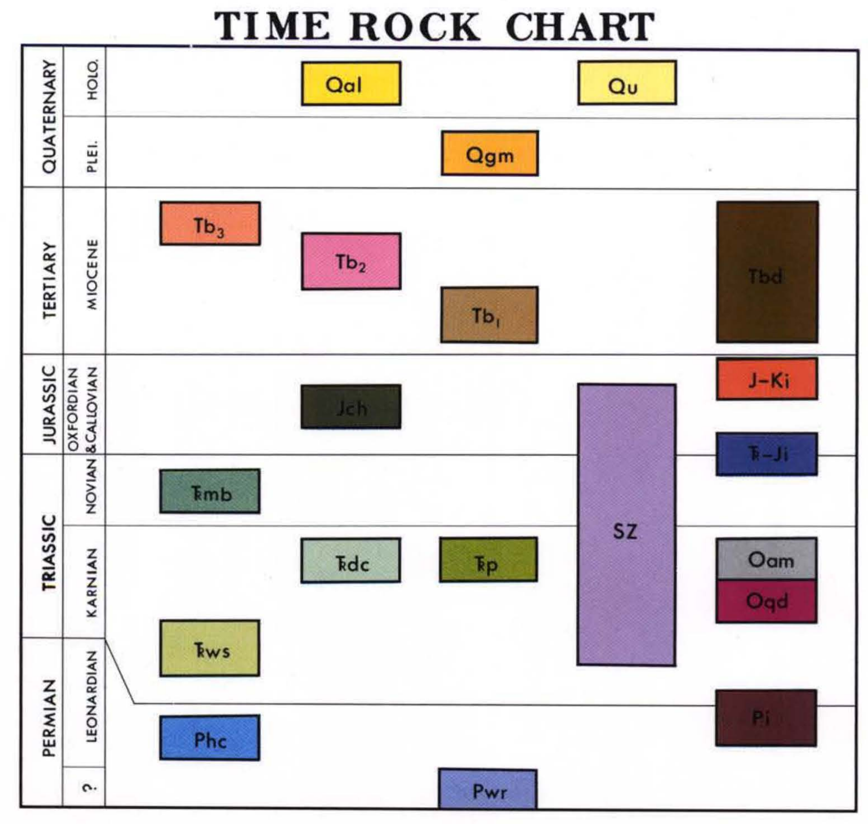
GEOLOGIC MAP
of the
SNAKE RIVER CANYON
OREGON & IDAHO

Geology
by T. L. Vallier 1973

Base Map from AMS 1:250,000 Topographic Series:
Grangeville sheet Idaho, Oregon, Wash. 1955
and Baker sheet Oregon, Idaho 1955
Sheets joined by Menlo Park Base Map Unit,
U S G S , 11-72(8-32)

TIME ROCK CHART



State Dept. of Geology & Mineral Ind.
Snake River Canyon. 303805

EXPLANATION

BEDDED ROCKS

Qal — Alluvium
Includes valley flats and fans.

Qu — Undifferentiated
Includes alluvium, landslides, and terrace deposits.

Qgm — Glacial Deposits
Most are morainal deposits which remain on ridge crests in western part of the area.

UNCONFORMITY

Tb_3, Tb_2, Tb_1 — Columbia River Basalt
Tb_3 is composed of breccias, cinders, and irregular flows near vents; Tb_2, the younger flow unit, is in part equivalent to the Yakima Basalt; Tb_1, the older flow unit, probably is in part equivalent to the Picture Gorge Basalt.

UNCONFORMITY

Jch — Coon Hollow Formation
Black shale and argillite, brown sandstone and pebble conglomerate. Rare thin limestone beds. Most outcrops in northern part near the Washington border; some exposed at Pittsburg Landing.

UNCONFORMITY

Ꞧmb — Martin Bridge Formation
Limestone and dolomite, some very carbonaceous. Includes coarse reef debris.

? UNCONFORMITY ?

SEVEN DEVILS GROUP:

Ꞧdc — Doyle Creek Formation
Maroon and green volcanic breccia, metabasalt and keratophyre, volcanic sandstone and shale, tuff, conglomerate, and thin limestone beds.

Ꞧp — Pittsburg Formation
Laterally equivalent to TRdc, composed of brown and green conglomerate, sandstone, shale, volcanic breccia, tuff, and thin metabasalt flows. Some thin limestone beds. This unit is exposed only at Pittsburg Landing.

? UNCONFORMITY ?

Ꞧws — Wild Sheep Creek Formation
Flows of metabasalt, pillow metabasalt, and pillow breccia with coarse volcanic breccia and volcanic sandstone overlain by argillite, volcaniclastic rocks, limestone, and metabasalt flows. The former is particularly abundant in Hells Canyon and the Seven Devils; the latter is widespread north of the mouth of the Imnaha River.

UNCONFORMITY

Phc — Hunsaker Creek Formation
Predominantly volcanic breccia, sandstone, and siltstone with abundant conglomerate and tuff. Keratophyre and spilite flow rocks are rare.

? UNCONFORMITY ?

Pwr — Windy Ridge Formation
Keratophyre flow rocks and keratophyre tuff breccia.

INTRUSIVE ROCKS

Tbd — Columbia River Basalt Dikes
Most are coarse grained, related to Tb_1.

J-Ki — Late Jurassic and Cretaceous (?) Intrusives
Granodiorite, quartz diorite, diorite, and gabbro. Most are unmetamorphosed or only slightly metamorphosed.

Ꞧ-Ji — Late Triassic through Middle Jurassic Intrusives
Some plutons, particularly in Oxbow area, may be Permian or Early Triassic. Rock types include gabbro, norite, diorite, quartz diorite, and albite granite. All have undergone some metamorphism.

Oam — Oxbow Amphibolite
Metamorphosed gabbro and basalt.

Oqd — Oxbow Quartz Diorite
Mostly quartz diorite but includes zones of diorite and albite granite. Both units may be either equivalent to the TR-Ji plutons described above or may be part of the Permian and Triassic Canyon Mountain Magma Series.

Pi — Permian Intrusives
Small irregular intrusives of gabbro, keratophyre porphyry, and diabase.

STRUCTURAL – INTRUSIVE ZONES

SZ — Shear Zones
Mylonite, gneissic mylonite, amphibolite, schist, and phyllite with dikes of gabbro, diabase, quartz diorite, albite granite, and diorite. Includes the Oxbow-Cuprum Shear Zone along Indian Creek, the Cougar Creek Shear Zone south of Pittsburg Landing, and a shear-dike zone near the mouth of Imnaha River. The Cougar Creek and Oxbow-Cuprum shear zones both show evidence of right lateral strike-slip faulting. Most shearing and intrusive activity occurred during the Triassic and Jurassic periods.

GEOLOGIC SYMBOLS

Contact
Dashed where approximate, dotted where concealed, queried where uncertain.

High Angle Fault
Dashed where approximate, dotted where concealed, queried where uncertain; U, upthrown side; D, downthrown side.

Strike-Slip Fault
Arrows show direction of relative movement.

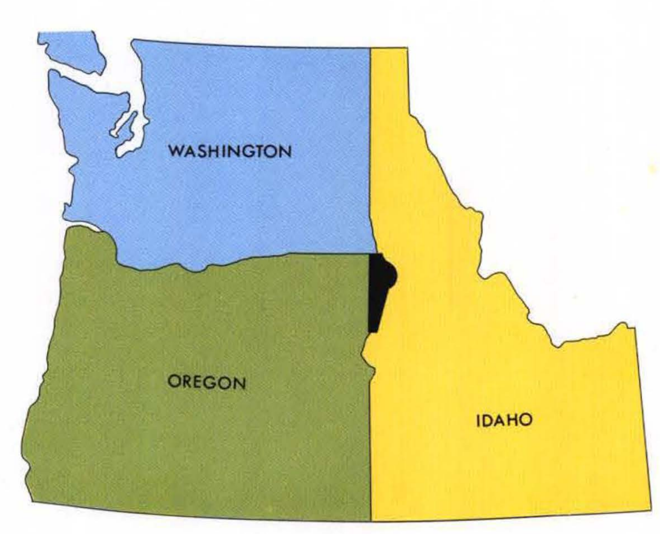
Thrust Fault
Teeth on side of upper plate.

