GEOLOGY AND MINERAL RESOURCES OF THE
SALMON QUADRANGLE, LEMHI
COUNTY, IDAHO

by

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FOREWORD

This work by Dr. Alfred L. Anderson, issued as Pamphlet 106 by the Idaho Bureau of Mines and Geology and describing the Geology and Mineral Resources of the Salmon Quadrangle, Lemhi County, Idaho, is a comprehensive, detailed analysis of the geologic situation. It is one of the projects initiated by the Idaho Bureau of Mines and Geology and it was undertaken not only to yield a benefit toward development of the over-all mineral wealth of eastern Idaho but it has been done also as a part of the broad program of carefully studying and mapping all parts of the state.

J. D. FORRESTER
DIRECTOR
January 1956
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Geographic and topographic setting:-- The Salmon quadrangle, whose geology and mineral resources are described herein, covers some 200 square miles of eastern Lemhi County, Idaho. Within its borders are the eastern slope of the Salmon River Mountains, the north end of the Lemhi Range, the foothills of the Beaverhead (Bitterroot) Range, and the wide intervening intermontane Salmon Basin. The area is drained by the Salmon River, which crosses the Salmon Basin from south to north, and by the Lemhi River, which flows northwest along the broad Lemhi Valley to its junction with the Salmon River at the town of Salmon.

Stratigraphic features:-- The rocks within the quadrangle are bedded sedimentaries and volcanics, several groups of igneous intrusives, and a variety of surficial deposits. The bedded rocks are represented by a thick succession of quartzitic strata belonging to the Belt series (pre-Cambrian); by flows, tuffs, and ignimbrites of the Challis volcanics (oligocene); and by siliceous shales, sandstones, limestones, and basalts assigned to the newly defined Carmen formation (Lower Miocene). The intrusives include small bodies of meta-gabbro (late pre-Cambrian), some masses of granitic rock occurring as outliers of the Idaho batholith (Cretaceous), several vitrophryic dikes which apparently served as feeders to the extrusives belonging to the Challis volcanics, and dikes and small stocks of dacite and quartz latite porphyry (Lower Miocene). The surficial deposits comprise some glacial debris (early and late Pleistocene), terrace gravels of outwash origin, terrace gravels of outwash origin, terrace alluvium, and landslide debris (late Pleistocene and Recent), and Recent stream alluvium.

These various rocks and rock formations have a rather restricted distribution. The quartzitic rocks of the Belt series are confined to the more mountainous terranes and compose much of the eastern slope of the Salmon River Mountains and the north end of the Lemhi Range with some exposures in the canyon of the Salmon River between the two mountainous groups. The rocks of the Challis volcanics blanket much of the southern part of the quadrangle not otherwise occupied by the Belt rocks. These volcanics are locally divisible into two units: (1) a lower unit of andesitic and latitic flows, with some intercalated tuffaceous materials, and (2) an upper unit composed chiefly of tuffs but containing some intercalated rhyolitic and quartz latitic flows and ignimbrites and a basaltic-calcic andesite member. The anesite-latite unit is confined to the Salmon River Mountain area in the southwestern part of the quadrangle. The upper tuffaceous unit extends across the Salmon River and wraps around the north end of the Lemhi Range, deploying widely over the region to the east and southeast. The Carmen formation is contained entirely within the Salmon Basin, resting unconformably on all the older rocks.

The intrusive rocks are widely scattered. The meta-gabbro was observed only in the Belt rocks on the Salmon River Mountain slope west-northwest of Salmon. The outliers of the Idaho batholith occur in the northwestern part of the quadrangle as bodies of granitized quartzite. The vitrophryic dikes intrude the Challis volcanics near the southeast corner of the
quadrangle, and the bodies of dacite and quartz latite porphyre pierce the Belt rocks and Challis volcanics just east of the north end of the Lemhi Range.

The surficial deposits are mainly in the basin area and on the lower mountain slopes. The till and outwash left during the earlier epoch of glaciation (Nebraskan?) are retained as hill and ridge caps in the foothill region of the Beaverhead Range and on the lower slopes of the Salmon River Mountains, in part on hills and ridges carved in the Carmen formation. Thin gravel caps on each of three high dissected ridge terraces may be related to this early glaciation. Gravel terraces related to the late Pleistocene (Wisconsin) outwash border the present stream courses and are particularly pronounced along the Salmon and Lemhi Rivers and their larger tributaries. Landslide debris is conspicuous in the southwestern part of the quadrangle, where one mass of tremendous size blocked the valley of Lake Creek and impounded Williams Lake on its upper side. Recent alluvium is most widespread along the Salmon and Lemhi Rivers, forming broad valley floors 1 to 2 miles wide.

Structural geology:— Structural deformation is evident in all but the youngest of the surficial deposits. The pre-Cambrian Belt strata have been the most intensely deformed and are so highly jointed and possess so much cleavage that the bedding has been almost obliterated. The beds have been folded and faulted but, because of the competency of the quartzitic strata, the folds are broad. In the Salmon River Mountains the beds have been folded into a broad northerly trending anticline whose eastern flank lies within the borders of the quadrangle. In the northern part of the area the anticline has been complexly faulted and invaded by granitic rock related to the Idaho batholith. Elsewhere the trend of the anticline has been locally interrupted by faults of transverse trend. In the Lemhi Range the strata have been folded into a broad syncline of generally northerly trend, locally offset by cross faults and broken by longitudinal faults. A part of the deformation of the Belt rocks may have taken place at the close of the pre-Cambrian; but most of the folding and fracturing was probably associated with the Sierra Nevada orogeny of late Jurassic time and some of the faulting with the Laramide orogeny at the close of the Cretaceous period and with early Tertiary crustal disturbances.

The Challis volcanics have not been much fractured but have been folded and within the quadrangle form the northeast flank of a broad anticlinal arch whose northwesterly trending axis lies several miles to the south. In places the volcanics have been faulted and locally intruded by bodies of porphyry. Deformation of the Challis volcanics apparently took place at the close of Oligocene time and later.

The Carmen formation which shows evidence of accumulation in a structural basin produced by downwarping of the Challis volcanics and older rocks, possesses "basin" type of structure with the beds dipping away from the flanks of the mountains toward the center of the basin, apparently a product of downwarping in early Miocene time. The beds within the basin have since been gently deformed by broad shallow anti-
clinal and synclinal folds which have a northerly to northeasterly trend south of Salmon and the Lemhi Valley and a northwesterly trend north of the town and Valley. In places the formation has been broken by faults of minor magnitude. The deformation within the basin may reflect a crustal disturbance that occurred at the close of the Tertiary.

The position of the early glacial deposits as hill caps and the dissection of the Carmen formation indicate as much as 1,000 feet of uplift and canyon cutting before the late Wisconsin glaciation.

Geomorphic development:-- The relations of the Challis volcanics to the Belt rocks indicate accumulation on a hilly erosion surface of considerable relief, with accumulation interrupted now and then by intervals of quiescence and erosion. During the early stages of volcanism the extrusions were composed largely of flows of intermediate composition, but later the extruded materials were more silicic and gave rise to a thick accumulation of tuffs with some intercalated flows and ignimbrites (welded tuffs) of rhyolitic and quartz latitic composition. At one stage the extrusion of silicic materials was temporarily interrupted by the outpoural of basaltic and basic andesitic lavas. As the volcanism came to an end, crustal movements arched the volcanic blanket into a broad anticline. Erosion then reduced the region to one of rather low relief.

Local downwarping in early Miocene time then produced the basin in which were deposited the materials of the Carmen formation, composed in considerable part of erosional debris derived from the Challis volcanics. Erosion continued through the remainder of the Miocene and through much of the Pliocene, terminating with the formation of an old erosion surface, remnants of which are now well preserved on the summits of the ridges composing the Salmon River Mountains.

Crustal disturbances beginning at the close of the Pliocene, marked by renewed warping and uplift and accompanied outside the quadrangle by block faulting, initiated a new cycle of erosion and the integration of the present topographic features. After the mountain groups had become fairly well-perfected and the intervening basin reestablished, glaciers appeared on the higher mountains and spread down the slopes and in places onto the flanks of the bordering basin, leaving an accumulation of till and outwash on the piedmont slopes. The glaciers then disappeared and there followed up to 1,000 feet of canyon cutting, probably in response to renewed uplift. During this time the beds of the Carmen formation, which formed the basin floor, were deeply dissected and converted into the hilly surface much as it is today. Glaciers then returned to the region, but these later glaciers were not nearly so extensive as the earlier and were restricted to considerably higher altitudes. These glaciers carved small cirques at the heads of some of the steep valleys in the Lemhi Range, sculptured the Beaverhead Range extensively, and developed a fringe of small cirques along the crest of the Salmon River Mountains with several tongues of ice barely extending within the borders of the quadrangle.
The late gladiers fed a vast amount of debris to the streams and caused extensive filling of valley bottoms within the quadrangle area. After the melting away of the late glaciers, the less heavily debris-laden streams removed a part of the valley fill, remnants of which remain as terraces bordering the present valley floors. Above and below the basin, the Salmon River is actively engaged in canyon cutting, but within the basin the river is at grade and is widening its valley floor.

Mineral resources:— The mineral resources of the quadrangle include deposits of gold, copper, lead, possible radioactive minerals, coal, building stone, bentonite, clay, gravel, road metal, and thermal waters. All of these have received some attention, but the main interest of late has been in the copper deposits and in the possible occurrence of radioactive minerals.

The copper deposits have been among the most productive of the metaliferous resources. These occur as replacement lodes along poorly defined zones of shearing in the Belt strata and are distinguished by a relative abundance of chalcopyrite, minor pyrite, and locally delafossite in a gangue of altered micaceous country rock. The Pope-Shannon is the only currently active mine in the quadrangle. This type of copper mineralization is widespread through the region. At no place does it show any relationship to the Idaho batholith and from present information may be a product of possible late pre-Cambrian or early Tertiary metallization.

The gold deposits, which were of chief interest in the early days, include both lodes and placers; the former as gold-quartz veins and lodes localized in or near the borders of granitic rock, the latter as accumulations in the gravels along Kirtley Creek. Because of the distribution of the gold-bearing lodes in or around bodies of granitic rock, there is a temptation to relate the gold mineralization genetically to the Idaho batholith, but it is possible that the relationship is purely structural and that the gold is a product of an early Tertiary metallization. Neither lodes nor placers have been worked for some years.

The lead deposits have not been very productive. The only deposits within the quadrangle are several miles northwest of Salmon. These are small lead-silver lodes along zones of shearing in the quartzitic Belt rocks. Just outside the quadrangle on Carmen Creek is a broad zone of altered and locally intensely silicified rock that contains some disseminated galena. The lead mineralization probably belongs to one of the early Tertiary epochs of metallization.

Some radioactivity has been revealed by the Geiger counter along the weak zones of lead mineralization in the quartzitic rock northwest of Salmon, but no showings of commercial province had been found within the quadrangle at the time this field study was made. The most promising areas of investigation are those underlain by faulted or complexly fractured Belt rocks.
The coal deposits have been worked intermittently to supply local needs, especially when higher rank coal has not been readily available from outside sources. The coal is lignite but, except for considerable ash, it appears to be of good quality. The lignite occurs as thin lenses up to 4 feet thick in the Carmen formation a mile or so west of Salmon.

Some building stone has been quarried in past years to supply local needs but the demand has been small. All the quarried rock has come from beds of well-indurated sandstone in the Carmen formation, mostly from exposures close to Salmon. Volcanic tuffs, flows, and ignimbrites in the southern part of the quadrangle are also available as building material.

Thin beds of impure bentonitic clays occur in the Carmen formation, particularly in the area south of the Lemhi River and east of the Salmon River. Some of this material has been utilized as a lining of irrigation ditches to seal against loss of water.

Clay beds occur in the Carmen formation but the clays are generally sandy or silty and have little potential value. Some of the clay near the coal beds, however, appear to be of better quality. There has been little attempt to utilize the clay.

Gravel is the quadrangle's most abundant mineral resource. Utilization so far has been restricted to some of the residual sand and gravel formed by disintegration of the granite northwest of Salmon, to channel deposits in the Salmon River, and to the flood plain deposits along the Salmon and Lemhi valley floors. Little, if any use has been made of the extensive gravel terraces along the Salmon and Lemhi Rivers and their principal tributaries. The gravel resources are virtually unlimited.

Road metal is another very abundant resource. In addition to the gravel, much of which finds use on the roads, some quartzitic rock about four miles north of Salmon and some talus debris derived from rhyolitic flows or ignimbrites along Williams Creek have been used as road metal. The volcanic flows and ignimbrites in the south part of the quadrangle could provide an almost inexhaustible supply of road metal.

The only thermal waters in the quadrangle issue along a fault in the Challis volcanics near the north end of the Lemhi Range. Known as the Salmon Hot Springs, these waters have been developed for use in a hotwater plunge.
INTRODUCTION

PURPOSE AND SCOPE

Study of the Salmon quadrangle, Lemhi County, marks the first step in a comprehensive investigation of the geology and mineral resources of the Salmon region. The Salmon quadrangle was selected for this initial study in part because it provided an excellent topographic base for geologic mapping and in part because it was thought that the findings might prove useful in the investigation of regional geologic problems and in the mapping and study of adjacent areas.

All phases of the local geology received some consideration but not equally so. Because of time limitations, the studies were not so detailed as desired but were sufficient to provide considerable information on the stratigraphic, structural, petrologic, geomorphic, and economic aspects of the geology. The information on some of the stratigraphic and structural problems, however, leaves much for future investigations.

In addition to providing a record of the local geology and mineral resources, the study has given further insight into some of the regional geologic problems. It may have solved some of them, and it has uncovered others in need of much broader and more detailed investigations. Among the present findings may be mentioned (1) that the Salmon "lake beds" (now defined as the Carmen formation), which long have been considered an upper part of the Challis volcanics, are separated from the Challis by a marked angular unconformity and represent a product of later sedimentation in an isolated structural basin produced by local downwarping; (2) that locally much of the rhyolite and quartz latite in the Challis volcanics is composed of ignimbrites (welded tuffs) and not of flows; (3) that the granitic rock occurring as outliers of the Idaho batholith is "granitized" quartzite and not consolidated magma; (4) that the copper mineralization supposedly related genetically to the Idaho batholith has neither geographic nor geologic associations with the batholith and may be a product of either late pre-Cambrian or early Tertiary metasomatism; (5) that the gold deposits, which occur in or near the granitized quartzite, may be related genetically to the Idaho batholith or may have made use of the same zone of structural weakness during a later Tertiary metasomatism; and (6) that there is further evidence of two stages of Pleistocene glaciation separated by as much as 1,000 feet of interglacial canyon cutting.

FIELDWORK AND ACKNOWLEDGMENTS

Work in the field got underway on June 21, 1954, and continued through July and August. There was little trouble in recognizing and mapping the broader rock units, but the extensive mantle of broken rock on the mountain slopes did hinder stratigraphic and structural studies of the older rocks and did greatly impede foot traverses. Except at the Pope-Shenon mine, underground studies were greatly handicapped by lack of accessible workings.
The writer wishes to acknowledge his gratitude to Mr. Frank Taft in charge of the exploration work at the Pope-Shenon mine for his cooperation in providing copies of mine maps and otherwise providing information useful in the mine studies. Acknowledgments also go to Mr. Allen C. Merritt and others who in one way or another provided services or helpful information. Thanks are extended to Mr. Warren B. Schipper, graduate student in geology at the University of Idaho College of Mines, who served as field assistant.

PREVIOUS GEOLOGIC WORK

Previous geologic work in the quadrangle has been largely incidental to studies of much larger areas. The most pertinent work has been by Umpleby and Ross. The bibliography so far as it pertains to the immediate area is given below:


The Copper Deposits Near Salmon, Idaho, U. S. Geol. Survey Bull. 774, 43 pps (1925). The best and most complete report on the copper mineralization in the Salmon region. The report covers the time when most of the copper deposits were active and the workings accessible. Describes the copper deposits in as well as outside the boundaries of the quadrangle.


Umpleby, J. B., Geology and Ore Deposits of Lemhi County, Idaho, U. S. Geol. Survey Bull. 528, 182 pp. (1913). A reconnaissance treatment of the geology and ore deposits of Lemhi County. Describes some of the gold-bearing lodes near Salmon both in and outside the boundaries of the present quadrangle but has little data on the copper mineralization.

GEOGRAPHY

LOCATION

The Salmon quadrangle is in the eastern part of Lemhi County in east-central Idaho, close to the Montana line (Fig. 1). It is bounded by parallels 45° 0' and 45° 15' north latitude and meridians 114° 45' and 114° 00' west longitude, a quadrangle about 17 miles long north and south and 12 miles wide east and west. The quadrangle covers about 214 square miles and is included in part or in whole in T. 19, 20, 21 and 22 N., R. 21, 22, and 23 E., Boise meridian. Salmon, the town from which the quadrangle takes its name, is several miles north of the center of the quadrangle.

SURFACE FEATURES

PHYSIOGRAPHIC SETTING

The Salmon quadrangle lies far within the Northern Rocky Mountains about 100 miles from the edge of the Snake River Plain, the nearest border of the mountainous mass. The most impressive feature of the quadrangle, however, is not the mountainous terrane but a broad intermontane basin which has interrupted the continuity of the mountains and separated them into well-defined units (Pl. 7). This broad opening in an otherwise mountainous region is referred to herein as the Salmon Basin, named for the town near its center and the river that courses its length.
Fig. 1 Index map showing location of Salmon quadrangle.
The mountains that border the basin and also extend into the quadrangle are the Salmon River Mountains on the west, the Beaverhead (Bitterroot) Range on the northeast, and the Lemhi Range on the southeast. Also entering the quadrangle and merging with and enlarging the Salmon Basin is the Lemhi Valley, another broad but long intermontane valley or basin, which with its southeastward continuation, the Birch Creek Valley, separates the Beaverhead and Lemhi Ranges and provides a long, open corridor to the Snake River Plain.

The quadrangle is drained by the Salmon and Lemhi Rivers and some of their tributaries. A water feature of special interest is Williams Lake on Lake Creek, a tributary of the Salmon River.

LAND FEATURES

Salmon River Mountains

The Salmon River Mountains rise abruptly as a north-south escarpment along the west side of the Salmon Basin, with spur ridges extending up to a high drainage divide 1 to 4 miles west of the boundary of the quadrangle. These spur ridges reach altitudes of 7,000 to 8,000 feet within the quadrangle, some 3,000 to 4,000 feet above the Salmon River but 500 to 1,500 feet below the main divide. The maximum relief measured from the town of Salmon at 3,940 feet to the top of Baldy Mountain at 9,150 feet about 6 miles southwest of town and one half mile west of the map boundary is just under a mile (Pl. II, A). Only some 2 to 4 miles of the eastern flank or slope of the mountains lie within the map area. From the summit the mountains spread westward across Central Idaho as a vast dissected plateau upland composed of an intricate pattern of ridges with accordant summit levels.

The eastern slope is deeply incised by steep-walled canyons which end at the edge of the basin. The frontal slope continues but is less well-defined south of the basin, with the narrow canyon of the Salmon River there separating the Salmon River Mountains from the Lemhi Range.

Beaverhead Range

The foothills of the Beaverhead Range (designated on the topographic map as the Bitterroot Range) form the northeast slope of the Salmon Basin, with the main range just off the northeast corner of the quadrangle. This is a very imposing range, rising higher than the Salmon River Mountains to altitudes well over 10,000 feet, the rugged rocky crest showing abundant evidence of the former presence of glaciers. The range has a bold, steep, rocky, front, straight-lined for many miles, directed in a southeasterly direction (Pl. II, B). North of the basin the range tends to merge with the Salmon River Mountains and loses its identity. Southeastward from the basin it continues as a sharply defined range, bordered on the southwest by the long intermontane trench composed of the Lemhi and Birch Creek Valleys. The crest of the range marks the Continental Divide and forms the boundary between Idaho and Montana.
A. SALMON RIVER VALLEY

Shows the Salmon River as it crosses the south rim of the Salmon Basin before entering the Basin proper. The relatively smooth slopes in the foreground are of quartztic rock. The prominently tilted ledges beyond belong to flows and ignimbrites of the Challis volcanics. The long uniform slope in the distance forms the east border of the Salmon River Mountains. The highest point on the slope is Baldy Mountain, just west of the boundary of the quadrangle.

B. LEMHI VALLEY

View across the town of Salmon and obliquely up the Lemhi River Valley and against the Beaverhead Range. Shows the arable land under irrigation along the floor of the Lemhi Valley and on the terraces extending several miles up Kirtley Creek toward the Beaverhead Range.
Lemhi Range

The Lemhi Range comes to a rather blunt end in the southern part of the quadrangle, forming a wedge-shaped mass which seems to project well into the Salmon Basin though it actually separates the Salmon Basin from the merging Lemhi Valley. The range is one of the longest in the region and extends in a southeasterly direction for 100 miles before it disappears at the edge of the Snake River Plain. It is a very imposing range, rising quite boldly above the Lemhi-Birch Creek corridor and even more boldly above the floors of the broad Pahsimerai and Little Lost River Valleys on its southwest side, which form another long corridor to the Snake River Plain. North of the Pahsimerai Basin Basin the range is separated from the Salmon River Mountains by the deep, narrow canyon of the Salmon River.

Within the quadrangle the range rises steeply above the more gentle basin slopes and reaches an altitude of 9,592 feet at Sal Mountain, the highest point in the area (Pl. III, A). Southward the range becomes even higher and eventually reaches a maximum somewhat more than 11,000 feet. Locally it has comparatively smooth slopes, although the foothill country on its east flank is rather deeply incised by canyons.

Salmon Basin

The Salmon Basin covers about a third of the quadrangle, with considerably more outside the borders. The basin is elongated in a northerly direction, but is decidedly asymmetric with a big southeasterly bulge into the merging Lemhi Valley basin. Its length is about 20 miles and its width up to 12 miles or more measured across the bulge.

The basin is composed of a relatively low, broad hilly depression with hills rising as much as 1,000 feet above the stream courses in the marginal foothills of the Beaverhead Range and as much as 200 to 400 feet above the broad bottomlands along the rivers in the more central areas (Pl. III, B). Although the mountain slopes may be regarded as forming the flanks of the basin, the 6,000-foot contour is taken as the approximate rim; for that contour closely coincides with the upper boundary of the "lake bed" formation in which the hilly floor is carved and is marked by a fairly abrupt increase of slope as the softer rocks of the basin give way to the harder rocks of the mountains proper. From the "lake bed" rim the hilly surface slopes downward to altitudes of 4,400 to 4,200 feet, with the broad river bottoms incised at a still lower level. The wide river bottomlands and bordering terraces are also conspicuous features of the broad intermontane basin.

WATER FEATURES

Salmon River

The Salmon River emerges from a deep canyon on entering the Salmon Basin (Pl. II, A) and then continues its northward course through a broad,
A. LEMHI RANGE

North end of the Lemhi Range with its scattered cliffs of pre-Cambrian quartzite and extensive mantle of talus and more or less continuous cover of timber. Saddles across the top of the range mark the crossings of transverse zones of structural weakness. Dumps at the Pope-Shenon mine appear on the lower timbered slope on the left of the picture. Rather steep timberless slopes immediately below the timbered area are underlain by tuffaceous beds of the Challis formation. The lower more gentle, light-colored slopes in the middle distance are composed of beds of the Carmen formation. Picture is taken from a gravel terrace west of the floodplain of the Salmon River.

B. SALMON BASIN

View across part of the Salmon Basin showing the dissected, hilly character of the basin floor and the broad expanse of essentially level bottom land along the Salmon River. The mountains in the background belong to the rugged Beaverhead Range, which carries the Continental Divide. The hilly terrane in the basin is carved in the Carmen formation, except in the immediate foreground where the rocks belong to the tuffaceous unit of the Challis volcanics.
shallow bluff and terrace-bordered valley only to pass into a deeper and
even more spectacular canyon as it leaves the basin, shortly to change
its direction and continue westward across the state. The river has carved
a wide valley floor across the basin, measuring up to \( \frac{1}{8} \) miles for several
miles above and below the town of Salmon, with the channel crowded first
to one side of the valley floor and then to the other, mainly by the all-
luvial material deposited at the mouths of the larger tributary streams.
Where deflected against the side the river has cut steep bluffs, particular-
ly striking for several miles along the west side of the valley floor above
Salmon and for a similar distance along the east side of the valley below
the town (Pl. V, B). In its airline journey of 17 miles across the quad-
rangle, the river descends from an altitude of about 4,220 feet to about
3,850 feet. Within the basin the river is building up and widening its
valley floor, a process temporarily interrupted by a brief period of down-
cutting during which the flood-plain was incised and another started at a
slightly lower level. As the readjustment to this lower level has not yet
extended entirely up the basin, low terraces of the earlier flood-plain
still remain. (Pl. I).

Each of the larger tributaries has built an alluvial fan on the Salmon
River flood-plain, each terraced by the river. Such valley-floor fan
terraces are especially prominent at the mouths of Perreau, Jessie, and
Pollard Creeks on the west side of the river. The upper fan terraces ex-
tend up the tributaries as their present-day flood-plains. The valley
floors of all the tributaries are terraced with respect to the Salmon River
flood-plain, with their floors some tens of feet above that of the Salmon.
This topographic discordance between the tributaries and the river is
one of the interesting physiographic features of the area.

In addition to the tributaries already mentioned, there are Lake,
Williams, Spring, Gorley, Chippa, Bob Moore, Fenster, and Deriar Creeks
on the west side of the river, each cut into the eastern slope of the
Salmon River Mountains. These are named from south to north. For the
complete listing, Perreau Creek lies between Williams and Spring Creeks;
Jessie and Pollard Creeks between Chippa and Bob Moore Creek. On the
other side of the river Twelvemile, Termile, Seventmile, Eli, and Hot
Springs Creeks join from the Lemhi Range, and Carmen Creek at the extreme
north end of the quadrangle from the Beaverhead Range. Particular mention
is made of these streams here because of the references made to them else-
where in the report.

**Lemhi River**

The Lemhi River, which flows northwest along the broad Lemhi Valley,
joins the Salmon River at the town of Salmon. This river also flows over a
broad valley floor well over a mile wide (Pl. II, B). The gradient is
somewhat steeper than that of the Salmon, the water dropping 350 feet in
an airline distance of about 8 miles. Because of its steeper gradient and
hence more vigorous action, the Lemhi has succeeded in pushing the Salmon
River hard against its western bank. The thick fan accumulation at the
mouth of Jessie Creek at and just below the town, however, has deflected
the Salmon back to the east side of its valley floor just below the mouth
of the Lemhi.
As along the Salmon, the widening of the Lemhi River flood-plain was temporarily interrupted and then resumed at a slightly lower level, an action which extends about 9 miles up the valley. Much higher terraces at 40-foot and 80-foot levels mark the position of former, more extensive flood-plain, remnants of which occur continuously along the northeast side of the valley and here and there along the southwest side. The floors of the main tributary valleys northeast of the Lemhi River are stranded at the lower terrace level. Such valleys are occupied by Kirtley and Geertson Creeks, both of which drain from the high Beaverheads and are themselves flanked by terraces.

Streams which join the Lemhi River from the Lemhi Range include Mulkey, Baker, Withington, Cheney, and Kadietz Creeks, all of which, except Mulkey Creek, enter the river east of the boundary of the quadrangle. Both Mulkey and Withington Creeks have carved deep narrow canyons in the upper foothill country.

**Williams Lake**

Williams Lake on Lake Creek in the southwest corner of the quadrangle is a water feature of exceptional interest. This lake, the largest for some miles around, is about 1½ miles above the mouth of the creek and is held behind a high dam of landslide debris (Pl. IV). The lake is a little over one mile long, somewhat more than one-half mile wide near the dam, and several hundred feet deep (Pl. IV, A). The landslide blocks the valley to a height of 480 to 660 feet. The dam is nearly a mile long at the top and about one-half mile at the base (Pl. IV, B). The ponded water behind stands at 5,255 feet and the level would have to rise to about 5,300 feet to overtop the dam. The lake has no outlet except underground, the water emerging as a big spring near the bottom of the slide at an altitude of about 4,880 feet. A gigantic amphitheater-like scar north of the slide debris marks the source of the slide material.

**CLIMATE**

Because of the considerable variation in altitude, there is an appreciable difference in climatic conditions within the area. In the higher mountains the climate may be typed as fairly severe, humid continental; and in the basin as less severe, subhumid continental. In the mountains the snow comes early in the autumn, accumulates to depths of some feet, and does not disappear from the drifted areas until well into the summer. Fresh snow may be expected about the higher peaks and ridges any month except July and August, and has been known to occur even during those months. On the other hand, in the lower country the snow comes late in the autumn and rarely accumulates to more than a few inches or remains on the ground for more than a few days. Whatever snow may accumulate on the upper slopes of the basin is generally gone by early spring. Snow may block the mountain roads for winter-time use but it almost never interferes with travel in the lower country. Rain as well as snow may be expected in the mountains during spring and autumn months. The summer is the dry season, but it rarely without some rainfall, usually as scattered
A. WILLIAMS LAKE

The lake impounded behind the huge landslide that blocked the valley of Lake Creek. The prominent cliffs back of the lake belong to thick flows of the latite-andesite unit of the Challis volcanics. Salmon River Mountain crest on the distant skyline.

