its thickness. The related exposures here are probably part of a much thicker section of fine-clastic sedimentary rocks exposed to the south and east.

Fossils have not been found in these rocks and their assignment to the Triassic is based on their lithologic similarities with Upper Triassic rocks exposed in the East Range to the southeast. In particular, they resemble the Raspberry formation which is the youngest recognized Triassic unit in the East Range (Ferguson, Muller, and Roberts, 1951). The most plausible correlation of these rocks with the sections in other areas is shown in figure 9.

JURASSIC ROCKS

Diorite

Three diorite bodies which have been assigned a Jurassic age are exposed at the north end of the range, along Bobs Canyon near the south end of Trout Creek Spur, and in the low hills about 3 miles southeast of Roberts Ranch. Two of these bodies intrude the Happy Creek volcanic series and one intrudes the Triassic phyllite. Other small diorite bodies intrude the Happy Creek volcanics northeast of De Long Peak and in the vicinity of the Iron King mine, but these have not been mapped. The large body at the north end of the range is overlain by basalt, the Bobs Canyon body is in fault contact with younger rocks and the southern body is overlain by Lake Lahontan sediments. Several other small masses of diorite, which have not been shown on the map, are present within the Happy Creek volcanic series in the north part of the range.

The contacts of these diorite bodies with the rocks they intrude have been studied in detail at only a few places, but at these places the diorite becomes progressively finer grained near the contacts. Where the intruded rock is andesitic material of the Happy Creek

volcanic series the contacts are generally indistinct, owing to the similarity of the chilled diorite and the andesite. In the low hills southeast of Roberts Ranch, where the intruded rock is phyllite, the diorite also is fine grained near contacts, but the contacts are sharp where they are exposed. A few dikes of diorite can be traced from the stocks into the country rock a short distance, but, in general, the dikes observed cutting the pre-Jurassic rocks could not be related to larger intrusive bodies. Inclusions of the intruded rock were not observed in the diorite bodies, but at one locality on the southern contact of the intrusive at the north end of the range blocks of volcanic material are partly surrounded by diorite. This relationship can be interpreted as an indication of piece-meal stoping, and with somewhat better exposures inclusions of volcanic rock might be found in the diorite.

The metamorphic effect of these diorite bodies on the rocks they intrude has been largely obscured by the later regional metamorphism. Rocks of the phyllite unit in the hills southeast of Roberts Ranch have been converted to hornfels along the contact with the diorite, but metamorphic effects in the volcanic rocks directly attributable to the diorites have not been identified.

These intrusive bodies are made up largely of diorite but locally the composition changes to syenodiorite, quartz diorite, and gabbro. These compositional variations seem to be internal features of the individual bodies rather than separate intrusions. The diorites contain from 60 to 80 percent plagioclase, 15 to 35 percent mafic minerals (probably nearly all pyroxene prior to metamorphism but now include considerable hornblende and chlorite, and some biotite), and 5 to 10

percent black opaque minerals. The syenodiorites contain 15 to 20 per-
cent potassium feldspar, 50 to 65 percent plagioclase, 10 to 30 percent
mafic minerals (which include either pyroxene and hornblende, or horn-
blende and biotite), and up to 5 percent black opaque minerals. The
gabbros are much like the diorites except that they contain 50 percent
or more dark minerals. A single specimen of quartz diorite contains
20 percent quartz, 72 percent plagioclase, 7 percent biotite, and 1
percent black opaque minerals.

The plagioclase grains in all these rocks now consist of twinned
albite or sodic oligoclase rims surrounding aggregates of sericite,
clay, and some epidote. Clinozoisite commonly occurs on the borders
of grains and in veinlets that cut the plagioclase. The pyroxenes are
commonly partially altered to chlorite or hornblende or in some speci-
mens to both (see fig. 10).

The clinozoisite associated with epidote, albite (and sodic oligo-
clase), sericite, and chlorite is characteristic of the greenschist
facies of metamorphism. This metamorphic assemblage in the diorites
and related rocks is the same as that developed in the Happy Creek
volcanics and is compatible with the metamorphic grade of the Triassic
rocks.

The rocks that are the principal basis for assigning these diorites
a Jurassic age have not been observed in place. They are known only
from boulders in the lower conglomerates of the King Lear formation.
In hand specimen they look much like the diorites described above but
in thin section they are quite different. They contain 60 to 80 percent
plagioclase An_{35-40}, 10 to 30 percent original mafic minerals, and
up to 5 percent black opaque minerals all of which are close to the

31

Figure 10.--Photomicrograph of Jurassic diorite showing replacement of pyroxene (px) by chlorite (ch) and development of hornblende (hb) crystals in chlorite
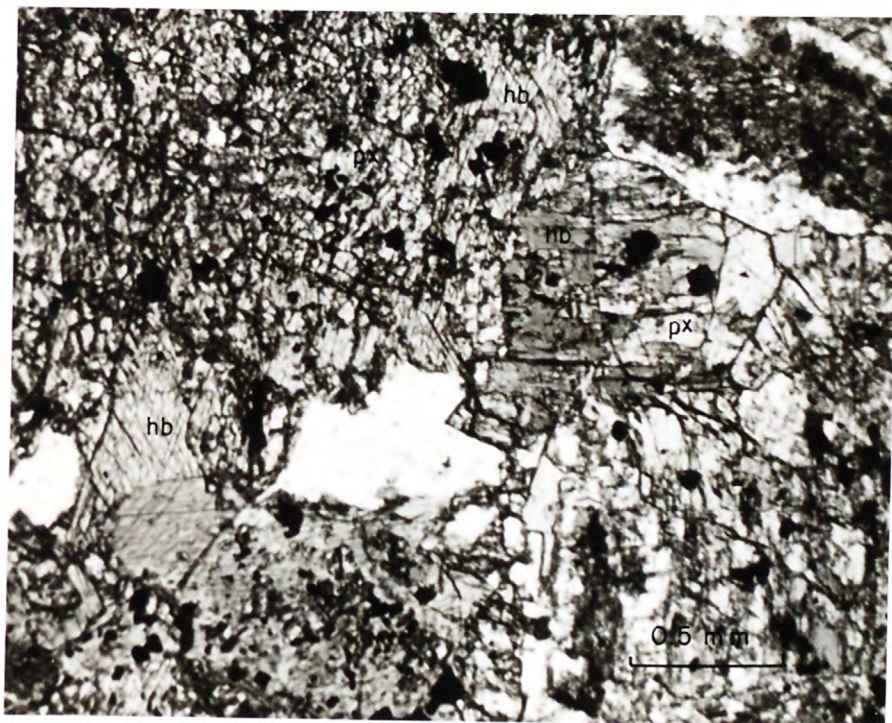
Figure 11.--Photomicrograph of Cretaceous diorite showing replacement of colorless pyroxene (px) by red-brown hornblende (hb)

percentages listed for the intrusive bodies, but they also contain a few percent of interstitial quartz and some zircon and sphene. The mafic minerals are nearly completely altered to chlorite and the chlorite is quite distinctive in that it is crowded with red iron oxide dust. This red oxide was probably produced as a surface weathering phenomenon from free magnetite produced along with chlorite during the alteration of the mafic minerals. The plagioclase in these rocks has not been albitized as has that in the intrusive diorites, although sericite and clay and occasionally some epidote have developed within plagioclase grain boundaries. The absence of clinozoisite and albitized plagioclase in these rocks suggests that they have not been subjected to the low grade regional metamorphism that has affected the intrusive diorites. The alteration exhibited by the diorite clasts in the King Lear may well be explained as a combination of deuteric alteration of the mafic minerals and perhaps of the plagioclase with later weathering to produce the clay, red iron oxide, and perhaps the sericite.

An age of 135 ± 15 million years for the diorite has been obtained by means of a lead-alpha age determination on zircon from diorite boulders in the basal King Lear formation. This one lead-alpha age, the absence of intrusive relations with post-Triassic rocks, the metamorphic minerals developed in the rocks (which are lacking in the diorites that cut the King Lear formation), and the fact that diorite boulders are abundant in the mainly locally-derived King Lear formation have been the basis for assigning these rocks a Jurassic age.

All of the pre-Cretaceous rocks in the Jackson Mountains contain mineral assemblages characteristic of the greenschist facies of regional metamorphism. The Happy Creek volcanic rocks and the Jurassic diorites contain albite or sodic oligoclase, chlorite, epidote, clinozoisite, and sericite. Original shales in the undivided Permian-Triassic unit and in the Triassic phyllite unit are now generally phyllites or phyllitic shales, and they contain chlorite and sericite as newly formed minerals and, in a few specimens, sodic plagioclase which may or may not represent albitized calcic material.

Metamorphic structures include cleavage that cuts the bedding of the fine clastic rocks at a small angle, bandinage structures, and flattened elongated pebbles in the pebble conglomerates (see figs. 8a and 8b). The bondinage structures have developed in what was probably originally an interbedded sequence of shale and fine-grained quartzite with some limestone beds. The quartzite and limestone beds have been pulled apart and ellipsoidal fragments of quartzite and limestone are now surrounded by phyllite. The fragments have been elongated parallel to the intersection of the cleavage and bedding. The flattening of the pebbles in the conglomerates has taken place in the plane of the cleavage and the pebbles are elongated parallel to the intersection of the cleavage and the bedding.

The Triassic rocks throughout central Humboldt County and as far east as the Santa Rosa Range exhibit the same metamorphic structures and contain the same metamorphic minerals of the greenschist facies as those in the Jackson Mountains (Compton, in press; Willden, in press).

The widespread Tertiary volcanic rocks west of the Jackson Mountains limit determination of the western extent of the regional metamorphism, but the Permian rocks at the south end of the Black Rock Range recently discovered by Gianella and Larson (in press) do not exhibit metamorphic structures, and the limestones in the section are not recrystallized although the volcanic rocks contain chlorite. The rocks in the Jackson Mountains and the region to the east of the range have probably been subjected to more intense metamorphism of regional extent than those in eastern Humboldt County or the area west of the Jackson Mountains.

CRETACEOUS ROCKS

Two units of Cretaceous age are shown on the map. These are the King Lear formation and the diorite known to intrude the King Lear. Other units of possible Cretaceous age but which will be described in the next section on Tertiary and Cretaceous rocks include the Pansy Lee conglomerate and a granodiorite intrusive.

King Lear formation

The King Lear formation, which consists of locally derived clastic rocks, including pebble to boulder conglomerate with interbedded silt-stone and graywacke and lenses of limestone, was named for exposures on the southeast side of King Lear Peak (Willden, 1958, p. 2382-2391). The following description has been taken from the paper cited above with only minor modifications.

The King Lear formation, in addition to its exposure on the south-east flank of King Lear Peak, is exposed west of the crest of the range in the vicinity of Deer Creek Peak, Parrot Peak, and DeLong Peak; near

35

the divide separating the Jackson Creek drainage area from the Trout
Creek drainage area; along the east front of Trout Creek Spur south
of Willow Creek; along the west front of the range northwest of the
abandoned town of Red Butte; on the south side of Rattlesnake Canyon
at the west front of the range; along the road to Navajo Peak just be-
low the peak; and on the low hills about 3 miles south-southeast of
Red Butte.

The formation is thickest at the exposure on the southeast side of
King Lear Peak but here a number of faults with small displacements
offset the beds and the section is therefore incomplete. The section
exposed along the road south of the DeLong mine is the only one that
has been measured. The best preserved fossils come from the section
exposed on Cedar Creek just east of Navajo Peak. At this locality
exposures are poor and the beds are broken by several faults of un-
certain displacement.

The King Lear formation rests on the Happy Creek volcanic series
at all localities where it is exposed except on the south side of
Rattlesnake Canyon where it rests on folded crystalline limestone of
the undivided Permian and Triassic unit. The limestone has been
folded into an almost isoclinal anticline with the axial plane
slightly overturned toward the west. Conglomerate and sandstone beds
of the King Lear formation, which unconformably overlie the limestone,
strike from N. 30° E. to N. 80° E. but dip fairly uniformly about
55° SE. At other localities where the King Lear formation overlies
the volcanic series the structure of the volcanic rocks is poorly known.

The King Lear formation is overlain by dacitic flow-breccias, rhyo-
lite, and tuffs along the ridge southwest of the divide between Jackson

36

Creek and Trout Creek. These volcanic rocks, which are assumed to be Tertiary in age, strike about N. 30° E., dip 10°-30° SE., and apparently are conformable with the underlying King Lear formation. The only other place where younger rocks overlie the King Lear formation is on the north side of Deer Creek Peak where the Pansy Lee conglomerate rests on it with no apparent angular unconformity. At this locality the King Lear formation is represented by about 150 feet of coarse pebble to cobble conglomerate composed of andesitic material, and exhibits a marked contrast with the overlying Pansy Lee conglomerate which is represented by 150 to 200 feet of pebble conglomerate and coarse sandstone composed entirely of quartzite and chert particles.

The section described in the following three paragraphs is a generalized section that applies to the outcrop areas west of DeLong Peak, on the south side of Jackson Creek, and on the southeast side of King Lear Peak. At the other localities the section is less complete.

The basal part of the King Lear formation is invariably a poorly sorted conglomerate, composed almost entirely of subrounded to rounded clasts of the subjacent rock type overlain by pebble to cobble conglomerate with some interbedded red siltstone (figs. 12-15). The conglomerates, with the exception of the basal bed at some localities, are typically bi-modal. This basal conglomerate unit is 200 to 300 feet thick and is overlain by 300 to 500 feet of dusky red and greenish-gray to brown siltstone interbedded with greenish-gray to brown sandstone and graywacke. Lenticular bodies of light- to dark-gray finely crystalline dense limestone occur locally in the basal conglomerate and the overlying siltstone-sandstone unit. This siltstone-sandstone unit is overlain by about 200 feet of pebble to cobble conglomerate

Figure 12.--Basal conglomerate of King Lear formation. Light clasts
are diorite, remainder of material has been derived from Happy
Creek volcanic series

Figure 13.--Typical outcrop of mudstones of King Lear formation

interbedded with sandstone, graywacke, and siltstone, which is in turn overlain by an upper unit of uncertain thickness consisting of inter-bedded siltstone, graywacke, and sandstone. Although the major units of the King Lear formation persist over considerable distances, many individual beds within the four units are lenticular, especially the limestone beds and the conglomerate beds, which in the lowest unit are abruptly lenticular.

The sandstone commonly contains subangular to rounded quartz, chert, feldspar, and volcanic rock fragments, with a small amount (5 to 10 percent) of finely divided matrix material and here and there some detrital hematite grains. The graywacke contains the same constituents as the sandstone but the grains are commonly more angular and the matrix material is much more abundant (15 to 50 percent of the total rock). The red color of some siltstone and a few sandstone beds is due to hematite in discrete grains and as a coating on the other detrital particles.

Some beds in the basal conglomerate exposed on the east side of Navajo Peak contain abundant clasts of hematite and some magnetite, and the lower conglomerates exposed on the southwest side of DeLong Peak contain a few scattered clasts of hematite and magnetite. These clasts indicate a period of iron mineralization prior to the deposition of the King Lear formation.

A section of the formation has been measured on the southwest side of DeLong Peak and is given in Appendix A.

The King Lear formation probably was deposited in a fluviatile environment that was intermittently the site of fresh-water lakes. The lenticular, bi-modal conglomerate beds containing subrounded to well rounded clasts are typical of channel deposits. The siltstone, sandstone,

40
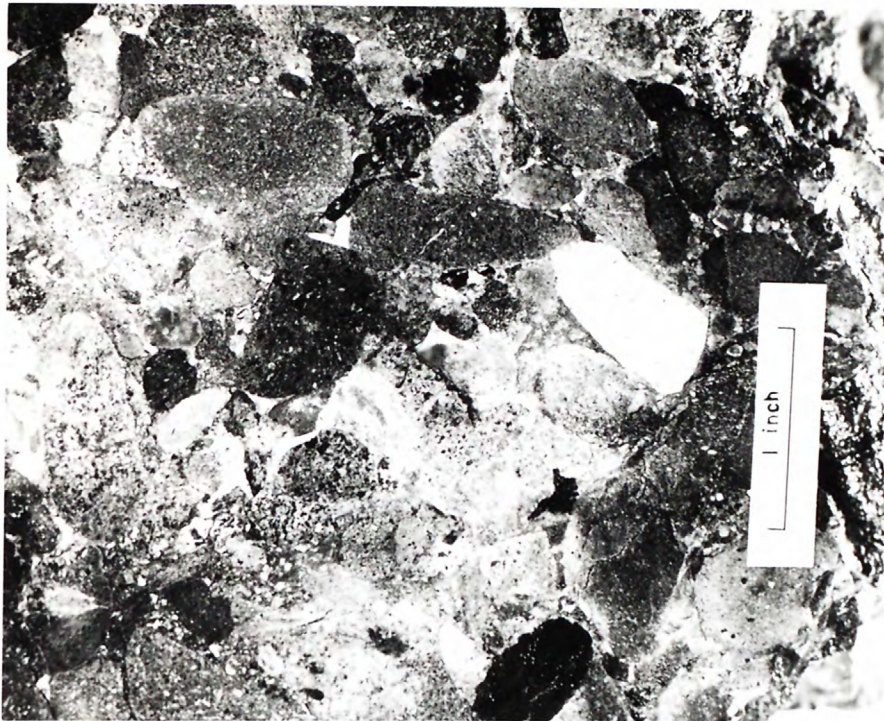
Figure 14.--Specimen of lower conglomerate of King Lear formation. Most of the clasts are volcanic rock

Figure 15.--Specimen of conglomerate near the top of the lower part of the King Lear formation. Clasts include andesite, diorite, silicified volcanic rock, quartzite, and chert. Large feature in right center is hole in rock

41

and graywacke units are probably flood-plain deposits in part deposited under oxidizing conditions as indicated by the red color of some beds, and in part under reducing conditions as indicated by the green and greenish-gray color of other beds. The limestone lenses containing the fresh-water fossils listed below were deposited in lakes.

