

Pamphlet No. 113

August, 1957

RECONNAISSANCE GEOLOGY OF THE LEESBURG QUADRANGLE

LEMHI COUNTY, IDAHO

By

PHILIP NELSON SHOCKEY

IDAHO BUREAU OF MINES AND GEOLOGY

MOSCOW, IDAHO

TOPOGRAPHIC MAPS AVAILABLE

A topographic map of the Leesburg quadrangle, published by the U. S. Geological Survey is available for purchase from this office at 30 cents a copy; it is a valuable supplement to Dr. Shockey's report. The topographic map of the Salmon quadrangle is likewise available at the same price.

As a new service this office is now stocking a complete selection of Idaho topographic sheets in print. A free copy of the index to available topographic sheets will be sent upon request. There is no charge for handling the maps if they are to be sent folded; however, if the purchaser wants rolled maps, there will be an additional 15-cent charge on each order to help defray the cost of mailing tube and postage.

ERRATA

On page 4, line 10, W. B. Oref should be W. R. Oref.

On page 11, line 23, tourmalinite should be tourmaline.

FOREWORD

The Idaho Bureau of Mines and Geology in 1954 started a comprehensive investigation of the geology and mineral resources of the region about Salmon, Idaho. This Greater Salmon project has been under the general direction of Dr. A. L. Anderson who has published reports on the Salmon and Baker quadrangles, as Pamphlets 106 (in 1956) and 112 (in 1957) of this Bureau.

The Leesburg quadrangle adjoins the Salmon quadrangle on the west, as the Salmon adjoins the Baker. The present report by Dr. Shockey thus completes reconnaissance investigation and geologic mapping of an east-west row of three quadrangles, representing an area of about 600 square miles.

The reader whose main interest lies with economic mineral deposits is advised to turn to page 29 of this pamphlet where the section on Economic Geology begins. Structural and stratigraphic features mentioned in the economic section are more fully described and explained in preceding sections dealing with the geologic environment or setting of the mineral deposits.

Dr. Shockey's report is the result of his work during two field seasons and two winters in the laboratory at Cornell University. He carefully spells out the factors which prevented this from being an exhaustive study of the quadrangle. Despite these limitations, Dr. Shockey presents us with a report of considerable interest and worth, both to the practicing geologist and to the seeker after minerals.

E. F. COOK
Director

TABLE OF CONTENTS

	Page
ABSTRACT.....	1
INTRODUCTION.....	3
Purpose and scope.....	3
Previous geologic work.....	3
Field work.....	3
Acknowledgments.....	3
Location and general features.....	4
STRATIGRAPHY.....	7
General statement.....	7
Upper Precambrian metasedimentary rock units.....	7
General features.....	7
Southwest (hanging wall) section.....	7
Phyllite formation.....	7
Impure gray quartzite formation.....	8
Northeast (foot wall) section.....	9
Impure gray quartzite formation.....	9
Age and correlation.....	9
Ordovician metasedimentary rock unit (Kinnikinic quartzite).....	10
General features.....	10
Age and correlation.....	10
Cretaceous granitic rocks.....	10
Early Tertiary conglomerate.....	11
Challis volcanics.....	12
Tertiary lake beds.....	12
Late Tertiary ash.....	13
Quaternary deposits.....	13
Pleistocene glacial deposits.....	13
Age relations.....	13
Pre-Wisconsin glacial deposits.....	14
Wisconsin glacial deposits.....	14
Pleistocene alluvium.....	14
Recent alluvium.....	14
STRUCTURAL GEOLOGY.....	15
Structure of the Precambrian and Ordovician metasediments.....	15
Mapping note.....	15
Pre-Middle Ordovician structure.....	15
Mesozoic structure.....	15
Folds.....	15
Major folds.....	15
Leesburg synclinorium.....	15
Minor folds.....	16
Faults.....	16
Major faults.....	16
Leesburg fault.....	16
Sharkey Creek fault.....	17
Minor faults.....	17
Joints.....	17
Cleavage.....	17
Structural conclusions.....	18
Structure of the Cretaceous granitic rocks.....	18
Structure of the Challis volcanics.....	19

	Page
Structure of the Tertiary lake beds.....	19
Post-Late-Tertiary-ash structures.....	20
METAMORPHISM OF THE PRECAMBRIAN AND ORDOVICIAN SEDIMENTARY ROCKS.	21
Main features.....	21
Dynamic metamorphism.....	21
Igneous metamorphism.....	21
SEDIMENTATION.....	23
Upper Precambrian sedimentation.....	23
Deposition of the phyllite formation.....	23
Deposition of the impure gray quartzite formation.....	23
Regional applications.....	23
Paleozoic sedimentation.....	24
GEOMORPHOLOGY.....	25
Geomorphic evolution.....	25
Stream piracy.....	27
Structurally controlled landscape features.....	27
ECONOMIC GEOLOGY.....	29
Main features.....	29
Metallic deposits.....	29
Cobalt deposits.....	29
Copper deposits.....	30
Location and structural control.....	30
Blackpine mine.....	30
Bowman mine.....	34
Deposits of radioactive rare-earth elements.....	36
Gold deposits.....	36
Lode gold.....	36
Placer gold.....	37
Tungsten deposits.....	38
Wolframite.....	38
Scheelite.....	38
Lead-silver deposits.....	39
Nonmetallic deposits.....	39
Opalized wood.....	39
Quartz crystals.....	39
Building material.....	40
REFERENCES CITED.....	41

TABLE OF ILLUSTRATIONS

FIGURES	Following page
1. Leesburg, Idaho.....	6
2. Cobalt, Idaho.....	6
3. Generalized stratigraphic column.....	8
4. Geologic setting of the Leesburg quadrangle.....	8
5. Upper Precambrian correlation across the Leesburg fault.....	10
6. Two-toned quartzite in Pollard Canyon.....	10
7. Oscillation(?) ripple marks in impure gray quartzite...	10
8. Evidence of lit-par-lit injection of granitic material into metasediments.....	12
9. Xenolithic metasedimentary remnants in quartz monzonite.....	12
10. Hypothetical pre-Challis drainage.....	26
11. Hypothetical pre-Tertiary-lake-bed drainage.....	26
12. Wallace Lake.....	30
13. Blackpine copper mill.....	30

TABLES	Page
I. Production statistics.....	31
II. Sequence of mineralization at the Blackpine Mine.....	35

PLATES	
I. Reconnaissance geologic map.....	In pocket
II. Generalized structure sections.....	16

RECONNAISSANCE GEOLOGY OF THE LEESBURG QUADRANGLE

LEMHI COUNTY, IDAHO

By

Philip Nelson Shockey

ABSTRACT

The Idaho Bureau of Mines and Geology sponsored study of the Leesburg quadrangle as part of a comprehensive investigation of the geology and mineral resources of the region about Salmon, Idaho.

Upper Precambrian, Upper(?) Belt, metasediments about 35,000 feet thick outcrop over somewhat less than two-thirds of the quadrangle and are subdivided into phyllite and impure gray quartzite formations. The impure gray quartzite formation is unconformably overlain by white Ordovician Kinnikinic metaquartzite about 4000 feet thick. Precambrian sedimentary environments indicate a progressively shallowing Belt sea with a possible westerly sediment source. The Kinnikinic quartzite is a basal sand deposited during northeasterly transgression of a shallow Ordovician sea. The Precambrian rocks were warped during the pre-Middle Ordovician Skull Canyon disturbance. In Late Mesozoic time the Precambrian and Ordovician rocks were deformed into a reverse-faulted synclinorium trending approximately north 45° west. This synclinorium plunges gently to the southeast and may form the Lemhi Range. Subsequent to major deformation and accompanying dynamic metamorphism, apophyses of the Idaho batholith were emplaced. Field and petrographic studies indicate that considerable marginal portions of these apophyses are the product of igneous metamorphism. Alternate erosion and deposition in Tertiary times are represented by erosion surfaces and Early Tertiary conglomerate, Challis volcanics, Tertiary lake beds, and Late Tertiary ash. These Tertiary formations are less extensive than the pre-Tertiary formations. During Mid-Tertiary time the Challis volcanics were warped into a broad gentle anticline trending about north 45° east. During the Pliocene epoch, an erosion surface of mature character was cut across the late Tertiary ash and all older rocks. Available relief during erosion of this surface was less than either previously or since in the Cenozoic era. Quaternary deposits include pre-Wisconsin and Wisconsin drift, which are separated in time by an interval adequate for 1000 feet or more of canyon-cutting.

Deposits of cobalt, copper, radioactive rare-earth elements, gold, tungsten and lead-silver are present and range in age from Late Mesozoic to Mid-Tertiary. Gold placers are Wisconsin and younger. Opalized fossil wood is an important nonmetallic product of the quadrangle.

INTRODUCTION

PURPOSE AND SCOPE

The Idaho Bureau of Mines and Geology initiated a comprehensive investigation of the geology and mineral resources of the region about Salmon, Idaho, in 1954. The first step in this program was a study of the Salmon quadrangle by A. L. Anderson (1956). The Leesburg quadrangle immediately to the west was a logical subsequent undertaking. Because of the size of the Leesburg quadrangle, its rugged topography and the limited time available for field investigation, only a detailed reconnaissance was possible.

Precambrian and Ordovician rocks, which outcrop over the general Salmon region, received most attention. Because they are the oldest and most widespread, a study of their genesis, stratigraphy and structure is fundamental to any broad regional study.

PREVIOUS GEOLOGIC WORK

The earliest published geologic work on the Leesburg quadrangle was by George Hapgood Stone in 1893. Joseph B. Umpleby (1913) made a geologic reconnaissance of Lemhi County in 1910. Clyde P. Ross has made numerous detailed and reconnaissance studies in east-central Idaho. Among these, study of the Casto quadrangle by Ross (1934) has been especially helpful. Various publications by Alfred L. Anderson are also pertinent. Most significant is Anderson's work in the adjoining Salmon quadrangle (1956). Robert Scholten's recent (1957) study of Paleozoic relationships provided a regional framework into which data from the Leesburg quadrangle can be fitted.

FIELD WORK

Field investigations were carried on during the summers of 1955 and 1956. The highly dissected youthful topography of the Leesburg quadrangle (maximum relief 4575 feet, local relief 1000-2500 feet) and heavy forestation slowed field work by impeding traverses. Vegetation, rubble and talus effectively obscures bedrock over much of the quadrangle. Aerial photographs were used to select traverses in areas which appeared promising for outcrops.

Of several dozen underground workings in the quadrangle, only three are accessible. These were examined, but only the Blackpine mine was studied in any detail.

ACKNOWLEDGMENTS

The Idaho Bureau of Mines and Geology, under the direction of Dr. J. D. Forrester, sponsored the project by assuming field expenses. Grants from the Charles Bean DeLong research fund, Cornell University, helped to meet the cost of thin sections and transportation to and from Idaho.

The study was directed by members of the Department of Geology, Cornell University. The writer was privileged to have Dr. Charles M. Nevin

supervise all phases of the work. Dr. Alfred L. Anderson visited the writer in the field and gave helpful advice and constructive criticism, especially with regard to the section on economic geology. Dr. Ernest H. Muller helped particularly with the section on geomorphology. Discussion with Dr. Robert Scholten, Pennsylvania State University, was very helpful and added much to the value of the study. Dr. Aureal T. Cross, West Virginia University, examined fossil plant material from the Leesburg quadrangle.

Mr. C. K. Davis outlined on aerial photographs some of the broader rock units and coarser geologic structures. Mr. W. B. Oref did most of the final drafting on plates and figures included in the report.

Mr. A. J. Kauffman, Jr., Chief, Division of Mineral Industries, Region I, Albany, Oregon, supplied mineral production statistics for the Leesburg quadrangle.

Officials and employees of the Montana Coal and Iron Company, owners of the Blackpine mine, permitted free access to that property.

Residents of the area extended generous hospitality to the writer. The A. B. Cutlers and Howard Sims deserve special mention.

Grateful acknowledgment is here made to these people and agencies.

LOCATION AND GENERAL FEATURES

The Leesburg quadrangle is located in north-central Lemhi County, east-central Idaho. Its eastern border lies about five miles west of the city of Salmon, the seat of Lemhi County; Leesburg (Fig. 1), a ghost mining town, and Cobalt (Fig. 2), a modern mining town, are within its borders.

The quadrangle is well within the Northern Rocky Mountains physiographic province. Specifically, it lies on the eastern fringe of the Salmon River Mountains.

Streams of the quadrangle flow in deep, steep-walled valleys to Panther Creek or directly to Salmon River. These streams are dissecting an old erosion surface of 6500 feet and greater elevation.

Climate of the Salmon region is controlled primarily by elevation. Semiarid conditions prevail at the lowest elevations, and climatic types change gradually through humid-continental to subarctic at mountain summits. Climate of the Leesburg quadrangle varies between the two latter types. Of particular interest is the frequency (more than 130 times per year: Visher, 1945) of freezing and thawing, which explains the unusually large amount of rubble that blankets outcrops.

Type and distribution of vegetation in the quadrangle are largely controlled by climate and composition of bedrock. Sagebrush and grasses are characteristic of the lower elevations where semiarid conditions are approached, and of areas underlain by volcanics. Where these conditions coincide, as in the southeastern part of the quadrangle, the surface is desert-like.

Coniferous trees and grasses of various kinds are commonest. Conifers extend from well-watered stream courses at lower elevations upward to the highest summits of the quadrangle, which lie just below tree line. A pest has been killing lodgepole pines in the Salmon National Forest for the past two decades. The dead trees readily blow down to form almost impenetrable windfalls over about 25 percent of the quadrangle.

All of the roads of the quadrangle are unpaved and of light-duty quality. Access roads enter from the east, north and west. Of these, Williams Creek road on the east and Panther Creek road on the west are the best. The remainder of the roads, including some wood-cutter's roads and bulldozed former trails not indicated on the topographic map of the quadrangle may not be passable, depending upon weather conditions and the type of transportation.

Numerous trails, formerly kept open by the Forest Service, no longer give access to many parts of the quadrangle. With the advent of the "Smoke Jumpers" most of the forest trails were abandoned. Each year, however, the Forest Service does clear some trails so that a few are in excellent condition.

Approximately 1000 persons are permanent residents of the Leesburg quadrangle; they have been attracted by the mining industry. All but half a dozen live at Cobalt, the townsite of the Blackbird mine. During the summer months a few transients move into the quadrangle for mining, ranching, cattle-grazing, wood-cutting and Forest Service work.



Figure 1.—Leesburg, Idaho.

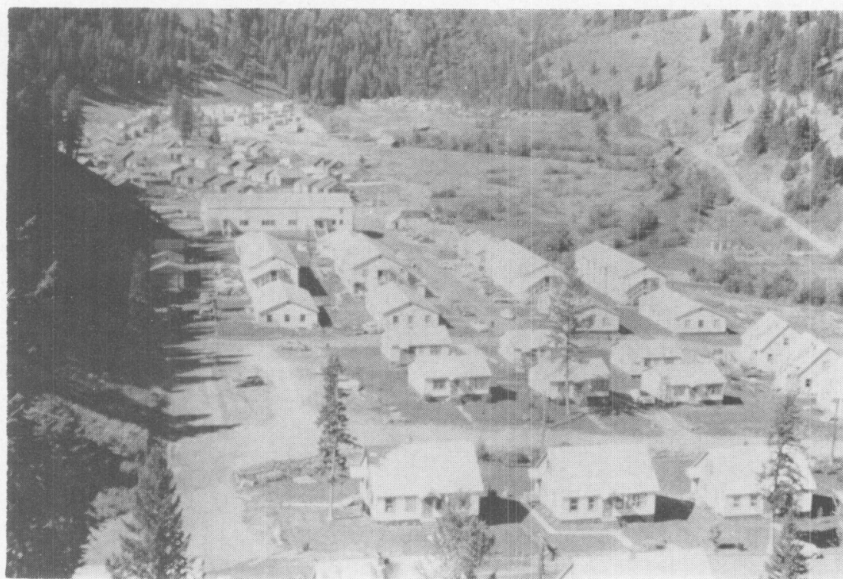


Figure 2.—Cobalt, Idaho.

