R 53

GEOLOGY AND HIGHWAY LOCATION CONSIDERATIONS
. IN THE
OROFINO-KAMIAH-NEZPERCE AREA, IDAHO

A Thesis

Presented in Partial Fulfillment. of the Requirements for the

DEGREE OF MASTER OF SCIENCE

Major in Geology

in the

UNIVERSITY OF IDAHO GRADUATE SCHOOL

by

Michael Curtis Shea

November, 1970

e.

ACKNOWLEDGMENTS

Mr. Robert Charboneau, Idaho State Highway Geologist, suggested the general thesis topic and contributed helpful comments during the study. In addition, he arranged for the Idaho State Department of Highways to furnish suitable maps, aerial photographs, and a field vehicle.

Special thanks must go to Dr. John G. Bond, the author's thesis advisor. His patience, expenditure of time, and valuable criticism during every phase of the study are most gratefully acknowledged.

Doctors William B. Hall and J. Preston Jones served on the author's thesis committee and assisted with the many revisions which have brought this report to its present form.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

ILLUSTRATIONS

Page

Oblique Aerial Photographs

(From the Camas Prairie Location Study)

Figure

Photographs

Photomicrographs

ILLUSTRATIONS (Continued)

Maps

Diagrams

ILLUSTRATIONS (Continued)

Page

Plates

Plate

ABSTRACT

The general geology of the Orofino-Kamiah-Nezperce region, Idaho, was examined in the field during July, August, and September of 1969. This field study and subsequent laboratory examination were directed toward determining the geologic feasibility of constructing a new road between Nezperce and the floor of the Clearwater river canyon.

Study of existing roads and proposed routes indicates that if a new road is to be constructed, the Lawyer's Canyon Plan and the Suzie Creek Plan are geologically and topographically the best choices.

General geology within the study area consists of horizontal flows of Columbia River Group Basalt which partially bury an eroded metamorphosed igneous and sedimentary mountainous terrain. The Orofino Series consists of a succession of metamorphosed intrusive granitic rocks and metamorphosed Precambrian Belt Supergroup (Wallace) sediments. Intrusion, deformation, and metamorphism are believed to have taken place prior to the intrusion of the Idaho Batholith. Furthermore, the Orofino Series does not represent Cretaceous feldspathization related to the Idaho Batholith.

Granitic rocks between Orofino and Kamiah are believed to be intrusive in origin, pre-batholith in age, and metamorphosed through at least the quartz-andalusite-plagioclase-chlorite subfacies of the Abukuma-type facies series of Winkler.

Plateau (Plate I). Access is easy from the north and south by U. S. Highway 12 and from the east and west by State Highway 64 (Figure 1).

The area is within the Tristate Uplands section--Central Highlands subprovince--Columbia Intermontane physiographic province (Figure 12). To the north and west lie the Uniontown Plateau and the Lewiston Basin; to the east, the Weippe Plateau and Clearwater Mountains; and to the south, the Kooskia Basin, Camas Prairie, and Doumecq Plateau (Bond, 1963, fig. 17).

Geologically, the area is dominated by three principle rock types--(1) nearly horizontal flows of basalt overlying metamorphosed, (2) igneous, and (3) sedimentary rocks. The basalt and metamorphic rocks are separated by a regional unconformity represented in most localities by a sedimentary bed or residual weathered material.

Topography

Five types of features form most of the topography; they are:

(1) The Nez Perce area basalt plateau with its mildly undulating surface.

(2) Steep walled "V" shaped canyons deeply incised into and through the basalt flows (Figure 2).

(3) Mass gravity features, and major basalt talus and colluvium accumulations.

(4) Eroded mountainous metamorphic and igneous terrain on and against which the basalts accumulated.

Figure 1 Geographic Location of the Thesis Area The study area encompasses approximately 125 square miles in north-central Idaho.

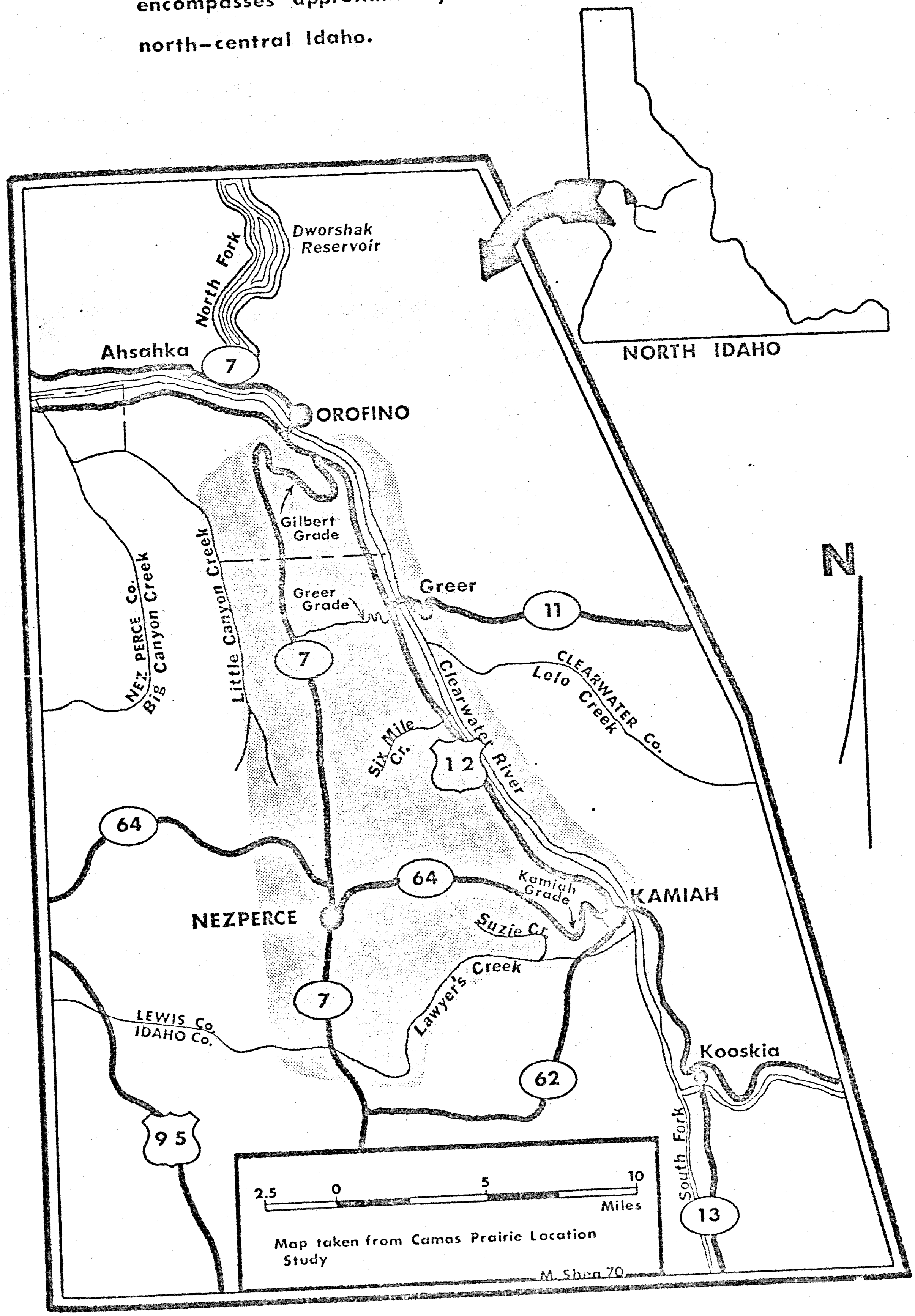
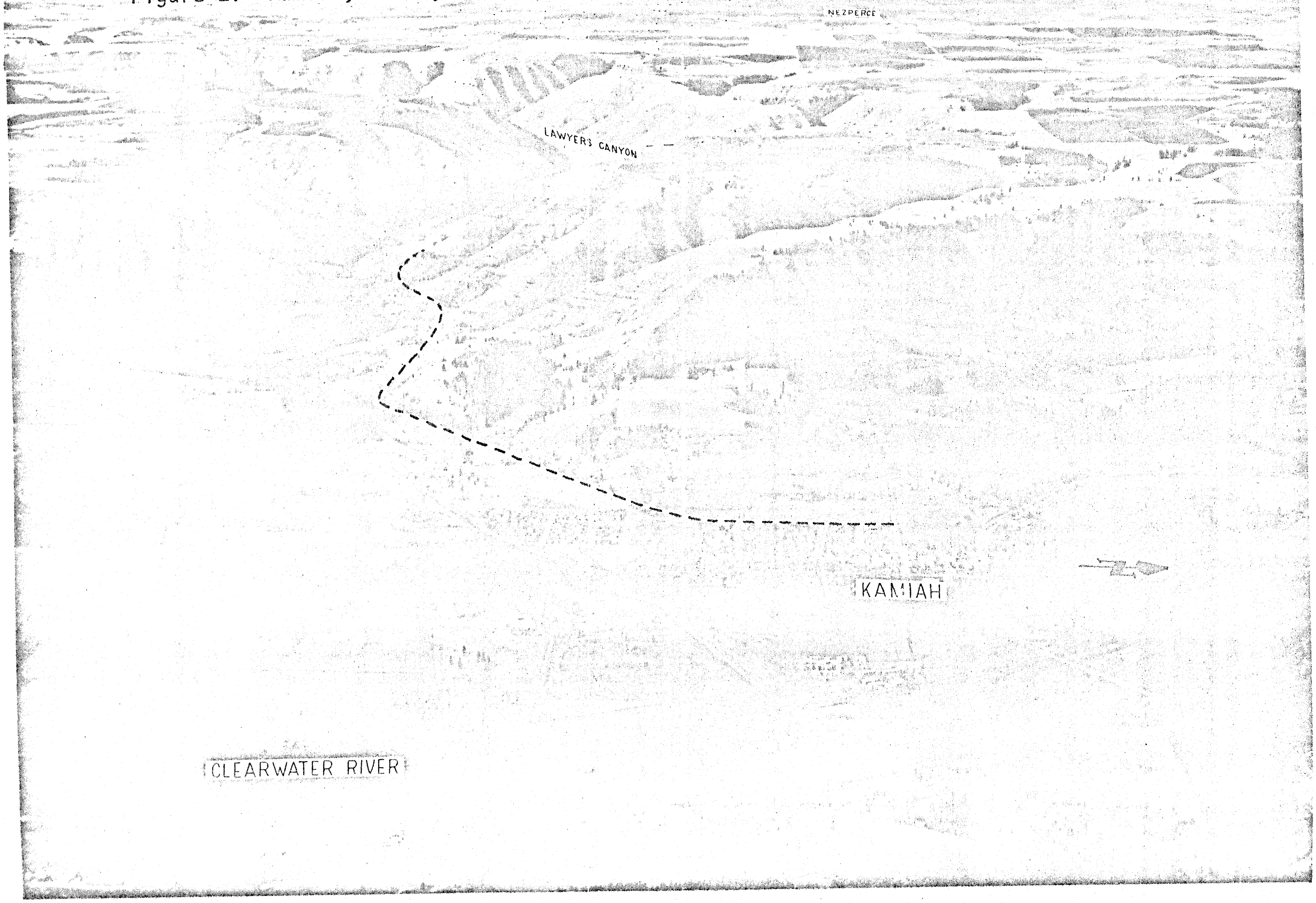


Figure 2. Kamiah, Idaho, and vicinity.



(5) Esplanades in the lower portions of the Clearwater canyon (see footnote, p. 14).

Most of the area could be characterized as a youthful basalt plateau exhibiting some narrow and steep stream dissections. Relief is approximately 2480 feet; the highest point is atop a basement high in the southwestern portion of the region and is just under 3500 feet in elevation. On the surface of the basalt plateau maximum elevations descend northward and eastward, so that near Nezperce and above Kamiah and Orofino the elevations are 3300, 3020, and 3040 feet, respectively. River-level elevations within the Clearwater river gorge decrease northward from 1200 feet at Kamiah to 1020 feet at Orofino.

Drainage

The entire study area lies within the Clearwater river drainage (Plate I). This river comes into nomenclatural existence east of the study area at Lowell, Idaho, at the confluence of the southwestward flowing Lochsa and northwestward flowing Selway rivers (Figure 7). Here it is referred to as the Middle Fork of the Clearwater. At Kooskia, Idaho, the Middle Fork is joined by the South Fork to form the main course of the Clearwater river. From Kooskia, the river flows northward to Orofino where it turns sharply westward and flows about 50 miles to Lewiston, Idaho, and confluence with the Snake river.

The Clearwater river system drains approximately 6500 square miles of north-central Idaho. U. S. Geological Survey records at Kamiah indicate that peak runoff normally comes in May, with the greatest measured discharge of 99,000 cubic feet per second recorded for May 29, 1948. The same source lists a minimum discharge of 179 cubic feet per second for December 1, 1952 (U. S. G. S. Water Supply Paper No. 1317).

Lawyer's Canyon creek forms the southern boundary of the area and Little Canyon creek the western boundary. Other major tributaries of the Clearwater within the area are the westward flowing Big, Lolo, and Jim Ford creeks and eastward flowing Six Mile creek.

Climate and Vegetation

Summers within the study area are hot and dry, and the winters cold and rainy. Precipitation at Kamiah and Orofino averages 21.57 inches and 25.93 inches per year respectively (Soil Survey Report, 1966, p. 265a). Mean annual temperatures are 52 degrees F. at Orofino and 47 degrees F. at Nezperce (Camas Prairie Location Study, 1969, p. 1).

Vegetation consists primarily of grasslands on the plateau surface and coniferous forest on canyon slopes. In general, northward and northeastward facing slopes are heavily forested; and the dryer southward and southwestward facing slopes support less timber and may be grass covered.

Field Methods and Mapping

Mapping and locating were done on U. S. Geological Survey preliminary topographic quadrangle maps at a scale of 1:24,000. Plate II is a compilation of eight such maps, reduced in scale to 75 percent of original size. The Cottonwood NE quadrangle has a preliminary name which is subject to change.

Description and collection of major rock types and mapping of geologic contacts, joints, faults, dikes, and mass gravity phenomena were confined primarily to canyon exposures. Possible highway alignments were studied in detail along the Clearwater river and within Lawyer's, Suzie, and Six Mile creek canyons. Roadcuts along U. S. Highway 12 and the Kamiah, Greer, and Gilbert grades (Figure 1 and Plate II) provided many additional exposures.

Aerial photographic coverage was available for most of the area, but oblique photographs within the Camas Prairie Location Study proved to be particularly useful for detecting some large mass gravity features.

Summary of Previous Geologic Work

A. L. Anderson (1930) made a geologic reconnaissance of a large area in central Idaho. His work was drawn upon for much of the geology in northern Idaho depicted on the current Idaho State Geologic Map (1947).

R. S. Kopp (1959), in a master's thesis, dealt with the petrology and structure of the Orofino metamorphic and igneous units.

Anna Hietanen (1961, 1962) has mapped in detail the igneous and metamorphic rocks in and near the study area.

J. G. Bond (1963) completed detailed studies of the basalts of the Clearwater Embayment which includes the Orofino-Kamiah-Nezperce area.

GENERAL GEOLOGIC RELATIONS

Distribution of Major Rock Types and Relative Ages

The oldest exposed rocks are polymetamorphosed sediments and igneous intrusions of the Orofino Series (Anderson, 1930). These crop out in the extreme northern portion of the study area. This unit consists of well foliated quartz-biotite gneiss (orthogneiss),[1] reddish quartzite, and marble.

Orofino Series rocks have been intruded by quartz diorite which has subsequently been metamorphosed to orthogneiss. This latter, younger orthogneiss is homogeneous, variably foliated, and is informally designated Clearwater orthogneiss in this paper. Outcrops of Clearwater orthogneiss are well-jointed. They occur on both sides of the Clearwater river southward from Orofino to slightly north of Kamiah, deep within Six Mile creek canyon, and at one isolated Lawyer's Canyon location in the southwestern portion of the study area (Plate II). Here, a sub-basalt hill has been exposed by stream downcutting.

When collectively referred to, the sub-basalt Orofino Series and Clearwater orthogneiss shall be called Basement.

Separating basement rocks from overlying Columbia River Group Basalts (Waters, 1960) are bedded sands and finer detritus derived from the erosion of pre-existing basement highlands. These sediments

[1]A gneiss is a foliated metamorphic rock. The terms orthogneiss and paragneiss are used to differentiate gneisses which have developed from the metamorphism of igneous rock and sedimentary rock respectively.

are visible in a few canyon walls--principally in the Clearwater canyon southwest of Orofino (Location 4).

Two distinctive basalt types comprise the Columbia River Group Basalts in the area. An older, decidedly porphyritic basalt sequence is exposed on the lower canyon slopes south of Orofino and has been designated Lower Basalt by Bond (1963, p. 6). A younger group of non-porphyritic basalts, Upper Basalt, accounts for the rest of the basalt exposures. Approximately 300 feet of Lower Basalt is exposed on the west slope of the Clearwater canyon south of Orofino, and the greatest exposed thickness of Upper Basalt is along Lawyer's Canyon creek near Kamiah where 14 (?) flow units are well displayed.

Sand-silt-clay units are interbedded among some of the flow units; they can be observed at widely scattered locations, and some are given member status in the Columbia River Group.

Overlying the basalt are younger residual and loess soils of variable thicknesses (Appendix C).