Syncline

Anticline
Fold axes; arrow on axial trace indicates direction of plunge.

Bedding
Strike and Dip of Beds
Strike of Vertical Beds

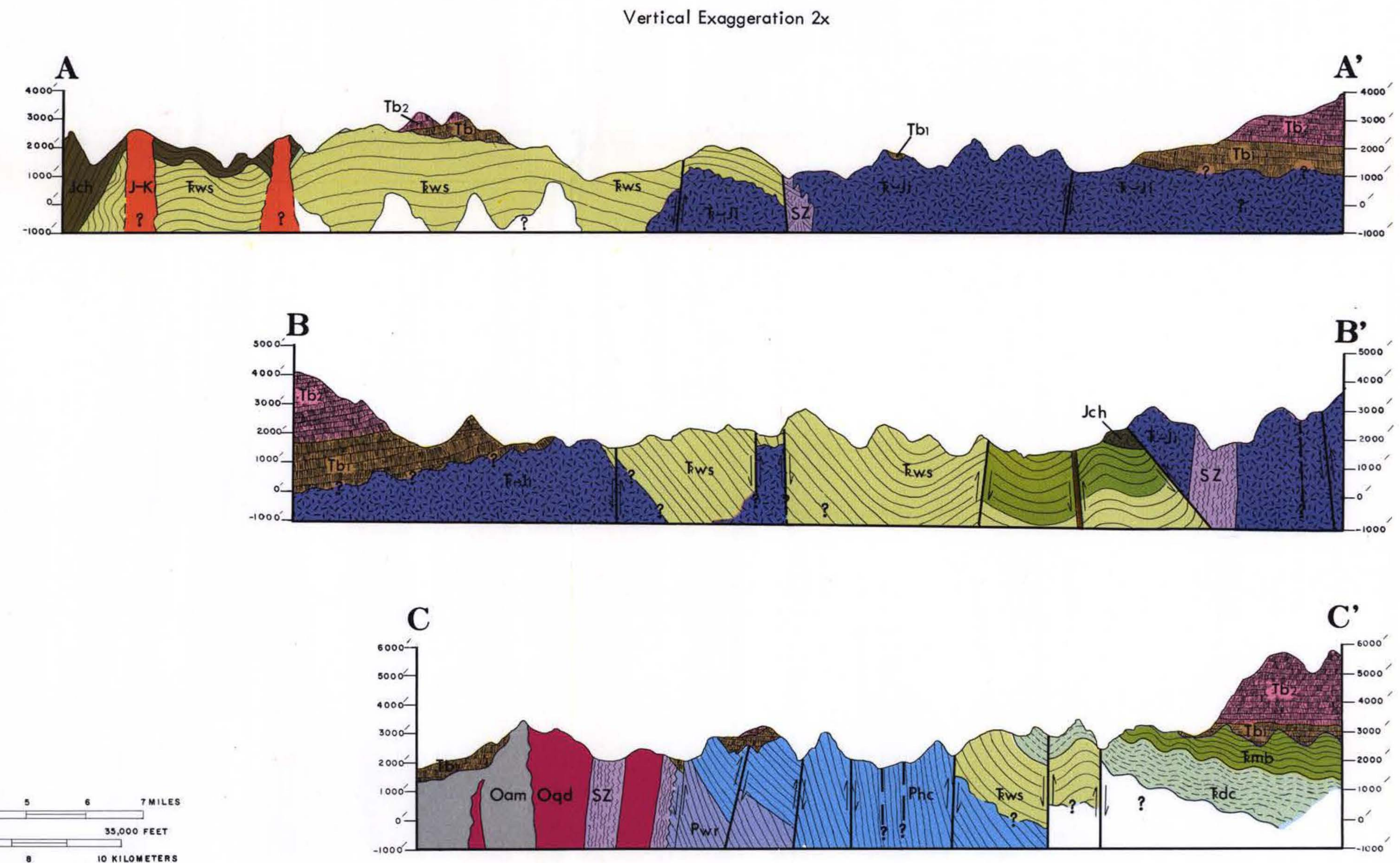
Foliation
Strike and Dip of Primary Igneous Foliation
Strike of Vertical Primary Igneous Foliation
Strike and Dip of Metamorphic Foliation
Strike of Vertical Metamorphic Foliation
Major Fossil Localities



STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
R. E. CORCORAN, STATE GEOLOGIST

Geologic Cross Sections

Vertical Exaggeration 2x



ISOGONIC CHART
Approx. Declination
1973

SCALE 1:125 000

1 0 1 2 3 4 5 6 7 MILES
5000 0 10,000 20,000 35,000 FEET
1 0 2 4 6 8 10 KILOMETERS

CONTOUR INTERVAL 200 FEET
DATUM IS MEAN SEA LEVEL

Cartography by S. R. Renoud and
W. H. Pokorny 1973

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
1069 State Office Building, Portland, Oregon 97201

GEOLOGICAL MAP SERIES

GMS - 6

A PRELIMINARY REPORT ON

THE GEOLOGY OF PART OF THE SNAKE RIVER CANYON

OREGON AND IDAHO

by

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Scripps Institution of Oceanography
University of California, San Diego

1974

CONTENTS

INTRODUCTION

This preliminary report on the geology of the Snake River Canyon and some adjacent areas between Oxbow, Oregon and the Washington border is written to complement the accompanying geologic map. It gives brief explanations of the major stratigraphic units, the intrusive sequence, and some aspects of structure. Also included are comments on metamorphism and geomorphology. A short section on the geologic history of the area summarizes the major interpretations.

Map coverage

The geologic map base was prepared by the U. S. Geological Survey from the Grangeville and Baker AMS 1:250,000 Topographic Series, and the final geologic map scale is about 1:125,000. The reader should consult the following U. S. Geological Survey topographic maps for the many locations mentioned in this text that do not appear on the geologic map: Copperfield, Cuprum, Harl Butte, He-Devil, Homestead, Imnaha, and Kernan Point 15-minute quadrangles; plus Cactus Mountain, Deadhorse Ridge, Grave Point, Jim Creek Butte, Kirkwood Creek, Wapshilla Creek, and Wolf Creek 7½-minute quadrangles (see index map).

The accompanying geologic map is mainly a compilation and reinterpretation of mapping by Morrison (1963), Vallier (1967, 1968), and White (1972). Work by Ozier (1972) and Morganti (1972) assisted interpretations. Some mapping might best be described as reconnaissance in nature, particularly in the area between Hells Canyon Dam and the mouth of Imnaha River. The map is a result of all or part of eight field seasons during the 1963-1973 interval; the last field work was completed in April of 1973.* Mapping was supported mainly by the Oregon Department of Geology and Mineral Industries. Some support also was given by the Idaho Bureau of Mines and Geology, the U. S. Geological Survey, Indiana State University, The Geological Society of America, and Sigma Xi.