STRATIGRAPHY

GENERAL STATEMENT

Field traverses were concentrated over the Precambrian and Ordovician terrains, because these rocks are of greatest interest. Even so, data are sparse or lacking locally, for two reasons. Density distribution of traverses was not uniform. For example, the area drained by Little Deep Creek was inadequately covered. Elsewhere, extensive rubble from frost-riven bedrock, although permitting determination of the physical character of the rock, concealed structural relationships. On Plate I, areas blanketed by rubble are indicated as "areas of sparse outcrops" to distinguish them from areas where traverses were inadequate.

The oldest rocks in the quadrangle are Precambrian and Ordovician. They have been altered by regional dynamic and igneous metamorphism. Dynamic metamorphism did not destroy original sedimentary features, but near intrusive contacts igneous metamorphism transformed the sedimentary rocks to varying degrees, with quartz monzonite as an end product. Consequently, where these rocks have retained sedimentary characteristics, they are classed as Precambrian and Ordovician metasediments, and where they have been thoroughly transformed to quartz monzonite, they are classed as Cretaceous granitic rocks.

Major rock types occurring within the Leesburg quadrangle, their thicknesses and interrelationships are generalized in Figure 3.

UPPER PRECAMBRIAN METASEDIMENTARY ROCK UNITS

General features

Precambrian metasedimentary rocks outcrop irregularly over somewhat less than two-thirds of the Leesburg quadrangle. These metasedimentaries have been deformed into a reverse-faulted synclinorium (Leesburg synclinorium), which trends approximately north 45° west (Plates I and II). Regional relations of the Precambrian metasediments of the Leesburg quadrangle are shown in Figure 4.

Because of the absence of recognizable fossils, differentiation of the Precambrian metasedimentaries must be by differences in lithology. On this basis it has been possible to subdivide the thick Precambrian section (±35,000 feet) into two formations, namely: phyllite and impure gray quartzite.

Because of faulting (Leesburg fault) the Precambrian section is most conveniently discussed in two parts, i.e., the Southwest (Hanging Wall) and Northeast (Foot Wall) sections. Comparison of these two sections will be made, omission by faulting established, and a probable composite section constructed (Fig. 5).

Southwest (hanging wall) section

Phyllite formation

Approximately 10,000 feet of folded phyllitic strata (PGp) outcrop in the southwestern portion of the Leesburg quadrangle (Plate I). The base of the formation is not exposed.

Although the phyllite is mapped as a single formation the following units can be recognized: gray phyllite and graywacke quartzite of about equal volume, and minor black slate. Formerly these were silty shales, low-rank graywacke siltstones, and dark muds. Graywacke quartzite with green tint becomes increasingly important toward the lower part of the phyllite formation. Graywacke quartzite units range from 10 to perhaps 50 feet in thickness and are separated by thin beds of phyllite. Gray phyllite units are hundreds of feet thick, and an average specimen has the following composition: quartz 35% (average maximum diameter 0.05 mm.), muscovite and sericite 25%, biotite 20%, feldspar 15% (albite and subordinate microcline), and accessory apatite, zircon, tourmaline and iron.

Bedding is not easily recognized in the gray phyllite, is rather common in the graywacke quartzite, and can be seen on a smooth surface of the black slate. This bedding is commonly crumpled and broken. Neither cross-bedding nor ripple marks were noted in the phyllite formation.

There must have been some clacareous mud in the upper part of the phyllite formation because scapolite (probably hydrothermal) is found in a small area near the northwestern end of Pepper Creek Ridge. The scapolite makes up about 40% of a black phyllite, which also contains a minor amount of calcite. Two miles to the southwest, on Spring Creek, at approximately the same horizon, two clastic dikes occur (Plate I). They are in well-developed, nearly vertical dip joints, which strike north 80° east. The westernmost dike is 10 feet wide, makes a topographic low and can be traced for several hundred feet. The other dike, which occurs about one-half mile farther east, is four feet wide and can be traced for 30 feet. These dikes are spotted black phyllite containing: biotite 60%, chlorite 15%, calcite 15%, quartz and muscovite.

The phyllite formation grades into the overlying impure gray quartzite formation through a wide zone.

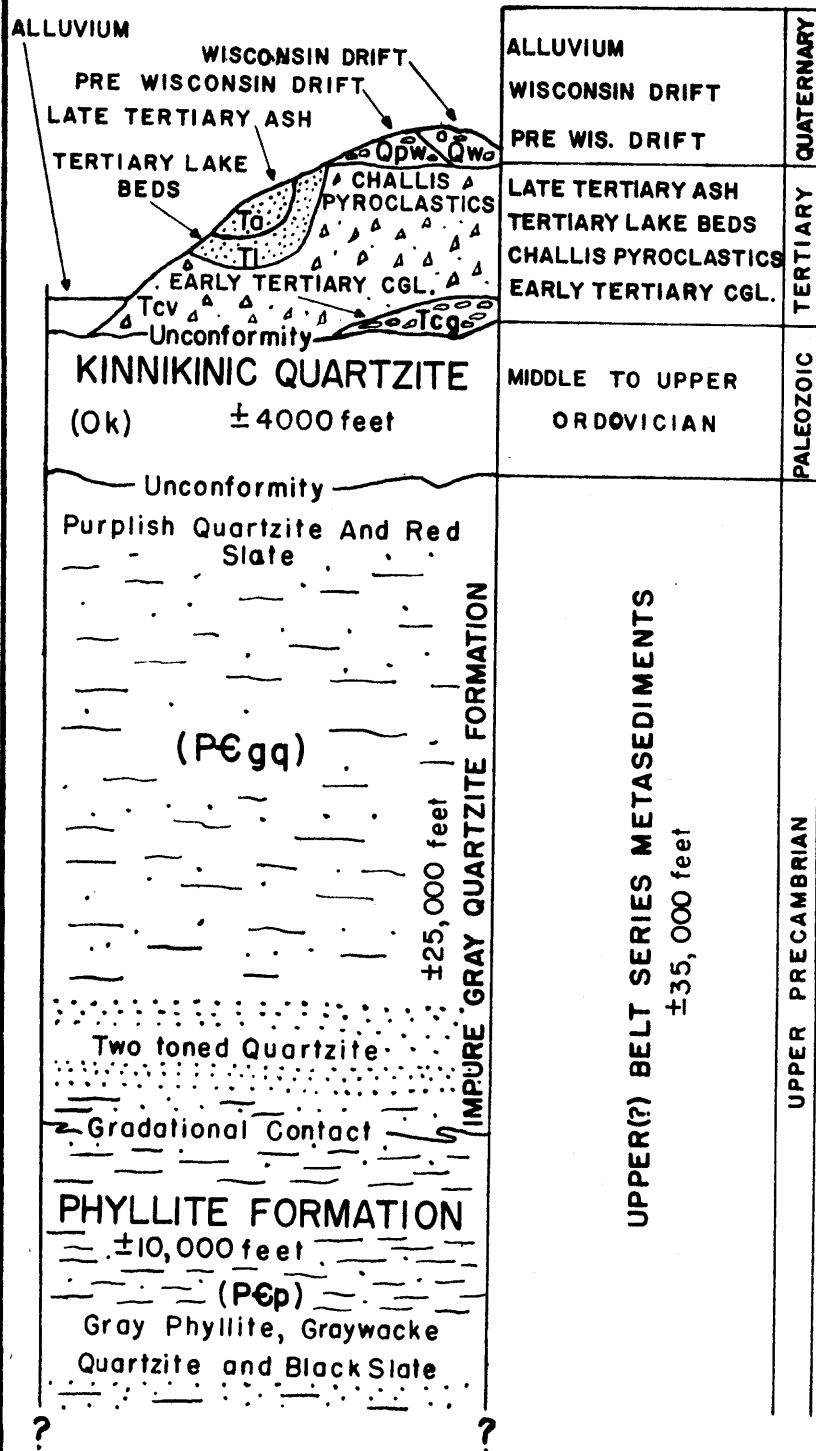
Impure gray quartzite formation

Impure gray quartzite (PGgp), approximately 7500 feet thick, outcrops over most of the southwestern half of the Leesburg quadrangle (Plate I). This formation was originally a series of lenticular impure siltstones and sandstones. Individual beds are one or two feet thick and lens out commonly within about 200 feet. Cross-bedding and ripple marks are common.

Black tourmaline (schorlite), associated with cobalt mineralization, occurs as a network of finely crystalline veins and pods scattered through the impure gray quartzite of the hanging wall.

Typical impure gray quartzite has the following composition: quartz 55% (average maximum diameter 0.1 mm.), albite 20%, sericite and muscovite 10%, biotite 10%, and accessory tourmaline, apatite, epidote, zircon and iron. Concentrations of albite (probably hydrothermal) form light-colored bands in the gray quartzite, thus producing a distinctive two-toned quartzite. The lightest-colored albite-rich interbeds contain: quartz 40%

SEDIMENTARY ROCKS



IGNEOUS ROCKS

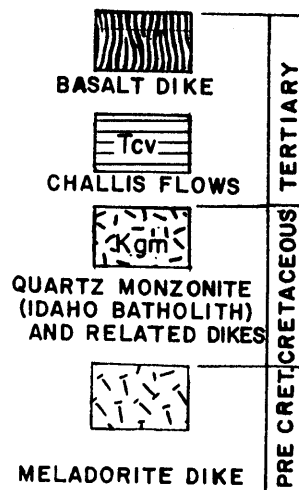


Figure 3.—Generalized stratigraphic column.

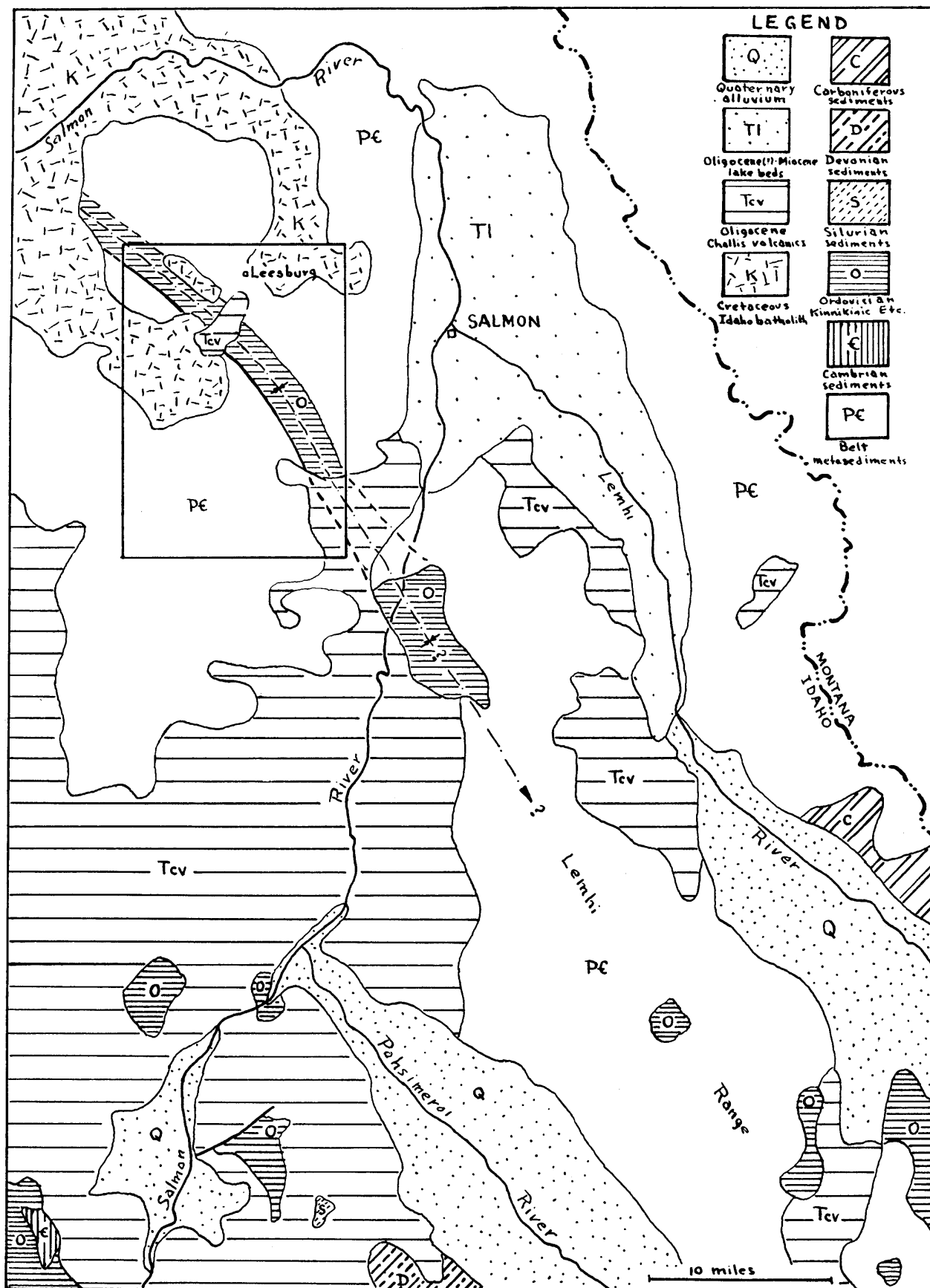


Figure 4.—Geologic setting of the Leesburg quadrangle. Modified from Ross and Forrester (1947).

(average maximum diameter 0.15 mm.), albite 40%, sericite and muscovite 10%, and accessory biotite, chlorite, epidote, apatite, tourmaline and zircon. This two-toned quartzite is here made a subdivision of the impure gray quartzite formation. Exceptionally dark quartzite containing few light-colored interbeds is more abundant on Deep Creek Ridge and northeastward than to the southwest. This generalization seems to hold along strike for some distance.

Northeast (foot wall) section

Impure gray quartzite formation

Impure gray quartzite, approximately 22,000 feet thick, outcrops over most of the northeastern half of the Leesburg quadrangle (PGgq, Plate I). In the lower portion of this section two-toned quartzite (Fig. 6), which appears similar to the two-toned quartzite of the hanging wall section, outcrops from Pollard Canyon northeastward. Strata underlying the Jesse Creek-Sharkey Creek divide and Baldy Mountain are noticeably darker than typical impure gray quartzite. This tends to substantiate equivalence of the two-toned quartzite on either side of the Leesburg fault (Fig. 5).

Oscillation(?) (Fig. 7) ~~and current ripple marks and cross-bedding~~ are common sedimentary features in the northeastern (foot-wall) impure gray quartzite.

A melilite meladiorite dike in the south wall of Wallace Lake cirque (Plate I) makes a topographic high, is about 20 feet wide and can be traced northwesterly for several hundred feet. Anderson (1956) has described similar igneous rocks in the adjoining Salmon quadrangle and assigned them a Precambrian age. The Wallace Lake dike may be Precambrian, but for lack of certainty is classified as pre-Cretaceous.

In the cirque due north of Phelan Mountain, at the top of the impure quartzite section, the strata are purplish and include a five-foot band of red slate. In the same area, evidence of clay galls is abundant. These strata are truncated by a regional unconformity, better exposed one and one-half miles to the southeast.

Assuming equivalence of the two-toned quartzite on either side of the Leesburg fault, a composite Precambrian section for the quadrangle (Fig. 5) shows $\pm 10,000$ feet of the phyllite formation gradationally overlain by $\pm 25,000$ feet of impure gray quartzite. Thus the total thickness of the section is $\pm 35,000$ feet, and the gap across the Leesburg fault is $\pm 17,000$ feet. It should be understood that these figures can only be very approximate.

Age and correlation

Umpleby (1913) tentatively correlated Precambrian metasediments of the Salmon region with Algonkian rocks of the Coeur d'Alene section, and he thought "that they are near the top of the Algonkian system." Ross (1925) implied a general correlation with the Belt series of Montana and northern Idaho. More recent detailed work, particularly by Scholten (1957),

suggests that Precambrian metasedimentary rocks of the Salmon region are in the upper part of the Belt series.

