GEOLOGY OF THE CENTRAL MINERAL RANGE

BEAVER COUNTY, UTAH

by

Fred Nelson Earll

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by

Fred Nelson Earll

Has been approved by

Chairman, Supervisory Committee

Reader, Supervisory Committee

Reader, Supervisory Committee

Reader, Supervisory Committee

Head, Major Department

Dean, Graduate School
The subject area covers approximately 250 square miles, which includes the central portion of the Mineral Range, an elongate belt of rugged mountains located in the eastern third of Beaver County, Utah. In gross detail, the range is formed of a large granite pluton, which is flanked by Paleozoic and Mesozoic sediments on the south, and lower Paleozoic sediments on the north. Mesozoic sedimentary rocks crop out on the east and west flanks, and a belt of Precambrian metamorphic rocks are exposed along the west side. The area is bounded by Beaver Valley on the east, Milford Valley on the west, Hot Springs Canyon on the north, and by Utah State Highway 21 on the south. Boundary lines have been drawn to include a standard fifteen minute quadrangle except for a small additional area north of Highway 21 on the south.

Stratified rocks, exposed within the mapped area, include from the base to the top: 3,000 feet of Precambrian gneiss, schist, and metaigneous rocks; 3,000 feet of lower Paleozoic limestone and dolomites; 1,000 feet of Mississippian limestones referred to the Topahe formation; the Permian Coconino and Kaibab formations aggregating almost 2,000 feet; the Triassic Moenkopi group some 2,000 feet in thickness; the Jurassic Navajo sandstone and Carmel limestone with an aggregate thickness of roughly 2,000 feet, the Cretaceous Clarion (?) conglomerate; and Quaternary deposits of Bonneville age which are exposed on the western flanks of the range.

Unconformities are recognized above the Precambrian; at the base of the Mississippian; at the base of the Permian and; at the base and at the top of the Cretaceous. Two stages of faulting are recognized in late Cretaceous or early Tertiary time associated with the Laramide orogeny.

Igneous rocks include the Mineral Range pluton; the small Lincoln stock and numerous related bodies; andesite, aplite, and pegmatite dikes; large granite sills; a northern rhyolitic volcanic series; and a southern volcanic series composed of basal andesites, grading into quartz latites,
and capped by basalt.

Emplacement of the Mineral Range pluton is believed to have occurred in late Cretaceous or early Tertiary time. The body is remarkably homogenous, throughout its central part, being composed of coarse grained granite which is characterized by a marked deficiency in the normal ferro-magnesian components and calcium. The western margin of the body, however, has a gradational contact with the Precambrian rocks which forms a linear belt of ferro-magnesian rich rock. The southern volcanics post-date folding and initial fault movements, and pre-date the second stage of faulting. The northern, late Tertiary volcanics, post-date uplift of the range and pre-date the Pleistocene Lake Bonneville.

At the present writing, mining activity is at a near standstill throughout the range. In past years, however, the area supported four mining districts: the Bradshaw, Lincoln, Granite, and North Granite districts, the last two of which are treated as a unit in the present report. Deposits mined were complex ores of gold, silver, lead, and copper, with some tungsten being mined during the late war years. The Bradshaw district, largest producing district of the range, has a total production record of 11,000 tons valued at approximately $305,000.00, two-thirds of this gross being recovered in gold and silver values. Production of the Lincoln district is over 7,000 tons valued at $161,000.00, more than half of which was in lead and silver values. The Granite and North Granite have produced 948 tons of base and precious metal ores valued at $50,000.00, again largely in gold and silver. Tungsten production, begun during the war years, was largely from two mines in the Granite district. Total tungsten production of all districts was 1,182 tons, valued at $20,000.00. Beryllium ore has recently been discovered at the Miller Mine, and development work is currently in progress.

Other deposits of economic importance that have been exploited include pumice, perlite, and some building and decorative stone. Large reserves of pumice and perlite are available in the northern volcanic area, but market conditions have retarded development to a large degree.
ACKNOWLEDGEMENTS

The writer is deeply indebted to Dr. F. W. Christiansen, of the Department of Geology, University of Utah, for his constant encouragement, and help with the stratigraphic and structural problems of the range. Dr. W. L. Stokes identified fossil collections and suggested correlations of the formations involved, and all members of the faculties of the Departments of Geology, Mineralogy, and Mining and Geological Engineering offered assistance, suggestions, and facilities. Thin section studies were done by J. D. Stephens, Petrographer. The writer would also like to express gratitude to Mr. P. Elden Dennis, and the U.S. Geological Survey for making field notes and a preliminary map of a part of the area available to him, and in offering assistance whenever needed. Mr. Homer C. Liese, who mapped the northern part of the range, provided valuable information with regard to structural and stratigraphic relationships to the north of the subject area, and the writer can never repay his many friends and associates, whose understanding and encouragement went far in bringing this work to completion. Finally the writer expresses gratitude to his wife, Frances, for her assistance in the completion of the manuscript, and for maintaining a comfortable home away from home during the many weeks in isolated camps during field work in the range.
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INTRODUCTION

LOCATION AND ACCESSIBILITY

The Mineral Range is an elongate, north-south trending mountain range in the eastern third of Beaver County, Utah, extending some ten to twelve miles into Millard County on the north. The area of the present report is a standard fifteen-minute quadrangle, bounded by the 112°14'5" and 113°00' meridians on the east and west, and by the 36°30' and 38°15' parallels on the north and south. A small additional area, north of State Highway 21, was included on the south end of the area. Total area is approximately 250 square miles, some 140 square miles of which is mountainous terrain. (See Index Map, Fig. 1.)

Access to the area is afforded by Utah State Highway 21 which forms the southern boundary, and then turns north to Milford, Utah along the southwestern boundary. In addition there are some 80 miles of graded dirt road and innumerable unimproved dirt roads and jeep trails which permit access to the northern and central part of the range.

Milford, Utah (population 1673), lies just beyond the subject area to the west on the Union Pacific Railroad line, and is the shipping point for ores, farm produce, and stock from the surrounding region. Beaver, Utah (population 1685), the county seat of Beaver County, lies some six miles east of the mapped area on U.S. Highway 91. Minersville, Utah, is situated at the southwest corner of the area, on Utah State Highway 21, and the small town of Adamsville lies within the southeast corner of the
area, immediately north of the Minersville Reservoir.

PREVIOUS WORK

The earliest published work concerning the Mineral Range appears in 'Water Resources of Beaver Valley, Utah' (Lee, 1908), which includes a measured section of the Permian and Triassic rocks exposed in Beaver Canyon. The geology of the range is outlined in general terms by Butler in 'Ore Deposits of Utah' (1920), and his report gives a good discussion of the Mining Districts and their production. In 1935-1936, P. Elden Dennis did reconnaissance mapping in the southern part of the range. This work was never finished, but field notes and a sketch map begun during that period were made available to the writer. Crawford and Buranek (1945) investigated the tungsten deposits of the range and the contact effects on sediments adjacent to the Mineral Range Stock. Finally, the northern extension of the range, which was mapped concurrently with the present study, by Homer C. Liese, has been presented as a Masters Thesis at the University of Utah.

PRESENT INVESTIGATION

The writer first became interested in the Mineral Range during a visit to the area in August, 1955. It was decided to map the range as a thesis project in November, 1955, and field work began shortly thereafter and continued through the summer of 1957.

The base map for the southwest quarter of the area, was adopted from the U.S. Geological Survey topographic maps of the Cave Canyon and Minersville Quadrangles. The base map of the remaining three-quarters of the
area was developed from aerial photographs taken by the U.S. Department of Agriculture Soil Conservation Service.

TOPOGRAPHY

The Mineral Range rises sharply from the wide pedimented and alluviated slopes which border Beaver Valley to the east, and the Milford agricultural belt and the Escalante desert to the west. The range proper stands in strong relief, being precipitous on the west face, and only slightly less steep on the east. Maximum elevation is 11,000 feet or somewhat in excess of 5,000 feet above the floors of the bordering valleys.

Among the most characteristic features of the topography are the steep, narrow canyons and sharp spires of granite which are particularly common along the west side of the range. Large canyons, eroded in the granite and subsequently filled with volcanic ejectamenta and flows, are now sharply incised attesting to the rejuvenation of streams that had reached the early mature stage in an earlier cycle.

Less obvious from ground level, but strikingly clear from the air, is the ancient shoreline of Lake Bonneville, which occupied the Escalante Desert basin in Pleistocene time. This feature consists of a pronounced terrace in the alluvial slope.

Where the shoreline crossed pre-Bonneville drainage courses, small deltas developed. The deltaic sediments are composed mainly of volcanic material, thus establishing the age of volcanism to be pre-Bonneville.

Volcanic deposits have influenced topography through the formation of steep-sided buttes, capped by resistant vitrophyre flows in Ranch Canyon, and as moderately dipping flows which mask the sediments and form
rounded hills in the southeastern part of the range.

CLIMATE

A U. S. Weather Station was first established at Milford, Utah in November, 1906. The present station, at Milford airport, was established in July, 1947. Essentially complete weather data have been kept since 1908.

The normal annual temperature is 49.0 degrees F, with a summer high of 70.5 degrees and winter low of 27.6 degrees. The highest recorded temperature was 104 degrees, which occurred in July, 1943, and was repeated in June 1954. Record low was -34 degrees, recorded in January, 1937.

Normal annual precipitation is 8.44 inches, more than half of which falls in spring and summer. Average annual snowfall is 34.1 inches, with a record fall of 63.4 inches in the winter of 1948-1949.

Overall climate is classified as dry temperate. Summer days are warm, but cool nights prevail due to relatively high elevation.

FLORA AND FAUNA

The valleys, flanking the range, support small desert plants. The lower slopes are covered by juniper and scrub oak. Intermediate slopes support pinyon pine and juniper, and cottonwood groves are found where water is available. The higher slopes and ridges support thick stands of aspen, fir, and some yellow pine.

The natural fauna of the region includes deer, rabbits, ground squirrels, porcupines, and a few hardy wildcats and coyotes which have managed to avoid the traps set for them. Hawks, magpies, and bluebirds are the most common birds, though a few dove and grouse inhabit the higher valleys.
INDUSTRIES

Farming

Approximately 6,500 acres of land are under cultivation within the quadrangle, 4,800 acres of which are in the Milford area, the remaining farm acreage being in and around the town of Adamsville. The principal crop is alfalfa, although some row crops are grown.

Stock Raising

The most important industry of the region is the grazing of stock. Most of the mapped area is open range, and large herds of cattle are allowed to graze freely throughout the summer and fall. Some sheep are also grazed here, and the lower elevations provide winter range for these animals.

Timber

The timber industry, at present, is confined to the cutting of juniper fenceposts and firewood, and some aspen which is cut for poles for corrals and etc. When mining was active, most of the timber for mine support was cut locally, the timber derived from pine, aspen, and cottonwood being adequate support for shallow workings.

Mining

The mining industry, in the Mineral Range, is at a virtual standstill at present. In the period 1871 through 1952, the part of the range under discussion supported four well-established mining districts. Total production can be estimated as slightly in excess of 20,000 tons with a gross
value in excess of $500,000.00. No mines were in full operation in 1956. Pilot shipments were made from the Miller Mine (Granite district) which is under development, and some fifteen tons of sorted ore was shipped from the Creole Mine (Lincoln district). Minor development and assessment work was performed on many properties, but no other shipments were made to the writer's knowledge. Ores mined in the past have been largely complex lead-silver ore carrying values in gold, copper and in some cases zinc. Some tungsten ore was mined during World War II.
STRATIGRAPHY

GENERAL STATEMENT

The Mineral Range pluton is flanked by Paleozoic and Mesozoic sediments on the south and lower Paleozoic sediments on the north. Remnants of Mesozoic sedimentary rocks crop out on the east and west flanks, and an extensive belt of Precambrian strata is exposed along the west side.

Stratified rocks, exposed within the mapped area, include approximately 3,000 feet of Precambrian gneiss, schist, and complex meta-igneous rocks. These are followed by 3,000 feet of undifferentiated lower Paleozoic limestones, and dolomites, and 1,000 feet of Mississippian limestone referred to the Topache formation. The Permian Coconino and Kaibab formations follow, aggregating almost 2,000 feet in thickness. The Mesozoic is represented by the Moenkopi group, 2,000 feet in thickness of Triassic age, and the Navajo and Carmel formations aggregating roughly 2,000 feet of Jurassic age. The Cretaceous (?) Claron conglomerate, a blanket of coarse boulder conglomerate up to 55 feet in thickness, overlies Jurassic and Triassic sediments unconformably, and Quaternary deposits of the Pleistocene Lake Bonneville are exposed on the western flanks of the range.
PRECAMBRIAN ROCKS

Biotite Gneiss

Distribution

Biotite gneiss, of Precambrian (?) age, is exposed in an irregular belt along the northwest margin of the Mineral Range. The belt extends from Ranch Canyon on the south, to a point immediately south of Hot Springs Canyon on the north. The area of outcrop is approximately four and one-half miles long, and averages one-half mile in width.

Lithology

According to petrographic study the gneiss has the following composition: biotite, 50 percent; quartz, 40 percent; orthoclase, 8 percent; magnetite, 2 percent, and minor muscovite and zircon. The care taken to include the dark, predominantly biotite bands in thin sections has probably resulted in the inclusion of a higher-than-average percentage of biotite in the analysis. Schists and phyllites are also found in the area, but these lithologies represent a small fraction of the exposed section of Precambrian rocks.

Thickness

The thickness of the gneiss section can be estimated from the maximum width of outcrop measured perpendicular to the strike of foliation (6,300 feet) and the average regional dip. This computation indicates a thickness of approximately 3,000 feet.
Fig. 2. View of contorted pre-Cambrian gneiss exposed at the mouth of Wildhorse Canyon.
Contact Relations

The gneiss belt is bounded on the east by the Mineral Range pluton and on the west is overlain by recent alluvium and volcanic debris. The contact with the Mineral Range pluton is gradational, in varying degree, throughout its length. The contact zone, ranging up to one-quarter mile in width, contains numerous blocks of gneiss which have been separated from the main mass by the intruding granite, and innumerable smaller inclusions of the older metamorphic rock. The granite, which is essentially free of ferro-magnesian minerals in its central part, exhibits a gradual increase in biotite content in the contact zone. This suggests that the biotite gneiss has been partly assimilated by the granite, resulting in an enrichment of the granite in ferro-magnesian constituents.

Metamorphic Complex

Distribution

Precambrian (?) rocks are also exposed from Pass Canyon southward to the north side of Cave Canyon, on the west side of the range. The area of outcrop is approximately two miles in length from north to south, and has a maximum width of three miles.

Lithology

Several rock types are present in the southern Precambrian area. Rocks exposed in the western part of the belt are clearly meta-sedimentary in origin and the original bedding can be recognized in many outcrops. Eastward, the exposures grade into complex meta-sedimentary and meta-igneous rocks. This complex includes granite, granodiorite, biotite and hornblende-biotite schist, and phyllite. These have been fractured, dis-
placed, and intruded in several stages. The sequence of events resulting in the formation of this complex appears to be as follows: (1) formation of biotite and hornblende-biotite schist and phyllite from Precambrian sediments; (2) introduction of granodiorite, which may be intrusive or formed in place through metamorphic processes, and which is shown to be younger than the schists by its cross-cutting relation to foliation; (3) introduction of granite which is believed to be related to the Mineral Range pluton. Again, introduction may be essentially intrusive, but in local areas granite has been formed in place. Intrusion of this granite is shown to be later than the foregoing events by the fact that it cuts across both granodiorite and schist; (4) intrusion of granite sills, presumably at the same time that the previously mentioned granite was emplaced; (5) intrusion of aplite dikes and associated pegmatite which cross both granite and older rocks; (6) intrusion of andesite dikes along fault fissures of post-granite age; (7) formation of serpentine veinlets which occupy joints and fractures crossing all older features.

