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Reconnaissance Geology of the Selway-Bitterroot Wilderness Area

William R. Greenwood
Donald A. Morrison

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ABSTRACT

The major geologic structures and rock types of about 3000 square miles in and around the Selway-Bitterroot Wilderness Area have been mapped during 1965, 1966, 1967, and 1968. The most extensive rock unit, the Idaho batholith, is a composite unit of several igneous rock textures and compositions, structural characteristics, and presumably, ages of intrusion. Quartz monzonite is the predominant rock type in the Idaho batholith unit. The batholith cuts metasediments of the Belt Supergroup and metamorphosed igneous bodies of several ages.

Tertiary granite bodies of batholithic size cut the quartz monzonite. The granite bodies, and all other rock types, are cut by numerous aphanitic dikes.

The metasediments were deformed by four regionally-penetrative fold events prior to intrusion by quartz monzonite of the batholith. Separate phases of igneous intrusion preceded or accompanied each event of folding and metamorphism. Preliminary petrographic investigation indicates that at least two periods of prograde metamorphism occurred, with a maximum in the sillimanite-almandine subfacies of the amphibolite facies. A third crystallization event, under retrograde conditions, has modified the higher grade mineral assemblages.

Numerous small copper prospects have been mapped. Whereas the size of the individual prospects may not warrant development, their number suggests that an economic copper deposit might be found by a more detailed geologic investigation.

INTRODUCTION

In 1965 the Idaho Bureau of Mines and Geology began a program of geological and geochemical reconnaissance mapping of the Selway-Bitterroot Wilderness Area. The program was designed to determine the mineral potential of the wilderness area and to determine in general form its geologic history. Approximately 3000 square miles within and adjacent to the wilderness area were mapped from 1965 to 1968. Field parties were led by E.M.P. Lovejoy in 1965, and W.R. Greenwood in 1966, 1967 and 1968. Personnel participating in the geologic mapping are listed in the appendix.

The following is a summary of the results of the geologic mapping. (The results of the geochemical mapping are being completed and will be held on open file).

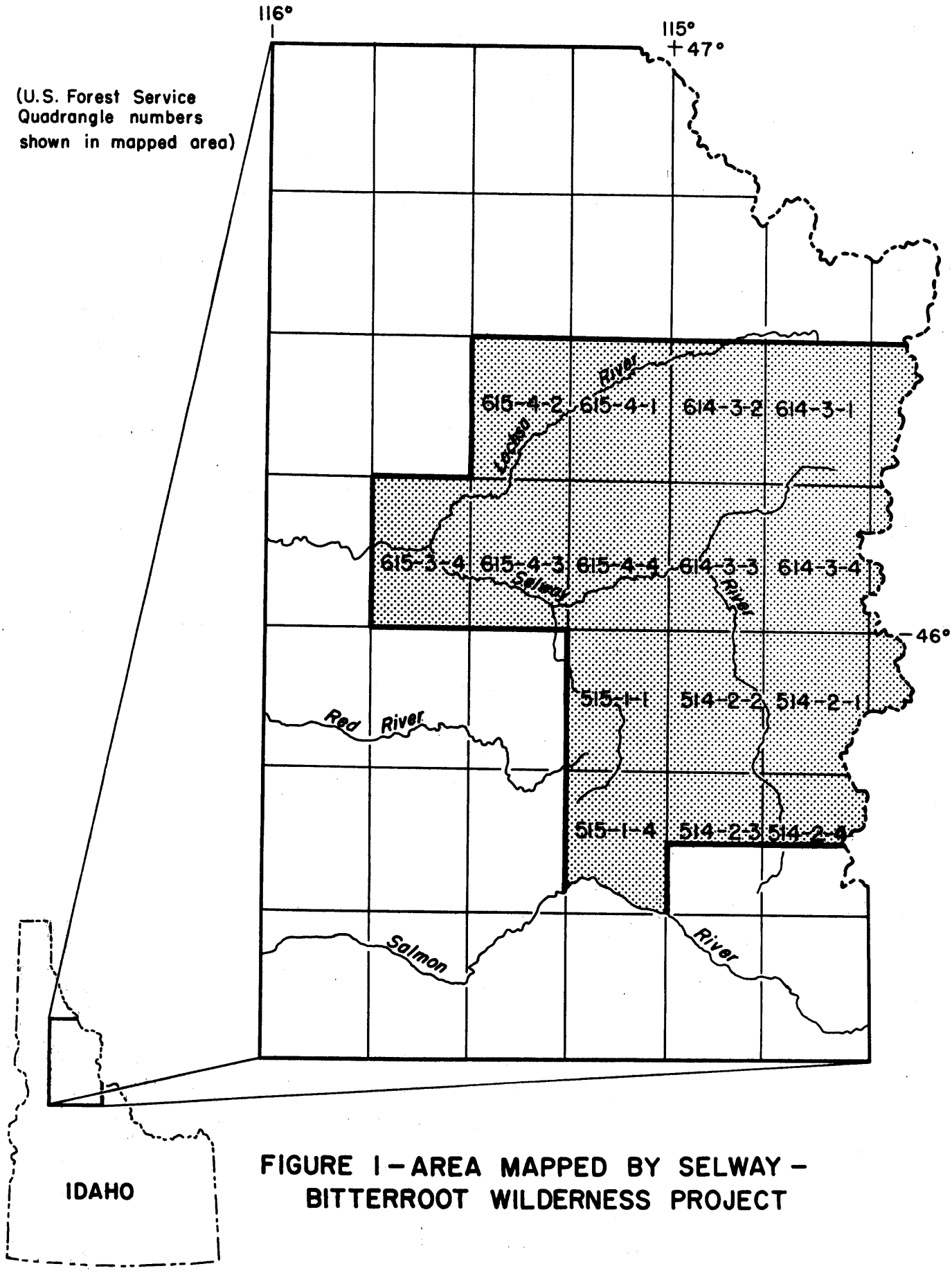

FIGURE 1 – AREA MAPPED BY SELWAY – BITTERROOT WILDERNESS PROJECT

REGIONAL SETTING

THE CLEARWATER OROGENIC BELT

The Selway-Bitterroot Wilderness Area is located in a tectonic province that extends southward from the St. Joe River on the north to some undetermined distance south of the Salmon River. The province generally is underlain by rocks of the Precambrian Belt Supergroup, metamorphosed with a maximum in the upper almandine-amphibolite facies. The Belt metasediments are intruded by igneous rocks of Precambrian to Tertiary age. This region is termed a tectonic province because of its regionally consistent deformation-recrystallization history and uniform plutonic history. The province is named the Clearwater orogenic zone after the Clearwater River which drains a great part of the area (Reid and Greenwood, 1968).

At present, a relatively small part of the Clearwater orogenic zone has been studied in detail. As a result, the boundaries of the zone cannot be drawn on the south or west. The St. Joe River is the approximate location of the north boundary of medium to high grade metamorphism. The eastern boundary appears to be defined by a set of north to north-west trending transverse faults in the Bitterroot Mountains. Although mostly contained in Idaho, the zone extends into the Bitterroot Mountains and perhaps the Sapphire Range of Montana.

In general terms, the Clearwater orogenic zone consists of a sheath of north-south trending metasedimentary and metaigneous rocks enclosing the north-south trending Idaho batholith and related rocks. Within this region, the wilderness area is underlain primarily by granitic rocks of the batholith, with salients and septa of metasedimentary and metaigneous rocks forming a relatively minor part.

The metasediments of the orogenic zone and the wilderness area are correlated with rocks of the Belt Supergroup. Metamorphic facies range from the zeolite to the almandine amphibolite facies, but the existence of post-metamorphic strike-slip faults and thrust faults within and on the margins of the tectonic zone suggests that fault dislocation may have drastically altered the geometry of the metamorphic isograds as well as intrusive patterns. Dislocation of isograds by north-south trending strike-slip faults has been mapped in the St. Joe area (Reid and Greenwood, 1968). Also in the St. Joe area, almandine-amphibolite facies rocks are juxtaposed against zeolite facies rocks of the same formation by the west-northwest trending St. Joe fault zone. At least 30 miles of left-lateral motion on this zone has been proposed to explain the juxtaposition of anomalous metamorphic mineral assemblages (Reid and Greenwood, 1968). It is possible that by a combination of north-south trending and west - northwest trending strike-slip fault movements, major portions of the belt have been isolated. For instance, the high grade metamorphic metaigneous and metasedimentary terrain near Spokane, Washington may be an offset portion of the Clearwater orogenic zone.

Unmetamorphosed igneous rocks are late Mesozoic to Tertiary in age, and comprise the Idaho batholith as well as older and younger masses. This complex sequence of igneous rocks forms the largest portion of the Selway-Bitterroot Wilderness Area. The batholith is composed predominantly of quartz monzonite of several textural and compositional facies. The quartz monzonite is commonly accepted as having been intruded during late Jurassic to Cretaceous time.

Intruding the quartz monzonite bodies are batholiths and smaller bodies of granite. A large granite body which crops out along Running Springs Creek has been dated tentatively at 49 m.y. by potassium-argon techniques (Greenwood, 1970). Dikes of several rock types intrude the granite and the quartz monzonite bodies. The dikes have not been radiometrically dated but probably they are of early Tertiary age.

The structural history of the orogenic zone has been studied in the St. Joe area (Reid and Greenwood, 1968; Greenwood, 1966; Nord, 1967), in the area northwest of the Idaho batholith (Hietanen, 1961, 1962, 1963a, 1963b, 1963c, 1967a, 1967b), the Lochsa-Selway area (Morrison, 1968), the Elk City area (Reid, 1959), and the Red River region (Greenwood, 1967). From these reports it seems probable that these separate parts of the orogenic belt have had similar structural histories. For a detailed statement of the evidence for structural similarity the reader is referred to the papers by Reid, Hietanen, Morrison, and Greenwood listed in the bibliography.

