# THE GEOLOGY OF THE MOUNT ROSE AREA, NEVADA

by

JAMES GREGORY MOORE

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This report is preliminary and has not
been reviewed for conformity with U. S.
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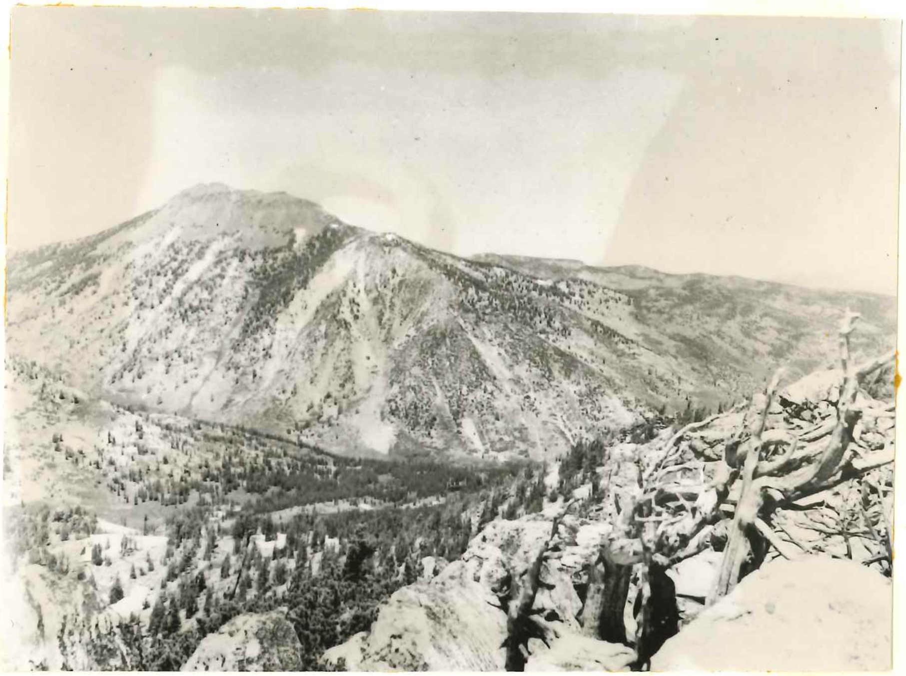

Frontispiece. The southeast side of Mount Rose viewed from the summit of Slide Mountain. Andesitic lavas and breccias 800 feet thick form the summit of the mountain and overlie unconformably the lighter colored granodiorite. Photograph by George Thompson.

# THE GEOLOGY OF THE MOUNT ROSE AREA, NEVADA

## INTRODUCTION

### GEOGRAPHY

The Mount Rose area is in the Carson Range, a part of the Sierra Nevada separated from the main range by the deep basin occupied by Lake Tahoe. The mapped area is in the east-central part of the range in western Nevada immediately north and northeast of Lake Tahoe, between west longitudes 119 degrees, 48 minutes, and 120 degrees, 00 minutes, and north latitudes 39 degrees, 17 minutes, and 39 degrees, 25 minutes. The region includes approximately 100 square miles of mountainous terrain. The city of Reno is about six miles north of the northern border on the mapped area.

State highway 27, the Mount Rose road, provides access to the region by connecting the southern part of Truckee Meadows with the Tahoe basin on the west of the Carson Range (Figure 1). Other passable roads penetrate several miles into the range in the valleys of Thomas and Whites Creeks. The higher part of the area is well served by trails, especially in the northern part.

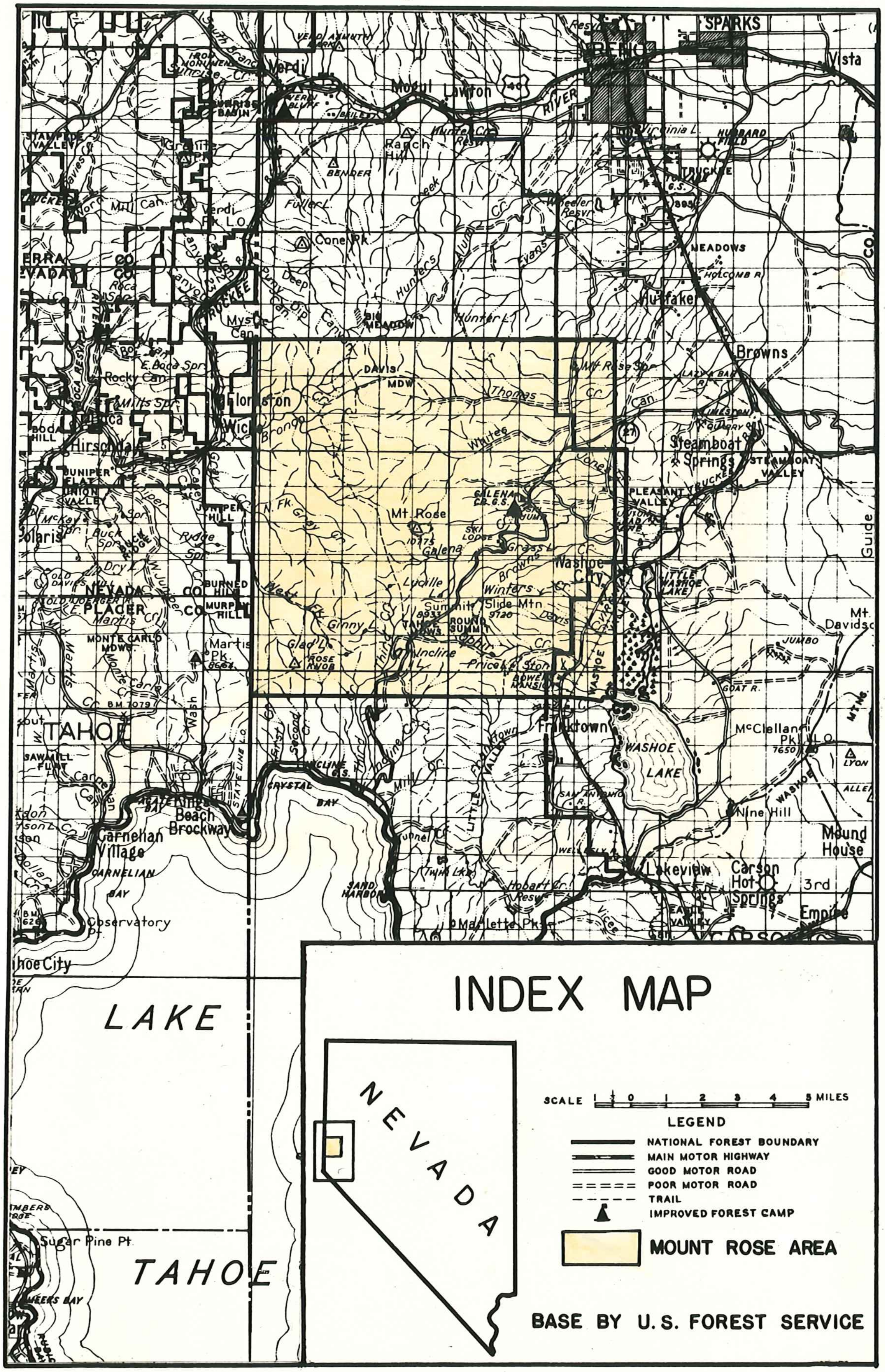
INDEX MAP
NEVADA
SCALE 1 ½ 0 1 2 3 4 5 MILES
LEGEND
NATIONAL FOREST BOUNDARY
MAIN MOTOR HIGHWAY
GOOD MOTOR ROAD
POOR MOTOR ROAD
TRAIL
IMPROVED FOREST CAMP
MOUNT ROSE AREA
BASE BY U.S. FOREST SERVICE
SPARKS
Reno
Vista
Verdi
Mogul
Lawton
Steamboat Springs
Washoe City
Mt. Rose
Franktown
WASHOE LAKE
Lakeview
Carson Hot Springs
Mound House
Nine Hill
Floriston
Hirschdale
Boca
Polaris
NEVADA
PLACER
TAHOE
Kings Beach
Brockway
Carnelian Village
CRYSTAL BAY
LAKE
TAHOE
Sugar Pine Pt.
Tahoe City

FIG. I

The crest of the Carson Range separates two profoundly different climatic provinces. In the heavily forested mountain regions to the west precipitation is high - from thirty to forty inches a year. Thick forests of pine, fir, and hemlock flourish up to timberline at 10,000 feet. Lakes, chiefly of glacial origin, are abundant and snow closes up the country in the wintertime.

The Great Basin to the east of the crest is semi-arid. Rainfall averages about eight or ten inches a year since the Sierra serves as a barrier for clouds from the Pacific Ocean. Sagebrush and pinion pine are about the only plants which can survive in such a climate.

## PREVIOUS WORK

The Mount Rose area has received only reconnaissance geological study prior to this investigation. W. Lindgren in 1897 made the earliest geologic investigations in the general region, in the Truckee quadrangle, which includes the area immediately to the west of the mapped area. G. D. Louderback published on the general geologic features of the entire Truckee region east of the Sierra Nevada in 1908 and again in 1926 discussed certain features of the Mount Rose area in connection with basin range structure. J. A. Reid (1911) made a detailed geomorphic investigation of the region south of the mapped area. J. C. Jones and V. P.

Gianella (1933) made a reconnaissance of the Carson Range and published the general geologic features as part of the 16th international geologic congress guidebook.

## ACKNOWLEDGMENTS

Geologic study of the Mount Rose area is part of a larger project conducted by the United States Geological Survey. The project centers about Steamboat Springs, Nevada, where mineral-depositing, thermal waters have long been of interest to geologists. In 1945 Dr. Donald White of the United States Geological Survey began a detailed examination of these hot springs, which lie just to the east of the area included in this thesis. In the summer of 1948, Dr. George Thompson, also of the Survey, began geologic mapping of the 15-minute quadrangle to the east of the springs, the Virginia City quadrangle, so as to investigate the regional structure and geology of the Steamboat Springs area. In the summer of 1950, Dr. Thompson and the author began mapping the adjacent 15-minute quadrangle to the west, the Mount Rose quadrangle. Field work was continued during the summer of 1951 in the Mount Rose area.

The author is most indebted to Dr. George Thompson under whose direction the geologic study in the Mount Rose area was done. Dr. Donald White, chief of the Steamboat Project, has aided by his extensive knowledge of the entire region, and by giving freely of his time in reading the manuscript. Acknowledgments are also due Wilfred Carr, Frank Campbell, and Russell Pomeroy for assistance in the field.

The entire faculty of the Department of Geology at the University of Washington, under whose direction this thesis was written, aided whenever possible. Dr. Peter Misch directed the parts on structural geology and basement rocks, Dr. Howard Coombs on volcanic rocks, and Dr. J. Hoover Mackin on physiography. Professor G. E. Goodspeed, chairman of the Department of Geology, extended innumerable courtesies.

The results of these geologic studies was authorized for use as thesis material by the Director, United States Geological Survey.

# TOPOGRAPHY AND DRAINAGE

The Mount Rose area includes the summit region and eastern slope of a part of the Carson Range. This north-trending mountain range is bounded on the west by the Lake Tahoe trough and the Truckee River canyon and on the east by Washoe Valley and other connected valleys to the north and south (Figure 1). The range is terminated on the north by the canyon of the Truckee River, but the range joins the main Sierra Nevada on the south in the vicinity of Jobs Peak and Freel Peak west of Genoa, Nevada. The surface of Lake Tahoe, west of the Carson Range, is 6,225 feet in elevation, but the floor of the Tahoe basin (approximately 5,600 feet) is roughly comparable in elevation to Washoe Valley (5,040 feet) east of the range. The Carson Range rises to a maximum of about 5,000 feet above these two basins. The highest point in the range is Mount Rose (10,770 feet); other high peaks in the mapped area are Slide Mountain (9,694 feet), North Rose (10,238 feet), and Rose Knob (9,800 feet).

The summit region of the range displays the topography typical of much of the lightly glaciated areas of the Sierra Nevada. Deep valleys and sharp peaks are somewhat subdued by post-glacial erosion and mass-wasting of the relatively soft rocks. Abundant glacial lakes still exist, though many have given way to high mountain meadows.

The Carson Range is drained by streams flowing east and west from the crest. Streams flowing down the west slope of the range reach the Truckee River west of the California state line and north of Lake Tahoe. Streams on the east flank of the range flow east to the system of flat-floored valleys bordering the range on the east. The east-slope drainage is conducted north to the Truckee River east of Sparks. All of the drainage is eventually conducted to Pyramid Lake, forty miles to the northeast, via the Truckee River.

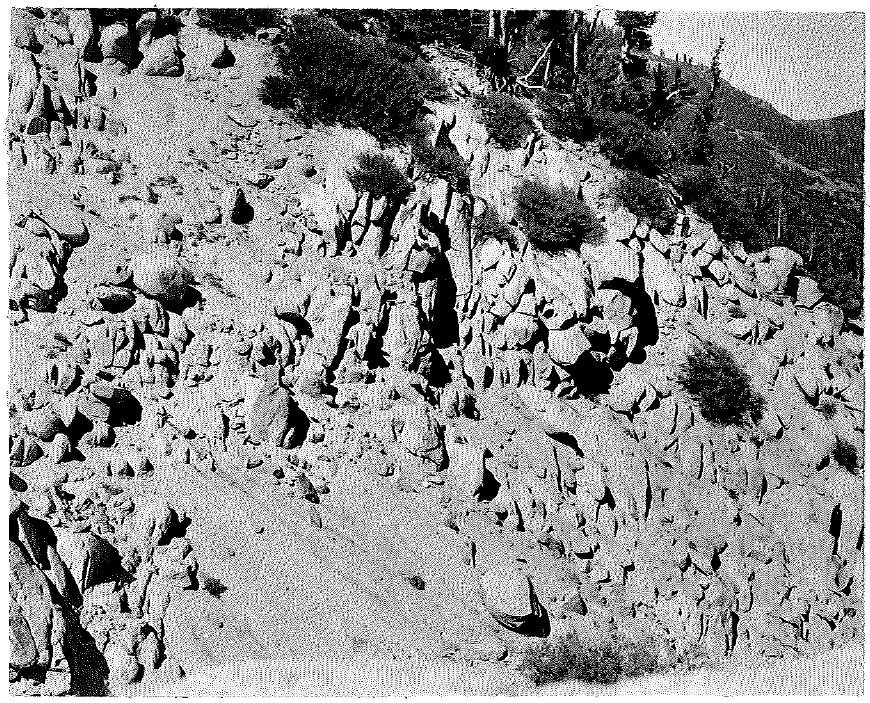

Fig. 2. Typical outcrop of granodiorite in the headwaters of Whites Creek. Rapid weathering along joints disintigrates the rock to coarse granitic sand.

