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PROGRESS REPORT ON THE GEOLOGY OF PART OF THE SNAKE RIVER CANYON, OREGON AND IDAHO

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Introduction

This report presents a summary of the principal geologic and physiographic features of the upper part of the Snake River Canyon between Oregon and Idaho. The area discussed extends from Farewell Bend near Huntington, Oregon downriver to Granite Creek 6 miles below Hells Canyon Dam (figure 1), a distance of 94 miles. Photographs and a series of geologic maps (plates I to VIII) are included to illustrate the topography and geology. The information presented synthesizes the results of geologic mapping in progress by the writers and others. Future field studies will continue the mapping northward to the Washington State line and more detailed work will be done in parts of the area described here. When the mapping in the canyon is completed, the information will be published by the Department of Geology and Mineral Industries as part of its Geologic Map Series.

In the present report, the major stratigraphic units observed in the Snake River Canyon between Farewell Bend and Granite Creek are described in the order they appear as one traverses the canyon from south to north, rather than chronologically. Because the region is geologically complex and stratigraphic and structural relationships in parts of the area are imperfectly known, the stratigraphic column which accompanies the maps is subject to revision as work progresses. The geological coverage of the Oregon portion of the canyon from Farewell Bend to Powder River was prepared by Brooks. Map data for the Idaho part of this segment was furnished by Dr. George Williams of the Idaho Bureau of Mines and Geology with respect to the Mineral quadrangle, and Dwight Juras, candidate for graduate degree at the University of Idaho, in reference to the Olds Ferry quadrangle. The geology of the Powder River to Brownlee Dam section was taken from Livingston (1923). The material for the Brownlee Dam to Granite Creek section was prepared by Vallier and was extracted largely from his doctoral dissertation (Vallier, 1967).

Fossil identifications were made for the writers by Doctors Ralph Imlay and N.J. Silberling of the U.S. Geological Survey, Francis Stehli of Western Reserve University, and Takeo Susuki of the University of California at Los Angeles.

Previous Mapping

Previously, little geologic mapping has been done in the Snake River Canyon, although work in surrounding areas of easier access has facilitated geologic interpretations presented here. Lindgren (1901) included the area from Farewell Bend to

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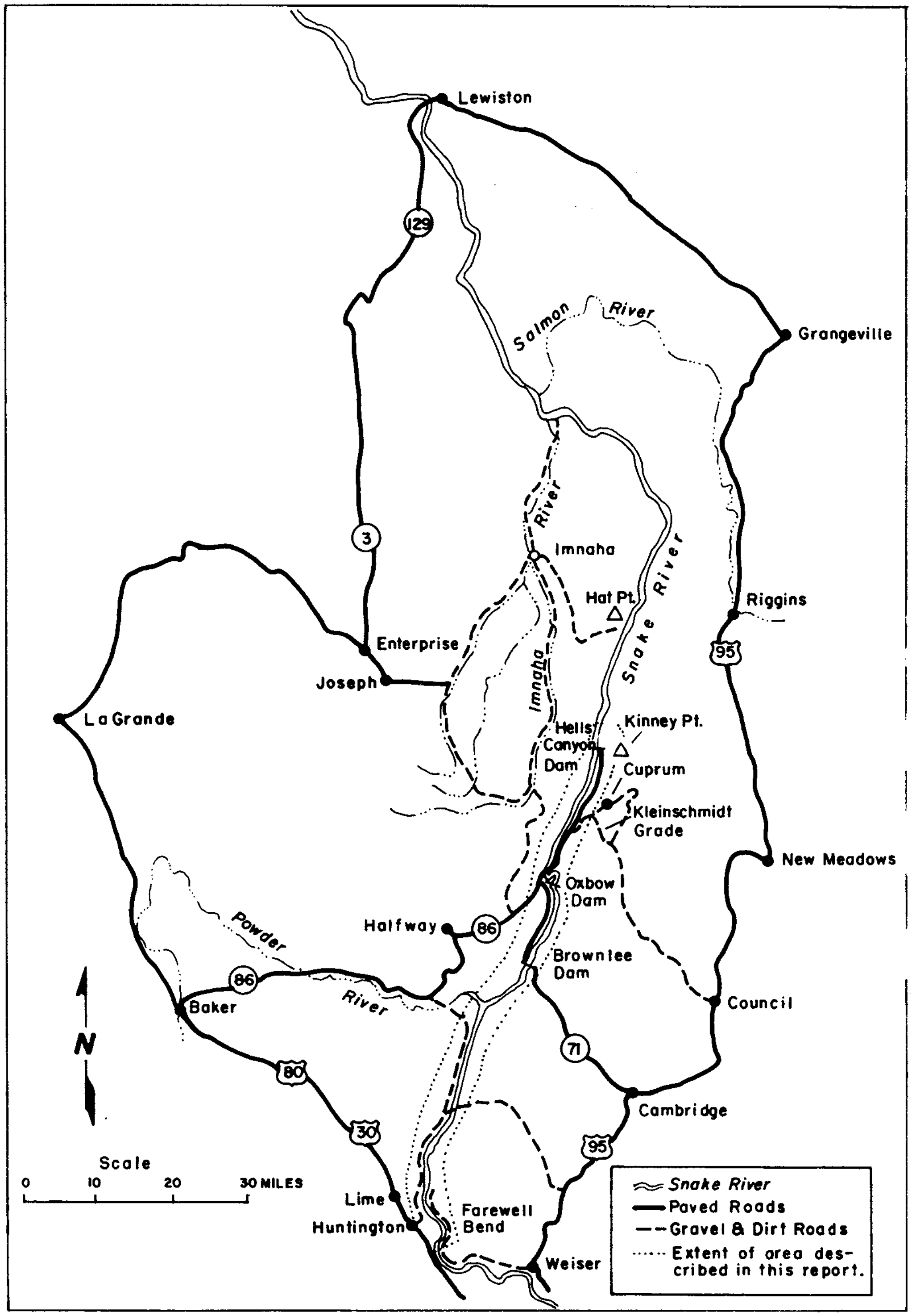


Figure 1. Index map of the Snake River Canyon and environs.

Ballard Creek in his large-scale geologic map of the gold belt of the Blue Mountains. Livingston (1923) mapped a narrow strip along both sides of the river from the mouth of Burnt River to Oxbow. Unpublished work in the Cuprum quadrangle during 1938-1941 by Ralph Cannon of the U.S. Geological Survey was adapted by Hamilton (1963). Parts of the Huntington and Olds Ferry quadrangles were mapped by Beeson (1955), Berry (1956), and Spiller (1958). A 20-mile section of the canyon in the vicinity of the Imnaha and Salmon Rivers, about 40 miles downstream from the area of this report, was mapped by Morrison (1963) for his doctoral dissertation.

Geography

General setting

At Farewell Bend, the Snake River leaves the relatively flat Tertiary lava- and sediment-filled Snake River Plain. From there northward for more than 160 miles the river flows in a deep canyon carved through the rugged mountains and gentle marginal slopes of the Blue and Seven Devils Mountains. Water-level elevation is 2077 feet at Farewell Bend and 860 feet at the Washington State line. Between Farewell Bend and Oxbow the river winds through an open, mountainous area characterized by long, narrow ridges, V-shaped canyons, and steep, predominantly soil-covered slopes cut by a multitude of draws and gulches. For most of this distance the canyon is 2000 to 3000 feet deep. At Oxbow the river makes a 180° bend and forms a curious topographic feature, the origin of which is described later in this report.

A few miles below Oxbow the river enters Hells Canyon, the deepest gorge in North America (figure 2). For more than 60 miles the canyon is 4000 to 6000 feet deep, as measured from the west rim. To the east the highest peaks of the Seven Devils Range tower nearly 8000 feet above the river. From promontories such as Hat Point on the west rim and Kinney Point on the east wall one sees a vast panorama of angular erosional features stepping precipitously down toward the river below. Nearly vertical cliffs, narrow benches, talus slopes, and countless sharply incised side canyons characterize the terrain. The river channel is generally narrow and in many places is deeply entrenched between sheer rock walls. Below Hells Canyon Dam, white-water rapids are numerous. Some are navigable only on a downriver course by highly skilled boatmen.

Vegetation is sparse within the canyon and is limited chiefly to grass on the slopes and brush and small trees along water courses. Patches of timber grow above 4000 feet elevation. The climate is one of moderately severe winters and hot summers. Summer temperatures on the canyon floor can rise to more than 115°.

Settlements in the canyon area are widely separated. Operation and maintenance of the dams and the raising of cattle and sheep provide employment for most of the permanent inhabitants.