The major structural elements are (1) four fold systems which appear to represent four tectonic events, and (2) a regional system of faults and folding, representing rotation and offsetting of a portion of the orogenic zone (Reid, Greenwood, and Morrison, 1970).

The first fold event (1.5 b.y., Long et al., 1960, Reid, Greenwood, and Morrison, 1970) produced large isoclinal folds with a well developed axial plane schistosity. The degree of recrystallization accompanying the first deformation appears to increase from north to south in the orogenic zone.

Second generation folds overprint the folds and fold the schistosity of the first event. These folds tend to have northwesterly trending axes. Diabase injected and metamorphosed during the second deformation indicates that a recrystallization occurred at 669 $\pm$ 25 m.y. (K/Ar of hornblende, Reid and Greenwood, 1967a). Pressure and temperature conditions were intermediate and less than during the first event.

Northeast-trending third generation structures refold earlier folds. These northeast folds are observably isoclinal in some areas and in others are defined by statistical analysis of folded axes of large second generation folds (Greenwood and Morrison, 1967). Metamorphic crystallization in the greenschist facies accompanied and followed the third fold event.

A fourth deformation is indicated by upright shear folds, trending north-south, which deform the earlier folds (Greenwood, 1966; Morrison, 1968). This folding appears to have been cataclastic, and mortar zones of this event are not recrystallized. Epidote fills the shear zones related to the fourth fold event in the Red River region.

Structural control of topography of the Clearwater orogenic zone is readily apparent from an inspection of either topographic maps or aerial photographs. Air photo analyses of the Lochsa-Red River region (Greenwood and Morrison, 1967; Pober, 1968) show that the predominant lineations trend north-east. Secondary lineations are north-south, northwest, and east-west, in order of their respective importance. For a lineation map and a statistical analysis of the lineations see Pober (1968).

The Clearwater orogenic zone has been the site of intermittent plutonic activity since the Precambrian.

During the first fold event, diabase was intruded in sills, dikes and small stocks. The diabase bodies were sheared and recrystallized in the first folding event. The resulting amphibolite is massive to locally strongly schistose with incipient compositional layering of plagioclase and hornblende. Tabular hornblende defines both a schistosity parallel to the composition layering and a lineation in the plane of the schistosity. In the St. Joe area, diabase sills and dikes were also intruded during the second fold event (Reid and Greenwood, 1967b). In the Red River region, the amphibolite of Green Mountain is tentatively correlated with the earliest diabase intrusions in the St. Joe area.

Augen gneiss crops out as sills and dikes at numerous localities in the Lochsa-Selway and Red River regions. The augen gneiss of Red River cuts the amphibolite of Green Mountain and is deformed by the first fold event. Therefore, the augen gneiss was intruded during the first fold event (Greenwood, 1967).

Orthogneiss bodies of quartz diorite to granodiorite composition were intruded during the first, second and third fold events. The relative chronology of the orthogneiss bodies is based on cross-cutting contacts, composition, petrographic character, and structural environment. For a detailed analysis of the orthogneiss bodies see Morrison (1968). The oldest orthogneiss described by Morrison is a biotite quartz diorite, with a strong foliation which is isoclinally folded about second generation axes. An orthogneiss of similar composition and tectonic style cross cuts augen gneiss on the ridges leading south from the Nez Perce trail to Sheep Hill. Therefore, the orthogneiss bodies may all be younger than the augen gneiss. Subdivision of orthogneisses was limited to exposures along the Clearwater, Lochsa and Selway Rivers.

The sequence of events within the Clearwater orogenic belt as indicated by the rocks and structures present may be summarized as follows:

1. Deposition of Beltian sediments prior to about 1.6 b.y.

2. Deformation and recrystallization of the sediments at 1.5 b.y. plus intrusion of granitic and mafic rocks.

3. Deformation and intermediate grade recrystallization plus intrusion of granitic rocks at approximately 700 m.y.

4. Deformation and lower grade recrystallization accompanied by igneous activity; of uncertain age, probably pre-Jurassic.

5. Intrusion of pre-batholith igneous rocks, primarily quartz diorites of late Jurassic to Early Cretaceous age.

6. Intrusion of the Idaho batholith and related rocks possibly accompanied by the fourth fold event. Age of intrusion of the batholith is generally approximated as 100 m.y.

7. Intrusion of post-batholith igneous rocks of Tertiary age.

8. Intrusion of late Tertiary dike swarms.

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ROCK TYPES

Rocks which occur in the wilderness area may be divided into four general groups:

1) Metasedimentary rocks, 2) metaigneous rocks, 3) migmatites, and 4) igneous rocks. Of these groups the igneous rocks, of varying age and composition, underlie most of the wilderness area.

The rocks may be arranged in order of oldest to youngest as follows:

1. Precambrian metasedimentary rocks correlated with rocks of the Belt Supergroup.

2. Metaigneous rocks, ranging in age from Precambrian to Mesozoic. The largest of these masses is the Red River augen gneiss which is Precambrian (Greenwood, 1967; Reid and Greenwood, 1968).

3. Mesozoic igneous rocks and migmatites, primarily quartz diorites and granodiorites which pre-date the Idaho batholith.

4. Late Mesozoic igneous rocks primarily quartz monzonites and granodiorites which form the Idaho batholith. Extensive migmatite zones are associated with these rocks.

5. Late Cretaceous to Tertiary granitic rocks which intrude the Idaho batholith.

6. Tertiary dike rocks ranging from diabasic to rhyolitic in composition.

METASEDIMENTARY ROCKS

Metasedimentary rocks are confined largely to the west and east borders of the batholith although batholithic rocks contain metasedimentary septa throughout the wilderness area. A thick sequence is exposed along the Lochsa and Selway Rivers and the Middle Fork of the Clearwater River. The easternmost exposure of these rocks occurs near Split Creek on the Lochsa River and is within the west boundary of the wilderness area. From this point the sequence extends across strike to Swan Creek, a tributary of the Middle Fork, where it is separated by a fault from a metaigneous mass. The sequence is cut by a pre-Idaho batholith quartz diorite pluton and by quartz monzonite of the batholith to the north, but reappears in the vicinity of Pierce and Bungalow (Hietanen, 1963). The sequence is discontinuous to the south because it is interrupted by igneous rocks, migmatite zones and metaigneous rocks, but sections occur near Otter Butte, immediately south of the Selway River, and in the Red River, Elk City area (Greenwood, 1967; Reid, 1959).

The sequence is divided into three broadly defined units. They are:

1. A calc-silicate bearing unit broadly correlative with the Wallace Formation. Diopside gneisses intercalated with pelitic schists and gneisses and quartzites are typical of the upper part of this unit. Pelitic rocks and quartzitic pelites with minor diopside-hornblende layers are typical of the lower section of this unit.

2. A quartzitic-pelitic unit broadly correlative with the Ravalli Group. The abundance of quartzites within this unit is distinctly greater than in the overlying Wallace Formation and calc-silicate rocks are usually absent. Garnet and kyanite are relatively common.

3. A pelitic-quartzite unit broadly correlative with the Prichard Formation. Biotite-muscovite schists and white, garnet-free quartzite intercalated within pelitic schists and gneisses are typical of this unit.

This sequence is correlated with Beltian rocks on the basis of lithological and structural similarity with Beltian rocks in the vicinity of Pierce, Bungalow and Headquarters mapped by Hietanen (1963) and Beltian rocks in the vicinity of Avery as mapped by Reid, 1964; Greenwood, 1966; and Nord, 1967.

The Wallace Formation

Metasediments of the Wallace Formation (unit 1 above) are exposed on the west side of the batholith along the Lochsa River from Pete King Creek eastward to Split Creek, and probable Wallace Formation rocks occur as blocks within the batholith.

As previously indicated the Wallace Formation is divided into a lower unit composed of quartz-rich pelitic rocks and an upper unit in which diopside gneisses are common. These subdivisions appear to correspond broadly to the Wallace schist and Wallace gneiss units in Clearwater County described by Hietanen (1963c).

The lower section noted as PcWs, Plate 1, is exposed from Pete King Creek eastward to Glade Creek, and consists of quartz-plagioclase-biotite quartzites and gneisses, and quartz-biotite-plagioclase schists.

This unit (PcWs, Plate 1) is equivalent to the schist unit of Morrison (1968). The unit is an unusually homogeneous sequence of pelitic rocks estimated to be 12-15,000 thousand feet thick. Biotite, quartz and plagioclase are the primary constituents of all of the rocks. Garnet, aluminosilicates and muscovite occur sporadically. Locally the pelitic rocks merge into quartz-rich rocks, but the relatively massive white or vitreous quartzites of the underlying Ravalli Group are absent. The rocks do not have pronounced gneissic compositional layering. Good exposures indicate that layering typically is thick-bedded (1-2 + feet) but weathered exposures are thin-bedded and fissile.

In the Lochsa area the lower Wallace becomes more feldspathic eastward and is succeeded by the cumulatively more siliceous and calcium-rich rocks of the Wallace gneiss (PcWg, Plate 1). The contact between the two, however, is partially masked by orthogneisses and an augen gneiss unit qualitatively similar to the Red River aguen gneiss (Agn, Plate 1). The latter sequence is exposed at the Apgar Creek campsite on U.S. Highway 12.

Westward the schists of the lower Wallace are succeeded by the quartzites of the Ravalli Group.

The lower Wallace strikes NW-SE and forms a large part of Coolwater Ridge, but it appears to be increasingly masked by migmatization along the Selway River and Meadow Creek. Significant thickness, however, was mapped southeast of Bargamin Creek T 28 N, R 12 E, and a contact similar to that which occurs in the Lochsa area between massive white quartzites correlated with the Ravalli Group and schists of the lower Wallace was mapped east of Meadow Creek at T 29 N, R 12 E. A relatively large block of lower Wallace schists occurs within quartz monzonite typical of the Idaho batholith east of the South Fork of the Selway River T 30 N, R 14 E.