Fig. 3. Looking west to the crest of the Carson Range south of North Rose. Kate Peak andesite overlies the granodiorite and forms steep crags and bluffs because of its greater resistance. Deep canyons expose the jointed character of the granitic rocks below.

# DESCRIPTIVE GEOLOGY

## METAMORPHIC ROCKS

### General Statement

A series of metamorphosed sediments are the oldest rocks in the Mount Rose area. These metamorphic rocks are exposed only in very small areas where they are surrounded by the Mesozoic granitic rocks or overlain by Tertiary volcanics.

The geologic map shows that the largest areas of metamorphic rocks are present at the headwaters of Jones Creek on the eastern scarp of the Carson Range. Other small outcrops occur along Whites Creek and Galena Creek and on the west flank of Slide Mountain.

The contact between metamorphic and granitic rocks is rather distinct, though in many places a gradational relation between normal metamorphic and normal granitic rocks may exist in a zone five or ten feet wide. Along these contacts inclusions of metamorphic rock, in part still preserving foliation, are scattered throughout the granitic rocks. The foliation within these inclusions is not parallel to that in the adjacent metamorphic rocks, and its orientation is different in different inclusions. Rotation of these inclusions

Fig. 4. Photomicrograph of andalusite-sillimanite hornfels from south of Whites Creek. Note the abundant, high-relief sheafs and cross-sections of sillimanite. Lower nicol. X23.

Fig. 5. Photomicrograph of hornfelsic biotite-diopside schist from western slope of Slide Mountain. The small, high-relief grains are diopside. Lower nicol. X20.

in grains which poikiloblastically enclose sillimanite and andalusite. There is some muscovite, apatite, rutile and later pyrite in the rock. The presence of the alumina-excess minerals, andalusite and sillimanite, indicates that this rock was derived from a pure argillite very low in lime and that it was subjected to high grade temperature conditions. The lack of any directional structure demonstrates that recrystallization took place under static conditions.

The small metamorphic body just north of upper Jones Creek is a biotite-andalusite hornfels with an incipient growth of sillimanite needles. About twenty-five per cent of the rock is composed of small, irregular grains of andalusite which are set in a hornfelsic mosaic of intergrown quartz and andesine-labradorite grains. This rock was originally a somewhat calcic sediment as shown by the development of calcic plagioclase. However, the presence also of the aluminum silicates, andalusite and sillimanite, indicates that the sediment was akali-poor and had, in spite of its Ca-content, an Al-excess, so that the aluminium silicates were not converted into akali feldspar and the plagioclase did not become more sodic. The rock underwent medium to high grade thermal metamorphism and developed its present mineral assemblage and directionless hornfels texture. Later hydrothermal alteration has impregnated the rock with pyrite and has chloritized the biotite.

The large east-west belt of metamorphic rocks south

## TABLE I

## OUTLINE OF ROCK FORMATIONS OF THE MOUNT ROSE AREA, WASHOE COUNTY, NEVADA

| | | |
|---|---|---|
| Quaternary | Alluvium and Valley Fill | Gravels, sand, silt, and alluvial fan material. |
| | Pediment Gravels | Veneer of unconsolidated gravels covering large pediment areas. |
| | Landslide | Unconsolidated rock debris. |
| | Moraines | Till of four glacial stages, tentatively correlated with Sherwin, Tahoe, Tioga, and Little Ice Age. |
| | unconformity | |
| Late Pliocene or Pleistocene | Lousetown Basalt | Olivine-bearing basalts forming flows and small intrusions. Thickness about 350 feet. |
| | unconformity | |
| Late Miocene Or Pliocene | Truckee Sediments | Thin-bedded, diatomaceous lake sediments containing charcoal, reeds, and stems. Thickness greater than 500 feet. |
| | erosion interval | |
| | Kate Peak Andesite | Pyroxene andesite flows, breccias, and small intrusions. Thickness greater than 1200 feet. |
| | unconformity | |
| Jurassic ? | Granodiorite | Hornblende-biotite granodiorite and associated dikes. Intrusive into metamorphic rocks. |
| | unconformity | |
| Triassic | Metamorphic Rocks | Hornfelsized shales, limey shales, and limestones. |

of Whites Creek is made up largely of dense-appearing, quartz-rich hornfels. Under the microscope these rocks are seen to have a fine-grained groundmass of quartz and potash feldspar. Large porphyroblasts of oligoclase up to four millimeters in length are present throughout the rock. The porphyroblasts include poikioblastically the minerals of the groundmass and show slightly crenulate and irregular borders. Biotite, muscovite, magnetite, and apatite are also present in the rock in small amounts. Judging from the mineral assemblage, this rock was originally a quartzose siltstone which has recrystallized under high temperature and static conditions forming the present quartzose hornfels. It is very possible that prior to the final recrystallization, the rock had developed some other metamorphic form, perhaps as a result of regional metamorphism, but all traces of any earlier stage of metamorphism have been obliterated by the final static recrystallization and development of porphyroblasts.

The metamorphic body mapped on the western flank of Slide Mountain is made up primarily of rocks derived from limy sediments. One specimen examined is a hornfelsic biotite-diopside schist containing a small amount of garnet. The rock has an overall hornfelsic texture, with a relict alignment of biotite plates still preserved from some earlier stage of synkinematic regional metamorphism (Figure 5). Diopside is present throughout the rock as equidimensional grains which have been altered in part to hornblende. Quartz and orthoclase form a hornfelsic groundmass composed of a tightly interlocking mosaic of small xenoblastic grains.

The rock probably originated from a dolomitic argillite which underwent first a period of regional metamorphism in which the rock acquired a distinct foliation. During a later static phase of high temperature recrystallization biotite crystallized and formed a mimetic foliation after the original schistosity, and diopside crystallized in equidimensional grains. Finally a later period of retrogressive metamorphism caused hornblende to develop from the diopside.

### Age and Origin

The age of the metamorphic rocks cannot be definitely established in the Mount Rose area. These rocks are older than the granitic rocks which intrude them. Hence the metamorphic rocks are earlier than late Jurassic which is the age traditionally assigned to the Sierra Nevada granitic rocks, judging from their relations in other areas (O. P. Jenkins, 1932).

Lindgren (1897) has found in the Truckee quadrangle, immediately to the west of the mapped area, Jurassic-Triassic ammonites in metamorphosed sediments similar to those of the Mount Rose area. From these data it might tentatively be assumed that the metamorphic rocks in the Mount Rose area are of Jurassic-Triassic age, though they might also be of late Paleozoic age.

All of the metamorphic rocks studied in the Carson Range were originally derived from sedimentary rocks. However, these original sediments were highly varied, comprising lime-free sandstones, argillites, and siltstones, as well as limy shales, dolomitic argillites, etc. In nearby areas, meta-tuffs are abundant. These rocks probably represent the remains of great thicknesses of sediment laid down in the Cordilleran eugeosyncline during Paleozoic and Mesozoic times which have survived the emplacement of the Sierra Nevada granitic complex. As shown by relict foliation in some of the metamorphic rocks, they were subjected to synorogenic regional metamorphism prior to the emplacement of the granitic rocks. A later period of high grade thermal metamorphism affected all the rocks by almost completely recrystallizing them. This later, static stage of metamorphism accompanied the emplacement of the Sierra Nevada granodiorite in late Mesozoic time.

## GRANITIC ROCKS

### General Statement

The bedrock which forms the core of the Carson Range and which outcrops throughout the entire range is a granular plutonic rock best described as a hornblende-biotite granodiorite. The rock is extremely uniform over vast areas;

similar rocks occur to the east in the Virginia range (Gianella 1936, p. 41) and as the backbone of the entire Sierra Nevada covering hundreds of square miles to the north and south. Lindgren (1897) describes the granodiorite in the Truckee quadrangle, just west of the Mount Rose area, in the following paragraph:

> The normal granodiorite is a light-gray rock, weathering into rounded outcrops and easily disintigrated by erosion. . . . The granodiorite is a medium- to course-grained rock, the average diameter of the grains being 2 to 3 millimeters. The grayish quartz and white feldspar grains are about of equal size. Black mica and hornblende are usually present in about equal quantities. The foils of the former reach 2 to 3 millimeters in diameter, while the hornblende is roughly prismatic, the crystals sometimes reaching 1 centimeter in length. Titanite is nearly always present in isolated, small, brownish grains. Magnetite is another universal accessory constituent. The appearance and composition of the rock are very constant over large areas, with only small variations in the quantity of hornblende or biotite.

Megascopically, the proportion of the pinkish potash feldspar to the plagioclase varies from 1:2 to perhaps 1:1. Therefore much of the rock might best be classified as a quartz monzonite; Gianella (1936) describes the granitic rock of the Virginia Range as quartz monzonite. A chemical analysis of the granodiorite from the foot of the Carson range is given in Table II with average analyses of granodiorite and quartz monzonite.

Granodiorite is exposed in larger areas in the southern part of the mapped area, especially in the vicinity

## TABLE II

## CHEMICAL ANALYSES OF GRANITIC ROCKS

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| $SiO_2$ | 64.6 | 65.9 | 66.6 | 65.0 | 57.5 | 57.2 |
| $Al_2O_3$ | 16.3 | 16.7 | 15.5 | 15.9 | 17.6 | 17.0 |
| $Fe_2O_3$ | 2.2 | .60 | 1.9 | 1.7 | 2.8 | 3.5 |
| FeO | 2.6 | 2.2 | 1.9 | 2.6 | 3.9 | 4.0 |
| MgO | 1.6 | 1.5 | 1.4 | 1.9 | 4.0 | 3.5 |
| CaO | 4.4 | 3.8 | 3.5 | 4.4 | 5.0 | 6.2 |
| $Na_2O$ | 3.6 | 3.6 | 3.4 | 3.7 | 4.3 | 3.4 |
| $K_2O$ | 2.9 | 2.8 | 3.7 | 2.7 | 1.6 | 2.2 |
| $TiO_2$ | .68 | .52 | | | .76 | |
| $P_2O_5$ | .34 | .15 | | | .20 | |
| MnO | .20 | .16 | | | .18 | |

1. Granodiorite from drill core, Geological Survey drill holes, Steamboat Springs (4 miles east of Mount Rose area). Rapid analysis by Geochemistry and Petrology Branch, U.S. Geological Survey, 1951.

2. Granodiorite from west of lower terrace, Steamboat Springs. Rapid analysis by Geochemistry and Petrology Branch, U. S. Geological Survey, 1951.

3. Average quartz monzonite, Wahlstrom (1948) page 283.

4. Average granodiorite, Wahlstrom (1948) page 283.

5. Dark, fine-grained inclusion in no. 2. Rapid analysis by Geochemistry and Petrology Branch, U. S. Geological Survey, 1951.

6. Average diorite, Wahlstrom (1948) page 307.

of Slide Mountain. To the north it outcrops chiefly in the bottom of the deep valleys of the east-flowing streams. This outcrop pattern suggests that the southern part of the Mount Rose area has been uplifted more than the northern part, and consequently more of the Tertiary volcanics have been stripped off in the southern areas exposing the granodioritic bedrock.

Figure 3 shows the typical sequence: granitic rocks overlain unconformably by the later Tertiary volcanic rocks. The granodiorite is quite subject to weathering and disintigration into granitic sand and hence it is etched away by erosion while the volcanics above stand out in cliffs.

The granitic rocks possess a remarkably uniform directionless structure. At no place is any distinctive alignment of the elongated minerals noted in the field. As mentioned above, the composition of the granodiorite is also extremely uniform over wide areas, but there are some notable exceptions. Adjacent to the metamorphic rocks south of Whites Creek the granitic rock becomes finer-grained and more basic in composition, approaching the composition of a quartz diorite and of a diorite (Figure 6). This more fine-grained, more basic variety is found to extend approximately one-quarter mile north, and slightly south, of the small metamorphic body at the crest of the ridge south of Whites Creek. Its position adjacent to the metamorphic body suggests that this diorite may be genetically connected with the metamorphic rock. The diorite fades imperceptibly into the granodiorite, but forms

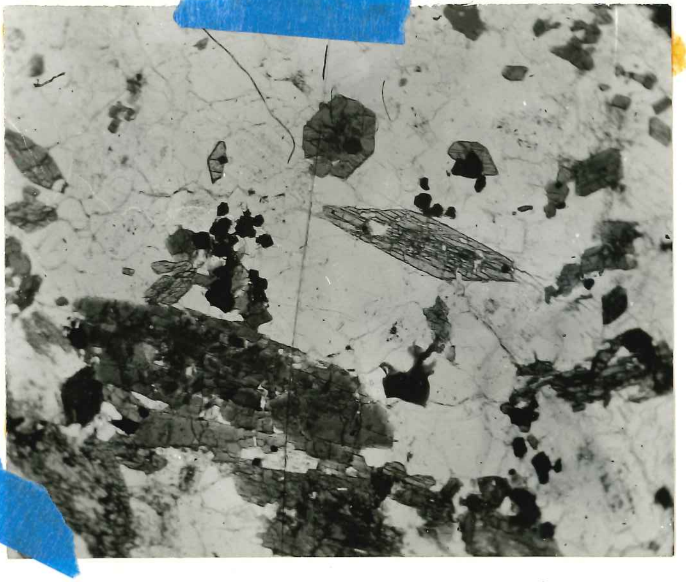

Fig. 6. Photomicrograph of diorite forming basic phase of granitic rocks near Whites Creek. Hornblende altering to biotite is enclosed primarily by plagioclase. Lower nicol. X20.

