THE IDAHO BATHOLITH AND RELATED SUBDUCTION COMPLEX

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Introduction

The purpose of this trip is to show the tectonic and lithologic setting of the Idaho batholith.

To the west the subduction complex is in contact with the old continental basement and its overlying metasedimentary packet. Granitic rocks of the Idaho batholith intrude both of these continental units.

The general relationships are illustrated in the map (Figure 1) and cross-section (Figure 2).

On the first day of the field trip (Stops 1-10, Figure 3) we will examine ultramafic, basaltic, and sedimentary units of the subduction complex and its relationship to the high-grade continental infrastructure and western outliers of the Idaho batholith.

On the second day (Stops 11-18, Figure 3) we will make a second traverse across the subduction zone-continental boundary but will spend most of the time examining the high-grade metamorphic infrastructure and the Idaho batholith itself.

ROCKS OF THE SUBDUCTION COMPLEX

By subduction complex we mean that deformed packet of rocks on the oceanic side of the older sialic continental crust. The subduction complex includes parts of an ophiolitic complex and genetically associated sedimentary rocks which have been jammed against and under the continental margin.

In the Riggins area of western Idaho the subduction complex is dominantly the Seven Devils Volcanics with lesser volcanogenic sediments of the Riggins Group. Full descriptions of these rock units are contained in Hamilton (1963) and Vallier (1974).

Seven Devils Volcanics

The Seven Devils Group consists of a strongly deformed, heterogeneous complex of submarine lavas, tuffs and agglomerates (greenstones) with minor sedimentary rocks. Basalt, andesite, dacite and their altered sodic equivalents, spilites and keratophyres are dominant: pillows and slump breccias are common. Minor interlayered sediments contain a shallow benthonic fauna of Permian to late Triassic age. Sediments include volcaniclastic rocks, quartz-rich graywacke, and argillite. Intercalations and blocks of these and limestone are incorporated in submarine melanges. The limestones appear to have been deposited on volcanic islands or seamounts. Plutonic igneous clasts include metamorphosed gabbro, diorite, quartz diorite, and trondhjemite, the latter probably derived from small plutons which cut the volcanic pile.

Wide zones of multiple dike injection of metadiabase, metabasalt, metagabbro, and keratophyre were emplaced not long after deposition of the mafic flows and breccias. An extensive mafic plutonic complex underlies the volcanic pile on the west. Rock types include metagabbro, amphibolite, metadiabase, metadiorite, and plagiogranite (c.f. Coleman and Peterman, 1975).