J. B. Reeside, Jr., of the U. S. Geological Survey, has identified the following fossils collected from a limestone lens exposed along the Cedar Creek road, 6.6 miles west of the Jungo-Iron King mine road.

USGS Collection 25457

Musculiopsis russelli MacNeil

Mesoneritina sp.

Physa aff. P. prisca Walcott

Valvata? sp.

Lioplacodes? sp.

Reeside says of the collection:

"Though this collection lacks most of the species that at some localities mark the fauna, and though all of the gastropods were damaged in fossilization and are difficult to study, I consider the fauna Cretaceous and believe it to belong to the middle Lower Cretaceous fauna that has turned up at several places in Nevada and is widely known in the Kootenai and Cloverly formations of the Rocky Mountain region. The only description of it in Nevada was published by F. S. MacNeil (1939) for the Eureka area * * * . A much more remote possibility is the fauna and flora near the boundary between the Lower and Upper Cretaceous found by Longwell (1949, p. 931-933)

42

in the Overton fanglomerate of the Muddy Mountains near Las Vegas."

USGS Collection 26616 from about 3 miles south of Jackson Creek and 1½ miles west of the Jungo-Iron King mine road, in sec. 15, T. 39 N., R. 31 E. (projected), has been reported on by Mr. Reeside as follows:

"The only well-preserved fossils in this collection are the opercula of a viviparoid gastropod indistinguishable from those found at Eureka and called by MacNeil "Scales powelli (Walcott)" (Jour. Paleontology, v. 13, p. 355-360, 1939). A number of cross sections of gastropod shells show on surfaces but do not break out and are indeterminable. Some of the tiny blebs could represent oogonia of charophytes or ostracodes but do not show any diagnostic features. I would say the assemblage is definitely of fresh-water origin, and for the region, must represent the Lower Cretaceous fauna now known at several places beside Eureka."

A collection from about 0.6 mile northwest of the junction of the Jackson Creek-Iron King mine road, in sec. 35, T. 40 N., R. 31 E., has been reported on by Mr. Reeside as follows:

"This material * * * shows cross-sections of gastropods, probable fragments of pelecypods, ostracodes, algal masses resembling Stromatopora, and ramose bodies suggesting a charophyte alga. It resembles, in the types of organisms present, associations at other places that are of Cretaceous age. I am not able, however, to identify any of the fossils

43

closely enough to justify or to condemn such a judgment.

It has to remain a guess, but I would guess the Cre-
taceous assignment to be correct."

The Cretaceous fauna found in the Eureka area (MacNeil, 1939)
occurs in the Newark Canyon formation described by Nolan, Merriam, and
Williams (1956, p. 69) as consisting "of fresh-water limestone, con-
glomerates that contain both siliceous and limestone boulders, silts,
sandstones, and grits." As such it is lithologically similar to the
King Lear formation as well as being a faunal equivalent.

The Cretaceous fossils from the Muddy Mountains area were collect-
ed from rocks originally mapped as Overton fanglomerate but since re-
mapped and divided into two formations of Cretaceous age and the Overton
fanglomerate of Cretaceous or Cenozoic age (Longwell, 1949, p. 931-1933).
The two Cretaceous formations are the Willow Tank formation, consisting
of a basal conglomerate overlain by about 300 feet of fine-grained
deposits which contain the Cretaceous fossils, and the Baseline sandstone.

Diorite

Dioritic rocks intrude the King Lear formation on the east side of
Navajo Peak, west of the Red Butte mine, along Rattlesnake Canyon, and
along Shawnee Canyon. A dioritic intrusive body, exposed on the east
side of the range along Post Creek, is included in this map unit, al-
though it does not cut the Cretaceous rocks. Interpretation of an
aerial magnetic map of the range suggests that all of these bodies
connect at depth as three of them are shown to do on section cc',
plate 2.

The contacts of the Cretaceous diorite bodies are well exposed at

only a few localities east of Navajo Peak, west of Red Butte, and south
of Post Creek. The diorite generally is somewhat finer grained near
intrusive contacts. This reduction in grain size (chilling) was not
observed along the contact with the conglomerates of the King Lear
formation southeast of Navajo Peak. Here the diorite is uniformly
medium grained for several hundred feet from its contact. Dikes have
not been observed projecting into the country rock from these stocks,
excepting one large dike west of the Red Butte mine. Inclusions of
country rock have not been observed in the diorite but one large
block--believed to be a roof pendant--of conglomerate is enclosed in
the diorite south of the Cedar Creek road about one and a half miles
southeast of Navajo Peak.

The Cretaceous diorites have exerted only a minor metamorphic
effect on the rocks they intrude. Mudstones of the King Lear forma-
tion are more indurated near intrusive contacts than elsewhere but
they have not recrystallized. No metamorphic effects were noted in
the King Lear conglomerates or graywackes. Limestone lenses in the
undivided Permian-Triassic unit south of Post Creek are recrystallized
to medium- and coarse-grained calcite aggregates near the diorite,
and the phyllitic rocks in the unit have been converted to hornfels.
The volcanic rocks of the Happy Creek have not been obviously metamor-
phosed by the diorites.

The Cretaceous dioritic intrusive bodies have a mineral composition
much like the pre-metamorphic mineralogy of the Jurassic diorites. They
also exhibit a wide variation in composition, but it is quite different
from the variation shown by the Jurassic diorites. Gabbroic facies
are abundant in the Cretaceous dioritic intrusives and varieties close

45

to anorthosite are present. Rocks containing quartz and potassium feldspar are virtually absent. The rocks contain from 30 to 90 percent plagioclase, 10 to 65 percent mafic minerals (pyroxene in various stages of alteration to hornblende), and up to about 5 percent black opaque minerals.

In the gabbros and diorites the plagioclase is strongly zoned. The inner parts of the larger crystals are so completely altered to sericite and clay that the composition cannot be determined. The smaller crystals are generally fresher and show a composition range from about An_{25} on the rims to An_{55} in the centers. Some of the crystals show oscillatory extinction indicating reversals in the trend from calcic to sodic compositions outward. The pyroxene, which seems to be entirely augite, is nearly always partially altered to hornblende, producing a mottled appearance (see fig. 11). Chlorite is developed in some sections but is not abundant in any.

In the rocks close to anorthosite in composition the plagioclase is zoned, but not strongly so, with the composition ranging from oligoclase to sodic andesine. The cores of the plagioclase grains are generally somewhat altered to clay and sericite. Orthopyroxene (probably hypersthene) is the only mafic mineral. These high-plagioclase rocks also contain a small amount (about 1 or 2 percent) of potassium feldspar.

The general absence of definite metamorphic minerals in these rocks indicates they were intruded after the regional metamorphism. The non-metamorphosed King Lear formation, which they cut, also stands as evidence that the metamorphism took place prior to the intrusion of the Cretaceous diorites.

However, some specimens of rock collected from what were thought

to be Cretaceous diorites in the field contain sericitized, albitic plagioclase and a small amount of clinozoisite. Such samples may represent unrecognized pendants of Jurassic diorite or they may be small parts of the Cretaceous diorites subjected to metamorphic stresses sufficiently high to produce this alteration.

The Cretaceous age of these diorites is based on their crosscutting relation with the King Lear formation and the absence of crosscutting relations with the Pansy Lee conglomerate. Admittedly the Pansy Lee is not well dated but evidence to be discussed below indicates it is late Cretaceous or early Tertiary.

Apart from one small gabbro intrusive on the southeast side of Blue Mountain, all the quartz-free pre-Tertiary intrusive rocks in Humboldt County are in areas where the intermediate to basic volcanic rocks of the Happy Creek volcanic series and correlative units are widely exposed. The one area in the county where dioritic rocks are abundant, the Jackson Mountains, is also the one area where the Happy Creek volcanic series is by far the most abundant rock. The dioritic intrusive body in the Pine Forest Range cuts the Happy Creek volcanics and is in turn cut by granodiorite. The intrusive in the Pueblo Mountains shown with a granodiorite pattern on the map, is in reality a quartz diorite and intrudes a section of metamorphic rocks that include much chlorite schist. This section is probably the metamorphosed equivalent of the upper part of the Happy Creek volcanics and the lower part of the overlying undivided Permain and Triassic unit.

The apparent preference of the diorites for areas where the intermediate and basic volcanic rocks are exposed might be taken as evidence that the diorites have been formed from the volcanic rocks. Regional

47

stratigraphic relations indicate that the 20,000 feet or so of Permian
or older volcanic rocks of central and west-central Humboldt County
were buried by somewhere between 25,000 to 40,000 feet of Triassic
and possibly lower Jurassic sediments. It is conceivable that some
of the volcanic rocks were buried deeply enough to have been recrystal-
lized to rocks indistinguishable from diorite; some of the volcanic
material may even have melted and then been intruded into higher
parts of the section. It is much less conceivable however that
this process would have conveniently taken place sometime in the
Jurassic and then again in the Cretaceous to account for the two ages
of diorite in the range. It is particularly difficult to explain the
Cretaceous diorites by this mechanism because at the time, or only
shortly before, the Cretaceous diorites were intruded the Permian or
older volcanic rocks were exposed at the surface and undergoing erosion
to produce the King Lear formation.

CRETACEOUS OR TERTIARY ROCKS

The Pansy Lee conglomerate and the granodiorite intrusive body
have been assigned a Cretaceous or Tertiary age. The Pansy Lee is
assumed to be the older because it does not contain granodioritic
material, although the two units have no mutual contacts.

Pansy Lee conglomerate

The Pansy Lee conglomerate was named for exposures in sec. 1,
T. 36 N., R. 36 E., and sec. 6, T. 36 N., R. 37 E., just north of the
Pansy Lee mine on the north side of the low hills about 10 miles north-
west of Winnemucca (Willden, 1958, p. 2391-2394).

In the Jackson Mountains, the Pansy Lee is exposed on the north side of Deer Creek Peak, on the northeast flank of King Lear Peak and on the east side of the south end of Trout Creek Spur. The Pansy Lee rests on the King Lear formation on the north side of Deer Creek Peak; it rests on the Happy Creek volcanic series on the northeast flank of King Lear Peak, and on the undivided Permian and Triassic rocks at the south end of Trout Creek Spur. The King Lear formation is absent at the last two localities. At the type locality the Pansy Lee conglomerate rests with an angular unconformity on phyllitic shale correlated with the Raspberry formation of Late Triassic age (Ferguson, Muller, and Roberts, 1951). The top of the Pansy Lee conglomerate is not exposed in the Jackson Mountains, but at the type locality it is unconformably overlain by basalt flows and tuffaceous shale and sandstone that are thought to be late Tertiary in age.

The basal unit of the Pansy Lee conglomerate is a poorly sorted pebble to boulder conglomerate with about one-half to one-third locally derived material. At the type locality, the locally derived material consists of fine-grained feldspathic quartzite, slate, and shale derived from the underlying Raspberry formation. In the Jackson Mountains the locally derived material in the formation consists of andesitic to basaltic volcanic rocks, diorite, and sparse slate and feldspathic quartzite. The conglomerate becomes better sorted upward and the amount of locally derived material decreases to the point where it becomes difficult to find. Coarse-grained sandstone is interbedded with pebble conglomerate through most of the section.

The exotic chert and quartzite clasts are the most striking feature of the formation and they serve to differentiate it from all other

conglomerates in the stratigraphic column (fig. 16). The chert clasts
are light- to dark-gray, green, and a few are red or reddish brown.
The quartzite clasts are dark-gray to almost white, well sorted, fine-
to medium-grained, and clean. These exotic clasts look very much like
rocks of the Valmy formation of Ordovician age, the nearest exposure
of which is in the north end of the Sonoma Range east of Winnemucca,
and light- to dark-colored, well sorted, clean quartzite and dark
chert present in a unit mapped as the Leach formation in the East Range
(R. J. Roberts, personal communication). Either of these units may
have been the source of the Pansy Lee conglomerate.

A section of the formation exposed on the northeast side of King
Lear Peak has been measured and is given in Appendix B.

The only fossils thus far obtained from the formation are some
indeterminate root-like impressions, so that no precise age assignment
can be given. The formation certainly predates the upper Tertiary
volcanic rocks, which are thought to be no older than Miocene, and
postdates the Lower Cretaceous King Lear formation. The apparent
conformity between the King Lear formation and the Pansy Lee conglom-
erate in the northern part of the Jackson Mountains must be regarded
as coincidence because on the northeast slope of King Lear Peak the
Pansy Lee conglomerate rests directly on the Happy Creek volcanic
series with no intervening King Lear formation, and about 3 miles
farther south the King Lear formation attains its greatest thickness.
It seems unlikely that the King Lear formation could thin to zero
thickness in 3 miles when the formation is present over a 25-mile
length of the range. Also, the King Lear formation has been folded
into a tight slightly overturned syncline on the southeast side of
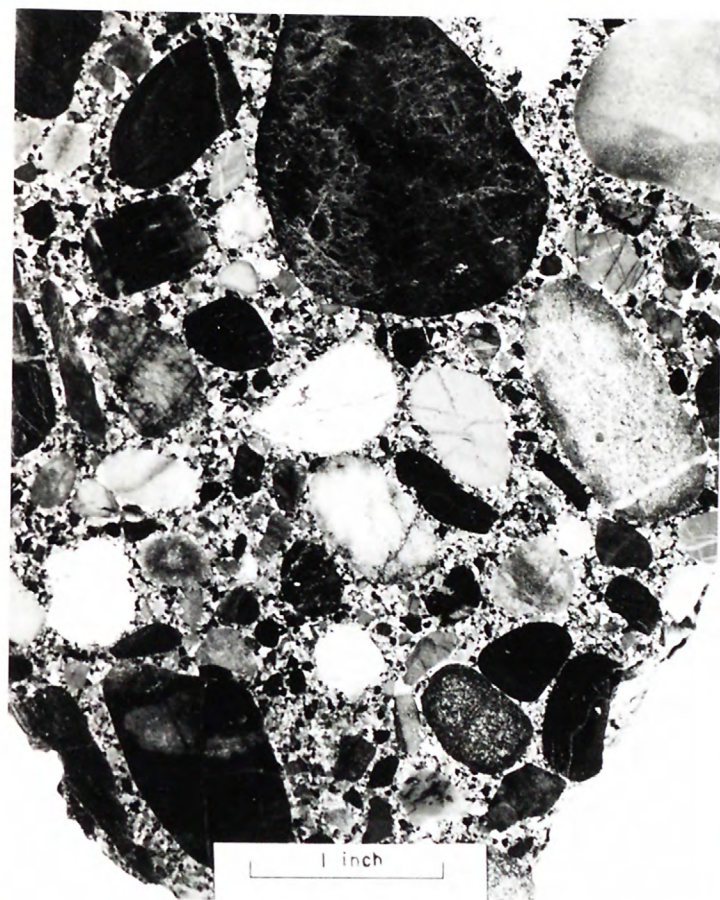
Figure 16.--Specimen of Pansy Lee conglomerate. Clasts are all quartzite
and chert except white clast in lower left part of picture which is
altered diorite

King Lear Peak, and the Pansy Lee conglomerate on the northeast side of the peak has a fairly uniform gentle eastward dip. It seems evident that the King Lear formation was folded and in places completely eroded before deposition of the Pansy Lee conglomerate.

A contemporaneous unit may be the "Paleozoic-pebble conglomerate" unconformably overlain by the Miocene to Pliocene volcanic and sedimentary rocks of eastern Nevada and western Utah reported on by Van Houten (1956, p. 2806-2808). He suggests the "Paleozoic-pebble conglomerate" and associated rocks may be correlated with the "Wasatch" conglomerate of Paleocene or early Eocene age of north-central Utah and points out (p. 2807) that Christiansen had previously suggested that similar rocks in eastern Nevada and western Utah may be the result of an Early Cretaceous orogeny.

Granodiorite

One fairly large granodiorite intrusive body is exposed on the west side of the range north of Jackson Creek. This body is about 3.5 miles long and 2.5 miles wide. It intrudes the Happy Creek volcanics and is not in contact with the younger rocks.

The contact of the granodiorite and the Happy Creek volcanic series was examined in detail at the north end of the stock northwest of Parrot Peak and at the south end in the area north of Jackson Creek. The southern end of the intrusive body is in fault contact with the Happy Creek volcanics. The fault is marked by a zone about 1 to 10 feet wide filled with crushed volcanic rocks and thin mylonite stringers. Granodiorite in the crushed zone forms sliver-like blocks, but is not intensely crushed. The amount of displacement on the fault is unknown but is

believed to be small, because granodiorite dikes from a few inches to several feet thick cut the volcanic rocks south of the fault. The granodiorite dikes south of the fault have fine grained margins, except the thinner dikes which are uniformly fine grained. The dikes contain inclusions of volcanic rock, but the granodiorite immediately north of the fault lacks inclusions; however, some large boulders of granodiorite in the canyon bottom near the fault contain abundant inclusions. Granodiorite dikes are less abundant at the north end of the stock, but the stock contains abundant inclusions at places.