Access

Main access routes to the Snake River Canyon at Oxbow, Oregon are Idaho State Highway 71 from Cambridge, Idaho and Oregon State Highway 86 from Baker, Oregon. Between Oxbow, Oregon and Hells Canyon Dam, Idaho Power and Light Company (IPALCO) maintains an all-weather road. There are only two major access roads to the canyon floor between Hells Canyon Dam and the Washington-Oregon border. One is from White Bird, Idaho to Pittsburg Landing and the other is from Imnaha, Oregon along the Imnaha River. Access within the Snake River Canyon is restricted to horse trails, some of which can be traversed by trail motorcycles, and to the river, where boats must be especially designed to run the many rapids.

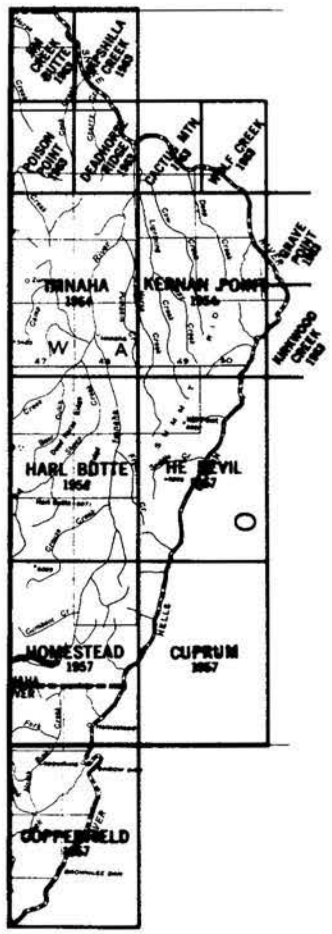
Previous work

Previous work in this part of the Snake River Canyon was restricted to broad reconnaissance surveys and to detailed studies of small areas. Lindgren's (1901) pioneering work in northeastern Oregon extended into the southern part of the Snake River Canyon near Homestead. Livingston and Laney (1920) described the general geology and copper deposits of the Seven Devils Mountains in Idaho and published a map that is overlapped by the map included with this report. Wagner (1945) and Cook (1954) mapped parts of the Canyon in their reconnaissance studies. Ralph Cannon mapped the Cuprum 15-minute quadrangle during the summers of 1938 through 1941, and a simplified version of his map was published by Hamilton(1963). Morrison (1963) and Vallier (1967, 1968) completed maps which cover parts of the area described in this report. Stearns and Anderson (1966) and Vallier and Brooks (1970) completed detailed maps of small areas near Oxbow and Homestead, respectively. Other maps were those completed by White (1972) of the Pittsburg Landing area, by Ozier (1972) of the angular unconformity between pre-Tertiary rocks and Miocene lavas, and by Morganti (1972) of an area west of Cuprum, Idaho.

* See addendum, page 14.

Acknowledgments

Particular thanks are due R. E. Corcoran, present director, and Hollis Dole, past director, of the State of Oregon Department of Geology and Mineral Industries, for their encouragement and support during this investigation. I also thank Roland Reid of the Idaho Bureau of Mines and Geology and George Walker of the U. S. Geological Survey for their assistance. H. C. Brooks and N. S. Wagner provided stimulating discussions, encouragement, and logistics support. I appreciate the exchanges of ideas with W. H. Taubeneck, W. H. White, D. A. Bostwick, and C. W. Field concerning regional geologic interpretations. Fossil identifications were given by R. W. Imlay (Jurassic), N. J. Silberling (Triassic) and F. G. Stehli (Permian). Field assistants were D. L. White, James Waldrip, S. S. Shimer, R. L. Ozier, and D. E. Fredley.



Index map of quadrangles in study area.

GENERAL GEOLOGY

The Snake River Canyon area of northeastern Oregon and western Idaho lies in the easternmost bulge of the Columbia Arc (Taubeneck, 1966), just west of the margin of the Idaho Batholith. The pre-Tertiary stratified rocks are marine volcanics and sediments, part of an old island arc assemblage, that were folded, faulted, intruded by plutons, and deeply eroded. Late Tertiary plateau basalt covered the older rocks and subsequent uplift and ero sion created the present topography.

Rocks in the area can be broadly grouped into three assemblages. The first includes Permian, Triassic, and Jurassic stratified rocks. Permian and Upper Triassic rocks form a thick accumulation of marine volcaniclastic and flow rocks that is capped by an Upper Triassic limestone unit. The Jurassic rocks are mudstone, shale, and sandstone. A second assemblage is the plutonic rocks, mostly gabbro, norite, and quartz diorite of probable Triassic and Jurassic ages. Rare Jurassic-Cretaceous plutons cut the older rocks. A third major assemblage of rocks, the Miocene Columbia River Basalt, covers a large part of the mapped area and is separated from the underlying pre-Tertiary rocks by a profound angular unconformity.

Structural trends are mainly northeast and northwest. Tectonic stresses were compensated by high-angle faulting in the brittle volcanic rocks and by folding in the more plastic limestone and shale. Major zones of shearing and multiple dike injections involving gabbro-quartz diorite plutonic complexes are recognized near Oxbow, Oregon and south of Pittsburg Landing. Another zone of shearing and multiple dike injections was mapped near the confluence of the Snake and Imnaha Rivers.

Diastrophism and regional metamorphism culminated after the deposition of lower Upper Jurassic mudstone and before the intrusion of uppermost Jurassic-Lower Cretaceous plutons. Subsequent uplift created a Paleogene erosion surface and Miocene lavas were extruded over that terrain. Block faulting, followed and accompanied by glacial and stream erosion, accounts for the present rugged topography.

STRATIGRAPHY

The major stratigraphic units are the Permian and Triassic Seven Devils Group, the Triassic Martin Bridge Formation, the Jurassic Coon Hollow Formation, the Miocene Columbia River Basalt, and the Quaternary deposits. The several new rock stratigraphic names proposed in this report have been approved by the U. S. Geological Survey Geologic Names Committee. A more comprehensive report on the stratigraphy is in preparation.

Seven Devils Group

Previous workers, including the writer, have generally followed the terminology of Anderson (1930) by referring to the chiefly metavolcanic rock sequences of the Seven Devils Mountains and Snake River Canyon as the "Seven Devils Volcanics." In this report, the name Seven Devils Group is substituted and redefined to comprise five formations: the Permian (?) Windy Ridge Formation, the middle Permian Hunsaker Creek Formation, the Middle and Upper Triassic Wild Sheep Creek Formation, and the Upper Triassic Doyle Creek and Pittsburg Formations. Although some of the formations crop out only in the deepest parts of the Snake River Canyon, the name "Seven Devils" is retained to facilitate future literary reference and correlation. "Group" is substituted because "volcanics" is considered too restrictive lithologically. The Seven Devils Group correlates with the Clover Creek Greenstone (Gilluly, 1937; Ross, 1938) and the "Lower Sedimentary Series" (Smith and Allen, 1941) that are well exposed in or near the Wallowa Mountains of northeastern Oregon.

Windy Ridge Formation (Pwr)

The name Windy Ridge Formation is proposed for keratophyre and quartz keratophyre flow and pyroclastic rocks that are exposed on Windy Ridge, northeast of the town of Oxbow, Oregon. Abundant metamorphosed mafic dikes cut the keratophyric rocks. The base of the formation is not exposed, and the top is difficult to trace because of faulting and deep weathering. Along the northwest side of Windy Ridge, the formation is separated from the younger Hunsaker Creek Formation by a high-angle fault. Elsewhere, the contact was drawn where the grayish-green keratophyric rocks are overlain either by conglomerate or mafic volcanic breccia of the Hunsaker Creek Formation. This contact most likely is an unconformity but neither structural relationships nor fossils prove its existence. Unconformity is inferred from the abrupt change in stratigraphy. Furthermore, conglomerate in the lower part of the Hunsaker Creek Formation contains clasts that are very similar to rocks of the Windy Ridge Formation. Because of the poorly defined bedding and deeply weathered outcrops, a stratigraphic section was not measured. An estimate of the thickness is 500 meters.