Precise correlation of Belt formations of the Leesburg quadrangle with rock units outside the quadrangle is not possible at this time. The Yellowjacket formation (Ross, 1934), a part of the Belt series 15 miles to the southwest, may lie across the contact of the phyllite and impure gray quartzite formations. Probably the two latter formations are closely related to the (Belt) Lemhi and Swaiger quartzites (Ross, 1947), 75 miles to the southeast.

ORDOVICIAN METASEDIMENTARY ROCK UNIT (KINNIKINIC QUARTZITE)

General features

White quartzite (Ok), about 4000 feet thick, overlies the impure gray quartzite formation. The contact is an unconformity which has been recognized regionally (Scholten, 1957). In one good exposure, about 200 feet wide, the white quartzite strikes N. 38° S. and dips 25° west on the average, whereas the underlying impure gray quartzite has an average N. 51° S. strike and a 50° west dip. The white quartzite forms the axis of the Leesburg synclinorium and consequently a double width of outcrop strikes northwesterly across the quadrangle (Plate I).

Mineral constituents of the white quartzite are: quartz 75% (average maximum diameter 0.3 mm.), albite 20% (probably hydrothermal), and accessory sericite, chlorite, zircon and iron. The original sediment was clean, probably medium-grained sand. Ripple marks and cross-bedding have persisted through dynamic metamorphism.

Age and correlation

Although white quartzites have been recognized in the Belt series, circumstantial evidence points very strongly to correlation of the white quartzite of the Leesburg quadrangle with Ordovician Kinnikinic quartzite. Supporting data are: (a) uniform lithologic character of the quartzite, (b) its thickness, which fits a regional isopach map of known Kinnikinic (Scholten, 1957, Fig. 2), (c) the unconformity at the base of the white quartzite, (d) lithologic character of the strata immediately below this unconformity, (e) apparent correlation with nearby white quartzite mapped as Ordovician. Consequently the white quartzite of the quadrangle is considered to be Kinnikinic and of Middle to Upper Ordovician age (Scholten, 1957). A projection of the Kinnikinic along strike from the quadrangle about 10 miles to the southeast, beneath Challis volcanics, meets similar white quartzite in the Rattlesnake Creek-Salmon River area. Starr (1955) described this thick white quartzite and assigned it a Precambrian or possible Ordovician age. Ross and Forrester (1947) mapped white quartzite three miles east of the Rattlesnake Creek exposures as Ordovician, presumably Kinnikinic. It seems probable that all of the above white quartzite will prove to be Kinnikinic.

CRETACEOUS GRANITIC ROCKS

Rocks having more or less granitic texture and quartz-monzonitic average composition are scattered over about 40 square miles of the

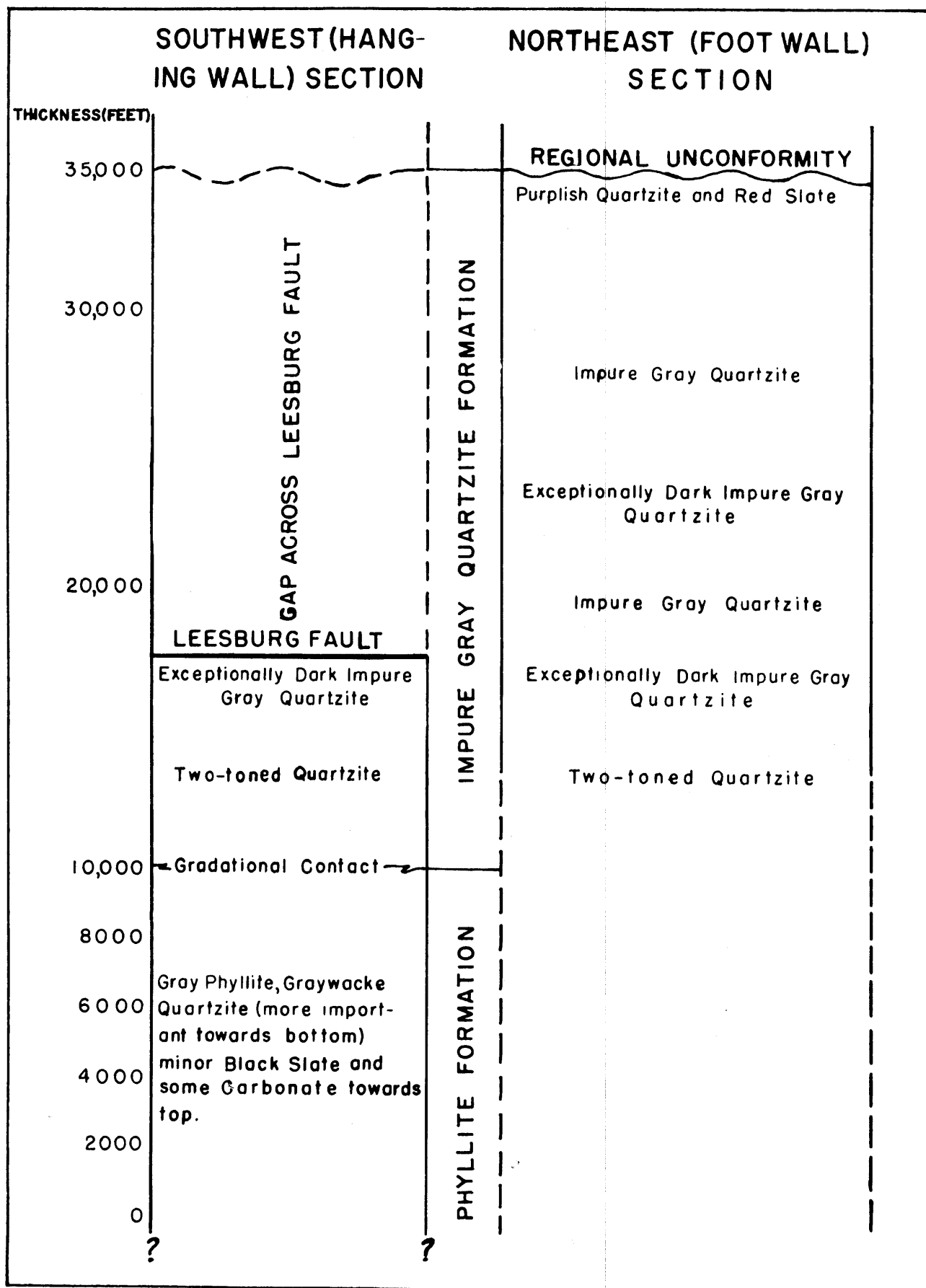


Figure 5.—Upper Precambrian correlation across the Leesburg fault.



Figure 6.—Two-toned quartzite in Pollard Canyon.

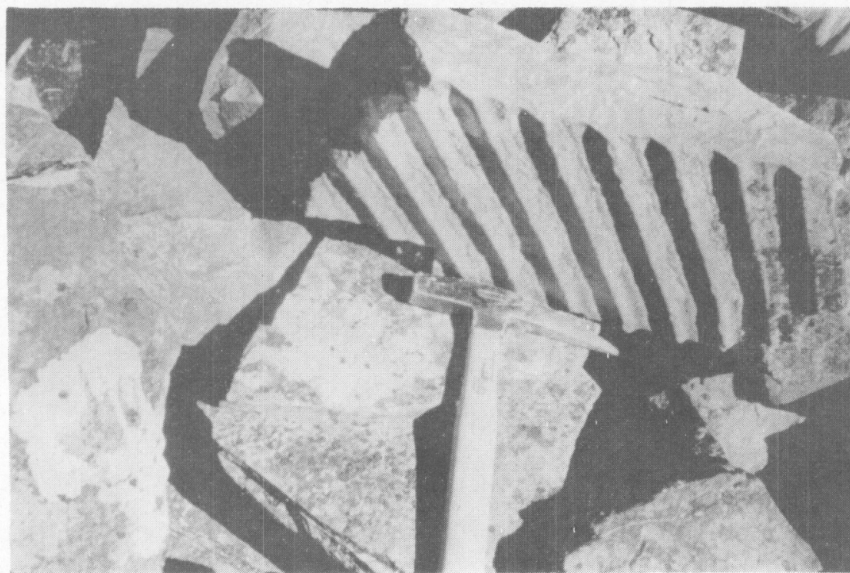


Figure 7.—Oscillation (?) ripple marks in impure gray quartzite on West Fork of Perreau Creek.

Leesburg quadrangle (Kqm. Plate I). These granitic rocks have intrusive contacts with the Kinnikinic and all of the Belt strata except the phyllite formation. They are apophyses of the Idaho batholith (Fig. 4). Ross (1928) assigned an Early Cretaceous or possibly Jurassic age to the Idaho batholith. Eardley (1951) and others feel that at least the eastern margin of the batholith, which includes the granitic rocks in the quadrangle, may be younger than the main body. On the basis of regional structural evidence it seems probable that the granitic rocks of the Leesburg quadrangle are of Late Cretaceous age.

This granitic rock is characteristically light-gray and porphyroblastic. Microcline porphyroblasts, commonly twinned according to the Carlsbad law, occur as blocky ellipsoids up to four inches long in a coarse-grained granodioritic matrix. Porphyroblasts have formed by late addition of potash to granodiorite; their borders are irregular and enclose ragged fragments of older rock. Margins of granitic bodies are more or less gneissic, especially in the vicinity of Big Jureano Creek. Field evidence suggests that marginal gneissic structure is relict sedimentary bedding. Syenite occurs in the marginal zones at the southern extremity of Leacock Point and along the southeastern border of the Arnett Creek intrusive. Hornblende, which is present in the syenitic rock and in the gneissic rock along Big Jureano Creek, is absent from the main quartz monzonite bodies. Scattered aplite, pegmatite, and monzonite dikes, as well as quartz and tourmalinite veins, cut the granitic rock. In the Big Jureano-Cliff Creek area and near the mouth of Deep Creek basic rocks, perhaps the altered equivalents of pre-Cretaceous meladiorite dikes, were found as float.

Contacts between Cretaceous quartz monzonite and metasedimentary rocks are gradational over a zone commonly about 200 feet wide. However, the two-toned quartzite (Fig. 6), described in an earlier section, may represent a hydrothermally produced gradational contact, which is on the order of two miles wide. In contrast, granitic magma has apparently been mechanically injected lit-par-lit into metasedimentary rocks near Wallace Lake (Fig. 8). In the marginal zone are remnants of metasedimentary rock; some of these xenoliths are mappable, most are not. Many of the smaller xenoliths have blocky shapes and show poorly preserved bedding.

Contacts of the large granitic bodies in the quadrangle flare upward, not downward as might be expected. Consequently the term chonolith (Daly, 1905) might be applied to these bodies. Actually the dip of the contact toward the interior of granitic bodies is variable and may locally be reversed.

EARLY TERTIARY CONGLOMERATE

The oldest Tertiary rock in the quadrangle is a coarse conglomerate, which is as much as 100 feet thick and buries an erosion surface cut across Belt metasediments and all pre-Tertiary rocks. Local relief on this erosion surface is 500 feet or greater, and within a distance of a few miles the relief must have been several thousand feet. Probable Oligocene volcanics overlie the conglomerate, which outcrops along Williams Creek in the core of a Tertiary anticline (Tcg, Plate I).

This conglomerate is composed of quartzitic and granitic pebbles, cobbles and boulders up to several feet in diameter. The matrix (probably

clay minerals) which gives the deposit a dark reddish-brown color is weathered and unresolvable. The aggregate is unsorted and unbedded.

Scholten et al. (1955) and others have described similar conglomerates over a broad region in southwestern Montana and adjacent states and assigned them generally an Early Tertiary age. Presumably these conglomerates were deposited in response to Laramide uplifts. Probably the conglomerate of the quadrangle is genetically related to the above widespread similar deposits and it may be of Paleocene age. However Scott (1938) has described Eocene glacial deposits beneath Tertiary volcanics in southwestern Montana, and other workers have reported Eocene glacial deposits elsewhere in the Rocky Mountains. Available evidence does not preclude the possibility that the Early Tertiary conglomerate of the quadrangle is Eocene till, but a recent paper by Van Houten (1957) generally discredits glacial origin of similar conglomerates in the Rocky Mountains.

CHALLIS VOLCANICS

Volcanic flows and pyroclastics, in nearly equal proportions, cover about 25 square miles along the central part of the Leesburg synclinorium (Tcv, Plate I). These are erosional remnants of a thick Tertiary volcanic sequence, which has regional distribution (Fig. 4). Ross (1934) has assigned the name Challis volcanics to "all the Tertiary volcanic rocks in this part of Idaho." On the basis of paleobotanical and other evidence, Ross (1937) is of the opinion that "the Challis volcanics are possibly, if not probably, of Oligocene age and that they **can** hardly be younger than early Miocene."

Challis volcanics were deposited on an erosion surface modified from that which received the Early Tertiary conglomerate. Relief on the pre-Challis surface was apparently on the order of that now existing regionally. Volcanic remnants are so distributed that all but the highest summits must originally have been buried. Mappable variations exist within the formation, but no attempt was made to differentiate Challis volcanics in the Leesburg quadrangle.

The flows may be classed generally as andesite, but basalt and rhyolite are not uncommon. Pyroclastic units appear to be largely acidic and include some ignimbrites. Individual volcanic units are of limited horizontal extent and are commonly less than 100 feet thick. Scores of flows and pyroclastics interfinger to give the Challis formation a maximum thickness of at least 3500 feet, measured from South Fork of Williams Creek eastward. Minor erosion surfaces occur within the formation.

A columnar-jointed, steeply dipping outcrop of basalt with dike-like topographic expression was mapped on the south slope of Deep Creek Ridge (Plate I).

TERTIARY LAKE BEDS

Three outcrops of lake beds lie within or very near the southern border of Leesburg Basin, another is on a tributary to Deep Creek, and a fifth outcrop is on Williams Creek (Tl, Plate I).

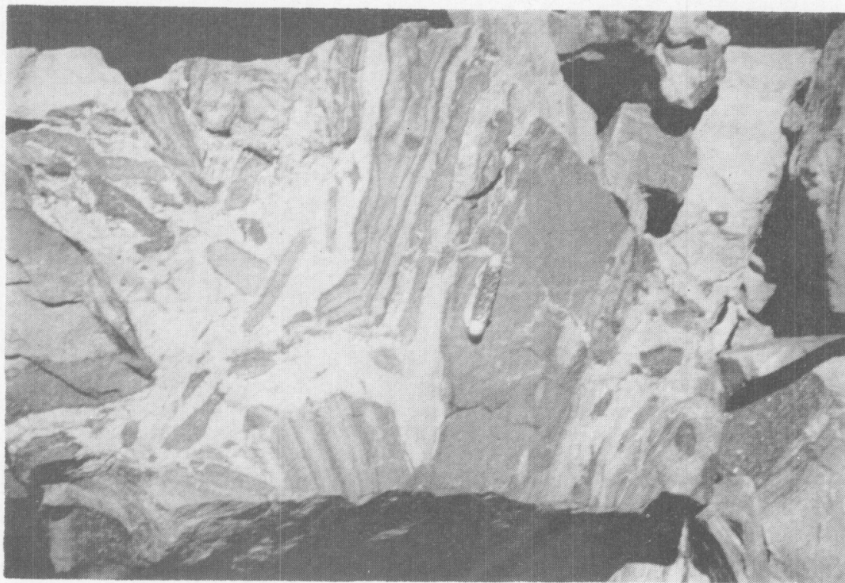


Figure 8.—Evidence of lit-par-lit injection of granitic material (light-colored) into metasediments. Talus block near Wallace Lake.