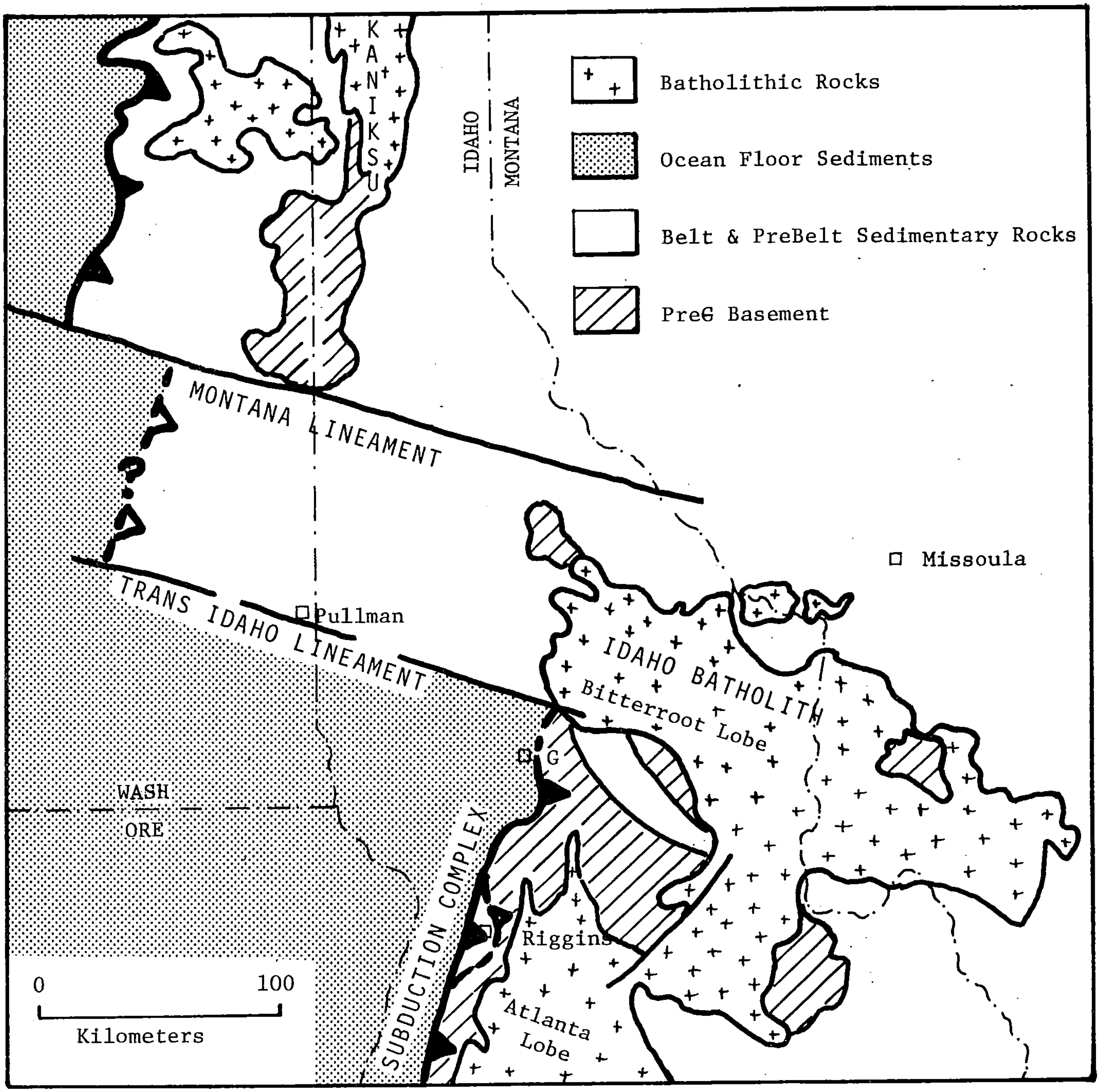

Figure 1. Sketch map outlining relationship between the subduction complex, older continental rocks and the Idaho batholith. The Columbia River basalts are omitted for clarity.

