Geology of the Harpster Area, Idaho County, Idaho

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by

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ABSTRACT

Three major structural elements of the western batholith margin southeast of Harpster, Idaho, are fault blocks separated by broad zones of reverse faulting and cataclasis. Shear zones and isoclinal folds dip steeply eastward to southeastward, and units thin northward along strike. The faults become generally steeper eastward across the area. Cataclasis occurred before, during, and after diapiric emplacement of the Idaho batholith in Late Cretaceous time. The northwestern (Harpster) footwall block contains massive and phyllonitic greenstones belonging to the Seven Devils Group of Permian and Triassic age cut by mafic and ultramafic dikes and the younger tonalite of the Harpster pluton. Triassic and Jurassic(?) metasediments in the central (Blacktail) fault block consist of dark, micaceous and calcareous schists and amphibolites of the Riggins Group cut by the younger Blacktail trondhjemite pluton. Injection gneiss and plutonic wedges of the eastern (Quartz Ridge) hanging wall block dip steeply eastward. The plutonic wedges plunge gently northward and widen down-dip between pendants of Precambrian(?) metasediments including coarse schists, quartzites, and calc-silicate rocks. Granitic magmas, generated anatectically down-dip rose synkinematically with upward mushrooming of the batholith diapir. Deeper portions of the diapir are exposed progressively eastward. Cataclasis and retrograde metamorphism during latest Cretaceous or early Tertiary time were followed by deep erosion and the intrusion of quartz latite dikes (Peasley Creek). Subsequent erosion preceded the widespread extrusion of the Columbia River Basalt Group, which invaded the ancestral Clearwater Mountains from the west in Miocene and Pliocene time. Glaciers spread northward into the area from the Buffalo Hump area in Pleistocene time as the Blacktail fault block was dropping McComas basin about 1,100 feet along the Browns Creek-Lightning Creek fault. Subsequent Recent erosion has deepened glacial valleys and stripped out most of the high-level gravels and glacial deposits.

Although small deposits of magnetite, copper, gold, and asbestos have been mined in the region, no mining is presently taking place. The region may have significant potential for copper and uranium production.

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INTRODUCTION

This report concerns the structural, metamorphic, and magmatic history of the Idaho batholith margin east of Grangeville, Idaho (Figure 1). Geologic mapping, begun in 1959 in connection with Ph.D. research at the University of Michigan (Myers, 1968), has continued sporadically to the present. The Harpster area of this report comprises the Harpster quadrangle and parts of adjacent Corral Hill, Huddleson Bluff, and Hungry Ridge quadrangles. The total area covers 117 square miles.

PREVIOUS WORK

Works by Ross (1927, 1952, 1963) and Anderson (1930, 1942, 1952), supplemented by those of Lindgren (1904), Thomson and Ballard (1924), Shenon

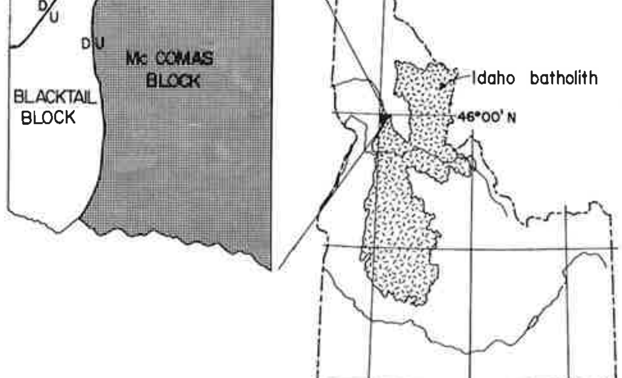

Figure 1. Index map showing major tectonic elements of the Harpster area, Idaho County, Idaho.

(1933), Shenon and Reed (1934), and Capps (1941), outlined the essential elements of the geology of north-central Idaho as shown on the geologic map of Idaho by Ross and Forrester (1947) and revised by Bond (1978).

Recent studies in this region have been on the tectonic history and the mode of emplacement of the Idaho batholith. Of greatest relevance to the Harpster area are studies by Hamilton (1963, 1969), Onasch (1976, 1977, 1978), and Vallier (1977) in the area to the southwest, Hietanen (1962, 1963) and Morrison (1968) to the north, and by Reid (1959, 1960), Hall (1961), Kuhns and Cox (1974), and Reid and others (1970) to the east (Figure 2). The tectonic history of the region has been described most recently by Armstrong (1975), Armstrong and others (1977), Brooks and Vallier (1978), Chase and Hyndman (1977), Hyndman and Talbot (1975), Hyndman and others (1975), Mudge (1970), Scholten and Onasch (1976), Talbot (1976, 1977), Talbot and Hyndman (1973, 1975), and Yates (1968). Geochronometry in and adjacent to the Idaho batholith was studied by Armstrong and others (1977), Armstrong (1974, 1976), Ferguson (1975), Larsen and others (1958), McDowell and Kulp (1969), and Nold (1974). La Salata (1982) determined from detailed strain analyses that the Squaw Creek Schist adjacent to the Blacktail pluton was folded three times. Carlson (1981) studied the structure, petrology, and geochemistry of high-grade metamorphic and plutonic rocks along Idaho Highway 14 east from Surveyor Creek nearly to Elk City.

GEOLOGIC SETTING

The Harpster area is on the western slopes of the Clearwater Mountains and the eastern edge of the Camas Prairie, a plateau underlain by Columbia River basalt (Figure 1). The area is drained by the South Fork of the Clearwater River (hereafter referred to as the South Fork) and its tributaries, which generally follow the north-northeast-trending structural grain. Elevations range from 1,550 feet near Harpster to 6,400 feet at China Point about 7 miles to the east. The best rock exposures are in the canyon of the South Fork and along the many logging roads.

The Downey Creek and Browns Creek reverse fault systems (Figure 2) divide pre-Miocene rocks in the Harpster area into three major blocks: (1) the Harpster block composed of the Seven Devils Group of Permian and Triassic age and the Harpster gabbro-tonalite pluton; (2) the Blacktail block containing schists of the Riggins Group of unknown age cut by the Blacktail trondhjemite pluton of Cretaceous(?) age; and (3) the McComas block composed of Precambrian(?) metasedimentary rocks intruded subconcordantly by tonalite, trondhjemite, and adamellite wedges of the Idaho batholith (Atlanta lobe). These rocks are overlain with strong angular unconformity by Columbia River basalt of Miocene and Pliocene age. Unconsolidated, high-level gravels and glacial deposits are Pliocene(?) to Recent in age.

The Harpster area (Figure 3) is on the northward-plunging serrated northern edge of the Atlanta lobe of the Idaho batholith (Armstrong, 1975, p. 437-467) and near the intersection of the Salmon River arch with the western edge of the Mesozoic craton as delineated by the .704 initial Sr^{87}/Sr^{86} contour (Armstrong and others, 1977, p. 407). The Idaho batholith is an asymmetrical plutonic diapir with a steep western edge (Myers, 1972), which collided with a eugeosynclinal "subduction complex" (Hyndman and Talbot, 1975a) as represented mainly by the Seven Devils Group. "Mushrooming" along the eastern batholith margin produced low-angle thrust faults (Hyndman and others, 1975; Chase and Johnson, 1976). Within the Harpster area, metamorphic grade increases consistently from greenschist facies in the Seven Devils Group to amphibolite facies in the Quartz Ridge block. Folds become progressively ptygmatic eastward toward the batholith: their axial planes dip east and southeast at 50 to 85 degrees. Contiguous units tend to be subconcordant.

DESCRIPTION OF ROCK UNITS

The mineral compositions of major rock units, the properties and occurrences of the most important minerals, and the chemical compositions of plutonic rocks are tabulated in twelve appendices which supplement the descriptions that follow below. Sample locations are shown on Plate I.

PRECAMBRIAN(?) METASEDIMENTARY ROCKS

Shenon and Reed (1934) tentatively correlate gneisses, schists, quartzites, and calc-silicate rocks in the Elk City region with Belt rocks to the north. Augen gneisses "intruding" Prichard-equivalent metasedimentary rocks in the Elk City region are found by Reid and others (1970, p. 714) to be at least 1,525 million years old. Rocks of concordant trend and lithologic similarity to those east of Meadow Creek cross the Middle Fork of the Clearwater River east of Kooskia. These units probably correlate with metasediments in the Orofino area which were named the Orofino series by Anderson (1930) and tentatively correlated with the lower part of the Wallace Formation by Hietanen (1962, p. 48). Armstrong (1975, p. 450) states that high-grade metamorphic rocks in the

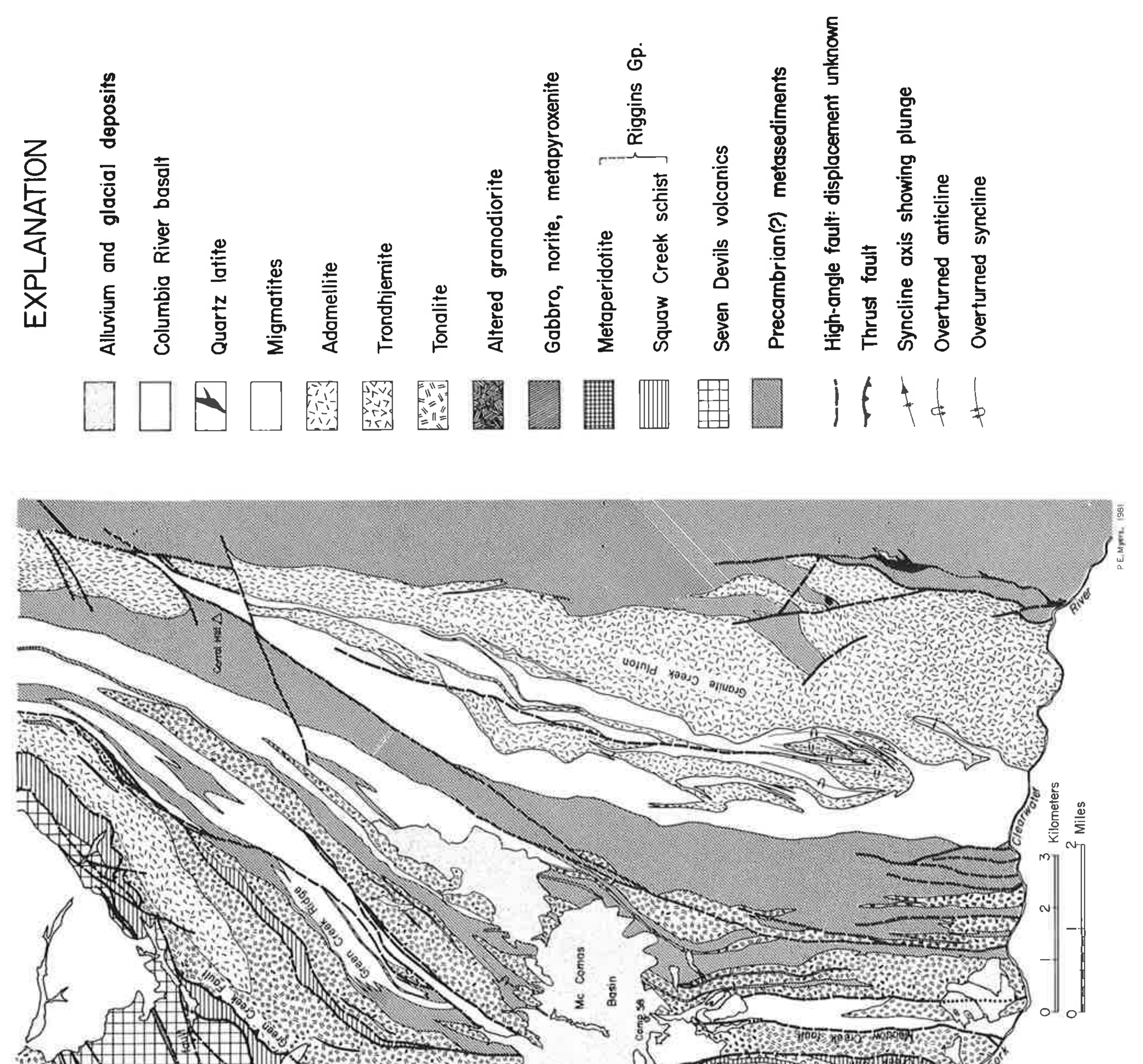

Figure 2. Generalized geologic map of the Harpster area, Idaho County, Idaho.

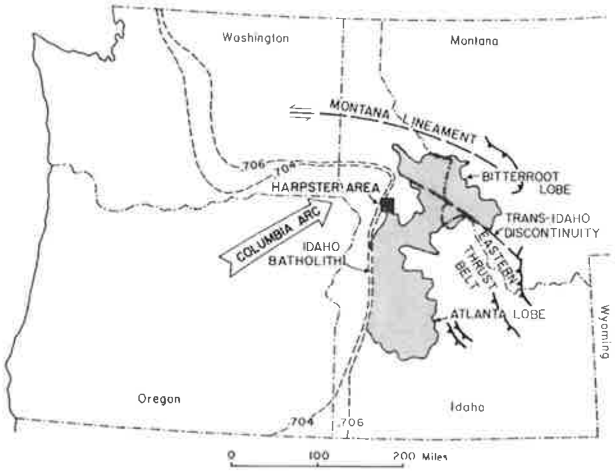

Figure 3. Map of the northwestern United States showing initial Sr ratios for Mesozoic and Cenozoic igneous rocks and their relation to the Idaho batholith. Modified from Armstrong and others, 1977, p. 407.

Harpster area, "may belong in part to the pre-Belt complex, may include metamorphosed Belt sediments, and probably contain much igneous material of Mesozoic age." Therefore, it is likely that pre-Belt and Belt rocks are tectonically intercalated in the Idaho batholith margin east of the Browns Creek fault.

The aggregate thickness of the Precambrian(?) rocks in the Harpster area is unknown owing to complex deformation and dilation accompanying batholith emplacement. Before metamorphism, the Precambrian(?) sedimentary rocks included thinly intercalated argillaceous and calcareous siltstone, sandstone, and dolomite. In the order of decreasing abundance, the Precambrian(?) rocks are mica schist and gneiss, quartzite, calc-silicate rocks, and amphibolite (Table 1). Compositional heterogeneity, thin layering (bedding?), and an abundance of quartzite suggest shallow-water, near-shore conditions of deposition.

Table 1. Major metamorphic and parent sedimentary lithologies in the Precambrian(?) rocks of the Harpster area, Idaho.

Approximate percent	Metasediment	Protolith
75	mica schist and gneiss	siliceous siltstone, possibly of volcanic derivation
18	quartzite	fine-grained, argillaceous, dolomitic, and carbonaceous sandstone
6	calc-silicate rock	thin-bedded, siliceous and argillaceous dolomitic and calcitic siltstones
1	hornblende-garnet schist	basic volcanic sediment; rounded zircon indicates detrital origin

Mica schist units become more gneissic with an attendant increase in feldspar toward granitic plutons. Muscovite, the principle mica, is preferentially distributed along axial planes of folded biotite foliation. Schorl and sillimanite increase markedly in the contact aureole of the Granite Creek pluton. The appearance of sillimanite (Appendix 2) and subordinate cordierite is accompanied by a decrease in the abundance of biotite. The schists grade into biotite gneiss composed predominantly of sodic-andesine or oligoclase, microcline, and quartz. Common accessory minerals are biotite, muscovite, almandite, schorl, sillimanite, allanite, zoisite, clinozoisite, epidote, sphene, magnetite, pyrite, apatite, and zircon. Gneiss-schist contacts are biotite-rich.

Although too small and sparse to map, hornblende-quartz-almandite schist and gneiss occur abundantly as lenses in mica schist and diopside-bearing quartzite and as angular blocks in agmatite along the edge of the Granite Creek pluton. Poikiloblastic almandite (0.5-15 mm diameter), with quartz and hornblende inclusions, shows no evidence of rotation.

Impure quartzites, 2 to 140 feet thick, make up approximately 15 percent of the Belt sequence and are intergradational with siliceous schist, gneiss, and calc-silicate rock. More persistent marker units core many of the ridges in the area. The quartzites are medium to coarse grained and vary from white through greenish and brownish gray to dark gray. Mineral assemblages (in order of decreasing abundance) are: (1) quartz-muscovite, (2) quartz-muscovite-biotite, (3) quartz-actinolite-diopside-calcite-tremolite, (4) quartz-muscovite-almandite with or without biotite, (5) quartz-diopside-grossularite, (6) quartz-graphite-pyrite ± biotite, garnet, and sphene, (7) quartz-biotite in hornblende-almandite, (8) quartz-muscovite-sillimanite-biotite-dravite-cordierite, (9) quartz-schorl, and (10) quartz-grossularite-clinozoisite-epidote-calcite-phlogopite. Textural and compositional banding, undulatory foliation, and thin augen structures are characteristic of micaceous quartzites. Euhedral schorl is a major component with mica in some laminated quartzites near the Granite Creek pluton. Dravite, commonly rimmed with schorl, occurs as disseminated grains and laminae in calc-silicate-bearing strata intercalated with sillimanite-bearing quartzites within 2 miles (3.2 km) of the Granite Creek pluton. Laminar distribution of tourmaline suggests detrital origin, but euhedral form and confinement to the contact aureole of the Granite Creek pluton indicate a metasomatic origin. The rimming of dravite by schorl indicates two ages or mechanisms of tourmaline formation. Dark gray, graphite-rich quartzite is especially abundant along the east side of Quartz Ridge.

SEVEN DEVILS GROUP

The Seven Devils Volcanics, as described and defined by Anderson (1930), were recently renamed the Seven Devils Group by Vallier (1977) and subdivided into four formations: the Windy Creek Formation of Early Permian age, the Hunsaker Formation of Early Permian age, the Wild Sheep Creek Formation of Middle and Late Triassic age, and the Doyle Creek Formation of Late Triassic age. Their aggregate thickness in Hells Canyon of the Snake River is nearly 7,000 meters. A local angular unconformity separates the Permian and Triassic portions of the section (Vallier, 1982, oral communication). In the type locality the Seven Devils Group consists mainly of spilitic and keratophyric flows, pyroclastics, and volcanogenic sedimentary rocks, which represent fragments of arc-trench accumulations most of which were consumed by post-Early Triassic subduction. Brooks and Vallier (1978) identify the remnants of two northeast-trending volcanic arc terranes separated by a dismembered, ophiolitic oceanic crust terrane and a wedge of Jurassic flysch. In western Idaho, the Fiddle Creek and Lightning Creek Schists of the Riggins Group, as originally defined by Hamilton (1963), are assigned by Brooks and Vallier (1978) to the "dismembered oceanic crust terrane," whereas the overlying Squaw Creek Schist of the Riggins Group is included in the "Jurassic flysch terrane." These terranes pinch out northeastward against complex fault zones separating them from the cratonic slab containing the Idaho batholith and its metasedimentary envelope.

Quartz keratophyric crystal and lithic tuffs, tuffaceous siltstone, chert, graywacke, and volcanic conglomerate intercalated with porphyritic basalt and andesite flows are cut by dikes and sills of diabase and coarsely porphyritic andesite in prominent outcrops along the South Fork for about 8 miles upstream from Harpster. The tuffaceous graywackes and siltstones display graded and disturbed bedding characteristic of turbidites. Bedding, although not conspicuous in most places, dips consistently to the south and southeast at high angles. Chert beds and clasts in siltstone turbidites (location 407) contain siliceous microfossils.

Volcanic and sedimentary rocks of the Seven Devils Group were involved in the following postdepositional sequence: (1) intrusion of diabase and andesite dikes and sills, (2) burial metamorphism with the formation of greenstones composed of albite, quartz, chlorite, epidote, sericite, and calcite, (3) intrusion of pyroxenite, gabbro and diorite dikes, (4) folding, (5) intrusion of small granodiorite and tonalite plutons (Lightning Creek pluton), and (6) shearing with local conversion of greenstones to phyllonites accompanied by prograde regional metamorphism (subduction?). Relict vesicular, lithic, and porphyritic textures were nearly obliterated by cataclasis along shear zones which become wider and more abundant eastward. Interlensing shear, cataclasis, and prograde regional metamorphism apparently accompanied the collision of a eugeosynclinal pile (Seven Devils and Riggins sequence) with a cratonic slab composed mainly of Precambrian(?) metasedimentary rocks.

RIGGINS GROUP

Metasedimentary and metavolcanic rocks (Table 2) structurally overlying the Seven Devils Group in western Idaho were named the Riggins Group by Hamilton (1963, p. 16-24) and divided into the Fiddle Creek Schist (base), Lightning Creek Schist, metaperidotite, Berg Creek Amphibolite, and Squaw Creek Schist. These formations, whose aggregate thickness in the Riggins region is 25,000 to 30,000 feet (7,500-9,000 m), are confined to the upper plate of the Rapid River thrust and occur in similar sequence on opposite limbs of the Riggins syncline. Metamorphic grade increases eastward within the group from low-grade schists to migmatites.

Vallier (1977, p. 8-9) believes the Fiddle Creek Schist and Lightning Creek Schist may correlate with the Elkhorn Ridge argillite and Burnt River Schist in the Baker quadrangle, Oregon, and the Squaw Creek Schist could be correlative with the Jurassic flysch sequence in the same area. He believes (1977, p. 8) that the Berg Creek Amphibolite "probably is a metamorphosed (by the Idaho batholith) ultramafic and mafic assemblage that lies between the older Fiddle Creek and Lightning Creek Schists and the younger Squaw Creek Schist." Amphibolite closely resembling the Berg Creek Amphibolite crops out along Highway 14 on the west side of the Browns Creek fault.

The Squaw Creek Schist, metaperidotite, and possibly part of the Berg Creek Amphibolite occur in the

Table 2. Major lithologies in the Riggins Group.

Approximate percent	Metasediment	Protolith
64	biotite-muscovite schist, metatuff	hypersiliceous, carbonaceous siltstone(?)
17	phyllite	quartz keratophyric tuff grading upward into carbonaceous, calcareous siltstones
12	calc-schist, calc-silicate gneiss, and marble	carbonaceous, locally cherty dolomite and limestone
7	hornblende-garnet schist	andesine(?) tuff or siltstone

Harpster area on the east side of Blacktail Butte and as fault slices along North Meadow Creek. Phyllonitic greenstones, here included in the Seven Devils Group, may correlate with a lower unit in the Riggins Group, probably the Fiddle Creek Schist. Before metamorphism, the Riggins sediments in the Harpster area included "dirty, thin-bedded siliceous siltstones and dolomitic limestones derived in part from volcanic sources" (Hamilton, 1963, p. 34).

The Squaw Creek Schist in the Riggins region consists of thinly laminated gray phyllite and fine-grained biotite-hornblende-schist, which were metamorphosed from sedimentary rocks derived chiefly from volcanic sources (Hamilton, 1963, p. 27). Plagioclase, quartz, biotite, muscovite, graphite, calcite, and ankerite are the chief minerals (Appendix 5). Accessory minerals include epidote, clinozoisite, garnet, hornblende, and prochlorite. These rocks are characteristically gray owing to the presence of finely disseminated graphite. Their gray color distinguishes them from units in the Seven Devils Group which are green.

In the Harpster area, Squaw Creek Schist overlies the Seven Devils Group. The Squaw Creek Schist consists of fine-grained, dark gray, and thinly laminated graphitic quartz-mica schist, hornblende-garnet schist, and calcareous rocks including schist, gneiss, and marble. Tightly folded and boudinaged quartz and granitoid veinlets indicate considerable extension in the plane of eastward dipping schistosity.

Thinly laminated, fine-grained graphitic quartz-mica schist is the dominant rock type in the lower half of the Squaw Creek Schist below the metaperidotite in the North Blacktail syncline and in correlative rocks between the Blacktail pluton and the Castle Creek fault. Isoclinally folded compositional lamination and schistosity dip steeply eastward. Discordant quartz and pegmatite stringers and lenses are abundant.

A 50-foot (15 m) layer of sheared and partly recrystallized, coarse crystal tuff interstratified with quartz-biotite schist in the North Blacktail syncline (Plate I, location 539) is composed of coarse, ovoid plagioclase porphyroclasts in a mylonitic matrix of quartz, muscovite, and biotite.

Calcareous rocks are mainly confined to the upper half of the Squaw Creek Schist. Laminated, fine-grained calcareous schist crops out between Castle Creek and Browns Creek near the base of the North Blacktail syncline and along Green Creek Ridge and Whitman Creek where it occurs as thin fault slices. Probably correlative schists cross the Salmon River 2 miles east of Riggins. The schists are characterized by thin compositional interlensing. From Castle Creek eastward, hornblende, epidote, and almandite increase in abundance at the expense of calcite, phlogopite, and quartz. The degree of alteration increases northeast from the South Fork as does the relative volume of granitic intrusive rocks. The following mineral assemblages (in order of decreasing abundance) were recognized petrographically: (1) quartz-phlogopite-calcite with or without actinolite, (2) quartz-clinozoisite-calcite-actinolite with or without tremolite and plagioclase, (3) quartz-diopside-actinolite-clinozoisite with or without grossularite, and (4) quartz-hornblende-almandite with or without biotite. Calcite-bearing schists occur in and adjacent to banded, siliceous marbles. Goethite, which is prevalent in calcareous layers, was probably formed by alteration of pyrite or iron-bearing carbonates.