Access

From Hells Canyon Dam upriver nearly to Weiser, Idaho, the floor of the canyon is flooded by water impounded by three dams recently constructed by the Idaho Power & Light Co. These are, from south to north, Brownlee, Oxbow, and Hells Canyon. Access to the dams is by way of Oregon Highway 86 from Baker to Oxbow, and Idaho Highway 71 from Cambridge to Brownlee. Paved roads along the three reservoirs connect Brownlee Dam on the south with Hells Canyon Dam on the north. A

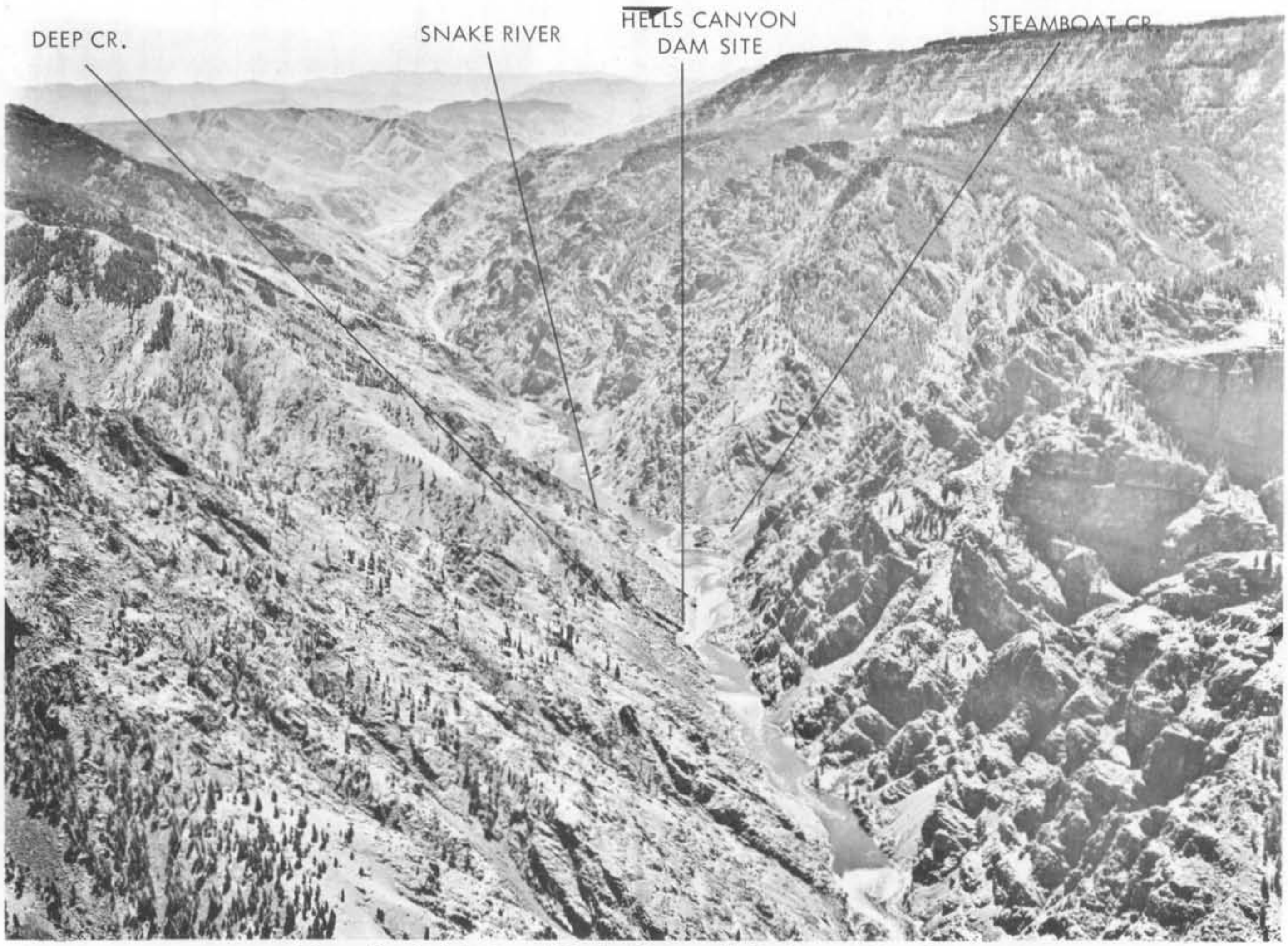


Figure 2. Aerial view of Snake River at Hells Canyon Dam Site.

gravel road from Huntington follows Burnt River to its confluence with the Snake, near the upper end of Brownlee Reservoir. This road then continues northward along the reservoir to the general vicinity of Sturgill Creek. From here it climbs out of the canyon and connects with Oregon Highway 86 at Richland. Gravel and dirt roads from Weiser, Idaho provide access to short segments of Brownlee Reservoir. The Kleinschmidt Grade climbs the canyon wall on the Idaho side from a point about 6 miles north of Oxbow to Cuprum. Between Hells Canyon Dam and the Washington State line there are no roads along the river and access is difficult.

Mineral Deposits

Although there is little or no mining at present, deposits of gold, silver, copper, and gypsum have been commercially exploited in past years. In addition, there are important limestone reserves in the Connor Creek and Big Bar areas. Known areas of mineralization are described in mining reports on the Seven Devils region by Livingston and Laney (1920) and Cook (1954); the Mineral and Cuddy Mountain districts by Livingston (1923); the Mineral district by Anderson and Wagner (1952); and the Iron Mountain district by Mackin (1953). Other reports concerned with mineral deposits in the Snake River Canyon are by Swartley (1914), Moore (1937), Libbey (1943), and McDivitt (1952).

Geology

Before the Snake River Canyon existed, the Blue and Seven Devils Mountains were partly, if not entirely, buried by Miocene basalt flows of the Columbia River Group. These lava flows poured out on rugged, mountainous terrain, accumulating to a thickness of thousands of feet in low places and forming a vast plateau. During Pliocene time the mountains were uplifted by folding and faulting, and much of the lava has since been eroded, exposing ancient metamorphic and igneous rocks beneath. For much of its length the canyon of the Snake River has been cut through the plateau-forming basalts and deep into the old mountains. The profile of the old land surface beneath the lavas is visible at many places in the canyon.

Livingston (1928) and Wheeler and Cook (1954) discussed the origin of the canyon and postulated that in late Tertiary time Snake River followed a far different course than the present one.

Pre-Tertiary rocks

Rocks representative of most of the major pre-Tertiary stratigraphic units of the eastern Blue Mountains are exposed on the canyon walls. They comprise a heterogeneous assemblage of eugeosynclinal volcanic and sedimentary rocks and a wide variety of plutonic rocks that represent at least two major stages of intrusive activity. The bedded rocks include thick sections of Paleozoic phyllite, chert, siliceous argillite, massive to schistose greenstones and limestone; Middle and Upper Triassic volcanic flows, volcaniclastic rocks, limestone, and conglomerate; and Upper Triassic (?)-Jurassic metagraywacke, slate and phyllite. The older group of plutonic rocks includes gabbro, diorite, quartz diorite, and serpentinized ultramafic rocks of Permian-Triassic age. The younger plutonic rocks, probably of Cretaceous age, are mainly granodiorite. A multitude of dikes, many unrelated to the major intrusive episodes, cut the pre-Tertiary units.

Figure 3. Air view of upper part of Brownlee Reservoir downstream from Farewell Bend. Union Pacific Railroad crosses the Snake River at mouth of Burnt River. Upper Triassic rocks are exposed along both sides of reservoir.

Figure 4. Air view northwest from a point about 5 miles north of Huntington. Contact (dashed line) between Upper Triassic greenstone sequence below and younger Mesozoic graywacke sequence above. Contact marked by red and green conglomerate layer. Old gypsum mine in center.

The bedded rocks and older intrusives have been folded and regionally metamorphosed to the greenschist facies. Rocks of higher metamorphic grade are found near the margins of plutonic bodies.

The pre-Tertiary strata have a general east-to-northeasterly trend and the river has cut diagonally across them. The prevailing strike of compositional layering, planes of schistosity, and major fold axes is east to northeast and dips are generally to the northwest. Many large and small faults complicate the structure.

Tertiary rocks

The Tertiary lava series consists mainly of a great number of superimposed flows. Most of the rocks are brownish olivine basalts. Volcaniclastic units, many of them light colored, are sparsely distributed through the sequence. The Tertiary rocks have in most places been only gently warped and are relatively little altered. They are cut by steeply dipping normal faults of predominantly north to northwesterly trend.

Geologic Traverse along the Snake River Canyon

The following eight sections describe the geology that one encounters in traversing this part of the Snake. Most of the 94-mile stretch is accessible by road. Exceptions are between Sturgill and Brownlee Dam and below Hells Canyon Dam.

1. Farewell Bend to Rock Creek

From Farewell Bend north to the mouth of Rock Creek most of the rocks exposed on the canyon walls are altered lavas and volcaniclastic rocks of Upper Triassic age (plates I and II). Massive andesitic flows and pyroclastic rocks intercalated with coarse breccias and conglomerates composed mainly of volcanic detritus are the dominant rock types. Thin-bedded tuffaceous sandstone, shale, argillite, and limestone interbeds found throughout the sequence locally contain abundant Upper Triassic marine fauna. The general area described is shown in figure 3.

A small granitic body is exposed about 3 miles by road north of the mouth of Burnt River. The age of this intrusive has not been determined. The rocks are metamorphosed to a slightly higher degree than is typical of the Cretaceous granitic rocks elsewhere in the region and hence may be somewhat older.

This predominantly volcanic sequence is unconformably overlain by a distinctive red and green sheared conglomerate unit, which is well exposed on the south side of the mouth of Rock Creek and above the old gypsum mine (figure 4). The unit is 300 to 400 feet thick and is almost continuously traceable in a northeast-southwest direction for more than 20 miles (Brooks, 1967). At Rock Creek the conglomerate is underlain by a thin limestone unit which is absent on the Oregon side of the canyon. The limestone may be buried beneath the conglomerate or possibly it was eroded prior to deposition of the conglomerate. Limestone again appears beneath the conglomerate farther west in the vicinity of Lime.

