THE GEOLOGY AND TECTONICS OF THE IDAHO PORPHYRY BELT FROM THE BOISE BASIN TO THE CASTO QUADRANGLE

by

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I hereby recommend that this dissertation prepared under my direction by Harry J. Olson entitled The Geology and Tectonics of the Idaho Porphyry Belt from the Boise Basin to the Casto Quadrangle be accepted as fulfilling the dissertation requirement of the degree of Doctor of Philosophy

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ABSTRACT

The portion of the Idaho porphyry belt studied forms a northeast-trending polygon encompassing approximately 750 square miles in west-central Idaho. Geology was mapped along a series of irregular lines cross-cutting the north-east trend of the porphyry belt, and plotted on a 1:125,000 scale geologic map.

The map area is underlain by quartz monzonite on the Idaho batholith which, structurally and tectonically, occupies a unique position at the junction of arcuate segments of the Nevadan and Laramide orogenic belts and a belt of Tertiary plutonism. Metamorphosed xenoliths and roof pendants of Ordovician (?) sedimentary rock are common throughout the northern portion of the map area, but do not constitute a large volume of rock. Small Eocene and Eocene (?) plutons of diorite, quartz monzonite, granodiorite, and pink granite intrude earlier rocks, but do not form a conspicuous element of the Tertiary intrusive features. Eocene and Oligocene (?) dike swarms are the most conspicuous geologic feature of the map area. The dikes vary in composition from diabase to rhyolite. They were intruded as an imperfect differentiation sequence commencing with fine-grained diorite, quartz latite and latite dikes; and terminating with quartz latite, rhyolite, and basic dikes.

An unrelated minor period of Miocene or Quaternary diabasic intrusion may have followed the major episode of Tertiary plutonism.

The deforming stresses which provided the openings for the intrusion of the Tertiary plutons and dikes apparently were not everywhere equally and uniformly applied in either intensity or direction, and the Idaho porphyry belt in the map area is a composite of several well-defined dike swarms, each differing somewhat in composition and age from the others, and each controlled by its own set of guiding fractures.

The forces controlling the emplacement of magma were essentially vertical and caused doming and fracturing of the batholithic rocks in and around three intrusive centers in the map area: the Boise Basin, Red Mountain, and the Cape Horn-Seafoam-Beaver Creek area. North-northeast and east-northeast trending fractures controlled the direction of the majority of the dikes. However, older structures were also effective in controlling pluton and dike directions.

After emplacement of the dikes the area was modified by Basin and Range type block faulting, the formation of intermontane basins, strike-slip faulting, Pleistocene glaciation, and periodic uplift and erosion.

The map area has been prospected from the early 1860s, and has produced small quantities of gold, silver, lead, zinc, and copper from placer and lode deposits. Minor tungsten and molybdenum mineralization is present but is uneconomic. The radioactive rare-earth placer deposits in Bear Valley were mined in the late 1950s and now represent an important low-grade reserve for uranium, thorium, columbium, tantalum, and the rare-earths, as well as magnetite, ilmenite, garnet, and monazite.

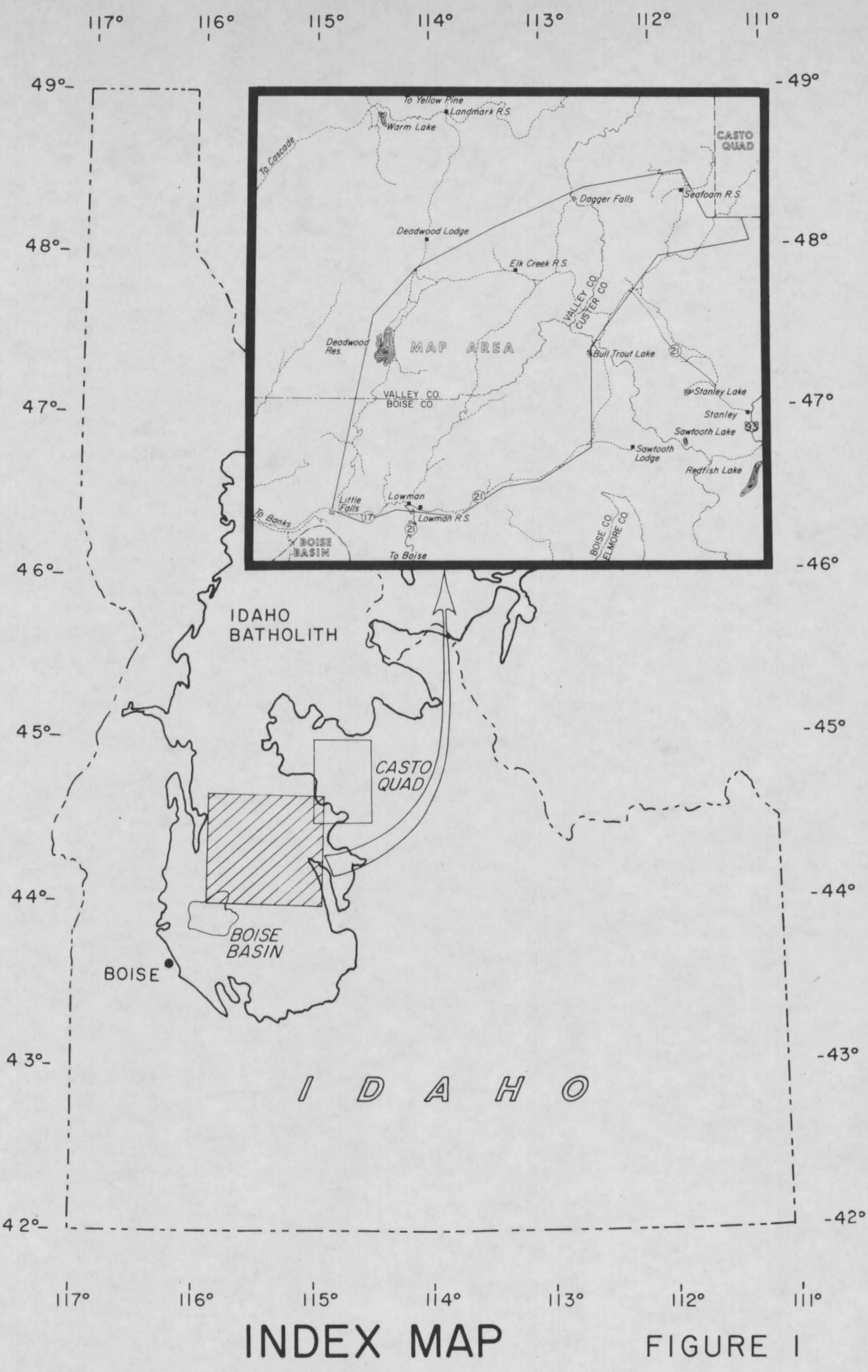
INTRODUCTION

The Idaho porphyry belt is a broad zone of structural weakness which extends from southwestern Idaho to north-central Montana. This northeast-trending system of faulting and Tertiary dikes and plutons is transverse to the structure of the western Cordillera. It has had a complex tectonic and intrusive history, and represents one of the important structural features of the northwestern United States.

Although much detailed geologic work has been done along portions of the porphyry belt, large areas, especially in Idaho, are largely unknown, and much remains to be done before a full understanding of the geology and tectonics of this regional structural feature will be attained.

Location and Accessibility

The portion of the Idaho porphyry belt mapped during this study is in west-central Idaho between the Boise Basin and the Casto Quadrangle (Fig. 1). The map area forms a northeast-trending polygon approximately 50 miles long by a maximum width of 24 miles. It is bounded by the meridians of 114°55' and 115°46' west longitude, and the parallels of 44°05' and 44°35' north latitude. The area encompasses approximately 750 square miles in portions of the Boise and Challis National Forests in Boise, Custer, and Valley



INDEX MAP FIGURE 1

Counties, Idaho; and lies within nine 15-minute quadrangles: Bear Valley 1, Bear Valley 2, Bear Valley 3, Chinook Mountain, Custer 2, Deadwood Reservoir, Garden Valley, Garden Valley 4, and Greyhound Ridge.

The area is readily accessible by road, and can be reached by driving north from Boise via Lowman or Banks, west from Stanley, and southeast from Cascade. Although the area is inaccessible from the north and east during the winter months, roads from Boise to Lowman are passable all year except for short intervals during extreme winter conditions. The roads in the interior of the map area are kept open until the end of hunting season early in December, and then are allowed to close until the spring melt which may not come until late June.

The interior of the map area is fairly accessible in all but the winter months by a network of typical, well-maintained, gravel mountain roads. Few spots are more than four miles from a road, and accessibility is slowly improving as logging roads are constructed into new timber areas.

Geography

The map area is in the south-central part of the Salmon River Mountains--a poorly defined mountainous mass lying between the Salmon and Payette Rivers--and lies wholly within the drainage basins of the South Fork of the Payette and the Middle Fork of the Salmon Rivers. According to Anderson (1947), the area "resembles a more-or-less deeply dissected plateau made up of ridges rising to approximately accordant levels separated by valleys and canyons of considerable depth (Figs. 2 and 3). In places the mountainous terrain is interrupted by scattered depressed areas and intermontane basins".

The area is maturely and uniformly dissected, and valley walls commonly slope more than 30°. However, slopes too steep to hold soil and vegetation are rare except in glacial cirques. The eastern portion is by far more rugged than the southern and northwestern portions which are more rounded and have less relief.

Elevation varies from approximately 3350 feet above sea level at the confluence of Big Pine Creek and the South Fork of the Payette River in the extreme southwest corner of the area, to slightly over 9400 feet at Ruffneck Peak in the northeast. Throughout the area, ridges and peaks are usually over 8000 feet, except in the northeast portion where several individual peaks are over 9000 feet. The high mountain valleys in and around Bear Valley and the northwest end of the Stanley Basin vary in altitude between 6400 and 7000 feet.

Because of the mountainous nature and high relief, there is quite a wide climatic range in the area. As a generalization, the winters are rather long and severe, and the summers and early autumns are cool and pleasant. At lower elevations, however, along the South Fork of the

Figure 2. View from Hole-in-the-Wall Creek

View to the northeast from Hole-in-the-Wall Creek across the valley of the South Fork of the Payette illustrating the deeply dissected nature of area. Deadwood Ridge is in the middle ground.

Figure 3. Aerial View of Miller Mountain Ridge

Aerial view (looking northeast) of Miller Mountain Ridge illustrating accordant ridge levels resembling a deeply dissected plateau. Clear Creek drainage separates Deadwood Ridge in the middle ground. Whitehawk Mountain is the high point on Deadwood Ridge in the middle background. The southern portion of Bear Valley can be seen to the right of Whitehawk Mountain.

Payette, temperatures between 90° and 100° F are common during the summer months.

Precipitation is varied and depends on altitude and degree of protection from the prevailing west and south-westerly winds. Annual precipitation varies from less than 15 inches in some of the deeper canyons to about 30 inches at higher elevations. Annual precipitation probably averages somewhere between 20 and 25 inches.

Most of the precipitation falls during the autumn, winter, and spring months. The summers are usually dry, and the scattered rains which fall during this time are usually accompanied by electrical storms which create a great fire hazard. At higher elevations snow may fall at any time of the year, and from late September until May most of the precipitation is in this form.

Dense growths of Ponderosa pine and Douglas fir cover most ridges, north slopes, and steep valleys, and support an extensive lumbering industry. The drier south slopes are usually unforested and are covered with sagebrush and bunch grass.

Previous Work

Comparatively little geologic mapping has been done in the Idaho batholith and at present it is the least known of the great batholiths of the western United States.

Although some reconnaissance work was done in the area, and some detailed geologic mapping is recorded around its periphery, the map area itself until recently remained largely a geologic question mark.

On the Geologic Map of Idaho (Ross and Forrester, 1947, 1:500,000), the map area is shown as a structureless mass within the Idaho batholith extending between the Tertiary intrusions of the Boise Basin and the Casto Quadrangle.

Mackin and Schmidt (1953, 1:38,016) mapped the radioactive placer deposit and the glacial features of the Big Meadow portion of Bear Valley. At the same time Kline, et al. (1953) did extensive drilling in the placer deposits along Bear Valley Creek and its tributaries. Storch (1958) studied and conducted reconnaissance drilling in the radioactive placer deposits along the Deadwood River.

In recent years some interest has been shown in the Idaho batholith as a whole. Larsen and Schmidt (1958) carried out a reconnaissance of the entire batholith by road, and concluded that the mass is composed of at least nine major rock types.

Schmidt (1958), working in Valley County, suggests a metamorphic and metasomatic origin of the batholith with or without mobilization of the interior portion.

Bonini (1963) conducted a reconnaissance gravity survey of the state which revealed that the most negative Bouguer anomalies (-236 mgals), and isostatic anomalies near zero (± 20 mgals) are in the Idaho batholith and the area to the east. He concludes that the region is approximately in isostatic equilibrium. The structures and intrusives of the Idaho porphyry belt are not reflected by obvious trends on the Bouguer map.

A considerable amount of work has been done in areas peripheral to this one. To the southwest Lindgren (1898, 1:62,500), Jones (1916, 1:250,000), Ballard (1924, 1:125,000), and Anderson (1947, 1:24,000) have mapped the Boise Basin, and Anderson (1947) summarizes other work which has been done in that district. Donovan (1962, 1:6000) mapped the Little Falls area and studied the origin of the molybdenum mineralization there.

To the southeast Reid (1963, 1:62,500) mapped the Tertiary Sawtooth batholith. To the east Choate (1962, 1:62,500) studied the geology and ore deposits of the Stanley area, and Williams (1961, approximately 1:125,000) mapped the glacial geology of the Stanley Basin. To the northeast Ross (1934, 1:125,000) studied the geology and ore deposits associated with the Tertiary dike swarms and batholithic intrusions of the Casto Quadrangle. Ross (1930) and Treves and Melear (1953) prepared reconnaissance geologic maps and studied the ore deposits of the Seafoam Mining District. Kiilsgaard (1947, 1:190,080) mapped and compiled previous mapping in Valley County.

Purpose and Scope

Although many of the broad geologic features of south-central Idaho and the Idaho porphyry belt are now known, many details of regional importance are still lacking. This study was undertaken to add to the basic knowledge of regional geology and, in particular, to determine the expression, continuity, and controls governing the emplacement of the Tertiary dike swarms and plutons of the Idaho porphyry belt between the Boise Basin and the Casto Quadrangle. Although many features were noted during the course of the study, the emphasis of the work was directed toward the igneous Tertiary geology and the tectonics of the area. In many instances, the lack of outcrop, complexity of detail, restrictions of time and wide spacing of traverses, have necessitated generalization. These limitations are noted, but regrettably are inherent in any study of a reconnaissance nature.

Method of Investigation

Field work in the area consumed approximately nine months in the summer and fall of 1965 and 1966. Geology was mapped along a series of irregular lines crosscutting the northeast trend of the porphyry belt as well as along many of the roads which cross the area. These traverses, as well as many geographical names, are shown on Figure 4.

Much time was spent in detail mapping the excellent exposures along state highway #17 between Deadwood River and Big Pine Creek. The majority of the off-road traverses were run along ridges, as outcrop along the valley sides and bottoms is erratic or lacking, and thick underbrush makes passage an exhausting struggle.

Geology was plotted in the field on acetate overlays of 1:15,840 scale U. S. Forest Service aerial photographs, and later transferred to 1:31,680 scale Forest Service planimetric maps. The finished planimetric maps were then assembled, the geology generalized, and replotted on a screened, 1:125,000 scale enlargement of a portion of the Challis 1:250,000 scale, AMS sheet.

Some alluvial deposits were mapped on the ground, but as mapping in the valleys was limited, the majority of the stream, valley, and glacial deposits were mapped from aerial photographs. A study of structural lineaments was made on 1:60,000 scale AMS serial photos and the linears plotted directly onto the 1:125,000 scale base map. Major structural features were later transferred to the geologic map.

Field Assistance and Support

I was assisted during the summer of 1965 by Robert Randolph, and during the field season of 1966 by James M. Robertson and Peter Kun. Robertson mapped supplemental traverses in areas of complex geology in the Deadwood Ridge, Cape Horn Mountain, and the Seafoam-Beaver Creek areas; and Kun mapped short traverses in the Bull Trout Lake, Sack Creek, and Clear Creek areas. All contributed valuable ideas and stimulating discussions of the problems encountered during the field work.

Age dating of several rock samples was done in the geochronological laboratory of the University of Arizona by Mrs. Judy K. Percious under the direction of Dr. Paul E. Damon. This work has been extremely valuable in the interpretation of the geologic events.

Many informative conversations were held with Larry Rychener during the summer of 1966 in the course of his study of the metasedimentary rocks northwest of Stanley, Idaho. These "conversations" were continued through the course of this study by correspondence, and I am indebted to Rychener for much information and many valuable ideas which were freely given in the best traditions of academic cooperation.

Finally, I would like to acknowledge with thanks the assistance provided by American Metal Climax, Inc. in permitting me to select and study a dissertation problem within the framework of my duties with the company, and for permission to publish the results. Especially I would like to thank R. I. Davis, T. G. Moore, H. T. Schassberger, and R. J. Wright for their help and support; M. H.

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REGIONAL GEOLOGIC SETTING

The Idaho batholith occupies much of the Idaho portion of what was once the Cordilleran Manhattan Geanticline -- a broad north-trending upwarp which formed along the line separating miogeosynclinal and eugeosynclinal tectonic provinces of the Cordilleran geosyncline. The Idaho batholith partly intrudes the Pacific eugeosynclinal province, and its eastern part intrudes miogeosynclinal sediments. This area intruded by the batholith has been positive, with a possible exception during the Ordovician, throughout the Paleozoic to the present, and has been a site of almost continuous tectonic and igneous activity since the end of the Jurassic period.

Structurally and tectonically the Idaho batholith occupies a unique position at the junction of great arcuate segments of both the Nevadan and Laramide orogenic belts (Fig. 5). The Nevadan segments are more tightly arced, and meet at a more acute angle than those of the Laramide. Both orogenic events have influenced the evolution of the Idaho batholith, and have provided it with a long and complicated geologic history.

To the north of the Idaho batholith, the continuity of the Cordillera is interrupted by a zone of west-northwest-trending valleys known as the Lewis and Clark line. These

Figure 5. Relation of Idaho Batholith to Orogenic Belts and the Cordilleran Geosyncline

Relation of the Idaho batholith to the North American Nevadan and Laramide orogenic belts in the area of their overlap, and to the Cordilleran geosyncline. The Nevadan belt is outlined in bold dashed lines, and the Laramide belt is dotted and lined. The bold lines in the Laramide belt are axes of prominent folds, thrust faults, and major trends. The eugeosynclinal and miogeosynclinal provinces of the Cordilleran geosyncline are labeled and are separated by a bold dotted line. The shelf area lies to the east of the miogeosyncline.

After: Eardley, 1962; and King, 1959, with modifications.

Figure 5. Relation of Idaho Batholith to Orogenic Belts and the Cordilleran Geosyncline

valleys, which are transverse to the general trend of the Cordillera, are formed by a series of parallel, discontinuous high-angle wrench faults -- the best known of which is the Osborn fault of northern Idaho (Fig. 6). In a general sense, the structures of the Lewis and Clark line wrap concordantly around the northeast portion of the batholith and its satellites, and merge into a north-trending zone of folds and thrust faults. This structural pattern suggests that the Idaho batholith has moved eastward as a rigid mass, and that the thrusts along its east side are a direct compressional result. However, as the strike-slip movement on the Osborn fault, and other well-known parallel faults of the Lewis and Clark line, is right-lateral (Hobbs, et al., 1965), this possibility seems incorrect. On the other hand, according to King (1959) and Hobbs, et al. (1965) strike-slip movement along the eastern extension of the Lewis and Clark line is left-lateral -- suggesting many complex adjustments of differing directions in both time and space along the faults of the Lewis and Clark line.

The structures of the Lewis and Clark line, however, are only one feature of a much larger discontinuity in the North American Cordillera. North of the Lewis and Clark line, the ranges and valleys of the Cordillera extend north-northwest and consist of geosynclinal sediments of Belt and later ages which have been thrown into folds and

Figure 6. Detail of the Laramide Orogenic Belt and the Idaho Batholith

Both major fold axes and thrust faults of the Laramide orogeny are shown by lines. The main batholith is stippled, and plutons of known Laramide and Tertiary ages are black.

After: Tectonic Map of the United States, 1944; and Eardley, 1962, with modifications.

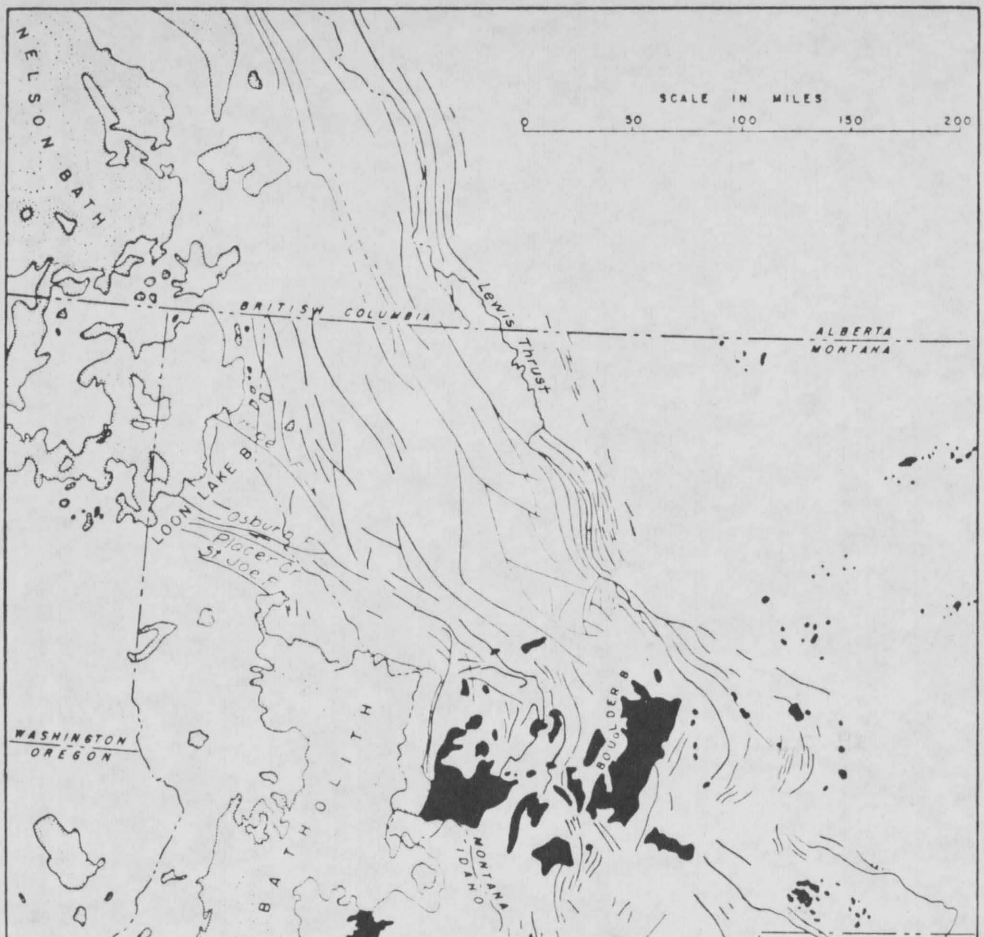


Figure 6. Detail of the Laramide Orogenic Belt and the Idaho Batholith

thrust blocks, or were transported eastward on low-angle faults such as the Lewis thrust. South of the Lewis and Clark line the ranges are more disordered and some trend north-northeast -- a direction transverse to the main trend of the Cordillera. Folded and faulted miogeosynclinal sediments occur in patches, but many of the mountains consist of Precambrian basement rocks older than the Belt series, of acidic plutonic rocks, and of Tertiary volcanics.