Of particular interest as a marker unit is a 300-foot (100 m) layer of calcite-phlogopite-quartz-schist (Plate I, location 627). The rock is medium gray and contains lenticular clusters and coarse porphyroblasts of pale orange phlogopite. Associated marble and calc-schist layers contain nearly colorless phlogopite interlensed with calcite, quartz, and sparse actinolite or diopside.

Calc-silicate gneiss, which occurs in the upper 2,500 feet of the Squaw Creek Schist west of Browns Creek and in fine-grained schists structurally overlying the metaperidotite body in the North Blacktail syncline, consists of thin laminae of quartz and actinolitic hornblende, calcite and diopside, and andesine and quartz with or without clinozoisite. Coarse clinozoisite and prochlorite replace plagioclase and hornblende respectively. These rocks were probably metamorphosed from calcareous siltstones.

Sparse marble layers in the Squaw Creek Schist were useful as marker units despite wide mineralogical variation due to local differences in metamorphic grade.

Fine-grained, thinly laminated and strongly lineated hornblende-garnet schist crops out along the east side of the Blacktail pluton and west of Browns Creek in the southern part of the area. With the recent demise of Hamilton's Berg Creek Amphibolite (Onasch, 1976, p. 35) the taxonomy of this unit is in doubt. In addition to predominant hornblende and accessory almandite, the schist contains disseminated quartz, sodic plagioclase (commonly as augen), and thin seams of epidote. Quartz lenses up to 2 feet long occur between some layers. Disseminated sooty graphite is a ubiquitous accessory, a factor suggesting sedimentary origin. Quartz-biotite-almandite and subordinate quartz-hornblende-diopside-plagioclase layers locally constitute up to 60 percent of the schist. Before metamorphism the rock was probably a mafic tuffaceous siltstone.

A crudely stratified, strongly foliated metagabbro and metaperidotate body of lenticular form is exposed on North Blacktail Butte (Figure 2). Its maximum thickness is about 850 feet (260 m), and it is symmetrically concordant in the hinge of the North

Blacktail syncline. Its upper and lower contacts are reverse faults dipping 40 to 60 degrees eastward. From a basal layer of sheared and metamorphosed olivine-pyroxene gabbro, the rocks grade upward into a core of metaperidotite and finally to a discontinuous layer of highly altered pyroxenite. These three types of rock show considerable local variation in texture and mineral composition (Appendix 6) and are moderately resistant to erosion. Fresh exposures are pale bluish brown to olive gray and deep green. The metaperidotite is generally schistose or gneissic with lenticular masses of coarse magnesian amphibole porphyroblasts. Relict olivine and pyroxene have been almost completely altered to antigorite, talc, tremolite, prochlorite, zoisite, and magnetite. Accessory minerals include phlogopite and actinolite. The epidote-ferroan, prochlorite in magnetite rock at the top of the metaperidotite (Plate I, location 527) is probably a sheared and metamorphosed pyroxenite.

Ultramafic rocks in the northwest quarter of the Riggins quadrangle (Hamilton, 1963), although similar in form and structure, are less thoroughly sheared and contain a lower percentage of original minerals. Magnesite, which is abundant in the Riggins region, was not observed in the Blacktail Butte unit, and ferroan prochlorite and magnetite are correspondingly more abundant at Blacktail Butte. According to Hamilton (1963, p. 65):

> *The ultramafic rocks north of Riggins lie along the contact between the dissimilar Squaw Creek and Lightning Creek Schists. South of Riggins, some masses lie between the same formations and other rocks were intruded fortuitously along a major lithologic break in a stratigraphic succession; but much more likely, the formations are separated by a thrust fault along which the ultramafic rocks were intruded, probably during thrusting.*

A similar emplacement mechanism is suggested for the Blacktail Butte ultramafic body, although the mass was probably remobilized during the formation of the North Blacktail syncline that accompanied the intrusion of the Blacktail pluton.

A southeastward-dipping layer of white and gray phyllite capped by a thin stratum of hornblende schist separates schistose Seven Devils metasedimentary and metavolcanic rocks on the west from structurally overlying tonalitic mylonite gneiss northeast of Sugarloaf. The phyllite bears a close resemblance to parts of the Lucile Slate as described by Hamilton (1963, p. 12).

The lower 300 feet of the phyllite unit at Wall Creek consists of pale green and white phyllites and a few 1- to 12-foot strata of medium-grained bluish gray marble, which superficially resembles a micrite but possesses a strong lineation. Optically amorphous phosphatic, acid-leach residues from these marbles probably represent fecal material. The phyllites are composed of quartz, aluminian prochlorite, muscovite, oligoclase, yellow-green actinolitic hornblende, and calcite. The white phyllite is muscovite rich.

The middle 900 feet of the phyllite unit is olive gray and composed of quartz, biotite, reverse-zoned albite or oligoclase, actinolitic hornblende, graphite, calcite, muscovite, and epidote. Iron-stained calcareous laminae were probably sideritic strata. Concordant quartz lenses up to 3 feet in diameter may represent recrystallized chert nodules, or less probably lenticulated quartz veins.

Black hornblende appears abruptly in strongly lineated schists in the upper 150 feet of the phyllite unit. The transition is most likely related to an increase in metamorphic grade with the formation of hornblende at the expense of actinolitic hornblende and some of the prochlorite (Plate IV).

Hamilton (1963, p. 35) classifies the Riggins Group as a eugeosynclinal assemblage probably derived mainly from the reworking of andesitic and keratophyric tuffs (Seven Devils Group?). He describes the Riggins rocks along the South Fork as follows: "Septa of gray, biotitic and calcareous schists dip steeply east-southeast between plutons of granitic rocks and are similar to rocks of the Squaw Creek Schist."

Vallier (1976, p. 417) states that the Squaw Creek Schist may correlate with Late Triassic(?) or Jurassic carbonate and shale overlying Triassic volcanic strata in the Snake River canyon north of Huntington, Oregon. Thus, it is possible that the Seven Devils-Lucile-Riggins assemblage may be an original stratigraphic sequence. If so, it is probable that the Riggins Group was derived in part from the erosion of the already exposed Seven Devils terrain.

The possibility of a correlation of the Riggins Group with Precambrian(?) amphibolite grade metasedimentary rocks east of the Browns Creek fault has been examined. Although both rock assemblages have similar structures and protoliths, the Riggins Group contains less quartzite and amphibolite and is characterized throughout by the presence of graphite. However, graphite-bearing quartzite was found in the higher grade metamorphic assemblage just east of Ralph Smith Creek at location 354 (Plate I, and compare Tables 1 and 2).

PLUTONIC ROCKS

The major plutonic assemblages in the Harpster area are grouped compositionally (Figure 4) as follows: (1) gabbro and tonalite (Harpster pluton), (2) tonalite (Lightning Creek pluton and Meadow Creek complex), (3) trondhjemite (Blacktail pluton and wedge intrusions northeast of Sugarloaf), and (4) adamellite (Wall Creek and Granite Creek plutons). Their chemical compositions are given in Table 3. Smaller felsic lenses, stringers, and dikes are mainly leucocratic granite.

Deeper basement rocks were raised on the east side of the Browns Creek fault, and plutons west of it are dominantly tonalitic to trondhjemitic. The trondhjemite plutons were intruded into and contaminated by sodium-rich, albitized quartz keratophyres of the Seven Devils Group and their eugeosynclinal derivatives—the Riggins Group(?). The Harpster and Blacktail plutons are strongly discordant and have conspicuous metamorphic aureoles. Using criteria established by Buddington (1959) these plutons are classed as mesozonal. By contrast, the subconcordant, wedge-shaped plutons of the high-grade metamorphic terrane east of the Browns Creek fault were emplaced in the catazone.

Harpster Pluton

Contaminated gabbro and tonalite in mafic Seven Devils metavolcanic rocks at Harpster are separated from overlying Columbia River basalt by an iron-rich weathered zone up to 33 feet thick. The faulted south edge of the pluton is norite, whereas its highly contaminated roof zone is a hornblende gabbro (classed as quartz gabbro by Larsen and Schmidt, 1958, p. 5) containing numerous mafic xenoliths and pendants, which disappear eastward because the roof slopes more steeply west than the land surface. Contaminated intrusive rocks of the roof zone are mainly coarse, hornblende-clinopyroxene gabbro and norite. With the diminished relative volume of mafic xenoliths eastward, the rock grades into hornblende tonalite.

At megascopic scale the contacts between hornblende gabbro and greenstone country rock comprise three concentric but overlapping zones of intrusion and assimilation up to 20 feet (6 m) wide. The outermost veined zone is coarsely recrystallized hornblende-rich greenstone cut by a web-work of coarse plagioclase or hornblende veinlets (Figure 5). A transitional zone, in most places a few feet wide, contains coarsely veined, angular greenstone xenoliths with hornblende-rich rims. Interstitial gabbro is mottled. The innermost zone of assimilation overlaps the transitional zone and is broader. Hornblende-rich xenoliths become rounded,

Table 3. Normalized chemical compositions of plutonic rocks from the Harpster area, Idaho.*

	Gabbo	Diorite	Tonalite			Trondhjemite			Adamellite						
	5	211-D	56	181-G	324	408	550-B	553-A	64	289-A	399	401-A	414	620	621-A
SiO_2	49.63	56.64	60.97	59.19	55.62	68.12	75.21	70.13	72.93	76.54	71.17	72.56	70.45	70.63	72.37
Al_2O_3	18.14	17.78	18.95	17.63	20.80	17.46	14.62	17.38	15.83	13.52	16.46	15.88	17.40	16.74	16.36
TiO_2	0.82	0.70	0.63	0.90	0.73	0.34	0.09	0.29	0.24	0.35	0.33	0.20	0.21	0.23	0.19
Fe_2O_3	5.25	4.20	2.36	3.46	2.79	1.15	0.26	0.84	0.55	0.82	0.84	0.53	0.41	0.57	0.44
FeO	6.02	4.80	2.71	3.96	3.19	1.33	0.29	0.97	0.62	0.95	0.96	0.61	0.47	0.66	0.50
MnO	0.21	0.16	0.09	0.13	0.09	0.08	0.01	0.02	0.02	0.08	0.01	0.02	0.02	0.03	0.02
CaO	10.58	7.97	6.14	6.30	9.08	4.50	2.47	2.89	2.51	2.30	2.63	2.18	2.79	2.43	2.72
MgO	6.26	3.97	2.20	2.74	3.59	1.14	0.51	0.75	0.70	0.61	0.76	0.57	0.60	0.74	0.59
K_2O	0.09	0.34	1.59	2.07	1.53	1.24	2.60	2.48	2.80	0.92	2.86	3.70	3.39	4.06	2.80
Na_2O	2.97	3.36	4.18	3.38	2.47	4.52	3.92	4.19	3.75	3.87	3.92	3.66	4.21	3.82	3.96
P_2O_5	0.03	0.08	0.19	0.23	0.10	0.14	0.03	0.07	0.06	0.04	0.05	0.08	0.06	0.08	0.05
Niggli Values															
Si + Ti	0.836	0.951	0.935	1.278	1.022	1.253	1.138	1.705	0.996	1.216	1.188	1.210	1.175	1.178	1.207
Al	0.178	0.174	0.204	0.133	0.186	0.143	0.171	0.170	0.173	0.155	0.161	0.156	0.171	0.164	0.160
fm	0.307	0.220	0.170	0.040	0.123	0.009	0.062	0.043	0.168	0.033	0.043	0.023	0.027	0.035	0.027
c	0.189	0.142	0.162	0.041	0.110	0.044	0.804	0.052	0.113	0.045	0.047	0.039	0.050	0.043	0.049
alk	0.489	0.058	0.056	0.072	0.084	0.091	0.086	0.094	0.077	0.090	0.094	0.098	0.104	0.105	0.094

*Analysis (percent) by the Rock Analysis Laboratory, Washington State University, 1979.

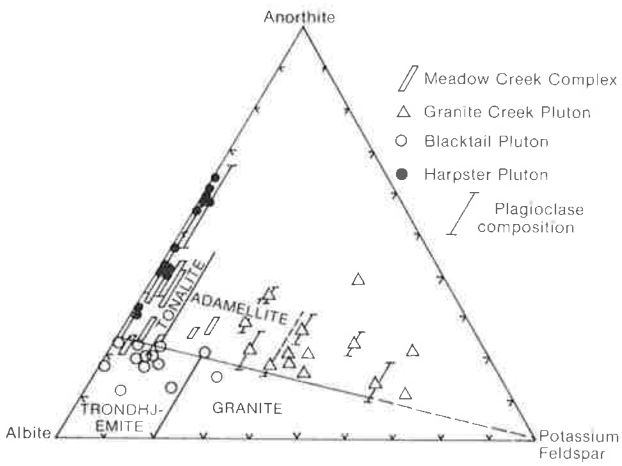

Figure 4. Modal classification of granitoid rocks in the Harpster area according to the classification by O'Connor (1965, p. 579-584). Point counting by the Chayes method.

and their grain size increases until relict xenoliths are recognizable only as slightly darker clots in the gabbro. Zoned pegmatite dikes and veinlets of plagioclase, epidote, and chlorite were emplaced along joints.

Within 1,300 feet (400 m) of their sheared contact with the Harpster pluton, the Seven Devils metavolcanic rocks become darker and coarser grained. Shearing and cataclasis are concentrated in rocks of the southern edge of the pluton. With the replacement of chlorite and epidote by hornblende and plagioclase, the assimilated greenstone was converted to a gabbroic rock.

The Blacktail Trondhjemite Pluton

The Blacktail trondhjemite pluton on the west side of Blacktail Butte is semicircular in plan with a diameter of approximately 5 miles (8 km). West of the area the pluton is in fault contact with coarse hornblende and chlorite schists probably belonging to the Riggins Group. The core of the pluton is foliated trondhjemite composed of oligoclase, quartz, biotite, muscovite, and orthoclase. Plagioclase is about twice as abundant as quartz. A common coarse-textured variant is a strongly foliated trondhjemite containing bent sheets of black biotite up to 1 centimeter in diameter. Pegmatites in this rock contain abundant muscovite and occasional garnet. The abundance of muscovite, epidote, and almandite increases in proportion to the extent of mylonitization. Muscovite and epidote are oriented along plagioclase cleavages. Mineral distributions in sheared trondhjemite show that almandite and muscovite formed at the expense of biotite in zones of most intense mylonitization.

A wedge-shaped fault slice of foliated trondhjemite between Castle Creek and Browns Creek is probably an uplifted segment of the Blacktail pluton. Intrusive wedges of trondhjemite in this segment are nearly concordant in strike, and they dip more steeply than the enclosing Squaw Creek Schist. As the schist screens become relatively thicker southward between intrusive wedges, they show a corresponding reduction in metamorphic grade. For example, a calc-silicate gneiss unit on the east slope of Blacktail Butte grades southward into impure marble, and almandite disappears in the intercalated quartz-biotite schist. Microcline and muscovite in the dikes increase southward at the expense of oligoclase, and the rocks are more strongly mylonitized. Abundant, tightly folded granitic dikes and stringers in the Squaw Creek Schist around the Blacktail pluton commonly contain layers of spessartitic almandite.

Lightning Creek Pluton

A small, sheared, highly altered granodiorite-tonalite pluton south of Lightning Creek is roughly triangular in plan and tapers southward against a fault.

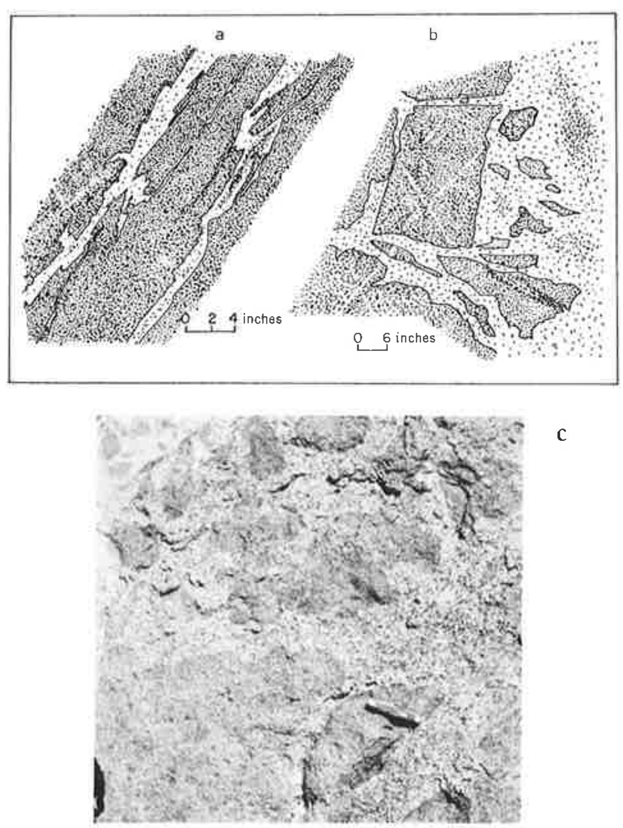

Figure 5. Contact features of the Harpster pluton: (a) granitic veinlets in greenstone, (b) transition zone containing angular greenstone xenoliths, and (c) inner assimilation zone consisting of rounded, partly assimilated greenstone xenoliths in a gabbroic matrix. Pocketknife for scale.

Its northern end is 0.7 mile (1 km) wide and has a nearly flat roof containing abundant greenstone xenoliths and pendants. Imbrication of the pluton along northeast-trending faults tectonically intercalated slices of phyllonitic greenstone and granitoid rocks west of the main mass. Only the largest of these fault slices were mapped. The granodiorite and tonalite were not mapped separately, owing to the extent of alteration which has made them difficult to distinguish from each other and from the enclosing greenstones. Plagioclase is partly replaced by sericite or mixtures of epidote, clinozoisite, and quartz; microcline is sericitized; hornblende is replaced by chlorite and epidote; and biotite is thoroughly chloritized. Rocks of the Seven Devils Group in contact with these intrusive rocks are veined by chlorite and epidote. The pluton has a chilled margin, a factor indicating shallow intrusion. The Lightning Creek pluton is tentatively assigned a Jurassic age, because it shows much more alteration and mylonitization than other plutons in the area.

Meadow Creek Complex

Tabular and wedge-shaped granitoid plutons compose more than half the migmatitic border zone of the Idaho batholith east of the Browns Creek fault zone. The laminar assemblage of tonalite, adamellite, and coarse-grained schists making up the Meadow Creek complex has the appearance at map scale of a coarsely veined gneiss. Similar gneissosity characterizes the northeastern border zone of the Idaho batholith (Chase, 1973; Nold, 1974). Gradational contacts and mylonitic fabrics indicate considerable contamination of the granitic magmas during and prior to their synkinematic emplacement. The Meadow Creek complex between Browns Creek and Quartz Ridge is composed dominantly of foliated and lineated hornblende-bearing biotite tonalite composed essentially of andesine, quartz, and biotite. Near McComas basin the granitoid units bend concordantly toward the northeast, and the tonalite units pinch out between sheets of metasediments and adamellite (oligoclase, microcline, quartz, biotite, and muscovite). The larger granitoid units are roughly concordant, wedge-shaped bodies that dip steeply eastward. Medial cores of the wedges are relatively massive, whereas their sheared margins are migmatitic. Screens of coarse gneiss, schist, quartzite, and calc-silicate rock are drag folded and locally brecciated. Randomness of folding in the screens is proportional to the volume ratio of granitoid and metasedimentary components in the migmatites.

The gneissic, porphyritic, hornblende tonalite (Figure 6) is slightly coarser and darker gray than the gneissic biotite tonalite with which it broadly intergrades. The two types are considered to be comagmatic.

The dominant mineral in the gneissic tonalite is coarse (0.3-8.0 mm), well-oriented, zoned plagioclase (An_{40} to An_{25}) most of which shows marginal fracturing, lenticulation, and rotation by shearing. Plagioclase content in granitoid bodies decreases eastward and northward at the expense of microcline as the tonalite grades into adamellite. In the tonalites, microcline is an anhedral accessory mineral showing considerable bending and comminution by cataclasis. The gradation from tonalite to adamellite is accompanied by an increase in muscovite and almandite. Accessory minerals, in order of decreasing average abundance are sphene, epidote, muscovite, chlorite, apatite, allanite, zircon, pyrite, and calcite. Exceptionally large and abundant sphene, allanite, zircon, and apatite are conspicuous in hand specimens of the tonalites.

Subordinate trondhjemite occurs as (1) a transitional rock type between tonalite and adamellite, (2) coarse augen and concordant, irregular masses in the enclosing gneissic tonalite, and (3) dikes cutting tonalites. Many of these dikes have been folded.

Tonalite of similar lithology and, in some places, analogous structural position has been described and classified as tonalite or quartz diorite gneiss by other workers in areas bordering the Idaho batholith. A "quartz diorite gneiss," essentially identical to that in the Harpster area, crosses the Salmon River about 13 miles (21 km) east of Riggins. Hietanen (1962, p. A55) and Johnson (1947) concluded that the biotite-hornblende tonalite gneiss of the batholith margin in western Clearwater County is largely of metasomatic origin, having replaced diopside-plagioclase gneiss. Mineralogically similar rocks in the Elk City region, classified by Reid (1959, p. 48) as quartz diorites, occur mainly as dikes.

Granite Creek Pluton

The Granite Creek pluton (Plate III) is wedge-shaped with an apical edge which plunges gently northward and an axial plane which dips steeply eastward. Within the Harpster area the deepest part of the pluton is exposed along the South Fork. This pluton probably represents the serrated northern edge of the Atlanta lobe of the Idaho batholith (Armstrong, 1975, p. 439). From its migmatitic margin of foliated, medium-grained biotite-muscovite adamellite the pluton grades inward to a core of nearly structureless, coarse-grained biotite adamellite. The northern part of the pluton is offset laterally by several high-angle faults. Enclosing migmatites contain bands of coarse-grained sillimanite-bearing biotite-muscovite-almandite schist, augen gneiss, and subordinate amphibolite. The veined and banded gneisses grade away from the adamellite into

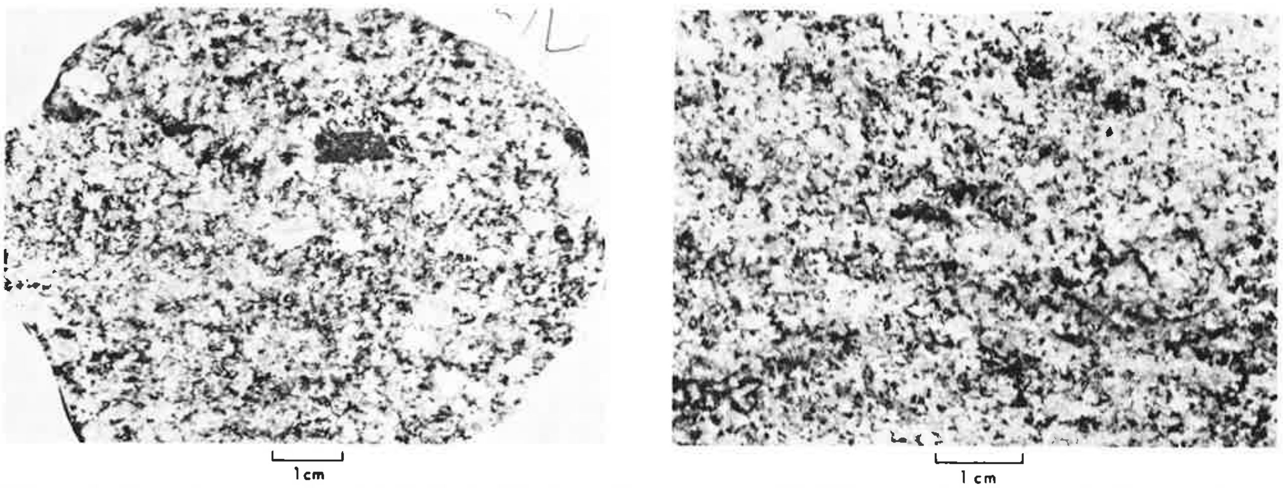

Figure 6. Specimen photographs of gneissic biotite-hornblende tonalite from location 664 (left) and gneissic biotite tonalite from location 553 (right).

strongly granitized metasedimentary rocks cut by swarms of leucocratic granite and adamellite dikes probably derived from the pluton.

