Geology of the Southern Part of the Lemhi Range, Idaho

By CLYDE P. ROSS

CONTRIBUTIONS TO GENERAL GEOLOGY

GEOLOGICAL SURVEY BULLETIN 1081-F

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1961

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C.

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GEOLOGY OF THE SOUTHERN PART OF THE LEMHI RANGE, IDAHO

By Clyde P. Ross

ABSTRACT

This report covers the southern part of the Lemhi Range and adjacent areas in Butte and Clark Counties in central Idaho. The rocks include the Swauger quartzite (Precambrian), Kinnikinic quartzite (early Upper Ordovician), Saturday Mountain formation (Upper Ordovician) with remnants of Laketown dolomite (Middle Silurian) locally, several units of Devonian age that are mapped together, the Milligen formation (Mississippian), the Brazer limestone (Mississippian) and related rocks younger than the Brazer, a few dikes, patches of volcanic rocks of probable late Tertiary age, alluvial materials of Pliocene(?) and younger age and scanty glacial deposits of Quaternary age. The Paleozoic rocks vary markedly in thickness within the mapped area and most of them are thinner than their equivalents farther north and west. The Brazer limestone and associated beds, as mapped, are very thick and include beds of post-Mississippian age.

The Swauger quartzite was flexed before the Paleozoic rocks were laid down. The latter have been arched and, locally, complexly folded, probably in several pulses of deformation. In addition, the Brazer limestone is crenulated in unsystematic fashion. The whole assemblage has been broken by steep thrusts, apparently belonging to a single zone that has been so folded as to produce a zigzag pattern. The steep thrusts are locally overridden by more gently inclined thrusts. Relatively recently the Lemhi Range appears to have been uplifted with concomitant downflexing of the valleys on either side.

Prospecting for lead, zinc, copper, and other metals began in the area about 1880. Mining was inactive at the time of visit, in 1954 and 1955, but the Wilbert lead mine has a long record of production on a rather small scale and other properties have been active from time to time. Many of the deposits are replacements in carbonate-bearing rocks and all are in zones of fracture, including thrust faults.

INTRODUCTION

LOCATION AND SCOPE OF THE REPORT

The area is in the southeastern part of the mountains of central Idaho (fig. 14). The area geologically mapped (pl. 7) is bounded by 43°45′ and 44°10′ north latitude and approximately by 112°50′ and

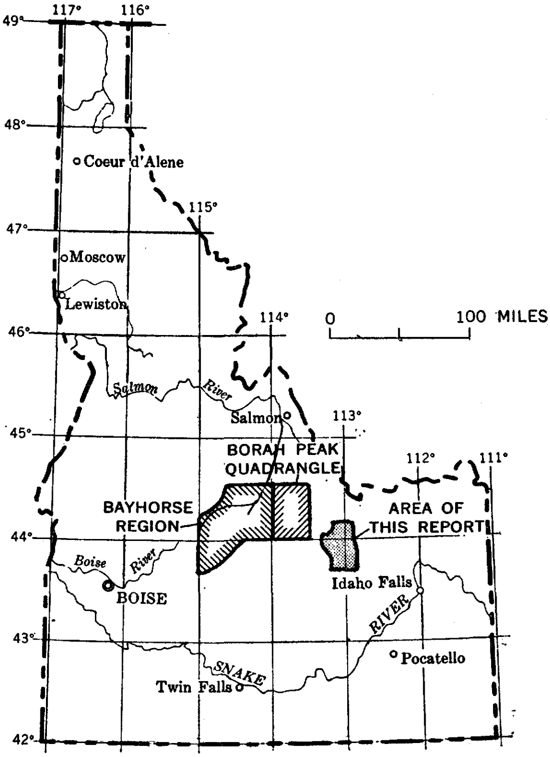


FIGURE 14.—Index map of Idaho showing the area of this report, the Borah Peak quadrangle, and the Bayhorse region.

113°15′ west longitude. This area includes the portion of the Lemhi Range from near Cedar Run to the southern end of the range and small parts of the Beaverhead Mountains, and the Arco Hills; also parts of the valleys of Little Lost River and Birch Creek. The northeastern part of Butte County and the southwestern corner of Clark County are included. The mountains are in parts of the Lost River Division of the Challis National Forest and the Western Division of the Targhee National Forest, whose approximate boundaries are shown.

The area was chosen for study because it provides a convenient means of evaluating differences in stratigraphy and structure between central Idaho and western Montana. The investigation is a part of that carried on intermittently by the writer in south-central Idaho since 1923. A number of small mines and prospects are present but these were not examined during the present investigation. Most of them were inactive and not safely accessible in 1954 and 1955. Only one, the Wilbert, has attained much recorded production and this one has been reported on previously (Umpleby, 1914; Ross, 1933; Anderson, 1947; Anderson, 1948). A summary of available data regarding the mineral deposits is appended to this report.

Fieldwork was carried on during nearly three months in the summer of 1954 and about the same period in 1955; the area was revisited briefly by the author in 1956, in company with Robert H. Morris. The mapping was done mainly on vertical aerial photographs, scale about 1:20,000, which were taken for the Agricultural Adjustment Administration in 1946. These show part of the valley of the Little Lost River and the mountains on its eastern slope. High-altitude vertical aerial photographs made for use of the Army Map Service in 1955, at the approximate scale of 1:62,500, include the entire area but were not available until most of the fieldwork had been done. The base for plate 7 is adapted from a map compiled in the Geological Survey, from the Army Map Service manuscript, with various corrections, especially as to cultural features. For the valley of Little Lost River and most of that part of the Lemhi Range in which units of pre-Brazer age appear, the large-scale aerial photographs permitted careful study in the field. Most of the rest of the area of plate 7 was reconnoitered in the field. Data thus obtained have been amplified by photogeologic interpretation of high-altitude photographs by Robert H. Morris, who completed the tracing of a number of contacts left incomplete in the fieldwork and added much structural detail.

ACKNOWLEDGMENTS

The present report would not have been possible without the hearty cooperation of Robert H. Morris and others in the preparation of the base map, transferring geologic information from the photographs used in the field to the base map and interpreting the photographs.

Jack Terry assisted in the fieldwork early in the summer of 1954. D. W. Hinckley assisted throughout the field season of 1955. He did much of the reconnaissance work, especially on the eastern flank of the range, and also part of the more detailed geologic mapping incorporated in plate 7. Both he and Terry aided in the planetable and Locke level surveys that were made, mainly in the measurement of stratigraphic sections.

The field party was visited in 1955 by P. E. Cloud, Jr., R. J. Ross, Jr., and Mackenzie Gordon of the Geological Survey. They contributed much paleontologic information, particularly as to Devonian and Mississippian rocks.

TOPOGRAPHY

LEMHI RANGE

The Lemhi Range is one of several mountain masses in south-central Idaho that are long, narrow, and separated from each other by rather broad intermontane valleys. Such ranges are in marked contrast to the irregular assemblages of mountains that occupy most of the central part of the State. The Lemhi Range has a total length of about 80 miles, of which somewhat more than 27 miles are within the area of the present report (pl. 7). Except for the southernmost 5 or 6 miles, the part of the range shown in plate 7 is high and intricably dissected. In spite of the dissection, some comparatively level ridge crests remain at high altitudes (mostly above 10,000 feet) and there are patches of rolling topography at lower altitudes, probably remnants of originally more extensive surfaces. Diamond Peak is 12,197 feet high and is thus one of the highest peaks in the State, a fact not heretofore appreciated. The relief within the mountains is almost 1 mile and the total relief within the mapped area is about 7,400 feet.

The general character of the topography in the area of plate 7 can be judged from figure 145 of a report by Reuben J. Ross, Jr. (1959, p. 442). This figure is based on the manuscript map mentioned above but embodies some of the corrections to that map made in the course of the fieldwork for the present report. It does not include all the area of plate 7. The level ridge crests and patches of rolling topography mentioned above can be discerned by inspection of the map here cited. Those interested in the geomorphic character of the Lemhi Range will find these features displayed in greater detail in the map of the Diamond Peak quadrangle issued by the Geological Survey in 1957. This map includes the northern part of the area of plate 7.

Most of the streams that drain the eastern slope are intermittent but lie in deeply incised valleys that are almost perpendicular to the trend of the range crest, with channels that are well marked far out into the valley of Birch Creek. Ponds have formed in the upper reaches of a few streams. West of the crest the mountain valleys are longer and more irregular, and in part have gentler, sloping sides. On both slopes the valleys that reach high altitudes have ill-defined cirques at their heads, but few valleys appear to have the U-shaped cross sections common in many of the comparably high valleys elsewhere in central Idaho. Where the streamways emerge from the mountains on the western slope they break up into distributary channels, many of which become ill defined in a short distance. Some cannot be traced continuously even as far as the outer borders of the fans. Most of the mountain valleys on the west side, are choked with debris to an exceptional extent. In consequence, these valleys have water flowing at the surface only in immediate response to heavy rains. This hampers use of the affected drainage areas for stock grazing and other purposes. South, North, Uncle Ike, Badger, and Williams Creeks do not have excessive detrital fill along present stream channels. These streams are perennial as far as the mountain border, where their water is in large part channeled into irrigation ditches, of which only the more prominent are mapped. Several springs emerge low on the western slope. Some of these are so large that they are used for irrigation.

VALLEY OF BIRCH CREEK

Birch Creek, the master stream east of the southern part of the Lemhi Range, is about 45 miles long and has a drainage area of 630 square miles, 2,000 to 3,000 acres of which is under irrigation (Hoyt, 1935, p. 137). It sinks into the alluvial deposits of the Snake River Plain in T. 6 N., R. 31 E., beyond the limits of plate 7, and is drawn upon so heavily for irrigation that, late in the summer, flow in its channel does not always reach this area. Settlement in the part of the valley shown is limited to motels and to some farmed areas near the northern border, at the location shown as Kaufman on some maps.

VALLEY OF LITTLE LOST RIVER

Part of the valley of Little Lost River is shown on plate 7. The valley is bordered by the Lemhi Range on the east and the Lost River Range on the west, and in places is 10 or more miles wide. The river is 50 miles long (Hoyt, 1935, p. 140) and has a drainage area of more than 700 square miles and an average discharge of 69.1 cubic feet per second (50,030 acre-feet per year (U.S. Geol. Survey, 1959, p. 91)). In 1935 it served 16,000 acres with adjudicated water rights (Hoyt, 1935, p. 140). At the time the present study was made, much of the land under ditches was not being irrigated. Prior to irrigation, the water of this stream sank from view southeast of Howe, but now much of the water is diverted into irrigation ditches. A silt-floored depression immediately south of the Lemhi Range with its rim about 4,800 feet above sea level constitutes the terminus of the Big Lost River. This stream rises in the mountains west of the Lost River Range but during most of the year did not normally maintain flow at the surface as far as the depression even before irrigation diversions were established.

The inner part of the valley of Little Lost River is bordered by a fairly well defined and continuous set of terraces. Most of the streamways that emerge from the mountains have cut into the alluvial fans at the mountain border, but many of them reach the terraces above present grade and consequently have dumped small fans at the points where they meet the terraces. The most persistent and pronounced of the terraces borders the silt-floored inner valley of the river close to the contact around the periphery of that floor, as shown on plate 7. The fans between the mountains and the inner valleys have been cut into by gullies, many of which are not shown.

The part of the valley of Little Lost River that is on plate 7 contains a number of ranches and farms, mostly concerned with stock and forage crops. The village of Howe is in the southwestern part of the valley and the community of Clyde is near the northern end of the mapped part of the valley.

STRATIGRAPHY AND PETROGRAPHY

GENERAL FEATURES

In south-central Idaho east of the Idaho batholith, each of the mapped areas that contain strata of Paleozoic age shows significant differences in stratigraphic characteristics from adjacent areas (Umpleby and others, 1930; Ross, 1934, 1937, 1947). An area about one-half degree wide intervenes between the areas hitherto mapped east of the Idaho batholith and those in southwestern Montana. For this area little other than reconnaissance work has been published (Umpleby, 1917; Kirkham, 1927; Shenon, 1928; Anderson and Wagner, 1944; Anderson, 1948; Sloss, 1954). Appreciation of this situation was a compelling reason for the present investigation, which is in the area where stratigraphic information was deficient. As expected, the results obtained have differed in some respects from those on record to the west and to the east. In southwestern Montana, east of the mountains along the Idaho boundary, the rocks of Paleozoic age are so very different from those in central Idaho (Sloss and Moritz, 1951; Scholten and others, 1955) that conditions governing sedimentation must have differed sharply. The difference is emphasized by the presence of a considerable thickness of Mesozoic strata in southwestern Montana, whereas almost none are known in adjacent parts of Idaho.

The southern part of the Lemhi Range contains a thick sequence of quartzitic, argillaceous, and dolomitic rocks correlated with the

Swauger quartzite (Precambrian), overlain successively by about 1,000 feet of the Kinnikinic quartzite (Ordovician); 280–1,000 feet of the Saturday Mountain formation (Upper Ordovician) and locally Laketown dolomite (Middle Silurian), about 300–1,200 feet of carbonate rocks of Devonian age that have not been divided into formational units, and about 7,000 feet of the Brazer limestone and related rocks (Mississippian and later). Here and there small amounts of material that may correspond to the Milligen formation (Mississippian) underlie the Brazer. Patches of volcanic rocks believed to be of late Tertiary age cap the rocks of Paleozoic age in a few places. Flows of probable Pleistocene age belonging to the Snake River basalt are present in the lower reaches of the valleys of the Little Lost River and Birch Creek, although not exposed at the surface along Little Lost River. Alluvium of Tertiary and Quaternary age, in part deformed, is widespread in the two major valleys. In one place it contains an intercalated ash bed. A little material of definitely glacial origin is present in the mountains. Intrusive rocks are represented only by a few small dikes, presumably of Tertiary age. These are not large enough to be mapped on plate 7.

It will be seen from the above summary that the Paleozoic rocks of the southern Lemhi Range have similarities with those in the Borah Peak quadrangle (Ross, 1947, p. 1094–1117) (fig. 14). The outstanding differences are that the Kinnikinic quartzite is thinner; the Laketown dolomite (Silurian) is almost completely absent; and the Devonian rocks are thinner and more variable. The three Devonian formations recognized in the Lost River Range were therefore not mapped separately in the Lemhi Range. The Milligen formation is absent in many localities and is nowhere well developed. The Brazer limestone overlies the Milligen but rocks here mapped with the Brazer appear to include some of Pennsylvanian and perhaps later age. If similarly young rocks are present in the Borah Peak quadrangle, they have not been recognized as yet.

PRECAMBRIAN ROCKS

SWAUGER QUARTZITE

DISTRIBUTION

Rock here correlated with the Swauger quartzite (Ross, 1947, p. 1097–1102) underlies the lower slopes of the southwest flank of the Lemhi Range almost continuously in the area here described. Exposures are interrupted between Badger and Williams Creeks. The hills that project into the valley of the Little Lost River north of South Creek expose the formation only at their western tip, but two areas underlain by it lie in the mountains immediately to the east.

CHARACTER

In the localities in the Borah Peak quadrangle where the Swauger quartzite was first described, the formation consists (Ross, 1947, p. 1097–1098) of purple, lavender, pink, and white quartzite, with some green quartzite. Lenses of conglomerate and of rusty, impure dolomite are included locally. Maroon, green, brown, and dark-gray argillite is present at several horizons, especially low in the sequence. In the area of the present report the rocks are similar but even more varied in color and composition. A few of the more distinctive, well-exposed aggregates of especially massive quartzite and of quartzitic dolomite are distinguished on plate 7. The general character of the formation can be judged from plates 8*A* and *B* and 10*A*.

In the southern Lemhi Range, as in its type locality in the Borah Peak quadrangle, the Swauger quartzite is characterized by moderately pure quartzite, mostly in various purplish shades. The color of this material, according to the "Rock-Color Chart" (Goddard and others, 1948), ranges from grayish red purple to pale pink, the darker shades predominating. Most exposures also contain beds of various shades of yellowish green. Dark-gray to greenish-black beds are distinctly subordinate. Most of the green beds and some of the others are argillaceous. Where weathered, the carbonate-bearing beds are in various shades of yellowish brown and yellowish orange, but on fresh fractures these beds generally show purplish tones. The purer quartzite beds, including those mapped separately, are more nearly white than most of the quartzite, and many of them so closely resemble the overlying Kinnikinic quartzite as to be confusing where stratigraphic relations are obscure. Some of the purplish quartzite, notably near the mouth of the canyon of Uncle Ike Creek (pl. 10*B*), is decidedly schistose, but the greater part of the formation is not (pl. 8).

Most of the quartzite consists dominantly of quartz grains and distinctly subordinate grains of alkalic plagioclase and microcline. Much of the quartz was subjected to enough pressure to develop undulatory extinction before it was incorporated in the rock. A few of the grains consist of fine-grained quartzite. Colorless mica, mostly in small shreds, is commonly present but nowhere abundant. Apatite and tourmaline are sparsely distributed. The color is derived from hematite in the cement between the grains.

Originally the clastic grains were rounded to subangular and moderately well sorted. Crushing has tended to obliterate the rounded forms. In different beds the average diameter of the component grains ranges from 0.05 to 0.4 mm, the smaller sizes predominating.

The massive, nearly white beds are similar, except that they consist of even purer quartzite, containing less hematitic coloring matter. In many the component grains are as much as 1 mm in diameter.

The argillaceous beds are much like the quartzitic ones except in grain size and proportions of the component minerals. In most of them, chlorite is the dominant coloring matter. The dolomitic beds consist of crystalline dolomite, through which small rounded grains of quartz are scattered. Feldspar and mica are rare. The original texture of the carbonate has been obliterated, but the quartz and feldspar retain the form of the original clastic grains.

In the area between Middle and Black Canyons, little more than 1,000 feet of the Swauger quartzite is exposed, the lower part of the formation being faulted out. Here the formation consists mainly of moderately dark red-purple quartzite; but low in the exposed sequence, is a little white quartzite, which at one exposure includes some fine conglomerate. At the top, the formation includes quartzitic dolomite and dolomitic quartzite. The dolomite member, here mostly 65–75 feet thick, has been mapped along the range front on both sides of Black Canyon. Similar rocks, mostly more quartzitic, which were noted at various places farther north, are mostly not well enough exposed to be mapped. Dolomitic rocks are not everywhere confined to the uppermost part of the formation.

The ridge immediately south of the place where South Creek leaves the mountains exposes about 2,500 feet of the Swauger quartzite, the base of which is hidden under alluvium. The lower part of the exposure consists largely of impure light gray-purple quartzite beds, too much deformed to be measured, followed upward by 200–300 feet of more massive, lighter colored quartzite. Next is about 250 feet of white quartzite and, above this, a little purple quartzite. The upper part of the purple quartzite has lenses of conglomerate containing pebbles up to one-fourth inch in diameter. The white quartzite unit and similar ones along South Creek are distinguished on plate 7. Above this is crumpled sandy shale, perhaps 200 feet thick, capped by about 50 feet of pink quartzite. Next above is impure, purplish quartzite and beds of green and olive shale, totaling roughly 1,000 feet. The upper 500 feet of the section consists of rather massive dark red-purple quartzite, overlain by Kinnikinic quartzite.