Fig. 7. Outcrop of hornblende-biotite granodiorite with typical dark, fine-grained inclusion. The inclusion protrudes from the surface because of its greater resistance to weathering.

a fairly sharp contact (where visible) with the metamorphic rocks. Near the contact the fine-grained dioritic rock is altered and stained an iron-brown color and is hence difficult to distinguish from the metamorphic rocks in the field.

Dark, fine-grained inclusions are very abundantly scattered throughout the granodiorite (Figure 7). They generally have rounded forms and are commonly two or three inches in diameter. Chemical analyses (Table II, numbers 5 and 6) show that the inclusions are dioritic in composition and considerably more basic than the granodiorite which encloses them. Near the contact of the granodiorite with the older metamorphic rocks, the inclusions become more abundant, and display angular outlines and metamorphic foliation which has been rotated relative to the foliation of the adjacent metamorphic country rock.

Dikes are common in the granitic rocks. Aplite dikes up to a foot or more in width are quite prevalent. In nearly all of the dikes, intrusive relations are demonstrated by the parallel, matching walls. Some dikes have sharp boundaries, but others show indistinct and fuzzy boundaries indicating continued crystallization after their intrusion. The dikes frequently show displacement by numerous small faults and shears which seldom offset the structure more than two feet. Pegmatite dikes are sometimes associated with the aplite dikes and occur parallel with them. Quartz and coarse potash feldspar crystals up to six inches in length make up the body of the pegmatites. Black tourmaline is common in the pegmatites, occurring either in large prismatic crystals or as a fine-grained aggregate. Graphic granite is also found associated with the pegmatites.

Microscopic Petrography

Most of the granitic rocks in the Mount Rose area display a typical hypidiomorphic granular texture with the crystals averaging two millimeters in diameter. Some granodiorites however suggest a crystalloblastic origin of both the mafic minerals and the feldspars as shown by irregular sutured boundaries and numerous inclusions within the minerals. The exact genetic relations of these granitic rocks have not been studied in detail and certainly deserve further investigation, preferably in an area where the relationships between metamorphic rocks and granitic rocks are widely exposed.

Plagioclase is universally present in the granitic rocks. The plagioclase generally is zoned progressively, with slight oscillations, from a calcic core to a more sodic rim. The center may have a composition of 35 to 55 per cent anorthite and the rim from 25 to 40 per cent anorthite; thus the plagioclase nearly always stays within the andesine range. Many of the plagioclases develop not only subhedral external form, but euhedral zones in their interior, and also euhedral zones of inclusions of magnetite.

Orthoclase and quartz do not show good crystal form and are usually interstitial to the plagioclase and mafics. Both contain inclusions of the other minerals; the orthoclase often contains smaller euhedral plagioclase crystals and is often partially altered to sericite.

Biotite is usually the most abundant varietal mineral though it is always associated with almost as much hornblende. The biotite occurs in clean, highly pleochroic plates which often show crenulated borders. The biotite is usually intergrown with secondary penninite. Euhedral needles and tabular crystals of apatite are nearly always found included in the biotite; the apatite occurs more commonly in biotite than in any other mineral. Large rounded pieces of magnetite are also often included in the biotite.

The other varietal mineral of the granodiorite, green hornblende, generally shows good crystal form, but is often poikilitic, containing a large number of inclusions among which magnetite, quartz, and apatite are the most common.

Accessory minerals such as sphene, apatite, magnetite, and zircon are almost always present in small quantities. Sphene is very common in the granitic rocks, and often occurs in grains large enough to be visible in hand specimen.

## Age and Origin

The age of the Sierra Nevada granitic complex has received long and careful study by geologists and is still the subject of some controversy. Lindgren (1897) in the Truckee quadrangle describes Jurassic-Triassic fossils in some sedimentary beds which are older than the granodiorite. In other parts of the Sierra, Chico beds of Cretaceous age lie unconformably on the granitic rocks. Hence the age of emplacement of the granitic rocks is probably latest Jurassic and/or early Cretaceous.

The granitic rocks have not been studied sufficiently to determine their mode of origin, though some suggestions may be made. One striking fact about the granodiorite is the wide areal extent over which there is little textural or mineralogical change. Also the rock displays no apparent directional structure in the entire area. These facts coupled with fairly sharp contacts and unoriented inclusions of metamorphic rock surrounded by granodiorite, indicate that at least much of the granitic rock is of intrusive, magmatic origin. Some small areas which have been briefly described, may be the result of local granitization.

## KATE PEAK ANDESITE

### General Statement

The dominant volcanic rock in the area is a very heterogeneous sequence of andesites occurring as lava flows, dikes, and breccias. Because of the close resemblance of these rocks to the Kate Peak andesites described by Gianella (1936, page 68) in the Virginia Range eight miles to the east, this sequence is given the same name. Very similar andesites are present over large regions to the west on the crest and western flank of the Sierra Nevada.* From a distance the Kate Peak formation appears brown or buff in color and hence contrasts sharply with the lighter granodiorite it overlies. The greater resistance of the Kate Peak to weathering makes it stand out in bold cliffs and bluffs (Figure 3).

In the field the andesites are seen to be of a great variety of types; in a typical outcrop of andesite breccia, as that shown in Figure 11, many varieties of andesite may be seen. The color ranges from light buff, gray, and pink, to dark brown, red, and black. Some andesites are very vesicular and glassy, others close-grained and stony. Most common are pyroxene andesites, containing phenocrysts of augite, hypersthene, and plagioclase, and displaying a marked porphyritic texture.

Perhaps forty or fifty per cent of the Kate Peak sequence is made up of lava flows which are interbedded with volcanic breccias. The various flows are themselves so local, and so intermixed with the breccias, that no attempt was made to map the flows and breccias as separate units or to differ-

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*Described by W. Lindgren (1896, 1897).

entiate the various lava flows. Commonly the breccias are abundant near the bottom of the sequence with flows near the top. The lava flows often develop a platy parting parallel to the flow planes (Figure 8); however, there seems to be no tendency toward the development of columnar jointing in the flows.

Porphyritic pyroxene andesites, predominantly with hyperathene, are most common in the flows. The clinopyroxene is often augite or pigeonite-augite. Basaltic hornblende is also a common mafic mineral, but biotite has never been seen in Kate Peak andesites in the Carson Range, though it is commonly a varietal mineral in the Kate Peak series of the Virginia Range.

Andesitic dikes which cut the Kate Peak extrusives are thought to be the feeders of the extensive andesitic volcanism in the area. These intrusives occur chiefly as elongated dikes near the crest of the Carson Range (Plate I). Undoubtedly, far more intrusive dikes and sheets of Kate Peak andesite exist than it was possible to distinguish in the field because of their close lithologic similarity with the lava flows. The presence of good columnar jointing is characteristic of the Kate Peak necks and dikes (Figures 10 and 12). Very often andesitic dikes display clearly marked dark, fine-grained selvages, while lava flows in the area do not.

The fact that the intrusive andesitic bodies are confined to the crest of the Carson Range indicates that Kate

Fig. 8. Closeup of porphyritic Kate Peak andesitic lava showing platey parting parallel to the flow planes.

Fig. 9. Photomicrograph of the andesitic lava shown in figure 8. The plagioclase phenocrysts have zoned inclusions of fine magnetite dust. The large mafic mineral in the center is augite, while most of the others are hypersthene. Note the three average sizes of the plagioclase crystals. The matrix is brown glass. Lower nicol. X20.

Fig. 10. Small, irregular andesite dike on the ridge at the head of Gray Creek. A well-formed dark, fine-grained selvage marks the intrusive contact with andesitic breccia below. Columnar jointing becomes finer and more irregular near the contact. The pick (arrow) indicates scale.

Fig. 11. Photomicrograph of specimen taken from fine-grained border of dike shown in figure 10. The groundmass is made up of a mesh of extremely small plagioclase microlites. Embedded in the groundmass are phenocrysts of oscilatory-zoned plagioclase with zoned inclusions of glass (left) and phenocrysts of green hornblende with reaction rims of magnetite (right). Lower nicol. X85.

Peak volcanism is genetically related to the range. The same is true of the Virginia Range to the east, for here also the volcanic rocks are largely confined to the range while the intervening valley appears to be relatively free of volcanism. This fact indicates that the structural conditions which controlled the uplift of these ranges is also related to the andesitic volcanism. The existence of the ranges as structural features therefore predates the Kate Peak volcanics, and is earlier than Pliocene-Miocene time.

Pyroclastic andesites are scattered stratigraphically throughout the Kate Peak sequence; however, they are most common at the base. In a typical outcrop as that shown in Figure 15, the size of the fragments may range from silt-size water-laid tuff to boulders over ten feet in diameter. Interbedded with coarse, mixed boulders are stream-laid deposits of fine arkosic sand and tuff. In a single outcrop these stream deposits may have a divergence of dip of as much as thirty degrees, due to crossbedding. The coarse material in the breccia is usually made up of subangular, andesitic fragments, widely differing in texture and composition. The ashy matrix is frequently lighter in color than the enclosed fragments and is less resistant to erosion than the fragments, causing the outcrops to weather to a knobby appearance.

In the western portion of the mapped area there are several regions in which the andesitic rocks are altered and bleached to a white, chalky material. Much of this bleached

Fig. 12. Small intrusion of Kate Peak andesite one and one-half miles southeast of Rose Knob (off the mapped area). The andesite displays good columnar jointing. Lake Tahoe is visible in the background.

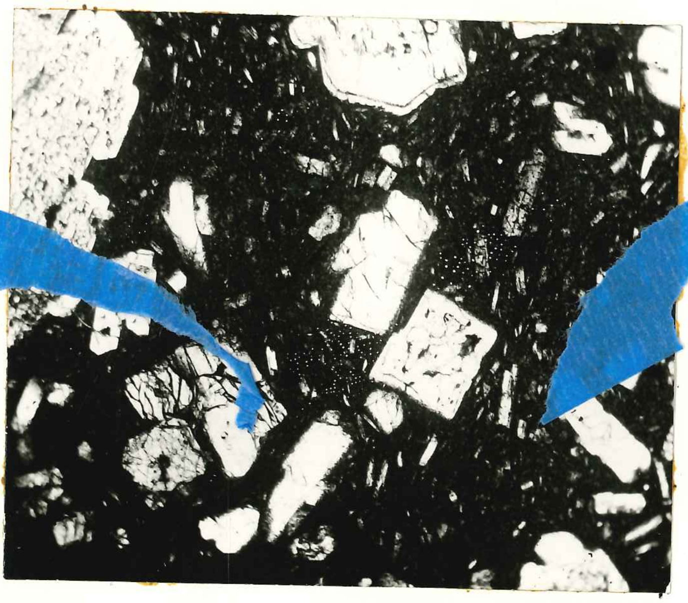

Fig. 13. Photomicrograph of the hypersthene andesite which forms the intrusion shown in figure 12. Zoned feldspar phenocrysts and large hypersthene phenocrysts are enclosed by an extremely fine-grained, nearly opaque groundmass. Lower nicol. X20.

andesite is impregnated with large amounts of pyrite which fills small cracks and fissures in the rock and in some cases replaces the ferromagnesian phenocrysts of the original andesites. These areas apparently underwent widespread alteration as a result of ascending, sulfurous waters which intimately penetrated the fractured lavas and porous breccias.

### Microscopic Petrography

The texture of the Kate Peak rocks varies widely with the mineral composition and the field relations. However, almost all the andesites are decidedly porphyritic with an average of thirty per cent of the volume of the rock made up of phenocrysts. The groundmass is usually a closely-packed mesh of small plagioclase microlites without interstitial glass, i.e. the texture is pilotaxitic as shown in Figures 11, 13, and 14. Abundant interstitial glass is important in some andesites (Figure 9). The dark-colored selvage of many of the dikes is due to the extremely fine grain-size of the plagioclase microlites adjacent to the intrusive contact rather than to the development of a large amount of glass.

Plagioclase is the dominant mineral in all the Kate Peak series. It averages perhaps seventy per cent of the total volume of the rock and eighty per cent of the volume of phenocrysts. Almost invariably the plagioclase phenocrysts display good crystal outline and prominent oscillatory zoning with a progression from a core of labradorite to a rim of

Fig. 14. Photomicrograph of hornblende-hypersthene andesite from lower Thomas Creek. A chemical analysis of this rock is shown in Table III, no. 1. Note the three distinct sizes of the andesine crystals. The black areas are hornblende phenocrysts almost completely oxidized to magnetite. Lower nicol. X20.

## TABLE III

## CHEMICAL ANALYSES OF ANDESITE

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| $SiO_2$ | 62.6 | 60.3 | 63.8 | 62.08 | 63.16 |
| $Al_2O_3$ | 18.5 | 16.9 | 15.9 | 17.25 | 18.22 |
| $Fe_2O_3$ | 3.0 | 3.7 | 3.2 | 1.80 | 1.36 |
| FeO | 1.3 | 1.9 | 1.2 | 3.32 | 3.33 |
| MgO | .67 | 2.2 | 2.2 | 2.91 | 2.30 |
| CaO | 5.5 | 5.6 | 4.4 | 5.43 | 5.24 |
| $Na_2O$ | 4.4 | 3.9 | 3.9 | 4.18 | 4.06 |
| $K_2O$ | 1.7 | 2.1 | 2.5 | 1.84 | 1.86 |
| $TiO_2$ | .38 | 1.1 | .63 | .20 | .54 |
| $P_2O_5$ | .23 | .26 | .16 | .85 | .14 |
| MnO | .08 | .02 | .03 | .08 | trace |

1. Hornblende-hypersthene andesite from lower Thomas Creek, Mount Rose area, Nevada (fig. 14). Rapid analysis by Geochemistry and Petrology Branch, U. S. Geological Survey, 1951.

2. Biotite-hornblende andesite from the Lousetown road near Long Valley, Virginia Range, Nevada. Rapid analysis by Geochemistry and Petrology Branch, U.S. Geological Survey, 1951.

3. Intrusive biotite andesite from quarry on hill north of Mount Grosh, Virginia Range, Nevada. Rapid analysis by Geochemistry and Petrology Branch, U.S. Geological Survey, 1951.