The Idaho batholith was emplaced with markedly discordant relations locally, especially to the east of the map area. However, sedimentary structures wrap concordantly around the north and east portion of the batholith, and it is fairly clear in other areas where the contacts can be observed that overall concordance prevails.

The northern portion of the Idaho batholith appears to be offset to the southeast along a broad northwest-trending zone (Fig. 6) defined by Laramide structures to the north and south of the Snake River downwarp, northwest-trending structures in metamorphosed Paleozoic and Mesozoic rocks, and northwest faulting in Washington, Oregon and northwestern Idaho. This offset is not shown on all maps, because many maps (i.e., Tectonic Map of the United States, 1961) include the large embayment of gneissic border rocks in the Middle Fork of the Clearwater-Selway-Lochsa River area (Anderson, 1930) as a portion of the batholith. An offset may exist, but as the intrusive relations and the actual size of the batholith are imperfectly known, the offset may be more apparent than real.

The outcrop of the main mass of the Idaho batholith extends from the Snake River downwarp northward through central Idaho and into western Montana. According to Ross and Forrester (1958), where observations can be made the sides of the batholith are rather steep and flare outward with no evidence of a floor or of contraction in depth. A number of plutonic masses which crop out to the south of the Snake River and on the eastern and western sides of the batholith are similar to and could possibly be extensions of the main batholith. To the north, large plutons, such as the Loon Lake and Nelson batholiths of northern Idaho, Washington, and British Columbia, are also similar to and appear to link with the main mass of the Idaho batholith. Most of the western, all of the southern, and part of the eastern borders of the batholith are blanketed by later volcanic and sedimentary rocks, and the batholith is probably much larger than surface exposures suggest.

The Idaho batholith is obviously composite. However, field mapping is difficult, sharp contacts are few, and such subdivisions that have been made are subtle and somewhat arbitrary. The overall composition of the batholith is between that of quartz monzonite and granodiorite, but variations as silicic as granite and calcic as quartz gabbro are included in the mass. Anderson (1942), suggests that the pluton was originally quartz diorite, and that endomorphism on a regional scale supplied potassium and silicon to the batholith. This implies that some of the chemical and textural inhomogeneties are due to variations in the intensity of this process. Certainly many of the original features and relations of the rock have been obliterated by this or some similar process.

The subdivision of the batholith into a complex, calcic gneissic border zone and a fairly homogeneous, silicic interior is also fairly obvious, although boundaries are difficult to locate and the gneissic border zone is not everywhere continuous. As would be expected in a complex plutonic mass with a long and involved tectonic history, cases can be made for both intrusion and granitization. There is little doubt that portions of the gneissic border zone have been granitized, but the origin of the entire batholith is still a matter of conjecture.

The age of the Idaho batholith is important in understanding the tectonic setting, but as the batholith cannot be closely dated geologically, its age is still a matter of controversy.

According to Eardley (1962), the Idaho batholith is similar in size and composition to the batholiths of the Nevadan orogeny and entirely dissimilar to the plutons of the Laramide belts. On the other hand, although the batholith is locally discordant with Laramide structures, an overall concordance prevails. This would imply that either the batholith was already consolidated to the extent that it served as a buttress around which Laramide structures formed --the discordant structures being due to later intrusions -- or that it shouldered aside adjacent surficial crust and formed the Laramide structures during emplacement. Ross (1963a) states, however, that it cannot be demonstrated that the oldest batholithic rocks are not as old as Jurassic, and that the emplacement could have taken tens of millions of years.

The western portion of the Idaho batholith intrudes Triassic strata. The remaining contacts with older rocks are either with the Precambrian Belt series to the north and northeast, or Paleozoic sedimentary rocks to the east and southeast. Much of the western portion of the batholith is overlain by Miocene Columbia River basalt, and all of the southern portion, by the Quaternary Snake River basalts, which fill the Snake River downwarp. Extensive Tertiary volcanics of a more acidic nature overlie a large portion of the eastern border. According to Axelrod (1966) the Challis Volcanics, which overlie much of the east-central border of the batholith, are Eocene in age. In the Casto Quadrangle these volcanics rest on a well developed erosional surface -- indicating a considerable time lapse since the batholith was unroofed.

McDowell (1966) in his work with K-Ar dating concludes that major portions of the pluton are early Cretaceous, and some portions may be of Jurassic age. However, he notes that major portions of the batholith have been affected by an 'uncharacterized' Eocene and a less definite Laramide thermal event.

It is reasonable to assume that such a large intrusive body as the Idaho batholith could have been emplaced or formed in more than one orogenic episode -- especially in an area that was a locus of intense igneous activity during all or part of at least two major orogenies. The batholith probably had its inception during the Nevadan orogeny, but as plutonic activity in the area was prolonged, it was probably enlarged or modified during subsequent tectonic activity.

During the Laramide orogeny the region east of the Idaho batholith became a plutonic realm also. Numerous masses, the largest of which is the Boulder batholith, were emplaced in western Montana south of the Lewis and Clark line. This zone of intrusion was extended during the Tertiary period across the Lewis and Clark line into north-central Montana to the northeast and across the southern portion of the Idaho batholith to the southwest. These Tertiary, and to a lesser extent, Laramide intrusives form the broad northeast-trending zone of igneous activity and associated structures known as the Idaho porphyry belt (Fig. 7).

Figure 7. Idaho Porphyry Belt

Relation of the Tertiary intrusives of the Idaho porphyry belt with the Idaho batholith and other igneous activity. The Idaho batholith and other Jura-Cretaceous intrusions are outlined. Tertiary plutons are black, and known Tertiary dike swarms are shown as short lines. Late Tertiary-Quaternary volcanoes and volcanic cones are illustrated as clusters. The approximate outline of the Idaho porphyry belt is shown by parallel lines.

After: Tectonic Map of the United States, 1961 with modifications.

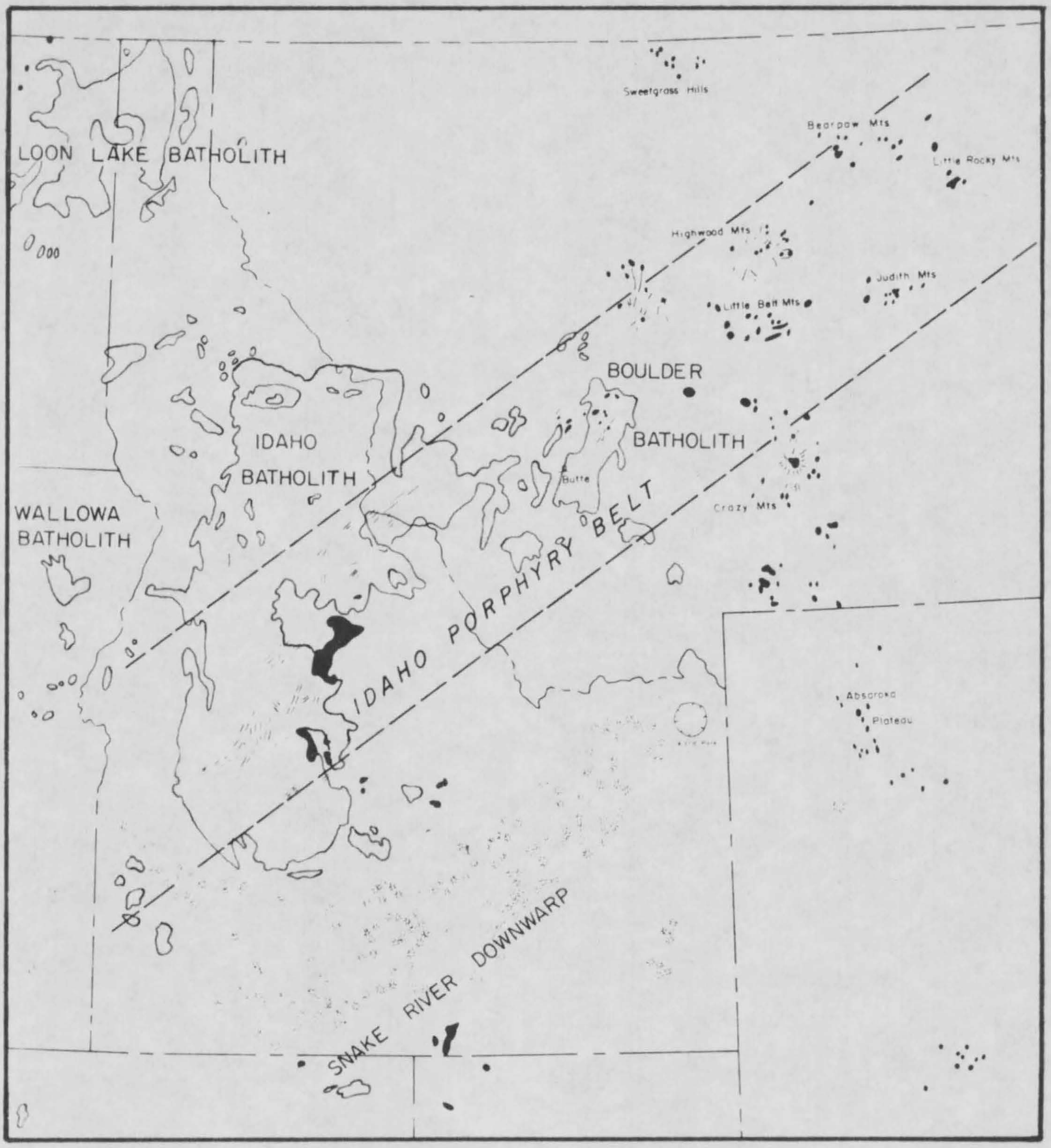


Figure 7. Idaho Porphyry Belt

The Idaho porphyry belt is transverse to the structural trends of the Cordillera. It probably originated in the Precambrian, and represents a major structural feature of the North American continent. The map area is in the southwestern portion of this belt.

ROCKS

The area between the Boise Basin and the Casto Quadrangle is a region of igneous rocks with relatively minor amounts of metamorphosed sedimentary strata. No unequivocal geological evidence exists within the area by which either the igneous rocks or the metamorphosed sedimentary rocks can be dated. Although several age dates are available from within the map area, they are not definitive in themselves, and are valuable mainly in establishing a Tertiary period of plutonism. Therefore, the tentative ages postulated herein are of necessity based in part on tenuous correlations with formations and igneous events outside the area studied. The evidence and reasoning used in determining the relative ages of the rocks are discussed in the section at the end of this chapter.

In the classification of the rocks, previous designations are followed unless conflicting evidence is established or different groupings used. Some erroneous designations based on early mining terminology are changed to conform with a standard rock classification. Because of the reconnaissance nature of the mapping, some generalization is necessary, and several rock types which probably could be further divided in a more detailed study are grouped under a single classification. Although more than one hundred thin sections were examined, and the resulting data used in naming the rocks, emphasis is placed in rock classification on criteria which can be recognized and used in the field.

The entire area is underlain by granitic rocks of the Idaho batholith. The batholith in the map area is fairly uniform in composition, but varies considerably in texture. However, as the main emphasis of this dissertation is the study of the Tertiary igneous intrusions, no attempt is made to define the intrusive details of the Idaho batholith. Metamorphosed inclusions and roof pendants of varying size are common throughout the northern part of the area. Although these represent a variety of rock types, they are grouped under a single classification on the geologic map (Fig. 8). A sequence of dikes and plutons of Tertiary age intrude the earlier rocks. The dikes in many places form massive swarms which are the most conspicuous geologic feature of the area.

Although the Challis Volcanics probably at one time covered portions of the area, they were not encountered during the mapping.

Recent surficial deposits were not studied in detail and were mapped largely from aerial photographs as unconsolidated sediments and glacial deposits.

Metamorphosed Sedimentary Rocks

Quartzites, marbles, schists, and lesser occurrences of gneisses and bands of calc-silicate rocks and amphibolites are common as inclusions and roof pendants throughout the northern half of the area. The metamorphosed sedimentary rocks vary in size from small blocks about ten feet in diameter to large blocks more than five square miles in area. The largest block forms the northeast side of Cape Horn Mountain and a portion of the south side of the Ruffneck Peak mass. Another large block, which is intricately intruded by batholithic and Tertiary intrusive rocks (Fig. 9), forms Bernard Mountain and probably caps the north-trending ridge which lies to the east of the Deadwood Mine. The blocks are foliated and in many places are highly contorted (Fig. 10). The larger blocks are usually highly limonite stained, and make conspicuous color anomalies on bare ridges and slopes.

Although some of the metamorphosed sedimentary blocks are composed of a single metamorphic rock type, most of the larger blocks are composed of interbedded rocks of the various types. Quartzite is by far the most common rock type. The quartzites are massive to thin bedded and are usually fairly clean. They commonly contain intercalated marble and calc-silicate members. In places, both the marble and the quartzite are highly graphitic. Biotite and mica schists are fairly common, whereas gneisses, which are

Figure 9. Metasedimentary Roof Pendant

Aerial view looking southwest of Bernard Mountain Ridge and the Deadwood Valley. A large metasedimentary roof pendant which forms the ridge to the northwest of Bernard Mountain is intricately diked by quartz monzonite of the Idaho batholith. The Deadwood Reservoir is in the background. The low narrow hills in the middle background are blocks lying between faults of the Deadwood River fault zone.

Figure 10. Contorted Quartzite and Schist Xenolith

Highly contorted interbedded quartzite and schist xenolith on Bernard Mountain. Rock in upper left hand corner is quartz monzonite of the Idaho batholith.

locally garnetiferous, and amphibolites are much less common.

These rocks have not been satisfactorily dated. Ross (1934) mapped blocks of quartzite and magnesian limestone to the south of Feltham Creek Point. He considers these to be Ordovician (?) in age because of their resemblance to the less metamorphosed sequence near Gilmore in Lemhi County described by Umpleby (1913a, 1913b, 1917) as Ordovician; to an equally metamorphosed assemblage of Ordovician age in the Bayhorse district (Ross, 1937); and to strata of Paleozoic (?) age in the Yellow Pine district (Schrader and Ross, 1926).

In the northeast corner of the Casto Quadrangle, Ross (1934) mapped quartzite, and quartzite with interfingering calcareous beds, which he considers to be Beltian in age, because of their extension from the Beltian mass mapped by Umpleby (1913a) in Lemhi County.

To the east of Pinyon Peak, about five miles to the northeast of the map area, Ross (1934) mapped a sequence of Ordovician (?) marble, quartzite, and magnesian limestones overlying a highly contorted schist with a pronounced angular unconformity. He considers the schist to be Algonkian in age mainly on the evidence of the angular unconformity, because he believes that unconformities between lower Paleozoic formations in Idaho and adjacent states show little or no angular discordance.

Larry Rychener (personal communication), who is currently working on the stratigraphy of the metasedimentary inclusions in the Cape Horn-Bernard Mountain area, considers the metamorphosed rocks to be certainly Paleozoic in age, because of the abundance of limestone. The quartzites appear to be lower Paleozoic and possibly correlative in part with the Kinnikinic Quartzite of Ordovician age. He further considers from work in the Pinyon Peak area, that no difference exists in the ages of the schists and the quartzites, and that the schists are not Algonkian.

It is obvious from the above discussion that insufficient data have been accumulated to permit absolute dating of the metamorphosed sedimentary rocks in the map area. As no work was done in this study to advance the understanding of this problem, these rocks are herein considered to be lower Paleozoic-Ordovician(?) in accordance with the thinking of Rychener and because of the proximity of rocks considered by Ross (1934) to be Ordovician (?). It is recognized, however, that these rocks may be wholly, or in part, Precambrian in age.

Idaho Batholith and Related Rocks

The exposed part of the Idaho batholith has an irregular rectangular form approximately 85 miles wide by 240 miles long in central Idaho and western Montana. Arms and isolated bodies of the batholith extend beyond the main mass, and may be connected with the batholith at depth. In the northern part of the batholith, many inliers of older rock are included within the mass. The outcrop of the batholith, including the inliers, covers an area of about 16,000 square miles. Approximately 85% of this area is composed of granitic rock.

The batholith is readily divided into a southern and northern part. According to Larsen and Schmidt (1958), the southern half is characterized by the relative absence of inliers, and is composed of a few huge bodies of granodiorite and quartz monzonite. The northern half contains many inliers, and individual bodies of granitic rock are smaller and more diverse in texture than in the southern portion. Although components of the Idaho batholith vary from quartz gabbro to granite, the principal masses range from quartz diorite to quartz monzonite. The average composition of the mass is estimated to be calcic quartz monzonite (Larsen and Schmidt, 1958). The subdivisions of the Idaho batholith were determined by Larsen and Schmidt (1958) during a road reconnaissance of the entire batholith, and are given below.

Rock Type	Percent (Approx.)	Estimated Area (Square Miles)
Quartz Gabbro	0.25	40
Tonalite	9	1,500
Granodiorite:		
Cascade type	11	1,800
Atlanta type	12.5	2,000
Fine-textured Quartz Monzonite	25	4,000
Fine dark Quartz Monzonite	2	300
Coarse Quartz Monzonite	37.5	6,000
Microgranite	0.25	40
Porphyroblastic Gneiss	2.5	400
TOTAL	100.0	16,080

Although the Idaho batholith forms an area of rugged mountains, weathering over large areas is quite deep and, except in recent roadcuts where deep soil cover is absent, outcrops are not common. Along steep slopes and in areas of restricted vegetation, the batholith weathers to a light brown to whitish, coarse, friable sand. Along ridges, boulders of disintegration are present but not common.

Quartz Monzonite Porphyry

Within the map area, the Idaho batholith is fairly uniform in composition, but varies considerably in texture and grain size. Although fine-grained, medium-grained and coarse-grained granitic granular facies are common, most of the rock is moderately coarse-grained and slightly porphyritic. In several areas in the northern portion and along the South Fork of the Payette to the east of Five Mile Creek, the rock becomes highly porphyritic (Figs. 11 and 12) with white and pink potassium feldspar phenocrysts attaining lengths of up to ten centimeters. Although facies of the batholith are uniform over large areas, in other areas textures and grain size vary erratically over short distances. Contacts between the various textural types were not observed, and differences in texture and grain size may represent slightly different facies and later deuteric porphyroblastic growths (Fig. 13) within an essentially uniform intrusive. The rock is unfoliated except near contacts of the larger metamorphosed inclusions (Fig. 14). In scattered localities rare biotite accumulations form schlieren.

The Idaho batholith in the map area is predominantly a speckled, white to light gray, quartz monzonite porphyry. Generally the rock contains about 30 to 35 percent quartz and between 1 and 5 percent biotite. The remainder

Figure 11. Porphyritic Quartz Monzonite of Idaho Batholith atop Bear Valley Mountain.

Porphyritic quartz monzonite of the Idaho batholith at the Lookout Tower atop Bear Valley Mountain.

Figure 12. Porphyritic Quartz Monzonite of Idaho Batholith along Bear Valley Road.

Porphyritic quartz monzonite of the Idaho batholith with exceptionally large porphyroblasts (?) of orthoclase, along road through Bear Valley about one mile east of the Deadwood River.

Figure 13. Potassium Metasomatism in the Idaho Batholith.

Coarse-grained, slightly porphyritic, quartz monzonite of the Idaho batholith cut by a thin pegmatitic dike of orthoclase reflecting possible post-consolidation potassium metasomatism. Note the large orthoclase porphyroblasts. In cirque wall at headwaters of Cliff Creek.

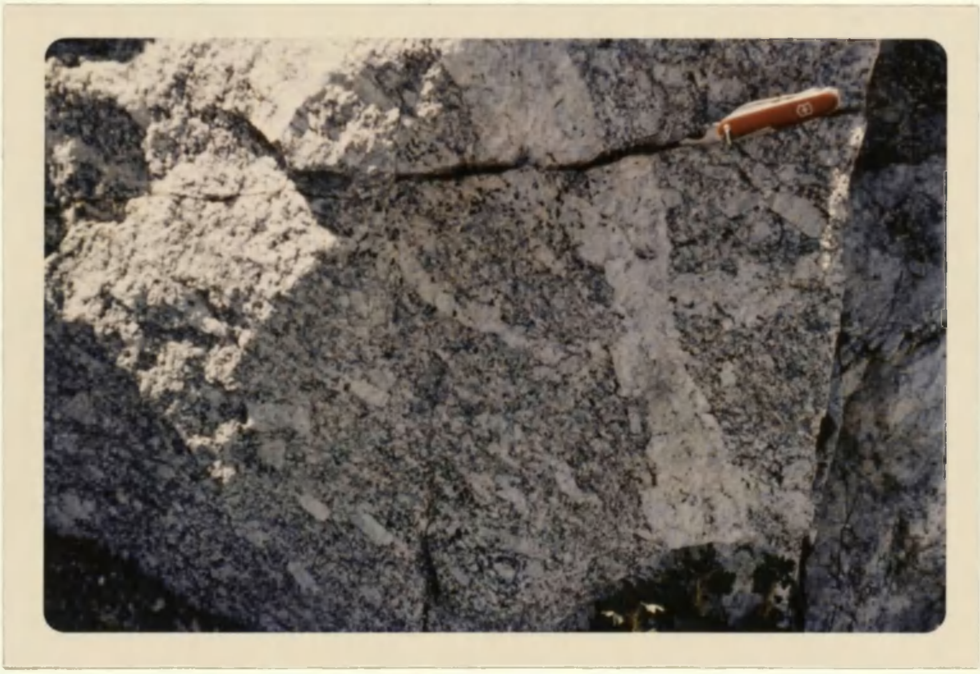


Figure 14. Foliated Idaho Batholith

Highly foliated, coarse-grained, porphyritic quartz monzonite of the Idaho batholith near a metasedimentary roof pendant in the Lola Creek cirque headwall.

of the rock is usually composed of nearly equal amounts of orthoclase and oligoclase. In some rocks, small amounts of muscovite and hornblende are present, and most rocks contain trace amounts of magnetite, apatite, zircon, and monazite.