The Swauger quartzite has been studied in more detail at the Wilbert mine than elsewhere (Ross, 1933, p. 3–5). The components here, tabulated below, are somewhat more diverse than is characteristic of the formation. At one locality in the Borah Peak quadrangle (Ross, 1947, 1099–1102), an almost equally diverse assemblage was described as of doubtful age because of its contrast with the more uniform character of most exposures of the formation in that area. It can now be assigned to the Swauger quartzite with confidence. When the rocks at the Wilbert mine were originally studied, the fact that the white quartzite at the top of the local sequence belonged to a different formation than the rest was not appreciated. Regional mapping shows clearly that this quartzite belongs to the Kinnikinic quartzite.

Section of Swauger quartzite at the Wilbert mine

	Thickness (feet)
Kinnikinic quartzite	1,000+
Unconformity (?)	
Dolomite, quartzitic	85
Quartzite, white, crossbedded	65
Quartzite, purple, crossbedded; includes local beds of shale	400
Shale, green	165
Pebble quartzite, white to purplish, somewhat crossbedded; contains scattered pebbles up to one-half inch in diameter	200
Total thickness of Swauger quartzite	915

About one-half mile north of North Creek a conspicuously massive member appears in the Swauger quartzite. It is similar in character to the massive beds mapped near South Creek but here is about 500 feet thick. It consists mainly of coarse, somewhat crossbedded, yellowish white quartzite that, in varying degree, weathers rusty. Some purplish beds are included. Locally the rock is crossbedded. In exposures south of Uncle Ike Creek it is overlain by pale purplish shale, which has a silvery luster on parting planes because of abundant mica. Above this is a rather dark red-purple quartzite, less resistant to weathering than the massive member. The thickness varies, and on the southeast slope of Uncle Ike Creek the massive member approaches contact with the overlying Kinnikinic quartzite. The part of the Swauger quartzite below the massive member in the vicinity of Uncle Ike Creek consists of originally fairly uniform red-purple quartzite in which bedding planes are less conspicuous than schistose partings in many outcrops, though the bedding is obvious in distant views (pl. 10*B*).

Much of the rock is a quartzite schist, whereas farther south the Swauger quartzite shows little or no schistosity in most exposures. The total exposed thickness of the Swauger quartzite near Uncle Ike Creek may exceed 2,000 feet.

In most of the area between Uncle Ike and Badger Creeks the Swauger quartzite was not studied in detail. Broadly, its characteristics are those of the same formation near Uncle Ike Creek and its exposed thickness is even greater (section B–B′, pl. 7). Near Badger Creek, scattered outcrops of quartzitic dolomite and dolomitic quartzite are present. The massive member is prominent and in general appears to be in contact with the Kinnikinic quartzite, from which it is distinguished mainly by a more dirty appearance and a less vitreous luster on fresh fracture.

North of Badger Creek only a small amount of Swauger quartzite is exposed within the mapped area. It consists almost entirely of laminated grayish red-purple quartzite. Specularite, in flakes readily visible to the unaided eye, is more abundant here than farther south. In this part of the range, Umpleby (1917, p. 23–24, pl. 1) in his original reconnaissance used the break in continuity of exposures of the old rocks as a convenient place to divide the rocks to the north, which he regarded as of Precambrian age, from those to the south, which he grouped with strata of Paleozoic age. Such a division is improbable in view of the lithologic similarities.

As noted above, the exposed thicknesses of Swauger quartzite in the southern Lemhi Range vary to a maximum of about 2,500 feet, but the base is nowhere visible and the true thickness of the unit may greatly exceed this. In the Borah Peak quadrangle the Swauger quartzite was estimated to be at least 1 mile thick (Ross, 1947, p. 1099).

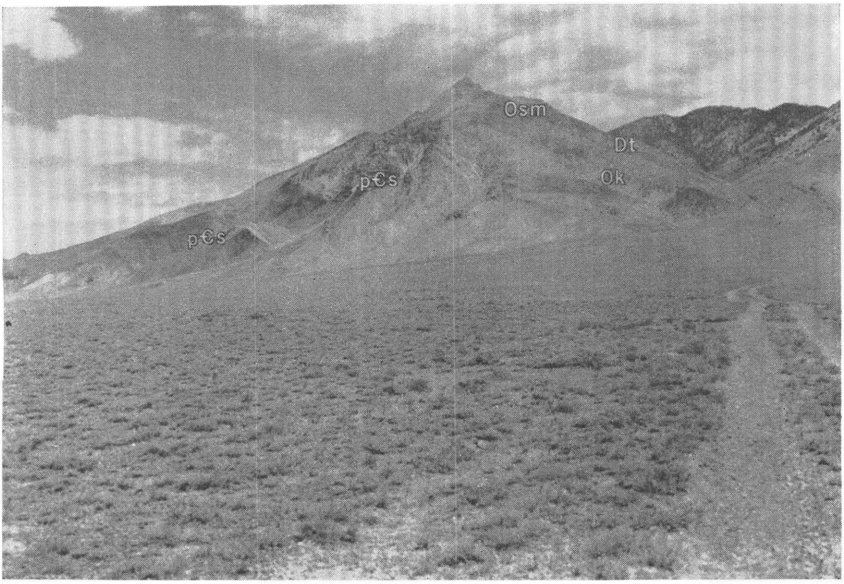
AGE

The unit here correlated with the Swauger quartzite contains no diagnostic fossils, so that its age has to be inferred from relations to other rocks. In previous investigations, as noted below, the formation or parts of it have been assigned to the Precambrian, Cambrian, and Ordovician. These inferences were based on the fact that the unit is the lowest in the local sequence and the first fossiliferous formation above it is of Ordovician age.

The Kinnikinic quartzite rests on different components of the Swauger quartzite in different localities in the southern Lemhi Range. Dolomite is the uppermost component of the Swauger quartzite in several places, but, where mapped, it feathers out within short distances, and along much of the contact this rock is absent or so inconspicuous that it was not mapped. Much of the conglomerate within the Swauger quartzite is in the upper part of the formation, which may indicate gradual emergence from a shallow-water body. All three of these features accord with the idea of an unconformity at the top of the Swauger, although in a unit that varies so markedly in details of stratigraphy within itself they are not conclusive. On the south slope of the valley of Uncle Ike Creek, one of the units of relatively pure, massive quartzite in the Swauger quartzite is much closer to the contact with the Kinnikinic than the same unit is farther south, along the range front. The relations favor the concept of a small angular discordance between the Swauger and the Kinnikinic. Differences in attitude of beds on the two sides of the contact are in agreement with this but are of slight significance in irregularly bedded clastic rocks such as these. The Swauger quartzite is somewhat more thoroughly recrystallized than any of the sedimentary units above it and is locally schistose. Taken together, these various bits of evidence support the conclusion arrived at on a similar basis in the Borah Peak quadrangle—that the Swauger quartzite is of Precambrian age and a component of the Belt series, and is distinctly older than the Kinnikinic quartzite, whose similarity to it has caused confusion as to relationship.

In southwestern Montana a stratigraphic break exists locally between the Belt series and the beds of Cambrian age. Another is recognized between the latter and Devonian beds (Hanson, 1952, p. 20–22; Scholten and others, 1955, p. 363). The unconformity at the top of the Swauger may be a combination of these two.

Kirkham (1927, p. 16–18) long ago pointed out that the oldest part of the sedimentary sequence in the southern Lemhi Range is very similar to rocks farther north that were regarded as of Algonkian age by Umpleby (1917, p. 23–24). Kirkham recognized that these rocks are coextensive with those now correlated with the Belt series, particularly the Swauger quartzite of present nomenclature in the Borah Peak quadrangle. Reconnaissance by the present writer along the front of the Lemhi Range from the Borah Peak quadrangle southeastward tends to confirm Kirkham's concept. The lithologic similarities furnish strong support, a fact that was appreciated by R. A. Anderson (1948, p. 6–7) for part of the old rocks. Apparently in Kirkham's study of the rocks at the Wilbert mine in the southern Lemhi Range he grouped together rocks assigned in the present report to the Swauger and Kinnikinic quartzites, although he realized that the region contains a quartzite equivalent to what is here called Kinnikinic. Anderson's map (1948, fig. 5) shows a similar grouping for most of the quartzitic rocks. The present writer's earlier map of the Wilbert mine (Ross, 1933,



A. RECUMBENT FOLD NORTH OF BLACK CANYON

The rock on the lower slopes, mostly dark-colored, is Swauger quartzite (*p€s*); the lighter beds overlying it belong to the Kinnikinic quartzite (*Ok*); the dark rock of the sharp peak and the lower part of the dip slope to the right of the peak belongs to the Saturday Mountain formation (*Osm*); the still darker rock overlying this on the same dip slope in the wall of Black Canyon is of Devonian age (*Dt*).

B. CONTORTED ROCKS ALONG THE NORTHWESTERN SLOPE OF THE VALLEY OF SOUTH CREEK

The rock in the lower part of the view belongs to the Swauger quartzite (*p€s*), a competent unit that has been crumpled locally. The contorted rocks along the ridge crest belong to the Brazer limestone (*Mb*). The two formations are separated by a thrust fault.

pl. 1) similarly groups all the rocks as of Ordovician age. Anderson (1948, p. 6–8) was the first to map any of the rocks in the southern Lemhi Range as possibly as old as Precambrian, a conclusion that is here accepted and extended to include most of his quartzite series.

No diagnostic fossils have been found in the Swauger quartzite. However, in the massive member on the south slope of the valley of Uncle Ike Creek, certain tubular bodies crowded together in parallel arrangement were noted. Examination by Richard Rezak (written communication, May 4, 1956) shows that these closely resemble the structures described by Walcott (1914, p. 108) as "*Greysonia*," from the Greyson shale near White Sulphur Springs, Mont. Fenton and Fenton (1936, p. 612–615) have raised doubt as to the organic origin of these structures, but Rezak notes that their ideas as to genesis do not explain the occurrence in a quartzite.

No part of the Swauger quartzite is as reddish as many of the components of the Missoula group in Montana (Clapp and Deiss, 1931; Ross, 1949). However, the Swauger quartzite, wherever recognized, is the stratigraphically highest unit of the Belt series and in color and other lithologic features has more resemblances to the Missoula group than to any other part of the Belt series in Montana or northern Idaho that is of pre-Missoula age. The correlation implied by this statement must be regarded as highly tentative and provisional; it is based on unpublished studies by the present writer. The fact that Walcott (1914, p. 108) found *Greysonia* in beds now regarded as belonging to the Missoula group may be without significance in this connection.

LOWER PALEOZOIC ROCKS

KINNIKINIC QUARTZITE

DISTRIBUTION

The Kinnikinic quartzite is well displayed along the western flank of the Lemhi Range, from the mouth of Middle Canyon northward beyond the limits of plate 7. The structure is such that for much of the distance the quartzite forms two separate elongate areas of outcrop. It is especially well displayed in cliffed slopes that rise above the more gently sloping, lower part of the range front, which is underlain by Swauger quartzite. Reconnaissance observations show that the unit continues northward, with minor interruptions, into the areas in the Borah Peak quadrangle where it has been mapped previously (Ross, 1947, p. 1102–1104, pl. 1). The type locality is in the Bayhorse region (Ross, 1937, p. 17–18), (fig. 14).

CHARACTER

The Kinnikinic quartzite is one of the most uniform and easily recognized formations in this part of Idaho. In the southern Lemhi Range most of it is a nearly white, moderately coarse quartzite, locally with pink and purple tints, generally faint. Here and there, especially near the base, the quartzite contains conglomerate lenses. The pebbles are mainly white and purple quartzite, probably derived from the more resistant beds in the underlying Swauger quartzite. Some of the resistant beds in the Swauger are so much like the Kinnikinic that uncertainties arise where stratigraphic relations are not clear. In a few places, notably near Williams Creek, small lenses near the base of the formation are closely similar in color and other features to the underlying Swauger quartzite. These presumably consist of unmodified detritus from the Swauger quartzite, whereas most of the Kinnikinic quartzite lacks the hematite that gives color to the older rocks. High in the sequence, lenses of dolomite closely resembling those in the overlying Saturday Mountain formation are present. The thickness of the formation is 600–800 feet north of Middle Canyon, and in the neighborhood of 1,000 feet throughout the southern Lemhi Range.

Under the microscope the Kinnikinic quartzite contrasts definitely with the quartzite in the older rocks beneath. The component grains in the Kinnikinic quartzite are clearer, with less conspicuous strain shadows, than those in the Swauger quartzite. In both formations some grains show closely spaced lines of fluid inclusions. Feldspar is absent and mica is confined to the interstitial material. The grains are fairly well rounded and range up to 0.5 mm in diameter. This fact is not appreciated at first glance, for the interstitial quartz is recrystallized and grown on to the clastic grains in such a way that the boundaries are almost invisible. Thus, the rock appears to be composed of interlocking grains of quartz, and the original sedimentary texture is almost destroyed. Crushed borders around the clastic grains, so conspicuous in the Swauger quartzite, are absent in the Kinnikinic quartzite. This evidence of recrystallization without crushing of the sandstone is the most diagnostic difference between the two rocks. In this respect the other beds of Paleozoic age resemble the Kinnikinic quartzite. This difference between the quartzites of Precambrian and Paleozoic age is present in the Borah Peak quadrangle but seems more conspicuous in the southern Lemhi Range. Tourmaline and epidote are plentiful among the accessory constituents in some beds.

The dolomite beds high in the sequence consist mainly of a fine-grained uniform-textured aggregate of carbonate grains, probably little altered from the texture of the original rock. Here and there patches of coarse carbonate crystals show the effects of incipient marmorization.

AGE

The Kinnikinic quartzite farther north in the Lemhi Range has been shown by Josiah Bridge (Ross, 1947, p. 1104) to be of "early Upper Ordovician age, approximately that of the Fernvale formation of the Mississippi Valley." The stratigraphic relations in the area of the present investigation are essentially similar. A few poorly preserved fossils were found in one of the trenches at the Ajax prospect, on a ridge south of South Creek, in a lens of dolomite near the top of the Kinnikinic quartzite. According to R. J. Ross, Jr. (report dated Jan. 19, 1955), these include *Diceromyonia* sp., *Glyptorthis* sp., and *Streptelasma* sp. These are reported to indicate an Ordovician age, but whether Middle or Late Ordovician is uncertain. Here and there the quartzite contains masses of fine-grained silica that resemble the fucoids abundant in the Kinnikinic quartzite near Challis (Ross, 1937, p. 18) but are not useful in determining the age. As the top of the Kinnikinic locally contains dolomite lithologically like that of the Saturday Mountain formation, and the latter near its base includes quartzitic beds, the two formations are gradational and hence not greatly dissimilar in age.

SATURDAY MOUNTAIN FORMATION AND OVERLYING DOLOMITE

DISTRIBUTION

A formation that on the basis of lithologic character, stratigraphic character, and faunal content seems clearly to be correlated with the Saturday Mountain formation (Ross, 1937, p. 18–22; 1947, p. 1104–1105) is plentiful along the southwest flank of the southern Lemhi Range. The fossil data summarized below show that in two spots collections were made that contain fossils of both Ordovician and Silurian age. Evidently the cliffs at these places expose beds of Silurian age, doubtless equivalent to the Laketown dolomite farther northwest (Ross, 1937, p. 23–25; 1947, p. 1105–1107). At both places beds with the lithologic characteristics of Jefferson dolomite overlie the rocks from which the collections came. Thus, at these spots the rocks of Silurian age now present are very thin. If there are other localities within the area of plate 7 in which Silurian rocks are exposed, they were not detected and the amount must be small. Any large amount of the Laketown dolomite would contain so great a proportion of beds conspicuously lighter in color than those characteristic of the Saturday Mountain formation that they should be readily recognized. Special search in the southern part of the map area, especially along Black Canyon, has eliminated the probability of any Silurian beds being present there.

The distribution of the Saturday Mountain dolomite is somewhat more irregular than that of either the Swauger or Kinnikinic quartzites. From the mouth of Middle Canyon northward two narrow, irregular areas of outcrop extend into the valley of North Creek. Between North Creek and Uncle Ike Creek one rather broad area is present. Along Uncle Ike Creek the exposures of the formation are offset to the west. From Uncle Ike Creek northward one narrow and irregular area, with outliers, extends beyond the northern boundary of plate 7.

CHARACTER

By far the greater part of the Saturday Mountain formation in the southern Lemhi Range consists of dolomite essentially identical in character with the dominant rock of the Saturday Mountain formation in the Borah Peak quadrangle (Ross, 1947, p. 1104–1105). A few beds are argillaceous and some, especially near the base, are quartzitic; but clastic material is far less abundant in the southern Lemhi Range than in the type locality of the formation (Ross, 1937, p. 18–22), which is somewhat more than 20 miles west of the northern part of the western boundary of the Borah Peak quadrangle. The thickness increases from about 280 feet in the southern part of the mapped area to about 1,000 feet toward the northern border. This may be compared with thicknesses of 500–700 feet in the Borah Peak quadrangle and about 3,000 feet in the type locality still farther west.

The overlying dolomite of Silurian age present in the northern part of the mapped area is probably so thin that it does not affect significantly the estimate of about 1,000 feet for the thickness of the Saturday Mountain formation there.

Much of the quartzite in the lower part of the formation has a cement of magnesian carbonate. Rare grains of microcline and plagioclase are present, whereas feldspar was not noted in the Kinnikinic quartzite. In some beds of dolomite the component grains average close to 0.02 mm in diameter, and some patches and veinlets of coarser crystals are present. In others, although many of the grains are only about 0.03 mm across, others range up to 0.16 mm in diameter. The larger grains tend to be clearer and more angular than the rest.

Planetable measurements were made of the Saturday Mountain formation and the Devonian rocks that overlie it in Black Canyon, at a locality immediately upstream from the gorge cut in the Kinnikinic quartzite. An area about 1,200 feet long and 900 feet wide was covered, and individual components of the formation were found to be somewhat varied within this small area, most of which is on the east slope of the canyon wall. As nearly as can be determined, the location is the same as that at which Sloss (1954, p. 365–368) has recently made some observations. The results summarized below differ markedly from those of Sloss, in part because entirely different beds were taken to be the basal unit in the Devonian. Sloss appears to have assumed that the lower one of the two quartzite units on the east slope was at the base of the Devonian sequence, leaving only the small amount of dolomite between that quartzite and the main mass of the Kinnikinic quartzite to be assigned to the Saturday Mountain formation. In many places throughout the region, quartzite and dolomite are interbedded along the contact between the Kinnikinic and Saturday Mountain formations. In one locality in the Borah Peak quadrangle (Ross, 1947, p. 1105), this transition zone is 200 feet thick. At the locality in Black Canyon under consideration, two sets of quartzitic beds are interbedded in dolomite above the top of the main mass of the Kinnikinic quartzite. These and the dolomite with which they are interbedded are here regarded as the lower part of the Saturday Mountain formation. The correctness of this interpretation is clear when the beds are traced across Black Canyon. Further, the quartzite is lithologically like that in the basal part of the Saturday Mountain formation in other localities, and unlike quartzite of Devonian age.