The metamorphic effect of the granodiorite on the Happy Creek volcanics was much greater than that of the diorite intrusives. The volcanic rocks at some places adjacent to the granodiorite have been recrystallized to biotite-quartz-plagioclase schists, but generally the metamorphic recrystallization has been on a microscopic scale. Biotite is commonly developed near the contact and the plagioclase has been reconstituted to a more calcic variety than that in the non-contact metamorphosed Happy Creek volcanics. Epidote and clinozoisite all but disappear in the volcanic rocks although chlorite, which was originally much more abundant, remains in considerable abundance and, at places, epidote veins cut the rocks.

This granodiorite is highly varied in composition (see fig. 17). It contains from 5 to 30 percent quartz, 2 to 30 percent potassium feldspar, 35 to 55 percent plagioclase (oligoclase and sodic andesine), 5 to 35 percent mafic minerals (biotite, hornblende, and chlorite as an alteration product of both), and 1 to 5 percent black opaque minerals. Rocks in the interior of the stock, at the chilled margins of dikes, and in the narrow dikes have a high content of quartz and also contain large
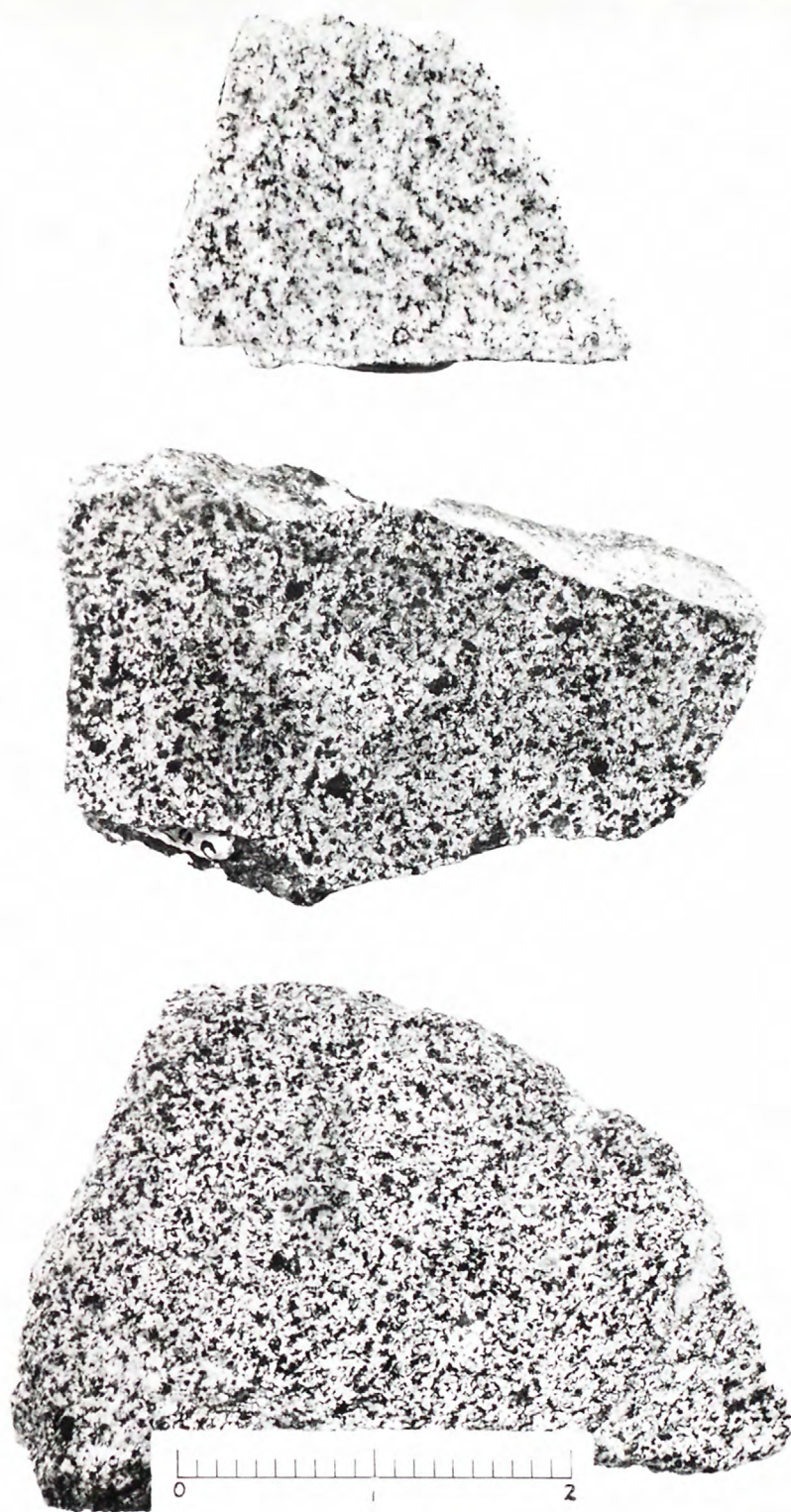
Figure 17.--Specimens of granodiorite showing considerable variation in mineralogy. Scale is in inches

amounts of potassium feldspar, and contain only small amounts of mafic material that is locally biotite but elsewhere includes some hornblende. Rocks from the central parts of wide dikes and in a border zone of the stock several hundred yards wide contain abundant plagioclase and hornblende and only small amounts of potassium feldspar. Inclusions are commonly surrounded by material containing only plagioclase, hornblende, and biotite. Plagioclase aggregates are abundant in the granodiorite where inclusions are abundant. Some inclusions have sharp borders but the borders of others are indistinct.

Biotite, part of which is partly chloritized, is the only mafic mineral in rocks with only 5 to about 10 percent mafic minerals. The increase in total mafic minerals beyond about 10 percent is accomplished by increase in the amount of hornblende. The hornblende is nearly always altered to some degree; some of it is completely converted to chlorite or to chlorite-magnetite aggregates, some has only the borders altered to chlorite, and some is merely mottled with non-pleochroic material that is otherwise apparently identical with the host hornblende.

The wide variation in composition of the granodiorite stock is probably due to reaction of the granodiorite with the intruded Happy Creek volcanic rock. Evidence for this is found in: 1) the distribution of plagioclase-hornblende-rich material in the border zone of the stock and quartz-potassium feldspar-rich material in the chilled margins and in the interior of the stock; 2) plagioclase-rich material surrounding inclusions and as segregations in inclusion-bearing granodiorite; and 3) the indistinct borders of some inclusions.

The age assignment of the granodiorite is a speculative matter. The granodiorite has not undergone the regional metamorphism that has

affected the diorites or the rocks they intrude, and granodiorite clasts are not found in the Cretaceous King Lear formation or the Pansy Lee conglomerate. The granodiorite is exposed within about half-a mile of the King Lear, and it is highly unlikely that granodioritic clasts would not have been contributed to the King Lear had the granodiorite been emplaced prior to the deposition of the King Lear. Thus a post-Early Cretaceous age for the granodiorite is fairly well established. The possibility of an early Tertiary age for the granodiorite is based on 5 lead-alpha age determinations on zircons from 5 granodiorite intrusives in eastern Humboldt County (H. W. Jaffe, written communication, Sept. 1956; T. W. Stern, written communication, Sept. 1959). These lead-alpha ages range from 35 ± 10 to 65 ± 10 million years.

TERTIARY ROCKS

Tertiary volcanic, intrusive, and sedimentary rocks are widespread in the Jackson Mountains. These Tertiary rocks have been divided into a total of eight map units that include 2 intrusive units, 2 sedimentary units, and 4 volcanic units. The intrusive units are a dacite porphyry and a felsite of dacitic composition which is shown on the map as a microdacite. Diabase dikes occur in the Bottle Creek quicksilver district in the northeast part of the range (Roberts, 1940), but they have not been shown on the map. The sedimentary units are a silicified pebble conglomerate and a unit consisting of shale, water-laid tuff, shaly sandstone, and diatomaceous shale. The volcanic units include a predominantly dacite series of flows and some tuffs, rhyolite tuff, basalt flows, and rhyolite flows.

The correlation of the various Tertiary units in the Jackson

Mountains with other sections in Humboldt County is shown on figure 18.

Dacite porphyry

Two intrusive bodies of dacite porphyry have been mapped. One small body intrudes the King Lear formation just south of Jackson Creek in the central part of the range. A larger body, to the southwest, cuts the King Lear, the Happy Creek, and the Pansy Lee formations. The large dacite porphyry intrusive is overlain by flows and tuffs of mainly dacitic composition that have been assigned to the oldest Tertiary extrusive unit in the range.

The dacite porphyry contains about 40 percent phenocrysts whose length ranges from about 1 mm to 1 cm and 60 percent matrix material (see fig. 19). The phenocrysts are plagioclase, quartz, and chlorite-hematite relicts of amphibole. Under the microscope the rock can be seen to contain about 60 percent plagioclase (sodic andesine), 5 percent quartz, 10 percent relict amphibole, and about 25 percent finely divided low-birefringent matrix material. The plagioclase shows a nearly complete gradation in grain size from 0.05 mm to 1 cm in length. The larger phenocrysts have a narrow rim with lower extinction angle than the inner part of the crystal, but most of the phenocrysts are unzoned. The larger crystals also show alteration of their inner parts to clay. The quartz phenocrysts are embayed and rounded, a feature lacking in the other crystals.

The dacite porphyry has been assigned a Tertiary age because it intrudes the Pansy Lee conglomerate, and because dacitic rocks are abundant in the Tertiary section in most of Humboldt County (Willden,
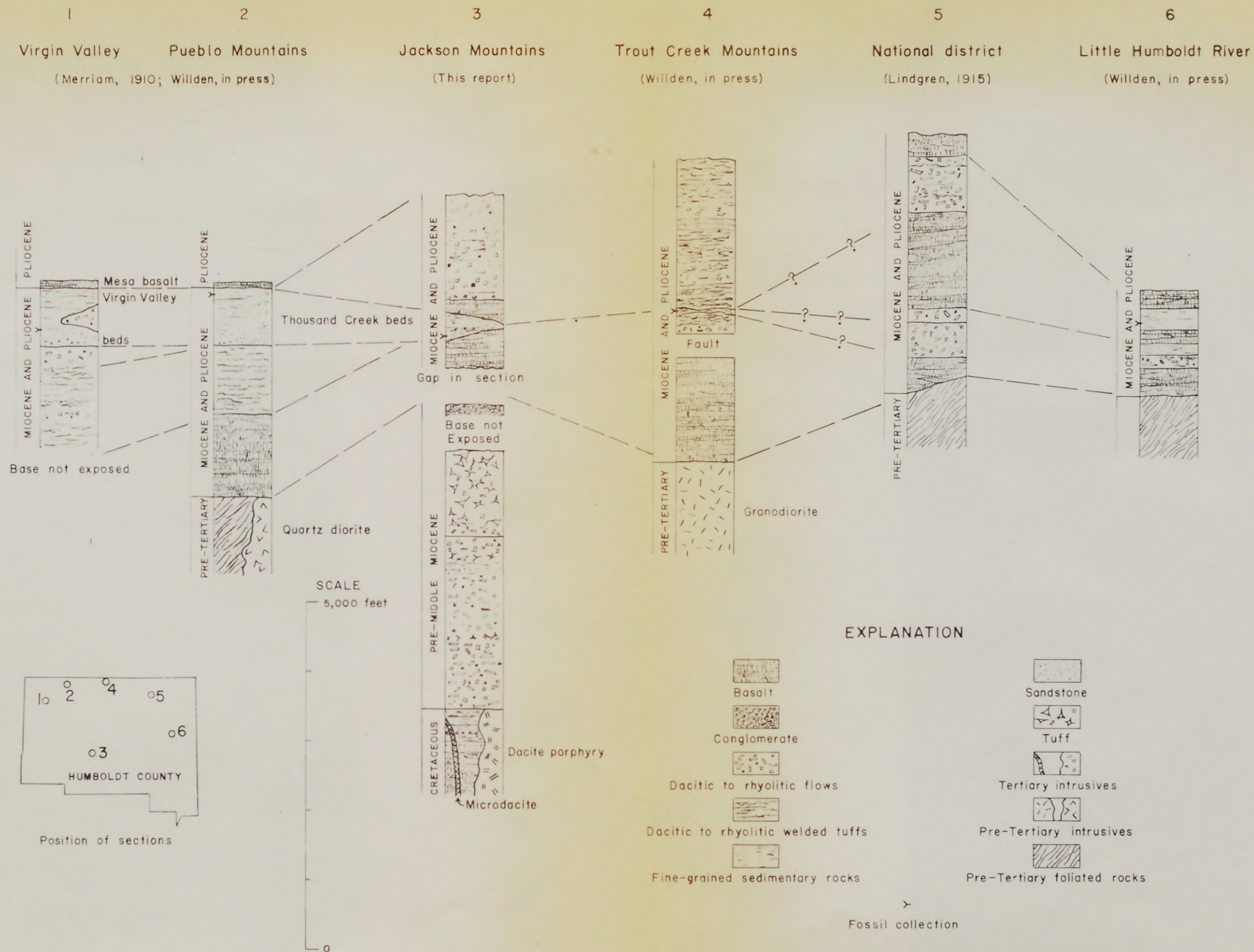
Fig. 18 Suggested correlation of the Tertiary rocks in the Jackson Mountains and other areas in Humboldt County
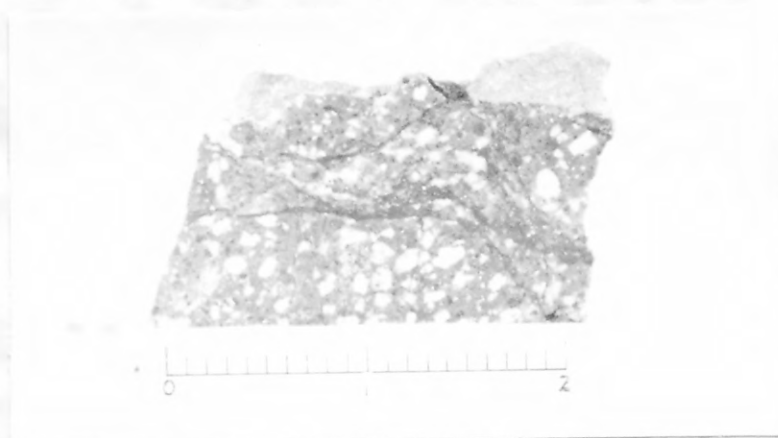
Figure 19.--Specimen of dacite porphyry intrusive.
Scale is in inches
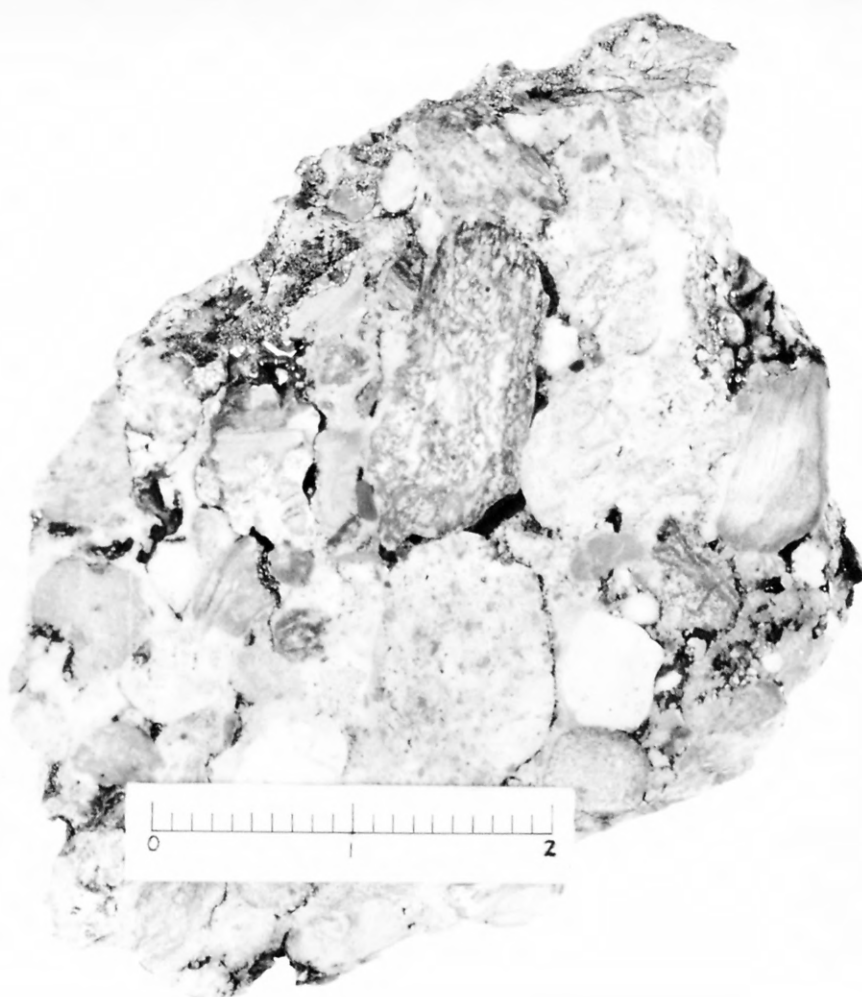
Figure 20.--Specimen of Tertiary conglomerate. Most of the clasts have
been derived from the dacite flow unit. Scale is in inches

in press). It is overlain by the dacitic flow unit which is believed
to be the oldest Tertiary volcanic unit in the range.

Microdacite intrusives

The rocks shown on the map as microdacite occur as dikes, sills,
plugs, and small stocks intruding the Happy Creek volcanics, the King
Lear formation, and the Pansy Lee conglomerate. These rocks, which
have been recognized only in the north half of the range, are nearly
white and so fine grained that no minerals can be identified in hand
specimens.