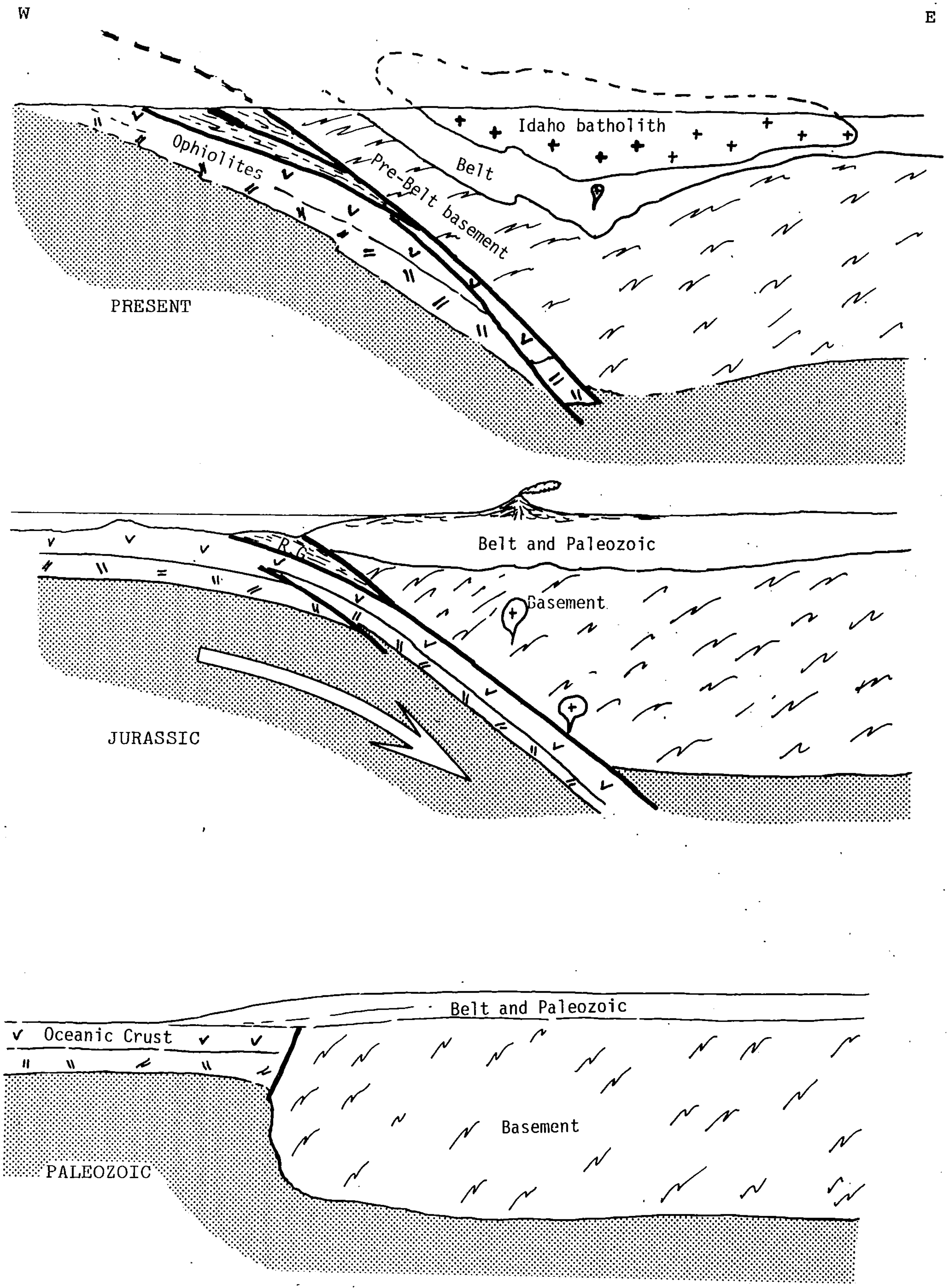

Figure 2. Sequence of interpretative cross-sections across the subduction complex and continental crust.

We view the Seven Devils Group as the upper part of an ophiolite complex-arc-volcanic suite. The mafic plutonic rocks deep in the Snake River Canyon on the west, are interpreted as part of layer 3 of the oceanic crust. Submarine flows and breccias of basalt and andesite and parts of a possible sheeted-dike complex are tentatively interpreted as parts of layer 2 and as a structurally-incorporated arc-volcanic suite recognized by Hamilton. The few available chemical analyses represent both meta-andesite arc volcanics and low-K spilitic basalts. A classic ophiolite series has not been demonstrated but the combination of appropriate lithologies, regional relationships, and east-over-west thrusts which repeat parts of the section, suggest a continental margin subduction complex active during the Mesozoic. An arc-volcanic suite contributed heavily to the exposed portion of the complex.

Riggins Group

The Riggins Group is separated from the Seven Devils Volcanics by the east-dipping Rapid River thrust. The group consists of medium- to fine-grained volcaniclastic rocks, including mafic, intermediate, and silicic volcanic equivalents, some amphibolite and pelitic schist. Lenses of meta-peridotite have been tectonically emplaced into the Riggins Group. The deceptively simple structural style is dominated by strong transposition with isoclinal hinges. The rocks are strongly schistose parallel to the layering and superposed deformation is widespread. The metamorphic grade rises from the biotite zone on the west to the lower amphibolite facies on the east.

The Riggins Group is interpreted as a sedimentary wedge, with subsidiary slicing, stuffed under the edge of the adjacent continental plate.

THE SUBDUCTION COMPLEX-CONTINENTAL CRUST TRANSITION

The lower-grade metasediments and metavolcanics of the subduction complex are separated from the high-grade geneisses of the basement by an east-dipping transition zone of up to a half-mile wide. This zone varies from a mappable thrust to an apparently subtle transition from fine-grained schists in the west to coarse-grained gneisses in the east. The subtle nature of the transition is however a result of shearing along and adjacent to the contact, which has the effect of reducing the grain size of the original gneisses. This resultant textural convergence serves to obscure the original marked differences between the two groups of rocks. Retrogressive alteration also is prominent in the transition zone.

ROCKS OF THE CONTINENTAL CRUST

Old Continental Basement

The basement rocks contain a variety of orthogneisses, augen gneisses, amphibolites and pelitic schists. They are generally medium- to coarse-grained, multiply deformed, polymetamorphic and intruded by a variety of igneous rocks, most of which are foliated. Numerous workers have interpreted them as metamorphosed Belt equivalents but enough ages in excess of 1500 million years indicate that many of these rocks are pre-Belt basement. Armstrong (1975) shows only a minor band of Belt rocks west of the Idaho batholith. Indeed, workers familiar with shield geology will feel at home with these basement rocks.