In the area in Black Canyon where detailed measurements were made, the basal dolomite unit consists of beds of dark- to light-gray dolomite containing small chert nodules and stringers and is 35–60 feet thick in different places. The Kinnikinic quartzite on which it rests is somewhat sheared and rusty at the contact. The dolomite contains poorly preserved brachiopods and crinoid stems. This appears to be the unit assigned to the Ordovician by Sloss (1954, p. 365); (Fish Haven dolomite in his nomenclature) but acknowledged by him to be equivalent to the Saturday Mountain formation. The next unit above this consists of quartzite, in beds a few inches to 2 feet thick, which is interbedded with dolomite above and below and contains a few thin dolomite beds. A little fine quartzitic conglomerate is present. The unit is 15–25 feet thick on the east slope of the canyon. On the west slope it is locally thicker and in places is highly irregular in form, apparently the result of original deposition in depressions or channels, but partly also the effect of later deformation in which the hard but relatively brittle quartzite was jammed against more pliable dolomite beds.

The dolomite next above is dark colored and thick bedded. It appears to vary in thickness from 65 to about 160 feet. The dolomite in some nearby outcrops is brecciated.

The unit next above is ill defined and in places poorly exposed. It constitutes the second zone of quartzite. Some of the quartzite contains carbonate that weathers rusty. In places quartzite beds, commonly about 1 foot thick, alternate with dolomite beds in a zone up to 20 feet thick.

The next unit above constitutes the uppermost component of the Saturday Mountain formation in this exposure. The color is various shades of gray, mostly rather light. In much of the unit the bedding is indistinct, but some of the dolomite has closely spaced parting planes on bedding surfaces and is laminated between these planes. Chert nodules are fairly common. A few quartzitic beds, up to 3 feet thick, are included. No fossils except crinoid stems were found in the area where the section was measured, but R. J. Ross, Jr., identified in the field fossils of probable Late Ordovician age on the same slope farther south, apparently from the unit described in this paragraph. Within the area where measurements were made, this unit is 140–160 feet thick.

The various unit measurements listed above show that at the locality represented by the planetable measurements the Saturday Mountain formation is at least 280 feet thick, and at the northern end of the area of measurement it may be even 100 feet thicker. Less detailed planetable work in the area along the range front between Black and Middle Canyons indicates thicknesses close to 350 feet.

Search here and in other localities by Cloud, R. J. Ross, Jr., and the writer agree with Sloss' conclusion that no rocks of Silurian age are present in this part of the Lemhi Range.

On the high ridge east of Black Canyon and somewhat more than a mile from the border of the range, the Saturday Mountain formation differs in detail from the rocks just described. On the basis of a traverse made with Abney level and tape, the first unit above the Kinnikinic quartzite is about 135 feet of moderately dark dolomite in beds about 3 feet thick. Dolomite containing chert nodules, partly in beds 3 inches to 2 feet thick, lies above and has a total thickness of about 285 feet. The next 100 feet of beds consists of alternating dark- and light-gray dolomite, in part laminated. The total apparent thickness of the formation here is 520 feet. One zone of fractures parallel to the bedding was noted but is not believed to record a fault of significant displacement. Northward along the same ridge the Saturday Mountain formation appears to exceed the thickness just given, but the exposures do not permit satisfactory measurement.

Northward throughout the area, the unit mapped as the Saturday Mountain formation retains its broad lithologic characteristics. The transition zone at the base varies from place to place and is absent in many localities. The beds have been so much deformed that measurements of thickness are difficult to obtain. R. A. Anderson (1948, p. 9) estimated the thickness at 400–700 feet, which agrees in a general way with observations made during the present study. Near Badger Creek the thickness is certainly greater than it is farther south. Planetable data coupled with that obtained during mapping lead to the opinion that the formation in that area is over 1,000 feet thick but probably less than 1,500 feet thick. Variations in the attitudes of the beds are too marked to permit accurate measurement.

As noted below, two collections made immediately under beds mapped as of Devonian age contain a mixture of fossils of Ordovician and Silurian age, a fact which indicates that at these localities, and perhaps at others in the northern part of the mapped area, remnants of Laketown dolomite are preserved but have not been separately mapped. The remnants are certainly not large, perhaps only a few feet in stratigraphic thickness.

It is not clear to what extent the wide variations in stratigraphic thickness in the Saturday Mountain formation result from variations in original deposition. As the overlying map unit is of Late Devonian age, there was time enough for erosion to have affected materially the differences in thickness noted.

AGE

The Saturday Mountain formation in certain localities contains numerous well-preserved fossils, which have been studied and are reported on by R. J. Ross, Jr. (1959). Most of the good collections were obtained within about 100 feet stratigraphically of the base of the formation. The rest of the formation contains rather sparsely scattered and poorly preserved cup corals and crinoid stems, except for an occasional bed containing other fossils. Ross in the paper just cited concludes that the unit mapped in the field by the present writer as belonging to the Saturday Mountain formation, is partly of Late Ordovician, partly of Silurian age. The part of Silurian age is represented by the remnants of such rock mentioned above and these do not belong to the Saturday Mountain formation. At its type locality, northwest of the area here described, the Saturday Mountain formation was regarded as stratigraphically equivalent to the Fish Haven dolomite of Utah and the upper portion of the Bighorn dolomite of Wyoming (Ross, 1937, p. 22). In the southern Lemhi Range the unit is lithologically more like the Fish Haven dolomite than it is farther northwest, to the extent that it is dominantly a carbonate rock, and the suggestion has been made (Sloss, 1954, p. 365) that this name should be applied to it. The lithologic change from the type locality in the Bayhorse region (fig. 14) to the southern Lemhi Range is gradual and consists largely of a variation in the proportions of the components. For this reason, and because the southern Lemhi Range is closer geographically and geologically to the type locality of the Saturday Mountain formation than to that of the Fish Haven dolomite, the former is the preferable name.

One collection (USGS 3831-SD), reported on by Jean Berdan, from talus below field station 124 (in Bunting Canyon, pl. 7) contains *Halysites* (*Halysites*) cf. *H. labyrinthicus* (Goldfuss), a phacelloid coral with long septa and arched tabulae, the mold of a pentameroid brachiopod, a phacelloid coral with thick walls and no observable septa, and a Stromatoparoid(?). Berdan says that the presence of the *Halysites* and the poorly preserved pentameroid indicate a Laketown (Silurian) age for at least part of this collection. She adds that reexamination indicates that the phacelloid coral, although poorly preserved, is probably *Palaephyllum* and of Ordovician age. Lithologically, the rock from which this collection came was correlated with the Saturday Mountain formation without hesitation, and the area contains no strata that resemble the Laketown dolomite of the Borah Peak quadrangle (Ross, 1947, p. 1105–1107). The collection was made near the contact with strata of Devonian age and a few feet of beds of Silurian age may well have been overlooked.

Additional material collected by Jack Terry from this spot yielded only some poorly preserved fossils (collection JT 21), concerning which R. J. Ross, Jr. (written communication) reported as follows: "Most specimens from this collection are too badly recrystallized to preserve critical structures. One *Favosites*-like coral may belong to the genus *Nyctopora*. If forced to choose an age, I would guess Ordovician for this collection."

Another collection from the main fork of Badger Creek near field station H 185 (pl. 7), reported on by Jean Berdan in consultation with Ellis Yochelson, is similar. This collection (USGS 4450-SD) was obtained from talus near the contact between the Saturday Mountain formation, as mapped in the field, and Devonian rocks. It was found to contain *Halysites* sp., cross sections of pentameroid brachiopods, and *Palaeophyllum* sp. The first two are of Silurian age and "are types common in the Laketown dolomite," whereas the *Palaeophyllum* "is Upper Ordovician and is a common coral of the Fish Haven and Saturday Mountain dolomites." Thus this collection constitutes a second instance in which beds of apparent Silurian age are present close to the top of the unit. Both are in the drainage basins of Badger Creek and have yielded fossils of both Ordovician and Silurian affinities. Collection USGS 5236–SD from field station 137, a short distance downstream from collection USGS 4450–SD and stratigraphically only a little below it, yielded, according to Jean Berdan, only "unidentifiable streptelasmoid horn corals." She adds: "These appear to be the same types as those from collections labeled Saturday Mountain."

THREE FORKS LIMESTONE AND OLDER ROCKS

DISTRIBUTION

Rocks that are regarded definitely equivalent to the Three Forks limestone of the Borah Peak quadrangle and others that are almost as certainly equivalent to the Jefferson dolomite of that quadrangle are present in the southern Lemhi Range. Presumably equivalents of strata of the Grand View dolomite are also present (Ross, 1947, p. 1107–1112) (fig. 14). Exposures are mostly poor and fossils inadequate for separating the formations, so that it has been found necessary to map as a unit all rocks regarded as of Devonian age.

Devonian rocks lie just east of the Saturday Mountain formation and any Silurian strata mapped with it, from Middle Canyon to the valley of a prominent but unnamed stream between North Creek and Uncle Ike Creek. They are again exposed farther west, north of Uncle Ike Creek, and occupy a broadening area from there to the northern border of the mapped area. Small exposures were noted along Horse and Williams Creeks also.

CHARACTER

The rocks in the southern Lemhi Range that appear to be of Devonian age are, with few exceptions, poorly exposed and of varied character. In the Borah Peak quadrangle (Ross, 1947, p. 1107–1112) the rocks of that age, in ascending order, are the Jefferson dolomite, Grand View dolomite, and Three Forks limestone. Beds reminiscent of all three formations were noted in the southern Lemhi Range. The aggregate thicknesses in most localities are much less, and some beds are lithologically different from those in the Borah Peak quadrangle. In a general way, the beds above those characteristic of the Saturday Mountain formation and below those of Mississippian age include dolomite, largely darker than any in the Saturday Mountain formation, and commonly containing some beds replete with white calcite stringers, yellow-weathering quartzitic sandstone, a few conspicuous nearly black limestone beds, and thin-bedded impure limestone that weathers in small, thin, rust-colored slabs. The aggregate thickness, as shown in the detailed descriptions below, ranges from about 300 feet near Black Canyon to about 1,200 feet at the head of the north fork of Uncle Ike Creek and even more in the upper drainage basin of Badger Creek. For comparison, it may be noted that south of Challis (fig. 14) only the Jefferson and Grand View dolomites are recognized, about 2,100 feet in aggregate thickness; whereas, in the Borah Peak quadrangle (fig. 14) the Jefferson dolomite averages nearly 800 feet in thickness, the Grand View dolomite somewhat over 2,100 feet, and the Three Forks limestone about 300 feet.

Under the microscope, the rocks of Devonian age differ little from those of the Saturday Mountain formation, except that relatively coarse clear carbonate grains are somewhat more plentiful. Some of those in limestone beds are as much as 2.0 mm in diameter. The cement of the quartzite beds has been recrystallized. Some grains have been crushed, somewhat like those in the Swauger quartzite. The clastic grains in the quartzite include some rounded bits of fine-grained quartzite and rare grains of plagioclase, both of which may have been derived from the Swauger quartzite.

The hill east of Black Canyon, where the Saturday Mountain formation was measured in detail, contains strata of Devonian age that were similarly measured. The basal unit, assigned to the Devonian, is a yellow calcareous quartzitic sandstone, identical in appearance with beds that are prominent in the Jefferson dolomite of the Borah Peak quadrangle (Ross, 1947, p. 1108). In Black Canyon these beds are a few inches to a foot thick and are discontinuous. They are interbedded in the lower part of a massive dolomite unit. Most of the unit is nearly black dolomite, commonly with ramifying calcite stringers that may represent traces of organisms now unidentifiable. Some beds of lighter gray dolomite are intercalated in the black dolomite, especially near the base. Gray dolomite associated with the yellow sandstone locally contains abundant stromatolites of at least two kinds. One of these has been identified by Richard Rezak (oral communication, 1956) as *Collenia frequens*. This one is shown in plate 9*A*. The unit is 50 feet thick and forms a cliff. The overlying unit also forms cliffs but is a lighter colored, somewhat sandy dolomite 50–90 feet thick. The greater thickness of the lighter dolomite is at the north end of the area of measurement, where exposures are poor and the estimate may include part of the next unit above. The latter consists of beds of light- and dark-gray dolomite that weathers brown. In the southern part of the area measured it is about 50 feet thick. The next overlying unit consists largely of soft carbonate-rich siltstone, with some dolomite beds, 1–2 feet thick. It weathers brown and is about 50 feet thick. The next unit, roughly 100 feet thick, is fairly light-gray magnesian limestone in beds 1–3 feet thick containing small chert concretions. Above this is impure, argillaceous limestone that weathers brownish yellow and is so poorly exposed that its thickness was not determined. Sloss (1954, p. 366) estimated it as 33 feet. On this basis the Devonian assemblage has a total thickness in this hill of at least 330 feet.

The rocks of Devonian age on the high ridges between Black and Middle Canyons are poorly exposed and much deformed. Thick beds of nearly black and dark-gray limestone are common and parts of these are fossiliferous. Much of the limestone is sheeted, roughly parallel to the bedding. Some beds, mostly light-colored, are dolomitic. In a few places rusty-weathering, slabby argillaceous limestone is conspicuous. Limy argillite and siltstone, with chert, are also present. Estimates of thickness of the Devonian assemblage, made in different places along these ridges, range from 50 to more than 400 feet, at least in part because beds have been faulted out locally.

The rocks mapped as of Devonian age on the west slope of Black Canyon upstream from the measured area are largely dark dolomite similar to that with sandstone at its base. Fossils are few. On the ridge fissile rocks are included, and the contact with the Milligen formation is ill defined and probably gradational. Strike faulting may have thinned the Devonian rocks here.

Between the locality just mentioned and Uncle Ike Creek, a number of masses of rocks assigned to the Devonian are mapped. All are poorly exposed and are deformed, so that stratigraphic details are obscured. In some places dolomitic rocks without diagnostic fossils that are mapped as belonging to the Saturday Mountain formation and overlying dolomite, if any, might be of either Silurian or Devonian age, but the quantity of this questionable material is so small as to be of slight importance.

At the head of the north fork of Uncle Ike Creek the entire assemblage of Devonian rocks is exposed along the crest of a narrow ridge. The beds here were measured by D. W. Hinckley, with the results tabulated below. At this locality, as in Black Canyon, subdivision is necessarily on a lithologic basis. Part of the lowest unit listed in the table may belong to the Saturday Mountain formation or the Silurian rocks locally mapped with that formation.

It seems probable that the upper three units listed correspond to the Three Forks limestone of the Borah Peak quadrangle. The base of the measured section is at station H 159 (pl. 2).

Section at the head of the north fork of Uncle Ike Creek

	Thickness (feet)
Devonian:	
Brazer limestone (thin-bedded basal member):	
Limestone or dolomite, thin-bedded; with some argillaceous beds	57
Limestone, pale-gray to white; with thin sandy layers	71
Limestone, pale; with abundant chert	131
Dolomite, light- and dark-gray, passing upward into limestone	84
Dolomite, dark-gray, at base; then tan sandy dolomite; light-gray dolomite; and white quartzite, in part calcareous	202
Dolomite, light- to medium-gray; followed upward by 25 feet of rusty quartzite, 10 feet of gray dolomite, and thin beds of impure quartzite	77
Dolomite, light-gray, medium-gray, yellowish-brown, and nearly black, interbedded with rusty to white quartzite	90
Dolomite, light to nearly black; with 30 feet of nearly pure quartzite at top	91
Dolomite, gray to nearly black; interbedded with slightly argillaceous and calcareous quartzite	181
Limestone, magnesian, black and gray; with calcite stringers and beds of yellowish-brown sandy dolomite	94
Dolomite, light-gray to nearly black; in part laminated	127
Saturday Mountain formation and overlying dolomite (if any)	?
Total thickness of beds of Devonian age	1,205+

North of Uncle Ike Creek the Devonian beds enter an area that was not studied in detail. Along the upper forks of Badger Creek these rocks are abundant. They include dolomite like that described above, some limestone, and, especially low in the sequence, yellowish-brown quartzite or quartzitic sandstone. The rocks are so folded and broken as to preclude measurement, but the thickness is over 1,000 feet, possibly nearer to 1,500 feet.

AGE

The rocks mapped as of Devonian age received that assignment largely on the basis of their lithologic character and stratigraphic position. In the paleontologic work fossils from the uppermost beds have proved to be the most diagnostic. The nearly black dolomite, seamed with calcite, that is the major component of the lower part of the sequence is so similar in appearance to rock mapped as Jefferson dolomite in the Borah Peak quadrangle that its assignment is made with confidence. P. E. Cloud, during his visit to Black Canyon in 1955, agreed with the assignment on the basis of his familiarity with the Jefferson in Montana. The yellow sandstone in Black Canyon tends to support this conclusion. Similarly, the rock in the drainage basin of Badger Creek includes beds with characteristics of the Jefferson and Grand View dolomites in and west of the Borah Peak quadrangle. The uppermost beds of the Devonian assemblage in the southern Lemhi Range do not weather with the bright yellow colors that make the Three Forks limestone in the Borah Peak quadrangle so conspicuous. However, they are similar in that they are limestone, in part argillaceous, rather than dolomite, and in places are rusty on weathered surfaces.

A collection (USGS 4441–SD) from the lower part of the uppermost unit of the measured section in Black Canyon contains *Cyrtospirifer* sp. and undetermined bryozoa. It is regarded by Jean Berdan as of Late Devonian age. Another collection (USGS 4442–SD), which was obtained just above the end of the measured section but still within the uppermost unit, is reported by Jean Berdan in consultation with Ellis Yochelson to contain *Cyrtospirifer* cf. *C. animasensis* (Girty), *Cyrtospirifer* sp., *Athyris angelica* Hall?, *Camarotoechia* cf. *C. horsfordi* (Hall), *Bairdia* sp. This assemblage apparently represents the *Athyris angelica* zone commented on by Dutro.

J. Thomas Dutro, Jr., has studied a number of collections from the limestone at the top of the Devonian sequence. He regards all the collections listed below, with one possible exception (USGS 4425–SD) as representative of a single faunule. He thinks this faunule can be correlated with the *Athyris angelica* zone of Warren and Stelck (1956), which is at the top of the Devonian sequence in western Canada. He further sees resemblances to the highest faunule in the Three Forks formation of southwestern Montana and to recent collections from the uppermost part of the Devonian beds in Logan Canyon, Utah. His determinations of the fossils from localities in the southern Lemhi Range follow. The localities from which the principal collections came are plotted on plate 7.

USGS 4418–SD From high on ridge east of Black Canyon. Station 42.
Camarotoechia cf. *C. nordeggi* Kindle
aff. *C. horsfordi* (Hall)
Pugnoides cf. *minutus* (Warren)
Nudirostra sp.
Cyrtospirifer aff. *C. animasensis* (Girty)
sp.
gastropod, indet.
cephalopod, indet.