Geologic Structures

Figure 3 shows that there is no preferred attitude for the several minor faults and shear zones mapped in the area. Plate II, however, illustrates a northwesterly trend for the major faults east of Kamiah and on the plateau surface northwest of Six Mile creek. In both cases, the northeastern side is downthrown. The faults can be recognized by low, straight, subdued escarpments, abrupt changes in the elevation of the plateau surface, and offset basalt flow units. The style of this faulting is consistent both with subsidence and sourceward tilting of the basalt pile during and subsequent to

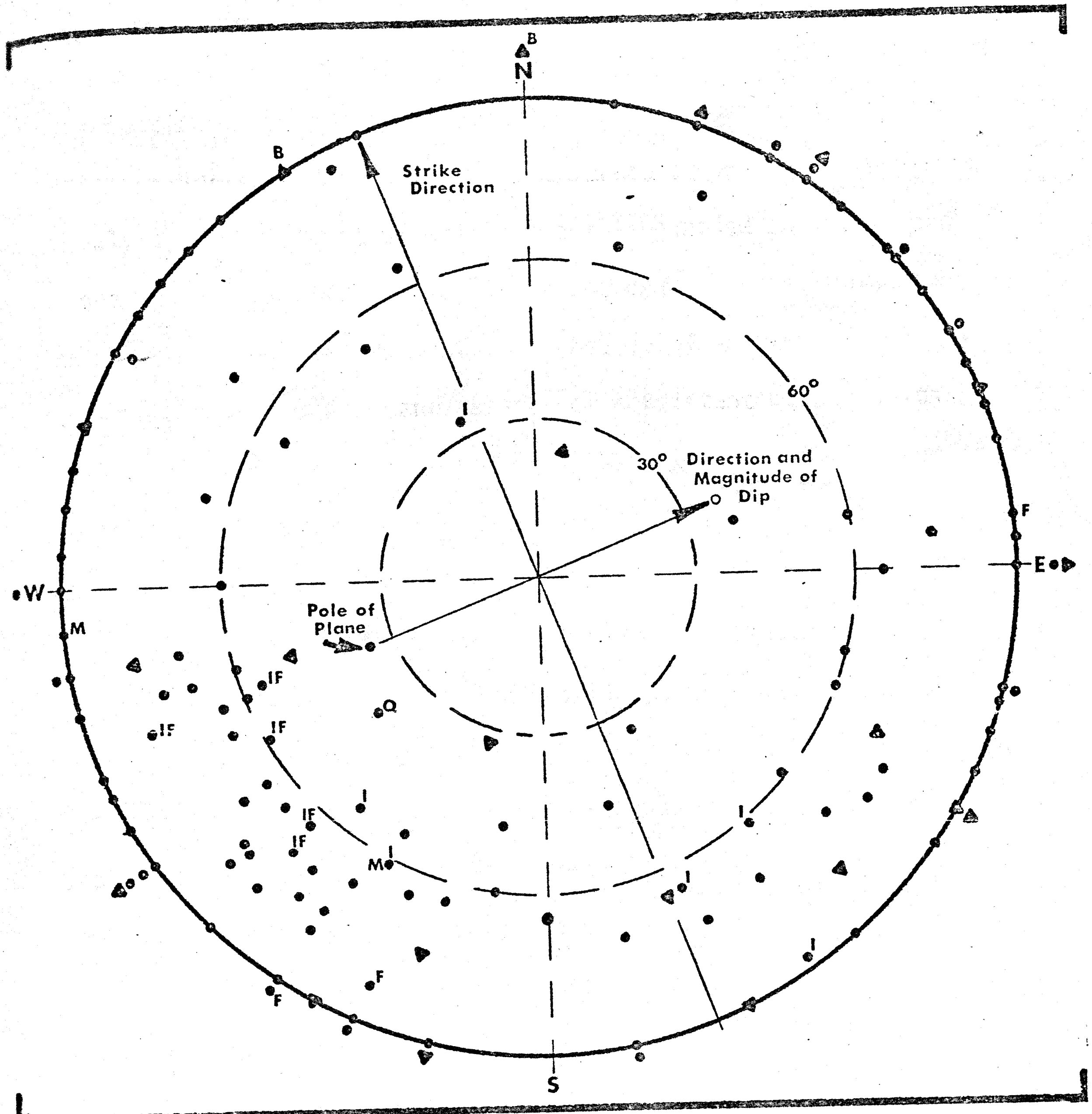


Figure 3. Equal area plots (lower hemisphere) of the poles of 118 joints and 20 faults.[1] The enclosing rock is Clearwater orothgneiss except where noted. Orofino Series: M - Marble, Q - Quartzite, I - Quartz-biotite orthogneiss, B - Basalt. • - joints, ▲ - faults, F - trend of foliation.

---

[1]Use of the pole of a plane allows that plane to be represented by a single point. Figure 3 shows that the indicated joint plane strikes approximately north 20 degrees west, and dips 35 degrees to the northeast.

extrusion, and with local and regional warping in post-basalt time (Baldwin, 1950, p. 60-61). These considerations will be discussed in the section dealing with the Columbia River Group Basalt (p. 33).

Minor shear zones within the basement rocks were recognized mainly by the presence of offset and slickensided surfaces, and by gouge zones. Generally, the author was unable to determine the relative movement of basement rock because of poor exposures, lack of topographic expression, and absence of persistent marker units. In a number of cases the shear zones were observed to cut joint surfaces; therefore, the shearing is presumed to postdate some of the joint development.

Joint surfaces are, as a rule, broad in area, well-exposed, and fresh looking. Figure 3 shows that the majority of joints have northwesterly trends and dip at a high angle to the northeast. Representative joint measurements are plotted on Plate II; Appendix A shows the location of the joints where attitudes were measured.

The Orofino Series rocks mapped near Orofino are but a small part of a much larger metamorphic and structural unit in the region. The outcrop pattern and structural trends illustrated on Plate II should be interpreted with reference to the geology north, west, and east of Orofino. Hietanen (1962) and Kopp (1959) provide information on the structural and metamorphic history of this region. Overall map pattern for Orofino Series rocks suggests large scale openfolding with axial planes trending northwest (Hietanen, 1962, plate 4). Metamorphosed granitic intrusives occupy the axial portions of the folds and can be shown to be large axial plane dikes (Reid, 1970b).

Other major structural trends in and near the study area are indicated by:

(1) Apposing regional dips of the plateau surface on opposite sides of the Clearwater river related to (2) below.

(2) The presence of faults and major structural depressions along the present course of the Clearwater river (Bond, 1963, fig. 16).

(3) The location of abrupt right angle bends of the Clearwater river at Kooskia and Orofino.

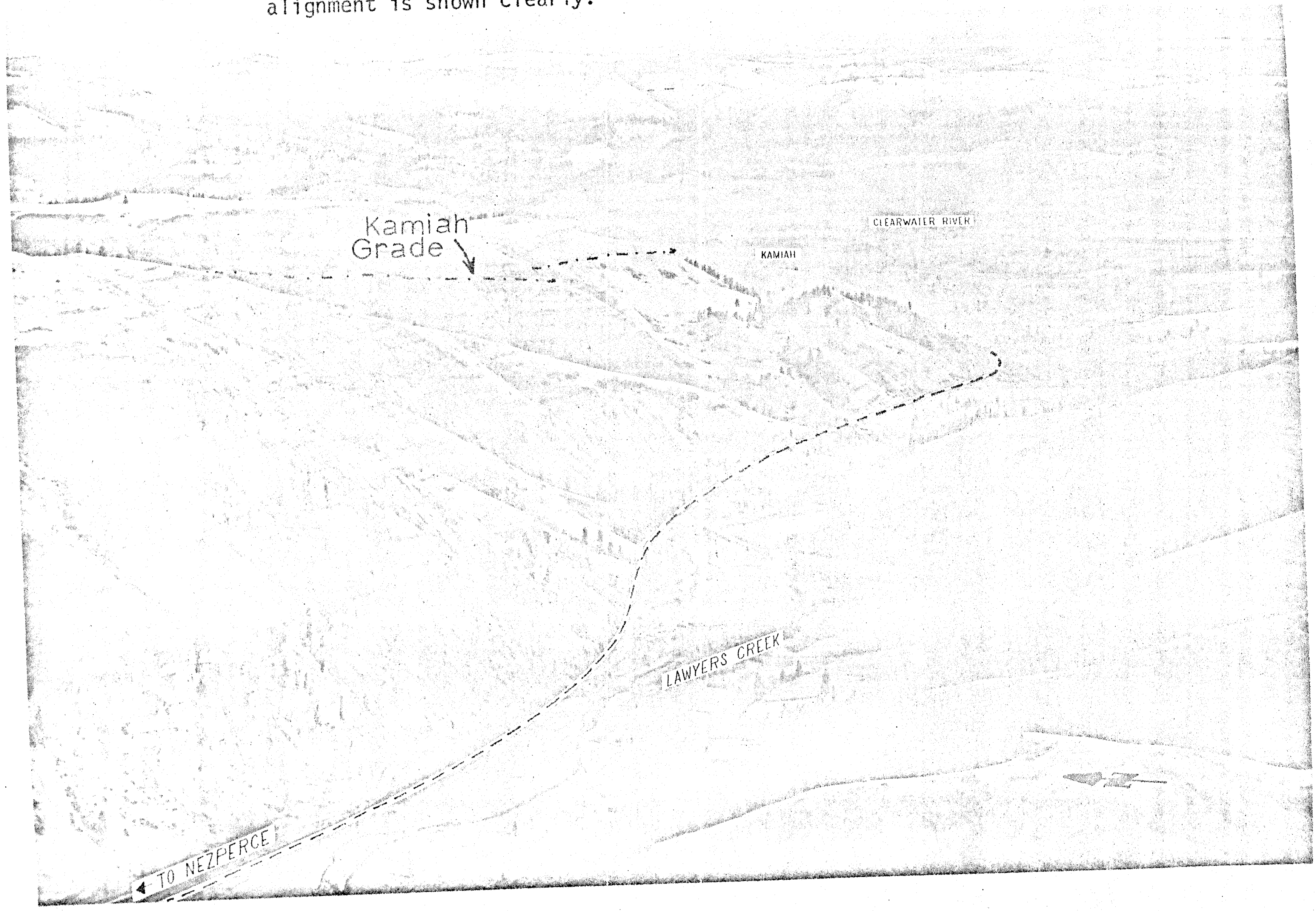
Geomorphology

Canyon cutting combined with differential erosion has placed a distinctive morphology on canyon slopes underlain by basalt. The terraced appearance of many canyon slopes (Figure 4) is the result of differential erosion between different basalt flows along flow contacts and interbeds and within individual basalt flows along zones separating basalt of different jointing characteristics. In many cases the latter type of differential erosion is responsible for the progressive removal of columnar portions (colonnade)[1] of a flow from under the massive wavy-columnar portion (entablature)[1] causing an overhang, ledge, or "rock shelter" to develop (Figure 6). The presence of many interlocking joint surfaces in the entablature commonly makes this portion of a flow more resistant to physical disaggregation, and this is manifested by a massive appearance. The superior resistance

---

[1]The entablature of a basalt flow is that portion which exhibits seemingly haphazard jointing into small irregular "interlocking" columns. Typically, the entablature rests upon the more regularly jointed colonnade portion of a flow which consists of relatively larger, more or less discrete vertical columns.

Figure 4. Looking east toward the mouth of Lawyer's Canyon Creek. The proposed alignment is shown clearly.



of the entablature is often seen in exposures of Upper Basalt. Conversely, the entablatures of Lower Basalt are less resistant to erosion than the colonnade, probably because of deuteric alteration.

Figures 5 and 6 and Plate II illustrate terrace or benchlike features (esplanades)[1] southwest of Orofino in the Clearwater river canyon caused by differential erosion. Esplanades here have been interpreted to be the result of sapping of an interbed and caving and removal of overlying basalts (Bond, 1970).

Tributary canyons to the Clearwater river canyon within the area are steep walled; nearly vertical slopes are not uncommon, especially in the lower portion of the canyons. The sharply "V" shaped canyon profiles attest to the resistant cliff-forming character of basalt flows (Figures 4 and 22).

Mass-gravity features within the study area can be separated into two rather distinct categories: (1) potentially unstable colluvial slopes consisting of basalt talus, basement detritus, and soil; and (2) large rock masses resulting from down-slope movement of basalt overlying interbedded sediments. Basalt talus and mixtures of basalt-soil colluvium are obvious on the lower slopes of the canyons within the study area. Plate II shows the location of potentially unstable areas and the location of major talus accumulations along the several proposed highway alignments.

Bond (1963, p. 68-70) has suggested that the Clearwater river is a consequent stream, developed on the initial surface of the

---

[1]The term <u>esplanade</u>, as used in this paper, refers to a bench-like feature within canyons resulting from erosion (stripping) of interbedded sediments and caving and scarp retreat of overlying flows.

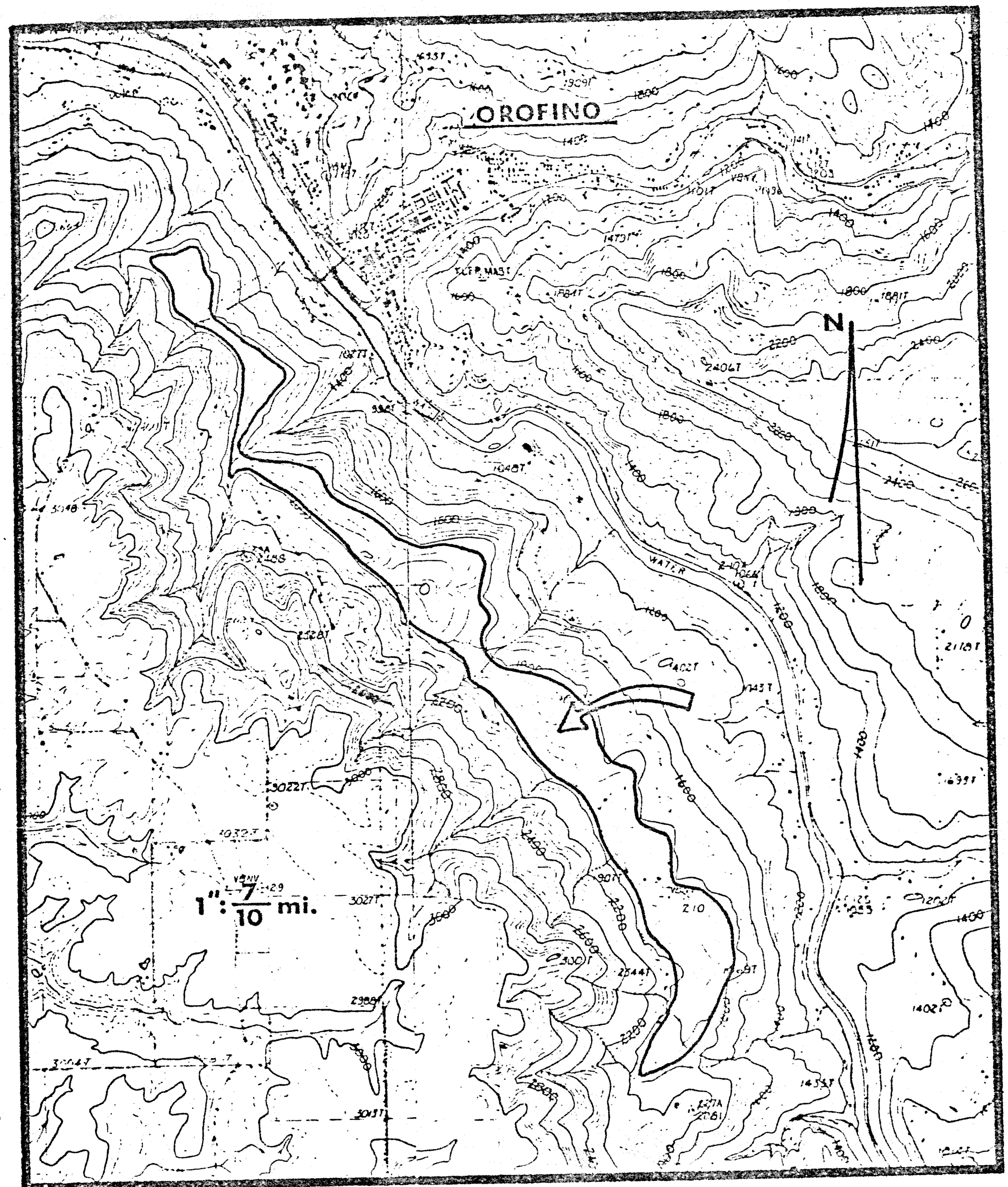


Figure 5. This esplanade is at the contact between Lower and Upper Basalt (Plate II). The esplanade has resulted from the erosion of interbedded sediments from between two basalt flow units and the caving of overlying flows.

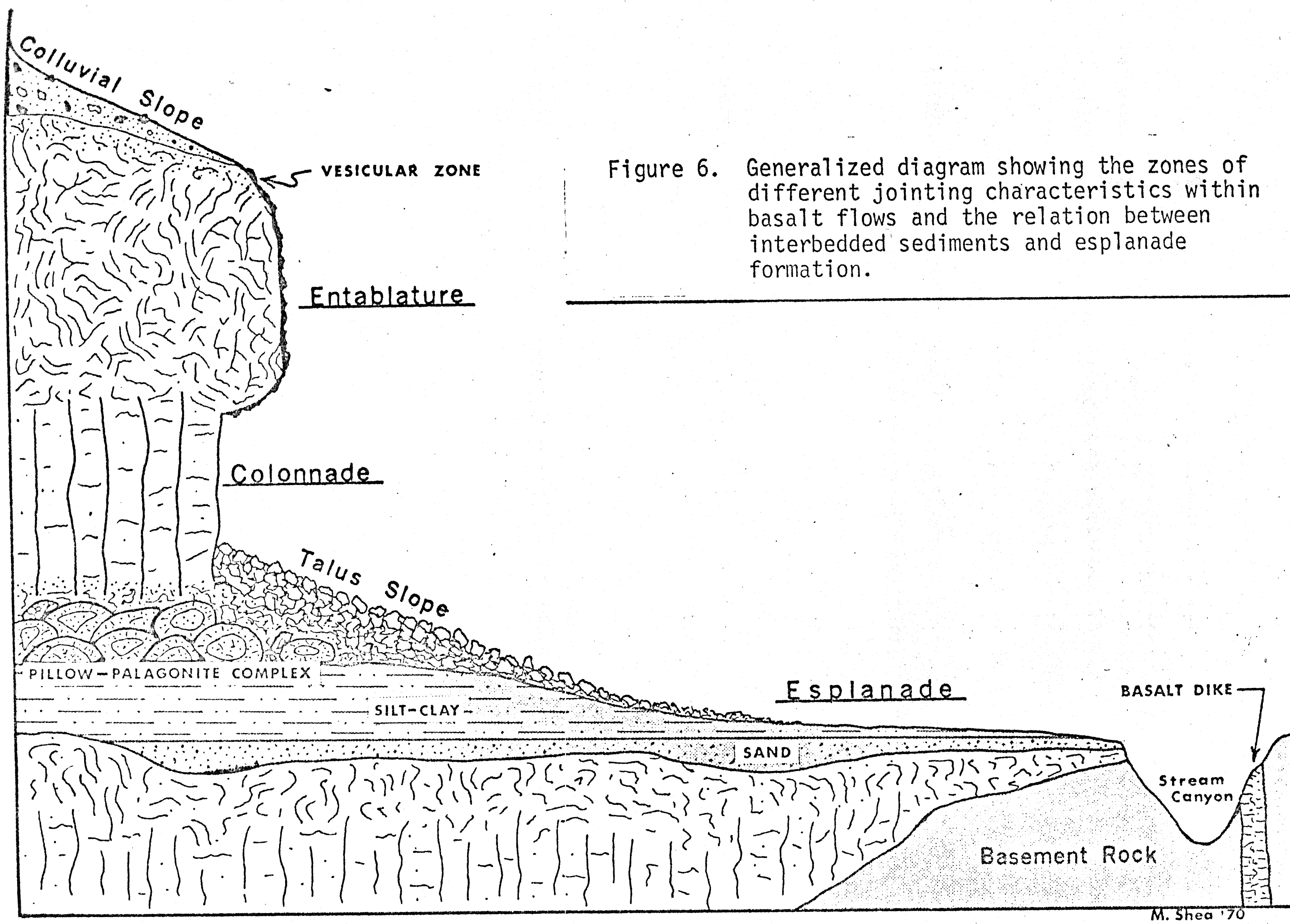


Figure 6. Generalized diagram showing the zones of different jointing characteristics within basalt flows and the relation between interbedded sediments and esplanade formation.

basalt plateau and well established in its present course prior to Pleistocene deformation. Hence, the river is antecedent to late developing structure. However, it may also be correct to say that when established along its present course, the river must have post-dated some of the deformation of the plateau. This is suggested because of the present placement of the river along major structural trends (Bond, 1963, fig. 16)--an occurrence which is probably not fortuitous.