2. Rock Creek to Soda Creek

Overlying the red and green conglomerate unit and extending northward from the mouth of Rock Creek nearly to the mouth of Soda Creek is a thick sequence of

Figure 5. This photograph illustrates the steeply dipping, tightly folded aspect of the graywacke, slate, and phyllite sequence (mouth of Connor Creek).

Figure 6. Characteristic erosion surface of phyllite-greenschist-marble sequence in the Sturgill Creek area. Tertiary lavas in background.

sheared graywacke, slate, and phyllite with minor amounts of conglomerate, tuff, and limestone (plates II and III). The rocks are mainly thin bedded, tightly folded, and in most places dip steeply northwest (figure 5). Bedding and slaty cleavage are usually almost parallel. A faint silvery sheen is visible on cleavage surfaces in many of the rocks and is due to the development of sericite and chlorite.

The apparent thickness of the sequence is more than 20,000 feet. Probably there has been repetition of beds by isoclinal folding and faulting, so that the actual thickness may be considerably less. Upper and Lower (?) Jurassic fossils have been collected from strata in extreme southern parts of the sequence immediately above the red and green conglomerate unit (Livingston, 1932; Imlay, 1964; and Imlay, written communication, 1966). Although no supporting fossil evidence has yet been found, it is surmised that older Mesozoic rocks are also present.

About a third of a mile south of Soda Creek there is exposed in the road cut a major fault or unconformity which forms the northwest boundary of the graywacke sequence.

3. Soda Creek to the mouth of Powder River

The rocks north of the graywacke contact near Soda Creek consist of thinly layered siliceous to pelitic phyllites with lesser amounts of massive to schistose greenstones and marble (plates III and IV) (figure 6).

A thick marble unit, which forms the ridge south of Soda Creek, extends southwestward across the heads of Connor (figure 7), Fox, and Hibbard Creeks, and eastward into Idaho. Elsewhere marbleized limestone occurs as detached lenses and pods from a few inches to several hundred feet in longest dimension (figure 8).

Rocks included in the phyllite series are traceable westward into the Baker quadrangle, where Gilluly (1937) subdivided them into two formations: the Burnt River Schist of unknown age and the Elkhorn Ridge Argillite largely of Permian age. The phyllites are lithologically different and more intensely deformed and metamorphosed than the graywacke sequence to the south. Cleavage intersections and crenulations form lineations on planar surfaces in the phyllitic rock (figures 9 and 10). Sills, dikes, and small irregular masses of gabbro, diabase, and serpentine locally intruded into the sequence have been folded and metamorphosed to approximately the same degree as the enclosing rocks.

The pre-Tertiary section is in fault contact with basalt flows of the Columbia River Group at the mouth of Powder River (figure 11). Other post-Miocene faulting can be seen in this general region (figure 12).

4. Mouth of Powder River to Oxbow, Oregon

From the mouth of Powder River nearly to Oxbow, pre-Tertiary rocks appear only as small inliers surrounded by flat or gently dipping basalt flows (plate V). The flows are more than 2000 feet thick at Brownlee Dam. A serpentine body now almost inundated by the reservoir occurs about 5 miles above the dam. Metamorphosed pre-Tertiary rocks crop out in two places along the road between the Brownlee and Oxbow Dams. The Oxbow of the Snake River is also cut in pre-Tertiary rocks.

The first inlier occurs about 2 miles north of Brownlee Dam. Pre-Tertiary rocks rise nearly 1000 feet above the river on the Idaho side of the canyon. Metamorphosed quartz diorite, gabbro, and diorite are sheared along northeast-trending faults.

Figure 7. Headwaters of Connor Creek. Marbleized limestone in phyllite-greenschist-marble sequence forms rough, jagged exposure. Tertiary basalt covers the limestone at upper right edge of the photograph. Rounded slopes in foreground are underlain by Mesozoic graywacke.

Figure 8. Visible outcrops on the slope above are mostly detached pods and lenses of limestone that have been "tectonically scattered" by folding and shearing out of once continuous limestone beds.

Figure 9. Typical outcrop of siliceous phyllite. Steep southwest-plunging lineations parallel to fold axes mark intersections of bedding and axial plane cleavage.

Figure 10. Close-up of similar structural features in limestone. Note small, steeply plunging folds.

Figure 11. Air view down Snake River. Powder River is on the left. Pre-Tertiary rocks in the foreground are in fault contact with flat-lying Miocene lavas.

Figure 12. Large Tertiary fault at the head of Quicksand Creek drops Tertiary lavas about 1200 feet on the right-hand side of the creek.

Fluxion structure parallels the faults. Volcaniclastic rocks, limestone, and argillite of uncertain age are faulted against the plutonic rocks. These bedded rocks dip steeply and in places are isoclinally folded. Similar intrusive relationships probably occur on the Idaho side of the canyon.

Miocene volcanics are at river level for about 4 miles between inliers of pre-Tertiary rocks. Some basalt tuffs of Miocene age occur along the road. About a mile south of the Oxbow, near the mouth of Warm Springs Creek, travertine deposits jut out as white shoulders against the somber browns of the basalt.

The second inlier, at the mouth of Cottonwood Creek, is composed of sheared and mylonitized rocks of the Oxbow-Cuprum shear zone (Taubeneck, 1966). Across the river, dark-colored diorite and gabbro are exposed.

The Oxbow of the Snake River is a conspicuous physiographic feature that is characterized by abrupt bends and straight segments (figure 13). It probably was carved when the river was superimposed from the overlying Columbia River Basalt onto the pre-Tertiary rocks. Two wind gaps, representing former stream channels, cross the ridge of the Oxbow. The long, straight segments of the river are controlled by a set of pre-Miocene faults which trend N. 30° E. to N. 80° E. parallel to the Oxbow-Cuprum shear zone.

The geology of the Oxbow was described by Stearns and Anderson (1966). Rocks of the older intrusive complex are metamorphosed and consist of albite granite, quartz diorite, diorite, and gabbro. The plutonic rocks intruded Permian rocks and all were later sheared and mylonitized along the Oxbow-Cuprum shear zone (figure 14), which continues to the northeast for more than 20 miles. The northern part of the Oxbow-Cuprum shear zone is being studied by W. H. White, doctoral candidate at Oregon State University.

5. Oxbow, Oregon to the Kleinschmidt Grade

For the first $1\frac{1}{2}$ miles north of Oxbow, along the Idaho Power & Light Co. road, the rocks are bluish-green keratophyre flows and keratophyre tuffs that are cut by blackish-green dikes (plate VI). Since these rocks are overlain by Permian strata, they may be of Permian age or older. Along the road, changes in color and rock types mark a fault contact between the older rocks and the Permian strata.

Near Homestead a section of Middle Triassic rocks, consisting of graywacke, spilite flows, volcaniclastic rocks, and limestone, is faulted into the Permian strata.

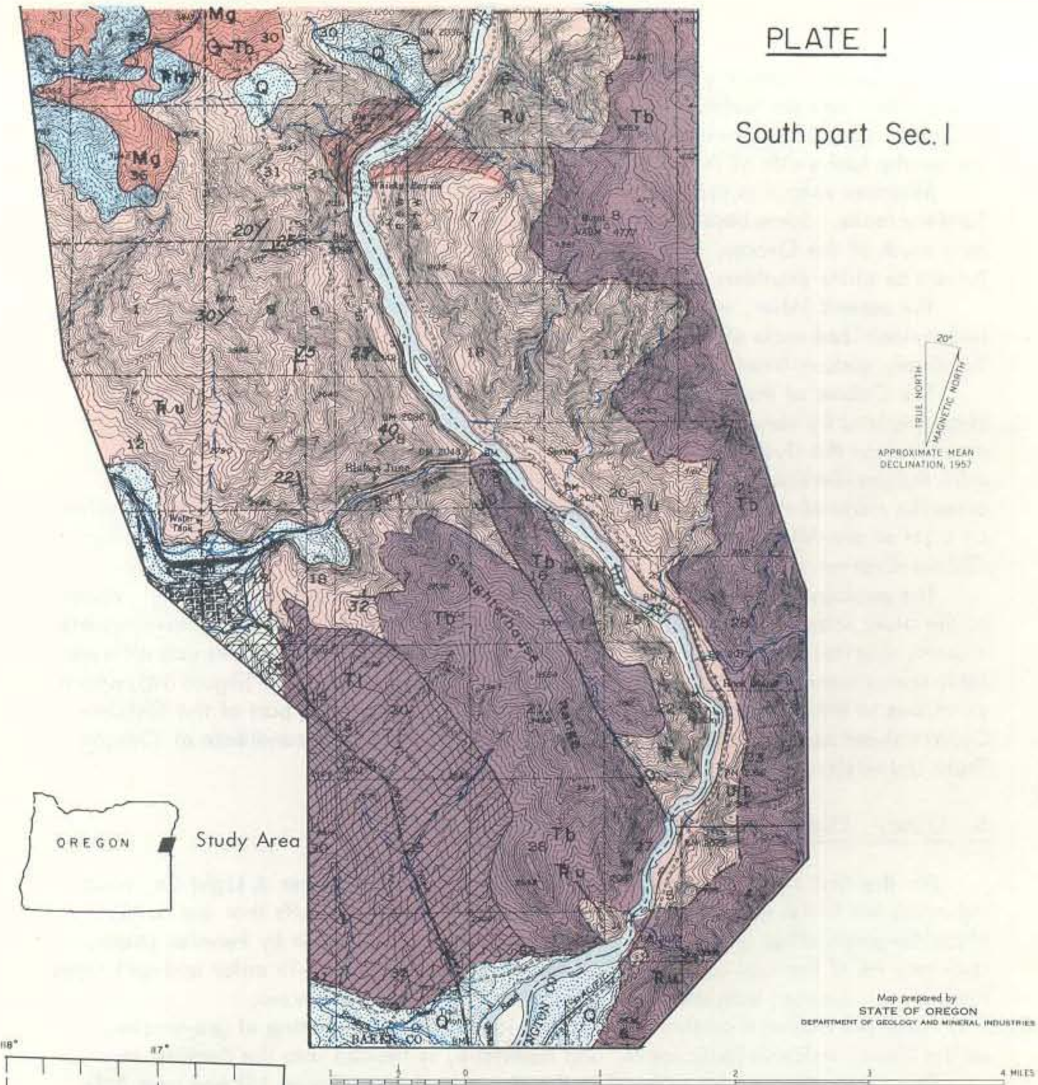
Permian rocks are best exposed in the Homestead area (figure 15) and near Ballard Creek (figure 16). Volcaniclastic rocks, spilite and keratophyre flows, conglomerate, argillite, and limestone are the dominant rock types. The stratigraphic thickness may exceed 8000 feet. Vertically graded tuff units, from 1 to 50 feet thick, are common. Conglomerate beds reach thicknesses of more than 40 feet and some beds contain clasts more than a foot in diameter. The occurrence of granitic clasts in the Permian conglomerates is important in any paleotectonic interpretations, since they consist of rock types very similar to the old plutonic sequence of gabbro, diorite, and quartz diorite.