In addition to some of these, A. J. Boucot found *Pugnax minuta* in this collection and in collections 4419–SD and 4420–SD.

USGS 4422–SD From east slope of the ridge east of the lower part of Black Canyon and somewhat east of the measured section in that canyon. Station T2.
Camarotoechia cf. *C. nordeggi* Kindle
aff. *C. horsfordi* (Hall).

USGS 4420–SD From high on a ridge between Black and Middle Canyons. Station 139.

Camarotoechia cf. *C. nordeggi* Kindle
aff. *C. horsfordi* (Hall)
Pugnoides cf. *P. minutus* (Warren)
Cyrtospirifer aff. *C. animasensis* (Girty)

USGS 4419–SD From ridge crest east of Black Canyon and nearly 2 miles north of the mountain front. Station 221.

Productella cf. *P. coloradoensis* Kindle
Pugnoides cf. *P. minutus* (Warren)
Cyrtospirifer sp.
Athyris aff. *A. angelica* Hall

USGS 4423–SD From the middle fork of South Creek. Station 321.

brachiopod indet.
gastropod indet.

(Note: Field evidence suggests this collection is from beds lower in the Devonian sequence than others listed here.)

USGS 4421–SD From near the head of the middle fork of South Creek. Station 355.

Cyrtospirifer sp.

USGS 4424–SD From the upper reaches of Camp Creek. Station 425.

Leioproductus? sp.
Planoproductus? sp.
Cyrtospirifer aff. *C. animasensis* (Girty)

W. H. Hass found *Palmatolepis* sp. in this collection. He regards this "conodont genus as an index of the Middle and Upper Devonian" but notes that some stratigraphers believe it "ranges naturally into the lower Mississippian." This collection was also examined by A. J. Boucot, who reported *Cyrtospirifer* sp., productillid with spinose pedicle valve, and smooth trachial valve and a leioproductid with apparently smooth valves. He said the collection was "of Upper Devonian age."

USGS 4425–SD From slope above Uncle Ike Creek. Station 516.

Cyrtospirifer sp.

Boucot noted that collections 4418–SD, 4419–SD, 4420–SD, and 4421–SD are of Late Devonian age and contain fossils similar to those from the Minnewanka limestone of the Banff region. The Minnewanka corresponds in age to the Three Forks and Jefferson of Montana (Cooper, 1942).

In addition to the above, two collections of poor fossils from near the ridge crest west of the upper part of Black Canyon were regarded by R. J. Ross, Jr., as probably Devonian. One of these contains *Cyrtospirifer* near *C. monticola*. He also noted that a collection from near Camp Creek shows outlines of "spirifers" and *Camarotoechia*-like forms and hence is probably of post-Ordovician age. The rock at this location is mapped as Devonian. He further states that collection JT 14, from station T 1, contains *Cyrtospirifer* sp. *Camarotoechia*? sp. and *Productilla* sp., and is probably of late Devonian age.

A number of other collections have been reported on by Jean Berdan in consultation with Ellis Yochelson. Of these, collections USGS 4438–SD, 4439–SD, and 4440–SD are from the narrow exposure of rocks mapped as of Devonian age in the outlying hills north of latitude 43°55' and west of longitude 113°05'. The first of these collections contains unidentifiable fragments of brachiopods; the second contains gastropods and poorly preserved brachiopods, not sufficiently diagnostic for an age determination but not opposed to the assignment to the Devonian made in the field.

USGS 4444–SD is from station 746, south of Dry Creek. It contains *Athyris?* sp., *Bairdia* sp., undetermined bryozoa, pelmatozoan debris. USGS 4445–SD from station 752, contains *Camarotoechia* cf. *C. nordeggi* Kindle, *Bairdia* sp. These two collections are thought to represent the horizon that has been likened by Dutro to the *Athyris angelica* zone at the top of the Devonian sequence in western Canada.

USGS 4446–SD and USGS 4447–SD are from at and east of station 813 near the middle of the measured section of Devonian rocks on the ridge at the head of the north fork of Uncle Ike Creek. The first of these contains *Amphipora?* sp., probably from the upper Middle or lower Upper Devonian. The other contains *Atrypa* sp., which has a wide stratigraphic range but in the present instance is thought to be from the upper Middle or lower Upper Devonian.

USGS 4449–SD from station 900 high on the slope east of the upper reaches of Badger Creek contains *Amphipora?* sp. and is probably of late Middle or early Late Devonian age.

USGS 4451–SD is from station 971 above Williams Creek. It contains *Cyrtospirifer* sp., *Rhipidomella* sp., and undetermined bryozoa and is of Late Devonian age.

USGS 4452–SD is from station 1006 north of Williams Creek, mapped as near the base of an assemblage of Devonian age. It contains *Reuschia?* sp. This coral is very poorly preserved but, if correctly determined, indicates Late Ordovician rather than Devonian age. In view of the uncertainty as to identification, the map has not been modified to fit the determination. USGS 4453–SD from station 1011, farther up the same ridge, contains *Cyrtospirifer?* sp., a rhynchonellid brachiopod, and other brachiopod fragments. It is of Late Devonian age.

USGS 4453–SD is from station 1011 above Horse Creek and contains *Cyrtospirifer?* sp., rhynchonellid brachiopod, and other brachiopod fragments, all badly distorted. The age is Late Devonian.

In summary, the above reports show most of the rocks to be of Late Devonian age, none older than late Middle Devonian. The best of the collections appear to be of very late Late Devonian age, corresponding to the top of the Three Forks formation in Montana and similar horizons in western Canada and northern Utah. These results, coupled with the lithologic characteristics of the rocks that were mapped in the field as of Devonian age, lead to the conclusion that the Three Forks limestone is definitely present and rocks essentially equivalent to the Jefferson and Grand View dolomites are also represented. The three names are here employed in the sense in which they were used in the Borah Peak quadrangle (Ross, 1947, p. 1107–1112). There is nothing to show that Devonian rocks older than the Jefferson dolomite are present in the southern part of the Lemhi Range. It may also be remarked that the southern Lemhi Range has yielded no evidence that suggests that the Three Forks limestone includes any beds of Mississippian age as the corresponding unit in Montana is reported to do (Wilson and others, 1959, p. 496).

UPPER PALEOZOIC ROCKS

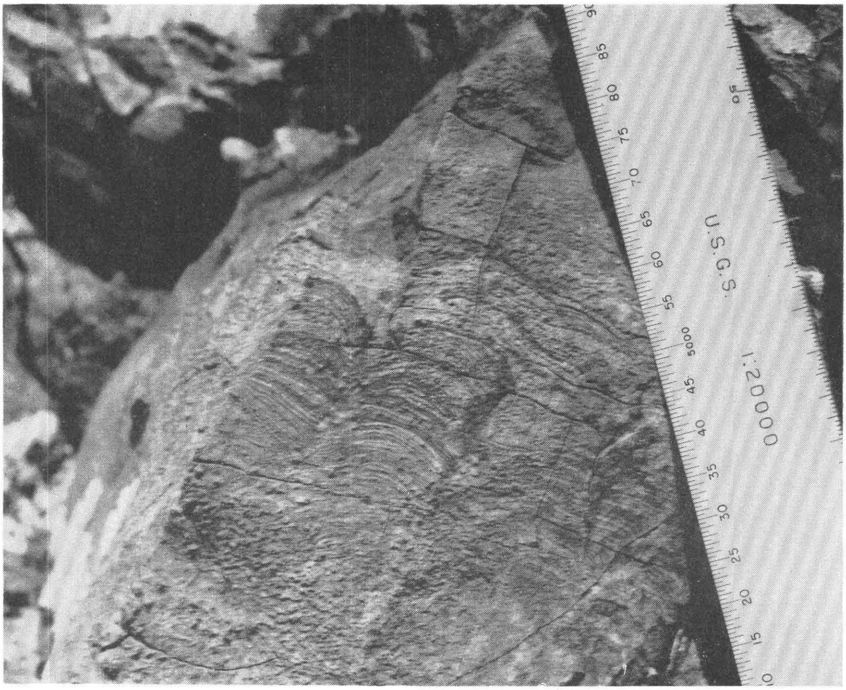
MILLIGEN FORMATION

DISTRIBUTION

In several spots, rock that seems best regarded as belonging to the Milligen formation is exposed. The largest and most characteristic of the exposures are in small hills east of the lower part of Black Canyon and narrow exposures are present over the ridge east of that valley. A small amount of similar rock is present beneath the slab of thin-bedded Brazer limestone nearly 2 miles above the mouth of Black Canyon and in the saddle 1 mile to the north of that place. Narrow exposures were noted along the upper reaches of South Creek. The hill slope south of the lowest prominent fork of South Creek contains an area underlain by rock assigned to the Milligen with some hesitation. Bedrock exposures are almost nonexistent here, therefore part of the material mapped as Milligen may belong to the Brazer limestone. North of South Creek no exposures of the Milligen formation were mapped. Perhaps the lower parts of the thin-bedded component of the Brazer limestone here are stratigraphic equivalents of the Milligen, but on a lithologic basis the assignment shown is the most logical.

CHARACTER

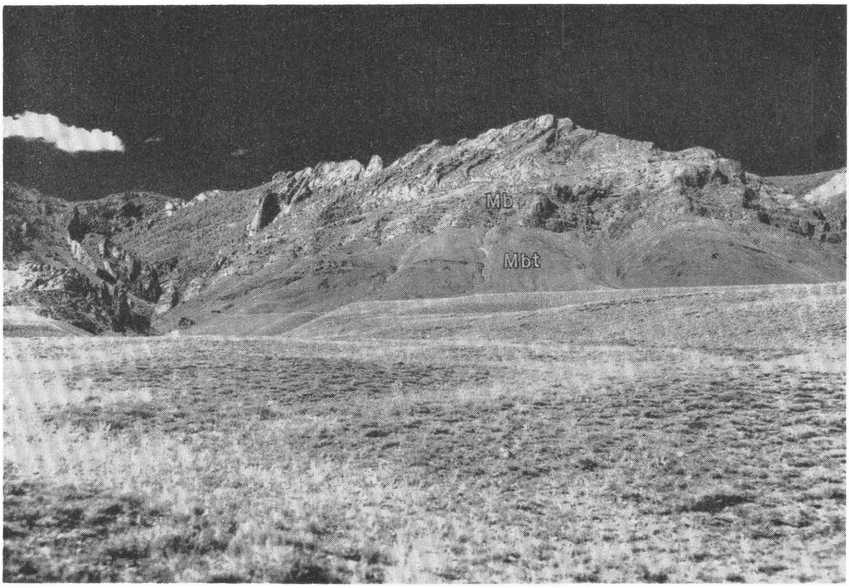
The Milligen formation in the Borah Peak quadrangle (Ross, 1947, p. 1113) consists mainly of dark-gray to black carbonaceous shale. In the southern Lemhi Range the rock so designated in-



A. COLLENIA FREQUENS IN DOLOMITE OF DEVONIAN AGE IN BLACK CANYON

B. INFRARED PHOTOGRAPH OF BRAZER LIMESTONE AT THE HEAD OF SURRETT CANYON, 2 MILES SOUTHEAST OF THE COPPER MOUNTAIN MINE AND JUST EAST OF THE CREST OF THE LEMHI RANGE

These beds are overturned to the southeast, contrary to the regional pattern. Also, the recumbent syncline in the upper right-hand part of the view appears to be separated from the contorted anticline in the left part of the picture by a thrust that dips gently southwest.



A. INFRARED PHOTOGRAPH OF CRUMPLED BRAZER LIMESTONE (*Mb*) NEAR THE MOUTH OF MIDDLE CANYON

The recumbent syncline has no systematic relation to the steep beds to the left, nor to the regional structure. The smooth slopes in the foreground are underlain by the basal, thin-bedded unit of the Brazer limestone (*Mbt*); one massive limestone bed is visible in it.

B. VIEW WHERE UNCLE IKE CREEK EMERGES FROM THE MOUNTAINS

The gentle saddle with lines of bushes in it is the former valley of Uncle Ike Creek, and the gorge to the right, which now contains the channel of the stream, is of later origin. The high, tree-covered bench to the right of the creek is floored with boulders, presumably of glacial origin (*Qg*). The peak behind the bench exposes nearly white Kinnikinic quartzite (*Ok*) capped by gray rocks belonging to the Saturday Mountain formation (*Osm*). The rocks between the bench and the valley floor belong to the Swauger quartzite (*p€s*), here showing steep, indistinct schistose partings.

cludes similar shale, some fine-grained siltstone, and much nearly black chert in thin layers. Locally impure limestone or limy shale beds are included. The chert is identical in appearance to that in the lower part of the Brazer limestone and the two formations presumably grade into each other. In the present report only those rocks in which shale is an outstanding constituent are mapped with the Milligen.

The Milligen formation in the southern Lemhi Range is too intricately contorted and poorly exposed for reliable measurement. Near the mouth of Black Canyon it is several hundred feet thick. Sloss (1954, p. 366) has estimated the thickness in this locality at 200 feet. The maximum there is surely less than 500 feet and decreases northward until rock characteristic of the formation is absent entirely. This contrasts with thicknesses of about 1,000 feet in the Borah Peak quadrangle (Ross, 1947, p. 1113) 3,000 feet still farther west (Ross, 1937, p. 31), and 5,500 to 7,500 feet near the type locality of the formation (Killsgaard, 1950, p. 40). R. A. Anderson (1948, p. 9) reports a measured thickness of 400 feet of "black shale" north of North Creek, near the road to the Bighorn mine. Clearly his statement applies to thin-bedded cherty material here mapped as low in the Brazer limestone.

The shale consists largely of angular quartz grains, embedded in chert, chlorite clay, and sericite. Minor constituents include epidote, apatite, and tourmaline. A few grains may be plagioclase. Carbonaceous films anastomose through the rock, and some beds contain carbonaceous dust and grains of organic matter that is red in transmitted light. The quartz grains are commonly 0.01–0.02 mm in diameter and rarely as large as 0.05 mm. Rounded aggregates of interlocking grains of quartz in some beds range up to somewhat more than 0.5 mm in diameter. These were probably originally quartz pebbles.

AGE

No fossils were found in the Milligen formation in the southern Lemhi Range, but the position between rocks of Three Forks age and those in the lower part of the Brazer limestone is in agreement with the age assignment made in the Borah Peak quadrangle. There the Milligen formation was stated to be clearly of Mississippian age and more or less equivalent in age to the Madison limestone.

BRAZER LIMESTONE AND RELATED ROCKS

SUBDIVISIONS AND DISTRIBUTION

In areas in south-central Idaho farther west, a unit high in the Paleozoic sequence and composed mainly of limestone has been designated the Brazer limestone in previous studies (Ross, 1934, p.

977–985; 1937, p. 33–36; 1947, p. 1113–1117) even though it was realized that incompatibilities existed among the fossils contained therein. Most of the rocks mapped as Brazer in those areas are surely of Late Mississippian age, like the Brazer in its type locality (Richardson, 1913, p. 413–414) and also in southeastern Idaho (Mansfield, 1927, p. 63–71) but some may be post-Mississippian. In the southern part of the Lemhi Range rocks in a similar stratigraphic position are even thicker and more complex than those just cited. There are so many lithologic similarities among them that subdivision into formational units is impractical on the basis of present information. On the other hand, as noted below, faunal evidence shows that they include beds of Middle Pennsylvanian, and perhaps also of Permian age, and thus are not strictly comparable to the original Brazer limestone. For the present the assemblage is termed the Brazer limestone and related rocks, formal designation of the subdivisions being left for the future.

The entire northeastern slope and the crest of the part of the Lemhi Range here described, with the exception of small patches of Cenozoic rocks, consists of Brazer limestone and related rocks. It is in this part of the area that the beds of post-Mississippian age have been found. The higher parts of the southwestern slope of the range are underlain by rocks belonging to the same map unit but believed to be all of Mississippian age. Similarly the greater part of the outlying hills between South and North Creeks consists of the part of the map unit that is correlatable with the Brazer limestone itself. Comparable beds are plentiful near the range front between Badger and Williams Creeks and also in the part of the Arco Hills that has been mapped. In these three areas no limestone of post-Mississippian age has been recognized.

Within the Lemhi Range the Brazer limestone and related rocks were examined in more detail south of latitude 43°54′ than north of there and east of the vicinity of the range crest. For the latter area, no large-scale aerial photographs were available and the high-altitude photographs were not obtained until most of the fieldwork had been concluded. In the area examined in comparative detail, several subdivisions were mapped. Of these, the main body consists essentially of limestone like that characteristic of the Brazer limestone in previously mapped areas to the northwest, cited above. A basal, thin-bedded unit which thins and is less distinctive northward, was distinguished. This member is present also in the Borah Peak quadrangle but is thin and not separately mapped there. Higher in the sequence in the southern Lemhi Range a soft sandy member is conspicuous south of Saddle Mountain. If present farther north, this member was not detected either in the field or in studies of high-altitude photographs by Morris. Still higher in the sequence is another member characterized by the presence of crinoidal beds. Judging by the high-altitude photographs, this member pinches out northward. It is succeeded upward by comparatively thick-bedded limestone such as is characteristic of the main body.

CHARACTER

The basal member in the southern Lemhi Range is much like the basal part of the Brazer limestone in the Borah Peak quadrangle, except that joint faces are less conspicuously stained by iron oxides in the southern Lemhi Range. Much of the unit in that area consists of rather dark gray impure limestone in beds 2–6 inches thick, interleaved with black chert laminae a fraction of an inch to a few inches thick. Locally the chert is the predominant component. A few of the noncherty beds contain very nearly as much noncalcareous material as much of the rock in the underlying Milligen formation.

Many of the beds contain abundant calcite, mostly in irregular grains but in part in rhombs. Commonly the carbonate grains are about one-half millimeter in diameter. Angular grains of quartz, subordinate plagioclase and shreds of white mica together may make up perhaps 40 percent of the rock, although the proportions of noncalcareous constituents vary from bed to bed. Tourmaline, in clastic grains, is a minor component.

Several dark-gray comparatively pure fossiliferous limestone beds a few feet to about 20 feet thick are interspersed in the thin-bedded material. These are relatively resistant to erosion and form raised ribs on gentle slopes and cliffs on steeper ones (pl. 10*A*). The thin beds contain few fossils but parts of the thick ones have corals and brachiopods in some abundance. The thickness is varied and difficult to determine accurately. In most places it exceeds 1,000 feet.

The main body of the Brazer limestone and related rocks is likewise similar to that of the Brazer limestone as mapped in the Borah Peak quadrangle. It consists almost entirely of limestone, some of which contains intermixed sand and most of which contains chert in layers and nodules. The limestone is distinctly bedded in units that are commonly one to several feet thick. The color on fresh fracture varies but is commonly some shade of bluish gray; weathered surfaces are lighter gray. This part of the formation is more fossiliferous than the other members mapped. Its general character is visible in plates 8*B*, 9, and the upper part of plate 10*A*. The planetable traverse tabulated below is representative of a large part of the unit between the sandy and crinoidal members.