Within the study area a transverse relationship exists between the Clearwater river and sub-basalt drainage divides of the Clearwater orthogneiss and fold structures of the Orofino Series. The river has cut down through geologic structures which antedate the Clearwater river canyon, but which were not exposed at the time cutting of the valley began.

Further discussion of the development of the Clearwater river drainage prior to Pleistocene deformation is in a following section under Origin, Emplacement, and Subsidence of the basalts (p. 37).

Tabular Summary of Geologic History

EVENT

11. Recent erosion and mass gravity phenomena.
10. Periglacial conditions gradually decreasing to present. Streams readjusting themselves.
9. Region in a periglacial environment, and valley sedimentation heavy.
8. More pronounced Pleistocene uplift, deformation, and warping of the basalt plateau. Rapid downcutting of the Clearwater river and major creeks concomitant with uplift.
7. Establishment of consequent drainage on the surface of the plateau, often related to insipient movement along zones of structural adjustment.
6. Extrusion of Columbia River Group Basalts leading to blocked drainages and deposition of sedimentary interbeds between various basalt flows. Subsidence concomitant with the extrusion of basalt.
5. Continuing uplift and erosion throughout rest of Mesozoic and into early Tertiary time resulting in mature dissection of the area, joint formation, and deposition of feldspathic sands.
4. Cretaceous intrusion of the Idaho Batholith.
3. Paleozoic or early Mesozoic intrusion of the quartz diorite and possible synkinematic metamorphism to form the Clearwater orthogneiss.
2. Metamorphism and deformation of the Belt rocks and possible synkinematic intrusion of a granitic magma to form the Orofino Series.

1. Precambrian deposition of Orofino Series sediments (Belt Supergroup--Wallace).

PETROLOGY AND PETROGRAPHY

The discussion to follow is not intended as a definitive treatment of basement and basalt rocks in the study area. In the case of the various basalt types observed, the author has attempted to summarize and supplement the work of Bond (1963, p. 5-30, and references cited therein), and to provide additional examples.

Thin sections were prepared from 40 rock samples collected in the area. Of these, half were from basement rock exposures and the rest from rock throughout the basalt section. For the sake of consistency, thin sections of basalt were taken, where possible, from the basal colonnade portion of different flows.

Representative rock types are discussed in the text; Appendix B furnishes thin section locations and gives a general description of the rock.

Sub-Basalt Rocks

Sub-basalt rocks near Orofino and within the Clearwater canyon are mapped as Jurassic-Cretaceous on the current Idaho State Geologic Map (1947). The rocks are represented on the map either as part of the Idaho Batholith or as Border Zone of the Idaho Batholith.

Interpretation of the origin of basement rocks is open to question. Currently, research on the igneous intrusions and metamorphic rocks around the margins of the batholith is being conducted by R. R. Reid of the University of Idaho. Zircon morphology studies and age determinations of zircons from the region about Orofino are being made. Until the results of these studies become available, it will not be possible to give positive answers to the following questions:

(1) What is the age of the sub-basalt rocks relative to the Idaho Batholith?

(2) Are the rocks the result of metasomatic feldspathization (granitization)[1] or igneous intrusion?

The following observations suggest that intrusion of the Idaho Batholith may significantly post-date the sub-basalt rocks in this area.

OROFINO SERIES

Near Orofino, the metasediments and gneisses are currently mapped as: "Border Zone of the Idaho Batholith." While this statement may be true in a geographic sense, geologically the phrase implies a time association which may be incorrect as the following paragraphs discuss.

It was pointed out (p. 8) that the Orofino Series consists of gneiss, quartzite, and marble. The petrography of these lithologies is discussed following a review of probable metamorphic history. Anderson (1930) related the Orofino Series to the lower portion of the Belt Series (currently--Belt Supergroup). Anderson (1930, p. 9) states:

---

[1]Granitization is any process or group of processes involving entry and exit of material and by which solid rock is converted (or transformed) to a granitic rock without passing through a magmatic stage. The term feldspathization is essentially synonymous with granitization and simply implies the formation of feldspar. Metasomatism is a type of granitization involving replacement of one or several elements by others that migrated in solution or as free ions from outisde sources (i.e., transformation of solid rock by volume exchange of introduced and released materials of different chemical composition).

> Assigned provisionally to the Belt is a series of highly metamorphosed igneous and sedimentary rocks with beds of exceptionally pure crystalline limestone or marble in the lower Clearwater drainage near Orofino. These cannot be correlated with any of the Belt members farther north. They must either be older or belong in the lower part of the Prichard whose counterpart in other places has not been exposed by erosion or is not present.

This interpretation is in part correct, although the Orofino Series is probably correlative with the Wallace Formation and not with the Prichard (Reid, 1970b, and Hietanen, 1963, p. A48).

Anderson went on to relate much of the metamorphism to intrusion by the Idaho Batholith, and some workers since then also have done so. Considering the proximity of the batholith (Figure 7), the interpretation is readily arrived at. Anderson (1930, p. 9) does state, however, that part of the metamorphism was probably much earlier. This is an important point.

Radiometric dates on igneous zircons within the granitic gneisses and amphibolites may show that intrusion, metamorphism, and deformation took place prior to emplacement of the batholith (Reid, 1970b). There is reason to suppose that intrusion may be shown to have been synkinematic to late synkinematic with pre-Mesozoic deformation and recrystallization.

For a nearby area Reid (1970a, p. 915) states:

> Radiometric dating of zircon indicates a 1525 ± 82 m.y. age of crystallization for augen gneiss that intrudes metasedimentary rocks (near Elk City, Idaho [Figure 7 this report]) correlated with the Prichard Formation of the Belt Supergroup. The augen gneiss appears to be late synkinematic with the first deformation and metamorphic event in the metasedimentary rocks. Therefore, the first deformation and metamorphism are also Precambrian in age. Diopside-gneiss-bearing rocks on the Lochsa River, Idaho, correlated to the Wallace Formation [emphasis mine] of the Belt Supergroup, have a structural history similar to the rocks intruded by augen gneiss. Therefore, the diopside-gneiss-bearing rocks also were metamorphosed at 1525 m.y.

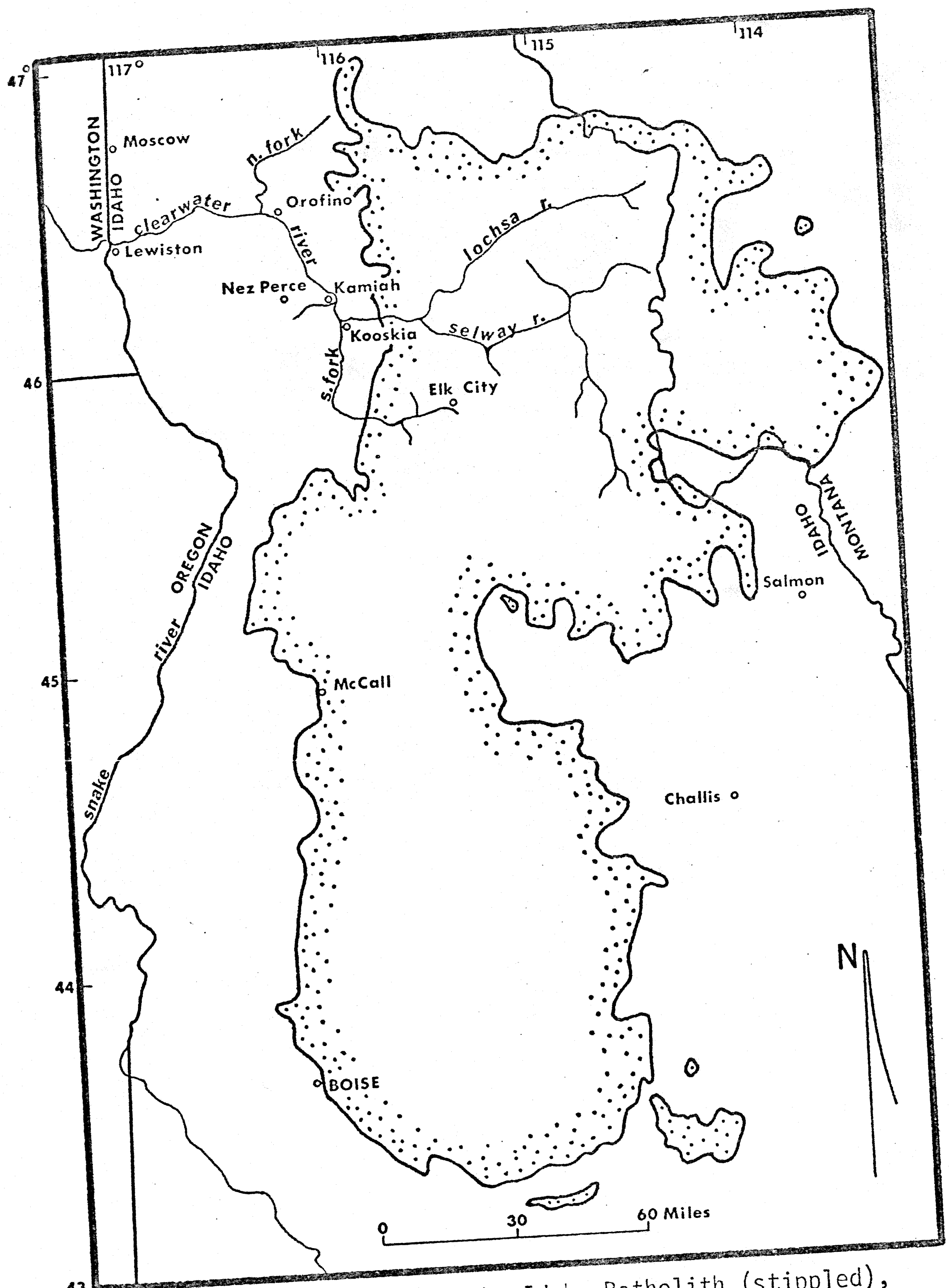


Figure 7. Sketch map of the Idaho Batholith (stippled), after Ross (1963).

Reid (1970b) also suggests that the gneiss and amphibolites are igneous in origin, and are, therefore, orthogneisses and ortho-amphibolites. This conclusion is in contrast to that of Hietanen (1961, p. A64) who interprets the granitic gneisses of the Orofino Series as feldspathized (granitized) sediments related to igneous metasomatism by the Idaho Batholith.

The writer believes that the granitic gneisses and amphibolites are intrusive meta-igneous rocks for the following reasons:

(1) An igneous zircon suite is present (Reid, 1970b). Metasediments or granitized sediments would contain a sedimentary zircon suite.

(2) The rocks have a homogeneous composition. A non-homogeneous composition would suggest sedimentary origins.

(3) Feldspars generally lack inclusions. This indicates metamorphic recrystallization (solid state mineral growth).

Quartz-biotite orthogneiss

Quartz-biotite orthogneiss of the Orofino Series is exposed in a road-cut along U. S. Highway 12 south of Orofino (location 2). The gneiss (TS-12 and 23) has been injected in a lit-par-lit fashion by quartzo-feldspathic dike rock (TS-13). Late-synkinematic injection and metamorphism are suggested by weakly developed schistosity in the dike rock parallel to well developed schistosity and foliation in the gneiss.

The orthogneiss (Figure 8)[1] is pinkish-gray and displays well developed schistosity. Overall texture is crystalloblastic. Twinned

[1]The photomicrographs to follow have letters indicating specific minerals. The letter symbols are: A - Andesine; B -

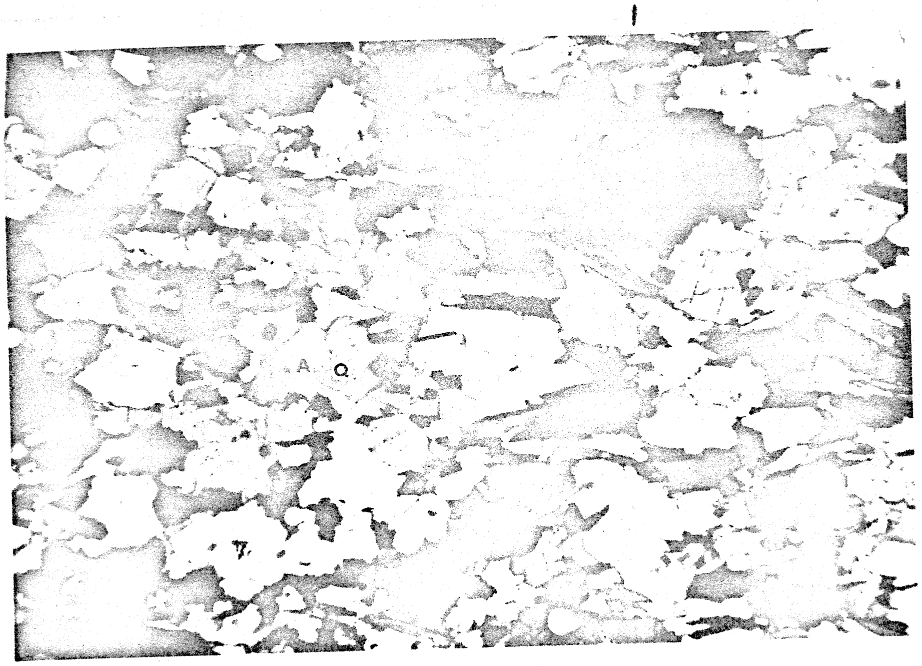


Figure 8. Photomicrograph of the quartz-biotite orthogneiss at location 2. 6X magnification.

and untwinned plagioclase is xenoblastic and exhibits some bent cleavages. The plagioclase has approximately the same relief as quartz, hence, is in the andesine range.[1] Quartz makes up at least 10 percent of the rock as part of the ground mass and as inclusions in plagioclase. Schistose green and brown biotite defines a weak to moderate foliation. Sericite is present as an alteration mineral along plagioclase cleavages. Accessory minerals include epidote, sphene,

---

Biotite; BG - Blue-green Hornblende; L - Labradorite; O - Olivine; P - Pigeonite; Q - Quartz.

[1]Relative relief of plagioclase and quartz can be used as an indicator of anorthite concentration when other optical tests fail. Andesine and quartz have approximately the same relief; the other plagioclases have either higher or lower relief than quartz.

magnetite-hematite, and garnet. Absence of potassium feldspar and the presence of 10 percent quartz give the rock a quartz diorite composition.

The dike rock which intrudes the orthogneiss of the Orofino Series is composed almost entirely of quartz and plagioclase (andesine). Some of the plagioclase is twinned. Overall texture is crystalloblastic. Green and brown biotite defines a weak schistosity. Accessory minerals include sphene, magnetite, pennine, and rounded xenoblastic garnet.

Quartzite

Quartzite in the Orofino Series is exposed south of Orofino on the east side of the Clearwater river (Plate II, location 39). The rock is composed of quartz and appreciable amounts of white feldspar. Both biotite and muscovite are present, and they define a very weak schistosity. Garnet is an accessory mineral.

Marble

Marble in the Orofino Series is exposed in a small quarry south of the quartzite locality mentioned above (Plate II, location 28). In thin section, the rock is 99 percent coarsely crystalline carbonate. Microscopic quartz and tremolite(?) are present as inclusions within the carbonate.

CLEARWATER ORTHOGNEISS

As noted in the opening paragraph of this section, the massive and well-jointed gneissic rocks within the Clearwater canyon between Orofino and Kamiah are mapped as Idaho Batholith on the current Idaho

Geologic Map (1947). The rocks also have been referred to as the "border zone" of the batholith. However, evidence is accumulating which suggests that these rocks, like those of the Orofino Series, are older than the batholith. The Clearwater orthogneiss, however, is younger than the Orofino Series and therefore nearer in age to the batholith.

In this regard, Ross (1963, p. C88) states that the "outer envelope" or border zone is more calcic than the interior rocks of the batholith, and that the border rocks are older than the main mass. He expected the boundaries of the batholith to be modified very extensively.

Potassium-Argon dating by McDowell and Kulp (1969, p. 2379) of biotite and hornblende from various parts of the batholith suggests that:

(1) Primary igneous activity was early Cretaceous (125 m.y.) or earlier.

(2) The most recent thermal event occurred in late Eocene.

The same authors also state (p. 2379) that:

(1) The complex and variable gneissic structures of the "border" rocks indicate a period of active deformation which preceded the intrusion of the more regular interior rocks.

(2) Dating studies (currently underway) may reflect a pre-Cretaceous origin of much of the batholith.

Further evidence of the relative age of "border" rocks and the batholith can be found in the mountains east of the study area. Here, the batholith can be seen to intrude the "border zone" gneisses (Reid, 1970b).

It is suggested that the rocks were originally igneous, and, therefore, are orthogneisses for the following reasons:

(1) The rocks have a relatively homogeneous composition.

(2) An igneous zircon suite is present (Reid, 1970b).

(3) Relict zoned igneous plagioclase is present (Figure 9). Zoned euhedral plagioclase indicates crystallization from a melt.

(4) Relict hypidiomorphic-granular texture is present.

(5) Feldspar lacks inclusions.

One rock type is consistently present and forms the bulk of the Clearwater orthogneiss. This rock is: medium- to coarse-grained, crystalloblastic, variably foliated and schistose, hornblende--(and or biotite)--quartz diorite orthogneiss. (See footnote next page.)

Figure 9. Photomicrograph of the Clearwater orthogneiss showing relict zoned igneous plagioclase. 6X magnification.

The geology of the main body of rock is complicated by the presence of numerous metamorphosed intrusive bodies, namely:

(1) Quartzo-feldspathic dikes.

(2) Mafic dikes.

(3) Quartz-feldspar-muscovite dikes.

(4) Quartz-feldspar-hornblende dikes.

Also, zones of possible tonalite[1] and quartz-bearing gabbro(?)[1] exist (Plate II), but these form very minor rock components, and thin section studies were not made of them.

Concerning the variability in rock type within the Clearwater orthogneiss, the author suggests that much more field work would have to be done and more thin sections studied before the following questions could be answered:

(1) Are the tonalite and quartz-bearing gabbro intrusions in the quartz diorite?

(2) If the tonalite and quartz-bearing gabbro are not intrusions, do they represent igneous or metamorphic differentiation, or both?

