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Geology of the Oxbow on Snake River near Homestead, Oregon

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GEOLOGY OF THE OXBOW ON SNAKE RIVER NEAR HOMESTEAD, OREGON

by

Harold T. Stearns
and
Alfred L. Anderson (deceased)

ABSTRACT

Identified as a sharp, conspicuous loop in the Snake River and the site of a recently completed dam and powerplant, the Oxbow, set in a deep canyon in the Columbia River Plateau, is carved in a thick succession of complexly deformed Permian metavolcanic and sedimentary rocks belonging to the Seven Devils Volcanics (Permo-Trias), overlain unconformably by flows and pyroclastics of Columbia River basalt (Miocene). These rocks are in part blanketed by surficial stream, river, and talus deposits of Quaternary age.

The Seven Devils Volcanics in the Oxbow area are composed chiefly of altered andesitic and rhyolitic flows and pyroclastics with a few associated basic dikes. They also contain a local schist-gneiss unit. These older rocks were complexly folded and faulted during a late Jurassic(?) orogeny and locally were deformed into a faulted and what appears to be a tightly compressed syncline of northeasterly trend. They were intruded along the belt of schistose-gneissic rocks by small bodies of quartz diorite (late Jurassic(?)).

Resting on a deeply weathered and dissected erosion surface, the Columbia River basalt composed of essentially flat-lying flows of basalt with a basal tuff breccia and minor intercalated beds of tuff, is cut by many basaltic feeder dikes, including two composed entirely of glass, and by some prominent and many minor normal faults. Guidance by a large northeast-trending post-basalt fault and by northeast structures in the older rocks is chiefly responsible for the oxbow loop.

INTRODUCTION AND GEOGRAPHY

This paper describes a small area in the Snake River canyon of Idaho and Oregon. The Oxbow, the name given a sharp, pronounced loop or "oxbow" in the Snake River, is a conspicuous feature in the otherwise regular course of the river (Fig. 5). More than four miles around and no more than one half mile across, the loop is the site of a hydroelectric plant of the Idaho Power Company (Fig. 1).

Study and mapping of the geology at the Oxbow was carried on by Stearns at intervals from 1952 to 1954 in connection with dam site investigations for the Idaho Power Company. Petrographic study of the rocks collected by Stearns was made by Anderson after a brief visit to the area in company with Stearns in 1954. The surface geologic investigation was supplemented by data from 200 diamond drill holes at four sites along the river and in three tunnels. Additional information was obtained from an abandoned railroad tunnel that was cleared of debris, and from excavations made for the new powerhouse and the new tunnel leading to the powerhouse.

Mr. Carl Tappan, consulting engineer for Morrison Knudson Company, contributed much to the study and deserves special recognition for making the geologic map of the abandoned railroad tunnel available for this report (Fig. 4). Mr. Warren Hamilton of the U. S. Geological Survey critically read the report. His criticisms were particularly valuable because of his extensive work in the nearby Riggins area, Idaho (Hamilton, 1963).

GEOGRAPHIC FEATURES

The Oxbow is in the Snake River canyon where it forms the boundary between Idaho and Oregon about 20 miles upstream from Hells Canyon, one of the deepest gorges on the North American continent. It lies along the boundary between Baker County in Oregon and Adams County in Idaho about five miles south of Homestead, Oregon.

The area is reached by roads from Cambridge and Council, Idaho, and from Baker, Oregon.

The townsite of Copperfield, built at the time of the mining rush into the region during the 1890's is within the Oxbow area and is now occupied by a new village built during construction of the dam and powerplant and maintained for the present operators of the plant.

TOPOGRAPHIC SETTING

The Snake River canyon cuts a high but warped plateau which at the canyon rim near the Oxbow stands at approximately 4,700 feet. Locally the canyon is 3,000 feet deep, the walls descending to an altitude of 1,750 feet at the river. This descent is interrupted near the 2,750-foot contour by a prominent shoulder. Above this topographic break the canyon slopes are steep and in part precipitous; below, the slopes are less steep and rugged.

Two prominent tributaries join the Snake River within the area, each in its own narrown canyon, Indian Creek on the Idaho side and Pine Creek on the Oregon side. Both are alined in northeast-southwest directions, with Indian Creek flowing southwest at a barbed angle to the Snake. Its canyon is rugged, practically impassible. The less rugged Pine Creek canyon is followed by road from the river to the plateau surface.