Nearly white, coarse-grained, biotite adamellite with faint foliation or lineation is the most common rock type in the core. It is composed essentially of oligoclase, microcline, quartz, and biotite. Most of the plagioclase (4-12 mm) contains cleavage-oriented muscovite, anhedral microcline, and quartz blebs. Biotite, as interstitial clusters in plagioclase-rich adamellites, probably crystallized later than the plagioclase. With an increase in the abundance of potash feldspar, biotite shows more extensive alteration to muscovite and magnetite. Sparse pegmatite occurs as schlieren in adamellite near the margin of the pluton. A faint foliation, where present, dips vertically to steeply eastward, and lineation generally plunges gently northward.

In contrast to the core, the margin is foliated, finer grained, and richer in potash feldspar and muscovite. Microcline-rimmed plagioclase subhedra (1-3 mm) are surrounded by quartz and ragged biotite. The foliated adamellite grades outward into migmatites containing layers of quartzite, calc-silicate rock, mica schist, and amphibolite. The contact of the pluton is drawn approximately where 25 percent of the rock is banded.

Garnetiferous adamellite in sharp contact with intercalated mica schist and mica-sillimanite augen gneiss forms a system of north-northeasterly trending folds in the upper Cougar Creek area. Filaments of coarse biotite schist in the adamellite increase in abundance toward schist and augen gneiss units. The doubly plunging anticline east of location 96 (Plate I) has an adamellite core. Schist and augen gneiss typically core synclines, as at Cougar Mountain. These relict folds embedded in the roof of the Granite Creek pluton are offset, especially in the northern part of the area, by numerous east-northeasterly trending cross faults.

Smaller Granitoid Bodies

Small, prekinematic and synkinematic granitoid bodies increase in abundance eastward across the Harpster area. These bodies are characteristically lenticular or sigmoidal and show varying stages of segmentation and dispersal along interlensing shear planes. Their length is 6 to 30 inches (15-75 cm), and their length/width ratios are between 3 and 10.

Ptygmatically folded aplite and pegmatite stringers in the Riggins Group show mutually cross-cutting relations, and they increase in abundance toward the Blacktail pluton. Folded stringers in trondhjemite show more pronounced axial thickening and lower amplitudes than corresponding stringers in the Squaw Creek Schist. Adamellite is the most common rock type in these stringers.

Very coarse, postkinematic, biotite-muscovite pegmatite dikes cut the plutonic units with strong discordance. Their abundance is greatest in and near the Blacktail pluton and the Meadow Creek complex. Although the dikes produced dilation offset, they do not show effects of chilling. These dikes commonly contain coarse accessory garnet, schorl, sphene, and apatite. The pegmatite locally contains very large microcline phenocrysts (up to 5.4 centimeters long) surrounded by masses of coarse-grained gray quartz.

Geochemistry

All plutonic units in the Harpster area are peraluminous with $Al_2O_3/CaO + Na_2O + K_2O = 1.33$ to 1.91. Their average Peacock alkali/lime index is 64 percent, thus placing them in the calcic category. Their chemical compositions are shown in Table 3.

MIGMATITES

Migmatites in the Harpster area consist of granitoid layers, composed of trondhjemite, adamellite, and granite, and intercalated metasedimentary layers of coarse schist, quartzite, calc-silicate rock, and amphibolite. Migmatites are most abundant along the margins of the Granite Creek pluton. They are probably the most abundant rocks making up the Idaho batholith at the latitude of South Fork. A detailed petrologic study of migmatites along the South Fork east of the area (Carlson, 1981) shows an increase in migmatization toward the Granite Creek pluton and an origin compatible with the constraints of partial melting. The migmatites have an overall tonalitic composition and are associated with metasedimentary gneisses of sillimanite-orthoclase grade. Although different types of migmatite were not mapped, they are described briefly below.

Banded gneiss is composed of alternating granitoid and metasedimentary layers between 0.2 inch and 8 inches (0.7-12 cm) thick and of about equal abundance. The granitoid layers are foliated, nearly leucocratic muscovite or biotite adamellite, trondhjemite, or granite with accessory garnet, biotite, and tourmaline. Metasedimentary layers are most commonly muscovite schist. Impure quartzite and calc-silicate laminae are less common. The banding displays a remarkable uniformity of thickness and trend. Discordant, garnetiferous aplite and pegmatite dikes, with foliation parallel to banding in the enclosing gneiss, have been isoclinally folded.

The veined gneiss consists of contorted, flamose and sigmoidal granitoid lenses in a schistose or gneissic matrix relatively rich in mica, garnet, and sillimanite. Discordant granitoid masses commonly contain relict mafic septa which are oriented in structural continuity with the enclosing veined gneiss (Figure 7). Strong contortion of granitoid masses in the veined gneiss indicates deformation and flowage during partial melting.

Agmatite occurs along the west side of the Granite Creek pluton and more abundantly east of the area. At location 614 (Plate I), banded biotite gneiss is breached by irregular, lenticular masses of adamellite containing clots of coarse biotite adamellite pegmatite (Figure 8). Angular xenoliths of banded gneiss and almandite amphibolite are surrounded by the adamellite

QUARTZ LATITE AND RHYOLITE VITROPHYRES

A glassy quartz latite dike crops out along the west side of Peasley Creek. The dominant rock is a pale yellowish gray, flow-laminated, microcrystalline quartz latite containing euhedral calcic oligoclase and ovoid quartz phenocrysts (0.1-2.0 mm). The glassy dike margin contains abundant flow-oriented microlites and angular xenocrysts of plagioclase, strained quartz, and brown biotite. The plagioclase is anastomosed by microscopic veinlets of glass ($n = 1.487 \pm 0.001$). Very fine muscovite in and around plagioclase grains and along some flow laminae may have formed during a late phase of solidification.

A cylindrical body of flow-laminated, pink, glassy rhyolite(?) containing 1 to 2 millimeter-long euhedral quartz and sanidine(?) phenocrysts crops out on the ridge just southeast of Cougar Mountain. The plug has a diameter of approximately 200 feet and appears to be vertical. Flow lamination dips vertically and is roughly concentric. The rhyolite magma rose along the intersection of a fault and quartzite bed. The rhyolite was quarried for road aggregate in 1975 and 1976.

Dikes of similar trend and lithology occur throughout the region south of the map area. They were probably intruded along north-south normal faults in mid-Tertiary time. Although vesicular diabase (lower part of Columbia River Basalt Group) occurs only a few feet from the dike, it was impossible to ascertain their age relationships. The absence of felsic dikes in units of the Columbia River Basalt Group throughout the region suggests that the quartz latite is older.

Figure 7. Veined gneiss; banding truncated by zone of anatexis (location 611, Plate I). View looking north.

Figure 8. Agmatite with biotite schist fragments cut by lenticular masses of adamellite (location 614, Plate I).

COLUMBIA RIVER BASALT GROUP

Within the Harpster area the Columbia River Basalt Group is on the eastern edge of the Clearwater embayment (Bond, 1963), a lobate extension of the Columbia River plateau into northeastern Idaho. Aggregate thickness of the flows increases westward within the area to about 800 feet. Basalts on the plateau edge west of Harpster and in the headwaters of Wall Creek in the northern part of the area are part of the main body of the Clearwater embayment, whereas the basalts on Blacktail Butte, in McComas basin, on the ridge east of lower Meadow Creek, and at the mouth of Peasley Creek have been separated from the embayment by faulting and erosion.

The Columbia River Basalt Group of western Idaho was divided by Bond (1963) into two formations: the "Lower" and "Upper" Basalts. More comprehensive geochemical and paleomagnetic studies by Wright and others (1973), Hooper (1974), Swanson and others (1981), Camp and Hooper (1981), and Camp (1981) have developed a new stratigraphic nomenclature for the Columbia River Basalt Group (Swanson and others, 1979) and permitted studies of Late Cenozoic deformations of the Columbia River plateau and its margins (Hooper and Camp, 1981). A geologic map of basalts in the Harpster quadrangle by Camp and Hooper (1981) shows that the "Lower" Basalt of Bond corresponds to the Imnaha Basalt which has an age of 17.0 to 16.5 million years (Hooper and Camp, 1981, p. 325). The overlying "Upper" Basalt of the Grande Ronde Formation, whose age is 16.5 to 14.5 million years, is confined to the terrane east of South Fork and the lower area east of Blacktail Butte. Formations younger than 14.5 million years, including Asotin and Weippe(?) flow units, occur on the east edge of the Camas Prairie west of South Fork. For more details, see Camp and Hooper (1981) and Hooper (1982).

Faults cutting Grande Rond Basalt along the north side of Mt. Idaho west of the map area and along the east side of Blacktail Butte have displacements up to 2,000 feet and were active no more than 15 million years ago and probably less than 5 million years ago.

The Imnaha ("Lower") Basalt in the Harpster area is vesicular pyroxene diabase (Table 4) containing up to 30 percent randomly oriented labradorite laths up to 14 millimeters long in a matrix of granular pigeonite. Poikilitic, zoned andesine phenocrysts (x = 1.548; y = 1.555) up to 35 millimeters long containing abundant augite inclusions occur sparsely in vesicular diabase on Sheep Ridge (Figure 9). Partly devitrified olive brown glass contains pigeonite microlites and skeletal magnetite. Accessory olivine is partly altered to iddingsite. Fragments of weathered granite and quartzite occur locally near the base of the Imnaha Basalt. Vesicles are lined with pale green glass. Ophitic and porphyritic textures characteristic of the Imnaha Basalt are absent in the Grande Ronde and younger ("Upper") basalts within the map area. The occurrence of the Imnaha Basalt within the South Fork valley suggests that a lobe of Columbia River basalt moved up the valley in nearly the same location as the present westward-flowing part of the South Fork.

The Grande Ronde and younger ("Upper") basalts, which represent more extensive inundation of the western flanks of the Clearwater Mountains, are thickest in the northwestern corner of the Harpster quadrangle.

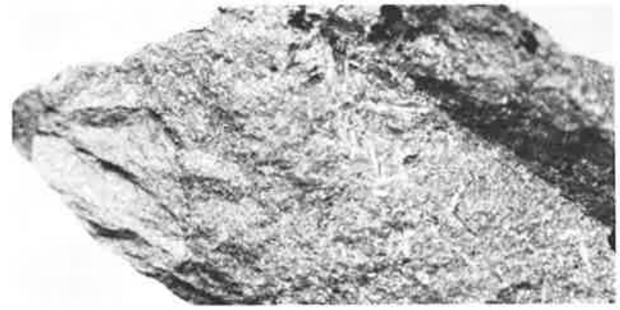

Figure 9. Coarse poikilitic plagioclase phenocryst (left) in a diabasic matrix (location 545, Plate I).

Several valley-filling flows occur on the hillside east of Harpster, in McComas basin, and on the west side of Blacktail Butte. Tributary valley walls were locally as steep as 70 degrees. Basalt in contact with the walls is vesicular and contaminated with abundant rock and mineral fragments.

The Grande Ronde and younger basalts are uniformly fine grained. Flow tops are vesicular, and columnar

Table 4. Synthesis of kinematic history of the region surrounding the Harpster area, Idaho, as excerpted from Morrison (1968), Hall (1961), Reid (1959), and Onasch (1978).

TIME ↓

BELT OR PRE-BELT METASEDIMENTARY ROCKS, OR BOTH			RIGGINS GROUP ABOVE RAPID RIVER THRUST FAULT
Morrison (1968)	**Hall (1961)**	**Reid (1959)**	**Onasch (1978)**
Large-scale, recumbent isoclinal folds; axial plane schistosity	Tight isoclinal ("B-1") with strong axial plane schistosity ("S-2") subparallel to bedding ("S-1") "Crinkly lineation" parallel to fold crests	Tight isoclinal with strong axial plane schistosity ("S-2")	Isoclinal ("F-1") with axial plane schistosity ("S-2")
—	—	—	Asymmetrical of diverse axial trend, movement east over west ("F-2")
Upright-isoclinal with axial plane schistosity and biotite along no. 2 axes; plunge made near-vertical by no. 3 folds	Open-subisoclinal ("B-2") with or without axial plane schistosity ("S-3")	Tight concentric or "open isoclinal"; slip along "S-2" during formation no. 2; plunges NW and SE; granitic stringers formed	Upright-symmetrical ("F-3") small scale
Warps of no. 2 axes, large scale; related to batholith intrusion or formation of "Clearwater orocline" (p. 114) or both; discordant into batholith	Large, gentle open folds ("B-3"); axes nonparallel to B-2 axes. Drag folds on limbs have wrong direction of tectonic transport; drag folds nonparallel to axes of larger B-3 folds	Large gentle warps of no. 2 axial planes; axial planes vertical	Upright symmetrical ("F-4"); large scale
Cataclastic shear and kink folds related to reverse faulting, intrusion of batholith and recrystallization		"Microchevron-phyllonite" deformation related to batholith emplacement	Open warps ("F-5") or kink band folds

jointing characterizes the thicker flows. These flows are composed essentially of acicular, subhedral labradorite in a fine-grained, granular matrix of pale olive green pigeonite. Olivine is locally an essential mineral, although its abundance does not exceed 15 percent.

A remnant of Grande Ronde basalt on the ridge east of lower Meadow Creek is massive and fine grained. This flow rests upon deeply weathered ferruginous gravel consisting of rounded pebbles of quartzite, gneiss, and schist. The top 2 to 3 feet of the gravel is cemented with basaltic glass. This exposure may represent a remnant flow that temporarily dammed the ancestral South Fork.

Poorly consolidated yellow-brown and pale yellow alluvial and lacustrine silts and subordinate cross-bedded sands occur between thin, vesicular flows in McComas basin. The interbeds are best exposed in a road cut 0.5 mile northwest of location 666 (Plate I). Contaminated, vesicular Grande Ronde (Tgr_1) basalt, which forms a thin ridge along the west side of McComas Meadows, contains subangular pebbles of gneiss, schist, and clay. The ridge is probably a remnant valley-filling flow, which is apparently overlain on the west by about 13 feet of massive clay, well-stratified mud and silt, and cross-bedded sand containing abundant plant fragments. Vesicular basalt at Orchard Creek (location 36, Plate I) contains clots of thinly laminated porcellainized clay formed when basalt flowed into a pond or lake and picked up mud from the bottom.

TERTIARY AND QUATERNARY DEPOSITS

Unconsolidated, nonfossiliferous sediments occur (1) in McComas basin, (2) on the summit of Blacktail Butte, (3) on ridges beside major streams, and (4) along present streams. Glacial till at the head of Lightning Creek was deposited by a lobe of ice which flowed up Meadow Creek from the south. Because of differences in lithology and elevation relative to present streams, these deposits were mapped separately and are described below.

McComas Basin

McComas basin is a broad southward-opening elliptical depression east of the Blacktail Butte fault scarp. The flat, central part of the basin is referred to as McComas Meadows. Poorly stratified, pale brown to white clay and silt overlie deeply weathered granitoid rocks and metasedimentary rocks in McComas basin. Their elevation ranges from 3,200 feet at the south end of McComas Meadows to 4,400 feet near the head of False Creek. Meadow Creek north of McComas Meadows has cut through these deposits. The clay and silt contain sparse, angular to rounded, and glacially transported gneiss, schist, and quartzite clasts or erratics up to 10 feet in diameter. These deposits grade downward with no visible boundary into highly decomposed locally ferruginous gneiss and schist. Although the clay and silt may be mainly residual, the rounded quartzite fragments in and on top of these materials indicate transport from nearby sources. Clay and silt similar to that described above were incorporated in the base of basalt flows at Orchard Creek. Therefore, at least some of these deposits are older than the youngest Columbia River flows.

Blacktail Butte

The nearly flat basalt surface on Blacktail Butte is veneered with thinly stratified and well-sorted gravel composed of rounded pebbles and cobbles of iron-stained quartzite. Maximum thickness of the deposit is about 20 feet. Because of its high elevation about 2,000 feet above the South Fork and its isolation from present streams, its age is believed to be Pliocene or Pleistocene.

Fisher Placer

Columbia River Basalt on the ridge east of the mouth of Meadow Creek forms a flat divide separating two remnant stream channels underlain by coarse fossiliferous sand, silt, and gravel. The deposit east of the ridge, called Fisher Placer, was almost completely excavated during gold mining in the early 1900's. The gravel contains rounded pebbles, cobbles, and boulders of granitoid and metasedimentary rocks similar to those which crop out upstream along the South Fork. A thin, dark gray silt bed near the top of this sequence contains decomposed plant debris and probably represents a slackwater deposit. The deposits are from 300 to 700 feet above the South Fork and at least 70 feet thick. They were probably deposited east of a basalt dam, which was breached when the river established a channel around the south end of the basalt cap. Similar deposits on the saddle west of Meadow Creek indicate the location of this channel. Stream channel deposits above Fisher Placer have been offset by small north-trending normal faults (Figure 10) with displacements between one foot and four feet downward on the east side. The age of the Fisher Placer deposits and the similar high-level gravels along the valley of the South Fork is probably Pleistocene.

CATACLASIS

Cataclasis, involving progressive comminution and small-scale penetrative displacement along interlensing

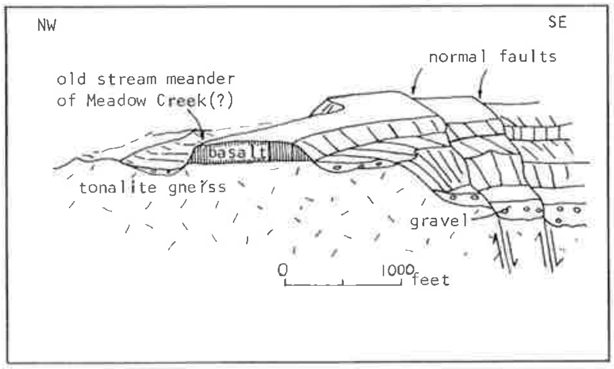

Figure 10. Normal faults offsetting old stream terraces and Pleistocene(?) gravels deposited against basalt dam. Location ridge west of Meadow Creek at the South Fork of the Clearwater River.

slippage surfaces, was closely associated with shear folding, reverse faulting, and metamorphism before, during, and after emplacement of the Idaho batholith. Although early stages of cataclasis are widespread in pre-Tertiary rocks throughout the Harpster area, fabrics showing intense cataclasis are confined mainly to mylonitic zones separating rocks of disparate lithology. Faults were mapped only where displacements could be proven. Episodic intrusion and penetrative displacement along cataclastic foliation caused a pronounced attenuation of pegmatite and aplite dikes.

The significance of crushing in the "gneissoidal shell" of the Idaho batholith was first recognized by Thomson and Ballard (1924, p. 25-26) who, in describing a coarse granitic gneiss at Concord about 19 miles southeast of the Harpster area, refer to "numerous large feldspar crystals crushed into closely interleaving lenses separated by thin bands of biotite." Subsequently, Anderson (1930, p. 24) stated that "the pressure and thrust attendant upon the intrusion of the Idaho batholith magma, with resulting mashing, have produced gneiss from older intrusive rocks where they border the younger intrusive mass." Cataclastic features in the Riggins region, well described by Hamilton (1962 and 1963), are essentially analogous to those in the Harpster area. Ross (1952), Wehrenberg (1972), Chase (1973), and Hyndman and others (1975) describe similar cataclastic features for the eastern margin of the batholith. According to Chase and Johnson (1976) the entire batholith may have a cataclastic margin which developed during its emplacement.

Two composite cataclastic rock types were mapped from 1959 to 1962: (1) phyllonite derived mainly from volcanic rocks and (2) flaser gneiss, mostly of plutonic derivation. Although my subsequent field work shows that a more complicated assemblage of cataclastic rocks exists in the Harpster area, I have not altered the original geologic map. A comprehensive classification of cataclastic rocks was published by Higgins (1971). According to the Higgins classification (1971, p. 32), rocks mapped as phyllonite in the Harpster area actually include mylonite, ultramylonite, and fine-grained blastomylonite. Accordingly, the flaser gneiss, as mapped, includes mylonite gneiss, coarse blastomylonite, and some protomylonite.

Fluxion structure, which evolves during cataclasis, is a diagnostic feature of cataclastic rocks. Fluxion structure is defined by Higgins (1971, p. 3) as

> *a cataclastically produced, directed, penetrative texture or structure commonly involving a family or set of s-surfaces: cataclastic foliation. May be visible megascopically or only microscopically. Does not necessarily involve compositional layering, although many examples do show such layering.*

The Higgins definition unfortunately omits criteria for recognizing fluxion structure and for distinguishing it from similar structures of other origins. I therefore redefine fluxion structure as a textural lamination characterized by any one or more of the following: (1) interlensing slippage surfaces of concentrated attrition enclosing relatively coarse-grained rock or mineral clasts, (2) detached folds, (3) bent cleavage and twin lamellae, and (4) crush trails. The scale of interlensing ranges from microscopic to that best seen on geologic maps.

Phyllonite and flaser gneiss are confined mainly to subconcordant zones of mylonitization up to 1.5 miles wide. A structure section across the major reverse fault zone at Sugarloaf (Figure 11) exemplifies these shear zones. Massive Seven Devils rocks in the footwall block grades eastward through mylonitized and recrystallized Seven Devils rocks and highly deformed, incompetent Squaw Creek Schist (bms) into adamellite and tonalite flaser gneisses of the hanging wall. Detailed relationships of rocks across the contact of the flaser gneiss are shown in Plate IV.

METAMORPHISM

GENERAL STATEMENT

Metamorphic zones bordering the Idaho batholith in this map area (Figure 12) generally coincide with major lithologic and structural units. From the biotite isograd in the Squaw Creek Schist to the sillimanite isograd in metasedimentary rocks west of the Granite Creek pluton the distance is between 3 and 8 miles. The relative volume of granitoid rock increases eastward through a broad migmatite zone which extends eastward nearly 50 miles to the massive core of the Idaho batholith.

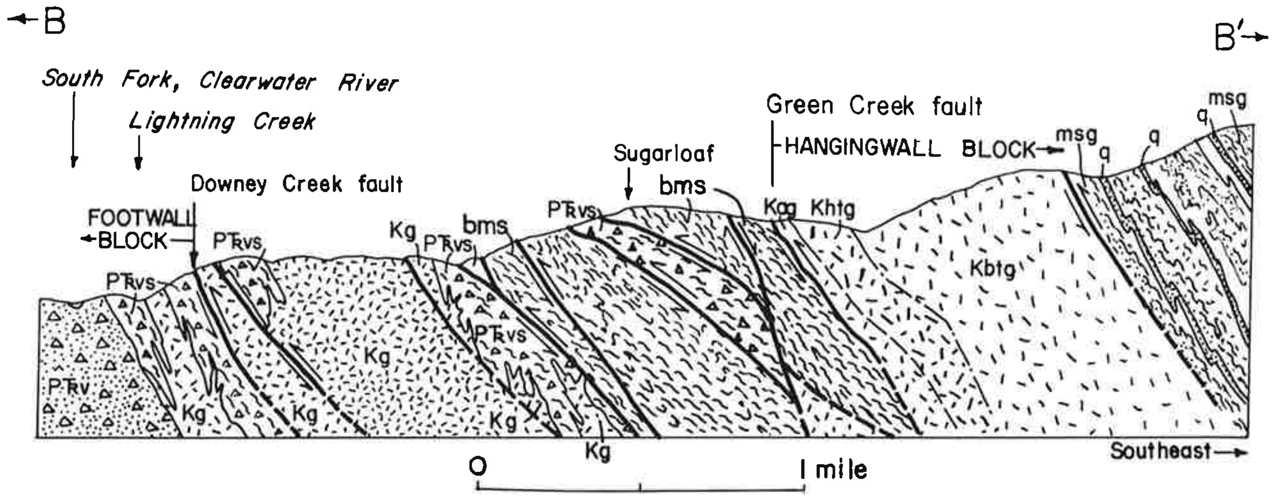

Figure 11. Structure section southeast across the batholith margin at Sugarloaf. No vertical exaggeration.

METAMORPHIC ZONES

Definition

Hamilton (1963, p. 79-82) adapted Eskola's (in Barth and others, 1939) facies classification to portray stability ranges of index minerals in metamorphic rocks of the Riggins region. Hamilton's zonal classification is adopted here with modifications explained below.

The widespread occurrence of ferroan prochlorite and clinozoisite as retrograde minerals (e.g., replacing garnet) disqualify them as zonal index minerals in the Harpster area. One of the most common occurrences of clinozoisite is with ferroan prochlorite in the altered Seven Devils Group. In the Harpster area a conspicuous transition from green to black hornblende occurs between the biotite and almandite isograds. Thus, black hornblende takes the place of clinozoisite of Hamilton's classification but is included in the epidote amphibolite facies. Prograde muscovite appears near the middle of the phyllonitic greenstone unit. Although reverse-zoned oligoclase, developed at slightly higher grade, it is combined with muscovite in a single zone, because its appearance is not observable in the field. A sillimanite-cordierite zone is added to the amphibolite facies replacing Hamilton's "clinopyroxene zone." Diopside appears in calc-silicate rocks of the Squaw Creek Schist near the almandite isograd and persists in calc-silicate rocks through the sillimanite zone. The close association of cordierite and sillimanite justifies their use as companion index minerals. Distribution of the metamorphic zones is shown in Figure 12 and Plate I. Approximate zonal stability ranges of specific minerals are presented in Figure 13. Major components are represented by broad lines; thin lines indicate minor components; dashed lines show the probable extensions of mineral stability as indicated by sparse occurrences.