(3) Does the Clearwater orthogneiss represent multiple intrusion, and if so, what are the relative ages of the various units?

---

[1]In this respect, quartz diorite, tonalite, and quartz-bearing gabbro are defined as follows: (1) quartz diorite: (a) coarse-grained; (b) greater than nine-tenths total feldspar is plagioclase with An 35 to 50; (c) greater than 5 percent quartz; (d) 25 to 40 percent dark minerals (hornblende, biotite, pyroxene, opaque oxides, etc.). (2) tonalite: (a) medium- to fine-grained; (b) greater than nine-tenths total feldspar is plagioclase with An 15 to 50; (c) greater than 10 percent quartz; (d) relatively fewer dark minerals than a quartz diorite. (3) quartz-bearing gabbro: (a) coarse-grained; (b) greater than nine-tenths total feldspar is plagioclase with An 50 to 90; (c) greater than 2 or 3 percent quartz; and (d) 40 to 70 percent dark minerals.

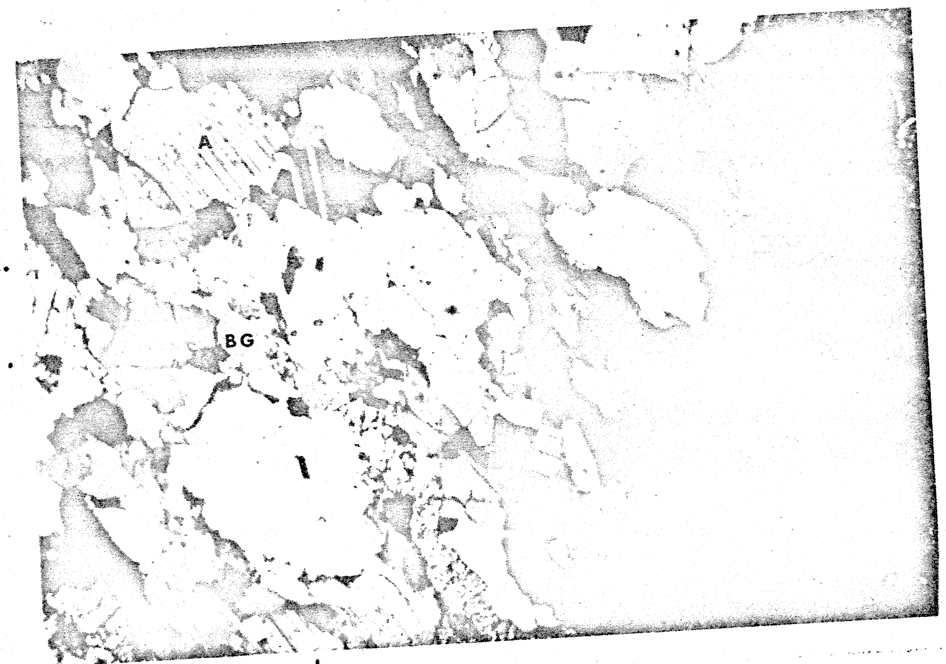


Figure 10. Photomicrograph of the Clearwater orthogneiss showing crystalloblastic texture. 6X magnification.

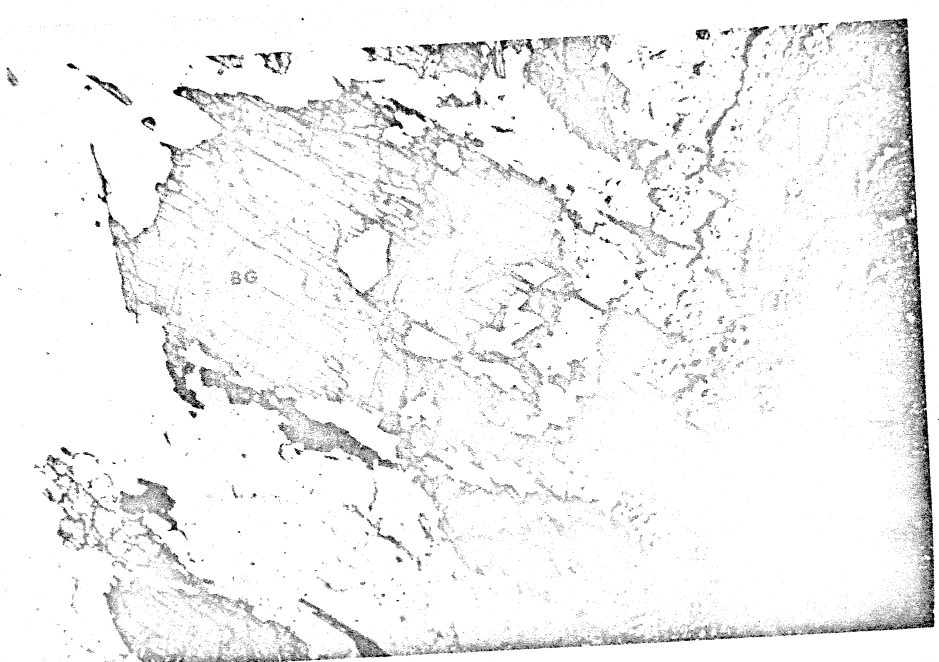


Figure 11. Photomicrograph of the Clearwater orthogneiss showing the appearance of blue-green hornblende in plane polarized light. 6X magnification.

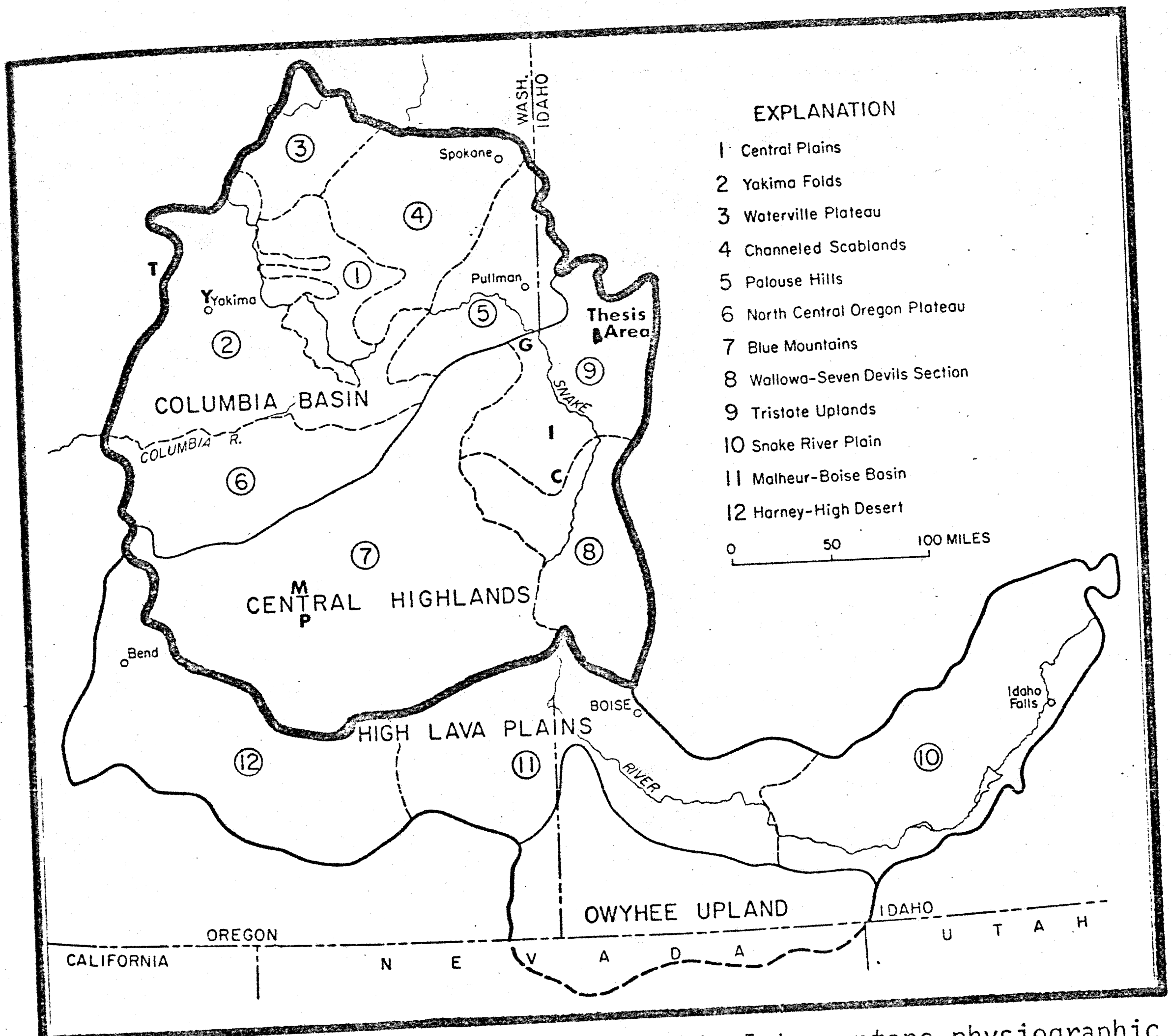


Figure 12. Divisions of the Columbia Intermontane physiographic province (after Freemon, Forester, and Lupher, 1945) showing approximate confines of Columbia River Group Basalts (heavy black line). Location of basalt dike swarms (after Waters, 1961): G - Grande Ronde, C - Cornucopia, M - Monument, and T - Tieton. Y - type area for Yakima Basalt (Smith, 1901), I - Imnaha river canyon: good exposures of Upper Basalt overlying Lower Basalt (Waters, 1961), P - type area for Picture Gorge Basalt (Waters, 1961).

METAMORPHIC FACIES[1] CONSIDERATIONS

Petrographic examination of the Clearwater orthogneiss reveals a high percentage of blue-green hornblende. This mineral is formed only within the Abukuma-Type facies series of Winkler (1967, p. 118-122). In particular, the mineral can be formed only within the upper Greenschist facies (quartz-andalusite-plagioclase-chlorite sub-facies) and the lower part of the Amphibolite facies (andalusite-cordierite-muscovite sub-facies). Based on the thin section studies, the author tentatively places the Clearwater Group rocks within the former quartz-andalusite-plagioclase-chlorite sub-facies because of the presence of quartz, plus blue-green hornblende, plus actinolite (or tremolite), plus epidote, plus andesine.

According to Winkler the subfacies requires a metamorphic environment as follows:

(1) Depth between 5 and 15 kilometers.

(2) Pressure between 2 and 4 kilobars.

(3) Temperature between 500 and 600 degrees centigrade.

Thin section evidence is not sufficient to discuss the metamorphic facies of the Orofino Series rocks.

Columbia River Group Basalts

The stratigraphy of the basalt flows of the Columbia Plateau has been the subject of confusion and debate for some years. This is

---

[1]The term Metamorphic Facies refers to a group of metamorphic rocks characterized by particular mineral associations indicating origin under rather specific temperature and pressure conditions. Further explanation of the facies concept may be found in Winkler, 1967, p. 15-22.

not surprising when one considers the vast area covered by the plateau basalts, and the many feeders from which the flows came (Plate I and Figure 12). Continuous vertical sections and horizontal exposures suitable for study are confined to deep canyons and at no one locality has it been possible to study the entire basalt thickness. According to Cook (Foreword to Bond, 1963, p. iii):

> For many years the drab uniformity of the numerous basalt flows that make up the Columbia Plateau discouraged geologists from attempting to trace individual flows and to make stratigraphic studies in that region. Furthermore it was not believed possible to trace individual flows beyond canyon exposures. . . . Until recent years the conviction persisted that basalt stratigraphy would be impractical, both because the flows are too much alike to be identified in widely spaced exposures and because individual flows probably have no great extent.

In the 1950's and 60's, however, the feasibility of detailed stratigraphy and correlation of the basalts was demonstrated--notably by W. N. Laval, A. C. Waters, J. H. Mackin, J. G. Bond, D. A. Swanson, H. U. Schminche, and I. L. Gibson.

The first organized geologic studies of the Columbia Plateau began in the 1890's. Excellent accounts of the history and development of stratigraphy, correlation, and nomenclature related to the basalts and sedimentary interbeds are available in Baldwin (1950), Waters (1961), and Bond (1963).

NOMENCLATURE

The term Columbia River basalt as used by most workers refers to the Upper Tertiary (Miocene--Early Pliocene) plateau basalt flows of the Pacific Northwest. These are distinct from the Pleistocene flows of the High Lava Plains section of the Columbia Intermontane physiographic province to the south (Figure 12).

Waters (1961), based on his work and that of Russel (1893 and 1901), Merriam (1901), Smith (1901), Pardee and Bryan (1926), and Scheid (1947), synthesized the available evidence pointing to the existence of two different stratigraphic units within the basalts. Waters (1961, p. 607) proposed to:

> . . . elevate the Columbia River basalt to group status, and recognize two distinct formations within it: (1) the Yakima basalt as defined by G. O. Smith, and (2) the older basalts of the John Day Basin called the "Columbia Lava" by Merriam, but herein renamed the Picture Gorge basalt, with the section at Picture Gorge designated as the type section. This nomenclature also provides the flexibility to add additional formations or other stratigraphic subdivisions as the need may arise. . . .

The two-fold division of the Columbia River Group Basalts in the study area is based on the definitions of Waters (1961) and Bond (1963). The existence of two distinctly different basalt types was verified by field and laboratory observation. As noted in the introduction, these are called "Upper" and "Lower" Basalt after Bond (1963) using non-porphyritic versus porphyritic character, respectively, as the main field criterion for separation. According to Bond (1963, p. 9):

> . . . a number of porphyritic flows constitute a recognizable formation deep in the canyons of the Snake, Salmon and Clearwater rivers. These flows underlie a relatively non-porphyritic formation in which only the top flow (Lolo Creek Member) consistently contains phenocrysts. As previously stated, the two formations, "Lower" and "Upper" Basalts, are generally the same as those exposed in the Imnaha River canyon [Figure 6, this report] and are probably correlative to the Picture Gorge and Yakima Formations.

Plate I illustrates the general confines of the Columbia River Group Basalts. This area includes both the Columbia Basin and Central Highlands subprovinces of the Columbia Intermontane province (Figure 12). Parenthetically it could be mentioned that the informal term

Columbia Plateau is incorrectly used by many people. The term is not synonymous with the whole of the Columbia Intermontane province. Rather, Columbia Plateau refers to the dissected plateau topography of the Columbia Basin subprovince.

ORIGIN, EMPLACEMENT, AND SUBSIDENCE

It seems certain that the basalts are of fissure origin. In this regard, Bond (1963, p. 41) states:

> This source of supply is suggested by the great lateral extent and tabular nature of the flows, by the absence of volcanic mountains and cindercones on the plateau, and by the presence of denuded dikes which were formed by the cooling of the lava in fissures. (after Russel, 1901, p. 29)

Dike swarms are located around the margins of the Columbia Plateau (Figure 12). The Grande Ronde swarm, however, is of particular interest because of its proximity to the study area. This swarm is a likely source for the Upper Basalts in the area because of:

(1) Fanning combined with thinning of the lava pile to the north and east away from the swarm (Gibson, 1969, fig. 6).

(2) Flow direction studies indicating that the source for the basalts lay in the southeastern portion of the plateau (Waters, 1961, p. 586, and Swanson, 1967, p. 202).

The Columbia River Group Basalts moved into Idaho from the west and southwest to form the Clearwater Embayment (Bond, 1963, p. 3). The flows buried all but the highest areas of a mountainous topography developed on metamorphic and igneous rocks. Within the study area the Columbia River Group Basalts lie unconformably on the Orofino Series and on Clearwater orthogneiss. Eastward movement was ultimately checked by the western slope of the Northern Rocky mountains. Minimum relief of the sub-basalt surface was at least 3000 to 4500 feet (Peterson, 1955, p. 1, and Bond, 1963, p. 35).

Concerning the environment of accumulation, Gibson, 1967, p. 430) states:

> It seems likely that repeated eruptions from the dike swarm (Grande Ronde) produced a low elongate shield of lavas, which formed in the middle of a pre-existing basin of pre-Tertiary igneous and metamorphic rocks.

Eruption and spreading of the lavas was concomitant with subsidence (Bond, 1963, p. 45, and Gibson, 1969, p. 433)--with greatest subsidence occurring in the vicinity of the dike swarm. This fact accounts both for the thickening of the basalt mass basinward (toward a dike swarm) and for the thinning or termination of individual flows away from the swarm.[1]

Spreading of the basalts irrevocably altered the pre-existing Clearwater river drainage. Streams were either ponded against the advancing lava front or diverted to new directions around the margin of the growing plateau. The end of volcanism was followed by overspilling of the marginal lakes and establishment of consequent drainage on the plateau surface controlled by local subsidence and basement salients. The present course of the Clearwater river, sub-parallel with the margin of the plateau, may, as noted on pages 17 and 18, represent the end result of lateral northeastward shifting controlled by plateau subsidence, uplift, and developing fold-fault zones.

---

[1]Subsidence also could account for the presence and greater thickness of late-Yakima lavas (Lolo Creek Flow) toward the center of the plateau, and their absence or thinness within the study area.

LOWER BASALT (PICTURE GORGE)

The largest exposures of Lower Basalt within the study area are found south of Orofino at and near location 31 on the Gilbert Grade. Here, the basalt lies just below an esplanade (Figure 5 and Plate II). At location 31 the columns of the colonnade radiate from vertical to horizontal, and prisms one to two feet in diameter are common. Individual columns of the colonnade are jointed and form irregular blocks. The entablatures are massive and irregularly jointed, forming large blocks.

In hand specimen, Lower Basalt is dense and fine- to medium-grained. Color of the fresh surface is dark brown to black; weathered surfaces are buff to slightly orange. Distinctly porphyritic character typifies Lower Basalt in the study area; phenocrysts up to one centimeter in thickness are common and present in almost every hand specimen. The clear phenocrysts appear to take on the color of the ground mass, but cleavage flashes betray their presence and size.

In thin section (Figure 13), Lower Basalt is holocrystalline and displays labradorite phenocrysts (An 62) in a matrix of glass and felted plagioclase microlites. Phenocrysts average 5.5 mm by 2.5 mm and make up about 5 percent of the rock; microlites average 1.2 mm long and compose 55 to 65 percent of the rock. A few phenocrysts are zoned and the larger unzoned ones are poikilitic containing inclusions of magnetite and pyroxene growing along the cleavage. Five to 10 percent olivine is present, and it is partially altered to yellowish saponite(?). Clinopyroxene in the form of pigeonite make up 10 to 20 percent of the rock. Minor sub-ophitic texture is present. Other minerals include apatite and long slender magnetite.