B. WILLIAMS LAKE LANDSLIDE

The huge landslide that dammed the valley of Lake Creek and impounded the waters of Williams Lake on its upper side. The landslide dam is as much as 600 feet high.
showers of short duration. The accumulated precipitation in the mountains is probably several times that in the more central part of the basin, where at Salmon the annual rainfall is 9.31 inches.

The area experiences a marked daily and annual range in temperature. A daily range of 50° is not uncommon in either the basin or mountain country, especially during cloudless weather. Except when there is an inversion of temperature, the basin is always considerably warmer than the mountains in both summer and winter. During the winter the town of Salmon may have an occasional spell of zero weather but mean temperatures are in the upper twenties and freezing temperatures at night usually give way to mild thawing temperatures during the day. During the summer the daily temperatures may reach into the nineties for several weeks at a time and may even enter the low hundreds for a day or two, but evening temperatures are invariably cool, in the forties and fifties. On the other hand the temperatures in the higher mountains may fall to zero and below and remain at those levels for considerable periods of time. During the summers the days are pleasantly warm, never hot, and the evenings are always cool, even frosty, at the highest levels.

VEGETATION

The vegetational cover reflects both the variations in altitude and climate and the character and condition of the rock or subsoil. The basin country is rather scantily covered with sagebrush and a few small cacti and grasses, but this appearance of semiaridity is not so much the lack of precipitation as the inability of the basin rocks to retain the water in sufficient amounts to support a forest growth. Greater evaporation at the higher basin temperatures may also contribute to the general appearance of aridity.

The mountain areas are generally more or less continuously forested, except where cliffs and talus and especially well-drained land make such growth impossible. In the Lemhi Range the forest, except in the cliff and talus areas and on sagebrush-covered lower slopes, forms a fairly continuous cover, it is heavier on intermediate slopes than on the peaks and higher ridges (Pl. III, A). On the Salmon River Mountain slope the forest is more patchy but forms a more or less widespread cover, especially up to an altitude of about 8,000 feet. Above that bare rocks and talus slopes restrict the forest to scattered trees and groves. The forest cover is composed largely of medium-sized evergreens rising above a surface thickly clad with grasses and small shrubs, including sagebrush. The evergreens are composed chiefly of Douglas fir, Englemann spruce, lodgepole pine, and yellow pine, the distribution of each depending chiefly on altitude and moisture conditions. The Douglas fir is generally most widespread, growing mostly in open scrubby stands on north slopes and other moist places up to altitudes of 8,000 feet. The Englemann spruce has a wide range of altitude but is confined mainly to the moist canyons. The lodgepole pine covers most of the higher areas, the yellow pine occurs as scattered trees on some of the lower-drier south slopes. All the forested areas are within the boundaries of the Salmon National Forest.
The floodplains along the main streams are well-watered and support a tangled growth of small deciduous trees and bushes and luxuriant grasses, except where the land has been cleared for irrigation. Little of the floodplain now remains unclaimed.

POPULATION AND INDUSTRIES

The quadrangle is more thickly populated than the surrounding region, with most of the people living in or close to Salmon and along the valley floors of the Salmon and Lemhi Rivers and Carmen, Kirtley, and Geertson Creeks. Salmon, the county seat and headquarters for the Salmon National Forest, is the trading and distribution center for a large surrounding region. The 1950 Census credits Salmon with a population of 2,648, but recent building activity indicates some later growth. Carmen, a community of a few families, is the only other settlement in the quadrangle. The county has a population of 6,278.

Most of the area is range country with cattle raising the largest and most important industry. The grass in the basin and bordering mountain slopes supports a large cattle population during the open season and hay raised under irrigation on the bottomlands and on some of the bordering terraces carries the stock through the winter. Hay is the major agricultural crop.

Logging is another industry of some importance. Several small sawmills are located at or near Salmon, supplied with logs trucked mainly from the Salmon River Mountains. Poles are also cut and trucked to Salmon, with later delivery to outside points.

Other industries include mining and trade. In late years the only mining activity in the quadrangle has been at the Pepe-Shenon mine, with small periodic shipments of copper ore. Salmon, however, serves a much larger mining area and benefits from the activities of such distant camps as the one at Cobalt. Salmon is the trade and distribution point for practically the entire county.

ACCESSIBILITY

Despite its location far back in the mountains, the area is readily accessible. For some years Salmon was the terminus of the Gilmore and Pittsburgh Railroad, which connected with the Union Pacific System at Armitstead, Montana, 95 miles to the east. In 1939 the line was abandoned and the tracks removed. Since then Salmon has been dependent entirely on automobile and truck transportation, the nearest railheads being at Armitstead, Montana; at Darby, Montana (terminus of a branch of the Northern Pacific Railway, 74 miles to the north); and Mackay, Idaho (the terminus of a branch line of the Union Pacific System, 118 miles to the south).

Traffic in and out of Salmon is now over two fine, modern highways, U. S. Highway 93 and State Highway 28 (Pl. I). U. S. Highway 93 passes
through Salmon and provides a paved road north to Darby and Missoula, Montana, and south to Challis. At Challis the southbound traffic transfers to U. S. Highway 93-A and continues through Mackay to Arco, where connection is made with U. S. Highway 20 for Boise and points West or Idaho Falls and points East, or with U. S. Highway 26 for Blackfoot and thence with U. S. Highway 91 for Pocatello and points South and East. State Highway 28 ends at Salmon, providing a shorter and faster access route from Idaho Falls by way of the Birch Creek-Lomhi Valley corridor. Except for a few miles near Leadore, this road is paved the entire distance from Salmon to Idaho Falls. The only high passes are on the route to Darby, Montana. All highways are open to travel throughout the year.

Salmon has adequate stage service. Passenger stages operate daily to and from Pocatello via Blackfoot, Mackay, and Challis, and to and from Missoula, Montana. Stages also operate on State Highway 28 to and from Idaho Falls. Mail is received and sent out several times daily, except Sunday, by mail trucks to Armead, Missoula, and Pocatello. Truck lines provide Salmon with adequate freight and express service.

The needs of those off the main highways are served by gravelled secondary and unimproved roads. Most of the gravelled roads are in the farming areas, but a few extend into the mountains, one up Williams Creek, another up to Stormy Peak in the mountains northwest of Salmon. There are a number of unimproved roads, used mainly by cattlemen and those needing access to mines or prospects and timber lands. Some of these unimproved roads may be more aptly described as Jeep trails.

GEOLGY

FOREWORD

The Salmon Quadrangle contains a varied assemblage of bedded sedimentary and volcanic rocks, of intrusive igneous rocks, and of surficial deposits. The bedded rocks comprise two groups of widely separated ages, one of pre-Cambrian age composed of a considerably metamorphosed sedimentary formation, the other of Tertiary age composed of a volcanic formation, the Challis volcanics, and of a sedimentary formation, the Carmen formation. The intrusives include some outliers of the Idaho batholith (Cretaceous) and some other bodies both older (pre-Cambrian) and younger (Tertiary). The surficial deposits of glacial and non-glacial origin are Quaternary.

The area is in a broad zone of structural weakness and has been the scene of numerous structural disturbances beginning in late pre-Cambrian time and renewed at the close of the Jurassic (Sierra Nevadan orogeny), Cretaceous (Laramide orogeny), and Tertiary periods, with some additional crustal movements within the Tertiary. Consequently, the older rocks have been considerably folded, faulted, and otherwise affected by rock breakage, whereas the younger rocks involved in fewer crustal disturbances are less severely folded and broken. The geomorphic development, which is largely a reflection of the later crustal disturbances, is an eventful one.
STRATIGRAPHY

SEDIMENTARY AND VOLCANIC ROCKS

The volcanic and some of the sedimentary rocks in the quadrangle are parts of widespread and fairly well-known formations, but some of the rocks are of local occurrence and cannot be given names used elsewhere for equivalent formations. Thus the old metamorphosed sedimentary rocks belong to and are a continuation of the pre-Cambrian Belt series so widespread in northern Idaho and northwestern Montana, and the Tertiary volcanic rocks are a part of the Challis volcanic formation which outcrops extensively over much of south-central Idaho. The Tertiary sedimentary rocks on the other hand are restricted to the Salmon Basin and, because of their local distribution, cannot be given the names of formations of probably equivalent age in other parts of the country. The logical name for these beds would be the Salmon formation or the Salmon Basin formation. However, the name Salmon formation has been preempted for other formations elsewhere and is not available for use locally. Therefore it is proposed that this formation be called the Carmen formation after the settlement of Carmen, which is well within theformational area, with excellent exposures above and below the settlement and along Carmen Creek to the east. No formational names are yet justified for the Quaternary deposits, which include patches of old glacial till and outwash, several younger gravel terraces, and the present stream alluvium.

Belt series (pre-Cambrian)

Distribution

The Belt rocks are the main mountain makers and compose much of the northern two-thirds of the Salmon River Mountain slope and the main part of the Lemhi Range (Pl. I). They also compose the adjacent parts of the Beaverhead Range. They probably underlie the younger formations in the broad Salmon Basin and the volcanics that blanket much of the southern part of the quadrangle. They are exposed where this blanket has been pierced by Williams Creek and by the Salmon River, appearing as a window in the lower canyon walls of Williams Creek and on both sides of the Salmon River near the mouth of Twelvemile Creek. There is another fairly large exposure at K Mountain in the southeast corner of the quadrangle which is entirely surrounded by volcanics, and a much smaller exposure which projects through the volcanics on a small tributary of Mulkey Creek about 2 miles from the nearest outcrop in the Lemhi Range.

These old sedimentary rocks may be traced northward through the Salmon River Mountains for many miles beyond the quadrangle, westward far into the Leesburg and Blackbird quadrangles, and for many miles south and southeast along the Lemhi Range.
Character and composition

The Belf rocks show such little variation in lithologic character that they cannot be subdivided until studied in much greater detail. They comprise a thick, rather monotonous succession of generally thin-bedded, dark-gray, finely micaceous quartzites with some intercalations of lighter-colored quartzitic beds and exceptionally of nearly pure quartzite. Some of the rock in the Lemhi Range has a greenish cast resulting from local alteration. Otherwise the rock throughout the area is quite uniformly the same, with the rock in the Lemhi Range essentially a duplication of that in the Salmon River Mountains. In some places, particularly on the Salmon River Mountain slope near lower Spring Creek and again north of Fenster Creek, there are several hundred feet of more massive, light-colored beds that may provide a mappable unit. Otherwise there appears to be little to distinguish one part of the quartzitic succession from another.

Except in some of the more massive quartzite, the bedding is generally rather indistinct but can usually be distinguished on close examination. Bedding planes, except in the more massive rock, are fairly closely spaced and may in places compose several to the inch or more commonly several to the foot. Many of the beds show ripple markings and some of the thicker beds also show local crossbedding.

The indistinctness of the bedding is not so much a primary feature of the rocks as it is the result of superposed secondary structures. In general the bedding has been obscured by a fairly pronounced schistosity, which in places is far more conspicuous than the bedding and from a distance may be easily mistaken for bedding. The beds are also cut by several sets of closely spaced joints and these too tend to give the impression of bedding structures, especially when viewed from a distance. Some of the joint sets are conspicuously reflected in the topography. Local fracture cleavage also adds to the confusion of what is and what is not bedding. Because of the extensive fracturing, the mountain slopes are generally buried beneath a thick mantle of talus fragments bounded by these fracture surfaces, with outcrops of bedrock confined to scattered cliff-like exposures on steep frontal slopes and in canyon walls. The schistose structure and jointing appear to be much more pronounced at the north end of the Lemhi Range and westward across in the Salmon River Mountains from Williams Creek to Bob Moore Creek than elsewhere in the region. It is through this region that the bedding is most difficult to detect. To both north and south the bedding becomes more pronounced and schistosity and jointing correspondingly less conspicuous. The beds also tend to become more massively bedded and less impure.

Although the individual mineral grains cannot be distinguished by the unaided eye, the microscope reveals that these impure siliceous rocks are fine-grained micaceous quartzites, with the mica grains generally less than 1 millimeter in diameter. The rock shows complete recrystallization. In addition to the recrystallized quartz and occasional grains of albite and microcline, it contains about equal amounts of biotite and fine flaky muscovite which together make up about a third or, exceptionally, as much as
half the rock. The quartzite also contains grains of accessory zircon and magnetite, apparently inherited from the original sedimentary rock. The dark greenish rock in the Lemhi Range contains much chlorite and epidote, secondary after biotite. The schistosity characteristic of much of the rock is also revealed under the microscope by rude parallelism of the mica grains.

The thickness of the succession of Belt strata was not measured but is estimated to be at least 4,000 feet and may exceed 5,000 feet. The top and bottom of the succession is not revealed anywhere within the quadrangle. The beds in the Lemhi Range are essentially a duplication of those across the Salmon River, in the Salmon River Mountains.

The Belt strata locally are more highly metamorphosed than those in the northern part of the state and direct correlation with any particular member of the Belt series is impractical, if not impossible. The higher degree of metamorphism probably reflects more intense deformation than farther north and may have been assisted by the action of heated emanations associated with the emplacement of the Idaho batholith.

Challis volcanics (Oligocene)

Distribution

The Challis volcanics are confined to the southern part of the quadrangle, where they blanket much of the southern third of the Salmon River Mountain slope and the foothill country of the neighboring Lemhi Range (Pl. I). These volcanics rim the south end of the Salmon Basin and then continue around the north end of the Lemhi Range into the Lemhi Valley, composing there much of the hilly and mountainous area between the high range and the lower flank of the Valley. A deep embayment encircles K Mountain and rejoins the main body of volcanics in the Lemhi Valley several miles beyond the boundary of the quadrangle.

On the west side of the Lemhi Range and in the adjacent Salmon River Mountains the volcanic blanket continues southward with little interruption into the Challis region from which the formation receives its name. Northward the volcanics disappear beneath the Carmen formation of the Salmon Basin and apparently die out before reaching the other side of the Basin.

General character

The Challis volcanics in the Salmon quadrangle are much the same as in other parts of south-central Idaho and comprise a thick succession of flows of mostly intermediate composition with much associated and interbedded pyroclastic materials. As in other localities the volcanic formation can be subdivided into units of somewhat variable composition, recognizable as equivalent to similar units in other parts of the region. Thus the lower part of the volcanic formation, which locally consists largely of flows of andesitic and latitic composition with some interbedded
tuffaceous materials, corresponds very closely with the lower latite-
andesite member recognized by Ross as widespread over south-central Idaho.

1. Ross, C. P., Geology and Ore Deposits of the Bayhorse Region, Custer

Above the latite-andesite unit the local rocks are largely tuffaceous
but contain some intercalated latitic and rhyolitic flows especially in
the lower middle part, and some intercalated basalt and calcic andesite
wall up toward the top. Although the tuffaceous unit contains more
flows than in the type locality, it is nevertheless very much like the
"Garner tuffaceous member" named and described by Ross in the Bayhorse


quadrangle, which also lies above or is intercalated with the upper part
of the latite-andesite member and contains some intercalated basalt, in
places forming a large part of the volcanic formation. The top unit,
the Yankee Fork rhyolite member, is not present in the Salmon quadrangle.

Despite the general agreement in stratigraphic relations and rock
types, there are some pertinent differences in rock character, particular-
ly in the local abundance of ignimbrites (welded tuffs), bodies of rock
with most of the external characteristics of lava flows but not formed
directly from molten lava. These occur throughout the volcanic formation
but are more numerous in the tuffaceous member than in the underlying
succession of latites and andesites. These flow-like bodies of rock have
a rhyolitic to quartz latitic composition and are in general indistinguish-
able from the flow rock, except under the microscope. Instead of being
composed of consolidated lava, these rocks are made from tuffaceous ma-
terials welded by heat into a rock with most of the external character-
istics of a consolidated lava flow. The rock is thought to have been
generally developed from incandescent ash or tuff flows streaming down
slope from the crater vent as rapidly moving clouds or floods of intense-
ly heated, disrupted minute particles or fragments of volcanic material,
buoyed up by intermingled gases and deposited while temperatures were
so high that the materials will still viscous and adhered and were welded
together as they reached the ground. Much of the rocks of the region
previously described as rhyolite and in part as quartz latite are pro-
bably ignimbrites.

In mapping the Salmon quadrangle the lower latite-andesite and the
overlying tuffaceous units were not differentiated, but the basalt and
a related basic andesite in the tuffaceous member were mapped separately.
With detailed study, the volcanics can perhaps be further subdivided,
with the tuffaceous unit resolvable into several flow and tuffaceous
members.
Latite-andesite unit

Distribution

The latite-andesite unit underlies the extreme southwestern part of the
quadrangle and is advantageously exposed on the ridges bordering Williams
Lake and the upper course of Henry Creek (Pl. I). The upper boundary is the
thick succession of light-colored, well-beded tuffs exposed along Termite
and lower Henry Creek and across the high ridge to Williams Creek. It is pos-
sible that the unit reappears on the east side of the Lemhi Range near the
south boundary of the quadrangle.

Character

The unit may be appropriately characterized as a diversified aggregate
of andesitic and quartz latitic flows, quartz latite ignimbrites, and tuffs
of essential rhyolitic composition. The tuffs make up a very small part of
the unit, which otherwise is dominated by the andesitic and latitic flows.
These flows as well as the flowlike ignimbrites are individually of variable
thickness, from several tens of feet up to 200 feet or more, and may abruptly
thicken and thin. Some that have apparently filled old valleys or have been
dammed against ridges are locally as much as 500 feet thick (Pl. IV, A).
These thick flows stand out boldly in the canyon walls and along ridge crests,
forming prominent cliffs and ledges. Thinner flows are generally rather in-
conspicuous. Some of the flows show columnar jointing, and those of quartz-
latitic composition are invariably topped by black obsidian. The ignimbrites,
which otherwise resemble the flows, are without columnar structures and with-
out obsidian tops. Because the unit accumulated on a surface of considerable
relief, its thickness varies considerably from place to place. Locally it
may exceed 2,000 feet.

The petrographic features of the various components of the unit are
described separately.

Andesite.-- The andesites show some differences in appearance and com-
position, the differences being reflected chiefly in color and in the character
of the dark minerals. The colors range from moderate to dark gray, even
black, and less commonly from pinkish or lavender-gray to red. All flows are
composed of rather fine-grained rocks studded with small phenocrysts, mostly
feldspar with subordinate hornblende or augite. They may be classified as horn-
blende andesites, hornblende-augite andesites, and augite andesites depend-
ing on the nature of the predominant dark mineral. Some of the augite an-
desites also contain hypersthene. There is little in the hand specimen to
distinguish the hornblende andesites from the augite andesites, as both min-
erals, unless altered, are black.

All the andesites are conspicuously porphyritic in thin section and
contain numerous andesine phenocrysts and fewer ones of hornblende and/or
augite, all mostly up to 2 millimeters long, in fine-grained groundmasses
composed largely of tiny plagioclase laths with some grains of augite or
otherwise with a little orthoclase and quartz. Accessory zircon, apatite,
and magnetite are usually present, but in some of the hornblende andesites
the magnetite is quite abundant, mainly as crowded aggregates from the decom-position of hornblende crystals. The andesite phenocrysts may comprise up to 30 per cent of the rock, the dark minerals up to 15 per cent. The andesine crystals appear glassy in the hand specimens and as clear grains showing albite and Carlsbad twinning and some zonal development in thin section. The hornblende in some of the flows is the ordinary brownish variety, but in other flows it is the reddish-brown basaltic hornblende. In most hornblende flows the hornblende is heavily rimmed by small crystals of magnetite and in some flows is changed entirely to magnetite, with the original hornblende recognized only by outline. The augite shows no unusual features.

Intercalated with the andesites near the north shore of Williams Lake is a flow of hypersthene-augite latite. This flow is dark gray like so many of the andesites and contains small, inconspicuous phenocrysts of hypersthene, augite, and olivine in a finely crystalline groundmass composed of augite, magnetite, orthoclase, and andesine. The andesine occurs as very tiny laths showing fluidal alignment engulfed poikilitically in considerably larger unoriented grains of orthoclase. The orthoclase is more abundant than the plagioclase and the rock therefore is not properly an andesite. Were it an intrusive rock, it would certainly be classed as a shonkonite.

Quartz latite:— The flows of quartz latite are lightly colored in shades of pink to lavender and are thus easily distinguished from the grayish but not the reddish-tinted andesites. Most of the flows are conspicuously porphyritic and contain an abundant distribution of sodic andesine or oligoclase and quartz grains and in some places also a light springling of sandine and biotite crystals, none more than 2 millimeters long but all considerably larger than the materials that compose the groundmass. These phenocrysts, chiefly plagioclase and quartz, may make up as much as 40 per cent of the rock. The groundmass characteristics vary somewhat from flow to flow and even within the same flow. The rock well within some of the thicker flows may possess groundmasses composed of microgranular orthoclase and quartz, but the groundmasses of the rock from the thinner flows and the more quickly chilled parts of the thicker flows are commonly composed of fine to coarse microspherulitic intergrowths of orthoclase and quartz with the interstices between the microspherulites filled with granular aggregates of orthoclase and quartz. In the highly chilled rock the groundmass is composed of glass. As in the andesites, apatite, zircon, and magnetite occur as accessories. The plagioclase, phenocrysts commonly show oscillatory zoning, albite and Carlsbad twinning, and usually some evidence of corrosion, such as partial resorption and groundmass embayments. Most of the quartz crystals are also rounded, embayed, and partly resorbed, but a few remain with perfect crystal outlines. Some of the biotite also shows partial resorption with liberation of grains of magnetite. As hornblende rarely occurs in the quartz lattes and biotite seldom in the andesites, the presence of one or the other may generally suffice to indicate whether the rock is an andesite or quartz latite. Any rock with detectable grains of biotite is likely to be either a quartz latite or an ignimbrite.
Ignimbrites—Except for the absence of obsidian tops, the sheet-like bodies of ignimbrites are virtually indistinguishable from the flows of quartz latite. Like the latter they appear as "flows" commonly thick and ledge-forming, composed of rock that is porphyritic with abundant phenocrysts in a dense, pinkish-gray to lavender groundmass, superficially no different from that of the quartz latite flows. Compositionally, most of them are quartz latites.

The ignimbrites generally contain an abundance of quartz and feldspar phenocrysts and usually considerable biotite; but unlike those in the flows, many are broken and the rock also appears to have an unduly large proportion of small included rock fragments, largely of volcanic derivation. In many of the ignimbrite, quartz phenocrysts exceed those of feldspar, a relation not observed in the quartz latite flows. These various broken and unbroken phenocrysts are set in aphanitic groundmasses which under the microscope prove to be decidedly plastic and show characteristics intermediate between those of lava flows and volcanic tuffs. The groundmasses may show streaks of microgranular quartz and potash feldspar, patches of glass or partly devitrified glass, irregularly distributed areas of microspherulites of very small size, and lentils of welded shards. Small openings between shards may be lined with small grains of tridymite. In some ignimbrites the matrix is chiefly glassy material, ashlike in appearance, or chiefly flattened shards, which because of their flattening appear as though flow-banded. Devitrified or partly devitrified glass occurs in most groundmasses and predominates in some. Some of the rock fragments held in the groundmass cement are altered, but most fragments are fresh. The crystal phenocrysts are commonly corroded and embayed. The feldspar phenocrysts may include sandine but are composed mostly of oligoclase or sodic andesine. The plagioclase phenocrysts commonly are white and of earthy appearance in the hand specimen in contrast to their usual glassy look in the flows.

Tuff:—The tuff intercalated in the unit resembles that which distinguishes much of the overlying tuffaceous unit. The tuffs are light-colored, mostly medium grained, and appear to be composed largely of rhyolitic materials. Little attention was paid to these tuffs in the field and their rock was not examined with the microscope.

Tuffaceous unit

Distribution

The tuffaceous unit is much more widespread than the latite-andesite unit and comprises much the larger part of the volcanic rock in the quadrangle. To conform with Ross, the unit is composed of all volcanic rock above the series of latite-andesite flows and thus all the volcanics northeast of a line which extends diagonally northwest across the lower course of Henry Creek; the line taken representing the base of the thick succession of well-bedded, light-colored tuffs, which occur above the group of andesitic and quartz latitic flows. Much of the rock between Henry and Perreau Creeks on the Salmon River slope and all the volcanic rock surrounding the north end of the Lemhi Range and extending down its east side belongs to the unit (Pl. I).
A. CHALLIS VOLCANICS

Tuffs and massive, ledge-forming ignimbrites in the upper tuffaceous unit of the Challis volcanics along the Salmon River below the mouth of Tenmile Creek. Tuff beds are light colored, the ignimbrites are darker and in the outcrop resemble flows of lava rock.

B. UNCONFORMITY BETWEEN THE CARMEN FORMATION AND THE CHALLIS VOLCANICS

More steeply dipping tuffaceous beds of the Challis volcanics overlain by the more gently dipping beds of the Carmen formation. View across the Salmon Basin against the background of the Beaverhead Range.
Character

Although defined as tuffaceous, the unit actually contains much volcanic rock not of pyroclastic origin, including a considerable amount of flow and ignimbritic material of quartz latitic and rhyolitic composition (Pl. V. A) and some widespread flows of basalt and locally associated basic andesite. As the character of the unit varies so much from place to place, subdivision into members applicable to the area as a whole does not seem practical.

On the Salmon River Mountain slope and across the river against the Lemhi Range, the lower part of the unit consists of at least 1,000 feet of well-bedded, light-colored tuffs which, locally, could be given member status. Above this thick exclusively tuffaceous horizon, the unit contains an abundant intercalation of quartz latite flows and rhyolitic ignimbrites, some of which are among the thickest and most prominent cliff-makers in the quadrangle, with especially good exposures on the ridges bordering Williams and Perreau Creeks. This succession of flows and tuffs could be given member status were it as highly perfected in the remainder of the area. The rock above is again largely if not wholly, tuffaceous, but much of it has been removed by erosion or covered by the Carmen formation.

Around the north end of the Lemhi Range and along its east flank the tuffs lose their prominent bedded structure and become less like tuffs and more like fine breccias. These fine volcanic breccias, which may in part be ignimbritic, appear basal over the pre-Cambrian Belt rocks. Some light-colored, better-bedded tuffs appear above these fine breccias, followed by considerable intercalated quartz latite, in part as flows but more abundantly as ignimbrites, both with pronounced ledge-forming tendencies. This succession of tuffs, flows, and ignimbrites may correspond to the similar succession in the area west of the Lemhi Range. Above this succession the unit again becomes chiefly tuffaceous, except for an intercalated basaltic member and its basal andesite and a thin "flow" of rhyolitic ignimbrite not far above the basalt. This basalt with its closely associated andesite is the only member of the unit singled out for separate mapping. Much of the tuff above the basalt member has been lost by erosion or covered by the Carmen formation. The thickness of the unit was not measured but may well exceed 4,000 feet.

The compositional aspects of the main rock types are described below in more detail.

Tuff: The tuffs appear to show little variation throughout the unit. Those in the lower part are conspicuously bedded, the beds ranging from an inch or less up to a foot or more thick; and are composed of light-gray, compact but soft rock, usually of medium grain but with some intercalations of finer-grained rock (Pl. V.). Grains of quartz, feldspar, and bits of various kinds of volcanic rocks are generally distinguishable in the more coarsely-grained rocks without a lens. The microscope confirms the abundance of quartz, plagioclase, potash feldspar, and biotite as clastic grains of phenocrystic size, forming up to 25 per cent of the
rock. Quartz generally predominates among the larger grains, with plagioclase next in abundance. These grains are in a matrix of glassy and semiglassy material composed in considerable part of incompletely devitrified glassy ash. Some compacted but not welded shards may also be recognized in the ashy matrix. The matrix also holds numerous small fragments of pumiceous or ignimbrites. The texture of the tuffs resembles that of the ignimbrites, except that the materials are not fused or welded together and the rock, though fairly compact, is soft and rather easily crumbled.

Much of the tuff has apparently originated from ash falls. Some, however, has been water-borne, composed of ash that has been washed into and deposited in bodies of shallow water. Small shells were noted in some of the beds. Fragments of petrified wood are widely scattered throughout the tuffaceous rocks. Some of the tuffs contain clay and a few beds might be classed as shales.

The tuffs intercalated with the flows and ignimbrites are not so well exposed as the beds in the lower tuffaceous sequence, largely because of a cover of talus debris from overlying flows and ignimbrites. Where exposed, the tuff is similar to that in the lower section.

The tuffaceous beds above the basalt in the upper part of the unit appear to be similar to those in the lower part. The beds are light-colored and are interbedded with some sedimentary materials derived from volcanic debris. Bedding is generally prominent. Some of the beds are composed of rather fine-grained materials, but much of the tuff is fairly coarse.

Breccia:— The fine volcanic breccia is restricted to the north end of the Lemhi Range and for a short distance along the east slope, resting on a basement of quartzitic rocks. Except where bleached and softened by hot spring action in the vicinity of Salmon Hot Springs, the rock is hard and dense and for the most part rather dark-colored, largely because of the abundance of small fragments of dark-gray quartzite.