The dikes generally trend northerly and several can be followed
for more than a mile. Only the larger dikes are shown on the map;
several smaller ones cut the King Lear north of Jackson Creek and
one is present in the Happy Creek volcanics just east of the Iron King
mine.

Only one sill has been shown on the map, and this body intrudes
the King Lear east of the mine symbol on the north fork of Jackson
Creek.

The plugs and small stocks range in size from a quarter of a mile
long by an eighth of a mile wide to a little over a mile long by half
a mile wide. Dike-like apophyses extend south from the plug on the
east side of Parrot Peak and the one at the head of the north fork of
Jackson Creek.

Even the largest of these intrusives has exerted no noticeable
metamorphic effect on the intruded rocks.

The microdacites contain about 70 to 80 percent plagioclase, 20
to 25 percent quartz, about 5 percent of potassium feldspar, and

60

virtually nothing else. The plagioclase was identified as such by stain-
ing techniques and it was determined to have an index of refraction
greater than balsam; the rock is so fine grained further determinations
could not be made.

The microdacite intrusives have been assigned a Tertiary age be-
cause one small plug cuts the Pansy Lee conglomerate. Their age with
respect to the other Tertiary units is not known, but, because of their
dacite composition, they have been shown as the same age as the dacite
porphyry intrusives.

Dacite flows

The dacitic flow unit is exposed from Jackson Creek southward
along the ridge west of the Jungo-Iron King mine road for about 4 miles.
It rests on the King Lear formation, apparently conformably, and on the
dacite porphyry intrusive. It is covered on the east by alluvium.

The unit consists mainly of dacite flows but also includes some
flow-banded rhyolite, some silicified tuff, and some thin sandstone
and mudstone beds. The tuffs and sedimentary rocks occur in the upper
part of the exposed section. The unit is about 2,500 feet thick.

The volcanic rocks (flows and tuffs) generally contain between
30 to 70 percent identifiable crystals or foreign rock inclusions in
a microcryptocrystalline matrix. The crystals include plagioclase
(oligoclase and sodic andesine), quartz, hornblende, and biotite.
The quartz crystals are usually rounded and embayed. The hornblende
is a dark-brown strongly pleochroic variety. In some specimens the
biotite or hornblende (the two rarely occur together) is partially
altered to chlorite. The plagioclase commonly shows alteration of the

61

central parts of the crystals to clay and some sericite. Rock fragments
are abundant in the tuffs and are also found in some of the flows from
the lower part of the sequence. These rock fragments include shale,
basic volcanic rocks, glassy volcanics, some chert, and some grano-
diorite.

The dacitic flow unit is believed to be the oldest of the Tertiary
volcanic units because dacitic material much like that in the flow unit
occurs in the lower part of the next younger map unit, the tuff, and
the tuff unit is overlain elsewhere by basalt with intercalated sedi-
mentary rocks that can be dated by means of fossils. The basalt and
intercalated sediments are part of a fairly well established sequence.

The dacitic flow unit is probably of pre-Middle Miocene age as is
indicated in the Tertiary correlation diagram (fig. 18).

Tuff unit

An unnamed tuff unit is exposed in a large area in the southeast
part of the Jackson Mountains and in a much smaller area in the south-
central part of the range. Within the area of plate 1 the only con-
tacts of the tuff units with older rocks are faults, but about one
mile south of the map area it rests on the undivided Permian and
Triassic unit. The tuff is overlain by basalt and the sedimentary rocks
that are interlayered in the basalt in the central part of the south end
of the range. The exposed section of the tuff is on the order of 1,200
feet thick.

Some dacitic rocks similar to those in the dacite flow unit are
exposed in the lower part of the exposed section of tuff in the north
part of the large outcrop area. The bulk of the unit, however, is of
quartz latite to rhyolite composition.

62

The few specimens of the tuff that were examined contain about 10 percent crystals and a few limy siltstone fragments in a microcrypto-crystalline matrix in which a few shard-like structures can be seen. Most of the crystals were ground away in preparing the slides but they include quartz, microcline, chlorite relicts of pyroxene or amphibole, and clay relicts of feldspar. Sodium cobaltinitrite staining indicates that much of the finely divided matrix material is potassium feldspar.

The tuff unit is believed to be younger than the dacite flow unit because of the dacitic material in the lower part of the tuff, and it is known to be older than the basalt unit. It can be assigned a Tertiary age rather confidently because of its stratigraphic position.

Conglomerate

A silicified pebble conglomerate completely surrounded by alluvium is exposed on a low hill east of Trout Creek about 2 miles south of the junction of the Jackson Creek-Iron King mine road. This conglomerate is composed almost exclusively of rounded pebbles of dacitic and rhyo-litic volcanic rocks some of which are identical to rocks exposed in the dacite flow unit a short distance to the west (see fig. 20). The pebbles have been firmly cemented together by silica but not all the pore spaces have been filled. The high degree of sorting of the con-glomerate suggests it had its origin as a beach or off-shore bar in a Tertiary lake.

The conglomerate would probably not merit designation as a separate map unit if it had not been recognized elsewhere, but it is much like some rocks exposed on the west front of the Kamma Mountains just south of the Jackson Mountains. The rocks at the west front of the Kamma Mountains consist of several hundred feet of pebble conglomerate, sandy

pebble conglomerate, and conglomeratic sandstone all of which are composed principally of volcanic clasts. The prominent cliff at the range front northeast of Sulfur is a silicified pebble conglomerate much like the one described above. Nevada's only currently mined sulfur deposits are developed in these conglomerates.

The conglomerate, because it contains material much like that previously assigned a Tertiary age, must be of Tertiary (or later age) and because it lacks basalt clasts it is probably older than the basalt.

Basalt

Basalt extends in discontinuous patches along the east side of the range from one end to the other. On the west side of the range it is not exposed north of 2 small hills about 2 miles north by northwest of the Red Butte mine. It is also exposed in several low hills east of the range front and at the west front of a broad terrace in the southwest part of the map area. An aerial magnetic map of the range indicates that the basalt along the northeast front of the range extends at least 2 miles east of the alluvium-bedrock boundary with only a shallow alluvial cover.

At various places in the range the basalt rests on the Happy Creek volcanic series, the undivided Permian and Triassic rocks, the King Lear formation, the Jurassic and the Cretaceous diorites, and the Tertiary tuff unit. Basalt also rests on the Tertiary sedimentary unit in places, but the sedimentary unit is actually interbedded with basaltic rocks, so that in some places basalt rests on sediments and elsewhere the sediments rest on basalt. The basalt unit is overlain by rhyolite in the northeast part of the range. The basalt unit has

64

a variable thickness but locally it is at least 600 feet thick.

The lowermost part of the basalt unit is a distinctive porphyritic rock that is exposed at the north end of the range, in the southwest part of the range, and on the terrace west of the south end of the range. The distinctive appearance is caused by strongly zoned plagioclase phenocrysts up to 2 inches long, 1 inch wide, and about two-thirds of an inch thick. The phenocrysts commonly make up from 15 to 20 percent of the rock and show crude parallel alignment. The plagioclase pheno-crysts are complexly zoned with multiple alterations of calcic and sodic varieties; they are also crowded with microcrystalline inclusions. Their composition is thus difficult to determine but ranges from at least as calcic as An_{60} to at least as sodic as An_{25}. The phenocrysts are set in a matrix of unzoned sodic labradorite (as determined by maximum ex-tinction angle), with olivine, augite and probably pigeonite, and black opaque minerals. The rock contains from 40 to 60 percent plagioclase, from 5 to 15 percent olivine, about 30 percent pyroxene, and 3 to 8 percent black opaque minerals. The rock is wholly crystalline and usually rather dense. Vesicles, where they occur, are commonly partly filled with calcite.

The basalts higher in the section are generally non-porphyritic or contain only scattered small augite phenocrysts in a black dense matrix. Most of them are intermediate between basalt and andesite in composition, containing calcic andesine as the plagioclase and gener-ally less than 50 percent mafic minerals. Some very similar rocks from the Osgood Mountains quadrangle (Hotz and Willden, report in preparation) have been analyzed and they contaon about 58 percent SiO_2, 16 percent Al_2O_3, 6 percent total iron, 8 percent MgO+CaO,

and 6.5 percent total alkalies.

The sedimentary rocks interlayered with the basalt contain fossil leaves and diatoms, but no fossil collections have been made from the unit within the area of this report. A collection of diatoms from about a mile south of the area has been assigned a late middle Miocene to early Pliocene age by K. E. Lohman, and fossil leaves from identically appearing rocks elsewhere in Humboldt County give the same age range (Willden, in press). A Miocene to early Pliocene age seems to be fairly well established for the basalt.

Sedimentary rocks

Tertiary sedimentary rocks consisting of shale, water-laid tuff, shaly sandstone, diatomaceous shale, and bedded opaline chert, are abundant in the south end of the range and are exposed in the Bottle Creek quicksilver district. Thin sedimentary units are present at places in the basalt from Bottle Creek south to Cedar Creek, but have not been shown separately on the map.

The sedimentary rocks are interlayered with basalt although at some places, probably owing to an irregular pre-basalt topographic surface, they rest on pre-basalt Tertiary rocks. The sedimentary rocks attain a maximum thickness of about 400 feet west of the south end of the range. At other localities they are much thinner.

The sedimentary rocks are generally light buff to white, fine grained, and except for some water-laid tuffs, thin-bedded. The diatomaceous shale locally becomes nearly pure diatomite and commonly has been converted to bedded opal.

The sedimentary rocks have been dated, as noted above, as late

middle Miocene to early Pliocene. K. E. Lohman has reported on a collection from about a mile south of the area of this report (written communication, May 1958), as follows:

"This freshwater diatom assemblage is dominated by pelagic species suggesting that the lake in which they were deposited may have been either fairly deep or that the water was too turbid to allow light to penetrate in sufficient strength to the bottom where a bottom living assemblage could prosper."

Mr. Lohman's report is reproduced as Appendix C.

At other localities in Humboldt County identically appearing sedimentary rocks, which contain fossils of the same age or range in age, occur intercalated with rhyolitic rocks or between rhyolite and basalt with either basalt or rhyolite below the sediments (see fig. 18).

Rhyolite

The rhyolite is exposed only in the northeast part of the range where it rests on the Happy Creek volcanics, the undivided Permian and Triassic rocks, the Tertiary basalt, and the Tertiary sedimentary rocks. Dacite flow breccias occur at the base of the rhyolite unit on the east side of Buff Peak, but elsewhere it consists mainly of rhyolite flows. The unit is about 1,500 feet thick.

The dacite flow breccia (see fig. 21) at the base of rhyolite contains abundant large fragments (up to $1\frac{1}{2}$ inches) of chert, hornfels, fine-grained quartzite, and some limestone in a dacite matrix. The matrix consists of quartz, plagioclase, chlorite relicts after biotite and amphibole. Epidote and calcite occur as secondary minerals in the rock.

67
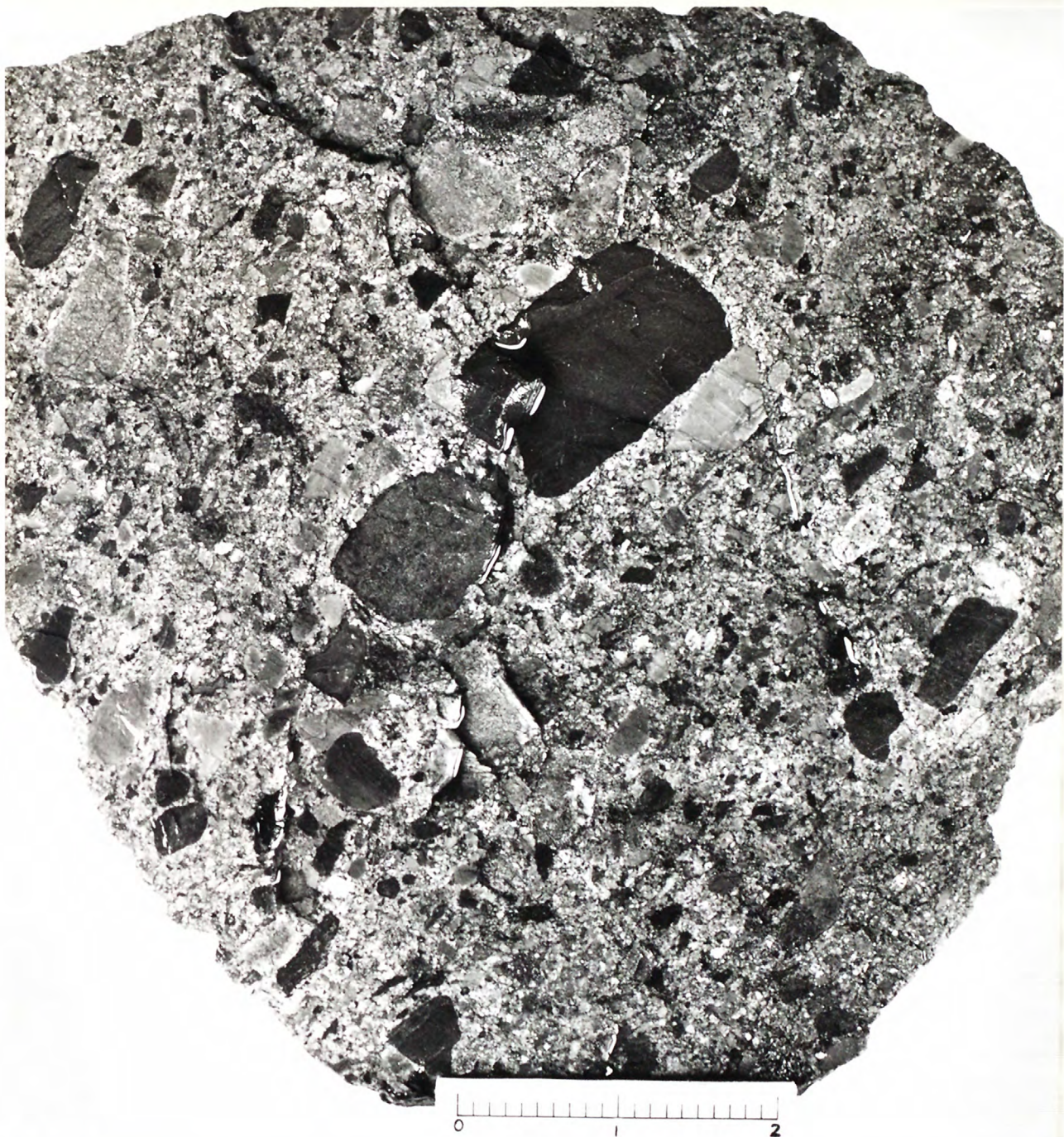
Figure 21.--Specimen of dacite flow-breccia from basal part of rhyolite
section in Bottle Creek quicksilver district. White streaks are re-
flections from water covering specimen. Scale is in inches

The rhyolite flow rocks contain quartz, sanidine, biotite, and
plagioclase in a cloudy partially devitrified glassy matrix. Most
of the quartz crystals are rounded and some are embayed. The sanidine
is also partially rounded and embayed. The plagioclase crystals are
skeletal with glassy material inside the crystal outlines. Crystals
make up only about 15 to 20 percent of the rock.

The rhyolite is the youngest Tertiary unit in the range. It
probably correlates with some part of the thick sequence of rhyolitic
to dacitic rocks exposed in the upper part of the Tertiary section
at several places in Humboldt County (see fig. 18); but exact cor-
relation is difficult to make because at most other places this silicic
part of the Tertiary section is composed principally of welded tuffs.

QUATERNARY DEPOSITS

Three units of Quaternary or probable Quaternary age have been
shown on the map. These are from oldest to youngest: gravel deposits,
older alluvium and younger alluvium. Of these the younger alluvium
covers by far the greatest area.

Gravel

Gravel mounds apparently produced in some earlier geomorphic cycle
are present at two places in the southern part of the map area. Both
of these mounds are composed of angular to subrounded clasts of locally
derived material, but with well over half the clasts derived from the
Tertiary tuff unit. The clasts exhibit a wide range in size but cobble
size clasts are most abundant.

The angularity of the clasts and the general poor sorting suggest

69

that these gravel mounds are remnants of alluvial fans that predate the present physiographic expression of the range.

Older alluvium

The older alluvium includes the dissected alluvial fan deposits along most of the east side of the range and parts of the west side, and the alluvial cover in some upland valleys.

The older alluvium is for the most part poorly sorted subangular to subrounded sand to cobbly gravel. The coarser material is found high on the alluvial fans and the finer material low on the fans.

The fans have all been dissected, and the present day perennial streams occupy channels cut in the fans. The downcutting, in most cases, appears to have begun at the upper terrace of Lake Lahontan or a terrace near the upper level (see fig. 22), and has extended headward.

Scarps other than wave-cut terraces are present in the older alluvium in the southeast part of the range. These scarps mark the extensions of faults from the bedrock areas of the range.

Younger alluvium

Younger alluvium consisting of Lake Lahontan sediments surrounds the bedrock area of the Jackson Mountains. The younger alluvium also includes the alluvial material in the stream channels entrenched in the alluvial fans. The contact between the younger and older alluvium is generally drawn at the highest recognizable terrace of Lake Lahontan.