The volcanic rocks originally were "acidic" flows and tuffs which at a later time were metamorphosed to the greenschist facies, thereby forming the keratophyric association. The monolithology of these rocks, a lack of any known epiclastic debris, and the interlayered nature of pyroclastic and flow rocks suggest both quiet and violent eruptions from the same magma source. Whether eruptions occurred on land or in water is not known because distinctive criteria for establishing the origin are not present. No fossils were found in the formation and a probable Permian(?) age is inferred from the overlying Permian rocks of the Hunsaker Creek Formation and from the fact that no rocks older than Permian have been reported from adjacent areas.

Hunsaker Creek Formation (Phc)

The name Hunsaker Creek Formation is proposed for a thick sequence of metamorphosed Permian strata, mostly volcaniclastic and volcanic flow rocks, that is exposed for about 20 kilometers along both sides of the Snake River Canyon north of Oxbow, Oregon and in the southeastern Wallowa Mountains. Particularly good exposures are along Hunsaker Creek near Oxbow and in Ballard Creek Canyon, which lies about 8 kilometers north of Homestead, Oregon.

At least 2,500 meters are exposed in the Snake River Canyon and in the southeastern Wallowa Mountains. Most rocks are marine volcaniclastic rocks, with minor amounts of spilite and keratophyre flow rocks, argillite, and recrystallized limestone. At Hunsaker Creek, the type locality for this formation, a 720-meter thick stratigraphic section has marine volcaniclastic rocks (94 percent), spilite and keratophyre flow rocks (4 percent), and other rock types (2 percent). A 580-meter thick section in Ballard Creek has about 90 percent volcaniclastic rocks and 10 percent flow rocks.

The volcaniclastic rocks are vertically graded in beds as thick as 15 meters. Some sequences, with successive graded beds, are more than 100 meters thick. Many of these graded beds probably are marine pyroclastic deposits. Conglomerate comprises about 13 percent of the section in Hunsaker Creek and also is abundant in the southeastern Wallowa Mountains. The conglomerate ranges from pebbly mudstone to well-sorted boulder conglomerate. Clasts in the conglomerate include keratophyre and quartz keratophyre (50 percent), volcaniclastic rocks (40 percent), spilite (6 percent), and unknowns, plutonic rocks, and limestone (4 percent). Plutonic rock clasts are metamorphosed gabbro, diorite, and quartz diorite.

Greenschist metamorphism in this unit has progressed nearly to equilibrium. Feldspars are albite and few mafic minerals remain. Common mineralogies of the keratophyric rocks are albite, quartz, chlorite, epidote, and sphene. In the spilitic rocks, common minerals are albite, chlorite, epidote, calcite, sphene, and iron ores.

Brachiopods are of middle Permian (Leonardian/Guadalupian) age. Correlative rocks occur in the southern Wallowa Mountains in part of the Clover Creek Greenstone and in part of the Elkhorn Ridge Argillite (Taubeneck, 1955).

The rocks in the Hunsaker Creek Formation were deposited in relatively shallow water near a rugged landmass which was composed of volcanic flow rocks, volcanic sediments, limestone, and rare plutons. Turbidity currents, generated by the oversteepening of submarine slopes and by subaqueous pyroclastic flows, were the prevalent transporting mechanisms.

Wild Sheep Creek Formation (Ꞧ ws)

Wild Sheep Creek Formation is the name proposed for a thick metamorphosed unit of flow rocks, volcaniclastic rocks, limestone, and argillite that is exposed throughout a large part of the Snake River Canyon. This name replaces the informal names Imnaha Formation (Wetherell, 1960), Grassy Ridge Formation (Vallier,(1967), and Volcanic Sedimentary Sequence (Morrison, 1963).

Best exposures are in the Wild Sheep Creek-Bull Creek area, about 8 kilometers north of Hells Canyon Dam. Probably the best section, mostly undisturbed, is along the north side of Bull Creek. Other good reference sections are directly north of Saddle Creek and in the Cherry Creek drainage basin. Thickness estimates range from 2,000 to 2,500 meters, but rapid lithofacies changes over short distances, similarities of rock types in many parts of the section, structural complications, and a scarcity of fossils make thickness determinations difficult.

Basalt and possibly basaltic andesite massive lava flows, pillow lava, pillow breccia, and aquagene tuff are the dominant rock types in this formation, with volcanic breccia, volcanic sandstone, graywacke, limestone, and argillite also comprising a large percentage. Although there are many facies changes, a general breakdown of the formation shows that in the Wallowa and Seven Devils Mountains, and in the middle part of the mapped area, thick flows comprise most of the lowest member. The highest parts of the Seven Devils Mountains are made up of this unit, where it is at least 1,000 meters thick. The upper part of the formation is composed of volcaniclastic rocks, limestone, graywacke, and argillite with rare flow rocks. Graywacke generally is quartz-rich. At Saddle Creek, and also farther north near Cook and Jim Creeks, some limestone units are more than 50 meters thick. Rare exotic blocks of recrystallized limestone in coarse volcaniclastic units probably are the result of massive gravity slides.

Greenschist metamorphism has not reached equilibrium; calcic plagioclase and pyroxene still are abundant. Some plagioclase phenocrysts have been partly or wholly replaced by albite, chlorite, calcite, and epidote; many are rimmed by clear albite. The original glassy matrices also have been replaced by chlorite, calcite, and epidote.

The age of this formation is late Middle Triassic (middle and late Ladinian) based on the occurrence of Daonella and early Late Triassic (early Karnian) based on ammonite identifications (N. J. Silberling, written communication, 1965).

The rocks were erupted and eroded from basaltic islands and seamounts. Sedimentation occurred in surrounding basins where relatively restricted (euxinic) basin conditions existed. The increase of quartz content in the upper part of the section signifies the erosion of a quartz-rich terrane, probably related to the unroofing of plutonic rocks. Tectonism in the nearby landmasses was common.

Doyle Creek Formation (Ꞧ dc)

The Doyle Creek Formation (Vallier, 1967) and the Pittsburg Formation (Wagner, 1945) are in part equivalent. Because of the nature of the Pittsburg Formation and because no good fossil collections were made from the Doyle Creek Formation, it seems best to separate the two rock units at this time. Later studies may indicate that there is no necessity for this separation. If so, the name Pittsburgh Formation should be retained and the name Doyle Creek Formation dropped.

The name Doyle Creek Formation is proposed for a thick (500+ meters) section of metamorphosed maroon and green volcaniclastic rocks, graywacke, conglomerate, argillite, and volcanic flow rocks that is well exposed in Doyle Creek, the first major creek north of the limestone (Martin Bridge Formation) at Big Bar on the Oregon side of the river. This formation is irregularly exposed, mostly along the Oregon side of the Snake River, between Ashby and Saddle Creeks in the southern part of the area and north of Cook Creek in the northern part of the area. The southern outcrops have more coarse volcaniclastic rocks and more volcanic flow rocks, whereas the northern section has more conglomerate, graywacke, and argillite.

In the Ashby Creek-Saddle Creek area, the lower contact is taken as the bottom of the first major maroon volcanic breccia. Here, the formation seems conformable on the Wild Sheep Creek Formation. North of Cook Creek there is a sharp break between the green volcaniclastic rocks and limestones of the Wild Sheep Creek Formation and the maroon conglomerate, tuff, graywacke, and argillite of the Doyle Creek Formation. In this particular area, the contact probably is unconformable, and until fossil evidence is more conclusive, the contact in the entire area should be considered unconformable (?).