The most striking feature of the rock is the abundance of rock fragments, both quartzitic and volcanic, which has given it a prominent breccia-like appearance. These rock fragments are small, generally less than a half inch in diameter, but too coarse to be a tuff. The fragments are firmly held in a matrix containing much partly devitrified glass. The rock appears to have the attributes of a welded breccia and might perhaps be considered an ignimbrite. Until more is known about the origin of the rock, it will be classed as a finely textured volcanic breccia.

Flows:— The flows in the tuffaceous unit trend to be somewhat more acidic than those that make the lower unit and, though still classed as quartz latite, they closely approach rhyolite. The flows are few but thick, the one on the ridge north of Williams Creek being one of the thickest and most conspicuous in the district. These intercalated in the tuffs east of the Lemhi Range are widespread but thinner. All the flows are topped by black obsidian.
The quartz latites differ little in appearance from those in the lower unit. The rocks are more or less conspicuously porphyritic with few to abundant phenocrysts in dense, pinkish to pale-red and lavender groundmasses. The phenocrysts are represented by glassy crystals of sodic plagioclase, smoky grains of quartz, and scattered crystals of biotite. The plagioclase grains are generally more numerous than those of quartz, but exceptions occur. A few scattered crystals of basaltic hornblende were noted in one of the flows in the Mulkey Creek area north-east of the Lemhi Range. The plagioclase (oligoclase or sodic andesine) generally shows oscillatory zoning, the usual albite and Carlsbad twinning, and some evidence of corrosion. The quartz is invariably rounded or deeply embayed. The biotite, too, is generally strongly corroded and its crystals are commonly completely decomposed and its former presence is evident only from pseudomorphous aggregates of small magnetite grains.

In the Salmon River area the phenocrysts are contained in coarsely microspherulitic groundmasses with some intergranular quartz and sandine between the spherulites. Elsewhere the microspherulites are not so large and the groundmasses tend to be glassy rather than crystalline. In some flows the groundmass is entirely glass, usually in part somewhat devitrified. The accessory minerals are zircon, magnetite and apatite.

Most of the flows contain just enough plagioclase, exclusively as phenocrysts, to keep the rock from being classed as rhyolite; but some exceptions occur and a few flows are actually rhyolite.

Iglimbrites:— The ignimbrites in the tuffaceous unit are much more numerous than the flows and include much of what was first considered flows in the field. The ignimbritic beds are mostly thin (Pl. V, A) but some in the Withington Creek area are thick and form ledges as high and bold as those of the quartz latite flows. Like the flows in the tuffaceous unit, the ignimbrites tend to be somewhat more silicic than those in the latite-andesite unit and have the composition of rhyolite rather than quartz latite.

The rock composing some of the ignimbrites has the pinkish-gray and lavender colors of the quartz latite flows, but more commonly the rock is more lightly colored and is either white or light gray. As in the older unit the ignimbrites are conspicuously porphyritic and contain abundant quartz and less abundant plagioclase and biotite phenocrysts in groundmasses of stony but in some cases of dull, earthy appearance. The quartz and feldspar phenocrysts are generally broken and the biotite grains shredded and bent. Most of the ignimbrites also contain a host of small fragments of various kinds of volcanic materials which are incorporated as an essential part of the rock. The groundmasses are glassy or semi-glassy, composed for the most part of welded, partly devitrified ash or of welded glass shards. Textures are varied. Groundmasses commonly show patches of material composed of tiny microspherulites intermingled with areas of partly devitrified glass or with streaks of pumice showing collapsed cells. The texture is more or less typically tuffaceous with the constituents firmly welded together.
An ignimbrite in the tuffs just above the basalt member on the ridge north of Withington is deserving of separate treatment. This ignimbrite forms a ledge up to 30 feet high on the upper valley slope and is composed of a mottled pink and white aphanitic rock studded with small quartz phenocrysts and having all the essential characteristics of a rhyolite flow without an obsidian top. The rock abounds in rounded and broken quartz crystals which, unaccompanied by feldspar phenocrysts, are contained in a glassy matrix composed largely of welded glass shards and collapsed pumice, with small grains of tridymite filling some of the former openings in the groundmass.

Basalt-andesite member

Distribution:— The basalt-andesite member is intercalated in the tuffaceous rocks north and northeast of the Lemhi Range. Elsewhere the member appears to have been lost by erosion. Where present, it appears as isolated exposures on ridge slopes and crests. Some of these exposures are extensive. The largest is on the Lemhi Valley slope and extends from the ridge west of Mulkey Creek eastward almost to Baker Creek, a distance of a little more than 3 miles. This exposure covers several square miles, but is not so large as one east of Cheney Creek which extends far beyond the boundaries of the quadrangle. Smaller exposures border lower Withington Creek and Baker Creek and some minor remnants occur at and on the ridge east of Salmon Hot Springs and on the high divide at the head of Baker Creek.

The basalt is present in all the exposures mentioned above, but the andesite was observed only on the ridges bordering Mulkey Creek. The largest exposure is east of the creek, where it forms roughly the upper third of the area mapped as underlain by the basalt-andesite member. Downslope the andesite passes beneath the basalt and disappears from view. West of the creek it forms the larger part of the high ridge cap southeast of Salmon Hot Springs.

Andesite:— The andesite flows are neither extensive nor thick. They apparently occur as local, rather widely separated flows and thus do not extend continuously under the basalt. The andesite probably accumulated in low areas as flows some tens of feet thick.

These andesites bear some resemblance to the grayish andesites of the lower unit but differ somewhat in mineralogic composition. They are moderately dark-gray rocks, though appreciably lighter than the overlying blackish basalts, and are generally inconspicuously porphyritic with only a scattered sprinkling of small and not readily distinguishable phenocrysts. As the rocks in the exposures on the two sides of Mulkey Creek are somewhat different in mineralogical composition, they are described separately.

The andesite in the large exposure east of the creek contains scattered small phenocrysts of sodic labradorite along with fewer grains of augite, hypersthenes, olivines, and reddish-brown basaltic hornblende in an essentially medium-grained groundmass composed of small andesine
laths with subordinately augite, magnetite, and orthoclase. The plagioclase phenocrysts are somewhat larger than the others and are corroded and deeply penetrated by the groundmass materials, leaving only rims of clear feldspar.

On the ridge southeast of Salmon Hot Springs the andesite contains small phenocrysts of andesine, brownish hornblende, augite, and magnetite in a groundmass composed largely of brownish glass with a sprinkling of tiny andesine laths and small crystals of magnetite. Zircon and apatite occur as sparse accessories.

Basalt:—Except in the extensive exposure between Mulkey and Baker Creeks, the basalt member is thin and composed of only one or two flows, individually 50 feet or more thick. But for a mile or two southeast of Mulkey Creek the member is much thicker and is made up of a succession of thin flows and intercalated basaltic tuffs. These flows are highly scoriaceous and in places amygdaloidal. Although ordinarily black, the flows and especially the intercalated tuffs in a small part of the area are quite reddish, evidently a consequence of oxidation by volcanic gases. This spot was evidently a center of volcanic activity and these flows and intercalated tuffs apparently represent an accumulation of basaltic materials around the vent. The basaltic tuffs disappear within a comparatively short distance and the flows decrease in number. Those that continue on apparently increase in thickness and lose their scoriaceous character, but they remain vesicular at tops and bottoms while the rock within becomes dense, massive.

The basalt shows little change in appearance from flow to flow or from place to place. The rock is ordinarily black and weathers a deep reddish-brown. It appears slightly porphyritic in the hand specimen and more conspicuously so under the microscope. The phenocrysts include augite, olivine, and here and there a crystal of labradorite. In some places the phenocrysts are relatively abundant, in other places quite sparse. Augite generally predominates and occurs either as scattered crystals or more commonly as clusters of crystals, which in the hand specimen appear as supersized phenocrysts. The olivine content varies from abundant in some flows to almost nil in others. It always shows good crystal outline, even when partly altered to brownish-red iddingsite and exceptionally to greenish serpentine. In some places the crystals are relatively large, in other places little larger than the grains in the groundmass. The groundmass itself is composed of small grains of labradorite and augite with scattered crystals of magnetite and in some rocks also of a little brownish glass.

Age

Although some fragmentary fossils were noted in the bedded rocks of the Challis volcanics, no systematic search was made for material suitable for age determinations. Until such materials become available local
tuffaceous member, the probable equivalent of the tuffaceous unit in the Salmon quadrangle. These remains were figured by R. W. Brown, who concluded that the general aspect of the flora indicated a probable upper Oligocene or lower Miocene age. He intimated that the beds in the Bayhorse quadrangle might be somewhat older than those near Salmon (the Carmen formation) in which he identified a flora of Miocene age, occupying a chronologic position between the flora of Bridge Creek (upper Oligocene or lower Miocene) and the Latah flora (middle or upper Miocene). This difference in age between the beds in the Bayhorse quadrangle and those at Salmon can now be verified on stratigraphic and structural relationships. It is now established that the Carmen formation is separated from the Challis volcanics by a marked unconformity (Pl. V, B) and that a considerable part of the formation locally is composed of material derived by erosion of the upper part of the Challis volcanics. Thus, the Challis volcanics are clearly older than the Miocene beds in the Salmon Basin and are probably no younger than upper Oligocene.

**Carmen formation**

**Distribution**

The Carmen formation is contained wholly within and forms the floor and flanks of the broad intermontane Salmon Basin. The formation laps well up on the Salmon River Mountains, reaching altitudes up to 6,000 feet, its boundary with the older quartzite rock marked by an abrupt steepening of slope. It laps even a little higher on the Beaverhead Range, but mainly less than 5,000 feet on the Lemhi Range. Its boundary against the Challis volcanics at the south end of the Basin is not so sharply defined as against the quartzites and, as mapped, may enclose some outcrops of the older tuffaceous beds, some of which, as between Eli and Hot Spring Creeks, may have been bared by erosion of the overlying Carmen beds. Some exposures of the older tuffaceous rocks may also have been uncovered and lie within the basin area just north of the terraces on lower Kirtley Creek.

Although covered by broad strips of alluvium along valley floors and by broad gravel terraces on lower valley slopes, the Carmen forma-

...
Character

In previous reports the beds now assigned to the Carmen formation were designated as "lake beds" a designation which, except for some fluvial materials in marginal and basal areas, still holds for the greater part of the formation. The formation is made up of detrital material from the surrounding region, but apparently the bulk of this material has been contributed from the more easily erodable tuffaceous beds of the upper part of the Challis volcanics. In the southern part of the Salmon Basin the Carmen formation appears to consist almost entirely of reworked tuffs and associated rocks.

For the most part the Carmen formation consists of moderately well-indurated, thin-bedded, fine-grained clastic rocks, most of which can be classed as shales with a considerable amount of intercalated sandstone and locally some conglomerate and lignite. Except for the lignitic beds, the rocks are light colored, and their light color, mostly white or light gray, gives the formation as a whole a distinctive appearance (Pl. VI, A) unlike that of any other formation, except for the light-colored tuffaceous beds in the Challis volcanics. The Carmen formation, however, contains no lava flows or ignimbrites nor other products of direct volcanic origin.

The conglomerates in the Carmen formation are largely confined to the base of the formation and are exposed here and there in marginal areas. One such conglomerate crops out in the side of a gulch occupied by an intermittent stream less than half a mile north of Perreau Creek, more precisely near the center of sec. 35, T. 21 N., R. 21 E. This conglomerate is some tens of feet thick and rests with angular discordance on the tuffaceous beds belonging to the upper part of the Challis volcanics. It is fairly well-cemented boulder conglomerate with volcanic and quartzitic pebbles and boulders up to a foot or more in diameter. Several thin beds of conglomerate also occur at or near the base of the formation in the upper Sevemile Creek drainage basin, unconformably again on the tuffaceous beds of the Challis volcanics. The most striking exposures of conglomerate, however, are several miles north of the quadrangle, where beds of massive conglomerate more than 100 feet thick crop out along the main highway. This conglomerate is composed of angular waterworn materials, most of it measuring less than a foot in diameter but including some boulders several feet thick. This conglomerate rests directly on the Belt rocks. Minor thin pebbly beds were noted rather high in the formation, but these are apparently of limited distribution. The gravelly and bouldery material capping the formation near the base of the mountains does not belong to the Carmen formation but is considerably younger.

The beds of sandstone are rather abundant throughout the formation and in many places tend to be somewhat better cemented and more resistant to erosion than do the other rocks and thus stand out in some relief. In some places sandstone rather than conglomerate occurs at the base of the formation. Much of the sandstone is well bedded. Beds are rather thin, rarely more than a foot or two, but in some places 4 to 5 feet thick. Some of these thicker beds appear in the bold river bluffs just northwest of Salmon and have been quarried for use as building stone. Similar beds also occur and have been
A. CARMEN FORMATION

Exposed light-colored beds of the Carmen formation in the bluffs bordering the Salmon River below the town of Salmon. These beds form the floor and lower slopes of the broad Salmon Basin. The mountains in the background belong to the Beaverhead Range. The low land to the left of the river is a part of the Salmon River floodplain.

B. BENTONITE

Typical surface exposure of the bentonitic shales in the Carmen formation showing characteristic shrinkage pattern formed on drying.
utilized in other parts of the area. Much of the sandstone is fine-grained and under the microscope appears well sorted and composed of sharply angular to subangular grains, chiefly quartz but including some microcline, orthoclase, and muscovite and commonly a little plagioclase and glass. Other sandstones contain considerable clay and show transitions into sandy shale.

The shales, the most abundantly exposed rocks of the formation, are everywhere distinguished by good stratification and by variable differences in physical and compositional characters. Some of the shale beds are highly siliceous, others are composed of thinly laminated clay. Those above and below the beds of sandstone are generally sandy, but sandy shales are also intercalated throughout the formation. Much of the shale is white or light gray, but some beds are pale tan and those with vegetable debris are chocolate colored in weathered exposures. Interspersed through the formation are also beds of gray to pale tan bentonitic shales which are distinguished in surface exposures by an intricate pattern of shrinkage cracks induced by loss of water on drying (Pl. VI B). These beds measure from a few inches to several feet thick but, because of the tendency of the wet clay to creep down slope and cover the rocks below, the beds commonly appear to be much thicker. These bentonitic beds are thicker and more numerous south of the Lemhi River than to the north and tend to disappear in the northern part of the quadrangle. All shales contain bits of quartz, feldspar, mica, and variable amounts of volcanic ash as well as clay. In some places the shales contain abundant fossil plant remains.

Thin impure beds of lignitic material are fairly widespread in the formation, but the only beds thick and pure enough for commercial interest are contained in shales near the mouth of Pollard Canyon, about a mile west of Salmon, and near Baker, just off the east edge of the quadrangle.

Correlation and age

Fossils from the Carmen formation have been studied by R. W. Brown of the United States Geological Survey, who collected much of the material himself from the Lignite locality west of Salmon and from a site near the electric power plant on the Lemhi River just north of the town of Salmon. The fossils identified by him and published by Ross include the following.


- Comunsa sp.  
- Pteris silvicola C.C. Hall.  
- Sequoia langsdorffii (Brongniart) Heer.  
- Glyptostrobus sp.?  
- Typha lesquereuxi Cookerell.  
- Grass?  
- Salix californica Lesquereaux
Alnus carpinifoliae Lesquereux.
Alnus hollanderianna Jennings.
Betula multirrhis Jennings.
Bankia eaffordi (Lesquereux) Berry.
Laurus simillmis Knowlton.
Umbellularia dayana (Knowlton) Berry.
Philadelphus bendirei (Knowlton) Chaney.
Amelanchier dignantus (Knowlton) Brown.
Chamaebatia prefolioida Brown.
Malus idahoensis Brown.
Acer Omonti Knowlton.
Ceanothus idahoensis Brown.
Rhamnus idahoensis Brown.
Cercidiphyllum crenatum (Unger) Brown.
Arctostaphyllos cuneata Brown.
Fraxinus denticulata Heer.
Symphoricarpus salmonensis Brown.
Potentilla salmonensis Brown.

From his interpretation of the fossil plant evidence, Brown concluded that the flora was Miocene and that it occupied a chronologic position between the flora of Bridge Creek (upper Oligocene or lower Miocene) and the Latah flora (middle or upper Miocene). As pointed out earlier, the Carmen formation rests with angular unconformity on the Challis volcanics (Pl. V, B), the angular discordance ranging from 12 to 20 degrees in the southern part of the quadrangle, and therefore cannot be correlated with the Challis volcanics. As the beds are apparently lower Miocene, they must be the equivalent of the Payette formation of southwestern Idaho, formed at the same time but in a local isolated basin.

Quaternary deposits

Unconsolidated deposits of Quaternary age are plentiful in the Salmon quadrangle, especially on lower mountain or upper basin slopes and on and bordering the main valley floors. These deposits differ considerably in character, age, and origin. They include till, outwash, fan material, and alluvium of early Pleistocene age now occurring on tops of ridges; alluvial terraces probably formed as an aftermath of late Pleistocene (Wisconsin) glaciation; landslides of more recent date; and Recent floodplain alluvium. Unfortunately, time did not permit mapping of more than the younger, more conspicuous alluvial terraces, the more prominent masses of landslides, and the Recent flood plain alluvium.

Early Pleistocene deposits

Glacial deposits

Glacial deposits recognized as considerably older than those assigned the Wisconsin stage of Pleistocene glaciation occur in several parts of the quadrangle at levels much below those reached by the glaciers of
Wisconsin age. These deposits occur on the ridges as much as 1,000 feet above the bottoms of valleys occupied by the Wisconsin ice, indicating an erosional interval with as much as 1,000 feet of canyon cutting after the early epoch of Pleistocene glaciation and before the younger Wisconsin glaciation. Such early glacial deposits have been reported elsewhere in the region, and the present study has served to increase somewhat the known extent of such deposits, thought to belong to the Nebraskan stage of early Pleistocene glaciation.

Distribution:—These old glacial deposits have been found on the lower slopes of both the Salmon River Mountains and the Beaverhead Range and may eventually be identified on lower parts of the Leshi Range. The deposits recognized so far have been found on the ridges at altitudes of about 6,000 feet or somewhat above and thus far-removed from the younger Wisconsin deposits, which remain in the valleys, generally above 7,000 feet. One exposure better than most remains on the face of the ridge between Pollard Canyon and Jesse Creek, overlooking the Salmon Basin from an altitude of about 6,000 feet. Smaller exposures were also noted on other parts of the Salmon River Mountain slope in situations where they had escaped erosion. The largest and probably the best exposure is in the northeast corner of the quadrangle, where the deposit occurs as a broad cap on the hill top at the base of the Beaverhead Range at an altitude reaching above 6,200 feet and more than 1,000 feet above the floor of Kirtley Creek not far to the south.

Character:—Morainal topography, though much subdued, is still recognizable on the broad hill summit in the northeast corner of the quadrangle. The thin soil cover fails to conceal the till entirely and in many places sharply angular to subangular soled boulders and blocks of rock are exposed on the surface. These materials show a considerable range in size from sand to boulders several feet in diameter, all of them derived from the quartzitic Belt rocks that compose the higher rising Beaverhead Range. Some pebbly material also occurs in the deposit and no doubt accumulations would disclose the usual heterogeneous mixture of fine to coarse materials so characteristic of deposits of glacial till.

The morainal forms are not clearly distinguishable on the Salmon River Mountain slope, but some of the larger blocks of rock stand out as erratics and these rocks are invariably composed of granitic rock obviously brought down from the bodies of granite along the main divide several miles to the east. These blocks and boulders of granitic rock are scattered irregularly about the surface, partly embedded in a soil debris which locally covers the finer till and the underlying quartzitic bedrock.
Outwash

The ridges that compose the basin slopes are also mantled by coarse gravelly debris deposited as outwash from the early glaciers and as early piedmont fan materials. These materials accumulated before dissection of the basin floor occurred and still blanket the upper ridge slopes so effectively that the beds of the underlying Carmen formation are visible only on lower gulch and valley slopes.

The gravelly material is rather poorly sorted and contains many angular and subangular pieces of rock. This material is coarser near the mountains than away from there and much of it tends to reflect torrential deposition. It is derived from whatever rock composes the bordering mountain slopes and thus is made up largely of quartzitic and volcanic pebbles and boulders near the Lemhi Range and mostly of quartzitic materials elsewhere. However, in the northern part of the Salmon River Mountain slope there is a large admixture of granite, some of which forms boulders up to several feet in diameter. Those deposits apparently consist of outwash from the early Pleistocene glaciers, but much of the debris elsewhere may have accumulated as alluvial fans, made by torrential streams emerging from the mountains and dropping their load on the then undissected basin floor. Some of these fan materials are considerably weathered, especially those composed of the impure Belt rocks from the Lemhi Range, and have imparted a prominent brownish coloration to the ridge tops.

High-level terrace gravels

In the lower, more central part of the basin are remnants of high-level terraces, capped by well-washed gravels. These terraces are higher and thus older than the low, more continuous terraces so conspicuous along the present valleys. These terrace levels are still fairly well-preserved on the hills of Carmen formation east of the Salmon River, just below the town of Salmon. The lowest terrace near the confluence of the Salmon and Lemhi Rivers is just under 4,200 feet, the second stands at about 4,280 feet but rises somewhat higher to the east as though tilted by basin warping, and the third is at about 4,480 feet. Each of these terraces is broad and the lowest, though considerably dissected, may be traced down river for more than 3 miles. The other two comprise broad summit flats.

The several terraces are covered by a thin veneer of well-worn gravels composed largely of quartz and quartzite with admixtures of granite and the more resistant volcanic rocks. Gravels of this character are widespread on the ridges bordering the Salmon and Lemhi Rivers, even though the terraces on these ridges are no longer sharply defined. They are apparently river gravels and may have been deposited during the interval between the early Nebraskan (?) and late Wisconsin glaciation. They seem to mark early stages of dissection of the basin fill and probably record an interesting bit of Pleistocene history.
Glacial deposits

Deposits made by glaciers during the Wisconsin stage barely reach into the area. The local glaciers of that time formed at altitudes above 8,000 feet and rarely descended below 7,000 feet. The only glaciers to enter the area from the Salmon River Mountains were along Bob Moore and Wallace Creeks in the northwest corner of the quadrangle and these extended less than half a mile from the map boundary. Some steep-walled cirques occur on the northeast side of the Lemhi Range in the vicinity of Sal Mountain, but little till can be distinguished on the steep slopes below the cirques.

The deposits are more or less typically morainal and carry the uneven, hummocky surface usually associated with morainal topography. They are composed of a heterogeneous assemblage of small to large blocks of granitic and quartzitic rock with some subangular boulders of the same materials. These materials are of fresh rock, showing little if any evidence of weathering. The deposits are heaped up on the floors of the present valleys.

Terrace deposits

Terrace deposits are conspicuous features along the rivers and larger tributary valleys. They are more extensive and better-preserved along the northeast side of the Lemhi River valley than on the southwest side or along the Salmon River (Pl. I). There are three sets of these alluvial terraces. One comprises the present floors of the tributary valleys, which are topographically out of adjustment with the floors of the river valleys and stand 20 to 40 feet above them. The others stand at levels of 80 and 160 to 200 feet above the main valley floors.

Only one large remnant of the highest alluvial terrace remains and this is on the protected valley slope southeast of Kirtley Creek. This sloping terrace remnant is nearly 3 miles long, measured along Kirtley Creek, and as much as a mile across. It rises rather abruptly above the intermediate terrace, but a little more than a mile up stream the intermediate terrace is cut off by erosion and the upper terrace rises directly from the valley floor.

The intermediate terrace is the most extensive. Except where incised by the younger valley-floor terrace at the mouths of tributary valleys, it may be traced continuously along the northwest side of the Lemhi Valley and for some distance up Kirtley and Geertson Creek valleys (Pl. I). It is exposed in only two places along the southwest side of the Lemhi Valley, but may be traced for nearly 3 miles south along the east side of the Salmon River and elsewhere at the mouths of tributary valleys, particularly on the south sides of Perreau, Pollard, and Carmen Creeks. Except west of the Salmon River, these terraces extend considerable distances up each of the tributaries. The terraces are from one-fourth to one-half mile wide.
The lowest terrace, a terrace only because the tributary streams failed to keep pace with the rivers in the excavation of the earlier valley fill, is well-exposed at the mouths of the valleys of Carmen, Kirtley, Geertson, Ferreau, Pollard, and Jesse Creeks. From the Salmon and Lemhi valley floors the terrace rises steeply and stands out in bold relief. Above the escarpment the terrace becomes the valley floor occupied by the present streams. The streams have incised the escarpment only slightly on leaving the terrace floor to flow on the river floodplains. These valley-floor terraces measure up to a third of a mile across.

Two minor terraces appear below the intermediate terrace just above the mouth of the Lemhi River. These terraces disappear within a mile or two upstream. They apparently reflect some minor stream adjustments not carried much above the mouth of the river. They probably have only local significance.

Although the upper terrace is fragmentary, the intermediate terrace may be traced without interruption far up the Lemhi Valley and more or less continuously up and down the Salmon River.

The terraces are made up of coarse gravelly, fairly well-sorted materials, composed of the different rocks exposed in the nearby mountains, except the softer volcanic materials. The terrace fronts stand steeply, but the deposits appear to be unconsolidated. Only sand and silt occur in the interstices between the pebbles.

These terraces line the middle and lower courses of the valleys once occupied by Wisconsin glaciers and continue into the valleys to which they are tributary. The gravelly material apparently accumulated in the valleys below the glaciers as trains of outwash debris. The streams that received the melt waters from the glaciers were much larger than now and were so overloaded with glacial debris that they were forced to deposit the overload in their lower courses and thus raise the valley floors high above their former levels. After the glaciers disappeared and the streams returned to normal size and were no longer fed with more debris than they could carry, they set to work to remove the valley fill. Reexcavation is incomplete and terraces of the old fill remain along the valley borders.

Landslide deposits

Downslope shifting of surface debris is evident in many parts of the quadrangle, mostly in the form of slowly moving bodies of talus or in some cases as small rock glaciers. But the deposits of particular note are the landslides along Lake Creek in the southwest corner of the quadrangle which are striking features of the landscape. They form deposits large enough to be mapped (Pl. 1).

The largest mass of landslide is the one that has dammed the valley of Lake Creek and formed Williams Lake, the only sizable body of water in the region (Pl. IV, A). The landslide dam is about a mile across, well over half a mile wide at the base, and as much as 600 feet high (Pl. IV, B). It is composed entirely of volcanic rock from the high ridge to the north, which now carries a huge, vertical-walled scar very similar in appearance to a glacial cirque. Some material may also have been added from the ridge to the south.
Another slide of somewhat different character and of smaller size heads in a cirque-like scar high on the north slope more than a mile from the lake. This slide has a glacier-like appearance and occupies the bottom of a steeply sloping valley. It ends at the shore of the lake, measuring a little more than a mile long and less than a fourth of a mile wide. This slide reflects not a rapid mass movement like the other, but a slowly moving mass much like that of a glacier.

These slides are comparatively young. The smaller one is in actual movement today, but the other may be as old as late Pleistocene. Had it formed during the Wisconsin stage of glaciation, the lake probably would have been filled with glacial outwash. In view of the small amount of filling, the landslide must be post-glacial but sliding must have occurred long before the arrival of the early settlers. Old slide debris partly buried beneath the younger gives evidence of recurrent sliding over a considerable period of time.

Young alluvium (Recent)

The young alluvium is confined to the river lowlands and underlies the broad valley flats bordering the Salmon and Lemhi Rivers (Pl. I). Young alluvium also borders most of the larger tributary streams but, because of its terraced relations with respect to the river valley floors, the alluvium has been mapped with the terrace deposits. Along the Salmon River, the alluvium is largely found within the borders of the Salmon Basin and is absent in the canyons above and below. The alluvium makes its appearance just below the mouth of Tenmile Creek (Pl. II, A), expands as the valley floor widens, and then forms a strip up to 14 miles wide through the central part of the quadrangle. It gradually narrows to little more than half a mile as it leaves the quadrangle and ends altogether several miles beyond. Along the Lemhi River the alluvial strip is from 1 to 14 miles wide and extends from the Salmon River up the Lemhi Valley for many miles beyond the map area.

These alluvial strips are built up of floodplain deposits and are composed largely of gravel with some sand and silt, much of it derived from the bordering terraces. Only a part of the valley flat is now subject to floods, but the whole flat shows well-defined meander scars that are readily apparent in aerial photographs.

As this alluvium may be conveniently separated into older and younger floodplain deposits, a two fold distinction is made in mapping (Pl. I). The valley flats are composed of two floodplains, one a few feet higher than the other and no longer subject to flooding. The younger floodplain occupies much of the valley floor in the lower reaches of the Salmon and Lemhi Rivers and gradually pinches out upriver. Apparently the removal of some temporary obstruction in the course of the Salmon River at or beyond the lower end of the Salmon Basin caused the rivers to renew their down-cutting and reestablished their grade at a somewhat lower level. Consequently, the rivers started to remove the previous floodplain and create a new one a few feet below the other. They have not had time to complete removal of the older floodplain, which remains as a low terrace bordering the younger floodplain.
rejuvenation and the development of the new floodplain has not worked very far up either river.