The younger alluvium includes fine silt on the playas on both sides

70
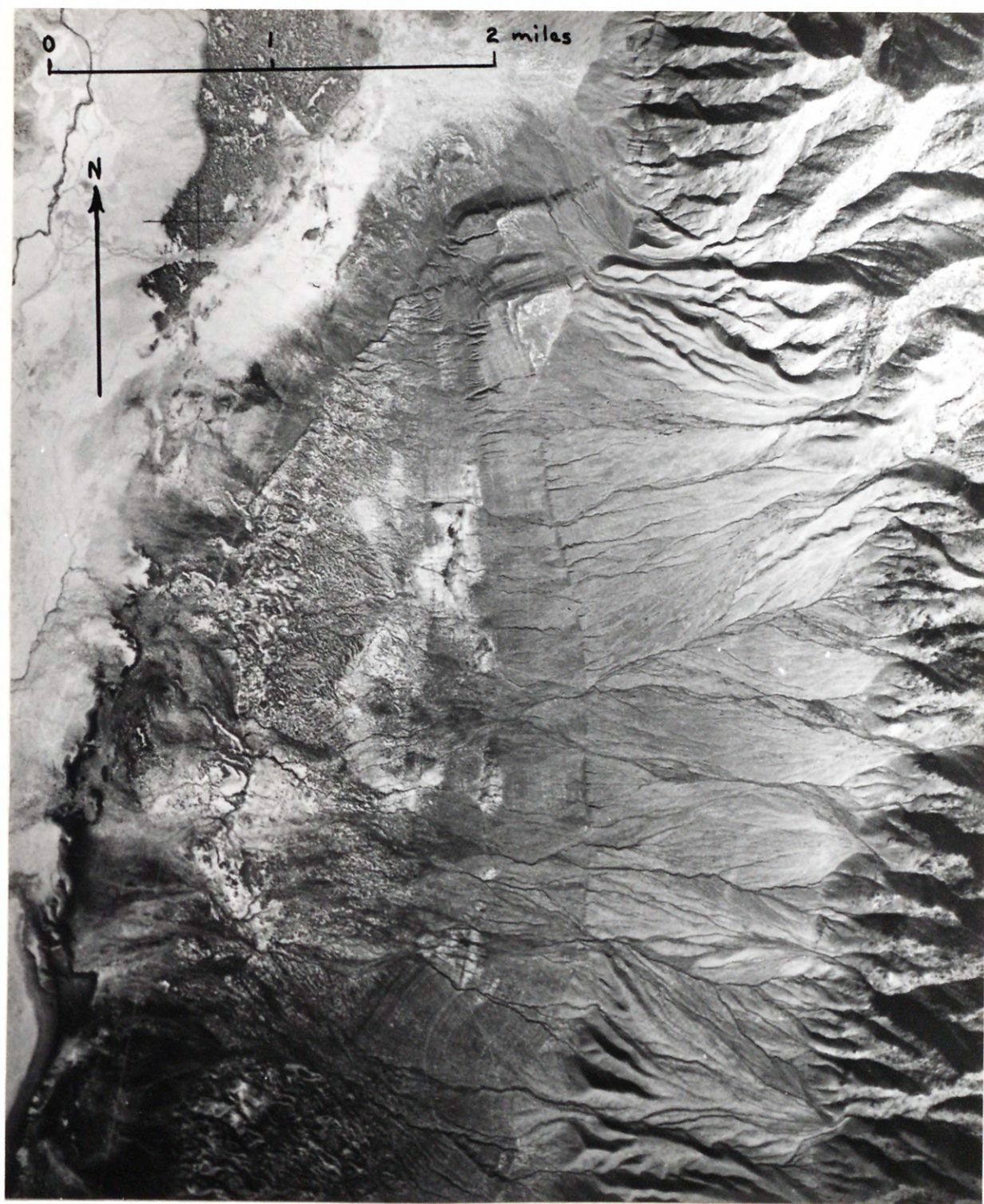
Figure 22.--Dissected alluvial fans on the west side of the Jackson
Mountains south of McGill Canyon

of the range, lake shore deposits such as well-sorted pebble bars and spits, stream gravels, and some wind-blown sand. The younger alluvium is generally much finer grained than the older alluvium, except in the former shore areas of Lake Lahontan where the younger alluvium includes reworked fan material and in the bottoms of the present stream channels.

STRUCTURE

General statement

The structure of the Jackson Mountains is of considerable significance in deciphering the structural history of the Great Basin, because this range is one of very few areas where late Mesozoic rocks are present to record the late Mesozoic and early Cenozoic structural events. In addition to the late Mesozoic and early Cenozoic orogeny recorded in the rocks of the range, at least one and perhaps two or more pre-late Mesozoic periods of deformation have affected the range, and it has been subjected to a long period of adjustment to vertically directed stresses in late Tertiary to Recent time.

At least four periods of intense orogenic activity characterized by the development of tight folds and thrust faults have affected much of north-central Nevada (Roberts, and others, 1958, p. 2850-55). These orogenic periods include the Antler orogeny of late Devonian to early Pennsylvanian age, which predates the rocks exposed in the Jackson Mountains; a Permian orogeny, the effects of which are rather obscure in the Jackson Mountains; a Jurassic orogeny, which is responsible for part of the deformation and virtually all of the metamorphism of the rocks in the range; and the late Cretaceous to early Tertiary orogeny, which is responsible for many of the structural features of the range.

These repeated periods of deformation have undoubtedly produced a complex structural pattern in the Jackson Mountains but much of the complexity is lost in the massive and generally featureless Happy Creek volcanic series.

Folds.--The various periods of deformation in the Jackson Mountains have produced a few large folds that are shown on the map or sections and many smaller ones, too small to show. The smaller folds have been recognized in most of the rock units and include drag folds associated with faults, dome-like folds produced by intrusive bodies, and small isoclinal folds in the phyllitic units that may be related to unrecognized overriding thrusts or may be drag folds on the limbs of larger folds which at most places likewise have not been recognized. The axial planes of these small folds are inclined at many different angles and have a random trend, except that the isoclinal folds in the unnamed phyllite unit of Triassic age generally trend about N. 70° E.[2] and dip from 30° to 70° NW. The larger folds trend north-northeast and the axial planes recognized in the undivided Permian and Triassic unit and in the Cretaceous rocks are vertical or nearly so.

Faults.--Faults were undoubtedly developed in most of the periods of deformation but nearly all those shown on the map cut Cretaceous or younger rocks. Faults wholly within the monotonously similar rocks of the Happy Creek volcanic series or the undivided Permian and Triassic rocks are particularly difficult to recognize. Most of the mapped faults are high-angle faults with essentially dip-slip displacement

───────────────────

2/ Incorrectly reported as N. 10° E. in Willden, 1958, p. 2396.

but one discontinuous thrust fault, the Deer Creek thrust, has been mapped through much of the length of the range. The fault that forms the south limit of the Pansy Lee conglomerate at its exposure on the northeast side of King Lear Peak appears to be a strike-slip fault and may be a tear fault related to the Deer Creek thrust.

Range-front faults are conspicuous only along the west side of the range in the vicinity of the mouth of Alaska Canyon. The abrupt west front of the northern two-thirds of the range suggests that much of it may be controlled by a fault.

Pre-Triassic deformation

Pre-Triassic deformation in the Jackson Mountains is difficult to establish. The Antler orogeny of late Devonian to early Pennsylvanian age can hardly have affected the rocks exposed in the range if their admittedly tentative age assignments are correct. The Permian (pre-Koipato) orogeny, whose effects are particularly noticeable in the East and Tobin Ranges (Roberts and others, 1958, p. 2854-55), however, has probably had some effect on the older rocks of the Jackson Mountains. Structures produced during a Permian orogeny have not been recognized, but the conglomerates and other clastic sediments in the lower part of the undivided Permian and Triassic unit are evidence of nearby positive areas.

The Permian orogeny in the East Range was characterized by the development of north-northeast-trending folds the axial planes of which dip westward (Muller, Ferguson, and Roberts, 1951). This folded terrane was so extensively eroded in Permian time that nearly the entire Inskip formation is missing beneath the Koipato formation in the

north part of the East Range (Ferguson, Muller, and Roberts, 1951). Erosion of such a terrane, exposing rocks like the Inskip, may account for the conglomerates in the undivided Permian and Triassic unit which are composed mainly of chert and quartzite pebbles.

Pre-Cretaceous deformation

The effects of pre-Cretaceous post-Permian deformation in the Jackson Mountains can be identified with considerable confidence, although only a few structures can be assigned such an age. These effects include the nearly universal regional metamorphism of the pre-King Lear rocks, the tight fold in limestone assigned to the undivided Permian and Triassic unit beneath the King Lear formation at the mouth of Rattlesnake Canyon, and possibly the folds in the Triassic phyllite unit, which are best exposed south of the map area. The intrusion of the diorite stocks probably can be regarded also as related in some fashion to the deformation.

The stretched-pebble conglomerates in the undivided Permian and Triassic units (see figs. 8a and 8b) are regarded as evidence of compressive deformation, which was probably contemporaneous with the metamorphic recrystallization of the other rocks. The stretching, which was accompanied by marked flattening, may have been accomplished by crystal gliding or fracture dislocation of the pebbles, but in either case the pebbles now show no fractures. The absence of fractures contrasts sharply with the stretched-pebble conglomerates associated with the Deer Creek thrust (see fig. 26), in which the fractures along which gliding has taken place are clearly visible. The absence of fractures in the pebbles of the older conglomerates is

75

believed to indicate that the deformation was accomplished under much greater load. The quartz veinlets visible in the photographs may be related to the later thrusting or to some other post-metamorphic tectonic event.

The metamorphism exhibited by all the pre-King Lear rocks is recognized in the Triassic rocks as far east as the Santa Rosa Range (Compton, in press). The Tertiary volcanic cover to the west hides the greenschist facies metamorphic rocks to which the Jackson Mountains rocks belong but probable greenschist facies metamorphic rocks are present in the northern Sierra Nevada (Durrell and Proctor, 1948). The boundary of low-grade metamorphism of the Triassic rocks swings abruptly to a nearly east-west line some distance south of Winnemucca and then swings southward on the west side of the Humboldt Range (R. E. Wallace, oral communication).

Folds.--At least one small fold can be dated as definitely pre-Cretaceous and post-Permian. This fold is a nearly isoclinal anticline with a vertical axial plane in limestone beds mapped as part of the undivided Permian and Triassic unit at the mouth of Rattlesnake Canyon. The King Lear formation is unconformable on the limestone indicating that the folding pre-dates the King Lear.

The folds in the Triassic phyllite unit along the east front of the range south of the map area may also be pre-Cretaceous but positive evidence of their age is lacking. Their east-northeast trend and universal overturned character contrast markedly with the vertical north-northeast-trending folds in the rest of the range. The King Lear formation is involved in these nearly vertical folds (see fig. 23) and provides evidence that at least some of the folds with vertical axial planes are Cretaceous or younger.

76

EXPLANATION

Qal
Alluvium

Tu
Undifferentiated Tertiary rocks

TKpl
Pansy Lee conglomerate

KJi
Dioritic intrusive rocks

Kkl
King Lear formation

pKu
Undifferentiated pre-Cretaceous rocks

Contact
*Dashed where approximately
located or inferred*

Fault
Dashed where approximately located

Thrust fault
*Saw-teeth on side of upper
plate; dashed where approx-
imately located*

⊤25
Strike and dip of beds

⊤45
Strike and dip of overturned beds

x
Fossil locality

Line of measured section

Mapped by Ronald Willden, 1956

0   5 Miles

W
A
8000'
KJi   Kkl   Deer Creek thrust   pKu   Kkl
6000'
Tu
4000'
pKu   ?
E
A'
SECTION ALONG LINE A-A'

NW
B
pKu
8000'
Deer Creek thrust
Kkl
6000'
pKu   pKu
4000'
SE
B'
SECTION ALONG LINE B-B'

W
C
8000'
pKu   pKu   TKpl
6000'
TKpl   Qal   Tu
4000'
E
C'
SECTION ALONG LINE C-C'

0   1   2 Miles

TRUE NORTH   MAGNETIC NORTH   19°

Fig. 23 Geologic map and sections of King Lear Peak area, Jackson Mountains, Humboldt County, Nevada; reproduced from Bull. Amer. Assoc. Petrol. Geol., vol. 42, no. 10, p. 2385

77

The large folds in the range involving only the Permian and Triassic rocks (see pl. 1 and secs. A-A' and C-C' of pl. 2) are generally tighter folds than those involving the Cretaceous rocks and for this reason might be assigned a pre-Cretaceous age.

Faults.--Faults of definite pre-Cretaceous age have not been recognized in the range, but there is some indirect evidence that thrust faults of possible pre-Cretaceous age are responsible for the present distribution of some of the units in the range. The change of strike of the metamorphic facies in north-central Nevada lends some support to the supposition that large-scale post-Triassic thrusting is responsible for the distribution of various late Paleozoic and Triassic formations in the East, Tobin, and Sonoma ranges (Roberts and others, 1958, p. 2854-55; Ferguson, Muller, and Roberts, 1951). Evidence of post-Triassic thrusting of undetermined magnitude but probably with at least several miles displacement is found in the anomalous fold pattern of the Triassic phyllite unit in the southern part of the Jackson Mountains. The folds in the phyllite, which are common but not large, trend about N. 70° E. and their axial planes dip from 30° to 70° NW. with the folds generally close to isoclinal. The major fold axes in the northern part of the range trend about N. 30° E. and their axial planes are vertical or nearly so. The phyllite unit is separated from the older rocks by Tertiary volcanic rocks and by a high-angle fault south of the map area, but the phyllite may have been thrust on the older rocks with the thrust contact hidden by Tertiary volcanic rocks or with later high-angle displacement along the surface trace of the thrust. The abrupt eastward swing in the strike of the metamorphic facies is the chief reason for considering the phyllite

to be on the upper plate of the hypothetical thrust.

Intrusive activity.--The Jurassic diorites in the range are not
foliated but they are metamorphosed to the same low-grade facies as
the other pre-Cretaceous rocks in the range. If the metamorphism and
compressive deformation were contemporaneous the diorites must have
been intruded and crystallized prior to the compressive deformation.
Had the diorites been still crystallizing when the deformation took
place, it is likely that some preferred orientation would have been
imparted to the crystallizing rock.

Cretaceous and early Tertiary deformation

The Cretaceous and early Tertiary deformation of the Jackson
Mountains is important to the unraveling of the complex structural
history of north-central Nevada. A major orogeny consisting of
several pulses or phases through Cretaceous and early Tertiary time
has been assumed to have affected all of the Great Basin (Nolan, 1943,
p. 173-178), but this orogeny can be definitely dated in only a very
few areas. Most of the effects of compressive deformation visible in
the Great Basin might be assigned to the Permian or probable Jurassic
orogenic phases if it were not for such areas as the Muddy Mountains
in southern Nevada (Longwell, 1949), the Jackson Mountains, and the
Eureka mining district (Nolan, Merriam, and Williams, 1956) where
Cretaceous rocks are present to record the effects of Cretaceous and
Tertiary deformation.

The late Mesozoic and early Tertiary orogenic period in the Great
Basin province as a whole was characterized by first the development
of folds followed by thrust faults some of which on the east side of

79

the province must have moved many miles. This sequence of structural events is repeated in the Jackson Mountains.

Folds.--The King Lear formation has been folded into a tight northeastward-plunging syncline on the south side of King Lear Peak (see fig. 23 and pl. 1) and into a gentler syncline east of Navajo Peak (see fig. 23, sec. A-A'). This folding predates the deposition of the Pansy Lee conglomerate which has a uniform 25° eastward dip only 3 miles north of the tight fold in the King Lear formation on the south side of King Lear Peak. These two folds in the King Lear are the only folds that can be definitely dated as Cretaceous, but their general parallelism with the major folds in the Triassic and older rocks and the essentially vertical axial planes of the 2 sets of folds suggest that the major folds in the Triassic and older rocks may also be of Cretaceous age.

Faults.--One extensive thrust fault and many high-angle faults have been recognized in the range. The thrust fault, which has been named the Deer Creek thrust, belongs to this late Mesozoic and early Tertiary orogenic period, but most of the high-angle faults are diffi-cult to date.

Many of the high-angle faults involve the late Tertiary rocks and thus are late Tertiary or younger, although some late Tertiary or Recent displacement has probably taken place on older faults. Other high-angle faults involve only pre-Tertiary rocks and some of these are probably of late Mesozoic or early Tertiary age.

A north-trending fault in the King Lear formation on the east side of Navajo Peak terminates against intrusive diorite on the south and is cut off on the north by a fault that is in turn cut off by a high-angle

fault involving late Tertiary basalt. The two pre-basalt faults cut two other faults involving the King Lear formation. The four faults involving only the King Lear or older rocks can all be regarded as of Cretaceous or early Tertiary age. Other faults involve rocks no younger than the King Lear or Pansy Lee formations but their age with respect to the late Tertiary rocks cannot be established.

Deer Creek thrust.--The King Lear formation and the Pansy Lee conglomerate have been overridden by the Happy Creek volcanic series on a thrust sheet that can be traced over a 25-mile segment of the range. This thrust has been named the Deer Creek thrust for excellent exposures on the north side of Deer Creek Peak (fig. 24). The southernmost exposure of the thrust is at Rattlesnake Canyon on the west front of the range near the southern boundary of the map. A small klippe of the Happy Creek volcanic rocks rests on the King Lear formation on Cedar Creek east of Navajo Peak (section A-A', fig. 23). The thrust is also exposed on the southeast flank of King Lear Peak (fig. 25), and it can be traced from the southwest side of DeLong Peak to the north side of Deer Creek Peak, a distance of about 8 miles. On the west and north sides of Deer Creek Peak the thrust overrides both the Pansy Lee conglomerate and the King Lear formation. The relation of the thrust and the King Lear formation is shown in sections A-A' and B-B' figure 23, and A-A' plate 2.