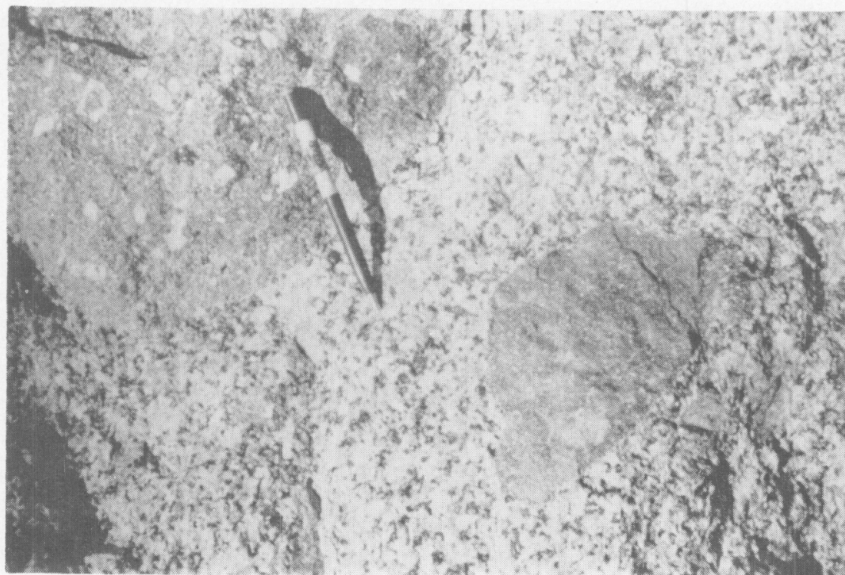


Figure 9.—Xenolithic metasedimentary remnants in porphyroblastic quartz monzonite near Delvin Falls, Napias Creek. The larger xenolith shows incipient development of porphyroblasts. These xenoliths are more rounded than those nearer the contacts of granitic bodies.

The lake beds are thin-bedded, light-colored volcanic siltstones and sandstones, and most contain fossil plant material. Marginal deposits contain coarser strata including pebbles and cobbles of quartzite and other pre-lake-bed rocks. A few non-bedded tuffaceous layers, several feet thick, are interbedded with the lake sediments.

These lake beds, for the most part, appear very similar to the Upper Oligocene(?) Kenney and Geertson and Lower Miocene Carmen formations of the Salmon and Baker quadrangles (Anderson, 1956, 1957). This is especially true of the lake beds along Phelan Creek, which are several hundred feet thick and partially fill a deep valley (Fig. 11) cut into Challis volcanics and older rocks. Lake beds in the Leesburg quadrangle could be equivalent to any of the above formations, because the same structural adjustment caused ponding of waters in both areas.

LATE TERTIARY ASH

Volcanic ash overlies Tertiary lake beds in Leesburg Basin (Ta, Plate I). The partly indurated ash is typically brown, homogeneous and structureless except for a few irregular joints. It is at least 500 feet thick in the vicinity of Phelan Creek basin. Irregular masses of white ash occur randomly in the brown ash on the north slope to Phelan Creek basin. Associated small outcrops of a very coarse conglomerate with volcanic matrix may be seen on the north slope at the lower end of Phelan Creek basin and along Napias Creek road where it crosses Arnett Creek. Near Leesburg typical brown ash is overlain by bedded ash and coarser volcanic detritus.

The ash in Leesburg Basin is considered to be of Late Tertiary age because it overlies Upper Oligocene or Lower Miocene lake beds and is veneered with Pleistocene glacial deposits. Before glaciation the ash and all older rocks were truncated by an erosion surface of mature character. This must have required considerable time, and the ash can hardly be younger than Early Pliocene and probably is of Miocene age.

QUATERNARY DEPOSITS

Pleistocene glacial deposits

Age relations

Drift of two Pleistocene stages, Wisconsin and pre-Wisconsin, is mapped separately in the Leesburg quadrangle. More than 1000 feet of canyon-cutting occurred between these two glaciations, and they must be separated by an appropriate time interval. The younger drift is Wisconsin. Stone (1893) recognized the older drift but made no age assignment. Ross (1929, 1934) tentatively assigned a Nebraskan age to the older drift. However granitic boulders in the older drift of the quadrangle appear less weathered (none is friable) than Nebraskan age would imply. Also, if the older drift is Nebraskan, there is no evidence of the intermediate Pleistocene stages. In this regard, it should be noted that Richmond (1957) has recognized three pre-Wisconsin glacial stages in the Rocky Mountain region. Until more data become available the older drift is best considered as pre-Wisconsin.

Pre-Wisconsin glacial deposits

The pre-Wisconsin glacier was an extensive ice cap which lay west of the crest of the Salmon River Mountains, with distributary outlet glaciers. Deposits from this glacier, of which only the most conspicuous have been mapped, are preserved as a veneer over much of the northern part of the quadrangle (Qpw, Plate I). Most of these deposits are of glacio-fluvial origin, and they consist of quartzitic, granitic and volcanic cobbles and boulders and lesser fine material. On Deep Creek Ridge well-rounded cobble- and boulder-sized erratics are scattered over several acres. Here, also, numerous huge quartz monzonite erratics were found. In contrast the Perreau Creek-Phelan Creek divide is formed by an extensive glacio-fluvial deposit more than 100 feet thick. The hill whose summit lies in the NE $\frac{1}{4}$ Sec. 35, R 20 E, T 21 N apparently is composed wholly of pre-Wisconsin drift, which may be more than 500 feet thick. This moraine (Plate I) contains so much quartz monzonite that its only possible source was the Idaho batholith, at least eight miles to the west.

Wisconsin glacial deposits

Wisconsin glacial deposits are almost entirely restricted to the eastern border of the quadrangle. Each major stream flowing eastward from the crest of the Salmon River Mountains begins in a cirque. A few cirques have developed west of the crest also. Valley glaciers commonly extended only one or two miles below the cirques, descending about 1000 feet to elevations near 7000 feet. Glaciers from large snow-fields, as in the head-water area of Williams Creek, reached lower elevations. Coarse-textured terminal and lateral moraines and some glacio-fluvial debris were left by all of the mountain glaciers, but only the Wisconsin moraine on Williams Creek and two minor terminal moraines were mapped (Qw, Plate I).

Pleistocene alluvium

Two levels of coarse terrace gravel, probably deposited by torrential meltwater streams from Wisconsin glaciers, were mapped in Leesburg Basin (Qt₁ and Qt₂, Plate I). The terrace gravel consists of well-rounded boulders and cobbles, primarily of quartzitic and granitic rock. Volcanic rock had been largely eroded from tributaries to the Basin before Wisconsin glaciation and is seldom found in the gravel.

Recent alluvium

Because all streams are in a youthful stage Recent alluvium is scarce. It occurs only above temporary base levels and very locally at stream junctions (Qal, Plate 1).

STRUCTURAL GEOLOGY

STRUCTURE OF THE PRECAMBRIAN AND ORDOVICIAN METASEDIMENTS

Mapping note

Detailed structural mapping in the metasedimentary rocks is difficult because the formations are thick and lack key beds. Interpretations are based upon: (1) attitude and relations of bedding, joints, faults and cleavage; (2) the stratigraphic sequence established in this paper; and (3) geomorphic evidence.

Pre-Middle Ordovician structure

The regional unconformity between Upper(?) Belt strata and Middle to Upper Ordovician Kinnikinic quartzite requires pre-Middle Ordovician uplift. This uplift caused erosion of an undetermined thickness of Belt strata and, presumably, of a thick Cambrian section. Scholten (1957) has termed this the Skull Canyon uplift, which, he says, represents "one of the strongest Early Paleozoic disturbances in the Northern Rocky Mountain geosyncline." Although important, the Skull Canyon disturbance was only a warping; virtually all deformational structures seen in Belt and Kinnikinic strata are of later age. Skull Canyon structural trends were probably obliterated or possibly intensified during the powerful Mesozoic orogeny. Ross (1947) implies that schistosity developed in Belt strata of the Borah Peak quadrangle, about 75 miles to the southeast, during the Skull Canyon disturbance. This does not appear to be true in the Leesburg quadrangle.

Because the Ordovician Kinnikinic quartzite is the only Paleozoic formation in the quadrangle, it is impossible to discuss adequately Mid- and Late Paleozoic disturbances (Scholten, 1957). However, it seems very probable that these disturbances were negligible in the Leesburg area.

Mesozoic structure

Folds

Major folds

Leesburg synclinorium. The largest structural feature in the Leesburg quadrangle, here named the Leesburg synclinorium, strikes about N. 45° W. through the central part of the quadrangle (Plate I). To the northwest, within a few miles, the synclinorium is truncated by the Idaho batholith; and to the southeast, it extends toward and probably forms the Lemhi Range (Fig. 4); if so, the synclinorium plunges southeast. The axial plane dips about 70° southwest and the axial zone is more or less isoclinally folded and locally brecciated (Plates I and II). If the Kinnikinic quartzite, which is the most competent metasedimentary unit, were not underlain by a less competent section, its close folding and brecciation in the synclinal axis would be surprising.

Related smaller folds on the southwest flank of the synclinorium are typically about one mile in breadth and appear to be doubly plunging. However, apparent dying-out of these folds as they approach the quartz

monzonite intrusive may be the result of isoclinal folding rather than plunge (Plate I). No attempt has been made to map moderately intricate deformation in the phyllite formation, but a general northeasterly dip has been indicated.

Strata on the northeast flank of the synclinorium are characterized by a general 35° southwesterly dip (Plate I). In spite of sparse data, it seems that smaller related folds are fewer, broader, and have gentler dips than those on the southwest flank. In addition to the two fold axes just northwest of Baldy Mountain and two similar axes west of Leesburg, there are other small folds, for example, in the Jesse Creek-Wallace Lake area (Plate I).

Minor folds

Drag folds occur in each of the metasedimentary formations. These folds are most common in the phyllite formation and have dimensions ranging from several inches to perhaps 50 feet. The most significant drag folds occur in the impure gray quartzite formation, with dimensions of hundreds of feet; closely spaced folds near Lake Mountain are excellent examples (Plates I and II). Drag folds in the Kinnikinic quartzite are along the axial zone, for example, near Cougar Point Camp.

Strata of the impure gray quartzite formation show local drag along the Leesburg fault (Section C-C, Plate II). This drag is seen best in the vicinity of the South Fork of Williams Creek, over a width of more than one mile southwest of the fault trace. Locally, strata in this zone are overturned, brecciated, and intricately deformed.

Belt strata are sub-parallel to the margin of the Idaho batholith and dip steeply toward it near Blackbird townsite and for several miles to the northeast. Emplacement of the batholith probably has produced this attitude of the metasedimentary beds. Rather commonly, subtypogenic folds have developed in the metasedimentary rocks adjacent to quartz monzonite bodies.

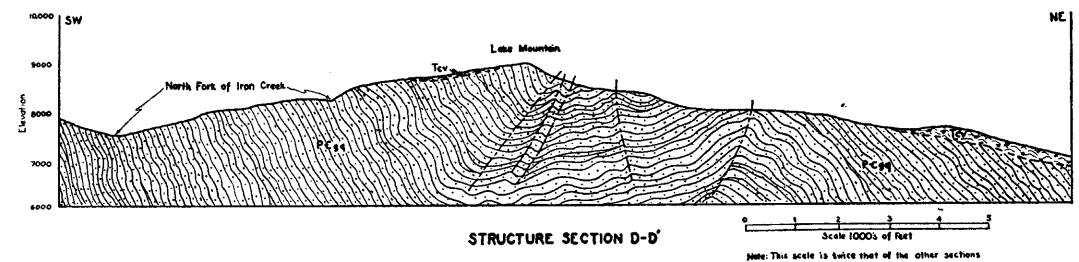
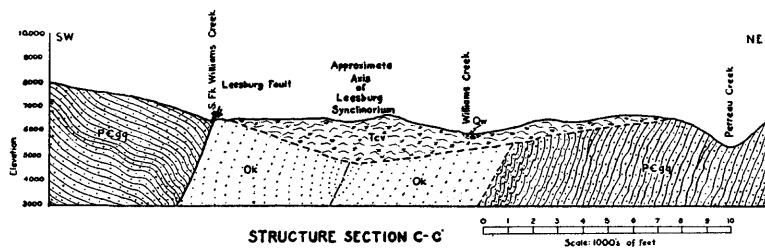
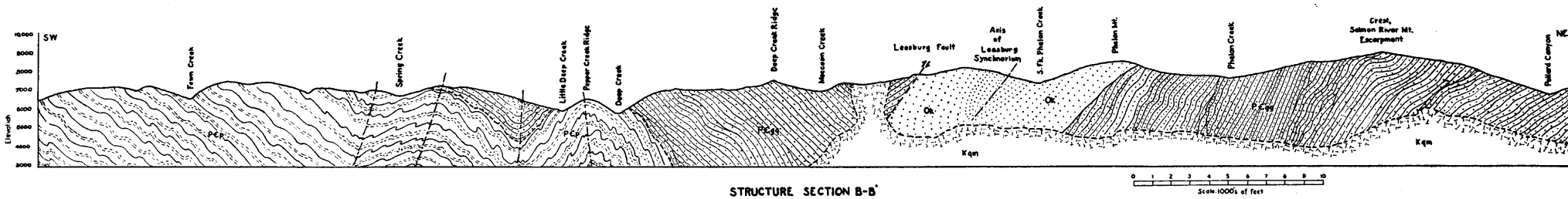
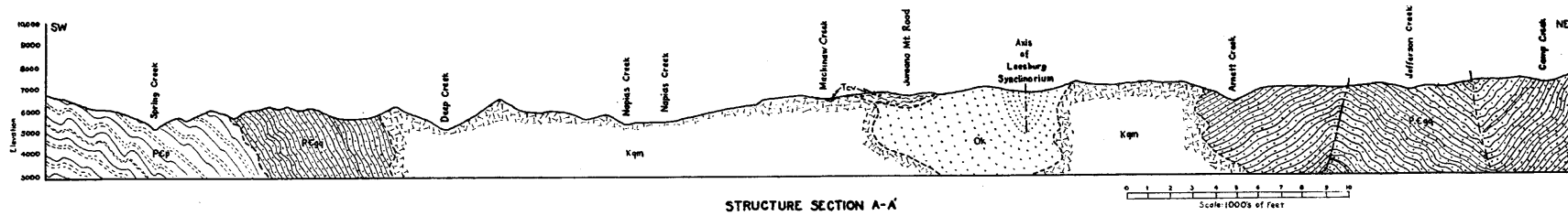
Faults

Major faults

Leesburg fault. The major fault in the quadrangle, here named the Leesburg fault, is high angle-reverse. It is longitudinal and the fault plane is the sole of the overturned Kinnikinic quartzite on the southwest flank of the Leesburg synclinorium (Plate II). Near the South Fork of Williams Creek, because of this fault the Kinnikinic dips under abutting, older, impure gray quartzite along a brecciated and intricately deformed zone. Here both the overturned Kinnikinic and the Leesburg fault dip about 75° southwesterly. Dip of the fault probably decreases with depth. To the northwest the fault is less well defined, so that its location and attitude were not accurately determined. To the southeast the fault is buried by Challis volcanics. However Starr (1955) reports extensive faulting on Rattlesnake Creek, 10 miles to the south.

In the section on stratigraphy it was shown that probably about 17,000 feet of the impure gray quartzite formation are missing from the southwest flank of the Leesburg synclinorium because of the Leesburg fault.

Plate II. Generalized Structure Sections



EXPLANATION

UPPER PRECAMBRIAN, Belt series	ORDOVICIAN	CRETACEOUS	TERTIARY	QUATERNARY
Phyllite formation	Kinnikinnick quartzite Idaho batholith	Quartz monzonite	Challis volcanics	Wisconsin drift

Sharkey Creek fault. A transverse N. 45° E. strike-slip fault, here named the Sharkey Creek fault, extends from the headwaters of Rabbit Creek at least four miles to the UP mine (Plate I). The fault plane is essentially vertical, although on a tributary to Jesse Creek it dips steeply southeast. Displacement was not established with any certainty. It appears that deformation of the southeast side has generally been somewhat more intense; if so, left-lateral (southeast side moving relatively north-east) displacement is probable. On aerial photographs it appears that this fault is a narrow zone of multiple shears rather than a single continuous break.