INTRUSIVE IGNEOUS ROCKS

Foreword

The intrusive igneous rocks are varied as to kind and occurrence, but may be resolved into four groups which differ in rock texture and composition and in age. These groups reflect four separate epochs of igneous activity: two before the extrusion of the Challis volcanics, one with and one after their extrusion. Like the Belt rocks in which they occur, the earliest intrusives are considerably metamorphosed and are probably a product of late pre-Cambrian igneous activity, when there was widespread invasion of the lower members of the Belt series by extensive sheets of gabbroic magma. The next group is a part of or consists of outliers of the Idaho batholith, which was for the most part emplaced in Cretaceous time. The members of the other two groups are of Tertiary age. The members of the older of these probably served as feeders to the local flows and ignimbrites during the extrusion of the Challis volcanics and therefore are probably Oligocene. The members of the younger group intrude the Challis volcanics probably after a crustal disturbance at the close of the Oligocene and therefore may belong to the group of early Miocene intrusives recognized in a number of localities in south-central Idaho.

Pre-Cambrian intrusives

The late pre-Cambrian igneous activity is very weakly manifested within the Salmon quadrangle as compared with other parts of the state. Only a few small intrusive bodies were observed and had not these been exposed in road cuts they might have been missed altogether. The bodies are less than 50 feet thick. Their length and trend were not determined, nor is it known whether the magma was intruded as sills, as in the northern part of the State, or as dikes. The only thing certain about them is their composition and striking resemblance to the pre-Cambrian intrusive rocks in other localities. They are composed of altered gabbro of rather distinctive appearance and petrographic characteristics.

Gabbro

Distribution

The bodies of gabbro that were examined are along the old road between Salmon and the U. P. mine at the head of Bob Moore Creek about a mile east of the map boundary. They are near the top of the ridge at an altitude just under and above 6,800 feet near the boundary between secs. 27 and 28, T. 22 N., R. 21 E. These intrusives were not mapped.
Character

The intrusives are composed of a medium to moderately coarse-grained granular rock of dark-gray to nearly black color. The rock has a dull, altered appearance, that tends to set it apart from the fresh appearance of the unweathered rocks belonging to the younger intrusives.

The microscope reveals that the rock is composed largely of hornblende with quite subordinate amounts of plagioclase and such minerals as quartz, biotite, and epidote and the accessory minerals sphene, apatite, and magnetite. The hornblende is the most striking mineral in the rock. It shows the distinctive bluish-green pleochroïsm characteristic of the pre-Cambrian intrusives in the northern part of the state. The hornblende is apparently not original in the rock but has formed by alteration or replacement of pre-existing minerals, presumably pyroxenes but also the plagioclase. Many of the grains of hornblende are fringed with actinolitic-like needles which penetrate deeply and even across the plagioclase crystals. The plagioclase, originally more abundant than now, comprises not more than 10 per cent of the rock. Most of the grains are heavily saussuritized and their original composition is in doubt, but they may have been labradorite or bytownite. The sphene occurs in exceptionally heavy concentrations, apparently as a late introduction in the rock. The quartz also appears to have come from outside sources. The epidote grains are large and are an alteration of the plagioclase and hornblende. The other minerals show no unusual properties or relationships. The most impressive feature of the rock is its extensive amphibolitization.

Correlation

The rock in these intrusives is indistinguishable from the rock in the Purcell sills in the northern part of the state 9/ in either megascopic or


microscopic features. Like the invaded rocks, the local gabbro shows the effects of somewhat more intense metamorphism than do the corresponding rocks to the north. Otherwise there is no appreciable difference, not even in the pleochroïsm characteristics of the amphiboles. The local intrusives are unquestionably the equivalent of the Purcell sills of late pre-Cambrian age in the northern part of Idaho and in British Columbia.
Cretaceous granitic rocks (Idaho batholith)

The granitic rock belongs to the marginal rock of the Idaho batholith and thus differs somewhat from that of the main mass, particularly in textural characteristics. The local rock is a quartz monzonite closely approaching granite, but the texture is such as to suggest that the rock had a replacement origin and that it is actually granitized quartzitic rock.

Quartz monzonite

Distribution

The bodies of quartz monzonite are in the Belt rocks in the northwestern part of the quadrangle and are outliers and parts of much larger masses that crop out extensively west of the area (Pl. 1). The largest exposure forms a stocklike body a mile wide and not less than 3 miles long. It appears from beneath the cover of Carmel formation not much more than a mile northwest of Salmon and continues in a northerly direction to and beyond the edge of the quadrangle. It encloses scattered pendants of quartzitic rock, one of which is large enough to map. Along the east side of the stock is an elongated dikeslike body of granitic rock which extends across the ridge south of Derlar Creek.

Except for a small mass about midway up Bob Moore Creek, the other exposures of granitic rock are at the west margin of the quadrangle, one at the head of Bob Moore Creek and the other near the head of Wallace Creek. The two exposures merge outside the quadrangle and continue across the Leesburg quadrangle into the main body of the Idaho batholith.

Character

The most striking features of the rock within the quadrangle are its coarse grain size and its marked textural variations within short distances. Most of the rock is gneissic, some of it very prominently so, and some is a coarse-grained augen gneiss. Much of the rock is also porphyritic and is studded with microcline phenocrysts up to an inch and in some places up to 2 inches long in what is otherwise a coarse-grained, granular rock composed of grains 0.3 to 0.4 inch in diameter. Except in the augen gneiss, the phenocrysts have good crystal outlines. Those that occur as porphyroblasts in the augen gneiss are ovoid or lens-shaped. The rock is gray to moderately dark gray and is thus appreciably darker than that of the main mass of the batholith, which contains from one third to one half as much of the dark minerals. The mineral that darkens the rock is biotite.

The leading minerals in the rock include andesine and quartz as well as the microcline and biotite already mentioned. The rock also contains an unusually high concentration of the accessory minerals sphene, zircon, and apatite; and generally an abundance of secondary minerals such as sericite, zoisite, and epidote. Tourmaline and magnetite are very minor accessories.
The biotite comprises 8 to 15 per cent of the rock; quartz, 20 to 30 per cent; and the adaeide and microcline, which are about equally abundant, most of the remainder. In some of the more highly porphyritic rocks, however, microcline may be considerably more abundant than plagioclase and the composition of the rock approaches granite. The sphenne may compose up to 5 per cent of the rock and its golden-brown crystals are easily distinguished by the unaided eye.

The minerals have an irregular distribution through the rock and show relations highly suggestive of a replacement origin. Some of the quartz occurs as mosaics of fairly coarse interlocking grains scattered irregularly through the rock. This is surrounded and at margins penetrated by the feldspathic and other mineral constituents. A few of the mosaics contain shadow outlines or remnant inclusions of a fine-grained quartz exactly that of the quartzite. They are actually quartzite that has not been reorganized or recrystallized into grains of larger size. Small remnants of these quartz mosaics are not uncommon as inclusions in the other rock-forming minerals. They are especially plentiful as detached, island-like grains in the microcline and large lobate grains of quartz, which not only retain island remnants of the quartz mosaics but also penetrate unevenly into the biotite and the feldspars. Thus there is more than one age of quartz in the rock.

The biotite grains show a marked tendency to group as clusters, especially in the zones of mosaic granular quartz. Such biotite grains commonly display a tendency for parallel or subparallel alignment and are chiefly responsible for the gneissic foliation the rock possesses. As the content of the feldspathic minerals increases, the quartz mosaics become more scattered and much reduced in size, disappearing altogether in the highly feldspathic rock. At the same time the cluster habit of the biotite becomes less conspicuous and the grains tend to appear as interlocked with the feldspar, although they are actually penetrated by the feldspar and usually also by the large grains of lobate quartz.

The two feldspars are easily differentiated in the hand specimen. The plagioclase occurs as dull, chalky-white grains and the microcline as vitreous or glass-like crystals. In thin section the plagioclase shows good crystal outline, except against the microcline and lobate quartz, where its borders are most uneven. The reason for its dull appearance also becomes apparent, for its grains are largely converted to saussuritic mixtures of sericite, scissite, and epidote or to aggregates of fairly coarse sericite. The alteration has obscured much of the twinning, but in grains engulfed in the microcline the alteration is not so intense and the twinning is much better preserved. Extinction angles measured on the twinning lines indicate a composition of sodic andesine.

Although the microcline appears to have good crystal outline in the hand specimen, its borders are actually somewhat uneven and tend to enter between or wrap around the neighboring mineral grains. More significantly the crystals retain numerous remnant inclusions of plagioclase and mosaic quartz and less commonly of biotite. Most of the inclusions are mere remnants of once much larger grains and some are recognized only by shadowy outlines. Obviously the microcline has formed at the expense of other minerals and an in-
crease in the amount of microcline is always balanced by a decrease in the content of plagioclase. The lobate quartz usually does not come in contact with the microcline. But where it does, it tends to impress its lobate outline against the microcline in the same way it does with the other minerals.

The accessory minerals sphene, zircon, and apatite are unusually abundant in the rock and occur as small crystals in the altered andesine and biotite, usually showing some preference for cleavage lines and grain boundaries. The sphene tends to favor the biotite, but with the zircon and apatite may occur abundantly in the plagioclase. The magnetite and tourmaline grains are too few to establish relationships.

The abundance of sericite, zoisite, and epidote as alteration products of the plagioclase has been mentioned. In such occurrences these minerals form relatively fine-grained aggregates, but some of the epidote occurs abundantly as large grains as a replacement of the biotite and plagioclase. Some of the sericite is also coarse and here and there a grain is large enough to be classified as muscovite. These larger grains are usually associated with an alteration of biotite.

Genesis

The mineral relations indicate clearly that the quartz monzonite was not formed from consolidated magma but originated by extensive replacements of a rock which, from the remnant inclusions, was originally quartzite or siliceous rock belonging to the Belt series. Before its conversion to granitic rock, the small grains of quartz in the quartzite were reorganized into much larger grains. Then large grains of biotite formed in the more coarsely crystalline quartz, probably largely from materials introduced into the rock. At this early stage the quartzite was transformed into a biotite schist. The schist in turn was converted to a gneissic rock with impregnation by plagioclase and then to granitic rock with the addition of abundant microcline. In these changes the plagioclase was formed at the expense of the biotite and the quartz and the microcline at the expense of all three. Where the substitutions were less complete, the schistose rock was converted to augen gneiss; but generally the replacements of the earlier minerals by younger continued to a more advanced stage and the rock ended as a porphyritic quartz monzonite. As the microcline ceased to form, the accessory minerals and the late quartz were introduced into the rock. The accessory minerals entered extensively into the plagioclase and biotite and in some places also into the remnant recrystallized quartzite, and the late quartz sent penetrating lobes into all the earlier minerals as well as into the remnant quartzite.

The quartz monzonite was thus formed by intense but incomplete granitization of quartzite and is a metamorphic rather than a truly igneous rock. Recrystallization of quartzite, however, will not produce a granitic rock unless alkalis and other materials needed to form the micas and feldspars are introduced. Thus such elements as iron, magnesium, calcium, sodium, potassium, aluminum, titanium, zirconium, phosphorus, and silicon were brought in presumably by "granitizing" solutions from some deeper source within the earth. These entered into and caused successive development of biotite,
andesine and microcline and then of quartz and the various accessory minerals. The solutions also induced the formation of secondary minerals, mainly by alteration of the biotite and plagioclase. These "granitizing" solutions were unusually enriched in potassium, titanium and zirconium and caused the formation of exceptionally large amounts of potash feldspar and more than ordinary quantities of sphene and zircon.

Tertiary intrusive rocks

Intrusives related to the Challis volcanics (Oligocene)

The intrusives believed to be related to the Challis volcanics have the same composition as the flows or ignimbrites and probably occupy the vents through which the lavas and associated pyroclastics emerged on the surface. Such vents must be abundant in the region, but because of the close resemblance of the intrusive rock to the flow rock they usually escape detection. The only ones recognized in the present study contained rock most aptly classed as intrusive vitrophyre.

Vitrophyre

Distribution:-- The vitrophyre composes two closely spaced dikes on the ridge between Withington and Cheney Creeks in the southeastern part of the quadrangle in Sec. 20, T. 20 N., R. 23 E (Pl. I). The larger of the dikes is fairly broad and its location is marked by a low, blunt ridge that ascends steeply from Withington Creek almost to the Cheney Creek divide. The other dike is narrow, but it extends across the ridge and appears to be responsible for a prominent knoll on the top of the ridge. The larger dike has a northerly trend; the smaller strikes northeast. A related dike of slightly different composition was observed underground at the Pope-Shenon mine.

Character:-- On cursory inspection the vitrophyre appears to resemble a light-gray granular rock, especially where partly disintegrated by weathering. Closer examination reveals that it is a porphyritic rock with scattered quartz and feldspar phenocrysts in a light-gray, pitchstone-like glass base. The thin section shows the phenocrysts composed of corroded grains and fragments of quartz along with some grains of oligoclase and biotite in a perlitic groundmass of glass with numerous trichites, longilites, cumilites, globilites and other embryonic crystal forms. Some small grains of magnetite also appear in the section.

Although it was consolidated below the surface, the cooling was so rapid that, except for the transported crystals, the molten material congealed as glass. These intrusives probably served as feeders to some of the post-basalt tuffs and ignimbrites. The dike at the Pope-Shenon mine has all the compositional and textural features of a surface ignimbrite.

Post-Challis intrusives (Miocene)

The post-Challis intrusives are more readily recognized than those related to the Challis volcanics. Aside from the contrast in appearance of
the intrusive rock and the intruded flows and tuffs, these younger intrusives tend to stand out in topographic relief and to form bodies of considerable size. Two of them may be classed as small stocks, the larger of which covers about 2 square miles. The others are dikes, most of them considerably larger than those associated with the volcanic extrusions.

These post-Challis intrusives are concentrated in the vicinity of Mulkey Creek near the north end of the Lemhi Range. The rock appears the same in all the bodies, but its composition ranges from dacite porphyry to quartz latite porphyry.

**Dacite porphyry**

**Distribution:**-- The dacite porphyry is not so widespread as the quartz latite porphyry and, in the rocks that were examined microscopically, is restricted to the small stock at the north end of the Lemhi Range and to some of the marginal rock of the larger stock that extends across upper Mulkey Creek (Pl. I). Several small bodies nearby may also be composed of dacite porphyry.

The small stock at the end of the range rises high above its surroundings and forms an imposing landmark visible from all but the more southerly parts of the Salmon Basin. The stock is partly within the Belt rocks and partly within the Challis volcanics. All the other intrusives are in the Challis volcanics.

**Character:**-- The dacite porphyry is a conspicuously porphyritic light-gray rock with numerous plagioclase phenocrysts accompanied by a springling of hornblende and biotite in a finely crystalline groundmass, which can be resolved only in thin section. The plagioclase phenocrysts comprise about 25 per cent of the rock. Hornblende and biotite together are about 20 per cent, one or the other locally predominant. These plagioclase grains measure up to 0.1 inch long. Those of hornblende and biotite are a little smaller, but all are conspicuously larger than the grains of the groundmass.

The microscope reveals that the plagioclase phenocrysts consist of oscillatory zoned andesine crystals, generally somewhat rounded or resorbed and that -- in addition to the andesine, hornblende, and biotite -- the phenocrysts also include some rounded and embayed quartz grains. All are contained in a microgranular groundmass composed largely of small oligoclase along with some grains of quartz and orthoclase and such accessory minerals as spherule, zircon, apatite, and magnetite. The orthoclase composes less than 5 per cent of the rock and the quartz, including the phenocrysts, from 5 to 10 per cent.

**Quartz latite porphyry**

**Distribution:**-- The quartz latite porphyry composes the two large dikes on lower Mulkey Creek and, except for a marginal zone of dacite porphyry, most of the large stock on upper Mulkey Creek (Pl. I).
As the two dikes are more resistant to erosion than the intruded volcanics, they stand out in rather bold relief, especially on upper ridge slopes, and can be recognized from a distance. The large stock is not so conspicuously reflected in the topography, but the outcrops are sufficiently distinctive that they need not be confused with outcrops of the volcanics.

Character:-- The quartz latite porphyry greatly resembles the dacite porphyry in the outcrop, but the rock contains only trivial amounts of hornblende, if any at all. The groundmass is commonly pinkish-gray rather than gray. These differences are ordinarily sufficient to distinguish the two porphyries in the field. The quartz latite porphyry is otherwise more or less conspicuously porphyritic but has fewer phenocrysts than the dacite porphyry. These phenocrysts include relatively abundant andesine, subordinate biotite, scattered grains of rounded quartz, commonly a few crystals of orthoclase, and in some places a sparse sprinkling of hornblende. These are contained in a microgranular groundmass composed of orthoclase with minor quartz and generally small but variable amounts of oligoclase. Accessory minerals include zircon, apatite, and magnetite. The quartz latite porphyries differ fundamentally from the dacite porphyries only in the larger proportion of potash feldspar and thus in a somewhat more alkaline and silicic composition.

Correlation and age

The dacite and quartz latite porphyries show a marked resemblance to rocks of similar composition along some of the porphyry belts elsewhere in Idaho. /7/. In these belts the porphyries have been intruded along major

zones of structural weakness. The Challis volcanics and older rocks have been complexly faulted and then invaded by a succession of porphyries directed upward along the faults and zones of highly fractured rock. As the intrusive bodies along Mulkey Creek are aligned in northeast and northwest directions, their intrusion also appears to have been structurally controlled and directed by faults or fractures of corresponding trend. The Carmen formation was not involved in the structural disturbance hence the porphyries must have been intruded at the close of the Oligocene or in early Miocene time, the date assigned the intrusions along the porphyry belts in other parts of the state.

STRUCTURE

FOREWORD

All but the youngest rocks in the quadrangle show some evidence of structural deformation, the younger formations by warping or gentle folding and minor faulting, the older by more pronounced folding and faulting and in part by prominent jointing and cleavage. The characteristics of the folding in each of the formations is known in a general way, but the faults are too well-concealed for ready recognition and the faulting is too complicated for easy interpretation. Only a few of the faults are shown on the map.

DEFORMATION IN THE PRE-CAMBRIAN ROCKS

The pre-Cambrian rocks have been more highly deformed than the rocks of younger formation but the deformation, except for widespread rock brecciation and cleavage, does not seem particularly severe. The rocks have been folded, but the folds are broad and open. Apparently the thick succession of competent quartzitic rocks could be bent into broad open folds, but the rock was more prone to fracture than to bend and hence yielded to breakage by faults, joints, and fracture cleavage.

Folds

The pre-Cambrian strata have been folded into broad open anticlines and synclines. Faults have greatly marred two of the folds but left two others fairly intact. One of the latter is a large anticlinal fold along the eastern edge of the Salmon River Mountains which, for convenience, is called the Salmon River Mountain anticline. The other, an impressive synclinal fold in the Lemhi Range, will be referred to as the Lemhi Range syncline. Two imperfect, much disturbed folds, an anticline and a syncline, lie between these two major folds and are partly revealed along the Salmon River and the foothills of the Lemhi Range south of the Salmon Basin.

Salmon River Mountain anticline

Only the eastern flank of the Salmon River Mountain anticline falls within the boundaries of the Salmon quadrangle. The axis of this broad fold lies a short distance west of the map boundary. The anticline has a general northerly trend but in places there are abrupt changes in trend, apparently caused by faulting. From Ferreau Creek northward to the vicinity of Jesse Creek, the beds on the flank of the anticline strike east of north. At that point the strike changes abruptly and runs northwest to Fenster Creek, then changes back to the northeast. The dip of the beds on the outer flank of the anticline ranges from 25° E. to 40° E. The dip is somewhat steeper than would be expected from the known characteristics of the folding in the pre-Cambrian rocks but is easily understandable when it is considered that the flank of the anticline has been involved in the subsequent downwarping that produced the Salmon Basin and accentuated the dip of the beds.
The westerly dip of the beds south of Lake Creek and on both sides of Twelvemile Creek suggests that the Salmon River Mountain anticline is bordered by a syncline which is hidden from view by the cover of Challis volcanics and Carmen formation.

Lemhi Range syncline

The Lemhi Range syncline is broad and relatively shallow with the inwardly dipping beds generally inclined at angles less than 20°. The syncline has a general northwesterly trend, but its axis, which is mostly west of the crest of the range, appears to have been offset repeatedly by cross faults which have caused the trend of the axis to shift to east of north at the extreme end of the range. The position of the axis cannot be fixed on the map until the range has been more completely covered by traverses.

The beds on the lower west side of the range roughly parallel to Twelvemile Creek and about 1,800 feet above it show an abrupt reversal of dip from east to west, a relationship which suggests that the syncline has been faulted against the flank of the bordering anticline, the same anticline mentioned in connection with the syncline on the east side of the Salmon River Mountain anticline.

Faults

Too few faults were mapped to establish a fault pattern or to decipher the mechanics of faulting, but some of the observed faults appear to fit into the framework of regional patterns. For convenience, the faults are distinguished on a geographic basis and are separated into those in the Salmon River Mountains and those in or near the Lemhi Range. Most of the faults are relatively small, but some may prove to be tectonic faults of the first order of magnitude. Undoubtedly, the faults of greatest magnitude are those which have controlled or influenced basin and main valley alignments, but such faults are hidden from view by volcanic cover and basin fill.

Faults in the Salmon River Mountains

From Williams Creek northward to Jesse Creek the pre-Cambrian rocks appear to have escaped faulting of consequence. There are numerous faults of small displacement, none large enough to cause appreciable offsets of the beds forming the flank of the anticline and none worthy of mapping. Beginning at the edge of the lake beds about midway between the mouth of Pollard Canyon and Jesse Creek and extending northwesterly across the ridge and along the north side of Jesse Creek, the beds show a right-angle change in strike which is difficult to explain in any way except by faulting (Fl. 1). This abrupt change in strike is reflected in the topography by changes in ridge and gulch alignments near the base of the mountain and again by alignments of gulches up the valley of Jesse Creek. The fault can be classed only as a transverse fault with little or nothing known yet of its direction and angle of dip or of its direction and amount of displacement. This fault has the same trend as the Lemhi Valley and, if continued beneath the cover of lake beds and...
volcanics it would extend up the valley of the Lemhi River. It may be
one of the major faults of the region and may have had much to do with
the development and alignment of the Lemhi Valley.

North of Jesse Creek the flank of the anticline has been complexly
faulted and the faulted rock invaded and replaced by granitic material.
The boundaries of the stock and other granitic bodies suggest that the
granite invasion was directed by faults of northwest and northeast trend.
Those of northwest trend closely parallel the big fault that passes up
Jesse Creek. This area of faulting and granitization is in direct line
with the axis of the Lemhi Valley and may mark the northwesterly continua-
tion of the zone of structural weakness along which the Lemhi Valley has
been directed.

Faults in the Lemhi Range

The Lemhi Range also has its supply of small faults, but it has
others at least prominent enough to be reflected in the topography. These
include a series of transverse fractures that cross the range in a west
to northwesterly direction, disappearing abruptly at the edge of the vol-
canics on the two sides of the range (Pl. I). These structural breaks
were not examined at close range, but they are of such magnitude that
they have controlled the alignment of shallow gulches that reach up the
flanks into the saddles on the crest of the range. These aligned gulches,
which appear to straddle the range, stand out sharply on aerial photographs
and serve to divide the range into well-defined segments. These structural
breaks show a change in trend from northwest near the end of the range to
somewhat south of west farther to the south. Their curvature across the
range indicates a moderate dip to the north.

Another fault, probably of large magnitude, is inferred along the west
flank of the range, emerging from under the volcanic blanket just south of
Termile Creek and then extending southeast up the valley of Twelvemile Creek
far beyond the borders of the quadrangle. Within the map area the fault
lies some distance up the slope east of Twelvemile Creek and may be traced
by an alignment of terrace-like interruptions on the mountain slope and
locally by the abrupt change in the course of one of the tributaries of
Twelvemile Creek. This fault may control the present straight course of
Twelvemile Creek from the map boundary far up into the headwater region.
This deep straight-line valley has the effect of nearly splitting the Lemhi
Range into two parts. The fault apparently belongs to the set of northwest
faults which are among the most prominent in the general region. It appears
to have brought the Lemhi Range syncline alongside the oppositely dipping
flank of the adjacent anticline. The fault may dip steeply northwest.

The structural relations of the Belt strata near the mouth of Twelve-
mile Creek and a prominent saddle near the river just south of the map
boundary suggest the possibility of a fault of large magnitude extending
northward the length of the quadrangle under a cover of volcanics and Carmen
formation. It is possible that such a fault may have played an important
role in providing the setting or control of the Salmon Basin and its norther-
ly elongation.
Joints and cleavage

Although the joints and cleavage are the most widespread and the most conspicuous structural features in the pre-Cambrian rocks, they were not given much attention, mainly because of the large amount of time needed for their proper investigation. Time could not be spared from the study of the more demanding geologic problems. Suffice it to state that the joints and cleavage are such prominent features that the bedding is obscured and generally difficult to distinguish except at close range. From a distance the joints and cleavage give the appearance of bedding and unless checked may lead to erroneous conclusions. The joints and cleavage dip much more steeply than do the beds.

Instead of one set of joints, there are several sets, any one of which may be the dominant set and may impart its control on rock outcrops. In some places two sets are about equally developed and slice the rock in such a way as to give the impression of beds dipping steeply in opposite directions in the same exposure. Joints are generally closely spaced and in many places difficult to distinguish from fracture cleavage. Most of the joints conform to well-defined sets, one of which strikes northeast, a second nearly due north, a third northwest, and in some places a fourth west or west-northwest. The northeast and northwest sets are generally the master sets. The joints account for the extensive rock breakage and the abundance of talus on mountain slopes.

The jointing is generally more conspicuous than cleavage in the rocks of the Salmon River Mountain area. On Williams and Ferrea Creeks the joints are so highly perfected, so closely spaced, and associated with so much fracture cleavage that bedding has been practically obliterated. From Spring Creek north the cleavage becomes less pronounced but jointing remains conspicuous. It does not seriously obscure the bedding except in the vicinity of Pollard Canyon and Jesse Creek, where the rock becomes even more highly jointed, apparently because of the presence of additional sets of joints and an increase in cleavage. Farther north near the Stormy Peak road, which winds up the slope past the Queen of the Hills mine, the jointing becomes less pronounced and the bedded structures are more prominent, probably because of the change to a thicker-bedded, more siliceous kind of rock.

In the Lemhi Range the cleavage appears to play a more prominent role than in the Salmon River Mountains and has had a profound influence on the shape of the range itself. The steep lower flanks of the range, especially on its west side, and the steeply projecting ledges reflect this influence. For whereas the beds near the north end of the range strike N. 15°-20° E. and dip 10°-30° E., the cleavage strikes a few degrees east or west of north and dips 55°-70° W. and induces local oversteepening of the slope near the base of the range. From a distance the cleavage has the appearance of bedding and gives the impression that the range is steeply antilinal. This cleavage is the result of essentially parallel alignment of the platy minerals and has produced planes of easy rock breakage.
The wide extent of the jointing together with the abundance of joints and the presence of several sets of joints implies regional deformation associated with more than one orogeny. Two of the sets are probably complimentary sets, but all told, the various sets suggest two major orogenies with one set probably developed at the time of the major folding. Other crustal disturbances must also have added to the rock breakage.

Age of deformation

The pre-Cambrian rocks have been subjected to every crustal disturbance since late pre-Cambrian time and the present structural features reflect the combined effect of all these disturbances. However, the dominant structural features such as the folds, the more prominent faults, most of the joints, and the cleavage were in existence at the time of the extrusion of the Challis volcanics and hence were formed prior to Oligocene time.

As these pre-Cambrian rocks are in an area known to have been subjected to orogenies at the close of pre-Cambrian time and then again at and near the end of the Mesozoic, their deformation must reflect each of the orogenies, though not necessarily to the same extent. From the relations of the local and nearby structures to the Idaho batholith and its outliers, it is evident that most of the folding and perhaps much of the major faulting occurred prior to the emplacement of the granitic rock at the close of the Sierra Nevada orogeny (late Jurassic time). Some of the jointing may have been an inheritance of the late pre-Cambrian disturbance, but most of the folding and cleavage probably reflects Mesozoic deformation. The Laramide disturbance at the end of Cretaceous time probably accentuated the Jurassic and earlier folds and added to the number of faults and joints, but otherwise produced few changes. The metamorphic effects displayed by the pre-Cambrian rocks are probably associated with both the late pre-Cambrian and Sierra Nevadan orogenies and may have been somewhat intensified by the emplacement of the granitic rock.

INFORMATION IN THE CHALLIS VOLCANICS

The deformation in the Challis volcanics has been of moderate intensity, but the structural forms are much less complicated than those in the pre-Cambrian rocks. The volcanics have been folded and faulted, but the folds are broader and more open than those in the pre-Cambrian rocks, and the faults are more widely scattered and of much less magnitude.

Folds

The volcanics within the borders of the quadrangle form a part of the northeast flank of a broad anticlinal arch whose axis lies several miles south of the map area. Near the axis of this broad fold and for some distance out on the flanks the dips are low but they increase to 22° on the ridge north of Williams Lake and then to 30° or more on approaching the Salmon Basin. The increase in dip near the basin is obviously produced by
the downwarping of the basin itself. The superposed downwarping has probably added 10° to 12° to what would have been the normal dip of the volcanics on the flank of the anticline. The effect of the downwarping is also carried around the end of the Lemhi Range and into the Lemhi Valley.