The upper contact of the Doyle Creek Formation with the Martin Bridge Formation seemed conformable when first studied at Big Bar by Vallier (1967). However, subsequent studies in the headwaters of Limepoint Creek, near the mouth of the Grande Ronde River, in the northern Wallowa Mountains, and in the eastern Seven Devils Mountains, indicate that there are significant differences in lithology beneath the contact. Although this might be entirely a function of lithofacies changes, it is more likely that the limestones were deposited at somewhat different times on widely separated volcanic pedestals or benches. Therefore, this contact probably is unconformable.

The predominantly clastic nature of the rocks and the ubiquitous maroon color are diagnostic criteria for the recognition of the Doyle Creek Formation. Clasts in conglomerate beds reach diameters of 50 cm, and in some breccias clasts approach lengths of more than one meter. Most clasts are basalt, although abundant limestone clasts occur in some layers. Metamorphosed quartz-diorite, diorite, and gabbro clasts are abundant in some conglomerate beds high in the section.

The greenschist facies of regional metamorphism has been attained in some beds, whereas other beds, particularly the pyroclastic units, still have abundant glass and some zeolites. Many of the flow rocks retain their glassy groundmasses. Rocks in the Pittsburg Formation have similar low-grade metamorphic mineralogies.

The few fossils discovered thus far have been of no assistance in age determinations. Fossil hash collected from limestone pods is not diagnostic of age. The rocks most likely are Late Triassic (Karnian and/or early Norian) in age because they overlie known Karnian rocks of the Wild Sheep Creek Formation and underlie the early Norian Martin Bridge Formation.

The Doyle Creek Formation includes the "Triassic Epiclastic Beds" described by Morrison (1963) and is considered to be correlative and partly equivalent to the Dunn Creek Conglomerate in the northern Wallowa Mountains (Nolf, 1966), the Pittsburg Formation (Wagner, 1945), and, particularly in the upper part, to the "Lower Sedimentary Series" (Smith and Allen, 1941) of the Wallowa Mountains.

The basin of deposition was relatively close to a volcanic landmass made up predominantly of basaltic flow and volcaniclastic rocks. Limestone, and quartz-diorite, diorite, and gabbro plutons also were exposed. Abundant pyroclastic activity, some probably subaqueous, contributed tuffaceous material to the basin. Local accumulations of agglomerate, irregular flows, and coarse tuff may represent vent areas.

Pittsburg Formation (T p)

The name Pittsburg Formation was given to a thick clastic sequence that is very well exposed in the Pittsburg Landing area west of Whitebird, Idaho (Wagner, 1945). It overlies the flows and coarse breccias of the Wild Sheep Creek Formation and has a thickness greater than 500 meters.

Weakly metamorphosed conglomerate, sandstone, breccia, shale, limestone, and tuff are dominant rock types. Clasts in conglomerates reach diameters of more than 1 meter and are made up predominantly of volcanic flow and volcaniclastic rocks. Clasts of plutonic rocks and limestone also are present. Thickest conglomerate units, generally made up of several beds that grade from conglomerate to sandstone, are more than 50 meters thick. Some pebble conglomerate-sandstone beds have steep crossbedding that indicates a current direction from the east and southeast. Plutonic clasts are metamorphosed gabbro, quartz-bearing diorite, quartz diorite, and trondhjemite. In one sample locality, more than 3 percent of the clasts were derived from plutonic rocks. Sandstones are mineralogically immature, consisting of feldspar, rock fragments, and small amounts of quartz in brown and green clay/chlorite matrices. Albite, epidote, chlorite, and calcite are common replacement minerals. Some tuff beds contain abundant palagonite, and preliminary X-ray diffraction studies indicate the presence of small amounts of zeolites.

Halobia and ammonite collections give a Karnian age for the formation, although one limestone unit may be as young as middle Norian (Silberling, written communications, 1968 and 1969). Even though the Doyle Creek and Pittsburg Formations probably are partly equivalent, there are some major differences. The Pittsburg Formation is almost entirely clastic and is green and dark brown in color, whereas the Doyle Creek Formation is maroon and green and contains more volcanic flow rocks.

Rocks in the Pittsburg Formation were deposited in a local basin, probably in part as a submarine fan. Pyroclastic activity provided a significant amount of debris. The black carbon-rich shale and the limited benthonic fauna indicate that the basin was poor in oxygen. The source terrane, mostly made up of basaltic volcanic rocks, was to the east and southeast.

Martin Bridge Formation (Ŧmb)

Near Big Bar, about 20 kilometers north of the town of Oxbow, Oregon, a thick unit of Upper Triassic limestone is exposed in a broad, southwest-trending syncline. This limestone unit, because of its stratigraphy and age, is assigned to the Martin Bridge Formation (Ross, 1938). Earlier studies of this particular limestone in the Snake River Canyon include those of Lindgren (1901), Laudon (1956), and Cannon (see Hamilton, 1963).

The best stratigraphic section is along the south side of Kinney Creek Canyon (near the northern end of Big Bar) where 530 meters of limestone and dolomite were measured (Vallier, 1967). Good reference sections occur in Allison, Eckels, and Spring Creeks. Strata of this formation also can be observed on the ridge between the Limepoint Creek drainage basin and Indian Creek near the top of the Kleinschmidt Grade. Here, the exposures of underlying rock are poor; the Martin Bridge Formation seems to be in depositional contact with the underlying Doyle Creek Formation along the east side but is in fault contact along the west side.

Rock types are limestone (mostly sparite, biosparite, and micrite), dolomite, and limestone breccia that formed as a shallow platform deposit which included reef facies. Thick, massive beds of brecciated, partly dolomitized limestone may be reef cores. The limestone is carbonaceous and some units are clay-rich. In rare samples, dolomite, as determined from X-ray diffration studies, comprises from 5 to 95 percent.

N. J. Silberling (written communication, 1966) identified a well-preserved fauna from collections north of Spring Creek that included more than 70 kinds of marine invertebrates. This fauna is typical of the *Majsisovicsites kerri* Zone of earliest Norian age.

The Martin Bridge Formation and correlative limestone units are widespread in northeastern Oregon, southeastern Washington, and western Idaho. Thick sections are in the southern and northern Wallowa Mountains, at the mouth of the Grande Ronde River in Washington, along the eastern side of the Seven Devils Mountains, and near Lucille, Idaho.

Coon Hollow Formation (Jch)

Coon Hollow Formation is the name given to a weakly metamorphosed Jurassic mudstone and sandstone unit that is exposed along both sides of the Snake River Canyon south of the Washington-Oregon border (Morrison, 1964). Similar rocks exposed along the Snake River Canyon farther south, across the river from Pittsburg Landing probably are in part equivalent. The base of the unit unconformably overlies the eroded surface of the Upper Triassic Wild Sheep Creek Formation in the northern part of the Canyon, whereas to the south, in the Pittsburg Landing area, the formation overlies folded strata of the Pittsburg Formation. In both places, a basal conglomerate forms the oldest bed.

The major lithology is black mudstone, and minor lithologies are fine-grained sandstone and siltstone. Rare beds of pebble conglomerate and fine-grained breccia also occur in the sequence. The mudstone is well indurated and forms individual beds up to 20 meters thick. Most sandstone and siltstone beds are from 5 to 35 cm thick; many are vertically graded from fine sand to fine silt.

Deep weathering and strong folding prevented satisfactory measurements of stratigraphic sections. Morrison (1964) estimated that the thickness is at least 2,000 feet (about 610 meters), but his estimate seems conservative.