Contact Relations

The southern Precambrian rocks are overlain by alluvium on the north and west, are in fault (?) contact with early Paleozoic sediments on the south and east and are in intrusive contact with the granite of the Mineral Range pluton on the east. The contact with the Mineral Range pluton, like that of the northern Precambrian rocks, is not a clear-cut line of demarkation. Transition from the Precambrian rocks to the granite occurs throughout a zone one-half to three-quarters of a mile in width. Through this zone, granite which is petrologically similar to that of the main
intrusive body, has evidently formed in place through the reconstitution of the pre-existing Precambrian rocks. This granite is shown to have been formed in place by the fact that it cuts across the older rock without physical displacement or separation of older diagonal structural elements. Areas of granite, within the Precambrian rock, are generally small, ranging in size from a few inches to a few feet in maximum dimensions. When viewed in two dimensions, these small granite blebs appear to be isolated from each other, but there may be an interconnection in the third dimension which cannot be observed. At the eastern extreme of the contact zone, inclusions of the Precambrian rocks can be found in the granite, and like the northern contact zone, there is an enrichment of the granite in ferromagnesian minerals.

UNDIFFERENTIATED PALEOZOIC ROCKS

Distribution

A thick sequence of dolomite and dolomitic limestone beds are the oldest unmetamorphosed sedimentary rocks in the range. They crop out in a wedge-shaped area from Cave Canyon southward to Shearing Corral Spring along the southwest side of the range, and on the north side of Cave Canyon where they are in fault (?) contact with Precambrian rocks. The area of outcrop is four miles in length and three-quarters of a mile in maximum width.

Lithology

In the main, the sequence is composed of thin-bedded to massive, tan to white dolomite and dolomitic limestone. The sediments are intruded,
at several points south of Cave Canyon, by small igneous bodies that range in composition from quartz monzonite to hornblende granite, and by granite related to the Mineral Range pluton north of Cave Canyon. Throughout the belt of outcrop, the limestone beds have been bleached, silicified, or converted to marble, attesting to the probable presence of intrusive rock at shallow depth.

Thickness

Thickness of the carbonate section measured at its widest outcrop on the south side of Cave Canyon is 2,712 feet. The base of the section is not exposed, being covered by alluvium, so the measured thickness is a minimum.

Age and Correlation

In spite of diligent search no evidence of fossil remains could be found, and because of this, the rocks have not been precisely dated or correlated. Work in the San Francisco Range to the west (Butler, 1913), provides the only nearby attempt at differentiation of pre-Permian rocks and this section fails to provide a unit which can be correlated with exposures in the Mineral Range on the basis of lithology alone. The only unit in the San Francisco Range section that is of similar thickness, is the Grampian limestone of Cambrian (?) and Ordovician age. This formation is described as heavy-bedded blue and grey limestone with some dolomite and shale near the top. The upper part of the Grampian limestone as exposed in the San Francisco Range contains definite Ordovician fossils. The variation in lithology between the Mineral Range exposures and those of the San Francisco Range could be attributed to normal facies
change, particularly since the section in the Mineral Range would correspond, roughly, to the upper one-half of the San Francisco Range section. The lack of fossils in Mineral Range exposures, however, precludes absolute correlation. None of the remaining units, overlying the Cretaceous limestone and underlying the Mississippian Topache formation, are at all similar to the rocks in question.

Contact Relations

The base of the section is not exposed, being covered by alluvium south of Cave Canyon, and by talus in the northern exposures where the beds are in fault (?) contact with Precambrian rocks. The undifferentiated limestones and dolomites are overlain, in angular unconformity, by thick grey limestones of upper Mississippian (?) age which are referred to the Topache formation.

Measured Section

Section measured at the mouth of Cave Canyon.

Upper Mississippian limestones.

Unconformity.

Undifferentiated Paleozoic.

21. Dolomite, thick-bedded to massive, light grey, dense, light grey on fresh surfaces. -------------------------- 67 feet

20. Dolomite, massive to thick-bedded, tan, sucrose, white on fresh surfaces. ------- 62 "

19. Dolomitic limestone, medium-bedded, tan to light grey, dark grey on fresh surfaces. ------------------------------- 15 "
18. Dolomitic limestone, medium- to thin-bedded, white to tan, dense, white on fresh surfaces. 200 feet

17. Dolomitic limestone, thin-to medium-bedded, buff to tan, brown on fresh surfaces. 78 feet

16. Dolomite, massive to thick-bedded, tan to light grey, dense, white to light grey on fresh surfaces. 410 feet

15. Dolomitic limestone, medium-bedded, light grey, mottled, medium grey on fresh surfaces. 315 feet

14. Dolomite, thick-bedded, tan, sucrose white to light grey on fresh surfaces. 77 feet

13. Dolomite, massive, white to tan, white on fresh surfaces. 270 feet

12. Dolomite, massive, white to tan, sucrose, white on fresh surfaces. 70 feet

11. Dolomite, medium-bedded, light grey, buff to tan on fresh surfaces. 15 feet

10. Dolomite, medium-bedded, light tan, sucrose, white on fresh surfaces. 125 feet

9. Dolomite, thick-bedded to massive, light grey. 115 feet

8. Dolomitic limestone, medium-bedded, grey to black, mottled. 280 feet

Intrusive quartz monzonite

7. Limestone, thick-bedded, grey, forms a talus slope. 295 feet

6. Limestone, massive to thick-bedded, grey, mottled. 55 feet

5. Limestone, massive, buff, sucrose, white on fresh surfaces. 56 feet
Measured section continued.

4. Dolomitic limestone, medium-bedded, buff to tan, dense, forms a talus slope. -------- 40 feet

3. Dolomite, thick-bedded, buff, light grey on fresh surfaces. ------------------------ 12 "

2. Dolomite, thin-bedded, tan to white, forms a talus slope. ------------------------ 40 "

1. Dolomite, sandy, medium bedded, tan, coarsely crystalline, white on fresh surfaces. ------------------------ 115 "

Total undifferentiated Paleozoic. ------------------------ 2,712 feet

Base not exposed.

MISSISSIPPIAN ROCKS

Upper Mississippian (?) Topache Limestone

Distribution

The Topache formation crops out in a narrow belt from the north divide of Cave Canyon southward to the Guyo Canyon fault, and as isolated exposures from Lincoln Gulch to Beaver Canyon. The belt of outcrop is offset by the Cave Canyon fault, and again by the Guyo Canyon fault.

Lithology

The formation is composed of thin-bedded to massive, tan to grey limestone. The section has been intruded by a thick aplite dike, and beds below the dike are altered to a grey to white, sucrose marble. Two of the massive units are intricately fractured, the fractures being filled with secondary calcite, and two units contain abundant, though poorly preserved fossils (see measured section).
Thickness

Thickness of the Topache formation, as measured on the south side of Cave Canyon is 917 feet. The formation thins southward to Guyo Canyon where it terminates against the Guyo fault. Exposures south of Lincoln Gulch are limited in area, and the base of the formation is not exposed.

Age and Correlation

The poorly preserved fossils collected from the Topache formation, in the Mineral Range, serve only to indicate a probable late Mississippian age for the formation. Exposures in the San Francisco Range, (Butler, 1913), are described as heavy bedded blue and grey limestone with some dolomite and quartzite at the base. Thickness is given as 1,500 feet. Fossils collected in the San Francisco Range establish Mississippian age for these deposits. The Mineral Range section is considerably thinner than that exposed in the San Francisco Range, and no quartzite is exposed at the base. In view of the general lithologic similarity and the fossil evidence, correlation with the San Francisco Range exposures seems justified. This correlation is enhanced by similar lithologic sequence in overlying formations in both localities.

Contact Relations

The Topache formation is overlain unconformably by the Permian Coconino sandstone, and lies unconformably on undifferentiated Paleozoic dolomites. Angularity of the basal contact with the lower Paleozoic dolomites ranges from a minimum at Cave Canyon, where the two units strike parallel to each other, to a maximum at Herb Eyre Hollow where there is a
divergence of 80 degrees in strike and 9 degrees in dip. Angularity of the upper contact with the Coconino sandstone is slight, and is recognizable through the southward thinning of Topache formation exposures rather than measurement of the attitude of the beds.

Measured Section

Section measured along the south side of Cave Canyon.

Coconino sandstone.

Unconformity.

Topache limestone.

29. Limestone, massive to thick-bedded, grey-green, dense, light grey on fresh surfaces. 162 feet
28. Limestone, massive, dark grey, with calcite stringers, medium grey on fresh surfaces. 140 "
27. Limestone, thin-bedded, tan to light grey, dark grey on fresh surfaces. 39 "
26. Limestone, beds one to three feet, dark grey, dark grey to blue on fresh surfaces. 88 "
25. Limestone, massive, grey, mottled, with calcite stringers, dark grey to blue on fresh surfaces. 39 "
24. Limestone, massive, grey, crinoidal debris, dark grey to blue on fresh surfaces. 41 "
Intrusive, aplite dike (240) "
23. Limestone, massive to thick-bedded, light grey, sucrose, white to light grey on fresh surfaces. 260 "
22. Limestone, massive to thick-bedded, tan, coarse crystalline, mottled, light grey on fresh surfaces. 148 feet

Total Topache limestone. 917 feet

Unconformity.

Undifferentiated Paleozoic.

PERMIAN SYSTEM

Coconino sandstone

Definition

The Coconino sandstone was named and described by Darton (1910) to include the grey to white, cross-bedded sandstones of the upper Aubrey group of older reports. The formation, as presently defined, underlies the Kaibab limestone, and overlies the Hermit shale. Baker and Reeside (1929) and Moore and Gregory (1931) show that the Coconino, in southern Utah, is thicker than in the type section in northern Arizona, and occupies a part of the time interval of the underlying Supai formation and Hermit shale and the overlying Kaibab limestone. This may account for the absence of Hermit shale equivalents, and the excessive thickness of the Coconino formation in the Mineral Range.

Distribution

The Coconino formation crops out in a narrow belt from Beaver Canyon, at the south end of the range, to the divide north of Cave Canyon on the north, a distance of approximately seven miles. In addition, quartzites which are tentatively correlated with the Coconino are exposed
for about two miles along the east flank of the range, where they are in intrusive contact with the Mineral Range pluton. A small exposure of the formation can be observed in an inselberg on the west central flank of the range.

**Lithology**

The Coconino, as exposed in the Mineral Range, is a medium-bedded, buff to pink, cross-bedded orthoquartzite, owing its lithification to the presence of secondary silica as a cementing material. This lithology is consistent with that of quartzites occupying the same stratigraphic interval in the San Francisco Range to the west, (Butler 1913), and the Marysvale district some 25 miles to the east, Callaghan (1938).

**Thickness**

Thickness of the Coconino formation, as measured along the south side of Cave Canyon, is 1,181 feet and is relatively constant wherever the base and the top of the formation are exposed. Exposures believed to be Coconino equivalents, exposed along the east flank of the range indicate a greater thickness, but talus and alluvial cover may obscure a fault repetition of the section of this area.

**Age and Correlation**

The Coconino sandstone, as exposed in the Mineral Range, apparently correlates with the Talisman quartzite of the San Francisco Range to which Butler assigned a tentative Pennsylvanian age. Tentative dating of the formation in the San Francisco Range was based upon its position above Mississippian limestones, and below the Elephant limestone which Butler
believed to be of Pennsylvanian age. Although the formation is more highly silicified than the Coconino of the type section, the lithology and relationship to other formations support a correlation between the exposures of the Mineral Range and those of the Grand Canyon area. Callaghan (1938) also found quartzite underlying Permian limestone in the Tushar Range, 25 miles east of the Mineral Range. He did not, however, assign a name to the formation.

Contact Relations

The basal contact of the Coconino sandstone with the Topache formation is an angular unconformity, as is shown by the gradual pinchout of the underlying formation. The upper contact with the Kaibab limestone is disconformable, with minor local angularities.

Measured Section

Section measured along the south side of Cave Canyon.

Kaibab limestone.

Unconformity.

Coconino sandstone.

35. Quartzite, medium-beded, buff
to tan, cross-beded. ------------------ 178 feet

34. Quartzite, thick-beded, buff to
tan, medium-grained, spotted by
small concentrations of iron
oxide. ------------------------------ 135 "

33. Quartzite, medium-beded, buff
to pink, cross-beded, fine
grained. -------------------------- 148 "
32. Quartzite, medium-bedded, buff to pink, cross-bedded, white to light tan on fresh surfaces. = 705 feet

31. Quartzite, medium-bedded, tan to brown, medium grained, buff brown on fresh surfaces. = 10 "

30. Quartzite, thin-bedded, brown to red-brown, very fine grained. = 5 "

Total Coconino sandstone. = 1,181 feet

Unconformity.

Topache limestone.

Kaibab Limestone

Definition

The Kaibab limestone was first described by Darton (1910), as the upper limestone member of the Aubrey group, overlying the Coconino sandstone, and underlying the Moenkopi formation. Noble (1928), described a complete section of the formation exposed in Kaibab Gulch, near Paria in southern Utah, which has since been accepted as the type section.

Distribution

The Kaibab formation as seen in the Mineral Range, crops out from the southeast corner of the range to the north side of Cave Canyon, a distance of approximately seven miles. A small exposure is present in the Pass Canyon area, where it has been isolated by normal faulting along the eastward extension of the Cave Canyon fault. Limestone exposures which are believed to be Kaibab are present along the eastern contact of
the Mineral Range pluton from Pass Canyon northward for several miles. These exposures are highly altered, and the writer was unable to find identifiable fossils in them. The lithologic sequence of limestone underlain by quartzite, however, suggests that the limestone is properly identified as Kaibab. There are also three small inselbergen of Kaibab limestone on the west central flanks of the range.

Lithology

The Kaibab formation in the Mineral Range is a medium-bedded to massive, tan to light grey limestone, characterized by an abundance of chert. Chert ranges from spongy masses; which form discrete bands two to three feet in thickness and which are traceable for many hundreds of feet along the outcrop, to lenticular masses a few inches to a few feet in maximum dimension. The formation is a strong cliff-former, as compared with the overlying Moenkopi shales, and is found capping steep and rugged ridges throughout the belt of outcrop.

Thickness

Thickness of the formation, as measured three-quarters of a mile north of Beaver Canyon, is 698 feet. Another section measured along the south side of Cave Canyon correlates almost perfectly with the Beaver Canyon section, the measured thickness being 702 feet. Lee (1910), measured a section along Utah Highway 21 which is 1,150 feet thick. The present work has shown that faulting has caused a partial repetition of the formation, producing the apparent excessive thickness.
Age and Correlation

The writer made no large fossil collections from the Kaibab formation since its age and fauna had already been established by Lee (1910). The fossil fauna collected by Lee was identified by G. H. Girty as upper Aubrey (Permian). Fossils identified from the formation include: Zaphrentis (?) sp., Fistulipora sp., Septopora sp., Productus aff. P. subhorrudus, Meekella (?) sp., Spirifer aff. S. cameratus, Squamularia aff. S. perplexa, Spiriferina aff. S. kentuckyensis, Spiriferina sp., Composita aff. C. subtilita, Hustedia aff. H. meekana, Pugnax aff. P. osagensis. Additions to this fauna, collected by the writer in routine mapping of the area, and identified by W. L. Stokes are: Marginifera meridionalis, Spirifer pseudocameratus (?), Plagioglypta sp., Dictyoclostus sp., Euphemus sp., Schizodus sp.

Contact Relations

The basal contact of the Kaibab limestone with the underlying Coconino sandstone is disconformable, as is shown by the fact that the width of Coconino exposures does not vary to a noticable degree from one end of the outcrop belt to the other. Local angular discordance of the contact has been noted at several places, however, suggesting slight relief of the underlying Coconino beds. The upper contact of the Kaibab formation with the basal Moenkopi sediments is also apparently disconformable, being marked locally by the presence of a basal conglomerate.
Measured Section

Section measured three-quarters of a mile north of Beaver Canyon, two miles east of Minersville, Utah.