Prochlorite Zone

Aluminian prochlorite, a major component of massive and phyllonitic greenstones, formed at the expense of primary pyroxenes and amphiboles. Its abundance decreases abruptly near the biotite isograd, beyond which it is retrograde. Minerals typically associated with aluminian prochlorite in massive and phyllonitic greenstones are colorless epidote, quartz, albite, magnetite or ilmenite with or without actinolite and ferroan prochlorite. Because of its widespread occurrence both as a prograde and retrograde mineral, aluminian prochlorite has limited value as an index mineral. Hamilton (1963, p. 75) indicates a different stability range for prochlorite minerals in the Riggins region, when he states that "aluminian prochlorite persists in rocks of suitable composition to about the andesine isograd, whereas ferroan prochlorite is stable only into the garnet zone." Ferroan prochlorite occurs much more widely in the Harpster area, where it appears to have formed mainly from iron-rich pyroxenes and amphiboles during or after shearing.

Assuming an original similarity of composition, the relative abundance of sodic plagioclase, muscovite, and quartz in the phyllonitic greenstones indicates an addition of water, sodium, potassium, silicon, and possibly a loss of calcium. The chlorite minerals indicate hydration.

Muscovite-Oligoclase Zone

Fine-grained muscovite occurs widely as a minor alteration product of plagioclase and disseminations in massive greenstones. Its relative size and abundance gradually increase southeastward in phyllonitic greenstone to the base of the white phyllonites at the base of the Squaw Creek Schist(?), where an abrupt increase in

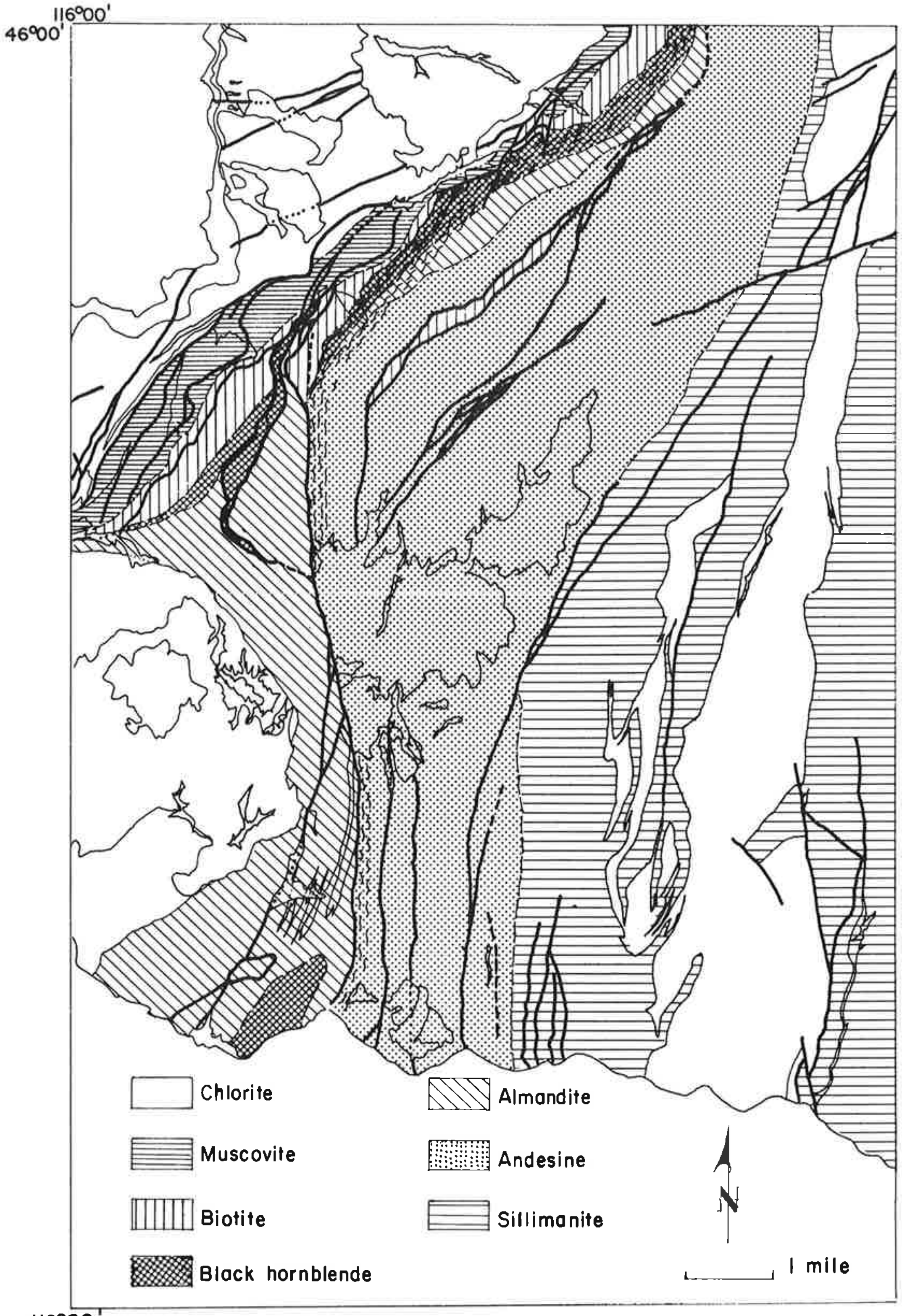

Figure 12. Metamorphic index mineral zone map.

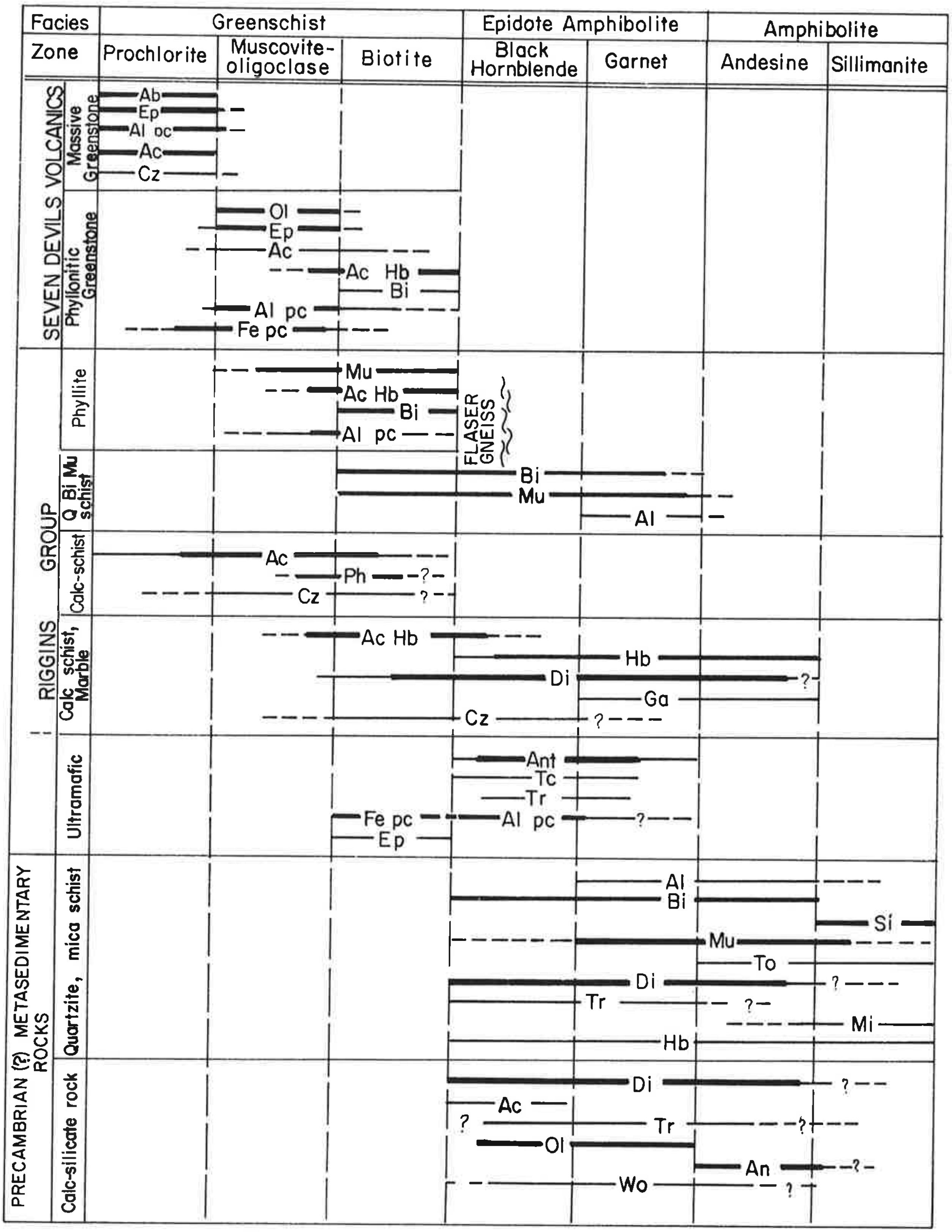

Figure 13. Zonal stability ranges of minerals in the Harpster area.

its abundance accompanies the appearance of essential microcline. The oligoclase isograd is approximately parallel to and several hundred feet northwest of the base of the white phyllonites. Reverse-zoned oligoclase porphyroclasts in white phyllonite indicate prograde crystallization of oligoclase before or during shearing. Epidote, formed at the expense of plagioclase, actinolitic hornblende, prochlorite, and quartz are additional components of rocks in the muscovite-oligoclase zone.

Biotite Zone

The biotite isograd passes diagonally across the lower part of the slate-phyllite sequence in basal Squaw Creek Schist(?) between Green Creek and Wall Creek. Elsewhere, the isograd is near the top of the phyllonitic greenstones. Prograde biotite first appears in the phyllites and persists in quartz-mica schist and hornblende-garnet schist of the sillimanite zone. Its initial appearance is in pressure shadows behind magnetite grains where it is interlayered with aluminian prochlorite. Within 50 feet southeast of its first appearance, the biotite has become an essential mineral with an orientation parallel to shear planes. Commonly associated prograde minerals are oligoclase, microcline, muscovite, almandite, actinolitic hornblende, and graphite. Phlogopite, very near biotite in optical properties, occurs in calc-schist interlayered with the biotite-bearing schists. Its distribution indicates a stability range near that of brown biotite.

Black Hornblende Zone

The black hornblende isograd, which is roughly concordant with strata in the north limb of the North Blacktail syncline, is truncated by a thrust fault west of Sugarloaf. It reappears on the east side of the Browns Creek fault east of Sugarloaf and follows the base of the Squaw Creek Schist(?) to the north edge of the map area. The paucity of hornblende in metasedimentary rocks of the North Blacktail syncline prevented accurate mapping of the black hornblende isograd there. The sheared, gradational contact between phyllite and adamellite flaser gneiss at location 181 (Plate I) was studied in detail, and a series of specimens was taken across the black hornblende isograd (Plate IV). Black hornblende southeast of the isograd replaces green actinolitic hornblende in the phyllite sequence. The appearance of black hornblende probably represents oxidation of constituent iron—a phenomenon, which in this area, appears to be an indicator of epidote-amphibolite grade of metamorphism. An abrupt increase in average grain size and the appearance of lenticular porphyroblasts of pink orthoclase and albite accompanies the development of black hornblende. At location 181 (Plate IV), the transition from carbonaceous, calcareous quartz-biotite-muscovite phyllite to biotite tonalite flaser gneiss with and without hornblende is accomplished over a lateral distance of about 700 feet. The bending and fracturing of quartz and feldspar and augen structure reveal that shearing accompanied and followed these metamorphic reactions. Many of the orthoclase augen show marginal concentrations of hornblende (181-F, Plate IV), and laminations curve around the augen. Many augen also contain oriented biotite and hornblende inclusions. The concentration of biotite around coarse, ovoid orthoclase and oligoclase in the quartz monzonite occurs at location 181-G. The appearance of potassium (K) feldspar and hornblende in schists (181-B) adjacent to leucogranite (181-C) and adamellite flaser gneiss (181-G) suggests the migration of potassium into the schists at temperatures sufficient to convert actinolitic hornblende to black hornblende. Petrographic evidence of this transformation, such as an intermediate form, was not found. Black hornblende schists, containing garnet and lacking K-feldspar augen, occur adjacent to the Blacktail pluton and west of Browns Creek, where they are in contact across a major shear zone with coarse-grained biotite-hornblende tonalite gneiss. The absence of K-feldspar augen in these rocks suggests a correspondence of feldspar composition between the schists and adjacent granitic rocks. Plagioclase in the hornblende schist adjacent to the Blacktail pluton is mainly sodic oligoclase, whereas it is dominantly calcic oligoclase at Browns Creek. Subordinate K-feldspar occurs in both units.

Garnet Zone

As approximately located, the garnet isograd crosses fine-grained schists in the north limb of the North Blacktail syncline, disappears in the fault system at Sugarloaf, reappears in adamellite gneiss east of the Browns Creek fault, and continues to the north edge of the map area. Mica schist septa in biotite adamellite flaser gneiss near Switchback contain sparse garnet. A subgarnet node occurs in Squaw Creek Schist between Castle Creek and Browns Creek where granitic intrusive rocks are less abundant.

Small, pale red almandite is common in siliceous mica and hornblende schists adjacent to the Blacktail pluton and in coarse metasedimentary rocks and pegmatites east of Browns Creek where its abundance is roughly proportional to that of muscovite. Coarse grossularite, which occurs in calc-silicate rocks cut by pegmatite and in banded diopside-bearing quartzite (location 339, Plate I), can be directly attributed to local contact metamorphism. Thus, grossularite does not strictly qualify as a zonal index mineral. X-ray studies (Appendix 12) show that cell dimensions of garnets in pegmatites are close to those in the enclosing rocks. The localization of almandite in Squaw Creek Schist adjacent to the Blacktail pluton shows that the pluton produced a relatively broad contact aureole. East of Meadow Creek, pale red almandite occurs chiefly in muscovite and microcline-bearing metasediments and tonalite orthogneiss, where it replaces biotite. Fine-grained, pale orange grossularite in hornblende schist in the garnet zone contains optically continuous inclusions of hornblende and quartz. "Snowball" garnets were seen only in strongly folded muscovite-biotite schist. Zonal arrangement of almandite along the inner margins of pegmatite dikes is common throughout the garnet zone.

Sillimanite-Cordierite Zone

Sillimanite and accessory, isofacial cordierite appear in metasedimentary rocks about 9,000 feet west of the Granite Creek pluton in the southern part of the area and only about 1,000 feet from the pluton at the northern edge, an additional indication that the Granite Creek pluton is more deeply eroded in the south. The sparseness of high alumina minerals in rocks of higher metamorphic grade in the Harpster area suggests that premetamorphic assemblages were relatively low in alumina. Staurolite in pegmatite pods at location 588 (Plate I) accompanies biotite, garnet, muscovite, and schorl. Cordierite was seen in several thin sections of mica schist and impure quartzite where it was invariably accompanied by sillimanite. Sillimanite is more widespread but rarely exceeds 10 percent. Kyanite and andalusite were not found.

ORIGIN OF THE GRANITOID ROCKS

Granitoid rocks in the southern part of the area grade eastward from oligoclase-rich trondhjemite in the Blacktail pluton through andesine-rich tonalite just east of the Browns Creek fault to microcline-bearing adamellite of the Granite Creek pluton. Feldspar composition in the granitoid bodies corresponds closely with its composition in adjacent migmatites and metasedimentary rocks, the correspondence diminishing away from contacts. For instance,. quartz-diopside-tremolite schist near the Granite Creek pluton contains microcline, and hornblende schist near the contact between phyllites and adamellite flaser gneiss contains coarse microcline augen. Sheared pegmatite dikes and stringers contain feldspars of similar composition to those in the enclosing foliated granitic rocks as well as many of the same metamorphic minerals.

The tonalite, trondhjemite, and adamellite were probably emplaced by both synkinematic injection of magma and by metasomatism of sedimentary rocks. Evidences for both modes of emplacement are presented below.

Evidence for Magmatic Emplacement

Obliquely cross-cutting, subconcordent contacts typify the granitoid plutons in the Harpster area. Metasomatic effects are most pronounced in the wallrocks immediately adjacent to them and in xenoliths. The contacts typically show the following features:

1. Sharp, discordant contacts of many units (Figure 14).
2. Dilation offset and drag folding of metasedimentary rocks and adjacent to contacts (Figure 14).
3. Rotated xenoliths (Figure 15) and contorted wedge-shaped roof pendants.
4. Symmetrical contact metasomatic aureoles, especially in calcsilicate layers.
5. Drag-folded wallrocks are locally cut by granitoid veinlets which are themselves complexly folded. This type of contact suggests synkinematic intrusion.
6. Coexistence of rounded and euhedral zircons (many in delicate, nonrandom aggregates) indi-

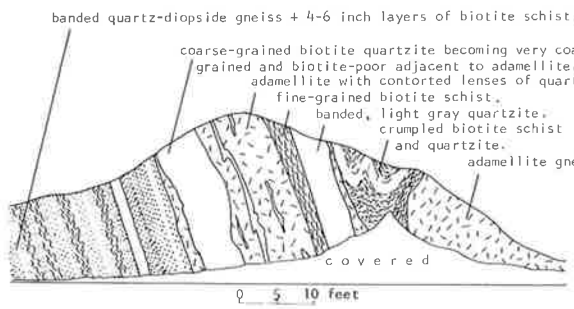

Figure 14. Discordant gneissic adamellite intrusives intercalated in metasediments. Note folds in partly detached block at right (location 424, Plate I).

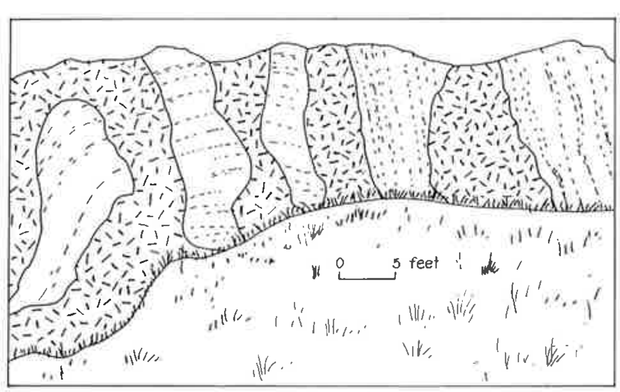

Figure 15. Stoped blocks of banded muscovite-quartzite in faintly foliated adamellite. Blocks show rotation (location 390, Plate I).

cates a contamination of the granitic magma by refractory detrital zircons, while the rest of the metasediments were assimilated. Metasomatic crystallization of such euhedral zircon aggregates without simultaneous development of faceted overgrowths on the rounded grains is otherwise difficult to explain (Myers, 1968, p. 137-163).

7. Migmatites showing features of partial melting in place are cut by granitic intrusions probably derived from more thorough melting of rocks at greater depth.

Evidence for Metasomatic Origin

Highly contaminated border phases of plutons, especially those emplaced at temperatures and pressures necessary to produce metamorphic assemblages in the amphibolite facies, contain abundant pendants, schlieren, and screens of highly granitized metasedimentary rocks. The homogenization process must have involved considerable metasomatism. Metasomatic features of granitoid bodies are as follows:

1. Selective preservation of thin beds of quartzite and calc-silicate rock as in the Quartz Ridge area. Rafted segments would more commonly show rotation.
2. Continuity of structures across contacts between granitoid rocks and metasediments (Figure 16).

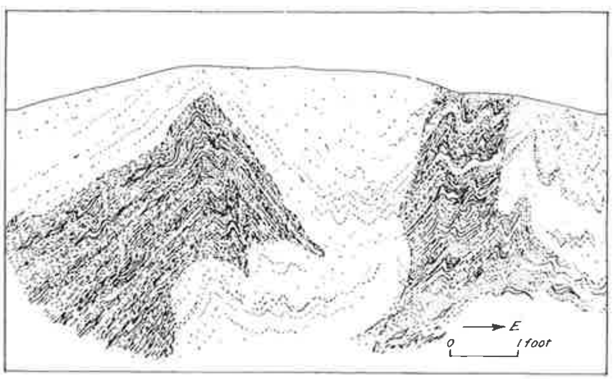

Figure 16. Metasomatic "dike" or remnant, exhibiting some degree of mobilization during late metasomatic event, of biotite tonalite gneiss. Shows continuity of banding across sharply defined contact (location 310, Plate I).

3. Foliated granitic rocks intercalated with metasediments contain only rounded (detrital) zircons in most places.
4. Composition and relative abundance of garnets and feldspars in metasedimentary rocks closely approximate those of the adjacent granitic body, and the degree of correspondence tends to diminish outward from the contact.
5. Gneissic adamellite east of the map area (Figure 17) contains relict folds and boudins similar to those in Squaw Creek Schist and metasedimentary units in the margin of the Granite Creek pluton.

Figure 17. Foliated, banded adamellite(?) containing relict isoclinally folded and boudinaged pegmatite stringer and ragged lenticular sheets of hornblende schist (foreground). Location: Highway 14 about 6.5 miles east of Peasley Creek.

STRUCTURAL GEOLOGY

Orientations of foliation, compositional layering, shear cleavage, lineations, and fold axes are shown on Plate I. Structure sections are in Plate II. I consider the structural data from the Harpster area insufficient to accurately define fold geometry and details of kinematic sequence. However, a tentative synthesis has been constructed (Table 4) from field observations combined with more detailed structural studies in nearby areas. Reid (1959), Hall (1961), and Morrison (1968) working in Precambrian terranes east and north of the

Harpster area report three episodes of folding. La Salata (1982), who studied fold geometries in Squaw Creek Schist in the Harpster quadrangle, found evidence for three deformations. Onasch, in a study of structures in the correlative schists structurally overlying the Rapid River thrust in the Riggins area, describes (1978) five folding events. Three generations of folds were observed in rocks beneath the thrust. According to these authors the oldest folds are isoclinal folds with strong axial planar foliation which has been folded. The youngest folds are those developed during shearing and cataclasis. A late Precambrian age is tentatively assigned by Reid (1959, p. 66) to the isoclinal folds. Morrison (1968, p. 122) states:

> *The first deformation occurred in the Precambrian, and has been tentatively dated following radiometric data obtained by other workers. It is postulated that the first fold event produced an isoclinal recumbant fold of regional scale, possibly overturned to the southwest, and that the metasediments now exposed represent one limb of this structure.*

The second and third deformations, according to Reid (1959, p. 69), occurred in the Late Triassic and Late Jurassic respectively. Cataclasis followed Late Cretaceous emplacement of the Idaho batholith and involved only low temperature microchevron folding and retrograde metamorphism. Onasch (1978) does not assign specific times to the various deformations, although at least three of them must postdate Seven Devils island arc volcanism. If the Squaw Creek Schist is Jurassic as suggested by Vallier (1977, p. 8), the Mesozoic eugeosynclinal sequence is probably upright and downfolded on the east against the Browns Creek reverse fault, and the tight to isoclinal folds in the incompetent Squaw Creek Schist within the Blacktail block would have probably developed during large-scale shearing with east-over-west movement nearly parallel to the steeply inclined bedding. Accordingly, the Precambrian basement, acting as a buttress, would have risen along the steep eastward dip of the Browns Creek fault.

Lithologies and structures within the Harpster block correlate best with those below the Rapid River thrust in the Riggins region, and those in the Blacktail block are analogous to the rocks above the Rapid River thrust. The Downey Creek fault is thus structurally analogous to the Rapid River thrust. Lithologies and structures in the McComas block most closely resemble those described by Hietanen (1962, p. 33-68) for the Orofino district with the exception that plutonic rocks in the Orofino district most closely resemble those emplaced in the Seven Devils Group near Harpster, namely the hornblendite, metagabbro, norite, quartz diorite, and tonalite.

In the fold classification of Fleuty (1964), as used in this report, isoclinal folds have parallel limbs, and tight folds have limbs which converge at less than 30 degrees.

FOLDS

Folds in the Harpster Block

Sedimentary units in the massive Seven Devils Group are compressed into northwesterly and northeasterly plunging open folds which are segmented by numerous small faults. Hamilton (1963, p. 4) states that rocks of the Seven Devils Group beneath the Rapid River thrust in the Riggins region are "obviously shingled by faults but apparently not deformed isoclinally." The overlying marble of the Martin Bridge Formation and the Lucile Slate, although thinly imbricated, appear to be in their original stratigraphic sequence. Southwest of the Riggins region, these formations are less metamorphosed and are compressed into large open folds with axes trending north to northeast.