Minor faults

Innumerable minor faults in the metasedimentary rocks have not been mapped. Bedding-plane faults are probably more numerous than any other type. The only true schist found in the entire metasedimentary section probably is a bedding-plane-fault mylonite. This low-grade mica schist, eight inches thick, lies between beds of typical impure gray quartzite in a cirque at the head of the southernmost tributary to Pollard Canyon. Much of the mineralization in the quadrangle has occurred along bedding plane faults. Fresh exposures in road cuts and underground workings show many minor cross-cutting faults. Near Lake Mountain dips change markedly in such short distances that faulting seems probable.

Joints

One hundred and sixty joint attitudes were taken from 80 randomly scattered outcrops of metasedimentary rocks where both bedding and joints are distinct. The small number of readings reflects time limitations and the relative paucity of outcrops in which both bedding and jointing are distinct.

Joint data show a definite regional pattern, closely related to folds in the metasedimentary rocks. A contour diagram of these data as read in the field reveals a well-developed system consisting of strike and dip-joint sets. The dip-joint set is commonly the better developed.

If the joints are the earliest major structure they should be nearly perpendicular to bedding. Concentration of most of the joint poles around the margin of a contour diagram based on joint data (as they would appear if bedding were rotated into a horizontal plane) shows that the joints must be the earliest structure and indicates that there was probably only one later major deformation. The strike-and dip-joint sets are double; a more or less anomalous joint set indicated by concentrations about the north and south poles of the contour diagram may be related to the Skull Canyon disturbance.

Cleavage

Fracture cleavage of two magnitudes has formed parallel to axial planes of folds in the Belt metasedimentaries. The incompetent phyllite

closely spaced fracture cleavage. Thin phyllitic beds between more competent impure gray quartzite strata may also show well-developed fracture cleavage. Lack of fracture cleavage in the Kinnikinic quartzite reflects lithology and does not imply that fracture cleavage developed in the Belt strata prior to deposition of the Kinnikinic.

Metamorphic foliation in the Belt rocks is commonly parallel to relict sedimentary bedding. Probably this relationship results from flowage (elongation) parallel to bedding, although it may be the result of mimetic recrystallization. The Kinnikinic quartzite, which is thoroughly recrystallized, shows little or no foliation. However, in view of their different lithologic character, Belt and Kinnikinic strata appear to have undergone metamorphism of about equal intensity.

Structural conclusions

The following structural data indicate that tangential forces, acting from approximately S. 45° W., produced all of the structures seen in the metasedimentary rocks, with the possible exception of joints: (1) southwesterly inclination of the axial planes of major and minor folds, (2) southwesterly concavity of the traces of axes of larger folds, (3) nature and attitude of Leesburg and Sharkey Creek faults, (4) attitude of fracture cleavage, (5) predominant southwesterly dip of strike joints. These features also indicate that the greatest deformational force was rotational in a vertical plane, and that there was some rotation in a horizontal plane. Development of cleavage implies that the Precambrian and Ordovician sediments lay at moderate depths, on the order of 5 to 10 miles, when they were deformed.

It is difficult to date major deformation of the metasedimentary rocks in the quadrangle. The joint data suggest that there was probably only one time of major deformation; regional studies indicate that this occurred during the Mesozoic era. Certainly, apophyses of the Idaho batholith were emplaced after major deformation of the metasedimentaries. However the apophyses give no definite dating criteria, because Eardley (1951) and others maintain that the eastern margin of the batholith may be younger than the Early Cretaceous or Late Jurassic age assigned to the batholith as a whole (Ross, 1928).

Ross (1947) states that: "Data are in accord with the general concept of eastward migration of deformation and intrusion during the latter part of Mesozoic time from the Pacific coast into Montana and Wyoming." Thus, major deformation of Belt and Kinnikinic strata in the Leesburg quadrangle probably is neither classic Nevadan nor Laramide. Rather, this deformation is intermediate and may be closely related to unquestionable Laramide structures not far to the east.

STRUCTURE OF THE CRETACEOUS GRANITIC ROCKS

Study of the Cretaceous granitic rocks was restricted to mapping contacts and examination of associated marginal features.

In the quadrangle, discordant intrusive relation of granitic rocks to metasedimentary rocks is most common. Therefore it is probable that

apophyses of the Idaho batholith are near its roof. Regional trends have generally not been deflected by emplacement of the granitic rocks. The Arnett Creek intrusive, for example, formed along the unconformable contact of the impure gray and Kinnikinic quartzites (Plate I). Lobe-like extension of the Idaho batholith (Fig. 4) may reflect regional structural control.

Quartz monzonite exposures are massive, and this accounts for granitic float and erratic material being larger than other rock types. Widely spaced joints are common, and underground workings show minor faults, in the granitic bodies. A larger, northwesterly trending fault may cut the quartz monzonite near the junction of Gold Bug Gulch and Arnett Creek, where a rather extensive breccia was recognized (Plate I). Marginal gneissic banding in the granitic rocks is interpreted as relict sedimentary bedding.

By the time of emplacement of the granitic rocks in the quadrangle, the general Late Mesozoic orogeny had migrated eastward from the Leesburg area. Probably some of the structures seen in the granitic rocks formed while pronounced Laramide deformation occurred farther east, but the batholith apparently protected the local region from intensive folding and faulting.

STRUCTURE OF THE CHALLIS VOLCANICS

Attitudes of volcanic strata in the quadrangle were not determined in outcrop, except in a very few places where flow structures or columnar jointing made this possible. For the most part stratification in the volcanics was evident only at considerable distances from outcrops. From a distance changes in composition, and consequently in color, make bedding apparent. Obviously, structural data obtained in this manner are generalized.

Basal volcanic stratification is controlled by the shape of buried topography and is not useful in structural interpretation. Where the volcanic sequence is thick enough to overcome the influence of pre-volcanic topography, it forms a broad anticline. The axis of this anticline strikes about N. 45° E. and lies approximately along the South Fork of Williams Creek (Plate I). Dips on the southeast flank are about 10 degrees, and on the northwest flank about 5 degrees. Minor flexures are superimposed upon the major fold.

Ross (1934) suggested that intrusion of a Miocene batholith in the Casto quadrangle was associated with warps in the Challis volcanics. Challis warping ponded waters in the Leesburg quadrangle and in the Salmon Basin, and made possible deposition of Tertiary lake beds.

STRUCTURE OF THE TERTIARY LAKE BEDS

Outcrops of Tertiary lake beds in the Leesburg quadrangle are few and poorly exposed. Of the five small areas where lake beds were found, they dip 5° to 20° northerly at four areas, and are nearly horizontal at the fifth (Williams Creek road). Anderson (1956, 1957) has shown that in Salmon Basin, structure and interrelationships of Oligocene(?) and Miocene lake beds are rather complex.

POST-LATE-TERTIARY-ASH STRUCTURES

Regional warping may have affected the Leesburg area twice since deposition of the Late Tertiary ash. Geomorphic evidence can be interpreted as requiring regional depression during Late Tertiary time and regional uplift during latest Tertiary or earliest Quaternary time, but an alternate explanation is possible.

A probable small fault near Leesburg cuts Pleistocene but not Recent alluvium (Plate I). Presumably Devlin Falls on Napias Creek is a portion of the fault scarp. If so, the north wall of the fault is upthrown and tilted northerly. Accordingly, this northerly tilt caused deposition of Recent alluvium in upper Napias Creek (Plate I). Because Devlin Falls is about 50 feet high, this is considered to be the magnitude of dip-slip displacement. The fault, on topographic evidence, also shows about 50 feet of right-lateral displacement.

METAMORPHISM OF THE PRECAMBRIAN AND ORDOVICIAN SEDIMENTARY ROCKS

MAIN FEATURES

Precambrian and Ordovician sediments of the Leesburg quadrangle have been altered by dynamic and igneous metamorphism on a regional scale. Dynamic metamorphism recrystallized the sedimentary rocks and produced quartzites, phyllites, and slates. Igneous metamorphism gave all gradations from metasedimentary rock to an end product of quartz monzonite.

DYNAMIC METAMORPHISM

Dynamic metamorphism occurred contemporaneously with Late Mesozoic folding. Foliation is the result of this metamorphism, which must have been low-grade as indicated by preservation of sedimentary features. The representative mineral assemblage, quartz-albite-microcline-biotite-muscovite-epidote, places these rocks in the greenschist metamorphic facies. Collectively they may be considered quartzo-feldspathic schists of the biotite-chlorite metamorphic subfacies (Turner and Verhoogen, 1951). Implications of this classification are that the metamorphic environment was one of relatively low temperature and moderate confining pressure. Consequently, these rocks were deformed at depths on the order of 10 miles, and deforming forces were of moderate intensity.

No gradation of metamorphic rank was found. However, 25 miles to the northeast, beginning approximately along the Continental Divide, Belt series strata are less metamorphosed (Anderson, 1957). Accordingly, increased metamorphic grade should be expected southwest of the quadrangle. Ross (1934) described several schists of Precambrian and perhaps Lower Paleozoic age from the Casto quadrangle about 25 miles to the southwest. These schists contain andalusite and amphibole and are therefore of higher metamorphic grade than any of the Belt rocks in the Leesburg quadrangle. Thus, there is some evidence that, over a zone extending northeasterly for 50 miles from the Casto quadrangle, metamorphic grade progressively decreases.

IGNEOUS METAMORPHISM

Igneous metamorphism was associated with emplacement of the Idaho batholith. It is felt that considerable marginal portions of the apophyses of the Idaho batholith in the quadrangle are of metamorphic origin, i.e., granitized metasedimentary rocks. The following evidences support this conclusion: (1) contacts of the intrusive bodies are gradational over a zone commonly about 200 feet wide; (2) there appear to be no high temperature contact phenomena; (3) the granitic bodies have not made room for themselves by deforming preexisting structures, with possible local exceptions; (4) judging from mineral content and paragenetic sequence, the marginal granitic rocks do not appear to have formed from eutectic mixtures; (5) mosaics of quartz grains suggestive of quartzite relics occur at random in the quartz monzonite; (6) marginal gneissic structure is apparently relict sedimentary bedding; (7) "granitic gneisses near Shoup, about 15 miles north of the quadrangle, have been considered part of the Idaho batholith; recent mapping has indicated, however, that they are metamorphosed sediments" (E. P. Kaiser, personal communication).

SEDIMENTATION

UPPER PRECAMBRIAN SEDIMENTATION

Deposition of the phyllite formation

Graywacke quartzites of the phyllite formation represent typical low-rank graywacke siltstones, i.e., poorly sorted quartz-clay rocks with graded bedding (microscopic) and without cross-bedding or ripple marks. Dark phyllites of this formation represent more argillaceous counterparts of the low-rank graywacke siltstones. Black slates, minor units of the formation, were largely clay material with some silt. Negligible amounts of calcium carbonate were deposited with more argillaceous units of the formation.

The graywacke quartzite and phyllite units indicate rapid deposition by turbidity currents during tectonic instability. The rate of sedimentation exceeded the rate of geosynclinal subsidence. Because they were deposited by turbidity currents, individual graywacke quartzite and phyllite units are much more extensive than lenses of equivalent thickness in the impure gray quartzite formation. Muds (black slates) settled on the sea floor when turbidity currents were not operating. These black slate units are more extensive than the graywacke quartzite beds. The phyllite formation was deposited in deeper water than the overlying impure gray quartzite formation.

Deposition of the impure gray quartzite formation

The impure gray quartzite formation represents partially sorted quartz-clay sandstones and siltstones in which ripple marks and cross-bedding formed. These rocks were deposited at a time of greater tectonic stability than the time of deposition of the phyllite formation. Low-velocity distributive currents formed these sandy lenses as a huge sedimentary lobe in the Belt geosyncline. Ripple marks and cross-bedding indicate that the sea was relatively shallow during deposition of the impure gray quartzite. These features also suggest that distributive currents came from the west-south-west and, consequently, that the source area lay in that general direction. The red slates and purplish quartzites at the top of this formation indicate a swing to a continental environment.

Regional applications

Ripple marks and cross-bedding suggest that Belt sediments of the Leesburg quadrangle, and perhaps of a considerable bordering region, were derived generally from the west. The source can probably be assumed, on the basis of character and composition of the Belt formations, to have been older (pre-Belt) sediments in a mobile, cannibalistic geosyncline. Belt formations in the quadrangle indicate tectonic stability increasing with time. The gradation upward from relatively deep to shallow water, to probable continental deposition indicates a regressive sea. If the sediment source did lie westward, this regression was eastward. Accordingly, lithologic correlations might be successful to the north and south, but to the east or west, facies changes would make correlation difficult.

PALEOZOIC SEDIMENTATION

It seems probable that a thick Cambrian section was deposited over most of the greater Salmon region. The pre-Middle Ordovician Skull Canyon uplift (Scholten, 1957) caused erosion of all of this Cambrian section and an undetermined amount of the Belt series. Subsidence was renewed during the Middle and Upper Ordovician, allowing a shallow sea to transgress northeastward (Scholten, 1957) across the Skull Canyon erosion surface. The Kinnikinic quartzite, which must have been largely derived from Belt sedimentary rocks, represents the basal deposit in this transgressing sea. The Kinnikinic of the quadrangle should be somewhat older than the same formation to the northeast. Paleozoic sediments younger than Ordovician must have been deposited conformably over the Kinnikinic sands, but these have been removed by subsequent erosion. The nearest remaining post-Ordovician marine sediments are Carboniferous, about 30 miles to the southeast (Fig. 4).

GEOMORPHOLOGY

GEOMORPHIC EVOLUTION

The lower Paleozoic erosion surface beneath the folded Ordovician Kinnikinic quartzite is the earliest evidence of land form development in the Leesburg quadrangle. Relief on this surface is slight to moderate. Sixty miles to the southeast, "the surface of the unconformity seems to have considerable relief," an impression caused partly by local faulting (Scholten, 1957).

Major drainage features first developed during the Early Tertiary, after regional uplift in response to profound Mesozoic deformation and intrusion. The warped erosion surface beneath the Early Tertiary conglomerate indicates that by Early Tertiary time most of a thick Paleozoic section and some of the underlying Belt had been removed, that local relief in the quadrangle was several hundred feet and that regional relief was several thousand feet. Apparently, drainage from the southeastern part of the quadrangle was to the southeast.

Prior to Oligocene volcanism the Early Tertiary surface had been modified by partial stripping away of the Early Tertiary conglomerate. Present distribution of Challis volcanic remnants indicates that regional relief on the pre-volcanic surface was of similar magnitude to that now existing.

Leesburg Basin was developed prior to Challis volcanism. Figure 10 is a sketch of hypothetical pre-Challis drainage in the Leesburg quadrangle. As in Early Tertiary time, regional drainage seems to have been to the southeast.

Tertiary lake beds were deposited in ponded drainage on exhumed pre-Challis topography, for the most part. Figure 11 is a sketch of pre-lake-bed drainage in the southern part of Leesburg Basin.

During Pliocene time the region was eroded to late maturity. Pliocene age of this mature surface is verified by the facts that the surface cuts Late Tertiary ash and is veneered with pre-Wisconsin glacial debris. This correlation confirms the regional conclusion reached by Anderson (1929) and others, following an extended argument concerning Idaho erosion surfaces.

Available relief on the Pliocene surface was apparently less than at any other time in the Cenozoic era. This reduction of available relief may have been the result of depression in response to profuse outpouring of Tertiary volcanics. An alternative hypothesis to explain this reduction of available relief is that pre-Pliocene drainage channels were clogged by alluvium or volcanics or both.

The quadrangle apparently represents the headwater portion of a mature Pliocene valley, which has been tilted approximately one degree to the northeast. The central part of this valley is marked by accordant ridges about 7000 feet in elevation and the valley sides slope gently upward about 2000 feet to elevations near 9000 feet. Swan Peak is a local prominence rising 400 feet above the Pliocene surface. Pliocene drainage may have been southward from the quadrangle.