Moenkopi formation.

Unconformity.

Kaibab limestone.

7. Limestone, dolomitic, light tan with numerous small cherts, light grey on fresh surfaces. ------------------ 200 feet

6. Limestone, buff to tan, bands of dark spongy chert give a banded appearance, light grey on fresh surfaces. ------------------ 100 feet

5. Quartzite, yellow brown, fine grained, light brown on fresh surfaces. ------------------ 130 "

4. Limestone, light tan, banded, medium bedded with large dark chert lenses, grey on fresh surfaces. ------------------ 115 "

3. Limestone, massive, light grey, with dark chert lenses, dark grey on fresh surfaces. ------------------ 85 "

2. Limestone, thick bedded, tan, porous, tan on fresh surfaces. ------------------ 48 "

1. Limestone, thin bedded, tan, slightly banded, dark grey on fresh surfaces. ------------------ 20 "

Total Kaibab limestone. ------------------ 698 feet

Unconformity.

Coconino sandstone.
TRIASSIC SYSTEM

Moenkopi Group

Definition

The Moenkopi group was first described by Ward (1901) to include the thick series of shales, sandstones, and limestones underlying the Shinarump conglomerate, and overlying the upper Aubrey (Kaibab) limestone. Reeside and Bassler (1922) subdivided the formation, giving member status to the Shnabkaib, Virgin, and Rock Canyon conglomerate units. Gregory and Williams (1947) redefined the lower (Rock Canyon conglomerate) member of Reeside and Bassler, under the name Timpoweap, and recognized three additional units, the lower, middle and upper red members. The formation as presently defined includes, from the base to the top; the Timpoweap conglomerate, the lower red member, and Virgin limestone, the middle red member, the Shnabkaib limestone, and the upper red member.

Distribution

The area of outcrop of the Moenkopi group, in the Mineral Range, is an elongate belt extending from the southwest corner of the range to Cave Canyon on the north where it terminates against the Cave Canyon fault. The formation is repeated, in part, by faulting at the eastern end of Cave Canyon where its characteristic red shales cover extensive areas. There is also a small outcrop present in an inselberg on the west central flank of the range.
Thickening and Lithology

Lower Red Bed Unit. - The basal portion of the Moenkopi group in the Mineral Range consists of red, brown, and yellow calcareous sandstone and sandy shale. Locally a basal conglomerate up to 15 feet thick is present. This is composed of chert fragments and cobbles and pebbles of limestone apparently derived from the underlying Kaibab limestone. Total thickness of the lower red bed unit, as measured three-quarters of a mile north of Beaver Canyon, is 111 feet.

Middle Limestone Unit. - Overlying the lower red bed unit is a thick sequence of medium-bedded to massive grey limestone interbedded with thin-bedded, grey and brown limestone and calcareous shale. Thickness of the unit, measured three-quarters of a mile north of Beaver Canyon, is 567 feet.

Upper Red Bed Unit. - The upper red bed unit of the Mineral Range is a thick series of red-brown to maroon, ripple-marked, sandy shale, and minor interbedded limestone. Thickness of the unit, measured three-quarters of a mile north of Beaver Canyon is 574 feet. The unit appears to thicken northward from the measured section, but this is in part due to fault repetition of the beds. The writer was unable to find a recognizable marker horizon to determine the degree of repetition, so the thickness is estimated to range from 574 to 1,000 feet.

Summary. - The Moenkopi group, as exposed in the Mineral Range, is composed of a lower and upper red bed unit, separated by grey to brown limestone and calcareous shale. Total thickness of the group ranges from 1,282 to 1,708 feet.

Age and Correlation

The middle limestone unit is the only member of the Moenkopi group
in which fossils were found in the Mineral Range. Fossils collected by Lee (1910) and identified by G. H. Girty include: Pleurotomaria (?) sp. Bakewellia n. sp. Naticopsis sp. Xenodiscus (?) sp. Aviculopecten weberensis, A. aff. A. occidentalis, Myalina aff. M. perattenuata, and Pleurophorus sp. Additions to this fauna, collected by the writer and identified by W. L. Stokes are: Monotis sp. and Flemingites sp. This fauna belongs to the Meekoceras or middle zone of early Triassic faunas as understood by Smith (1932) and establishes the middle limestone unit of the Mineral Range as being the approximate age equivalent of the Sinbad limestone unit, of the lower red member of the Moenkopi formation. Red beds, underlying the middle limestone unit, can then be correlated with the basal lower red member, and the conglomerate which is found at the base of the Mineral Range section locally would appear to be equivalent to the Timpoweap member of the formation. No fossils were found in the upper red bed unit of the Mineral Range. In view of the lack of evidence of younger age, it is proposed that these beds be considered older than the Virgin limestone (Tirolites zone), and thus equivalent to the upper part of the lower red member of the Moenkopi formation as described by Gregory and Williams (1947).

Contact Relations

Wherever the base of the Moenkopi group is exposed, it rests upon Kaibab limestone. Angularity of the contact, if any, is very slight and the unconformity is recognized by the presence of local, basal conglomerate. In Beaver Canyon, the upper red bed unit is overlain unconformably by the Cretaceous (?) Clarion conglomerate. Elsewhere in the range, the Moenkopi
group in overlain unconformably by the Navajo sandstone. Angularity of the contact is slight, ranging up to 8 degrees.

**Measured Section**

Section measured three-quarters of a mile north of Beaver Canyon, two miles east of Minersville, Utah.

Claron (?) conglomerate.

Unconformity.

Moenkopi group

**Upper red bed unit.**

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>31.</td>
<td>Limestone, medium-bedded, tan, mudball conglomerate, light tan on fresh surfaces.</td>
<td>27 feet</td>
</tr>
<tr>
<td>30.</td>
<td>Shale, beds 1/8 to 1/4 inch thick, chocolate brown.</td>
<td>11 &quot;</td>
</tr>
<tr>
<td>29.</td>
<td>Shale, calcareous, thin-bedded light grey, medium grey on fresh surfaces.</td>
<td>123 &quot;</td>
</tr>
<tr>
<td>28.</td>
<td>Limestone, thick-bedded, reddish-brown, light grey on fresh surfaces.</td>
<td>22 &quot;</td>
</tr>
<tr>
<td>27.</td>
<td>Limestone, thick-bedded to massive light grey with many small cherts, medium grey on fresh surfaces.</td>
<td>27 &quot;</td>
</tr>
<tr>
<td>26.</td>
<td>Shale, sandy, in beds 1/4 to 1 inch thick, chocolate brown, ripple-marked.</td>
<td>64 &quot;</td>
</tr>
<tr>
<td>25.</td>
<td>Shale, calcareous, in beds 1/8 to 1/4 inch thick, red-brown.</td>
<td>80 &quot;</td>
</tr>
<tr>
<td>24.</td>
<td>Sandstone, calcareous, thin-bedded, tan, buff on fresh surfaces.</td>
<td>12 &quot;</td>
</tr>
<tr>
<td>23.</td>
<td>Shale, calcareous, thin-bedded, variegated, chocolate brown, red, and grey, ripple-marked.</td>
<td>208 &quot;</td>
</tr>
</tbody>
</table>
Measured section continued.

Total upper red bed unit. ---------------------------------- 57.4 feet

Middle limestone unit.

22. Limestone, thin-bedded, grey, light grey on fresh surfaces. ------------------ 130 feet

21. Limestone, thin-bedded, grey-green, light grey on fresh surfaces, very fossiliferous. ------------------ 15 "

20. Limestone, shaley, in beds 1/4 to 1 inch thick, grey-brown, dark grey on fresh surfaces. ------------------ 18 "

19. Limestone, medium-bedded, grey-brown, dark brown on fresh surfaces. ------------------ 12 "

18. Shale, calcareous, beds 1/4 inch thick, buff to tan, dark grey-brown on fresh surfaces. ------------------ 10 "

17. Limestone, medium-bedded, grey-brown, dark grey-brown on fresh surfaces, fossiliferous. ------------------ 8 "

16. Limestone, shaley, beds 1/4 inch thick, grey-green. ------------------ 25 "

15. Limestone, 1/2 to 6 inch beds, tan, grey-brown on fresh surfaces. ------------------ 8 "

14. Limestone, beds 1/8 to 1/4 inch thick grey to buff, dark brown on fresh surfaces. ------------------ 120 "

13. Limestone, medium-bedded, buff, light grey on fresh surfaces, fossiliferous. ------------------ 10 "

12. Limestone, shaley, thin-bedded, red-brown, grey-brown on fresh surfaces. ------------------ 83 "

11. Limestone, medium-bedded, brown, dark brown on fresh surfaces. ------------------ 128 "

Total middle limestone unit. ------------------ 567 feet
Lower red bed unit.

10. Shale, sandy and calcareous, beds
    1/8 to 1/2 inch thick, red, brown, and yellow, with very minor inter-
    bedded limestone. 61 feet

9. Sandstone, calcareous, medium-bedded, bright yellow and orange, some inter-
    bedded thin limestone. 70 "

8. Conglomerate, lenticular, pebbles and cobbles of Kaibab limestone, and chert
    nodules in a limestone matrix. 10 "

Total lower red bed unit. 111 feet.

Total Moenkopi group. 1,282 feet

Unconformity.

Kaibab limestone.

JURASSIC SYSTEM

Navajo Sandstone

Definition

The name Navajo sandstone was first used by Gregory (1915) for the light red, massive, cross-bedded sandstones underlying the Mc Elmo formation. In a later paper (1916) he re-defined the formation as underlying the Mc Elmo formation and overlying the Todilto formation. The name Navajo, as currently used, applies to the Jurassic sandstone overlying the Kayenta formation and underlying the Carmel limestone.

Distribution

The formation is exposed in the southern part of the Mineral Range,
south of Pass Canyon, and extending south in a generally arcuate belt 6 miles long and up to 2 miles in width.

Lithology

The formation, as exposed in the Mineral Range, is a medium-to-thick-bedded, buff to pink, cross-bedded sandstone. The lower units of the formation are noticeably more red than the upper units.

Thickness

Thickness of the Navajo sandstone, as measured at the head of Cave Canyon and along the divide east of Cherry Creek Canyon is 1,538 feet.

Age and Correlation

Identification of Mineral Range exposures as Navajo sandstone equivalents is made on the basis of lithology, and the stratigraphic position of the formation underlying the upper Jurassic Carmel limestone. Similar sandstone has been mapped and correlated with the Navajo in eastern Iron County, Utah, 10 to 20 miles south of the Mineral Range (Gregory, 1950), and in the Pavant Range to the north by Maxey (1946). In both of these areas the Navajo is separated from the underlying Moenkopi formation by the Chinle formation and the Shinarump conglomerate, neither of which is present in the Mineral Range.

Contact Relations

The basal contact of the formation with the upper Moenkopi shales is an angular unconformity, angularity ranging up to 8 degrees. The upper contact, with the limestone of the Carmel formation, is also unconformable.
Measured Section

Section measured at the head of Cave Canyon, and along the divide of Cherry Creek Canyon.

Carmel formation.

Unconformity.

Navajo sandstone.

77. Sandstone, thin-to-medium-bedded, brick red and red-brown, tan to red brown on fresh surfaces. 92 feet

76. Sandstone, medium-to-thick-bedded, buff to salmon, fine grained, banded and cross-bedded. 320 "

75. Sandstone, medium-bedded, buff to tan, medium grained, cross-bedded. 105 "

74. Sandstone, medium-bedded, tan, cross-bedded, white to tan on fresh surfaces. 180 "

73. Sandstone, thin-to-medium-bedded, brick red, medium grained, dark red, on fresh surfaces. 168 "

72. Sandstone, medium-bedded, grey-brown, coarse grained, arkosic, light grey on fresh surfaces. 20 "

71. Sandstone, thick-to-medium-bedded, red to salmon pink, banded, white to buff on fresh surfaces. 100 "

70. Sandstone, medium-bedded, brick red, fine grained, banded and cross-bedded. 108 "

69. Sandstone, medium-to-thick-bedded, buff to pink, cross-bedded, salmon on fresh surfaces. 325 "

68. Sandstone, medium-to-thick-bedded, brown to red-brown, coarse grained, buff on fresh surfaces. 118 "

Total Navajo sandstone. 1,538 feet

Unconformity.

Moenkopi formation.
Carmel Formation

Definition

The Carmel formation was first described by Gilluly and Reeside (1926) as dense limestones with buff and red sandstone at the base, and red and green shales at the top, overlying the Navajo sandstone, and underlying the Entrada sandstone. The name is taken from the type locality at Mount Carmel, western Kane County, Utah.

Distribution

The formation crops out over extensive areas in the south-central part of the Mineral Range. The section is partially repeated three times, by faulting, in the belt of outcrop and each fault is bordered by a sheer cliff formed by the massive member some 50 feet above the base of the formation.

Lithology

The formation, in the Mineral Range, is composed of a basal member of thin to medium bedded limestone which is overlain by a massive, cliff forming member 36 feet in thickness. This is overlain by a thick sequence of red-brown, tan and grey limestones and calcareous shales.

Thickness

Thickness of the Carmel formation, as measured at the head of Cherry Creek Canyon, is 574 feet.

Age and Correlation

Several members of the formation are fossiliferous, and some beds are
essentially a fossil hash. Whole and well preserved fossils, however, are not abundant. Fossils collected from the formation and identified by W. L. Stokes include: *Ostrea strigilecula, O. sp.*, and *Pentacrinitus sp.*, which establish the age of the formation as upper Jurassic and as equivalent to the Carmel and Twin Creek formations. The Carmel formation is also found, unconformably overlying the Navajo sandstone, in eastern Iron County some 10 to 20 miles south of the Mineral Range (Gregory, 1950).

**Contact Relations**

The Carmel formation lies unconformably on the Navajo sandstone. Angularity of the contact ranges up to 10 or 12 degrees. The top of the formation is covered over most of the area of outcrop by Tertiary volcanic rocks. In a small area one-half mile south of Pass Canyon the Cretaceous (?) Claron conglomerate rests on the eroded surface of the Carmel.

**Measured Section**

Section measured southeastward from the head of Cherry Creek Canyon.

Volcanics, southern series.

Erosional surface.

Carmel formation.

- **82. Limestone, beds 1/4 to 1 inch thick, tan to grey, laminar, fossiliferous, grey-brown on fresh surfaces.**
  
  70 feet

- **81. Limestone and calcareous shale, beds 1/4 to 1/2 inch thick, grey to red-brown, laminated, light grey to grey-brown on fresh surfaces.**
  
  286″
80. Limestone, beds 1 to 6 inch thick, light grey, fossiliferous, dark grey on fresh surfaces. 128 feet

79. Limestone, massive, buff to tan, oolitic, a cliff forming member. 36 "

78. Limestone, medium-to-thick-bedded, light grey with calcite stringers, dark grey on fresh surfaces. 52 "

Total Carmel limestone. 574 feet

Unconformity.

Navajo sandstone.

CRETACEOUS (?) SYSTEM

Claron Conglomerate (?)

Distribution

The Claron conglomerate (?) is exposed in a narrow belt north of Beaver Canyon, where it overlies the upper shales of the Moenkopi group, and a small exposure is present one-half mile south of Pass Canyon, where it rests on limestones of the Carmel formation.

Lithology

The basal beds of the conglomerate, north of Beaver Canyon, contain large angular blocks derived from the underlying Moenkopi formation. Above the base, the bulk of the deposit is composed of well-rounded cobbles of limestone, with subordinate sandstone and quartzite apparently derived from the Navajo and Coconino formations. The limestone cobbles resemble the Carmel, Kaibab, and Topache formations but no fossils were found to
verify this derivation. Interstitial material is largely composed of finer debris from the upper Moenkopi shales giving the deposit a pronounced red-maroon coloration. Cement is calcareous, and in some beds constitutes as much as 50 percent of the deposit.