In contrast to the massive Seven Devils greenstones, the phyllonitic greenstones are characterized by closely spaced, interlensing schistosity and detached microchevron folds. Isoclinal folds like those in the Riggins Group were not seen in the Seven Devils Group. Details of structure in the Seven Devils Group remain obscure because of faulting and the paucity of marker units.

Folds in the Blacktail Block

High amplitude, tight and isoclinal folds with strong, eastward-dipping axial planar foliation are well-exposed along the South Fork between Sheep Creek and Browns Creek. These folds plunge gently northward. Fold limbs in the schistose rocks are convergent at angles of less than 30 degrees. Granitic stringers, which cut compositional layering at low angles, are folded about axes which are nearly coaxial with the tight folds but with lower amplitude and rounded hinges (Figure 18). This fold morphology indicates flattening perpendicular to layering. Many of the folds are discontinuous owing to nearly axial-planar slippage. High amplitudes of the tight to isoclinal folds suggest that axial-plane schistosity intersects bedding at very low angles. Hamilton (1963, p. 34) states:

> *The schists have been folded isoclinally and extremely sheared. Discontinuous lenses have formed by shearing apart of limbs of isoclines and by boudinage. The result of these diverse processes of pervasive shear is a lamination that appears on casual observation to consist of a conformable sedimentary succession. Actually, many contacts between laminae are shear, not bedding features, and right-side-up and upside-down layers alternate. The compositional differences are inherited from sedimentary laminae but their present succession is in considerable part due to shearing.*

The truncation of fold limbs due to the interlensing of shear planes in the phyllonitic Seven Devils Group accounts for their discontinuity and small amplitude. Tight folds attain maximum amplitude in fine-grained Squaw Creek Schist about 1 mile east of the Blacktail

Figure 18. Folded granitoid stringers in quartz-biotite schist (location 260, Plate I). Axial planes of these folds are slightly flexed.

pluton (location 62, Plate I). Recumbent tight folds in fault slices of Squaw Creek Schist on Green Creek Ridge (Figure 19) indicate the rotation of axial planes during later faulting. The tight folds have similar form regardless of size, which ranges from microfolds seen in thin sections to folds with amplitudes of tens of feet. Biotite along axial planes becomes coarser eastward with the increasing grade of metamorphism. Pegmatite boudins, representing prekinematic or early kinematic granitic intrusion, have comminuted and serrated edges, and generally show an angular discordance of 5 to 15 degrees with compositional banding. Boudins on fold limbs are elongate and parallel to fold axes.

Folds Associated with Magma Intrusion

The forceful intrusion of the Blacktail pluton compressed eastward-dipping phyllite, schist, and metaperidotite of the Squaw Creek Schist into a series of eastward-plunging cross folds whose amplitudes diminish northeastward away from the pluton. Cross folds of this shape and orientation are confined to this particular setting adjacent to the Blacktail pluton. The largest of the cross folds is the North Blacktail syncline, which plunges east-northeast at 25 degrees. Metamorphism accompanying intrusion and folding also produced a strong mineral lineation coincident with the syncline axis. Quartz boudins, formed during earlier deformation, were rolled into rod-shaped masses whose elongations are parallel with the mineral lineation.

Small asymmetrical folds become abundant close to granitic intrusive bodies. Their form becomes more random (ptygmatic) near the intrusive contacts. Where the magma/rock ratio was less than one (Figure 20), these small asymmetrical folds are superimposed, in most places with oblique discordance, upon larger tight folds possessing coarse axial plane foliation. With increasing magma/rock ratio, as in screens of metasediments between relatively thick intrusive wedges, the folds become progressively chaotic (Figure 21) until, in rafted septa, the detached, rootless folds are refolded ptygmatically (Figure 22). The morphology of the last two folds indicates an increasing plasticity of metasedimentary units with the increasing magma/rock ratio. Local variation in strike of their axial planes is less than 15 degrees, whereas their dip angles vary as much as 50 degrees. At no place in the map area were completely chaotic folds observed.

Late Shear Folds in Flaser Gneiss

Imbricate thrust movements and associated cataclasis, especially east of the Browns Creek fault zones, caused further deformation of the already refolded metasedimentary rocks and isoclinally shear-folded pegmatite stringers in the flaser gneisses (Figure 23). Repeated shearing and pegmatite intrusion are indicated by the more chaotic, segmented form of older dikes. The younger dikes, whose relative ages are indicated by cross-cutting relations, are less deformed and generally more discordant.

Early tight folds were offset locally by close-spaced normal faults within parts of older fault sheets (e.g., Wall Creek, Green Creek). New drag folds and fault breccias were formed by this displacement (Figure 24).

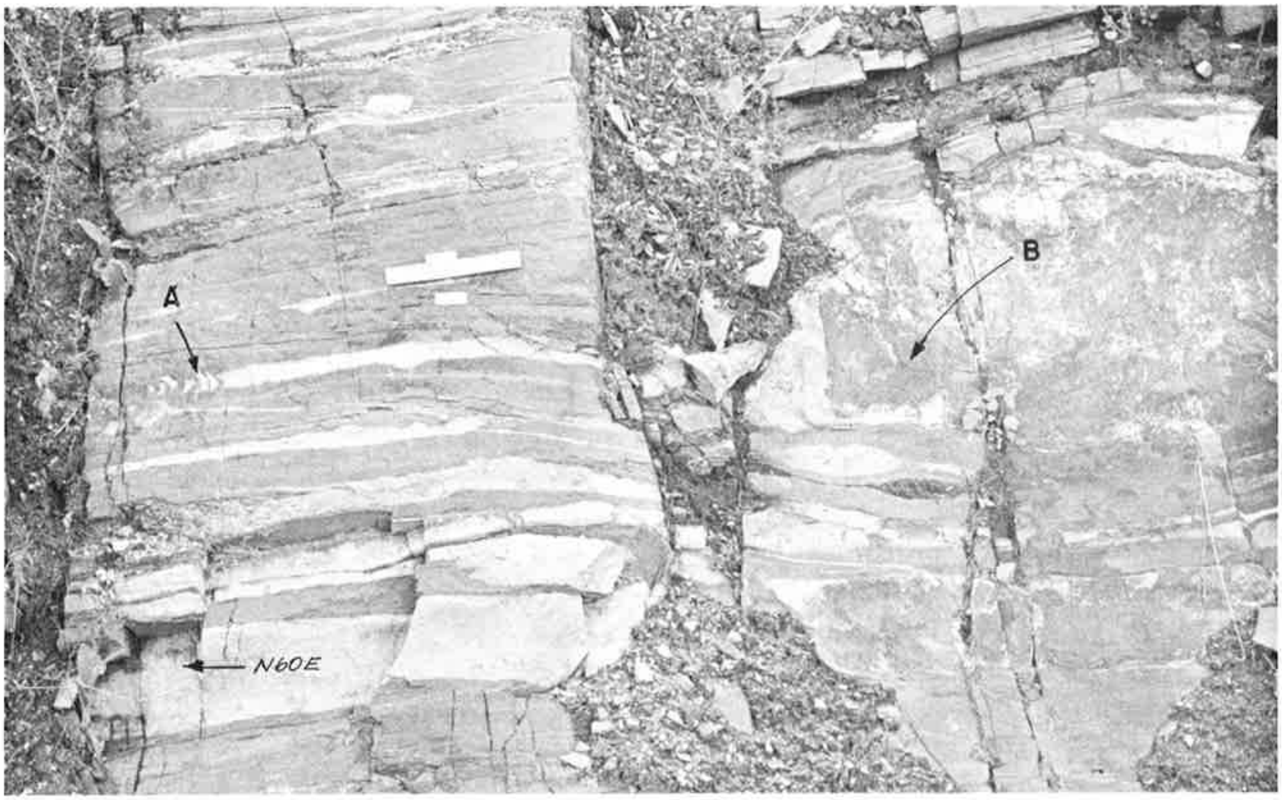

Figure 19. Recumbent, tight folds in a fault slice of Squaw Creek Schist (Green Creek Ridge, location 285, Plate I). Note tensional brecciation of granitic layer at A and in B in axial portion (location 285, Plate I).

FAULTS

Shear Zones with Reverse Displacement

Drag folds, slickensides, and offsets show that the subconcordant, high angle faults in the Harpster area are predominantly reverse faults with east side up. These faults dip eastward and southeastward 25 to 70 degrees. Major fault zones along the east side of Blacktail Butte (Castle Creek and Browns Creek faults) and along the top of the Seven Devils Group from Schwartz Creek to Sugarloaf (Downey Creek fault) merge near Sugarloaf and continue northeastward across the head of Wall Creek into the headwaters of Clear Creek. Imbrication along interlensing slippage surfaces produced complex reverse displacement and structural superposition of units east of the massive

Figure 20. Small asymmetrical folds in biotite-muscovite-sillimanite schist (adjacent to an intrusive body at location 616, Plate I). Axial planes of folds are curved. Muscovite is in the axial plane orientation.

Figure 21. Small folds in biotite schist adjacent to subcordant body of gneissic tonalite (location 320, Plate I).

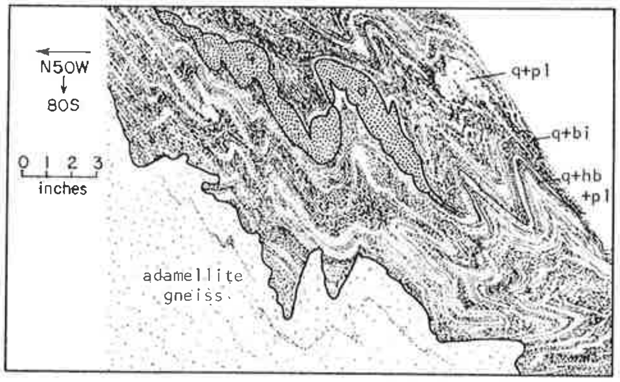

Figure 22. Ptygmatic folds in quartz-, plagioclase-, biotite-, and hornblende-bearing schist and gneiss are roughly concordant with the contact of the gneissic adamellite (location 620, Plate I). Symbols are quartz (q), plagioclase (pl), biotite (bi), and hornblende (hb).

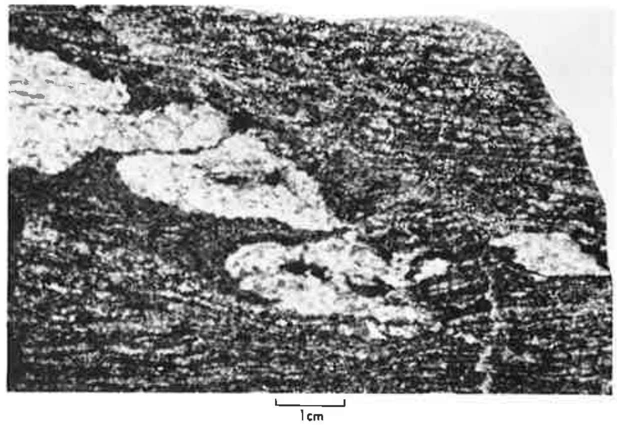

Figure 24. Faulted tight folds in Squaw Creek Schist (location 654, Plate I).

Seven Devils rocks. Strongly sheared metaperidotite of North Blacktail forms a fault slice which dips eastward between 55 and 60 degrees. Sugarloaf is underlain by at least three reverse faults with eastward dips of 50 to 65 degrees. Reverse faults in banded gneisses north of McComas Meadows dip southeast at 50 to 70 degrees. Faults are difficult to recognize in the south half of the area because of their concordance and the pervasiveness of shearing.

Figure 23. Isoclinally shear-folded pegmatite in biotite adamellite flaser gneiss. Axial planes are parallel to shear planes (location 262, Plate I).

Close-spaced folding and faulting characterize the phyllonitic Seven Devils greenstones. Fold axes plunge gently to moderately northeast. Axial planes, although somewhat divergent within a single outcrop, dip moderately to steeply southeast. Folds and faults are locally so chaotic that the rock becomes a tectonic breccia. Green phyllonites in a major fault crossing Green Creek 0.9 mile (1.4 km) east of South Fork (Figure 25) are thrown into tight chevron folds whose axial planes dip gently southeast. This fault (striking N. 28° E. and dipping 70° SE.) is part of the Sugarloaf imbricate fault system and is offset by northwest-dipping reverse faults, which are probably contemporaneous with normal faults near Wall Creek.

Sparse thrust faults in the area dip southeast. Drag folds and slickensides, which indicate low-angle oblique, southward (normal) displacement, have been reoriented by later folding and shearing. A low-angle thrust(?) fault of this type is exposed in a small roadside quarry along the south side of Wall Creek at location 263 (Plate I). Gently dipping phyllite of the upper plate truncates intensely drag-folded phyllite and clay gouge (Figure 26). The fault plane strikes N. 85° E. and dips 20° S. Drag fold axes within the fault zone plunge southward 15 to 40 degrees and eastward 20 to 35 degrees and are overturned toward the southwest. Although orientation of the drag folds indicates low-angle, oblique, normal displacement toward the southwest, it is probable that later folding and normal faulting have deformed the fault plane.

Phyllonites between Green Creek and Schwartz Creek are cut by numerous low-angle thrusts which dip eastward 25 to 50 degrees. Approaching the Blacktail pluton near Schwartz Creek, these faults curve sharply westward, and their dips increase to nearly vertical. The intrusion of the pluton, while shoving these faults into their present positions, caused renewed thrust displacement along them.

The contact between flaser gneiss and phyllite northeast of Sugarloaf is a broad shear zone across which there has probably been considerable net reverse displacement. The telescoping of isograds in this zone (e.g., location 181, Plate I) indicates postmetamorphic imbrication and upward displacement of the coarser tonalitic flaser gneiss of the hanging wall.

Metasedimentary units north of McComas basin show a broad eastward flexure. The axis of the flexure extends S. 60° E. from the intersection of Green Creek and the South Fork to the vicinity of North Meadow Creek. The greater abundance of granitoid rocks and slices of Squaw Creek Schist (Green Creek Ridge) accounts for the wider metasedimentary border zone along the flexure axis. This flexure probably developed during or after reverse faulting. Reverse faults dip more steeply than lithologic units in this zone.

Figure 25. Folded shear cleavage in phyllonite between major faults (location 11, Plate I). Fold morphology in the footwall suggests normal displacement.

Although the Rapid River thrust in the Riggins region has been strongly folded, its probable extension, the Downey Creek fault, into the Harpster area is only mildly folded and generally more steeply dipping. Faults in both areas separate the Seven Devils Group from the Riggins Group, although the lower units of the Riggins Group are probably absent in the Harpster area.

High-Angle Faults of Uncertain Displacement

Numerous high-angle faults of uncertain displacement have a consistent northeast trend throughout the area. Because of their relative concordance and lack of topographic expression in most areas, they were difficult to map. Where best exposed, their strike is more northerly and their dip steeper than the metasedimentary and granitoid rocks which they offset. At Wall Creek and Meadow Creek they displace thrust faults and are locally overlain by Columbia River basalt (Figure 27). Their age is therefore believed to be early Tertiary. Slickensides observed on several faults plunge northeastward between 15 and 80 degrees, and a large component of strike displacement is indicated for some. The faults appear in outcrop as broad zones of mylonite and gouge that locally contain sparse, disseminated pyrite and chalcopyrite (Wickiup Creek).

Cross Faults

Several east-northeast-trending strike-slip faults in the northeastern part of the area displace the northeast-trending, high-angle faults described above. Displacement on these minor faults is less than 1,000 feet. Faults of similar trend but unknown displacement occur in the Seven Devils Group south of Harpster.

Tertiary to Recent Normal Faults

Discordant, northeast-trending normal faults, some of which offset Columbia River basalt, dip steeply eastward. Minor normal displacements of high-level gravels near the mouth of Meadow Creek show that movement along these faults has continued to Recent time.

The Mount Idaho fault (Reed, 1934, p. 7) crosses Idaho Highway 14 about 1 mile north of the mouth of

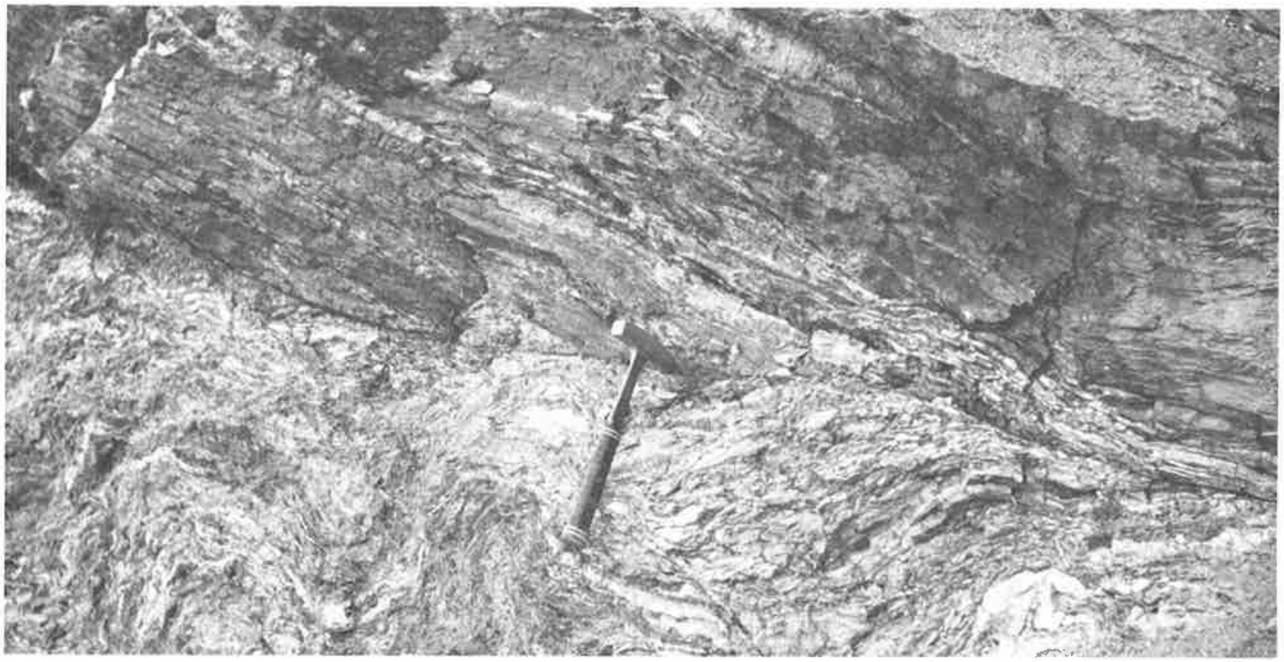

Figure 26. Drag folds under a thrust(?) fault plate which dips gently southeast. Hammer for scale (location 263, Plate I).

Downey Creek and probably joins the Downey Creek fault zone about 0.7 mile inside the map area. From Mount Idaho, where normal displacement on this fault (north side down) is 1,580 feet, displacement diminishes eastward.

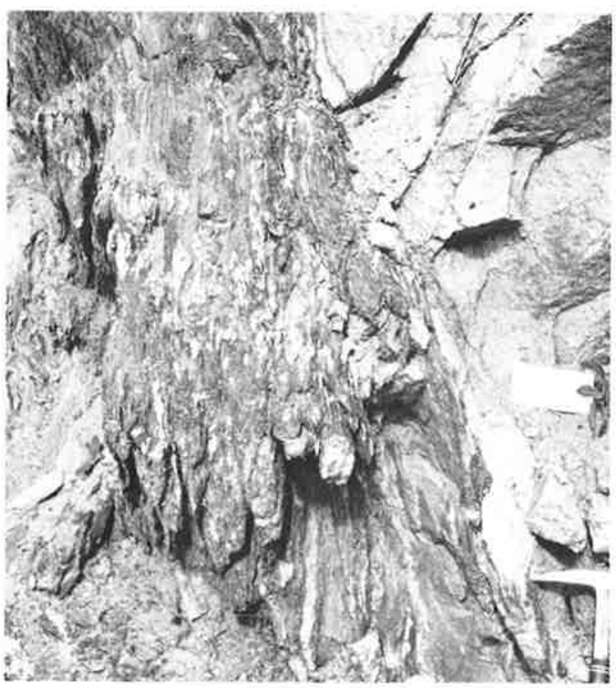

Figure 27. Segmented pegmatite dike in biotite-rich fault zone. Hammer for scale (location 120, Plate I).

The Browns Creek fault has a maximum normal throw (east side down) of approximately 1,000 feet along the east side of Blacktail Butte, which is a prominant scarp. This fault is considered by Capps (1941, p. 7) to be an extension of the Long Valley fault, which can be traced southward for over 150 miles to the vicinity of Boise. Several high-angle faults of unknown displacement parallel to and east of the Browns Creek fault are overlain by Columbia River basalt. Displacement on the Castle Creek fault has dropped Columbia River basalt about 200 feet.

GEOLOGIC HISTORY

The tentative chronology developed in this study (Table 5) is based in part on speculative correlations with rock units of uncertain age in noncontiguous areas. Comparisons are made with chronologies for surrounding areas in Table 5.

PRECAMBRIAN(?) SEDIMENTATION

The sedimentary protoliths of the migmatitic terrane east of the Browns Creek fault were thinly intercalated calcareous, argillaceous, and bituminous quartz sandstones, silty dolomite, and mafic extrusive(?) rocks. The paucity of high-alumina, argillaceous sedimentary protoliths suggests a near-shore depositional environment. The carbonates indicate warm climate. Aggregate thickness of the Precambrian sedimentary rocks in the Harpster area was probably more than 4,000 feet.

If these metasedimentary rocks are indeed part of the (1,500 m.y.) Salmon River arch, as suggested by Armstrong (1975), their apparent continuity with and close similarity to rocks in the Orofino area (Hietanen, 1962, p. A33-68) brings out a problem requiring additional field work and age dating. Hietanen (1962, p. A46) suggests that because of lithologic dissimilarity, the metasedimentary rocks near Orofino do not correlate with Beltian rocks as do the metasedimentary rocks to the east and north. The rocks in the Orofino area are richer in biotite and hornblende gneiss and lack the aluminous layers. Anderson (1930) suggested that the Orofino Series may be the lowest part of the Prichard Formation not exposed elsewhere. On the basis of lithologic similarity the Orofino Series correlates will with metasedimentary rocks east of Meadow Creek, and it is tentatively proposed that both units are pre-Beltian in age as suggested by Armstrong (1975, p. 439).

PERMIAN AND TRIASSIC VOLCANISM AND SEDIMENTATION

An incomplete Permian through Early(?) Jurassic sequence, represented in the Harpster area only by the

Table 5. Chronology for western Idaho and eastern Oregon.

TIME UNITS	Hamilton, 1963	Armstrong and others, 1977	Myers
QUATERNARY			Erosion, canyon cutting Glaciation, McComas basin, Meadow Creek, normal faulting, Blacktail Blacktail gravel deposition
TERTIARY	COLUMBIA RIVER BASALT Erosion Extensive erosion	COLUMBIA RIVER BASALT Challis Volcanics and dike swarms (55 m.y.)	Erosion Intrusion of quartz latite dike Extensive erosion Postkinematic pegmatite intrusion Shearing, reactivation of old faults, retrograde metamorphism
CRETACEOUS	Emplacement of Idaho batholith Rapid River thrust	Emplacement of Idaho batholith (80-70 m.y.) Older intrusion along western edge as old as 140 m.y. Intrusion of Wallowa batholith (160-149 m.y.)	Injection of Granite Creek pluton, reverse faulting, wedge injection Folding, anatexis at depth Intrusion of Harpster tonalite and Blacktail trondhjemite Synkinematic injection of Meadow Creek tonalite wedge Emplacement of ultramafic rocks Reverse faulting, isoclinal folding, metamorphism, and anatexis at depth
JURASSIC	Intrusions in Seven Devils Group, widespread, low-grade metamorphism Deposition Riggins Group Deposition Lucile Slate	Major orogenic and magmatic culmination (160-130 m.y.) in eugeosyncline Ochoco Orogeny, central Oregon (Dickenson and Vigrass, 1965) (255-200 m.y.)	Intrusion of Lightning Creek pluton Open folding(?) and low-grade regional metamorphism Deposition of Squaw Creek Schist
TRIASSIC	Deposition Martin Bridge Limestone Eugeosynclinal volcanism and sedimentation-Seven Devils Group	Erosion	Hiatus (?)
PALEOZOIC	Erosion (?)	Deformation, metamorphism, emplacement of gabbro, peridotite trondhjemite (Canyon Mt. Oregon) Devonian to Permian sedimentation, NE Washington	Eugeosynclinal volcanism and sedimentation-Seven Devils Group, intrusion of mafic dikes and sills; subsequent load metamorphism-quartz keratophyres Erosion (?)
PRECAMBRIAN(?)			Sedimentation and probable subsequent folding, metamorphism

Seven Devils Group and possibly part of the Riggins Group, is a portion of the depositional record of a maturing volcanic island arc complex. The Lucile Slate and Martin Bridge Formations are apparently absent. The Seven Devils volcanic rocks and closely associated volcanogenic sediments accumulated rapidly in a eugeosyncline east of an island arc. The shallow intrusion of diabase and diorite dikes and sills was followed after deeper burial by the intrusion of gabbro and pyroxenite. A pervasive alteration of andesites, basalts, and volcanogenic sediments to quartz keratophyres and spilites(?) composed of albite, quartz, prochlorite, epidote, sericite, and magnetite occurred throughout the volcanic pile during or soon after burial and probably in contact with connate sea water. Hornblende, pseudomorphic after clinopyroxene, was mostly converted to chlorite and epidote.