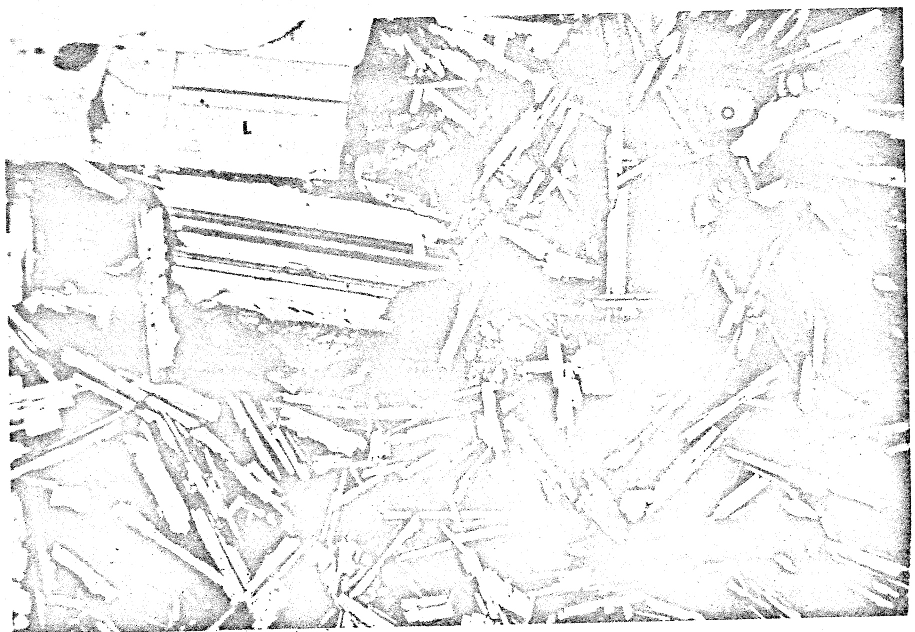


Figure 13. Photomicrograph of Lower Basalt at location 31 showing phenocrysts. 6X magnification.

UPPER BASALT (YAKIMA)

Upper Basalt comprises most of the basalt exposed in the study area. Ten to 14 flows are present, but the author was generally unsuccessful in tracing any one particular flow beyond its canyon exposure.[1]

Correlation criteria are primarily macroscopic. Outcrop appearance, degree and kind of vesicularity, relative position in the sequence, and jointing characteristics should enable an experienced observer to trace individual flows.

[1]Nevertheless, the feasibility of tracing and correlating individual flows from canyon to canyon has been definitely shown by many workers, including Mackin (1961) and Bond (1963).

On the other hand, if one relies on the possibility of petrographic separation and correlation of flows, a disappointment can be expected. With one exception, that being the highest flow in the Upper Basalt, the various flows of Upper Basalt were found to be monotonously similar in mineralogy, texture, and structure. Glass content and grain size vary slightly from flow to flow, but these characteristics are very dependent on position within the flow and upon the cooling history.

In hand specimen, Upper Basalt is brownish-black to black in color, dense, and, with the exception of the uppermost flow, non-porphyritic. Bond mapped the uppermost flow unit and named it the Lolo Creek Flow (1963, p. 27). He describes it as being porphyritic and petrographically distinct from the other flows of Upper Basalt. Remnants of this flow were found capping the plateau surface within the study area at and above 2800 to 2900 feet. Waters (1961, p. 601) recognized this type of flow and referred to it as a late-Yakima varient.

Stratigraphic descriptions of Upper Basalt were made on the Gilbert Grade and within Suzie Creek canyon (Plate III). Overall, the younger flows have less well developed basal columnar portions than Lower Basalt; the entablature forms the bulk of flow thickness. Within Little Canyon creek and on the Gilbert Grade a flow with a distinctive and thick entablature was observed (locations 89 and 21). The elevation of the base of the flat lying flow at both locations is at approximately 2500 feet, and the two are considered correlative. This flow might serve as a stratigraphic marker; it is tentatively correlated with the thick terrace-forming flow(s) within Suzie Creek canyon at and near location 37.

In thin section (Figure 14), the flows of the non-porphyritic portion of Upper Basalt are fine- to medium-grained, felted, and vary from holocrystalline to hypocrystalline. Plagioclase laths and microlites compose at least 50 percent of the rock in each basalt thin section studied. Anorthite content of plagioclase varies essentially within the labradorite range, and no basis for differentiating flows by anorthite content was established. Pigeonite is present as an essential mineral, and the twinned variety is common. Accessory minerals include sanidine, chalcedony (secondary in vesicles), magnetite, and various alteration products of glass.

The Lolo Creek Flow (Figure 15) is fine- to medium-grained holocrystalline to hypocrystalline, porphyritic, cumuloporphyritic, and exhibits good sub-ophitic to ophitic texture. Both felted and trachitic varieties were studied. Plagioclase (labradorite) microlites and phenocrysts comprise 60 to 70 percent of the rock; phenocrysts as large as 5 mm by 7 mm are present, but not common. Slender white plagioclase phenocrysts are common and can be seen in hand specimen. Twinned pigeonite comprises at least 10 percent of the rock, and accessory minerals include minor olivine, chalcedony (secondary in vesicles), sanidine, magnetite, and glass alteration products.

SEDIMENTARY INTERBEDS

The sedimentary interbeds between the various flows of Columbia River Group Basalt are laterally discontinuous. These beds ,

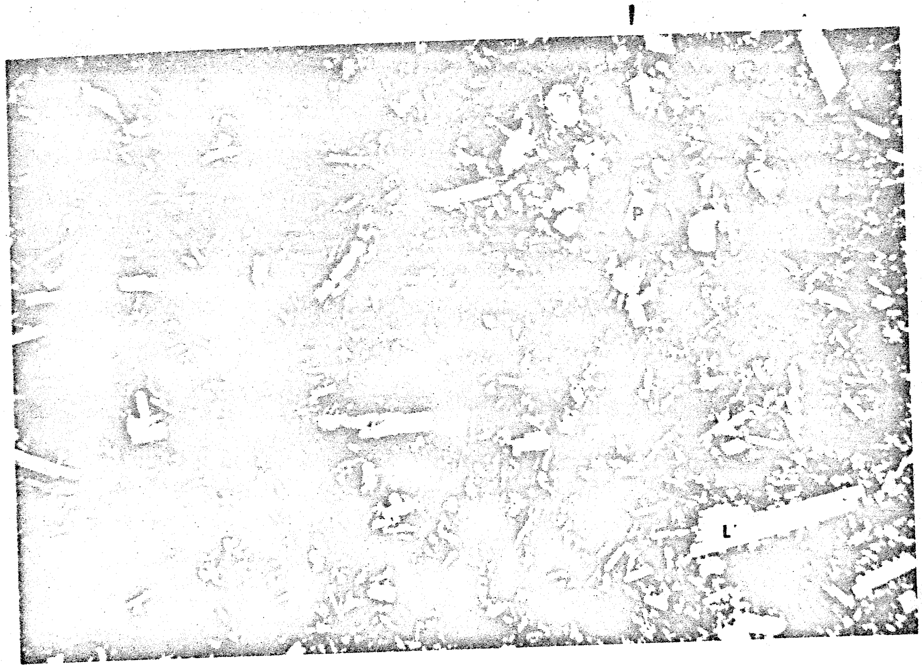


Figure 14. Photomicrograph of a typical example of Upper Basalt. 6X magnification.

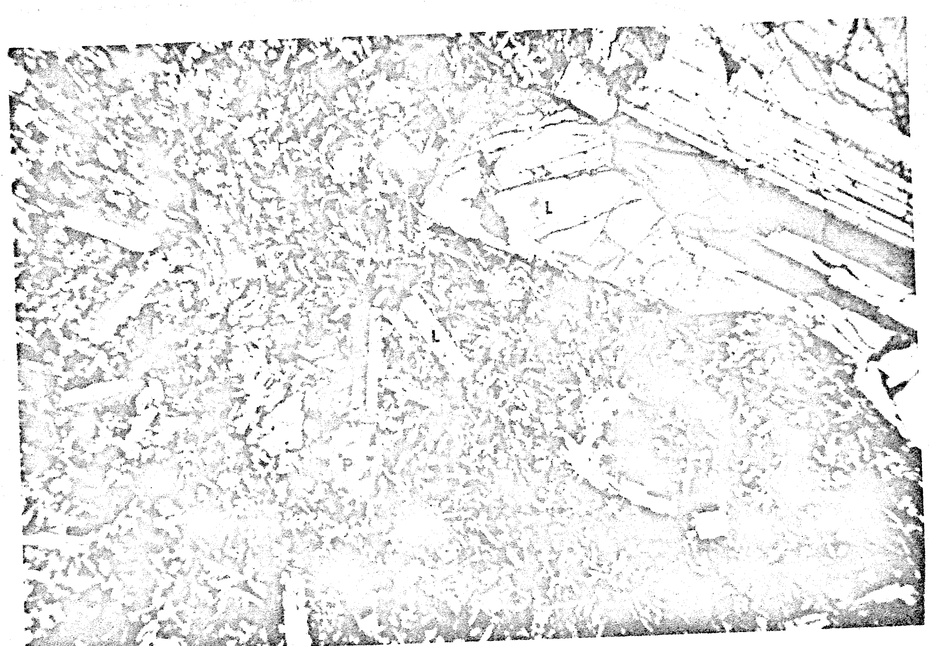


Figure 15. Photomicrograph of the Lolo Creek flow. 6X magnification.

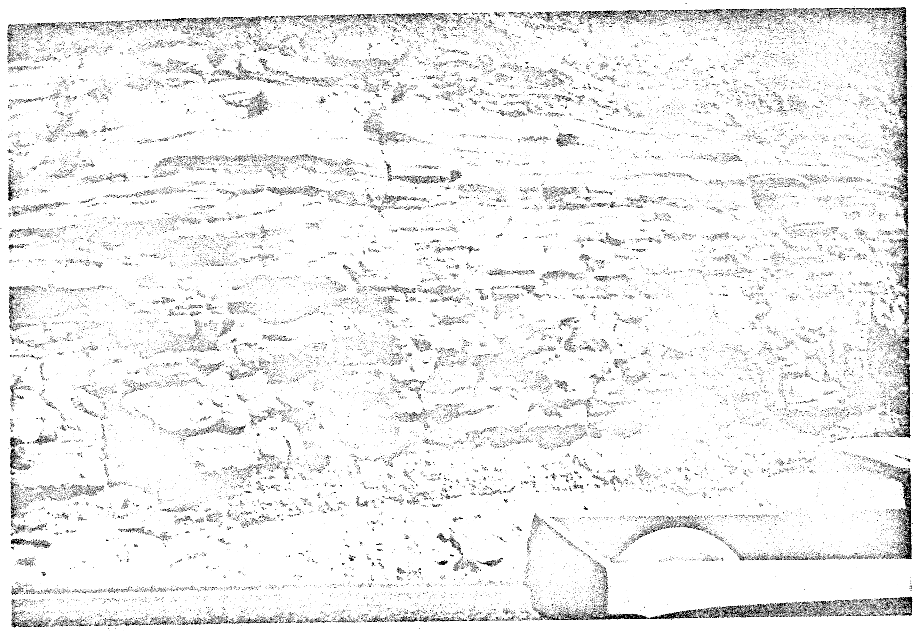


Figure 16. The Kamiah Interbed at location 6.

together with sediments lying below and above the basalt, have been referred to as the Latah Formation by many writers. Formational status may be questionable because the sediments can be older than, contemporaneous with, or younger than the basalts with which they are associated. Individual interbeds, however, can be recognized at widely scattered locations. They are useful both as indicators of structural offset, and as correlation markers when accurately placed in stratigraphic position (Bond, 1963, p. 6-8).

Interbeds were locally deposited throughout the period of basalt extrusion around the margins of the plateau and in localized basins on the surface of individual flows. Composition of the sediments generally reflects erosion of pre-existing basement highlands;

fluvial and lacustrine environments are recorded by sedimentary textures.

Plate II shows the location of the more persistent interbeds within the study area. From oldest to youngest they are the Gilbert, Kamiah, Six Mile Creek, and Effie Creek interbeds.

Gilbert Interbed

The Gilbert interbed is exposed at location 30 near the bottom of Gilbert Grade. The interbed lies beneath a flow of Lower Basalt and is underlain by Lower Basalt or Orofino Series quartz-biotite orthogneiss (Plate III). Colluvial cover at this location prevents one from seeing the bottom contact of the interbed. The sediment consists of interbedded fine- to coarse-grained, quartzo-feldspathic, micaceous, friable arenite, and moderately indurated clayey silt to silty clay lutite. In addition, the detritus is poorly sorted and individual fragments are angular; thus, short transport is indicated. A fluvial origin is indicated, but minor periods of lacustrine deposition are represented by thin beds of silty clay.

Kamiah Interbed

The Kamiah interbed is exposed west of Kamiah in a roadcut north of State 64 and deep within Mitchell creek canyon (Plate II). Approximately 30 feet of lacustrine, thinly bedded, moderately indurated, micaceous clayey silt lutite overlies another 30 feet of alluvial, quartzo-feldspathic, micaceous, friable arenite. The arenite portion is exposed only within Mitchell creek canyon; it pinches out eastward and is not exposed at the interbed location near Kamiah. Upper Basalt overlies and underlies the interbed. The underlying flow is the oldest exposed along Lawyer's Canyon creek; it is estimated to be not more than 2 or 3 flows above the basement (Bond, 1970).

Six Mile Creek Interbed

Sediments of the Six Mile Creek interbed are exposed at location 4 within Six Mile creek canyon. The interbed is overlain and underlain by Upper Basalt and Clearwater orthogneiss respectively. The sediment consists of interbedded fine- to coarse-grained, quartzo-feldspathic, micaceous, friable arenite, and moderately indurated clayey silt to silty clay lutite. Fossil flora are present in the silt-clay portion. The interbed represents a gradation upward from fluvial sand to lacustrine silts and clays; short transport is indicated by poor sorting and angular fragments in the arenite portion.

Effie Creek Interbed

Sediments of the Effie Creek interbed are named for one exposure south of Six Mile creek and for another near the top of Gilbert Grade (locations 6 and 3 respectively). Both interbeds are intercalated between flows of Upper Basalt about two or three flows down from the top of the plateau. The interbeds are drastically different in composition but are correlated on the basis of topographic and stratigraphic position. The compositional differences probably represent different distances from a basement source and local depositional controls.

At location 3 the interbed is 10 to 15 feet thick, brightly colored in reds and yellows, and composed of sticky and plastic clay. The unit probably represents residual soil development in lacustrine sediments. Impedence of downward movement of water by the interbed is indicated by vegetative cover at the base of the overlying flow and by the moist condition of the sediment.

At location 6 the interbed is composed of 15 to 20 feet of white to buff, very fine- to fine-grained, massive to slightly bedded, micaceous, silty quartzo-feldspathic arenite. Homogeneous character combined with the presence of silt and a slightly laminated appearance suggests that lacustrine conditions persisted during the deposition of this interbed. It is tentatively correlated with the Sweetwater Creek interbed of Bond (1963, p. 24).

Dikes

BASALT

Basalt dikes were observed at locations 11, 17, 18, 23, and 27. At these locations they were intrusive in Clearwater orthogneiss. Figure 17 is particularly illustrative of this relation. Figure 18 shows the thin section appearance of the dike at location 11. This section is typical for all of the basalt dikes studied. Based on composition and relative position in adjoining areas, the dikes are believed to be related to extrusion of valley filling flows which are younger than Columbia River Group plateau basalt (Bond, 1970).

The dike at location 23, east of Greer, is interesting because it lies within a northwest trending fault zone and has been sheared between the enclosing basement rocks. Thus, it clearly illustrates relative direction of structural movement (Plate II).

In hand specimen the dike rock is very similar to Lower Basalt, except that it lacks phenocrysts. The rock is brownish-black to

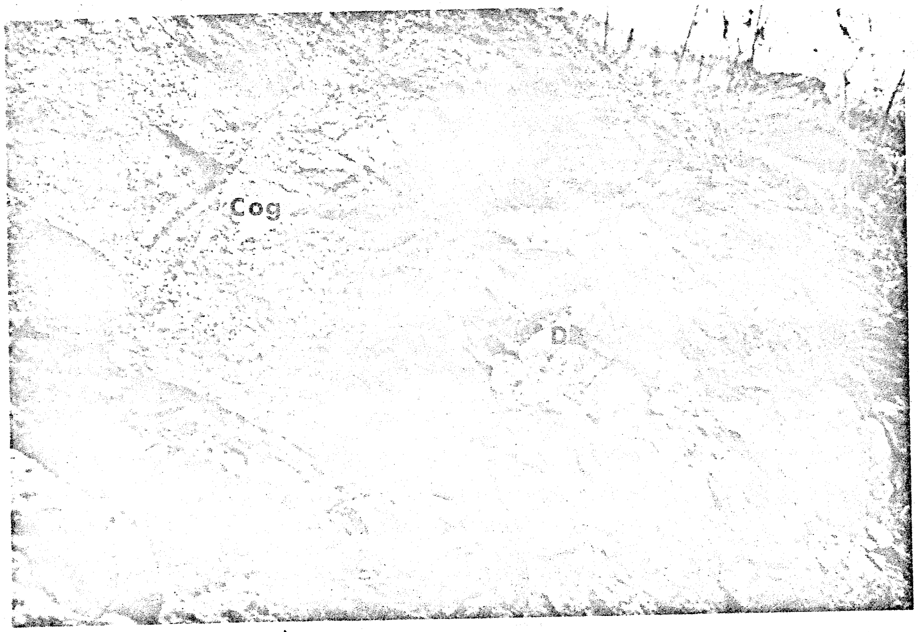


Figure 17. A dike of basalt (Db) cutting Clearwater orthogneiss (Cog) at location 11.

Figure 18. Photomicrograph of the basalt dike rock. 6X magnification.

black and weathers to a rusty brown. On weathered and etched surfaces it can be seen to be distinctly coarser grained than any of the flows of Upper Basalt with the possible exception of the Lolo Creek flow.

At locations 11 and 23 near Six Mile creek and east of Greer respectively, the dike rock exhibits "onion structure."[1]

Jointing within the various dikes is irregular to coarsely columnar with a suggestion of column formation perpendicular to the intrusive contact.

In thin section the dike rock is holocrystalline to hypocrystalline, fine- to medium-grained, and felted. Good sub-ophitic to ophitic texture is common. Labradorite (An 60) crystals and microlites make up 50 percent of the rock, and pigeonite 30 to 40 percent. As much as 10 percent augite with "hourglass" structure was observed in thin section 20. Accessory minerals include magnetite, minor olivine, and glass alteration products.

AMPHIBOLITE

Amphibolite dikes at locations 9 and 32 cut differing rock types and are widely different in character. Figure 19 illustrates the thin section appearance of the dike rock at location 9. Intrusive relations of the amphibolite in and south of the study area, and the presence of an igneous zircon suite in similar amphibolites cutting Orofino Series rocks north of the study area (Reid, 1970a) warrant use of the term ortho-amphibolite.