Age and Correlation

These deposits were observed by Lee (1910) and by Dennis (1935) and were related to the Wasatch formation. Conglomerate of similar, but not identical lithology, has been mapped by Liese (1957) in the Northern Mineral Range, and tentatively correlated with the basal Indianola conglomerate of the Canyon Range. This conglomerate rests unconformably on Cambrian sediments, and in the absence of complete lithologic correlation or similarity of stratigraphic sequence, the two exposures cannot be equated. The writer proposes a tentative correlation of the conglomerate exposed in the Beaver Canyon area with the basal Clarion formation as exposed at Iron Springs in Iron County, Utah, Mackin (1947). The lithologies are similar and the deposits are overlain by similar volcanics. The thick Clarion limestones sequence which overlies the basal conglomerate at Iron Springs is missing or covered in the Mineral Range, making absolute correlation impossible. Dating of the deposit must therefore, remain tentative.

Contact Relations

The Clarion conglomerate (?) rests unconformably on the upper shales of the Moenkopi group, north of Beaver Canyon, and on the Carmel lime-
stone south of Pass Canyon. The formation is overlain by Tertiary volcanic rocks.

PLIOCENE-PLEISTOCENE DEPOSITS

Bonneville Sediments

Distribution

Surface exposures of Bonneville age are rather sparsely distributed along the west flank of the range. The deposits consist of a series of gravel bars and delta deposits at the intersection of the old drainage channels and the shoreline of the lake which occupied the Escalante desert basin in Pleistocene time. Lake deposits underlie alluvium to depths in excess of 300 feet at Milford, on the west side of the range, and are also found in Beaver Valley to the east of the range.

Lithology

Surface deposits consist almost equally of sand and well-rounded pebbles, ranging from one-half to three inches in maximum dimension. The pebbles are mainly of volcanic material, rhyolite, rhyolite porphyry, and obsidian, with a minor proportion derived from the finer grained granitic facies of the central mass. Sand sizes are derived, apparently, from the quartz of the deeply eroded Mineral Range pluton. Pebbles are well rounded, suggesting movement and resorting at the site of deposition, as the distance of travel from the original source is not great. Bedded lake deposits have been penetrated in water wells at Milford, adjacent
to the subject area, which are composed of alternating gravel, sand, and clay. Similar deposits are also found in Beaver Valley on the east side of the range.

**Thickness**

The maximum known thickness of lake deposits adjacent to the subject area is reported from the Lewis well at Milford. Drillers' records of this well show a thickness of 750 feet of alternating gravel, sand, clay, and quicksand. No detailed log of this well is available. A detailed log of the San Pedro, Los Angeles, and Salt Lake Railroad (now Union Pacific) well, at Milford is given as a measured section for the area. This well penetrated 310 feet of lake deposits, but the base of the section was not reached. Similar deposits have been penetrated to depths ranging from 150 to 250 feet by wells in Beaver Valley on the east side of the range as well.

**Measured Section**

Reproduced from the driller's log of the San Pedro Los Angeles and Salt Lake Railroad well at Milford. After Lee, W. T. (1908).

<table>
<thead>
<tr>
<th>Layer</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>18. Soil (recent)</td>
<td>4 feet</td>
</tr>
<tr>
<td>17. Sand (recent)</td>
<td>6 &quot;</td>
</tr>
<tr>
<td>16. Blue clay</td>
<td>22 &quot;</td>
</tr>
<tr>
<td>15. Sand</td>
<td>33 &quot;</td>
</tr>
<tr>
<td>14. Blue clay</td>
<td>10 &quot;</td>
</tr>
</tbody>
</table>
13. Sand and gravel -------------------------- 15 feet
12. Blue clay ------------------------------- 25 "
11. Hardpan ------------------------------- 4 "
10. Quicksand ----------------------------- 35 "
  9. Blue clay ------------------------------- 15 "
  8. Sand ------------------------------- 5 "
  7. Red clay ----------------------------- 81 "
  6. Quicksand ----------------------------- 10 "
  5. Sand ------------------------------- 5 "
  4. Clay ------------------------------- 8 "
  3. Sand ------------------------------- 10 feet
  2. Yellow clay --------------------------- 17 "
  1. Cemented gravels ---------------------- 5 "

Total depth (base of the section not reached) ------ 310 feet

Older Valley Fill

Distribution
Bedded deposits of gravel and sand of Quaternary (?) age are exposed in a small area in Pass Canyon near the head of Russell Creek. The deposits can be traced for a distance of approximately one-half mile along the channel eroded by Russell Creek. No similar deposits are exposed in other drainage channels of the range, either because of recent alluvial cover, or due to complete removal through erosion.

Lithology and Thickness
The deposits, as exposed on the steep walls of the channel eroded
by Russell Creek, are 30 to 40 feet in thickness, and are composed of al-
ternating gravel, sand, and soil. The gravel and sand are apparently
derived from erosion of the Mineral Range pluton, which flanks the deposit
on the north, and from the Navajo sandstone which is exposed to the south.
The deposit has a varved appearance, on an exaggerated scale, which may
be due to a seasonal increase in the quantity of organic material in-
corporated in the deposit, and the addition of greater quantities of
coarse material during spring runoff at the time of deposition.

Age and Correlation

The elevation of exposures of older valley fill, being approximately
1,500 feet above the floor of Beaver Valley, indicates that they may have
been deposited at a time when the local base level was much higher than
at present. In view of the presence of lake sediments under covering al-
luvium in Beaver Valley, it would seem probably that this alluviation of
the upper reaches of Pass Canyon occurred at the time that base level was
controlled by the presence of a lake in the bordering valley. The age of
this lake is not known, but Lee (1910) postulates that it was contem-
poraneous with Lake Bonneville which occupied the basin west of the Mineral
Range in Pleistocene time. Because of this relationship, the writer has
assigned a tentative Pleistocene age to these deposits.
Fig. 3. View of older valley fill, exposed near the head of Russell Creek in Pass Canyon.
PLEISTOCENE AND RECENT DEPOSITS

Recent Alluvium and Pediment Gravels

The youngest deposits of the area are the pediment gravels and alluvial fan material currently accumulating on the flanks of the range, and the finer material which is carried far into the valleys on the east and west.

Alluvial fans are far less extensive than would appear at first glance. Close examination of the deposits flanking the range, show that except where older drainage channels have been alluviated, the deposits are but a thin veneer covering the pedimented bedrock. The granite of the Mineral Range pluton erodes to form a coarse wash, composed of pebbles ranging in size from one-eighth to one inch in diameter, which is the dominant material found in the pediments.

The contact between the pediment gravels and the alluvium has been drawn, in some cases rather arbitrarily, at the pronounced topographic change where the relatively steep pediments flatten and extend into the valley. The character of the deposits shows a continuous gradation from pediment gravel to alluvium, although taken as a whole the pediment cover is coarser than that which reaches the more gentle valleyward slopes.

Alluvium forms an extensive, but relatively thin cover, extending across the valleys bordering the range. Examination of the section penetrated by the Milford well, shows that even at a distance of eight miles from the range the well entered lake sediments at a depth of ten feet. Other wells, drilled both east and west of the range, show thicknesses of soil and alluvium ranging from two to sixty feet.
Fig. 4. View looking north at the pediment slopes on the west side of the Mineral Range.
IGNEOUS ROCKS

GENERAL STATEMENT

Intrusive igneous rocks exposed in the central Mineral Range include; (1) the large Mineral Range pluton composed of coarse grained granite, (2) several small quartz monzonite stocks which are found along the southwest flanks of the range, (3) aplite and andesite dikes which are widely distributed around the margins of the Mineral Range pluton and in the sediments and meta-sediments of the contact zone, (4) pegmatite deposits which are associated with the aplite dikes, and, (5) granite sills which have been intruded along relic bedding planes of the Precambrian meta-sediments north of Cave Canyon. Extrusive rocks include; (1) rhyolite, rhyolitic obsidian and vitrophyre, and acid pyroclastics which occur in the north-central part of the range, and, (2) a southern volcanic series composed of basal andesite flows and agglomerate, quartz latite flows and tuff, and capping olivine basalt flows exposed along the southern margins of the range.

The present study is not intended to be an exhaustive study of the petrography of igneous rocks exposed in the range. Identification of rock species is based upon field observation and petrographic examination of from one to three thin sections representing the major groupings used. Figures given for the percentage mineral composition of samples are based upon visual estimate.
INTRUSIVE ROCKS

Mineral Range Pluton

Distribution

The name Mineral Range pluton is applied to the large granite body which forms the central mass or backbone of the Mineral Range. It crops out in an elongate belt having a slightly northeasterly trend. The exposed length of the body within the mapped area is fourteen miles and it continues several miles farther into the northern Mineral Range (Liese, 1957). The pluton reaches a maximum of slightly over five miles in width, with an average of about four miles giving an outcrop area of approximately fifty-four square miles. The presence of numerous inselbergen of granite which project up through the veneer of coarse unconsolidated sediments on the flanks of the range, indicates that the mass is of considerably larger size than indicated above. The writer's estimate of the true surface area of the mass would be seventy square miles within the mapped area, and one hundred square miles with inclusion of the northern extension. In plan, the pluton is irregularly shaped, cutting discordantly through bordering sediments on the east flank of the range. The west flank of the pluton presents an extremely irregular front, deeply embayed by canyons, with narrow saddles and inselbergen extending westward onto the pediment. (see map, Plate I).

Petrography

In the gross, the pluton is composed of a coarse grained white
granite which is conspicuously deficient in ferro-magnesian constituents. Grain size ranges from one-eighth to one-quarter of an inch in diameter. Variation from aplite to pegmatite is common locally. Mineral content also provides variety, but these variations are largely confined to marginal areas, the central mass being generally homogenous in composition.

Petrographic study of three samples taken at widely separated parts of the pluton indicates an average mode of: quartz, 10 to 25 percent; orthoclase, 70 to 80 percent; plagioclase (variety oligoclase), 3 to 5 percent; biotite, less than 1 percent. For a granite, the rock is noticeably deficient in iron, magnesium, and calcium. Texture of the granite is hypautomorphic granular, feldspars occurring as euhedral to subhedral laths, with adhedral quartz filling the interstices.

Along the western margin of the body, where the granite is in contact with Precambrian rocks, there is a belt up to three-quarters of a mile in width through which a gradual increase in the biotite content of the granite toward the Precambrian rocks takes place. This suggests either assimilartion of reconstitution of the biotite-rich Precambrian rocks by the granite.

**Contact Relations**

The most conspicuous feature of the body are the ferro-magnesian deficient composition of the central mass and the presence of a ferro-magnesian enriched zone along its western border. This marginal facies cannot be traced continuously because of alluvial cover, but the evidence provided by isolated inselbergen, and more or less continuous exposures
where the granite and Precambrian rocks are in contact, strongly suggests that the zone is a continuous one. The fact that this marginal zone is marked by a gradational change in the composition of the granite towards that of the adjacent Precambrian rocks suggests that gradation has resulted either from the assimilation or the reconstitution of the Precambrian rocks. In support of the contention that reconstitution may be the mechanism involved is the presence of apparently oriented inclusions in the granite of the northern Mineral Range (Liese, 1957), and similar though less clearly oriented inclusions of meta-sedimentary rock in the granite of the contact zone in the central Mineral Range, south of Ranch Canyon. Further evidence is provided by the presence of granite, which has formed in place, within the Precambrian meta-igneous rocks exposed north of Cave Canyon. This granite crosses structural features of the older rock without causing displacement, thus precluding intrusive origin for these small marginal bodies.

The eastern margin of the pluton is in contact with Permian (?) limestones and quartzites. The contact is sharply discordant with the sedimentary bedding, and the sediments have been upturned and sheared against the granite. The limestones of the contact zone north of Pass Canyon are strongly metamorphosed, with formation of garnet tactite, epidote, and tremolite close to the contact, and marked silicification and recrystallization of the beds at greater distance from the contact.

**Age**

The youngest rocks intruded by the pluton are Jurassic limestones of the Carmel formation. The oldest rocks overlying the pluton are volcanics of pre-Bonneville age. The volcanics are deposited in deep
Fig. 5. View, showing inclusions of meta-sediments in granite south of the mouth of Ranch Canyon.
valleys of early mature profile that have been eroded into the granite to
depths of several thousand feet, and thus post-date the granite body by
a sufficient time to allow uplift of the range to essentially its present
position, and to permit erosion to remove the covering sediments and
cut deeply into the underlying granite.

Quartz Monzonite Intrusives

Distribution

The name Lincoln stock is applied to the small quartz monzonite
body exposed in Lincoln Gulch, on the southwest side of the range. The
stock trends northwesterly from Lincoln Gulch to the mouth of Guyo Can-
yon. The small exposures of quartz monzonite north of Shearing Corral
Spring and extending northward to the mouth of Cave Canyon are considered
to be related to the Lincoln stock, and all are grouped together for pur-
poses of discussion. The Lincoln stock is the largest body in the group,
having a length of one and eight-tenths miles, and a width of one-half
mile. Total surface area of quartz monzonite exposed, including the
smaller bodies south of Cave Canyon, is approximately one square mile.

Petrography

The quartz monzonite of the Mineral Range is a medium grained,
brown to lavender, biotite-quartz monzonite. Petrographic study of one
sample indicates that the rock has the following mode: quartz, 20 percent;
orthoclase, 40 percent; plagioclase (variety oligoclase) 25 percent;
biotite, 10 percent; and minor accessory minerals, hornblende, 2 percent;
magnetite, 2 percent; sphene and apatite, 1 percent. Sericite and clay minerals are found as alteration products of the feldspars. The texture of the rock is hypautomorphic granular, containing euhedral feldspars 2 to 3 mm in diameter, subhedral biotite 1 to 2 mm in diameter, and anhedral quartz 2 to 3 mm in diameter. Orthoclase crystals have carlsbad twinning, and plagioclase crystals exhibit both carlsbad and albite twins.

Contact Relations

The quartz monzonite bodies intrude lower Paleozoic sediments, south of Cave Canyon, and Permian limestones and quartzites in Lincoln Gulch. The northern and southwestern margins of the Lincoln stock abut sharply against the Guyo Canyon and Lincoln faults, suggesting a relationship in time between emplacement and the formation of these faults.

Sediments in contact with these intrusives have been considerably metamorphosed. The Coconino quartzite is not greatly affected, but where the Kaibab limestone is in contact with the Lincoln stock, the limestone has been marbleized and silicified, with formation of tremolite and epidote near and at the contact. South of Cave Canyon, where small quartz monzonite bodies are in contact with lower Paleozoic dolomites, the principal metamorphic effect is silicification and recrystallization of the dolomite, and recognizable bleaching of the sediments.

Age

The youngest rocks intruded by the quartz monzonite bodies are Permian limestone of the Kaibab formation. The oldest deposits clearly overlying the quartz monzonite are recent pediment gravels, although
volcanic deposits exposed west of the Lincoln stock may post-date intrusion. The sharply linear fault contacts on the north and southeast margins of the stock suggest that emplacement pre-dates the latest period of fault movement which in turn is tentatively dated as mid-Tertiary.

Andesite Porphyry Dikes

Distribution

Andesite porphyry dikes are widely distributed around the margins of the Mineral Range pluton, and in the sediments and meta-sediments of the contact zones of the Mineral Range pluton and the Lincoln stock. A number of these dikes also cross the small inselbergen along the west flank of the range, west of Rock Corral and north of Wildhorse Canyon. The dikes are largely restricted to a north-south orientation, having been emplaced along fault planes which dip steeply westward or vertically. Dikes are small, ranging in width from 3 to 20 feet, and can rarely be traced continuously for more than a few hundred feet. The dikes tend to weather more rapidly than the intruded rocks and only rarely crop out in relief as shown in the photograph (Fig. 6.). Erosional saddles develop on the dike rock and the presence of dike rock is betrayed only by surface debris, or exposures in small road cuts which expose a vertical section.