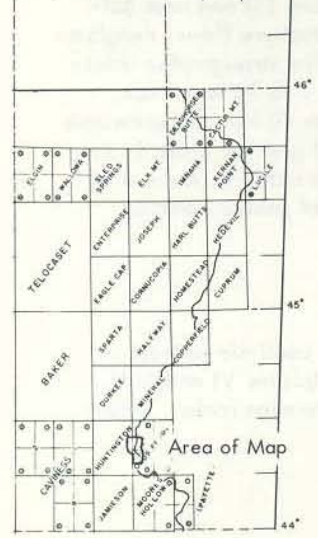
6. Kleinschmidt Grade to Big Bar, Idaho

Permian rocks, well exposed on the Kleinschmidt Grade, continue to crop out along the IPALCO road for about 2 miles to Limepoint Creek (plates VI and VII). Here, a fault or series of faults separates Upper Triassic and Permian rocks. About

PLATE I

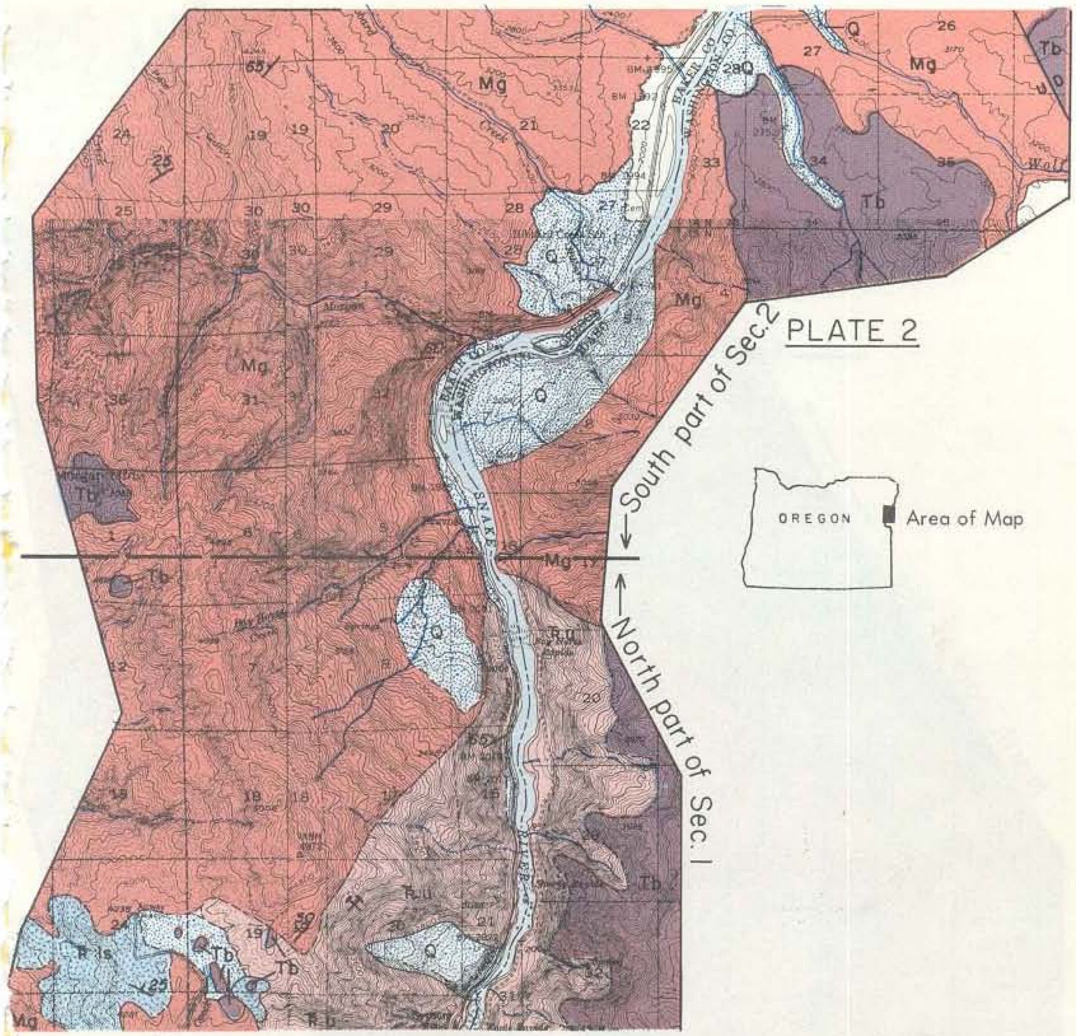
South part Sec. I

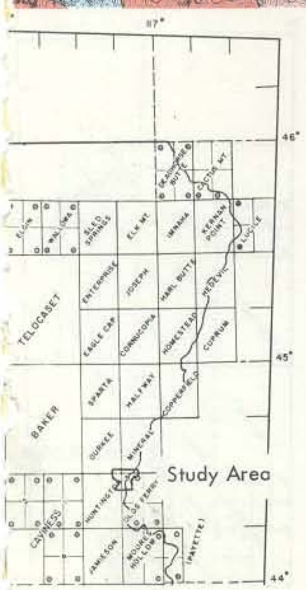




Q	Quaternary deposits
Tl	Tertiary lake sediments
Tb	Tertiary basalt
Ji	Granitic intrusives
Mg	Mesozoic metasediments
Ru	Undifferentiated marine volcaniclastics
Rls	Limestone and calcareous shale

See explanation on page 250.





Q	Quaternary deposits
Tb	Tertiary basalt
Mg	Mesozoic metasediments
₸u	Undifferentiated marine volcaniclastics
₸ls	Limestone and calcareous shale

See explanation on page 250.

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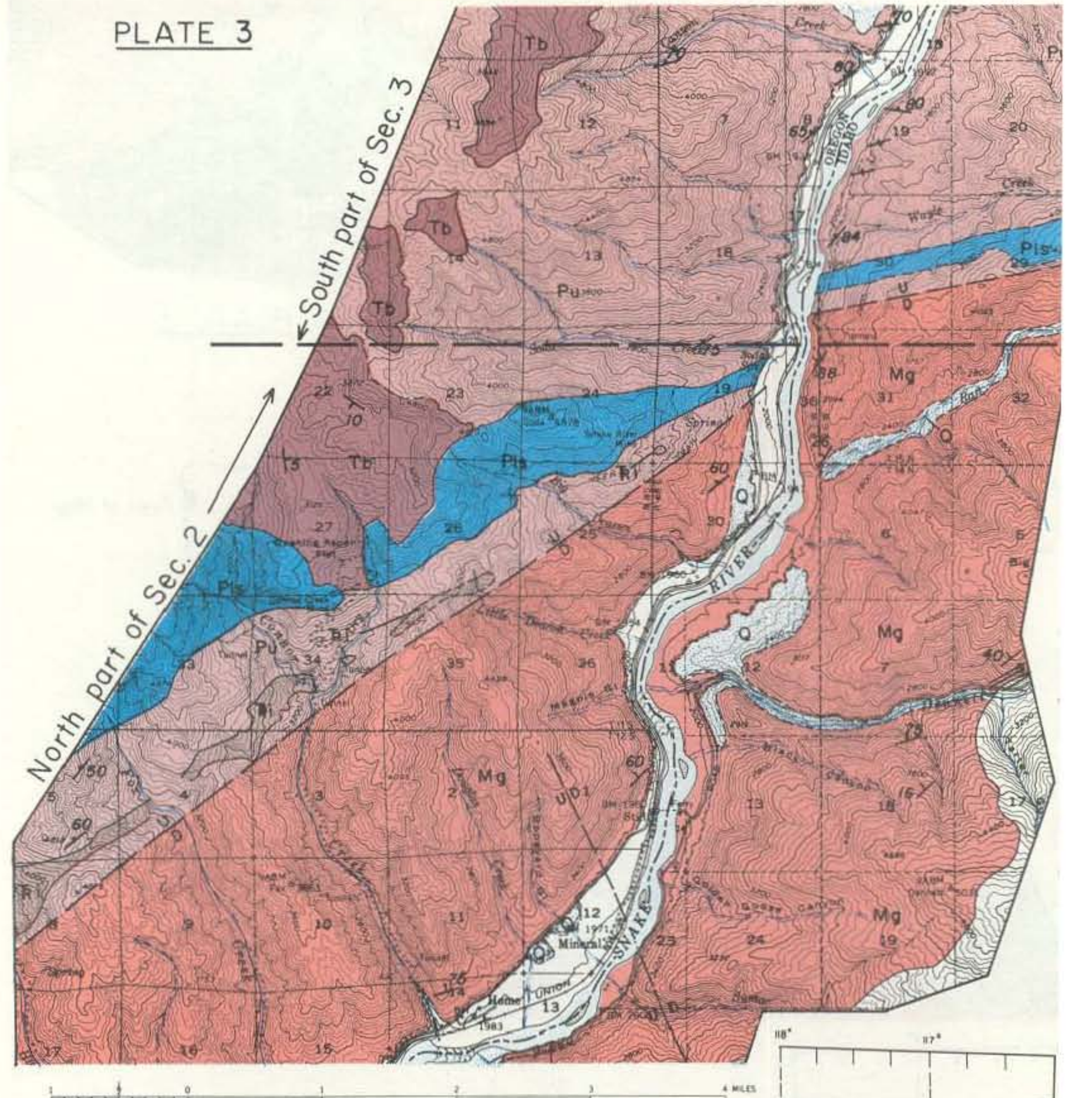
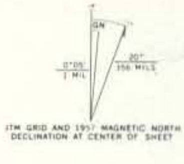
PLATE 3