In an assemblage as thick as that here described many variations in lithologic details are to be expected. As viewed in the field, the principal variations among the limestone beds of the main body are in the thicknesses of the beds and in the proportions and shapes of chert nodules. Another variation, whose significance cannot be judged on present data, is in the abundance of masses of colonial corals. Some beds are composed almost entirely of such masses for distances of scores of feet along the strike.

Some of the beds consist mainly of ill-defined carbonate aggregates in which the larger grains reach diameters of about 0.05 mm and many rounded granules have diameters of 0.005–0.01 mm. In other beds clear, fairly well defined calcite grains up to 1 mm in diameter are embedded in a cement composed of carbonate grains about 0.002 mm in diameter. Both kinds of beds have scattered, angular to subangular grains of quartz up to 0.1 mm in maximum dimension, and some beds also contain enough sericite to be conspicuous. In general, many beds are probably comparable in purity to that in the Borah Park quadrangle (Ross, 1947, p. 1178), which was found to contain 96.13 percent calcium carbonate, or to that at Arco (Loughlin, 1914, p. 1384), which averages 98.2 percent. Much of the carbonate is in clear, crystalline grains that may be products of recrystallization.

The sandy beds in the sandy member, mapped east and southeast of Middle Canyon and described in the section tabulated below, are more quartzitic than might be inferred from their tendency to yield to erosion. The clastic quartz grains are not as well rounded as most of those in the beds of Devonian and Ordovician age, but this characteristic is exaggerated, when viewed in thin section, because quartz has been added, producing an interlocking mosaic. The boundary between the original grain and the newly crystallized quartz is faintly visible in some grains but was not detected in many. Closely spaced lines of bubbles are conspicuous in many of the clastic grains and aid in distinguishing between old and new quartz.

Part of the crinoidal member is included in the tabulated section already referred to. The rest is so poorly exposed and so variable in attitude that it was not measured. Although exposed along the range crest, this member yields readily to erosion, forming gentle slopes cut by shallow drainage ways. The member consists mainly of soft limestone of various light colors. Most of it weathers in slabs. Massive tan-weathering limestone beds a few feet thick are interspersed. The distinctive beds with crinoid fragments are dark-gray to black chert, through which calcite is irregularly scattered. The chert contains various fossil fragments but the most abundant and obvious are pieces of crinoid stems up to about 2 mm in diameter. Some of the limestone beds contain well-rounded sand grains up to 0.25 mm in diameter. These are mostly quartz but include a little plagioclase and microcline.

Section of part of the Brazer limestone northeast of lat 43°52½′ N. long 112°55′ W.

	Thickness (feet)
Rolling, soft beds including dark chert layers crowded with bits of small crinoid stems, and thin beds of limestone that breaks in thin slabs and forms inconspicuous outcrops. Some beds of limestone have a sugary texture and grayish-yellow color	?
Beds similar to the above but on steeper slopes, so the attitudes are somewhat better seen. Basal part of this unit is sugary white limestone that weathers rusty. Some of the limestone is pinkish gray. This unit and that above it belong to the member mapped on plate 7 as containing crinoidal chert beds	450±
Limestone, somewhat soft, indistinctly bedded, mostly light colored but with some dark beds; weathers yellowish brown	110
Limestone, gray to pale-orange, rather thick bedded; in part coarsely crystalline, in beds 2 or more feet thick	160
Limestone, light- to dark-gray, locally almost black; in beds 2–4 feet thick, interspersed with beds of shelly limestone that do not crop out; lower part of unit includes white to gray, thick-bedded, mostly coarsely crystalline limestone with sparse chert kidneys	220
Limestone, mostly light- to dark-gray, well-bedded; beds a few inches to over a foot thick; chert sparse in lower part but higher beds include chert layers and kidneys of chert up to 2 feet long	150
Limestone, gray, well-bedded; contains some layers and nodules of chert	1,290
Limestone; poorly defined beds containing chert nodules and layers	530
Limestone, mostly rather thick-bedded; contains some chert; in upper part alternating 4-inch layers of chert and limestone, with a few beds of soft, sandy limestone	360
Limestone, thick-bedded, with chert; includes beds of chert up to 3 feet thick and nearly white calcareous sandstone beds	120
Sandstone, calcareous, and sandy limestone (pl. 7); includes some shaly beds and others of limestone and chert nodules; fresh rocks show various shades of light gray but most of them are stained with iron oxides so that the unit as a whole looks brownish in outcrop	320

The Brazer limestone and related rocks are everywhere so contorted that thickness measurements are difficult to make. Section D–D′, plate 7, suggests that the total exposed thickness is close to

8,000 feet. The top is nowhere visible. A series of measurements northeastward from East Canyon across the range to Cline Canyon furnishes some details. Here the limestone between the top of the thin-bedded basal member and the base of the soft, sandy member is estimated to be roughly 2,500 feet thick. Planetable measurements that include the sandy member and extend almost to the low range crest give a total of 3,710 feet of beds. Details of this traverse are tabulated on page 221. The crinoid-bearing unit underlies the undulating terrain on both sides of the divide. The beds roll at low to moderate angles and direct measurement is impractical. The thickness of these beds exceeds 1,000 feet. Measurements were not carried east of the divide but the moderately thick-bedded gray limestone that overlies the crinoid-bearing unit is fully 500 feet thick. Thus the total thickness above the thin-bedded basal unit of the Brazer is about 7,700 feet in this locality.

AGE

The rocks here mapped as belonging to the Brazer limestone and related rocks were so assigned during the fieldwork on the basis of lithologic character and stratigraphic position. Except for a larger proportion of clastic deposits and, locally, of crinoidal chert beds, the unit has close similarities in lithology and stratigraphy to the assemblage mapped as Brazer limestone (Upper Mississippian) in the Borah Peak quadrangle (Ross, 1947, p. 1113–1117). Much more than half of the total here mapped is confidently regarded as equivalent to the Brazer limestone of the Borah Peak quadrangle. This conclusion is in agreement with opinions expressed by P. E. Cloud and his associates during their field inspection in 1955.

The basal member is nearly unfossiliferous, except that the thick limestone beds within it locally contain brachiopods and corals. According to Cloud and his coworkers, some beds in the main part of the formation contain numerous fossils, including some that resemble *Penniretepora*, *Buxtonia*, *Schellwienella*, *Syringopora*, *Lithostrotionella*, *Straparollus*, *Syringothyris* and *Leiorhynchus*, cf. *L. carboniferum* Girty. Fossil algae may also be present. The soft, sandy member contains "*Buxtonia*," aff. *B. arkansanus*. Enough fossils were seen by Gordon and Cloud in the crinoidal member to indicate to them that this member, like the beds below it, is of Mississippian age. However, the comparatively thick-bedded limestone above the crinoid-bearing member, as noted below, includes beds that have yielded fossils of Middle Pennsylvanian age. Other beds farther south contain fossils believed to be of Permian age. Thus a large part of the Brazer limestone and related rocks as mapped in the present report is of post-Mississippian age. Perhaps only the lower part of the unit in the southern Lemhi Range is the approximate equivalent of the Brazer in its type locality (Richardson, 1913) but formal subdivision cannot be set up on the basis of present data.

Near the southern tip of the Lemhi Range, in sec. 27, T. 6 N., R. 30 E., a collection of fossils was made by Blackstone (Blackstone, 1954) in 1949 and submitted to M. L. Thompson for identification. Thompson found *Schwagerina* in it, considered by him to be indicative of middle Wolfcamp (Permian) age. The locality in which the collections were made suggests that the beds from which it came may be stratigraphically below the crinoid-bearing member.

In 1957 a collection was made by Betty A. L. Skipp of the Geological Survey as nearly as could be determined in the same general locality as that of Blackstone. This collection was examined by L. G. Henbest, whose report follows.

USGS f–12428 collection.—The bodies in the samples of dolomitic limestone that appear to be the remains of Fusulinidae are unrecognizable, for certain, even as having been fusulinids. The silicified streaks, however, bear recognizable Schwagerininae that seems to represent one or more species of *Pseudofusulina* of the general form of *P. longissimoidea* (Beede and Kniker, 1924). The general structure of the shells is obscure, but the keriothecal structure of the walls is clearly preserved in a few instances. Early Permian age is indicated, but on the basis of the present thin sections, the possibility that these fusulinids actually are species of *Kansanella* and accordingly of early Upper Pennsylvania age cannot be definitely eliminated. Early Permian age seems a fairly safe assumption.

In addition to observations made in the field by Cloud, Gordon, and R. J. Ross, Jr., a number of fossil collections were made during the mapping. A report on these, prepared by W. J. Sando in consultation with Helen Duncan, J. T. Dutro, Jr., E. L. Yochelson, and L. G. Henbest, is abstracted below. The stations from which collections of determinable fossils were obtained are plotted on plate 7. In most of the collections corals are the dominant forms, but brachiopods and other fossils are plentiful in some. The corals, although poorly preserved and incomplete, include, according to Sando, forms typical of the fauna described from the Brazer limestone of Utah by Parks (1951). A few exotic forms are also present. Most of the fossils indicate a Late Mississippian age, but one collection from near the top of the exposed sequence is of Middle Pennsylvanian age, and another locality has yielded fossils of Permian age.

Report on fossils collected during mapping

[Abstract of reports by W. J. Sando, Helen Duncan, J. T. Dutro, Jr., E. L. Yochelson, and L. G. Henbest. Asterisks in front of the names of fossils indicate forms regarded as especially significant]

USGS locality no.	*Description*
16500	Brazer, station 89, northwest of mouth of canyon of South Creek. Collected by C. P. Ross, July 3, 1954. **Turbophyllum* cf. *T. multiconum* Parks *Turbophyllum* was described from about the middle of the Brazer limestone of Utah by Parks (1951). The collection is presumably of Brazer (Late Mississippian) age.
16501	Brazer, collected loose on fan, station 93, north of South Creek. Collected by C. P. Ross, July 3, 1954. **Lithostrotion* (*Siphonodendron*) *whitneyi* Meek **Ekvasophyllum* sp. *Ekvasophyllum* was described from the lower Brazer limestone of Utah by Parks (1951). *Lithostrotion* (*Siphonodendron*) *whitneyi* Meek is common in Upper Mississippian rocks of the Cordilleran region. It has been reported from the middle of the Brazer limestone of Utah by Parks (1951). Kelly (1942) summarized other occurrences of this species, which include the Brazer limestone or its equivalents in Utah, Idaho, Montana, and Nevada. The reported occurrence of this species in the Pennsylvanian of Canada by Shimer (1926, p. 5, 14, 15, 26, 27) is erroneous. The collection is therefore presumably of Brazer (Late Mississippian) age.
16502	Brazer, station 101, on hills that project into valley of Little Lost River. Collected by C. P. Ross, July 5, 1954. **Ekvasophyllum* sp. The presence of *Ekvasophyllum* in this collection indicates a Brazer (Late Mississippian) age assignment.
16503	Brazer, station 102, on hills that project into valley of Little Lost River. Collected by C. P. Ross, July 5, 1954. **Ekvasophyllum* sp. **Turbophyllum* cf. *T. multiconum* Parks *Syringopora* (*Kueichowpora*) sp. *Ekvasophyllum* and *Turbophyllum* have been described from the lower and middle Brazer limestone of Utah. The presence of *Kueichowpora*, known from the Lower Carboniferous of China and Alaska confirms a Late Mississippian age assignment.
16504	Brazer, station 105, on hills that project into valley of Little Lost River. Collected by C. P. Ross, July 5, 1954. **Ekvasophyllum* cf. *E. turbineum* Parks The presence of *Ekvasophyllum* in this collection indicates a Brazer (Late Mississippian) age assignment.
16505	Station 148, lower Brazer, from talus from the thin-bedded basal member of the Brazer below Diamond Peak. Collected by C. P. Ross, July 10, 1954. Indet. koninckophyllid coral Crinoid columnals Worm trails?

Report on fossils collected during mapping—Continued

USGS locality no.	*Description*
	This collection consists of a piece of limestone containing corals, a piece of limestone containing crinoidal remains, and a piece of siltstone containing supposed worm trails. The coral is indicative of rocks of late Paleozoic age, hence does not contradict a Brazer assignment. The worm trails(?) and crinoidal remains are of no value for age assignment.
16506	Station P129, near Black Canyon, from a massive limestone bed in the thin-bedded, basal member of the Brazer. Collected by C. P. Ross, July 22, 1954. Indet. gastropods Indet. zaphrentoid coral The material in this collection is inadequate for precise age determination. The zaphrentoid coral present may belong to *Rotiphyllum*, a Mississippian form, but the specimen is too incomplete for even generic identification. The gastropods are of no value for precise age determination. Sando thinks the age may be late Paleozoic, possibly Mississippian.
CPR–73	(Collector's number) Brazer, station 259, in hills in valley of Little Lost River. Collected by C. P. Ross, Aug. 7, 1954. Indet. horn corals The corals in this collection, although indeterminate, suggest the genus *Ekvasophyllum*, a Brazer (Late Mississippian) element. Although they do not permit a precise age assignment, the age is certainly late Paleozoic.
16507	Brazer, station 268, near Great Western mine. Collected by C. P. Ross, Aug. 9, 1954. **Caninia* cf. *Caninia* sp. B of Parks Brazer (Late Mississippian) age is indicated by the large coral similar to that described from the upper Brazer limestone of Utah by Parks (1951).
16508	Brazer, station 287, in hills in valley of Little Lost River. Collected by C. P. Ross, Aug. 11, 1954. *Diphyphyllum* sp. Crinoid columnals The presence of the coral genus *Diphyphyllum* in this collection indicates a Mississippian age assignment.
16509	Brazer, station 687, low hills that project into valley of Little Lost River. Collected by C. P. Ross, July 2, 1955. Indet. zaphrentoid corals Crinoid columnals Indet. encrusting bryozoans *Indet. echinoconchid brachiopod **Composita* sp. **Punctospirifer* aff. P. *transversa* (McChesney) Indet. bellerophontid gastropod According to Dutro, the brachiopods in this collection suggest a Late Mississippian age assignment. The other fossils in the assemblage are compatible with this determination but add no further information.

Report on fossils collected during mapping—Continued

USGS locality no.	*Description*
16510	Station H28, base of soft, sandy member of the Brazer limestone near East Canyon. Collected by D. W. Hinckley, July 7, 1955. *Orbiculoidea* sp. The material in this collection is inadequate for precise age determination. The brachiopod genus *Orbiculoidea* ranges from Ordovician to Permian.
16511	Station H29, lower part of soft, sandy member of the Brazer, near East Canyon. Collected by D. W. Hinckley, July 7, 1955. Indet. encrusting bryozoan **Diaphragmus* aff. *D. cestriensis* (Worthen) **Chonetes* aff. *C. oklahomense* Snyder *Orthotetes* sp. Indet. pectinoid pelecypod According to Dutro, the brachiopods in this collection indicate a Late Mississippian age. The other fossils in the assemblage are compatible with this determination but add no further information.
16512	Station H44, from main body of Brazer limestone below soft sandy members near point where section tabulated on p. 221, starts. Collected by D. W. Hinckley, July 18, 1955. **Caninia* cf. *Caninia* sp. B of Parks Indet. productid brachiopods **Diaphragmus* cf. *D. cestriensis* (Worthen) Indet. bellerophontid gastropod The coral present in this collection is similar to a form recently described from near the top of the Brazer limestone in Utah by Parks (1951). Supporting evidence of a Brazer assignment are the brachiopods, which, according to Dutro, suggest a Late Mississippian age.
16513	(Colln. of Foraminifera f–12371.) High in Brazer, station H219, Cedar Canyon. Collected by D. W. Hinckley, Sept. 3, 1955.

Megafossils	**Foraminifera*
**Lithostrotion* (*Stylostrotion*) sp. A.	*Earlandia* sp. aff. *E. perparva* Plummer
**Lithostrotion* (*Stylostrotion*) sp. B.	*Spiroplectammina*? sp.
Syringopora sp.	*Climacammina* 2 sp.
Dibunophyllum sp.	*Endothyra* sp.
Crinoidal remains	*Bradyina* sp. aff. *B. magna* Roth and Skinner
Echinoid spines	*Globivalvulina* sp.
**Ascopora* sp.	*Tetrataxis* sp.
Rhabdomeson sp.	*Paramillerella* sp.
**Rhombotrypella* sp.	*Millerella*? sp.
**Rhomboporella* sp.	*Pseudostaffella*? sp.
Straparollus (*Straparollus*) sp.	*Profusulinella* sp.
Indet. euomphalid gastropods	*Fusulinella* sp. (early form)
Indet. bellerophontid gastropods	

Report on fossils collected during mapping—Continued

USGS locality no.	*Description*
	According to L. G. Henbest, "The foraminifer assemblage characterizes the lower part of the Bend group in Texas and of the Atoka series in the midcontinent. In Idaho rocks of that interval are classed as of early Middle Pennsylvania age." Helen Duncan has observed also that "the bryozoans *Ascopora, Rhombotrypella* and *Rhomboporella* first appear in western Carboniferous faunas about the same time as the fusiform fusulinids." The type of lithostrotionoid coral differentiated as *Stylostrotion* is based on a Chinese species from the Middle Carboniferous (approximately equivalent to Middle Pennsylvanian of American usage). The critical fossils, therefore, point to an early Middle Pennsylvanian assignment for beds high in the sequence mapped in this report as Brazer limestone and related rocks in southern Lemhi Range. The other fossils in this collection are compatible with this determination but add no further information.
16514	Station H235, on west side of range, near its south end. From the main body of the Brazer just above the soft, sandy member. Collected by D. W. Hinckley, September 12, 1955. **Diaphragmus?* sp. *"*Productus*" aff. "*P*". *inflatus* McChesney Indet. productid brachiopod According to Dutro, the brachiopods in this collection indicate a Late Mississippian age. The locality is close to that where the foraminifera reported to be of Permian age were obtained.
16515	Fossils from talus composed of thin-bedded, basal member of Brazer limestone (Mississippian). Station 8 near top of jeep road leading up north side of valley of North Creek, collected by Jack Terry, June 23, 1954. *Lithostrotion* (*Siphonodendron*) sp. Indet. carcinophyllid coral *Fenestella* sp. *Polypora* sp. The material in this collection is inadequate for precise age determination. It is definitely late Paleozoic and does not contradict a Mississippian assignment.
16516	Cup corals in breccia composed of Brazer limestone, station 11, at mouth of Middle Canyon. Collected by Jack Terry, June 24, 1954. **Ekvasophyllum* sp. *Indet. gigantoproductid brachiopod The coral genus *Ekvasophyllum* was described by Parks (1951) from the lower Brazer limestone of Utah. The gigantoproductid brachiopod identified by Dutro in this collection supports a Brazer (Late Mississippian) assignment.
16517	Fossils, mostly from talus from nearby cliffs, Brazer? Near station 14 west of Middle Canyon. Collected by Jack Terry, June 24, 1954. **Ekvasophyllum* sp. *Lithostrotion* (*Siphonodendron*) aff. *L. scoticum* Hill This collection consists of pieces of gray limestone containing *Ekvasophyllum* and a large piece of chert containing *Lithostrotion* (*Siphonodendron*) aff. *L. scoticum* Hill. A Brazer (Late Mississippian) assignment is indicated by *Ekvasophyllum,* which occurs in the lower

Report on fossils collected during mapping—Continued

USGS locality no.	*Description*
	Brazer limestone of Utah (Parks, 1951). The chert may have come from the same horizon inasmuch as *L. scoticum* is known from rocks, in Scotland and Ireland, considered equivalent to Upper Mississippian.
16518	Station 127, range front near Badger Creek. Crinoids and corals, collected by Jack Terry, July 8, 1954. **Ekvasophyllum* sp. Crinoid columnals The presence of *Ekvasophyllum* in this collection indicates a Brazer (Late Mississippian) age.
16519	Brazer(?), station 139, on a fork of Badger Creek. Coral, collected by Jack Terry, July 9, 1954. **Ekvasophyllum* sp. **Diphyphyllum* aff. *D. ingens* Hill The two corals in this collection indicate a Late Mississippian age assignment. *Ekvasophyllum* was described by Parks (1951) from the lower Brazer of Utah. *Diphyphyllum ingens* occurs in rocks of Late Dinantian age in Scotland; similar forms are also known from the Upper Mississippian of Alaska.
JT–29.	(Collector's number) Station 143, right slope of Middle Canyon, from thin-bedded basal member of the Brazer. Collected by Jack Terry, July 26, 1954. Indet. zaphrentoid corals Crinoid columnals Indet. spiriferoid brachiopods The material in this collection is inadequate for precise age determination. It is suggestive of a post-Devonian Paleozoic age, but even that is uncertain.