Petrography

Petrographic study of two thin sections of the andesite porphyry show them to have the following average mode: plagioclase (variety andesine ?), 50 percent; hornblende, 25 percent; chlorite, 15 percent; sericite, 5 percent, and magnetite, 5 percent. Plagioclase crystals are
Fig. 6a. View, looking northward, along the outcrop of an andesite porphyry dike, located in inselberg west of Rock Corral.

Fig. 6b. View of aplite dikes, east of Rock Corral.
sericitized to such degree that the variety was not definitely ascertained. Ground mass of the dike rock is fine grained, composed largely of minute feldspar laths. Structure of the ground mass is pylotaxitic.

**Age**

The age of the andesite porphyry dikes can only be determined with certainty as having followed fault uplift of the range. The extensive erosion of exposures suggests middle to late Tertiary emplacement.

**Aplite Dikes**

**Distribution**

Aplite dikes are widely distributed throughout the marginal areas of the central Mineral Range pluton and less frequently in the sedimentary and metamorphic rocks bordering the mass. They are especially numerous in the granite east of Rock Corral, where dikes ranging in width from one to two inches, to three feet are to be found along almost every joint plane. No attempt has been made to map these innumerable small dikes. The writer has shown all large dikes encountered in the field, with particular emphasis on dikes which occur in sedimentary and metamorphic strata. Dikes found within the central granite mass of the range are generally small, the average width being of the order of six inches, and only rarely as great as three feet. Dikes cutting the sedimentary and metamorphic strata are larger, being from eight to ten feet in width on the average and can usually be traced for several hundred feet along the strike. Exceptionally large dikes are found on either side of Cave Canyon, which are up to 250 feet in width and have been mapped for more than a mile along the strike. These dikes strike roughly parallel to
the sedimentary bedding, but are classified as dikes in the absence of absolute evidence of concordance.

Petrography

Two thin sections examined show an average mode of: quartz, 30 to 40 percent; orthoclase, 55 to 60 percent; oligoclase, 3 to 5 percent; minor hornblende, biotite, and magnetite, 2 percent. Zircon occurs as a trace constituent, and sericite is found as an alteration product of the feldspars. Texture is typically aplitic (saccharoidal), and in hand specimen the rock is white to slightly pink in color. Sericitization of feldspars is more pronounced in samples taken from the mineralized contact zone, eg. north of Pass Canyon on the east side of the range, and in Cave Canyon on the west side.

Age

Age of the aplite dikes can be established as following the emplacement of the Mineral Range granite, and previous to the intrusion of the andesite porphyry dikes. The fact that aplites are to be found both in the contact zone, associated with mineralized deposits and occupying joints in the Mineral Range pluton, plus their close association with pegmatite deposits containing high temperature minerals, leads the writer to suggest emplacement during consolidation of the inner portions of the granite pluton.

Pegmatites

Distribution

Pegmatites are distributed around the margins of the Mineral Range
pluton, and in the sediments and meta-sediments of the contact zone. The greatest number observed crop out east of Rock Corral, but there are also numerous exposures in the granite and the contact sediments of the east flank of the range, north of Pass Canyon. One rather large pocket is located near the northeast corner of the mapped area a short distance southeast of Hope triangulation station. Pegmatite bodies examined by the writer ranged from small pods six inches to one foot in maximum dimension to bodies several feet in length. None of the pegmatite deposits is large and they generally lack extension along strike. Pegmatite is most commonly found in small pod-or pipe-shaped bodies distributed at irregular intervals along the strike of the more extensive aplite dikes, and is frequently localized by the intersection of joints.

Petrography

The major constituent minerals of the pegmatites are quartz and orthoclase. Quartz is present as euhedral crystals which range from one-half to six inches in length, and may be clear to milky or smoky in color. Some high quality piezoelectric crystals have been reported from the area (Crawford and Buranek 1945), but the writer did not find any such material. Orthoclase crystals are well developed, ranging from one-half to 3 inches in length. Accessory minerals include; small well formed red garnets, epidote (generally small clear crystals), light blue, pale green, and white beryl crystals up to one inch in length, topaz, helvite, and apatite. Helvite, occurring as vitreous to earthy, red-brown crystals are reported to have been identified by mineralogists of the U.S. Bureau
of Mines, Crawford and Buranek (1945) also report the occurrence of
titanite, but this mineral was not found by the writer.

Age

The pegmatites which contain valuable or rare minerals are clearly
related to the intrusion of the Mineral Range pluton, and probably re-
sulted from emanations from the cooling magma. The late differentiates
ascended along fractures developed in the solidifying shell, and in some
instances entered the sediments of the contact zone, (e.g., Miller Mine.)
The barren pegmatites may or may not be contemporaneous with the mineral-
ized deposits. Barren pegmatites are apparently confined to the margin
of the Mineral Range pluton, and may represent the late (barren) stage
emanations of Emmons (1946).

Granite Sills

Distribution

Granite sills are restricted to the area of Precambrian outcrops
north of Cave Canyon. Capping the divides north of Cave Canyon is a
series of exposures of granite which have been intruded along relic bed-
ding planes of the Precambrian meta-sediments. An interesting feature
of two of the sill exposures is the fact that post-emplacement deformation
has resulted in movement along the basal contact. This has produced a
zone of gouge and breccia ranging from a fraction of an inch to several
feet in thickness. At one location the breccia has been removed by erosion
to provide a view under the sill (see Fig. 7b).
Fig. 7a. View of granite sill, north side of Cave Canyon.

Fig. 7b. View of natural window where gouge and breccia have been removed from beneath granite sill.
Petrography

Petrographic study of three thin sections taken of the granite sills show an average mode of quartz, 30 to 40 percent; orthoclase, 55 to 60 percent; plagioclase (variety andesine), 1 to 2 percent; with accessory biotite and magnetite, 3 to 5 percent, and sericite, 1 percent. Texture is medium to coarse grained, hypautomorphic granular, with euhedral to subhedral feldspars, and anhedral quartz. Fault movement has produced a cataclastic texture near the base of the sills.

Age

The granite sills are not directly connected with the granite of the Mineral Range pluton at any of the outcrops examined. They are found within one-half mile of outcrops of the pluton, however, and this fact plus mineralogical similarity to the large body indicates that they may be contemporaneous in age. Further evidence of age is provided by the fact that the sills pre-date normal fault movements which are probably coincident with the second stage fault displacements which followed emplacement of the pluton.

EXTRUSIVE ROCKS

Northern Volcanics

Distribution

The northern volcanic rocks occur in an irregular north-south belt in the center of the range, extending from Ranch Canyon on the south to Hot Springs Canyon on the north. The volcanics all appear to have been
extruded from the Bearskin Mountain volcano, which rises from the eroded granite bedrock of the pluton to an elevation of approximately 9,500 feet, making it the highest peak in the northern half of the range.

The deposits include basal deposits of tuff and pumice aggregating 1,000 feet in thickness. The tuffs are overlain by rhyolite and rhyolite porphyry flows several hundred feet in thickness. These are overlain by obsidian and vitrophyre flows which form ledges sixty to eighty feet in thickness, and the uppermost deposits of the series show a return to pyroclastic activity with ejection of rhyolitic tuffs, and small fragments of obsidian which are found as float as far south as Pass Canyon. Total thickness of the deposits is in the order of 2,000 feet.

The northern volcanics are well exposed in Ranch Canyon. The basal tuffs and rhyolites flanking the canyon are capped by thick, resistant, vitrophyre flows which erosion has shaped into nearly circular buttes. The flanks of the buttes provide an essentially complete section of the volcanic series. The topographic expression of these buttes is almost identical to that of volcanoes, but the essentially horizontal attitude of the pyroclastic beds shows them to be erosional features.

The Bearskin Mountain volcano, which appears to have been the source of the northern volcanic flows, is located on the crest of the range, and is the highest peak in the northern half of the range. The volcano is roughly circular in plan and stands as a symmetrical cone some 2,000 feet above the granite bedrock. The volcanic flows and interbedded pyroclastics which are exposed on the flanks of the cone dip away from the center at 25 to 30 degrees. Post-volcanic erosion has largely destroyed the central crater of the volcano, but a marked flattening at the
summit, and a slight eroded depression are recognizable.

Petrography

Petrographic examination of one section of the rhyolite flows show that they are composed of a glassy groundmass which aggregates 50 percent of the mass. Spherulitic intergrowths of quartz and orthoclase constitute an additional 40 percent, while phenocrysts of quartz, orthoclase, and andesine, in approximately equal quantity constitute the remaining 10 percent. Trace amounts of magnetite are also present as dust size particles. The vitrophyre has a groundmass of rhyolitic glass comprising 90 percent or more of the mass. Phenocrysts are of quartz, ranging in size from one-half to two millimeters in diameter.

Age

The age of volcanism in the northern area pre-dates the great Pleistocene Lake Bonneville as evidenced by the fact that erosional debris from the volcanic deposits is incorporated in shoreline deposits of the lake. The volcanic activity post-dates uplift of the range as is shown by the deposition of volcanics in deep valleys eroded into the granite of the uplifted block.

Southern Volcanics

Distribution

The southern volcanics cover a generally north trending belt approximately two miles in width and five miles long. The belt extends from Utah Highway 21, on the south, almost to Pass Canyon. This volcanic field continues for several miles south of the mapped area, where it constitutes the
Fig. 8a. View of butte composed of pyroclastics capped by vitrophyre, exposed on the south side of Ranch Canyon.

Fig. 8b. View of the Bearskin Mountain volcano, rising above the granite in the north-central part of the range.
bulk of the surface outcrop of the southern Mineral Range. Numerous small exposures of the volcanics occur along the southwestern margin of the mapped area west of Lincoln Gulch and along the east side of Utah Highway 21. The deposits grade from basal andesite flows and agglomerate, 500 to 1,000 feet in thickness, to quartz latite flows, tuff, and agglomerate up to 1,000 feet in thickness. The uppermost deposits of the series are composed of dense, scoriaceous olivine basalt flows approximately 500 feet in thickness.

Petrography

Petrographic study of two samples of the basal andesite indicate an average mode of: andesine 50 to 55 percent; hornblende, 5 to 10 percent; magnetite and other opaque minerals, 30 percent; with serpentine, hematite, sericite and clay minerals appearing as alteration products. In hand specimen the rock ranges from dark grey to dark red in color, the latter due to oxidation of magnetite to hematite, and is dense to slightly porous. The quartz latite has a mode of: acidic groundmass (glassy), 60 percent; with phenocrysts of andesine, 15 percent; orthoclase, 10 percent; and quartz, 10 percent. Accessory minerals include hornblende, biotite, and magnetite, which aggregate 5 percent of the mass. In hand specimen the material is light brown to tan in color, somewhat porous, and tuffs are interbedded with the flows and agglomerate. The capping olivine basalt has a mode of; labradorite, 60 percent; olivine, 15 percent; augite, 20 percent; magnetite, 2 percent; with minor sericite and serpentine. Hand specimens are dense, black, highly vesicular, and weather to dark grey in color.

Age

The southern volcanic deposits overlie the Cretaceous (?) Claron conglomerate north of Beaver Canyon. Minor faults which offset the sediments
north of Beaver Canyon are not traceable into the volcanic deposits, but second stage fault movement on the master faults south of Pass Canyon and along the southwest front of the range have displaced and tilted the volcanic beds. The age of second stage fault displacement is dated as following emplacement of the Mineral Range pluton.
In the main area of sedimentary rocks of the Mineral Range (T.29 S., R.10 W.) the dips are dominantly eastward, and the structure might be taken as a homocline. The homocline is believed to be the west flank of a syncline, however, whose axis is located just west of Pass Canyon Spring in Section 10. By inspection of the map the outcrop pattern is seen to express a syncline plunging to the south. Immediately east of the syncline is a southward plunging anticline. The surface exposures are largely of the Navajo sandstone. Because it is massive and cross-bededded true dips are generally difficult to recognize. Also the exposures are largely obscured by brush and alluvium, and strike and dip symbols to support the synclinal and anticlinal interpretation are few.

The steeply dipping strata exposed north of Pass Canyon along the east flank of the range may be a part of the east limb of the anticline. The bulk of the sedimentary rock exposures in the range which extend westward from the head of Pass Canyon to the western margin are on the western limb of the syncline, and there the entire stratigraphic sequence of the range is exposed.
FAULTS

Fault Pattern

Recognized faults are largely restricted to the sedimentary belt south of the Mineral Range pluton. The master fault of the area is the east-west trending Cave Canyon fault. The Lincoln fault branches off from the Cave Canyon fault in a southwesterly direction, and the Guyo Canyon fault branches from the Lincoln fault in a more westerly direction. Several other unnamed faults cross the sedimentary belt south of these major faults in a southwesterly direction, cutting the belt into a series of fault blocks.

Fault Dip and Displacement

The fault planes, as shown by their straight to slightly curved traces, are nearly vertical. If not vertical, they dip steeply to the south.

The Cave Canyon fault has had the greatest displacement. The stratigraphic throw of the fault at the mouth of Pass Canyon is between 1,200 and 2,000 feet. At the western extension of the fault in Cave Canyon the stratigraphic throw is estimated to be 1,500 feet. The intersection of the Cave Canyon fault and the Lincoln fault defines a graben. The stratigraphic throw of the Lincoln fault is approximately 500 feet, and displacement on the minor southern faults immediately north of Beaver Canyon ranges from 50 feet to 200 feet.

Relation of Faults to Igneous Bodies

Parts of both the Mineral Range pluton and the small Lincoln stock are in fault contact with adjacent sediments. The large Mineral Range pluton
terminates abruptly on the south against the Cave Canyon fault. The northern margin of the Lincoln stock abuts against the Guyo Canyon fault, and the southeastern margin of the stock is partially controlled by the Lincoln fault. Elsewhere the plutons have discordant irregular contacts with adjacent sediments and apparently are not controlled in any way by the bedding.

Possible Strike-Slip Movement on Faults

Local anomalous relations of the outcrop pattern of the sediments along the faults suggest that there may have been a component of strike-slip movement. In general the cross-sections demonstrate that vertical movement is several times any possible strike slip movement on the faults, and therefore it is assumed that lateral displacements have been slight.

AGE OF STRUCTURES

Age of Folds

The age of folding in the sedimentary belt exposed in the southern part of the range appears to be post-Claron (?) conglomerate. The Claron outcrops north of Beaver Canyon dip eastward as do the underlying Moenkopi beds and have participated in the folding of the syncline. A small outcrop of Claron conglomerate is also exposed south of Pass Canyon where it has been preserved in the synclinal fold. Its position is somewhat asymmetrical to the axis of the syncline and therefore it could be post-folding, but considering the Beaver Canyon evidence, it probably was downfolded in the syncline. Age of the Claron conglomerate is not definitely established. The conglomerate exposed in the Iron Springs district some 20 miles south of the Mineral Range has been considered to be late Cretaceous to Paleocene (Maxey,
1946). More recent work in the Iron Springs district (Proctor, P.D., personal communication) suggests that it may be as young as Eocene. The folding is therefore late Paleocene or younger.

Since the Mineral Range pluton occupies the position of projection of the syncline and anticline it is presumed to be younger than the folding. The igneous contacts cut across the sedimentary bedding without regard to fold structures.