Belt Supergroup Equivalents

No unconformity between the Belt and basement rocks is seen in the region. Part of the problem is that the lowermost Belt unit, the Prichard Formation, is pelitic, so where strongly metamorphosed is very difficult to distinguish from basement. The Ravalli Group (quartzites and pelites) and Wallace Formation (impure carbonates) are more distinctive chemically so can be recognized at high grades of metamorphism.

If we restrict the Belt to those readily correlated units then only a narrow band outcrops along the Lochsa River. These rocks are heavily deformed and metamorphosed to the amphibolite facies. Outcropping as they do near the Idaho batholith they are cut by numerous granitic veins and are generally migmatites.

Idaho Batholith

The main body of the Idaho batholith is exposed within the Belt metasedimentary rocks to the east. Marginal plutons along its western edge intrude both the Belt and pre-Belt basement. The rocks of the Idaho batholith include both older foliated granodioritic rocks and younger massive, characteristically more felsic granites. In places, such as near its northern end, the borders of the batholith are marked by a broad zone of parallel northerly-trending, steeply-dipping granitic sheets intercalated with the country rocks. These sheets become larger and more abundant as the main mass of the batholith is approached from both east and west. The batholith itself consists of a composite of smaller plutons, very few of which have yet been mapped. The borders of the batholith as shown on the accompanying maps have been placed where these granitic sheets become dominant. These borders differ from those on the Idaho State map of 1950 primarily because the latter included within the batholith, rocks of the surrounding high-grade infrastructure.

The bulk of the Idaho batholith appears to be Late Cretaceous, the few available radiometric ages (e.g.: McDowell and Kulp, 1969, Armstrong, 1975) indicate the northern half, the Bitterroot Lobe (61-38 my) is slightly younger than the southern half, the Atlanta Lobe (95-43 my), the younger ages presumably reflecting the Eocene Challis volcanic-plutonic event (Armstrong, 1974). The northern lobe may be as old as 70-80 my, the age of the Boulder and other batholiths immediately to the east.

Country rocks for the Idaho batholith include the granitoid and amphibolitic pre-Belt basement complex and the Belt metasedimentary sequence which prior to intrusion consisted of undeformed lower amphibolite facies rocks resulting from late Precambrian regional load metamorphism (Norwick, 1972). Higher-grade regional dynamothermal metamorphism to the sillimanite zone localized around the borders of the batholith occurred during the Mesozoic, shortly before emplacement of the Idaho batholith. Both the regional metamorphism and the batholith are a consequence of subduction immediately west of the present exposures of the batholith.

Structural History

Clearly the basement rocks have undergone a long history of deformation, metamorphism, and igneous activity prior to the deposition of the Belt rocks. Subsequent to the deposition of Belt rocks, the 1200 my East Kootenai orogeny may have affected the Belt rocks in this part of Idaho (Reid, et al., 1973) but if it did it was restricted to the extreme western part of the basin, as most of the Belt rocks sat undisturbed until Cretaceous time. Subduction and understuffing of the sedimentary packet probably began in Jurassic time. Most of the sediments now visible in the subduction complex are volcanogenic and therefore related to ocean-floor processes. There is no convincing evidence that erosion of the Belt and preBelt terrain contributed heavily to the subduction zone.

The rocks of the subduction complex are strongly deformed although as most of them are rather massive volcanics, the deformation is expressed generally as shearing. The rocks are mostly "greenstones" in the true sense of the word. Deformation is extreme in the sedimentary packet closest to the continental margin, the original structures being heavily transposed, recumbent folds common, and schistosity being the dominant structure. The level of erosion is now too deep to determine what effect, if any, there was on the Belt sedimentary packet close to the margin.

A primary consequence of subduction is the generation of the Idaho batholith. The source rocks for the batholith are not apparent. Sr^{87}/Sr^{86} in the basement is clearly too high (in excess of .8, Armstrong, 1975) to have been the source for the batholith (.71). Granulites near the base of the crust, or the basalts and sediments of the subduction complex seem to be the only likely candidates for partial melting.

Subsequent rise of the plutons of the Idaho batholith resulted in a mobile envelope of reactivated basement and metamorphosed Belt rocks. The rise and mushrooming of this packet has resulted in large scale gravity spreading away from the infrastructure on the north and the east (Hyndman, Talbot and Chase, 1975). The situation is less clear in the west where we observe a tectonically deeper zone. It appears, however, that the combined effects of understuffing and heating has resulted in an isostatic rise of the infrastructure with upward movements acting in the opposite sense to subduction. Subsequent erosion has removed all but a small keel of Belt rocks and has exposed large areas of basement rocks.