4. Andesite from Mt. Rainier, near the terminus of the Nisqually Glacier. H. A. Coombs (1939) page 1506, no. 7.

5. Pyroxene andesite (Pleistocene) with 18.7 per cent normative quartz: Mount St. Helens, Washington. J. Verhoogen (1937) page 293, no. 4.

calcic andesine. The phenocrysts are often made up of a group of intergrown feldspar crystals; penetration and cruciform twins are common. The plagioclase phenocrysts often contain zoned inclusions of glass near their periphery. Also inclusions of fine magnetite dust may be zoned parallel with the crystal faces. Usually in random orientation are fine needles of apatite.

Plagioclase usually occurs in three or four distinct size ranges in the andesites (Figure 14). The large phenocrysts of one specimen are 1.5 millimeter in diameter, an intermediate size is 0.3 millimeter in diameter, and the groundmass microlites are about 0.1 millimeter in diameter. This size relationship of the plagioclase crystals has been pointed out by G. O. Smith (1904, p. 58) and again by H. A. Coombs (1939, p. 1502) in the Cascade andesites of Washington. Even the small microlites usually show zoning from a calcic core to a more sodic rim.

Perhaps the most common mafic mineral in the Kate Peak andesites is augite, but very commonly the axial angle of the clinopyroxene is from forty to sixty degrees - hence the pigeonite molecule is often present, and in many of the andesites common pigeonite has been identified. The clinopyroxenes also show zoned inclusions of magnetite, and often the central core has a higher birefringence than the borders. Most of the rocks have the clinopyroxene present both as euhedral phenocrysts and as small grains scattered through the

Fig. 15. Outcrop of typical Kate Peak andesitic tuff-breccia on upper Thomas Creek. Cross-bedded stream deposits are interbedded (up to three feet in diameter) embedded in a tuff matrix.

Fig. 16. Photomicrograph of the tuff matrix shown in figure 15. Pyroclastic fragments of andesite, basalt, and all manner of crystals are scattered in a devitrified groundmass. Lower nicol. X20.

groundmass.

Hypersthene is very characteristic of the Kate Peak series and often it is the most abundant mafic mineral, though hypersthene has never been seen in an andesite which did not also contain some clinopyroxene; many rocks have augite but no hypersthene. The hypersthene generally shows good pleochroism and parallel extinction, although extinction angles up to ten degrees sometimes occur.

Basaltic hornblende is the most common amphibole in the andesites, though in some specimens ordinary green hornblende is present. Almost always the hornblende is jacketed by a thick reaction rim of black magnetite (Figures 11 and 14). In some rocks only pseudomorphs of magnetite after hornblende indicate that hornblende was at one time present, but has since been completely changed over into magnetite. Hornblende has never been seen in the groundmass.

Biotite has never been observed in any Kate Peak andesites from the Mount Rose area. Lindgren (1897), however, describes biotite andesites from the Truckee quadrangle just west of the mapped area and Gianella (1936) notes that biotite is one of the most prominent mafics in the type Kate Peak series of the Virginia Range east of the mapped area.

The most common accessory minerals in the andesites are magnetite and apatite. The magnetite occurs as abundant inclusions in phenocrysts of plagioclase and mafic minerals and also as an important constituent of the groundmass. Apatite usually is present as tiny needle-like microlites in the groundmass.

## Age and Origin

The age of the Kate Peak rocks is based on a study of the fossiliferous Truckee formation with which the Kate Peak is closely associated. Near Verdi, Nevada, north of the mapped area, the Kate Peak andesites grade up into, and are interstratified with the lower part of the Truckee formation. Also north of Thomas Creek in the northeastern part of the mapped area, the Truckee formation appears to rest conformably on the Kate Peak andesites (Plate I). The Kate Peak rocks are believed to be contemporaneous or slightly older than the Truckee beds. Calkins (1944) writes concerning the age of the Kate Peak formation:

> The best indication as to the age of the Kate Peak andesitic series is given by fossil leaves and diatoms found in lake deposits interbedded with tuffs of the series, at and near the diatomite quarries in Long Valley, about 7 miles northeast of Virginia City. K. E. Lohman, who studied the diatoms, and Roland W. Brown and Ralph W. Chaney, who studied the leaves, all agree in placing the age of these beds near the passage from Miocene to Pliocene.

The Kate Peak andesites were extruded as a complex mixture of lava flows and pyroclastic ejections presumably having their source of eruption near what is the present crest of the Carson Range. At roughly the same time similar andesites were being extruded in the Virginia range and over very large areas to the west on the main crest of the Sierra Nevada.

The surface on which the andesites were ejected was not as steep as that of the present range, but there was moderate relief.

The vast amount of pyroclastic material was probably ejected from vents and was distributed throughout a wide area from these vents. There are no indications of the development of prominent volcanic cones in the area. The pyroclastic material becomes somewhat coarser in size near its source at the crest of the range. Volcanic avalanches and mudflows, as well as streams, were active in moving and reworking the unconsolidated pyroclastic material.

## TRUCKEE SEDIMENTS

### General Statement

Large areas of distinctive, well-bedded lake sediments are exposed just north of the mapped area in the gorge of the Truckee River. These beds were called the Truckee series by Louderback (1908), and were first described from the Kahsoh Mountains and along the eastern edge of the Virginia Range. Similar beds, considered part of the Truckee series, are found near the summit of the Virginia Range northeast of Virginia City; north of Peavine mountain; in the Mount Rose area on the eastern foot of the Carson Range; and high in the

Carson Range.

The Truckee sediments are generally poorly consolidated, friable shales and siltstones which display excellent stratification. The unit is very soft and non-resistant and therefore is usually exposed only in stream gorges or recent excavations such as road cuts. Much of the series contains diatomaceous earth of great purity which has been mined in several localities in the Virginia Range. There are also fossil localities in the Truckee series in which leaves, stems, and seeds of plants have been found, as well as some shells and fish.

In the northeastern corner of the mapped area the Truckee sediments are present as a belt at the foot of the range. The sediments in this region are very soft, thin-bedded, white diatomaceous shales which can be traced only in road-cuts on these low mountain slopes. The sediment is very thinly bedded, and is capable of being split into sheets less than one-quarter of an inch thick. Just to the north of this area the sediments are well exposed in the pediment gorge of Dry Creek, and here masses of stem and reed accumulations are interbedded with diatomaceous shales. Charcoal is also common either as separate fragments or associated with the lignite accumulations of twigs and stems. The beds mapped in the northeastern corner of the area are dipping strongly (about 30 degrees) to the east.

Only one other locality of the Truckee sediments has been found in the Mount Rose area; it is at an elevation of 8,800 feet in the headwaters of Galena Creek (Plate I). A young stream, which has cut through the thick morainal deposits of upper Galena Creek, has exposed these sediments only in one small area. However, the sediments, though poorly bedded, display the same reed and stem remains as is common in the Truckee sediments at the foot of the range.

## Age and Origin

Louderback (1908) on the basis of field relations and fossil leaves in the Truckee beds set the age of the sediments as upper Miocene or Pliocene. This early estimate has been further verified by detailed study of the leaves and diatoms preserved in the Truckee sediments.*

The Truckee sediments were deposited in lakes which must have occupied large areas in Nevada and may have been comparable to the younger (Quaternary) Lake Lahontan and Lake Bonneville. The presence of interbedded coarse material, lenses of fossil beds, and cross-bedding, indicate that the lakes had considerable periodic fluctuations in areal extent. Fossil stems, reeds, diatoms, and the leaves of deciduous trees in the Truckee sediments demonstrate that the beds were deposited in lakes in a humid, temperate climate at a fairly low elevation. The Truckee beds at an elevation of

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*F. C. Calkins (1944).

8,800 feet in the Carson Range and those near the crest of the Virginia Range at 5,800 feet must have been considerably elevated after their deposition.

The disruption of drainage, resulting in the lakes in which Tuckee sediments were deposited, may well have been due to the initial upwarping and upfaulting which has continued since and has formed the present basin-range type of physiography.

## LOUSETOWN BASALT

### General Statement

In the northern part of the Mount Rose area on the generally well-developed flat upland of the range, basaltic rocks cover large areas. Because of the similar field and petrologic features of these basalts with the Lousetown series (described by T. P. Thayer, 1937, page 1648) in the volcanic sequences of the Virginia Range, the basalts in the Carson Range have been given the same name.

In the Sierra Nevada the Lousetown series is confined to the northern portion of the mapped area with the exception of several small necks or equidimensional intrusions in the southern part of the area. Even south of the mapped area in Little Valley there are some small intrusive bodies of an olivine basalt which does not look unlike the Lousetown basalt to the north. The Lousetown basalts in the northern portion of the mapped area are predominantly lavas which probably originated in quiet fissure eruptions. The basalt of these flows forms a fairly thin sheet which lies unconformably on the older, somewhat tilted, Kate Peak andesites. The thickness of the basalt may be as great as 350 feet in some places.

The predominance of the younger rocks in the northern part of the range has already been mentioned in regard to the distribution of the Kate Peak series. It follows that if the entire area had been covered evenly at one time by the basalts of the Lousetown series, the uplift of the range must have been more pronounced in the southern part, resulting in the more rapid removal of younger rocks to the south.

The Lousetown basalts are generally aphanitic, nonporphyritic rocks with a general fresh appearance. The rock is usually quite dark on a fresh surface, but weathering produces a red-brown, pitted surface. Occasionally small phenocrysts of feldspar and olivine are megascopically visible.

The Lousetown basalts commonly develop a remarkable platy cleavage which splits a rock mass into innumerable shingle-like sheets. This platy parting is parallel to the flow banding (Figure 17). Cleavage in the basalt is produced by late planes of flow which align the feldspars and serve as avenues for late volitiles to alter the rock and form the planes of weakness (Figure 18). Aside from the basalts which show good platy parting, are large areas of blocky material which probably represents the irregular aa surface of lava

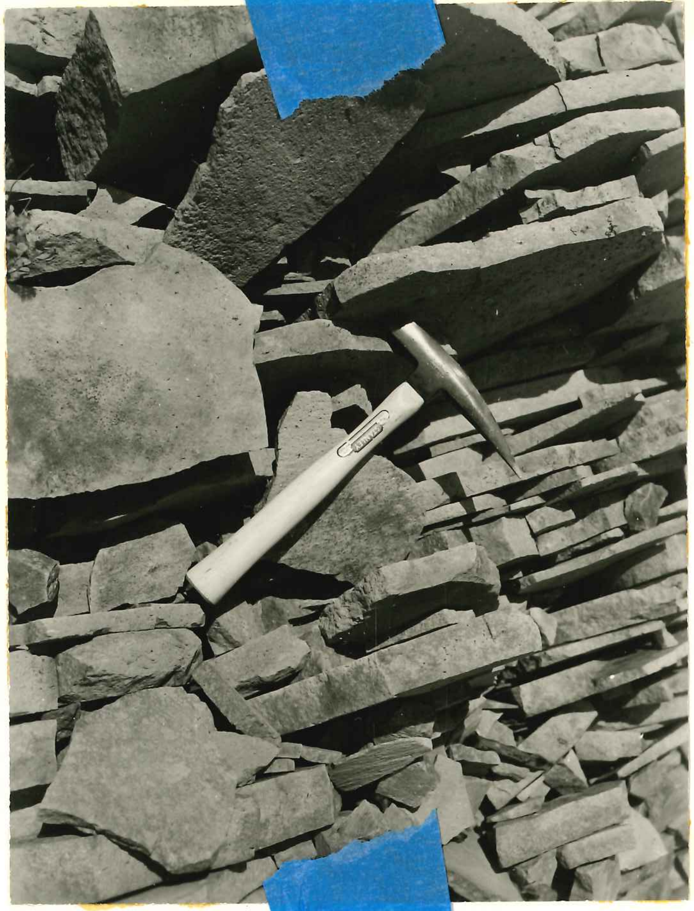


Fig. 17. Lousetown basalt east of Davis Meadow with typical development of platy parting.

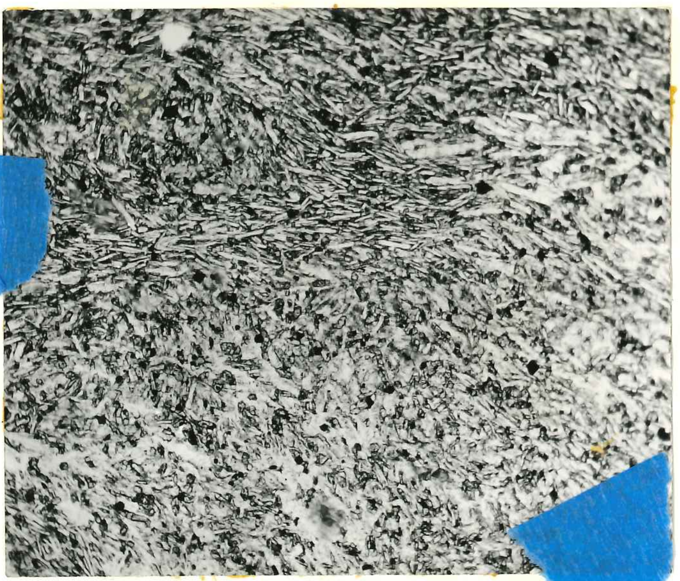


Fig. 18. Photomicrograph of platy Lousetown basalt shown in figure 17. Cleavage in the basalt is produced by late planes of flow (center), which align the feldspars and serve as avenues for late volatiles which alter the basalt along certain planes. Lower nicol. X60.

flows (Figure 19). The basalts of these blocky areas are commonly scoriaceous and often there are areas of reddish, hydrothermally altered basalt.

In the northwestern corner of the mapped area is a basaltic cinder cone developed during the extrusion of the Lousetown basalts. Although considerably eroded, the cone is now a gentle ridge made up of reddish, frothy basalt scoria. Scattered about the area are masses of ropy lava and fragments of volcanic bombs.