Fossils are sparse in this rock unit. Euxinic depositional conditions discouraged the development of benthonic faunas, and deep weathering has destroyed near-surface fossils. Imlay reported (Morrison, 1964) that one fossil locale in the northern area contains fragments of the ammonite genus *Cardioceras*, which is diagnostic of the lower part of the Oxfordian Stage in Europe. From exposures near Pittsburg Landing, Imlay identified ammonites of Callovian age (written communication, 1968). Therefore, at least some parts of the formation were deposited in latest Middle and earliest Late Jurassic times.

The rocks were deposited during a transgression of Jurassic seas over folded and truncated older rocks. The basin(s) was fairly deep and restricted (euxinic). Although most sediment is fine grained, turbidity currents carried in some coarse terrigenous sediments from adjacent landmasses which probably were undergoing contemporaneous uplift.

Columbia River Basalt (Tb_1, Tb_2, Tb_3)

The Columbia River Basalt (Columbia River lava of Merriam, 1901) is subdivided into three unnamed units on the geologic map; from oldest to youngest these are: unit 1 (Tb_1), unit 2 (Tb_2), and unit 3 (Tb_3). The contact between Tb_1 and Tb_2 was mapped along the Oregon side of the Snake River between McGraw Creek and the Washington border by Ozier (1972), and elsewhere the contact was drawn from reconnaissance traverses and air photo interpretation. Therefore, most Tb_1 - Tb_2 contacts should be remapped before extensive interpretations of the distributions are made. Unit 3 (Tb_3), represented by cindery debris and irregular vesicular flows that mark vents, occurs mostly on the high plateau west of the Imnaha River canyon.

The older flows, Tb_1, are dominantly porphyritic, although some of the thinner ones are fine grained. They weather to gentle slopes and have a distinctive waxy luster on fresh surfaces. Thickest sections, between 150 and 200 meters, are exposed near the mouth of the Imnaha River and in the canyon of Pine Creek, southwest of Oxbow, Oregon. Flows were extruded over an irregular topography that had a regional relief of 500 to 700 meters.

The contact between Tb_1 and Tb_2 generally is marked by a change in topography from the gentle slopes of Tb_1 to the steep slopes of Tb_2. Locally, this break is marked by a line of springs.

Flows of Tb_2 are well exposed throughout most of the area. South of Saddle Creek, for several kilometers, they are the only flows that cap the old pre-Tertiary topography; this seems to indicate that Tb_1 accumulated in low areas around topographic highs, leaving them as steptoes until covered by flows of Tb_2. Basalt samples from Tb_2 have a higher glass content and are finer grained than the underlying flows of Tb_1. The maximum thickness of Tb_2 is about 600 meters along parts of the Snake River and Imnaha canyons.

The age of the Columbia River Basalt has been discussed by Baksi and Watkins (1973), who compiled a synthesis of K-Ar dates from nine sections in northeastern Oregon, western Idaho, and southeastern Washington. The age range of 112 dates from basalt flows throughout the region is 13.5 ± 0.3 m.y. (Owyhee Basalt) to 15.4 ± 0.3 m.y. Disregarding the more southerly Owyhee Basalt, the age range is 14.3 to 15.4 m.y., which is only a short period of time in the early middle Miocene (time scale of Berggren, 1972).

Quaternary Deposits (Qgm, Qu, Qal)

The Quaternary deposits in the Snake River Canyon region can be divided broadly into glacial deposits, landslide deposits, terrace deposits, and alluvial fan-valley flat deposits. Most deposits are thin and discontinuous.

Glacial deposits (Qgm)

Glacial deposits were mapped along the western edge of the mapped area, mostly on the ridges between Imnaha River and Duck Creek and between Duck Creek and Lake Fork Creek. Some glacial debris also occurs in the higher parts of the Seven Devils Mountains. Morainal material extends down to elevations of about 4,000 feet (1,220 meters) in both the Imnaha River and Duck Creek canyons.

Landslide deposits (Qu)

Landslides have formed some major topographic features in the Snake River Canyon (Vallier and Miller, 1974). The largest of these, at Big Bar, was created by a landslide from the west wall of the canyon and now occurs as an elongate drumlin-like feature which extends for nearly 1 km and rises 60 meters above the valley floor.

Other major landslides occur in the following locations: near the mouth of Cooper Creek, about 14 km north of Homestead; north of the mouth of Bernard Creek; at Johnson Bar; and at Pittsburg Landing. Landslide potential is particularly great just south of Sheep Creek above Johnson Bar on the Idaho side of the Snake River.

Terrace and alluvial fan deposits (Qu and Qal)

Terrace deposits occur near Pittsburg Landing, Johnson Bar, Temperance Creek, and at Big Bar. The terraces all have formed in wide parts of the river valley, and as many as three levels can be identified. Most of these terraces are the results of rapid accumulations of debris (landslide, flood gravels, and tributary stream alluvial fans) with subsequent smoothing by high waters.

Thick deposits of alluvium form valley flats in the upper reaches of Imnaha River and in Duck Creek. Alluvium also is thick at Big Bar, were it is composed of coarse river gravels (some are boulder size) and alluvial fan debris. Most alluvium, however, occurs as irregular deposits along streams and as alluvial fans.

INTRUSIVE ROCKS

The pre-Cenozoic plutonic history of the map area is complicated by episodic intrusion, deformation, and metamorphism over a long span of time and will not be unraveled until additional mapping, petrologic studies, and radiometric age dating are done. Most of these plutons probably are volcano-root stocks of an island arc suite.

Among the oldest intrusives are those of hypabyssal origin (Pi) that have been found only in Permian stratified rocks. The largest intrusive bodies, the Oxbow Complex (Oam and Oqd) and the Late Triassic-Middle Jurassic intrusives (₨ -Ji), are multi-phase plutons in which wide variations in rock type and in the degree of metamorphism and deformation are characteristic features. Since most of the external contacts are faults, age relationships are uncertain. It is assumed that, because these rocks are metamorphosed, they are no younger than Late Jurassic. Some exposures appear to be "basement" rocks upon which Late Triassic stratified rocks were deposited and therefore may be fragments of deeper crust.

Small unaltered plutons (J-Ki) intrude the older plutons and the overlying Triassic and Jurassic sediments. These and Columbia River Basalt dikes (Tbd) are shown separately where exposures are of mappable size.

Permian Intrusives (Pi)

Best exposures of these small intrusives are on the Oregon side of the Snake River between the towns of Oxbow and Homestead. The abundant mafic dikes that cut the Windy Ridge Formation in Idaho may be related. Included in this category are small irregular discordant bodies plus sills and dikes of metadiabase, metabasalt, metagabbro, and keratophyre porphyry. Many are related to the volcanic rocks in the Permian Hunsaker Creek Formation and probably were small plugs and feeders. Sills were mapped that deformed unconsolidated Permian sediments, thereby suggesting a close age relationship. Others, however, may be younger and possibly were intruded after middle Permian sedimentation and before the Upper Triassic stratified rocks accumulated.

Oxbow Complex (Oam and Oqd)

The Oxbow Complex is a mixture of intrusives with metagabbro, amphibolite, meta-quartz diorite, metadiabase, metadiorite, and "albite granite" plus their mylonitized equivalents as the major rock types. Rocks are divided into two mappable units for simplification and convenience: the Oxbow amphibolite (Oam) and the Oxbow quartz diorite (Oqd). The Oxbow amphibolite includes metagabbro, amphibolite, metadiabase, metadiorite, hornblende schist, and some hornblende-rich microtonalite. The Oxbow quartz diorite mostly is meta-quartz diorite, "albite granite", and their sheared and mylonitized equivalents. Zones of multiple dike injections, mostly metadiabase, occur in strongly sheared and mylonitized areas.