The Pliocene erosion surface in the Salmon River Mountains was covered by an extensive pre-Wisconsin ice cap. This glacier, which was more than 2000 feet thick, moved generally eastward. Evidence of pre-Wisconsin glacial erosion is slight west of the crest of the Salmon River Mountains. However, outlet glaciers from the ice cap did considerable cutting. For example, the abrupt hill whose summit lies in the SE. $\frac{1}{4}$, SW. $\frac{1}{4}$, Sec. 36, R.20E., T.21N., was carved from volcanics by an outlet glacier moving southeasterly from the Phelan Mountain area across the present Perreau Creek-Williams Creek divide. This outlet glacier was about 1000 feet thick, for it flowed around and covered the hill and deposited a thick moraine to the northwest.

Available relief was restored to its pre-Pliocene magnitude before recession of the pre-Wisconsin glacier. Consequently, meltwater streams initiated canyons in the relatively subdued topography emerging from beneath the ice. Prior to Wisconsin glaciation some of these canyons reached depths greater than 1000 feet, and Perreau Creek Canyon is an excellent example. A branch of the outlet glacier just described gouged a U-shaped valley parallel to and about 1000 feet above Perreau Creek. Meltwater from the pre-Wisconsin glacier followed the glacially gouged valley and initiated Perreau Creek Canyon. Before Wisconsin glaciation pluvial streams cut this canyon about to its present aspect.

Locally, ice blocks forced meltwater streams to cut gorges in unlikely places. For instance, lower Napias Creek is cut in volcanic flows and pyroclastics, although less resistant ash lies just to the east in the most natural drainage line of Leesburg Basin. It is suggested that a meltwater stream adjacent to stagnant pre-Wisconsin ice in the axis of Leesburg Basin became entrenched in the volcanics and could not escape after melting of the ice.

Not all canyons of the quadrangle were initiated by pre-Wisconsin meltwater streams. However, canyons started by meltwater streams have dominated pluvial drainage development by providing increased gradients for their tributaries. Therefore, it is concluded that pre-Wisconsin meltwater streams initiated marked local changes in topography, but did not affect overall regional relief. Presumably, a relatively undissected late-mature Pliocene surface emerged from beneath the pre-Wisconsin glacier. This surface was deeply incised by meltwater and subordinate pluvial streams to its present rugged aspect, which is one of youthful valleys in late youthful or early mature topography.

Wisconsin glaciers cut cirques at the heads of predominantly pre-Wisconsin canyons located to the lee of westerly winds. Because mountain summits in the Leesburg quadrangle are relatively low, Wisconsin glacial features are only moderately developed, although classic Alpine features are characteristic of adjacent higher areas. Wisconsin glaciers are responsible for virtually all of the ponded waters in the quadrangle. The only significant exception is Pony Lake, which was dammed for placer gold operations. Several small lakes, like Wallace Lake (Fig. 12) and UP Lake, are tarns. Others, like the small lakes northeast of Lake Mountain are impounded behind Wisconsin terminal moraines.

Since Wisconsin glaciation topography has been little modified. Wisconsin alluvium forms terraces in Leesburg Basin, and recent alluvium is collecting in a few favorable localities.

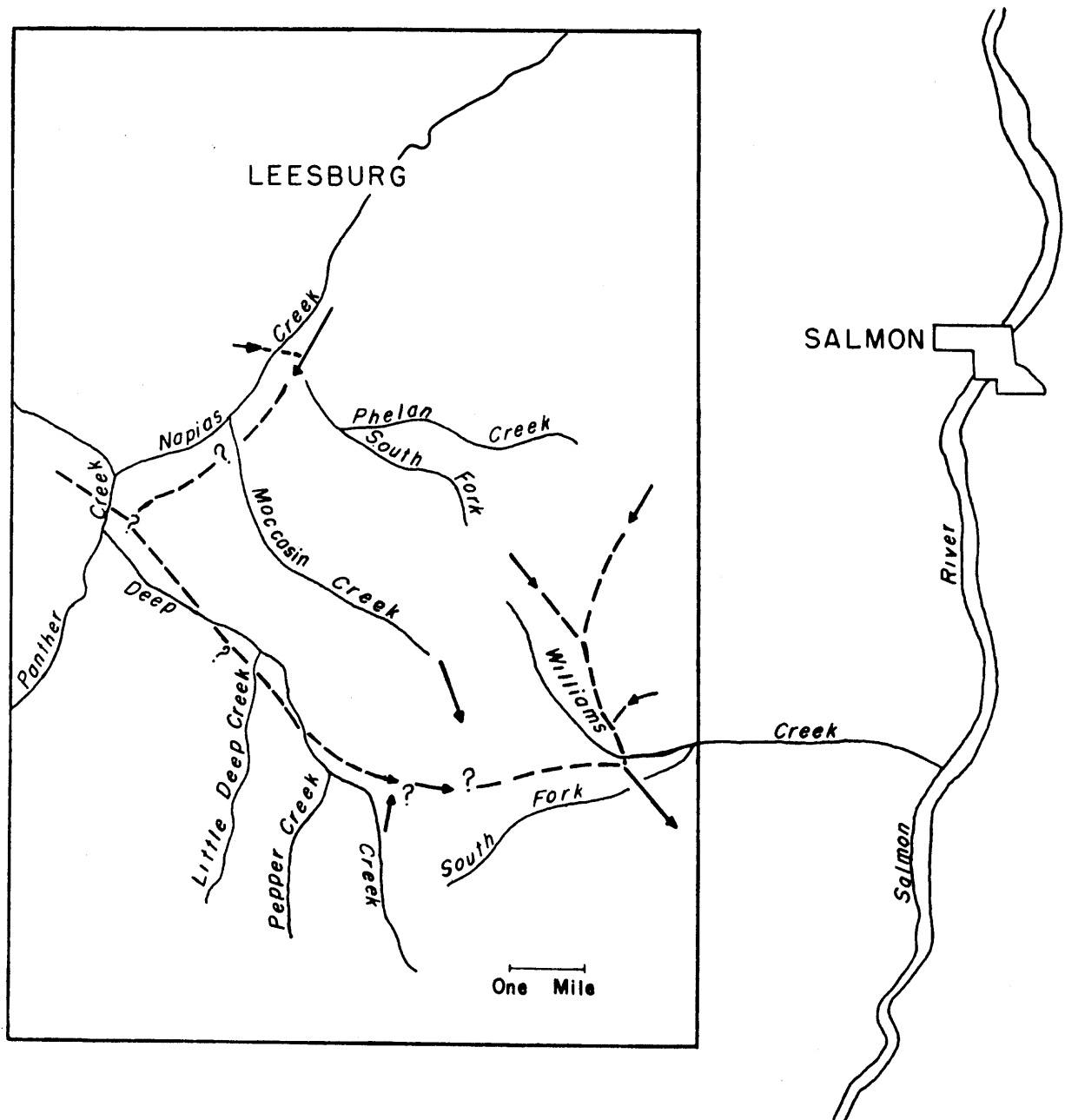


Figure 10.—Hypothetical pre-Challis drainage of the Leesburg quadrangle—shown by arrows and dashed lines.

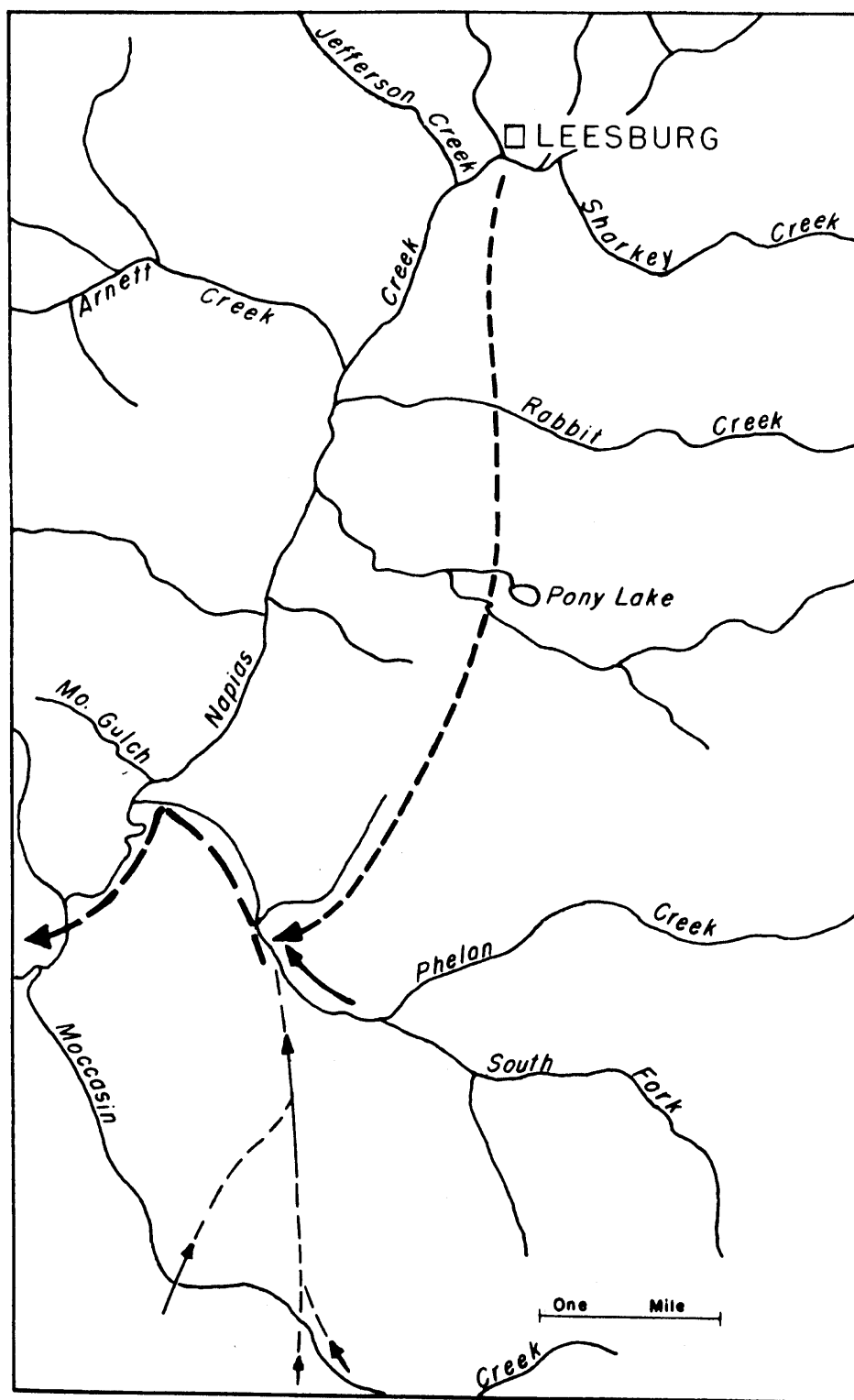


Figure 11.—Hypothetical pre-Tertiary-lake-bed drainage in part of Leesburg Basin—as shown by arrows and dashed lines.

STREAM PIRACY

Mackinaw Creek beheaded Missouri Gulch after pre-Wisconsin recession and possibly before Wisconsin glaciation. Pre-Wisconsin glacial fill caused drainage derangement one and one-half miles north of Leesburg. As a result of this derangement, Wards Gulch was beheaded by Camp Creek, and a bedrock terrace, along the middle portion of Camp Creek above the elbow of capture, was incised to a depth of about 25 feet.

STRUCTURALLY CONTROLLED LANDSCAPE FEATURES

All of the major basins of the Leesburg quadrangle are structurally controlled. Leesburg Basin is differentially erosional, because of the resistant Kinnikinic quartzite, which causes a temporary base level on lower Napias Creek. This basin has been in existence at least since pre-Challis (Oligocene) time and probably since the Early Tertiary. Other basins, partly filled by alluvium, have formed since pre-Wisconsin time. Blackbird townsite (Fig. 2) is located in a basin differentially eroded in the phyllite formation just upstream from the more resistant impure gray quartzite. Deep Creek basin, near the mouth of Deep Creek, is the result of igneous metamorphism which made the contact zone along the quartz monzonite more resistant to erosion than the metasedimentary rocks in which the basin is formed. A similar situation occurs at the horseshoe turn in Panther Creek. Phelan Creek basin along lower Phelan Creek, has formed in volcanic ash upstream from more resistant volcanic flows and pyroclastics.

Lake Mountain (9274 feet) and Baldy Mountain 9149 feet), the highest summits in the quadrangle, are formed by more or less closely folded impure gray quartzite. Other high summits, like Phelan Mountain, are aligned along the outcrop of the resistant Kinnikinic quartzite, which forms the axial zone of the Leesburg synclinorium. Locally, these Kinnikinic summits are separated by a valley which marks the axial line of the synclinorium.

The Leesburg fault has left a steep scarp southeast of Williams Creek summit. The Sharkey Creek fault makes a topographic low which is barely visible in the field but is distinct on aerial photographs. Devlin Falls on Napias Creek is probably on a fault scarp.

The drainage pattern is predominantly dendritic. Where relief is moderate to slight, drainage is much finer textured on the granitic and volcanic rocks than on the metasedimentary rocks. Consequently the different rock types may be frequently recognized on aerial photographs. Deep Creek, Little Deep Creek, Pepper Creek and in part Spring Creek are subsequent streams controlled by differential resistance of the folded impure gray quartzite. The pattern made by these streams is in strong contrast with the dendritic drainage on the adjacent phyllite formation. The sharp meander in Deep Creek is locally controlled by joints and bedding.

On aerial photographs the volcanics stand out clearly as light-toned positive areas, and the volcanic contacts can be more accurately mapped on the photos than in the field. Less successfully, the contact of the granitic rocks can be traced on aerial photos. The Late Tertiary ash fills an old valley, and contacts are marked by breaks in slope.

ECONOMIC GEOLOGY

MAIN FEATURES

Metallic and nonmetallic deposits of economic interest occur in rocks of the Leesburg quadrangle. Cobalt and copper are closely associated in the Belt metasedimentary rocks; radioactive elements and gold are closely related to the granitic rock and may occur in adjacent metasedimentaries; tungsten is in the Belt metasedimentary rocks; and lead-silver deposits are in the granitic rocks. Cobalt and copper are probably pre-batholith; radioactive elements and gold are clearly late-batholith; tungsten is probably post-batholith; and lead-silver deposits are Mid-Tertiary. Probably these metals and the granitic rocks were derived from differentiating sub-crustal magmas, and Cretaceous granitization can be considered a type of intense wall rock alteration preceding deposition of radioactive elements, gold, and possibly tungsten. Only the copper, gold, and lead-silver deposits have been commercially important.

Gold has been secondarily concentrated as Quaternary placer accumulations in and around Leesburg Basin. Silver and radioactive rare-earth minerals also occur in these placers. The value of placer gold has exceeded all other deposits by several million dollars, but future value of base metals may ultimately be greater.

Nonmetallic deposits of economic interest are opalized wood, quartz crystals, and building materials.

METALLIC DEPOSITS

Cobalt deposits

Although no cobalt properties have been located in the Leesburg quadrangle, the largest known cobalt reserves in the United States are being exploited at the Blackbird mine, just seven miles west of the quadrangle. Therefore, there is good probability of finding cobalt deposits within the quadrangle.

Both Anderson (1947) and Vhay (1948), who have made studies of the Blackbird district, found extensive tourmalinization and biotitization associated with the cobalt mineralization. As have been pointed out, black tourmaline in networks of finely crystalline veins and veinlets is scattered throughout the impure gray quartzite on the hanging wall of the Leesburg fault. This tourmalinization is the same as that in the Blackbird area. Other factors being similar, cobalt mineralization might well be expected in the quadrangle along the outcrop of the impure gray quartzite on the hanging wall of the Leesburg fault. That this is a reasonable expectation is demonstrated by the occurrence of erythrite (cobalt bloom) at several localities in the specified terrane. The most notable of these, about 0.4 mile north of Blackbird townsite, is shown on Plate I. Future prospecting, using the black tourmaline and pinkish erythrite as guides, might lead to discovery of economic cobalt deposits in the quadrangle.

Because the Leesburg fault has localized tourmalinization and associated cobalt mineralization the cobalt apparently was deposited after Late

Mesozoic deformation. These deposits are considered by Anderson (personal communication) to be older than the Cretaceous granitic rocks, because: (1) cobalt deposits have not been found within the granitic rocks, and (2) they have formed in an environment of higher temperature and pressure than deposits which are definitely related to the granitic rocks. Thus the cobalt deposits appear to be post-deformation and pre-batholith, or Late Mesozoic.