The rocks immediately below the thrust are commonly sheared, and stretched-pebble conglomerates (see fig. 26) have been produced at some places. The stretched-pebbles produced by the thrust appear quite different from those in the conglomerates of the undivided Permian and Triassic unit (see figs. 8a and 8b). Fractures along which gliding has

Figure 24.--Deer Creek thrust on the north side of Deer Creek Peak

Figure 25.--Deer Creek thrust on the south side of King Lear Peak
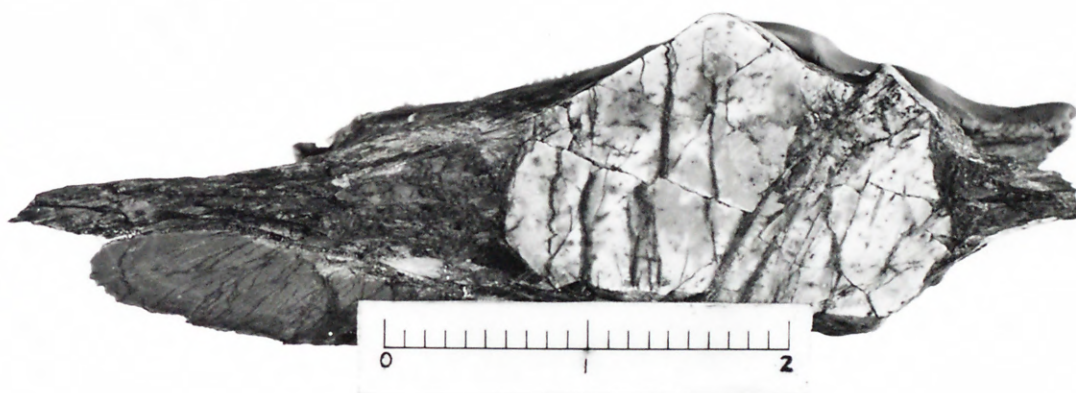
Figure 26.--Specimen of stretched-pebble conglomerate from King Lear
   formation below Deer Creek thrust south of Rattlesnake Canyon.
   Scale is in inches

taken place are still clearly visible in the stretched-pebbles due to the thrust.

The volcanic rocks on the upper plate of the thrust are cut by innumerable, more or less randomly oriented slickensided surfaces. Serpentine and calcite are commonly developed on the slickensided surfaces but otherwise the rocks lack evidence of shearing or recrystallization.

The Tertiary volcanic rocks widely exposed in the range are not involved in the thrusting. Thus the thrusting predates the Tertiary volcanic rocks, and post-dates the deposition of the Pansy Lee conglomerate.

The dip of the thrust plane provides no information about the direction of displacement because the plane dips east in the northern part of the range, northwest on the southeast flank of King Lear Peak, east under the klippe north of Cedar Creek, and south at Rattlesnake Canyon. These apparently anomalous dips on segments of the thrust plane may be due to folds produced by continued action of compressive forces after the thrust ceased to move or they may be a result of tilting by essentially vertical displacement on late Tertiary faults. However, the direction of displacement on the thrust is shown by a drag fold observed in the King Lear formation on the south flank of King Lear Peak (section B-B', fig. 23). On the west limb of the syncline south of the thrust, conglomerate beds of the King Lear strike from N. 15° E. to N. 30° E. and dip about 50° SE., but the beds underlying the thrust have been overturned and dip about 45° W. with a N. 15° E. strike. This drag shows that the relative movement of the upper plate was from west to east.

The amount of displacement is not known but is thought to be small

because all the rock units involved in the thrusting are part of a compatible sequence.

Intrusive activity.--The Cretaceous diorites were emplaced after the folding of the King Lear formation and after the development of at least some of the high-angle faults involving the King Lear formation. Their age with respect to the thrust faulting or the deposition of the Pansy Lee conglomerate is unknown. The Pansy Lee contains some dioritic pebbles, but these pebbles could have been derived from the Jurassic diorites.

The time of emplacement of the granodiorite stock is unknown. It has not contributed detritus to the Cretaceous or Tertiary conglomerates exposed in the range, and has not been involved in any known faults except possibly the range bounding faults.

Regional significance of late Cretaceous and early Tertiary orogeny.-- Much of the deformation of the Triassic rocks in north-central Nevada might better be assigned a late Cretaceous or early Tertiary age than a Jurassic age as it has been assigned in the past.

The Jurassic age of the northern Nevada orogeny has been based on comparison with the well-dated Jurassic thrusting and folding of the Hawthorne and Tonopah quadrangles (Ferguson and Muller, 1949), and on the fact that the thrust plates involving Triassic rocks have been cut by granodiorite intrusive bodies (Ferguson, Muller, and Roberts, 1951; Muller, Ferguson, and Roberts, 1951). The granodiorite intrusive bodies were believed to be "satellitic to the Sierra batholith", which was believed to be late Jurassic. The late Jurassic age of the Sierra bathylith is not supported, however, by recent potassium-argon and lead-alpha age determinations. Potassium-argon age determinations

of rocks from Yosemite National Park range from 76.9 to 95.3 million years (Curtis, Evernden, and Lipson, 1958, p. 7-9), and lead-alpha ages of rocks from Yosemite National Park and from an area near Bishop, California range from 88 to 117 million years (Larsen, and others, 1958, p. 52). These rocks by either method of age determination would be assigned to the Cretaceous according to the Holmes B time-scale (Holmes, 1947). The granodiorite intrusive bodies used to date the orogeny as Jurassic, however, may be considerably younger than those in the Sierra bathylith. The non-foliated granodiorite intrusive bodies in Humboldt County show a range in age by the lead-alpha method from 35 ± 10 to 65 ± 10 million years (H. W. Jaffe, written communication, Sept. 1956; T. W. Stern, written communication, Sept. 1959).

The tight folding and the overthrusting which characterized the late Cretaceous and early Tertiary orogeny in the Jackson Mountains are the same sort of features--thrust faults and tight locally over-turned folds in the lower plate rocks--ascribed to the Jurassic orogeny in north-central Nevada. The Jurassic age of an orogeny in northern Nevada cannot be wholly discounted, especially in view of the well-established Jurassic age of orogenic activity in the Hawthorne-Tonopah area, but many of the structural features assigned a Jurassic age should be reexamined for evidence of Cretaceous or early Tertiary age.

Late Tertiary deformation

The late Tertiary deformation was almost exclusively a response to vertically directed stresses. This response was principally displace-ment on high-angle faults but includes some apparent folds, such as the deformed thrust plane previously described and the fold indicated

86

by opposing dips in the Tertiary rocks in the Bottle Creek quicksilver district (see sec. A-A', fig. 27). The late Tertiary deformation, although of a relatively small magnitude, has probably taken place over a considerable span of time and has resulted in the formation of new faults and in renewed movement on older faults.

Folds.--The fold-like structures, particularly the one in the Tertiary rocks of the Bottle Creek quicksilver district, may be a result of differential displacement on high-angle faults or they may be true folds produced by compressive forces. Such late Tertiary compressive forces are probably best explained, however, as secondary features produced by the subsidence and uplift, respectively, of basin and range blocks bounded by non-vertical faults.

Faults.--The late Tertiary to Recent faults shown on the map, with the possible exception of the range front fault in the vicinity of Alaska Canyon, are probably all relatively minor structures with at the most a thousand feet of displacement on any one fault. Range boundary faults responsible for the principal uplift of the range are probably buried under the alluvium some distance to the west and east of the range.

A gravity profile across the south end of the range by D. R. Mabey (see fig. 28) suggests the presence of an eastern range boundary fault with rather small displacement somewhere near or east of Jungo. Desert valley on the east side of the range has a minimum of 6,000 to 8,000 feet of low density fill in it, with the deepest part of the valley near its eastern side. The deepest part of Desert Valley at the north end of the range, however, is near its western side (see fig. 29); but no depth calculations have been made on the northern part of the valley.

EXPLANATION

Qsg — Stream gravels — QUATERNARY

Qal — Alluvium and slope wash

Tr — Rhyolite (Partly extrusive and partly intrusive)

Td — Diabase dikes

Tu — Upper tuffs and clays — TERTIARY (?)

Tb — Basalt

Tl — Lower tuffs, conglomerate, and sandstone

pT — Phyllite, greenstone, quartzite, etc. — PRE-TERTIARY

Fault (Solid where exposed, dashed where concealed, dotted where inferred; arrow shows dip)

Strike and dip

Shaft

Tunnel

Prospect

Geology and topography by Ralph J. Roberts and A.E.Granger

Contour interval 25 feet
Assumed sea level datum

Figure 27.--Geologic map and sections of Bottle Creek district, Humboldt County, Nevada. Reproduced from U. S. Geol. Survey Bull. 922, plate 1

88

SCALE

-130 Milligals

-140

-150

-160

-170

5000 feet — -180

Bouguer anomaly

Tertiary volcanics and sediments   Triassic and Jurassic(?) rocks   Quaternary deposits

4000

41°

118°

3000

Depth of fill = 6,000 to 8,000 feet
$\Delta\sigma$ = -0.4 to -0.5 g per cm^3

O-141   O-155   O-159
                                         Winnemucca

O-144

-142   O-141
-166   N
-173   -158
-167
Jungo   -158
□   Western Pacific Railroad $\triangle$-176

-143

O-153

-137   -140

-158   -153
+O—□—+
Sulphur

Gravity profile by D. R. Mabey, 1959
Surficial geology from Geologic Map of Humboldt Co., Nev.

0   10   20 miles

Fig. 28   Gravity profile and hypothetical geologic section from Sulphur to Winnemucca across south end of Jackson Mountains

Scale

−140 Milligals

−150

−160

5000 feet −180

4000

Bouguer anomaly

Topographic profile

Quinn River
Crossing

−152

−157

Leonard Creek
Ranch
−154

−158

8A

−150   −163

−151

−158

−153

−154

−148

−155

−168

−163

−159

−156

Sod House
−145

−145

−151

−161

−170   −157

−158

95

N

Gravity profile by D. R. Mabey, 1959

0   10   20 miles
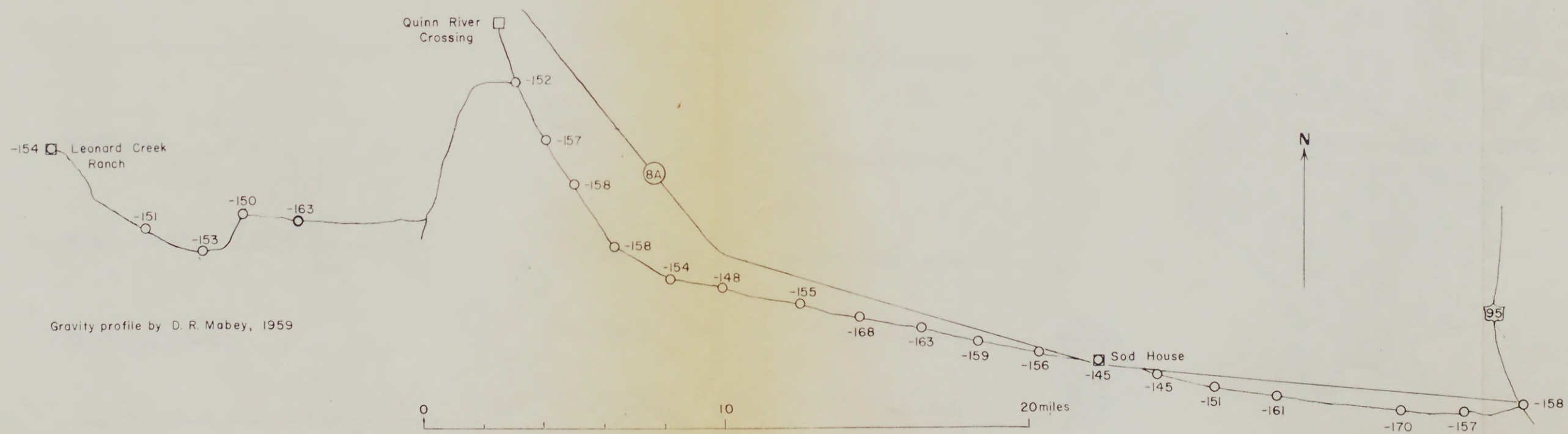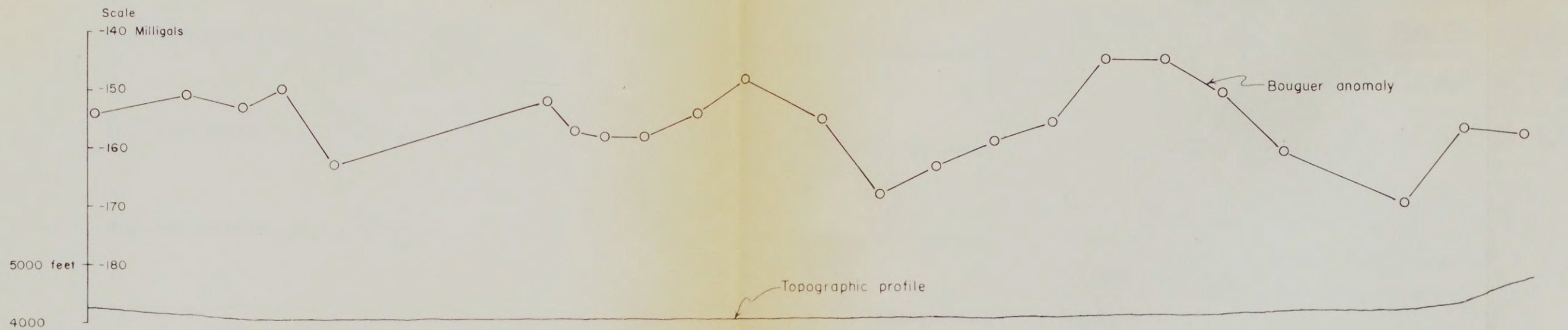
Fig. 29   Gravity and topographic profiles from Leonard Creek Ranch to junction of Nevada 8A and U.S. 95 across north end of Jackson Mountains

The gravity profile across the north end of the range--also by D. R. Mabey--indicates that the eastern boundary fault is probably 2 or 3 miles east of the range front. This is in good agreement with the aerial magnetic map of the northeast part of the range (see fig. 30) which indicates that the volcanic rocks extend a considerable distance east of the range front with only a shallow alluvial cover.

The western side of the range is also controlled by faults, probably two or more faults with an en echelon arrangement and with greatest displacement at their south end and gradually decreasing displacement northward. One such fault is the range front fault exposed at the mouth of Alaska Canyon. It can be projected southward to just west of the isolated basalt-sediment outcrop in the southwest part of the map area where its displacement probably amounts to 2,000 to 3,000 feet (based on projection of gravity stations several miles north from along the Western Pacific Railroad southwest of Sulphur). Another such fault has probably controlled the west front of the range north of Alaska Canyon but it is not exposed in the bedrock of the range.

The aerial magnetic map of the northeast part of the range (fig. 30) and the geologic map of the Bottle Creek quicksilver district (fig. 27; see also pl. 1) provide evidence that the late Tertiary faulting has persisted for a considerable time. There is a pronounced trough-like magnetic low just east of the north-trending fault that separates the undivided Permian and Triassic rocks from the Tertiary rocks on the east. The small highs and lows along this trough indicate that volcanic rocks underlie the trough and it seems best explained as a downfaulted block of basalt. If so, this downfaulting must have taken place and the basalt on the relatively upthrown block to the west must
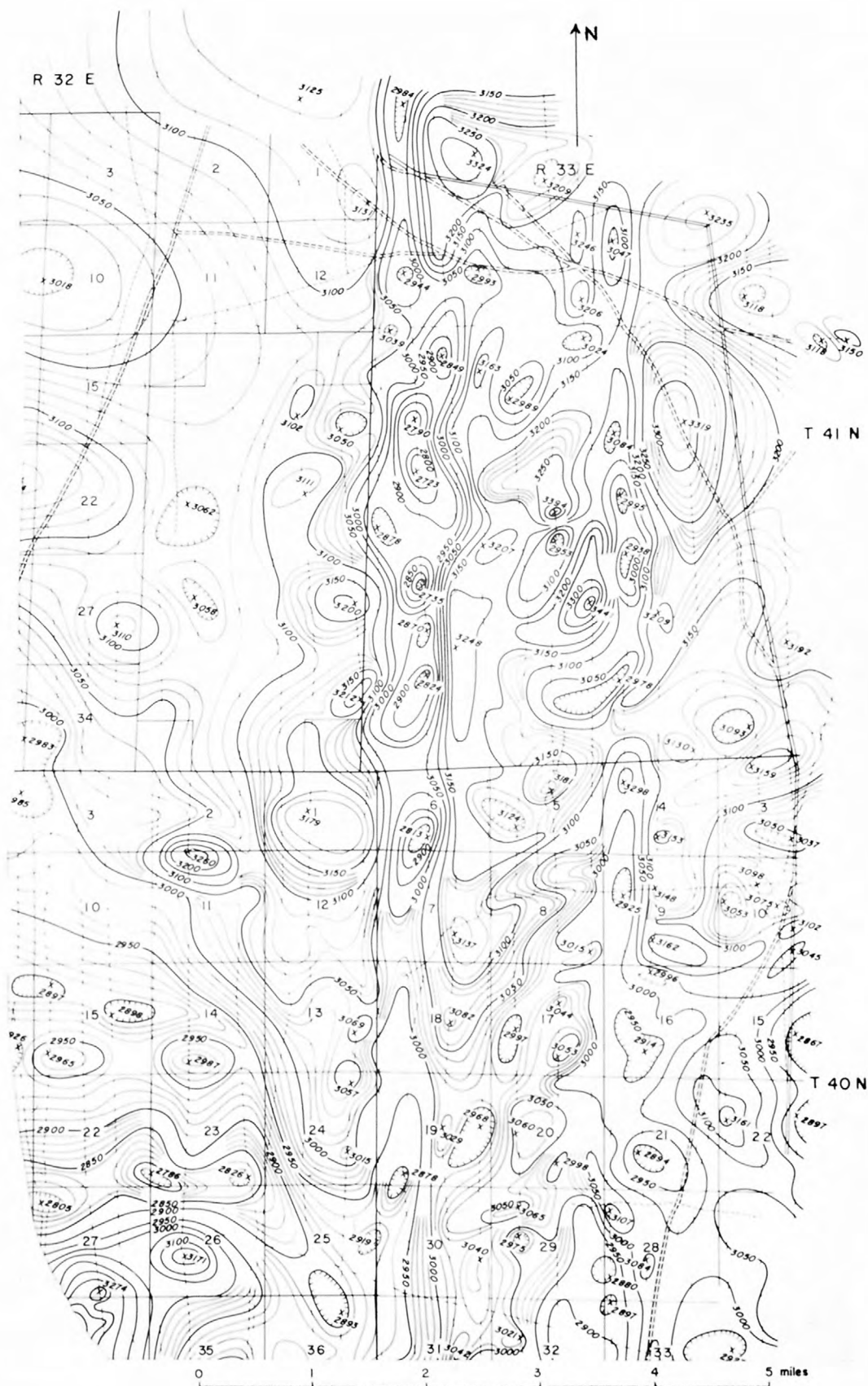
Fig. 30   Aerial magnetic map of northeast part of Jackson Mountains flown at 500' above ground

have been eroded prior to the extrusion of the rhyolite, which rests on the Permian and Triassic rocks west of the fault, and on basalt east of it. This sequence of extrusive volcanism, faulting, erosion, more extrusive volcanism, and more faulting demonstrates the complexities of the late Tertiary history of the area.