Strata of the Permian (?) Windy Ridge Formation are the youngest rocks known to have been affected by emplacement of the Oxbow Complex. Similarities to the Canyon Mountain Magma Series (Thayer, 1963; Thayer and Brown, 1964) suggest that parts of the complex may be late Permian to Middle Triassic in age, yet Field and others (1972) dated somewhat similar rocks in the Cuddy Mountain as Late Triassic (195-215 m.y.). Thayer (written communication, 1974) reports that radiometric dates of "plagiogranite" and amphibolite from melange of Canyon Mountain are approximately the same as those reported by Field and others (1972). Since the "plagiogranite" in the Canyon Mountain area cuts keratophyre and gabbro, ages date only the youngest major intrusive event. It is conceivable that amphibolite and metagabbro in the Oxbow Complex are Permian crustal rocks which were intruded by quartz diorite (Thayer's "plagiogranite") and diabase at a later time (Late Triassic?).

Late Triassic-Middle Jurassic Intrusives (Ꞧ -Ji)

Late Triassic-Middle Jurassic intrusives are well exposed in three areas. These are in the Sheep Creek drainage on the north side of the Seven Devils Mountains, in an area just south of Pittsburg Landing, and along the Snake River Canyon between Imnaha River and Getta Creek. Rock types are mainly metagabbro, metanorite, and meta-quartz diorite. Minor rock types are amphibolite, metadiorite, "albite granite," and unaltered gabbro and diabase. Wide zones of multiple dike injections and shearing were mapped in the complex south of Pittsburg Landing and in the intrusives near the mouth of the Imnaha River. Most of these dikes are aligned and are sheared and mylonitized, whereas others are unsheared and cut across the aligned dikes.

Most contacts are structural between the metamorphosed intrusives and Upper Triassic volcanic and sedimentary rocks. In Sheep Creek, the contact seems to be depositional, with Upper Triassic argillite, graywacke, and limestone resting on metagabbro and meta-quartz diorite. In places, unaltered plutons do cut overlying stratified rocks. Therefore, it appears that the oldest plutons are pre-Late Triassic in age and that the very youngest were intruded after regional metamorphism in the latest Jurassic and Early Cretaceous and that most of the intrusive activity probably occurred during intervening Late Triassic-Middle Jurassic time. White (1968) assigned a Triassic-Jurassic age to similar plutons, and the plutons of Late Triassic age dated by Field and others (1972) may be the same age as some of those described here.

There are several similarities and several differences between the Oxbow Complex and the Triassic-Jurassic intrusives. Similarities include a primary mafic phase, intrusions of quartz diorite and diabase, and multiple dike injections along zones of shearing and mylonitization. On the other hand, the Oxbow Complex has no norite, includes much more amphibolite (metamorphosed gabbro?), has a larger percentage of "albite granite", and is closely related to the keratophyric rocks of the Windy Ridge Formation. These differences warrant a separation even though later studies may show that they have essentially the same origin and history.

Late Jurassic-Cretaceous(?) Intrusives(J-Ki)

Late Jurassic regional metamorphism (Hamilton, 1963) is an event that is used to separate the Triassic-Jurassic intrusives from the Late Jurassic-Cretaceous(?) plutons. The latter are not metamorphosed and K-Ar dates from similar plutons in the Cuddy Mountain area yield ages of 120 to 130 m.y. (Field and others, 1972).

Most plutons (J-Ki) are in the northern part of the mapped area. However, some of the Triassic-Jurassic plutons are intruded by rocks which could be assigned to the younger Jurassic-Cretaceous intrusive episode. Rock types are as mafic as norite and as silicic as muscovite granodiorite, although most are quartz diorite and biotite quartz diorite.

Abundant sills of quartz diorite cut the Jurassic Coon Hollow Formation near the Oregon-Washington border. These are partly metamorphosed, which indicates intrusion before the Late Jurassic regional metamorphism.

Columbia River Basalt Dikes (TRbd)

Columbia River Basalt dikes cut the pre-Tertiary rocks in several areas. Generally, the dikes are marked by strong negative relief due to differential weathering and erosion. All of the Columbia River Basalt dikes examined that cut the pre-Tertiary rocks are related to Tb_1, the oldest unit. The dikes are much more abundant than shown on the map, where only the most accessible and thickest are outlined. Widths of the dikes on the map are exaggerated; in reality, none has a width greater than 20 meters.

METAMORPHISM

Regional metamorphism affected most pre-Tertiary rocks in the area. The effects of thermal metamorphism are limited to zones around the J-Ki intrusives.

In the pre-Tertiary stratified rocks, there is a time relationship between the age of the rocks and the degree of metamorphism. In Permian rocks the mineralogies have reached greenschist facies equilibrium, whereas in the younger rocks this equilibrium has not been attained. Furthermore, the lower or older parts of the Triassic sequence have undergone a higher degree of metamorphism (greenschist, not to equilibrium) than the younger strata where glass and zeolites are associated with greenschist mineralogies. In the Jurassic bedded rocks, zeolites and clays (with secondary micas) are associated with chlorite, thereby implying metamorphic effects of low grade.

Decrease of metamorphism with time suggests that metamorphism is associated with depth of burial, which in turn is most likely related to the proximity of the rocks to a heat source. Metamorphism probably occurred over a long time interval, culminating in the Late Jurassic.

Metamorphism in and around the plutonic rocks is not as easily explained. Within any group of TR-Ji plutons, particularly the ones near Pittsburg Landing and between Getta Creek and the mouth of the Imnaha River, metamorphism ranges from the amphibolite facies to essentially unaltered rocks. The differing degrees of metamorphism are related not only to a complex intrusive history but also to extensive movements and recrystallization along wide shear zones.

STRUCTURAL GEOLOGY

Northeast and northwest structural trends are prevalent in the area, although a younger north-south trend is also evident. Bedding, fold axes, shear zones, and fault traces typically strike northeast and beds generally dip to the northwest. However, many of the major faults strike northwesterly, and a wide shear zone near the mouth of Imnaha River trends about N. 70° W.

Except for deformation in the major shear zones, where cataclasis and recrystallization record a complicated movement history, most pre-Tertiary rocks are only moderately deformed, likely the result of one orogeny. Furthermore, development of the two major trends probably began at about the same time. An obvious exception to this can be observed along the northwest-trending fault at Ashby Creek, which separates Permian from Triassic strata. This fault truncates northeast-trending faults and, therefore, moved at a later time. Farther north at Pittsburg Landing, west-trending structures are truncated by a northeast-trending thrust fault.

Shear Zones

In the Snake River Canyon there are three major shear zones: the Oxbow-Cuprum Shear Zone, the Cougar Creek Shear Zone, and an unnamed shear zone in the area near the mouth of the Imnaha River. Extensive deformation, recrystallization, and plutonism have occurred along these zones. The rocks have been crushed and partly or wholly recrystallized under stress to form cataclastic breccia, schist, mylonite, gneissic mylonite, amphibolite, and even ultramylonite. In some zones, basic dikes have been transformed to amphibolite and hornblende schist. These zones also have served as loci for multiple dike injections and probably should be referred to as shear/dike zones.

The Oxbow-Cuprum Shear Zone extends from a point south of the Oxbow Dam and thence northeast along the Indian Creek canyon for a distance of about 7 km, where it is overlapped by the Columbia River Basalt. If foliated plutons are considered as part of this shear zone, the maximum width approaches .5 km near the mouth of Indian Creek. This shear zone trends about N. 40° E. to N. 50° E. Farther north, in the Seven Devils Mountains, White (1968) mapped a shear zone in an intrusive complex on the same northeast trend, and Morganti (1972) mapped a shear zone in the Indian Creek canyon nearer Cuprum which has many similarities with the one at Oxbow. Possibly these all are related, but certainly more detailed mapping should be done before conclusions are made with regard to the tectonic pattern.