The full extent of this broad anticlinal fold will not be known until work is done in the surrounding region. The main folds in the Challis volcanics have northeast rather than northwest trends. The local fold may be complementary to the others, its position influenced locally by a zone of structural weakness of northwest trend.

Faults

As most of the faults in the Challis volcanics appear to be of minor magnitude, they were given little attention. Only one is shown on the map and this is the one that has dropped the block of basalt against the tufaceous rocks and provided a channel for the emergences of the hot water at the Salmon Hot Springs. This fault strikes about N. 20° E. and dips steeply west. Its course may be traced for about half a mile.

The dike pattern in the Mulkey Creek area indicates two additional sets of faults, one with strike of about N. 20° W. and the other with strike of N. 70° E. These two directions probably mark the dominant trends of the faults in the Challis volcanics. They accord with the structural trends in the volcanics elsewhere in south-central Idaho. There are also some faults of more northeasterly trend which probably reflect the influence of older trend lines. Faults may explain the somewhat spotty distribution of the basalt-calcic andesite member of the upper tufaceous unit of the Challis volcanics, with parts of the member cut out by faulting.

Age of deformation

The Challis volcanics have been subjected to all crustal disturbances since cessation of volcanism near the close of the Oligocene. However, the dominant structural feature, the broad anticlinal arch, had come into existence before the Salmon Basin made its appearance and the Carmen formation had been deposited therein. Thus the time of the major deformation is limited to the interval between the end of Oligoclase volcanism and the initiation of the Salmon Basin with its partial fill of lower Miocene lake beds. This would place the deformation at the close of the Oligocene or in early Miocene time, just preceding the intrusion of the dacite and quartz latite porphyries, which are thought to be of early Miocene age.
BASIN STRUCTURE

Salmon Basin

The Salmon Basin is the largest and most obvious structural feature in the area. This basin in which the Carmen formation has accumulated has every aspect of a basin produced by downwarping. Not only do the Carmen beds dip inward toward the center, but the older rocks around the rim of the basin also dip inward and then pass under the basin. This relationship of the older rocks is particularly noticeable in the case of the Challis volcanics. Even the ridges forming the eastern slope of the Salmon River Mountains slope downward in such a way as to suggest that they too are involved in the downwarp and that the mountain slope passes under and forms the under floor of the basin.

Whatever part faulting may have had in the development of the basin has been effaced by the fill of sedimentary materials. There appear to be no encircling faults at the margin of the basin and thus no evidence that subsidence might have accompanied faulting. It is anticipated, however, that earlier zones of structural weakness may have had something to do with controlling the location and shape of the basin.

The total subsidence involved in the downwarping is probably well over a mile. The fill, once thicker than now, probably does not exceed 2,000 feet and may be somewhat less.

The origin of the basin must be ascribed to crustal warping.

Age of Basin

As the broad anticline in the Challis volcanics is involved in the crustal warping, the subsidence must have started shortly after the post-Challis folding, faulting, and igneous intrusion and continued through the lower Miocene, in part contemporaneous with the accumulation of the Carmen formation. Dips of the beds around the margins of the basin indicate that some subsidence continued after the accumulation of the basin materials, probably in response to more recent crustal movements. The basin may be dated as mainly lower Miocene.

DEFORMATION IN THE CARMEN FORMATION

Deformation in the Carmen formation is on the mild side. In addition to the evidence of subsidence during and after sedimentation, the formation also shows minor folds and a few faults.
Folds

The folds in the Carmen formation are broad and shallow and consist of alternating synclines and anticlines. South of Salmon and the Lemhi River the folds have general northerly trends. One broad shallow syncline west of the Salmon River trends nearly due north until within a mile of Salmon and then curves to the northeast, losing its identity near the mouth of the Lemhi River. An anticline separates the syncline from another on the east side of the Salmon River. The axis of this anticline is beneath the broad floodplain of the river, but the strike of the beds on the two sides of the river suggests that the anticline also curves to a more northeasterly direction several miles south of Salmon. The shallow syncline east of the river starts out in a northerly direction but, after crossing Ell Creek, swings to the northeast and continues in a northeasterly direction to the edge of the Lemhi Valley, where it apparently comes to an abrupt end.

The folds north of Salmon and the Lemhi River do not match or align with those to the south. The north and northeasterly trending folds on the south die out and are replaced on the north by a broad syncline. It parallels the Lemhi Valley to the vicinity of Kirtley Creek and is then replaced by another, which continues on in a more north-northwesterly direction. No satisfactory explanation has yet been found to account for the abrupt interruption and change in the trend of the folds along the line of the Lemhi Valley other than possible influence of earlier trend lines in localizing deformation. The odd shape of the basin produced by the merging Lemhi Valley may have caused local reorientation of the regional compression and thus the changing trend and alignment of the folds.

Faults

Faults in the Carmen formation are generally inconspicuous and are rarely observed unless the beds are well-exposed as in the bluffs bordering the Salmon River. Even under those circumstances the faults are few and far between. One larger than most and with a throw of perhaps a few tens of feet is exposed in the bluffs a short distance below the mouth of the Lemhi River. This fault has caused a marked local steepening of the beds. Other faults down river have displacements of a few inches to a foot or two. Not all faults, however, are as inconsequential as these. One several miles north of the quadrangle is bordered by a steep escarpment from 50 to 100 feet high that may be traced for a mile or two. Umpleby 8/ has reported a fault west of Salmon that has caused a duplication of the lignite beds with an indicated downdrop on the west of possibly 400 feet.

So far as observations have been made, all faults are normal.

Age of deformation

Downward bending of the Carmen beds had to accompany the downwarping of the Salmon Basin, but the shallow folds and small faults must have been produced during a later crustal disturbance. These folds had been completed before early Pleistocene time, for the early glacial deposits accumulated on a surface cut across the folds. The deformation is probably a consequence of a locally mild orogeny that occurred at the close of Tertiary time. Some warping has continued into more recent time, for some of the older terraces on the Carmen beds are slightly tilted.

GEOLOGIC HISTORY

Big gaps occur in the geologic record, particularly in Paleozoic and early Mesozoic time. However, by drawing upon data outside the quadrangle it is possible to partly fill these gaps and present a fairly complete story of the geologic history.

PRE-CAMBRIAN RECORD

The geologic record goes back no farther than the accumulation of the great thickness of Belt strata during the latter part of pre-Cambrian time. These strata accumulated in shallow seas which covered much of the region now occupied by the Rocky Mountains of this country and Canada. The accumulation apparently took place in a very broad, slowly subsiding geosyncline in which sedimentation kept pace with subsidence so that the seas remained shallow while many thousands of feet of sediments were being deposited. Much of the sediment deposited was well sorted and consisted chiefly of fine sandy and silty materials and muds, all of which eventually consolidated as siliceous and argillaceous sedimentary rocks. These rocks were later converted by heat and pressure into the chiefly micaceous quartzites now found in the Salmon River Mountains and the Lemhi and Beaverhead Ranges.

While sedimentation was still in progress or perhaps shortly after, the lower part of this thick synclinal accumulation was invaded by extensive sheets of basic magma. Some of this magma found its way into the sedimentary rocks in the Salmon area and solidified as small bodies of gabbro.

Eventually crustal unrest caused withdrawal of the seas and put an end to further sedimentation. Then followed a profound orogeny during which the thick accumulation of sedimentary materials was deformed by warping and perhaps in some places also by faulting. To what extent these sedimentary rocks in the Salmon area were deformed may never be known but they probably did respond to some warping and to breakage by jointing. This crustal disturbance was accompanied by deep and widespread erosion which locally removed all but the lower part of the thick accumulation of sediments. With this deep erosion the stage was set for the Paleozoic Era.
No vestige of the Paleozoic record remains in the Salmon quadrangle, but from the distribution and relations of the Paleozoic rocks in the surrounding region, it is certain that the area was swept by seas during much of Paleozoic time and that a considerable thickness of sediments accumulated, only to be lost by subsequent erosion. Remnants of such sedimentary rocks (quartzites of Ordovician age) remain a short distance south of the quadrangle across from Rattlesnake Creek, and a thick succession of limestone and other rocks of Middle and Upper Paleozoic age appear a few miles to the southeast along the Lemhi and Beaverhead Ranges. The region was within the borders of the Cordilleran geosyncline and was periodically flooded by the Paleozoic seas. There are many unconformities in the rock succession but nothing to indicate any marked structural disturbance. Near the end of the Paleozoic much volcanic material was extruded in western Lemhi County, but marine sedimentation continued to the east with nothing to indicate what took place in the area between. The Paleozoic Era apparently came to an end without any marked structural event.

MESOZOIC RECORD

The incomplete record of events that occurred during the Mesozoic Era is preserved in the quadrangle. The record starts with the deformation that preceded and in part accompanied the emplacement of the Idaho batholith, but this event occurred in the latter part of the Mesozoic and there is no record of the earlier Mesozoic from Triassic into Jurassic time. During this lost interval volcanic debris and marine sediments accumulated in the western part of Idaho and sedimentary materials were deposited farther to the east. It is likely that the Salmon area was undergoing erosion at the time and was supplying debris to the geosynclinal trough not far east of the Montana boundary.

As the evidence supports a Cretaceous age for most of the rock of the Idaho batholith, the strong deformation that preceded its emplacement must have been associated with the Sierra Nevadan orogeny beginning rather late in the Jurassic period. During the orogeny the pre-Cambrian and Paleozoic rocks were extensively folded and faulted and the older pre-Cambrian rocks also were considerably metamorphosed and jointed. During the later stages of this orogeny, granitizing fluids made their way along zones of the structurally weakened sedimentary rocks and changed them to rocks of granitic character. This soaking of the older sedimentary rocks and their conversion to "granite" probably lasted well into Cretaceous time and when completed most of the Idaho batholith had come into place. During final stages of the batholith's formation, it is possible that mineralizing fluids made their way into fractures and fissures in and about its borders and deposited quartz and minor amounts of gold and pyrite, although these may have been introduced into the openings at a later time. Throughout the orogeny the mountains that were formed were being eroded and much of the cover, if not all the Paleozoic rocks that had been present in the Salmon quadrangle, was carried away.
Before the close of the Mesozoic there was another crustal disturbance, the Laramide orogeny, which began in late Cretaceous time and lasted into the early Tertiary. This deformation may have intensified the folding in the Salmon area and introduced additional sets of faults, joints, and fracture zones. Late during this orogeny magmas were intruded here and there along zones of structural weakness, but none into the rocks in the Salmon quadrangle. Mineralizing fluids ascending from possible deep magmatic sources did gain access to fractures along deep zones of shearing near and within the quadrangle and may have deposited copper, lead, and perhaps gold, each from a different source. Erosion continued during and after the orogeny and removed more of the older rocks, including any of the Paleozoic rocks that may have escaped earlier erosion.

**TERTIARY RECORD**

The Tertiary was an eventful time in the history of the Salmon quadrangle. With the end of the Laramide disturbance, erosion held full sway and before long had reduced the region to one of moderate topographic relief. Erosion was then interrupted by extrusions of volcanic materials (Challis volcanics) which buried most of the region under a thick blanket of flows and pyroclastics. These volcanics first filled the deeper, probably structurally controlled valleys. Then they encroached on the higher slopes and finally covered all except the highest mountains, among them perhaps the upper part of what is now the Lemhi Range. The earliest extrusions were of lavas of intermediate composition which gave rise to a thick succession of andesitic and latitic flows with some intercalated, somewhat more silicic tuffs and ignimbrites. The extrusion of this early unit of volcanics was followed by an interval of more violent explosive activity and by the accumulation of a thick succession of tuffaceous materials, with some intercalated flows of quartz latite and boids of rhyolitic ignimbrites in the lower middle part and some widespread flows of basalt with basal andesite in the upper part. It is not known exactly when the volcanic activity started, but the fossil record outside the area suggests that the materials of the upper tuffaceous unit accumulated in the upper part of the Oligocene.

The extrusions of these volcanics were then followed by a fairly marked crustal disturbance during which the volcanic formation was deformed into a broad anticlinal arch and also broken by faults. Intrusive magmas of dacitic and quartz latitic composition were then injected along some of the faults and fracture zones. The deformation probably began at the close of the Oligocene and lasted into the Miocene, with the intrusion of the magmas very early in the Miocene.

About the time the deformation of the Challis volcanics had come to an end and the intrusion had ceased, the area was hit by another crustal disturbance. This one involved broad crustal warping and formation locally of the Salmon Basin, in which were accumulated the sandy and silty beds of the Carmen formation. Much of the fill in the southern part of the basin was supplied by debris from the erosion of the tuffaceous unit of the Challis volcanics. The plant remains preserved in the Carmen beds suggest that the downwarping of the basin and the filling largely with lake bed materials
took place during lower Miocene time.

The local events through the remainder of the Tertiary are not well recorded. Apparently no further sedimentation or igneous activity occurred in the area after lower Miocene time and the record from then on is one of erosion that lasted through the Pliocene. During this interval the region was bevalled by erosion. The evidence is the old erosion surface that now forms the summits of the mountainous areas, a surface cut across the Challis volcanics and older rocks alike.

The Tertiary then culminated in another crustal disturbance that involved much uplift and much block faulting in the surrounding region, but only uplift and minor folding and faulting in the Salmon area. This crustal unrest continued into the Quaternary and may not yet be at an end.

**QUATERNARY RECORD**

The structural disturbance at the close of the Tertiary stimulated erosion which began to etch out the major features of the present landscape. Since erosion had little difficulty in removing the upper part of the easily erodable basin fill, the Salmon Basin was soon established, though not so deep as today. As the excavation of the basin fill continued, the bordering Salmon River Mountains and Lemhi and Beaverhead Ranges became more and more prominent though not so high and conspicuous as at the present time. The present surface features were in the process of evolution.

While the region was still in this early stage of sculpture, glaciers appeared in the mountains and crept down the slopes, reaching even into the basin. These glaciers left their moraines at and near the edge of the basin and their outwash streams far out on the basin floor, which was then undissected. These glaciers apparently made their appearance in early Pleistocene (Nebraskan?) time and then gradually melted away.

The early glaciation apparently was followed by uplift which stimulated erosion and caused the streams to carve their valleys, in places even deeper than those of today. At this time the floor of the basin was dissected and left as a hilly surface much as it is now, with the early glacial deposits stranded on the ridge and hill tops. There were some pauses in the uplift as indicated by several levels of high terraces now preserved near the tops of the hills in the basin and in the canyon walls above and below the basin.

After more than a thousand feet of valley carving, glaciers reappeared in the higher mountains, which by then were much like they are at the present time. These later (Wisconsin) glaciers were not so extensive as those of early Pleistocene time and were largely clustered around the higher peaks and ridges with short lobes projecting down some of the valleys. Two of them extended into the Salmon quadrangle from the heads of Bob Moore and Wallace Creeks. At this time the Beaverhead Range was extensively sculptured by glacial action and the Lemhi Range also had
some minor shaping by glaciers.

As the swollen streams, heavily charged with glacial debris, reached the lower country where gradients were less steep, they were forced to drop their overload. So they began to fill the valleys carved since the earlier glaciation. These valleys were filled to depths up to several hundreds of feet. Then as the ice disappeared the streams, no longer overloaded with outwash debris and reduced to more normal size, began to erode and clear their valleys of this alluvial fill.

The removal of the valley fill was interrupted several times, perhaps in response to briefly renewed glacial activity, and is yet far from complete. These interruptions alternately stimulated and retarded erosion so that valleys carved in the earlier fill were partly refilled and then again partly reexcavated, leaving terraces behind as testimony of past events.

In crossing the basin area the Salmon and Lemhi Rivers have carved wide valley floors below the terrace levels. As the tributaries were unable to keep pace with the rivers in erosion of their valley floors, they still occupy the lower of the terrace levels. Recently, perhaps because of the removal of some obstruction down river, the Salmon has reestablished its floodplain at a slightly lower level. This younger floodplain is now working headward on both rivers but has not yet passed the boundaries of the quadrangle.

Erosion of the mountains continues, without appreciable downcutting across the floor of the basin, although there is rapid incision above and below. Since the disappearance of the Wisconsin glaciers, the erosion has not advanced far enough to mar the erosional work of the ice, which is well-preserved in the deep scallop of cirques along the high ridges and peaks and in the relatively short U-shaped valleys below the cirques.

Among the surface features of special interest are the landslides along Lake Creek, particularly the immense slide that blocked the valley and imprisoned Williams Lake on its upper side. Although geologically rather recent, this slide occurred too early to be witnessed by man.

MINERAL RESOURCES

KINDS OF MINERAL RESOURCES

The Salmon quadrangle contains a variety of metallic and nonmetallic mineral resources, namely: gold (lode and placer), copper, lead, possibly uranium or other radioactive materials, coal, bentonite, building stone, road metal, gravel, and thermal waters. Each of these resources, except the radioactive, has been utilized at one time or another and most of them continue to receive some attention. In the early days it was the gold that was the center of attraction, but with the passing years the interest shifted to copper and very recently to the possible occurrence of uranium or other radioactive materials. The gold and copper have gone to markets outside the area, but the nonmetals have been utilized locally and this practice seems
likely to continue indefinitely.

GOLD DEPOSITS

Lode deposits

History and production

The gold-bearing lodes in the Salmon quadrangle were located in the early eighties, nearly 15 years after the discovery of placer gold on Napias Creek in the adjoining Leesburg quadrangle. These lodes were not actively developed, however, until about the turn of the century, when underground development was intensified and the mines were brought into production. After a few years the mines suspended operations, but some of them have since been reopened for short periods of time. Although some recent locations have been made in or near the quadrangle, no active mining or development has been done for a number of years and the workings in all the old mines are inaccessible.

The total gold production probably does not exceed $100,000, all of it from the Queen of the Hills mine.

Character of the deposits

The gold-bearing lodes are mostly small quartz veins and lenses along narrow zones of fissured and brecciated rock, with most of the quartz a filling between the fissure and fracture walls and between breccia fragments. Some of the deposits are simple fissure veins, but others are composite and contain bordering seams and stringers of quartz. As these deposits contain nothing of commercial value except the gold, they may be classed as gold-quartz veins. The veins contain only negligible amounts of copper, lead, and tungsten.

Geographic and geologic distribution

The gold-bearing veins are in the northwestern part of the quadrangle and are a part of a much larger belt of gold mineralization which spreads north and west. Most of the deposits, those now active or recently active, are outside the map boundaries. All are within the Eureka mining district.

These deposits show a geographic distribution that accords very closely with the bodies of granitic rock. All are near the borders of the granitic bodies, most of them just within but some in the quartzites a short distance away.

Structural relations

The veins are along faults and fracture zones of northeast and to lesser extent northwest trends. These trends are about the same as those of
the faults and fractures which aided in the emplacement of the granitic bodies. This structural relationship suggests that the faults containing the veins, though younger than the granitization, were formed during the orogenic activity which earlier had broken the rocks and facilitated the granitization. On the other hand, the fractures and fissures could have been formed by forces of later date applied in the same general direction as before and localized along this early zone of structural weakness. The northeast faults which appear to be the major faults, directed most of the mineralization. The northwest faults are the complementary set and are not so well represented as the others. These faults have nearly vertical dips, steeply in one direction or the other, with most of them, however, dipping steeply northwest.

Mineralogy

The gold-quartz veins have a simple mineralogy. Below the weathered zone the veins contain only minor amounts of sulfides, mainly pyrite, in places accompanied by a little chalcopyrite and galena. Scheelite is also known to occur sparingly in some of the veins, but may be detected only with the aid of the ultraviolet lamp.

The quartz is coarsely crystalline and fills most openings so completely that it appears massive. In places, however, vugs in the quartz are lined with quartz crystals, apparently of a younger generation. The sulfides are scattered irregularly through the quartz: the pyrite as coarse isolated cubes, bunches of cubes, and in some places also as fine-grained bands and the other sulfides as even more widely scattered grains and small granules. The chalcopyrite is generally not very conspicuous and the galena is even less so. Their distribution tends to be quite sporadic. Much quartz in the veins is entirely without sulfides.

As gold content is reported to increase as the sulfides and particularly the pyrite become more abundant, the gold is probably closely associated with the pyrite. However, if chalcopyrite is present, the gold appears to have a greater affinity for it than for the pyrite.

In the weathered zone the quartz is stained by iron oxides and contains small masses of limonite in pores or openings formerly occupied by the sulfides. In places the iron-stained quartz has thin patches or crusts of greenish malachite. Minor amounts of cerussite have been identified in some of the oxidized ore. The gold is freed from its mechanical association with the sulfides during weathering and the oxidized ore is free-milling.

Occurrence and distribution of the ore

The veins are along fault zones a few feet to 10 feet or more wide, but generally they occupy only a small part of the zone. They appear therein as quartz veins or bands a few inches to a foot or two wide along one wall, or as several quartz bands with quartz stringers in bordering fractures or with quartz filling in bordering or intervening breccias. Veins are narrow and tend to pinch and swell and in places to split into several bands or
stringers. Most deposits contain considerable gouge or crushed rock in addition to the vein matter, all of which is encased between fairly firm walls.

The ore is confined to more or less well-defined shoots which occur at irregular intervals along the veins. These shoots pitch to the south at angles steeper than 45°. The ore in them is generally bumpy or pocketed and the bunces are irregularly spaced. Pyrite is the only persistent sulfide, but its distribution is sporadic and its abundance quite variable, generally composing not more than 2 or 3 per cent of the vein filling, exceptionally as much as 15 per cent. The pyrite is accompanied here and there by small scattered grains of chalcopyrite and less commonly galena. The gold content appears to increase as the content of pyrite increases and especially with increase of the chalcopyrite. In the oxidized ores the gold is readily recovered, but in the unoxidized vein matter the recovery is reported at less than 90 per cent by amalgamation. The quantity of oxidized ore is relatively small for the zone of oxidation is shallow, generally within 100 feet of the surface.

Tenor of the ore

The ores are not the bonanza type, but the ore in some of the shoots was of substantial grade and according to reports ran as high as an ounce of gold per ton. Most of the mined ore, however, was of considerably lower grade and carried from 0.2 to 0.3 ounce of gold per ton. As the gold has a rather spotty distribution, individual assays may show a wide range of values. The tenor of the ore is reported to show material decline with increasing depth.

Genesis

The origin of the gold-quartz veins is still very much of an unsolved problem with two possible interpretations. One involves a genetic association with the Idaho batholith, the other with much later magmatic activity. Bearing on the first interpretation is the close association of the gold-quartz veins with the bodies of granitic rock, which would tend to imply a genetic relation between the gold metallization and the granitization. This relation is indicated not only by the geographic distribution of the veins in and about the borders of the granitic rock but also by the apparent timing of the gold metallization with respect to the granitization. The metallization occurred after granitization but so soon after that it took advantage of fractures presumably produced by the same orogenic forces as those which provided the setting for the granitization.

How and where the granitizing and ore-bearing fluids originated is a controversial problem open to much speculation. It is probable that the fluids rose from depth along zones of structural weakness, the granitizing fluids first and the metallizing fluids later. It is known that the granitizing fluids introduced much potash and at the end considerable silica, and that the later metallizing fluids were enriched in silica and carried minor amounts of several of the metals. There was a time interval between the two
uprisings, suggesting some interference with continuous movement of fluids. Perhaps this was caused by increased back pressure through strengthening of the weak escape zones by formation of the strong, massive granitic rock followed by release of pressure by structural breakage. This later breakage permitted the ore-forming fluids to gain access to the areas of granitic rock. It is supposed that the granitizing and metallizing fluids came from the same general source and were probably generated in the deep synclinal prism during the Sierra Nevadan orogeny. The source would then be the more acidocrustal material and not the basic subcrust from which ores are generally supposed to originate. Thus the deposits would be related to the Idaho batholith.

The alternative interpretation would admit a structural reopening of the late Jurassic zone of structural weakness long after the emplacement of the granitic rock, probably during the Laramide disturbance, with ore fluids from a deep subcrustal source utilizing those newly created fracture and fissure zones. The metallizing fluids would thus be of probable early Tertiary age.

The second interpretation has much to commend it. The metallizing fluids apparently possessed moderate temperatures at the time of mineral deposition and not the high temperatures that might have been expected were they a follow-up of the granitizing process. The deposits may be classed as mesothermal. Deposition apparently took place at moderate levels of the earth's crust and not at the depth at which the granitization probably occurred and this implies a considerable amount of erosion between the time of granitization and mineral deposition. The range of ore deposition is probably restricted to a relatively short vertical interval.

Study over a much more extensive region will be necessary before either genetic interpretation can be proved or disproved.

Outlook

Considering all the time and money expended in the development of these deposits, the returns have been very disappointing. Some ore will be produced in the future by small operators, especially on the properties outside the quadrangle, but no deposit appears to be large enough to sustain more than moderate-sized operations. Unless the price of gold increases substantially there will be little incentive to reopen and explore the old mines or try to develop new ones. Inasmuch as the ore probably has a rather moderate vertical range and much has already been lost by erosion, any attempt at deep development would probably end in failure.

Description of the mines and prospects

Queen of the Hills mine

The Queen of the Hills mine, the only notable gold producer within the quadrangle, is on upper Deriar Creek near the edge of the quadrangle in
in Sec. 14, T, 22 N., R. 21 E. The mine lies well up the Salmon River
Mountain slope at an altitude of 5,600 to 5,800 feet, but is within easy
reach of Salmon by 3 miles of paved highway and about 4 miles of well-
graded, all-weather road.

The veins on the property were located in the early eighties but re-
ceived little attention until 1898. Active development then got underway
and continued without letup for some years. When Unpleby visited the prop-
erty in 1910 the development comprised about 5,000 feet of work on five
levels spaced over a vertical distance of 400 feet. The mine had been
equipped with a 15-ton mill in 1909 and production by the following year
had totalled about $80,000. Sometime after Unpleby’s visit the mine sus-
pended operations and remained generally inactive until 1926, when a new
company, the Golden Queen Mining and Milling Company, obtained a lease and
option on the property. This company rehabilitated the mine plant and mill,
reopened a part of the old workings, and performed a small amount of new
development. One lot of lead concentrates rich in gold was produced.
Operations soon terminated and the mine has since been idle. The workings
are now inaccessible and the surface plant is generally dismantled.

The mine is known to have three veins, all well within the body of
the large granitic stock. These veins are essentially parallel and strike
close to N. 30° E. One of them, the Queen, dips 80°-85° SE. The other
two, the Nellie and Eva, dip as steeply northwest. The Eva, the most
westerly of the veins, is reported to occupy a fault zone about 5 feet wide,
but the vein itself is composed of 8 to 14 inches of quartz and lies first
on one wall of the fault zone and then on the other. The Queen, the central
vein, is reported to be along a fault zone about 12 feet wide, about half
of which consists of quartz, either as distinct bands or as a filling be-
tween fragments of the granitic rock. The Nellie vein, except for its
angle of dip, is reported to be very similar to the Queen.

The veing are reported to contain five ore shoots, two each in the
Nellie and Queen, and one in the Eva. Nothing was learned of the dimensions
of these ore shoots. The coarsely crystalline quartz which composes these
shoots is said to contain scattered crystals of pyrite, chalcopyrite, and
a little galena, together with their oxidation products. The average gold
content of the Eva shoot is reported at less than 0.2 ounce per ton, where-
as the better ore in the Nellie averaged little more than 0.25 ounces per
ton. The ore in some of the stope on the Eva vein, however, contained up
to nearly an ounce in gold.
Other properties

Old workings are visible on Derrier Creek above the Queen of the Hills mine and here and there along the granitic stock south to Bob Moore Creek, but none apparently of much consequence. No work appears to have been done on them for many years.

The most extensive workings next to those at the Queen of the Hills mine are on the south side of Bob Moore Creek just across from the small mass of highly gneissoid granitic rock in the northeast corner of Sec. 28, T. 22 N., R. 21 E. These workings are along a low ridge not far above creek level and are on one or more veins which lie entirely in the quartzite a very short distance from the granitic body. The workings are caved, but the position of the portals and the alignment of surface cuts suggest that the veins strike northwest at a rather wide angle. Much quartz is piled or strewn about the surface. This quartz is iron stained and resembles that at the Queen of the Hills mine. The size of the chunks of quartz suggests that the veins may measure up to several feet thick. No work has been done on the property for a long time and the road to the old workings is overgrown with brush and trees.

Much work has also been done on properties just outside the quadrangle. Some of these properties have almost as much work as the Queen of the Hills. Among the more important of these properties are the U. P. mine at the head of Bob Moore Creek and several in the granitic rock a mile or two north of the Queen of the Hills mine. Among the latter are the most recently active mines in the district, one of which was in the course of development during the summer of 1954.

Placer deposits

Distribution

The only placer deposits within the quadrangle are along Kirtley Creek. These deposits extend downstream from the mouth of the canyon at the base of the Beaverhead Range to within less than 2 miles of the Lemhi River. As the mouth of the canyon is at the very edge of the map area, the placers are entirely within the quadrangle, extending along the creek for about 5 miles.