Subsequent igneous and structural history is not well expressed in this part of the infrastructure/subduction complex boundary, although low north-dipping dikes of Columbia basalt affinities attest to continued offloading of the batholith during the Miocene.

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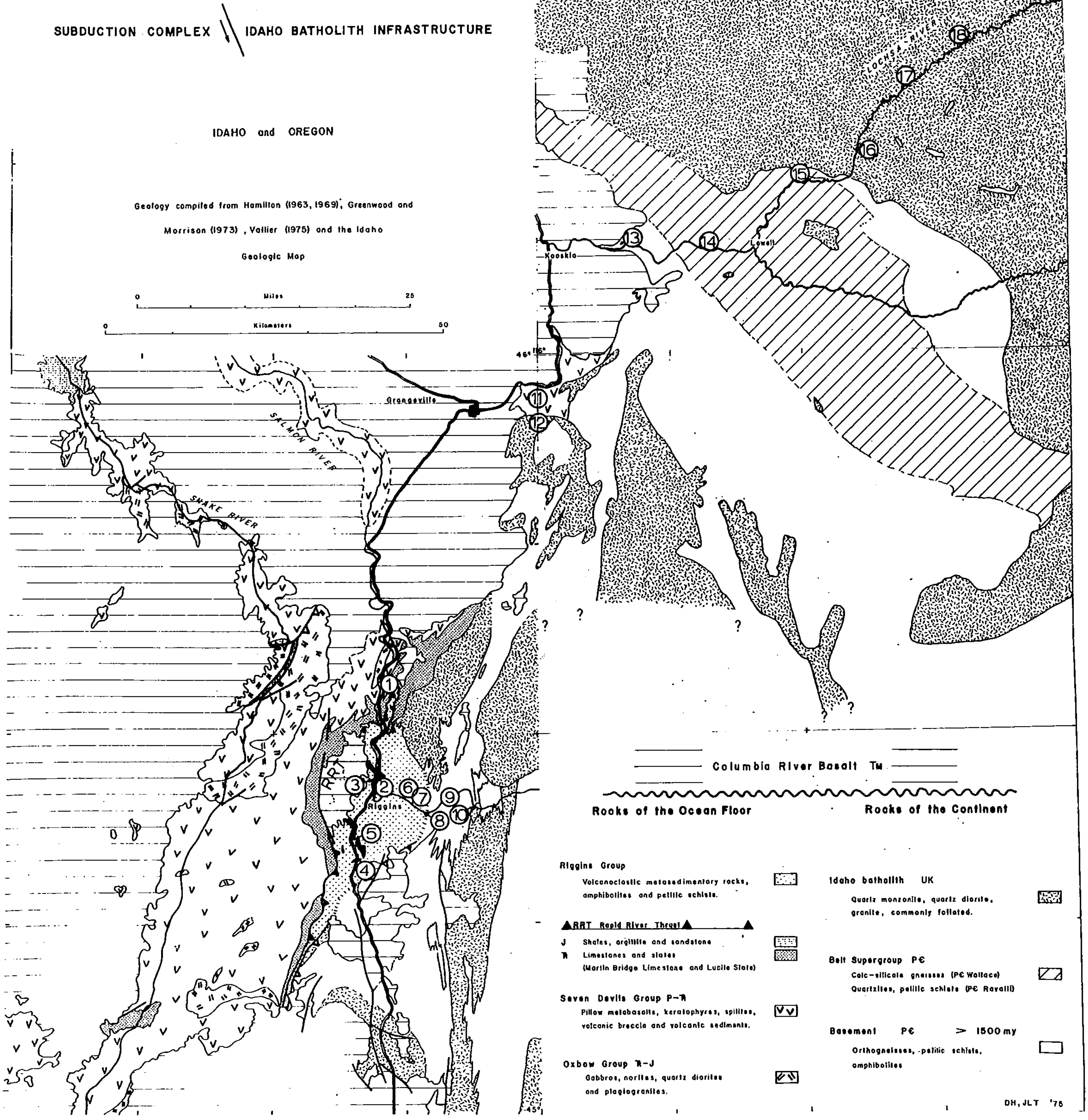
Figure 3