## Microscopic Petrography

The mineralogical composition of the Lousetown Series varies considerably from place to place in the Mount Rose area. The small basaltic intrusions to the south show particular variation, probably as a result of local, partial assimilation of the wall rocks. A few examples will point out the mineralogical variation in these basaltic rocks. Lava from the flows near Bronco Creek is an andesine basalt containing a few, small resorbed crystals of olivine and a finely granular pyroxene in the groundmass. A specimen from east of Davis Meadow is a typical olivine basalt with augite as the clinopyroxene (Figure 18). The basaltic neck east of North Rose is an olivine-hyperathene-augite basalt, slightly porphyritic, with good flow orientation of the well-developed labradorite laths. The basaltic intrusion south of Glad Lake in the southwestern corner of the geologic map is a very vesi-

Fig. 19. Blocky, irregular surface of Lousetown basalt lava flow north of Davis Meadow. Some of the basalt is quite vesicular.

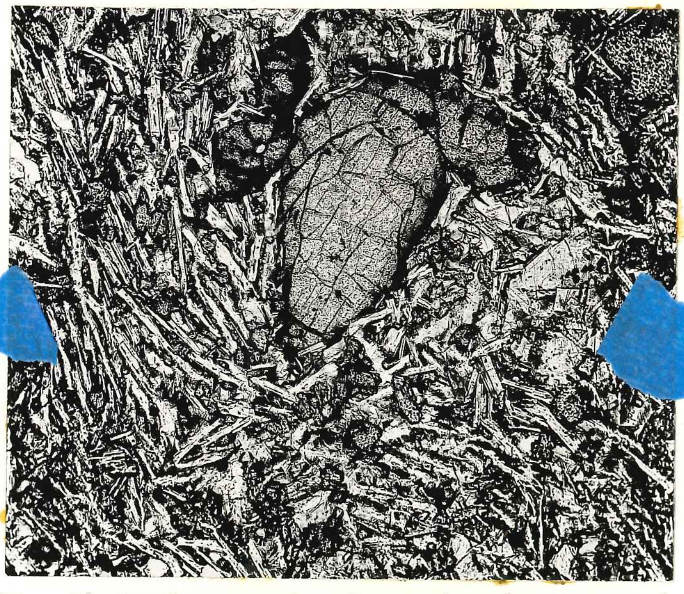


Fig. 20. Photomicrograph of massive Lousetown basalt from specimen similar to that shown in figure 19. Large hypersthene phenocrysts are embedded in intergranular groundmass of plagioclase laths and grains of clinopyroxene. Lower nicol. X50. Photomicrograph by Russell Pomeroy.

ocular basalt with a few resorbed crystals of olivine, and augite as its only pyroxene. The small intrusion south of Incline Lake is made up of a basalt with abundant phenocrysts of pigeonite, which also occurs in the groundmass as irregular grains; this neck contains a large amount of granitic inclusions, apparently torn from the walls and mixed throughout the mass during intrusion. The bodies mapped as intrusive show sharp contacts in the field.

In the field it is sometimes possible to detect on the borders of these basaltic intrusions an actual fusing of the granitic country rock to form a black, vitreous glass. Under the microscope this melting and alteration of the wall rock by the hot basaltic magma is especially apparent (Figures 21 and 22). The granodiorite forming the walls of a small intrusion in Little Valley (south of the mapped area) was affected only in a thin zone adjacent to the basalt, but the heat of the basaltic magma was sufficient to fuse the quartz of the granodiorite into an isotropic glass. Reaction rims of radial pyroxenes also developed around the quartz crystals of the granodiorite. The oligoclase of the granodiorite, having a lower melting point than the labradorite of the basalt, underwent incipient melting and alteration along minute cleavages.

All of the Lousetown basalts observed have a fine intergranular texture with small microlitic laths of plagioclase intermixed with tiny irregular grains of pyroxene. Very

Fig. 21. Photomicrograph of the contact between basaltic intrusion in Little Valley and an included fragment of granodiorite. The quartz of the granodiorite (center) is fused to glass on its borders and has developed reaction rims of radial pyroxenes, while the plagioclase has undergone incipient melting and alteration along minute cleavages. Lower nicol. X20.

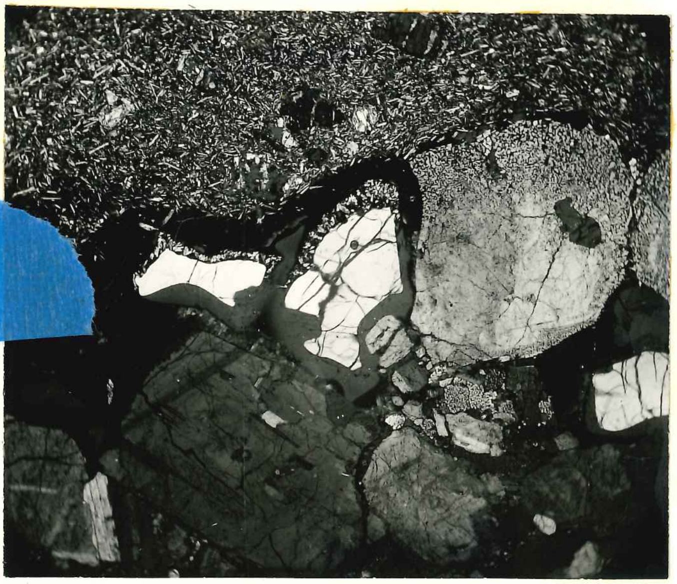


Fig. 22. Same as figure 21 under crossed nicols.

often the plagioclase microlites are aligned by flow, either throughout the entire rock, or in certain definite planes. Most of the rocks contain a very few scattered phenocrysts averaging about one-half millimeter in diameter and making up less than five per cent of the rock.

The plagioclase occurs in small lath-shaped microlites which average about 0.1 millimeter in length. Even these tiny microlites are zoned from a calcic core to a more sodic rim; the average composition of the microlites ranges from 45 per cent anorthite to 65 per cent anorthite. Phenocrysts of plagioclase are rare; those present often contain inclusions of pyroxene and possess rounded lobate borders. Plagioclase makes up on the average 55 per cent of the rock.

The main pyroxene in the Lousetown basalts is augite which is present both as rare phenocrysts, and as fine grains scattered abundantly throughout the groundmass. The phenocrysts rarely exceed one millimeter in diameter. Hypersthene is also very common in the basalts, especially in the flows to the north (Figure 20). The hypersthene is readily identifiable when it occurs as phenocrysts (about one millimeter in diameter in many of the lavas), but whether it also occurs in the groundmass is not definitely known. The fine, granular pyroxene in the groundmass always seems to be a clinopyroxene.

Olivine forms conspicuous phenocrysts in nearly all of the basalts. The olivine crystals are rounded and jacketed with iddingsite or iron-oxide. Sometimes the reaction rim on the border of the olivine crystal is extremely thick and often the olivine is entirely altered. Olivine occurs only as small phenocrysts (0.2 to 0.5 millimeter) and never as a constituent of the groundmass. Its general relations indicate that the olivine crystals are unstable in the melt at the time of consolidation and that it is therefore being resorbed.

The groundmass of all the basalts contains about five per cent magnetite. In addition fine apatite needles are seen in the groundmass and cristobalite was noted as a vesicule filling in one specimen.

### Age

The Lousetown Series overlies the Kate Peak andesites which have been described as Pliocene-Miocene in age. There is a general unconformity between the Lousetown and the Kate Peak andesites; in places the Kate Peak andesite is tilted, beveled, and more highly displaced by faults than is the overlying Lousetown Series. Elsewhere Lousetown basalts overlie Truckee sediments, unconformably in places.

Fragments of Lousetown basalt are found in Pliestocene moraines and on the high, dissected pediments of the Truckee River north of the mapped area.

Based on this limited evidence, the age of the Lousetown Series of the Mount Rose area is set at late Pliocene or early Pleistocene. Calkins (1944) regards the Lousetown of the Virginia Range as contemporaneous with Gianella's (1936, page 76) Knickerbocker andesite tentatively dated as late Pliocene. Thayer (1937) regards the Lousetown of the Virginia Range as similar in age to the Minto Series of Oregon which he considers (page 1619) as being late Pliocene or Pleistocene in age.

## QUATERNARY DEPOSITS

### Moraines

During Pleistocene time glaciers developed in the Mount Rose area. Compared with much of the Sierra Nevada to the south and west, the glaciation in the Carson Range was slight; however, the topography has been considerably altered as a result of erosion and deposition by glaciers that occupied the major canyons of the region. Today there are no glaciers in the mapped area and generally no snow patches survive the summer except following winters of more than average precipitation.

A reconnaissance study of the moraines themselves suggests that there were four glacial stages in the Mount Rose area which are represented by four ages of glacial till:

(1) The oldest-appearing till is exposed in the lower part of Galena Creek east of Grass Lake. This morainal material is highly weathered and has a strong soil development. Granodiorite boulders in the till at the surface are completely

decomposed to granite sand, and volcanic boulders, though deeply weathered, still have a hard core. Even in very deep exposures, this morainal material displays a total disintigration of its granitic components. These oldest till deposits preserve no original depositional landforms. It is noteworthy that in contrast with the younger tills, confined to the valleys, the remnants of the oldest till occur also on interstream uplands.

(2) The second group of moraines still show definite, though somewhat subdued, topographic form and are composed of fresher-looking till in which granitic boulders are weathered, but nevertheless intact. Figures 23 and 24 show the nature of this intermediate till. The till is made up of rock flour and granitic sand in which boulders of both granodiorite and andesite are scattered. Granodiorite is weathered to such an extent that it rarely retains glacial polish or striations, but the andesite boulders and ledges often display striations caused by ice movement (Figure 24).

The finest example of moraines in this second group is the large lateral moraine on the south side of Galena Creek canyon (Figure 25). This high lateral ridge can be traced for over three miles; its height indicates that the ice which flowed down Galena Creek was more than 480 feet thick. The Galena Creek canyon still preserves its typical glaciated U-shape (Figure 26).

The moraine of the second group in Third Creek in the

Fig. 23. Intermediate (Tahoe ?) glacial till exposed in a stream gorge in upper Galena Creek. Granitic and andesitic boulders of all sizes are embedded in a matrix of finer material.

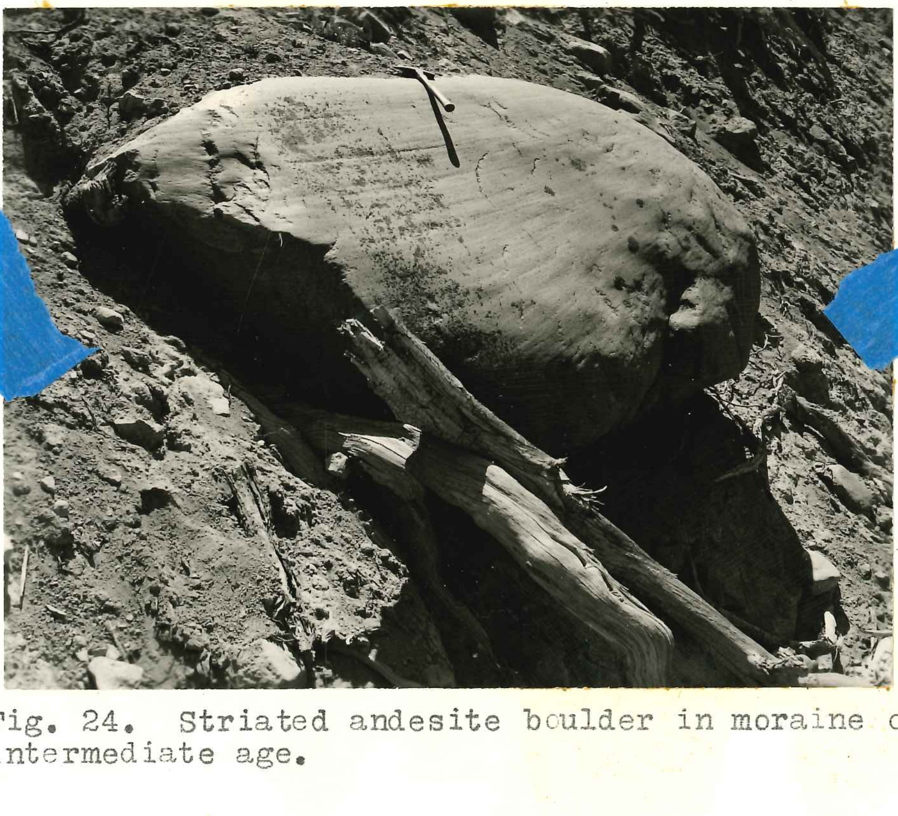


Fig. 24. Striated andesite boulder in moraine of intermediate age.

Fig. 25. The long, straight lateral moraine of Galena Creek as seen from the shoulder of Mount Rose. The Virginia Range is visible in the distant background.

Fig. 26. The glaciated canyon of Galena Creek from the west. The arrow indicates the direction of ice flow. Mount Rose, covered by andesite, is to the north.

southwestern part of the mapped area also displays excellent lateral moraines. This glacier drained to the west toward Lake Tahoe, but probably did not reach the lake. The terminal moraines of this, like all glaciers of this second group, are nearly completely obliterated and hence it is difficult to determine the exact extent of the ice tongue.

The large moraines of South Fork Bronco Creek, Gray Creek, and West Fork Gray Creek also belong to the second group of moraines. On the east side of the crest of the Carson Range, small moraines probably of the same age occupy high cirques at the headwaters of Thomas Creek, Whites Creek, and the north fork of Galena Creek.

(3) High in the valleys of the larger glacial canyons, there is a third fairly distinct group of moraines present. Superficially there is no distinct difference in the degree of weathering of the till from that of the second group. However, these moraines, which are generally confined to high-elevation valleys above 9,000 feet display well-preserved terminal moraines (Figure 28). Almost all of the high glacial lakes in the area are dammed by moraines of this third group.

(4) A fourth series of glacial moraines is very well developed in some of the high glacial cirques considerably above the moraines of the third group. These youngest moraines have an extremely fresh appearance as though they formed only yesterday. They are made up of unweathered, angular blocks and boulders of andesite or granodiorite with very little

Fig. 27. Granitic knoll overridden by ice east of Tahoe Meadows. Andesitic erratics lie on several inches of granitic sand from the disintigration of the granitic bedrock.