The pelitic rocks of the lower Wallace reappear to the east T 36 N, R 15 E as the east boundary of the Idaho batholith is approached.

The upper unit of the Wallace Formation (PcWg, Plage 1) as exposed in the Lochsa area from Hellgate Creek to Fire Creek consists of quartzites, pelitic rocks and diopside-bearing gneisses which form distinct subunits. In general terms, the subunits consist of a pelitic-quartzitic lower (western) section with minor calc-silicate layers (W4 of Morrison, 1968), an intermediate section in which diopside gneisses are very abundant (W3 of Morrison, 1968) and an upper section containing quartzites, pelitic rocks and diopside gneiss.

The diopside gneisses are the distinctive lithology of the upper Wallace. These rocks are grey-green, laminated and banded. Laminae of quartz-feldspar and biotite varying from 1 mm to 3 mm are interlayered with diopside-plagioclase and plagioclase-diopside $\pm$ hornblende layers. Layers consisting primarily of diopside-plagioclase gneiss are commonly one meter thick and seldom exceed 3 meters. In the western or lower part of the upper Wallace, individual layers composed of diopside-hornblende -plagioclase + biotite and/or plagioclase-hornblende occur very sparingly within pelitic rocks and commonly are 2-3 centimeters thick.

Although the diopside gneisses are most distinctive, pelitic rocks and quartzites are more abundant. The quartzites typically are feldspathic and none have the white appearance of quartzites of the Ravalli Group. Some quartzites are relatively massive units containing coarse-grained, vitreous, bluish-grey quartz with minor biotite and chalky, xenoblastic feldspar.

Quartzite abundance appears to increase and diopside gneiss abundance decreases eastward toward the presumed top of the Wallace, but the rocks are masked by igneous rocks and migmatites of the batholith to the east along U.S. Highway 12.

To the southeast the calc-silicates typical of the upper Wallace are masked by migmatites and primary gneisses apparently related to the Idaho batholith. A limited occurrence of diopside gneiss float was mapped near Otter Butte T 21 N, R 11 E, immediately south of the Selway River. Relatively small septa or pendants occur within the batholith rocks forming the ridges between the Lochsa and Selway Rivers. The largest of these T 33 N, R 12 E, consists largely of quartzites. Small exposures were also mapped to the south near the south fork of the Selway T 30 N, R 14 E in contact with schists of the lower Wallace and primary gneisses related to the Idaho batholith.

The Ravalli Group

Metasediments assigned to the Ravalli Group (unit 2 above) are exposed along the Lochsa, Selway and Clearwater Rivers, and along the Elk Mountain road from Green Mountain to Running Creek junction. Formations within the group were not separated in either locality. The contact between the lower pelitic unit of the Wallace Formation and the Ravalli Group in the Lochsa area was placed at the first appearance of massive quartzites west of Pete King Creek. Good exposures of massive quartzites typical of the Ravalli Group interlayered with pelitic rocks, occur near the confluence of the Lochsa and Selway Rivers.

In the Lochsa area, Ravalli Group rocks are characterized by the presence of thick layers of massive quartzites some of which contain garnet. The easternmost (upper?) layer of this rock type underlies the schist unit of the Wallace

Formation and consists of approximately 100 feet of garnetiferous fine-grained grey quartzite. This unit, taken to be the top of the Ravalli Group in the Lochsa area, is underlain by approximately 2000 feet of pelitic rocks distinguished from the schist unit of the Wallace in having a higher abundance of garnet-bearing layers and the sporadic occurrence of hornblende-bearing gneisses. Underlying these pelitic rocks westward are quartzites of variable type including grey, vitreous quartzites, plus variegated, vitreous quartzites ranging from reddish to brown-green to grey, and thin-bedded feldspathic quartzites with epidote-bearing laminae. Biotite-feldspar gneisses with minor hornblende-rich layers occur within these quartzites. Total thickness is at least 500 feet.

This sequence is underlain by an equivalent thickness of schists and quartzites characterized by abundant garnet with some schist layers 30 to 40 feet thick containing up to 50% garnet. Exposures suggest stratigraphic repetition within this subunit.

The garnet-rich pelitic rocks above are succeeded westward by approximately 2000 feet of white biotite-bearing quartzites interlayered with schists and gneisses. The white quartzites are characterized by white as opposed to vitreous-appearing quartz and the presence of 10-20% biotite. This type of quartzite is rare or absent in overlying units. Two subunits of 40 to 70 feet thick consist of white quartzite which contains muscovite. This sequence is succeeded westward by pelitic rocks, some of which are garnetiferous, and which include thin layers of white quartzite similar to that described above. Whether or not the 2000 feet of white quartzites and pelitic rocks described above are Ravalli Group or Prichard Formation rocks is uncertain. Morrison (1968) includes the sequence (and the underlying 1500 of pelitic rocks) in the quartzite-gneiss sequence correlated with the Ravalli Group.

White to greyish white quartzites crop out along the Elk Mountain and from Green Mountain - Running Spring junction to the south in the vicinity of Red River. The quartzite is massive and ranges in composition from a vitreous white quartzite to quartzites containing up to 40% feldspar. Mica is nowhere abundant and generally forms less than 5% of the rock. This quartzite is thicker than any observed in the Prichard Formation and it is in gradational contact with pelitic rocks assigned to the Prichard Formation and in gradational contact with rocks assigned to the Wallace Formation. Because of these stratigraphic relations and the lithological similarities with the quartzites of the Lochsa area assigned to the Ravalli Group, this unit is also tentatively assigned to the Ravalli Group. The unit was tentatively assigned to the Missoula Group in an earlier report (Greenwood and Morrison, 1967) but more complete mapping indicates that these rocks are more probably Ravalli Group equivalents.

The Prichard Formation

The limits of the Prichard Formation are not well defined in the study area. Probable Prichard rocks are intermittently exposed along the Middle Fork of the Clearwater River, and rocks of similar lithology occur in the vicinity of Elk City (Pc P, Plate 1).

The probable Prichard Formation exposed along the Middle Fork is faulted against a metaigneous mass at Swan Creek but occurs as isolated septa within the metaigneous mass (Middle Fork orthogneiss, Morrison, 1968) westward along the Middle Fork. To the north, these rocks are cut by Cretaceous quartz diorite and batholithic rocks, but reappear in the Pierce-Bungalow area (Hietanen, 1963-c) as biotite gneiss and biotite-muscovite schists. Reid (1959) mapped biotite gneisses in the vicinity of Elk City, and Greenwood (1966) extended this

unit eastward to the Red River area. These rocks are qualitatively similar to the probable Prichard rocks exposed along the Middle Fork and are also correlated with the Prichard.

At the fault contact on the Middle Fork, the Prichard Formation consists of garnetiferous mica schist several hundred feet thick. This unit is succeeded eastward by white, thick-bedded biotite ± muscovite quartzite (150 feet), quartz-rich garnetiferous mica schist (300 feet) and a layer of white to dark grey quartzite (300 feet). The remainder of the formation consists of pelitic rocks which may contain garnet and kyanite. Interlayered are relatively thin (10-50 feet) white to grey muscovite and/or biotite quartzites. This upper unit is at least several thousand feet thick but was not accurately measured. These dominantly pelitic rocks merge into the massive quartzites of the Ravalli Group which are distinguished from the quartzite layers in the Prichard in being more massive, vitreous and frequently variegated.

The biotite gneiss (Reid, 1959) in the vicinity of Elk City (Pcbg, plate 1) is described as a medium grained (1-2mm) rock containing 20-30% each of quartz, potassium feldspar, plagiocalse, and mica (including muscovite) which may contain garnet as small scattered grains. The biotite gneiss is strongly foliated and may form relatively massive outcrops. The gneiss merges into biotite quartzites.

The biotite quartzites are the predominant quartzites in the Elk City-Red River region but pure white quartzites, muscovite quartzites and feldspathic quartzites also occur. The latter are transitional to the biotite gneisses. The biotite gneisses and the interlayered quartzites, particularly the white quartzites, are similar to the rocks correlated with the Prichard Formation along the Middle Fork and are therefore considered to be equivalent. Eastward the Prichard Formation in the Elk City area is cut by the augen gneiss of Red River (Agn, plate 1) and batholithic rocks.

METAIGNEOUS ROCKS

Metaigneous rocks, which vary greatly in composition and structural complexity, intrude the metasediments at several localities. These rocks, ranging in composition from ultramafic to granitic masses, have participated in one or more of the petrogenic cycles and indicate that igneous activity preceded or accompanied each of the regional metamorphisms.

Augen Gneiss

Augen gneiss with a bulk composition of hornblende quartz monzonite crops out extensively in the headwaters of the Red River. Moderately good exposures of the augen gneiss can be seen in roadcuts on the Blackhawk road, the Shissler Creek road, and the Soda Creek road, all of which are logging access roads leading off the Red River road. Because the best exposures of this rock unit are along the Red River and its tributary streams, it has been informally designated the augen gneiss of Red River. This unit is described by Larsen and Schmidt (1958) as a "porphyroclastic gneiss" where exposed on the Elk City-Darby road.

The augen gneiss unit is readily distinguished from paragneiss and injection gneiss of the Prichard Formation by its generally uniform composition, coarse grain size, and the presence of megacrysts of potassium feldspar and smaller clasts of plagioclase. The potassium feldspar crystals range in size from less than one centimeter to 14 centimeters. The plagioclase clasts have not been observed to exceed one centimeter in length.