The deposits are in the Kirtley Creek mining district. This district covers a strip of country about 6 miles wide along the course of Kirtley and extends from the Lemhi River northeastward across the hilly lowlands of the Salmon Basin and up the steep rugged slope of the Beaverhead Range to its summit.

History and production

Just when gold was discovered in the gravels of Kirtley Creek was not learned, but records show that hydraulic mining was carried on from 1890 to 1894 and that a considerable amount of gold was recovered. The placers were
then abandoned and the ground sold. In 1910 the Kirtley Creek Gold Dredging Company of California acquired an option on the ground and, after testing, purchased about 400 acres of land along the stream valley. It installed a dredge of 9 cubic feet capacity capable of handling up to 150,000 cubic yards of gravel a month and had the dredge in operation the last two months of 1911. The dredge immediately became the largest producer of placer gold in Lemhi County, and within five years was the most important in the state. During these years the dredge worked a strip of ground a little more than 2 miles long and up to a third of a mile wide. By early 1918 the valuable placer ground had been worked out and the dredge was dismantled. During its eight years of operation the dredge produced gold estimated as worth around half a million dollars.

Geologic features

The placer ground covered the gravels along the floor of the valley and the low terraces on either side. Some gold was found in the conglomerate of the Carmen formation at the edge of the basin just below the mouth of the canyon, but the attempt to work the conglomerate, which appears in the valley slides above the recent stream deposits, was abandoned.

The placer deposits along the creek are reported to have averaged about 17 feet thick and, as exposed in the dredge tailings, are made up of water-worn pebbles and boulders of quartzite and related more or less schistose metamorphic rocks in a matrix of sand and clay. The boulders are mostly less than a foot in diameter. In the upper end of the deposit the gold was on bedrock or a few inches above, but farther down the valley it was reported found through the lower 6 to 8 feet of the gravel, with the greatest concentration, however, close to bedrock. Near the head of the deposit the grains of gold were about the size of shot but they changed gradually to flake size downstream.

The gold in the stream has been traced upstream to gold-quartz veins exposed and mined in the cirque at the head of the creek. The swiftly descending stream could not drop the transported gold until its gradient was checked as it entered and crossed the Salmon Basin. Then the gold accumulated in the gravels at the base of the range.

COPPER DEPOSITS

History and production

Just when the copper deposits in the Salmon quadrangle were discovered is not known. Some of the copper deposits in other parts of Lemhi County were known to settlers in the late fifties, but those around Salmon were probably not discovered until after the influx of placer miners in the late sixties or perhaps not until the seventies and eighties when search was made for sources of the placer gold. As the copper deposits in the area contained insignificant quantities of the precious metals, they were of little interest to the prospector, who passed them by in his search for deposits of more immediate worth. It is known that the first location at the Pope-Shenon was made in the
early nineties and that the location then was for gold and not for copper. Not until after the turn of the century was much interest manifested in the copper, and little copper mining was attempted until after 1910. Within the next five or six years active development was underway on all the properties now known and some of them made shipments of ore and concentrates. The greatest activity was probably in the early and mid-twenties. Work continued on several of the properties into the early thirties and then ended at all except the Pope-Shenon mine, which has remained recurrently active to the present day.

Data on copper production from 1901 to 1953 have been provided by the Albany office of the U. S. Bureau of Mines through the courtesy of Mr. A. J. Kauffman, Jr., Chief, Division of Mineral Industries, Region I. During these years there has been a total of 95,300 tons of ore and 8,947 tons of concentrates produced containing 5,030,803 pounds of copper, 162 ounces of gold, 10,583 ounces of silver, and 5,137 pounds of lead. The production by years is given in Table 1 prepared by the U. S. Bureau of Mines.

(table - next sheet)
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<th>Tons of concentrates</th>
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<th>Silver (fine ounces)</th>
<th>Copper (pounds)</th>
<th>Lead (pounds)</th>
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Total... 95,300 8,947 162 10,583 5,030,803 5,137

(a) Tooe-Shean (Grandview), Harmony, Tormay or Tormey, and Columbia mines.

(b) Estimated figure.
Character of the deposits

The copper deposits possess compositional and structural characteristics that make them unique among the metalliferous deposits of the region. They are not valued for several metals as are most of the other deposits of the region but have only the one metal, copper. Copper deposits within the quadrangle contain scarcely more than traces of the precious metals.

These deposits also stand apart from the others in their occurrence along zones of shearing rather than along zones of fissuring or breciation. Although not everywhere strongly evident, the shearing has generally been of such intensity that a more or less conspicuous schistosity has developed parallel to the shearing, entirely independent of the regional schistosity. The deposits occur along these zones of shearing as steeply inclined tabular bodies, chiefly as replacements of the sheared and schistose rocks, subordinately as fillings of minor fracture and fissure openings. The metasomatism along the zones of shearing has not been uniform and the ore is confined to shoots that have fairly definite strike limits. Wall-rock alteration is not conspicuous and, except for the somewhat increased schistosity, the rock along the mineralized zone is much like the surrounding country rock.

The outcrops of the copper deposits are rather inconspicuous. Some are marked by small amounts of limonite, by scattered copper stains, and by irregular masses and lenses of quartz. Others show little more than indistinct shearing in the rocks, locally heightened by the development of a weak schistose structure.

Geographic and geologic distribution

Although the copper deposits are widely but irregularly scattered through the region, those within the quadrangle are more or less closely grouped along a comparatively narrow zone that extends from the head of Ferrean Creek southeastward across the Salmon River to the north end of the Lemhi Range and thence along the southeast side of the range for some miles beyond the map boundary. This zone closely parallels the trend of the Lemhi Valley but, extending into the Salmon River Mountains, it assumes a more westerly direction before dying out. The more important mineralization is centered at the north end of the Lemhi Range, 4 miles to the south of it, and at lower Ferrean Creek on the Salmon River Mountain slope.

Unlike the gold-bearing veins, these copper deposits show no geographic relationship to known bodies of igneous rock. All deposits are contained in the metamorphosed quartzitic rocks of the Belt series, a geologic distribution common to all deposits of this type throughout the Salmon region. Their distribution appears to be structurally controlled, but without any relationship to the Idaho batholith.

Structural relations

All the deposits within the quadrangle, except at the north end of the Lemhi Range, are along zones of shearing of northwesterly trend. Those not of this trend are east-west zones of shearing, which, however, show local
departures of a few degrees to the north or south. The trend of those in
the northwest quadrant ranges between N. 30° W. and N. 70° W. with most at
about N. 55° W. Dips are either northeast or southwest at angles greater
than 50°. The east-west zones show alternately the influence of N. 70° W.
and N. 70°-80° E. shearing trends and consequently shift back and forth
from one to the other, but with one counteracting the other so that the
zone as a whole maintains a fairly persistent east-west course. Dips are
steeply north at angles in excess of 70°.

The zones of shearing may occur singly or, as at the Pope-Shenon mine,
as components of broader multiple zones of shearing, made up of a number
of individual roughly parallel, overlapping zones, some linked to others by
narrow branching diagonal shears. Some of the individual zones of shearing
split and, as at the Harmony mine, may contain pairs of lodes which come
together at a small angle and localize commercial shoots of ore.

Individual zones of shearing have their peculiarities. Most of them
possess considerable curvature, a characteristic particularly marked at the
Toomey mine on Perreau Creek where the trend of the zone gradually changes
from N. 30° W. to N. 70° W. The changes in curvature at the Pope-Shenon
mine are less simple, for the zones there swing from north of east to south
of east and back as the zones respond to the local influence of first the
No. 70°-80° E. and then the S. 70° E. sets of shears. These individual zones,
whether alone or parts of major systems, are structurally complex. As at
the Pope-Shenon they may be composed of fractures parallel to the shearing
and of fractures that are oblique thereto. The individual zones may also
possess well-defined schistose structures parallel to the shearing.

The alignment of the zones of shearing in a northwesterly belt essen-
tially parallel to the long dimensions of the Lemhi Valley, a depression of
probable structural origin, suggests that tectonic forces are in control
of the shearing.

Mineralogy

The deposits are distinguished by a simple yet interesting mineralogy.
Generally only one or at the most three primary ore minerals exists but
from these there have been derived a number of secondary copper minerals
which in the past have been the source of a considerable copper production
and even today continue to supply some of the ore. However, any extended
production will ultimately have to depend entirely on the primary ore min-
erals.

Primary minerals

The primary copper minerals of the unoxidized parts of the ore bodies
are represented by chalcocypirte and at the Pope-Shenon mine also by de-
lafossite and a little bornite. These ore minerals, accompanied by pyrite
and in places by magnetite and a little specularite, are in a gangue of
quartz and somewhat altered country rock containing sericite, muscovite,
biotite, actinolite, chlorite, and epidote.
Metallic minerals

The chalcopyrite and locally the delafossite are the only primary metallic minerals readily visible in the ore. Pyrite may be distinguished on close inspection, but it is much subordinate to the chalcopyrite and may easily escape notice. The chalcopyrite is by far the most abundant mineral in the deposits and in most is the only primary copper mineral. The bornite was noted as minor microscopic veinlets in the chalcopyrite of some of the ore from one of the stopes at the Pope-Shenon mine. It occurs in such trivial amounts as scarcely to warrant mention. The chalcopyrite and other metallic minerals are disseminated in both country rock and quartz and in places are concentrated into irregular bands and masses of nearly solid ore. The chalcopyrite penetrates the quartz and country rock as irregular fracture or cleavage-controlled veinlets which characteristically pinch and swell abruptly and which pass into large bunches of ore. Any pyrite in the chalcopyrite is rounded or corroded or is retained as minor remnants of formerly larger grains or crystals. The chalcopyrite or other minerals associated with the quartz tend to be more coarsely crystalline than those contained in the country rock.

The delafossite (Cu₉O₆Fe₂O₉) intimately associated with magnetite and mica occurs in some abundance at the Pope-Shenon mine, mainly in the walls of the shoots containing the chalcopyrite ore. This black mineral which, except for its lack of magnetism, resembles the magnetite, gives the rock in which occurs a peculiar banded or slightly curved layered structure, with some of the layers so arranged as to form conspicuous concentric, ellipsoidal, shell-like bodies. These concentric layers are independent of the bedding and stand out as dark-colored bands up to a fourth of an inch wide, alternating with generally much broader light-colored bands of country rock. The boundaries between the bands are not sharp and in most specimens the dark layers shade off into the lighter ones more gradually on one side than on the other. The color of the dark layers is caused by the concentration of the black, delafossite grains and lesser magnetite crystals and locally also by increased amounts of biotite. As the delafossite has been found in some abundance in the deepest part of the mine, some distance below the zone of oxidation and supergene enrichment, it is a primary and not a secondary mineral. Apparently it was produced by rhythmic deposition from a fluid that was diffused into the rock from openings produced by joints. It is a product of diffusion banding.

Aside from its association with the delafossite, magnetite occurs in some abundance at the "big ledge" along the crest of the ridge above the Harmony mine. A part of the magnetite occurs as disseminated grains but a part is contained as nearly massive bands. Some of the magnetite is penetrated and partly replaced by specular hematite.

Nonmetallic minerals

The nonmetallic gangue minerals, except for scattered, small irregular masses and stringers of quartz, are largely the components of the original rock. These minerals, however, have generally developed into grains of
somewhat larger size and show other modifications, among them realign-
ment of the grains to parallel the shearing instead of the regional
schistosity, along with some increase in the proportions of the con-
stituent minerals. Biotite and chlorite are ordinarily among the more
conspicuous minerals, but sericite is always among the most abundant. In
places the sericite is the most abundant mineral other than the quartz,
which is inherited from the quartzite. The biotite is generally consider-
ably altered, usually to chlorite but in small part to epidote and excep-
tionally to small needles of actinolite, which project from the chlorite
or biotite into the adjacent grains of quartz. Some chlorite apparently
has also developed in the quartz. The sericite is widespread and extends
not only into the grains of biotite and chlorite but also forms grains and
granular aggregates in the quartz. In some places the rock also contains
scattered small plates of muscovite, generally aligned at a wide angle to
the schistosity and apparently formed later than the sericite. Zircon
and other minerals originally present in the micaceous quartzite are re-
tained in the rock as gangue.

The quartz that has been introduced into the zones of shearing as
strings and lenses also permeates the bordering rock with more or less
complete elimination of the schistic rock materials. This quartz, white to
the unaided eye, is more coarsely grained than the quartz of the country
rock. The sulfides penetrate this quartz as well as the rock.

Secondary minerals

The secondary minerals include those of the oxidized ore as well as
minor amounts of supergene sulfides. The oxidized ore is found within the
zone of weathering and the supergene sulfides mainly just below, but there
is some intermingling of primary and secondary minerals in the oxidized
zone. Unless removed by erosion, the oxidized ore minerals predominate
near the surface and become less conspicuous with increasing depth until
their place is taken completely by primary ore minerals. The secondary
sulfides are nowhere conspicuous.

Oxidized minerals

The minerals of the oxidized ore include malachite, azurite, chryso-
colla, cuprite, native copper, and limonite. The malachite is the most
abundant of these minerals and is the only one other than limonite to occur
in and stain the cutcrops. It has provided much of the copper obtained from
the oxidized ore. Much of it occurs as greenish coatings on the partly
oxidized sulfides or on the surfaces of the fractured ore and country rock.
In places the malachite is accompanied by patches and irregular crusts of
bluish azurite. The azurite is distributed rather widely through the
oxidized ore, but it is always subordinate to the malachite. The chryscolla
resembles malachite and is easily overlooked, but it occurs sparingly here
and there in the ore. Cuprite also occurs in much of the oxidized ore but
rarely in conspicuous quantities. It did, however, provide much of the ore
in a small stope on one of the upper levels of the Pope- Shenon mine. Its
presence adds very materially to the value or tonor of the oxidized ore.
Native copper may be found with careful search in some 6 the more thoroughly
oxidized ore.
It has been reported in the exposed parts of most of the deposits. Limonite derived from the oxidation of the pyrite and chalcopyrite is present in all the oxidized ore and is abundant in some.

Supergene sulfides

The supergene sulfides are limited to two minerals, covellite and chalocite, both in intimate association with the chalcopyrite and pyrite. The covellite is sparingly present and can be discerned only as microscopic grains along chalocite veinlets in the partly oxidized primary sulfides. The chalocite is so much more abundant than the covellite that it generally receives credit as the only secondary sulfide. It has been observed in small masses surrounded by malachite and azurite and enclosing small remnants of chalcopyrite in some of the ore on the middle levels of the Pope-Shenon mine, and has been reported in similar form at some of the other mines. Most of the chalocite is recognized microscopically as irregular veinlets in the primary sulfides, with the veinlets directed along fractures and grain boundaries and extending unevenly into and replacing the host minerals. Because of its high copper content, the chalocite contributes considerably to the richness of the ore. Much of the chalocite shows incipient alteration to oxide material of indefinite composition usually referred to as copper pitch ore.

Paragenesis

The mineral relations and associations indicate an interesting and somewhat complicated paragenetic development. Of the primary minerals, those comprising the altered country rock were the first to form. The penetration of the quartz and biotite by actinolite and chlorite and in places by epidote and of all these by sericite and locally muscovite, indicates that quartz and biotite were the earliest minerals and that the biotite like the other minerals had formed in part at the expense of the quartz. The exact place of the epidote is in doubt but otherwise the mineral succession may be given as quartz, biotite, actinolite, chlorite, epidote (?), sericite, and muscovite.

The primary oxides, the delafossite and magnetite, may have formed at about the same time as the silicates. These oxides are clearly older and independent of the chalcopyrite mineralization, being confined to the rock in the bordering walls. Study shows that the dark bands represent concentrations of biotite as well as of the oxides and that the biotite, delafossite, and magnetite therefore must have formed at about the same time. As the three minerals were not observed in contact with each other, their relative ages are not known. The oxides fill interstices and fractures in the quartz and so are younger than the quartz but older than the sericite and muscovite. They may be about contemporaneous with the biotite. The specularite was not observed with the delafossite but elsewhere is known to penetrate and replace the magnetite.

The stringers and lenses of quartz were next to form along the zones of sheared and altered rock. As well as by its structural entrance into the altered rock, the quartz also reveals its younger age by the manner in
which it permeated the rock, engulfing and obliterating the micas, chlorite and other minerals that make up the rock.

The sulfides, introduced after minor and more or less sporadic silicification of the sheared and altered rock, probably were associated with the introduction of the bunches of vein quartz. After the quartz and bordering rock were fractured, the sulfides gained access along the fractures and cleavages and invaded and replaced the quartz and bordering rock. The corrosion of the pyrite by chalcopyrite and the veining and replacing of the chalcopyrite by small amounts of bornite indicate a succession of pyrite, chalcopyrite and bornite.

The paragenetic history of the secondary minerals was not worked out in detail and is not fully known. Oxidation of the pyrite and chalcopyrite led to solution of the iron and copper and later to deposition of some of the copper by reaction with and replacement of primary sulfides by a little covellite and much chalcocite. Incipient oxidation of some of the chalcocite led to the formation of some copper pitch ore while more complete oxidation formed malachite, azurite, and other oxidised minerals. Much of the copper that went into solution, however, was intercepted in the oxidised zone and by reaction with dissolved carbon dioxide was converted to the carbonates or in the absence of carbonates to cuprite or to native copper. Some of the partly oxidised chalcopyrite apparently went almost directly to malachite.

Occurrence and distribution of the ore

The occurrence and distribution of the ore show a considerable dependence on structural controls. Unfortunately these controls could be examined only at the Pope-Shenor mine, which was the only mine with accessible workings during the present investigation. According to earlier reports, the ore occurs or is distributed as irregular stringers and bunches along the zones of shearing, as irregular disseminations in which the grains may be so closely spaced as to compose essentially massive sulfides, and as roughly lenticular bands parallel to the shearing. This accords in a general way with the conditions at the Pope-Shenor mine, but the picture is not complete until these occurrences can be explained in relation to the controlling structures.

At the Pope-Shenor mine the distribution of the ore shows a marked dependence on the schistosity and on the fractures parallel and oblique to the shearing, a dependence shown to best advantage on the intermediate level of the mine. There the ore occurs as bands a few inches to several feet wide along the walls of the shear zone and as stringers generally less than an inch thick that extend obliquely toward the opposite wall. These stringers are commonly so closely spaced as to form an essential part of the milling ore. In places where seams of ore occur along both walls, they may be joined together by diagonal stringers. The hanging wall and footwall bands may be as much as 20 feet apart, but more commonly they are within 8 or 10 feet of each other and may even be only 4 or 5 feet apart. As the distance between these bands decreases, the connecting stringers generally become more numerous and the ore of higher grade. In other exposures the ore is along only one wall but may shift from one wall to the other as the directing fractures alternately strengthen and weaken.
The distribution of the ore at the Pope-Shenon also shows guidance by prominent diagonal fractures which enter the zones of shearing from the walls and then curve to conform with the shearing. These fractures may persist outward into the walls for some distance, but the ore in general is restricted to the band or to the fracture just before it changes its direction to conform with the shearing. These diagonal fractures may enter from either wall.

The ore also penetrates along the cleavage of the rock and may form irregular masses seemingly more or less independent of fractures. The bands and bunches of massive ore apparently owe much of their size and massive- ness to replacement rather than to actual filling of open spaces. Replace- ment also accounts for irregularities in seam width and for the presence of the irregular bunches of ore. The cleavage or schistosity has played an important role in facilitating entrance of minerals into the rock and in making replacement possible.

To what extent the conditions elsewhere may be like those at the Pope- Shenon mine is not known, but as all deposits are along zones of shearing, there should be considerable similarity in the controlling structures and hence in the occurrence and distribution of the ore. Since the lode schist- osity may not be so well developed at some of the other deposits as at the Pope-Shenon, the ore there may show greater dependence on fractures and fissures.

Ore shoots

The ore is not uniformly distributed along the zones of shearing, but is mostly concentrated into fairly well-defined shoots separated or terminat- ed by zones of sheared rock largely devoid of valuable minerals. The ore shoot generally occupies the greater part of the width of the shear zone but only a fraction of its known length. The ore shoots are of moderate size, with stopes widths up to 10 feet and exceptionally up to 20 feet, and with stope lengths up to several hundred feet. Present and past development indicates a vertical range of some hundreds of feet with no downward termina- tion yet in sight.

The distribution of the ore and hence the localization of the ore shoots appear to conform with zones of more than average permeability, where con- ditions during ore deposition were particularly favorable to the circulation of mineralizing fluids. At the Harmony mine the ore shoots occur where the branches of split or intersecting shear zones come together, with the rake of the shoots controlled by the inclination of the intersection. Apparently the abundance of fractures at the junction of the split or inter- secting shear zones provided the openings needed for the circulation of the ore fluids and the formation of ore shoots.

At the Pope-Shenon mine the ore shoots apparently reflect the distribu- tion and spacing of permeable fractures parallel and oblique to the shearing. These favorable zones appear to occur where the shearing has been most intense and the schistosity most pronounced. The spacing of these fractures has had much to do with regulating the amount of ore as well as
the dimensions of the ore bodies. The prominent diagonal fractures which enter the shear zones from the bordering walls have been especially important in controlling the position and pitch of some of the best ore. As these diagonal fractures dip steeply southwest, the ore seams rise upward and produce large bulges in the hanging wall, with local reversal of dip.

The factors that control the location of these structurally favorable zones are not well understood. Horizontal shearing stresses may account for the shear and oblique fractures and the schistosity parallel to the shearing. Variations in the angle of dip of the shear zones may have some bearing on the localization of the favorable structures, but variations in strike may have been of greater significance. The recurrent changes in the direction of shear from east-northeast to east-southeast of the Pope-Shenon may have considerable bearing on the problem. Movement along curved zones of shearing would readily provide the necessary openings for the channeling of mineralizing fluids and the consequent formation of ore shoots.

The precise cause for the localization of ore shoots doubtless differs with local controls from deposit to deposit so that each one must be studied individually.

Tenor of the ore

Most of the ore mined has carried from 2:8 to 6 per cent copper and negligible quantities of gold and silver, but the ore in some of the shoots or in parts of the shoots has been considerably richer and has provided shipments with from 10 to 20 per cent copper. Hand-sorted crude ore carrying 10 to 15 per cent copper has been shipped to the smelters whereas mill concentrates have averaged about 25 per cent copper. The crude ore has contained less than an ounce of silver and generally less than 0.01 ounce of gold per ton and the concentrates have contained no more than 1.5 ounces of silver nor more than 0.1 ounce of gold.

No sample records of the ore at the Harmony and Tormey mines are available, but the results of some of the sampling at the Pope-Shenon mine have been published. Most of these samples were in parts of the ore bodies mined since then but they showed that the ore carried from 2 to 20 per cent copper over sample widths of 2:8 to 6 feet, with much of the ore averaging about 5:8 per cent copper.

Wall-rock alteration

The mineralizing fluids have induced some changes in the rock in and along the shear zones, but the changes are not striking and the altered rock
does not stand out in sharp contrast with the unaltered country rock. The rock along the shear zones shows the effect of intense pressure and has in part been converted to schist but, except for differences in proportion, the minerals of the altered and unaltered rocks are much the same.

Thin section study reveals that the minerals of the country rock along the zones of shearing have been reorganized into grains of larger size and that materials have been added to increase the abundance of such minerals as chlorite and sericite and perhaps biotite. The increase in the quantity of these minerals must have meant the addition of some iron and potassium and exceptionally of copper, especially to account for the presence of such minerals as delafossite and magnetite in some of the altered rock.

After the reorganization and reorientation of the original minerals of the rock, the biotite was in part altered to chlorite and the chlorite in turn partly altered to sericite. Much sericite was also formed as a replacement of the quartz. In some places so much sericite was formed in the rock that it appears bleached and is not so hard as the darker rock. Quartz also has permeated some of the altered rock and has caused local silicification.

Apparently the fluids responsible for the wall-rock alteration possessed thermal qualities little different from those involved earlier in the metamorphism of the country rock and hence were in no position to induce any marked changes in the wall-rock mineralogy.

Oxidation and enrichment

Some oxidized ore occurs in all deposits but, except at the Pope-Shenon mine, the quantity of oxidized ore is small. It usually is contaminated with unoxidized or only partly oxidized sulfides even at or very close to the surface. In the upper levels of the Pope-Shenon mine the oxidized minerals were so abundant that a chlorination mill was erected to treat just the oxidized ore. Although mixed with residual sulfides, this oxidized ore was relatively abundant above the No. 4 level, less so between the No. 4 and No. 5, and absent below the No. 5, except along the western margin of the ore shoot. There it shows some evidence of oxidation, even to the No. 6 level. The bulk of the ore here and elsewhere has been composed largely of primary sulfides, somewhat enriched on upper levels by minor amounts of supergene chalcocite, usually recognized under the microscope. The oxide and sulfide enrichment has increased the value of the ore to some extent at the Pope-Shenon mine, but has been a negligible factor at other places. In general, erosion has been too active to permit retention of much oxidized ore.

Genesis of the deposits

The mineral associations and structural relations of these deposits are those generally considered characteristic of formation under moderately high temperature and pressure conditions. The rather high temperature is indicated by the nature of the minerals in the altered rock, particularly such minerals as the micas and oxides (magnetite and delafossite). The
high pressure is suggested by the shear deformation and the development of lode schistosity. When the sulfides were introduced the temperature was probably somewhat lower than during the earlier stage of wall-rock alteration but was still moderate rather than cool.

The associations and relations of the minerals indicate two or at the most three stages of mineralization. During the first stage the rock in and near the zones of shearing was more or less intensely altered with the regrouping and successive development of biotite, sparse actinolite, abundant chlorite, a little epidote, much sericite, and in some places minor amounts of muscovite. These minerals reflect the introduction of some new materials as well as the recrystallization of materials already present in the rock. At the Pope-Chenon mine considerable amounts of copper and iron were introduced with these materials and under the temperature conditions then prevailing, the copper and iron were deposited in the rock as grains of delafossite and magnetite. Elsewhere the iron was deposited as magnetite and specularite.

During the second stage of mineralization minor amounts of quartz were introduced along the zones of sheared and altered rock as a filling of scattered openings and as a replacement of some of the schistose rock. After weak structural adjustments the ore minerals were introduced, possibly as a third stage of mineralization, and were deposited successively as pyrite, chalcopyrite, and very sparingly as bornite.

The ores near the surface have since been affected by weathering and the sulfides have in part been changed to various oxidized minerals and locally replaced and enriched by minor amounts of supergene sulfides particularly chalcocite.

The source of the mineralizing fluids is open to much speculation. In earlier reports it was presumed that, since there was so little difference between the wall-rock alteration and the regional metamorphism, except in degree of intensity, metamorphism and mineralization were closely related. Hence it followed that the mineralization was related genetically to the Idaho batholith, the postulated source of the emanations that provided the heat and materials needed to transform the sedimentary strata into metamorphic rock. It was further presumed that fluids from deep within the congealing batholith were directed upward along channels opened by deeply extending shearing and that these fluids aided in the more intense alteration of the rock along the channelways and later supplied the ore materials. There is reason now to doubt the existence of any relationship between the mineralization and the Idaho batholith. Contrary to former beliefs, the copper deposits show no spatial relation to the batholite or its outliers and are not known to occur within or show any tendency for concentration in or near its borders. They appear to be structurally independent of the batholith.

If not related to the batholith, the copper deposits could be either older or younger. The evidence tends to support the older age, for the deposits have much in common with copper deposits of known pre-Cambrian age elsewhere.
in the Rocky Mountain region. Whether the deposits locally are pre-Cambrian or younger can be determined if the regional metamorphism can be definitely dated. If the metamorphism is largely a pre-Cambrian inheritance, then the deposits could have formed along zones of shearing in pre-Cambrian time. Such an age could perhaps account for the scarcity of the precious metals in the copper ore as contrasted with their relative abundance in deposits known to be younger than the Idaho batholith. Should the metamorphism be largely a product of the Sierra Nevadan orogeny of late Jurassic time, then the copper deposits could be along zones of shearing produced during the Laramide orogeny and could be related to an early Tertiary metatization. They do show some resemblance to the so-called contact metamorphic copper deposits in and around the Tertiary intrusives at Mackay, Idaho; but the writer believes that when all the facts are known, the copper mineralization will be found to be of pre-Cambrian age.

Regardless of the age of the deposits, the source of the mineralizing fluids must have been somewhere in the earth's basic subcrust.

Outlook

As these deposits appear to be localized along deeply seated zones of shearing and to possess the characteristics of deposits formed at considerable depth, they may be expected to cover an extended vertical range, with the ore persisting to depths greater than those yet reached in mining. Should the ore appear to bottom along one zone of shearing, it may well resume along another overlapping zone which continues the shearing to greater depths. The problem is not so much the persistence of the ore with increasing depth as it is the finding of ore shoots of sufficient size and ore of sufficient grade to warrant mining operations. So far the ore shoots at the Pope-Shenon mine have been the only ones to provide any sustained production. As the outcrops of the deposits are so poorly exposed, there is always the possibility that careful search may be rewarded by the discovery of other deposits. The outlook is for a moderate copper production from the Pope-Shenon mine for some time to come.