Massive units of the Seven Devils Group grade eastward through a 1,500- to 3,800-foot shear zone consisting of phyllonitized greenstones into folded and slightly metamorphosed green and gray, chloritic and carbonaceous, graphitic slate, phyllite, and fine-grained sandstone. Large quartz lenses in the slate and phyllite may represent recrystallized chert nodules. The upper part of the slate-phyllite sequence is lighter colored and more calcareous and contains several thin limestone strata. These aspects of lithology suggest a decreasing volcanogenic contribution as the island arc was being eroded and the volcanics were reworked.

JURASSIC(?) SEDIMENTATION—RIGGINS GROUP

Riggins sediments, as represented in the Harpster area by the Squaw Creek Schist, originally consisted of thin-bedded, siliceous, carbonaceous, and calcareous siltstone and subordinate cherty limestone and dolomite. The siltstone was metamorphosed to quartz-biotite schist containing 50 to 70 percent quartz, biotite plus or minus muscovite, plagioclase, and garnet (Appendix 5). Thin tuffaceous units in the Squaw Creek Schist indicate sporadic volcanic eruption. Hornblende-almandite schist exposed along the west side of lower Browns Creek, probably represents a metamorphosed diabase or gabbro sill possibly related to the ultramafic rocks in the North Blacktail syncline.

LATE MESOZOIC, SYNOROGENIC BATHOLITH EMPLACEMENT

A complex, alternating sequence of cataclasis, reverse faulting, folding, wedge-intrusion, and metamorphism accompanied diapiric upwelling or "mushrooming" (Hyndman and others, 1975, p. 401-404) of the Idaho batholithic mass giving rise to successive plutonic intrusions between Middle(?) Jurassic and Late Cretaceous time. The mushroom-shaped diapir (Figure 28) was asymmetrical with a steeper western edge. The Sapphire block (Hyndman and others, 1975, p. 401-404) represents the gravity-extended eastern edge of the diapir. The posterior detachment surface of the Sapphire block is a zone of intense cataclasis similar to that along the Downey Creek fault zone in the Harpster area. The average dip of reverse faults decreases only slightly westward across the Harpster area to the Downey Creek fault zone, where the faults have distinctly shallower dips (Plate I). The steeper western batholith margin probably represents a deeper root zone of the diapir than that seen along the eastern edge of the batholith. Hyndman and Talbot (1975a) propose that the autochthonous batholith rose along a subduction complex and that it involved the mobilization of an "envelope of reactivated basement and metamorphosed Belt rocks." According to Armstrong and others (1977, p. 397-411), these rocks may be pre-Beltian, at least in part.

Anatectic magmas rose along the steep, eastward-dipping lamination in Precambrian(?) metasedimentary rocks (Figure 29). With the exception of the Blacktail pluton and possibly the Harpster pluton, all of the major granitic plutons in the area are roughly wedge-shaped with gently plunging apical edges. They are roughly concordant and thicken irregularly down dip. Their contacts grade inward from granitized metasediments, essentially in place, to variously assimilated strata (schlieren) showing plastic deformation. Granitization and differential anatexis occurred adjacent to the larger intrusive bodies. Contact metasomatic aureoles become thicker down the eastward dip of compositional layering as the magma/pendant rock ratio increases. Wedge-shaped quartzite, calc-silicate, and amphibolite roof pendants, because of their relative resistance to assimilation, project further down into the predominantly granitic basement than the mica-schist and gneiss. Plasticity increased in proportion to the magma/wall rock ratio. The more refractory amphibolite xenoliths resisted assimilation as evidenced by their angular form. The occurrence of both rounded and euhedral zircons in granitoid rocks near the centers of the larger intrusive wedges indicates voluminous assimilation of metasedimentary rocks. Wedge intrusion accompanied dilation of the diapir as it rose. Consequent uplift and erosion of the land surface above the diapir rapidly brought the zone of early intrusion close to the surface. Shearing preceded magmatic injection at any given place in the rising mass. Thus, reverse faulting and cataclasis along the west side of the border zone accompanied granitic intrusion down dip. Whereas older tonalite gneisses are

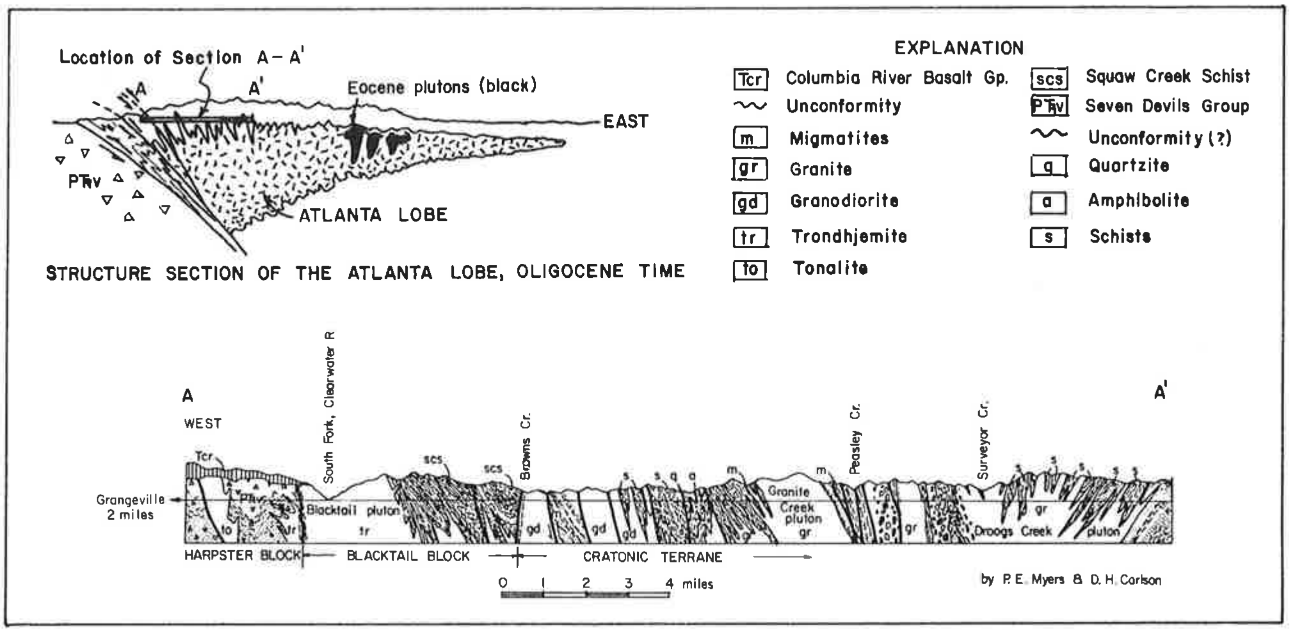

Figure 28. Cross section of the western margin of the Atlanta lobe.

abundantly intruded by pegmatites which were later folded, the adamellite core of the Granite Creek pluton contains only a few, relatively undeformed pegmatite dikes. Drag folds in metasediments near intrusive bodies indicate a localization of stresses along their contacts. Ptygmatic folds are closely associated with zones of anatexis.

The alignment of xenoliths and roof pendants in the contaminated roof zone of the Harpster pluton shows that the emplacement of this pluton was marginally controlled by the east-west structural grain in the overlying Seven Devils Group. However, the shape of the pluton is largely obscured by Columbia River basalt.

Although the Blacktail pluton has a semicircular outline within the map area, it shows consistent north-northeast foliation. Its contact against Squaw Creek Schist is dilational with little evidence of large-scale assimilation at the level of present exposure. The pluton produced a 0.9 mile (1.5 km) muscovite-garnet-tourmaline aureole in the Squaw Creek Schist. These factors suggest intrusion at shallower depth than the granitic plutons to the east. Its relatively high sodium content (trondhjemite) may be a consequence of voluminous assimilation of albitized Seven Devils Group at depth. The Blacktail pluton was intruded along a fault between the Seven Devils Group and Squaw Creek Schist with a consequent shouldering aside of the less competent Squaw Creek Schist to form the eastward-plunging North Blacktail syncline and the other subordinate cross folds in phyllites and phyllonites to the northeast. Small cross faults near Corral Hill were probably formed at this time.

Imbricate, reverse faulting, following tonalite, trondhjemite, and adamellite intrusion, produced the blastomylonites that show preferential synkinematic enlargement of feldspars. A slice of metaperidotite was carried up along a thrust fault on Blacktail Butte, and slices of Squaw Creek Schist were intercalated with more highly metamorphosed Precambrian(?) metasedimentary rocks and tonalite gneiss in the zone of northeastward flexure along Green Creek Ridge.

CENOZOIC HISTORY

Contraction and subsidence during the final crystallization of magmas in the Idaho batholith margin resulted in additional shearing but with normal displacement. Retrograde metamorphism mainly involved the chloritization of biotite and the replacement of plagioclase by epidote in zones of most intense displacement. Very coarse-grained biotite granite pegmatite dikes (with or without muscovite, garnet, and tourmaline) were intruded along joints at this time. The pegmatites do not have chilled margins.

The quartz latite vitrophyre dike at Peasley Creek and the rhyolite plug on Cougar Mountain were intruded into cold rocks at shallow depth. Thus, a considerable thickness of rock must have been removed between the intrusion of postkinematic pegmatites and the quartz latite-rhyolite rocks.

Although the Miocene topography of the Clearwater Mountains had a rugged, well-developed west-

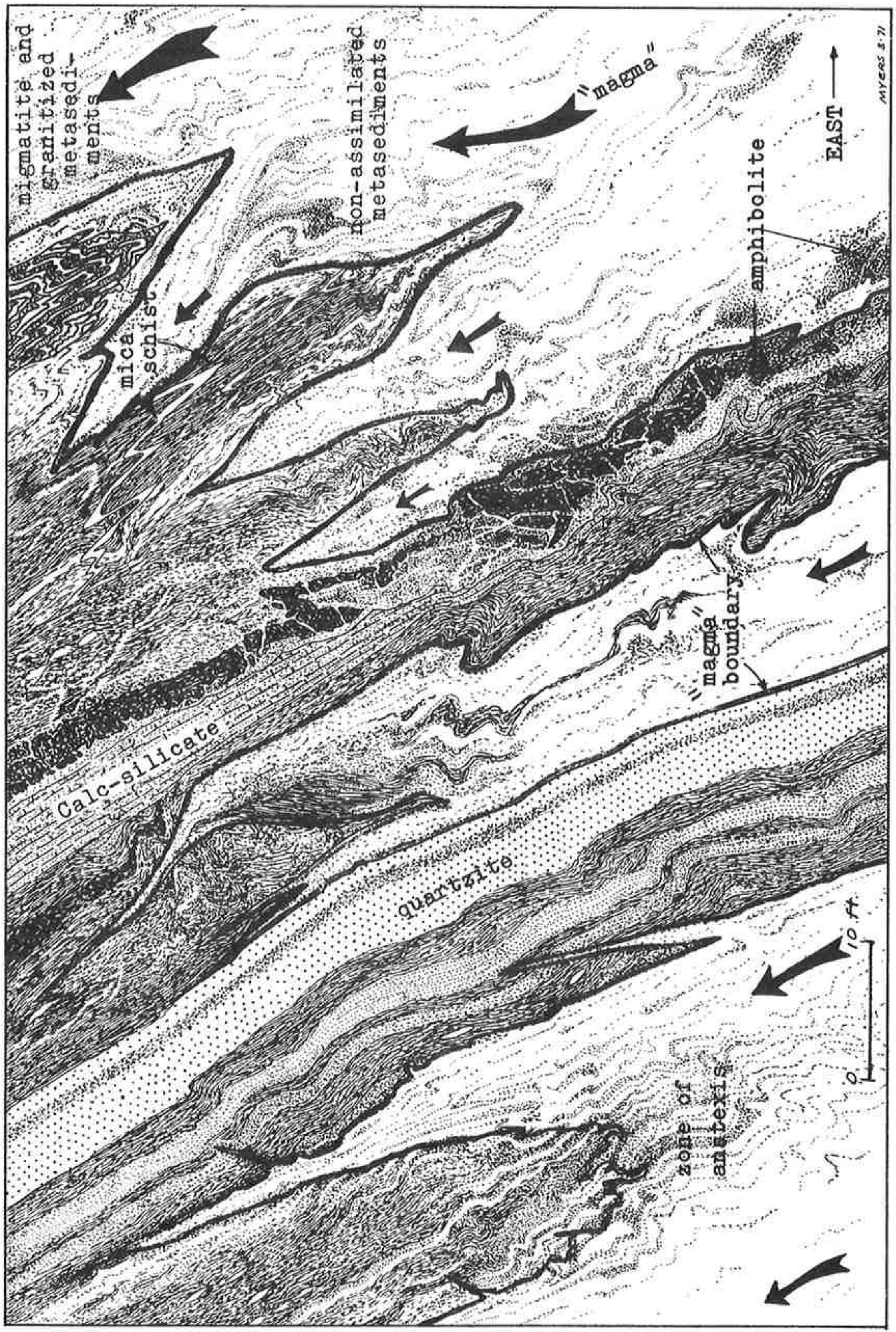

Figure 29. Cross section showing features and processes of wedge injection in the western margin of the Atlanta lobe.

ward drainage, ferruginous, clay-rich soils developed in depressions which were eroded preferentially into massive igneous rocks (e.g., Harpster and Blacktail plutons). McComas basin was also a low area in Miocene time. Columbia River basalt successively inundated the west-facing slopes of the old Clearwater Mountains, and basalt tongues eventually extended up the ancestral South Fork, temporarily damming the river and causing alluviation of the basalt plateau. Gravels such as those on Blacktail Butte were deposited at this time.

Pliocene to Recent block faulting along the east side of Blacktail Butte displaced Columbia River basalt and blocked the westward outlet of McComas basin, where drainage was internal until Recent rejuvenation by Lightning and Meadow Creeks. Regional uplift and consequent stream rejuvenation have lowered the channel of the South Fork approximately 200 feet below the level of Pleistocene(?) bench gravels.

A Pleistocene moraine along the west side of McComas basin, and the U-shaped profile of lower Meadow Creek valley suggest that ice moved northward across the South Fork and up the Meadow Creek valley to a terminus in McComas basin. The fine silts in McComas basin and the fossiliferous alluvium of Fisher Placer are probably outwash. Postglacial erosion has removed all but a few outwash deposits along the South Fork.

ECONOMIC GEOLOGY

Minor production of gold, magnetite, asbestos, and limestone within the map area took place between 1880 and 1935. No significant production of these materials has occurred in recent years.

The Harpster area retains significant mineral potential for the production of copper and possibly gold from sheared Seven Devils Group, for talc from metaperidotites on the summit of Blacktail Butte, and for radioactive minerals in tonalites. Recent interest in andesitic volcanic rocks and greenstones as hosts for massive copper-zinc sulfide ore deposits raises the possibility of these metals in the Seven Devils Group of the Harpster area. Numerous showings of copper sulfide minerals have been prospected, and small pits and tunnels can be seen along the South Fork canyon where it cuts through the Seven Devils Group. A geochemical investigation of the region might reveal significant copper or zinc anomalies. Despite the rising value of gold in recent years, the small placer deposits of the South Fork area do not yet present a significant potential for mining. Gold may be present along the numerous faults cutting granitic rocks throughout the region. Future prospecting for gold might be best concentrated in those areas near older gold mines, such as Peasley Creek. The region should be reinvestigated as a possible source of radioactive metals such as uranium. The tonalites carry unusually high concentrations of zircon and allanite. Other radioactive minerals may also be present, but in smaller quantities.

GOLD

Sparse disseminations of gold in association with pyrite and minor chalcopyrite occur in silicified and sericitized metasedimentary and granitic rocks near the mouth of Peasley Creek and along Wickiup Creek. Small mines at these two locations have had sporadic production since the early 1900's. The ores at both places occur in hanging-wall rocks adjacent to steeply dipping, north-northeast-trending faults along which there has been extensive development of gouge and mylonite. Silicified, iron-stained, and sericitized rocks at Peasley Creek form an alteration zone 600 feet (180 m) wide. Neither mine is presently in operation.

Many small gold and copper prospects can be seen in Seven Devils Group north of Schwartz Creek. The prospects were dug during the early 1900's (Anderson, 1930, p. 35). Until 1929 the Dewey Mine (outside the map area) produced low-grade ores from four, parallel, silicified and sericitized breccia zones along faults, which strike N. 10° E. and dip 75° SE. in rocks of the Seven Devils Group. The gold was associated with disseminations and thin veinlets of pyrite and very subordinate chalcopyrite deposited during silicification and seritization of the andesitic wall rocks within and adjacent to the fault zones.

Two small gold placer claims, the Clara Ophelia and the Geary (Big Cove) on the South Fork, and the Fisher Placer on a gravel bench about 250 feet (75 m) above the South Fork, were worked between 1890 and 1918. Descriptions of these deposits are contained in a report by Reed (1934, p. 23). Because of their small size and low values these deposits have not been reactivated.

MAGNETITE

Contact metasomatic alteration of marbles by granitic intrusive rocks in the North Meadow Creek, south Quartz Ridge, and Switchback areas has produced three small deposits of high-grade magnetite which were trenched in 1958-1959 by William McComas of Grangeville. The magnetite occurs in calc-silicate layers and in minor west-northwest-trending cross faults. Structural details are obscured by pervasive limonite staining. Boulders of nearly pure magnetite up to 14 inches (35 cm) in diameter were found at a prospect along the lower road west of North Meadow Creek at location

234. Maximum thickness of the magnetite is about 4 feet (1.2 m).

ASBESTOS AND TALC

Asbestos and talc occur in metaperidotites in the summit of Blacktail Butte. The deposits were extensively described by Anderson (1930, p. 49-51) who reports that the asbestiform mineral is anthophyllite. This study revealed no anthophyllite. The only amphibole found was tremolite. Bent cross-fiber asbestos with fibers up to 2 inches long was found near the base of the metaperidotite unit. The asbestos appears to have formed during serpentinization of the Blacktail Butte metaperidotite. Asbestos is a very sparse component in the rock which consists predominantly of talc, antigorite, and tremolite in poorly oriented aggregates. This deposit may be a source of talc in the future.

MARBLE

A thin, discontinuous bed of highly sheared, nonfossiliferous brownish gray calcite marble of high purity was quarried from the divide between the head of Sears Creek and Wall Creek for some years. The maximum thickness of the marble layer is about 9 feet. The marble, which is intercalated in light gray muscovite phyllite, can be followed northeast through a series of small faults across Wall Creek to the head of Sill Creek. In most places the marble occurs in two thin layers, a lower unit 5 feet (1.5 m) thick and an upper unit about 1.5 feet (.5 m) thick. The two layers are separated by a phyllite layer approximately 6 to 10 feet (1.8-3 m) thick. Each of these layers varies greatly in thickness along strike. At the Sears Creek locality the marble is a mottled, locally spongy, brownish gray rock seamed by thin secondary calcite stringers. At most other localities the correlative stratum is light blue gray. The marble at all locations has been intensely sheared. About 4 pounds of the marble from the Sears Creek quarry were dissolved in dilute hydrochloric acid leaving a dark olive gray, pasty phosphatic(?) residue of undetermined composition. Availability of much thicker marbles elsewhere throughout the region make the small marble deposits within the area relatively insignificant as potential commercial producers of lime.

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APPENDICES

Appendix 1. Estimated mineral compositions (percentage) of ten specimens of quartz-biotite-muscovite schist from Precambrian(?) metasedimentary rocks, Harpster area, Idaho.

Specimen Location No.*	490	491-A	494	495	498	520	538-A	541-A	541-C	630
Quartz	55	50	55	60	65	70	55	55	60	65
Biotite	20	15	15	20	5	20	20	15	30	25
Muscovite			20	10	15	5	10	3		1
Garnet		5	1		1	1	1	5	5	
Plagioclase		15	5					20		5
Graphite	5	3	1	5			5		5	2

Accessories include tourmaline, chlorite, clinozoisite, apatite, geothite, siderite, pyrite, and sphene.
*Locations shown on Plate I.

Appendix 2. Modes (percentage) of sillimanite-bearing Precambrian(?) metasedimentary rocks, Harpster area, Idaho.

Specimen Location No.*	Classification	Quartz	Muscovite	Biotite	Sillimanite	Cordierite	Plagioclase	Garnet	Dravite
421	Quartz-sillimanite-muscovite-magnetite(?)-zircon schist	82	5		9				
422	Muscovite-quartz-sillimanite schist	32	45	3	13				
588-B	Muscovite-quartz-sillimanite-biotite schist	35	56	2	5				
590-C	Quartz-muscovite-sillimanite schist	67	23		9				
601-A	Quartz-cordierite-sillimanite-biotite-muscovite gneiss(?)	76	3	3	4	12			
601-B	Banded quartz-sillimanite-muscovite-biotite-dravite schist	63	15	6	10				4
610	Quartz-sillimanite schist	81	1	2	14				
616	Microfolded quartz-muscovite-biotite-sillimanite-garnet schist	46	24	14	3		6	6	

Zircon, apatite, sphene, allanite, monazite, and pyrite are sparse accessories.
*Locations shown on Plate I.

Appendix 3. Mineral compositions (percentage) of calc-silicate rocks in Precambrian(?) metasedimentary rocks, Harpster area, Idaho.

Specimen **Location No.**	***141** **A**	**141** **B**	**180** **A**	**256** **A**	**256** **D**	**256** **E**	**286** **B**	**292** **A**	**292** **B**	**291**	**300**
Andesine			35								
Oligoclase				5				20	25	15	8
Albite		15									
Perthite						20	2	5		15	
K-Feldspar	25	25		35	12	40	5	10	20	5	
Quartz	35			10	60		70	20	15	15	18
Hornblende			5								
Act. hornblende											
Actinolite	15	45			5	10	3	2		12	
Tremolite											
Pargasite(?)											68
Biotite											
Muscovite		5									
Phlogopite											
Diopside	20	5	50	45	20		20	10	12		3
Di. augite											
Wollastonite											
Epidote						25		2		1	
Clinozoisite			2			2				1	
Allanite						1					
Dolomite											
Calcite											
Talc											
Antigorite											
Brucite											
Garnet								25	25		
Sphene	2	1	2	1		3		3	3	1	2
Zircon	1		1	1							1
Apatite			1					1			
Magnetite			1								
Pyrite											

*Specimen locations are on Plate I.

Appendix 3. (continued)

Specimen Location No.	305 A	305 D	305 G	345 A	364 A	381 C	381 D	411 B	419	430 C	551 A
Andesine				8			40				50
Oligoclase		2	2			20					
Albite											
Perthite											
K-feldspar							3				10
Quartz				51		32	20	5	55		
Hornblende						45	20				10
Act. hornblende											
Actinolite	4	80		7	15			15			
Tremolite									15		2
Pargasite(?)											
Biotite											
Muscovite					2?		4				
Phlogopite								1			
Diopside	19	10	75	32	60	95	10	70	25		20
Di. augite											
Wollastonite			5		20						
Epidote											
Clinozoisite											5
Allanite											1
Dolomite										95	
Calcite			1					5			
Talc			15					3		3	
Antigorite			2							2	
Brucite	3										
Garnet											
Sphene			1	1	2	3	1		1		2
Zircon			1	1					1		1
Apatite				1					1		
Magnetite		5				1			1		
Pyrite											

Appendix 3. (continued)

Specimen Location No.	561	592 B	583 B	595	603 B	604	605 A	605 B	638 A	656 B
Andesine	35		82							
Oligoclase		10			25		40	50	60	5?
Albite										
Perthite				15						
K-feldspar				15	5			5		
Quartz	13		1?	30	20	15	25	10	30	10
Hornblende	15					30	15			
Act. hornblende				10						
Acatinolite	3					5		?	?	25
Tremolite		20	3					25	1	55
Pargasite(?)										
Biotite							3			
Muscovite			3?	15					1	
Phlogopite										
Diopside	23	35	9		15	15	10	5	2	1
Di. augite				10						
Wollastonite										
Epidote	1			5			1			
Clinozoisite	5	1	1						1	
Allanite										
Dolomite					30	25				
Calcite			1							
Talc		25								
Antigorite		15	1							
Brucite										
Garnet										
Sphene	1		1	1	1	1	2	2	4	
Zircon	1							1		
Apatite	1						1			
Magnetite	1				1		1			
Pyrite								1		

Appendix 4. Estimated mineral compositions (percentage) of the Seven Devils Group, Harpster area, Idaho.