TABLE I

Comparison of Wallace Formation rocks in the Lochsa area and the Pierce-Bungalow area

Lochsa Area**	Pierce-Bungalow Area*
1. Upper Wallace:	1. Gneiss Units: Two separate units consisting of heterogeneous sequences of diopside-plagioclase gneisses interbedded with schists.
a. Approximately 4000 feet of pelitic and quartzitic schists and gneisses with minor diopside bearing layers.	
b. Approximately 7000 feet of pelitic schists and quartzites with abundant diopside gneiss layers.	
c. Approximately 7000 feet of pelitic schists and gneisses with minor diopside and hornblende bearing layers.	
2. Lower Wallace: approximately 10,000 feet of biotite schists, minor gneissic units and quartzites.	2. Schist Unit: Biotite-garnet-sillimanite schists with interbedded gneisses.

* After Hietanen, 1963-D, p. 5, Thicknesses of these units not given.

** Thicknesses corrected for attitude but not for structural repetition.

TABLE II

Generalized stratigraphic section of rocks correlated with the Ravalli Group in the Lochsa area and the Breakfast Creek area

Lochsa Area**:

a. Upper Unit: Approximately 100 feet of dense, fine grained quartzite with rare garnet, underlain by approximately 2000 feet of quartz-biotite-feldspar schists and biotite-feldspar quartz schists with minor hornblende bearing layers. Garnet prominent in some layers.

b. Intermediate Unit: Approximately 1000 feet consisting of a heterogeneous sequence of thin and thick-bedded quartzites interbedded with schists and gneisses. Quartzites vary from vitreous, coarse grained varieties to milky, feldspathic quartzites. Lower 500 feet consists primarily of garnet rich pelitic rocks.

c. Lower Unit: Approximately 2000 feet of white biotite quartzites interbedded with pelitic schists and gneisses and including minor muscovite bearing quartzites. Underlain by approximately 1000 feet of biotite-quartz-feldspar $\pm$ garnet schists and gneisses, and garnetiferous quartzites.

Breakfast Creek Area*:

a. St. Regis Formation: Approximately 400 feet (150 m) of muscovite-biotite schist containing up to 15% garnet. Upper part contains more garnet and less quartz than lower part.

b. Revett quartzite: Approximately 1700 feet (500 m) of quartzites consisting of light bluish grey quartzites overlain by thick beds of white quartzite which grades into pink or light brownish red quartzite. Quartzites are underlain by pelitic rocks possibly equivalent to the Burke Formation.

* from Hietanen, 1963-C, location given as T. 40 N, R. 3 E to T. 41 N, R. 3 E.

** Thickness corrected for attitude but not for structural repetition.

The pink, potassium-feldspar augen and the white plagioclase clasts are aligned in a generally light gray, variably schistose matrix. The matrix has flaser structure and the schistosity is defined by preferred orientation of hornblende, biotite, and muscovite. The quality of this definition varies with the degree of deformation to which the various parts of the body were subjected. Compositional layering, defined by alternate feldspar-rich and biotite-rich layers, is developed in the zones of greatest deformation.

In some outcrops the augen are spindled, and in outcrop the direction of shearing can be determined from the sense of rotation indicated by the tails of the spindles. In outcrop, microcline megacrysts show all stages of development from nearly idioblastic forms, with only the corners trimmed, to a flaser texture. Intensely sheared augen are present in the smaller sills which intrude the amphibolite of Green Mountain and the metasediments well east of the main augen gneiss body. Locally the augen gneiss schistosity is folded into second generation isoclinal folds. This folding has sheared and granulated the augen developing an overall flaser texture. Composition layering is accentuated so that feldspar-rich layers are separated by wavy biotite-rich layers. In outcrop some augen have the type of cleavage offset shown by Hobbs (1966, Plate 1, Fig. 3). It is thought that initial alignment of the megacrysts was accomplished largely without internal rotation of the megacrysts, although translation along cleavage planes has occurred later during locally intense cataclastic deformation.

The contact of the augen gneiss with the Prichard Formation on the west is cut out by a large Tertiary andesite porphyry dike, where exposed along the Red River road. To the east, the contact with the Ravalli Group is not exposed and has been mapped entirely by study of isolated outcrops, float, and soil composition.

The contact relations between the augen gneiss of Red River and the amphibolite of Green Mountain are not clearly exposed but sills of augen gneiss intrude the amphibolite. Within a few inches of these sills, potassium feldspar porphyroblasts grow in the amphibolite matrix. These observations indicate that the augen gneiss of Red River is younger than the amphibolite of Green Mountain.

Numerous septa of metasediments are included in the augen gneiss. These metasediments are correlated with the Prichard Formation and the Ravalli Group on the basis of lithology and regional structure (see Plate 1). Exposures of the augen gneiss-metasediment contacts are few and of small extent. In the outcrops studied, the compositional layering in the metasediments varies from subparallel to nearly normal to the schistosity in the augen gneiss. At most contacts, metasedimentary compositional layering and augen gneiss schistosity are subparallel, differing 5^{o} to 10^{o} from parallel. The axes of spindling of the augen are generally parallel to second generation folds and crinkly lineation in the adjacent metasedimentary strata. Potassium feldspar prophyroblasts grow in the metasediments within a few inches of the contact with the augen gneiss.

Sills, dikes, and larger bodies of medium-grained granodioritic material, having a low mafic mineral content (5% - 10%), cut the augen gneiss. The schistosity in the granodioritic material is parallel to the schistosity in the enclosing augen gneiss regardless of whether the contact is concordant or discordant. On the contacts and within a few inches from the contacts with the augen gneiss, potassium feldspar porphyroblasts grow in the granodioritic material. The granodioritic material is thought to be a late stage phase of the more hornblende-rich matrix material of the augen gneiss, which it cuts.

Pegmatitic to aplitic textured granitic dikes cut the augen gneiss at low to high angles. They are deformed by translation along the foliation which is axial plane for the folded dikes and parallel to the schistosity of the augen gneiss. The dikes have been deformed passivly and internally rotated about the line of intersection of their original plane and that of the augen gneiss schistosity at that point. The axes of the folded dikes are not necessarily parallel to any tectonic axis. These folds indicate the non-affine nature of shearing along the schistosity planes of the augen gneiss. Non-folded pegmatites also cut the augen gneiss. The non-folded pegmatite contains biotite in excess of muscovite, whereas the folded pegmatite contains muscovite as the dominant mica.

Mafic and ultramafic meta-igneous rocks

Small bodies composed of radiating clusters of anthophyllite, chlorite, tremolite and serpentine crop out in the Lochsa region. These bodies, which are resistant and stand above surrounding rocks, represent altered and metamorphosed mafic or ultramafic rocks. They appear to be similar to the asbestos bodies described by Anderson (1930) and probably are older than the Idaho batholith.

Ortho-amphibolite representing metamorphosed mafic dikes and sills occurs at numerous localities. Most such masses are too small to be shown on the geologic map. The ortho-amphibolite units are composed predominantly of plagioclase and hornblende and, characteristically, have a well developed lineation defined by prismatic hornblende. Schistosity may be indiscernible. Thin quartzofeldspathic layers in some ortho-amphibolites form well defined isoclinal folds.

The Green Mountain ortho-amphibolite (Plate 1), composed of roughly equal amounts of hornblende and plagioclase, is the largest single ortho-amphibolite unit mapped. A small amount of the rock mapped as amphibolite is composed predominantly of hornblende and may be called a hornblendite. A schistosity is well to poorly defined by parallelism of tabular hornblende and/or plagioclase crystals. Grain size of the plagioclase and hornblende is equal and ranges from 2 mm to 10 mm. Deformation appears not to have been penetrative. Strongly developed schistosity and compositional layering have been observed to grade to a barely discernible schistosity in a few feet across strike. In the most highly sheared zones biotite replaces hornblende. Chlorite replaces both hornblende and biotite.

The ortho-amphibolite units represent several generations of intrusion of mafic rocks. Several small ortho-amphibolite masses exposed along the Lochsa River were deformed by the second fold event. An ortho-amphibolite in Canyon Creek apparently is not deformed by the second fold event but has a lineation parallel to the northeast event, suggesting intrusion later than second fold event but prior to the third.

Quartz dioritic orthogneisses

Orthogneisses of quartz dioritic composition form several large bodies and numerous sill or dike-like bodies within the metasediments and migmatites of the western border zone of the batholith.

The largest of these masses occurs west of the Selway-Bitterroot Wilderness Area border where rocks of the Prichard Formation are in fault contact with hornblende-biotite quartz dioritic orthogneiss at Swan Creek, a tributary of the Middle Fork of the Clearwater River. The orthogneiss is coarse grained and has a well-developed schistosity. Primary components are biotite, plagioclase and hornblende $\pm$ epidote. A small mass of the orthogneiss which crops out north

of Syringa (Plate 1) is garnetiferous. Biotite quartz dioritic orthogneiss intercalated within layers of the Prichard Formation near the contact may represent dikes emanating from the larger mass. Numerous folded grantic stringers, some of which contain kyanite, occur within the Prichard Formation and lower Ravalli Group rocks and may also be related to the biotite-hornblende quartz dioritic orthogneiss.

The age of the orthogneiss is uncertain but the degree of recrystallization and the presence of garnet suggest participation in a metamorphic event, and an age older than the Cretaceous quartz diorite of similar composition immediately to the north (Kgd, Plate 1, and Hietanen, 1963).

A second large mass of quartz dioritic orthogneiss (?) forms a part of Coolwater Ridge. Biotite (15-25%) with quartz (15-30%) and plagioclase (45-60%) are the primary components. The orthogneiss contains biotite clots which resemble mafic cognate inclusions and quartz rich zones which may be paragneiss (?) lenses. Minor folds present have knife sharp fold crests and a well developed axial plane schistosity typical of first generation folds. The composition of the orthogneiss is similar to adjacent feldspathic pelitic schists and gneisses of the Wallace Formation. The orthogneiss therefore may represent Wallace Formation metasediments heavily injected with igneous material during a phase of deformation and recrystallization.