Mines and prospects

There are three mines and several prospects within the quadrangle, but only one of the mines, the Pope-Shenon, is currently active. The others have not been worked for some years and their underground workings are no longer accessible. Except at the Pope-Shenon mine, there is little to add to the information obtained by Ross in his examination of the copper properties some 30 years ago.

Pope-Shenon mine

Location

The Pope-Shenon mine is near the north end of the Lemhi Range, facing westward toward the Salmon Basin and the Salmon River Mountains. It lies in Sec. 9, T. 20 N., R. 22 E., just above the abrupt topographic break that marks
the contact between the Challis volcanics of the foothills and the pre-
Cambrian rocks of the higher range (Pl. III, A). Its position is thus on
the steep westward slope of the range at an altitude of 5,700 to 6,300
feet above sea level or 1,700 feet above the town of Salmon.

The mine is within easy reach of Salmon, the first 4 miles over U. S.
Highway 93, thence over 3½ miles of graded and gravelled road, and finally
over about 3 miles of graded but otherwise unimproved road. The mine is
accessible throughout the year.

History and production

Copper was discovered at the Pope-Shenon mine in the early nineties,
two years after a location had been made for gold. Nothing much was done
about the copper until some 10 or 15 years later. Work then got under way
and in 1908 a small shipment of hand-sorted ore weighing 21 tons was sent
to the smelter at Anaconda, Montana. Another shipment of hand-sorted ore
followed in 1917, but the smelter to which the ore was sent was not learned.
Two years later shipments totalling 360 tons of ore containing 12 per cent
copper were made to smelters, destination again unknown.

The development had in the meantime uncovered a considerable amount of
oxidized ore not adaptable to gravity concentration. This ore prompted the
construction of a chloridizing plant, which was begun in 1919 and placed
in operation in 1920. Because of high operational costs and extraction diffi-
culties, the plant closed in 1921.

In 1922 the mine was leased to W. M. and G. A. Snow, who directed their
attention to the sulfide ore that had been uncovered above the No. 5 level.
They changed the mill to a gravity concentrator, equipped with jigs and
tables and supplemented by a small flotation unit. First shipments of sul-
fide concentrates began late in the year and continued into early 1924.
Mining operations were suspended late in 1923 and the mine was idle for
several years thereafter.

In 1925 the Idaho Porphyry Copper Mining Company acquired a lease and
option on the mine and began to extend the No. 6 adit from mill level, but
after a year or two gave up the lease. In 1927 the mine was reopened by
the Winder-Stillman Copper Company. This company began shipments of con-
centrates the next year and continued to make shipments into 1930, although
mining operations were suspended in 1929. The mine remained inactive through
the early years of the depression and was later lost in default.

The Pope-Shenon mine was relocated in 1937 by Fred Brough, who made
some shipments of hand-sorted ore later that year and during the next. The
low price of copper, however, put an end to mining operations and the mine
was idle from 1938 until leased to L. J. Bills in 1941. Mr. Bills re-
equipped the mill and started small shipments of concentrates to the smelter.
In 1942 the mine reverted to the owners, Fred Brough and Challis Hall.
Since 1942 the mine has been worked off and on by lessors who have made shipments of crude ore and concentrates, the last several years mainly from bodies of oxidized ore uncovered in upper workings of the mine. In 1953 the Centrida Mines, Inc., obtained a lease and, backed by a government loan, began an extensive exploration program, designed to extend the drift on the No. 5 level an additional 150 feet and the one on the No. 6 level another 500 feet, with several thousand feet of lateral diamond drilling from these levels. Drifting on each of the two levels was under way in 1954.

Production data from smelter records show that 154.1 tons of crude ore and 5,074.4 tons of concentrates were shipped from the mine prior to 1943. This total includes 21.7 tons of ore containing 15.48 per cent copper shipped by Langendorf and Company in 1908; 2,606 tons of concentrates averaging about 25 per cent copper shipped by Snow Brothers from 1922 to 1934; 2,094 tons of concentrates also averaging about 25 per cent copper shipped by Winder-Stillman Company from 1928 to 1930; 126.1 tons of crude ore containing approximately 12 per cent copper shipped by Fred Brough in 1937 and 1938; 6.3 tons containing 6.44 per cent copper shipped by Joe Jones in 1939 and 74.4 tons of concentrates averaging about 25 per cent copper shipped by L. J. Bills and associates from 1940 to 1942. As the reported shipments of 1917 and 1918 could not be verified from smelter returns, they are not included in the total. Neither does the total include the copper recovered at the chloridizing plant in 1920 and 1921. Since 1942 the mine has shipped 1,424 tons of crude ore and 15 tons of concentrates containing 215,428 pounds of copper, 739 ounces of silver and 30 ounces of gold. The mine has produced altogether not less than 2,600,000 pounds of copper.

Development

The underground work at the Pepa-Shonon mine has been carried on along six levels numbered consecutively from 100 to 600 beginning with the uppermost level (Fig. 2). No work has been done on the upper three levels for some time, but some rather recent stoping has been carried on above the 400, and work is in progress along the 500 and 600 levels.

When Ross examined the property in 1923, the development had not gone below the 500 level, although the 600 level had been started at mill level and was then in about 40 feet. The 500 level then had about as much work as at the present time, excluding the work underway in 1954. When the writer examined the property in 1942, the 600 adit had been driven and, except for the recent exploratory work including a 150-foot crosscut to establish a diamond drill station in the hanging wall of the broad zone of shearing, had as much work as today. The level then had about 1,755 feet of drifts and crosscuts or as much as the rest of the mine combined. The level was connected by a raise with an intermediate 70 feet above and also with the 500 level 160 feet above. The intermediate level then had 400 feet of drifts. There were altogether more than 3,610 feet of drifts and crosscuts in the mine at that time. On completion of the present exploration program the drifts and crosscuts will total nearly 4,500 feet. The workings complete as of August, 1954, are shown in plan and longitudinal section in Figure 2.
Geologic setting

The country rock at the Pope-Shenon mine is a dark-green, impure quartzite with a notable abundance of chlorite as well as considerable amounts of biotite and sericite. It is generally darker and shows more of these minerals along or near the zones of shearing than it does some distance away. Some of the sheared rock, however, contains an exceptional abundance of sericite which has given the rock a bleached appearance. The bedding of the rock has generally been obscured by a rather pronounced schistosity, more prominent near or along the zones of shearing than elsewhere, but can generally be distinguished on close examination.

At several places underground the quartzitic rock is cut by small dikes, all but one so highly decomposed that compositions are indeterminate. The rock in the one that can be identified is from a dike cut by the main 600 crosscut and its character is such as to indicate that it served as a feeder to flows or ignimbrites in the Challis volcanics.

The mine is on the west flank of the broad Lamo Range syncline and the beds underground strike N. 150°-200° E. and dip about 10°, in one place as much as 35° E. The most conspicuous structural feature underground, however, is the cleavage which strikes a few degrees west of north and dips 55° W. to 70° W., essentially normal to the bedding. This cleavage apparently controls the pitch of the ore shoots as well as the way the rock breaks when blasted. This cleavage is the one that conforms to the regional schistosity and is not to be confused with the one restricted to and parallel to the zones of shearing.

Zones of shearing

The mine is along a broad multiple zone of shearing made up of smaller, roughly parallel, overlapping and branching shears. Until the work was carried to the 600 level, only one of these zones was known to exist, but the deeper, more extensive work has revealed three important zones of shearing and mineralization. The third was discovered while driving the crosscut for the new diamond drill station in what was presumed to be the hanging wall of the major zone of shearing. This newly discovered mineralized zone lies about 150 feet north of the two previously known zones. All three are apparently components of a major zone of shearing nearly 200 feet wide composed of these individual or branching shears a few feet to as much as 20 feet wide. This major zone of weakness is now being more fully explored. It is possible that other shears may be found and that the general zone of shearing may be even more extensive than is now indicated. Because of the strength of the shearing the zone is likely to persist for some thousands of feet, but individual shears are likely to die after a few hundred feet, their place taken by overlapping, more or less parallel shears. The general zone of shearing has an easterly trend and a steep northerly dip, but the individual shears show local departure from this trend.

The most southerly of the three shear zones exposed on the 600 level is the most important so far uncovered and appears on all levels of the mine.
(Fig. 2), having been stoped more or less continuously to the surface. For some distance along the 600 level the trend is about N. 70°-80° E., but it eventually changes to due east and then to east-southeast. The shearing along the zone is not altogether continuous, but appears to be made up of several closely overlapping shears. Just beyond the raise to the 500 level the shearing passes into the side of the drift and is lost, but another more prominent shear enters the drift and crosses 20 feet to the south. This shear appears to die out along the strike, but another appears in the drift just ahead on the other side of a transverse fault of unknown but probably small magnitude (Fig. 2). This shear zone continues on as far as the work has gone, but a short distance beyond the fault its trend changes from N. 70°-80° E. to directly east and then to S. 70° E. The trend continues in a south-easterly direction for only a short distance. Then the shearing swings back to the northeast and it continues to alternate between east-northeast and east-southeast until lost in the side of the drift, as the drift continues southeast and the shearing curves to a more easterly direction. The drift is continued southeast along some minor fractures which lead to a fault with prominent walls that dip 72° SW. When the drift uncovers another more prominent fault that strikes east-northeast and dips 80° S., it changes its course to follow the new fault. Because of the heavy ground (8 to 14 inches of gouge) the drift was directed into the hanging wall of the fault zone. The drift is now some distance south of the main zone of shearing, but is being continued along the fault for 400 or 500 feet so that the extension of the shear zone can be conveniently probed by the diamond drill. The change in trend of the shear zone from east-northeast to east and east-southeast is also shown on the Intermediate level and is partly revealed on the 500, where the zone appears to split before the main branch bears in a more easterly direction (Fig. 2). Where the strike of the shear zone is in the northeast direction; the dip is about 70° W. As the strike swings to the east and east-southeast, the dip steepens and in the east part of the mine is 80° N. to nearly vertical. This increase in dip is reflected on the plan of the mine workings by the closer spacing of the levels.

The middle shear zone was cut on the 600 crosscut about 30 feet short of the south shear zone. As the south shear zone showed little sign of mineralization at that point, the work was carried east-northeast along what appeared to be the more promising middle zone (then recognized as the north zone). At 80 feet the middle shear zone was cut by a narrow oblique shear that extended S. 70° E. into the south shear zone. The middle shear zone continued its east-northerly course beyond the intersecting shear and maintained this course until lost in the side of the drift about 260 feet ahead (Fig. 3). During this distance the strike of the shear zone ranged between N. 65° E. and N. 85° E. and the dip between 65° N. and 80° N. For most of its exposed length the shear zone is 6 to 8 feet wide. This middle zone of shearing does not appear in the hanging wall crosscut on the 500 level (Fig. 3) and thus must weaken and die out a short distance above the 600 level.

The intersecting shear that links the middle shear with the south shear has an exposed length of about 40 feet. On reaching the south shear zone it appears to curve and become a part of that zone, although it could continue across. This oblique zone apparently crosses the middle shear zone traced
northwest and continues on to the main crosscut. The shearing along this zone is neither so broad nor so pronounced as that along the other zones and is scarcely more than 2½ feet across.

The north shear zone, recently uncovered near the face of the diamond drill crosscut, is roughly parallel to and about 150 feet north of the middle zone of shearing. The zone shows about 5 feet of well-defined shearing with another 5 feet of less conspicuous sheared rock alongside. This zone apparently strikes about N. 75° E. and dips 70° N.

The individual shear zones are structurally complex. As pointed out earlier, the shear zones are made up for the most part of two sets of fractures, the more prominent set parallel to the shearing and the other set oblique thereto, each set marked by bands and stringers of ore minerals. Those parallel to the shearing change their trend with it and hence alternate between east-northeast and east-southeast. The oblique fractures make angles of about 40° with the shear fractures and bear always in a more southerly direction. The fractures parallel to the shearing always dip in a northerly direction, generally at angles of 70° to 80°. The oblique fractures dip southwest at about 70°. The zones of shearing are further complicated by the entrance of oblique laterals which, after they enter the zone, change their direction to conform with the shearing.

The fractures parallel to the shearing are the most prominent. There may be several of them along the shear zone, but those along the walls are generally the most conspicuous. Where the prominent fractures are along both walls, the oblique fractures generally extend across from one wall to the other. If along one wall, the oblique fractures may extend out to one side or to the other. If the main fractures follow the center of the shearing, then oblique fractures may extend out on both sides. Fractures parallel to the shearing are not necessarily persistent, but may die out and be replaced by others that overlap and carry on the shearing. Prominent fractures may appear on one wall and then within a short distance shift to the other wall. Generally minor, parallel slips appear at random throughout the shear zone.

The oblique or diagonal fractures commonly persist to the walls of the shear zone and then fade away. Most of them are breaks of minor magnitude, but some become strong enough to influence the direction of shearing and, as in the eastern part of the mine, may for a short distance control the direction of the shear zone itself. Those of minor magnitude may be a few inches to several feet long. Those of greater magnitude may be as long as 20 feet and may have a marked influence on the shape and size of the ore body, in places producing marked bulges in the hanging wall. Most of the oblique fractures of minor magnitude join the fractures parallel to the shearing at sharp angles, but the larger ones that come in from the walls curve and become a part of the system of fractures parallel to the shearing.

Cross faults

There are some faults that cross the zones of shearing, most of them small but some of appreciable magnitude (Fig. 2). The largest strikes about N. 80° W., dips 60°-65° SW., and passes diagonally through the mine. It is
exposed far back on the 500 level and at about the mid-part of the 600. It is marked by 12 to 24 inches of gowy material, reddish-colored on the 500 level, but contains no ore. The fault has produced no serious offsets. Reference has already been made to the southeasterly-extending fault followed some distance by the drift far back on the 600 level and to the east-northeast-erly fault along which the drifting was being directed in 1954.

Some minor cross fractures trend about N. 25° E. and dip about 60° W. These also cut the shear zones. They contain no ore, but have served as channels for descending surface waters and are bordered by zones of surficial alteration.

Mineralogy

The oxidized ore, found in such notable abundance in the upper levels of the mine and more sparingly in the extreme western parts of the ore shoots on lower levels, is composed largely of malachite with considerable azurite and in places cuprite. Native copper is also reported.

The primary ore consists largely of chalcopyrite with subordinate pyrite and a little microscopic bornite, but the mineral of greatest interest is the delafossite, which appears on all levels of the mine and along all three shear zones on the 600 level. The delafossite is accompanied by some magnetite and everywhere shows the distinctive rhythmic diffusion banding.

Some quartz is scattered along the shear zones, but the chief gangue is the siliceous country rock with its local concentration of biotite, chlorite, sericite, and subordinate muscovite and epidote.

Much of the sulfide ore, except on the lower levels of the mine, shows incipient oxidation, and that showing incipient oxidation usually also contains minor amounts of supergene chalcocite, ordinarily visible only under the microscope. In places, however, the chalcocite is more abundant and forms occasional small pods, generally crusty by malachite and azurite.

Occurrence and distribution of the ore

The occurrence and distribution of the ore along the zones of sheared and altered rock have already come in for considerable discussion. Although much of the ore occurs as a replacement of the more or less schistose rock, the replacement has been directed from permeable fractures, principally those parallel and oblique to the shearing. Those parallel to the shearing have provided the longest and most permeable and persistent channels, have directed much of the replacement, and hence have localized most of the ore. Thus the ore occurs as irregular bands a few inches to several feet thick along the one or the other of the walls of the shear zone with irregular seams and stringers extending out obliquely toward the opposite wall. These seams and stringers are generally less than an inch thick, but they compose an essential part of the milling ore.
The prominent diagonal fractures that enter the zones of shearing and curve to conform with the shearing also have had a marked influence in localizing the ore. Although the fractures may extend into the walls for considerable distances, the ore is mostly along the curve or in the fracture just before it curves to conform with the shearing. As these fractures dip steeply southwest, the ore rises upward into the hanging wall. These may appear to reverse the direction of dip of the mineralized zone, though actually producing a large bulge in the hanging wall. Because of this relation, the last stop on the 600 level is inclined to the south instead of to the north, and the stope at the east end of the Intermediate level stands nearly vertical. The hanging wall in places dips steeply south though the footwall continues to dip toward the north. The junction of these southwesterly-dipping lateral fractures with the main zone of shearing is reported to determine the position and pitch of some of the best ore bodies.

The dolafosite is widely distributed along the zones of shearing, but its distribution and occurrence are largely independent of the sulfides. Its curved and concentric bands are usually best displayed along the footwall of the shear zones, but they may also appear in the hanging wall. Apparently the mineral has infused into the rock from joint and other fracture planes.

The ore has been little disturbed by post-mineral faulting. In places a little gouge may appear along the walls, but nowhere in conspicuous quantities. Because of the absence of appreciable post-mineral movement, the ore is firm and stopes remain open without the aid of timbers.

Ore shoots

The ore is concentrated into shoots of moderate size whose extent along the south shear zone is shown by the distribution of the stopes in the longitudinal section of the Mine (Fig. 2). The main ore shoot has been stopped for about 270 feet along the 500 level, for 90 and 160 feet along the Intermediate, and for 270 feet along the 600, divided between two stopes, one about 210 feet long and the other 90 feet long. These stopes extend from the 600 level up to the 400 level, a vertical distance of more than 400 feet. Ore remains in the floor of the 600 level and in the bottom of a 40-foot winze below the 600. Most of the ore body is just under 10 feet thick, but in places it reaches a maximum of 20 feet. The shoot apparently pitches steeply west at about the same angle as the cleavage.

A small stope about 80 feet long and 20 feet high east of the main stopewhich on the 600 level offers some proof that other ore shoots may occur along the main zone of shearing.

Smaller ore shoots also occur along the middle zone of shearing on the 600 level, but have not been fully explored. A stope about 30 feet long, 25 feet high, and 4 feet wide has been made on the shoot near the west end of the drift. Just east of this stope is another about 50 feet long and 10 to 15 feet high. A third stope about 35 feet long and 30 to 40 feet high lies just beyond the second. As the middle zone of shearing has not been recognized on the 500 level, it is doubtful that the shoots extend much higher than the top.
of the present stops. The extensions of these shoots below the 600 level should be explored.

The ore body along the north zone of shearing has not yet been explored, but the diamond drill crosscut shows about 5 feet of sheared rock well impregnated with chalcopyrite and another 5 feet in the footwall with sulfide stringers and minor amounts of dolafosite.

The factors responsible for the distribution and localization of the ore shoots are not fully understood. The distribution of the workable bodies of ore apparently conforms with the distribution and spacing of originally permeable fractures which permitted introduction of the ore-bearing fluids. These more permeable zones appear to have been where the shearing was most intense and particularly where it had induced a prominent lode schistosity. The fluids took particular advantage of the fractures parallel and oblique to the shearing and schistosity. The spacing of these fractures as well as of the oblique laterals that enter the shear zone from the outside apparently has had much to do with controlling the amount of ore as well as the dimensions of the ore bodies.

The factors that control the location of these structurally favorable zones remain obscure. Horizontal shearing stresses may account for the shear and oblique fractures, and variations in the strike and dip of the shear zones may have considerable bearing on the localization of the more permeable zones and hence the ore shoots. In the upper levels of the mine the exposed ore is only along the shearing of east-northeast trend, but on the 600 level and on the Intermediate, the ore is along the east-southeast shears as well. The smaller shoots appear to favor the shearing of east-northeastly trend and terminate as the shearing changes to the southeast. Undoubtedly, the movement along these curved zones of shearing has provided the necessary openings for the circulation of the mineralizing fluids and localization of ore, but until more is known of the characteristics of the general shearing, the problem of ore-shoot control must remain largely unsolved.

Tenor of the ore

Most of the ore mined carried from 2½ to 6 per cent copper, but there were small bodies that contained 10 to 20 per cent copper, few of them large enough to be mined separately. By careful hand sorting crude ore containing 10 to 15 per cent copper has been shipped to the smelters. Mill concentrates usually contained about 35 per cent copper. In both the crude ore and concentrates, the precious metal content has been negligible. Crude ore has generally contained less than an ounce of silver and generally less than 0.01 ounce of gold per ton, and the concentrates have carried not more than 1.6 ounces of silver nor more than 0.1 ounce of gold per ton.

Old sampling records of the American Smelting and Refining Company and of the International Smelting and Refining Company show that a sample across 4 feet in the stope above the 400 level carried 8.13 per cent copper, 1.0 ounce of silver, and 0.08 ounce of gold per ton. More recent sampling around the edge of the stope shows much values as 12 per cent copper across 2 feet, 4.32 per cent copper across 2 feet, 3.58 per cent copper across 3 feet, 3.5.
per cent copper across 4 feet, 8.5 per cent copper across 4 feet, and
9.24 per cent copper across 3 feet. Some 650 tons of crude ore from the
stopes are reported to have contained from 10 to 11.2 per cent copper.

The old sampling records also show that six samples taken along the
east side of the stope between the Intermediate and 600 levels contained
16.4 per cent copper across a width of 2½ feet, 20.5 per cent copper across
2½ feet, 4 per cent copper across 4 feet, 5.5 per cent copper across 6 feet,
4.8 per cent copper across 3 feet, and 6 per cent across 5 feet. Another
sample from the west side of the same stope showed 4.36 per cent copper and
0.3 ounce of silver per ton across 4½ feet.

One sample of ore at the far east end of the Intermediate level con-
tained 15.09 per cent copper, 1.2 ounces of silver, and 0.01 ounce of gold
per ton across 5½ feet. In a small stope just above, 4 feet of the ore
carried 2.16 per cent copper, 0.5 ounce of silver, and 0.015 ounce of gold
per ton. Some 200 tons of crude ore shipped from the stope is reported to
have averaged about 12 per cent copper.

Two samples, each across 3 feet, along the east edge of the small stope
far back on the 600 level showed 10.65 and 7.55 per cent copper respectively.
Three samples at the ends of a small stope west of the main stope on the 600
level showed 3.37 per cent copper across 2.5 feet, 10.7 per cent copper across
2 feet, and 6.55 per cent copper across 2 feet.

Six samples along the middle zone of shearing on the 600 level, all but
one in the first stope, showed results as follows: (1) 8.24 per cent copper
across 2 feet of ore in the drift 50 feet west of the stope; (2) 18.35 per
cent copper across 2.7 feet of ore at the west edge of the stope; (3) 11.30
per cent copper across 2.5 feet of ore; (4) 9.17 per cent copper across 2.5
feet; (5) 12.37 per cent copper across 2 feet; and (6) 5.78 per cent copper
across 3 feet of ore at the east edge of the stope.

Outlook

Some ore still remains in the stopes, but the future of the mine will
depend on the development of ore at greater depth and along other parts of
the broad zone of shearing. The present exploration should do much to prove
the extent of the mineralization and the ultimate fate of the mine. Inasmuch
as the deposits are along deep zones of shearing, the ore can be expected
to have a vertical range considerably greater than that yet reached in min-
ing. It should be borne in mind that along such a broad, complicated zone of
shearing individual shears may lose strength and terminate on strike or dip
but that the general shearing may be carried on laterally and at depth by
overlapping shears. Consequently, the ore may transfer from one shear to
another as the individual shear zones weaken or gain strength, and the ore
which branches along one shear zone may continue its downward course along
another.
Harmony mine

Location

The Harmony mine is near the head of Withington Creek high on the steep east slope of the Lemhi Range. According to the Annual Report of the State Inspector of Mines for 1930, the property comprises 7 patented and 17 unpatented claims in Secs. 2 and 3, T. 19 N., R. 22 E. and Secs. 34 and 35, T. 20 N., R. 22 E. The mill and lower camp are on the creek at an altitude of about 7,000 feet, but the lowest mine workings are about 600 feet higher and the mine buildings and the portal of the formerly main haulage level about 1,200 feet vertically above the lower camp. Other workings extend almost to the summit of the range.

The mine is reached from Baker over a road that follows Withington Creek to the lower camp. The road is graded and maintained from Baker to the creek crossing about 1½ miles within the borders of the quadrangle and is unimproved from that point on. The road is no longer usable by car after it leaves the main fork of the creek about 2½ miles below the camp. The mine and camp were formerly connected by aerial tram.

History and production

Just when copper was discovered on the property is not known, but the date is probably prior to the present century. Little development work was done, however, until the Harmony Mines Company acquired the property in 1916. The company shipped crude ore for several years, then in 1919 installed a concentrating mill equipped with crushers, classifiers, and tables. Later the mill was converted to flotation. After the completion of the mill there was a steady production of concentrates except during 1921, when operations were temporarily suspended because of the low price of copper. Work was resumed in 1922 and continued without interruption through 1925. By 1924 much of the ore above the operating level had been stoped and the output of copper that year was only about one seventh of what it had been in 1923. Development work continued, but during the next year was transferred to a 1,200 cross-cut driven to intersect the ore at a depth of 600 feet below the former lowest level of the mine. The mill remained idle during 1925 and 1926 while the search for ore went on. In 1926 nearly a thousand feet of crosscuts and drifts were completed on the lower level. The next year new ore bins and a sorting plant were added to the mill and the moving of the aerial tram from the old operating level to the new level was completed. A small tonnage of concentrates was produced during the year and shipped to the smelter. After about three months of activity, the operations stopped, pending further financing. Some development work was carried on in 1928 and the mill was operated for a short time, but the company put most of its activities into the raising of funds. In 1929 the company installed a 450-H.P. Diesel electric plant at Baker and an 8-mile transmission line to the mine. New milling and mining equipment were added and the mine became one of the most completely equipped in the county. The mill operated about 3 months during 1930, apparently on ore mined by lessees. Lessees also carried on some work in 1931, but in 1932 the generator was dismantled and removed and all mining operations were suspended. The mine has since been inactive.
The production at the Harmony mine has been considerable. Records show that from 1916 to 1922 inclusive, the mine shipped 842 tons of crude ore and 1,502 tons of concentrates. The crude ore contained 132,597 pounds of copper, 0.68 ounce of gold, and 130 ounces of silver. The concentrates, on the other hand, contained 621,655 pounds of copper, 0.915 ounce of gold and 793 ounces of silver. These concentrates were obtained from 16,408 tons of milling ore. The smelter returns on 42 shipments of concentrates from January 4 to December 10, 1923, showed an average copper content of 22.7 per cent, 1.58 ounces of silver, and 0.01 ounce of gold per ton.

Development

The property has several groups of workings, but most of the work has been along four levels on the Continental claim, the first three at roughly hundred foot intervals, the fourth, 500 feet vertically below the third. All workings are now inaccessible, but Ross III reports that in 1923 the 100 level had a crosscut 265 feet long connecting with a drift 160 feet long and a stope above the drift; that the 200 level, 78 feet below the 100, had 1,000 feet of drifts and crosscuts; and that the 300 level, 95 feet vertically below the portal of the 200 and then the main haulage level of the mine, had more than 2,500 feet of drifts and crosscuts. All levels were connected by raises and stopes. The lowest level of the mine, opened during the middle and late twenties, is reported to have more than 2,650 feet of crosscuts and drifts.

Other workings include the Anderson and Income and several small shafts and cuts. The Anderson workings are about 2,000 feet west of the 300 level of the main mine and about 425 feet vertically above. These workings comprise about 500 feet of drifts and crosscuts with stopes to the surface. The Swift adit on the Income group is at about the same level as the Anderson workings but is about 1,100 feet beyond or about 3,000 feet southeast of the portal of the 300 level of the main mine. The Swift adit is about 900 feet long. Some shallow shafts and short adits lie above.

Geologic features

Some half-dozen mineralized zones have been found on the property, all in the rather dark-colored quartzitic rocks which locally form the lower east flank of the Lomhi Range syncline. The schistose cleavage is not so pronounced as at the Pope-Shenon and the bedding is more easily distinguished. The beds strike mainly N. 30° W. and dip less than 15° SW.

All the mineralized zones trend in northwesterly direction, not quite parallel to each other, and consequently some of them come together and continue on as single zones of shearing. Two of these zones merge at the main
mine. Each is mineralized. One of them is known as the Contention, the
other as the Leappyer. The mineralized shear zones also merge at the
Anderson workings. Several non-branching or merging shear zones are known
on the Income and other claims. The bulk of the production has come from
the lodes along the Contention and Leappyer zones of shearing.

Instead of merged zones, the Contention and Leappyer may represent
branches of a split zone of shearing. Whether the junction marks the merg-
ing of two independent shear zones or the branches of a split shear zone is
immaterial so far as the occurrence of the ore is concerned. The two joining
shear zones show considerable variation in strike, but the average strike
of the Contention is N. 50° W. and of the Leappyer, N. 40° W. Both also show
variation in dip, but the average for both is about 65° SW. In places the
dip is actually quite flat. Such relatively flat parts are reported to have
contained more and richer ore than the intervening steeper parts. The
two zones diverge toward the northwest.