Large quartz crystals are uncommon, and most of the quartz forms anhedral masses which are composed of an equigranular mosaic of smaller crystals. The feldspars are orthoclase and oligoclase. Both are usually white, but are less commonly clear, pink, or flesh-colored. The orthoclase is mostly untwinned, and is in part perthitic. It occurs as large subhedral phenocrysts or smaller anhedral crystals filling the interstices between the plagioclase crystals. Very large orthoclase phenocrysts appear to be porphyroblastic and may represent a period of post-consolidation potassium metasomatism. These crystals are usually partially filled with included remnants of quartz, oligoclase, and chloritized biotite. Oligoclase occurs as stubby euhedral to subhedral crystals around which most of the other crystals have formed. Biotite crystals are distinctly smaller than the feldspars and give the rock its speckled appearance.

The rock is usually fresh but shows some minor effects of deuteric alteration. The biotite is partly altered to chlorite along fractures and grain boundaries.

The feldspars are slightly altered to kaolin and sericite. Usually minor amounts of epidote and calcite are also present.

Pegmatites

Pegmatite dikes are widely scattered throughout the region. The dikes are usually small. Although thicknesses of several feet are common, most dikes are less than a foot thick (Fig. 15). The contacts with the surrounding batholith are commonly poorly defined, and are usually gradational over a short distance.

In the southern portion of the area, pegmatite dikes are noticeably flat-lying while those in the northern portion have a more variable attitude. The dikes are fairly evenly distributed throughout the area with the exception of the southern Bear Valley-Whitehawk Basin area, where they are exceptionally abundant.

Although the pegmatites are locally as variable in texture as the surrounding quartz monzonite of the Idaho batholith, they are usually coarsely granitic in texture with crystals varying from one-half to several inches in diameter. Occasionally the dikes are graphic in texture. Dikes showing both textures are relatively common.

The pegmatites are commonly pinkish with a greenish mottling. They are composed of about 30 percent each of quartz and oligoclase and about 20 percent each of

Figure 15. Pegmatite Dikes

Light, irregular pegmatite dikes form a stockwork in quartz monzonite of the Idaho batholith along highway #21 about 0.4 miles north of the South Fork of the Payette River along Canyon Creek. Note the rounded, friable weathering that is typical of rocks of the Idaho batholith.

microcline and muscovite. The quartz is gray, and forms anhedral masses composed of a mosaic of interlocking smaller crystals. Microcline is usually pinkish to flesh-colored and is in part perthitic. Oligoclase shows considerable alteration to kaolin. Muscovite occurs as interstitial shreds which give the rock its mottled appearance.

Garnet is a common accessory mineral and is usually found scattered throughout the dikes. In some instances garnet is quite abundant, and constitutes up to about 2 percent of the rock.

Although complex zoned pegmatitic lenses are reported in the Boise Basin to the south, all the pegmatites observed in the area are of the simple variety.

Aplite

Aplite dikes are common throughout the area, but are never conspicuous. Most of the dikes are thin and slightly irregular in outcrop. The rock is light-gray, whitish, or pinkish in color. Although occasionally the rock contains some pegmatitic streaks, the aplites are usually fine-grained, equigranular, and possess a distinct sugary texture.

Contacts between the aplite dikes and the quartz monzonite of the Idaho batholith are generally sharp. The rock differs from the batholith in that it contains fewer dark minerals and is less calcic in composition as would be expected of late-stage melts in a differentiating magma.

The aplites consist of an equigranular interlocking mosaic of quartz, albite, and orthoclase in approximately equal amounts. The albite is white and slightly altered to kaolin. The orthoclase is highly altered to kaolin and appears pinkish to flesh-colored. Interstitial sericite-muscovite composes a few percent of the rock volume and the remainder is made up of reddish garnet, trace amounts of magnetite and apatite, and rare biotite.

Tertiary and Tertiary(?) Intrusive Rocks

Small Tertiary and Tertiary(?) plutons are not common, and do not form a particularly conspicuous element of the Tertiary intrusive features of the map area. A small Tertiary(?) diorite stock in the Cape Horn-Ruffneck Peak area and a small Tertiary(?) quartz monzonite pluton in the Red Mountain area may be related to similar intrusive rocks in the Casto Quadrangle. One small satellitic pluton of the larger biotite hornblende quartz monzonite porphyry stock in the Boise Basin extends across the South Fork of the Payette into the southwestern portion of the map area.

To expedite the description of the rocks, the biotite hornblende quartz monzonite porphyry stock of the Boise Basin, herein, will be referred to as the Boise Basin stock. The related satellitic pluton in the map area will be referred to as Boise Basin quartz monzonite, and the related quartz latite porphyry dikes will be referred to as Boise Basin quartz latite.

Several small pink granite bodies are intrusive into the Idaho batholith along the Middle Fork of the Salmon, in the Bull Trout Lake area, and along the South Fork of the Payette in the southeastern portion of the map area. The intrusives along the South Fork of the Payette and in the Bull Trout Lake area are probably related to the pink granite of the Sawtooth batholith. The relation of the intrusive rocks along the Middle Fork of the Salmon are not as obvious, and these plutons may be related to either the Sawtooth batholith or to the pink granite batholith of the Casto Quadrangle.

Tertiary dikes are abundant throughout the map area, and form a nearly continuous band of intrusion between the intrusive centers of the Boise Basin and the Casto Quadrnagle. The dikes vary in composition from diabase, dark andesites, and fine-grained diorite through latite, quartz latite, and rhyolite. They were intruded as an imperfect differentiation sequence commencing with diorite, and becoming progressively more acidic with the passage of time. The sequence terminated in late rhyolites and basic dikes, and was followed by a later, perhaps unrelated, episode of diabasic intrusion. Some of the basic dikes may represent terminal phases of the Tertiary plutons.

Tertiary and Tertiary(?) magma was evidently intruded into an environment which became progressively cooler and more shallow with the passage of time. Because of extensive cover, contacts of the Tertiary and Tertiary(?) plutons with the Idaho batholith, with one exception, were not observed. The contacts may be highly complex or gradational, as frequently zones of intermediate or transitional appearing rock lie between readily recognizable rock types. With the exception of the Boise Basin quartz monzonite, the Tertiary and Tertiary(?) plutons are not conspicuously porphyritic. Contacts of the Boise Basin quartz monzonite were also not observed, but the conspicuous porphyritic texture and the development of an extensive dike system with marked contact effects indicates that the rock was intruded into a cooler and more shallow environment than were the earlier Tertiary and Tertiary(?) plutons. All Tertiary dikes exhibit chilling and many show flow banding not only against the Idaho batholith but also against previously intruded Tertiary rocks (Fig. 16).

With the exception of the Boise Basin quartz monzonite and the possible exception of the pink granite along the South Fork of the Payette, the plutons are intruded at the intersection of the northeast structural trend extending between the Boise Basin and the Casto Quadrangle intrusive centers and the northwest-trending zone of faults and fractures associated with the Sawtooth

Figure 16. Chilled and Flow Banded Contact of Rhyolite Dike

Rhyolite dike showing chilling and flow banding at its contact with the Boise Basin quartz monzonite along highway #17 about 1.1 miles east of Big Pine Creek.

batholith and Stanley Basin. Apparently, within the map area intersections of major structural directions provided favorable sites for the intrusion of plutonic masses, whereas areas of only one major structural direction were more favorable for dike intrusions.

Although Tertiary dikes in the map area are abundant, they are not ubiquitous, and tend to concentrate in swarms of varying preferred directions. The most prominent and conspicuous is the Boise Basin swarm which originates in the Boise Basin several miles to the south of the map area and crosses the South Fork of the Payette between Little Falls and Rattlesnake Gulch (Fig. 17) with trends varying between N15E and N30E. Farther north, the swarm assumes a N15E trend, and then swings N30E to N35E and continues to at least the Bernard Mountain area. Along the South Fork of the Payette, the swarm is composed mainly of Boise Basin quartz latite, Hell's Gate quartz latite porphyry, quartz latite porphyry, gray latite porphyry, and rhyolites. Most of the dikes terminate several miles north of the river, and only the Boise Basin quartz latite dikes continue on to the northeast.

An eastern branch of the Boise Basin swarm, the Miller Creek swarm, crosses the South Fork of the Payette in the vicinity of Lowman, and is named for the abundant exposures along Miller Creek. At the river, the swarm trends roughly N35E to N55E, but farther north assumes a

Figure 17. View of Boise Basin Dike Swarm from Hole-in-the-Wall Creek

Boise Basin dike swarm as seen from ridge west of Hole-in-the-Wall Creek looking northward toward Long Gulch. Limonite staining along road-cuts (bottom center) is not apparent. Although this area is approximately in the center of one of the most intense dike swarms in the map area, from a distance only a few discontinuous exposures may be inferred, and the great majority of the dikes have no apparent surface expression.

general N30E trend. It probably extends to and connects with the western portion of the Red Mountain swarm. The Miller Creek swarm is composed predominantly of quartz latite porphyry dikes, and lesser numbers of gray latite porphyry and Boise Basin quartz latite dikes.

The Red Mountain swarm radiates northward from the Tertiary(?) quartz monzonite pluton at Red Mountain. The swarm varies in trend from about N25E to about N15W. The northwest-trending dikes appear to swing to a more northerly direction in the Whitehawk Mountain area as they near the N35E-trending dikes of the Boise Basin swarm. The Red Mountain swarm is complex in composition. The western half is composed primarily of gray latite porphyry, Hell's Gate quartz latite porphyry and lesser numbers of gray quartz latite porphyry dikes. In the eastern half of the swarm, gray quartz latite porphyry and gray latite porphyry are the primary rocks with fewer dikes of rhyolite and minor numbers of Hell's Gate quartz latite porphyry. Near the eastern margin of the swarm, dikes related to the pink granite are common.

Dikes of nearly all compositions, except those of the Boise Basin quartz latite, are common in the Cape Horn-Ruffneck Peak-Blue Bunch Mountain area. This area is a structural crossroads, and many of the dikes in the Cape Horn-Blue Bunch Mountain area have northwest trends associated with structures related to the Sawtooth batholith and the Stanley Basin. The dikes in the Ruffneck Peak area have a N30E-N35E trend and probably represent a southwestern extension of the Seafoam Swarm. The Seafoam Swarm crosses the ridges to the south and west of Seafoam Creek, and possibly extends from the Ruffneck Peak area across Float Creek and the Rapid River in a general N30E to N35E trend. The swarm assumes a N15E to N20E trend to the north.

Diorite dikes are common in the Ruffneck Peak area in the vicinity of the Tertiary(?) diorite stock, but do not extend beyond the Ruffneck Peak mass. Rhyolites are most abundant, and lesser numbers of gray quartz latite porphyry and gray latite porphyry are common in both the Seafoam Swarm and the Cape Horn-Ruffneck Peak-Blue Bunch Mountain area.

The Cliff Creek swarm crosses the north-trending ridge to the west of the headwaters of Cliff Creek. It is a very dense swarm that trends N55E to N65E, and may extend as far to the southwest as the Ruffneck Peak area. It is composed mainly of gray quartz latite porphyry and gray latite porphyry. Lesser numbers of quartz latite porphyry and rhyolite dikes are also abundant.

The Beaver Creek swarm crosses the "U"-shaped ridge at the headwaters of Beaver Creek to the south of Feltham Creek Point. The swarm trends N20E to N35E, is very dense, and is composed primarily of rhyolites and minor numbers of gray latite porphyry and quartz latite porphyry dikes. The swarm forms the limonite-stained eastern limb of the "U"-shaped ridge (Fig. 18) which is one of the most prominent expressions of Tertiary diking in the map area.

The dikes and stocks ordinarily have inconspicuous outcrops and do not form linear features which can be recognized on aerial photographs except in certain very restricted areas. They are identified and traced mainly by weathered fragments in the soil. Rubble outcrops are common, but are generally less conspicuous than that illustrated in Figure 19. Less commonly the dikes form prominent outcrops along ridges and valley sides (Fig. 20). The spectacular dike walls which crop out along the South Fork of the Payette (Fig. 21) are not common, and were not noted elsewhere in the map area.

The various dikes do not form uniquely distinctive outcrops or weathering fragments and, in mapping, it is usually necessary to examine fresh broken surfaces to identify the Tertiary rocks. Some of the dikes tend to form blocky to platy talus piles along valley walls. These can readily be identified at a distance as dike material rather than Idaho batholith. However, it is still necessary to examine the rock to identify the dike. Tertiary dikes do not always weather to form talus slopes.

The dike swarms generally do not make distinctive color or topographic expressions. The Cliff Creek swarm does not have any noticeable limonite staining, and was not

Figure 18. Beaver Creek Dike Swarm

View of limonite-stained ridge at the headwaters of Beaver Creek looking northeast. The ridge is cut by the N20E to N35E trending Beaver Creek rhyolite dike swarm. Staining is due to oxidation of minor pyrite associated with the rhyolites. Note that individual dikes do not make noticeable outcrops.

Figure 19. Rubble Outcrop of Quartz Latite Porphyry Dike.

Excellent example of the typical platy rubble outcrop of quartz latite porphyry in area of thin cover along ridge about 1.6 miles south of the Deadwood Lookout.

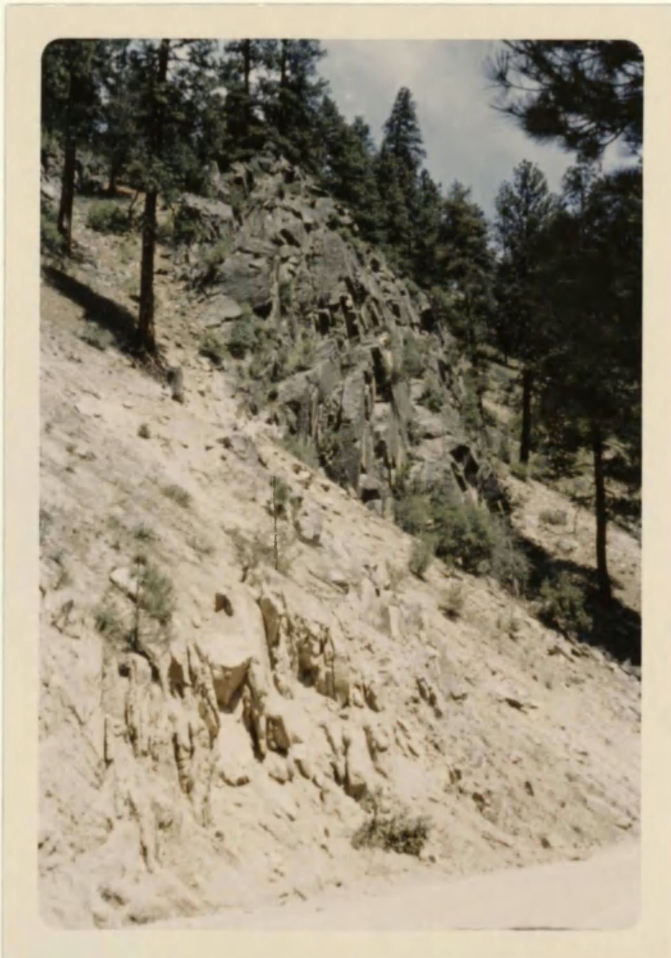


Figure 20. Prominent Outcrop of Gray Latite Porphyry Dike

Prominent outcrop of gray latite porphyry along highway #17 just east of the Deadwood River. Note gray latite porphyry dike in upper left-hand corner is an en echelon continuation of the dike in the foreground.

Figure 21. Large Rhyolite Dike

Large, slightly porphyritic rhyolite dike in a spectacular, massive outcrop along highway #17 about 1.4 miles east of Big Pine Creek. This is perhaps the most prominent single dike outcrop in the map area. Looking southwest across the South Fork of the Payette River.

recognized during the mapping until dike float was discovered in the creeks draining the area, and the ridges were traversed. Although minor limonite staining is readily noticeable on one of the ridges at Red Mountain, the main portion of the swarm is hidden in the forested area to the north of the mountain. The highly limonite-stained ridge crossed by the Beaver Creek swarm and the prominent outcrops and conspicuous limonite staining of the Boise Basin swarm along the South Fork of the Payette, are exceptions to the typical dike swarm expression in the map area.

Diorite

A small diorite stock and a limited diorite dike complex are restricted to the Cape Horn-Ruffneck Peak-Blue Bunch Mountain area. The contact of the diorite stock and the Idaho batholith is not well exposed, but apparently is a highly complex, and in part gradational, zone. The dikes vary in width from about 20 to 200 feet and average about 40 to 50 feet in thickness. Although they form conspicuous outcrops along ridges on the Ruffneck Peak mass and Blue Bunch Mountain, they are usually covered or make rubble outcrops on the lower slopes. The dikes are usually slightly more mafic than the stock, and may be younger. They were observed in apparent cutting relations along the ridge to the south of Ruffneck Peak, and are projected across portions of the stock along Marsh Creek. However, as the dikes appear to be fine-grained equivalents of the stock, and as both are compositionally and texturally similar in thin section, they are classified as a single rock type.

The diorite, as defined above, is similar to, but lighter than, the early Tertiary(?) pyroxene-hornblende-biotite diorite described by Anderson (1947), and is also similar to two small diorite plutons to the northeast which Ross (1934) describes as related to and essentially of the same age as the Idaho batholith. No evidence was found to precisely date the diorite as either related to the Idaho batholith or the Tertiary porphyry intrusives. Most of the Tertiary intrusive rocks cut the stock, and the stock is obviously older than these rocks. The diorite stock appears to be gradational into the Idaho batholith. The dikes, on the other hand, have well-developed chilled borders, and evidently were intruded into a much cooler environment. None of the more acidic porphyry dikes was observed cutting diorite dikes, and in only one instance was a basic dike observed to cut a diorite dike.

The diorite is assigned an early Tertiary age, mainly on the basis of its association with the center of Tertiary intrusive activity in the area. Also, the stock is aligned on a northeast trend with the two diorite plutons described by Ross (1934). The northeast trend is more characteristic of the Idaho porphyry belt, whereas the general trend of the Idaho batholith is north-south. However, the possibility exists that the stock may be related to the Idaho batholith, and the dikes are related to the basic intrusions which terminated the Tertiary porphyry intrusive episode.

The diorite is speckled black and white, and characteristically has a medium to coarse grain (stock) or fine to medium grain (dikes) equigranular texture. Small metasedimentary and dark igneous inclusions are common throughout the stock and are locally abundant (Figs. 22 and 23). Euhedral hornblende and biotite, and less commonly augite are intergrown with less distinct crystals of white to clear plagioclase. Glassy quartz averaging about one millimeter or less in diameter forms about five percent of the rock.

Microscopically the rock has a granitic granular texture. Stubby, subhedral to euhedral crystals of andesine, form an unoriented fabric with euhedral crystals of hornblende, augite, and shreds of biotite. Andesine, which is in part zoned, composes 30 to 75 percent of the rock, and usually varies between 50 and 60 percent. The mafic minerals vary between 30 and 45 percent in the dikes, and between 15 and 40 percent in the stock. Hornblende and biotite are commonly the most abundant dark minerals. Hornblende makes up 6 to 40 percent of the rock, and usually varies between 20 and 25 percent. Biotite is less abundant, and usually varies between 5 to 10 percent--

Figure 22. Quartzite Inclusions in Diorite

Quartzite inclusions in diorite stock along ridge above headwaters of Walker Creek.

Figure 23. Dark Inclusions in Diorite

Dark igneous inclusions, which are zoned in part, in diorite boulders in a talus pile to the west of Walker Creek.

although contents as high as 21 percent were noted. Augite is erratic in occurrence. In some places it is the most abundant dark mineral composing up to 22 percent of the rock. In other places it is absent. Minor anhedral quartz, and from 5 to 15 percent of orthoclase constitute the interstitial fillings. Less commonly orthoclase forms larger subhedral crystals. Small amounts of opaques, which locally form up to two percent of the rock, trace amounts of apatite, and rare zircon constitute the remainder of the rock.

The rock is largely unaltered. Augite commonly has hornblende rims of varying thickness. The mafic minerals commonly are slightly altered to chlorite, epidote, and calcite, and the feldspars show the effects of minor argillization and sericitization.

Granodiorite Porphyry

Only a single exposure of granodiorite porphyry was observed in the area. It crops out as a small pluton, approximately a quarter of a mile wide, along the South Fork of the Payette about a mile and a half east of Big Pine Creek near the center of the Boise Basin dike swarm. The rock is clearly intrusive into the Idaho batholith, as it can be seen in an excellent exposure in a roadcut along highway #17. The plug is cut by quartz latite porphyry and rhyolite dikes.

The granodiorite porphyry is a black and white, coarse-grained, slightly porphyritic, granitic rock. The phenocrysts are stubby white subhedral to euhedral laths of oligoclase, which are in part zoned, and range between six and eighteen millimeters in size. Biotite and hornblende are euhedral and vary in size from 0.5 to 2 millimeters. Hornblende is green and the biotite is brown in thin section. Quartz and untwinned orthoclase fill the interstices between the oligoclase and the mafic minerals, and often occur in micrographic intergrowths. Less than one percent of opaques and trace amounts of apatite and sphene make up the remainder of the rock.

The relative proportions of the original minerals are as follows:

Mineral	Percent
Quartz	15
Orthoclase	14
Oligoclase	35
Hornblende	20
Biotite	15
Opaques Apatite Sphene	1
TOTAL	100

The rock appears fresh in hand specimen. Microscopically the mafic minerals are replaced by trace chlorite. Oligoclase is altered unevenly: most grains are clear, but some are intensely altered to epidote and sericite. The orthoclase is unaltered.

Quartz Monzonite

A small stock of quartz monzonite crops out on the south side of Red Mountain. It is the only exposure of this rock observed in the area. The contacts of the stock were not exposed in the area traversed, and the relation of the stock to the Idaho batholith can only be inferred. The stock resembles some of the finer grained facies of the Idaho batholith, and may in fact represent a medium grained hornblende-rich facies of the batholith. However, as the rock becomes coarser grained and more porphyritic away from its inferred contact with the batholith, and occurs at the center of a partially radial swarm of Tertiary dikes, I consider the quartz monzonite to be Tertiary(?) in age.

The rock is similar to two small isolated Tertiary stocks in the Casto Quadrangle described by Ross (1934) as hornblende granite and quartz monzonite. The rocks described by Ross, however, contain microcline, whereas the potassium feldspar at Red Mountain is orthoclase.

The quartz monzonite is a speckled, whitish to flesh colored, medium grained, slightly porphyritic rock with a typical granitic texture. Near the inferred contacts the rock is equigranular, but toward the interior of the mass indistinct pinkish to flesh colored orthoclase phenocrysts averaging 8 to 10 millimeters in size are common, and give the rock a porphyritic appearance. Orthoclase makes up between 25 and 40 percent of the rock. Glassy quartz and clear to milky appearing plagioclase vary from about 2 to 4 millimeters in size. Quartz composes about 20 to 25 percent of the rock, and plagioclase varies between 30 and 40 percent. Smaller crystals of black biotite and hornblende vary from 0.5 to 2 millimeters in size. These mafic minerals form about 10 percent of the rock and give the rock its speckled appearance.