Fig. 28. Recessional moraine from third glacial stage. The small meadow was probably at one time a glacial lake. West fork of Gray Creek.

fine, interstitial material (Figures 29 and 30). Because of the coarse, angular nature of the rock fragments, the moraines are very porous and therefore even though they often form closed depressions, ponds do not develop.

These youngest moraines are generally within 500 feet of the cirque wall in which they have developed (from 9,300 to 9,700 feet in elevation). The very recent age of one such moraine is indicated by a large dead log which is precariously perched on the crest of the moraine (Figure 30). The log could not have grown on the moraine itself because of the total lack of soil; hence it must have slid down from some point upslope on ice or snow which filled the cirque to the level of the crest of the moraine. It is doubtful that the present-day snowfall is heavy enough to fill a cirque to such a level; more likely the log actually dates back to the period of the moraine development.

It is tentatively suggested that the first three glacial stages may be correlated with Blackwelder's (1931) Pleistocene glacial stages in the Sierra Nevada. The oldest moraines of lower Galena Creek would then correspond with the Sherwin stage, the second group with the Tahoe stage, and the third group with the Tioga stage. The youngest moraines closely resemble those described by Matthes (1939) in the Sierra Nevada as being formed during the "Little Ice Age" which reached its maximum in the 17th, 18th, and 19th centuries.

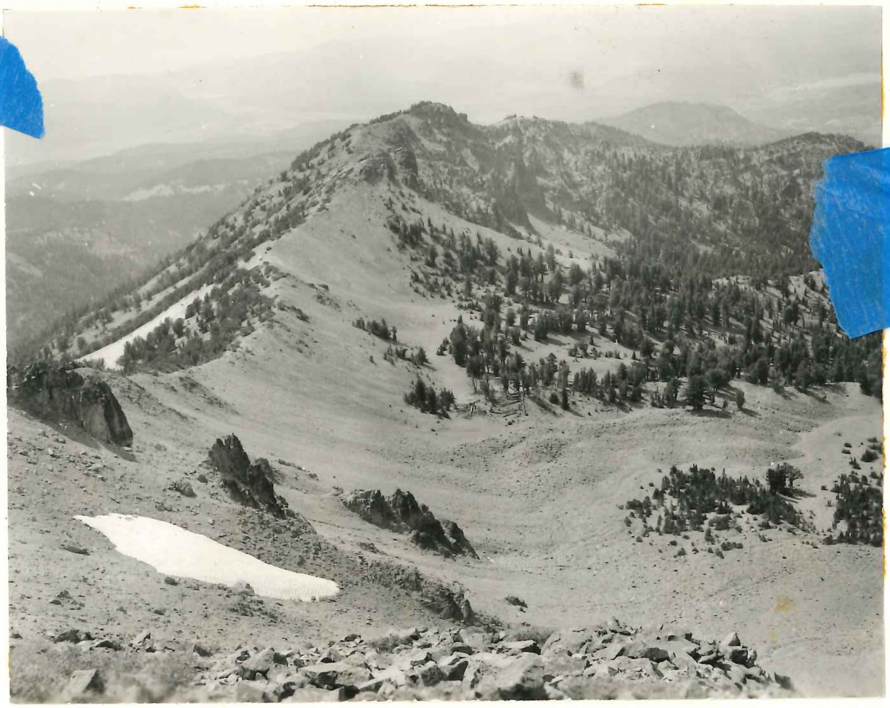


Fig. 29. Irregular piles of late unweathered morainal material in the cirque at the head of Gray Creek at 9500 feet in elevation. Photograph taken in September.

Fig. 30. Late terminal moraine in the cirque of Galena Creek west of Tamerack Lake. The large dead log on the crest of the moraine (on which the man is standing) indicates that ice or snow recently filled the cirque allowing the log to slide down from above to its present position.

The profiles of the major streams in the area were somewhat modified by glaciation as shown in Figure 35. Thomas Creek, Whites Creek, and north fork of Galena Creek show no modification in the normal smooth stream profile, which becomes progressively steeper upstream. These streams suffered only slight glaciation or were not glaciated.

The profile of Galena Creek displays an upward bulge, the high point of which is at 7,400 feet in elevation. This probably represents the material deposited near the snout of the active Galena Creek glacier during the larger part of its history. Aggradation near the terminus of the glacier was greater than deposition at any other place in the stream course, and hence deposition at the terminus was going on while ice was downcutting upstream and meltwater was downcutting downstream.

The odd profile of Browns Creek is due to the effect of glaciation on the course of the pre-glacial Browns Creek. Formerly the upper part of Browns Creek above the 7,800 foot contour drained north into Galena Creek canyon through the hollow now occupied by Grass Lake. However, when the glacier occupied the Galena Creek canyon, ice and moraines dammed up this north-flowing tributary stream and it ponded until it spilled over to the east forming the present course of Browns Creek.

### Slide Mountain Landslide

Slide Mountain, in the southeastern portion of the mapped area, takes its name from a large landslide scar on its southeast flank (Figure 33). The scar is largely devoid of vegetation and is therefore readily seen from the foot of the mountains in Washoe Valley. The scar is covered by a thin mantle of granitic sand which is continually moving downslope. Reid (1911, page 133) wrote concerning recent sliding:

> The biggest slide occurred a few decades ago, and deposited many hundred tons of rock in the canyon. The small lake south of the mountain was formed at this time.

The entire mass of Slide Mountain is made up of granodiorite which is especially prone to rapid weathering and disintegration into granitic sand. Several joint sets cut the granodiorite bedrock; one set strikes northeast and dips to the southeast, roughly parallel to the slip face.

The scar is a distinct concavity in the face of the mountain; it is approximately 2,000 feet high and a mile wide at the base (Plate I). The slope of the scar is as much as 35 degrees (Figure 32).

Extending three miles from the base of the scar to Washoe Valley is a long tongue of rock debris averaging one-half mile in width (Figure 31). The debris is made up primarily of angular, though weathered, blocks of granodiorite

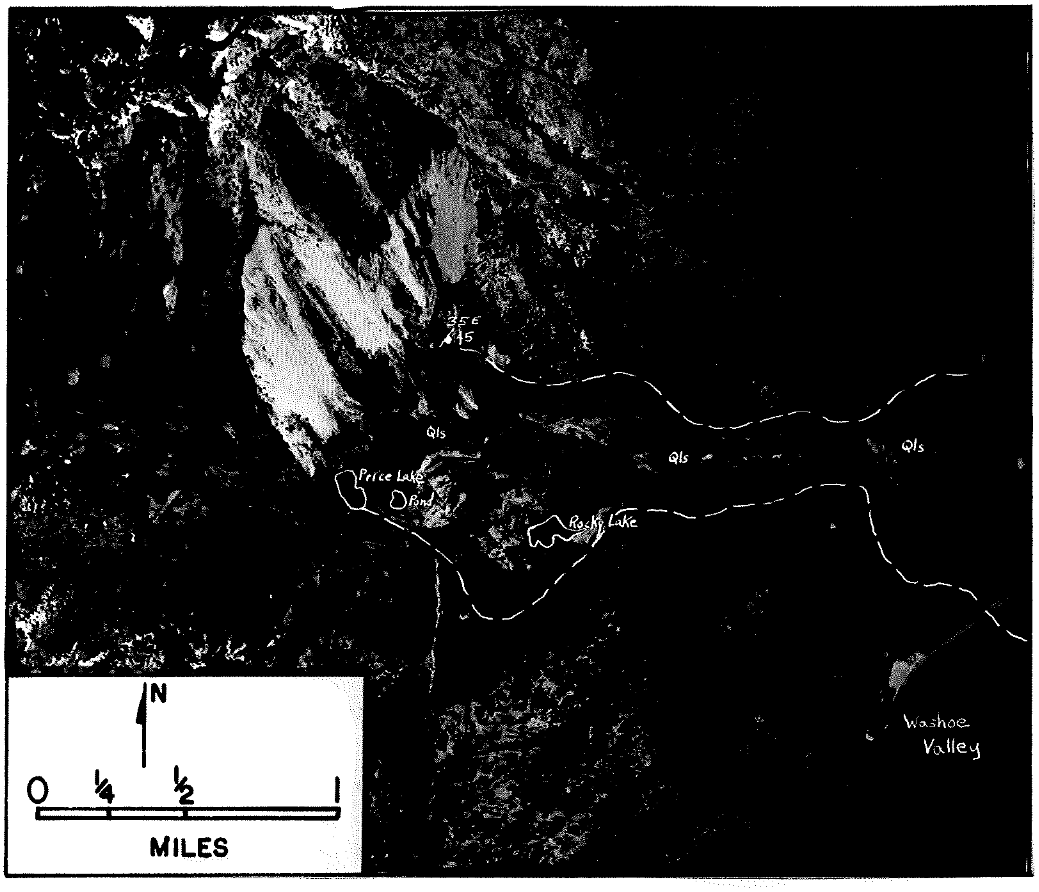


Figure 31. Aerial photograph showing the white landslide scar on Slide Mountain and the landslide tongue (Qls) extending east to Washoe Valley. Note the three ponds on the landslide. Photograph taken for the United States Geological Survey.

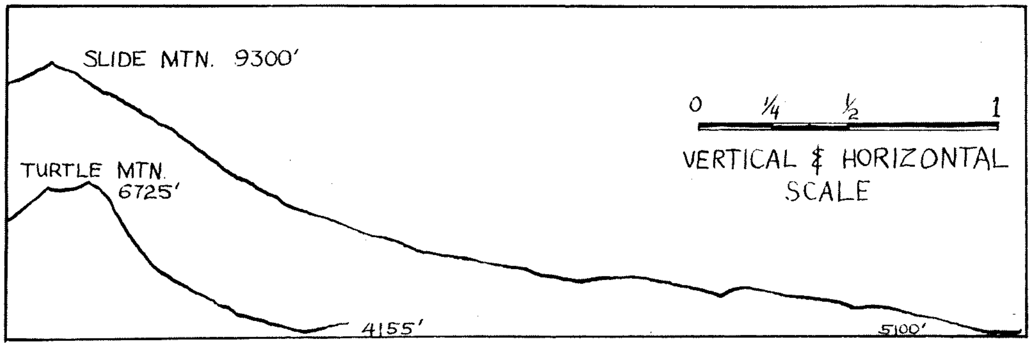


Figure 32. Comparative profiles of the Slide Mountain and the Turtle Mountain landslide at Frank, Alberta (from Daly, R.A., Miller and Rice, 1912).

up to ten feet in diameter, a great amount of granite sand, and finer clayey material admixed throughout the mass. At the upper end of the tongue are large piles of granodioritic blocks forming irregular depressions, three of which are now occupied by small lakes. The surface of the debris tongue below (to the east of) the small lakes becomes quite subdued, most of it being heavily forested. Except for the deep, young gorge of Ophir Creek cut in the debris tongue, it appears as a long, lobate mount.

Because the debris tongue has been subject to erosion over a considerable period of time, much evidence as to its origin has been obliterated. The surface is gulleyed and forested, and individual blocks of granodiorite have weathered and disintegrated in place. Judging by the degree of weathering and erosion of the debris compared to that of the moraines of the Sierra Nevada, the formation of the Slide Mountain debris tongue is set at about the period of Blackwelder's (1931) Tahoe glacial stage of late Pleistocene time. But there is some difference in the degree of weathering of the debris, especially near the foot of the debris tongue.

When first investigated in the field, the Slide Mountain debris tongue was described as a glacial moraine (J. C. Jones and V. P. Gianella, 1933, page 115). The nature of the transported material very closely resembles that of many moraines in the Mount Rose area. Hence a consideration of the

Fig. 33. View looking northwest toward the east front of the Carson Range across Washoe Valley and Washoe Lake. The white landslide scar of Slide Mountain is to the right (north) of the step-faulted shelf of Little Valley. Photograph by George Thompson.

Fig. 34. The landslide scar of Slide Mountain from Price Lake on the upper end of the debris tongue extending from the scar. Photograph by George Thompson.

cause of this striking feature must not disregard the possibility of glacial origin.

In other canyons of the Mount Rose area glacial moraines are not found at an elevation as low as that of the foot of the Slide Mountain debris tongue (5,070 feet). The relatively large glacier of Galena Creek descended only to approximately 6,400 feet while those of Thomas and Whites Creeks were confined to cirques above 8,000 feet. If the Slide Mountain debris tongue were a moraine, then to have descended this much lower than the other glaciers, a far larger source area for ice and snow would be required. It is true that a large snowfield and glacier once occupied the upper reaches of Ophir Creek east of Incline Lake. But this glacier did not form the debris tongue, for careful investigation has shown that virtually no andesitic fragments are present in the tongue, though the moraine mapped in upper Ophir Creek has a great amount of andesitic debris originating from the flows and breccias north of Tahoe Meadows.

The topography of the debris tongue further indicates its non-glacial origin. The topography of the eastern two miles of debris is that of an elongated mound, trenched by the gorge of Ophir Creek. There is no indication of a glacial valley or trough in which the ice of a glacier could have moved.

The volume of the Slide Mountain debris tongue was roughly computed from the map (Plate I) by reconstructing the contours before deposition took place and determining the volume of transported material. Likewise the volume of removed material was calculated by reconstructing the contours over the scar higher on the mountain. The volumes of removed and deposited material compare closely, considering the difficulties involved; the volume of both is approximately 125,000,000 cubic yards (Table IV). Hence the relation of the volumes of material removed from the scar and deposited on the slope indicate that essentially all the material deposited in the debris tongue was derived from the Slide Mountain scar and not from upper Ophir Creek where glaciers are known to have existed.