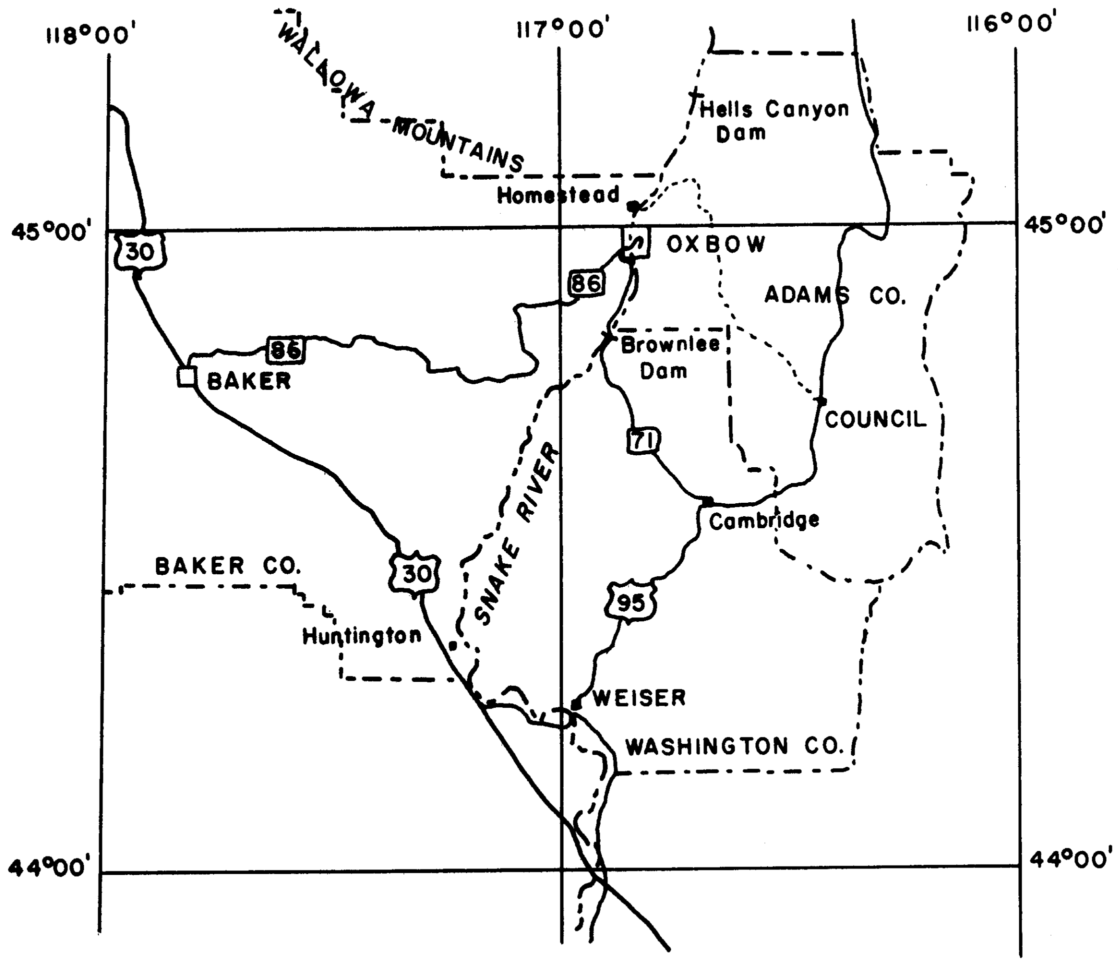

FIGURE I. INDEX MAP SHOWING THE LOCATION OF THE OXBOW, IDAHO-OREGON

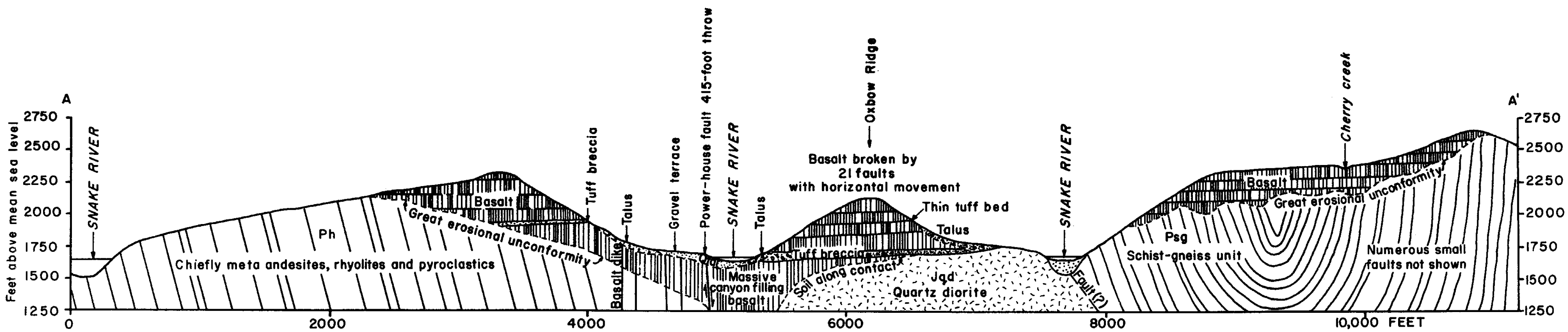

FIGURE 3. SIMPLIFIED GEOLOGIC STRUCTURE SECTION ALONG LINE A-A'
SHOWN ON FIGURE 2

VERTICAL SCALE = HORIZONTAL SCALE

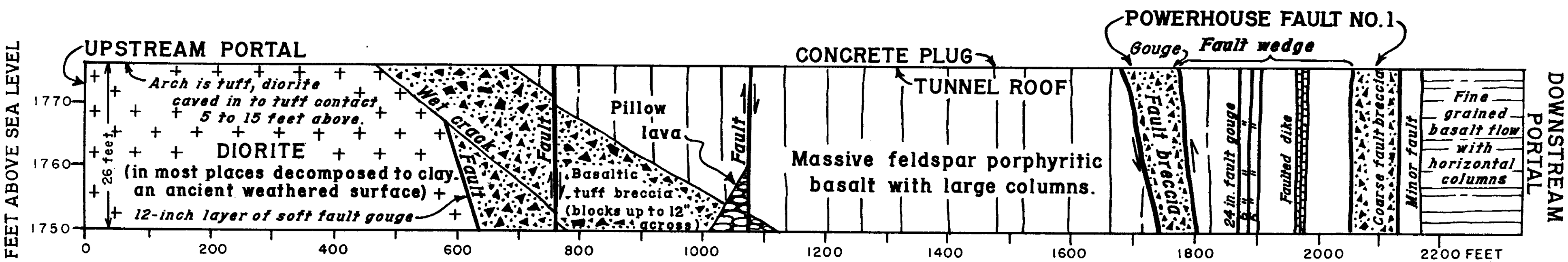

FIGURE 4. GEOLOGIC MAP OF THE ABANDONED RAILROAD TUNNEL (By Carl Tappan)

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MAJOR ROCK UNITS

The rocks at the Oxbow are chiefly metavolcanics and associated metasediments which form a part of the widespread Seven Devils Volcanics of Permian to Triassic age. Overlying them are the basalt flows and pyroclastics of the Columbia River basalt of Miocene age. The Seven Devils Volcanics are cut by a few genetically related dikes, by small intrusive bodies of Jurassic(?) age, and by the much younger dikes that served as feeders to flows of Columbia River basalt. Surficial deposits of Quaternary age are composed mostly of past and present deposits of the Snake River and its tributaries.

SEVEN DEVILS VOLCANICS (PERMO-TRIAS)

General features

The name Seven Devils Volcanics has been applied to a diverse assemblage of metavolcanic and sedimentary rocks widely exposed in and along the Snake River canyon and adjacent parts of Idaho and Oregon. The name was originally applied by Anderson (1930) to such rocks north of the Seven Devils Mountains area and was later extended by Cannon (Cook, 1954, Fig. 4) to include the rocks of the same complex in the Seven Devils and bordering Hells Canyon. These form the lower canyon walls of the Snake River from Hells Canyon to and beyond the Oxbow. The rocks of the Seven Devils Volcanics are not everywhere alike and those along the canyon from Homestead to the Oxbow differ considerably from those farther downstream. The typical greenstones (basic lavas) and thick beds of limestone which crop out so conspicuously in Hells Canyon are not present in the Oxbow area. No pillow lavas were recognized in the Oxbow area in these volcanics, in spite of the general belief that they are submarine.