Age of Faulting and Intrusion

The period of fault movement post-dates the development of folds in the sedimentary beds. The faults do not seem related mechanically to the folds either in map pattern or in the nature of stresses responsible for the two systems. The folds are probably due to east-west horizontal compression and the faults to vertical adjustments. Now, it is concluded that the intrusions and the faults are both post-folding. What is the relation of intrusions to faults? Parts of the intrusions are terminated by the faults and hence it might be assumed that the faults are later. However, if a fault should cut along a normally irregular intrusive contact then masses of the pluton would lie on the sedimentary rock side, but such do not occur along the particular fault in point, the Cave Canyon fault. It trims the intrusion so cleanly for a distance of three and one-half miles that a genetic relation is suspected, and the following stages of development of the structure are proposed to account for the interesting situation. An early stage of faulting was coincident with emplacement of the igneous masses. It is postulated that initial vertical movements occurred in response to the buildup of subjacent pressure, and that the magma pushed upward along the faults
elevating the sediments of the upthrown block. This concept is illustrated in the upper drawing of figure 9. A second period of vertical displacement followed emplacement and solidification and minor transgressive irregularities along the fault-controlled contact were trimmed off leaving a sharp, curvilinear contact (see lower diagram of Fig. 9). The presence of a small remnant of Kaibab limestone north of the Cave Canyon fault near the head of Pass Canyon illustrates the irregularities that may have existed along the early fault after intrusion.

Faulting which began with intrusion of the Mineral Range pluton and probably continues intermittently during the period following intrusion and consolidation of the igneous mass, is believed related to the Laramide orogeny. This is suggested by the fact that surface expression of the original displacement has been erased by subsequent erosion. The Cave Canyon fault, like most faults in the range, now occupies a valley along most of its course; the sedimentary exposures of the downthrown block south of the fault having approximately the same topographic relief as the granite of the uplifted northern block. This relationship shows the lapse of an extended erosional interval since the last stage of faulting.

The west face of the range rises sharply from a flanking pediment. East of Rock Corral the range front rises from an elevation of approximately 7,000 feet at the apex of the pediment to over 9,500 feet in a horizontal distance of less than one-half mile. This gives a slope at this point of approximately 45 degrees. Erosion following uplift along the west side of the range has cut deep canyons into the granite bedrock to depths in excess of 2,000 feet, and these canyons form re-entrants in the generally linear front and some extend eastward two and one-half miles. The canyons north of
<table>
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<th>BLOCK DIAGRAM</th>
<th>DESCRIPTION</th>
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<tr>
<td>Early erosion surface</td>
<td>Intrusion stage, boundary controlled by the fault, but with minor transgressive irregularities where the granite has crossed the fault.</td>
</tr>
<tr>
<td>Present erosion surface</td>
<td>Second stage of movement on the fault, boundary between the intrusive and the sedimentary rocks sharpened and made curvilinear. Minor irregularities trimmed off.</td>
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**Fig. 9.** Idealized relation of the Cave Canyon fault to the southern intrusive contact of the Mineral Range pluton.
Ranch Canyon have subsequently been filled with pre-Bonneville volcanic deposits, and therefore it can be concluded that the range had a relief about as bold and precipitous in pre-volcanic time as now, and also that the main uplift of the range was pre-volcanic. The volcanic rocks, which came from the Bearskin Mountain volcano on the crest of the range, cover a large area in the north-central part of the range, and remnant exposures and float indicate that they formed a protective cover overlying the granite pluton as far south as Pass Canyon. This protective cover is believed to have retarded erosion of the uplifted mass, and to have preserved the west facing scarp of the range, in part, long after vigorous uplift.

Relation of Volcanic Accumulations to Faults

Volcanic deposits are exposed in two large areas in the Mineral Range. The southern deposits overlie the eastward and southeastward dipping sediments in the southeastern part of the mapped area. Cross faults are not traceable into the flows, but the fact that the flows are displaced along the southwest flank of the range (Cross section D-D') shows that they pre-date the most recent fault movements.

The northern volcanic deposits, which cover a large area in the north central part of the range, have been deposited in deep valleys eroded into the uplifted granite block. The volcanics, composed largely of pyroclastic beds capped by rhyolitic flows, dip gently westward and the continuity of the beds has not been noticeably affected by fault displacement. This suggests that volcanism in the northern part of the range post-dates the most recent uplift of the range block.
Erosional debris from these deposits is found in the shoreline deposits of Lake Bonneville, which occupied the Escalante desert basin west of the range. This established an upper limit for the age of volcanism as pre-Bonneville.

Problems raised by the above relations are: (1) are faults of Basin and Range type present?, and (2) if present, how do they relate to the second stage of fault movement ascribed to the Cave Canyon fault?

By Basin and Range type faults is here meant those which are of such recent age that initial scarps are recognizable in the present topography. The bold westward-facing escarpment of the central part of the Mineral Range suggests recent uplift along a piedmont fault, but three observations militate against this conclusion; (1) the western piedmont is a pediment with long arms embaying the range; (2) the strong relief of the range was in existence before the northern volcanics accumulated; and (3) no scarps or tangible evidence of a piedmont fault were found.

It is possible that piedmont faulting occurred and that the range block was tilted upward before volcanism and before the erosion of the pediment (see cross section A-A'). If this is so, then the southern volcanic accumulations are older than the northern because they are down-faulted. This presumes, of course, that the supposed piedmont fault is the same age as the fault which dropped the southern volcanic rocks. In any event, such faults are old and initial scarps have been removed since or are protected by blanketing volcanic accumulations.

Physiographically, these faults on which block-tilting and block-uplift are supposed to have occurred are the same as the second stage faulting along the Cave Canyon and related faults. Therefore, they may be
the same age. They would not be Pleistocene or late Pliocene in age, but more likely mid-Tertiary.
GEOLOGIC HISTORY

PRE-MISSISSIPPIAN PALEOZOIC HISTORY

The pre-Mississippian sedimentary record of the Mineral Range is so incomplete that no definite conclusions can be drawn concerning the history of the range through this immense expanse of time. Approximately 3,000 feet of dolomite and dolomitic limestone, of pre-Mississippian age, are exposed on the southwest side of the range, but the writer has been unable to determine their age with certainty. The Mineral Range is believed to be within the area of the Paleozoic Rocky Mountain trough, but by Devonian time the area had become emergent and a part of the Utah-Wyoming Shelf (Eardley, 1951). Donovan (1951) has contoured the thickness of Devonian sediments of the Confusion Basin and he places the zero isopach of Devonian deposition west of the Mineral Range. From this it appears that the area became emergent somewhat before Devonian time, and may have remained a positive area until upper Mississippian time.

MISSISSIPPIAN AND PENNSYLVANIAN HISTORY

In middle to late Mississippian time the area was depressed to allow the deposition of the marine limestone of the Topache (?) formation. Uplift, marked by tilting and folding of the Mississippian beds followed in Pennsylvanian(?) time and this was followed by extensive erosion as is shown by the gradual pinch-out of the Mississippian rocks south of Cave Canyon.
LATE CRETACEOUS TO EARLY TERTIARY HISTORY

The early compressional phase of the Laramide orogeny, which brought a wave of thrusting in northern and western Utah, is marked in the central Mineral Range by folding in the sedimentary belt, and by an overthrust which brought lower and middle Cambrian sediments over middle and upper Cambrian limestones in the northern Mineral Range (Liese, 1957).

Intrusion of the Mineral Range pluton is believed to have occurred in latest Cretaceous or early Tertiary time because of its relation to folds which appear to pre-date intrusion. Faulting is believed to have been initiated by forces incident to intrusion, and to have accompanied intrusion of the igneous bodies.

EARLY TO MIDDLE TERTIARY HISTORY

The lower Tertiary in the Mineral Range was marked by extensive volcanic activity in the southern part of the mapped area. This was apparently followed by a renewal of activity along the older faults which displaced the volcanic deposits and resulted in uplift of the range block to essentially its present elevation. Uplift was followed by prolonged erosion which has erased the topographic expression of this period of faulting along most of the southern faults.

MIDDLE TO LATE TERTIARY HISTORY

A renewal of volcanic activity occurred in middle to late Tertiary time in which rhyolitic flows and thick accumulations of pyroclastics were deposited over the north-central part of the range. Age of this second
volcanic period is placed as post-dating uplift and extensive erosion of the range, and preceding Bonneville time.

PLEISTOCENE AND RECENT HISTORY

Milford Valley and the more extensive Escalante desert lying west of the range were occupied by an arm of Lake Bonneville in Pleistocene time. Another lake occupied Beaver Valley on the east side of the range which is believed to have been a tributary to Lake Bonneville (Lee, 1908). The Beaver Valley lake appears to have been formed by a lava dam which blocked the narrow outlet of the lake at Minersville Reservoir in Beaver Canyon. Overflow eventually cut a narrow channel through the lava allowing the lake to drain. No direct evidence of the age of the Beaver Valley lake has been found to date. The lack of recent-appearing shoreline features in Beaver Valley and of deep erosion scars or terraces in the outlet in Beaver Canyon indicate that drainage was not recent. Climatic conditions favorable for the development of a large lake are known to have prevailed in Pleistocene time, and in view of a lack of contradictory evidence it is tentatively suggested that the Beaver Valley lake was contemporaneous with Lake Bonneville which occupied the valley west of the range in Pleistocene time.

The Recent Epoch has brought extensive erosion, particularly of the relatively unconsolidated northern volcanics, and deposition of coarse debris on the pedimented flanks of the range, and alluvium on the bordering valley floors.
ECONOMIC GEOLOGY

GENERAL STATEMENT

None of the ore deposits of the Mineral Range was being actively mined during the present study. In past years, however, the range has supported four established mining districts, the Bradshaw, Lincoln, Granite, and North Granite districts.

Deposits mined included: complex ores of gold, silver, lead, and copper; some tungsten ore, and minor production of pumice, perlite, decorative stone, lime, sand, and gravel. Total reported production of the Bradshaw district is 11,000 tons valued at $305,000.00, two-thirds of which was in gold and silver values. The Lincoln district has a reported production of over 7,000 tons valued at $161,000.00, more than half of which was lead and silver. The Granite and North Granite districts combined report total production of 94.8 tons of base and precious metal ores valued at $50,000.00, again largely in gold and silver. The Granite district also produced most of the tungsten ore from the range. Total tungsten ore produced from all districts is 1,182 tons valued at $20,000.00.

Beryllium ore has recently been discovered at the Miller Mine, in the Granite district, and development work is being done.

Minor production of pumice and perlite, broadly estimated at 3,000 to 5,000 tons, has been produced from the Perlite Inc. mine in Range Can-
yon and several other small prospects and pits. Development work has been started, and very limited quantities of decorative stone produced from the Lee Opal placer on the northwest flank of the range. Several gravel pits are maintained by the State and County Road Departments around the margins of the range.

ORE DEPOSITS

Classification

All ore deposits of the range lie within a few hundred feet of intrusive rock. The deposits can be separated into two types, although all deposits tend to fall into both categories to a greater or lesser degree. Types of deposits are: (1) contact deposits, those deposits which lie directly on the contact or in altered rocks well within the contact metamorphic zone, and which are not localized by faults or fissures, and; (2) fissure veins, those deposits within or just beyond the strongly metamorphosed zone which are localized by fault fissures.

Examples of contact deposits include the majority of tungsten deposits of the east flank of the range, where scheelite occurs as fine disseminations in a garnet-epidote tactite which closely parallels the intrusive border. The tungsten-rich parts of the Crecle mine, in the Lincoln district, are also located at the contact of intrusive rock with limestone. An example of a contact lead-silver deposit is found at the Santa Claus prospect, in the Lincoln district, where a contact vein has been formed between the quartz monzonite of the Lincoln stock and the overlying limestone. The vein ranges from one to five feet in width and can
be traced for several hundred feet along the contact. This persistence is probably due, at least in part, to parallelism of the bedding of the limestone, at this point, with the intrusive body.

The majority of deposits, though clearly contact in nature, have developed in fault zones. Ore bodies of this type are present in the Bradshaw district, in several mines in the Lincoln district, and most of the base and precious metal ore bodies of the Granite and North Granite districts. Ore bodies of the Bradshaw district are localized by east-west faults, roughly parallel to the major Cave Canyon shear, by north-south faults related to the uplift of the range, and by the intersection of these two fault systems. Ore has been deposited in the fault fissures, and replacement bodies extend laterally from the fissures along favorable carbonate beds. Subsequent oxidation, and concomitant shrinkage has resulted in the formation of caves, with a concentration of oxide, carbonate, and sulfate minerals deposited on the floor. These deposits are overlain by a talus accumulation of material fallen from the roof. Individual caves are characteristically interconnected by narrow passageways or seams of limonite. In the Lincoln district, the Lincoln mine deposit is localized by the fault occupying Lincoln Gulch. The ore is deposited as fissure filling and replacement ore in the Kaibab limestone adjacent to the fault. The tungsten deposits of the Granite district, although predominantly contact deposits include fissure veins along east-west shears crossing the tectite zone. In addition, copper-lead and precious metal production of the Granite district is largely restricted to fissure veins within the contact zone.
Contact Metamorphism

The metamorphic effect of the intrusions on sediments in the contact zone is one of the most striking features of the range. Approaching the range, from the east along Pass Canyon road, a wide belt of bleached sediments can be seen extending northward from Pass Canyon for seven miles along the contact. A description of this zone will serve for the corresponding phenomena in the Lincoln and Bradshaw districts on the west side of the range as well, as contact effects are similar in all cases though less intense in appearance.

The sediments of the contact zone are limestone and quartzites of Permian (?) age. The heat and fluids released by the intruding magma have produced a belt of tactite up to one-quarter mile in width, which ranges from massive garnet next to the contact, to banded, epidotized and zoisitized marble with increased distance. The green epidotized and zoisitized bands are interspersed with bands which have been bleached to a hard, white, crystalline marble. Some of the limestone beds have been sanded, resulting in the formation of completely unconsolidated white to tan calcite, while others show only minor recrystallization of the limestone.

Crawford and Buranek (1945) give the following idealized zonation of the contact: (1) normal granite; (2) an irregular band of marginal facies (finer-grained) granite, biotite absent, pyroxene, amphibole, epidote, and clinozoisite groups abundant; (3) a narrow more or less crushed zone with some evidence of selvedge (sericitization). Evidence of hydrothermal and pneumatolitic alteration, formation of fluorite, muscovite, tourmaline, scheelite, and molybdenite; (4) garnetite, massive and hard; (5) calcite-
Fig. 10. View looking west at the contact zone, north of Pass Canyon.
wollastonite marble with occasional tremolite; (6) garnet-vesuvianite-epidote tactite band; (7) crystalline limestone; (8) epidote-clinozoisite tactite band, and; (9) crystalline limestone. All zones are not present at all points along the contact. Zones 5, 7, and 9 are present at all places where limestone is in contact with intrusive rock, but the remaining zones are only locally developed and grade into the more common contact facies.

Mineralogy

General Statement

The ores of the Mineral Range are mesothermal to hypothermal deposits. Scheelite, in deposits nearest to the contact, indicates high-temperature formation, while the primary minerals of the lead-silver and copper deposits indicate mesothermal deposition. Almost all of the ore produced has been from the oxide zone. Those mines which have penetrated the sulfide zone have been forced to shut down because of lowered ore grade, and to a gradual change from lead-silver to zinc ore with increasing depth. Mineral Range ores are universally high in iron minerals, a fact which has made much otherwise non-commercial ore saleable.

Gold and Silver

The precious metal content of some Mineral Range ores has been quite high, $800.00 per ton being reported at the Cave mine where concentration had been effected by deep oxidation of the primary ore. Such high grade ores are not common in the deposits of the range, average value of gold and silver being from $20.00 to $25.00 per ton in the Bradshaw district,
and lower in the other districts.

Few of the base metal ores could have been mined profitably without the values contained in gold and silver. In the primary ores, these metals are found as native gold, associated with pyrite, and the silver sulfide argentite which is closely associated with galena. In the oxidized deposits the gold remains as a residual metal, whereas some of the silver is altered to cerargyrite, the chloride of silver.