---

[1] Onion structure refers to columns which are divided into fairly equidimentional blocks. Each block is composed of concentric spheres separated by a contraction crack or line of weakness along which weathering takes place (James, 1920, p. 461-462).

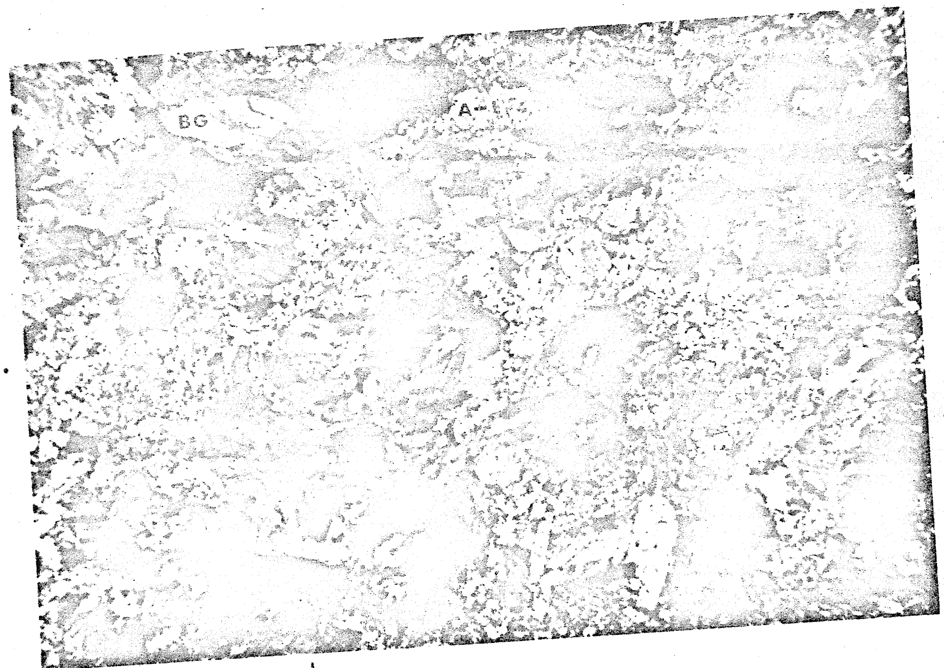


Figure 19. Photomicrograph of the amphibolite dike rock. 6X magnification.

The amphibolite at location 32, a little south of Orofino, intrudes Orofino Series rocks; it is distinctly coarse-grained and schistose. In contrast, the dike north of Kamiah at location 9 intrudes Clearwater orthogneiss, is fine- to medium-grained, and lacks schistosity.

In thin section, the dike at location 9 contains 60 to 70 percent green and blue-green hornblende in a matrix of crystalloblastic untwinned plagioclase (andesine - labradorite). Very fine shreds of talc(?) are present in abundance in the groundmass, and epidote, clinozoisite, hematite, and quartz are minor accessorites.

Other Sedimentary Rocks

Other sedimentary rocks in the study area consist of relatively recent alluvial sands and gravels deposited by the Clearwater river. The bedded sands and gravels at location 88 south of Greer form a terrace capped by four to five feet of soil. The deposit consists of well-rounded pebbles, cobbles, and a few boulders in a matrix of angular to subround, medium-sorted, fine- to medium-grained feldspathic quartz arenite. The ratio of basement lithologies to basalt is approximately 75:25.

A layer of volcanic ash is exposed within a truncated colluvial deposit on the north side of Lawyer's Canyon approximately twenty feet above stream level (Plate II). The thickness and purity of the ash deposit suggest that it is in place and that it has not been appreciably mixed, transported, or otherwise altered by slope wash since the ash-fall. Petrographic examination of the ash, comparison with other volcanic ashes of known age, and further study of the soils and colluvial deposits associated with the ash have yet to be accomplished. When completed, these studies are expected to provide the following information:

(1) Age of the volcanic eruption which produced the ashfall.

(2) Relative ages of the colluvial and alluvial deposits associated with, and in the vicinity of, the ash.

(3) Character of the climatic environment both prior to and subsequent to the ashfall.

ENGINEERING GEOLOGY CONSIDERATIONS

It is beyond the scope of this report to establish necessity or cost justification of a new highway alignment. The author's contribution will be to help select the best alignment based on geology.

One of the greatest road construction problems in semi-mountainous or mountainous terrain is that dealing with rock excavation and removal. In this regard, knowledge of the jointing and fracture characteristics of rock materials is highly desirable. Such information enables engineers to avoid or take advantage of potential planes of weakness or other characteristics of joints and fractures. That is:

(1) Dowels, anchors, and other holding devices can be placed or oriented for maximum strength (Aho, 1960).

(2) Grouting can be done most effectively by drilling holes oriented at a steep angle to planes of dominant fracturing (Aho, 1960).

(3) Pre-splitting of large cuts can be utilized where major joint or fracture planes parallel road alignment (Charboneau, 1970).

(4) Ripping and excavation without blasting is practical if basalt or basement is favorably jointed.

(5) Stable slopes for open rock faces can be anticipated if the attitude and density of jointing and fracturing is known.

The Problem--Existing Roads

If it is accepted that a road connecting Nezperce to the floor of the Clearwater river canyon is needed, that cost is no deciding factor, and that existing roads are unsatisfactory, then a number of solutions can be proposed. One could substantially improve and update any or all of the existing roads, or one could construct a new road that would incorporate none of the shortcomings of the old roads and at the same time be acceptable both to the State and to local residents.

As the situation now stands, in order to travel the most direct route by car from Nezperce to Orofino or Kamiah, one must traverse the Gilbert Grade (State 7) or the Kamiah Grade (State 64) respectively (Figure 1). Both of these roads are direct and expedient. However, they are dangerous because they:

(1) Are narrow gravel roads.

(2) Are confined to the slopes of steep-walled canyons.

(3) Have "hair-pin" turns which make it impossible to see oncoming traffic.

(4) Require year around maintenance to remove rock fall and fix "chuck-holes."

(5) Have inadequate guard-rail protection.

(6) Are built in part on potentially unstable ground.

(7) Require irritating slow speed travel.

If one assumes that the conditions cited above lead to the decision not to attempt to improve and update States 7 and 64, then the question arises--should a new road go from:

(1) Nezperce to Orofino?

(2) Nezperce to U. S. 12 via Six Mile creek canyon?

(3) Nezperce to Kamiah?

All three of these possibilities have been considered by the highway department. The results of the study have been published in the Camas Prairie Location Study. This report states that heaviest traffic volumes within the study area are north-south between Kamiah and Orofino via U. S. 12 and east-west between Nezperce and Kamiah via State 64. Any new road construction must be consistent with the fact that the least traffic volume is north-south via State 7 between Nezperce and Orofino and that the Gilbert Grade on this route incorporates all of the disadvantages of 1 through 7 previously listed.

One of the most serious problems which will face construction of a new road is grade. Elevation at Nezperce is 3200 feet; any road from here to the level of the Clearwater river has to descend approximately 2100 feet. For highway construction purposes this descent would normally present no engineering difficulties over the given map distances (average grade would be approximately 210 feet per mile which represents an angle of slightly more than 2 degrees). However, most of the descent has to take place over short distances within confined steep-walled canyons; here, problems related to maximum allowable road gradient arise. According to the Camas Prairie Location Study (1969, p. 16),

> The American Association of State Highway Officials and U. S. Bureau of Public Roads have agreed on nation-wide standards for Federal-aid primary highways. With current traffic volumes in the range of 400 to 750 vehicles per day, accepted standards are as follows: for rolling and mountainous terrain the maximum allowable grade is 4 and 7 percent (5 degrees and less) respectively, but steeper grades for shorter lengths may be used in mountainous terrain.

Proposed New Alignments

Discussion of proposed individual alignments is broken into sections dealing with the general topography over which the road would be constructed--for example, plateau surface or canyon slopes.

Reference is made to the major soil association(s) existing along the several alignments. General descriptions of the soils, and a statement concerning road construction problems associated with the particular soil and associated bedrock are given in Appendix C.

The reader is again reminded that the observations, remarks, and recommendations which follow stress a geologic point of view, perhaps at the expense of engineering possibilities and some economic considerations.

NEZPERCE TO OROFINO (15 MILES)

The Gilbert Grade Bypass Plans (Figure 20 and Plate II) represent attempts to solve some of the problems of the existing Gilbert Grade. Geologic problems present on the existing road, however, must be expected along parts of the new alignments.

Plateau Surface (8.7 miles)

Here, no geologic problems are anticipated. The alignment is probably underlain by the Kooskia soil association. Soil and underlying clay and silt may be relatively thick on the plateau in this area; Bond (1970) suggests that the absence of the Lolo Creek Flow over part of the area may be compensated for by ponded sediments. Near location 86, 7.5 miles north of Nezperce on State 7, basement "float" can be seen to litter the ground surface. This locates the vicinity

Figure 20. The Gilbert Grade Bypass Plan. An esplanade is visible at right center.

of probable encounter with basement rock during road construction, although the rock now is covered by soil on this portion of the plateau.

Canyon Slopes (6 miles)

Plate II illustrates the two possible alignments. Both are relatively straight and direct, but the road in places would be aligned along steep slopes. Construction problems would be much the same as those encountered on the Gilbert Grade. The west and east alignments would require 7 and 8 percent maximum grades for over half of the horizontal and vertical road distance from the plateau surface to the junction with U. S. 12 (Camas Prairie Location Study, p. 34).

Basalt. Most of the vertical and horizontal road distances from plateau surface to Orofino involve Columbia River Group Basalt (Plate II). Plate III illustrates the approximate elevations of the various flow units, and the general nature and jointing characteristics of the basalt in the northern portion of the study area. Dense, slightly vesicular basalt predominates, and jointing varies from irregular, hackly, and wavy diced, to regular vertical columnar.

A thick pillow-palagonite zone exists on the Gilbert Grade at about 2600 feet. A southern extension of this zone might be encountered in the upper canyon portion of both alignments.

Blasting of basalt will be required in most instances, but the density of jointing combined with the small natural breaking units of basalt will facilitate removal. Pre-splitting will probably work in the more densely jointed flows and pillow-palagonite complexes.

Sedimentary Interbeds. Two interbeds are exposed on the Gilbert Grade. It is expected that other interbeds will be exposed by excavation along the proposed routes, because of the proximity of the basalt-basement contact and detrital source to the north and east.

The thick sandy Gilbert interbed at location 30 might be suitable for aggregate or sub-grade, but the sticky and plastic clay-silt Effie Creek interbed at location 3 could present slope stability problems if encountered.

Between 1600 and 2200 feet, both of the proposed routes would cross portions of the large esplanade south of Orofino (Figure 5, and Plate II). The presence of interbedded sediments and basalt colluvium capping the esplanade is suggested by the relation between esplanade formation and sedimentary interbeds discussed earlier (p, 14, and Figure 6). Unstable conditions similar to those west of Whiskey creek on the road between Orofino and Grangemont should be anticipated.

Basement Rock. Along both proposed alignments it will be impossible to avoid the well-jointed, moderately competent, and steeply dipping gneiss of the Orofino Series. The large angular and blocky natural breaking units of the rock could hamper their removal even after blasting. Also, because the routes locally parallel the strike of the gneiss unit on the up-dip side, care would have to be taken, when establishing an open rock slope-face angle, not to undercut the dip. The foliation plane of the gneiss dips at a high angle to the northeast (Plate III) and is the plane of greatest weakness in the rock. Undercutting of the dip combined with good jointing in three mutually perpendicular directions would pose potential rock slide hazards. This condition is illustrated on Highway 12 one-tenth mile south of the Orofino bridge on the west side of the Clearwater river (location 2). Here, existing and potential rock falls are obvious.

Slope Stability. Plate II shows the location of existing and potential mass gravity features along and near the proposed alignments. Unstable earth materials consist of mixtures of soil, angular basalt talus, and basement detritus. They exist on virtually all lower canyon slopes along the entire road distance at and below 2200 feet, except where the alignments run on exposed basalt or basement bedrock. In this regard, the westernmost Nezperce-Orofino alignment would encounter fewer potentially unstable areas, especially from the 1500-1600 foot level to the junction with U. S. 12 near Orofino.

Large scale downslope movement might also occur if slippage takes place on or within the interbedded sediments associated with the esplanade discussed previously.

Soils. Canyon slopes underlain by basalt are probably composed of the Gwin-Klicker-Mehlhorn soil association. The Lochsa-Yakus association probably caps the lower canyon slopes underlain by basement rock (Appendix C).

NEZPERCE TO U. S. 12 VIA SIX MILE CREEK CANYON (10 MILES)

Six Mile creek is the most geologically interesting tributary to the Clearwater river within the study area. The creek flows obliquely across the plateau from southwest to northeast for 11 miles and descends a distance of 2160 feet. Within this canyon geology is more varied than within any of the other canyons studied.

The Six Mile Creek Plans 1 and 2 (Plate II and Figure 21) are geographical attempts to split the difference between the northern Nezperce-Orofino and the southeastern Nezperce-Kamiah descents to the Clearwater river canyon. Plan 1 requires a bridge to be built which connects the southern and northern sides of Six Mile creek canyon; this alignment is 10.2 miles long. The Plan 2 alignment, however, requires no bridge, stays in the canyon on the south side of Six Mile creek, and is 8.9 miles long (Camas Prairie Location Study, p. 26-32).

Plateau Surface (Plan 1--4 miles, Plan 2--3 miles)

No unusual geologic problems are anticipated. The construction of this alignment would encounter the Kooskia soil association, probably some lacustrine clays and silts, and basalt bedrock.

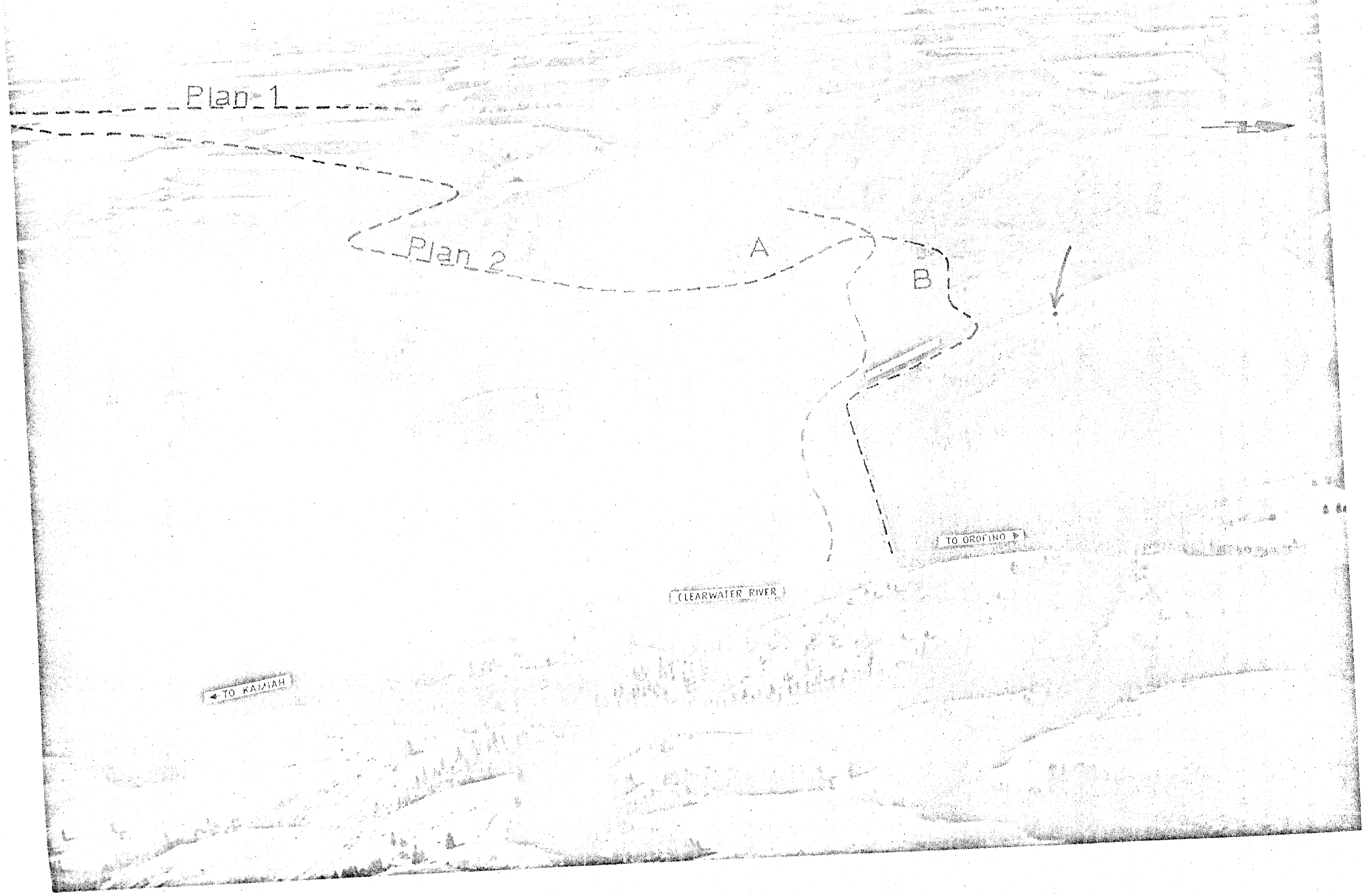
Canyon Slopes (Plan 1--6.2 miles, Plan 2--6 miles)

Plate II shows the two possible alignments. Plan 1 requires a 7 percent maximum grade for approximately four miles between elevations 1400 and 2850 feet, whereas Plan 2 requires an 8 percent maximum grade for three miles between 2000 and 3100 feet.

Basalt. Approximately 1200 vertical feet of Upper Basalt is present along both alignments from the plateau surface to near the bottom of Six Mile creek canyon (Plate III). Construction problems would be much the same as those encountered in the basalts on the Gilbert and Kamiah Grades. Blasting would be required in most instances. Diced units are present at the 2200 and 2750 foot levels.

Plan 2 would encounter a thick pillow-palagonite zone near the bottom of the canyon (Plate II, location 5), and this zone could

Figure 21. Six Mile Creek Plans 1 and 2, showing mass gravity features "A" and "B." A mineralized zone is at tip of arrow.



possibly be ripped without blasting. Underlying the basalt pillow zone is the massive quartz arenite portion of the Six Mile Creek interbed. An active spring line marks the contact between the two units.

Sedimentary Interbeds. As mentioned above, the Six Mile Creek interbed lies directly beneath the pillow-palagonite zone along the Plan 2 alignment. The presence of this interbed might cause slope stability problems because of active groundwater seepage between it and the overlying pillow zone.

The Effie Creek interbed (Plate II) and a weathered zone should be encountered along both alignments just beneath the plateau surface at about 2880 feet. Springlines can be expected at this stratigraphic position and slope-cut adjustments may have to be made to reduce sapping and caving.