Metamorphosed granitic stringers are ubiquitous in the metasediments and form useful structural markers. Reid (1959) has described minor structures delineated by granitic stringers in the Elk City area. Similar minor structures as indicated by deformed stringers occur throughout the wilderness area.

Stringers in the Red River region are composed of medium-grained quartz and plagioclase with lesser amounts of biotite and potassium feldspar. Preliminary thin-section study of these stringers indicates that the quartz and feldspars have been recrystallized to a granoblastic mosaic texture. Biotite plates generally parallel the schistosity in the adjacent metasediments. Plagioclase in the stringers has approximately the same anorthite content as the plagioclase in the adjacent metasediments, indicating Na-Ca equilibration across the contact of the stringer during metamorphism. The stringers range in width from one-fourth of an inch to over six inches. The thicker stringers comprise from 10-70 volume percent of the exposed rocks in the Red River region. The rocks along Red River are mapped as biotite gneiss because of the banded nature of the rocks. All of the stringers are not the same age; however, the majority probably were intruded during the second fold event. Isoclinally folded granitic stringers are common in the Red River region and are interpreted as indicating the intrusion of granitic material during a late shearing stage of the second fold event. The granitic material appears to have been mobile during folding and often appears to have been extruded along the noses of folds and down the axial planes.

The deformation which accompanied intrusion appears to have consisted of flattening and translation of planes parallel to the schistosity. As such, the granitic material was largely a passive marker rather than a competent member during the deformation, and appears to have been molten or relatively plastic during the deformation.

Dikes of fine-grained granitic material intrude the axial zone of first generation folds and have an internal schistosity parallel the axial plane of the folds. These stringers are conformable with the schistosity in the metasediments and in places are folded by second generation folds. The fine grained material apparently was intruded in the final phase of the first fold event.

IGNEOUS ROCKS

General

Igneous rocks mapped include the following types:

1. Foliated to massive quartz monzonite often with porphyritic potassium feldspar which forms most of the Idaho batholith in the area mapped.

2. Porphyritic to equigranular quartz monzonitic to quartz dioritic primary gneisses which appear to be compositional and textural variations of the above.

3. Biotite (±) hornblende quartz diorite which apparently represents a pre-Idaho batholith but post-metamorphic igneous event.

4. Porphyritic to equigranular granites which appear to be Tertiary in age.

5. Dikes of varying compositions, ranging from dolerite to aplite.

This classification and description of the igneous rock units is based mainly on field notes and brief field reports. Classification of the phaneritic rocks has been done megascopically. These units have proven to be mappable in the in the field but may or may not be genetic units. Detailed field study and microscopic analysis will probably modify the nomenclature used in this report.

The contact zones among the several igneous rock types and between igneous rocks and metasedimentary and/or metaigneous rocks generally are complex and some are zones of mixed rocks or migmatites. Depending on the observer, these contacts are reported to be: 1) gradational in texture, mineralogy, and structural style; 2) zones of mixed rock assemblages through which discrete contributions from the two rock types vary; or 3) some combination of 1 and 2. Migmatite is extensively developed on the western margin of the batholith but is not well developed at the eastern contact.

The origin of the migmatite zones cannot be determined without additional study; however, it should be noted that many of the structural features in these zones are older than the Idaho batholith rocks and may be Precambrian.

The igneous rock units will be described along with pertinent details of structural style and crossing relations with other units. The problem of rock genesis is beyond the scope of this report; however, evidence will be presented to establish the repetitive nature of pluton emplacement in the northern portion of the Idaho batholith.

Quartz monzonite

The bulk of the igneous rock in the wilderness area has been mapped as quartz monzonite. This rock type has been distinguished from granodiorite by some workers; however, poor exposures and deep weathering make consistent megascopic distinction of these two rock types difficult in most areas. In addition to a probably broad range of feldspar composition, the texture of this map unit ranges from porphyritic, fine-grained quartz monzonite through medium-coarse-grained quartz monzonite, to porphyritic coarse-grained quartz monzonite. The

genetic significance of the compositional and textural variation of this rock type should be evaluated by future investigations. Evaluations of this kind could be most easily made in the glaciated areas, such as in the Bitterroots. It could be, however, that genetic relations determined for the well exposed eastern portion of the Idaho batholith may not hold for the lower portion. Contact relations (e.g. less extensive migmatite development) suggest that the eastern portion of the batholith may have been emplaced later than the western portion and perhaps at a shallower depth.

For the purposes of compilation, the quartz monzonite has been divided into three units mostly on the basis of structural styles.

1. Directionless quartz monzonite. This unit includes porphyritic medium-fine grained rocks, coarse-grained rocks, and porphyritic medium to coarse-grained rocks. There is no internal structure visible in outcrops or hand specimens. The coarse-grained and the porphyritic medium to coarse-grained rocks each remain fairly uniform in texture and composition over wide areas. The porphyritic medium to fine-grained rocks have local variations in the relative proportions of plagioclase and potassium feldspar and grain size. The porphyritic medium to fine-grained quartz monzonite appears to contain small variolitic cavities which are partially to completely filled by medium-grained pink potassium feldspar crystals. This medium fine-grained rock appears to cross cut the coarse-grained directionless quartz monzonite.

The coarse-grained quartz monzonite is composed of coarse white, faintly pink-weathering potassium feldspar and finer white plagioclase (in approximately equal proportions), plus quartz and biotite. Hornblende is rare. The porphyritic phase is similar to the coarse-grained quartz monzonite except that it contains faintly-pink weathering potassium feldspar crystals up to 12 cm long. The porphyritic quartz monzonite generally occurs in 1-3 mile wide strips along the contacts of the directionless quartz monzonite bodies. Preliminary thin section studies indicate that the directionless quartz monzonite is variably cataclastic, with sutured, strained and lenticular quartz grains, mortared feldspar grain boundaries, and a system of parallel microshears, as a maximum expresson of cataclasis. Oscillatory zoning is common in plagioclase. Both feldspars are partially sausseritized. Pennine after biotite, epidote mantling plagioclase, and the sausseritization may be partly related to cataclasis and the effect of deuteric solutions.

Both the equidimensional and the porphyritic coarse-grained directionless quartz monzonite contain small bodies of medium to dark grey equigranular medium-grained quartz diorite. The quartz diorite bodies exhibit contacts which are sharp and embayed, apparently the result of partial resorption by the quartz monzonite.

Directionless quartz monzonite intrudes foliated granodiorite and foliated quartz monzonite and contains xenoliths of diorite. Granite bodies of batholith size and dikes of gabbro, diabase, basalt, andesite, rhyolite and aplite intrude directionless quartz monzonite.

2. Foliated quartz monzonite: Large bodies of quartz monzonite have an apparently primary schistosity defined by generally parallel alignment of biotite books. Potassium feldspar crystals, up to 10 cm, are generally lineated in the plane of the primary schistosity. Some potassium feldspar phenocrysts contain zonally arranged inclusions of plagioclase which decrease in An content from the center of the phenocryst outward. The plagioclase and quartz of the matrix is generally coarse-grained; the texture is hypidiomorphic granular. Plagioclase crystals have oscillatory zoning. Biotite occurs in generally equal-size

medium-grained books which have a thickness to length ratio of approximately one to four. Segregation into distinct biotite and quartzo-feldspathic layers is uncommon but occurs near contacts and xenoliths where friction of the boundaries or the flowing magma accentuated differences between flow laminae and promoted flow differentiation. The development of foliation through relatively homogeneous, batholith-sized quartz monzonite bodies indicates that the primary schistosity is not a boundary effect but probably results from the forceful intrusion of a mixture of potassium feldspar and biotite crystals suspended in melt largely of quartz and plagioclase composition. In the Bargamin Creek area the transition between foliated quartz monzonite and directionless quartz monzonite is concealed under the 100 foot wide alluvial fill of the creek bottom. The rocks on either side of the contact show no evidence of gradual transition. Dikes of directionless quartz monzonite cut bodies of foliated quartz monzonite. Therefore, we suggest that the difference in structural character between these two types of quartz monzonite reflects different times and tectonic conditions of emplacement, rather than related textural modifications of the same intrusion.

3. Quartz monzonite primary gneiss: Certain zones have been mapped as being primary gneiss. The zones are lithologically complex, containing variable proportions of metasedimentary septa and inclusions in a matrix of gneissose quartz monzonitic to quartz dioritic rocks. Igneous rocks of variable ages, textures, and compositions intrude the contact areas making reconnaissance mapping of these areas very difficult. The metasedimentary inclusions of pelitic composition often contain multiple metamorphosed and folded lit-par-lit granitic stringers which superficially appear to be related to the quartz monzonite matrix. The stringers generally have less potassium feldspar than the quartz monzonite, have a granoblastic texture, and lack the oscillatory zoned plagioclase found in the quartz monzonite. The quartz monzonite is medium to coarse-grained and weakly to strongly compositionally layered. Layering results from flow segregation of biotite. The metasedimentary inclusions are aligned parallel to the flow layering. Folds in the inclusions are of several generations and distinctly different in style from the flow folds found in the gneissose quartz monzonite. The flow folds probably result from irregular flow or eddies near the included metasedimentary blocks.

The relation of the primary gneiss to the foliated bodies of quartz monzonite is not clear. Map patterns suggest that the foliated quartz monzonite locally intrudes primary gneiss bodies but is of the same general intrusion cycle.

Granite

Batholith-sized bodies of pink granite and dikes of medium to coarse-grained granite intrude quartz monzonite of the batholith as shown on Plate 1. These bodies are generally structureless, coarse-grained, and equigranular. White plagioclase and biotite are minor. The granite batholiths and dikes are texturally and mineralogically similar to the rocks of the Sawtooth batholith of probable Tertiary age described by Reid (1963). Porphyritic granite and porphyritic microgranite are textural variations of the coarse-grained equigranular granite bodies.