Origin of the Jackson Mountains as a topographic feature.--It can hardly be doubted that the Jackson Mountains owe most, if not all, of their present relief to uplift on normal faults that in general bound the range. But the origin of these bounding faults and the forces that have caused the uplift is quite another matter. The problem of the origin of any one range is part of the larger problem of the origin of the Basin and Range structural province. A satisfactory explanation of the late Tertiary structures of the entire province is beyond the scope of this report, but there are certain features of the Jackson Mountains that must be explained by any theory of origin of Basin and Range structure and for this reason deserve mentioning.

These features include: 1) the nearly north trend of the range and its pronounced linearity; 2) the repeated movement on the faults through much of late Tertiary and Recent time; 3) the great depth of the basin on the east side and probably also on the west side of the range; 4) the presence of apparent compressional features in the late Tertiary rocks; 5) the large amount of displacement on the bounding faults; and 6) the fact that the present range is the site of older mountains or at least positive areas as shown by the unconformities below and above the Cretaceous and early Tertiary rocks.

To the end of 1957 the mines of the Jackson Mountains had a total production valued at somewhat more than $4,000,000 (Willden, in press). Most of this production has come from the Iron King mine, with much smaller amounts from the other iron mines and from the quicksilver and sulfur deposits. The few copper mines and prospects have had a very small production.

Nearly all the mines in the range have been studied in some detail by previous workers and reports on all this work except on the iron deposits are available in the literature (Ransome, 1909; Vanderburg, 1936; Roberts, 1940; Bailey and Phoenix, 1944; Benson, 1956; and Shawe, Reeves, and Kral, in press). Therefore, although the mines were visited as part of this study, detailed mapping was not undertaken.

The various ore deposits were formed in at least 2 and perhaps 3 or more widely separated periods of mineralization. The iron deposits, which were formed prior to the deposition of the King Lear formation, seem to be related in some fashion to the Jurassic intrusive rocks. At least part of the copper deposits are younger than the King Lear and they may be related to the Cretaceous diorites, or they may be a product of the late Tertiary period of mineralization. The quicksilver deposits are associated with diabase dikes that intrude the youngest Tertiary rocks and thus are of late Tertiary or younger age. The sulfur deposits are located south of the area of this study and therefore will not be discussed at any length. They are in Tertiary rocks and may be a product of the same late Tertiary period of mineralization as the quicksilver deposits, or they may be Recent deposits produced during the

highest stage of Lake Lahontan (E. H. Bailey, oral communication, 1956).

Iron deposits

Iron deposits are present as replacement bodies or as veins in the Happy Creek volcanic series on the west side of De Long Peak, on the west side of the north fork of Jackson Creek, and on the east and north sides of Navajo Peak. The deposits on the west side of De Long Peak are high-grade magnetite bodies. The other deposits are of somewhat lower grade, consisting of mixed hematite-magnetite ore with hematite most abundant.

The deposits on the west side of De Long Peak include the two largest known ore bodies in the range: the Iron King ore body and the Red Bird deposit, which may be a faulted continuation of the Iron King deposit. The Iron King deposit is a vein-like replacement body localized along the contact between a diorite intrusive and the Happy Creek volcanic rocks. Some shearing in the diorite and the volcanic rocks suggests that the contact is a fault rather than an intrusive contact. The mine-run ore has averaged about 65 percent iron. Four samples of ore from the Iron King, Red Bird, and Yellow Boy deposits have been analyzed by the chemical laboratories of a major mining company prospecting the range and the results are given in table 3.

Table 3.--Chemical analyses of iron ore

Sample Number	Fe	SiO_2	S	P	Mn	As	Cu	Ni	Pb	Zn	Ti	F
1	70.5	0.65	.025	.006	.05	.01	.01	.03	.01	.01	0.14	--
2	67.0	3.35	.004	.004	.07	.01	.01	.04	.01	.08	0.45	--
3	61.6	6.60	.008	.006	.07	.01	.01	.06	.02	.15	2.61	--
4	62.9	6.60	.009	.040	---	.02	.01	.015	---	---	---	128 ppm

Dash indicates value not reported.

Sample 1 and 2 from Red Bird claims, sample 3 from Yellow Boy claims, which adjoin Red Bird, and sample 4 from Iron King deposit. Analyses kindly supplied by mining company in the area.

A structural control of these deposits other than the diorite-volcanic rock contact has not been noted, but they are cut by several post-ore faults. All the available evidence indicates that they are on the upper plate of the Deer Creek thrust. The thrust must be several hundred to perhaps as much as a thousand feet lower than the deepest workings of the Iron King mine and considerably more than this below the Red Bird mine. The presence of the fault will thus be of little consequence to the mine operations unless deep underground development is undertaken.

The deposit on the north fork of Jackson Creek was not visited, but, according to Shawe, Reeves, and Kral (in press), consists of small pod-like replacement bodies of hematite and some magnetite in the Happy Creek volcanic rocks.

The deposits in the vicinity of Navajo Peak consist of veins of hematite with some magnetite in bleached and altered volcanic rocks assigned to the Happy Creek. Several of these deposits have been

explored by bulldozer trenches and some drilling has been done at one deposit but no ore has been shipped. The veins are generally narrow, ranging from a few inches up to about 5 feet, and have a maximum strike length of only a few hundred feet. No structural control of these deposits, other than possibly the joints in the volcanic rocks, has been noted.

Evidence of the pre-early Cretaceous age of the iron deposits is furnished by abundant hematite and magnetite clasts in the lower conglomerates of the King Lear formation on the east side of Navajo Peak (see figs. 31 and 32), and a few scattered magnetite clasts found in the King Lear conglomerates below the Iron King mine road about 4 miles by road southwest of the mine. The general scarcity of iron detritus in the vicinity of the largest ore bodies, and its abundance near the much smaller deposits near Navajo Peak is explained by the Deer Creek thrust, which has placed the large ore bodies in proximity to the King Lear formation.

Origin of the iron deposits.--The volcanic rocks in the vicinity of the hematite veins near Navajo Peak are generally bleached and some of them are cut by closely spaced parallel joints on the walls of which specular hematite has developed. A pebble in the lower King Lear conglomerate obviously derived from the jointed volcanic rocks is shown in figure 31. The bleached rocks consist almost wholly of albite (An content of 4 to 6 percent as indicated by X-ray diffraction patterns) with a small amount of quartz. The rocks have been subjected to some sort of soda metasomatism but its nature and extent is unknown because the bleached rocks were not mapped separately and few specimens are available for study.

Figure 31.--Specimen of King Lear conglomerate containing abundant
hematite (h) and magnetite (m) clasts

Figure 32.--Two specimens of King Lear conglomerate containing iron
clasts. Upper specimen contains a fragment of bleached Happy Creek
volcanic rock cut by three closely spaced joints and with specular
hematite developed along the joints. Lower specimen contains a
large fragment of granular hematite

As part of the alteration to which the rocks have been subjected, the iron contained in them has been mobilized and has become concentrated along the joints cutting the rocks. The possibility immediately suggests itself that the iron deposits, particularly the hematite veins, have had their ultimate source in the Happy Creek volcanic rocks with the diorite intrusives providing an energy source and possibly solutions to effect the transfer of iron from the volcanics to the joints and thence to the veins and replacement bodies.

The mechanism would be somewhat similar to that proposed by Mackin (1947, p. 43-47) for the origin of the iron deposits at Iron Springs, Utah. Here, however, instead of the iron being derived from the intrusive rocks during a late stage of auto-metamorphism, it would be derived from the country rocks during their alteration to extremely soda-rich rocks with the alteration probably triggered by the intrusion of the diorites.

To test the possibility that the iron of the iron deposits may have been derived from the Happy Creek volcanic series, 11 samples of unbleached rocks of the Happy Creek selected at random from my collection of over 50 samples from the formation were analyzed for their iron content by means of X-ray spectrograph techniques. The 11 samples were compared with 2 chemically analyzed samples of igneous rock from elsewhere in Humboldt County which contained 7.9 and 3.0 percent total iron. The indicated iron content of these 11 samples as determined by comparison with the high-iron standard was found to be from 0.2 to 1.5 percent higher than that determined by comparison with the low-iron standard (the higher the indicated iron content of the sample the greater the discrepancy). Therefore, the high-iron standard was used for

comparison purposes with samples with an indicated iron content near or greater than 7 percent and the low-iron standard was used for samples with an indicated iron content near 3 percent or lower. For indicated iron contents between 3 and 7 percent the average value obtained by comparison with both standards was used. The indicated iron content of the 11 samples of unbleached volcanic rock is given in table 4 along with the indicated iron content of 2 samples of bleached volcanic rocks and 1 sample of bleached rock from between 2 hematite lined joints.

Table 4.--Spectrographic analyses of iron content
of Happy Creek volcanic rocks

Sample No.	Rock Type	Location	Iron Content
56W27b	Unbleached rock	Just south of mine in south-central part of map area	9.0%
56W28b	do	South-central part of map area	7.4
56W33	do	3 miles SE of Red Butte mine	3.1
56W53a	do	2 miles SW of mouth of Rattlesnake Canyon	8.8
56W53d	do	do	7.6
56W72	do	1 mile W of contact with Permian-Triassic unit along Bottle Creek	5.6
57W23b	do	1 mile E of mouth of Jackson Creek	3.9
57W36	do	N end of ridge W of Happy Creek	4.6
57W37	do	0.7 mile SW of sample 57W36	4.5
57W38	do	E side Deer Creek Peak	1.8
57W39	do	Deer Creek Peak	2.2
56W60	Bleached rock from between 2 hematite lined joints	E side of Navajo Peak	1.3
56W62a	Bleached rock	do	0.4
56W62b	do	do	0.4

The 11 samples of unbleached volcanic rock have an average iron content of 5.3 percent. The 2 samples of bleached rock contain 0.4 percent iron and the intra-joint material contains 1.3 percent iron. These analyses show a marked decrease in the iron content from the average value for the unbleached rocks to the bleached rocks; however, the few samples of bleached rock available can hardly be regarded as representative of all the bleached rocks around the ore deposits. Nevertheless the data permit the assumption that the iron of the iron deposits has indeed been derived from the volcanic rocks.

The hypothesis can be further tested by calculating the amount of unbleached volcanic rock that would have to be altered to yield the known ore deposits. In the five years from the beginning of 1953 to the end of 1957 the Iron King mine had produced 401,386 long tons or 449,552 short tons of magnetite ore[3]. This ore generally averages about 65 percent iron so this figure represents 292,209 short tons or 584,418,000 pounds of iron. If we conjecture that the deposit contains about three times this amount of iron and if it is assumed that this iron was derived from the volcanic rocks, which contained 5.3 percent iron before the formation of the iron deposits and 1.3 percent afterwards, 25 times as much rock is required to be altered as there is iron in the deposit. This amounts to about 22 million short tons of volcanic rock or, using a specific gravity of 2.5 for the volcanic rocks, 275 million cubic feet. This figure is

_____

3/ Production figures furnished by and used with the permission of A. and B. Mining Company.

equivalent to about 2 thousandths (0.002) of a cubic mile. Thus a block of volcanic rock somewhat smaller than 100 feet wide by half a mile long and a quarter of a mile deep would yield sufficient iron for the vein-like replacement body of the Iron King mine, which is the largest known deposit in the range. This is certainly not an unreasonable amount of volcanic rock to be altered.

Copper deposits

The copper deposits are all small and have had no important production. The discovery at Red Butte in 1906 caused a brief flurry of prospecting activity but did not result in any important discoveries. None of the mines were active in 1937 when Vanderburg (1938) visited the area and there has been very little activity since then.

The deposits at Red Butte are in the Happy Creek volcanic rocks and a diorite intrusive. According to Ransome (1909, p. 27-30) the deposits consisted of oxidized ore (cuprite, covellite, native copper, and chryso-colla, associated with hematite, limonite, and a little barite) irregularly distributed through aplite dikes. I visited the deposits but found only a faint copper stain as evidence of the copper mineralization. The aplite dikes consist of 95 percent or more sodic oligoclase with some nearly colorless amphibole.

Several small prospects are located in the diorite intrusive east of Red Butte. One of these is developed by an inclined shaft and, judging by the size of the waste dump, considerable underground workings, but I found no record of production from it.

103

A prospect on the east side of Navajo Peak is located in mudstones of the King Lear formation cut by a quartz vein. The prospect is developed by an adit and a shallow shaft down to the adit level from the hillside above and about 500 feet northwest of the adit portal. A small pile of quartz on the dump at the shaft contains several percent copper as azurite and chalcocite. This was the only prospect visited that showed any evidence of copper mineralization in sufficient amounts to be profitably mined.

The small mine in the Happy Creek volcanics in the south-central part of the map area, although it contains some copper, is reported by local residents to have been operated as a gold mine.

The prospect located in the King Lear formation on the east side of Navajo Peak is evidence that at least part of the copper deposits are post-early Cretaceous in age. The vein may be related to the Cretaceous diorite and if so would indicate that the copper deposits, which are younger than the iron deposits, are older than the quicksilver deposits. Some support for this idea is the fact that quartz veins are altogether lacking near the quicksilver deposits; however, quartz veins are nowhere abundant in the range and their absence near the quicksilver deposits may be of little significance.

Quicksilver deposits

The quicksilver deposits in the Bottle Creek district, which had only been known a few years when Roberts and Granger (Roberts, 1940) mapped them in 1939, became important producers during the second World War. By the end of 1943 they had produced 4,544 flasks (Bailey and Phoenix, 1944, p. 80). After the war, production declined and ceased

altogether in 1947. The mines remained idle until late 1955 when the extraordinarily high price of mercury stimulated activity in most of the known quicksilver districts in the state. A mill was constructed for the purpose of upgrading low-grade material, and open-pit mining operations were begun at several of the old mines. In 1957 the mill was treating about 60 tons per day of material containing 2 to 5 pounds of quicksilver per ton and upgrading it by gravity concentration to about 20 percent mercury. The concentrates were fired in a "D" retort at Winnemucca.

The deposits occur for the most part as disseminated cinnabar in the diabase dikes, but there are some cinnabar-bearing fault zones in the rhyolite and pre-Tertiary rocks. Most of the early production from the district came from deposits in two of the diabase dikes. The recent production has been from the deeply weathered near surface parts of the diabase dikes.

The quicksilver deposits must be of late Tertiary or younger age because they are associated with the diabase dikes, which cut all the rocks of the district and thus are believed to be of late Tertiary age.

GEOLOGIC HISTORY

In Permian or older time a thick section of andesitic to basaltic volcanic rocks accumulated in what is now the Jackson Mountains. Pillow lavas indicating subaqueous origin have been observed only in the upper part of the section. The flow-breccias and tuffs are texturally much like the late Tertiary terrestrial volcanic rocks of northern Nevada. Perhaps a large proportion of these Permian or older volcanic rocks were of terrestrial origin.

The fusulinids and corals in the limestone in the lower part of
the overlying Permian and Triassic unit show that marine deposition
took place in the Permian and these conditions persisted through the
Triassic and possibly into the Jurassic. The conglomerates in the lower
part of the Permian and Triassic unit indicate upland areas somewhere in
the vicinity and may reflect the Permian orogeny recognized in much of
north-central Nevada.