Basement Rock. Both alignments would encounter Clearwater orthogneiss in and near the bottom of the canyon from the 1800 foot level to the junction with U. S. 12. Major joint trends are shown on Plate II. No geologic problems are anticipated.

Alluvial Deposits. The stream beds of Six Mile creek and its tributaries consist of a poorly-sorted (well-graded) chaotic assemblage of basalt and basement boulders, cobbles, pebbles, and sands.

Slope Stability. Plate II shows the location of existing and potential mass gravity features along the two alignments. As with the Nezperce-Orofino route, the unstable materials consist of mixtures of basalt talus or basement detritus and soil, and they exist on virtually all lower slopes within the canyon.

Area "A" (Plate II, Figure 21) south of Six Mile creek is an old mass gravity feature which has probably become stabilized. Ponded drainage on the surface of this bench-like feature suggests the existence of impermeable sediments on or below the surface and perhaps moderate spring activity on the north facing slope of the canyon.

Area "B" on the side of the canyon could be potentially unstable. Topographic location within the canyon and field relations suggest that the area is underlain at depth by the Six Mile Creek interbed. If so, large scale down slope movement could occur if slippage either on or within the interbed takes place. Groundwater movement, such as the spring line at location 5, could precipitate slippage and down slope transport. Unfortunately, both areas "A" and "B" will be disturbed if the cross-canyon bridge of Plan 1 is constructed.

Metallization. The only evidence of metallization found within the study area was at 2500 feet on the north side of Six Mile creek approximately one mile northwest of the mouth of the creek (location 87, Figure 21). Here, a small quarry can be seen that appears to have been abandoned for many years. Fracture surfaces of massive, very coarsely crystalline "bull" quartz have encrustations of manganese with chrysocolla and melanterite. The minerals are of secondary origin, and the deposit is surrounded on all sides by Clearwater orthogneiss.

Soils. Canyon slopes underlain by basalt are probably composed of the Gwin-Klicker-Mehlhorn soil association, whereas the Lochsa-Yakus association caps the lower canyon slopes underlain by basement rock (Appendix C).

NEZPERCE TO KAMIAH

Two Nezperce to Kamiah alignments are being considered as possible replacements for existing State 64--the Suzie Creek and Lawyer's Canyon Plans (Plate II). Because portions of these two alignments are the same, or nearly so, the text first discusses the similar portions: (1) Nezperce to the canyon breaks (plateau surface), and (2) The Suzie creek-Lawyer's Canyon junction to Kamiah. Next, the dissimilar portions are discussed: (3) The Suzie creek canyon portion of the Suzie creek Plan, and (4) The Mitchell creek breaks to the Lawyer's Canyon-Suzie creek junction portion of the Lawyer's Canyon Plan.

Plateau Surface (3.5 miles)

No geologic problems are anticipated on the plateau for either alignment. The alignments are underlain entirely by the Kooskia soil association and Columbia River Group Basalt.

Suzie Creek-Lawyer's Canyon Junction
to Kamiah (5 miles)

Figures 2, 4, 24, and 25 show portions of this alignment. Gradient is no problem along the floor of Lawyer's Canyon creek because the alignment drops less than 400 feet in 5 miles.

Basalt. As mentioned previously (p. 44), the lowest flow of Upper Basalt within the study area crops out near the bottom of Lawyer's Canyon creek. The basalt is blue-black, massive, highly vesicular, structureless, non-porphyritic and has a "clickery" appearance. The flow forms a small flat-topped esplanade on the north side of Lawyer's Canyon creek with its upper surface at approximately 1400 feet--40 feet above the creek's flood plain.

Sedimentary Interbeds. The esplanade discussed above is discontinuous and is formed on the Kamiah interbed; it owes its relief and form to downcutting of Lawyer's Canyon creek and to "sapping back" of the interbed.

The proposed alignment runs directly on top of the esplanade for 4.5 miles before descending slightly onto flat-lying alluvial and colluvial deposits at Kamiah, one-half mile south of U. S. 12. Spring drainage problems and some slope and road instability should be anticipated at locations which cut the interbed.

Slope Stability. Plate II shows the location of the existing and potentially unstable colluvial deposits and basalt talus accumulations along the alignment. It is anticipated that if the existing road on the canyon floor is widened, undercutting of the slopes on the north side of the canyon might lead to rock fall and other slope failure problems, particularly if the Kamiah interbed is disturbed.

Soils. Where present, the soils deep in Lawyer's Canyon belong to the Gwin-Klicker-Mehlhorn soil association (Appendix C).

Suzie Creek Canyon (4 miles)

The best exposed and most easily reached complete section of Upper Basalt in the study area is within Suzie creek canyon adjacent to the creek bottom. One need not climb the canyon slope to observe pertinent stratigraphic information.

Plate II and Figures 22 and 23 illustrate the confined tight "V" profile and extremely steep slopes of the canyon. The alignment

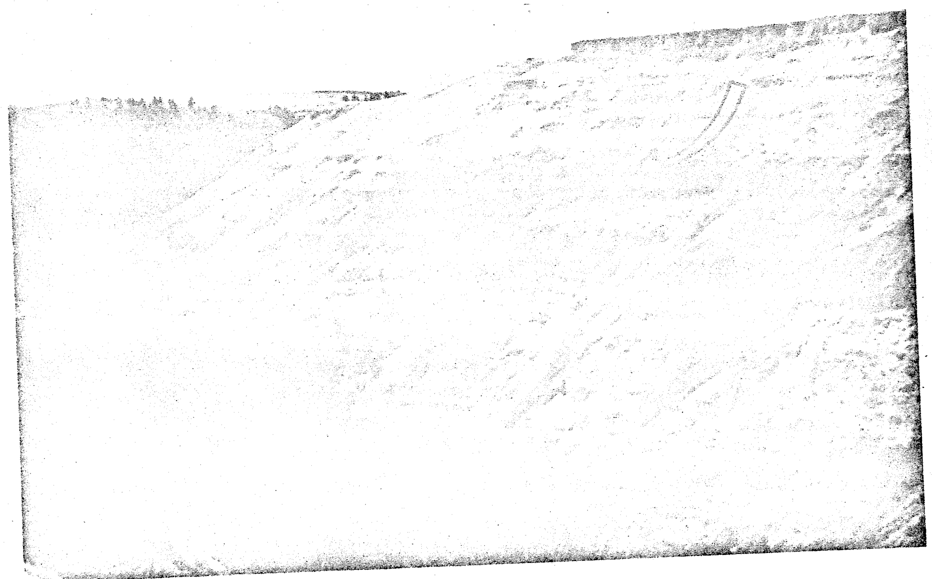
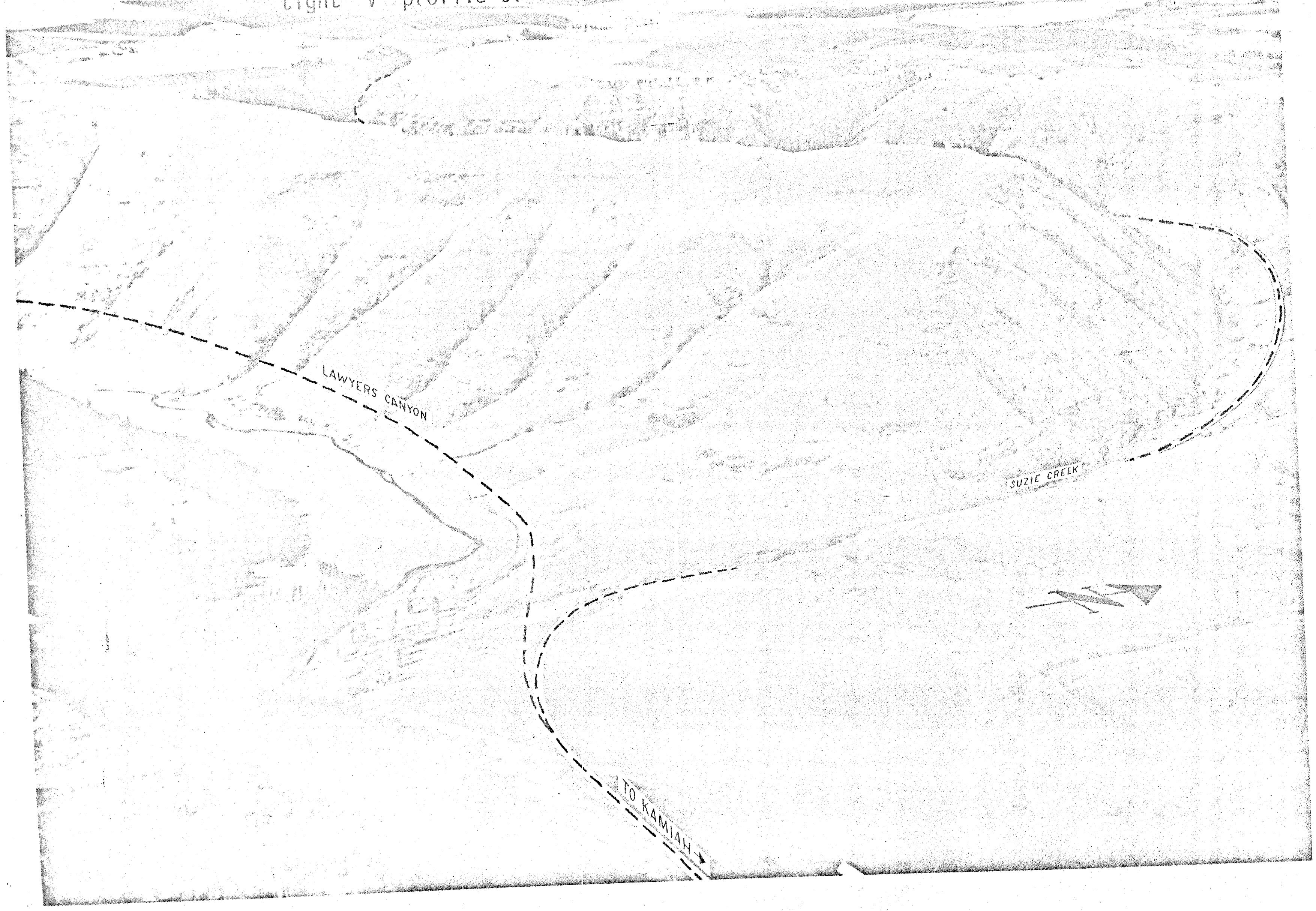


Figure 22. Looking northwest up Suzie creek canyon from location 84. Small caves or cavities are present in the entablature of the indicated basalt flow.

has a maximum gradient of 8 percent for about two miles between 2000 and 2800 feet.

Basalt. From plateau surface to the junction with Lawyer's Canyon creek, the alignment would cut through 1200 vertical feet of basalt consisting of 12 to 14 essentially horizontal basalt flows. Plate III shows the elevations and general nature of the flows that would be encountered. Diced units exist at 2200 and 2750 feet, and blasting would be required in most instances. Construction problems within the canyon would be much the same as encountered on the Gilbert and Kamiah Grades. Construction methods used on the Culdesac Grade of Highway 95 and as now being used on the Whitebird Grade should be considered.

Figure 23. The Lawyer's Canyon and Suzie Creek Plans. Notice the confined tight "V" profile of Suzie creek.



Caves and cavities formed from the differential erosion of probably pillow-palagonite complexes or basalt-breccia zones were observed high on the north slope of the canyon (Plate II and Figure 23). Other such complexes are well-exposed just above stream level in the east-west segment of Suzie creek. These form the cavernous steep slopes exposed on the south side of Lawyer's Canyon opposite the mouth of Suzie creek. The natural ability of these flows to stand with nearly vertical slopes is evident here (Figure 24), and they should respond similarly when laid bare as rock cut open slope faces.

Suzie creek exposes basalt bedrock along portions of its length and is effectively scouring narrower portions of the canyon bottom. At more than one such location, basalt flow breccia zones can be observed, as well as the eroded slightly concave tops of basalt columns, one to two feet in diameter, rising above midsummer creek level.

Sedimentary Interbeds. No basalt interbeds were observed to crop out within Suzie creek canyon, but excavation would perhaps uncover one or more. Bond (1963, p. 26) states:

> The Lawyer Creek Interbed derives its name from exposures along the rims of Lawyer Creek and tributary canyons. The interbed, although thin in most exposures is very widespread. It underlies the Lolo Creek Flow and can be found nearly every place that the base of that flow is exposed.

It would be reasonable to anticipate the presence of at least one interbed considering the thickness of basalt within Suzie creek Canyon, the proximity of basement source material to the east and north, and the presence of interbeds in surrounding exposures. Interbeds are most apt to be found beneath the Lolo Creek Flow, and beneath pillow-palagonite or basalt flow breccia zones (Plate III).

Alluvial Deposits. The character and condition of stream deposits in the bottom of Suzie creek canyon are the same as those within Six Mile creek canyon, except that exceedingly little basement detritus is present. The volume and size of the materials are such that they might be suitable for crushing.

At location 1 a boulder fan lies directly in the path of the proposed alignment and would require selective blasting to remove if the alignment did not pass above it. The fan is composed of well-sorted (poorly-graded) boulders and cobbles and has been deposited by the south flowing tributary of Suzie creek. It could be a source of crushable aggregate although some boulders might be too large to be handled easily by most crushers.

Slope Stability. Plate II shows the location of colluvial deposits and major basalt talus accumulations. Because of the extreme steepness of most Suzie creek canyon slopes along this proposed Nezperce-Kamiah alignment, these materials must be regarded as very near their angle of repose and potentially unstable.

Soils. Where present, soils on canyon slopes probably belong to the Gwin-Klicker-Mehlhorn soil association (Appendix C).

Mitchell Creek Breaks to Lawyer's Canyon-Suzie Creek Junction (7.6 miles)

The alignment descends Mitchell creek canyon (Plate II and Figure 25) and runs parallel with Lawyer's Canyon creek to the Suzie creek junction (Figures 23 and 24). Maximum grade is 8 percent for 2.5 miles between the approximate elevations of 1900 and 2750 feet.

Basalt. Plate III shows the elevations and character of the basalt through which the alignment would cut. Thickness of basalt,

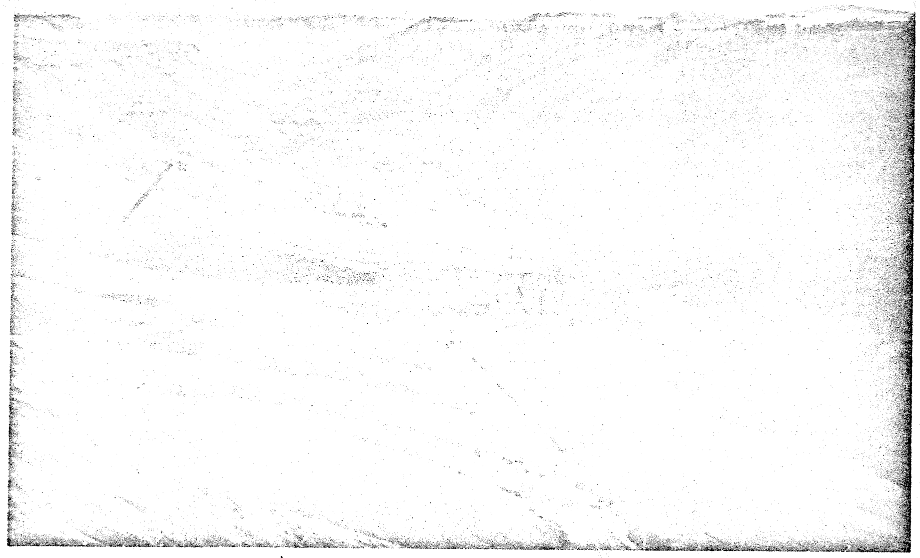


Figure 24. Lawyer's Canyon creek looking east from locality 84. Suzie creek enters from north at left center.

Figure 25. Looking west up Lawyer's Canyon creek from locality 84. Mitchell creek enters from northwest at right center.

number of flows, jointing characteristics, and construction conditions are the same as those to be found within Suzie creek canyon discussed above (p. 68). A complete vertical section of the basalt from plateau surface to flood plain is exposed on the south side of Lawyer's Canyon (Figure 25).

Sedimentary Interbeds. The Kamiah interbed is exposed deep within Mitchell creek canyon (Plate II). Colluvial deposits on the south facing lower slopes of Lawyer's Canyon prevent one from seeing the probable lateral extension eastward of the interbed. No other interbeds are exposed, but the Lawyer's Creek interbed (Bond, 1963) and a pillow-palagonite complex may be crossed just below plateau elevations.

Alluvial Deposits. The volume and size of stream gravels within Mitchell creek canyon are the same as within Suzie creek canyon.

Slope Stability. Water seepage associated with the Kamiah interbed is responsible for minor soil slips within Mitchell creek canyon. These, together with colluvium and talus are present on the lower slopes of the canyon but are well below the proposed alignment. Potentially unstable colluvial deposits will be encountered as the alignment descends toward the junction with Suzie creek.

Soils. Same as within Suzie creek canyon.

Recommendations

Based on the geology and topography along the several proposed routes discussed on the preceding pages, the author suggests that all of the proposed routes from Nezperce to the floor of the Clearwater river canyon will demonstrate the following characteristics. Each will:

(1) Descend over 1000 feet in elevation over short lateral distances within steep-walled canyons.

(2) Necessitate excavation and removal of massive to highly jointed and diced basalt flow rock.

(3) Encounter large open-work talus accumulations and potentially unstable colluvial deposits.

(4) Cut through sedimentary interbeds which may be associated with spring lines and other groundwater features.

The problem of recommending a route becomes one of balancing advantages against disadvantages rather than settling on one overriding criterion. The preferred route should have fewer disadvantages and unknowns.

The key geological justification for a final decision must strongly consider (3) and (4) above. The location, bulk, and geologic character of potentially unstable earth and rock materials and sedimentary interbeds along, or adjacent to, the several proposed alignments cannot be ignored.

For highway construction purposes, the proposed alignments are, in order of most desirable (least potentially unstable ground) to least desirable (most potentially unstable ground):

(1) Suzie Creek Plan.

(2) Lawyer's Canyon Plan.

(3) Six Mile Creek Plan 2.

(4) Western Gilbert Grade Bypass Plan.

(5) Six Mile Creek Plan 1.

(6) Eastern Gilbert Grade Bypass Plan.

Geologically, the two preferred alignments, the Suzie Creek and Lawyer's Canyon Plans, are very similar. The author is in favor of the Lawyer's Canyon Plan. It is possible, however, to argue in favor of either. The Suzie Creek Plan has fewer areas of potentially unstable colluvial deposits, but construction on the extremely steep slopes and narrowness of the Suzie creek canyon portion may prove to be prohibitively expensive. By way of contrast, the Mitchell creek canyon portion of the Lawyer's Canyon Plan is not as narrow as Suzie creek canyon, and road distance within Mitchell creek canyon is shorter.