The Cougar Creek Shear Zone (Vallier, 1968) borders a gabbroic complex between Pittsburg Landing and Temperance Creek. Although only one wide zone is mapped parallel to the river, other narrow ones were noted during reconnaissance traverses in tributary canyons. Particularly characteristic of these zones are multiple parallel dike injections which give a banded appearance to the exposures. These dikes were emplaced during strong tectonism which mylonitized the rocks and created strong foliations and nearly horizontal lineations. Common rock types are amphibolite, gneissic mylonite, mylonite, hornblende schist, and cataclastic gabbro, norite, diorite, diabase and quartz diorite plus "albite granite" and phyllite. Primary foliations in plutonic rocks, particularly in the narrow dikes, parallel the northeast trend. Trends of faults, dikes, and major foliations range from N. 50°E. to N. 70°E. and dips range from 60° in either direction to vertical. Lineations caused by quartz alignments in the mylonite, by the alignment of prismatic hornblende, and by slickensides on chlorite-plastered foliation planes approach horizontal. Measurements of lineations in slickensides, which admittedly record only the latest movement, indicate that there was some right lateral movement direction (written communication, Robert Lawrence, 1971).

A third shear zone is in an area near the mouth of Imnaha River. It should be noted that the unit near the Imnaha River, mapped as SZ on the accompanying map, is not entirely a shear zone. Rather, it includes a mixture of schist, mylonite, and irregular dikes in the northeastern part while just northwest of the Imnaha River mouth, a zone of multiple dikes invades both the country rock (Wild Sheep Creek Formation) and gabbro-quartz diorite plutons. Lineations measured in the zones of shearing are mostly horizontal or near horizontal with a slight northwest plunge. The older gabbroic intrusion near the mouth of the Imnaha River also exhibits a northwesterly foliation as defined by schlieren, aligned xenoliths, and platy plagioclase crystals.

Faults and Folds

Several faults in the area show large vertical separations. Particularly noteworthy is a low-angle fault that has thrust rocks of the Cougar Creek Complex northward over the Pittsburg Formation at Pittsburg Landing. East of Big Bar, a high-angle fault separates Permian strata from the Triassic Martin Bridge Formation. The vertical separation along this fault is at least 3,000 meters. Some faults had strike-slip components of movement.

Trends of fold axes are mainly northeasterly. The more competent and brittle volcanic rocks faulted under stress, whereas shale, limestone, and sandstone units generally deformed by folding. Some broad folds are apparent, such as the anticline south of Eckels Creek and the snycline at Big Bar.

GEOMORPHOLOGY

The flat-lying Miocene lavas and underlying pre-Tertiary rocks were deformed by broad warping and block faulting during the late Miocene to Recent time interval. These structures guided erosional patterns, and as the pre-Miocene erosion surface was exhumed, drainage patterns readjusted to pre-Tertiary structures. During the Pleistocene, increased rainfall and runoff accelerated dissection, which carved out the present rugged terrain.

Most streams follow remarkably straight courses or a series of straight-course segments which are the result of erosion along faults. Even the Snake River course follows a sequence of faults throughout most of the area.

The origin and history of the Snake River Canyon were outlined by Wheeler and Cook (1954). However, much of their evidence has been questioned (Vallier, 1967), with the result that these points still are open to study. Certainly, the late Tertiary and Quaternary block faulting has influenced the river's origin and course, but the exact mechanism and the length of time the river has flowed in its present canyon are not known.

The old erosion surface beneath the Columbia River Basalt is well exposed along the Snake River Canyon. Best exposures are on the truncated Martin Bridge Formation near Big Bar along the flat ridge tops which serve as divides between Nelson, McGraw, Spring, and Leep Creeks. Quartzite boulders, up to 40 cm in diameter, cover parts of these surfaces. Another good exposure is north of the map area, near the mouth of the Grande Ronde River, where boulder accumulations reach a thickness of 10 meters. Although most boulders are quartzite, many are quartz diorite at this locale, probably eroded from the Idaho Batholith. This old erosion surface formed in the Late Cretaceous-early Miocene interval and may be part of an old pediment surface that sloped westward from a high terrain in central Idaho.

Landslides have been a strong factor in the cutting away of canyon walls. However, few landslide deposits remain because of the rapid stream erosion, which carries away the debris. Nevertheless, landslide scars remain near Copper Creek, at Big Bar, near Sheep Creek, and at Bernard Creek.

River terraces formed along the wider parts of the Snake River Canyon where the river has been able to migrate more freely. Some of the highest ones, at Johnson Bar, Temperance Creek, and Pittsburg Landing, may have formed during the Bonneville Flood (Malde, 1968). Lower terraces resulted from floodwaters during the canyon's most recent history.

GEOLOGIC HISTORY

The geologic history of the region remains somewhat sketchy and incomplete. Only about 40 fossil localities have yielded meaningful dates, and these have a wide age range. No radiometric dates have yet been obtained, although some plutonic rocks in adjacent areas have been dated. The regional metamorphism date is an important one, but it too may need refinement. Assumptions are that only one regional metamorphic event occurred, yet there is some evidence that the metamorphic history is not so simple in and near the plutonic complexes. Regional metamorphism (admittedly low grade) affected black mudstones of Late Jurassic age (Oxfordian) but did not affect plutons as old as about 140 m.y. in closely adjacent areas. Therefore, this event must have culminated in the Late Jurassic.

With these facts in mind, a brief geologic history can be constructed for the area. Silicic volcanics and associated sediments were deposited on an older sea floor during the middle Permian. These accumulated in a relatively shallow basin close to a landmass. No upper Permian or Lower Triassic deposits remain in the area and the next recorded event is the thick accumulation of Middle and Upper Triassic marine volcanics and sediments. These were capped by an Upper Triassic shallow platform and reef limestone unit. No record of Late Triassic to Middle Jurassic (Norian to Callovian) sedimentation remains in the region. However, during this time interval some deformation occurred and a major plutonic event injected gabbro, norite, diorite, and quartz diorite. Middle and Upper Jurassic (Callovian and Oxfordian) black mudstone and brown sandstone were deposited over the deformed and eroded older rocks. After deposition of this unit, a major orogeny, accompanied by metamorphism, occurred. During the latest Jurassic and Early Cretaceous there was another plutonic event which, although small in the mapped area, might be related to the intrusion of the Idaho and Wallowa Batholiths. Uplift subsequently took place and a vast erosion surface formed in the Late Cretaceous and Paleogene. Middle Miocene lava flows were extruded over this old surface during a short time period of little more than one million years. Block faulting and broad regional warping in the late Miocene (?) through Quaternary time interval caused deep stream dissection and carved out the present topography.

ADDENDUM

Since the geologic map was compiled, short trips into the area showed that two changes should be made. A quartz diorite pluton extends nearly to the mouth of Little Granite Creek, the major tributary of Granite Creek. This area had been mapped as the Upper Triassic Wild Sheep Creek Formation (₨ ws) during original reconnaissance studies. A second change should be made in the shear zone (SZ) that runs through the Cougar Creek Complex just south of Pittsburg Landing. That unit (SZ) should be enlarged to incorporate most of the area west of the Snake River to the contact with the Columbia River Basalt and extended to the east to the contacts of an irregular line of plutons which roughly parallel the river. Although there is abundant shearing and dike injection throughout, some of the rocks are very similar to border zones that parallel contacts of large plutons in other parts of northeastern Oregon and western Idaho.

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