Microscopically quartz forms large anhedral phenocrysts and smaller anhedral crystals which occupy the interstices between larger crystals. Orthoclase forms large subhedral phenocrysts and smaller anhedral crystals. Untwinned crystals are usually more common than crystals with carlsbad twinning. The plagioclase is calcic oligoclase, which is in part zoned. The plagioclase tends to exhibit crystal faces more often than the orthoclase. Small shreds of brown pleochroic biotite and euhedral crystals of green pleochroic hornblende are equally abundant. Minor amounts of opaques, trace amounts of sphene, and rarer apatite and zircon compose the remainder.

The rock is relatively fresh. A small percentage of the mafic minerals are slightly altered to pennine chlorite. The feldspars are mostly unaltered, and only limited areas of minor sericite and clay minerals are scattered throughout the rock. Small grains of epidote are common, but are never abundant.

Pink Granite

Several pink granite stocks crop out in the eastern portion of the area. These rocks are similar to the pink granite batholith of the Casto Quadrangle, described by Ross (1934), and the pink granite of the Sawtooth batholith described by Reid (1963). These batholiths are probably related and the stocks probably represent outliers from these intrusive centers.

The largest of the pink granite stocks in the area lies to the west of Bull Trout Lake, and underlies an area of approximately 4 square miles. A smaller stock is well exposed along an east-trending ridge about two miles to the north. The contact of the northern stock is well exposed at Bull Trout Point. Here the contact is highly irregular, and forms a complex zone intruded by a network of limonite-stained aplitic dikes.

Another small pink granite pluton crops out on the west side of the Ruffneck Peak mass to the north of the diorite stock. Contacts here were not observed, and the southwest-trending elongated shape is postulated by inferring the continuation of the pluton to the large outcrop along Marsh Creek.

Several pink plutons of uncertain relation were also noted. These bodies resemble the Idaho batholith, but are distinguished from it on the basis of their color and lower calcium content. These rocks are generally coarse-grained, quartz monzonitic in composition, and are grouped with the pink granite mainly on the basis of color and the lack of features indicating potassium metasomatism to explain their low calcium content and pinkish color.

A small, coarse-grained, pink pluton crops out along the Middle Fork of Salmon to the southeast of the Soldier Lakes. This rock is borderline granite-quartz monzonite in composition. As contacts between the pluton and the Idaho batholith are covered, its relation to the batholith is not known.

Two other pink, coarse-grained, quartz monzonite plutons crop out along the South Fork of the Payette between Ten Mile and Warm Spring Creeks. The contacts of these plutons are also covered. However, as a wedge of pink granite intrudes the Idaho batholith along a roadcut on the west side of Ten Mile Creek (Fig. 24), the pink plutons along the South Fork of the Payette are probably intrusive into the batholith. These intrusions apparently are related to zones of crushing and pervasive chloritization which are described by Reid (1963) to be peripheral to the Sawtooth batholith. Also, Reid (1963, and personal communication) prefers to classify the Sawtooth batholith as a

Figure 24. Pink Granite Wedge Intruding Idaho Batholith

Pink granite wedge intruding coarse-grained, slightly porphyritic quartz monzonite of the Idaho batholith along Ten Mile Creek about 0.6 mile south of the South Fork of the Payette River.

quartz monzonite, and states that the northwestern portion of the Sawtooth batholith is difficult to distinguish from the Idaho batholith along the South Fork of the Payette.

The pink granite is a nearly equigranular, medium to coarse grained, pinkish to flesh colored rock, with a typical granitic texture. Grain size varies considerably, but except for biotite and the opaque minerals, most crystals measure between 2 and 10 millimeters in size. Quartz is abundant and conspicuous, and usually forms from 30 to 40 percent of the rock. Orthoclase forms slightly more than two-thirds of the total feldspar, and comprises about 40 to 50 percent of the rock. The orthoclase is mostly perthitic although crystals without albite exsolutions are common. Minor microcline is also present in some of the rock. Plagioclase in the oligoclase-andesine range forms about 20 percent of the rock. Biotite is the only mafic silicate mineral. It commonly forms small crystals a millimeter or less in size, and seldom forms more than one percent of the rock.

Microscopically the rock has a granitic granular texture. Quartz and orthoclase are mostly anhedral, and are in general slightly larger than the plagioclase crystals. Although the larger plagioclase crystals tend to be anhedral, most of the smaller crystals are subhedral. Biotite occurs as small brown pleochroic shreds. Minor amounts of opaques and rare amounts of apatite and zircon form the remainder of the rock.

The rock is essentially unaltered although some of the biotite is slightly altered to chlorite and the feldspars are often spotted with minor brown argillic dust and rare flecks of sericite.

Fine-grained, slightly porphyritic dikes with granitic compositions similar to the pink granites are apparently related to the pink granite stocks. These dikes were observed in the vicinity of the stock on the west side of the Ruffneck Peak mass, and are common to the west of the stocks near Bull Trout Lake where they have northerly and northwesterly trends. These dikes are generally about 10 feet wide, and are light fleshy-brown in color. Small pink and white feldspar phenocrysts average about 2 to 3 millimeters in size, and inconspicuous (one millimeter) rounded quartz phenocrysts are set in an aphanitic matrix with minor specks of biotite. The rock is relatively unaltered, and does not form prominent outcrops.

Gray Quartz Latite Porphyry

Grayish to light greenish-gray rocks with an aphanitic groundmass, numerous white feldspar phenocrysts, and smaller crystals of quartz, biotite, and/or hornblende are grouped as gray quartz latite porphyry. In outcrop, these rocks are similar in appearance to the Boise Basin quartz latite and to the gray latite porphyry dikes. They can be distinguished from the Boise Basin quartz latite dikes by their gray color, finer grained matrix, smaller less distinct feldspar phenocrysts, and their less altered appearance. They are distinguished from the gray latite porphyry, which they most closely resemble, by the presence of conspicuous, small quartz phenocrysts.

The rocks probably include some of the rocks described by Ross (1934) and Anderson (1947) as dacite porphyry. Although the gray quartz latite porphyry appears to be gradational into the gray latite porphyry, the rocks represent at least in part, two separate intrusive events as the two rocks were observed in parallel contact in one locality. At this location the younger, gray latite porphyry shows chill borders against, and apophyses into, the gray quartz latite porphyry.

The gray quartz latite porphyry forms dikes varying from about 20 to 200 feet in width (average 30 to 50 feet), and although most are probably shorter, appear to extend for at least one and a half miles in the prominent dike swarm at the headwaters of Beaver Creek. These dikes are restricted to the northeast half of the area, and are abundant only in the Red Mountain and Cliff Creek dike swarms.

The typical gray quartz latite porphyry is a gray to light greenish-gray porphyritic rock. It is characterized by numerous phenocrysts of chalky white andesine which vary in size from 1 to 5 millimeters and form 15 to 35 percent of the rock. Orthoclase phenocrysts with the same general size as the andesine are less abundant and form 5 to 15 percent of the rock. Total feldspar usually makes up 35 to 50 percent of the rock. Orthoclase in the groundmass varies from 20 to 40 percent. Round subhedral quartz phenocrysts are fairly prominent but are not numerous. They are usually 1 to 2 millimeters in diameter but attain maximum sizes up to 4 millimeters. They form from 5 to 20 percent of the rock, and usually average about 5 to 10 percent. The groundmass contains from 5 to 15 percent quartz and total quartz usually averages about 15 to 20 percent, suggesting a quartz latite classification. Small crystals of biotite and hornblende vary in abundance but usually represent about 15 to 20 percent of the rock. The groundmass is an aphanitic to fine-grained interlocking mosaic of feldspar and quartz. Less commonly myrmekitic, spherulitic and micrographic textures are present. Minor amounts of opaques, trace apatite and rare zircon compose the remainder of the original rock.

Rounded and embayed quartz phenocrysts which appear to be in the process of being resorbed are a characteristic feature of the alteration. They are similar to, but much larger than the corroded quartz of the gray latite porphyry. Biotite and hornblende alter to pennine chlorite, epidote, and less commonly to calcite. Biotite is usually completely altered whereas hornblende is commonly only partially altered or relatively fresh. The feldspars alter to sericite and a dense brown argillic dust.

Gray Latite Porphyry

Grayish and greenish-gray rocks with an aphanitic groundmass, numerous white plagioclase phenocrysts, and smaller crystals of biotite and/or hornblende are grouped as gray latite porphyry. The rocks vary from andesite and dacite to latite, and considerable variation in detail exists in the rocks thus grouped. A detailed study would doubtless result in subdivision. Microscopic examination, however, bears out the impression gained in the field that the resemblances are greater and more fundamental than the differences.

In outcrop, these dikes are similar in appearance to the Boise Basin quartz latite, but are recognizable by their gray, finer-grained matrix, the smaller, less distinct feldspar phenocrysts and more intense alteration. They also closely resemble the gray quartz latite porphyry, but can be readily distinguished from these rocks by the absence of conspicuous small quartz phenocrysts.

Umpleby (1913b) first described these rocks as diorite, but because of the fine-grained character of the groundmass and the constant presence of quartz, Ross (1934) preferred the term dacite. These rocks probably include most of the rocks described as dacite porphyry and andesite porphyry by Ross (1934) and the dacite porphyry of Anderson (1947). However, as quartz averages less than 10 percent, and is visible only under the microscope; and in the majority of the specimens examined the groundmass is predominantly composed of potassium feldspar, I prefer the classification of latite.

Gray latite porphyry dikes vary from about 3 to 150 feet in width and average between 20 and 50 feet. One dike was traced for about a mile, before it ended in a series of shorter en echelon dikes with exceptionally prominent outcrops. However, most of the dikes are probably much shorter, and the apparent lengths shown on the map are generalizations designated to illustrate the continuity of the dike swarms.

Anderson (1947) noted the diverse trends of these dikes in the Boise Basin, especially in the western portion where many of the dikes have a west-northwest trend that is essentially at right angles to the main trend of the porphyry belt. This west-northwest trend was also noted along the South Fork of the Payette and a northwest trend conforming to the structural direction of the Stanley Basin is a conspicuous feature of the dike pattern in the Cape Horn-Blue Bunch Mountain area.

The typical gray latite porphyry is light to dark gray on fresh surfaces and weathers greenish gray. It is characterized by numerous phenocrysts of white to clear andesine and smaller crystals of biotite and hornblende in an aphanitic groundmass. The andesine phenocrysts are commonly zoned, and vary in size from about 2 to 8 millimeters. They usually form from 20 to 50 percent of the rock. Biotite and hornblende commonly make up 10 to 20 percent of the rock, although local accumulations as high as 40 percent were noted. Biotite is usually more abundant than hornblende, but in at least one variety with a high mafic content, hornblende is the chief mineral. The groundmass is light to dark gray and usually composes 40 to 50 percent of the rock. It is composed of a very fine-grained interlocking mosaic of orthoclase and plagioclase, and scattered crystals of anhedral quartz. The amount of orthoclase varies between 5 and 45 percent of the total rock, and in the majority of thin sections examined, constituted greater than one-third of the total feldspar. Quartz is present as small interlocking crystals, and as rare, rounded and embayed crystals which appear to be in the process of being resorbed. Minor amounts of opaques and trace amounts of apatite and zircon make up the remainder of the original rock.

One of the main characteristics of the gray latite porphyry is its high degree of alteration. The biotite and hornblende commonly alter to pennine chlorite, and less commonly to calcite and epidote. The feldspars alter to sericite and a dense brown argillic dust.

Boise Basin Quartz Monzonite (Boise Basin Quartz Latite)

Although a biotite hornblende quartz monzonite porphyry, the Boise Basin stock, is the largest and probably the most conspicuous intrusive feature of the Boise Basin, only one small plug was mapped to the north of the South Fork of the Payette. It crops out along a roadcut about a mile to the east of Big Pine Creek and is perhaps about a half mile in width. Dikes which are related to the Boise Basin stock are abundant only in the western portion, where they form a broad, continuous NNE-trending swarm extending from the Boise Basin to at least Bernard Mountain--a distance of 36 miles. The dikes usually make rather inconspicuous outcrops, but can be easily traced from scattered outcrops and weathered fragments in the soil. In some places the dikes form massive outcrops such as are seen along the walls of the South Fork of the Payette valley to the east of Big Pine Creek, and along the road to the south of Deadwood Dam.

The dikes vary in width from about 10 to 200 feet, and may attain lengths of a mile or more. However, most of the dikes are probably shorter, and some of the apparent length may actually result from discontinuous intrusion along through-going fractures or slightly offset en echelon arrangements.

The Boise Basin quartz monzonite is a mottled pink, white, and greenish, coarse-grained, slightly porphyritic rock with a typical granitic texture. Large phenocrysts (up to 15 mm) of subhedral pink orthoclase and white oligoclase give the rock its mottled appearance, and usually compose about 60 to 70 percent of the rock. Orthoclase also occurs as interstitial filling. Oligoclase is commonly zoned, and usually represents about two-thirds of the total feldspar. Quartz is light-gray to glassy, and makes up about 15 to 20 percent of the rock. It occurs as rounded aggregates and in interlocking relationships with the interstitial orthoclase. Euhedral crystals of biotite (2 to 3 mm) and smaller euhedral crystals of hornblende compose about 15 to 20 percent of the rock. About 1 percent of opaques and trace amounts of apatite, sphene, and zircon make up the remainder of the rock.

The mafic minerals are usually slightly altered to chlorite along fractures and grain boundaries. Oligoclase usually contains traces of sericite and calcite, and the orthoclase is slightly altered to a brown argillic dust.

Boise Basin quartz latite dikes were probably intruded simultaneously, or nearly so, with the Boise Basin stock, and represent a fine-grained facies of the stock caused by more rapid cooling. The porphyritic dikes and the stock are similar in bulk mineral composition and differ mainly in texture and phenocryst composition. The dikes are pinkish and conspicuously porphyritic. Clear to white subhedral phenocrysts of oligoclase and small euhedral crystals of black biotite and hornblende are set in a fine-grained to aphanitic pink matrix. The groundmass is usually more distinctly granular than most of the other intermediate to acidic Tertiary porphyries, and is composed of a granular mosaic of altered orthoclase and quartz. The rock contains about 60 percent altered feldspar, 20 percent quartz, and 10 percent each of biotite and hornblende. Quartz is mostly in the groundmass, although it sometimes forms small corroded phenocrysts. Oligoclase phenocrysts usually compose 40 to 50 percent of the rock and represent about two-thirds of the total feldspar. Small amounts of opaques, apatite, sphene, and zircon make up the remainder of the rock.

The feldspar phenocrysts are usually so highly sericitized as to make Ab-An determination impossible. Mafics are commonly altered to chlorite and epidote, and the feldspars in the matrix are usually highly sericitized, argillized, and contain varying amounts of calcite.

Quartz Latite Porphyry

Light pinkish to greenish, bleached and limonite stained rocks with an aphanitic groundmass, prominent quartz phenocrysts, and rather indistinct phenocrysts of orthoclase and plagioclase are grouped as quartz latite porphyry. Some variation exists in the rocks thus grouped, and a more detailed petrographic study probably would result in a multiple classification. However, as the rocks are gradational through a series, and cannot always be separated in the field, subdivision would only represent a petrographic refinement. Two equally abundant varieties represent the majority of these rocks. A limonite stained, highly altered and bleached group is the most prominent in outcrop. A less altered, pinkish to greenish, more acidic variety represents the other group. These dikes are less conspicuous than the limonite stained dikes into which they may grade by increased alteration. The less altered dikes are commonly quite similar to the Hell's Gate quartz latite porphyry, which is described in the next section, and into which they may also grade. The Hell's Gate quartz latite porphyry contains large, scattered pink orthoclase phenocrysts. The lack of these conspicuous orthoclase phenocrysts serves to distinguish the quartz latite porphyry from the Hell's Gate quartz latite porphyry.

Quartz latite porphyry dikes are common throughout the area, and are especially abundant in the Boise Basin dike swarm. Limonite stained dikes of this group form the conspicuous brown bands along highway #17 between Rattlesnake Gulch and Big Pine Creek, and where abundant, make color anomalies along bare ridges and slopes. In areas of deep weathering the quartz latite porphyry usually fails to crop out but in areas of thin cover they can be readily traced by platy fragments in the soil.

The quartz latite porphyry dikes probably include some of the dikes described by Anderson (1947) as rhyolite porphyry. Anderson used the rhyolite classification largely to conform with local usage, although he noted that quartz latite would probably be a more correct designation for most of the group. The less altered dikes of this group, however, are borderline rhyolitic in composition, and the classification used is highly subjective. I have used the quartz latite designation because the majority of the dikes examined are quartz latitic in composition, and in all but the most altered rock, two types of feldspar can be recognized megascopically.

Although quartz latite dikes undoubtedly extend into the Casto Quadrangle, Ross (1934) does not describe similar rocks. The dikes evidently are too small to be included in his scale of mapping and Ross' emphasis seems to be on intrusive masses rather than on dikes and dike swarms.

The quartz latite porphyry occurs as dikes varying from about 10 to over 100 feet in width and averaging about 30 feet. The dikes show considerable textural variation and often show chilling and other contact effects. Some contact facies are difficult to distinguish from rhyolite dikes. Anderson (1947) described the dikes as narrow in proportion to their length and varying from 200 to 5000 feet in length. Although most are probably much shorter, several dikes in the vicinity of the Boise Basin and Miller Creek swarms are projected for over a mile in length.

The typical quartz latite porphyry is pinkish to greenish or highly bleached and limonite stained. It is characterized by numerous phenocrysts of rounded to dipyramidal quartz, less distinct phenocrysts of orthoclase and plagioclase and small chlorite or limonite pseudomorphs after biotite. The quartz phenocrysts are glassy and vary in size from 1 to 15 millimeters, but usually average between 3 and 5 millimeters. They form 5 to 20 percent of the rock. The feldspar phenocrysts are usually smaller than the quartz, and vary between 1 and 4 millimeters. Pink to flesh-colored orthoclase phenocrysts commonly form 10 to 25 percent of the rock. Whitish to greenish plagioclase phenocrysts are usually less abundant than orthoclase and compose between 10 and 20 percent of the rock. Small chlorite or limonite pseudomorphs vary between 0.5 and 2 millimeters and constitute the remainder of the visible crystals. The groundmass is aphanitic and even in the freshest rock appears to be highly altered.

Microscopically, the quartz phenocrysts are usually rounded, and are commonly embayed and surrounded by narrow reaction rims. Subhedral quartz crystals are common but less abundant, and frequently are dipyramidal. The feldspar phenocrysts are usually euhedral but, except in the freshest rock, are generally so highly altered that twinning is only faintly visible, and therefore, Ab-An determination is highly uncertain. As a generalization, untwinned and carlsbad twinned orthoclase are about equally abundant. The plagioclase phenocrysts in the limonite stained, bleached rock tend to be oligoclase-andesine in composition, whereas in the pinkish-greenish, fresher rocks, they tend to be oligoclase and perhaps albite. The fresher rocks are more rhyolitic in composition and the plagioclase content decreases to about 10 percent. However, as recognizable plagioclase is always present, the quartz latite classification is retained. Small biotite crystals are completely altered, and are inferred from the pseudomorphous alteration minerals.

The groundmass is usually an interpenetrating to granular mosaic of quartz and orthoclase. Less commonly radial feldspar spherulites or leaf-like structures occur. Some of these contain graphic intergrowths of quartz. The groundmass forms over 50 percent of the rock, and commonly contains slightly more orthoclase than quartz. Small quantities of magnetite, trace amounts of apatite, and rare sphene constitute the remainder of the rock.

The feldspar phenocrysts are usually highly argillized and sericitized, and although the groundmass is usually highly argillized, sericitization is usually not intense. In the bleached rocks, biotite is completely altered to muscovite, sericite and sometimes limonite. In the fresher rocks, biotite alters completely to pennine chlorite and sericite. Limonite staining as bands and accumulations is related to fractures and other porous areas of the rock, and is probably the result of late-stage solutions accompanying or closely following the intrusion of the dikes.

Hell's Gate Quartz Latite Porphyry

Quartz latite porphyry dikes with conspicuous large orthoclase phenocrysts are common throughout the Boise Basin and Red Mountain dike swarms. In the Boise Basin swarm, they form conspicuous outcrops on the walls of the South Fork of the Payette Canyon, and one dike forms the massive jagged wall known as "Hell's Gate" about a mile to the east of Big Pine Creek. To separate this distinctive quartz latite porphyry from other quartz latite porphyries in the map area, I propose the name Hell's Gate quartz latite porphyry in recognition of its most conspicuous outcrop.

The Hell's Gate quartz latite porphyry dikes in the Boise Basin swarm are confined to the southern portion of the swarm and do not extend as far north as the Valley County line. Hell's Gate dikes in the Red Mountain dike swarm are confined mainly to the western portion of the swarm and extend as far west as the east slope of Whitehawk Mountain and as far north as Sack Creek. The dikes are absent throughout the remainder of the area.

In outcrop, these dikes are similar to some of the relatively unaltered quartz latite porphyry dikes, but can be readily distinguished by abundant large orthoclase phenocrysts, and their unaltered appearance. They are included in the rocks described as rhyolite porphyry by Anderson (1947), who mentions their distinguishing characteristics, but classifies them along with the other quartz latite porphyries according to local usage.

The Hell's Gate quartz latite porphyry occurs as dikes varying from about 4 to over 100 feet in width. The lengths of these dikes were not determined, but the dike at Hell's Gate was observed to crop out more than 2000 feet along strike, and some dikes along Deadwood Ridge and at Red Mountain are projected over a mile in strike length.

The Hell's Gate quartz latite porphyry is a greenish to pinkish, fresh appearing rock with large pink to flesh colored phenocrysts of orthoclase, smaller phenocrysts of quartz and plagioclase, and scattered smaller crystals of hornblende and biotite. The quartz phenocrysts are rounded to subhedral and usually are glassy in appearance. They vary in size from 1 to 8 millimeters and usually make up about 10 percent of the rock. Prominent, large orthoclase phenocrysts, which are often widely scattered, are the most distinctive feature of the rock. Individual crystals reach lengths of up to 35 millimeters, but lengths of 10 to 20 millimeters are more common. These phenocrysts usually compose about 5 to 20 percent of the rock. They may, however, be lacking in individual hand specimens. Although plagioclase phenocrysts are numerous, they are usually inconspicuous as their color is frequently similar to that of the groundmass. Plagioclase phenocrysts vary in size between 1 and 8 millimeters and make up between 10 and 20 percent of the rock. Small crystals of greenish, chloritized biotite and hornblende are scattered throughout a fine-grained to aphanitic matrix. Biotite is usually more abundant than hornblende, although in some specimens biotite is absent and hornblende is the only mafic mineral. The mafic crystals usually vary from 0.5 to 2 millimeters in size with biotite crystals tending to be slightly larger than hornblende. Together, these minerals usually compose about 10 percent of the rock.