SUBDUCTION COMPLEX \\ IDAHO BATHOLITH INFRASTRUCTURE
IDAHO and OREGON
Geology compiled from Hamilton (1963, 1969), Greenwood and Morrison (1973), Vallier (1975) and the Idaho Geologic Map
0 Miles 25
0 Kilometers 50
46°
116°
45°
Grangeville
Kooskia
Lowell
Riggins
SALMON RIVER
SNAKE RIVER
LOCHSA RIVER
RRT
①
②
③
④
⑤
⑥
⑦
⑧
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?
Columbia River Basalt Tm
Rocks of the Ocean Floor
Rocks of the Continent
Riggins Group
Volcanoclastic metasedimentary rocks, amphibolites and pelitic schists.
RRT Rapid River Thrust
J Shales, argillite and sandstone
Ŧ Limestones and slates (Martin Bridge Limestone and Lucile Slate)
Seven Devils Group P-Ŧ
Pillow metabasalts, keratophyres, spilites, volcanic breccia and volcanic sediments.
Oxbow Group Ŧ-J
Gabbros, norites, quartz diorites and plagiogranites.
Idaho batholith UK
Quartz monzonite, quartz diorite, granite, commonly foliated.
Belt Supergroup P€
Calc-silicate gneisses (P€ Wallace)
Quartzites, pelitic schists (P€ Ravalli)
Basement P€ > 1500 my
Orthogneisses, pelitic schists, amphibolites
DH, JLT '76

ROAD LOG

N.B. Mileages refer to mileposts along the main roads.

U.S. 95 Day 1. Leave Lewiston at 7:00 a.m. and head south on U.S. 95.

We descend through flood basalts of the Columbia Plateau on Whitebird
211 Hill, entering granitoid rocks of the old continental basement complex
cut by fine-grained dikes of greenstone.

207.0 - STOP 1: Turnout on W side of Highway - caution blind corner.

Greenstone of Seven Devils Volcanics (TRP_V)

(unit below Rapid River thrust of Hamilton, 1963)
Large outcrops both north and south of side road.
Northern outcrops are massive greenstones with local volcanic breccias in the inch range. Heavily sheared in places. Hematite on some fractures. Some veins of chrysotile.

Southern outcrops are somewhat better layered (but still subtle) and tuffaceous. Layering dips steeply south and is more obvious across river.

204.0 Poor Turnout on E side of road opposite sign "Approaching Historic Lucile Bar".

Lucile Slate TR l

(unit below Rapid River thrust)
Graphitic schist, heavily deformed. Zones with contorted cleavage. Numerous stretched and broken quartz veins.

203.3 No turnout at this roadcut in middle of long straight stretch of highway 0.5 mi. S of Lucile Bar, but a big turnout 0.2 mi. farther S.

Martin Bridge Limestone TR mb

White sugary marble with thin, dark-gray, distorted laminations. Beds dip generally about 30°S. Subtle tight contortions are especially visible in large fallen block. To the west in Hell's Canyon, this limestone is gray and much less recrystallized.

197.5 - STOP 2: Large Turnout at north end of Goff Bridge 2 miles N of Riggins.

Ultramafic Unit UM (In units above the Rapid River thrust)
"A lens about 1500 feet thick of metaperidotite with subordinate non-ultramafic layers" (Hamilton, 1963, p. 60).
This unit lies along and near the contact between the Squaw Creek schist (rs) to the south and the Lightning Creek Schist (rl) to the north.

Near the south end of the roadcut is massive dark- to light-green, fine grained meta-peridotite with minor shear zones. Some inch- to foot-size breccia with serpentinized patches.

Farther north, a patch of white talc schist beneath a pod of rusty-weathering phyllitic metasediments. Near north end of parking area is pale pink and green grossularite-epidote pod surrounded by serpentine. Some clear coarsely crystalline magnesite.

196.8 - STOP 3: Turnout on E side of road just south of Race Creek.

Squaw Creek Schist (rs)

Spectacular outcrops along river bank, of dark gray phyllitic schist of metasedimentary origin with a pronounced foliation dipping gently south and southeast. Foliation deformed into broad open folds with some tight keels plunging 15° → 150°. An intense near-vertical crenulation cleavage parallels the axial surfaces of these folds. Bedding appears nearly parallel to the first foliation in most places but is heavily transposed as may be seen in the roadcut 60 yards south of the highway bridge.

Proceed S through Riggins. At mile 190 is a diversion, as the main road is blocked to the south by a large landslide. Cross the bridge, ignoring the diversion signs and continue along the east side of the Little Salmon River.