The rocks of the southern part of the Burnt Strip Mountain and Watchtower Peak quadrangles form a granitic complex. This complex is made up of porphyritic microgranite, coarse-grained granite, and rhyolite dikes. Coarse-grained granite dikes which extend from the complex into neighboring rocks have a N 30° E trend and steep dips. This area should be studied in detail to determine the genetic relations between the several textural phases of granitic composition. Portions of this complex were described as microgranite by Larsen and Schmidt (1958).

The granite bodies along Running Creek and especially at Moose Creek (Plate 1) show evidence for forceful intrusion at the levels now exposed. Large metasedimentary septa parallel the contacts on the east and south side of the plutons. Intruded quartz monzonite has a foliation, which also generally parallels the granite contacts. The quartz monzonite appears to become sheared and gneissic within about a mile of the contacts. The gneissic quartz monzonite has a significantly higher potassium feldspar content than the undeformed quartz monzonite and is pink in color.

The granite near the granite-quartz monzonite contact at Running Creek also shows considerable evidence of cataclasis. The cataclasis may be the result of fault activity in the Bargamin Creek-Running Creek lineament. It may also be the result of shearing produced by upward movement of the granite pluton after crystallization was essentially complete. The development of gneiss structure and extensive introduction of potassium feldspar in the intruded quartz monzonite may also be the result of the upward movement of nearly solidified plutons. Microgranite which intrudes the contacts of coarse granite as well as being gradational to the coarse-grained facies, may be crystallized from resurgent granite magma which produced a variably developed late doming of the granite plutons. Hydrothermal solutions from the resurgent magma could have permeated sheared quartz monzonite near granite contacts and produced the extensive alteration reported. Rhyolite and felsite stocks and dikes appear to be more numerous in the granite than in the quartz monzonite and may be related to the hypothesized resurgence of magma. Detailed mapping is required to evaluate the resurgence hypothesis.

Dikes of andesite, rhyolite, and aplite intrude the coarse grained granites.

The analytical data for potassium-argon ages of biotite and feldspar quartz separates from a fresh sample of granite from the Running Creek pluton are shown in Table 3. Additional work is necessary to determine the effect of chloritization on the potassium-argon age of the biotite. The simplest interpretations are that the biotite age of 49 $\pm$ 3 m.y. reflects post-emplacement biotite crystallization or an event of uplift, unroofing, and cooling of the granite.

Table III

Analytical Data for Potassium Argon Ages of Coarse Grained Granite at Running Creek

Sample Type	%K	Ar^{40*} Moles/9 gm X10 -9	Ar^{40*} / Ar^{40*} total	Age 10^6 years
Biotite	4.13	.365	72%	49 $\pm$ 3
Feldspar	4.90	.406	53%	46 $\pm$ 3

Potassium analysis by atomic absorption, K.V. Rogers, analyst, Lockheed Electronics, Manned Spacecraft Center, Houston, Texas.

Ar^{40*} Radiogenic argon. Argon, analysis and age calculation by J.B. Hartung at the Rice University Geology Department.

Quartz Diorite

Quartz diorite bodies, which are distinct from the quartz-dioritic-primary gneisses previously discussed, apparently represent pre-Idaho batholith igneous events, although the difference in age between the quartz monzonite of the batholith and the quartz diorite bodies may be relatively slight. A large mass of quartz diorite (which is discordantly intersected by rocks of the batholith) crops out north of the Lochsa River. This mass probably is equivalent to the quartz diorite mapped near Pierce, (Kgd) of Hietanen (1963). A second small quartz diorite (Hgd) which occurs south of the Lochsa River near Louse Point on the crest of Coolwater Ridge, may be approximately the same age as the larger mass (Kgd) to the north.

The quartz diorites contain hornblende, biotite, plagioclase and quartz. Hornblende, generally, is subordinate to biotite, and may be minor in some varieties. These rocks are coarse-grained but nonporphyritic in contrast to the quartz monzonite of the batholith. Some quartz diorites have a well defined schistosity formed by parallel orientation of biotite. Where hornblende is prominent, prismatic hornblende grains show a preferred orientation. Lineation in the pluton near Louse Point on Coolwater Ridge is particularly well defined.

Diorite

Fine-grained biotite diorite dikes intrude foliated quartz monzonite at numerous localities, especially along the Lochsa River. Medium to coarse-grained hornblende diorite xenoliths are found in directionless quartz monzonite. The biotite diorite and hornblende diorite may be compositional and textural variants of the same intrusion. Therefore it is possible that the diorite dikes are an early mafic phase of the massive quartz monzonites. Fine-grained biotite diorite is cut by rhyolite dikes and is included in porphyritic andesite dikes as xenoliths.

Gabbro

Medium to coarse-grained pyroxene gabbro crops out in several road cuts along U.S. Highway 12 near the Bald Mountain Highway Maintenance Garage. The description of these exposures is incomplete but the gabbro apparently intrudes foliated quartz monzonite.

Andesitic and rhyolitic dike rocks

Dikes of rhyolite, andesite, dacite, quartz latite and aplite are reported to cut all the phaneritic rocks except gabbro. Most of the felsites are porphyritic. Partially resorbed euhedral quartz and anhedral pink potassium feldspar are common in the rhyolite dikes. White plagioclase phenocrysts stand out against the medium-gray aphanitic matrix of the andesite dikes. No relative order of intrusion has been determined for these rocks except that aplite is apparently the youngest and cuts all the other rock types. Rhyolite and andesite dikes commonly have mutual contacts. The felsite dikes are generally confined to certain zones or perhaps swarms. The general trend of the felsite dikes is north-eastward.

Dacite is cut by diabase dikes. Fine-grained biotite-diorite xenoliths are included in dacite and andesite dikes.

Diabase-basalt dikes

Diabase and basalt dikes crop out in a number of localities in the wilderness area. Many of the basalt dikes are highly sheared and hydrothermally altered. Fine-grained mafic dikes intrude granite and quartz monzonite along the U.S. Highway 12, with a predominant attitude of N 50-80 E 40-70 W. In this same region, the predominant trend of felsite dikes is northeast with steep southeast dips, suggesting that the tectonic conditions during felsite and mafic intrusion were different.

Basalt float covers a weathered knoll near the confluence of Liz and Weitas Creeks. This occurrence may be a basalt stock or an isolated remnant of the extensive basalt flows which cap ridges many miles to the west.

Pegmatite

There are several generations of pegmatite in the wilderness area. At least two types of pegmatite intrude the metasediments. The first type has been sheared during faulting but not folded.

Pegmatite dikes have been reported cutting all the phaneritic rocks except gabbro. Detailed study of the pegmatites of the Idaho batholith rocks of the Sawtooth Mountains (Reid, 1963) indicates that each phase of plutonic activity had an associated period of pegmatite emplacement. In the Sawtooth area, the pegmatite composition of each phase corresponded to the composition of the related plutons in terms of calcium content of plagioclase, feldspar ratios, etc. Limited evidence suggests that the pegmatite to pluton relation reported for the Sawtooth area holds also for the batholithic rocks of the Selway-Bitterroot Wilderness.

The pegmatites are compositionally simple; predominantly quartz and potassium feldspar, with lesser amounts of plagioclase muscovite and biotite. Accessory minerals are magnetite and rarely beryl.

STRUCTURE OF THE SELWAY-BITTERROOT WILDERNESS AREA

GENERAL

The structures observed in the Selway-Bitterroot Wilderness Area are generally compatible with the structural history of the Clearwater orogenic belt as a whole. The structural features which have been observed in the metamorphic rocks of the wilderness area will be described in order to show this similarity. The structure of the igneous rocks will also be described briefly.

MAJOR FOLDS

A flexure of regional extent in the northwest trending regional strike of foliation occurs near Green Mountain (Plate 1).

This sigmoidal feature has been interpreted as being the result of right-lateral strike-slip motion on a northwest trending zone in the basement (Greenwood and Reid, 1969). The sigmoidal structure bends lineation related to second generation folds, and is, in turn, sheared by cataclastic folds, and intruded by quartz monzonite. Therefore, the sigmoidal folding could be from latest Precambrian to Jurassic in age.

MINOR FOLDS

Isoclinal folds of microscopic to outcrop size have been observed in the wilderness area. These folds are of three general kinds: (1) knife-sharp isoclinal folds of compositional layering (S_0) with the production of an axial-plane schistosity (Si) throughout; (2) tight isoclinal folds of schistosity (Si) with the production of an incipient axial-plane schistosity (S_2) in the noses of folds; and (3) moderately tight isoclinal folds of schistosity without production of a new schistosity parallel the axial-plane of the fold. Fold types one and two have been observed in the same outcrop and commonly diverge in axial trend by 20-30°. Folds of type 3 have been observed to refold Type 2 folds in outcrops on the Salmon River near Whitewater Ranch. North-south trending cataclastic folds have been observed along the Lochsa River and on the trail north of Sheep Hill. These structures differ in style and orientation and appear to represent four distinct periods of deformation.

FAULTS

The fault pattern of the Wilderness Area is very complex. Deep weathering in fault zones and the lack of marker beds makes directions and magnitude of movement difficult to determine. However, certain major trends can be discerned by the length and degree of development of certain linear features. One of the most prominent linear features is that of the N-S trending Bitterroot front just east of the border of Montana and Idaho. Within the Idaho portion of the wilderness area, just west of the front, there are numerous thick, brecciated and iron-stained zones which trend north-south. The simplest explanation is that these zones were produced by dip-slip motion during the uplift of the Bitterroot front. However, the degree of brecciation and alteration, the straightness, and length of the zones suggest the possibility of transcurrent movement. North-trending strike-slip faults are reported in the Salmon, Idaho, area to the south of the wilderness area (Ruppel, 1967).