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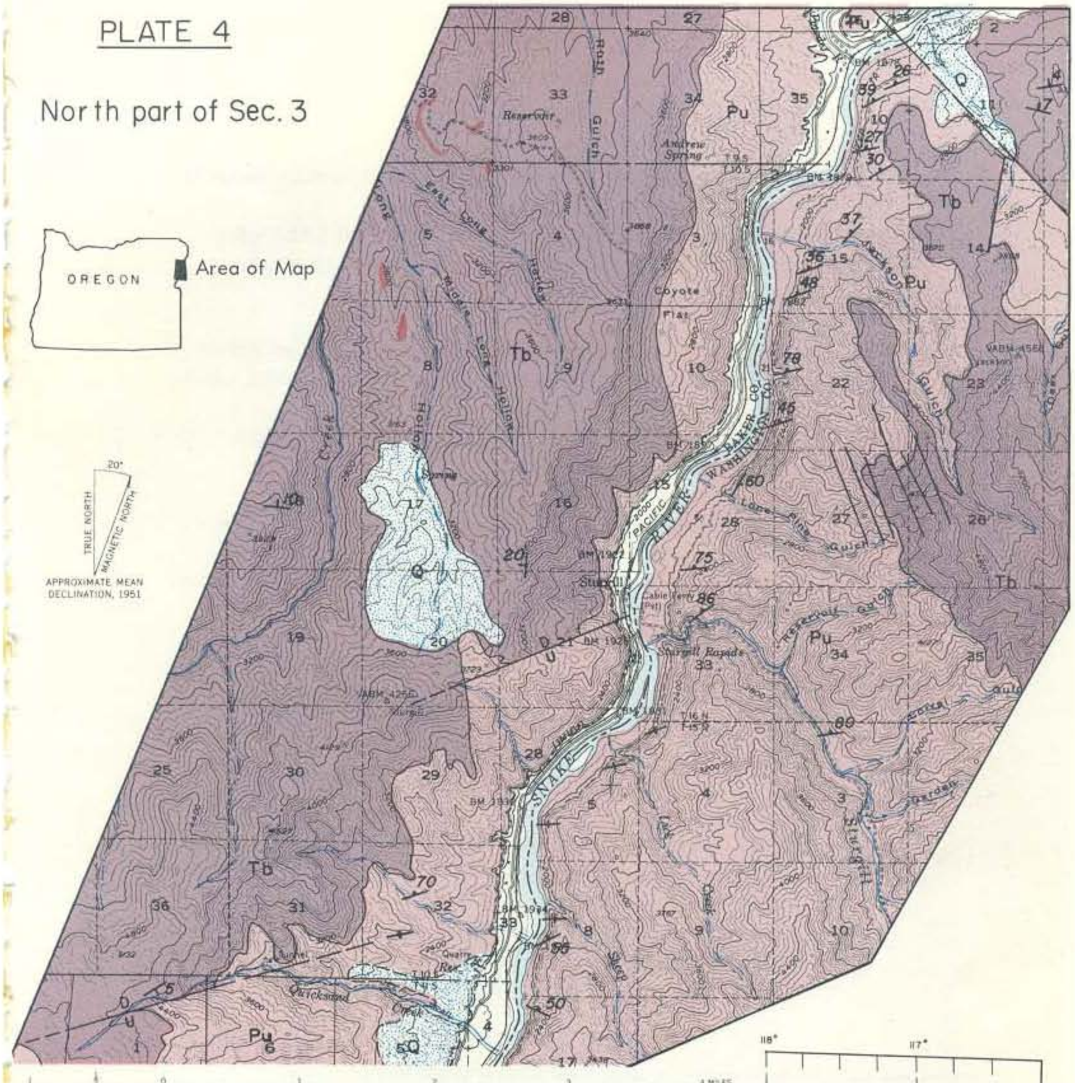
- Q — Quaternary deposits
- Tb — Tertiary basalt
- Mg — Mesozoic metasediments
- Pls — Massive to thin-bedded marble
- Ri — Gabbro and metagabbro
- Pu — Undifferentiated phyllites, greenstones, argillites, chert, and limestone

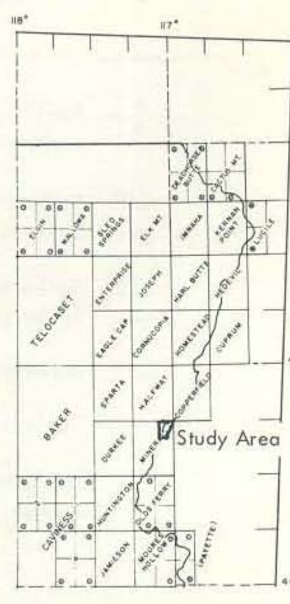
See explanation on page 250.

PLATE 4

North part of Sec. 3



Distance between top of PLATE 4 and bottom of PLATE 5, 8.5 river mile gap. Only Tb is exposed.



Q	Quaternary deposits
Tb	Tertiary basalt
Pu	Undifferentiated phyllites, greenstones, argillites, shert, and limestone

See explanation on page 250.

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EXPLANATION

Q	Quaternary alluvium, landslide debris, and terrace deposits.
Tl	Tertiary lake sediments. Loosely consolidated tuffaceous mudstone and sandstone with intercalated gravels, tuff, and basalt flows.
Tb	Tertiary basalt. Correlates with the Columbia River Basalt Group. Mainly basalt flows with minor volcaniclastic rocks.
Ji	Granitic intrusive rocks, age uncertain, probably Late Jurassic-Early Cretaceous.
Mg	Jurassic and possibly older Mesozoic metagraywacke, slate, and phyllite with minor conglomerate, tuff, and limestone. Tightly folded. Southern contact marked by red and green sheared conglomerate unit 300 to 400 feet thick.
Ꞧu Ꞧls	Upper Triassic. (Tru) undifferentiated marine volcanic and volcaniclastic rocks, with subordinate shale and limestone interbeds. (Trls) mostly limestone and calcareous shale.
Ꞧi	Lower Triassic intrusives, mainly gabbro and metagabbro.
Pu Pls	Intensely deformed rocks; probably mostly Paleozoic. Includes small Lower Triassic intrusive bodies (Tri). (Pu) undifferentiated siliceous, pelitic and calcareous phyllites, massive to schistose greenstones and volcaniclastic rocks, argillite, chert, and scattered pod-like bodies of limestone. (Pls) massive and thin-bedded marble with interbedded calcareous phyllite.

~~	Unconformity; questioned where uncertain.
U/D	Fault; U, upthrown side; D, downthrown side; dashed where approximately located.
60	Strike and dip of bedding
	Strike and dip of vertical bedding
40	Strike and dip of foliation
	Strike and dip of vertical or nearly vertical foliation
	Intrusive Dike
----	Contact; dashed where approximately located

Topographic base from U.S.G.S. 15-minute quadrangle maps: Durkee, Huntington, Mineral, and Olds Ferry

EXPLANATION

Q	Quaternary deposits; alluvium, landslide debris, and terrace deposits.
Tb	Tertiary basalt; correlates with the Columbia River Basalt Group; basalt flows and minor volcaniclastic rocks.
Ji	Jurassic intrusive; gabbro and diorite.
TRmb	Upper Triassic Martin Bridge Formation; gray limestone and dolomite with minor amounts of shale.
TRu	Middle and Upper Triassic undifferentiated; marine volcaniclastic rocks, spilitic flows, and minor amounts of limestone.
TRi	Lower Triassic (?) intrusives; quartz diorite, albite granite, diorite, and gabbro.
?	Uncertain correlation; probably Permian and/or Triassic marine volcaniclastic rocks, spilite flows, shale, and limestone (blue). Includes those rocks in the small inlier below Brownlee Dam.
Fz	Foliated zone; cataclastic and mylonitized Paleozoic and Triassic(?) rocks. Includes Lower Triassic (?) mylonitized intrusives. These rocks are part of the Oxbow-Cuprum shear zone.
Pu	Permian undifferentiated; marine volcaniclastic rocks, spilite and keratophyre flows, minor amounts of limestone and argillite.
P (?)	Permian (?) or older Paleozoic; keratophyre flows and tuffs.