	Tuffs and Tuff Breccias						Flows		Metadiabase			Tuffaceous Sediments	
Specimen Location No.	***231 A**	**565 C**	**211 B**	**289 B**	**396 B**	**404 A**	**196 B**	**203**	**199**	**405 A**	**196 A**	**405 B**	**569**
Labradorite													
Andesine		35						45	38	35	24		
Oligoclase	30		20			10	30						
Albite				30	35								
Microcline													
Pyroxene									3				
Hornblende	5					5	45	50	20		35		
Actinolitic hornblende	35		10										
Actinolite		10			20								
Tremolite				1									
Epidote	5	20	20	15	10	40	8	5	3	15	5	5	3
Clinozoisite	3	2		20		3			12	10	10		
Al-prochlorite	15	25		20		35				3		10	2
Fe-prochlorite													
Pennine			5		15				5	10	5		
Muscovite-sericite		2	10						5		20	20	10
Biotite													
Quartz	5	5	40	10	15		10	2	10	9		60	85
Sphene			2		1	1		1		1	1		
Magnetite	1			2		1	5		3	2		2	
Carbonates		1			1					1			
Carbon												3	
Others			3	2	4	6		2	1				

*Locations shown on Plate I.

Appendix 4. (continued)

	Hornblende			Green Phyllonite						White Phyllonite		
Specimen Location No.	***568 D**	**211 D**	**215**	**233**	**280**	**226 A**	**247 A**	**244 A**	**257**	**226 B**	**244 B**	**247 B**
Labradorite												
Andesine		35										2
Oligoclase	30											
Albite					35		15	10				
Microcline												
Pyroxene	4	1										
Hornblende		20										
Actinolitic hornblende	14		60	25			30	15				
Actinolite												
Tremolite												
Epidote	5	3	20	30		35	10	20	30	10		5
Clinozoisite	20			5					10			
Al-prochlorite	15				20				25			15
Fe-prochlorite		5				30		35				
Pennine				16						1		
Muscovite-sericite	10?	5		2	1							10
Biotite					15		15			5		
Quartz	1	25	5	15	15	25	20	15	30	60		65
Sphene	1	1						1	1			
Magnetite		2		5	5	5	5	2	3			3
Carbonates					5							
Carbon												
Others	1	3	5	2				3		4		

*Locations shown on Plate I.

Appendix 5. Mineral compositions (percentage) of quartz-biotite-muscovite schists from the Squaw Creek Schist, Harpster area, Idaho.

Specimen Location No.	*490	491-A	494	496	498	520	538-A	541-A	541-C	630
Quartz	55	50	55	60	65	70	55	55	60	65
Biotite	20	15	15	20	5	20	20	15	30	25
Muscovite			20	10	15	5	10	3		1
Garnet		5	1		1	1	1	5	5	
Plagioclase		15	5					20		5
Graphite	5	3	1	5			5		5	2

Accessories include tourmaline, chlorite, clinozoisite, apatite, goethite, siderite, pyrite, and sphene.
*Locations are on Plate I.

Appendix 6. Modes (percentage) of five metaperidotites from Blacktail Butte, Harpster area, Idaho.

Specimen Location No.	*499-A	499-B	526-A	526-B	527
Antigorite	82	32	14	71	
Talc	6	22	62	17	
Tremolite		18			
Zoisite			17		
Al-prochlorite		3	4	10	
Fe-prochlorite					76
Magnetite	12	7	1	1	10
Epidote					14
Relict Pyroxene		16			
Relict Olivine			2		

*Locations are on Plate I.

Appendix 7. Summary descriptions of feldspars in granitoid rocks from the Harpster area, Idaho.

Rock Type	Map Symbol*	Potash Feldspars	Plagioclase
pegmatite augen stringers dikes		microcline microperthite surrounded by quartz, muscovite, biotite, sparse garnet; most microcline grains strained	subordinate oligoclase mostly anhedral and deformed
adamellite	Ka Kag	strained microcline, some surrounded by orthoclase in flaser gneiss; microcline shows deformed twinning and mottled extinction	in Ka, oligoclase subhedra and anhedra (4-12 mm); muscovite along cleavages; microcline and quartz inclusions; in Kag, finer grained, more K-feldspar, foliated
tonalite gneisses	Kbtg	accessory, deformed microcline, some of which contains orthoclase inclusions	well-oriented, deformed oligoclase and andesine (An_{40}-An_{25}) subhedra (0.3-8.0 mm) showing marginal ablation and normal oscillation zoning; indistinct twinning in sheared rocks; muscovite along cleavages
hornblende tonalite- gabbro-norite	Kht	absent except in later pegmatite dikes which contain graphic and perthitic microcline	zoned (An_{65}-An_{40}) rectangular subhedra (0.2-3.0 mm); cores selectively altered to sericite, zoisite, and epidote; bent and broken in shear zones
trondhjemite (Blacktail pluton)	Kt	orthoclase with oligoclase in sheared adamellite margin of Blacktail pluton	deformed oligoclase (An_{20}-An_{25}) subhedra (0.3-4.0 mm) with cleavage-oriented inclusions of muscovite plus blebs of epidote and allanite in sheared trondhjemite
granodiorite, tonalite	Ji	sericitized microcline subhedra (0.1-3.0 mm) cut by prochlorite veinlets	bent and displaced andesine (?) subhedra altered to sericite, epidote, clinizoisite, and quartz

*Plate I.

Appendix 8. Summary descriptions of the micas from the Harpster area, Idaho.

Rock Unit	Muscovite	Biotite	Phlogopite
JKi	with pennine as retrograde alteration of biotite and with epidote as an alteration of plagioclase; books in pegmatite	brown biotite abundant folia concordant with enclosing metasedimentary rocks: green biotite abundant in flaser gneisses as an alteration of hornblende; coarse books of brown biotite abundant in late pegmatite dikes	absent
s	abundant in fine-grained quartz-biotite-almandite schist and phyllite	orange-brown biotite as folia in quartz-biotite-almandite schist	sparse in siliceous calc-schist and marble
PTRv	with clay as a replacement of plagioclase and with prochlorite in phyllonite	sparse in pressure shadows behind magnetite in phyllonite	absent
P€ (?)	relatively coarse in quartzite, schist and gneiss, abundant along fold axial planes and edges of granitic augen; most abundant in rocks containing almandite; inclusions of sillimanite in east part of the area	abundant as folded folia in mica schist, gneiss and migmatite; accessory in micaceous quartzite; abundant with almandite or muscovite around granitic augen	pegmatite margins in calc-silicate rocks

*granitold rocks.

Appendix 9. Optical properties of the amphiboles from the Harpster area, Idaho.

Host Rock	Location*	α	β	γ	Δn	Extinction Angle	Color in Hand Specimen	Pleochroism
				HORNBLENDE				
PTRv	212*	1.642 ± .001		1.661 ± .002	.019	17°	dark greenish gray	α = pale yellow brown; γ = medium olive green
PTR vs	247	1.643 ± .001		1.662 ± .001	.019	12°	dark green	cores, α = pale yellow green, γ = grass green; rims, α = light yellow green, γ = medium bluish green
s	633(cs) 447 549	1.641 ± .001** 1.642 ± .001 1.653 ± .002		1.652 ± .001 1.661 ± .001 1.676 ± .001	.011 .019 .024	16° 31° 21°	grayish green dark green dark green	α = pale green γ = medium greenish gray
Khtg	552 522	1.653 ± .002 1.665 ± .001		1.676 ± .001 1.681 ± .001	.023 .016	28° 16°	black black	α = pale yellow green; γ = olive brown or dark green
P€b cs	656	1.669 ± .001		1.680 ± .001	.011	28°	dark greenish gray	α = pale green γ = olive green
				PARGASITE				
cs	300	1.611 ± .001		1.635 ± .001	.024	23°	pale olive green	colorless
				ACTINOLITE				
cs	411	1.609 ± .001	1.624 ± .001	1.639 ± .001	.030	14°	pale green	colorless
				TREMOLITE				
cs	305	1.602 ± .001	1.615 ± .002	1.627 ± .001	.025	15°	pale greenish white	colorless

*See Plate I.
**Actinolitic hornblende.

Appendix 10. Optical Properties and occurrences of the chlorite minerals from the Harpster area, Idaho.

Aluminian Prochlorite
Optical Properties

Location	α	β	γ	Δn	2V	Color	Interference Color
216 517 488	1.605* 1.606 1.605	1.605	1.611 1.609 1.608	.006 .003 .003	5°	colorless and light yellow green, medium yellow green	anomalous yellowish gray to grayish yellow green

Occurrences

(1) replaces light green, actinolitic hornblende in andesite of the Seven Devils Group,
(2) accompanies muscovite and epidote as interlensing folia in phyllonitic greenstone,
(3) accompanies pennine as laninae in biotite of sheared granitoid rocks.

Ferroan Prochlorite
Optical Properties

Location	α	β	γ	Δn	2V	Color	Interference Color
226	1.612	1.614	1.620	.008	?	light yellow green to dark yellow green	anomalous orange-brown to deep brownish purple

Occurrences

(1) with clinozoisite and epidote replacing dark green hornblende in basalts and gabbros of the Seven Devils Group and ultramafic rocks of the Riggins Group and
(2) veinlets along shear planes cutting gabbro of the Harpster pluton

Pennine
Optical Properties

Location	α	β	γ	Δn	2V	Color	Interference Color
409	1.592*	1.594	1.595	.003	5°	light green, medium yellow green	anomalous ulta-blue to light blue gray
614	1.578		1.581	.003			
434	1.596	1.600	1.601	.005	5°		

Occurrences

(1) with aluminian prochlorite as a replacement of biotite in the border zone
(2) with ferroan prochlorite replacing hornblende and augite in gabbro of the Harpster pluton

*All indices ± .001

Appendix 11. Properties and occurrences of epidote minerals from the Harpster area, Idaho.

Mineral	Indices	Other Properties	Summary of Occurrences
Aluminian(?) Epidote (Location 464)	α 1.718 ± .002 β 1.732 ± .002 γ 1.742 ± .005 Δn = .024	colorless, nonpleochroic	most widespread as an alteration of plagioclase in sheared rocks, as rims on allanite, and as veinlets cutting Seven Devils Group
Ferroan(?) Epidote (Location 407)	α 1.726 ± .002 β 1.743 ± .001 γ 1.754 ± .002 Δn = .028	faintly pleochroic: pale yellow, yellow green commonly with quartz inclusions / / (100)	replaces pyroxene in Seven Devils Group and hornblende in tonalite and calc-silicate rocks, commonly associated with clinozoisite
Clinozoisite		colorless, nonpleochroic anomalous ultra-blue interference colors	replaces labradorite in Seven Devils Group and calc-silicate rocks and grossularite in calc-silicate rocks
Zoisite (Location 568)	α 1.698 ± .002 β 1.701 ± .001 γ 1.706 ± .002 Δn = .008	colorless, anomalous deep blue gray interference color, very small 2V	veinlets and replacements in mafic and ultramafic portions of the Seven Devils Group and Riggins Group
Allanite (Location 557)	α 1.703 ± .002 β 1.714 ± .001 γ 1.730 ± .002 Δn = .027	pleochroic: pale reddish brown, brownish yellow, reddish brown; twinned on (100), rimmed by pleochroic epidote, irregular radial fractures	coarse euhedra in hornblende-bearing tonalite and feldspathic calc-silicate rocks, associated with coarse clinozoisite, apatite, sphene, and zircon

Appendix 12. Semiquantitative spectrochemical analyses (percentage) of garnets from the Harpster area, Idaho.

Specimen Number	SiO_2	Al_2O_3	FeO + Fe_2O_3	MnO	MgO	CaO	Mineral Species Identified by X-ray Analysis*
535-A	33	21	26	16	1	3	spessartite + almandite(?) + muscovite
466-D	38	23	28	8	2	2	almandite + spessartite(?) + quartz
553-E′	46	27	17	7	3	1−	almandite
553-E″	44	23	24	6	2	1−	almandite + quartz
292-A	39	24	16	1	1−	21	grossularite + almandite(?)
588-A	48	10	38	3	1	1−	almandite + quartz
588-E	40	27	20	8	5	1−	almandite + quartz
339	32	18	33	4	1	12	grossularite(?) may be andradite in parts

*More than one species included only where lines for both were present. Other species seen in thin sections but not identified in these analyses include magnetite, clinozoisite, epidote, chlorite, and calcite.

Analysts: S. Mattarella and F. Marczik, January, 1968.

Descriptions of Specimens

535-A Muscovite-biotite-epidote-clinozoisite trondhjemite gneiss

466-D Adamellite aplite dike in quartz-biotite-hornblende-garnet schist

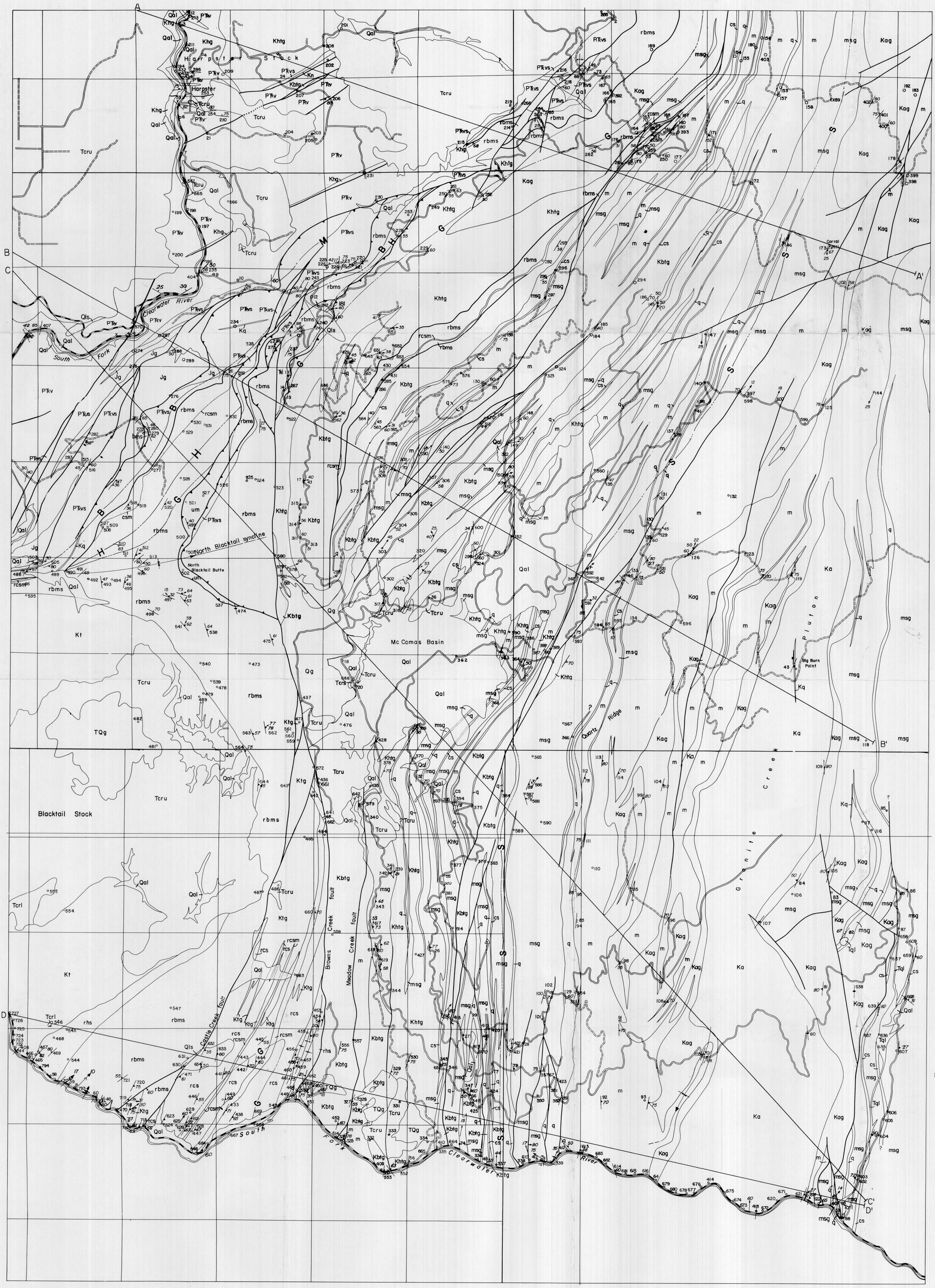
553-E Foliated biotite adamellite dike (553-E′) cutting ptygmatically folded migmatite (553-E″)

292-A Pale orange-brown garnet in coarse rock composed of perthite, quartz, and diopside. The garnet is approximately 15 percent altered to clinozoisite

588-A Biotite-muscovite-almandite sheath on pegmatite pod in biotite-muscovite schist

588-E Garnet from pegmatite pod

339 Quartz-grossularite-calcite-epidote gneiss. Grossularite altered along fractures to epidote (6%) + calcite (13%) neither of which was found in X-ray analysis.



Base map from U.S. Geological Survey Harpster, Corral Hill, Hungry Ridge and Huddleson Bluff quadrangles

Geology by Paul E. Myers 1959, 1960 and 1962.

GEOLOGIC MAP OF THE HARPSTER QUADRANGLE AND VICINITY, IDAHO COUNTY, IDAHO

1 1/2 0 1 Mile

CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL

EXPLANATION

QUATERNARY

- Qal — Alluvium
- Qls — Landslide debris
- Qg — Glacial deposits
- TQg — Unconsolidated, high-level sand and gravel

-- UNCONFORMITY --

TERTIARY

- Tcru, Tcrs, Tcrl — Columbia River Basalt. Tcru, "Upper" (Lower Yakima) basalt, Tcrs, fossiliferous silt and sand. Tcrl, "Lower" (Imnaha) basalt, porphyritic diabase and basalt

-- UNCONFORMITY --

- Tql — Quartz latite and subordinate rhyolite porphyries

CRETACEOUS

- Kq — Quartz veins
- Ka, Kag — Ka, massive biotite adamellite. Kag, gneissic adamellite border phase
- Kt, Ktg — Trondhjemite. Kt, massive phase. Ktg, gneissic phase
- Kn — Norite
- Khg — Hornblende gabbro
- Kbtg — Gneissic biotite tonalite
- Khtg — Gneissic hornblende tonalite

JURASSIC (?)

- Jg — Altered granodiorite
- um — Ultramafic rocks. Mainly talc-serpentine-chlorite schist

PERMIAN-TRIASSIC

- r: cs, csm, bms, hs — Riggins Group. cs, calc-schist. csm, calc-silicate marble. bms, biotite-muscovite schist. hs, hornblende schist
- PTrv, PTrvs — Seven Devils Volcanics. PTrv; quartz keratophyric tuffs, breccias, and volcanogenic sediments, including conglomerates, sandstones, siltstones, and cherts, mafic dikes and flows. PTrvs; phyllonitic equivalents of PTrv

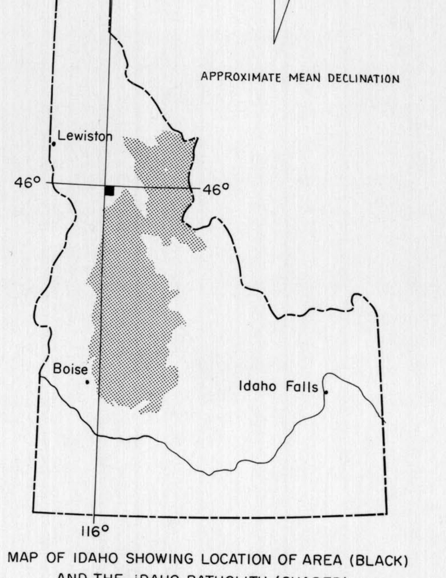
(?) -- UNCONFORMITY -- (?)

PRECAMBRIAN (?)

- m — Migmatites. Banded gneiss, veined gneiss, and agmatite
- msg — Mica schist and gneiss
- cs — Calc-silicate rocks
- q — Quartzites

Symbols

- Contact
- High-angle fault
- Reverse fault, barbs on upthrown side
- 17 — Plunge of minor syncline
- 20 — Plunge of minor anticline
- Plunge of fold axis
- 12 — Plunge of Lineation
- 50 — Strike and dip of bedding
- 60 — Strike and dip of compositional layering
- 70 — Strike and dip of shear cleavage
- 80 — Strike and dip of foliation
- 70 — Strike and dip of joints
- 220 — Field location
- M — Muscovite isograd
- B — Biotite isograd
- H — Black hornblende isograd
- G — Garnet isograd
- S — Sillimanite isograd



MAP OF IDAHO SHOWING LOCATION OF AREA (BLACK) AND THE IDAHO BATHOLITH (SHADED)

PLATE II

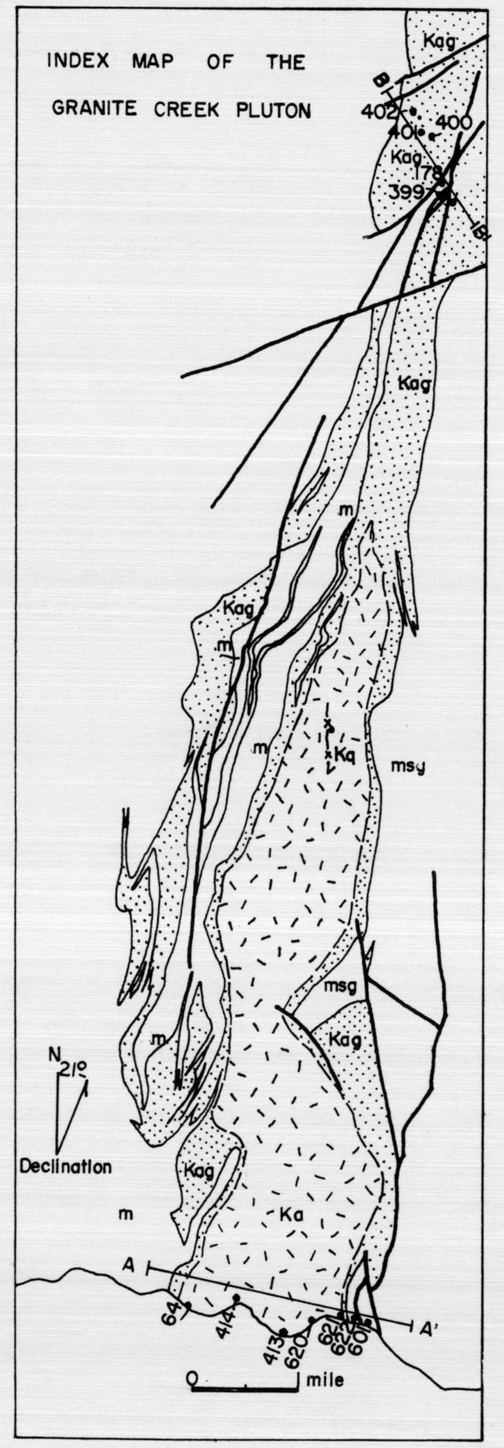
STRUCTURE SECTIONS - HARPSTER QUADRANGLE AND VICINITY, IDAHO

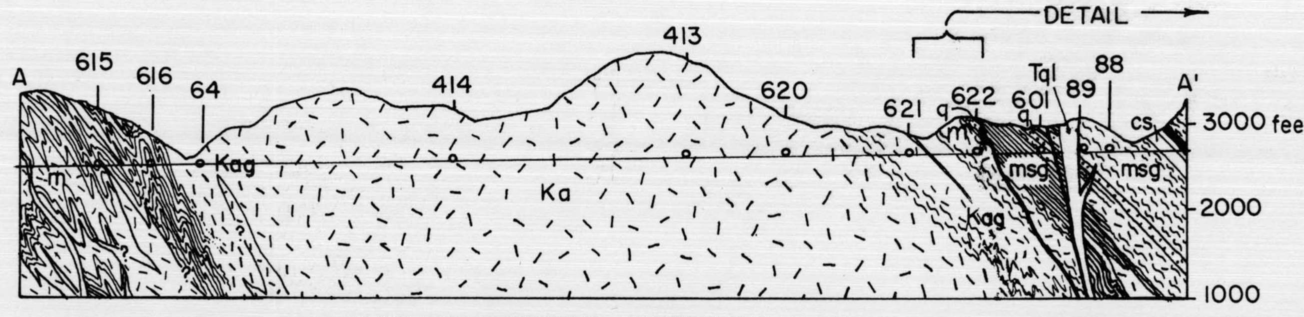
1 1/2 0 1 Mile

CONTOUR INTERVAL 40 FEET

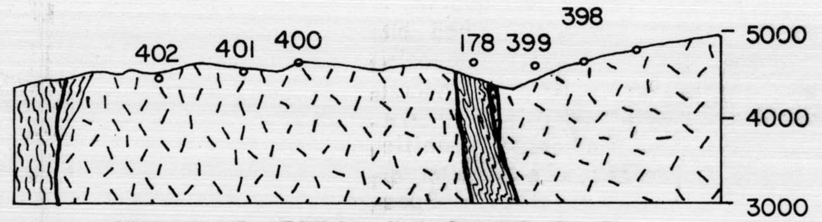
DATUM IS MEAN SEA LEVEL

PETROGRAPHIC CROSS SECTIONS OF THE GRANITE CREEK PLUTON



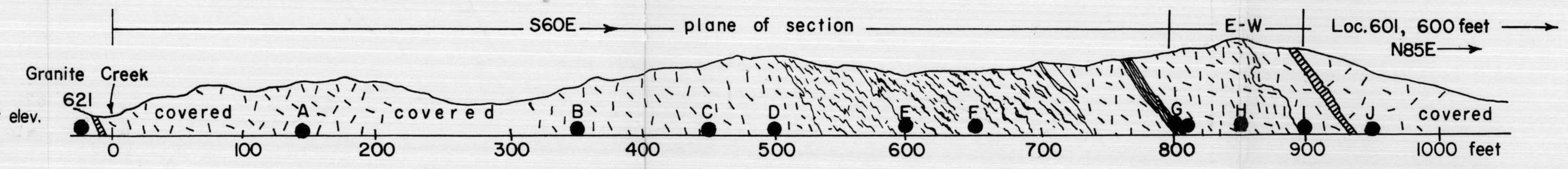


STRUCTURE SECTION ALONG LINE A-A'