Microscopically, the quartz phenocrysts are usually rounded and commonly are surrounded by reaction rims of varying widths, or are extensively embayed by matrix minerals. Less commonly the quartz phenocrysts show partial crystal development. The plagioclase crystals are subhedral to euhedral, but are generally so highly altered that twinning is only faintly visible. Ab-An determination is, therefore, highly uncertain. The plagioclase, however, is probably oligoclase-andesine in composition. Orthoclase phenocrysts are also mostly euhedral but are not as highly altered as the plagioclase. They sometimes have reaction zones at their crystal faces, and frequently contain small areas of interstitial quartz. Although the small biotite phenocrysts are usually completely altered to chlorite, the hornblende crystals are almost completely unaltered, and form prominent euhedral crystals which are commonly twinned.

The groundmass is a felty to granular mosaic of nearly equal amounts of quartz and orthoclase with varying amounts of hornblende and lesser amounts of biotite. The groundmass usually forms slightly more than 50 percent of the rock. Small quantities of opaques, and trace amounts of sphene, zircon, and apatite constitute the remainder of the rock.

Although the feldspar phenocrysts are usually highly sericitized and argillized, and the biotite completely replaced by chlorite, the remainder of the rock is relatively unaltered. The groundmass is usually only slightly sericitized and some hornblende crystals are slightly chloritized along fractures and crystal boundaries. Small areas of calcite and some minor accumulations of epidote complete the alteration picture.

Rhyolite

Rhyolite dikes are fairly common throughout the area. They are especially abundant in the northeast, and are common in the Cape Horn-Blue Bunch Mountain area and to the east of Red Mountain. In the Little Falls area, they have so completely invaded the Idaho batholith that Anderson (1947) mapped the swarm zone as "intrusive rhyolite". Donovan (1962) estimates that rhyolite dikes form up to 50 percent of outcrop in the Little Falls area. He further postulates that only septa of the batholith remain at surface, and that essentially one composite mass of rhyolite underlies the Little Falls area at depth.

To the east of Big Pine Creek, the rhyolite dikes form conspicuous outcrops on the precipitous valley walls of the South Fork of the Payette. In all other portions of the area, however, the rhyolite dikes have inconspicuous outcrops, and are usually identified by a platy rubble similar to that of the quartz latite porphyry.

The dikes vary from grayish-white to light buff and pinkish, are fine-grained, not noticeably porphyritic in texture, and sometimes show flow banding. The groundmass varies from very fine-grained to sugary in texture. Phenocrysts are small and usually amount to less than 10 percent of the rock. They usually vary from 0.5 to 1 millimeter in size, but rarely attain lengths of 2 millimeters. The phenocrysts are mainly quartz and lesser amounts of indistinct feldspar. The quartz is commonly euhedral, but frequently is corroded and shows reaction rims. Orthoclase forms most of the feldspar phenocrysts. It is usually euhedral and frequently has carlsbad twinning. Smaller amounts of euhedral plagioclase, probably albite, are common in some of the rocks but are usually smaller than the other phenocrysts and never amount to more than a few percent.

The groundmass is a granular mosaic of potassium feldspar and quartz with individual grains varying from less than 0.01 to 0.05 millimeters in diameter. Spherulitic textures are common, and in some of the sections, the groundmass is more felty than granular.

Accessory minerals are not common. Sparse magnetite(?) and zircon are present in some of the rocks.

Most of the rock has been sericitized and locally the rock is impregnated with pyrite.

Basic Dikes

Of all the dikes that cross the area, the basic dikes are perhaps the most ubiquitous. They form a complex assemblage that was intruded from shortly after the consolidation of the Idaho batholith until the termination of igneous activity in the area. In general, they are dark, fine-grained, and too small to map on a regional scale. Although these basic dikes probably represent multiple periods of intrusion, they have been grouped under one classification because of their general megascopic similarity, and the lack of definitive field criteria which could be used to effect a meaningful classification.

Ross (1934) describes two ages of basic intrusions in the Casto Quadrangle: (1) pyroxenite and kersantite dikes related to the Idaho batholith and (2) lamprophyre (kersantite) dikes relating to and terminating Miocene(?) intrusive activity. Anderson (1947) also recognizes the same two ages of basic intrusion, which are represented by his early Tertiary(?) and lower Miocene lamprophyre suites. He, however, did not map these dikes and does not describe any petrographic feature which can be used to distinguish the suites. Anderson also describes three episodes of basaltic extrusion--lower Miocene volcanics, mid- or upper-Miocene Columbia River basalts, and Quaternary Snake River basalts--but does not report any intrusive equivalent to these flows.

In addition to the basic intrusions associated with the Idaho batholith and the Tertiary intrusions of the porphyry belt, Donovan (1962) identifies two late Tertiary(?) olivine-bearing diabases, but does not attempt to correlate them with extrusive basalts to the south in the Boise Basin. Reid (1963) recognizes a basic suite associated with the Tertiary Sawtooth batholith as well as diabasic dikes which he suggests acted as feeders to the flows of the Columbia River Basalt.

In the southern part of the area, an older series of basic dikes which may be related to the Idaho batholith, are thin, irregular in outcrop, and limited in strike distance (Fig. 25). To the north, similar dikes are also thin, but tend to be flat-lying (Fig. 26) and can be traced over longer strike distances. This attitude, along with the abundance of metasedimentary roof pendants and xenoliths, suggests that the level of the batholith now exposed in this area is near the roof, and that basic dikes are occupying flat-lying release tension joints.

A northeast-trending basic dike swarm is associated with the pink granite stocks to the north and west of Bull Trout Lake. These dikes occur in two sets--vertical and gently southeast-dipping--and may be related to the pink granite as late-stage intrusions into fractures related to doming and stretching of the consolidating pluton.

Younger basic dikes in the southern portion tend to be wider and steeper than the older basic dikes (Fig. 27), but are still somewhat irregular in size and erratic in outcrop. They are intimately associated with the other porphyry dikes and commonly lie in fault zones along the contact of porphyry dikes and the Idaho batholith. These basic dikes cut all other dikes except a later diabasic series, and may represent the terminal phase of the igneous event in which the rocks of the porphyry belt were emplaced.

Figure 25. Irregular Cretaceous (?) Basic Dike

A small, irregular Cretaceous (?) basic dike is intrusive into the Idaho batholith and is offset by minor faults, along the Deadwood River road about 2 miles north of the South Fork of the Payette River.

Figure 26. Gently Dipping Cretaceous (?) Basic Dike

A thin, gently south-dipping Cretaceous (?) basic dike on the ridge north of Lola Creek at Cape Horn Mountain. This dike probably occupies a release tension joint in the roof portion of the Idaho batholith. The northern end of the Stanley Basin is visible in the background.

Figure 27. Tertiary Basic Dikes

Three thin, irregular Tertiary basic dikes cut a large Hell's Gate quartz latite porphyry dike in road cut along highway #17 about 2.5 miles east of Big Pine Creek. The basic dikes are from one to four feet in thickness.

In the southern portion of the area, a series of thin vertical diabasic dikes cut the older basic dikes and all other rocks (Fig. 28). The diabasic dikes are similar to those described by Donovan (1962) and may be intrusive equivalents of extrusive basalts that are later than the porphyry belt. They probably represent the last igneous episode in the area.

These dikes are more mafic than the other more dioritic basic dike series.

The basic dike series described above suggests at least four episodes of basic intrusion into the map area:

(1) an older series related to a terminal post-consolidation event associated with the Idaho batholith,

(2) a series related to a terminal post-consolidation event associated with the pink granite batholiths and their satellitic stocks,

(3) a younger terminal series related to the porphyry intrusives of the porphyry belt, and

(4) a diabasic series later than the intrusions of the porphyry belt.

It was not possible during the mapping to relate many of the basic dikes to a particular series. Little is known of the petrography, petrology, and spatial relations

Figure 28. Diabase Dikes

Two thin diabase dikes cut a Tertiary basic dike in a road cut along highway #17 about 2.5 miles east of Big Pine Creek.

of the basic dike series, and much detailed mapping and petrographic study is needed to classify and to solve the complexities of the intrusive history of the basic dikes.

In hand specimen, the basic dikes are light gray, drab or dark gray-black, aphanitic to fine-grained, and commonly equigranular, with indistinct dark clots. Although most dikes appear very fine grained, in many of the dikes a mat of feldspar laths and hornblende needles is readily seen without the aid of a hand lens. Some dikes have prominent phenocrysts of plagioclase and hornblende, but most of the phenocrysts are small (less than 2 mm) and inconspicuous.

Most dikes are deeply weathered and are usually covered. One variety can be recognized by its distinctive nodular weathering.

Microscopically, the basic dikes usually have a slightly porphyritic felty fabric. The phenocrysts are generally plagioclase and brown hornblende needles, although less commonly augite, quartz, and pseudomorphs of calcite after augite or hornblende, or chlorite after biotite are prominent. With rare exceptions, the phenocrysts are generally not much larger than the matrix minerals.

The groundmass is usually composed of anhedral to subhedral laths of plagioclase, variable amounts of hornblende, augite, and biotite, and relatively large amounts of magnetite and other opaques. Most of the rocks contain some disseminated pyrite and the more felsic dikes commonly contain small amounts of highly corroded interstitial quartz. Plagioclase usually forms at least 50 percent of the rock, but often appears more abundant than it actually is. Plagioclase laths are often highly zoned and vary in composition from oligoclase to calcic andesine.

The diabasic dikes contain labradorite, hornblende, magnetite, and variable small amounts of olivine.

Secondary calcite is abundant in most of the dikes and chlorite is usually present in variable but lesser amounts. The plagioclase is usually at least partially argillized and less frequently is slightly sericitized.

Quaternary Sediments

Unconsolidated sediments were not studied in detail, and were largely mapped from aerial photographs during the course of the field mapping. Probably most of the sediments are Pleistocene to Recent in age, and represent erosional products deposited by glaciers, streams, or combinations thereof. Material mapped as alluvium on Figure 8 includes all unconsolidated detrital deposits except that which can be clearly distinguished on the basis of form and association as glacial in origin.

Pleistocene Glacial Deposits

Glaciers were widely distributed over the northern portion of the area, and probably most of the valleys reaching altitudes in excess of 8000 feet had glaciers at their heads. Although some of the glaciers, such as those which occupied the valleys of Soldier, Float, and Cache Creeks, and the headwaters of Warm Spring Creek to the south of Bull Trout Lake, attained lengths of several miles or more, nearly all the glaciers were small, and evidently never extended much beyond the cirques in which they originated.

As can be seen by the arrows indicating direction of ice movement on Figure 8, most of the glaciers in the area were concentrated on north to east facing slopes in the high country in the northeastern portion of the area extending from Cape Horn Mountain to the Soldier Lakes area. This is the highest portion of the area with ridge and peak elevations exceeding 9000 feet. Other centers of glaciation include the high country to the south of Bull Trout Lake, Red Mountain, Whitehawk Mountain, Bernard Mountain and the high ridge to the west of Elk Meadow. Except for the glaciers which flowed northward down the steep narrow valleys from the Soldier Lake area, the glaciers seldom extended below 7000 feet in elevation.

U-shaped valleys are not common, and when present, seldom extend far from the cirque area of the larger glaciers. Glacial striae are common near the cirques on bedrock exposures high in the glaciated valleys, but are not abundant. Except where glaciers extended into the intermontane valleys, such as at the mouth of Cache Creek and along the western side of Elk Meadow, glacial detritus was deposited in steep, narrow valleys, and consequently much of this material has been removed or highly modified by stream erosion. The alluvium that floors many of the cirques is largely reworked glacial debris, and much of the gravel downstream is of fluvio-glacial origin. Large glacial erratics, such as are found in Elk Meadow, indicate that locally the outlets to restricted valleys may have become dammed and short-lived lakes formed behind the barriers.

Williams (1961) dates three major ice advances of Wisconsin age in the Stanley Basin, and gives evidence suggesting pre-Wisconsin glaciation. He also mapped small cirque moraines of Recent age on some of the higher peaks. Mackin and Schmidt (1953) in their work in Bear Valley, found no evidence of early Pleistocene glaciation, but on the basis of form and degree of erosion and weathering were able to differentiate two stages--Illinoian (?) and Wisconsin--of late Pleistocene alpine glaciation.

In the map area glacial moraines are composed of unsorted and unstratified clay, sand, and gravel, and subangular to subrounded cobbles and boulders. This material is mostly quartz monzonite of the Idaho batholith, but material contributed by the Tertiary dikes and metasedimentary roof pendants are common. In the steep narrow valleys the moraines are highly eroded and dissected, but at the valley mouths, the moraines are little altered by erosion.

Quaternary Alluvial Deposits

Material mapped as Quaternary Alluvium includes both older and recent sediments, and includes terrace gravels, alluvial fans, valley fill, and stream sediments. Terrace gravels are a conspicuous feature of the area, and are especially well developed along the South Fork of the Payette valley. These discontinuous gravels mark the stages in the process of valley formation. Ross (1934) reports five well-defined terrace remnants along the Middle Fork of the Salmon in the Casto Quadrangle and Anderson (1947) reports three fairly well defined, and possibly a fourth, terrace level along the South Fork of the Payette. All the terraces are cut in rock, and some are capped with thick sections of sand and gravel. The thick sedimentary sections are usually confined to the lower terraces, and the higher terraces are usually characterized by a thin veneer of coarse gravel.

In the major drainages, the younger alluvium is largely confined to the valley floors, and consists in part of reworked terrace gravels. The larger intermontane valleys, such as Big Meadow, Elk Meadow, and Bear Valley are filled with the clays and silts, and the coarse sands gravels, and cobbles deposited by aggrading streams carrying the products of the Pleistocene glacial outwash. The present streams are currently reworking this material along narrow meander belts.

Age Relations

As is evident from the preceding detailed descriptions, many of the igneous rocks are either not in physical contact or their contacts are covered. Field evidence showing one rock intruding or cross-cutting another is limited, and age relations are, therefore, imperfectly known. The following briefly summarizes the evidence and reasoning used to establish the mutual relations of the various rocks.

Potassium-argon radiometric age determinations reflect a period of intense igneous activity 40 to 50 million years ago. During this time, pre-existing biotite and hornblende crystals were altered to record this later thermal event, and potassium-argon determinations are of value mainly in establishing an Eocene, and possibly an Oligocene period of plutonism. The following dates were determined by the potassium-argon method (Percious, Damon, and Olson, 1967) from rocks in and adjacent to the Boise Basin dike swarm along highway #17, west of Lowman:

Rock	Age in M.Y.
Boise Basin quartz monzonite	48.0 ± 1.4 (biotite)
Idaho batholith	44.8 ± 1.3 (biotite)
Granodiorite	44.0 ± 1.3 (biotite)
Quartz latite porphyry	38.5 ± 1.2 (whole rock)

The number of age determinations from rocks in the general area is limited, but published dates substantiate the Eocene-Oligocene (?) thermal event. Ross and Forrester (1958) report a granite porphyry along the South Fork of the Payette to the west of Lowman gives a zircon lead-alpha age of 33 million years. The granite porphyry probably is either the Hell's Gate quartz latite porphyry or a quartz latite porphyry of this study. Axelrod (1966) reports a whole rock potassium-argon age of 49.0 ± 2.0 million years in the Challis Volcanics, and Ross and Forrester report a 59 million year zircon lead-alpha age of the pink granite in the Casto Quadrangle. Hamilton and Myers (1967), however, note that portions of the Challis Volcanics are metamorphosed by intrusion of the pink granite, and that the Challis Volcanics must, at least in part, predate the pink granite.

Although positive correlation with sediments outside the map area may be extremely difficult to prove, the metasedimentary roof pendants and xenoliths are tentatively assigned an Ordovician (?) age on the basis of Ross' (1934) study, and unpublished work by Rychener. The Idaho batholith is considered to be mainly of early to mid Cretaceous age on the basis of the radiometric age determinations of Larsen and Schmidt (1958) and McDowell (1966).

The diorite, quartz monzonite, and pink granite are cut by gray quartz latite porphyry dikes, and a gray latite porphyry dike intrudes the contact between the granodiorite and the Idaho batholith. The gray quartz latite porphyry is not intruded into the southern portion of the map area, and as the diorite, granodiorite, quartz monzonite, and pink granite are not in physical contact with each other, their relations and relative ages are uncertain.

The diorite and quartz monzonite are similar in texture to the Idaho batholith, and may represent related small mafic plutons. These plutons as well as the granodiorite are assigned a tentative Eocene (?) age mainly on their association with Eocene dike swarms and their alignment in a northeasterly direction which is more typical of the distribution of Tertiary intrusions than the northerly alignment of the Idaho batholith. The diorite dikes which locally cut the diorite stock are later than the stock, but appear related to it in composition, texture, and spatial relations.

The pink granite is assigned an Eocene age on the basis of its petrographic similarity to the Eocene pink granite batholith in the Casto Quadrangle.

The gray latite porphyry probably represents several closely related rock types. A gray latite porphyry dike cuts a gray quartz latite porphyry dike in the Cliff Creek swarm, and the gray latite porphyry must be at least in part younger than the gray quartz latite porphyry. The relation of the gray latite porphyry to the Boise Basin quartz monzonite is less obvious, as these rocks were not observed in mutual contact. The gray latite porphyry is probably the same rock as the dacite porphyry described by Anderson (1947). Anderson observes the dacite porphyry in intrusive relations to the pyroxene hornblende biotite diorite, but not to the younger Boise Basin stock. On this basis, he considers the dacite older than the Boise Basin stock, and for lack of conflicting evidence, I have assigned the gray latite porphyry a pre-Boise Basin quartz monzonite age.

The Boise Basin quartz monzonite is intruded by quartz latite porphyry, Hell's Gate quartz latite porphyry, rhyolite, and several varieties of basic dikes. The relation between the quartz latite porphyry and the Hell's Gate quartz latite porphyry is uncertain as these rocks were not observed in mutual contact. Rhyolites and basic dikes cut the quartz latite porphyry, and the Hell's Gate quartz latite porphyry is considered older than the rhyolites on the basis of its possible gradation into the quartz latite porphyry. Basic dikes were observed to cut both the Hell's Gate quartz latite porphyry and the rhyolite dikes.

The basic dike assemblage is complex and probably represents a number of intrusive events. Although spatial relations suggest that some of these dikes may be terminal phases of the Idaho batholith and the pink granite, intrusive relations with all Tertiary igneous rocks indicate that the majority of the basic dikes are younger than the rhyolites, and that a diabasic series is younger than the other basic dikes and may be unrelated to the Eocene-Oligocene (?) plutonic activity.

The main period of intrusive activity in the map area apparently terminated in the Oligocene (?), but some of the diabasic series may represent feeders to the extrusive Columbia River or Snake River basalts. If this is so, the diabasic dikes could possibly be Miocene or even Quaternary in age.

STRUCTURE

The map area is in a zone which has been subjected to repeated and complex structural adjustment throughout much of geologic time. The structures of the map area are probably controlled by ancient major north, northwest, and northeast fractures which may be related to the pattern of regmatic shearing in the crust of the earth. The north direction is characterized by the north trend of the Idaho batholith, the north trends of the Basin and Range structures of Nevada, and by major north-trending shears and normal faults in and on both sides of the Idaho batholith.

Northwest-trending structures of the deformed belt of southeastern Idaho appear to terminate against the batholith, but are more prevalent in the batholith than is shown by the Tectonic Map of the United States. The Sawtooth fault, and the Stanley Basin are strong northwest-trending structures. West-northwest-trending structures of the Lewis and Clark line and the northwest trend of the Cordilleran front bound the batholith to the north. Northwest-trending faults and volcanic flows form the apparent boundary of the Idaho batholith to the southwest.

Northeast-trending structures are prominent and complex in the map area. These structures are characterized by the northeast-trending fractures and aligned intrusions of the Idaho porphyry belt. The northeast trend of the Snake River downwarp and volcanic field forms the apparent boundary of the Idaho batholith to the south and southeast.

An east-west structural trend crosses the map area, but is not well defined in the Idaho batholith.

Evidence of pre-batholith deformation exists only in scattered and complexly folded metasedimentary roof pendants. Structures formed since the consolidation of the Idaho batholith consist of complex dike and fracture patterns, and a well developed system of intermontane basins. However, in the map area, the Idaho batholith is fairly uniform, reliable stratigraphic markers are basically absent, only a small percentage of rock is exposed, and structural data are insufficient to completely establish the nature and timing of the periods of deformation. Because of this difficulty, the various structural elements are described separately rather than in relation to specific rock types or periods of deformation.

Contacts and Inclusions

The map area is in the central part of the Idaho batholith and consequently contacts of the batholith with the surrounding country rock were not observed. Tertiary igneous rocks were intruded into well consolidated rocks of the batholith as intrusive features such as sharp contacts, apophyses, wallrock inclusions, chilled borders, banding, and parallel alignment of phenocrysts and the wallrock are common in those Tertiary intrusions seen in contact with the batholith.

The southern part of the map area is apparently free of inclusions, but large and small xenoliths and roof pendants of metamorphosed sedimentary rocks are common in the northern portion of the Idaho batholith. These inclusions are concentrated in a broad arc which extends from the Cape Horn-Ruffneck Peak area to the Bernard Mountain area. Contacts are sharp, and features indicating assimilation or melting of the inclusions are not widespread.

Flow Structures

Flow structures in the Idaho batholith are not readily apparent in the map area, and especially in the southern part, the rocks appear to be virtually structureless. Some aligned feldspar phenocrysts and schlieren are present in rocks of the Idaho batholith, but data are not sufficient to classify these as linear or planar features. Schlieren are apparently quite rare in this portion of the batholith, and as they were observed only in talus accumulations, their alignment in the batholith was not determined. In the northern part of the map area planar features are locally conspicuous, but were not mapped in great detail.

Foliation

Gneissic structures in the Idaho batholith are well developed in the vicinity of the metasedimentary roof pendants and the larger xenoliths, and are in general concordant with these blocks. The intensity of the foliation, however, rapidly diminishes with distance from the blocks, and grades into megascopically directionless facies which are characteristic of inclusion free portions of the batholith in the map area.

Gneissic and schistose structures are also well developed in the metasedimentary inclusions, and foliation in the roof pendants is generally concordant with foliation in the Idaho batholith. In the Cape Horn-Ruffneck Peak area, foliation in the roof pendants generally trends northwest and dips moderately to the northeast; in the Gates Creek area it is aligned in a northeasterly direction and dips steeply to the northwest; in the Bernard Mountain area, foliation generally trends to the northwest with variable dips.

Foliation was not noted in any of the Tertiary plutons.

Fractures

The map area is highly fractured. Jointing is common, and is easily recognized. On the other hand, faulting, although probably abundant, is rarely seen in outcrop and usually must be inferred.