West of the N-S trending zones the most prominent linear zones are aligned in a northeast direction. One such zone follows the valleys of Bargamin Creek and

Running Creek for a distance of over 15 miles. In this zone the rocks are highly sheared and intruded by many dikes. These dikes are, in turn, sheared suggesting recurrent motion in the shear zone. The northeast linear features parallel the trend of strike-slip fault in the Atlanta area of central Idaho (Anderson, 1948). In the Atlanta area, Anderson described northwest trending gash veins and faults as tension features related to northeast, right-lateral transcurrent motion.

STRUCTURE OF THE UNMETAMORPHOSED INTRUSIONS

The majority of the igneous rocks mapped have internal structural features observable in well exposed outcrops. These structures will be briefly described to assist future mapping in and near the wilderness area.

Structures of Dikes

Contacts

Many of the igneous dikes have undergone shearing following solidification and contacts are often sheared and highly altered. Such contacts are easily eroded leaving the more durable core of the dike standing in relief. Because of this differential erosion the location and trend of dikes can often be mapped from adjacent ridges or airphotos. Near Granite Peak contacts of 50' thick porphyritic dikes, which intrude feldspathic quartzite are exposed in a glacial cirque. At the contacts with the dikes, the quartzite is brecciated and cemented by rhyolite. This exposure probably indicates forceful injection of the rhyolite dikes near Granite Peak. The north-east trend of these dikes parallels a major shear trend. The scale of mapping precludes systematic mapping of individual dikes; however, preliminary observations suggest that dikes in this area are arranged in swarms with broad intervening areas of lower concentration. Not all the dikes of a swarm have the same composition. Rhyolite dikes often have a common contact with andesite or quartz dacite dikes. Dike swarms tend to occur in major shear zones and mapping of the swarms could possibly outline the boundaries of the major fault blocks in this area.

Flow features

Several of the dikes have a compositional layering which parallels their steep contacts. The layering in some dikes is defined by the density of spherules resulting from devitrification. In other dikes the layering is defined by variable concentrations of phenocrysts, the alignment of schlieren, or xenoliths. Limited observations in the Red River region suggest that plagioclase phenocrysts are lineated in the plane of the layering and have a nearly horizontal rake.

Structures in Granitic Material

Analysis of the structure of granitic material is critical in the batholith area because such analysis is one of the few means by which unmetamorphosed granitic rocks can be distinguished in the field from the metamorphosed granitic rocks.

Because of the complex and repetitive nature of the intrusive history in this area, great effort is required in order to distinguish the intrusive units. Crossing relations are the most conclusive evidence, but are commonly obscured by shearing, soil cover, and/or deeply weathered exposures. Among the metamorphosed units, a relative chronology can be constructed by observing the degrees of structural involvement in each local intrusive unit.

The younger units exhibit fewer sets of fold trends and generally have less well developed schistosity. The older units show one or two generations of folded and metamorphosed pegmatites and granitic stringers, which are absent in the youngest metamorphosed bodies. Close inspection of hand specimens of metamorphosed granitics will show a generally pervasive parallel alignment of individual biotite books. In foliated, unmetamorphosed granitic rocks, biotite books are often aggregated in clumps or pods in a matrix of quartzo-feldspathic material. These aggregates generally consist of equal-sized books, whose aggregation appears to be a fluid-dynamic process, not a growth phenomenon. The width/length ratio of the individual books is generally much higher than in metamorphosed granitic rocks. In contrast, the biotite books in meta-igneous rocks often form laminae which separate flattened rods of quartz-feldspathic material. In the extreme, shearing and metamorphic differentiation develops compositional layering which resembles sedimentary bedding in its perfection of development.

Unmetamorphosed granitic rocks in the batholith area can be divided into three broad structural groups:

1. Rocks which show no planar or linear structure in outcrop (i.e. "directionless").

2. Rocks which have planar structure and/or a linear structure defined by mineral alignment ("foliated" and/or "lineated"); and

3. Rocks which have a compositional layering defined by flow layering and/or alignment and partial incorporation of country rock material and which may contain complex folds resulting from non-uniform flow conditions ("primary gneiss").

At any extensive outcrop the granitic rocks can generally be classed according to: (1) whether they are metamorphosed, or (2) the particular broad unmetamorphosed structural group or combination of groups present. Mixed rock assemblages are very common at or near contacts of the major igneous bodies. Because the contacts continued to be zones of structural weakness following crystallization, subsequent intrusion commonly occurred in these zones, increasing their complexity.

THE RELATION OF INTRUSIVE STRUCTURE TO REGIONAL STRUCTURE IN THE METASEDIMENTS

As can be seen in Plate 1, the average strike and dip in the unmetamorphosed igneous bodies corresponds rather well to the regional strike and dip in the adjacent metamorphic rocks. The general trend of contacts suggests that the batholithic material is largely conformable with regional structure in the intruded rocks. Two types of granitic units depart from this general pattern of conformability; (1) certain granite bodies are aligned on north-south trends which cross the structure of both metasediments and previously intruded igneous rocks; and (2) portions of medium to fine-grained quartz monzonite bodies are locally discordant to metasedimentary structure in the Green Mountain area. Neither the granite nor the medium to fine-grained quartz monzonite bodies were observed to have internal flow structures.

ECONOMIC GEOLOGY

GENERAL

The land contained in the Selway-Bitterroot Wilderness Area is undeveloped for two obvious reasons: (1) rugged topography, and, more importantly, (2) the failure of early prospectors to locate payable mineral deposits. In the present research program, ground traverses were used to prepare a geologic framework for the interpretation of geophysical and geochemical anomalies.

An aeromagnetic map of the area has been prepared in cooperation with the U.S. Geological Survey. It has been published as the Survey's map G.P. 832. Aeromagnetic Map of Parts of the Hamilton and Elk City 1^{o} by 2^{o} quadrangles, Idaho-Montana, 1972. Anyone who wishes to use the map in conjunction with this report may obtain it from the U.S. Geological Survey for 75¢ a copy.

MINERALIZATION

Near the abandoned U.S. Forest Service Meadow Creek Lookout (see Plate 1) copper mineralization has been detected by ground traverse. Several old prospect pits show malachite and chrysocolla in highly fractured white quartzite. There is an abundance of fine disseminated pyrite, now altered to limonite, in the quartzite. Cobalt bloom and nickel stain are found on some joint faces. Spectrochemical analysis by Earth Sciences, Inc. of Golden, Colorado, of a selected sample indicates 1% copper with 10 ppm silver. Soil cover is deep in the area of Meadow Creek Lookout and the only rock observed in place was in a partially slumped prospect pit. Based on this small exposure and the distribution of malachite-bearing float, mineralization appears to be related to N-S to NNE bearing fractures in the quartzite. Sparse copper mineralization has been observed for more than a mile down the ridge which leads west of the abandoned lookout. This distance appears to be the exposed cross-strike width of the N-S to NNE trending mineralized zone. Quartz monzonite of the Idaho batholith complex cuts off the quartzite north and south of Meadow Creek Lookout (see Plate 1), giving a maximum possible mineralized strike length of about 6 miles.

In the vicinity of Watchtower Pass, a small prospect pit exposes massive pyrite, pyrrhotite, chalcopyrite, bornite, and galena. Limonite gossan gives way in a few feet of depth to expose the primary sulfides. No oxides other than limonite were noted and there did not appear to be any supergene enrichment. The gossan zone is 120 feet long and from three to 20 feet wide. Mineralization is located along fractures in a small microgranite stock which intrudes quartz monzonite primary gneiss. Limonite, siliceous veins and chalcopyrite float were found for a third of a mile north of the prospect pit. Soil samples in the immediate area over the prospect show high copper content. Other soil samples up to one mile away have slightly enhanced copper values.

On MacGregor Creek, bornite, chalcopyrite and malachite fill fractures in a 30 foot wide hornblende-diorite dike. The mineralized fractures are both horizontal normal to the strike of the dike. Anomalous trains of heavy metals in stream sediments radiate (up to two miles) from the MacGregor Creek prospect.

On Steep Hill, limonite and minor malachite fill fractures in a highly sheared siltite-argillite. The limonitic mineralization extends over a considerable area. However, no geochemical anomalies were found around the prospect.

In the vicinity of Lolo Pass, malachite and chrysocolla occur with pyrite in a highly sheared quartzite-phyllite exposed in a road-metal quarry beside U.S. Highway 12. The extent of this deposit has not been determined.

At Whitewater Point, malachite and chrysocolla occur with pyrite in highly sheared quartz veins and quartzite. A copper anomaly, small in size, in soil and stream sediments is associated with this showing.

Numerous small showings of copper have been found in quartzite of the Belt Supergroup, and in small stocks of apparent Tertiary age. Therefore, both disseminated epithermal copper and syngenitic sedimentary copper deposits are possible targets in this area.

GEOLOGIC HISTORY

The metasedimentary rocks of the Selway-Bitterroot Wilderness Area are correlated with units of the Belt Supergroup (Tables, 1, 2, 4), specifically, the Prichard Formation, the Ravalli Group, and the Wallace Formation. Younger units of the Belt Supergroup have not been positively identified within the wilderness area. Total thickness represented by the metasediments is substantial and may equal the thicknesses measured in relatively undeformed Beltain rocks.

Radiometric and structural data (Reid and Greenwood, 1968) suggest that the metasediments were deformed twice during late Precambrian time. Orthogneisses deformed and recrystallized by one or both of the Precambrian deformations (e.g. the Red River augn gneiss) indicate that intrusion of igneous rocks accompanied both Precambrian metamorphic events.

Lit-par-lit injection of small granitic sills and stringers also accompanied both Precambrian deformations, and was extensive enough in some areas to form migmatitic assemblages.

Physical conditions in the western and southern part of the wilderness area ranged up to the sillimanite-orthoclase subfacies during the first Precambrian deformation with less severe conditions prevailing during the second Precambrian deformation. Recrystallization conditions apparently were less severe on the eastern border of the wilderness area.