188 - STOP 4: Large Turnout on west side of highway.

Ultramafic lens along contact between Lightning Creek Schist and the Squaw Creek Schist to the south (um, rl, rs)

Large roadcut with prominent light green lens of ultramafic rock near the south end of the cut, associated with serpentine and greenish white talc schist and dark gray marble.

Towards the north end of the cut are finely laminated schists of the Lightning Creek unit, with a prominent thrust dipping gently east.

Turn Around, Return North.

189.1 Opposite rest area note gently plunging recumbent folds in schist.

190 - STOP 5: Turnout on east side of road just north of bridge.

Lightning Creek Schist (rl)

(100 yards north of parking area on west side of road) Schistose to nearly massive greenstone and laminated and lineated tuffaceous schist.

Cross bridge to south to large outcrop on east side of road.

Squaw Creek Schist (rs)
Dark gray finely laminated phyllitic schist similar to that at Stop #3 but with numerous tightly appressed folds which transpose the schistosity. Some crenulation cleavage and associated folds.

Salmon River road -
no mileposts

Return to Salmon River Road bridge at south end of Riggins. Cross bridge and proceed east, past the lumber mill, along dirt road up Salmon River canyon.

0 Mileages on this leg are measured from the bridge at Riggins.

4.6 - STOP 6: Turnout on bend in road at the Berg Creek sign. Outcrops are at west end of turnout.

Berg Creek amphibolite of Hamilton (rb)

Thinly laminated fine-grained amphibole-rich black schist with garnet; probably derived from basalt. Strong, near-vertical schistosity with amphiboles randomly oriented within the schistosity.

The metamorphic rank increases to the east of this outcrop.

5.8 - STOP 7: No turnout. Outcrops near where telephone line crosses the Salmon River. Disembark from bus at west end of outcrop. Board bus at east end of outcrop.

Lightning Creek Schist (rl)
Laminated black and light gray biotite-garnet-amphibolite with white layers to 2 inches and lenticular pods rich in plagioclase; derived from mafic tuff. Strong steep foliation. Rock coarser-grained and more strongly metamorphosed than at previous outcrop.

6.7 - STOP 8: Stop about one quarter mile west of bridge at tall light-colored cliffs and traverse to bridge.

Transition between lower-grade Riggins Group (rl) and the basement gneisses (gnc) of the older continental crust

From Stop #7 to just east of Stop #8 is a marked change in the appearance of the rocks from fine-grained schists with a few pegmatitic veins to medium-grained gneisses grading to migmatites through an east-dipping transitional zone which is a major element of the Mesozoic subduction zone of this part of western North America. Proceeding from west to east, note an increase in grain size from fine-grained schists of the Riggins Group to variable and coarser gneisses belonging to the old continental basement, which about 200 yards west of the bridge have been converted by shearing to augen gneiss and augen schist. The rocks include metasediments, foliated granites, biotite-amphibole schists with garnet, and mafic-rich tectonic breccias.

This transition which is subtle in the field expresses a sharp change in the texture and mineralogy of the rocks. In thin section the old "continental" rocks show coarse-grained relicts of e.g. garnet, biotite, and K-feldspar now highly retrograded with accompanying diminution in grain size. Thus the present gradational appearance masks what is clearly an original sharp contact between the basement and the adjacent sediments.

East of the bridge we are in the gneiss complex (gnc of Hamilton) composed of metavolcanic and metasedimentary schists and gneisses intruded by a variety of migmatitic veins and plutons (the infrastructure) which continue 150 km east into western Montana).

9.5 - STOP 9: Turnout 100 yards east of Riggins Hot Springs bridge.

Gneiss complex (gnc)

Strikingly layered black and white gneiss with layers to 10 cm. The dark layers are amphibolite and the light layers are garnet-hornblende-plagioclase gneiss. The near-vertical layers show high amplitude isoclinal folds on steeply-plunging curving axes. Discordant lenticular pegmatites have foliation parallel to main foliation. 150 yards east are refolded folds with crenulation cleavage parallel to second axial surface.

This is probably PreBelt basement.

13. - STOP 10: Park bus by Partridge Creek bridge. Outcrops are to the east.

Gneissic quartz-diorite of Hamilton (1969) (qd)

Strongly foliated hornblende-biotite quartz diorite with a few streaky pegmatites. An early mafic border phase of the Idaho batholith, making up about half of the plutonic igneous rocks of the Riggins quadrangle. Most of the remainder is gneissic biotite quartz monzonite and granodiorite (qm).