~?~ Unconformity; questioned where uncertain.

U/D Fault; U, upthrown side; D, downthrown side; dashed where approximately located.

Axes of folding; anticline, syncline.

60 Strike and dip of bedding

Strike and dip of vertical bedding

40 Strike and dip of foliation

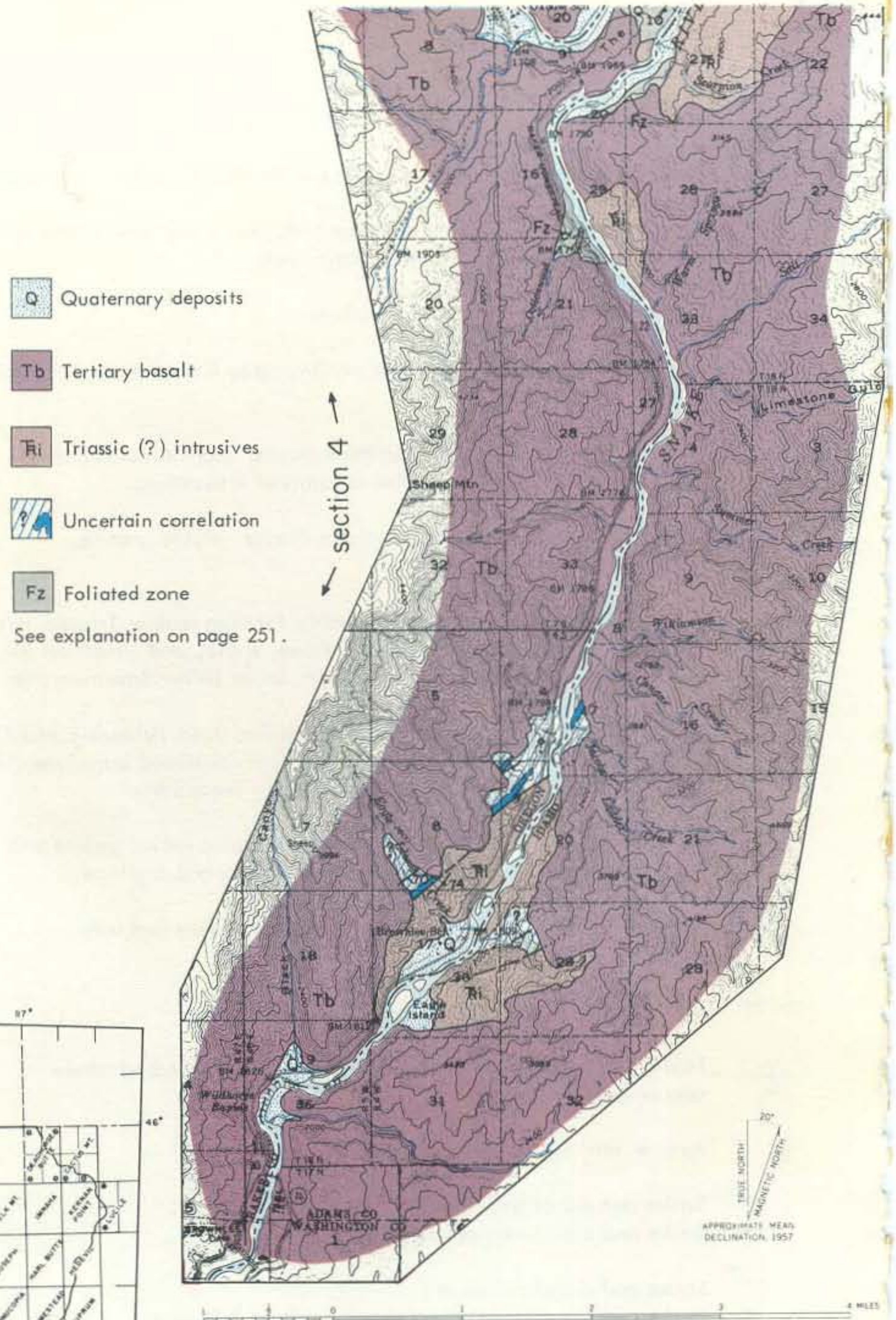
Strike and dip of vertical or nearly vertical foliation

Significant fossils

Contact; dashed where approximately located

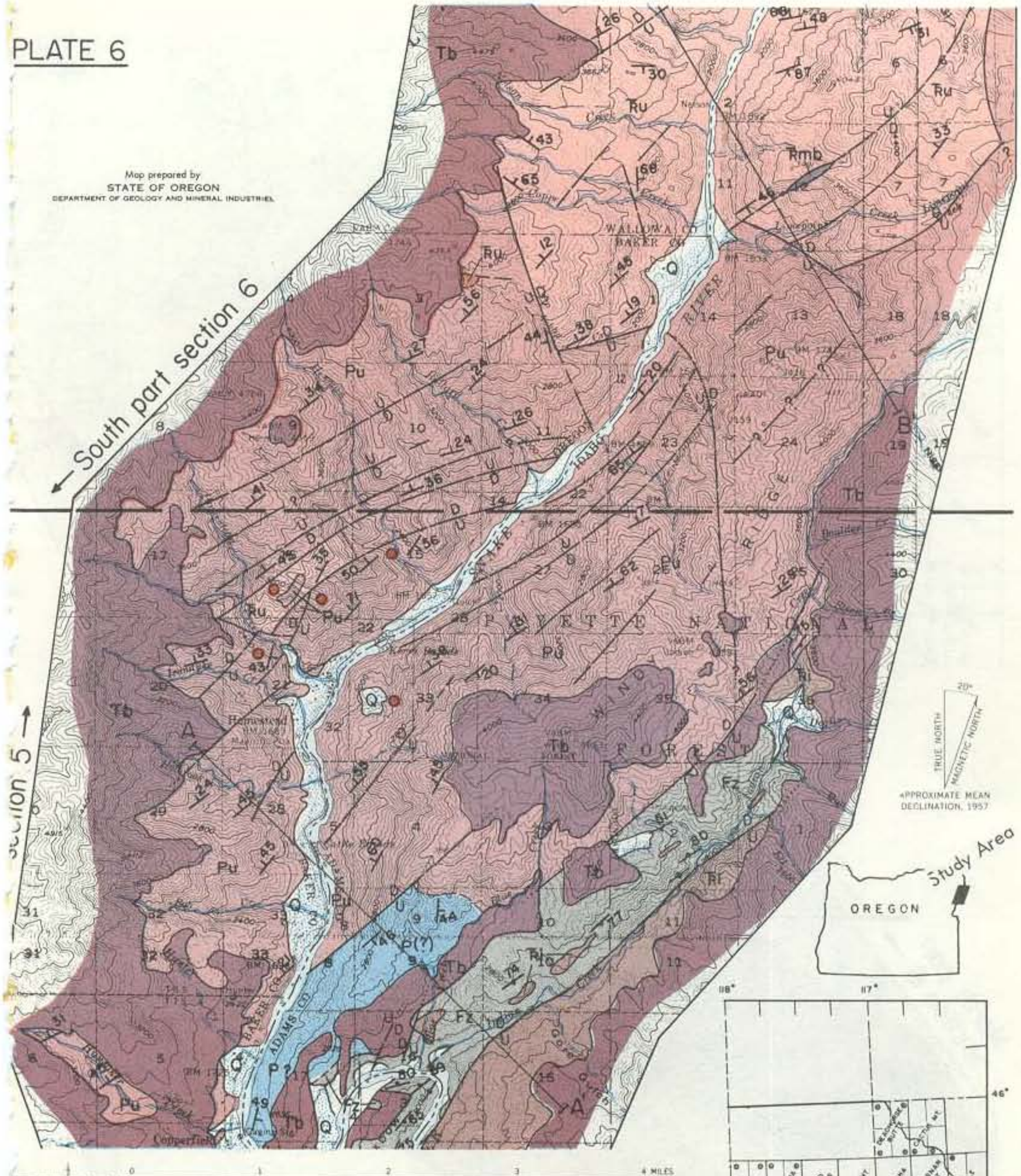
Topographic base from U.S.G.S. 15-minute quadrangle maps: Copperfield, Cuprum, Homestead, and He Devil.

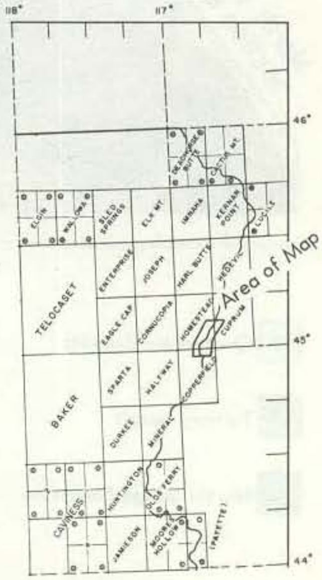
PLATE 5



Distance between bottom of PLATE 5 and top of PLATE 4, 8.5 river mile gap. Only Tb is exposed.