As explained above, the low elevation of the Slide Mountain debris, the very limited ice source area possible in the lower Ophir Creek drainage, the topography of the debris, and the relation of the volume of the scar to the volume of the debris, indicate that the debris of Slide Mountain is not of glacial origin. Rather, it is suggested that the Slide Mountain debris tongue originated from the Slide Mountain scar as a true rockslide, defined by Sharpe (1938) as: the downward and usually rapid movement of newly detached segments of the bedrock sliding on bedding, joint, or fault surfaces or any other plane of separation. Another possibility may be that the movement was slower, or an actual flowage like that of rock glaciers, mudflows, and debris avalanches. These forms of flowage differ primarily from landslides in their

## TABLE IV

## COMPARISON OF SLIDE MOUNTAIN LANDSLIDE WITH OTHER LANDSLIDES FOR WHICH DATA ARE AVAILABLE

| NAME | VOLUME (in cubic yd.) | AVERAGE STEEPEST ANGLE | DESCRIPTION |
|---|---|---|---|
| Elm, Switzerland[1] | 13,000,000 | 50° | Catastrophic rockfall in fractured, metamorphic rocks. |
| Frank, Alberta[2] | 40,000,000 | 50° | Catastrophic rockslide in jointed, steeply-dipping limestones. |
| Gros Ventre,[3] Wyoming | 50,000,000 | 20° | Bedding-plane rockslide in sandstone and limestone interbedded with shale. |
| Slide Mountain, Nevada. | 125,000,000 | 35° | Rockslide in jointed granodiorite. |

1 Heim, Albert (1932).

2 McConnell and Brock (1903).

3 Sharpe, C. F. S. (1938).

intermixed water or ice and consequent more fluid behavior; however, all gradations exist between flowage and landsliding or rocksliding. The flowage type of movement is characterized by lubricating silt, clay, and other fine interstitial material, and by a smoother, more uniform surface. The Slide Mountain debris contains angular blocks of bedrock and bedrock-derived finer material, much of which was doubtless formed by the slide itself. No large amount of fine soil or silt is present; indeed there is no source of original fine material, for there is only very little weathered material covering the bedrock on the surrounding slopes.

The landslide tongue of Slide Mountain appears to be unequally weathered throughout its length. At the foot of the slide two, and possibly three, ages of landsliding are suggested by the differences in topography and soil development of the landslide debris. Hence landsliding probably took place in more than one catastrophic event.

The Slide Mountain landslide is quite certainly related to fault uplift of the Carson block. Earlier investigators did not recognize the magnitude of the debris tongue, but regarded the sliding as being due directly to faulting. Reid (1911, page 133) writes:

> The great fault-scarp of this mountain rises almost perpendicularly for 2,500 feet. It gives evidence of being the most recent scarp of size in this part of the country. The name is sufficiently indicative of this evidence.

And Louderback (1926, page 14) states:

> An example of a cross-fault that has produced marked physiographic effects is shown in Plate 2. The Carson block west of Washoe Lake is cut by a transverse fault that has produced the south scarp of Slide Mountain . . . The upper part of this scarp is the original fault scarp modified somewhat by erosion and landsliding. The lower part has been produced by a stream, determined in its position by the fault, which has cut deeply down the fault zone. The total height of the present scarp is about 2,000 feet. The actual vertical component judged from the break in the summit topography is about 500 feet.

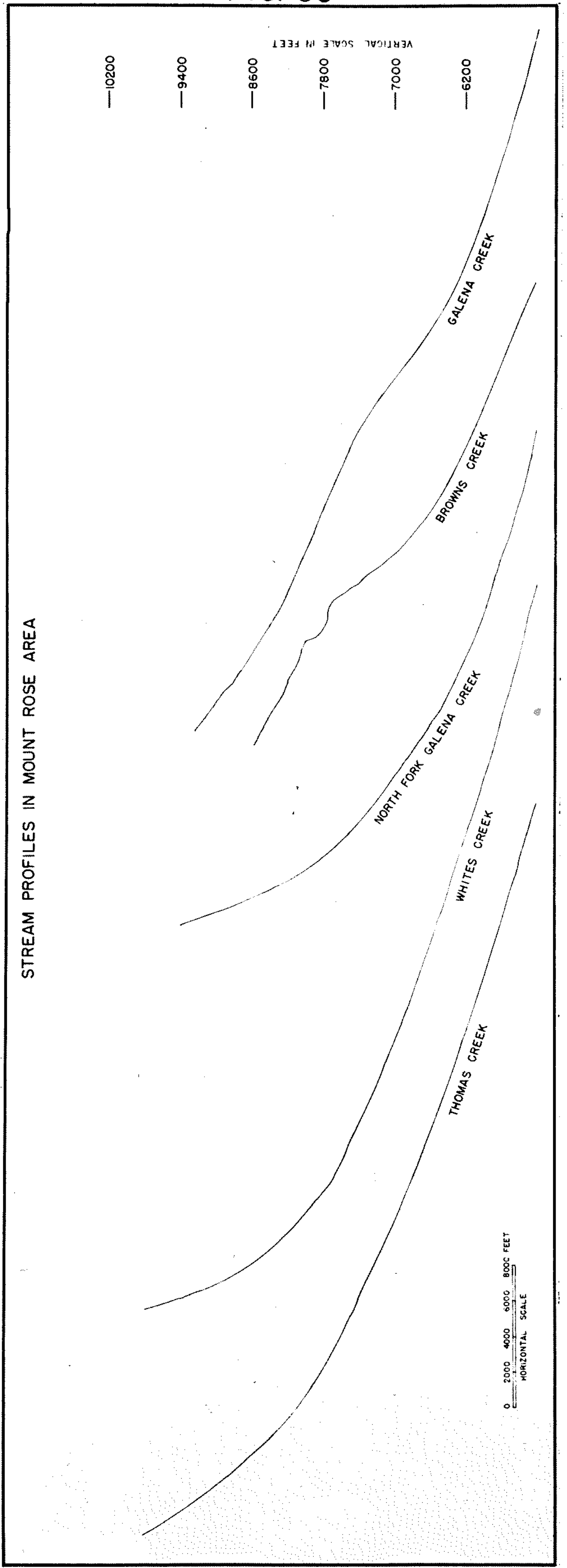
It is possible that the oversteepened southeast face of Slide Mountain is itself a fault scarp, but no geologic field evidence supports this view. The material at the base of the scarp interpreted by Louderback as a fault zone, is in fact a part of the landslide debris. Faults for which there is direct evidence trend north-south, and it seems entirely possible that the steep face of Slide Mountain is merely the north slope of the Ophir Creek valley which is very steep because of the rapid incision of the stream in a fault scarp.

### Other landslides

In the canyon of Bronco Creek near the northwestern corner of the geologic map, there are large piles of landslide rubble which mask the slopes of the canyon and cover much of the canyon floor. This debris is almost entirely Lousetown basalt.

From the geologic map it may be seen that the plateau

FIG. 35



STREAM PROFILES IN MOUNT ROSE AREA

both to the north and south of Bronco Creek is covered by the basaltic lava flows while the canyon is cut in the softer Kate Peak andesites. The landsliding has resulted from the rapid erosion of the underlying andesite and consequent undermining of the basalt which, when unsupported, has become unstable. The steep cliff at the edge of the basalt, from which large masses calve into the canyon below, can readily be seen on the geologic map.

Similar landsliding is occurring in other canyons which cut through Lousetown basalt and erode deep in the andesite below. Landslides were seen in Deep Canyon and Puny Dip Canyon north of the mapped area.

## Pediment Gravels and Valley Fill

Large sloping surfaces extending eastward from the range are veneered by a layer of gravel admixed with finer material. As can be seen in several streams which have dissected these surfaces, the depth of this veneer is fifteen to thirty feet, where the gravels can be observed to overlie the eroded surface of Truckee sediments or Kate Peak andesites. Generally, however, the streams have cut entirely in gravel with total thickness unknown. A well 400 feet deep north of the Mount Rose road and not far east of the map area is entirely in gravels. The areas mapped as pediment gravels comprise these sloping surfaces which are capped by coarse gravels. Some of the streams on the pediment surfaces have cut gorges from forty to eighty feet deep. Hence the surfaces are now undergoing dissection.

The area mapped as valley fill comprises chiefly the fine, stream-laid material in Washoe Valley to the east of the range. This material differs from the pediment gravels in being fine-grained and flat-lying. The valley fill is thought to be quite thick and to represent the large amounts of material washed from the range during its uplift and subsequent erosion.

The complex relations of the pediment surfaces and valley fill with the uplift of the range have not been investigated.

## STRUCTURE

### General Statement

The granodiorite of the Sierra Nevada, which was emplaced in Jurassic (?) time, now forms the core of the uplifted Carson Block of which the Mount Rose area is a part. Small areas of hornfelsized highgrade metamorphic sediments are preserved on top of the granodiorite. Unconformably overlying this crystalline basement are the Pliocene-Miocene Kate Peak andesites and the Pliocene-Pleistocene Lousetown basalts. There is ample evidence that the eastern slope of the Carson Range is cut by many north-south trending, high-angle faults, and that regional upwarping has been at last in part responsible for the uplift of the range.

## Faulting

Three general types of evidence indicate the presence of faults in the area: (1) stratigraphic evidence consisting of the displacement of the Tertiary volcanic sequence: (2) major topographic features within the range; and (3) recent fault scarps along the base of the range.

(1) The faults which are stratigraphically indicated can best be seen in the geologic sections of Plate II. Despite the somewhat irregular surface of the pre-Tertiary rocks on which the volcanic sequence was laid down, there are many displacements of the contact between volcanics and granodiorite which cannot adequately be explained by primary slopes and which by their abruptness strongly suggest fault displacements.

A north-south fault of middle Jones Creek (shown on sections 3 and 4, Plate II) displaces the volcanic sequence down to the west as much as 500 feet. A tilted structural graben at the headwaters of Jones Creek (section 4) forms a conspicuous north-south belt of volcanic rocks. Because of the greater overall resistance of the volcanic rocks, this graben stands up as a north-south ridge paralleling the main range crest to the west.

On the west and south flanks of Mount Rose, small cross faults noticeably offset the contact between granodiorite and the overlying Kate Peak andesite which forms the summit of the mountain.

Faulting of large magnitude is suggested by the displacement of the volcanic rocks shown in section 5, Plate II. If the displacement of the volcanic rocks from the summit of Mount Rose on the west, down to the mass of volcanics north of Browns Creek on the east was accomplished by one fault, then the displacement along this fault would be about 3,800 feet. However, it is very likely that several step faults have contributed to the uplift of the Mount Rose volcanics relative to those of Browns Creek.

South of Browns Creek several faults were mapped which displace the depositional contact between the Kate Peak andesite and the underlying granodiorite. The north-south fault which parallels the 7,000 foot contour north of Davis Creek (Plate I) has uplifted the volcanics on the west so that they have been removed by erosion.

Small north-south faults west of Slide Mountain form a small graben-like structure shown on section 7, Plate II. A large north-south fault must lie in the valley of Third Creek (section 7) and have uplifted the volcanics on the west where they cap the ridge at the headwaters of Gray Creek.

(2) Faults causing marked alignment of topographic features are perhaps more widespread than those for which an actual stratigraphic displacement can be demonstrated, but some of these faults are less definitely indicated than others. In the northernmost portion of the geologic map a north-south fault east of Davis Meadow is bordered by a straight ridge on

the west; the upward displacement of the basalt on the west side confirms the presence of this fault.

About one and one-half miles to the east a north-south fault north of the alluvial flat in Thomas Creek has its upthrow on the east and has caused a small lake to form on its west side just north of the map boundary. Another one and one-half miles to the east, there occurs a north-south fault paralleling the 6,800 foot contour, again with the upthrow on the east; this fault has caused a prominent bench to form which parallels the main crest and breaks the smooth eastward slope of the range.

A small isolated alluvial basin on the ridge crest south of lower Thomas Creek might indicate an older fault-disrupted drainage. This fault is also believed to have formed a flat spur to the north of Thomas Creek.

The peculiar direction of the north-northwest flowing stream on, and almost parallel to, the western slope of North Rose was probably caused by a fault which displaced the andesite surface, causing the stream to flow other than directly down slope.

North-northeast of Mount Rose a north-south trending granitic ridge is best interpreted as due to a north-south fault with the upthrow on the east. Similarly several faults have been mapped on the eastern flank of Slide Mountain on the basis of topographic features which transect the general erosive configuration of the east facing slope. Outstanding among these is a north-south fault extending south of Grass Lake, which forms a sharply uplifted ridge transverse to the slope of Slide Mountain. The actual fault plane is exposed in a quarry south of Grass Lake where the fault is seen to be normal, dipping seventy degrees to the west.

About three miles west of the southeast corner of the map is the northern end of Little Valley which lies south of the landslide of Slide Mountain. This odd valley forms a north-south trending, step-like shelf half way up the eastern flank of the Carson Range (Figure 33). It was probably formed by two secondary faults which dropped Little Valley relative to the uplifted range. Several basaltic plugs and dikes are present on the floor of Little Valley south of the mapped area. They presumably formed as basaltic magma rose along the fault zones bounding the valley.

(3) The many faults mapped along the east base of the range are indicated by very recent scarps which displace pediment surfaces and alluvium. They are prominent, only slightly eroded scarps (Figure 36) which occur generally in north-south trending swarms; the average displacement of the scarps is from five to fifteen feet. Some of the scarps have formed small closed basins which are presently undergoing alluviation. All of these faults are very recent and may still be active. Twenty miles south of the mapped area near Genoa is a very prominent scarp comparable in age to those of the Mount Rose area. Lawson (1912) states regarding

Fig. 36. Two small recent fault scarps which displace the pediment surface east of Whites Creek. Steamboat Hills in the background.