A third deformation of uncertain age, possibly Paleozoic, is indicated by warping of first and second generation fold axes. A fourth fold event occurred during the Mesozoic and produced north-south trending folds resulting in locally penetrative cataclasis.

Intrusion of the major quartz monzonitic units of the Idaho batholith began during the Cretaceous, apparently preceded by quartz dioritic rocks. Batholithic rocks are cut by Tertiary granites and all the phaneritic rocks are cut by felsic dikes, possibly related to the Challis volcanism reported southeast of the wilderness area. The felsic dikes and older rocks are cut by diabase dikes possibly related to the Columbia River basalts of Miocene and Pliocene age. This sequence of events is shown in Table 4.

Uplift and erosion accompanied each period of deformation and plutonism. The development of the present major drainage system in the batholith area probably preceded the extrusion of the Columbia River Basalt, which flowed up the valleys of the major rivers. Modification of the early drainage patterns by later Tertiary and Pleistocene faulting and uplift is probable but has not been studied in the wilderness area.

Faulting probably accompanied each major tectonic event. The major north to northeast linear trend probably developed during or before the intrusion of the granite batholiths, the contacts of which partially follow northeast trends, and was again active during intrusion of the Challis age dikes. The north-south trend of the Bitterroot front is probably a major crustal rift which was reactivated during block faulting and the uplift of the Bitterroot Mountains in later Tertiary time.

Table IV

Generalized stratigraphic column in the Selway-Bitterroot Wilderness Area

Rock Unit	Approximate Area
Diabase dikes	Miocene (?)
Felsite dikes	Oligocene (?)
Granite	49 m.y. (?)
Directionless quartz monzonite	
Diorite dikes	
Foliated quartz monzonite	Late Cretaceous (?)
Foliated granodiorite and foliated quartz diorite	
Younger orthogneiss bodies	?
Biotite quartz diorite orthogneiss	
Augen gneiss	1.5 b.y. (?)
Amphibolite	
	Precambrian
Wallace Formation	
Ravalli Group	
Prichard Formation	

APPENDIX

PERSONNEL

Geologists were:

1965

Earl M.P. Lovejoy, Chief geologist
Paul R. Krutak
Donald A. Morrison
Charles J. Waag

1966

Wm. R. Greenwood, Chief geologist
Russell E. Clemons
Richard V. McGehee
Donald A. Morrison
John L. Nold

1967

Wm. R. Greenwood, Chief geologist
Stuart L. Dean
William D. Pitt
William R. Seager
John L. Nold

1968

Wm. R. Greenwood, Chief geologist
Stuart L. Dean
Paul R. Krutak
William D. Pitt
William R. Seager

Field Assistants were:

1965

David Hall
Allan Holtzman
Richard Pfirman
Russell Smith

1966

David V. Huntsberger
Thomas P. Moore
Ronald L. Morton

1967

Michael R. Carter
Robert L. Koenig
Scott D. Martin
James S. McAndrew
Arthur K. Rosenboom
James Mc. Soule

1968

Earl C. Redman
Michael C. Shea
Richard Ruetschelling
E. Burk McWilliams
Lawrence E. Phillips
Wm. Hafterson
Robert B. Sweeney
David C. Hamilton
Christian K. Dahl

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IDAHO BUREAU OF MINES
R. R. REID DIRECTOR

COMPILED BY WILLIAM R. GREENWOOD

CONTRIBUTORS: RUSSELL E. CLEMMONS, STUART L. DEAN, WILLIAM R. GREENWOOD, PAUL R. KRUTAK, EARL M.P. LOVEJOY, RICHARD V. MCGEHEE, DONALD A. MORRISON, JOHN L. NOLD, WILLIAM D. PITT, WILLIAM R. SEAGER, CHARLES J. WAAG

DRAFTING: NANCY L. NIALS

ELK CITY AND VICINITY MAPPED BY R.R. REID 1959

DIXIE DISTRICT MAPPED BY JOHN R. BEEDER, 1958

PLATE 1

RECONNAISSANCE GEOLOGY of the SELWAY-BITTERROOT WILDERNESS AREA (1965 - 1967)

CONTACTS TRACED IN THE FIELD

CONTACTS INFERRED AND PARTIALLY FIELD CHECKED

EXTRAPOLATED CONTACTS

FAULTS SHOWING RELATIVE MOVEMENT, FIELD CHECKED

VERTICAL SCHISTOSITY / FOLIATION

STRIKE AND DIP OF SCHISTOSITY / FOLIATION

COMPOSITIONAL LAYERING

F_1 FOLD AXIS

LINEATIONS: MICROCRENULATION, MINERAL ALIGNMENT, RODDING

F_2 FOLD AXIS

PROSPECTS (Cu: COPPER)

Tcr	COLUMBIA RIVER BASALT
Td	ANDESITE AND DIABASE DIKES, MAY BE PORPHYRITIC
Tr	RHYOLITE, QUARTZ LATITE &/or DACITE DIKES, MAY BE PORPHYRITIC, ONLY THE LARGEST DIKES ARE MAPPED
Tg	TERTIARY (?) MEDIUM GRAINED PINK GRANITES, PORPHYRITIC TO EQUIGRANULAR
Kqm	CRETACEOUS QUARTZ MONZONITE OF THE IDAHO BATHOLITH GENERALLY COARSE GRAINED, LIGHT GRAY, AND CONTAINS PHENOCRYSTS OF POTASSIUM FELDSPAR AND PLAGIOCLASE. INCLUDES SMALL BODIES OF YOUNGER GRANITE & OLDER QUARTZ DIORITE & GRANODIORITE GENERALLY WEAKLY FOLIATED
Kqmf	FOLIATED PORPHYRITIC QUARTZ MONZONITE OF THE IDAHO BATHOLITH, INCLUDES SMALL BODIES OF PRIMARY GNEISS
Pgn	PRIMARY GNEISSES, PARAGNEISSES, AND ORTHOGNEISS BORDERING THE IDAHO BATHOLITH, ALSO DENOTES UNDIFFERENTIATED METASEDIMENTARY BLOCKS WITHIN THE BATHOLITH.
Kqd	HORNBLENDE-BIOTITE QUARTZ DIORITE, COARSE GRAINED, MAY BE CATACLASTICALLY SHEARED. (PROBABLY EQUIVALENT TO Kqd OF HEITANEN, 1963)
Hqd	HORNBLENDE-BIOTITE QUARTZ DIORITE, (LOUSE POINT PLUTON, KRUTAK et al, 1965) WELL DEFINED LINEATION OF PRISMATIC HORNBLENDE.
Bqd	BIOTITE-QUARTZ DIORITE, PRE-IDAHO BATHOLITH, WELL DEFINED PLANAR PARALLELISM OF BIOTITE.
Og	UNDIFFERENTIATED ORTHOGNEISSES
Ogd	BIOTITE(± HORNBLENDE) PLAGIOCLASE QUARTZ DIORITIC ORTHOGNEISS, MAY BE GARNETIFEROUS.
Ogn	BIOTITE-PLAGIOCLASE-QUARTZ ORTHOGNEISS, GRANODIORITIC COMPOSITION, POSSIBLY PRECAMBRIAN.
Am	AMPHIBOLITE, PRIMARILY ORTHOAMPHIBOLITE, PROBABLY OF SEVERAL AGES.
pEwg	DIOPSIDE-PLAGIOCLASE (+ HORNBLENDE) GNEISSES INTERLAYERED WITH BIOTITE AND FELDSPATHIC QUARTZITES AND BIOTITE-PLAGIOCLASE GNEISSES PLUS MINOR SCHIST UNITS. TENTATIVELY CORRELATED WITH THE WALLACE FORMATION (WALLACE GNEISS OF HIETANEN, 1963)
pEws	QUARTZ-BIOTITE-PLAGIOCLASE GNEISSES AND SCHISTS AND BIOTITE-PLAGIOCLASE QUARTZITES MAY BE INTERGRADATIONAL, KYANITE AND SILLIMANITE OCCUR SPORADICALLY, CALC-SILICATES ESSENTIALLY ABSENT. TENTATIVELY CORRELATED WITH THE WALLACE FORMATION
pEr	GARNETIFEROUS BIOTITE QUARTZITES AND PELITIC SCHISTS AND GNEISSES, WHITE QUARTZITES AND MINOR CALC-SILICATE LAYERS LOCALLY HEAVILY PENETRATED BY GRANITIC STRINGERS WHICH MAY CONTAIN KYANITE, TENTATIVELY CORRELATED WITH THE RAVALLI GROUP.
pEp	PREDOMINANTLY PELITIC SCHIST, GARNET AND KYANITE OCCUR, LOWER PORTION CONSISTS OF PELITIC SCHISTS INTERLAYERED WITH WHITE BIOTITE &/or MUSCOVITE QUARZITES. TENTATIVELY CORRELATED WITH THE PRICHARD FORMATION.
Agn	BIOTITE AUGEN GNEISS, COARSELY BANDED, WITH FELDSPAR PORPHYROBLASTS, POSSIBLY PRECAMBRIAN.
pEbg	BIOTITE GNEISS WITH THIN INTERLAYERS OF QUARTZITE AND MICA SCHIST, HEAVILY INJECTED BY SILLS, DIKES AND QUARTZO-FELDSPATHIC STRINGERS. POSSIBLY EQUIVALENT TO pEp ABOVE.
pEq	WHITE QUARTZITE, BIOTITE &/or MUSCOVITE QUARTZITE WITH THIN INTERLAYERS OF AUGEN AND BIOTITE GNEISS AND QUARTZO-FELDSPATHIC STRINGERS. POSSIBLY EQUIVALENT TO pE- ABOVE.

Granitic Complex

Approximate mean declination 1963

1 0 1 2 3 4 5 Miles

INDEX MAP

Planimetric base map, U.S. Forest Service, Nez Perce National Forest, (East Half), 1963

Hand coloring will enhance readability of this map.