Zones of weakness caused by fracturing control the drainage pattern in the map area. In addition to the linear nature of the drainage pattern, fracturing produces other topographic lineations which can be readily identified by stereoscopic examination of aerial photographs. Although fracturing in the less prominent and continuous linears may represent either faults or closely-spaced joint sets, the stronger, continuous linears probably represent major faults or fault zones.

The fracture pattern shown on Figure 29 is a photogeologic interpretation of topographic lineations. The more pronounced and continuous lineations are shown by wide continuous lines. Less pronounced and shorter lineations are thinner and dashed.

Rose diagrams of joint directions are superimposed on the fracture pattern, and rose diagrams of all measured joints and dikes are included to illustrate the relation between jointing and igneous intrusion. These diagrams are drawn to scale and reflect not only the relative amount of data collected, but also the relative intensity of fracturing and igneous intrusion in the various areas.

Quaternary sediments are shown to emphasize major drainages, and to illustrate basin areas.

Joints

Of all the structural elements observed, joints best illustrate the complexity of structural deformation. Joints are ubiquitous in all crystalline rocks, but are not everywhere abundant. Jointing is concentrated in the vicinity of the dike swarms and in areas of structural intersections. In areas of intense jointing, the main set may be so closely spaced that the joints resemble sheeting. Although in most instances two or three joint sets are well developed, several other less well-developed sets are generally readily apparent.

Although most joints show no visible evidence of movement, some joint surfaces have slickensides and some sets which closely parallel fault zones show minor movement.

As can be seen on Figure 29, the joints form a system with dominant sets trending N10-25E and N35E. Subordinate joint sets are oriented E-W, N60E, N80E, N20W, and N40W. The joints are predominantly steeply dipping. More than 80 percent of the joints measured dip 60^{o} or more.

Faults

Fault zones throughout the map area are usually covered and relatively few faults were actually observed in outcrop. Consequently, much of the character and abundance of faults in the map area is inferred from faults observed in excellent exposures along highway #17 to the west of the Deadwood River, and in roadcuts along the Deadwood River north of the South Fork of the Payette. Faults are common throughout these exposures, and are especially abundant in the vicinity of the dike swarms. Many breaks resemble joint sets, but can be recognized by well-developed slickensides, and minor apparent displacement of aplite and pegmatite dikes. Faults associated with dikes have gouge zones up to ten feet in width and show abundant slickensides, but displacements are apparently relatively small as planar features associated with the batholith do not show extensive offsets. The gouge zones are usually associated with rubble-covered areas or gulleys, and in some places could be related to well-developed drainage directions. In the dike swarms, faults commonly were noted along both sides of the larger dikes.

The northwest-trending Sawtooth fault (Reid, 1963) is a major component of an important structural feature which crosses the northern portion of the map area. Its eastern side is downthrown, and forms the Basin and Range type block fault valley of the Stanley Basin. Northwest and north-northwest-trending fractures associated with this feature extend across the map area, and influence dike emplacement in the Cape Horn-Blue Bunch Mountain area. The northeastern end of the basin is broken and offset by a number of northeast-trending fault zones and is abruptly terminated by the strong northeast-trending faults which control the Cape Horn and Beaver Creek drainages (Fig. 30).

Figure 30. View of Stanley Basin

View of the northwest end of the Stanley Basin looking southeast from a ridge south of Ruffneck Peak. Low, rounded tree-covered hills are underlain by the Idaho batholith. The rugged Sawtooth Mountains in the right background are formed by the Sawtooth batholith. The Sawtooth fault passes between the range front and the low tree-covered hill in the center middle ground. Marsh Creek flows along the northwest-trending grass-covered valley. Beaver Creek Valley is in the foreground and is controlled by a northeast-trending fault. Knapp Creek in the middle ground is also controlled by a northeast-trending fault.

Anderson (1934) describes a major north-trending fault which crosses the South Fork of the Payette at the confluence of the Deadwood River and extends northward along the west side of the Deadwood Reservoir. Anderson postulates the existence of his "Deadwood" fault, on the basis of topography and considers the movement to be normal with the west side upthrown.

No evidence for the existence of a fault as described by Anderson was found during the mapping. However, an extremely weak but continuous north-trending lineation crosses the South Fork of the Payette to the east of the confluence of Deadwood River, and merges with the postulated trend of the Deadwood fault in the vicinity of the Deadwood Reservoir. There does not appear to be any topographic offset along this lineation, and the lineation, if it is a reflection of faulting, is probably a continuation of a postulated fault which controls the Deadwood River drainage to the north of the reservoir.

The postulated fault zone along the Deadwood River to the north of the reservoir has no apparent vertical topographic offset, and the dominant movement is probably horizontal. The zone appears to break up at its southern end into a number of normal faults which form the Deadwood Reservoir basin.

North-trending fault zones, although not so well developed as the fault along the Deadwood River, appear to have terminated in normal faults and to have formed the Bear Valley-Sack-Cache Creek and the Bruce Meadow basins (Fig. 31). Although no strong evidence of faulting was noted, the general north-south alignment of Big Meadow, Bearskin Creek Valley, and Elk Meadow suggests that these basins are structurally controlled. Similarly the east-trending valley between Bearskin Creek and Bruce Meadow is probably also structurally controlled.

As can be seen in Figure 29, many of the less prominent fractures are more or less parallel to the strikes of prominent faults. However, a west-northwest fracture set is common that is not matched by prominent faults. Prominent faults appear to form an irregular north-trending set, a northwest-trending set, and two northeast-trending sets striking N25-35E and N65-70E.

Dike Trends

With a few notable exceptions, dikes fall into a well-regulated system of two sets trending north-northeast and east-northeast which are common throughout the area.

The Boise Basin stock is dike-like in form, and assumes a series of zig-zags which can be related in part to the north-northeast and east-northeast directions. The structure in the Boise Basin, however, is complicated by west-northwest-trending fractures which have also controlled dike emplacement. The Boise Basin stock is a relatively

Figure 31. Aerial View of Bear Valley

Aerial view of southern Bear Valley basin looking southwest. Cache Creek is in the left foreground and Big Meadow is in the middle ground. The placer workings of the Porter Bros. can be seen at the extreme end of Big Meadow. Whitehawk Mountain is the left knob on the bare ridge in the right middle ground.

large intrusion, and evidently was able to force its way into several fracture directions at once and thus was able to assume a zig-zag dike-like outline as various fracture directions were opened and became conduits for the intruding magma.

Dikes, on the other hand, evidently were confined to essentially one fracture direction at a time. The dikes apparently did not have enough intrusive force to open additional fracture directions and thus do not assume a marked zig-zag strike.

The Boise Basin dike swarm trends primarily north-northeast. The Miller Creek swarm parallels the Boise Basin swarm until it is deflected by north-trending structures which control the Red Mountain swarm. Dikes in the Cape Horn-Ruffneck Peak area exhibit both north-northeast and east-northeast trends. The north-northeast trends predominate and probably continue through to the Seafoam swarm to the north. The Cliff Creek swarm is the best developed example of the east-northeast trend. The Beaver Creek swarm trends north-northeast.

North-northeast and east-northeast-trending fractures may have formed at the time of the main period of dike emplacement, and consequently controlled the direction of the majority of dikes. However, older structures apparently were also effective in controlling dike directions.

The role of pre-existing fractures in controlling dike emplacement is well illustrated in the Cape Horn-Blue Bunch Mountain area. This area is a structural intersection in which major northwest pre-dike structures cross a strong zone of northeast-trending faults. This is the only area of pronounced northwest-trending dikes in the map area. The Red Mountain swarm is in an apparently older complex north-trending zone of fracturing. The dikes in this swarm have predominantly north trends which radiate outward from an intrusive center.

The relation between fractures, joints and dike intrusion is well illustrated on Figure 29. The dike and joint rose diagrams exhibit the same maxima with the exception that the east-west joint direction is not duplicated to the same extent in the dikes. This direction was apparently closed during most of the period of dike intrusion.

Fracture directions also are similar to the joint-dike trends, and north-northeast and east-northeast directions are particularly prominent and well developed.

TECTONICS

Because of the lack of structural control, a unique solution of the tectonics of the map area is not possible, and the following is presented only as a hypothesis of the geological forces and movements which have formed the geology which is exposed at present.

Little can be said of the pre-batholithic tectonics of the map area, except, that if the metamorphosed sediments of the roof pendants are Kinnikinic quartzite of Ordovician age, as postulated by Rychener (personal communication), then the Ordovician seas of the Paleozoic geosyncline in the western United States must have extended into the area now occupied by the Idaho batholith. This implies that Ordovician seas existed a considerable distance west of their presently postulated shorelines (Schuchert, 1955; Ross and Forrester, 1958) and that the map area was negative during a portion of the early Paleozoic. The structures in these metasedimentary rocks could be due to multiple periods of folding prior to the emplacement of the batholith or possibly to complex folding and metamorphism related to the emplacement of the batholith.

The manner of emplacement and the form of the Idaho batholith concern some of the interpretations of the data, and therefore, a few postulations on the rise of the magma are in order. According to Hamilton and Myers (1967), the original magma formed along a broad belt, became a cohesive mass, and began to rise. During its rise along a north-trending zone of weakness, the magma may have become completely detached from its zone of melting or maintained its connection by dike-like channels rather than by a full-sized chamber.

The rise of the magma was not uniform and the melt rose at varying rates as a series of lobes which coalesced to form the various segments of the batholith. The forces controlling the emplacement of the magma were largely vertical and related to gravity--the lighter magma rose and the heavier metamorphosed wallrock became plastic and flowed around the rising mass and sank. In forcing its way into the upper crust, the magma was not only increasingly affected by pre-existing structures, but also created new structures related to its rise. High in the crust, the density of the magma evidently became equal to that of the host rock and the magma spread out sill-like in a tongue or mushroom shape about 10 kilometers or less in thickness (Bott and Smithson, 1967; Hamilton and Myers, 1967). At this point, loss of heat and volatiles caused crystallization and loss of mobility.

After the consolidation of the main mass of the Idaho batholith, a much smaller north-trending pluton or plutons may have been emplaced along the west side of the batholith

(McDowell, 1966). This event is only sketchily outlined by potassium-argon dating. However, if the event is real, it would imply a north-trending doming along the western flank of the batholith and subsequent horizontal compression from the west, producing north-trending thrusts, east-trending tension faults and west-northwest and east-northeast shears.

The postulated rise and emplacement of the Idaho batholith is similar to the rise and emplacement of salt domes as described by Trusheim (1960). According to Hamilton and Myers (1967) an inference to be drawn from the salt dome analogy is that the size and spacing of intrusions is controlled by the supply of magma, and the position and shape of the intrusions are controlled by structural features of the crust. Batholiths form where the supply of magma is so great that the masses coalesce and rise toward the surface as large plugs and megadikes. Isolated plugs form where the supply of magma is small.

After the emplacement and consolidation of the Idaho batholith during the Nevadan period of plutonism, the batholith was subjected to the stresses of the Laramide orogeny. The great strength of the batholithic rocks apparently prevented any large-scale plastic deformation, but the batholith was extensively fractured and subjected to regional uplift. The abundance of xenoliths and roof pendants in the northern part of the map area and their absence in the southern portion suggests that the southern part of the batholith was uplifted relative to the northern part, and that the southern part has been eroded more, revealing a lower level of the batholith than the northern part.

After much of the Idaho batholith was deroofed by erosion, the area was again subjected to a period of plutonism in which magma rose along a transverse, northeast-trending zone of weakness which is now defined by the intrusions of the Idaho porphyry belt. The magma source of the intrusions of the Idaho porphyry belt was evidently much smaller than that of the Idaho batholith, and although intrusions of batholithic proportions rose along this northeast-trending zone, the intrusions were much smaller and did not coalesce to form one large intrusive body. The forces which controlled the emplacement of the plutons of the Idaho porphyry belt were similar to, but on a smaller scale than those that controlled the emplacement of the Idaho batholith.

Evidently more magma rose in the region of the Idaho batholith than in other parts of the Idaho porphyry belt. As the magma rose higher, besides creating new structures, it probably was influenced by structures associated with the Idaho batholith and the Laramide period of deformation; and spread out under, and intricately intruded the relatively thin sheet of batholithic rocks.

Along the main zone of intrusion between the Boise Basin and Casto Quadrangle, sufficient magma was available to exert a force sufficient to break through the batholithic cover. The Casto batholith was intruded along a northeast-trending break and may have broken through to the surface and solidified under a dome of its own (Challis Volcanics) ejecta (Hamilton and Myers, 1967). The emplacement of the Sawtooth batholith and the Red Mountain dike swarm was controlled by older north-trending structures. The Boise Basin stock was intruded along north-northeast and east-northeast fractures in a dike-like form, as was the majority of the dike swarms in the map area.

The deforming stresses which provided the openings for the intrusion of the plutons and the associated dikes apparently were not everywhere equally and uniformly applied in either intensity or direction, and the Idaho porphyry belt, at least in the map area, appears to be in part a composite of several well-defined dike swarms, each differing somewhat in composition and perhaps in age from the others, and each controlled by its own set of guiding fractures. In the map area, the intrusive centers in the Boise Basin and the Cape Horn-Seafoam, Beaver Creek areas were evidently elongated in a northeasterly direction and produced a northeast-trending dome in the batholith during their intrusion. The doming of the batholith was apparently accomplished by plastic deformation of the granitic rocks at depth, and brittle deformation at the surface. The force of the intrusion produced a set of northeast-trending tension fractures parallel to the elongation of the dome and two sets of shears trending north-northeast and east-northeast. The tension fractures evidently were surficial and many did not reach the magma chamber as the majority of dikes are aligned in different directions. Shearing, on the other hand, evidently was more deep seated, and as the upward thrust of the intrusion continued, the shears were opened and tapped the magma chamber. The magma intruded these fractures and formed the north-northeast and east-northeast-trending dike swarms which are predominant throughout the map area. Pre-existing fractures were also opened and intruded to produce dikes trending transverse to the main northeast trend of the porphyry belt, but for the most part, these fractures remained closed except in zones of strong transverse faulting.

In the Boise Basin intrusive center, both the north-northeast and east-northeast dike directions (as well as a pre-existing west-northwest direction) are prominent. However, to the north of the Boise Basin, the north-northeast fracture direction predominates and controls the alignment of the Boise Basin dike swarm.

The Red Mountain area is an intrusive center in which magma probably rose along pre-existing north-trending fractures and formed a nearly circular dome and magma chamber.

The north-trending fractures tapped the magma chamber and formed the north-trending dikes in the Red Mountain area. Fractures radiating outward from the center of doming also tapped the magma chamber and formed the radiating dike swarm to the north of Red Mountain. The strong northwest-trending fault to the south of Red Mountain may have localized the rise of the magma and restricted the dike swarm to the north side of the fault.

The Cape Horn-Seafoam-Beaver Creek area represents a large complex intrusive center that was influenced by complex pre-existing structures. The underlying intrusion is probably elongated in a northeasterly direction as is evidenced by the prominent and well developed north-northeast and east-northeast-trending dike swarms in the Cape Horn, Seafoam, Cliff Creek, and Beaver Creek areas. However, pre-existing northwest-trending structures extending from the Sawtooth batholith were also evidently opened during the period of intrusion to form the complex dike pattern on Cape Horn Mountain and the northwest-trending dike swarm on Blue Bunch Mountain.

Most dikes intruded the country rock along fractures with a minimum amount of disturbance of the wallrock, and the rocks of the Idaho batholith must have been arched and pulled apart considerably to permit the intrusion of the large quantity of Tertiary magma. In some local areas, Tertiary dikes constitute 50 percent or more of the rock area, and over distances measured in miles--in areas of the major dike swarms--may constitute 20 to 25 percent of the rock.

Withdrawal of the magma from the underlying chambers initiated subsidence and the process of basin formation began along normal faults. Old structures, as well as new breaks were utilized. The process of basin formation is continuing as V. L. Freeman (personal communication) reports that the Sawtooth fault can be identified through Pleistocene moraines, and B. F. Leonard (personal communication) reports recent offsets in moraines in the Yellow Pine-Big Creek area.

Basin formation was complicated by renewal of shearing possibly related to a regional north-south compression. Ruppel (1964) reports right lateral strike-slip faults which offset normal range front faults in the Mackay-Leadore region to the east of the map area. Anderson (1934) reports a series of north-trending normal faults in the central and west-central portion of the batholith. He further reports (1947) that a normal fault in the western portion of the Boise Basin has more than two miles of left lateral movement. B. F. Leonard (personal communication) reports older north-trending right lateral shear zones in the Yellow Pine-Big Creek area, and a younger system of right lateral northwest-trending shears and left lateral northeast-trending shears. The west-northwest-trending shears along the western portion of the Lewis and Clark line are right lateral (Hobbs, et al., 1965), and those along the eastern extension of the line are left lateral (King, 1959).

Although no single compressive force could produce the strike-slip movements described above, the complex displacements are readily explained if one considers the area to be broken into a series of polygonal blocks similar to those described by Moody and Hill (1956). These blocks are apparently bounded by major fractures along which much of the horizontal stress is dissipated. As movement continues along the boundary faults, any block could be freed from compressive forces or subjected to compressive forces from another direction. Blocks freed from compression could move vertically in response to other forces acting upon them, or blocks with altered compressional directions could form new shear systems or reverse directions on older sets.

The map area has continued to rise periodically since the intrusion of the dike swarms in the Eocene-Oligocene (?). This movement is evidenced by terrace gravels and rock benches at different levels, and by steep gorges currently being cut by the major drainages.

SUMMARY OF GEOLOGIC HISTORY

Certainly, few conclusions regarding the geologic history of the Idaho batholith and the Idaho porphyry belt can be reached from the study of such a small portion of these features. Therefore, only events which can be interpreted from data collected within the map area, or from the work of others immediately adjacent to the area which has a bearing on the features seen in this study are outlined. These events have been described in varying detail in the previous chapters and are summarized as follows:

1. Invasion of the area by Ordovician (?) seas and the deposition of a thick sequence of sandstone with intercalated limestone and shale members.
2. A possible period of diastrophism in which the sediments were complexly folded. However, the folding and metamorphism of the sedimentary rocks may have occurred as a single event during the intrusion of the Idaho batholith.
3. Intrusion, consolidation, and cooling of the Idaho batholith. The batholith possibly was intruded as a relatively thin sill-like body along a major north-trending zone of crustal weakness. The age of the Idaho batholith is still in question, but the main portions were

probably intruded in the interval between early- and mid-Cretaceous time during the Nevadan episode of plutonism.

4. Fracturing of the rocks of the Idaho batholith by stresses of possible Laramide plutonism to the west, and Laramide diastrophism to the south and southwest. During this period, the batholith was uplifted and subjected to erosion.

5. Erosional removal of the metamorphic and sedimentary cover of the Idaho batholith.

6. General uplift, fracturing, localized arching, and a major episode of plutonism aligned along the transverse structures of the Idaho porphyry belt. Magma rose along a major northeast-trending zone of weakness, and, utilizing these fractures, as well as other pre-existing fractures, spread out beneath, and intricately intruded the batholithic rocks. The plutonic event in the map area probably began with the intrusion of small basic to intermediate stocks, the extrusion of the Challis Volcanics and the intrusion of the Casto and Sawtooth batholiths. Later intrusions of a differentiating magma complex formed the Boise Basin stock and the various dike swarms associated with the intrusive centers of the map area. The plutonic event began in the

Eocene epoch and the main period of intrusive and extrusive activity probably took place between 40 and 50 million years ago. Some intrusive activity related to this event, however, may have continued into the Oligocene epoch. The Tertiary intrusions reheated the rocks of the Idaho batholith and effectively degassed the radiogenic argon in the biotite and hornblende crystals. The rocks of the Idaho batholith and Tertiary intrusions then cooled together and now give similar potassium-argon age dates.

7. Formation of Basin and Range type fault block valleys and intermontane basins, and subsequent modification by periodic uplift and strike-slip faulting. Movement along these fractures still continues. Intrusion of diabasic dikes which may be related to either the Columbia River or Snake River volcanic flows.
8. Pleistocene Alpine glaciation in the mountainous regions. Glaciers were generally small and confined to north- and east-facing slopes above approximately 8000 feet in altitude.
9. Continued intense erosion.

ECONOMIC GEOLOGY

Although the portion of the Idaho porphyry belt between the Boise Basin and the Casto Quadrangle has been prospected from the early 1860s, with the exception of the radioactive rare-earth placer in Bear Valley, little of economic importance has been discovered. The area was first known for production from relatively small placer gold deposits, and later for gold and base metal production from small lodes in the Seafoam and Deadwood Mining Districts. Scattered tungsten mineralization in the Deadwood Mining District and a single area of molybdenum mineralization at Little Falls represent interesting but uneconomic occurrences. Although the radioactive rare-earth placer deposits in Bear Valley are not presently in production, for a short period they represented a unique source for uranium, thorium, columbium, and tantalum; and now constitute an important low-grade reserve for these elements as well as magnetite, ilmenite, garnet, monazite, and the rare-earths.

History

The first white men to enter south-central Idaho may have been those of the Lewis and Clark expedition in 1805. Their route, however, carried them far to the north of the South Fork of the Payette, Deadwood, and Middle Fork of the

Salmon drainages (DeVoto, 1953). By 1811, American and Canadian trappers were operating in the area (Ross 1963b), and there are various reports of trappers and mountain men noticing gold in gravel in and near south-central Idaho. A trapper is reported to have recognized gold in the Boise Basin in 1844 (Wells, 1961), but these early observations were not pursued.

The first successful attempt at mining in Idaho was that of E. D. Pierce in 1860, who discovered gold at what is now Pierce, in Clearwater County (Staley, 1946). Later in the year the Orofino and Elk City discoveries were made. The following year the Salmon River placers were discovered, and prospectors penetrated into south-central Idaho. On August 2, 1862, a party led by George Grimes discovered placer gold in the Boise Basin, but mining was delayed by Indian trouble until the following year.

In 1863 and 1864, prospectors exploring out from Boise Basin made several important discoveries--Rocky Bar, Owyhee, Atlanta, and Banner--which expanded the mining region of south-central Idaho. The founding of Boise in the summer of 1863 resulted directly from this mining advance.

Lode mining in the Boise Basin began within a year after the discovery of the famous placers in 1862 (Anderson, 1947). By 1869, the first rush of placer mining had subsided, and lode mining dwindled as the free milling ores were exhausted. Little mining was carried on in the 1870s and 1880s with the exception of the Gold Hill Mine which was worked continuously from its discovery in 1863 until 1938. Interest in lode mining was briefly renewed in the 1890s but soon subsided. Another boom developed in 1935 shortly after the increase of the price of gold, but the activity was of short duration, and only sporadic, small-scale mining continues at present.

Location of the mines and mining districts surrounding the map area is well documented by previous references and is not shown here. Mineralization within the map area as well as the names of the more important properties is shown on Figure 32.