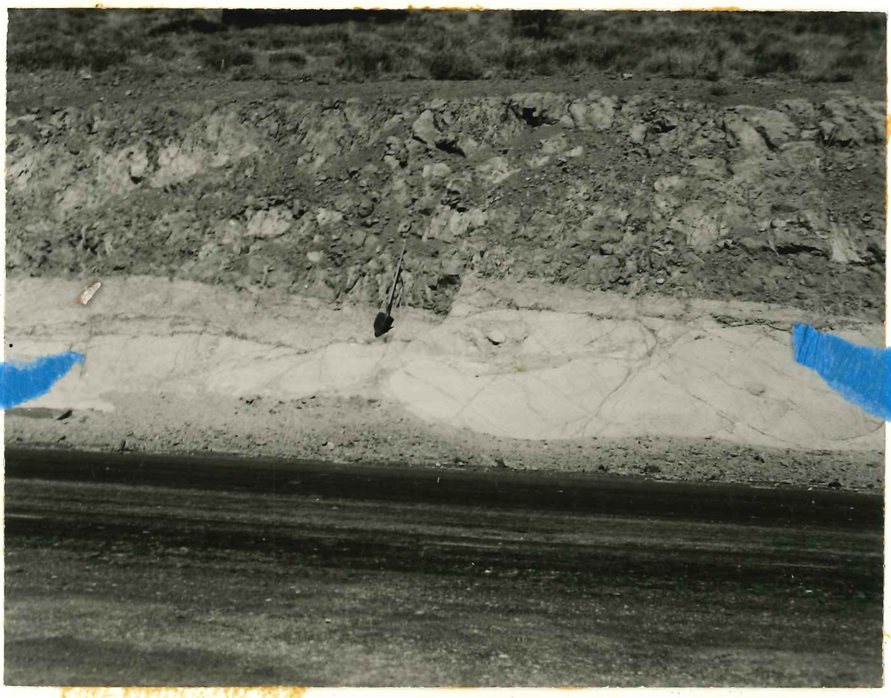


Fig. 37. Roadcut on Highway 27 north of Browns Creek showing Kate Peak andesite resting unconformably on granodiorite. The granodiorite is weathered down about two feet from its upper surface. Later normal faulting has displaced the contact.

the age of this fault scarp:

> The scarps appeared to me to be so fresh and so little degraded that I considered it possible that the displacement which caused them might have occurred within the memory of man. To settle this point I hunted up the oldest inhabitant, whom I found to be Mr. D. R. Hawkins, of Genoa, a very intelligent and well informed gentleman. He told me that he first came to Carson Valley in 1854 and that the scarps were then in apparently the same condition as they are today. The displacement of which they are the evidence occurred, therefore, more than fifty-eight years ago.

### Tilting and Warping

Tilting of the individual fault blocks is an important feature in the structure of the Carson Range. There is evidence that at many places the base of the Tertiary rocks has been tilted as shown in sections 3 and 4, Plate II.

Many of the north-south faults of the Carson Range are downthrown on their west side, yet the range rises toward the west. Therefore, if the mapped faults have been important in the uplift of the range relative to the basin to the east, uptilting to the west of each fault-block would be implied; the faults would, in other words, be antithetic.

The only well-bedded Tertiary sedimentary unit in the Mount Rose ara is a small area of Truckee sediments in the northeastern corner of the mapped area. These sediments show a strong tilting to the east (30 degrees). At other points along the eastern base of the range lake sediments dip to the east. Reid (1911) writes:

> The beds south of Franktown dip slightly to the east; those at Washoe dip southeasterly at a few degrees.

Proceeding to the north beyond the mapped area in the canyon of the Truckee River, the Truckee sediments have a general north and northeast dip. This north- and east-dipping sequence of bedded sediments on the north and east margins of the range may be part of a regional up-warping of the entire range.

## Conclusions

Because the Kate Peak andesites were extruded on a somewhat irregular and perhaps mountainous surface, cut in the crystalline basement, it is difficult to establish the exact magnitude and importance of the faulting and warping which has later affected this irregular surface.

The strong tilting of the Truckee sediments on the east and north flanks of the range demonstrates that post-Truckee warping occurred on a regional scale. The present height of the Carson Range may be a direct result of this upwarping, suggestive of compressional forces. The Carson Range can be likened to an anticlinal upwarped mass with the upturned edges of Truckee sediments on its north and east flanks and one small patch near its crest (see section on Truckee sediments). The exposure of larger areas of basement rocks to the south indicates that uplift has been greater on the south.

Extensive faulting accompanied the uplift of the range and probably outlasted uplift. The faulting has occurred in a definite north-south direction parallel with the axis of uplift. The faults are short and discontinuous and show a prevailing downdrop on the west. These features suggest that faulting probably is only a secondary adjustment within the range caused by its regional upwarping. The recent fault scarplets at the eastern front of the range, most of which have the same direction of displacement which prevails within the range, indicate that this adjustment has, at least in the east, been going on to the present day.

# GEOLOGIC HISTORY

## PRE-CENOZOIC HISTORY

The earliest geologic history apparent in the Mount Rose area is recorded by the pre-granodiorite, metamorphic rocks. These metamorphics remain as only small remnants of a once widespread sequence of sedimentary beds. They are older than the Sierra granitic complex (late Mesozoic) and are probably Jurassic-Triassic in age. These older rocks, though highly metamorphosed, were at one time typical sediments of the Cordilleran eugeosyncline. Sandstones, siltstones, argillites, limy argillites, and limestones are all represented. Sometime after the deposition of these sediments they underwent regional metamorphism and developed a schistose structure as a result of synkinematic recrystallization. The original sediments were at this time tightly folded and minutely sheared while under relatively high temperatures. The time of this orogony is unknown; perhaps the development of foliation in these sediments resulted from the so-called Nevadian period of orogony just before the large scale invasion of the existing rocks by granodiorite, or from any of the other periods of mountain-building which affected the region prior to the emplacement of the granitic rocks and after the deposition of the sediments.

The sediments were severely folded in the Nevadian orogeny, and were then invaded by great masses of granitic rocks in later Mesozoic time. During the emplacement of the granodiorite the rocks underwent high-grade thermal metamorphism. Minerals such as sillimanite, garnet, diopside, and andalusite testify to the high-grade character of this static contact metamorphism. The rocks became hornfelized and recrystallized to such a degree that in many cases their earlier foliation was lost.

The contacts of the metamorphic rocks with the granodiorite are locally very sharp and cross-cut the foliation of the metamorphic rocks. At the contacts there are often unoriented blocks of metamorphic rock included within the granodiorite. These criteria indicate that much of the granitic rocks are of intrusive, magmatic origin. Granitization and feldspathization of the country rock may be locally important.

Aplite and pegmatite dikes were intruded into both the granodiorite and country rock shortly after the emplacement of the granodiorite.

## CENOZOIC HISTORY

After the emplacement of the Sierra Nevada granodiorite, geologic history is unrecorded until the eruption of the

Kate Peak andesites in late Tertiary time. These andesites are late Miocene or Pliocene in age. They were extruded from vents in the Carson Range as well as on the main Sierra crest to the west. To the west and south of the mapped area the andesitic material is underlain by an earlier sequence of Tertiary rhyolite and andesite flows and pyroclastic rocks, which shortly predate the Kate Peak andesitic volcanism. Probably the entire map area was covered by andesitic flows and breccias during the Pliocene-Miocene period of volcanism. Thicknesses of andesite up to 1,200 feet still remain; the upper portion of Mount Rose, the highest point on the Carson Range, is unconformably overlain by 1,000 feet of andesite.

Dikes of andesite near the crest of the Carson Range mark the site of the vents which extruded such vast amounts of andesitic material. It is believed that no single large volcanic cone developed, but that a series of vents along what is now the crest of the Carson Range all contributed in supplying the great numbers of andesitic flows and in blasting out the even larger amount of pyroclastic material.

Following the Kate Peak volcanism, and even somewhat contemporaneous with it, was the deposition of the Truckee sediments. They were deposited in restricted lakes and were interbedded near the top of the Kate Peak andesite sequence. Fairly low elevation of deposition, and a humid-temperate climatic condition, is demonstrated by the remains of diatoms, leaves of deciduous trees, and reeds. Pumiceous tuff is present near the top of some of the Truckee sediments and indicates that rhyolitic volcanism was active somewhere in the general area.

The presence of the Truckee sediments in the Carson Range, and again near the crest of the Virginia Range to the east, indicates that at the time of their deposition, drainage of the region was in some way impaired, and lakes were formed. The formation of these lakes may have resulted from the initial disturbances which have since led to the uplifted blocks of the present basin-range type of structure. However, before this differential uplift began, a long period of positive epeirogenic tendency affected the area, resulting in the removal of great quantities of pre-Jurassic sediments from the Sierra Nevada pluton.

At the time of deposition of the Truckee sediments (and Kate Peak andesites) the range was not as high or rugged as at present. Low elevation plant remains are found in the Truckee sediments at 8,800 feet. Also the pre-Kate Peak surface of granodiorite which is now exposed on many of the high peaks is comparatively subdued compared to the present glacial topography with its deep canyons.

After a considerable erosional interval and faulting and displacement of the Kate Peak andesites, the Lousetown basalts were extruded on the eroded and beveled surface of the older rocks. The time of these extrusions is tentatively set at late Pliocene or Pleistocene. Lousetown lavas were apparently extruded on a more maturely eroded surface than the earlier andesites. The Lousetown lavas were also probably much more widespread than now, for Lousetown feeder dikes and necks survive in the southern portion of the mapped area.

Although continued structural unrest had existed in the range since late Miocene time, the present range was uplifted in the Pleistocene after the extrusion of the Lousetown basalts. This uplift was perhaps a regional upwarp accompanied by large displacement on a series of north-south high-angle faults on the eastern flank of the range. Uplift probably occurred along many of these faults and tilting was important as each block was forced up. Other faults now covered with alluvium may also have been important in the uplift of the range relative to the valleys to the east. The tilted nature of the Truckee sediments on the eastern foot of the range indicates that warping was responsible for much of the uplift.

After the major uplift of the range in early Pleistocene time, a consequent drainage pattern presumably developed in the area. This same drainage, somewhat modified by later minor faulting and glaciation, remains today.

Glaciation in the region began in later Pleistocene time and affected the area probably not less than four times. These four periods of glaciation are tentatively correlated with the Sherwin, Tahoe, Tioga and Little Ice Age stages described in the main Sierra Nevada range.

Contemporaneous with glaciation was continued minor faulting, primarily near the range front. Some of these small movements may have caused the shocks which triggered the Slide Mountain scarp, oversteepened by upfaulting, into its catastrophic rockslides.

During and after glaciation streams carried great amounts of material from the mountains into the valley to the east, carving large pediment surfaces in the process.

Continued diastrophism is affecting the area to the present day. Gravels on the pediment surfaces have been displaced by swarms of recent fault scarplets. Also many of the pediments are presently being dissected; this dissection may be a result of continued uplift of the range.

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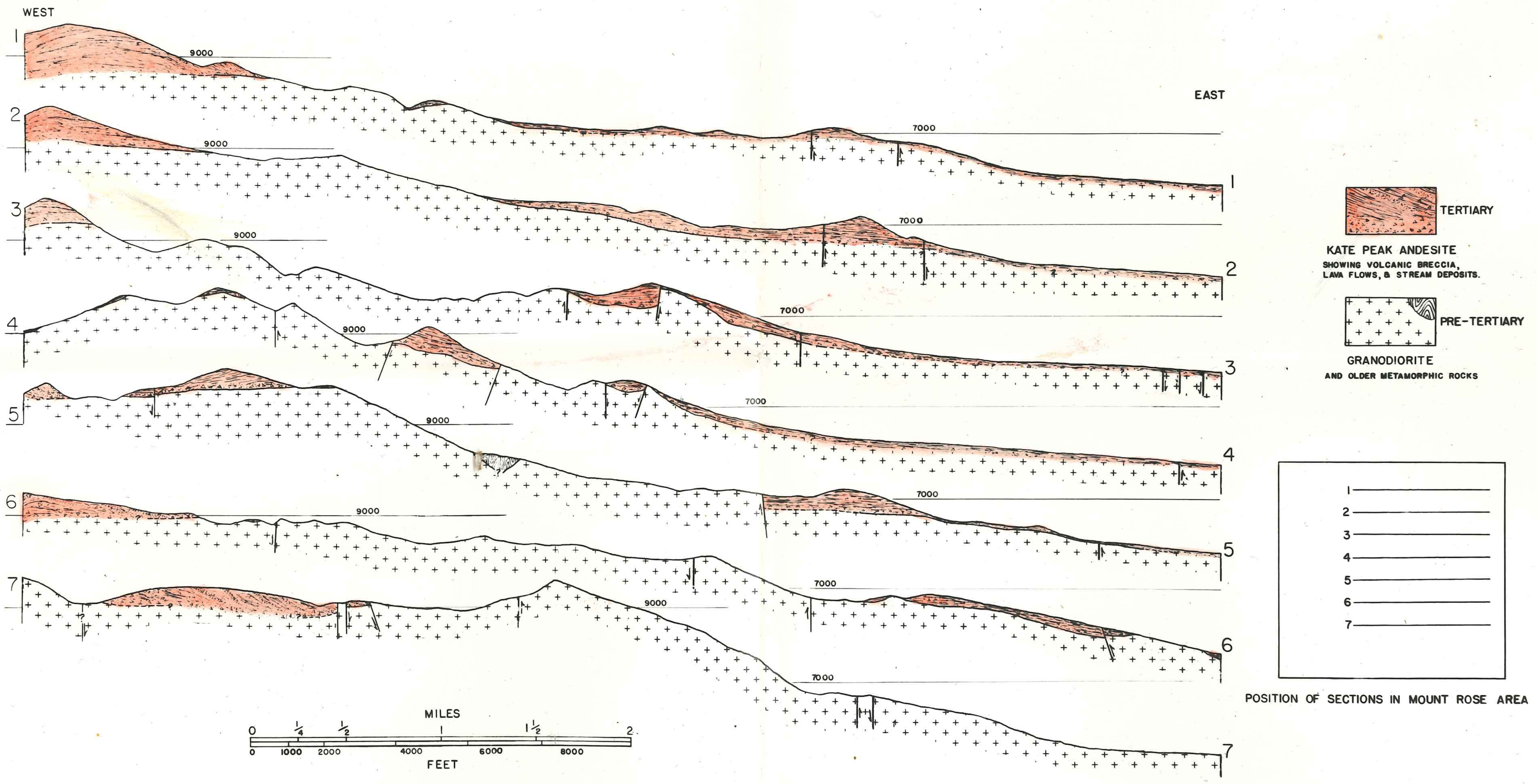
PLATE II

# GEOLOGIC SECTIONS ACROSS THE EAST SCARP OF THE CARSON RANGE



JGM 1952

DEPARTMENT OF THE INTERIOR PLATE I GEOLOGICAL SURVEY

BASE FROM U.S.G.S., 1951

JAMES G. MOORE, 1952

# GEOLOGIC MAP OF THE MOUNT ROSE AREA, NEVADA

SCALE IN MILES

0 ¼ ½ ¾ 1 2 3

CONTOUR INTERVAL 40 FEET