CENOZOIC ROCKS

LAVA AND ASSOCIATED ROCKS

DISTRIBUTION

Lava flows and pyroclastic rocks form scattered exposures at the southern end of the Lemhi Range and along its northeastern flank. One mass of such rocks extends, with interruptions resulting from erosion, from the place where State Highway 22 crosses the southern tip of the range northward to Kyle Canyon, a distance of about 7½ miles. Exposures in an outlying hill southeast of Kyle Canyon are included in this mass. Other exposures occur along Eightmile Canyon and Pass Creek, and in the northern part of the mapped area.

CHARACTER

Most of the rocks from Kyle Canyon south are rather silicic flows and welded tuffs. These probably differ more in appearance than in chemical composition. Some are white to very light gray.

Some, though rather light colored and grayish, have red-purple and orange-pink tones. A few are reddish or yellowish brown on fresh surfaces. Others are nearly black, streaked with grayish orange. Most are glassy, rather indistinctly and irregularly laminated rocks with inconspicuous phenocrysts of alkalic plagioclase, and, in some, of quartz and, rarely, of hornblende. In many rocks, nearly all the phenocrysts consist of oligoclase; in some, the feldspar is albite. Presumably these glassy rocks have the average composition of latite and quartz latite.

Table 1 gives the alkali and trace-element content of several of these rocks. It was prepared for comparison with data on broadly similar rocks assembled by Howard Powers of the Geological Survey in connection with studies in progress in the vicinity of Twin Falls in southern Idaho. The results of the comparison are inconclusive but suggest greater resemblance to rocks in southern Idaho regarded as of late Tertiary age than to those believed to be of Quaternary age. The stations at which the samples listed in the table were obtained are shown on plate 7.

TABLE 1.—*Partial analyses of volcanic rocks in the southern part of the Lemhi Range, in percent*

[Alkali content derived by standard gravimetric analysis, by Faye H. Neuerburg. Trace-elements content derived by quantitative spectrographic analysis—fluorine, by E. J. Tomasi; all others by Paul R. Barnett]

USGS laboratory No.	B 451	B 452	B 453	B 455	B 456	B 457	B 458
Field No.	CPR 99	CPR 100	CPR 157	DH 20	DH 21	DH 22	DH 26
Station No. (See pl. 7)	361	361	723	H 221	H 225	H 225	H 240
Potassium oxide	5.20	5.36	5.20	4.70	5.06	4.88	0.28
Sodium oxide	3.29	2.99	3.02	3.14	2.73	3.08	2.41
Fluorine	.10	.19	.07	.04	.10	.02	.01
Titanium	.2	.1	.15	.15	.25	.25	.60
Manganese	.02	.02	.025	.025	.04	.04	.08
Boron	.0015	.0015	.015	.015	0	0	0
Barium	.09	.09	.08	.08	.09	.10	.015
Beryllium	.001	.0006	.0007	.0015	.002	.0015	0
Cobalt	0	0	0	0	0	0	.008
Chromium	0	0	.0003	.0002	.00025	.00025	.01
Copper	.0002	.0003	.0004	.00025	.0003	.0004	.005
Gallium	.0015	.0015	.0015	.0015	.0015	.002	.002
Lanthanum	.009	.01	.009	.015	.015	.015	0
Molybdenum	.0006	.0008	.0004	.0004	.0007	.0005	0
Niobium	.004	.004	.003	.003	.004	.004	0
Nickel	0	0	0	0	0	0	.15
Lead	.003	.004	.003	.003	.003	.003	0
Scandium	0	0	0	0	0	.0007	.003
Tin	.0006	.0007	.0007	0	.001	.0008	0
Strontium	.003	.003	.007	.006	.008	.01	.04
Vanadium	.001	0	.001	.001	.0005	.001	.015
Yttrium	.005	.006	.006	.006	.007	.008	.004
Ytterbium	.0006	.0006	.0006	.0006	.0008	.0008	.0004
Zirconium	.02	.02	.03	.015	.04	.05	.008

The volcanic rocks along Eightmile Canyon include porous, nearly white tuff, in part given a green color by chlorite along joint surfaces, and basalt with calcite amygdules. The tuff has the general appearance of much of that in the Germer tuffaceous member of the Challis volcanics near and west of Challis (Ross, 1937, p. 53–64). Basalt crops out abundantly near Pass Creek. Near both Eightmile Canyon and Pass Creek much of the basalt is olive gray and fine grained, and consists of small laths of calcic plagioclase with small augite phenocrysts, in part converted to fibrous aggregates. Much of that near Pass Creek is darker colored than that near Eightmile Canyon and is a fresher rock. The basalt near and north of Pass Creek has interbedded with it beds of a grayish orange pink dense rock with scattered crystal fragments. The ground mass consists of partially devitrified shards and pumice fragments and the crystal fragments include quartz, two or more feldspars, hornblende, augite, and hypersthene. The rock is a silicic tuff different in appearance from the varieties common in south-central Idaho. North of Pass Creek there is an exposure of chalky white, porous, fossiliferous limestone, presumably a lake deposit. This rock contains a subordinate quantity of shards.

AGE

Fossils from the tuffaceous limestone north of Pass Creek (station 1016, pl. 7) were examined by D. M. Taylor, with the results listed below.

Fresh water clams:
- *Pisidium*
- *Sphaerium*

Fresh water snails:
- Valvate
- *Lymnaea* cf. *palustris* (Müller)
- *Planorbidae*, small species; *Gyraulus parvus* (Say) and (or) *Promenetus umbilicatellus* (Cockerell)
- Physidae, genus indeterminate

The material does not permit positive age assignment, but Taylor thinks it is probably Pliocene or Pleistocene. The possibility of a Miocene age cannot be ruled out because existing data on Miocene fresh water mollusks in general is inadequate.

The scattered exposures of volcanic rocks in the southern Lemhi Range may not all be of the same age, but, on the basis of the degree of weathering and erosion, it seems that those that have yielded fossils are at least as old as any of them. On the same basis, these rocks are more likely to be of Pliocene than Pleistocene age, an inference that is in line with that based on the trace element content. The volcanic rocks near Kyle Canyon are older than the old alluvium described below, which may be as old as Pliocene.

Vertebrate fossils regarded as somewhere between early Miocene and early Pliocene in age (Wilson, 1946, p. 1262) have been found in the valley of the Lemhi River north of the area here reported on. It is becoming increasingly clear that volcanic and interrelated sedimentary rocks were laid down in south central Idaho at intervals throughout much of Tertiary time. On the basis of present data, the relation between the beds that yielded the vertebrate fossils and those near Pass Creek is unknown.

OLDER ALLUVIUM

Tilted and somewhat consolidated alluvial deposits are probably widespread on the mountain flanks and throughout the valleys of Little Lost River and Birch Creek, although masked in most places by younger material. Patches of them have been distinguished in the hills between Badger and Williams Creeks. On the northeast flank of the Lemhi Range, similar deposits extend several miles south of Kyle Canyon. They may be extensive near Pass Creek, but have not been mapped separately there.

The older alluvium consists of silty sand and gravel indistinguishable from that of modern fans except that it is somewhat consolidated. In prospect tunnels and fresh stream cuts it can be seen to be inclined at angles up to more than 40°. The cement is mainly calcareous, furnishing a link between the old alluvium and deposits, described below, that contain much hot-spring tufa.

This alluvium resembles in several respects the Donkey fanglomerate (Pliocene?) (Ross, 1947, p. 1122–1124) of the Borah Peak quadrangle. The latter forms dissected hills while the old alluvium of the southern Lemhi Range is on the borders of the major valleys and has been trenched but otherwise little dissected by modern streams. This may reflect nothing more than a difference in the local erosional history but is sufficient to make correlation with the Donkey fanglomerate inadvisable at present.

As the older alluvium is cut by stream channels that at their heads bear evidence of glaciation assumed to be of the Wisconsin stage, it must be older than late Pleistocene. Because of the deformation it has been subjected to, its age may well be Pliocene.

TUFA AND TUFA-CEMENTED BRECCIA

Tufa and coarse material cemented thereby are present near Middle Canyon and also in the foothills west of Badger Creek. The tectonically brecciated limestone on the ridge crest north of South Creek appears to be bordered by tufa-cemented breccia derived from it but the amount is so small it was not mapped.

Porous, dirty-gray tufa of the sort commonly deposited by hot springs mantles the ground around Bartel Spring west of Middle Canyon. The water that drips through the tufa at present is not hot but is depositing carbonate. The thick cavernous deposits of tufa close to the channel of Middle Canyon suggest that at one time deposition was so vigorous that the water may have been heated. These deposits contain abundant, ill-sorted, and angular to somewhat rounded fragments of rock, mostly Brazer limestone. They appear to be a medley of copious precipitates from spring water and the slide rock of the mountain slopes.

The deposits west of Badger Creek are similar but less conspicuous. Some of the rock fragments in them are sufficiently well-rounded so that tufa-cemented breccia grades into old alluvium with calcareous cement. Further, some of the limestone in the vicinity is brecciated along faults, and fragments from the fault breccia mingle both with the old alluvium and the tufa-cemented breccia.

It is assumed that tufa began to be deposited from spring water early in the development of the mountains, especially in areas where ground water percolated through Brazer limestone. The tufa and breccia here mapped may range in age from Pliocene to the present day. It is analogous to the travertine and tufa of the Bayhorse and Borah Peak areas (Ross, 1937, p. 62–64; 1947, p. 1125), although a larger proportion of included fragments of older rocks is included.

GLACIAL DEPOSITS

Within the areas studied at close range, glacial deposits that can be distinguished from the alluvium of present streams are scanty. One patch is perched on a high bench between Uncle Ike Creek and the unnamed canyon to the south. That canyon also has glacial debris in its upper reaches. Small moraines are present along and probably also north of the north fork of Eightmile Canyon. It is possible that other glacial deposits are hidden in canyons, mostly on the northeast slope of the range, that were not traversed during the present investigation. If so, they are individually so small as to be inconspicuous on the high-altitude photographs.

The perched boulder field south of Uncle Ike Creek (lat 44°01′ N., long 113°02′30″ W.) is made up of subangular to rounded boulders a few inches to several feet in maximum dimension. Most of them consist of Kinnikinic quartzite. Some dolomite of the Saturday Mountain formation and, toward the west, components of the Swauger quartzite are included. The deposit, as can be seen in plate 10*B*, appears to lie on a fairly flat surface and may be only a few feet thick, just enough to mask the bedrock. Cliffs rise abruptly along its eastern border and fall away from it on the rest of its periphery. The flat surface might be interpreted as part of an old, dissected erosion surface, of which the broad, rolling ridge crest between South and Camp Creeks is another remnant. The latter has no accumulation of glacial boulders but, as already noted, does have a small amount of tufa-cemented breccia on the borders of a tectonically brecciated slab of Brazer limestone.

The glacial detritus in the unnamed valley between Uncle Ike and North Creeks is in a hummocky terminal moraine, somewhat incised by the present stream channel. That along the upper canyon of Pass Creek and Eightmile Canyon is in a group of irregular moraines that may have been deposited from one or more glaciers fed by icefields around the peak with a present altitude of 10,504 feet above the sea (pl. 7).

The deposits along present stream channels are presumably of Wisconsin age. The boulder field south of Uncle Ike Creek is completely independent of present drainage and is doubtless pre-Wisconsin. It may be correlated with other high-level glacial deposits in south central Idaho (Ross, 1937, p. 93–95) which have been very tentatively supposed to be of Nebraskan age. Perhaps they are older than the deposits of the Buffalo stage near the Idaho-Wyoming boundary, which have been tentatively correlated with the Kansan stage (Blackwelder, 1931, p. 918). The latter are more extensive and reach lower altitudes than the high-level glacial deposits in the mountains of south-central Idaho.

YOUNGER ALLUVIUM

Alluvial deposits that are loose or, at most, partially cemented rise above the silt-floored part of the valley of Little Lost River. These deposits floor the major parts of the valleys of Little Lost River and Birch Creek up to altitudes close to 5,000 feet at the southern tip of the Lemhi Range and close to 7,000 feet at the northern border of the mapped area. Within the mountains only the larger valleys have enough alluvium to be mapped on plate 7. In places alluvium and talus merge in such fashion that some talus has been included with the alluvium on the map. The only broad expanse of alluvium mapped in the mountains is along the left slope of the valley of Uncle Ike Creek.

The alluvium consists of gravel, sand, and silt, which, for the most part, have accumulated in coalescent fans. By far the greater part of the fan material is moderately coarse gravel with occasional boulders a yard in diameter. This material corresponds to the "older alluvium" mapped in the Bayhorse region.

About 3 miles south of the Badger Creek ranch, a cut in the terrace bordering the flood plains of Little Lost River, which was made in the construction of the main road, reveals a bed of white silicic volcanic ash in the alluvium (pl. 7). The ash is 1 inch thick and consists of pumaceous shards so tiny that they appear to have been carried from some distant source by wind. No probable source for material of this kind is known in the surrounding region. The volcanic vents on the Snake River Plain that might be of suitable age have yielded basaltic material.

The flood-plain alluvium within the mountains is not given a distinctive pattern on plate 7 but the relationship to modern stream channels is obvious. This alluvium corresponds essentially to the "younger alluvium" of the Bayhorse region (Ross, 1937, p. 72). Where mountain streams debouch on the fans at the mountain borders they tend to break up into small distributaries and their deposits spread out over the fans and lose their identities. A few of the streams are incised into the fans for a mile or more beyond the bedrock border. Those in Middle Canyon on the southwest slope of the range, and Eightmile Canyon and Pass Creek on the northeast slope, are among the more conspicuous of these. Terraces of this general character are both less well developed and less complex than they are in the Borah Peak quadrangle (Ross, 1947, p. 1149–1150). Those that border Little Lost River are cut into by the channels of intermittent streams that carry water from the mountains. These have dumped small fans immediately beyond the terraces.

The comparatively large mass mapped as alluvium on the left side of Uncle Ike Creek, within the mountains, underlies a steep slope, is trenched by the present streamways, and includes some boulders over 5 feet in diameter. The material may well be of glacial origin, but it has been so redistributed as to have lost whatever morainal form it may have had originally.

The younger alluvium, as mapped on plate 7, merges locally with glacial deposits and includes the product of modern streams. Hence, its age ranges from late Pleistocene to Recent.

SNAKE RIVER BASALT

The Snake River basalt covers wide expanses of the Snake River Plain, south of the area here reported on. A tongue of it extends some distance up the valley of Birch Creek, in part covered by a thin veneer of silt and gravel. The western border of this tongue is shown on plate 7. According to local report, shallow wells show that the basalt underlies the silt plain in the valley of Little Lost River to a point about 1 mile north of Howe and is in turn underlain by gravel. Evidently the flows in the valley of Birch Creek and Little Lost River belong to the upper part of the Snake River basalt. Hence they can be no older than Pleistocene and might be of Recent age.

SILT AND ASSOCIATED BEDS

The part of the valley of Little Lost River that borders the present river channel is floored by silt and mud between boundaries fixed by fairly continuous terraces cut in alluvium. The silt-floored area is less than 1 mile wide near the northern border of the mapped area and more than 5 miles wide in the southern part of that area. It includes the undrained depression south of the Lemhi Range known as the Lost River Sinks and continues south of the mapped area. This depression is the terminus of Big Lost River, which swings in an arc past Arco through the northern border of the Snake River Plain (fig. 14).

The silty material in the northern part of the area constitutes the modern flood plain of Little Lost River. At slight depths beneath the surface, coarser material is present (Stearns and others, 1938, p. 232–243). Much of the flood plain is swampy. Farther south, where a wider area is covered by it, the silt includes intercalated gravel beds, as revealed in pits dug for road metal and in wells. Close to the southern end of the range the bounding terrace is absent and the wind has carried silt over the alluvial fans almost to the mountain border. Here no sharp boundary with alluvium can be mapped.

Evidently water has spread in the past far beyond the present channel in the lower reaches of the river. Possibly the entire silt-floored flat from near South Creek southward was covered by a playa lake, presumably during a period of comparatively moist climate. These playa deposits are similar to and perhaps coextensive with the "lake beds of the Mud Lake region" (Stearns and others, 1938, p. 88–89, pl. 4; 1939, p. 37–38, pl. 3).

As the silty material is obviously younger than most of that mapped as younger alluvium, it cannot be older than very late Pleistocene and is presumably Recent in age. It may correspond broadly to the "flood plain alluvium" of the Bayhorse region (Ross, 1937, p. 72–73).

DIKE ROCKS

The southern Lemhi Range is notable for the paucity of intrusive igneous rocks. Only a few small bodies have been found. These are so much altered that accurate identification is difficult, and they cut rocks so low in the stratigraphic sequence as to give little basis for an age assignment. The intrusive rocks have been supposed to be of Tertiary age (Ross, 1933, p. 5–6; Anderson, 1947, p. 370) but this assignment is highly tentative.

Narrow dikes of two varieties are known in the Wilbert mine. A small amount of igneous rock was found in talus high on the slope east of Uncle Ike Creek and "basaltic dike material" has been reported near the place where Badger Creek emerges from the mountains (Anderson, 1948, p. 6). Those in the Wilbert mine intrude Precambrian rock, and the others, for which less reliable data are available, are presumed to have cut rock no younger than the Ordovician.