**Copper-Lead-Zinc**

The primary base metal minerals of Mineral Range deposits are chalcopyrite, galena, and sphalerite, the sulfides of copper, lead and zinc respectively. Most deposits are strongly oxidized, resulting in oxidation of chalcopyrite to malachite, and occasionally azurite. Pods of chalcopyrite frequently have a shell or coating of these carbonates which may be as much as one inch thick. The copper silicate chrysocolla is found at the Lincoln and Beaver View mines, but this mineral is not a common associate of Mineral Range ores. Galena, being less soluble than chalcopyrite, is normally unaltered, but where deposits have been deeply oxidized (e.g. Cave mine) the carbonate cerussite and the sulfate anglesite have been formed. Near the surface, sphalerite has been removed by the leaching action of surface waters, and in addition it may have had low original concentration. Sphalerite increases with depth while the galena decreases rapidly.

**Iron**

Iron occurs both as pyrite, associated with other sulfides, and as
limonite and hematite. Some deposits contain primary magnetite, but in most deposits this mineral has been altered to hematite. The oxidized pyritic ores of the west side of the range have been largely altered to a porous or spongy limonite. These limonite ores were exploited as fluxing material for the smelters, and much ore was shipped which would not have been of commercial grade except for the bonus paid for the fluxing qualities of the ore (Butler, 1920). Limonite is less commonly found in the Granite district on the east side of the range, iron being more commonly present as the anhydrous oxide hematite.

Bismuth and Beryllium

The only known occurrence of bismuth in the range is at the old Bismuth mine in the Granite district. Here, bismuthinite is found in association with molybdenite and pyrite. A few tons of ore assaying 3 percent bismuth are reported to have been shipped in the early days of development, but no continued production was realized.

Beryllium has long been known in the range, as crystals of beryl are not uncommon in the pegmatite deposits. Recently (1956), an effort has been made to produce beryllium in commercial quantities at the Miller mine, in the Granite district. A considerable portion of the beryllium of the Miller mine ore body is present as the mineral helvite. Identification of this mineral was reportedly made by U.S. Bureau of Mines mineralogists, and the writer performed confirming micro-chemical tests. The mineral occurs as vitreous to earthy, red-brown garnet-like masses associated with beryl, topaz, apatite, and quartz. Helvite is a relatively rare mineral which has not been previously described from Utah to the writer’s knowledge.
Beryl frequently crystallizes as pale blue and green prisms up to one-quarter inch in diameter, and one inch or more in length.

**Tungsten**

The only tungsten mineral occurring in the range is scheelite. Most of the scheelite of these deposits fluoresces yellow, indicating the presence of molybdenum which has replaced a part of the tungsten in crystal lattice. Occasionally pure calcium tungstate is found, which is recognizable by its blue-white fluorescence. Tungsten mineralization occurs exclusively in the contact metamorphic zone, immediately adjacent to intrusive rock and generally associated with massive garnet and epidote-rich tactite. Scheelite occurs both as disseminations in the tactite, and as vein concentrations along cross fissures in this material.

**Origin and Paragenesis**

The close association of ore deposits, universally rich in iron, with an intrusive body whose central mass shows a marked deficiency in iron-bearing minerals, poses a problem in ore genesis. The association of these deposits with: (1) local areas of ferro-magnesian enrichment on the east flank of the range; (2) the iron-enriched contact zone on the west flank of the range, and; (3) the biotite-quartz-monzonite of the Lincoln pluton, suggests that the ore deposits and iron enriched areas of the intrusives are genetically related. Furthermore, the marked enrichment in iron (magnetite) of subsequent extrusive rocks, suggests a major change in the composition of the residual liquid portion of the magma at depth, and that ore deposits, reflecting this change in com-
position, are late stage phenomena with respect to intrusion.

Polished-section studies indicate a temperature formation sequence of mineralization as follows: tungsten and magnetite replace limestone; pyrite and chalcopyrite replace limestone, and follow magnetite; galena and argentiferous galena replace both pyrite and chalcopyrite. Subsequent oxidation has altered magnetite to hematite, pyrite to limonite, and chalcopyrite to malachite.

Localization of ore deposits is controlled, in the case of the fissure veins, by the host fissure which channeled the mineralizing fluids, and locally along the fissure by the presence of favorable lithology in the wall rock. Deposits of economic size are universally replacement deposits in part, and the majority are replacements of limestone or dolomitic limestone (egs. Cave mine and Lincoln mine). The factors which render certain carbonate beds more favorable for replacement than others remains obscure. Some ore has been deposited in quartzite gangue (eg. Hecla mine), the ore being localized by fault brecciation of the host rock. Contact deposits are localized along the contact of intrusive rock and sediments, and the primary control of location is favorable lithology in the host rock.

Alteration and Enrichment

Oxidation of the deposits is widespread, and in some cases is almost complete. A good example of this is at the Cave mine where the original pyrite-galena ore has been almost completely altered to iron oxides and lead carbonates. The original ore was emplaced as fissure filling and replacement of limestone and dolomite, adjacent to and at the intersection
of fissures. Pyrite has been completely oxidized to cellular or spongy limonite. Galena, whose former presence can be inferred from relic voids in the limonite gossan, is predominantly found as the carbonate cerussite, but some has been precipitated as anglesite, possibly through reaction with ferric sulfate solutions derived from solution of pyrite. If copper and zinc sulfides were present in the original ores deposited here, as they are in the other districts of the range, they have been removed by leaching.

Other deposits show oxidation to a lesser extent, but all deposits of the range are oxidized to a greater or lesser degree to the maximum depth of the present development. Pyrite is altered to limonite in almost all cases, a condition which supplied targets for exploration which rarely eluded the early prospectors. Deposits of the Lincoln district are typical in that chalcopyrite is partially or wholly altered to malachite and limonite, due to deep oxidation and the presence of limestone. Galena, however, was not noticeably affected except for the surface alteration of crystals.

The Lincoln mine provides evidence of a change in the character of ores of the range with increasing depth. Surface and near surface ores at the Lincoln mine were of high grade lead and silver. The lowest level of the mine, at 350 feet, entered the sulfide zone, and at this depth the ore had graded into zinc sulfides with only minor lead, silver, and copper. Deposits on the east side of the range (Granite and North Granite districts) follow the same general pattern but with hematite as the common iron oxide mineral rather than limonite.
Mining Districts

Bradshaw District

History and production. - The Bradshaw district was organized May 1, 1875, and includes thirteen patented and numerous unpatented lode claims. The district is located in Township 29 South, Ranges 9 and 10 West, on the west flank of the Mineral Range.

The major production period of the district came in the thirty years following organization. Records from this period are regrettably incomplete, the best record of early production now available being incorporated in 'Ore Deposits of Utah' (Butler, 1920). The writer has summarized existing data on production in Table 1. It should be noted that these figures represent a minimum, and are probably far short of actual production. Mines, in the district, were intermittently operated through 1952. Tonnage figures for the period 1908 through 1934 are rank estimates, based on indefinite statements in U.S. Bureau of Mines statistics. The apparent resurrection of the district between 1934 and 1952, then, represents an improvement in the quality of data available, more than any significant change in activity. No accurate estimate of individual mine production can be made from available data, but records show that the Cave mine was the largest single producer. Other ore of record is reported from the Hecla and Jolly Boy mines, the remaining ore being reported as district totals.

Cave Mine. - The Cave mine is located in the E/4, NW/4, SE/4 of Section 12, Township 29 South, Range 10 West. Access is provided by an unimproved dirt road, portions of which were not passable at the time of
<table>
<thead>
<tr>
<th>Year</th>
<th>Tons</th>
<th>Oz. Au</th>
<th>Oz. Ag</th>
<th>Lbs. Cu</th>
<th>Lbs. Pb</th>
<th>Lbs. Zn</th>
<th>Value</th>
</tr>
</thead>
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<td>2,964</td>
<td>290,000</td>
<td>930,000</td>
<td>288,000</td>
<td></td>
<td></td>
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<td>1908</td>
<td>20</td>
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</tr>
<tr>
<td>1909</td>
<td>1,028</td>
<td>79</td>
<td>769</td>
<td>3,357</td>
<td>37,969</td>
<td>1,994</td>
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</tr>
<tr>
<td>1910</td>
<td>100</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1911</td>
<td>20</td>
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<td>1912</td>
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<td>1913-1915</td>
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<td>1918</td>
<td>20</td>
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<tr>
<td>1919-1933</td>
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<td>1934</td>
<td>272</td>
<td>3</td>
<td>6,519</td>
<td>54</td>
<td>5,783</td>
<td>453</td>
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<td>1935</td>
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<td>51</td>
<td>5,783</td>
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<tr>
<td>1938</td>
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<td>2,045</td>
<td>51</td>
<td>5,783</td>
<td>453</td>
<td>1,632</td>
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<tr>
<td>1939</td>
<td>91</td>
<td>3</td>
<td>2,263</td>
<td>5,783</td>
<td>453</td>
<td>973</td>
<td>1,641</td>
</tr>
<tr>
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<td>78</td>
<td>8</td>
<td>121</td>
<td>425</td>
<td>4,120</td>
<td>5,603</td>
<td>973</td>
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<td>1941</td>
<td>12</td>
<td>3</td>
<td>38</td>
<td>453</td>
<td>5,603</td>
<td>973</td>
<td>132</td>
</tr>
<tr>
<td>1942-1947</td>
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<td></td>
</tr>
<tr>
<td>1948</td>
<td>10</td>
<td>1</td>
<td>95</td>
<td>6,200</td>
<td>1,231</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1949</td>
<td>54</td>
<td>1</td>
<td>117</td>
<td>6,500</td>
<td>1,195</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1950-1952</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>11,020</td>
<td>3,073</td>
<td>302,232</td>
<td>3,887</td>
<td>990,572</td>
<td>5,603</td>
<td>$304,668</td>
</tr>
</tbody>
</table>

TABLE 1
PRODUCTION-BRADSHAW DISTRICT
Fig. 11. View looking eastward into Cave Canyon, and the Bradshaw Mining district.
the writer's visit. Workings consist of a series of adits at vertical intervals in the controlling fault fissure, and alternating rooms and connecting drifts which followed the ore bodies.

Ore deposits consisted of a series of cave-filling deposits along the host fissure, and replacement lodes in the adjacent dolomite and dolomitic limestone. Ore was composed of limonite and cerussite which contained values in gold and silver. This ore was the oxidized residual of primary sulfide bodies containing pyrite, galena, and argentite, probably minor chalcopirite, and sphalerite. Primary magnetite may have been present but the writer was unable to ascertain its presence. The process of oxidation resulted in shrinkage of the deposits, allowing void space to exist over the ore in some caves, and ore was sometimes found on cave floors covered by a talus of fallen roof material. Early reports indicate that the ore was richest at and just above the base of the deposits, decreasing in value upward, and barren or essentially barren at the top. Some high grade ore was produced, a maximum of $800.00 per ton being reported (Butler, 1920), but average grade was in the order of $25.00 to $30.00 per ton.

The oxide zone ore of the mine appears to have been depleted, and although the writer saw no sulfide ore at this mine, evidence of decreasing grade in the sulfide zone in the Lincoln district (Lincoln mine), and the marginal value of the oxide ore by present standards, suggests that the mine has been worked to the limit of production.

Hecla Mine. - The Hecla mine is located in the NW 4, NW 4, SW 4 of Section 4, Township 29 South, Range 9 West. Access to a point below, and
one-quarter mile south of the mine is provided by a steep, unimproved road. The mine is developed by a shaft and drifts in Permian Coconino quartzites. The writer did not attempt to enter and examine workings in detail.

In addition to gold and silver, the Hecla mine is credited in U.S. Bureau of Mines reports with having produced most of the reported copper from the district. Ores were oxidized equivalents of primary pyrite, chalcopyrite, galena, and argentite, deposited as fissure filling and disseminated replacement deposits. Ore was localized along a brecciated zone in the host quartzites.

Other Mines. - Other mines in the district include the Summit, New Era, King David, Three Percent, Nip and Tuck, and Jolly Boy mines. Most of the mines are clustered around the Cave mine. Workings are generally inaccessible, but the mines are located in similar geologic setting and examination of dump material indicates that ores were essentially identical in all cases.

The Two R's group claims, located in the northeast corner of the district in the 
NW$_1$ of Section 33, Township 28 South, Range 9 West, have produced 70 tons of tungsten ore from shallow open cuts. Ore averaged 0.58 percent $\text{WO}_3$, and returned a gross value of $1,218.00$.

Granite and North Granite Districts

History and Production. - The Granite and North Granite districts were organized in 1863 and 1865 respectively, and are located in Township 27 and 28 South, Ranges 8 and 9 West. There is no record of production from the district prior to 1916, in the U.S. Bureau of Mines statistics, although Huntley (1885) credits the Bismuth mine with having shipped
a few tons of ore. Small shipments are reported at intervals through the period 1916 through 1938. The years 1939 through 1950 appear to have been the banner years of the district, but production has never been large. Most of the ore produced has been credited to the Beaver View mine, with small shipments coming from other properties included in district totals. At the present writing, the only property being actively worked is the Miller mine, a new property now under development. Small shipments of beryllium ore have been made.

Beaver View Mine. - The Beaver View mine is located in the SE\textsubscript{4}, NE\textsubscript{4}, SE\textsubscript{4} of Section 31, Township 28 South, Range 8 West, and access is provided by a good dirt road. The mine is developed by a mine shaft at the site of the mine buildings, and additional small shafts adjacent to it. The workings were not accessible to the writer at the time of his visit.

The mine is located in limestones, in the contact zone. Primary control of ore location appears to be the presence of minor shears in the limestone sediments. Ore has been oxidized lead-zinc sulfides, containing values in gold and silver. U.S. Bureau of Mines statistics credit the Beaver View mine with most of the base and precious metal production of the district, small tonnage being given for the other mines as district totals.

Miller Mine. - The Miller mine is located in the SW\textsubscript{4}, SE\textsubscript{4}, NE\textsubscript{4} of Section 20, Township 28 South, Range 8 West, and access is provided by a good dirt road. Workings consist of two shallow shafts and a small open stope.
Fig. 12a. View of the Beaver View mine, Granite district

Fig. 12b. View of the Miller mine, North Granite district

Fig. 12c. View of the Big Pass mine, Granite district
TABLE 2

PRODUCTION GRANITE AND NORTH GRANITE DISTRICTS

<table>
<thead>
<tr>
<th>Year</th>
<th>Tons</th>
<th>OZ Au</th>
<th>OZ Ag</th>
<th>Lbs Co</th>
<th>Lbs Pb</th>
<th>Lbs Zn</th>
<th>Value</th>
</tr>
</thead>
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<tr>
<td>1863-1915</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1916-1917</td>
<td>140</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1917-1918</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td>1918-1921</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1922-1923</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1923-1933</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1933-1934</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16</td>
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<tr>
<td>1934-1938</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1939-1940</td>
<td>5</td>
<td>19</td>
<td>48</td>
<td>2,043</td>
<td></td>
<td></td>
<td>114</td>
</tr>
<tr>
<td>1940-1945</td>
<td>89</td>
<td>88</td>
<td>90</td>
<td>513</td>
<td>5,040</td>
<td></td>
<td>3,454</td>
</tr>
<tr>
<td>1941-1944</td>
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<td></td>
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</tr>
<tr>
<td>1945-1946</td>
<td>7</td>
<td>1</td>
<td>59</td>
<td>2,000</td>
<td></td>
<td></td>
<td>249</td>
</tr>
<tr>
<td>1946-1947</td>
<td>84</td>
<td>19</td>
<td>115</td>
<td>10,000</td>
<td>12,000</td>
<td>3,312</td>
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</tr>
<tr>
<td>1947-1948</td>
<td>140</td>
<td>64</td>
<td>779</td>
<td>1,870</td>
<td>79,500</td>
<td>77,100</td>
<td>24,116</td>
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<tr>
<td>1948-1949</td>
<td>251</td>
<td>40</td>
<td>716</td>
<td>1,100</td>
<td>54,000</td>
<td>36,800</td>
<td>16,847</td>
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<tr>
<td>1949-1950</td>
<td>19</td>
<td>1</td>
<td>53</td>
<td>2,800</td>
<td>2,300</td>
<td>810</td>
<td></td>
</tr>
<tr>
<td>1950-1951</td>
<td>10</td>
<td>3</td>
<td>52</td>
<td>100</td>
<td>4,600</td>
<td>2,200</td>
<td>1,106</td>
</tr>
<tr>
<td>1951-1952</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>948</td>
<td>216</td>
<td>1,883</td>
<td>3,631</td>
<td>159,983</td>
<td>130,400</td>
<td>50,024</td>
</tr>
</tbody>
</table>
The Miller mine is a new property in the initial stages of development. Ore has low grade beryllium, localized in pegmatite lenses along a persistent aplite dike which cuts the sediments of the contact zone on the east flank of the range. Ore minerals include beryl and helvite, together with topaz, apatite, and thulite, in a predominantly quartz-orthoclase gangue. At the time of the writer's visit, development work had not progressed to a point where an accurate appraisal of ore continuity and potential could be made.