The Permian and Triassic formations were intruded by diorite stocks
in probably late Jurassic time following which the rocks were subjected
to low-grade regional metamorphism, as a part of which stretched-pebble
conglomerates were produced and some folds developed. Following this
period of metamorphism the area was uplifted and so extensively eroded
as to completely remove the Permian and Triassic sedimentary rocks
through much of the range prior to early Cretaceous time. The iron
deposits in the range were formed sometime during this interval either
related in some fashion to the diorite intrusives or the somewhat later
regional metamorphism.

When the King Lear formation was deposited in early Cretaceous time
considerable relief existed in the area with most of the high areas
underlain by the Happy Creek volcanic rocks or diorite. The rocks were
again folded following the deposition of the King Lear, and again in-
truded by diorite stocks. The copper deposits may have been formed
following the intrusion of the diorite, or they may be of Tertiary age.
Uplift and extensive erosion followed, so that when the Pansy Lee con-
glomerate was deposited much of the King Lear formation had been re-
moved and the relief in the area was low.

Before the end of the deposition of the Pansy Lee the local relief

had disappeared and all the material contributed to it was brought in from some considerable distance.

The Deer Creek thrust fault developed after the deposition of the Pansy Lee conglomerate. The age of the thrust with respect to the granodiorite intrusive is unknown but it is believed the granodiorite postdates the thrust. The development of the thrust can be regarded as the culminating phase of the late Cretaceous and early Tertiary orogeny and the granodiorite is probably a post-orogenic intrusive.

Sometime prior to middle Miocene time the rocks were intruded by dacite porphyry and microdacite stocks and dikes, following which a thick section of dacite to rhyolite flows, flow-breccias, and tuffs accumulated. A thick section of tuffs of rhyolite to quartz latite composition is probably younger than the dacitic flows. These rocks were partially eroded to produce the Tertiary conglomerate.

In middle Miocene to early Pliocene time basalt with interlayered fine-clastic sedimentary rocks accumulated all around what is now the Jackson Mountains. The complete absence of basalt in the upland areas of the range suggests the range was a positive area when the basalt was extruded, but late Tertiary erosion could also explain its absence.

The range had begun to take shape by displacement on high-angle faults at least as early as the period between the extrusion of the basalt and the younger rhyolite. After the extrusion of the rhyolite, continued movement on the faults took place, diabase dikes were intruded, and quicksilver was deposited in the diabase dikes and some fault zones.

Probably in early Quaternary time the gravel mounds in the south part of the range accumulated, probably as alluvial fans. Continued

displacement on the faults obliterated the physiographic features that controlled the formation of these old fans. This was followed by the development of the present range-front fans, and later the water of Lake Lahontan occupied the basins on both sides of the range and cut terraces in the fans and otherwise reworked the fan material. Fine-grained sediments accumulated in Lake Lahontan, and following or accompanying its desiccation the alluvial fans were dissected and the stream channels were filled with younger alluvium.

REFERENCES CITED

Bailey, E. H., and Phoenix, D. A., 1944, Quicksilver deposits in Nevada: Univ. of Nevada Bull., v. 38, no. 5, p. 101-106.

Benson, W. T., 1956, Investigation of mercury deposits in Nevada and in Malheur County, Oregon: U. S. Bur. Mines, Rept. Inv. 5285.

Compton, R. R. (in press), Contact metamorphism in the Santa Rosa Range, Nevada: Geol. Soc. America Bull.

Curtis, G. H., Evernden, J. F., and Lipson, J., 1958, Age determination of some granitic rocks in California by the potassium-argon methods: Calif. Div. of Mines Special Report 54, 16 p.

Durrell, Cordell, and Proctor, P. D., 1948, Iron-ore deposits near Lake Hawley and Spencer Lakes, Sierra County, California: Calif. Div. of Mines Bull. 129, part L., p. 167-192.

Ferguson, H. G., and Cathcart, S. H., 1954, Geology of the Round Mountain quadrangle, Nevada: U. S. Geol. Survey GQ-40.

Ferguson, H. G., and Muller, S. W., 1949, Structural geology of the Hawthorne and Tonopah quadrangles, Nevada: U. S. Geol. Survey Prof. Paper 216.

Ferguson, H. G., Muller, S. W., and Roberts, R. J., 1951, Geology of the Winnemucca quadrangle, Nevada: U. S. Geol. Survey GQ-11.

Gianella, V. P., 1941, Nevada's common minerals: Nev. Univ. Bull., v. 35, no. 6, Geol. and Min. ser. 36, 110 p.

Gianella, V. P., and Larson, E. R., (in press), Marine Permian at Black Rock, Nevada: Geol. Soc. America Bull.

Hague, Arnold, and Emmons, S. G., 1877, Descriptive geology: U. S. Geol. Expl. 40th Par. (King), v. 2, 890 p.

109

Hill, J. M., and Lindgren, Waldemar, 1912, The mining districts of the
    western United States: U. S. Geol. Survey Bull. 507, p. 212-216.

Holmes, Arthur, 1947, The construction of a geologic time scale: Geol
    Soc. Glasgow, Trans., v. 21, pt. I, p. 118-152.

King, Clarence, 1878, Systematic geology: U. S. Geol. Expl. 40th Par.,
    (King), v. 1, 803 p.

Larsen, E. S., Jr., Gottfried, David, Jaffe, H. W., and Waring, C. L.,
    1958, Lead-alpha ages of the Mesozoic batholiths of western North
    America: U. S. Geol. Survey Bull. 1070-B.

Lincoln, F. C., 1923, Mining districts and mineral resources of Nevada:
    Nevada Newsletter Publ. Co., Reno.

Lindgren, Waldemar, 1915, Geology and mineral deposits of the National
    mining district, Nevada: U. S. Geol. Survey Bull. 601, 38 p.,
    8 pls.

Longwell, C. R., 1949, Structure of the northern Muddy Mountain area,
    Nevada: Geol. Soc. America Bull., v. 60, p. 923-968.

Mackin, J. H., 1947, Some structural features of the intrusions in the
    Iron Springs district: Utah Geol. Soc. Guidebook to the geology
    of Utah, no. 2, 60 p.

MacNeil, F. S., 1939, Fresh-water invertebrates and land plants of
    Cretaceous age from Eureka, Nevada: Jour. Paleon., v. 13, p. 355-360.

Merriam, J. C., 1910, Tertiary mammal beds of Virgin Valley and Thousand
    Creek in northwestern Nevada, Pt. I-Geologic History: Calif. Univ.,
    Dept. Geol. Sci. Bull., v. 6, no. 2, p. 21-53.

Muller, S. W., Ferguson, H. G., and Roberts, R. J., 1951, Geology of the
    Mount Tobin quadrangle, Nevada: U. S. Geol. Survey GQ-7.

Nolan, T. B., 1943, The Basin and Range province in Utah, Nevada, and
California: U. S. Geol. Survey Prof. Paper 197-D.

Nolan, T. B., Merriam, C. W., and Williams, J. S., 1956, The strati-
graphic section in the vicinity of Eureka, Nevada: U. S. Geol.
Survey Prof. Paper 276.

Ransome, F. L., 1909, Notes on some mining districts in Humboldt
County, Nevada: U. S. Geol. Survey Bull. 414, 75 p.

Roberts, R. J., 1940, Quicksilver deposits of the Bottle Creek district,
Humboldt County, Nevada: U. S. Geol. Survey Bull. 922-A, p. 1-29.

Roberts, R. J., Hotz, P. E., Gilluly, James, and Ferguson, H. G., 1958,
Paleozoic rocks of north-central Nevada: Am. Assoc. Petroleum
Geologists Bull., v. 42, no. 12, p. 2813-2857.

Russell, I. C., 1885, Geological history of Lake Lahontan: A Quaternary
lake of northwestern Nevada: U. S. Geol. Survey, Mon. 11.

Schrader, F. C., Stone, R. W., and Sanford, S., 1917, Useful minerals
of the United States: U. S. Geol. Survey Bull. 624, 412 p.

Shawe, F. R., Reeves, R. G., and Kral, V. E. (in press), Iron ore de-
posits of Nevada, Part C. Iron ore deposits of northern Nevada:
Nev. Bur. Mines Bull. 53.

Vanderburg, W. O., 1938, Reconnaissance of mining districts in Humboldt
County, Nevada: U. S. Bur. Mines Inf. Circ. 6995.

Van Houten, F. B., 1956, Reconnaissance of Cenozoic sedimentary rocks
of Nevada: Am. Assoc. Petroleum Geologists Bull. 40, no. 12,
p. 2801-2825.

Wallace, R. E., Silberling, N. J., Irwin, W. P., Tatlock, D. B., 1959,
Preliminary geologic map of the Buffalo Mountain quadrangle, Nevada:
U. S. Geol. Survey MF-220.

Willden, Ronald, 1958, Cretaceous to Tertiary orogeny in the Jackson

    Mountains, Humboldt County, Nevada: Am. Assoc. Petroleum

    Geologists Bull., v. 42, p. 2378-2398.

    _____ 1960, Geologic map of Humboldt County, Nevada: U. S. Geol.

    Survey MF-236.

    _____ (in press), Geology of Humboldt County, Nevada: Nev. Bur.

    Mines Bull. 59.

APPENDIX A

The following section of the King Lear formation was measured on the southwest side of DeLong Peak, just south of the line of section A-A' (pl. 1).

Measured unit	Thickness in feet
Happy Creek volcanic series separated from King Lear by thrust fault	
King Lear formation (from top to bottom)	
Largely covered interval with a few outcrops of siltstone and sandstone, which probably make up all of interval----	400
Sandstone, greenish gray---	5
Cobbly siltstone and sandstone, green to gray, and dark-gray sandstone---	70
Sandstone, green, with some thin pebble layers------------	9
Cobbly siltstone, green, interbedded with medium- to coarse-grained sandstone. Pebble layers in some sandstone beds, sandstone beds 1-2 feet thick and siltstone layers 2-4 feet thick---	20
Cobbly siltstone, green---	6
Sandy siltstone, green to greenish gray, with interbedded fine- to medium-grained sandstone------------------------	15
Sandstone, greenish gray, medium- to coarse-grained, with thin pebble layers---	3
Sandstone, green to gray, medium-grained-----------------	20
Sandstone, reddish gray (brown-weathering), coarse-grained, with pebble layers---	5
Siltstone, green---	2

	Thickness in feet
Covered interval--	6
Sandy siltstone and graywacke, green and gray---------------------	15
Covered interval--	4
Graywacke, greenish gray, coarse-grained, with scattered pebbles---	1
Covered interval--	4
Siltstone, greenish gray--	8
Pebbly sandstone, gray, coarse-grained-----------------------------	16
Pebble conglomerate, reddish gray---------------------------------	10
Sandstone, gray, coarse-grained-------------------------------------	12
Pebble conglomerate and sandstone--------------------------------	6
Covered interval--	59
Covered interval with red siltstone float----------------------------	2
Graywacke, gray, coarse-grained-------------------------------------	4
Covered interval--	31
Covered interval with green to greenish gray medium to very coarse sandstone and pebble conglomerate float-----------------	8
Pebbly graywacke--	1
Covered interval--	53
Covered interval probably underlain by red and green siltstone---	48
Mudstone, dusky red---	17
Covered interval--	9
Sandstone and siltstone, gray--	1
Covered interval--	14

114

	Thickness in feet
Shaly sandstone, light gray, fine-grained	1
Covered interval	9
Sandstone, gray, coarse-grained	1
Covered interval with gray coarse-grained sandstone float	10
Covered interval	11
Sandstone, green to brown, medium-grained	18
Graywacke, gray (brown-weathering)	3
Cobble conglomerate	13
Pebble conglomerate with graywacke lenses	5
Pebble conglomerate, coarse-grained	3
Siltstone, dusky red, interbedded with medium-grained pebble conglomerate and coarse-grained graywacke	9
Siltstone, dusky red	6
Graywacke	2
Siltstone, dusky red, interbedded with greenish brown graywacke	65
Pebble conglomerate with scattered cobbles	3
Siltstone, dusky red	1
Pebble conglomerate	8
Cobble conglomerate, reddish brown	42
Siltstone, dusky red	2
Cobble conglomerate, reddish brown, poorly sorted	23
Total thickness of King Lear formation	1,119

Unconformity

Happy Creek volcanic series--Not measured

The following section was measured at the exposure of the Pansy Lee conglomerate northeast of King Lear Peak just south of the line of section B-B' (pl. 1).

Measured units	Thickness in feet
Alluvium	
Pansy Lee conglomerate (top to bottom)	
Pebble conglomerate--	50
Pebbly sandstone and pebble conglomerate---------------------	10
Sandstone with 6-inch pebble conglomerate near middle of bed--	2
Coarse pebble conglomerate with scattered cobbles----------	12
Pebble conglomerate, well sorted-------------------------------	5
Covered interval--	22
Sandstone--	5
Covered interval--	12
Pebble conglomerate--	4
Sandstone with one-pebble-thick pebble layers--------------	4
Coarse pebble conglomerate-------------------------------------	28
Sandstone with one-pebble-thick pebble layers--------------	3
Pebble conglomerate--	1
Sandstone--	1
Pebble conglomerate--	1
Covered interval--	14
Sandstone--	8
Sandstone, poorly sorted, with many scattered pebbles-----	6

Pebble conglomerate, well sorted-------------------------------------- 3

Sandstone, very coarse grained, with several one-pebble-thick

pebble layers--- 3

Pebble conglomerate--- 10

Coarse pebble conglomerate with some scattered cobbles----------- 30

Pebble conglomerate-- 3

Pebble conglomerate and very coarse sandstone------------------- 1

Coarse pebble to cobble conglomerate---------------------------- 2

Sandstone with 3-inch pebble layer near middle of bed---------- 3

Pebble to cobble conglomerate---------------------------------- 10

Sandstone-- 1

Pebble conglomerate--- 3

Covered interval--- 44

Pebble conglomerate, poorly sorted, with sandstone layer

2- to 6-inches thick near middle of bed----------------------- 7

Covered interval-- 43

Sandstone and shaly sandstone------------------------------- 8

Pebble conglomerate with some interbedded sandstone--------- 65

Cobble to boulder conglomerate, poorly sorted------------- 69

    Total thickness of Pansy Lee conglomerate   493

Covered interval--- 122

Base not exposed but probably near top of covered interval

Happy Creek volcanic series-------------------------------------Not measured

K. E. Lohman (written communication, May 16, 1958) has reported on a collection of diatomite from about one-half mile west of Norton's Ranch as follows:

"USGS diatom locality 4409. Norton's Ranch, northern center of Lovelock 1° quadrangle, Nevada. Diatomite from about one-half mile west of Norton's Ranch in the southern Jackson Range. Appears to be youngest lake bed exposed in the range. T. 36 N., R. 31 E. Coll. C. R. Willden, 1956, field no. F56W20.

21 species and varieties of fresh water diatoms were found in this collection. They are listed below, where relative abundances are indicated by A - abundant, C - common, F - frequent and R - rare.

- -

Cymbella affinis Kützing	F
cf. C. cuspidata Kützing	F
Fragilaria sp. A*	C
sp. A var. A*	F
sp. A var. B*	F
construens var. subsalina Hustedt	A
construens var. venter (Ehrenberg) Grunow	A
Gomphonema longiceps var. subclavata Grunow	R
Hantzschia amphioxys (Ehrenberg) Grunow	F

Melosira sp. A*   A

        cf. sp. A*   C

        sp. A var. A*   C

        undulata (Ehrenberg) Kützing   R

Navicula bacillum Ehrenberg   F

        cf. N. dicephala (Ehrenberg) Wm. Smith   F

        sp.   F

Opephora martyi Heribaud   R

Pinnularia cf. P. subpolaris (Grunow) Cleve   R

Tetracyclus ellipticus (Ehrenberg) Grunow*   F

        cf. T. ellipticus (Ehrenberg) Grunow*   F

        cf. T. sp. A*   R

This freshwater diatom assemblage is dominated by
pelagic species suggesting that the lake in which they
were deposited may have been either fairly deep or that
the water was too turbid to allow light to penetrate in
sufficient strength to the bottom where a bottom living
assemblage could prosper.

The assemblage contains a total of 8 extinct species
and varieties of diatoms, indicated in the list by an
asterisk (*) following the name. Most of these are new
species (indicated by sp. A, etc.) which I have described
in my Prof. Paper on the Cenozoic nonmarine diatoms from
the Great Basin, now in final preparation. Seven of the
8 species, and 62% of the whole assemblage also occur in
the middle of a 440 foot measured section in the Esmeralda

Page 120 is upside d

formation on the East slope of Cedar Mountain, Nye Co., Nevada, from which J. C. Merriam and others have described a lower Pliocene vertebrate fauna. The same seven extinct species and 57% of the whole assemblage also occur in a 150 foot measured section in the upper part of the lower Virgin Valley beds in northern Humboldt Co., Nevada. J. C. Merriam (1910) described a late middle Miocene vertebrate fauna from these beds. It so happens that the extinct species in question have known geologic ranges of late middle Miocene to early Pliocene and occur in both localities. Each of these two localities, however, contains shorter ranging species confined to the late middle and late Miocene on the one hand and to early Pliocene on the other, but these do not occur in the assemblage from locality 4409 near Norton's Ranch. Therefore the best age assignment that can be made is early Pliocene (most probable) or late middle Miocene (possible). The younger of the two ages is suggested by the fact that the other species in the assemblage, which range from Miocene to Recent are also present in the higher percentage in the early Pliocene Esmeralda formation. As the difference is slight, the safest assignment would be late middle Miocene to early Pliocene.

One additional sample from the Norton's Ranch locality, but stratigraphically lower in the same section might yield some of the very short ranging species characteristic of the lower part of the Esmeralda formation and enable a more definite age assignment to be made."