STRUCTURE SECTION ALONG LINE B-B'

STRUCTURAL AND PETROGRAPHIC CROSS SECTION ALONG LINE A-A'



ROCK DESCRIPTIONS

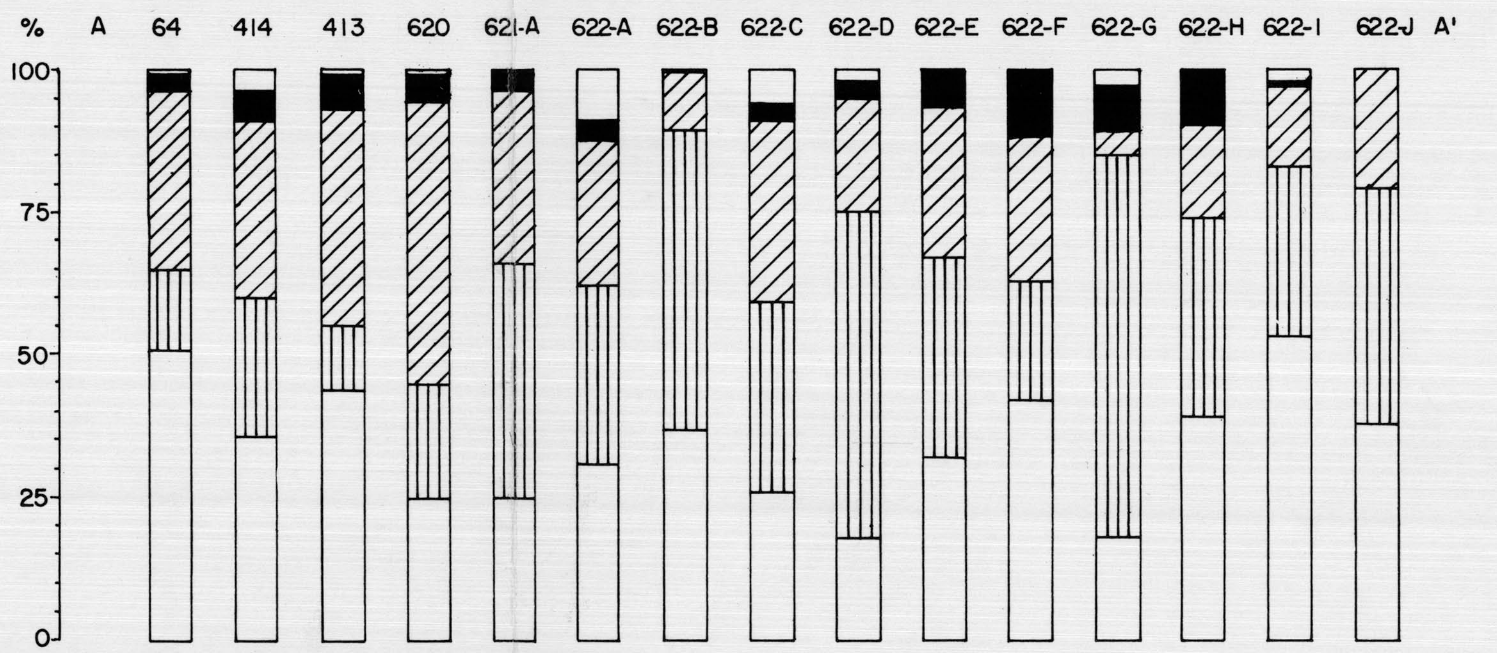
621 Biotite adamellite with irregular biotite pegmatite masses: 3-foot calc-silicate unit (cross-hatched) N47E; 41SE

622

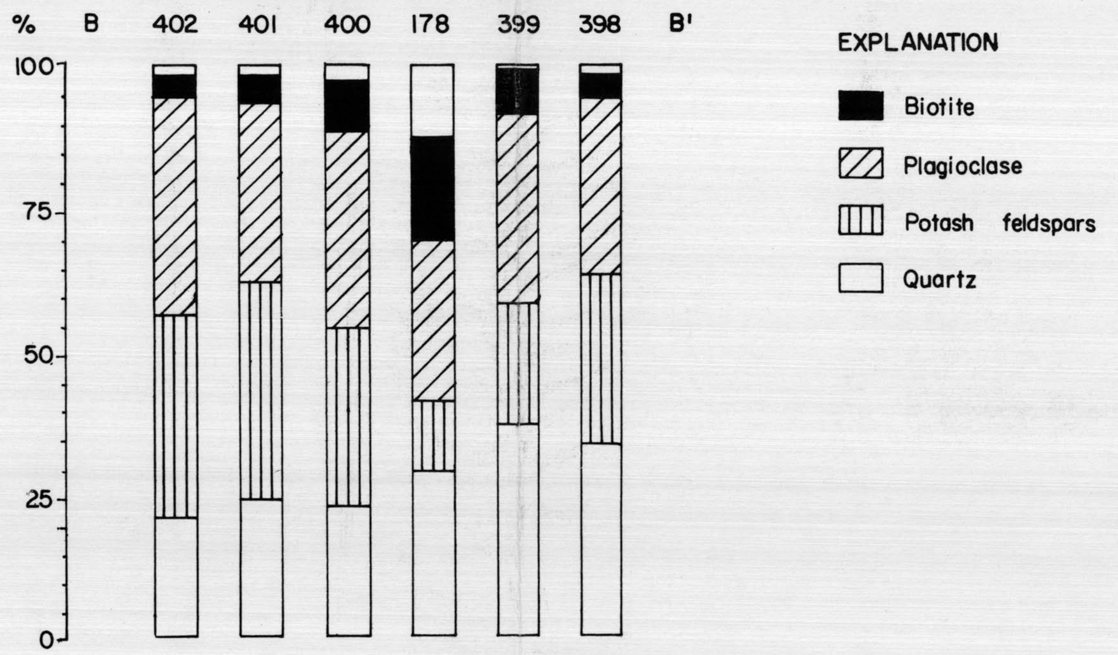
- A Foliated, medium-grained, garnetiferous quartz monzonite. Foliation, N15E; 78E
- B Same as A but with abundant, coarse-grained biotite pegmatite veinlets along foliation
- C Coarse-grained, foliated biotite quartz monzonite and pegmatite. Foliation, N12E; 55-60E
- D Same rock type as C but coarser. Contains coarse quartz, tourmaline, microcline, biotite clots
- E (545-600 ft.) Biotite schist with subordinate (1-4-inch) laminae of calc-silicate schist and quartzite; pegmatite boudin. Coarse feldspar porphyroblasts. Contorted granitic layers with axial planes parallel to foliation (N10E; 65SE) Contact with adjacent, coarse-grained, garnetiferous biotite quartz monzonite gneiss at 600 ft. is sharp. The gneiss contains quartz-tourmaline veinlets along joint surfaces. Specimen E taken 9 feet east of point E on section above.
- F Schlieren gneiss containing flamose septa and lenticular masses of biotite-deficient gneiss alternating with coarse-grained, biotite-rich septa. Discordant granitic lenses are isoclinally folded.
- G Biotite schist in sharp contact with coarse biotite quartz monzonite which cuts foliation. Schist contains 1-3 inch calc-silicate laminae.
- H Medium-grained, foliated, biotite-rich quartz monzonite
- I Medium-grained leucogranite; iron-stained through weathering of accessory pyrite.
- J Leucogranite with abundant quartz-microcline-tourmaline-muscovite clots.

601 Sheared sillimanite-tourmaline quartzite cut by irregular veins of very coarse biotite pegmatite.

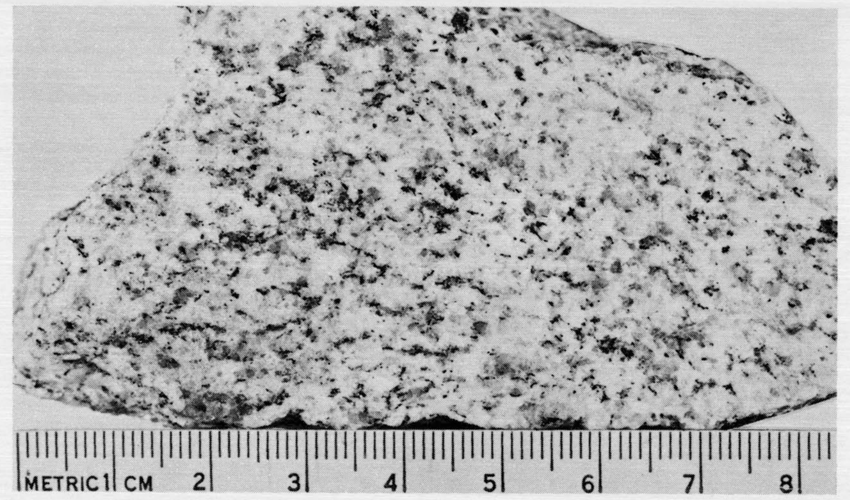
MODAL ANALYSES OF ROCKS ALONG LINE A-A'



MODAL ANALYSES OF ROCKS ALONG LINE B-B'



A



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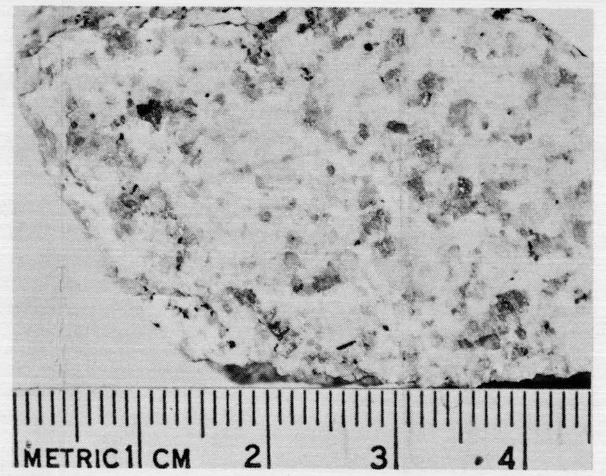

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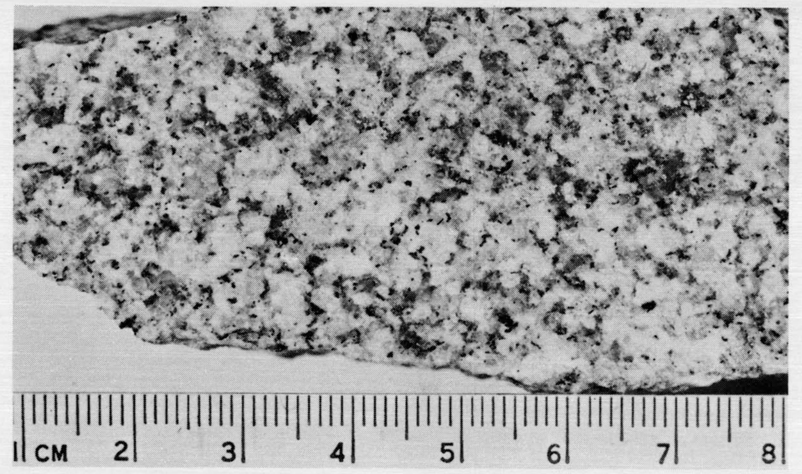

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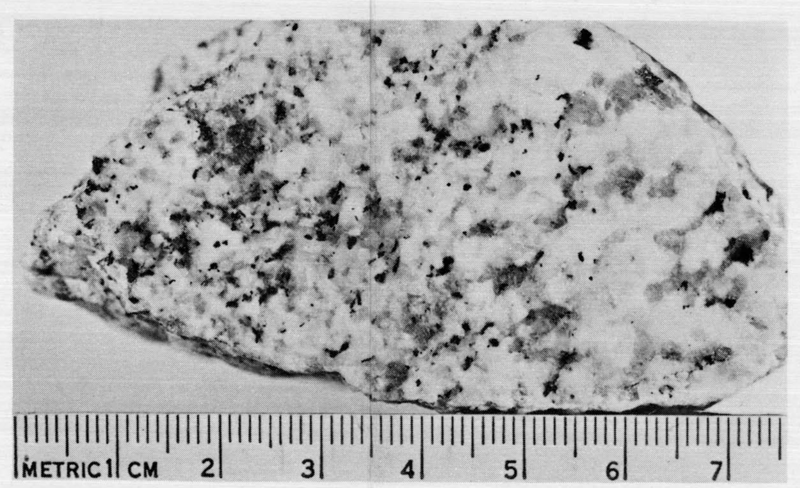
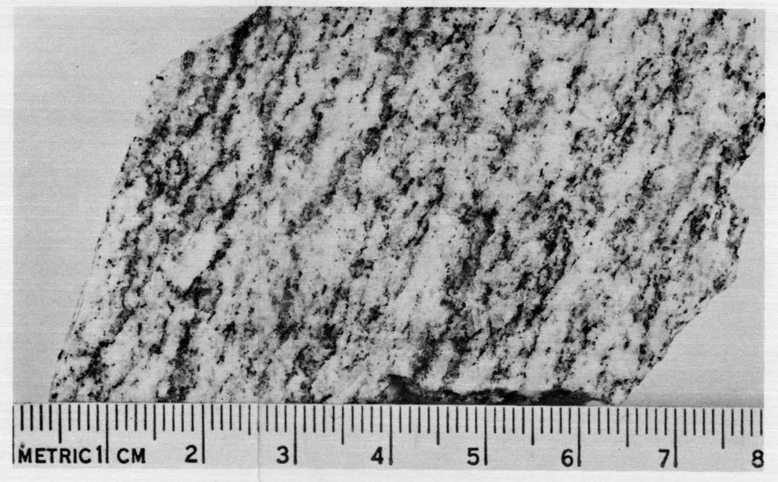


E



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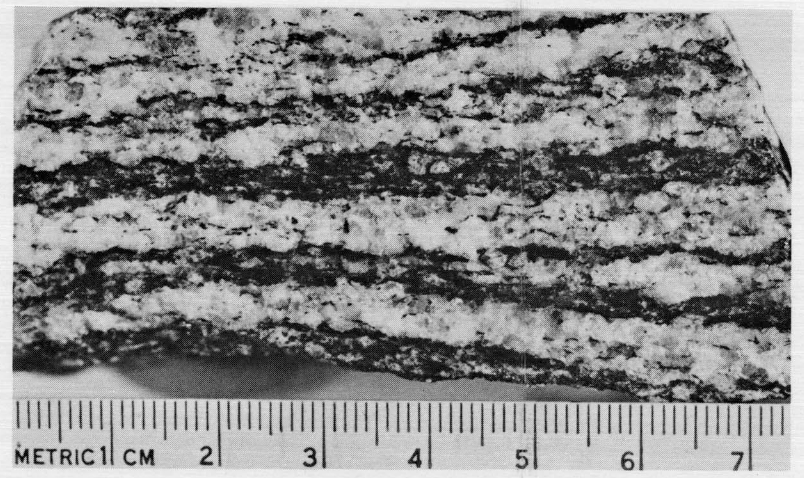

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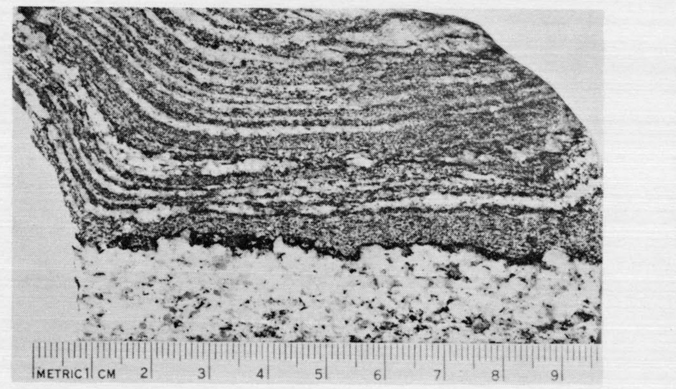
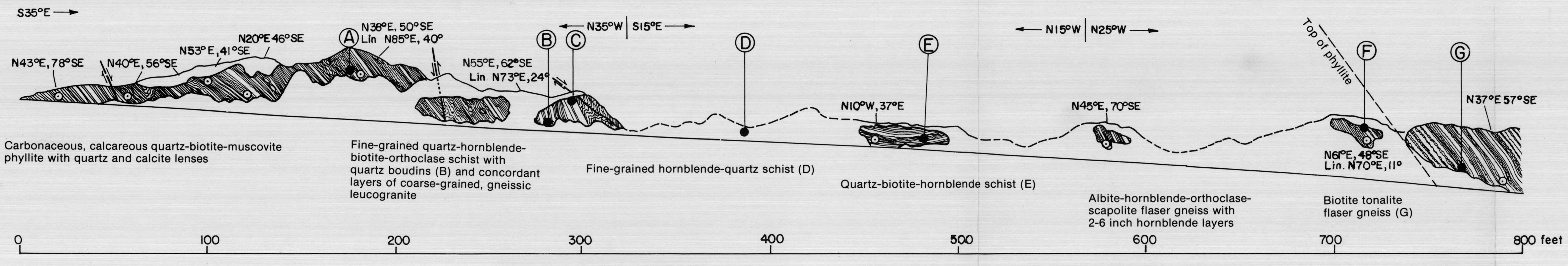
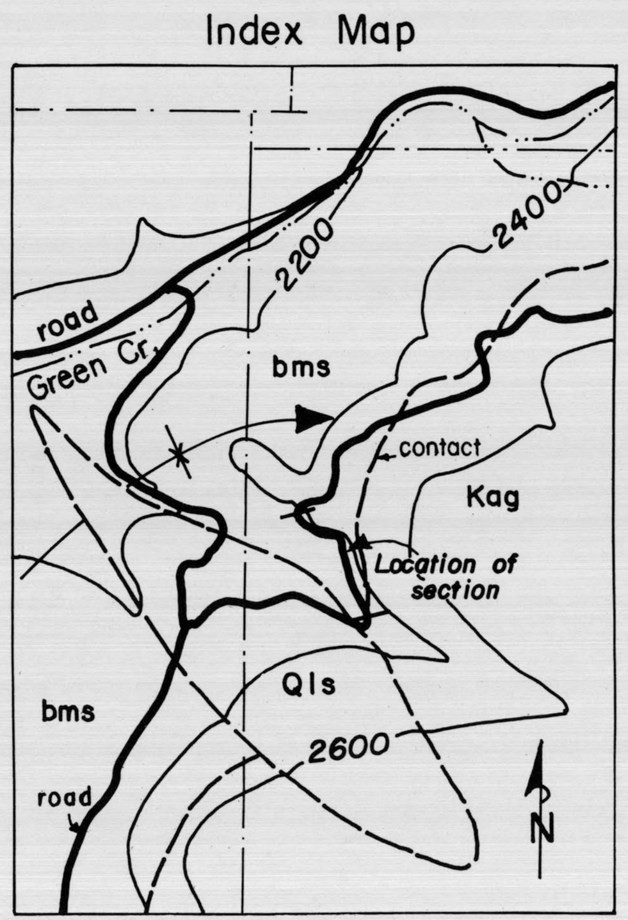


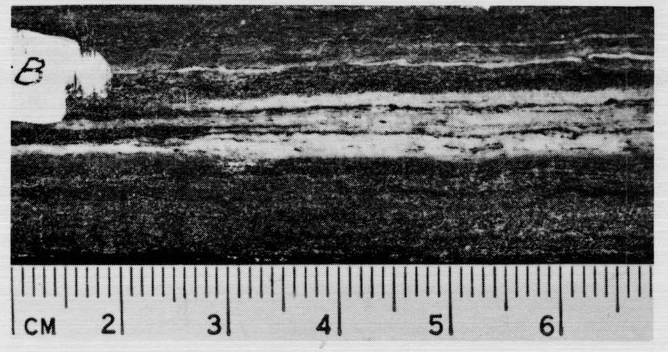
DETAIL OF CONTACT BETWEEN PHYLLITES AND CATACLASTIC ADAMELLITE GNEISS AT GREEN CREEK



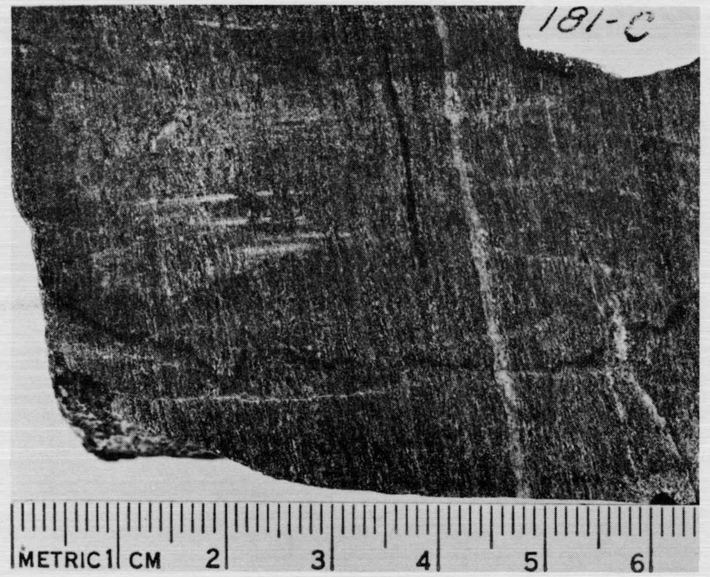


A

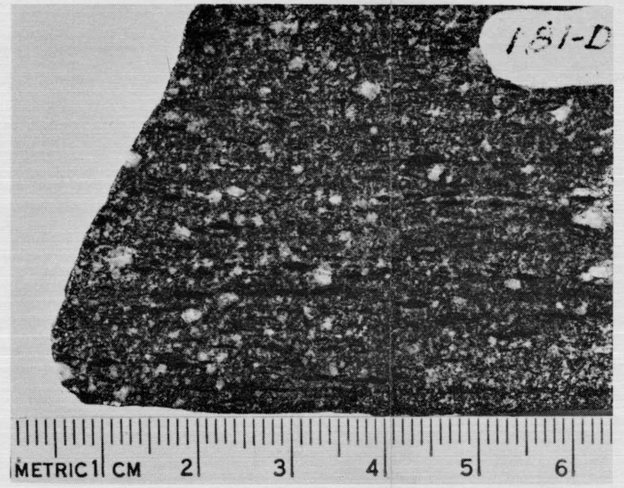
Photograph not reproducible



(B)

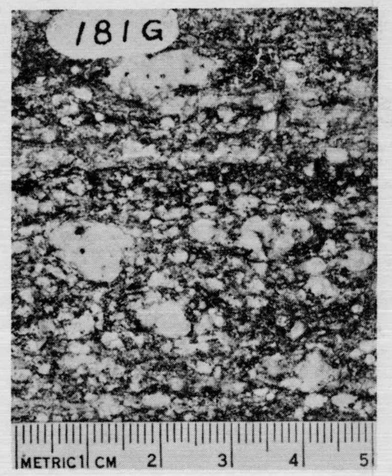


(C)



(D)

(F)



(G)

MINERAL COMPOSITION

Location	A	B	C	D	F	G
Quartz	71%	27%	43%	27%	12%	36%
Microcline					4	5
Orthoclase		12		38	14	17
Albite					37	
Oligoclase		5	4	35		19
Biotite	18	14		1	1	9
Hornblende		19	51		24	
Scapolite					5	

Accessory Minerals

Limonite	(A = 4%, C)	Epidote	(C, F, and G)
Graphite	(A = 2%)	Allanite	(G)
Apatite	(A and G)	Zircon	(G)
Magnetite	(A, C, and F)	Muscovite	(A, D, and G)
Sphene	(A, C, and F)		

*Modal analyses