Copper deposits

Location and structural control

Copper deposits have been exploited at the Blackpine and Bowman mines. These old mines have recently been reopened and because of prevailing economic conditions are receiving more attention than any of the others in the quadrangle.

The Blackpine and Bowman mines are on the flanks of the Leesburg synclinalorium, the Blackpine on the southwest flank and the Bowman on the northeast. The copper mineralization appears to be stronger in the more pelitic strata on the southwest flank. Consequently, much of the future copper production may be expected from the southwestern part of the quadrangle.

The copper deposits have the northwesterly strike characteristic of copper deposits in the Salmon region (Ross, 1925). According to Ross (1925, Fig. 3), virtually all ore deposits other than copper strike due north, northeasterly, or due east. If these trends, as plotted by Ross, were superimposed upon the rotated joint pattern of the Leesburg quadrangle, the two sets of data would coincide perfectly. This does not imply that all of the mineral deposits occur in joints, but does imply close relation of mineral localization and Mesozoic structures.

Blackpine mine

The Blackpine group of claims is near the headwaters of the north branch of Copper Creek. The earliest available reference to this property is a statement by Campbell in 1925 that the mine had been idle since 1904. Recently, under ownership of the Montana Coal and Iron Company, the property has been extensively explored by trenches and adits. The Defense Minerals Exploration Administration has assisted with this work. A small flotation mill (Fig. 13) was completed in the summer of 1956. The millsite is on Copper Creek, about 0.7 mile below the mine. The mine has had little, if any, production, although it is possible that the 1952 copper production of Table I represents a test shipment.

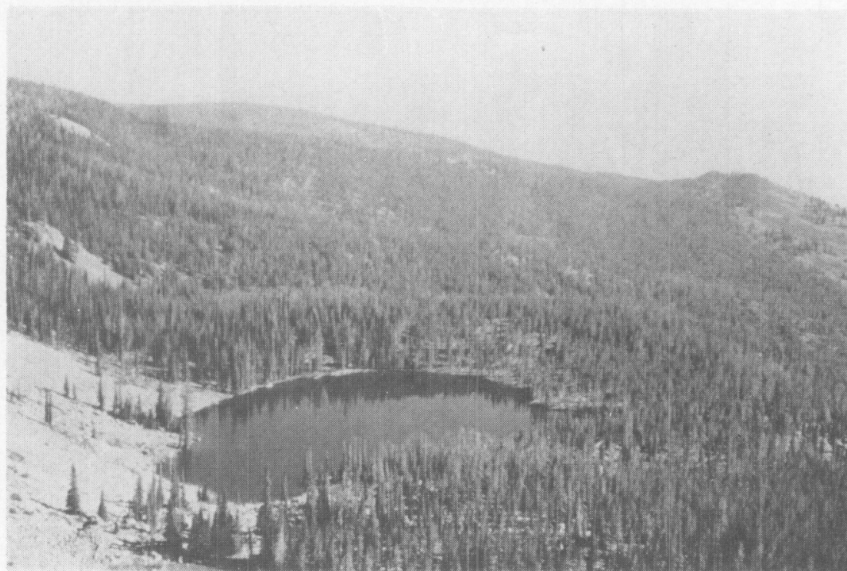


Figure 12.—Wallace Lake, a tarn at the head of Wallace Creek.

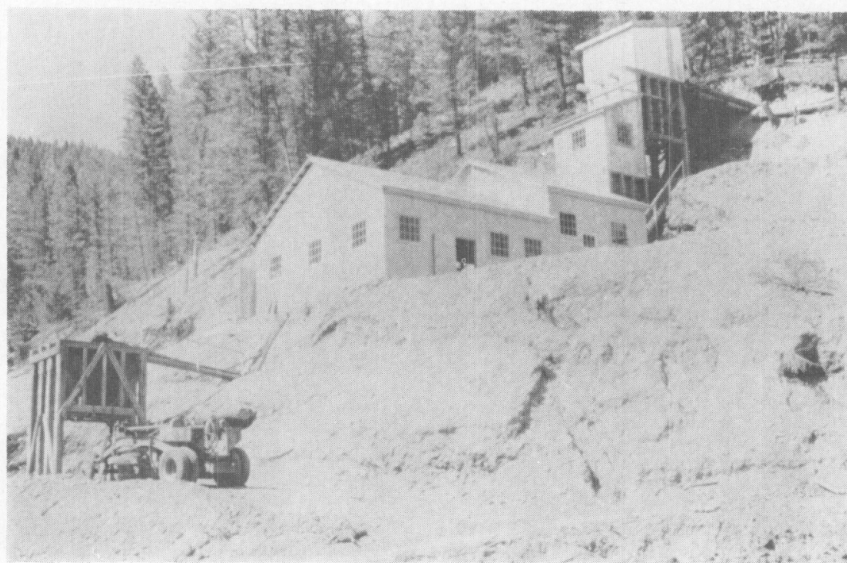


Figure 13.—The Blackpine copper mill, completed in 1956.

TABLE I*

Mines in the Leesburg Quadrangle

Mine Name	Location
Lode:	
Botte, or Betty group	Napias Creek
Blue Jay	Napias Creek
Golden Ridge, or Gold Ridge	
Gold Flint	
Italian (Golden Fissure)	
Ringbone Cayuse	
U. P. & Burlington	
Placer:	
Arnett Creek Placer (Sunset)	Arnett Creek
Big Jureano	Big Jureano Creek
Boulder Pit	Napias Creek
Camp Creek	Camp Creek
East Jureano & Left Fork of East Jureano	East Jureano Creek
Fraker	Napias Creek
Genevieve	3/4 mile from Leesburg
Hocken Smith	Arnett Creek
Isla & Paydirt	Napias Creek
Italian-Golden Fissure	Arnett Creek
Johnson	Sage & Camp Creeks
KGW	Arnett Creek
Leesburg Bonanza	Napias & Rapps Creeks
Mickey Boy	Rapps Creek
Nappias	Napias Creek
Never Sweet-Bull Moose	" "
Phelan Creek	Phelan Creek
Red Placer	Mackinaw Creek
Redemption #1, 2, 3	Napias Creek
Richardson	Napias Creek
Richardson	Near Leesburg
Sawpit	Sawpit Creek
Tough Gulch	" "

*Courtesy of A. J. Kauffman Jr., Chief, Division of Mineral Industries,
Region I, Albany, Oregon.

TABLE I (Continued)

Lode production of gold, silver, copper, lead, and zinc for the
Leesburg Quadrangle, Lemhi County, Idaho, 1901 through 1954^{1/},
in terms of recoverable metals.

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1902.....	200	41	8	---	---	---
1903.....	100	185	55	---	---	---
1904.....	300	145	50	---	---	---
1907.....	507	196	43	---	---	---
1908.....	62	31	7	---	---	---
1910.....	69	28	14	---	---	---
1911.....	835	65	20	---	---	---
1912.....	3	3	--	---	---	---
1914.....	30	26	8	---	---	---
1915.....	1,550	97	16	---	---	---
1920.....	52	16	1,314	471	30,604	---
1921.....	100	55	10	---	---	---
1922.....	65	45	5	---	---	---
1927.....	75	9	1	---	---	---
1931.....	17	18	190	---	5,805	---
1934.....	127	55	1,986	2,650	38,595	---
1935.....	327	97	1,536	747	25,700	---
1936.....	4	8	1	---	---	---
1938.....	15	3	240	82	6,583	---
1939.....	19	5	213	67	5,660	---
1940.....	50	17	99	---	641	---
1942.....	2	1	6	---	248	---
1952.....	89	--	--	24,200	---	---
Total.....	4,598	1,146	5,822	28,217	113,836	---

^{1/} No production recorded for 1901, 05, 06, 09, 13, 16-19, 23-26, 28-30, 32, 33, 37, 41, 43-51, 53, 54.

TABLE I (Continued)

Placer production of gold and silver for the Leesburg Quadrangle,
Lemhi County, Idaho, 1901 through 1954 ^{1/}

Year	Gold (fine ounces)	Silver (fine ounces)	Year	Gold (fine ounces)	Silver (fine ounces)
1901.....	560	--	1926.....	72	4
1902.....	584	--	1927.....	121	10
1903.....	173	--	1928.....	104	8
1904.....	187	--	1929.....	86	7
1905.....	119	11	1930.....	96	9
1906.....	97	14	1931.....	109	10
1907.....	98	7	1932.....	123	8
1908.....	187	12	1933.....	105	9
1909.....	145	20	1934.....	126	8
1910.....	109	8	1935.....	190	12
1911.....	99	21	1936.....	149	15
1912.....	73	10	1937.....	90	6
1913.....	87	11	1938.....	125	8
1914.....	133	28	1939.....	188	17
1915.....	42	6	1940.....	1,140	106
1916.....	59	7	1941.....	1,149	120
1917.....	102	9	1942.....	48	4
1918.....	83	6	1944.....	8	--
1919.....	91	14	1946.....	37	5
1920.....	53	--	1947.....	11	--
1921.....	80	8	1948.....	12	--
1922.....	106	9	1949.....	5	--
1923.....	87	8	1950.....	13	--
1924.....	78	6	1954.....	1	--
1925.....	95	8			
			Total.....	7,635	589

^{1/} No production recorded for 1943, 45, 51-53.

Chalcopyrite is the principal ore mineral. It occurs as massive fissure-filling and replacement veins, veinlets, stringers and pods up to one foot thick along zones of closely spaced high-angle reverse faults of small displacement. Ore shoots extend irregularly for hundreds of feet along the fault zones and dip 45° to 70° northeasterly. The country rock is sericitized and chloritized gray phyllite of the phyllite formation, which dips northeasterly. A few quartzitic strata are interbedded with the phyllite.

Table II lists the minerals identified in polished and thin sections from the Blackpine mine and shows the probable sequence of mineralization. Chalcopyrite is far more abundant than the other metallic minerals. In addition, chemical analyses indicate the presence of minor quantities of gold and silver, which are probably associated with the base-metal sulfides, and also the presence of cobalt, which reportedly occurs in cobaltiferous arsenopyrite (glaucodot). This cobalt is not recovered.

Character of the mineralization implies that the environment of deposition was one of moderate temperature and rather high pressure, such as would exist at considerable depth below the surface. Apparently the ore was precipitated in low-pressure fault zones. This copper mineralization is considered to be of the same general post-deformation and pre-batholith age as the cobalt mineralization. However, because copper in the Blackbird area was somewhat later than cobalt (Anderson, 1947), the copper in the Leesburg quadrangle is probably slightly younger than the cobalt.




















Bowman mine

The Bowman (formerly known as the Dishman) mine is on the south slope of Baldy Mountain about 700 feet above Perreau Creek. This property received only cursory examination, but Ross (1925) studied it in some detail in 1923. The property was originally staked in 1908 by Ora Dishman and Thomas P. Snook. Dave Edwards of Salmon, Idaho, is presently exploring the claims with an option to buy from the owner, E. N. Bowman of South Gate, California. Most, if not all, of the copper production shown in Table I has been from the Bowman mine.

Except that the country rock is more siliceous, the geologic setting is much like that at the Blackpine mine. Similar copper mineralization was also observed along a tributary to West Fork of Perreau Creek and is known to occur two and one-half miles to the east at the Tormay mine (Ross, 1925; Anderson, 1956).

TABLE II

Probable sequence of mineralization at the Blackpine mine.

Stage	I	II	III	IV	V	VI
Fracturing						
Sericite						
Chlorite						
Quartz						
Arsenopyrite						
Pyrite						
Chalcopyrite						
Bornite						
Oxidation						
Malachite						
Azurite						
Limonite						

Deposits of radioactive rare-earth elements

In all known occurrences, radioactivity in rocks of the Leesburg quadrangle is produced by thorium contained in rare-earth minerals, and not by uranium.

In 1925 R. N. Toolson of Cobalt, Idaho, discovered and located claims on radioactive deposits along Big Jureano Creek at the western border of the quadrangle. Here radioactive allanite occurs as irregular seams and masses, up to several inches long, scattered through vein-like pegmatites measuring up to two feet thick. These bodies are composed of milky quartz with scattered foliate crystals of biotite, up to one inch in diameter, and equally abundant knots of pink feldspar, up to several inches in diameter. The country rock is porphyroblastic granite gneiss which locally is in part penetrated by the pegmatitic minerals. This allanite, a cerium-bearing epidote, contains thorium which is the source of the radioactivity shown by these deposits. No attempt has been made to develop this property.

Monazite and some allanite are locally concentrated in the placer gravels of Leesburg Basin. For example, near the junction of Smith Gulch and Napias Creek, monazite is sufficiently concentrated to excite a Geiger counter. Monazite is also a possible source of thorium and could be recovered in gold-dredging operations.

Because the rare-earth pegmatites cut the granitic rocks and contain minerals which may be assumed to have formed late in the history of emplacement of these rocks, the deposits are probably of late-batholith age.

Gold deposits

Lode gold

With exhaustion of rich gold placers of Leesburg Basin in the early 1870s, efforts were directed toward development of the mother lodes. More than one dozen lode gold mines were brought into production. Some of these old mines are indicated on Plate I. According to Umpleby (1913), virtually none of the lode mines operated at a profit, and the statistics of Table I bear this out.

All of the lode gold mines have been long inactive, and underground workings are inaccessible. Jacobs (1903), Bell (1905-08, 1920), and Umpleby (1913) discussed most of these mines and the reader interested in detail is referred to their reports.

The lodes are represented by fissure and fracture fillings and comprise simple fissure veins and mineralized fracture zones. The filling is chiefly milky quartz accompanied by variable but generally scanty amounts of the base-metal sulfides--pyrite, arsenopyrite, chalcopyrite and galena. The gold, which is about 900 fine, occurs with the sulfides and as free gold in the quartz matrix.

Lode-gold deposits in valleys, which include most of the old mines, are oxidized only to slight depths, because insufficient time has elapsed

since pre-Wisconsin glaciation and subsequent canyon-cutting. Below the oxidized zone, gold associated with the base-metal sulfides has not been freed. In the early days, extraction of gold from the sulfides was so expensive that the low-grade primary ores were not economic.

Many lodes are within one mile of the contact between granitic rocks and older metasedimentary rocks and they occur across or on either side of this contact.

General character of the lode gold deposits reflects deposition in an environment of moderate temperature, pressure and depth. The quartz and associated gold-bearing sulfides may be later differentiated products of the Idaho batholith.

Placer gold

Rich placer gold with minor silver, reportedly yielding \$1.00 to \$5.00 per pan, was discovered near the mouth of Wards Gulch on July 16, 1866 (Kirkpatrick, 1934). Apparently the richest placer gold had been removed from Leesburg Basin by the 1870s. Because no records were kept, only estimates of this early production are available, and these range from \$5 million to \$35 million. Umpleby (1913) thought the smaller figure more nearly correct.

Placer gold has been produced from Leesburg Basin almost continuously since the early boom days. Available records of operating properties and their production are incomplete. Table I shows placer gold and silver production from the properties listed for the years 1901 to 1954. The greatest production over this period was in 1940 and 1941. During those years the Alaska Idaho Mining Company operated a washing plant on leased ground along Napias Creek (Campbell, 1941). This dredging operation left the tailing piles which are so conspicuous along Napias Creek.

The richest placer gold occurs in the lower few feet of the coarse gravels of the Basin. These gravels, which are of probable Wisconsin age, are more than 10 feet thick and overlie the Late Tertiary ash and associated deposits. The gold is commonly found as small flakes and "shot gold", although nuggets worth \$50 have been reported.