In the Wilbert mine, one or more dikes, a few feet wide, of white rock are present. The rock contains broken phenocrysts of quartz and altered feldspar in a rather fine granular groundmass that was originally composed of quartz, feldspar, mica, and a little apatite but has been in large part replaced by quartz and carbonate of hydrothermal origin (Ross, 1933, p. 5). Another variety of dike rock is exposed in the northern part of the mine. Where seen in 1930 (Ross, 1933, p. 5), it is a mere stringer of strongly altered black rock in which some phenocrysts are oligoclase. Fresher material was found by A. L. Anderson (1947, p. 370), who notes that it contains numerous small phenocrysts of olivine, augite, and biotite in a fine-grained groundmass composed of oligoclase and smaller amounts of biotite, augite, orthoclase, and magnetite. Anderson regards this rock as intermediate between kersantite and spessartite.

The rock near Uncle Ike Creek is now about as thoroughly replaced by carbonate as that in the Wilbert mine. It contains a calcic plagioclase, fibrous material that is at least in part altered biotite, apatite, pyrite, and magnetite, in addition to the abundant carbonate. It is a distinctly coarser rock than either of those in the mine and may have originally been a diabase.

STRUCTURE

The rocks of the southern part of the Lemhi Range have been extensively folded and broken by thrust faults. No major normal faults are recognized. Various interpretations remain possible as to the character and relative ages of the different structural features. The favored explanation, based in part on the regional setting, is that several pulses of major folding, in part obscured by late-stage, unsystematic wrinkling of limestone, have affected the rocks. Steep thrust faults, mostly not of great displacement, may be related to some of the folding and have originated under impulses from the west. These faults are themselves folded, and they are cut off by one or more thrusts of relatively gentle dip. Flexures that affect rocks of probable Tertiary age appear to record relative uplift of elongate mountain ranges and downwarp of intervening valleys, without recognizable faults of significant magnitude.

FOLDS

The Swauger quartzite (Precambrian) was flexed before any of the later rocks were laid down, but to such a slight degree that the resulting discordance with the overlying Kinnikinic quartzite is difficult to detect. Schist planes are prominent mainly near the mouth of Uncle Ike Creek. Here their attitudes are varied, but most strike a little east of north and dip 30°–70° west. Thus the old folding in the Swauger quartzite may trend northeast in contrast to the later folds in the vicinity which trend northwest. A similar situation was recorded in the Borah Peak quadrangle (Ross, 1947, p. 1128–1129).

The mapped part of the Lemhi Range contains most of the northeastern flank of a broad arch. The long, fairly even bands of color that represent the different formations on the map (pl. 7) are displaced as a result of faulting but otherwise have few of the irregularities of shape that would be present if the rocks had been complexly deformed on a regional scale. Thus, most of the conspicuous crumpled beds of pre-Carboniferous age record local features. The beds belonging to the Brazer limestone and related rocks have complexities of their own, commented on separately below.

The location of the southwestern flank of the arch is not known. The hills that project into the valley of Little Lost River northwest of South Creek may contain a segment of it that has moved relatively east, along the thrust pictured in plate 8*B*. The western part of section C–C′, plate 7, shows diagrammatically that the Brazer limestone in these hills is crumpled to such an extent that original structural relations are obscured. Much of the southwestern flank of the major arch may be buried under alluvial deposits in the valley of Little Lost River. So little is known about the eastern slopes of the Lost River Range in this latitude that one cannot judge whether any part of the arch extends so far west.

While the pre-Carboniferous beds, on the whole, behaved competently, there are plentiful local structural irregularities. Of these, the largest and most conspicuous is the fold visible in cliffs about 1 mile west of Black Canyon, shown in plate 8*A*. The exposures in and north of these cliffs indicate this is an S–fold that appears to rise above the crest of a more nearly symmetrical anticline (section D–D′, plate 7). In these respects, it is closely similar to the fold of somewhat greater amplitude in the rocks of Carboniferous age south of Saddle Mountain. If it was not for the fact that the two S–folds are separated by the fault zone in Black Canyon, the simplest explanation would be that the fold in the pre-Carboniferous rocks is the inner portion of the fold in younger rocks near the crest of the range. In the absence of definite evidence as to the displacements in that fault zone, this explanation remains a possible one. It seems, however, more likely that the S–fold in the old rocks has moved up into its present position as a result of thrusting. In this case, the fact that the two sharp flexures are now at nearly the same altitude would be a mere coincidence. A third possibility is that the two are actually parts of a single structure but that both have been tilted and moved around in such fashion that their original mutual relations are altered.

Various other intricate folds in the pre-Carboniferous rocks, mostly much smaller than those discussed in the preceding paragraph, are scattered throughout the mountains. As far as practicable these are plotted on plate 7. Others, still smaller, would be recorded if larger scale mapping were undertaken. Some of the local, crumpled folds are recumbent and most of these are broken by faults. Examples of intense, localized deformation are exposed along the lower reaches of South Creek. Plate 8*B* gives an idea of the structure here. The beds in the broken fold in the foreground belong to the Swauger quartzite which in places on this same slope is even more sharply contorted. The impure quartzite of this formation has crumpled, in restricted areas, almost as if it were an incompetent shale. Where present along South Creek, the even more resistant Kinnikinic quartzite tends to be less crumpled but is markedly jointed. Another area of crumpled beds is at the Wilbert mine between North and Camp Creeks. Here the Swauger quartzite is bent into an anticline sharply overturned to the northeast, in association with both thrusts and small normal faults. The interest in the Wilbert mine and the exposures afforded by its workings have resulted in exceptionally detailed structural data at this place (Ross, 1933, p. 6–7, pls. 1 and 2). All the features mentioned in this and the preceding paragraph are, in various degrees, associated with thrusts.

In the broad areas underlain by the Brazer limestone and related rocks, the major folds are moderately narrow and trend northwest. In the Lemhi Range, most folds parallel approximately the arch discussed above. In the Arco Hills trends are somewhat irregular. In both areas the axes shown on plate 7 were drawn by Morris from aerial photographs. He was able to follow some axes for more than 3 miles. Originally the folds may have been much larger but they are so thoroughly obscured by superimposed, apparently unsystematic folds that they cannot be traced far by inspection of the photographs. Some of the elongate folds are overturned and at least one, in the Arco Hills, may be broken by a thrust fault.

The feature of the structure in the Brazer limestone and related rocks that most impresses the casual observer is the multitude of heterogeneous, mostly small folds. These are the features that mask the long folds as noted in the preceding paragraph. Oblique photographs that include views of these rocks, such as plates 8*B*, 9*B*, and 10*A*, tend to emphasize the intricacy and irregularity of the deformation. Where thus deformed, the Brazer limestone and related rocks remind one of a piece of paper crumpled in the hand rather than of beds that have yielded to tangential stresses applied evenly over a broad region. Similar structure exists in the Brazer limestone of the Borah Peak quadrangle and has been illustrated and discussed in the report on that area (Ross, 1947, p. 1129–1132).

All the Brazer limestone and related rocks in the mapped area display unsystematic folds like those commented upon in the preceding paragraph. They are plentiful among the narrow folds in the drainage basin of Pass Creek and are subordinate, though striking, features of the big overturned folds near Saddle Mountain (pl. 10*A*). In the mapped part of the Arco Hills, folds of this type predominate and tend to mask the regional structures. Such folds throughout the region are a product of later deformation, which followed the shaping of the major regional structures. By that time the load on the rocks would have been decreased through erosion, thus facilitating heterogeneous flowage in the limestone beds. No Mesozoic beds are known in the Lemhi Range, and few remnants have been found in the Beaverhead Mountains, the next range to the east. Thus at the time of deformation the Brazer limestone and related rocks may have been under little cover, if any. The unit itself is so thick that the lower parts of it were under considerable load even if no later rocks were present. Whatever the superincumbent loads and regional pressures may have been, it is obvious that in addition to regional folding of the usual type, the Brazer limestone and related rocks were deformed in a manner fundamentally different from that of the older rocks. In this deformation, the limestone was not folded in response to forces exerted along definite and constant directions. On the contrary, it flowed like a laminated, plastic substance soft enough to be shoved in various directions in response to minor, variable forces. The limestone was a crystalline aggregate, not a plastic material but the effect reminds one of a plastic.

The rocks involved in the folds described above are all Paleozoic and older, and there is great structural discordance between them and the young consolidated rocks. The latter include lava, tuff, and alluvium that may range in age into the Pliocene or perhaps even the Pleistocene. Wherever their attitudes can be observed, the inclination is valleyward on both sides of the Lemhi Range. Recorded dips exceed 20°. Thus relatively the mountains were uplifted and the valleys now occupied by Little Lost River and Birch Creek were downflexed at a time that could hardly have been longer ago than the late Pliocene.

FAULTS

The dominant feature of the structure in the rocks of pre-Carboniferous age is the prevalence of faults, most of which appear to be thrusts. In contrast, the Brazer limestone and related rocks on the crest and northeast slope of the Lemhi Range and in the Arco Hills are not known to be greatly faulted. The lack of horizon markers that could readily be seen on aerial photographs hinders the recognition of fractures in these intricately crumpled beds, but long faults like those prominent on the southwest slope of the Lemhi Range have not been detected. One probable thrust fault in the Arco Hills is shown on plate 7, on the basis of photogeologic interpretation by Morris. Another at the head of Surrett Canyon is shown in plate 9*B*.

Along the southwestern flank of the Lemhi Range the major, steep faults all appear to belong to a single zone of fracture. This, in itself, implies similarity in character throughout, even though in certain localities diverse explanations seem possible. The zone is thought to be made up of thrusts that in places are nearly coincident with bedding planes. The pressure appears to have been from the west. Few of the faults afford evidence of the amount of forward movement but it is thought to be small everywhere. Many of the bedding plane faults die out within short distances.

The most southerly exposures of the fault zone are at the border of the range between Middle and Black Canyons. From here into Black Canyon the zone is narrow and the character of the displacement is obscure. Dips are everywhere steep, and fluctuate from northeast to southwest. The distribution of the different formations on the two sides of Black Canyon could be accounted for on the assumption of normal faulting with downthrow to the west. This is opposed by the fact that east of the lower reaches of the canyon most of the fault surfaces dip east. This fact is not perceptible on plate 7 but is readily apparent when the area is mapped in detail. When a planetable map on a scale of 1:10,000 was prepared, the first supposition was that the rocks were broken by steep thrusts with movement toward the west. However, in numerous places the Swauger quartzite is overturned toward the east and along the east slope of Black Canyon, north of the area mapped in detail, segments of the faults clearly dip west. When these facts are considered in relation to the regional structural pattern, the most probable explanation is that the fault zone along Black Canyon is part of a steep thrust zone in which the major displacement has been upward towards the east. Those fracture surfaces whose present dips do not fit this interpretation record local splitting. Perhaps this was coupled with subsequent deformation sufficient to reverse the dip of fault surfaces initially nearly vertical. A fault striking somewhat north of east is shown on plate 7, as possessing normal displacement. This is a minor and perhaps relatively recent feature.

Where the thrust zone crosses from Black Canyon to South Creek only a single fault, apparently of easterly dip, is recognized. Where this fault passes through the saddle between Black Canyon and the southerly fork of South Creek, and again along the slope south of that fork, slabs of argillaceous rock belonging to the Milligen formation are caught in the fault zone. Larger bodies of similar rocks are exposed along faults near the mouth of Black Canyon. These slippery rocks may have acted as lubricants along the fault movements.

The upper reaches of the southerly fork of South Creek are almost devoid of outcrops, but the fault zone here must trend about N. 40° W. for a distance of half a mile before it swings north across two ridges into the valley of the principal fork of South Creek. North of that fork the fault zone is wide and probably even more complex than might be judged from plate 7. It includes a fault along the contact between the Swauger and Kinnikinic quartzites that is prominent near South Creek and appears to die out within 1½ miles north of that stream. All the faults are steep and irregular and most of the better exposed ones dip west. The small exposures of Swauger quartzite and Saturday Mountain formation short distances above creek level near lat 43°56′30″ N., 112°0′30″ W., may be in the crush zone of a comparatively flat thrust, mostly buried.

The rocks composing the hills that project into the valley of Little Lost River north of South Creek constitute a slice floored by a relatively gently inclined thrust (pl. 8*B*) that causes crumpled Brazer limestone to override contorted and broken Swauger quartzite. This low-angle thrust moved eastward across and was later than the steep thrust zone. A slab of Brazer limestone that constitutes the most easterly recognized extension of the low-angle thrust is much brecciated, presumably in part because of adjustments along the steeper fractures beneath it. The center of this slab is near lat 43°57′15″ N., long 113°0′7″ W.

The zone of steep thrusts and steep westerly dips and drag folds overturned eastward extends past North Creek. In the general vicinity of the Sentinel and Johnson mining properties the rocks are shattered more intricately than can be shown on plate 7. Here and farther north some of the thrusts die out along bedding planes, so that, near the valley containing the Bighorn and Whitebird properties, the thrust zone narrows and becomes indistinct. The slopes near and north of these properties contain fractured and contorted rocks. These yield so few outcrops that the thrust zone has not been traced in detail. In the vicinity of the Copper Mountain mine and the saddle southeast of it, the rocks are brecciated, contorted and slickensided along a major zone of movement. Here strata of pre-Carboniferous age with average trends close to north are brought against crumpled beds of Brazer limestone along a line that trends nearly east, largely buried under talus and alluvium in the upper valley of Uncle Ike Creek. Farther down Uncle Ike Creek the rocks north and northwest of the creek are steep to overturned westerly while those on the opposite side of the valley are only gently inclined, showing clearly that the fracture zone continues although concealed under the alluvium of the valley. The fault zone passes westward through a conspicuous saddle about a mile from the place where the creek leaves the mountains (pl. 10*B*). A minor thrust with westerly dip extends northward from this saddle. This is regarded as a branch, or spur, from the main fault.

Roughly 1½ miles northwest along the front of the range a thrust fault emerges from the alluvium and continues northward through the mountains. This fault is inferred to join that along Uncle Ike Creek under the alluvium close to the mountain border. If so, it is a continuation of the major fault zone that stretches from near Black Canyon to the head of Uncle Ike Creek. The sharp deflection along that stream is explainable as the result of flexure of the master fault zone, of displacement of that zone by cross faulting, or of a combination of the two. The overturned beds on the northerly side of Uncle Ike Creek show that strong forces affected the rocks beneath the thrust zone concealed under the alluvium of Uncle Ike Creek. Such forces also would have been required if the thrust zone was folded enough to deflect its trace down the present valley of Uncle Ike Creek. Near lat 44°2′30″ N., long 113°3′ W., the beds stand close to vertical, and farther east they are irregularly crumpled. On the assumption that the master fault zone is folded, all these beds are in the overridden block; the deformation dies out eastward. The concept of a folded thrust zone can be visualized by inspection of section B–B′ plate 7. In this section, the fault buried under the alluvium of Uncle Ike Creek would be continuous with the fault northeast of the valley of that stream, near the Bighorn and Whitebird mining properties. However, any such connection would be so far underground that it has seemed best not to attempt to show it on the section. The idea of offset along cross faults, as opposed to flexure, is supported by fractures in the saddle at the head of Uncle Ike Creek east of the Copper Mountain mine, and by the thrust at the head of Surrett Canyon shown in plate 9*B*. The latter is small and is not plotted on plate 7. Some of the fractures near the Copper Mountain mine may be normal faults with northerly dips. All these fractures, both normal and reverse, seem best explained as minor features incidental to the flexure of the major thrust zone or to subsequent adjustments. The postulated flexure along Uncle Ike Creek is similar to but much larger than the one along the south fork of South Creek. The folding may have started during the thrusting but probably continued afterward.

The thrust that emerges from the alluvium northwest of Uncle Ike Creek near lat 44°01′00″ N., long 113°06′30″ W. continues northward to about 1½ miles southeast of the Badger Creek mine, where it appears to terminate in a zone of cross faults, not studied in detail. Much of this thrust surface appears to dip east. Flexures concomitant with those along Uncle Ike Creek, just discussed, may account for this.

Near the Badger Creek mine and thence southward to the range front the rocks are broken in a fault zone of moderate westerly inclination. Younger units rest on old ones, presumably a result of folding prior to thrusting. At the southern end of the zone Kinnikinic quartzite overlies rocks of the Saturday Mountain formation in more conventional thrust relationship. If rocks belonging to the Laketown dolomite are involved they have not been recognized.

The area of complex faulting between Badger and Williams Creeks presumably is closely allied to that described in the preceding paragraph. For the fault trace exposed immediately northwest of Badger Creek this seems self evident. Farther northwest the old rocks are so masked by various alluvial deposits that the details cannot be discerned. Apparently a slab composed mainly of rocks of Carboniferous age has been moved eastward or southeastward along one or more thrust surfaces that are themselves folded and perhaps also broken by cross faults. Section A–A′, plate 7, gives an idea of the structure but is manifestly incomplete. Along the line of this section, the highest hill west of Badger Creek has the lower thin-bedded member of the Brazer limestone at the summit, surrounded by thicker bedded limestone. This might appear to be the normal stratigraphic sequence, but there is so much disturbance at and near the contact as to imply fault movement there, as indicated in the structure section.

The small exposure of Devonian rocks northwest of Horse Creek includes a tight, contorted syncline, apparently overturned westward and surely out of harmony with the rocks of Carboniferous age above. Here also thrust faulting seems to be a required explanation. A logical interpretation of the structure described in this and the preceding paragraph is that the fault zone here is analogous to that in the outlying hills north of South Creek but more folded and cross faulted than the latter is known to be.

A feature exposed near upper Badger Creek about at lat 49°9′ N., long 113°7′30″ W., appears to record a kind of deformation different from any described above. At this place an approximately oval exposure of Kinnikinic quartzite, 2,000 feet in longest dimension, is surrounded by beds of Devonian age. Around the periphery, younger rocks are so broken and twisted as to afford convincing evidence that the contact is a fracture surface along which movement has been powerful. It would seem that a pluglike body of the quartzite has been shoved through the dolomite beds stratigraphically above it.

GEOLOGIC HISTORY

The geologic history of the southern Lemhi Range is related to that of the Borah Peak quadrangle, where available data are somewhat more complete. Hence the concepts outlined below are influenced by the concepts already expressed for that quadrangle and the region west of it (Ross, 1947, p. 1125–1155).

The shallow Belt sea, with its marked lateral variations in deposits is represented in the southern Lemhi Range by the Swauger quartzite but may never have spread far to the east at that latitude. Rocks correlated with the Belt series are present in the southwest corner of Montana about 20 miles northeast of the northern part of the area here discussed (Ross and others, 1955), but absent east and south of that locality. The Swauger quartzite appears to have been deformed and slightly metamorphosed in late Precambrian or, more probably, early Paleozoic time. No clues as to the form of the structures then produced have been obtained, except that the folds were probably so broad that the angular discordance at the base of the Kinnikinic quartzite is small.