**Big Pass Mine.** - The Big Pass mine is located in the SW₁, SW₂, NW₂, of Section 12, Township 29 South, Range 9 West, and access is provided by a good dirt road. Workings consist of two shallow shafts and some 150 feet of drifts, crosscuts, and connecting winzes.

The property is reported to have produced oxidized lead ore containing precious metal values, and some high grade gold ore is said to have been produced in the late thirties, but no official record of production was available to the writer, production of the mine being probably included in district totals. During the war years 1941 through 1945, the mine produced 279 tons of tungsten ore valued at $6,434.00.

The workings are located in the tactite zone at the contact of the Mineral Range pluton and Permian (?) limestones. Tungsten ore consisted of disseminated replacements and stringers in the tactite of the contact zone. The primary ore mineral is scheellite, which contains minor molybdenum replacing a part of the tungsten in the crystal lattice of the mineral.
TABLE 3
TUNGSTEN PRODUCTION MINERAL RANGE

<table>
<thead>
<tr>
<th>Mine</th>
<th>Tons</th>
<th>WO₃</th>
<th>Units</th>
<th>Value</th>
<th>District</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Pass mine</td>
<td>278.648</td>
<td>0.789</td>
<td>214.48</td>
<td>$6,434.40</td>
<td>Granite Dist.</td>
</tr>
<tr>
<td>Garnet mine</td>
<td>634.265</td>
<td>0.640</td>
<td>406.1h</td>
<td>12,184.33</td>
<td>&quot;</td>
</tr>
<tr>
<td>2-R's mine</td>
<td>70,000</td>
<td>0.580</td>
<td>40.60</td>
<td>1,218.00</td>
<td>Bradshaw Dist.</td>
</tr>
<tr>
<td>Creole mine</td>
<td>200.00</td>
<td>0.700</td>
<td>*</td>
<td>*</td>
<td>Lincoln Dist.</td>
</tr>
</tbody>
</table>

Total          | 1,182.923 | 0.682 | 661.22  | $19,836.73   |                 |

"Average grade of ores shipped

Garnet Mine. — The Garnet mine is located in the NW₁₄, SW₁₄ of Section 29, Township 28 South, Range 8 West, and access is provided by a dirt road. The mine is developed by two shafts and several hundred feet of drifts and crosscuts. Development was accomplished during World War II with the aid of an R.F.C. loan, and the property became the largest tungsten producer of the range. Production total is 634 tons of ore which averaged 0.64 percent WO₃, valued at $12,184.33.

Ore occurs as low grade disseminations and narrow stringers in garnet rich tactite bands which parallel the border of the Mineral Range pluton.

Other Mines. — Numerous other mines and prospects line the contact zone on the west flank of the range, from Pass Canyon on the south to Bearskin Mountain on the north. The geology of these properties is strikingly similar in all cases, being confined to near-contact tactite which has been developed from the limestone bordering the Mineral Range pluton.
These properties include the Molly, Oak, King of the Hills, and Burnt Hollow groups, and some others. More or less detailed description of these properties can be found in 'Tungsten Deposits of the Mineral Range' (Crawford and Buranek, 1945).

**Lincoln District**

**History and Production.** - The Lincoln district was formally organized on January 16, 1871, but the history of the district goes back to an earlier date when it was organized as the Pioneer district in 1864 (Butler, 1920). It is further reported that the Lincoln mine, formerly called the Rawlins Lode, was first worked in 1854 by the Mormon pioneer Isaac Grundy who smelted lead which was shipped to Salt Lake City to make bullets for the Mormon forces. This story is given by Eisler (1891) and seems to establish the mine as the oldest producer in Utah.

The district is located in Township 29 South, Range 9 West, and adjoins the Bradshaw district on the south. There are fourteen patented claims in the district, most of which date back to its early days.

Production from the Lincoln district, is summarized in Table 4. Again, the data for the period prior to 1907 is derived from incomplete reports given by Butler (1920). In this case it would seem probable that the known production represents but a fraction of the total. Tonnages for the period 1908 through 1934 are a reasonable estimate, but figures for metal content and gross value are lacking. Adequate data to allow an estimate of the production of individual mines is lacking, most reported production being reported as district totals.
<table>
<thead>
<tr>
<th>Year</th>
<th>Tons</th>
<th>Oz. Au</th>
<th>Oz. Ag</th>
<th>Lbs. Cu</th>
<th>Lbs. Pb</th>
<th>Lbs. Zn</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1871-1907</td>
<td>680</td>
<td>225</td>
<td>21,580</td>
<td></td>
<td>48,000</td>
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<td>1909-1912</td>
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<td></td>
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</tr>
<tr>
<td>1913</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1914</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1915</td>
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</tr>
<tr>
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<td>4,818</td>
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<td>1917</td>
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<td>92,658</td>
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</tr>
<tr>
<td>1919</td>
<td>20</td>
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<td>200</td>
<td>600</td>
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<td><strong>Total</strong></td>
<td>7,229</td>
<td>362</td>
<td>29,245</td>
<td>12,785</td>
<td>251,181</td>
<td>376,043</td>
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Lincoln (Rawlins) Mine. - The Lincoln mine is located in the NW$_4^1$, NW$_4^2$, SE$_4^1$ of Section 20, Township 29 South, Range 9 West, and access is provided by a good dirt road. The mine is developed by an incline shaft, reportedly to a depth of 350 feet. Track and collar timber had been removed at the time of the writer’s visit, so no direct examination of the workings was made. The workings are reported to be flooded to the 200 foot level or higher at the present time.

Ore is localized along sympathetic shears parallel to the Lincoln fault, along and near the contact of the quartz monzonite of the Lincoln stock and intruded Permian limestones. The ore body consisted of a fissure vein and replacement ore adjacent to the fissure in the contact limestones. Ore minerals were galena, chalcopyrite, sphalerite, argentite, and pyrite. Ore of the upper levels was oxidized to limonite, hematite, malachite, smithsonite, and minor anglesite on the surface of galena crystals. Primary magnetite may have been originally present, now present as micaceous and specular hematite. The lowest level of the mine is reported to have reached the sulfide zone where the primary ore is composed largely of sphalerite, with only minor lead, silver, and copper values.

Creole Mine. - The Creole mine is located in the SW$_4^1$, NW$_4^1$, NE$_4^1$ of Section 29, Township 29 South Range 9 West, and access is provided by a dirt road. Workings consist of a steep incline shaft and drifts, at the old workings, and short drifts along the contact of the Lincoln stock and intruded limestone at the newer workings. Base metals were produced from the older workings in the early days of the district, but no adequate record of production was available to the writer. The mine produced 200
Fig. 13a. View of a part of the Lincoln district.

Fig. 13b. View of the Lincoln Mine, Lincoln district.
tons of tungsten ore, from the newer workings, during World War II, which averaged 0.70 percent WO₃.

Tungsten ores were disseminations of the mineral scheelite in the garnet tactite of the contact. The older workings were not accessible to the writer, but examination of dump material indicates that the primary ore contained galena, chalcopyrite, and pyrite, and possibly magnetite. Oxidation has altered the primary minerals to limonite, some hematite, minor anglesite on the surfaces of galena crystals, and malachite.

Other Mines - Other mines in the district which have produced ore of record include the December group, and Henrietta mine. Many other properties are recorded, but no record of production was available. All deposits of the district lie in close proximity to the contact of the Lincoln stock and intruded sediments.

BUILDING MATERIALS

Sand and Gravel

The combined deposits of ancient Lake Bonneville, and recent deposits of the Beaver River, provide a large reserve of sand and gravel around the margins of the Mineral Range. The presence of amorphous silica (obsidian, chaledony, and chert) derived from volcanic and thermal spring deposits in the northern half of the range, and the concentration of potash feldspar from deep erosion of the granite Mineral Range pluton found in the gravels of the southern half of the range, make this material a poor concrete aggregate. A considerable yardage of this gravel is used by the State and County Road Departments, however, and some has been used as concrete.
aggregate locally. No estimate of yardage produced will be given here, but several pits have been indicated on the geologic map (Plate I). Most deposits that have been worked lie on the west flank of the range near Utah State Highway 21, although pits were also noted north of the highway east of Minersville, and east of Adamsville as well. Gravel and sand deposits are composed of well rounded pebbles and cobbles ranging from one-quarter to three or four inches in diameter, interbedded with arkosic sand and clay.

Dimension and Decorative Stone

Exploitation of Mineral Range deposits for production of building and decorative stone has been very small. One property, the Lee Opal placer, has a considerable tonnage of very attractive, red and white banded opalite. Some of this material has been shipped as decorative stone, and some has been collected by local people, but to date the property has had only preliminary development. Markets are distant, and the local market is incapable of sustaining a large scale operation.

There are tremendous quantities of marble within the contact limestones (Kaibab formation ?) of the east side of the range north of Pass Canyon and the lower Paleozoic dolomites and dolomitic limestones exposed south of Cave Canyon on the west side of the range. Much of this marble would be suitable for the manufacture of polished stone and stone chip, but none has been produced to the writer's knowledge, and there seems to be little likelihood of production in the foreseeable future due to economic conditions. Small quantities of the lava rock and tuff, which is exposed in the southern part of the range, have also been used for local building
purposes, but again no commercial production has been attempted.

Lime

Some lime has been manufactured from the limestones exposed along the east flank of the range, as is shown by the presence of a few old kilns. Limestone used was quarried from exposures of the Kaibab (?) limestone on the east side of the range, north of Pass Canyon.

Pumice and Perlite

The volcanic deposits of the northwest flank of the Mineral Range offer a large potential for the production of pumice and perlite aggregate. Two small pits have been opened in addition to the Perlite Incorporated mine in Ranch Canyon, but neither was equipped or in operation at the time of the writer's visit. Perlite Incorporated, a Salt Lake firm, has developed a large reserve of pumice and perlite at its Ranch Canyon mine. Development of the property has been retarded, however, because of poor market conditions, and the property was not in operation at the time of the writer's visit. The owner estimated that approximately 1,000 tons of perlite and 2,000 tons of pumice had been produced from the property in the period 1950 through 1955. Thick accumulations of pumice and perlite are found in the volcanic deposits of the northern area. These deposits are overlain by rhyolite and vitrophyre flows which form an erosion resistant capping for the deposits. Erosion has exposed the pyroclastics on the flanks of flow-capped buttes, thus allowing open-cut mining of the deposits.
SURFACE AND GROUND WATER

Surface water, within the mapped area, includes the Beaver River and seventeen springs. None of the springs flow across the wide pediments to enter the river as surface flow, and many, even in the higher elevations, are reduced to a mere trickle by late summer. The largest spring is North Spring, situated on the southwest flank of the range northwest of a belt of volcanic deposits. This spring was gauged by the writer at thirty gallons per minute in late August, 1956, which was one of the driest years on record. At present the spring flows through a three-inch pipe leading from a one-hundred-foot adit driven to increase the spring flow. Water flows on the surface for 300 yards, and then disappears into the alluvium of the channel.

The spring in Pass Canyon is probably the second largest spring in the range. Flow originates in the Cave Canyon fault zone, and gives rise to Russell Creek which flows on the surface for a distance of one and one-half miles before it sinks into the alluvium. Other perennial flowing springs, which provide good drinking water throughout the year, occur at the Ryan and Smith Ranch sites, Hot Springs Canyon, Ranch Canyon and Rock Corral. Drinking water cannot always be counted upon at the remaining springs, particularly in the late fall when they are apt to be reduced to muddy spots with possibly a small stagnant pool.

Two of the springs are hot springs, and in view of the presence of recent volcanic activity in the range, these springs may derive their
heat from the presence of heated rock at depth. Roosevelt Hot Spring, in Hot Springs Canyon in the north of the mapped area, was at one time commercialized as a medicinal spring. Bath houses were erected, and the water at a temperature of 190 degrees Fahrenheit was piped to them from the spring. Oak Spring, located near the mouth of Guyo Canyon on the southwest flank of the range, is warm and gives off sulfurous fumes. North Spring, although no longer a hot spring, has deposited a mound of siliceous material which indicates that it was hot in the past, and the deposits at the Lee Opal placer, on the northwest flank of the range, also appear to be thermal spring deposits.

Flow of the Beaver River, at the U.S. Geological Survey gauging station at Adamsville, has been charted since 1914. Average annual flow into the Minersville Reservoir, since 1914, has been 28,100 acre feet, with maximum flows of 59,700 and 57,170 acre feet being recorded in 1914 and 1937 respectively. Average flow over the last ten years has been 22,761 acre feet, and for the last four years has only been 13,140 acre feet, less than half the overall average. This reduced flow reflects the recent series of dry years. Current studies by government agencies, are directed toward achieving greater conservation of flood runoff due to normal spring thaw of the snow cap, and intermittent heavy summer precipitation.

FUTURE PROSPECTS OF THE RANGE

If present economic conditions continue, the immediate future prospects of the mining industry in the Mineral Range appear to be very poor. Known "bonanza" ores of the oxide zone are essentially depleted, and
evidence from the Lincoln mine indicates that ores of the sulfide zone will not be of commercial grade, nor would they be made commercial through such increased metal prices as can be reasonably expected at this time. The only hope of a revival of base metal production, in the range, would appear to rest upon the discovery of a new deposit of large size, and in this regard it should be remembered that the range has been intensively prospected over a period of more than ninety years. Some revived interest in the range has been occasioned by the discovery of beryllium ore at the Miller mine, but to date there is no evidence to suggest that a major industry will develop from this source.

The most favorable direction for future development of mining in the range is in the field of non-metallics. The tremendous reserves of lightweight aggregate and decorative stone provide interesting future possibilities, should market conditions improve, or if sufficient capital were invested in their development to create a self-contained industry for their use.
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<th>ERA</th>
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<th>FORM</th>
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<td>PRE-</td>
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<td>COMPLEX</td>
<td>3,300'</td>
<td>Biotite gneiss, schist, phyllite, and complex meta-sedimentary and meta-metasomatites</td>
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<td>LOWER</td>
<td>PALEOZOIC</td>
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<td>2,790'</td>
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<td>1,071'</td>
<td>Medium to thick bedded, white to buff and pink quartzite and quartzitic sandstone</td>
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<td>TRIASSIC</td>
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<td>1,181'</td>
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<td>Red Beds</td>
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<td>0-60'</td>
<td>Silt, siltstone, and coarse woody.</td>
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**COMPOSITE STRATIGRAPHIC SECTION**

**CENTRAL MINERAL RANGE**

**BEAVER COUNTY, UTAH**

Scale: 1 inch = 500 feet

By

Fred Nelson Earll

1957