One third mile east is a small stock of younger relatively massive biotite quartz monzonite.

End of Day 1. Return to Riggins for dinner and stay in Grangeville overnight.

Day 2. Breakfast in Grangeville.

Idaho 13 Follow Idaho highway 13 east towards Kooskia. Descend to South Fork of Clearwater River at milepost 11 at junction with Idaho 14.

The first two stops illustrate another example of oceanic crust-continent margin. The remaining stops show a variety of basement and metamorphosed migmatized Belt rocks as well as the border phases of the Idaho batholith.

Idaho 14 Turn south on Idaho 14. Mileages for stops 11 and 12 refer to Idaho 14 mileposts.

0.0

2.9 - STOP 11: Straight stretch of road. No parking area.

Seven Devils Volcanics

Massive greenstone with volcanic breccia. The breccia contains darker fragments of greenstone and a distinctive plagioclase porphyry with euhedral greenish white phenocrysts 1/2 to 1 cm long.
Weak layering dips 65°E.

6. - STOP 12: Large turnout on north-east side of road.

Coarse biotite granodiorite

White coarse-grained biotite granodiorite. Weak foliation dips steeply southeast. Cut by thin aplites and pegmatites containing almandine garnet. This granitic rock is at the western edge of the infrastructure. The main area of the Idaho batholith lies at least 20 km to the east.

Idaho 13 Return to Highway 13. Proceed north on Idaho 13 to Kooskia then east along U.S. 12 which follows the Clearwater River.

U.S. 12 Mileages for stops 13 to 16 are identified by reference to the green mileposts.

75.8 The east bridge over the Clearwater River at Kooskia.

82.7 - STOP 13: First small turnout on S side of road, east of side road at Sutter Creek. Prominent terraced outcrop.

Orthogneiss, probably Pre-Belt basement

"ogd" unit of Greenwood and Morrison (1973).

Homogeneous coarse-grained biotite-quartz-feldspar orthogneiss cut by muscovite-quartz-plagioclase pegmatites. Most of the pegmatites are deformed and slickensided and show augen.

A well-developed schistosity dips steeply east but the outcrop is unlayered.

92.8 - STOP 14: Turnout with litter barrel. Opposite Lodge Creek.

Migmatitic lower Belt

"P€r" unit, Ravalli equivalent of the Belt according to Greenwood and Morrison (1973). Schistose pelitic garnet two-mica gneiss with numerous small-scale isoclinal folds (best examples about 100 yards east of Coolwater Creek). Schistosity cuts crest of folds. Blue twinned kyanite and local more-strongly-deformed sillimanite in migmatitic quartzofeldspathic veins and in their dark pelitic schist host.

96.7 Bridge across Lochsa River at Lowell.

109.2 - STOP 15: Small turnout 100 yards west of Coolwater Creek sign.

Migmatitic diopside-plagioclase gneiss derived from Wallace Formation equivalent of the Belt. (P€$_w$ of Greenwood and Morrison, 1973).

Streaky diopside-plagioclase gneiss with some hornblende. Isoclinal folds prominent. Rock is cut by numerous irregular quartzofeldspathic veins which have reacted with the calc-silicate gneiss to form prominent selvages rich in black hornblende. Rare gently-dipping aplite dikes (opposite Coolwater Creek) show no reaction rims, presumably because of lack of water in the aplite.

111. East of here, sheets of Idaho batholith granitic rock appear in roadcuts.

116. To the east, the granitic rocks become dominant.

115.1 - STOP 16: First turnout east of mile 115, and 0.3 miles east of Horsetail Falls.

Migmatitic gneiss of the border zone of the batholith (kqmf of Greenwood and Morrison, 1973)

Remnant fine-grained biotite-quartzofeldspathic schist with numerous granitic streaks. Typical of the border-zone migmatites.

124.7 - ALTERNATE STOP 17: Turnout on north side of highway by side road. Outcrop 100 yards west of turnout.

Idaho batholith

Massive medium-grained biotite granite (quartz monzonite).

131.4 - STOP 18: 0.1 mile east of Castle Butte lookout. Large turnout on south side of highway.

Typical granite (quartz monzonite) core phase of Idaho batholith. Rocks at this outcrop are internally deformed, much of the biotite and quartz being fine-grained and showing sutured boundaries.

135.5 Eagle Mtn foot bridge. Bus turn around if snow.

139.5 Saddle Mtn side road. Bus turn around if snow.

Return to Pullman.