Gold Deposits

As the early prospectors spread out from the Boise Basin, placer gold was soon found in the Deadwood Basin and along the South Fork of the Payette, its tributaries, and the streams in the vicinity of the present Seafoam Ranger Station. These placers were soon exhausted, and with the exception of the lode deposits in the Seafoam District, attempts to discover the source of the placer gold were largely unsuccessful. Intermittent small-scale exploration for lode and placer gold continues, but nothing of importance has been discovered.

Small Placers and Lodes

Gold was discovered in the lower end of the Deadwood Basin--now the site of the Deadwood Reservoir--in the early 1860s, and placer mining continued for about 30 years on the benches and in the creek bottoms leading into the basin (Storch, 1958). No record of this production exists, and the only remaining evidence of the old placer mining is along Bummer Creek to the northeast of the Deadwood Reservoir.

Production from the benches and the gravels of the South Fork of the Payette is also unrecorded, and apparently was small and intermittent. A remnant of some old bench workings can be seen along the road about a mile west of Lowman. Although these properties are not currently in production, many are still occupied as cabin sites.

A small concern recently attempted to produce from the horseshoe bend in the South Fork of the Payette about a half mile west of the confluence of the Deadwood River. The company opened an old diversion tunnel through the neck of the horseshoe and diverted a portion of the flow of the Payette while the gravels were worked. The operation was not successful, and operations were discontinued soon after commencing in 1966.

A small adit was driven into batholithic rock on the ridge west of Eight Mile Creek. The showing here must be small as only sparse vein material was observed on the dump. A few prospect pits are scattered along the ridge to the southwest of Miller Mountain. At one of these sites, an attempt apparently was made to wash gravels which had collected in a small flat depression on the south side of the ridge.

In the Deadwood Reservoir area, the Mary Blue and the Mary Jane workings are erroneously reported on the Challis AMS sheet as lead-silver deposits. The Mary Blue property includes several prospect pits and an adit with approximately 1000 feet of workings. A two-foot vein at the property was once worked for gold (Kerr, 1946). The vein also carries tungsten values in wolframite. The Mary Jane workings consist of several shallow prospect pits sunk on two east-trending vuggy, milky quartz veins with some associated limonite staining and minor kaolinization of the batholith wallrock.

Hubbard (1955), on the Mineral Resources Map of the State of Idaho, shows gold and fluorite mineralization in the vicinity of the headwaters of Gates Creek and Bull Trout Point to the northwest of Bull Trout Lake. An old Forest Service trail marker also indicates the presence of a mine in this area. The workings were not visited, but Vanderwilt (1938) reports that several tons of hand-cobbed ore averaging 2.8 ounces gold per ton were shipped in 1937 to a smelter in Salt Lake City, Utah. The gold is in a highly oxidized vein, which lies along a sharp contact between a schist inclusion and the Idaho batholith.

Seafoam Mining District

The Seafoam Mining District is located in the northwest corner of Custer County and, as defined by Ross (1930), includes the Sheep Mountain area which is sometimes considered as a separate district. The area encompasses approximately 100 square miles and is essentially contained in the drainage basin of the Rapid River--one of the larger tributaries of the Middle Fork of the Salmon.

Gold was found in the Seafoam District in the 1880s and at one time the district was the scene of considerable placer mining. This placer activity was mainly in the area of the present Seafoam Ranger Station (Treves and Melear, 1953). As the workable gravels were of limited extent and contained many glacial erratics, the placer rush did not last long. However, the attention focused on the area resulted in the discovery of the precious and base metal lodes in the district.

Development of the lode deposits was intermittent and was hindered by extreme winter conditions and high freight costs to Hailey, the nearest railhead, approximately 100 miles to the south. Production of the district is not known, but it is not among the larger placer or lode camps (Ross, 1941). Partial production from a variety of mines, including the Seafoam, Silverbell, Greyhound, Rasche, and Mountain King mines and the Josephus Lake Prospects, is recorded (Ross, 1930), and Treves and Melear (1953) report production of gold, silver, lead, zinc and copper from the district, between 1933 and 1950, valued at $127,904. At present there is no production from the district, although some prospecting is being done around the Greyhound Mine.

The district lies in a marginal portion of the Idaho batholith close to its eastern border. The rock varies considerably in detail and contains many roof pendants as well as Tertiary dike swarms.

The Seafoam, Greyhound, and many of the other lodes consist of lenticular cavity-filled masses of quartz and altered rock generally arranged en echelon in shear zones within rocks of the Idaho batholith. In and near the lodes, the country rock is locally silicified and sericitized. Pyrite is the most common sulfide in a fine-grained and sparsely disseminated assemblage which includes chalcopyrite, galena, sphalerite and arsenopyrite. Although, locally, galena is sufficiently abundant to constitute a lead ore, gold and silver are the main ore metals.

Base Metal Deposits

Base metal deposits with minor values in gold and silver are not common in the Casto Quadrangle or the Boise Basin, and only two deposits of this general type have been mined in the map area. These properties--the Mountain King and the Deadwood Mines--are both small, and are not currently in production.

Mountain King Mine

The Mountain King Mine is on Sheep Mountain, and was one of the most extensively developed and productive mines in the Seafoam Mining District. Early production from the mine is not known, but intermittent shipments to Hailey are recorded in the 1880s and 1890s. According to Ross (1930) this early production is rumored to vary from $80,000 to as high as $500,000. From the 1920s on, the mine has been worked sporadically by a number of lessees, but at no time was a large ore reserve developed. Peak production occurred in 1948 when 467 tons of lead-zinc-silver ore was shipped.

Mineralization at the mine is quite different from that found in the remainder of the Seafoam Mining District. At the Mountain King, lead-zinc mineralization with associated copper-gold-silver values is confined as replacements in dolomitic limestone roof pendants projecting down into the rocks of the Idaho batholith. The ore assemblage usually contains galena, sphalerite, pyrite, chalcopyrite, and quartz, although locally contact metamorphic silicates are present with galena, pyrrhotite, and vein quartz.

Deadwood Mine

The Deadwood Mine, which is also known as the Lost Pilgrim Mine, is located on the Deadwood Reservoir-Landmark road on the east side of the Deadwood River valley just outside the northwest corner of the map area. The mine was worked between 1924 and 1932 by the Bunker Hill and Sullivan Mining and Concentrating Company. During this time, about a million dollars of lead-zinc-silver ore were produced (Ross, 1941; Anonymous, 1925). The mine is in a schist xenolith (Ross, 1963b) or roof pendant in the Idaho batholith. Quartz lenses with minor siderite and irregularly distributed sulfides were mined in and near the schist bodies. In many of the irregular ore shoots, sphalerite and pyrite were more abundant than galena.

The mine is now abandoned, and the mine buildings are utilized as a lodge, a small restaurant and a general store.

Tungsten Deposits

The map area lies to the south and west of the northwest-trending South-Central Idaho Tungsten Belt (Cook, 1955). Although three occurrences are reported in the literature, no production has come from the area. Cook (1956) reports huebnerite mineralization assaying as high as 30 percent WO_3 in the Whitehawk Basin. The huebnerite is in thin quartz veinlets and stringers associated with bleached zones in the Idaho batholith. The quartz veins vary in strike from N to N70E, and apparently have no single preferred direction. In the Deadwood Basin, Shannon (1926) reports the occurrence of reddish to brownish cleavable masses of wolframite disseminated in quartz in the Horsefly prospect and as very black indistinct friable material in vuggy quartz coated with a thin layer of chalcedonic silica at the Mary Blue Mine. No other tungsten mineralization was noted in the area.

Molybdenum Deposits

The Little Falls molybdenum prospect is the only molybdenum occurrence in the area. It is at the confluence of Big Pine Creek and the South Fork of the Payette River in T8-9N, R6E, at the extreme southwest corner of the map area. The prospect was investigated in 1961 by Congdon and Carey, Ltd., a Denver-based exploration syndicate, and staked the following year. P. R. Donovan (1962) mapped approximately five square miles of the prospect area and conducted a geochemical survey over the central portion of the area. Drilling with the assistance of an OME grant revealed significant, but sub-economic, molybdenum mineralization. Subsequently, the claims were allowed to revert to their previous withdrawn status and the property was abandoned.

The altitude of the prospect ranges from approximately 3350 feet to 4200 feet above sea level. Slopes are steep--

with many over 35°. South-facing slopes are dry, soil is thin and poorly developed, and vegetation is limited to grass, sagebrush and a few scattered pine trees. The north-facing slope on the south side of the South Fork of the Payette is more moist, and is covered by a pine forest.

The area is underlain by rocks of the Idaho batholith which are cut by a Tertiary dike swarm originating in the Boise Basin about two miles to the southwest. Although the swarm is complex in composition, the dikes are mostly rhyolite and represent an intrusive end product of the Tertiary differentiation sequence of the Boise Basin. No sedimentary or metamorphic rocks are present in the area.

The prospect area is within a pyritized zone about 3000 to 4000 feet wide by 22,000 feet long. Intense pyritization is confined to a zone about 2000 feet wide by 10,000 feet long. Oxidation of pyrite along the entire zone has produced a noticeable reddish-brown color anomaly.

The mineralization is controlled by a N30-35E-trending dike swarm. Visible molybdenite in thin quartz veinlets is common over an area 1000 feet wide by 3000 feet long within the most highly pyritized zone, and occurs in the batholithic host rock as well as in all dike rocks except late lamprophyres, diabases and the last of three generations of rhyolite dikes. Minor fluorite and trace chalcopyrite are associated with the molybdenum mineralization.

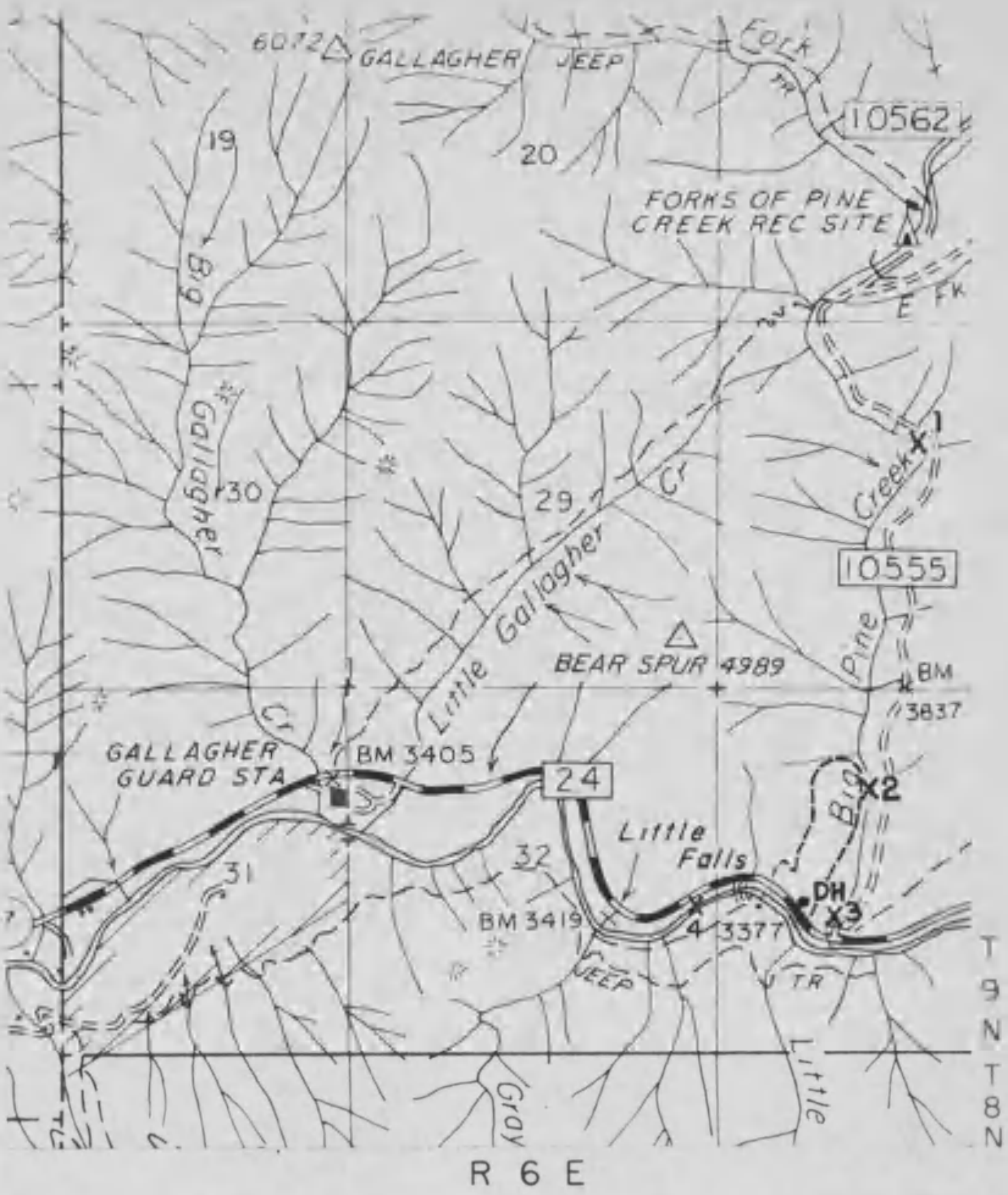
The area of molybdenum mineralization was defined by Donovan (1962) and AMAX geologists (Hansuld, 1962 and Rostad, 1962), by soil and rock chip geochemical surveys. However, water and stream sediment geochemical samples taken in drainages adjacent to molybdenum mineralization failed to give a response except in restricted circumstances.

Two factors apparently account for the absence of molybdenum in the stream geochemical samples. First, particles containing molybdenum which reach the drainages through physical downslope movement are promptly carried away by the streams which are fast moving even in the late summer and fall of the year when they are at their lowest, and second, because of the acid nature of the soil and the abundance of iron oxide particles due to the oxidation of pyrite, apparently very little chemical movement of molybdenum takes place.

Molybdenite in the rock preferentially occurs as fine disseminations in thin quartz veinlets. Oxidized molybdenum fixed by iron oxide and clay particles also tends to be quite small in size. As physical downslope movement to the streams is relatively slow, except during the spring runoff, and after heavy rains, the balance of supply and removal in the streams is such that stream erosion outstrips the supply and keeps the concentration of molybdenum in the finer sediments below the sensitivity level (2 ppm) of the geochemical analytical method.

During the late spring and summer of 1965, water samples were collected periodically at points along Big Pine Creek, the South Fork of the Payette and from artesian flow from a drill hole adjacent to highway #17 (Fig. 33). The results of analysis of these samples are shown on Table 1. Except for the drill hole water and samples taken near the end of the spring runoff and during the latter part of August and September when the fall rains began, all samples failed to give a molybdenum response.

As can be seen from Table 1, the pH of the water is slightly alkaline which is conductive to the solubility of molybdenum (Hansuld, 1966). This probably accounts for the high molybdenum values in the drill hole water. However, the water in the drill hole represents a different chemical environment than the surface waters. In the drill hole, the water presumably is in direct contact with molybdenite, and, therefore, any oxidized molybdenum would go directly into solution. On the other hand, at the surface sulfides are decomposed in a highly oxidizing, acid, iron-rich environment, and oxidized molybdenum is almost totally fixed by iron oxides and remains in situ. Not all of the oxidized molybdenum, however, is fixed by iron oxides. Some apparently goes into solution as Rostad (1966) reports that ilsemannite was noted at one spot along the road during dry periods, but was absent after rainfall.



LITTLE FALLS MOLYBDENUM PROSPECT

WATER SAMPLE LOCATION MAP

N

SCALE
1 31,680

0 — 1
MILE

160 ppm Mo Soil Geochem Anomaly

Figure 33

TABLE 1

WATER SAMPLING AT LITTLE FALLS
BOISE COUNTY, IDAHO
1965

Date	(ppb Mo)				
Sample No. --	1	2	3	4	DH
May 24*	2	2	2	4	240
June 15	Nil	Nil	Nil	Nil	200
July 8	Nil	Nil	Nil	Nil	300
July 21	Nil	Nil	Nil	Nil	640
August 3	Nil	Nil	Nil	Nil	2500
August 13**	Nil	4	Nil	Nil	300
August 27	4	12	12	4	1500
September 12	Nil	6	4	2	160
September 29	1	3	4	2	220
	pH				
May 24*	7.5	7.6	7.6	7.5	7.8
June 15	8.1	7.7	7.7	7.5	7.4
July 8	7.4	7.6	7.7	8.1	7.9
July 21	7.7	7.8	7.6	7.7	8.1
August 3	6.7	6.8	6.8	6.7	6.7
August 13**	7.5	7.4	7.1	7.5	7.6
August 27	8.0	7.9	7.9	7.8	8.3
September 12	7.4	7.5	7.6	7.5	7.4
September 29	6.6	6.8	6.9	6.7	6.9

* end of Spring runoff ** start of Fall rains

Undoubtedly some molybdenum reaches the streams in solution, or reacts in the alkaline aqueous environment to produce a soluble product. However, the amount is evidently so minor and the dilution so great that except during periods of abnormally high influx the concentration in the stream waters is below the level (2 ppb) of the geochemical analytical method.

Radioactive Rare-Earth Placers

Radioactive rare-earth minerals have been known in Idaho since 1897 when Lindgren (1898) first recognized monazite in gold concentrates in placer sands of the Boise Basin. Since that time, radioactive rare-earth placers have been discovered in various localities within the Idaho batholith, and have been worked commercially in Long Valley near Cascade and in Bear Valley.

In the map area, Storch (1958) reports ilmenite, as well as monazite and other radioactive rare-earth black sand minerals in placer deposits along the Deadwood River to the north of the Deadwood Reservoir. These deposits, however, are low grade, and are not economic at present. Armstrong (1953) reports that the Cosumnes Gold Dredging Company investigated the placer deposits in the Whitehawk Basin to the west of Bear Valley and found the gravels to be thin and to contain a low concentration of monazite and "radioactive blacks".

The most important radioactive rare-earth placer in Idaho is that located in Bear Valley near the headwaters of Bear Valley Creek at Big Meadow. Because of the interest of the United States Government in developing a domestic source of columbium, tantalum, uranium, and thorium; mapping by the U.S.G.S. in 1952 (Mackin and Schmidt, 1953, 1955); and reconnaissance drilling of the Bear Valley by the U. S. Bureau of Mines in 1951 and 1952 (Kline, et al., 1953); Porter Bros. Corporation began drilling on property acquired in Bear Valley, and conducted extensive research on the complex dressing problems for extracting mineral values from the radioactive black sands. The work continued through 1954. Placering operations were conducted from 1955 through 1959 during which time sufficient concentrates were processed to complete the Porter Bros. Corporation's contracts with the General Services Administration and the Atomic Energy Commission (Ross, 1963b).

Since that time, no further radioactive black sand concentrates have been produced, and by-product magnetite, ilmenite, and garnet concentrates from the stockpile at Porter Bros.' mill at Lowman are being sold for specialty uses. A monazite concentrate was also made and stockpiled, but is now depleted.

In 1966, Michigan Chemical Corporation exercised an option to acquire the assets of the Porter Bros. Corporation (Anonymous, 1966).

The Bear Valley placer is unique in that it provides a source of euxenite, columbite-tantalite, monazite, magnetite, ilmenite, and garnet from a single placer deposit. Other minerals associated with the placer deposits are quartz, feldspar, hornblende, sphene, allanite, biotite, epidote, limonite, hematite, sericite, ilmenorutile, and minor amounts of spinel, rutile, zircon, octahedrite, pyrite, brannerite, davidite, samarskite, xenotime and fergusonite (Cook, 1955; Lindgren, 1898).

Although placer minerals are found along lower, central and upper Bear Valley Creek (Kline, et al., 1953). only the upper Big Meadow area mined by Porter Bros. in T11N, R8E, contains sufficient concentrations of the valuable minerals to be considered as economic at present.

Big Meadow is surrounded by coarse-grained, porphyritic quartz monzonite of the Idaho batholith which is intruded by many related aplite and pegmatite dikes. The radioactive rare-earth minerals tend to occur as accessories within the quartz monzonite of the Idaho batholith in erratically spaced segregations which vary in size from a few inches to a few tens of feet in diameter (Mackin and Schmidt, 1955). Portions of the batholith containing high concentrations of radioactive rare-earth minerals are megascopically indistinguishable from surrounding rock which has a relatively low content. Apparently a poorly defined belt of high radioactive rare-earth mineral concentration that is the source for the radioactive rare-earth placers in Bear Valley and Whitehawk Basins extends across the southern portion of Big Meadow. Mineral variations exist within the belt of radioactive rare-earth segregations as, in general, monazite concentration across the Big Meadow placer deposits decreases from west to east, and euxenite concentration decreases from east to west. This indicates that the primary source area for the euxenite exists to the east of the valley and the monazite source area is to the west--probably in the Whitehawk Mountain area.

Although Mackin and Schmidt (1955) report no tendency for high concentrations of the radioactive rare-earth minerals in or near the pegmatite dikes, Fryklund (1951) reports large crystals of columbite (309 lb) and samarskite (100 lb) from small zoned pegmatite lens at the Columbite Mine in T8N, R4E in the Boise Basin. As the area adjacent to the Big Meadows radioactive rare-earth placer contains abundant pegmatite dikes, and some radioactive rare-earth minerals do occur in other pegmatites in the vicinity, some genetic relation may exist between the pegmatites and the radioactive rare-earth minerals. However, as the batholith itself is a complex intrusion, detailed study of the distribution of the heavy mineral suites in the batholith is needed before any definite statement can be made of the origin and occurrence of the radioactive rare-earth minerals.