PLATE 6

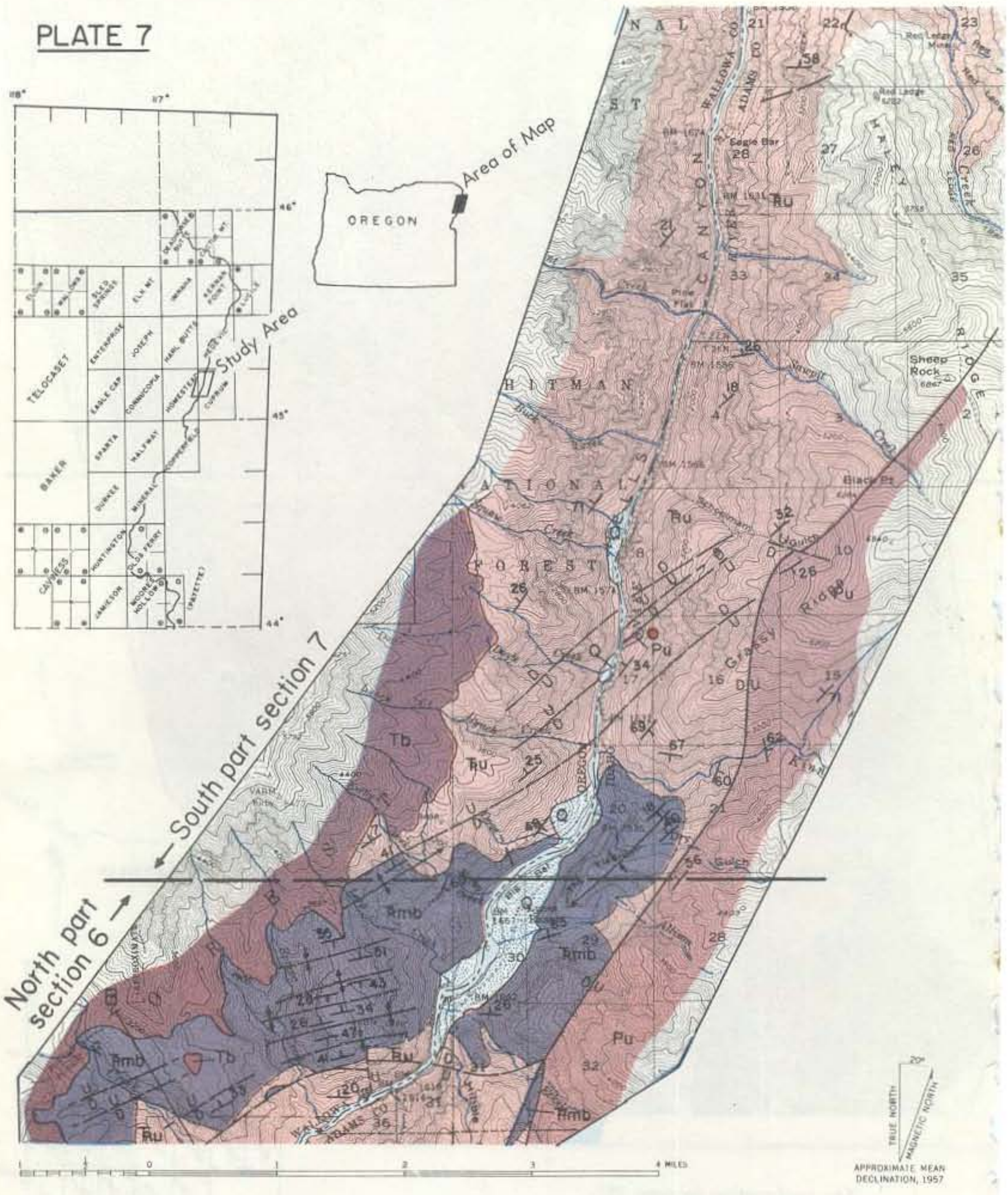




See explanation on page 251.

Q Quaternary deposits	Ti Triassic (?) intrusives
Tb Tertiary basalt	Fz Foliated zone
Tmb Martin Bridge Formation	Pu Permian undifferentiated
Tu M-U Triassic undifferentiated	P(?) Permian (?) or older

PLATE 7



Q Quaternary deposits

Tb Tertiary basalt

Rmb Martin Bridge Formation

Ru M-U Triassic undifferentiated

Pu Permian undifferentiated

See explanation on page 251.

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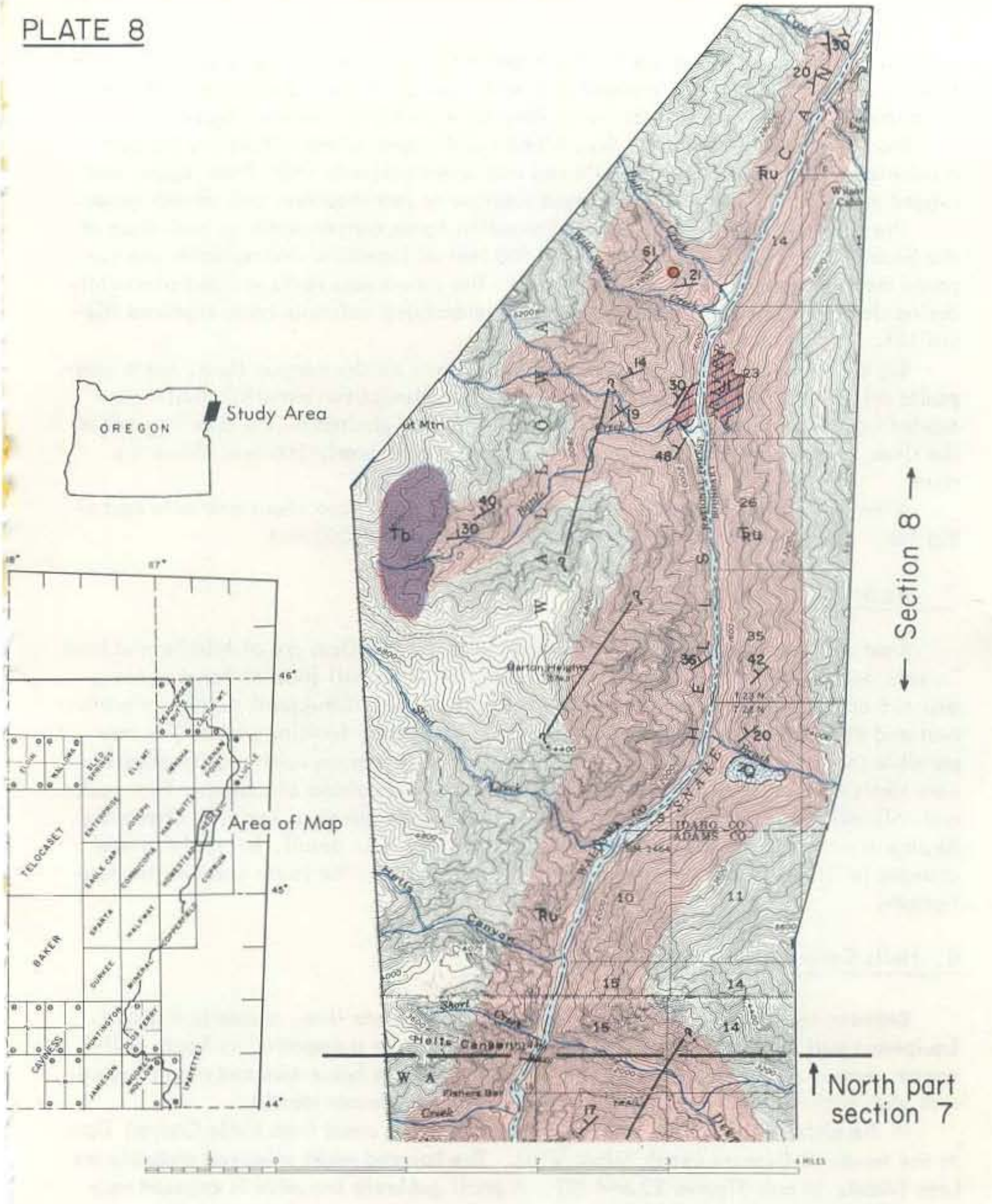
PLATE 8



Q Quaternary deposits

Tb Tertiary basalt

Ji Jurassic intrusive

Ru M-U Triassic undifferentiated

Map prepared by STATE OF OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

ee explanation on page 251.

half a mile northeast of the mouth of Limepoint Creek, a fault slice of Upper Triassic (Martin Bridge) limestone is exposed as a white peak. A fault slice in Eckels Creek is composed of limestone and separates Permian from Triassic strata (figure 17).

From Limepoint Peak to Big Bar, Middle and Upper Triassic rocks are exposed in a complex anticline. Upper Triassic red and green volcanic rocks form jagged and rugged outcrops. Middle Triassic strata weather to low shoulders and smooth slopes.

The Upper Triassic Martin Bridge Formation forms canyon walls on both sides of the Snake River at Big Bar. More than 1700 feet of limestone and dolomite are exposed along the south side of Kinney Creek. The calcareous rocks yielded plastically during deformation, but the more competent underlying volcanic rocks ruptured (figure 18).