During the Paleozoic era marine waters repeatedly flooded the area within which the Lemhi Range is now situated. During the Cambrian and much of the Ordovician periods the region may have been dry land, and parts of all the upper Paleozoic systems are missing. The thickness, and to a less extent the character, of the units is varied even within the small area covered by the present study. These facts testify to instability in the conditions affecting sedimentation. The different Paleozoic units that are present are so nearly conformable to each other that no sharp deformations can have taken place during the era.

In the extreme southwestern corner of Montana the Paleozoic rocks have similarities to those in the southern Lemhi Range; but in the aggregate the rocks are much thinner (Scholten and others, 1955, p. 352–366), just as the assemblage in the southern Lemhi Range is thinner than that in and west of the Borah Peak quadrangle. As is pointed out in the paper just cited, the Paleozoic units farther east in Montana, there termed the Montana facies, have more differences than resemblances to the units in south central Idaho, termed the Idaho facies. The Montana facies is there regarded as deposited on a shelf and the Idaho facies as deposited in a miogeosyncline. Measured across the trend of the beds, this geosyncline would be about 100 miles wide. In south-central Idaho the Paleozoic rocks therein extend along the strike for about 70 miles. Along the Idaho-Montana border they reach somewhat north of Leadore. To the west they are not exposed so far north, and to the south they terminate at the margin of the Snake River Plain (Ross and Forrester, 1947). It is commonly assumed that the geosyncline extended across the site of that plain into what is now southeastern Idaho and northern Utah and Nevada, an assumption that would make the geosyncline in south-central Idaho the northern, narrow end of a much larger feature (Eardley, 1951, p. 234–270; Ross, 1958).

If sedimentary rocks of Mesozoic and early Tertiary age were ever deposited in the southern Lemhi Range, no record has been found. Most of the rocks are Mississippian and older. In and near the southwestern corner of Montana and in southeastern Idaho, Pennsylvanian, Permian, and younger rocks were laid down in some abundance. Perhaps the diastrophism that culminated in the intrusion of the Idaho batholith started so early that marine deposition ceased in the area of the Lemhi Range by the end of Paleozoic time.

The absence of Mesozoic and early Tertiary strata in the southern Lemhi Range makes it impossible to date directly the complex folds and thrusts that involve the Paleozoic strata there. In the Borah Peak quadrangle, although Mesozoic sedimentary beds are absent, data relative to structure are somewhat more complete. There it was concluded that the deformation was a long-drawn-out process that preceded, accompanied, and followed introduction of the Idaho batholith. The last of the structures that resulted may have been formed in Late Cretaceous time. It may be assumed that similar events took place in the southern Lemhi Range. Judging by the record in the southwest corner of Montana, the events in the southern Lemhi Range may have been even more complex; possibly the last of them may have taken place later than in the Borah Peak quadrangle.

In the study of the Borah Peak quadrangle it was concluded that when the deformation above referred to ended, the region was well above sea level and subject to erosion. Hills or mountains ancestral to the Lemhi Range were present at the time the Challis volcanics were extruded rather early in the Tertiary period, and were in part buried under the volcanics. To a degree the same thing is true with respect to the volcanic rocks in the part of the range here reported on. These are younger than the similar rocks in the Borah Peak quadrangle. The mature or postmature erosion surface inferred to have been developed in the Borah Peak quadrangle would have extended over the southern Lemhi Range as well but is probably older than the younger volcanic rocks there. The long ridge crests, mostly at altitudes above 10,000 feet (Ross, R. J., Jr., 1959, fig. 145; also topographic map of Diamond Peak quadrangle), that radiate from Saddle Mountain and similar peaks are inferred to be modified remnants of the post-Challis surface. Later erosion has proceeded intermittently, and several erosion surfaces, each in turn dissected, have resulted. That above Fallert Springs is one of the best preserved remnants of such a surface (pl. 10*B*). The ancestor of Uncle Ike Creek reached the valley of Little Lost River across this surface, rather than through the gorge that now serves as its outlet from the mountains.

After the post-Challis surface had been thoroughly dissected and valleys corresponding approximately to those of Little Lost River and Birch Creek had been formed, the volcanic rocks, of which only patches remain, were erupted. Deposition of the old alluvium may have begun at about this time, but it continued after the volcanic rocks had begun to be eroded. Later the mountains rose relative to the valleys and the old alluvium was tilted valleyward. After this the alluvium filling the modern master valleys began to accumulate. Alluviation was interfered with at least once by flows of Snake River basalt. Flows of this formation underlie the Snake River Plain just beyond the borders of the area here described, and prior to ranching in the region the water of both Little Lost River and Birch Creek sank into this highly permeable material instead of continuing at the surface to a confluence with some master stream. At present much of the water of both streams is used up by irrigation before it reaches the old sinks.

MINERAL DEPOSITS

The Hamilton and Dome mining districts occupy the southwestern slope of the southern Lemhi Range. The boundary between the two appears not to be definitely fixed. Some place it near Uncle Ike

Creek; others near South Creek. The former appears to be the most generally accepted location (Ross and Carr, 1941, pl. 1) and is adopted in the present report. Prospecting in the area, which began about 1880, has resulted in the discovery of a number of deposits containing lead and silver and, locally, copper. Several mines have been productive on a small scale, but in recent years the two districts have yielded little. The Copper Mountain mine is reported to have shipped a small amount of copper ore in 1955, and development work has been done at several other properties. In the following descriptions, data assembled by R. A. Anderson (1948, p. 11–18) have been used to supplement information acquired incidental to the present fieldwork. Historical notes were obtained from the annual reports of the Idaho State Inspector of Mines (McDowell, 1954, 1955) and the "Minerals Yearbook" of the U.S. Bureau of Mines, (Gerry, 1919; Gerry and Luff, 1938; Miller and Luff, 1939; Needham and Luff, 1947, 1949a and b, 1950, 1951).

PROSPECTS ALONG BLACK CANYON

Numerous shallow prospect pits are scattered over the slopes on both sides of Black Canyon, mostly in the Swauger and Kinnikinic quartzites, and the Saturday Mountain formation. The Protection prospect (Anderson, 1948, p. 14), near the forks of the canyon, is reported to have about 100 feet of drifts along a major fault, with quartzite on the east and dolomite on the west. The quartzite is probably a component of the Swauger quartzite; the dolomite belongs to the Saturday Mountain formation. There are other shallow workings in the vicinity.

AJAX PROSPECT

The Ajax workings are high on the slope south of the south fork of South Creek, near the top of the Kinnikinic quartzite. Galena, in part oxidized, lined diverse fractures and with carbonate minerals of hydrothermal origin formed small replacement bodies. There are reported to be about 500 feet of drifts, and small surface cuts.

Other workings are scattered over the north slope of the main fork of South Creek. All are small and none appear to have encountered enough mineralized material to encourage further exploration, judging from the dumps. However, small shipments were made from them early in the century (Umpleby, 1917, p. 18).

GREAT WESTERN MINE

The Great Western mine is low on the slope of the range, south of Camp Creek. The mine yielded about $50,000 from ore containing about 130 ounces of silver to the ton during the eighties of the last century (Umpleby, 1917, p. 113). At the time of Umpleby's reconnaissance the property was reported to have about 2,000 feet of inaccessible workings. Since then mining has been undertaken at intervals and a little ore has been shipped. A few small opencuts and short adits have the appearance of having been made fairly recently. Small shipments were recorded in 1937, 1938, 1943, 1947, and 1948 (Gerry and Luff, 1938, p. 321; Miller and Luff, 1939, p. 350; Woodward and Luff, 1945, p. 366, 369; Needham and Luff, 1947, p. 1407, 1448, 1500). The workings are in the Swauger quartzite, largely in the dolomite at the top of that formation.

Ore is said to have been found at intervals over a strike length of 1,600 feet in the dolomite but in individually small masses in part along bedding faults. It contained galena, anglesite, and cerussite in silicified dolomite.

The production record for the region can be judged from tables 2 and 3. These are compiled from the records of the Bureau of

TABLE 2.—*Production of gold, silver, copper, lead, and zinc for the Dome district, Butte County, Idaho, 1901–1955, in terms of recoverable metals*

[Compiled by the U.S. Bureau of Mines]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1901–05 [1]						
1906	3	3	275		6,550	
1907	75	1	516	282	68,549	
1908	236		739		224,018	
1909	418		1,488		289,284	
1910	78		277	53	48,724	
1911 [1]						
1912	7,859	5	11,313	506	1,487,350	
1913	18,223		36,804		8,182,846	
1914	8,026	2	18,118	6,226	4,147,642	
1915	10,969	3	36,300	6,181	5,031,619	
1916	11,269		36,170	7,959	3,305,465	
1917	4,237	2	29,626	15,128	2,225,469	
1918	799		3,061		490,544	
1919–20 [1]						
1921	300		237		47,100	
1922–23 [1]						
1924	1,419	1	14,586	1,124	551,312	
1925	3,867		8,016	582	1,204,922	
1926	1,593		4,361	1,071	491,770	
1927	7,901	4	43,112	1,272	2,363,033	
1928	11,283		31,286	165	2,148,472	
1929	14,355	1	55,864	46	3,739,113	
1930	8,384		18,852	53	1,658,596	
1931 [1]						
1932	2	1	4		2,300	
1933–34 [1]						
1935–37 [2]	300		2,833	518	146,685	
1938	98	1	283	92	60,826	
1939–40 [1]						
1941	2,500		1,118		71,000	
1942	1,500		1,011		57,000	
1943	151		270		40,000	
1944	450		208		24,800	
1945	1,485	4	1,440	600	223,000	
1946	3,881	8	3,182	3,500	447,000	40,000
1947	1,363	5	2,242	100	310,100	50,000
1948	840	2	1,011	900	235,800	22,600
1949	166		21		24,300	29,400
1950	13		116		11,000	
1951 [1]						
1952	29		33		6,000	
1953–54 [2]	70	7	752	4,000	16,000	
1955	32	1	177	4,000	2,000	1
Total	124,174	50	365,702	54,358	39,390,189	142,000

[1] No production recorded.
[2] Combined to avoid disclosure of individual production.

Mines and furnished through the courtesy of A. J. Kauffman, Jr., of that Bureau. Table 2, which gives the production of the Dome district, contains the record for most of the recently active properties in the area of the present report. The Hamilton district, whose production is summarized in table 3, reaches a considerable distance north of the mapped area, but, so far as known, the principal production from that district has been from properties within the mapped area, including the Badger Creek and Copper Mountain mines.

TABLE 3.—*Production of gold, silver, copper, lead, and zinc for the Hamilton district, Butte County, Idaho, 1901–1955, in terms of recoverable metals*

[Compiled by the U.S. Bureau of Mines]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1901–06 [1]						
1907	66			9,716		
1908–09 [1]						
1910	47	1	793		32,558	
1911	83		1,294		59,422	
1912	64		1,011	194	52,447	
1913	29		297		16,673	
1914	136	1	2,698	101	96,910	
1915	71	1	1,479	48	32,879	
1916	137		506	11,395	24,776	
1917	1,032	56	2,482	11,827	204,365	
1918–19 [1]						
1920	1		2		144	
1921	1		7		221	
1922	4		524	212	1,115	
1923–24 [1]						
1925	180	1	115	31	28,226	
1926	150		82		20,491	
1927–32 [1]						
1933–37 [2]						
1938–40 [1]						
1941	13		24	4,600	200	
1942–46 [1]						
1947	5		31		400	
1948	71		221		13,800	
1949–50 [1]						
1951 [2]						
1952–55 [1]						
Undistributed [3]	36		259	728	14,712	
Total	2,126	59	11,825	38,852	599,339	

[1] No production recorded.
[2] Included with Undistributed.
[3] Combined to avoid disclosure of individual production.

According to the annual volumes of "Minerals Yearbook," 450 tons of tailings were treated in 1944, 930 tons in 1945, and 2,131 tons in 1946. In 1945, 555 tons of crude ore were shipped. In 1946, 1,750 tons of zinc-lead ore were shipped. In 1947 the amount of such ore was 1,020 tons, in 1948 it was 773 tons, and in 1950 it was 13 tons. The ore shipped in 1948 contained 3 ounces of gold, 776 ounces of silver, 876 pounds of copper, 243,886 pounds of lead, and 21,762 pounds of zinc. The zinc credited in table 2 to the Dome district in 1946–49 and the copper in 1945–48 may be inferred to have come largely from the Wilbert mine. Evidently the ore mined at that time was different from the ore previously obtained, as earlier records do not list copper or zinc. As the notes regarding other properties given below show, the Wilbert mine has so dominated production in the district that the production recorded in the table for the Dome district already given is, for most years, not far from being equivalent to production of the Wilbert mine.

WILBERT MINE

The Wilbert mine, which includes the Daisy Black, is along the front of the range between Camp and North Creeks. This property has the best production record of any in the southern Lemhi Range. It was discovered about 1882 and, with one interruption due to a fire, was in active production from 1906 into 1931. The production through 1929 is reported (Ross, 1933, table opp. p. 3) to have been 100,993 tons of crude ore mined and 29,753 tons of concentrates and sorted ore shipped, which contained 341,708 ounces of silver and 31,249,637 pounds of lead. In 1941, 2,500 tons of tailings from the dump were treated (Woodward and Luff, 1943, p. 348). Mining was again active in 1944–50 under lease.

The mine has over 12,000 feet of workings and extends through a vertical range of about 725 feet in the upper part of the Swauger quartzite, here cut by small dikes. Much of the ore is in replacement bodies in quartzitic dolomite at the top of the Swauger quartzite. Some follows a thrust fault in the tightly folded sedimentary rock and some is along subsidiary fractures. The hypogene minerals include galena, pyrite, sphalerite, quartz, and carbonates (both calcite and dolomite). Feldspar, chlorite, and mica are present in places in the mineralized rock but, like the major part of the quartz and carbonate in that rock, are original sedimentary components, somewhat affected by the mineralizing solutions. The supergene minerals reported include anglesite, cerussite, smithsonite, and linarite (hydrous copper-lead sulphate). No hypogene copper mineral has been recorded in the various geologic reports on the Wilbert mine (Umpleby, 1917, p. 81–83, 113–117; Ross, 1933; Anderson, 1947, Anderson, 1948). However, in 1945–48 the production record indicates the presence of such copper mineral.

SENTINEL PROSPECT

The Sentinel prospect (Anderson, 1948, p. 14) is nearly a mile up North Creek from the camp at the Wilbert mine. The country rock is dolomite of the Saturday Mountain formation in fault contact with quartzite that presumably belongs to the Kinnikinic quartzite. There are about 250 feet of workings and small shipments have been made at intervals. The annual volumes of the "Minerals Yearbook" record a total of 213 tons of zinc-lead ore in 1947–48. The lode is a replacement deposit in which mineralized material is reported to be in part along bedding planes, in part along fault fractures. The ore minerals include galena, sphalerite, cerussite, smithsonite, and wulfenite.

JOHNSON PROSPECT

The Johnson prospect is on a branch of North Creek a couple of miles from the Wilbert camp. It contains about 500 feet of workings (Anderson, 1948, p. 14) most of which were already in existence in 1912 (Umpleby, 1917, p. 81, 117). The production, if any, is not known. In 1952 (McDowell, 1954, p. 109) about 5,000 feet of diamond drilling was done but the results have not been recorded. There are replacement deposits in dolomite and in calcareous quartzite interbedded therewith, containing lead and zinc. These rocks belong to the Saturday Mountain formation. Umpleby called attention to a vein of comparatively pure smithsonite about 14 inches wide, whose significance does not appear to have been appreciated by the miners.

BIGHORN MINE

The Bighorn mine, also known as the Buckhorn (Anderson, 1948, p. 13), is one of two in the canyon of Morman Gulch and reached by a road built in 1948 up North Creek and thence over a steep ridge. The property is developed by several inclined shafts, up to 100 feet deep, and short adits. Some stoping has been done along two of the shafts.

The deposits have been worked intermittently on a small scale for a long time. In 1917 the workings were known as the Metta property (Gerry, 1919, p. 475). One stope at the surface trends N. 30° E. and is inclined 45° NW. in slaty shale. The workings were not accessible during the present study nor at the time of R. A. Anderson's visit. (Anderson, 1948, p. 13.) He stated that the ore body is a bedding plane replacement with a maximum width of 10 feet at the surface. He noted galena, barite, smithsonite, and limonite, with minor quartz veins traversing the ore body and stated that workings extend 500 feet along the strike and about 200 feet down the dip. The bedrock belongs mainly to the lower part of the Brazer limestone, which here includes some shale. Part of the workings may be in dolomite of Devonian age.

WHITEBIRD PROSPECT

The Whitebird prospect adjoins the property just described and is likewise in the lower part of the Brazer limestone. The principal workings are a shaft 110 feet deep and a separate crosscut adit 100 feet long farther down the hill (Anderson, 1948, p. 14). The vein trends nearly east and is steep. The vein matter is barite seamed with thin filaments of galena.

COPPER MOUNTAIN MINE

The Copper Mountain mine is at the head of one of the principal forks of Uncle Ike Creek and is reached by a road up that stream. Work here started about 1900, and the present operators began their activities in 1937. They are Elmer Jernberg, M. E. Staley, Jr., J. L. Sinknecht, M. E. Poole, and Ralph Taylor. There are a number of short adits, some of which did not encounter mineralized material. Some may not have reached solid bedrock. Bulldozer work, mostly in 1954, has cleared away overburden and cut across some of the old adits. Several new cuts have been made by bulldozer on the slope about 500 feet vertically above the main workings. In 1955 a shallow shaft was sunk in a breccia zone and a gently inclined winze was extended southwest from its bottom. Small shipments of handpicked copper ore were made.

It appears that the various adits explore a fracture zone closely related to a major fault that is hidden from direct observation in the stream channel. The adits are in beds low in the Saturday Mountain formation, but the rock immediately north of the stream channel is Brazer limestone. Kinnikinic quartzite is present below the workings recently opened. Some of the fractures strike northwest and dip southwest at low angles. The exposures seen during the present study are not sufficient to show whether a persistent lode is present or to give any information as to the size and attitude of ore shoots. The grade of ore found is such as to encourage further exploration. The rock in all exposures seen is oxidized, and most of it is broken and slumped in varying degree. The metallic minerals include malachite, chrysocolla, chalcocite, pyrite, galena, and probably cerussite.

BADGER CREEK MINE

Many old workings are scattered over the slopes bordering Badger Creek and over the range front on both sides of the place where that stream emerges from the mountains. The majority are pits and short adits but some are more extensive. The principal workings are in the Badger Creek mine, reached by a switchback road from Bunting Canyon.

Deposits in this part of the range have been known since the middle eighties of the last century (Umpleby, 1917, p. 113). Those along Badger Creek have been worked intermittently and on a small scale since that time. The Badger Creek mine, which has been inactive since 1954, is reported to have 3,938 feet of workings (McDowell, 1954, p. 109; 1955, p. 93). There are five principal adits, one of which is 2,350 feet long. Shipments of lead-silver ore have been made from this mine at various times during its long history. A large part of the ore credited to the Hamilton district in the production table above came from this mine.

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