To answer the problems related to potentially unstable ground conditions along both routes, test trenching and drilling of sediment cores would provide information about the exact nature and depth of the deposits.

If examination and testing of the colluvial, alluvial, and interbedded sediment within Mitchell creek canyon and Lawyer's Canyon were to find these materials unsuitable for road construction, the author would recommend the Suzie Creek Plan.

Furthermore, the author believes that the Lawyer's Canyon Plan represents less of a shock to the environment than the Suzie Creek Plan. Given the desirability of preserving two similar wildlife habitats:

(1) The entire length of Suzie creek canyon would be involved in highway construction if that route were chosen.

(2) Only a small part of the isolated portion of Lawyer's Canyon would be involved in the Lawyer's Canyon Plan.

(3) The most isolated, and most densely forested portion of Lawyer's Canyon would not be involved in the Lawyer's Canyon Plan because this part lies well to the south and west of the proposed route.

Finally, it is the author's opinion that the Lawyer's Canyon Plan is more scenic than the Suzie Creek Plan and offers to the traveler a better glimpse of canyons characteristic of the Columbia Plateau.

REFERENCES CITED

Aho, A. E., 1960, Graphical Statistical Analysis of Fracture Patterns in Rock Encountered in Engineering Projects: Geol. Soc. America Bull., vol. 71, p. 1719-1920.

Anderson, A. L., 1930, The Geology and Mineral Resources of the Region About Orofino: Idaho Bur. Mines and Geology Pamph., no. 34.

Baldwin, E. M., 1950, Summary of the Structure and Geomorphology of the Columbia River Basalt: Northwest Science, vol. 24, no. 2.

Bond, J. G., 1963, Geology of the Clearwater Embayment: Idaho Bur. Mines and Geology Pamph., no. 128.

________, 1969-1970, Personal Communication.

Charboneau, R. G., 1970, Personal Communication.

Cook, E. F., 1963, Foreword to: Bond, J. G., 1963, Geology of the Clearwater Embayment: Idaho Bur. Mines and Geology Pamph., no. 128.

Dept. of Agriculture, Soil Conservation Service and Forest Service in cooperation with University of Idaho, Idaho Agri. Exp. Station, 1966, Soil Survey Report, Kooskia Area, Idaho (revised manuscript).

Freemon, J. H., Forrester, J. D., and Lupher, R. L., 1945, Physiographic Divisions of the Columbia Intermontane Province: Assoc. American Geog., Annals, 35, p. 53-75.

Gibson, I. L., 1967, Grande Ronde Dike Swarm and its Relation to the Columbia River Basalts (abs): Geol. Soc. America Spec. Paper 87, p. 205.

________, 1969, A Comparative Account of the Flood Basalt Volcanism of the Columbia Plateau and Eastern Iceland: Bull. Volcanologique, Tome XXXIII-2, p. 419-437.

Hietanen, Anna M., 1961, Relation Between Deformation, Metamorphism, and Intrusion Along the Northwest Border Zone of the Idaho Batholith, Idaho: Art. 345, U. S. Geol. Sur. Prof. Paper 424-D.

________, 1962, Metasomatic Metamorphism in Western Clearwater County, Idaho: U. S. Geol. Sur. Prof. Paper 344-A.

James, A. V. G., 1920, Factors Producing Columnar Structure in Lavas and its Occurrence near Melbourne, Australia: Jour. Geol., vol. 27, p. 458-469.

Kopp, R. S., 1959, Petrology and Structural Analysis of the Orofino Metamorphic Unit, (Pre-Cambrian: Idaho): MS Thesis, Univ. of Idaho, unpublished.

Mackin, J. H., 1961, A Stratigraphic Section in the Yakima Basalt and the Ellensburg Formation in South-central Washington: Washington Div. Mines and Geology Rept. of Invest., no. 19.

McDowell, F. W., and Kulp, J. L., 1969, Potassium Argon Dating of the Idaho Batholith: Geol. Soc. America Bull., vol. 80, no. 4, p. 2379-2382.

Merriam, J. C., 1901, A Contribution to the Geology of the John Day Basin: California Univ., Dept. Geol. Sci., Bull., vol. 2, p. 269-314.

Pardee, J. G., and Bryan, K., 1926, Geology of the Latah Formation in Relation to the Lavas of the Columbia Plateau near Spokane, Washington: U. S. Geol. Sur. Prof. Paper 140-A, p. 1-17.

Peterson, D. W., 1955, The pre-Basalt Surface in the Vicinity of Peck, Idaho: Northwest Science, vol. 29, no. 1.

Reid, R. R., 1970a, Precambrian Metamorphism of the Belt Supergroup in Idaho: Geol. Soc. America Bull., vol. 81, no. 3.

________, 1970b, Personal Communication.

Ross, C. P., 1963, Modal Composition of the Idaho Batholith: U. S. Geol. Soc. Prof. Paper 475-C, p. 86-90.

Russel, I. C., 1893, A Geological Reconnaissance in Central Washington: U. S. Geol. Sur. Bull. 108, 108 p.

________, 1901, Geology and Water Resources of Nez Perce County, Idaho: U. S. Geol. Sur. Water-Supply Paper 53 and 54, pts. I and II, 141 p.

Scheid, V. E., 1947, Excelsior Surface--an Intra-Columbia River Basalt Weathering Surface (abs.): Northwest Sci., vol. 21, no. 1, p. 34.

Smith, G. O., 1901, Geology and Water Resources of a Portion of Yakima County, Washington: U. S. Geol. Sur. Water-Supply Paper 55, 68 p.

State of Idaho Department of Highways, 1969, Camas Prairie Location Study.

Swanson, D. A., 1967, Some Limitations of Flow Velocities During Eruption and Flooding of the Columbia Plateau by Lavas of the Yakima Basalt: Geol. Soc. America Spec. Paper 115, p. 202.

Thornbury, W. D., 1954, Principles of Geomorphology: John Wiley and Sons, Inc., New York, 618 p.

U. S. Geol. Survey Water-Supply Paper 1317, Compilation of Records of Surface Waters of the U. S., October, 1950, to September, 1960: Part 13, Snake River Basin.

Waters, A. C., 1960, Twofold Division of the Columbia River Basalt (abs.): Geol. Soc. America Bull., vol. 71, no. 12, p. 2082.

_______, 1961, Stratigraphic and Lithologic Variations in the Columbia River Basalt: American Jour. Sci., vol. 259, no. 8, p. 583-561.

Winkler, H. G. F., 1967, Petrogenesis of Metamorphic Rocks (revised second edition): Springer-Verlag New York, Inc., 237 p.

APPENDIXES

Appendix A

Locations of Joint Attitude Determinations

Location	Attitude
2	N 65°W, 60°NE N 30 W, 60 NE N 50 E, 56 NW
8	N 55 W, 90 N 10 W, 55 W
10	N 5 E, 90 N 50 W, 50 NE N 25 E, 90
12	N 30 W, 90
13	N 60 E, 30 NW N 40 E, 65 NW to 90
14	N 55 W, 90 N 35 E, 90 N 15 W, 64 E to 90
15	N 25 W, 90 N 55 E, 24 NW
16	N 30 E, 90 N 42 W, 90
23	N 15 W, 65 SW
25	N and N 40 W, 90
26	N 15 W, 55 NE N 15 W, 35 SW
28	N 5 W, 90 N 55 W, 62 NE
29	N 20 W, 75 NE
32	N 20 W, 55 NE
39	N 40 W, 40 NE
41	N 30 W, 90

Location	Attitude
42	N 67°E, 60°SE N 67 E, 60 NW N 72 W, 58 NE N, 90
43	N 23 W, 90 N 78 E, 65 NW N 30 E, 50 SE
44	N 30 E, 85 SE N 16 E, 90 N 42 W, 71 NE N 35 W, 65 NE
45	N 10 W, 90
46	N 20 W, 90
47	N 5 W, 70 SW
48	N 15 E, 90
49	N 60 W, 90 N 5 W, 90
50	N 60 W, 90
51	N 40 W, 90 N 80 W, 55 NE
52	N 55 W, 70 NE N 35 E, 90
53	N 55 W, 90 N 45 E, 90 N 35 E, 65 SE N 55 E, 65 NW N 35 W, 90
54	N 50 E, 90
55	N 55 W, 90 N 70 W, 90
56	N 60 W, 56 NE N 25 W, 90 N 5 E, 90 N 65 E, 80 SE

Location	Attitude
57	N 20°E, 55°NW N 75 E, 40 NW N 65 W, 90 N 20 W, 60 NE
58	N 30 W, 90 N 10 W, 65 NE N 15 W, 70 NE
59	N 35 W, 60 NE N 35 W, 90 N 55 E, 50 SE
60	N 50 W, 65 NE N 40 E, 55 NW N 15 E, 55 NW N 15 E, 90
61	N 20 W, 90 N 75 W, 60 SW N 50 W, 70 NE N 75 W, 90
62	N 15 E, 90 N 15 W, 90
63	N 50 W, 90 N 35 E, 90 N 60 W, 55 NE
64	N 20 E, 90 N 65 W, 75 SW N 45 W, 90
65	N 85 W, 90
66	N 55 W, 75 NE N 80 W, 90 N 30 E, 70 NW N, 60 W
67	N, 90
68	N 50 E, 90 N 15 E, 60 SE
69	N 80 E, 90 N 10 W, 90
70	N, 90

Location	Attitude
71	N 35 W, 90 N 80 E, 90
72	N 20 W, 75 NE
73	N 45 W, 75 NE N 65 E, 67 NW N 65 E, 30 SE
74	N 55 E, 85 NW N 45 W, 65 NE
75	N 5 W, 90 N 15 W, 30 NE
76	N 65 W, 80 NE
77	N 70 E, 90 N 40 W, 90
78	N 65 W, 90
79	N 60 W, 90
80	N 40 W, 75 NE N 90 W, 60 N
81	N 40 W, 60 NE
82	N, 90 N 35 E, 70 NW

Appendix B

Thin Section Number and Rock Type

(* Described in text)

The thin sections and rocks are on file with the Idaho Bureau of Mines and Geology.

Thin Section Number

1: Clearwater orthogneiss: Very coarse-grained, crystalloblastic, slightly schistose, quartz-plagioclase-biotite-muscovite (30 to 40 percent) orthogneiss (dike rock).

* 2: Upper Basalt: holocrystalline, fine-grained.

3: Upper Basalt: holocrystalline, very fine-grained.

4: Upper Basalt: holocrystalline, fine-grained.

5: Upper Basalt: hypocrystalline, very fine-grained.

6: Upper Basalt: holocrystalline, very fine-grained.

7: Upper Basalt: holocrystalline, fine-grained.

8: Upper Basalt: holocrystalline, fine-grained.

9: Upper Basalt: hypocrystalline, fine-grained, microporphyritic (Lolo Creek Flow?).

* 10: Upper Basalt: (Lolo Creek Flow) holocrystalline, fine-to medium-grained, microporphyritic.

11: Clearwater orthogneiss: coarse-grained, crystalloblastic, schistose, slightly foliated, andesine-hornblende-quartz diorite orthogneiss (20 percent blue-green hornblende).

* 12: Orofino Series: schistose, foliated, quartz-biotite orthogneiss.

13: Orofino Series: slightly schistose, quartzo-feldspathic dike (bears intrusive relation to number 12 above).

* 14: Amphibolite Dike: orthoamphibolite (70 to 80 percent blue-green hornblende).

15: Clearwater orthogneiss: coarse-grained, crystalloblastic, non-schistose, biotite quartz diorite orthogneiss (displays relict zoned igneous plagioclase, and relict hypideomorphic-granular texture).

16: Clearwater orthogneiss: coarse-grained, schistose, non-foliated, crystalloblastic, andesine-hornblende diorite orthogneiss (displays relict zoned igneous plagioclase).

17: Upper Basalt: hypocrystalline, fine- to medium-grained.

18: Clearwater orthogneiss: fine- to medium-grained, schistose, slightly foliated, crystalloblastic, labradorite-hornblende quartz diorite orthogneiss (contains 10 percent green and blue-green hornblende, in association with actinolite, and 30 to 40 percent ideoblastic quartz).

* 19: Lower Basalt: fine- to medium-grained, porphyritic.

* 20: Basalt Dike: fine- to medium-grained, holocrystalline.

* 21: Upper Basalt: fine- to medium-grained, holocrystalline, porphritic, cumuloporphyritic (Lolo Creek Flow).

* 22: Upper Basalt: fine- to medium-grained, hypocrystalline, cumuloporphyritic (Lolo Creek Flow).

23: Clearwater orthogneiss: fine- to medium-grained, very slightly schistose, crystalloblastic, biotite quartz diorite orthogneiss.

* 24: Orofino Series: essentially monomineralic coarse-grained marble with accessory quartz and tremolite (?).

* 25: Basalt Dike: fine- to medium-grained, holocrystalline (minor olivine).

26: Clearwater orthogneiss: coarse-grained, crystalloblastic, hornblende-andesine quartz diorite orthogneiss (contains 10 percent blue-green hornblende in association with actinolite).

27: Clearwater orthogneiss: coarse-grained, schistose, slightly foliated, crystalloblastic, biotite-hornblende-andesine quartz diorite orthogneiss (contains 20 percent blue-green hornblende in association with tremolite).

28: Clearwater orthogneiss: coarse-grained, non-schistose, crystalloblastic, hornblende-andesine quartz diorite orthogneiss.

29: Clearwater orthogneiss: coarse-grained, non-schistose, crystalloblastic, muscovite-biotic-andesine quartz diorite orthogneiss.

30: Clearwater orthogneiss: coarse-grained, slightly schistose, non-foliated, crystalloblastic, muscovite-biotite-andesine quartz diorite orthogneiss.

31: Clearwater orthogneiss: coarse-grained, schistose, non-foliated, crystalloblastic, biotite-hornblende-andesine quartz diorite orthogneiss (contains 30 percent blue-green hornblende in association with tremolite, and displays relict zoned igneous plagioclase).

32: Clearwater orthogneiss: coarse- to very coarse-grained, schistose, slightly foliasted, crystalloblastic, hornblende-andesine quartz diorite orthogneiss (contains 5 to 10 percent blue-green hornblende, and displays relict zoned igneous plagioclase, and relict hypidiomorphic-granular texture).

33: Clearwater orthogneiss: coarse- to very coarse-grained, non-schistose, crystalloblastic, biotite-hornblende, quartz diorite orthogneiss (contains 10 to 20 percent blue-green hornblende, and displays relict zoned igneous plagioclase. The plagioclase assemblage is very strained, and cleavages are bent. Tourmaline var dravite (?) is present).

34: Upper Basalt: fine- to medium-grained, hypocrystalline, microporphyritic.

35: Clearwater orthogneiss: fine- to medium-grained, non-schistose, crystalloblastic, andesine orthoamphibolite (dike rock cutting Clearwater orthogneiss quartz biotite orthogneiss. Contains 50 percent blue-green hornblende).

36: Clearwater orthogneiss: coarse-grained, non-schistose, crystalloblastic, biotite-hornblende-andesine quartz diorite orthogneiss (contains 10 percent blue-green hornblende. Tourmaline var dravite (?) is present).

* 37: Basalt Dike: fine- to medium-grained, hypocrystalline, and displays good ophitic to sub-ophitic texture.

38: Basalt Dike: fine- to medium-grained, hypocrystalline, and contains minor olivine.

39: Clearwater orthogneiss: coarse-grained, non-schistose, crystalloblastic, hornblende-andesine quartz diorite orthogneiss (contains 50 percent green and blue-green hornblende).

40: Clearwater orthogneiss: fine- to medium-grained, schistose, slightly foliated, crystalloblastic, biotite-andesine quartz diorite orthogneiss (contains minor blue-green hornblende).

Appendix C

Soils

At least three and possibly four major soil associations are present within the study area. The soils are the Kooskia, Gwin-Klicker-Mehlhorn, Lochsa-Yakus, and Suttler associations. Each particular association is connected in some way with road construction problems.

KOOSKIA

General Description

This association is found on the level (0 - 3 percent grade) to hilly (20 - 30 percent grade) dissected plateau surfaces at elevations ranging from 2000 to 3400 feet. The soils are formed in loess which overlies weathered basalt and consist of deep (50 - 60 inches) moderately well drained silt loams (USDA classification) over silty clay to clay subsoil. Wheat is the main cash crop, but the soil is also used for other crops, timber, and grazing.

Problems

According to the Soil Survey Report (1966, p. 6):

> Because of a perched water table and susceptibility to frost heaving, roads are difficult to maintain on most of these soils. Unsurfaced roads become soft and impassable during wet weather.

GWIN-KLICKER-MEHLHORN

General Description

The association is developed on steep (30 - 45 percent grade) canyon slopes along the Clearwater river and its tributaries where they are underlain by basalt or other basic bedrock. Occurrences range from elevations of 1000 to 4000 feet. The soil slopes are long and extend from ridges of the plateau to the bottom land. These soils have a forest vegetation primarily, but grass and shrubs exist on southerly and easterly slopes. These soils may be shallow (5 - 10 inches) or deep (30 - 50 inches) above bedrock. Silt loam to loam surface soil and a cobbly or gravelly clay loam or silt loam subsoil characterizes most of the soils in this association.

Problems

According to the Soil Survey Report, p. 9:

> Road building in most of this association is difficult because of the steep slopes and basalt bedrock. Roads need some surfacing material, which is available (sometimes) by crushing rock from local outcrops.

LOCHSA-YAKUS

General Description

This association, like the Suttler, consists of soils which have developed from rocks of granitic composition. They are present on steep (30 - 45 percent) to very steep (45 - 65 percent and greater) canyon slopes. Elevations of the soils range from 1100 to 3700 feet. The Lochsa series has a deep dark surface soil with a clayey subsoil and occurs mainly on canyon slopes. The Yakus series is shallow with a browner subsoil and occurs on southerly slopes. Most of the association is forested, but may have grass-shrub vegetation.

Problems

According to the Soil Survey Report, p. 11:

> Steepness of slopes is a hindrance to road building and recreation sites. Roads may be constructed satisfactorily on the contour.

SUTTLER

General Description

This soil association consists of moderately deep (20 - 30 inches) to very deep (greater than 50 inches) loamy soils, on sloping (3 - 10 percent) to very steep (45 - 65 percent) uplands, which have developed from granitic rock. Elevations for occurrences range from 2500 to 5000 feet. These soils are well-drained and have a thin organic layer, a thin grayish-brown or brown loam surface soil, and a loamy subsoil. The association is used mainly for producing timber or for producing grass for grazing.

Problems

According to the Soil Survey Report, p. 13:

> Road problems are subgrade, cutbank, and fill slope stability. The soft rock of the Suttler series soils is readily ripped and bladed with heavy machinery.