Big Bar (figure 19), a major topographic feature on the canyon floor, has a composite origin. River-bar gravels interfinger with alluvial fan materials that were eroded from the canyon wall. A landslide, which originated on the opposite side of the river, capped the bar and formed a hill that stands nearly 200 feet above the river.

A major fault separates Permian and Upper Triassic strata about one mile east of Big Bar. Apparent stratigraphic separation is at least 10,000 feet.

7. Big Bar to Hells Canyon Dam

Most of the rocks between Big Bar and Hells Canyon Dam are of Middle and Late Triassic age (plates VII and VIII). One exception is a small slice of Permian rocks exposed across the river from the mouth of Doyle Creek. Structural trends are northeast and beds dip to the northwest. Repetition of beds by faulting probably is responsible for the apparent thickness of the strata. The canyon continues to deepen near Hells Canyon Dam (figures 20 and 21). Rugged shoulders of volcanic flow rocks and volcaniclastic rocks cast long shadows in the early mornings and late afternoons. Stratigraphic relationships of these rocks are not known in detail, but rapid lateral changes in lithology are common and thick dikes that cut the strata confuse the stratigraphy.

8. Hells Canyon Dam to Granite Creek

Between Hells Canyon Dam and the Washington State line, access is difficult. Equipment and supplies required by field parties must be transported by boat, helicopter, horse, or backpack. The legwork of mapping is hazardous and requires unusual physical stamina in the high temperatures of the summer months.

In the summer of 1967, a brief reconnaissance was made from Hells Canyon Dam to the mouth of Granite Creek (plate VIII). The layered rocks observed probably are Late Triassic in age (figures 22 and 23). A small gabbroic intrusive is exposed near the canyon floor at Battle Creek.

Future Program

No geologic maps of the canyon from Granite Creek to the Washington State line have been published. This segment, as the aerial photographs (figures 24 and 25) clearly show, includes the most rugged and inaccessible part of Hells Canyon. As noted in the Introduction, future field studies are planned that will continue the mapping to the Oregon-Washington boundary. This section is expected to reveal

Figure 13. The Oxbow of the Snake River. Erosion along northeast-trending shear zones and foliations resulted in a 180° bend in the river.

GENERALIZED GEOLOGIC SECTION

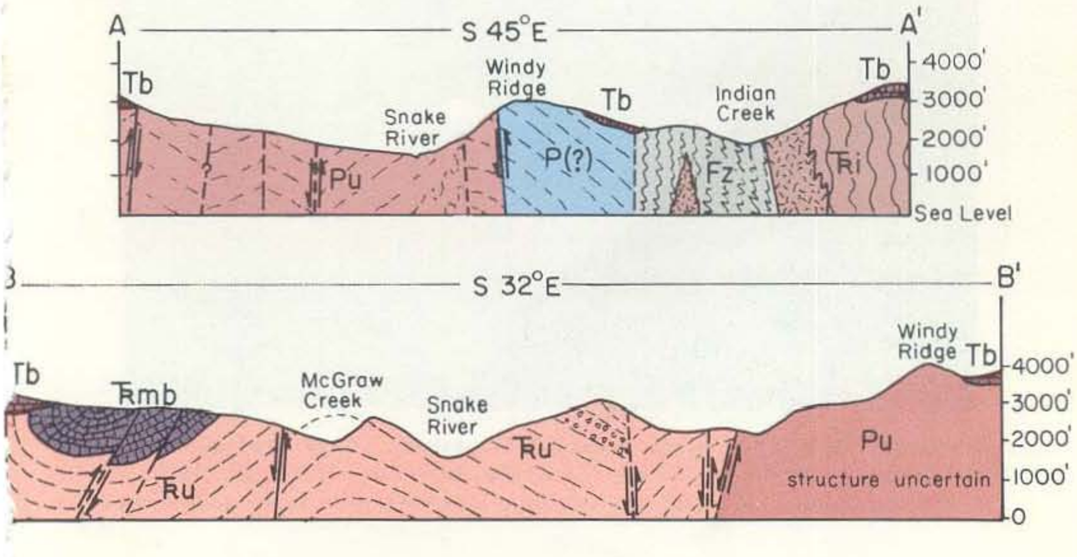


Figure 14. Nearly vertical, northeast-trending schists, mylonites, and gneissic mylonites of the Oxbow-Cuprum shear zone. This outcrop is at river level, about 100 yards east of the mouth of Indian Creek.

Figure 15. Permian and Triassic rocks near Homestead, Oregon are capped by Miocene basalt flows. The Iron Dyke mine, active during the early 1900's, is left of center. The Wallowa Mountains form the skyline in the background.

Figure 16. Outcrop characteristics of Permian rocks between Ballard and Ashby Creeks, Oregon. More than 1500 feet of northwest-dipping strata are exposed along the north side of Ballard Creek (left center of photograph). Road is the Kleinschmidt Grade.

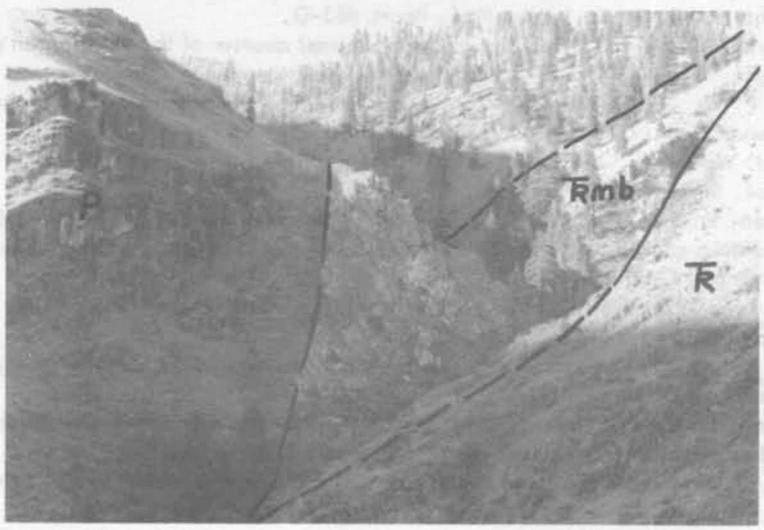


Figure 17. Martin Bridge Formation as a fault slice between Permian rocks (on the left) and Middle(?) Triassic rocks (on the right) in Eckels Creek, Idaho. Inked lines trace faults.

valuable stratigraphic and structural data necessary for understanding the geology of the whole canyon. The information obtained will be a major contribution to the geology of northeastern Oregon and western Idaho.

Upon completion of the work in the entire canyon, the Department plans to issue a publication consisting of a series of strip maps, accompanied by an explanation that will be of interest to the vacationer who comes to view the spectacular canyon of the Snake River.

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Figure 18. Folded Martin Bridge limestone near Big Bar. Flat surfaces between streams signify an old erosion surface. Quartzite boulders of unknown source and age are scattered over the surface in the upper left corner. Miocene basalt caps the limestone.

Figure 19. Big Bar, Idaho. The topographic high was formed by landslide debris. River gravels in Big Bar are more than 100 feet thick in some places.

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DEEP MINES OF THE WORLD

Man has been digging into the earth in the search for minerals since the Stone Age. In recent years the development of new mining techniques and equipment has made it possible to mine to depths never before considered. In the following table are listed some of the very deep mines in the world:

Mine	Country	Depth below surface
East Rand Proprietary Mines (1)	South Africa	11,246 feet
City Deep (1)	South Africa	10,645
Champion Reef (2)	India	10,000
Crown Mines (1)	South Africa	9,848
Western Deep Levels (1)	South Africa	9,804
Durban Deep (1)	South Africa	9,560
Morro Velko (2)	Brazil	8,501
Star (2)	Idaho, U.S.A.	7,100
Magma (2)	Arizona, U.S.A.	5,600
Anaconda Mountain (2)	Montana, U.S.A.	5,280
Homestake (2)	South Dakota, U.S.A.	5,000

(1) Data supplied by Information Service of South Africa.

(2) Written communication, Dr. Walter Hibbard, Director, U.S. Bureau Mines.

One of the big problems in very deep mines is heat. Elaborate refrigerating systems have been employed to bring the temperatures at the working faces down to acceptable levels. The cost of driving tunnels and sinking shafts to great depths is also a limiting factor. In deep mines the pressure of overlying rock is often great enough to shatter the tunnel walls; thus, concrete and steel reinforcement is commonly employed in permanent working and haulage areas. U.S. Bureau of Mines authorities report that the ultimate limit at which mining could be carried on in the South African deep mines would be about 12,500 feet below the surface.

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Figure 20. Upper Triassic rocks exposed in 32 Point Creek near Hells Canyon Dam.

Figure 21. Hells Canyon Dam. Chiseled into the Upper Triassic volcanic rocks, the 400-foot dam is dwarfed by the rugged canyon walls.

Figure 22. Rugged outcrops of Upper Triassic strata near Stud Creek. A probable fault extends from bottom to top. The Snake River is 3000 feet below the bench in the top-center of the photograph.

Figure 23. Upper (?) Triassic rocks exposed near Wild Sheep and Bull Creeks, Oregon. A stratigraphic section, several thousand feet thick, can be measured in this area. The relief is about 5500 feet.

Figure 24. Aerial view looking east across Snake River Canyon from Lookout Mountain in Oregon to Seven Devils Mountains in Idaho.


BERNARD CR.
WATERSPOUT CR.
SNAKE RIVER
SADDLE CR.

INDEX TO THE ORE BIN

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