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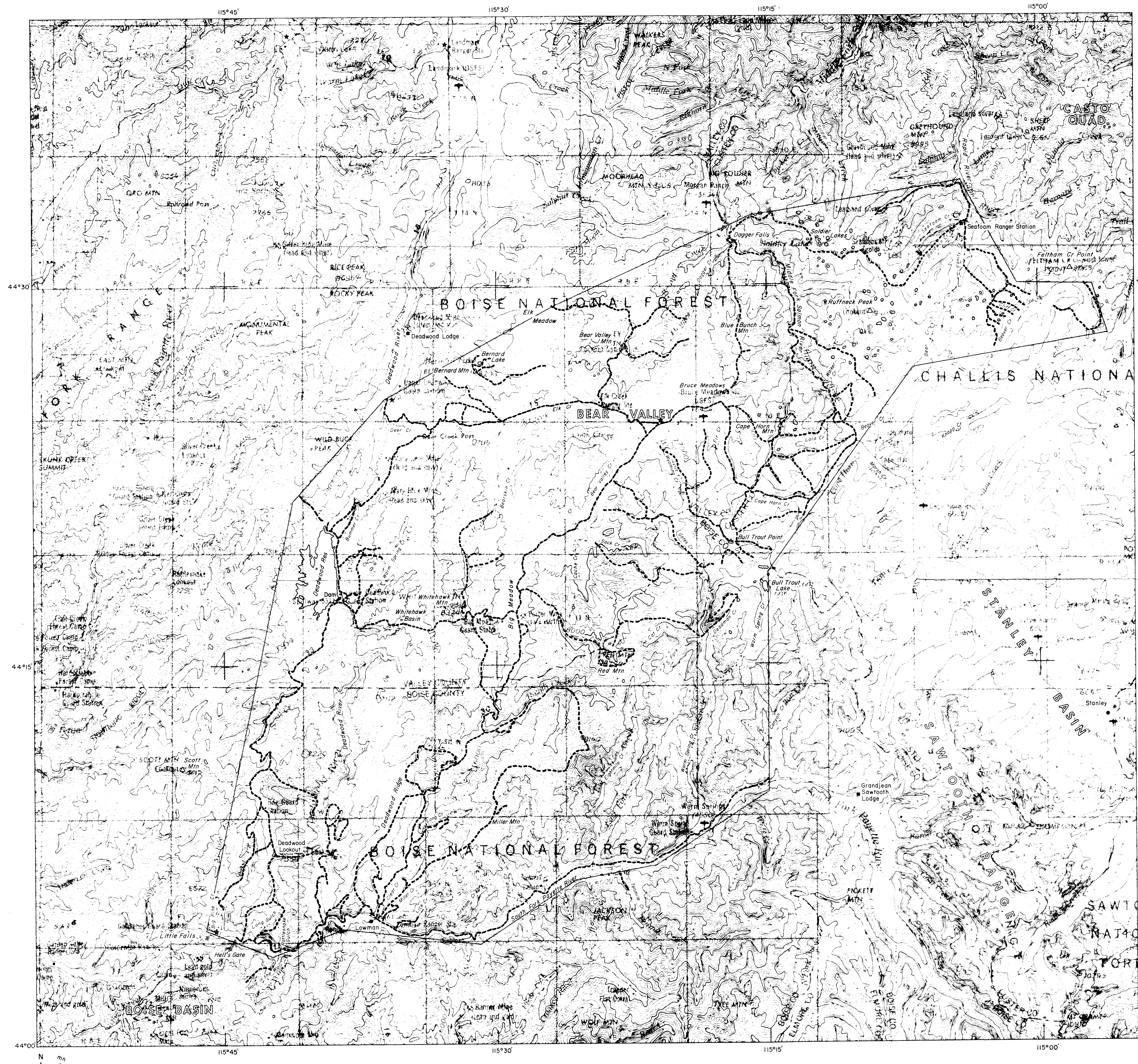
FIGURE 4

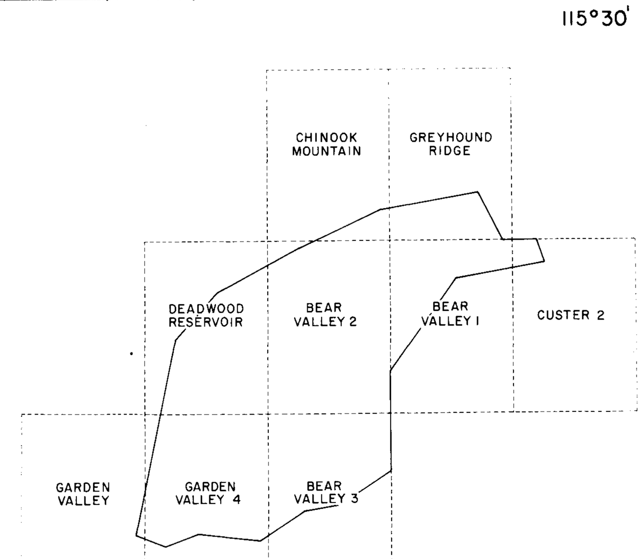


SCALE

5 0 5 MILES

Contour Interval 200 Feet

Harry J. Olson 1968

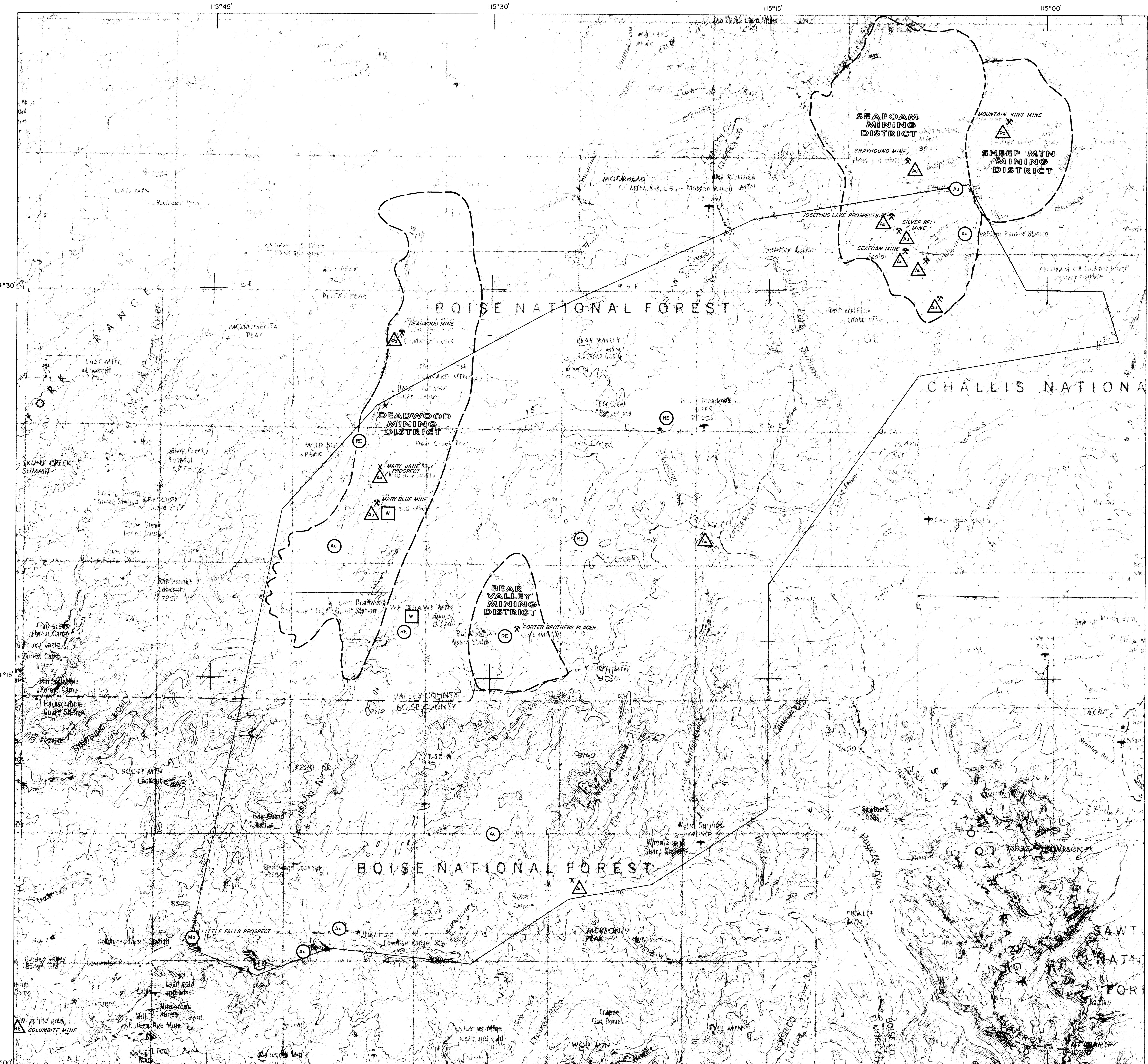


EXPLANATION

MAPPING TRAVERSES

MAPPING TRAVERSES AND GEOGRAPHICAL NAMES

FIGURE 4



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Contour Interval 200 Feet

Harry J. Olson 1968

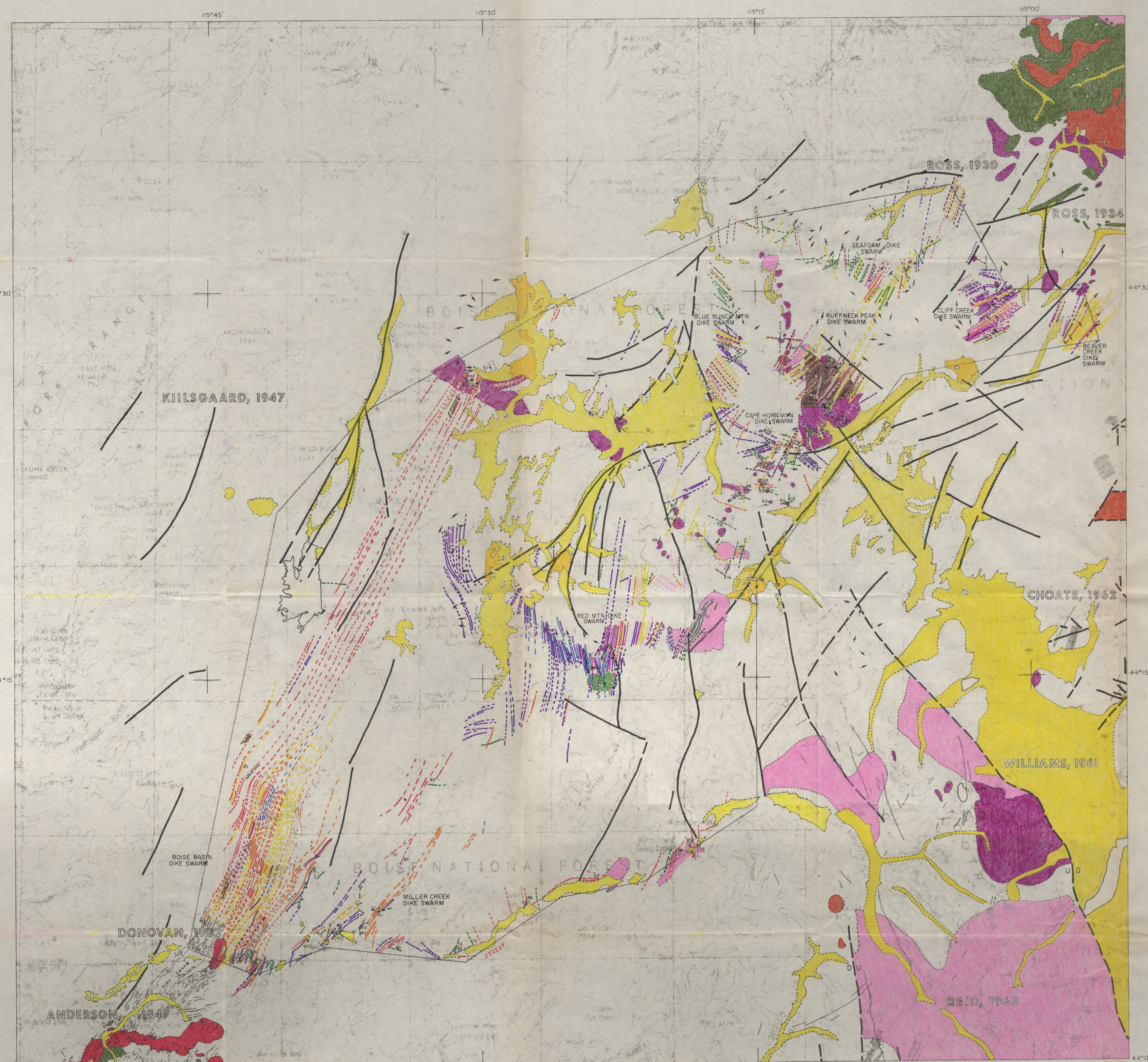
EXPLANATION

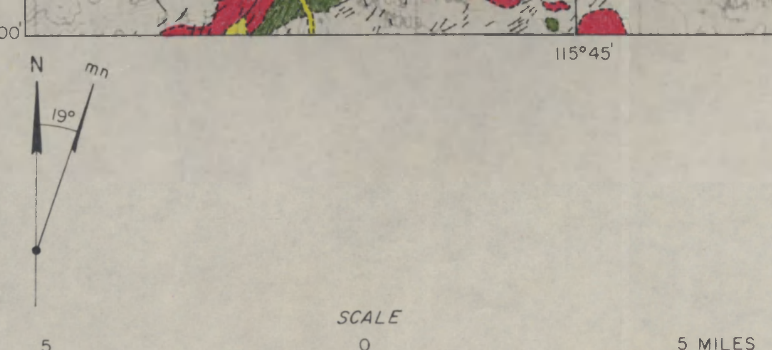
- MINING DISTRICTS
- MINES
- X PROSPECTS
- Au GOLD PLACERS
- Au GOLD-SILVER LODE DEPOSITS
- Pb LEAD-ZINC-SILVER LODE DEPOSITS
- W TUNGSTEN MINERALIZATION
- Mo MOLYBDENITE MINERALIZATION
- RE RADIOACTIVE RARE EARTH PLACERS
- RE RADIOACTIVE RARE EARTH PEGMATITE

MINES, MINERALIZATION AND MINING DISTRICTS

FIGURE 32

FIGURE 8

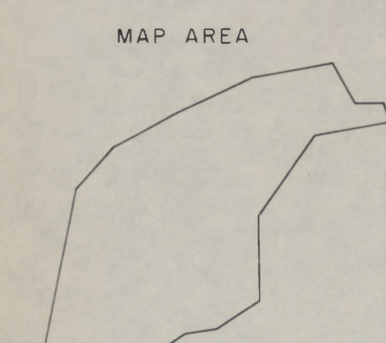


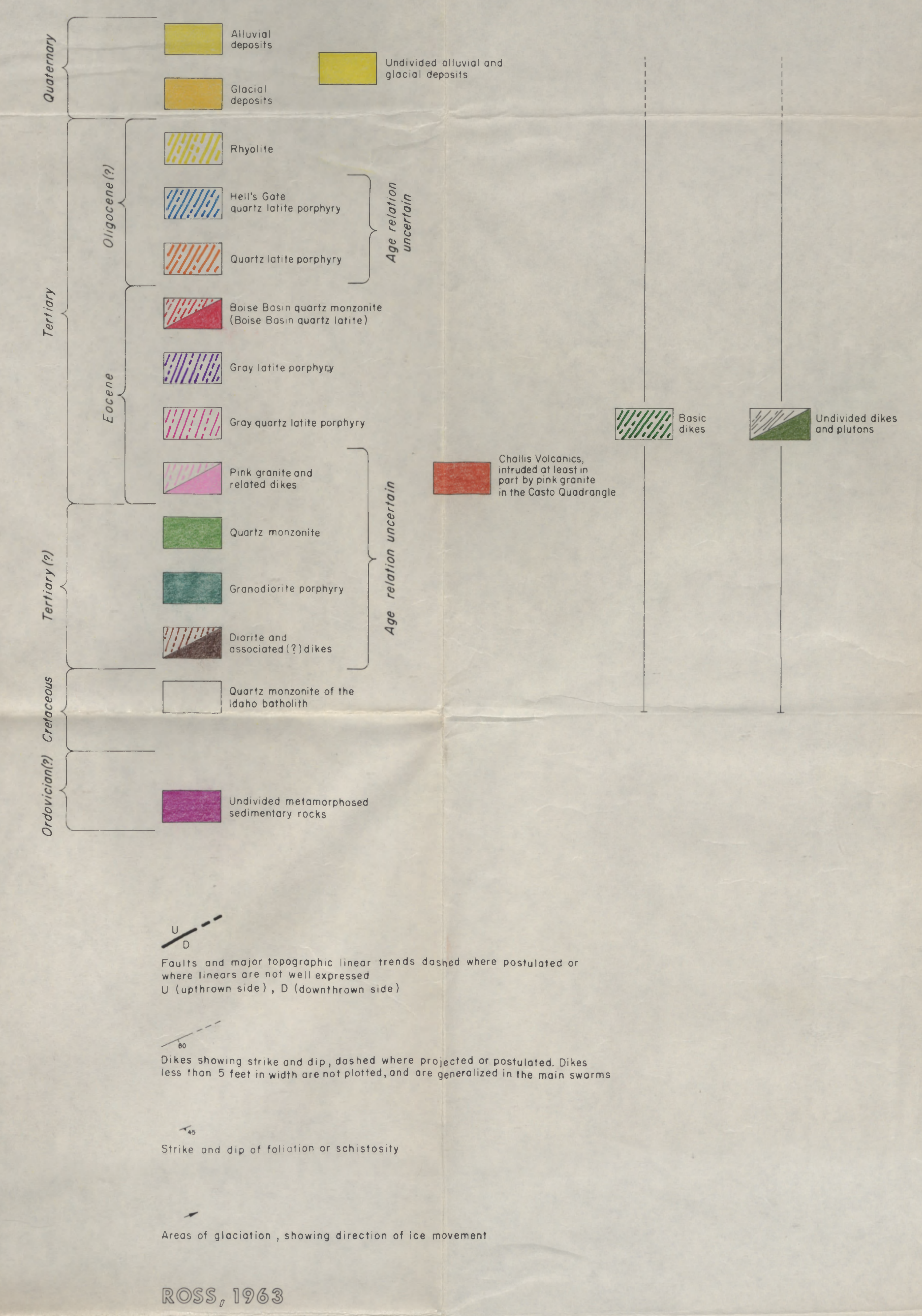


Contour Interval 200 Feet

Harry J. Olson, 1968

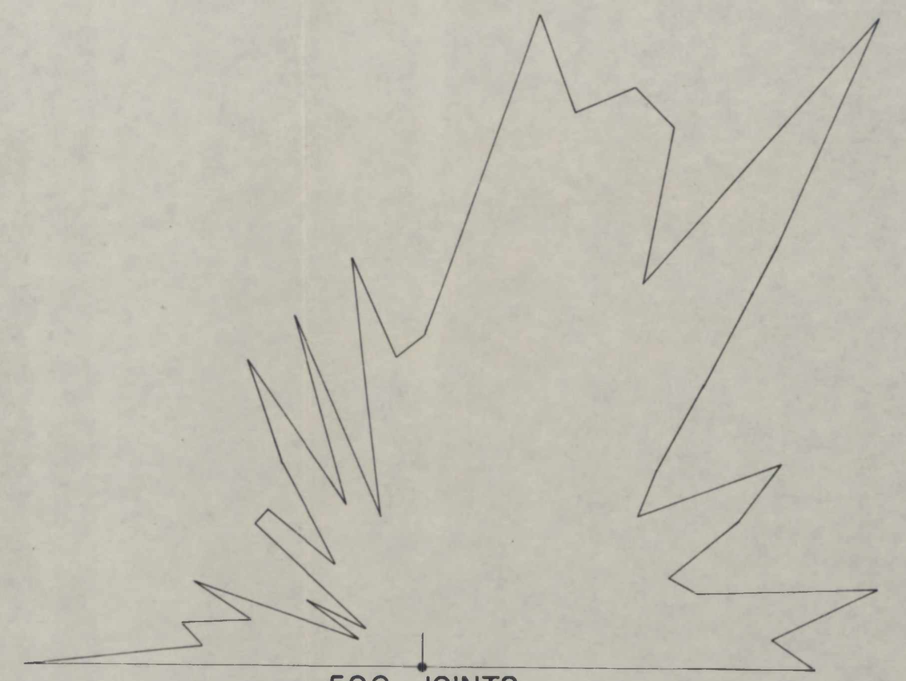
MAP AREA

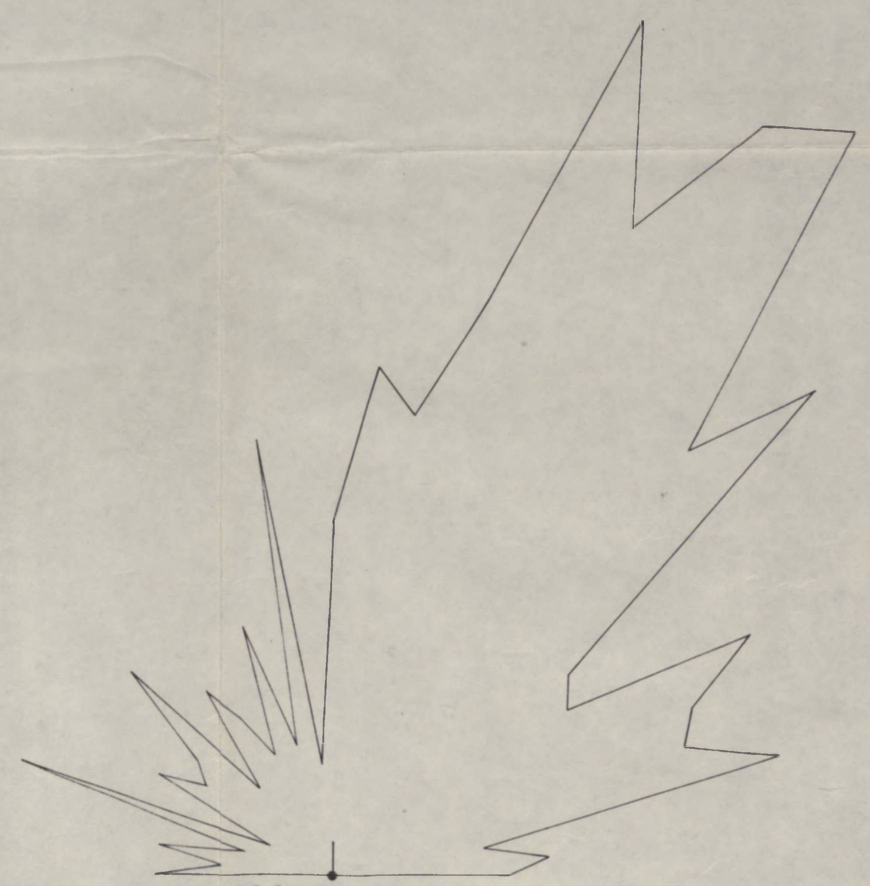




GEOLOGIC MAP OF THE IDAHO PORPHYRY BELT FROM THE BOISE BASIN TO THE CASTO QUADRANGLE

FIGURE 8





EXPLANATION

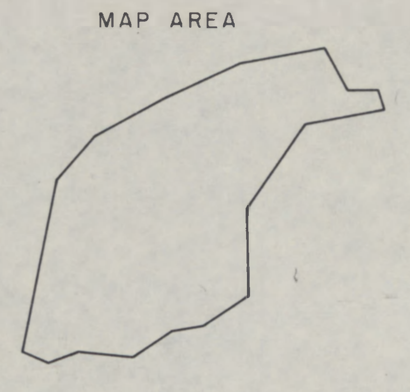
Unconsolidated Sediments

Faults, showing relative movement, and continuous topographic lineations thought to represent faults

Less prominent and less continuous topographic lineations thought to represent faults or joint sets

Rose diagram of measured joints — = one joint measurement

MAP AREA



Contour Interval 200 Feet

Harry J. Olson, 1968

STRUCTURE MAP OF THE IDAHO PORPHYRY BELT FROM THE BOISE BASIN TO THE CASTO QUADRANGLE

FIGURE 29