The Contention was not so highly mineralized as the Leappyer, but most
of the ore was near the common intersection, with the ore shoot raking ap-
proximately parallel to the line of junction. Most of the ore was on the
northwest side of the line and was followed on the Leappyer for 230 feet on
the 300 level of the mine. The ore body along this level measured from 6
to 10 feet thick, but in stopes above was somewhat thicker. The ore on this
level was unoxidised, but some oxidation was evident on and above the 200
level. Sulfide minerals predominated in most of the ore that was mined.
According to some of the Annual Reports of the State Inspector of Mines pub-
lished just after the mid-twenties, a good showing of ore was uncovered in the
workings 600 feet below the 300 level at a point about 950 feet from the portal
but nothing was said about the size and richness of the ore body. Appar-
etly the body failed to sustain much production, otherwise the mine would
not have ceased operations so soon after it had been completely re-equipped.
Several unmineralized, gouge-filled slits are exposed in the upper workings
of the mine. Two of them are reported to offset one of the mineralized zones
a few feet.

Conditions in the Anderson workings are reported to be similar to those
in the main mine. Two zones of shearing merge at a small angle but, unlike
the Contention and Leappyer, these diverge to the southeast instead of to
the northwest. The zone with the most development strikes N. 65° W. and dips
60°-70° SW. The other strikes about N. 55° W. and dips 50° SW. Ore is found
near their junction. The zone with the more westerly strike is exposed in the
face of a cliff about 90 feet vertically above the portal of the adit. The
lode contains sulfides on the surface. The other lode has been stope about
100 feet to the surface.

Other mineralized shear zones include one known as the "big ledge" which
has been uncovered in shallow trenches and which lies above the Anderson work-
ings just over the crest of the Lemhi Range. This zone strikes N. 55° W. and
dips 55° SW. The shearing is strong, but the only noticeable minerals are
chlorite and magnetite, the latter with a little specular hematite. Another
zone of shearing lies between the "big ledge" and the main mine. Its strike
is about N. 65° W. and dip, 70° SW. The only mineral reported is quartz. The zone explored by the Swift adit on the income group has a vertical to steep southerly dip. The work reveals no sulfides, but copper is reported about 900 feet southeast of the portal of the adit, perhaps on a continuation of this line.

Tormey mine

Location

The Tormey mine is on the eastern slope of the Salmon River Mountains near the crest of the high ridge north of Perreau Creek. The mine and some holdings to the north are all within Sec. 33, T. 21 N., R. 21 E. at an altitude of about 6,000 feet. The mine is about 1,000 feet above Perreau Creek and the holdings on the north are on a small tributary of Perreau Creek. The property is about 5 miles from U. S. Highway 93 and may be reached either by road from Perreau Creek and thence by steep trail or by a road which follows the ridge north of Perreau Creek.

History and production

The mine was located by John Tormey many years ago and much of the development was done by him prior to the twenties. First shipments of hand-sorted ore were made in 1918, with additional shipments in 1919 and 1920. In 1922 the mine was leased to W. M. and G. A. Snow and R. E. Wickham, who made some shipments of hand-sorted ore, but gave much of their time during the summer of 1923 to the construction of a small concentrating plant on Perreau Creek and the installation of an aerial tram to convey the ore from the mine to the mill. Shipments of concentrates began in 1924 and continued into the early months of 1925. Operations were then suspended and the lease surrendered. Since then the mine appears to have been inactive.

The production has not been large. The shipments of hand-sorted ore from 1918 to 1920 totaled 187 tons containing 70,126 pounds of copper, 0.56 ounce of gold, and 116 ounces of silver. The shipment of hand-sorted ore in 1922 totaled 26 tons containing 10,036 pounds of copper.

Development

Workings are now inaccessible but when visited by Ross 12/ in 1923 com-


prised two small adits and some cuts. The main workings are in an adit drift, the Greenhorn, then about 385 feet long and joined by several short crosscuts and stopes. The other adit, a crosscut known as the Rattlesnake, was about 300 feet long and was joined by two short drifts. This latter adit is about one-fourth mile west of the Greenhorn and at a somewhat higher level. Most of the work in the twenties was confined to the Greenhorn.
Geologic features

Several zones of shearing are known on the property, but only two of them have received much attention and only one of them has been appreciably productive. These are in the dark, finely micaceous quartzites on the east flank of the Salmon River Mountain anticline. The shear zones strike northwest. One dips steeply northeast, the other southwest.

The Greenhorn adit is along the most productive of the mineralized shear zones. Near the portal the shearing strikes about N. 30° W., but farther it swings gradually around to about N. 70° W., the dip remaining at about 55° NE. The first 270 feet of the shear zone along the adit show few signs of mineralization. From there on to the face are two small ore shoots, each about 45 feet long and separated by 30 feet of lean rock with scattered small bunches of ore. The ore bodies are reported to have been several feet wide, with milling ore in places over a considerably greater width. The ore consisted of chalcopyrite and pyrite with trivial amounts of secondary chalcopyrite. A little oxidized ore occurred on or near the surface. The ore shoots were stopped, presumably to the surface.

The Rattlesnake adit, which is driven in a general north-northeasterly direction, cuts a shear zone about 210 feet from the portal. This shear zone strikes about N. 66° W. and dips 55° SW. A 20-foot drift along the zone revealed a band of chalcopyrite about a foot wide.

Porterfield prospect

The Porterfield prospect is on the west side of a branch of Withington Creek on the lower east slope of the Lemhi Range, at an altitude of about 6,800 feet. It is practically on the line separating Secs. 26 and 27 in T. 20 N., R. 22 E.

When the prospect was examined by Ross in 1923, the development comprised an adit about 190 feet long with less extensive workings on the slope above. Some later work has been done on the property but the extent was not learned.

The prospect is not far from the contact between the pre-Cambrian quartzitic rock and the Challis volcanics nor from some small bodies of Miocene dacite porphyry. The immediate country rock is dark greenish, impure quartzite whose beds strike about N. 75° W. and dip 25° SW. The last 50 feet of the main adit is along a slip that strikes about N. 85° W. and dips 55° SW. The rock along this slip was somewhat brecciated and altered and contained some malachite and limonite.

Other prospects

Deposits also occur elsewhere in the area but have received comparatively little attention and little is known about them. A number of old cuts are visible on the west slope of the Lemhi Range in Secs. 31 and 32, T. 20 N., R. 22 E., at altitudes of about 5,500 and 6,500 feet. Some old cuts and caved adits are also known here and there on the Salmon River Mountain slope, but these reveal little of interest. Other prospects of somewhat greater promise
occur outside the quadrangle in both the Salmon River Mountains and the Lemhi Range.

LEAD DEPOSITS

History and production

Not much is known historically about the widely scattered lead deposits in the Salmon area. One of these deposits just off the northeast corner of the quadrangle was known during the early days and at one time was equipped with a mill, but nothing was learned of the discovery nor of the extent of the early production. The deposit has continued to hold some interest through the years but not enough to induce much expenditure for exploration and development. Other lead deposits were known about the same time, but some were not discovered until much later. Among the latter is one within the boundaries of the quadrangle which was explored and developed during the earlier twenties, making one and perhaps the only shipment in 1923. Another deposit several miles south of the quadrangle was discovered about 15 years ago. Work on this deposit has been carried on more or less continuously ever since its discovery. All others have been inactive for more than 30 years.

None of the lead properties has been an important producer. Probably not one has produced more than a few tons.

Character of the deposits

These deposits are chiefly replacements along zones of sheared and fractured rock. They comprise irregular, more or less tabular veins or lodes and less definitely shaped, disseminated replacement bodies. In addition to the lead these bodies also contain appreciable amounts of silver but only trivial amounts of copper or other metals.

Unlike other lead deposits of the general region, these are not associated with siderite or conspicuous amounts of tetrahedrite and are not accompanied by much pyrite sphalerite. They are not, therefore, related to the siderite-tetrahedrite-galena veins of the Wood River type. Like the copper deposits they make up a rather distinctive group of their own, allied perhaps to the lead-silver replacement deposits in Paleozoic limestones in the Leadore-Gilmore areas. They show evidence of formation under less deep-seated conditions and at somewhat lower temperatures than existed when the copper deposits were formed.

Geographic and geologic distribution

These lead deposits are not restricted to any one district or to any general zone of mineralization, but are scattered sporadically over a wide region, apparently independent of other sites or zones of mineralization. The only deposits within the quadrangle are in the Salmon River Mountains several miles northwest of Salmon in what is known locally as the Silvorton district, named for the principal prospect. The deposits are otherwise in the Eureka mining district. The deposit just off the northeast corner of the
quadrangle is in the Carmen Creek mining district. It forms what is known as the "Iron Dike" and is not near any other deposits in the district. This deposit is on the steep lower part of the Beaverhead Range directly back of the foothills carved in the Carmen formation. Other deposits are known a few miles down the Salmon River where the old rocks appear beyond the cover of Carmen beds. There the deposits are close to the highway and may be identified by the coal dumps visible from the highway. The deposits south of the quadrangle are on Rattlesnake Creek several miles west of the Salmon River. They comprise the deposits at the Twin Peaks mine.

Although unrestricted in their geographic distribution, the lead deposits are limited in their geologic distribution to the pre-Cambrian quartzitic rocks. They are not known to occur in the Challis volcanics, but probably could be found in the Paleozoic rocks were such rocks present in or near the quadrangle. So far as is known, they are not closely associated with any bodies of intrusive igneous rock.

Structural relations

As these deposits, and especially those outside the quadrangle, received little more than a cursory examination, there is much that is not known about their structural characteristics. Their structural trends apparently do not accord with those of either the gold or copper deposits but they appear to strike in an east-northeast or in the complementary northwest directions. Within the quadrangle the trend is about N. 80° E., but just outside it may be nearer N. 65° E. or N. 70° E. Not enough data are yet available to establish any definite trend or pattern.

The shear or fracture zones do not reflect the intensive deformation that characterizes the shearing along the zones that contain the copper deposits. There is no schistosity parallel to the shearing. At some places the fracturing is relatively weak and the mineralization has taken advantage of minor bedding slips in thinly bedded, argillaceous rocks.

Mineralogy

These lead deposits are characterized by a comparatively simple mineralogy. The primary ore contains a relative abundance of galena but only meager amounts of pyrite and little chalcopyrite or sphalerite. These sulfides are in some places accompanied by an abundant gangue composed largely of quartz, in part chaledonic, along with variable but generally small amounts of calcite. They may also occur as replacements of the altered wall rock, largely unaccompanied by quartz or calcite. Near the surface the galena shows various stages of oxidation to anglesite and cerussite. Limonite invariably appears among the oxidation products, which in some places also include small scattered patches of malachite.

The galena is generally fine or moderately fine grained. It is apparently argentiferous and supplies whatever silver there may be in these deposits. The galena may occur as irregular seams and bunches along the zones of fissures or fractures or may be distributed as disseminated grains through broad zones of altered rock. Little is known of the extent or distribution of the ore or of the factors in control of the distribution of the ore.
The rock in and bordering the mineralized zones is more or less conspicuously altered. Along some zones the rock is somewhat bleached and presumably contains considerable amounts of sericite. At some places it has been extensively chloritized and in other places extensively silicified.

Age and genesis

These lead deposits are known to be younger than the copper deposits. Should they be younger than the Paleozoic rocks, which seems likely from their mineralogic resemblance to the replacement deposits in Paleozoic limestones in the nearby region, they are probably the product of a metallizing epoch of early Tertiary time. Although they cannot as yet be correlated directly with early Tertiary igneous activity, they probably had their source in the basic subcrost and were formed by ore-bearing fluids which ascended along deeply extending fractures formed during the Laramide orogeny or later.

Outlook

No considerable amounts of ore have been found in any of these deposits. Mineralization appears to have been weak and lends little encouragement to further exploration. The disseminated deposits may offer the most promise, provided bodies of this low-grade ore can be found of such size as to permit large-scale, low-cost mining operations.

Mines and prospects

Brief descriptions will be given two of the lead properties: the Silverton within the quadrangle and the Iron Dike, just outside the quadrangle. The others have not been sufficiently studied.

Silverton prospect

The Silverton prospect is several miles northwest of Salmon, a short distance northeast of the old road to Leesburg. It lies within Sec. 27, T. 22 N., R. 21 E., at an altitude of about 5,800 feet. The workings are now inaccessible but include several cuts and adits. The principal one is an adit about 450 feet long with a raise to the surface. This is the adit and raise from which a shipment of lead-silver ore was made in 1923.


The lead ore is along a shear zone that cuts through beds of tilted, shaly quartzites of pre-Cambrian age, not far from the large body of quartz monzonite. This shear zone strikes N. 80°-85° E. and dips steeply north. The rock along the zone is somewhat altered and in places contains parallel seams of quartz, each a few inches thick and aligned in the direction of the shearing. Some of the quartz is chalcedonic. Calcite is abundant along parts of the shear zone. The sulfides are most conspicuous near the raise and especially up the raise near the surface. Galena is the only sulfide readily
detected. It is rather fine-grained, occurs in small bunches, and usually shows some alteration to cerussite and other oxidized products. All amounts of oxidized copper minerals are also present in some of the ore, perhaps derived from sparsely distributed chalcopyrite or tetrahedrite.

Iron Dike

The Iron Dike is on the south fork of Carmen Creek in Secs. 5 and 8, T. 22 N., R. 23 E., just off the northeast edge of the quadrangle. It extends from creek level up the steep slope of the Beaverhead Range for a thousand feet or more. The property is an old one that apparently was abandoned and then relocated in August, 1943. The development comprises several old adits near the base of the range and some recent cuts and trenches on the slope above. Remains of an old mill may be seen on the property.

The Iron Dike is a broad zone of more or less extensively fractured and altered quartzite rock with local zones of intense silicification in which occur rather widely disseminated grains of galena and fewer and smaller grains of pyrite. This general zone of alteration is some hundreds of feet across and extends up the steep mountain slope for several thousand feet. The zones of intensely silicified rock measure up to several tons of feet across. They mark the zones of most extensive fracturing. These zones appear to trend in a general northeasterly direction, but they are without well-defined boundaries. The disseminated galena is not uniformly nor persistently distributed along these silicified zones. Erosion has in general kept pace with oxidation and the galena appears in or just under the cuttop, which otherwise is distinguishable by small scattered patches of limonite. The disseminated galena forms bodies of low-grade ore, possibly containing up to 2 per cent lead. Any successful operations must depend on the development of bodies of such size as can be mined by large-scale, low-cost methods.

RADIOACTIVE MINERAL DEPOSITS

The area in and around the Salmon quadrangle has attracted seekers of radioactive mineral deposits. The efforts of those with the Geiger counter had not yet been rewarmed at the time this study was made although deposits of some promise have been located in the surrounding region. It is reported that some of the lead deposits several miles northwest of Salmon excited the Geiger counter but, so far known, no substantial quantity of radioactive material has been found.

Those in search of radioactive deposits would do well to ignore the lake-bed areas and perhaps, too, the Challis volcanics and to devote their time to the areas of pre-Cambrian rocks. Should radioactive minerals be present, they would most likely occur in these older rocks, particularly along zones of faulting. There is a possibility that the rock in and around the bodies of granitic rock in the northwest part of the quadrangle might contain small bodies of monazite like those between North Park and Shoup in the northern part of the county 14/. Such deposits, if present would have doubt-

ful commercial value because of the present lack of markets for the monasite. The best bet would be to search the areas of pre-Cambrian rock for possible uranium mineralization.

COAL

History and production

The presence of coal beds in the Salmon quadrangle has been known since the early days when some of the beds were worked to supply local needs before the arrival of the railroad in Salmon. Local coal could not compete successfully with coal by rail from Wyoming and other points, and the mines within the quadrangle were all but abandoned. After the removal of the railroad in 1939, coal continued to come in by truck. When gasoline and diesel fuel were in short supply during the war years and outside coal was not obtainable, the mines were reopened and they met local needs until coal could again be brought into Salmon. Since then the coal has been mined intermittently to supply a few users, but much of the time the mines have been idle.

Production records are not available, but the tonnage of coal mined has been small.

Geographic and geologic distribution

Beds of coal of such size and purity as to be of economic interest occur scarcely more than a mile west of Salmon. The coal beds crop out just below the mouth of Pollard Canyon, immediately south of Pollard Creek and east of its main tributary, Chipp's Creek. Where mined, the beds are close to the boundary between Secs. 2 and 11; T. 21 N., R. 21 E., near the top of a steep slope at an altitude of about 4,800 feet.

The coal is contained in the Miocene lake beds (Carmen formation) and is exposed where the formation abuts against the pre-Cambrian rocks of the Salmon River Mountains at the very edge of the Salmon Basin.

Descriptive features

The coal has been mined from several adits, only one of which is now maintained. This adit is driven about 70 feet above creek level and has several hundred feet of workings, including one long branch drift in which coal mined in the main drift is stored. As exposed underground, the easterly tilted coal bed is 1/4 to 3 feet thick, but contains some partings which tend to limit the thickness that is mined. There are, however, from 2 to 3 feet of massive coal unmarked by shale partings. The coal bed pinches and swells and is generally lenticular. It lies between beds of light-colored clay shale.

The coal is black lignite with a high water content which, on exposure, shrinks and cracks and breaks up into small fragments. Some of the coal is reported to have a fairly high ash content, perhaps because of admixed shale, but it burns well with a rather long, smoky flame and gives off considerable heat.
The lateral extent of the coal bed is not known. The mineral reserves are probably not large, though ample for expanded local needs for some time.

BUILDING STONE

The Salmon quadrangle is abundantly supplied with rock suitable as building material, but only minor use has been made of this resource. The available rocks include sandstones in the Carmen formation near Salmon and tuffs and lavas in a Challis volcanics. The rock preferred as building material at Salmon is the sandstone. Little or no use has been made of the other rocks.

Sandstone

The nature and properties of the sandstone near Salmon as building stone have been discussed in some detail by Behre [15]. Beds of sandstone make up


a variable but considerable thickness of the Carmen formation and are especially conspicuous near the town of Salmon, locally forming much of the rock exposed in the bluffs west of Salmon River. The beds average about 3 feet thick but there are a few as much as 8 feet thick. They are generally light-colored, either white or light gray, but some are tinted in shades of pink, buff, and cream. All show light rusting along fractures and on exposed faces.

The sandstone is not well-cemented and tends to be somewhat crumbly. The rock is easily worked and dressed when quarried and then hardens on exposure. It separates readily along bedding planes and hence is easily quarried.

The sandstone is composed largely of angular or only slightly rounded quartz grains, but in places may also contain minor amounts of feldspar and small grains of muscovite. These grains are in a clay matrix which also contains small flakes and needles of muscovite. The grains and matrix may be discolored by small but variable amounts of reddish and brownish iron oxides.

The rock has been quarried at several places near Salmon, the nearest on the west side of the river just above the town. It is exposed in the bluffs above the river. Much of the rock has been broken from the bluffs and is scattered in large chunks. The beds are thick, but apparently the rock is not so well-adapted for use as that at some more distant quarries. Comparatively small amounts of the rock have been taken for local use.
Another place where the sandstone has been worked is about 3 miles southwest of town near the boundary of Sec. 14, T. 21 N., R. 21 E. The quarry has been cut in a cliff exposure and the rock removed on a small scale. The beds locally strike N. 30° E. and dip 15° SE. A number of variously colored beds are exposed, but the thicker beds of pinkish color at the base of the local succession have furnished most of the building stone.

Another quarry is located a little more than half a mile to the south of the one just described. This quarry has attained a depth of about 15 feet and covers an area about 60 feet long and 60 feet wide. The upper beds exposed in the quarry are thin, but the light-gray rock in the lower 3 feet of the succession is massive, suitable for use as building stone.

Still another small quarry is located northeast of Salmon scarcely more than half a mile east of the town dump in Sec. 33, T. 22N. R. 22 E. A thick bed of massive sandstone projects somewhat above the surface and has been quarried along the outcrop for several scores of feet. Some of the sandstone is coarse and in places pebbly, but a white or light-gray sandstone, about 3 feet thick below the more coarsely grained rock, has been found suitable for use. This rock is composed almost entirely of well-sorted, angular quartz grains with some microcline, orthoclase, and muscovite and a very little plagioclase, clay, and magnetite.

Sandstone from the quarries a few miles southwest of Salmon has been used in several buildings in town, especially in some of the houses on the west side of the river. The sandstone is cut to a rectangular shape and then given a "rock face" or "chisel-dressed" finish. The rock is also adaptable to a smooth finish and such smooth-finished rock is used in the cylindrical columns of the Lemhi County courthouse. A striking mottled effect was achieved at the Episcopal church at Salmon by exposing the rusted joint surface in some of the blocks.

The Sandstone is not so popular as a building stone now as it was in the earlier days. But if it again comes into demand, it can supply needs for many generations to come.

**Tuff**

Volcanic tuff has not been used as building material in the quadrangle, but such rock has found rather extensive application at Challis and Clayton. As the tuff in the southern part of the quadrangle resembles that near Challis, it is likely that rock of acceptable quality and quantity may be found.

The beds of tuff are commonly of considerable thickness and usually are composed of quite massive rock. Some of the tuff is fine-grained and some is coarsely granular. Colors range from white to light gray. The rock is soft and is easily quarried and dressed. It hardens on exposure and serves well as building stone, except in foundations. The physical properties and
use of the rock in the Challis are discussed in some detail by Behre 16/.


The tuffaceous rocks are conveniently located for transportation and
are handily exposed along lower Tommile Creek and for a mile along U. S.
Highway 93 below the mouth of the creek.

Lava

The lavas are available in the southern part of the quadrangle, should
they ever be in demand as building material. The flows and ignimbrites
would serve equally well as building stone. There is little to distinguish
one from the other in the outcrop. Both are equally massive. The rocks with
the most pleasing qualities are those of rhyolitic and quartz latitic com-
position. Their colors are generally pinkish to gray.

The lava rock is hard and not easy to dress or trim, but is only
slightly porous and is more resistant to the weather than the tuff. It is
much better adapted for use in foundations.

Such rock may conveniently be had along both sides of the Salmon River
south of the mouths of Williams and Severmile Creeks. The most advantageous-
ly exposed flows are probably on the west side of the Salmon River.

BENTONITE

Impure bentonitic clays or shales in the Salmon quadrangle have been
utilized for some time for lining irrigation ditches to seal them against
loss of water by leakage. Most of this material has been used locally but
small amounts have been trucked for use in places as distant as Twin Falls.
The bentonitic material has been employed only where leakage has been severe;
therefore the amount so used has not been large. This use could be expanded
considerably.

Bentonitic deposits occur as thin beds in the Carmen formation, ex-
ceptionally in some of the tuffaceous members of the Challis volcanics.
Those which have been used have come entirely from beds in the Carmen forma-
tion. These impure bentonitic beds are most numerous and most widespread
in the region south of the Lochi River and east of the Salmon. Westward and
especially northward the beds become thinner and less numerous and near the
north end of the quadrangle appear to drop out altogether.

The beds range from a few inches to several feet thick. The surface
exposures generally appear thicker than they actually are because the ex-
panded wet clay tends to creep down the slope and conceal the rocks imme-
diately below. These beds are intercalated with beds of siliceous shales
and sandstones that make up so much of the Carmen formation. The bentonitic
material has a rather drab, gray to pale-buff color. Surface exposures may be recognized from a distance, in part because of the color but more because of the innumerable shrinkage cracks so characteristic of the dried material (Pl. VI-B). As the material does not encourage plant growth, outcrops are generally void of vegetation.

The impure bentonite swells considerably when wet and is quite plastic and sticky, making surface traverses difficult or strenuous in wet weather. It dries quickly after wetting, with much shrinkage and the formation of an intricate net of open cracks (Pl. VI-B). The clay material was not studied in the laboratory, but it is presumed that it is montmorillonite. The clay contains considerable admixed silt and sand, but could probably be upgraded by washing.

The beds appear to be of sedimentary origin and not the direct product of ash falls. Because the beds of impure bentonite are thicker and more numerous near the exposures of Challis volcanics and decrease in thickness and number away therefrom, they probably represent the sediment derived by erosion of the tuffaceous materials of the Challis volcanics. The material was probably changed to bentonite during or after deposition in the lake waters.

The bentonitic deposits have been worked at several localities, one on the slope at the edge of the Lemhi Valley about 4 miles southeast of Salmon and another just north of the road to Salmon Hot Springs in Sec. 28, T. 21 N., R. 22 E. The workings at the side of the Lemhi Valley are in plain view of State Highway 28 and are in Sec. 23, T. 21 N., R. 22 E., a little less than 200 feet above the valley floor. The overlying debris has been scraped aside and the bared bentonite is shoveled by bulldozer to the edge of the slope and down over a dump, where it can be loaded into trucks.

Although relatively thin, the beds are extensive and contain a considerable reserve of bentonite. The possibility of upgrading into a better product might be investigated. Because of the long distance to markets, the deposits will probably continue to serve a restricted local use.

CLAY

The clay resources other than those of bentonite were not investigated. Some sedimentary clays are contained in the Carmen formation, but most of the clays are rather sandy or silty. Some are darkened by carbonaceous matter and contain variable amounts of fossil leaves. The best clays are probably those found in close association with the coal beds. These beds are somewhat thicker and appear to be composed of a higher-grade, generally white clay. There is no local market for the clay.

GRAVEL

Gravel is the most abundant mineral resource in the quadrangle. It is generally present wherever needed and poses no problem of procurement. It
has provided for all local needs, but the amount used has scarcely made a dent in the available supply.

The gravel is in four types of deposits. These may be classed as (1) residual deposits, (2) channel deposits, (3) floodplain deposits, and (4) terrace deposits. So far, much of the gravel used has come from the first three types of deposits.

Residual deposits

The residual deposits are about 1½ miles northwest of Salmon in the northeast quarter of Sec. 36, T. 21 E. and lie at an altitude of about 4,500 feet within easy reach of Salmon but over a road in much need of improvement. A considerable amount of material has been removed from the deposit.

The deposits have been formed by deep weather-disintegration of coarsely crystalline granite rock and have not been moved from their place of origin. This deep disintegration has affected the rock at the far southeast end of the large granitic stock and has changed it to a very coarse feldspathic sand or fine gravel composed of coarse angular grains of feldspar, mica, and quartz. The component grains are somewhat larger than those usually associated with a sand but are much smaller than the pebbles that make up the water-laid gravels in the quadrangle.

Because of the extensive disintegration, the material is easily excavated. The use to which this feldspathic material was put was not learned, but it may have been used to surface some of the lightly travelled roads.

River-channel deposits

The river channels provide an inexhaustible supply of fairly coarse, well-washed, and considerably rounded gravels. Such gravels are utilized at Salmon and are taken from the bed of the Salmon River about a half mile above the town. The gravels are composed of the harder, more resistant varieties of sedimentary and igneous rocks from the upper drainage area. They contain a high proportion of quartzitic pebbles and boulders with a notable admixture of granite and lava. The gravels removed from the river channel during low water are replenished during the succeeding stage of high water.

Floodplain deposits

The floodplains of the Salmon and Lemhi Rivers have virtually an unlimited supply of gravel and can supply local needs indefinitely. This gravel is available anywhere along the valley bottoms, and pits have been opened, mainly for road construction, wherever needed. The gravel is beneath a thin, silty or gravelly overburden and is readily uncovered. The water table is generally near the surface and imposes a shallow limit on the depth of dry-pit operations. More extensive use has been made of these deposits than of any other kind.
Terrace deposits

The lower terraces bordering the Lemhi and Salmon River valley bottoms and those of the larger tributaries contain a tremendous reserve of gravel as yet practically untouched. With so much gravel more readily available along the valley bottoms, there has been little cause to utilize the gravel in the less conveniently located terraces. The terrace banks provide dry-pit operations.

ROAD METAL

The Salmon quadrangle is blessed with a very large reserve of road-metal materials. In addition to the gravels just mentioned, there are extensive supplies of quartzite and lava rocks available for use. The gravels have provided most of the surfacing material on the highways and secondary roads, but some use has been made of the quartzite and lava.

The impure quartzitic rocks in the cliffs on the west side of the Salmon River 3 to 4 miles below town have served as a source of some of the road material used locally. The talus debris and the highly fractured and easily worked rock above have been opened by a small quarry, which is located near the north end of the exposure within several hundred feet of a road that makes direct connection with the highway less than a fourth of a mile away. The quarry can meet all local need for quartzitic material indefinitely.

The volcanic rocks, particularly the lava flows and ignimbrites in the south part of the quadrangle, can provide an abundant supply of road metal. The tuffaceous beds are too soft and crumbly and are wholly inadequate, but the rhyolite and quartz latite flows and ignimbrites are composed of hard massive rock with good surfacing properties. Some use has been made of this kind of rock along the main highway and along Williams Creek. The rock used along Williams Creek consists of rather fine talus debris that can be loaded into trucks and applied to the roads without crushing or screening. The talus debris has come from quartz latite or rhyolite flows or ignimbrites exposed higher on the valley slope and has provided a large quantity of material available at road level.

HOT SPRINGS

The quadrangle has one hot spring. This lies in the volcanic rocks at the north end of the Lemhi Range in Sec. 3, T. 20 N., R. 22 E., about 9 miles by road from Salmon. It is appropriately called the Salmon Hot Springs and the waters are utilized by a bathing resort.

The springs issue from bleached and altered volcanics, emerging from a fault that has brought basalt in contact with older tuffaceous rocks. The water deposits a brown, iron-bearing ooze which has to be removed weekly from the floor of the concrete pool.
Fig. 3: Geologic map of the 500 and 600 levels at the Pope-Shenon mine (August, 1954).