Origin of placer gold deposits in the Leesburg quadrangle seems clear. The source was the lodes near the contacts of the granitic rocks. Weathering freed the gold from its sulfide association and quartz matrix, and alluviation concentrated it at favorable localities downstream. The extensive placer deposits below Leesburg on the east side of Napias Creek are an excellent example. Here only Sharkey and Napias Creeks and Wards Gulch drain from granitic rock and were gold-bearing. Jefferson and Camp Creeks, however, flowing largely or entirely across Belt metasedimentary rocks were essentially gold-free. The latter streams, entering the gold-bearing main channel from the northwest, forced the channel to the south-east. Consequently placer gold was deposited on the east and not the west side of Napias Creek in this area. For the most part, streams outside the Basin have such steep gradients that placer accumulation has not been possible.

On the basis of coarseness and stratigraphic and geographic position, these gravels are considered to have been deposited by Wisconsin streams, primarily of torrential meltwater. Recent streams have reworked some of the older placer accumulations. Neither pre-Wisconsin nor Wisconsin till carries commercial quantities of gold.

Because of prevailing economic conditions, the outlook for placer gold production from Leesburg Basin is poor. However, in spite of the fact that the richest placers have long since been depleted, a substantial increase in the price of gold or decrease in the cost of labor would probably allow profitable placer mining in the Basin. This mining would have to be done mechanically and not by hand, because the remaining gravels are lean. Recovery of other valuable placer minerals occurring with the gold would increase the probability of profitable operation. The most promising area for such mining appears to be in the young gravels along Napias Creek and its tributaries above Devlin Falls.

Tungsten deposits

Wolframite

Wolframite was discovered in the course of field work. This mineral occurs as tabular crystals up to one inch in diameter in a matrix of milky quartz. The veins are commonly only an inch or two thick, but a few measure up to six or eight inches. Much of the filling is drusy quartz crystals, in part showing comb structure. The presence of siderite and pyrite is indicated by pseudomorphous limonite and goethite.

Wolframite mineralization was seen only along dip joints in the impure gray quartzite on the northeast flank of the Leesburg synclinalorium. Adjacent to the veins, the quartzite has been bleached and pyritized, the bleaching extending outward less than one foot. The character of the deposits indicates that they were formed at moderate to low temperatures and at comparatively low pressures, and probably at shallow depth. Anderson (1948) described Early Tertiary tungsten (huebnerite) mineralization at the Ima mine, 50 miles to the southeast, and he believes that the mineralization there is closely related to local wall-rock granitization. Perhaps the wolframite of the Leesburg quadrangle is of similar age and origin.

The most pronounced wolframite mineralization occurs both north and south of Baldy Mountain. None of these deposits appears to contain commercial concentrations of wolframite; however, search for other deposits of possible economic value might be successful in the impure gray quartzite on the northeast flank of the Leesburg synclinalorium. Associated drusy quartz and limonite and goethite pseudomorphs are the best guide to the wolframite mineralization.

Scheelite

Small quantities of scheelite occur with the placer gold. This scheelite was probably derived from the gold-quartz veins in which it is known to be a minor constituent (Anderson, personal communication).

Lead-silver deposits

In value of production the lead-silver deposits rank next to the gold deposits. Table I shows that lead and significant silver production began in 1920. This production was from the Ringbone Cayuse mine along lower Napias Creek. The Blue Jay mine, about one mile to the southwest, came into production some time later. The Ringbone Cayuse mine has been inactive for many years, and workings are inaccessible. The Blue Jay mine is open for about 100 feet.

Mineralization at the Ringbone Cayuse and Blue Jay mines is similar. Ore consists of massive argentiferous galena in a gangue of jasperoidal hematite and vuggy opal. The country rock is altered porphyroblastic quartz monzonite. There is evidence of similar mineralization along the general zone connecting these two mines.

These lead-silver deposits appear to be considerably younger than the other metalliferous deposits, but perhaps not much younger than the tungsten. Their structural and textural characteristics indicate that they were formed at rather low temperatures and probably close to the surface, a feature common to regional deposits of Mid-Tertiary age. The N. 60° E. trend of this mineralization also accords with Mid-Tertiary structural trends, and their location on the northeast flank of the Mid-Tertiary anticline may be associated with strong Mid-Tertiary mineralization to the southwest along the same fold (Ross, 1933).

Search for other lead-silver deposits should be along the zone of known mineralization and its southwestward extension.

NONMETALLIC DEPOSITS

Opalized wood

A huge opalized butt of a fossil Sequoia buried in tuffaceous Challis volcanics has been uncovered along Mackinaw Creek. The exposed portion of this fossil tree is 62 feet in circumference and about 12 feet high. The opal, which has completely replaced the wood, is of various colorful hues and is of sufficiently high quality to sell at prices up to \$1.00 per pound to lapidaries. At this rate, the opalized tree has potential value of some \$500,000 and is one of the most important properties in the quadrangle. The mine is owned by A. B. Cutler of Moccasin Creek.

Opalized wood has been collected from the bedded material overlying the typical brown Late Tertiary ash near Leesburg. This fossil wood is of poorer quality than that from Cutler's tree, but several hundred pounds have been sold to tourists visiting Leesburg.

Quartz crystals

The quartz crystals associated with the wolframite mineralization are possibly of economic value as collectors' items. Locally, these crystals, which are well formed and clear or tinted bluish or yellowish by impurities, occur in considerable abundance. Commonly, the crystals are not more than two inches long, but F. A. Krause collected one crystal six inches long from his placer diggings at the head of Sawpit Creek. The best localities for quartz crystal prospecting appear to be the headwaters

of Pollard Canyon and its tributaries and the cirque at the head of Rapps Creek, just off the northern border of the quadrangle.

Building materials

The quadrangle contains abundant building material which has negligible value because of remoteness from populated areas. Alluvial gravels and finely weathered metasedimentary rocks, granitic rock, and volcanics are sources of ready-made road metal and have been so utilized to a slight degree. Challis volcanics have been used as building and refractory materials outside the quadrangle (Behre, 1929). The granitic rock has had negligible use as cut stone. The siliceous Late Tertiary ash might have some use as fill or other material.

REFERENCES CITED

- Anderson, A. L., 1929, Cretaceous and Tertiary planation in northern Idaho: Jour. Geology, vol. 37, p. 747-764.
- _____, 1947, Cobalt mineralization in the Blackbird district, Lemhi County, Idaho: Econ. Geology, vol. 42, p. 22-46.
- _____, 1948, Tungsten mineralization at the Ima mine, Blue Wing district, Lemhi County, Idaho: Econ. Geology, vol. 43, p. 181-206.
- _____, 1956, Geology and mineral resources of the Salmon quadrangle, Lemhi County, Idaho: Idaho Bur. Mines and Geology, Pamph. 106, 102 p.
- _____, 1957, Geology and mineral resources of the Baker quadrangle, Lemhi County, Idaho: Idaho Bur. Mines and Geology, Pamph. 112, 71 p.
- Behre, C. H., Jr., 1929, Tertiary volcanic tuff and sandstone used as building stone in the upper Salmon River Valley, Idaho: U. S. Geol. Survey, Bull. 811-E, p. 237-252.
- Bell, R. N., 1905-1908 and 1920, Sixth through Ninth and Twenty-first annual reports of the mining industry of Idaho for the years 1904-1907 and 1919.
- Campbell, Arthur, 1941, Forty-second annual report of the mining industry of Idaho for the year 1940, 265 p.
- Campbell, Stewart, 1925, Twenty-sixth annual report of the mining industry of Idaho for the year 1924, 249 p.
- Daly, R. A., 1905, Classification of igneous intrusive bodies: Jour. Geology, vol. 13, p. 485-508.
- Eardley, A. J., 1951, Structural Geology of North America: Harper and Brothers, New York, 624 p.
- Jacobs, M. H., 1903, Report of the mining industry of Idaho for the year 1902.
- Kirkpatrick, O. E., 1934, History of Leesburg Pioneers: Pyramid Press, Salt Lake City, Utah, 172 p.
- Richmond, G. M., 1957, Three pre-Wisconsin glacial stages in the Rocky Mountain region: G. S. A. Bull., vol. 68, p. 239-262.
- Ross, C. P., 1925, The copper deposits near Salmon, Idaho: U. S. Geol. Survey, Bull. 774, 44 p.
- _____, 1928, Mesozoic and Tertiary granitic rocks in Idaho: Jour. Geology, vol. 36, p. 673-693.

- Ross, C. P., 1929, Early Pleistocene glaciation in Idaho: U. S. Geol. Survey, Prof. Paper 158, p. 123-128.
- _____, 1933, The ore deposits of Idaho in relation to structural and historical geology: Ore Deposits of the Western States, Lindgren Volume, Am. Inst. Mining and Met. Eng., New York, p. 265-272.
- _____, 1934, Geology and ore deposits of the Casto quadrangle, Idaho: U. S. Geol. Survey, Bull. 854, 135 p.
- _____, 1937, Geology and ore deposits of the Bayhorse region, Custer County, Idaho: U. S. Geol. Survey, Bull. 877, 161 p.
- _____, 1947, Geology of the Borah Peak quadrangle, Idaho: G. S. A. Bull., vol. 58, p. 1085-1160.
- _____, and Forrester, James Donald, 1947, Geologic map of the State of Idaho, Scale 1:500,000: U. S. Geol. Survey, and Idaho Bur. Mines & Geology.
- Scholten, Robert, 1947, Paleozoic evolution of the geosynclinal margin north of the Snake River Plain, Idaho-Montana: G. S. A. Bull., vol. 68, p. 151-170.
- _____, Keenman, K. A., and Kupsch, W. O., 1955, Geology of the Lima region, southwestern Montana and adjacent Idaho: G. S. A. Bull., vol. 66, p. 345-404.
- Scott, H. W., 1938, Eocene glaciation in southwestern Montana: Jour. Geology, vol. 46, p. 628-636.
- Starr, R. B., 1955, Geology of the Twin Peaks mine, Lemhi County, Idaho: M. S. Thesis, Cornell University, unpublished, 38 p.
- Stone, G. H., 1893, An extinct glacier of the Salmon River Range (Idaho): Am. Geologist, vol. 11, p. 406-409.
- Turner, F. J. and Verhoogen, Jean, 1951, Igneous and Metamorphic Petrology: McGraw-Hill Book Company, Inc., New York, 602 p.
- Umpleby, J. B., 1913, Geology and ore deposits of Lemhi County, Idaho: U. S. Geol. Survey, Bull. 528, 181 p.
- Van Houten, F. B., 1957, Appraisal of Ridgeway and Gunnison "tillites", southwestern Colorado: G. S. A. Bull., vol. 68, p. 383-388.
- Vhay, J. S., 1948, Cobalt-copper deposits of the Blackbird district, Lemhi County, Idaho: U. S. Geol. Survey, Strategic Minerals Investigation, Prelim. Rept. 3-219, 26 p.
- Visher, S. S., 1945, Climatic maps of geologic interest: G. S. A. Bull., vol. 56, p. 713-736.

EXPLANATION

Sedimentary and Metasedimentary Rocks

- Recent
- Stream alluvium
- Quaternary
- Upper terrace gravels
Leesburg Basin
- Wisconsin drift
- Pre-Wisconsin drift
- Late Tertiary ash
- Tertiary lake beds
- Oligocene
- Challis pyroclastics
- Early Tertiary conglomerate
Williams Creek
- Ordovician
- Kinnikinnick quartzite
- Upper Cambrian
- Impure gray quartzite
- Phyllite formation
with clastic dikes

Igneous and Metamorphic Rocks

- Oligocene
- Columnar-jointed basalt dike
associated with Challis fm.
- Challis flows
- Quartz monzonite (Idaho
Batholith) and associated
contact and dike rocks
- Pre-Cretaceous
- Meladiorite dike
Wallace Lake

Geologic Boundaries

Inferred Boundaries

Known Fault

Inferred Fault

Hypothetical Fault

Dip of Fault Vertical Fault

Strike and Dip of Bedding

Vertical Bedding

Horizontal Bedding

Overturned Bedding

Anticlinal Axis

Synclinal Axis

Overturned Synclinal Axis

Active Lode Mine

Inactive Lode Mine

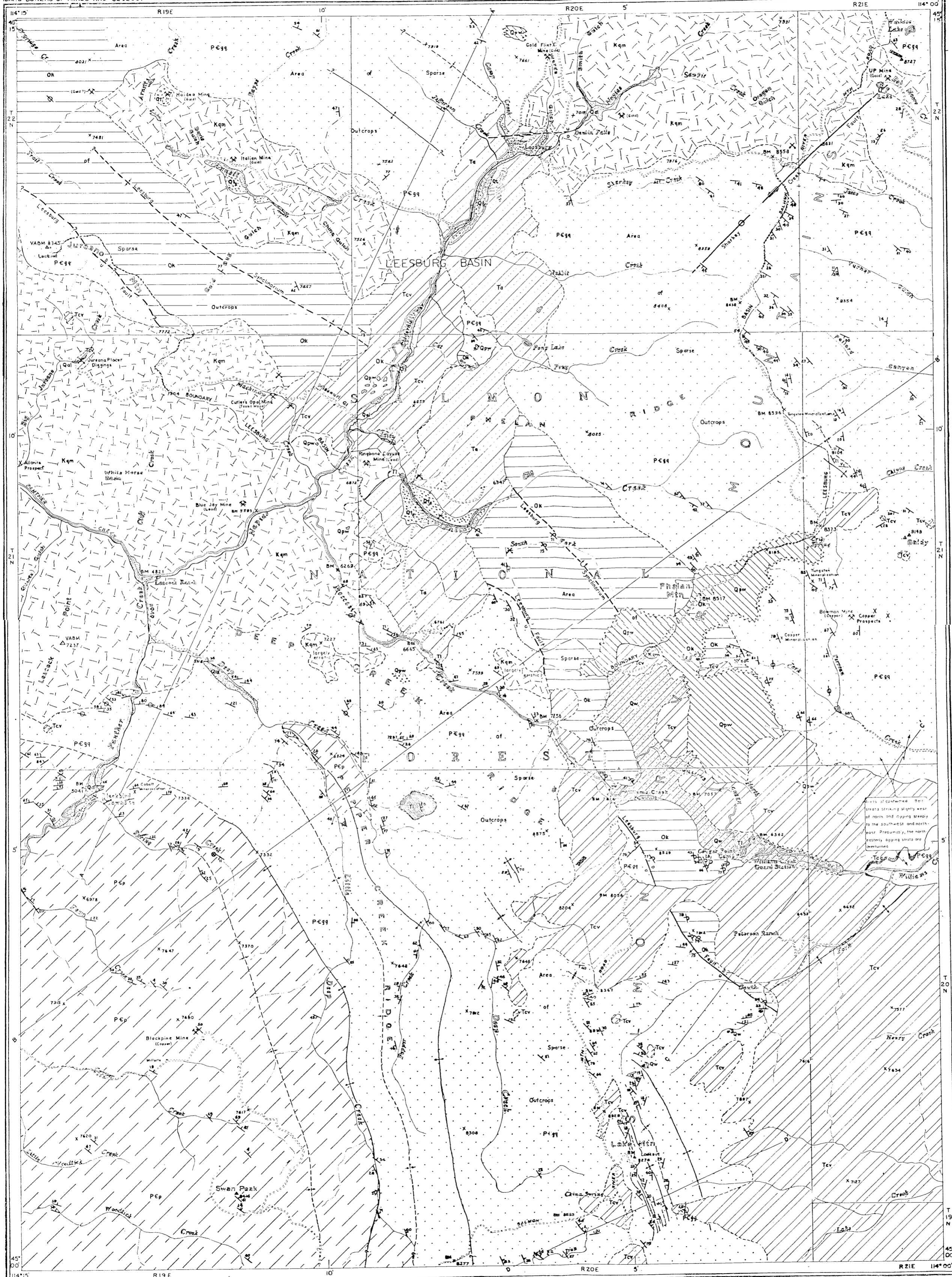
Active Placer Mine

Inactive Placer Mine

Prospect

Notable Mineralization

Tailings



Base Map: U.S. Geological Survey

Leesburg Quadrangle

APPROXIMATE MEAN
DECLINATION, 1950

RECONNAISSANCE GEOLOGIC MAP OF THE LEESBURG QUADRANGLE, LEMHI COUNTY, IDAHO

Geology by Philip N. Shockey
Surveyed: 1955-56
Drafted by W.R. Gref