According to Allen (1939), the rocks at Homestead include rhyolite dikes five to 50 feet thick as well as banded rhyolite flows 500 feet thick, greenstones (originally tuffs) 2,000 feet thick, tuff breccias, agglomerates, conglomerates, a few spilitized lava flows, and about 1,000 feet of purplish porphyritic andesite. The greenstones are reported to be highly saussuritized and in places are greenschists. Some of the waterlaid tuff contains intercalated shale and limestone, the latter in beds and lenses five to 25 feet thick. The limestones are highly fossiliferous and contain a Permian (Phosphoria) fauna. The Permian age of the rocks at Homestead was first recognized by G. H. Girty who identified Productus and other marine fossils as belonging to the Phosphoria (F. B. Laney, 1923, oral communication).

The rocks at the Oxbow lack the fossiliferous limy members but are otherwise much like those at Homestead and are composed of metamorphosed and andesite flows and agglomerates with intercalated thin beds of tuffaceous sediments. There are also some rocks so highly metamorphosed that they have been changed to schists and thin-banded gneisses. These more highly metamorphosed rocks are mapped separately as the schist-gneiss unit.

Metavolcanic unit

Except for the schist-gneiss member, the metavolcanic unit reaches but does not extend into the oxbow loop. Just north of the loop east of the river it forms a ridge 1,000 feet high, capped in places by the younger flows of Columbia River basalt. West of the river it passes under the younger rocks in the canyon wall at about the 2,400-foot contour. Farther north beyond the mapped area its contact with the younger rocks is as much as 1,000 feet above the river.

Although composed chiefly of metamorphosed andesitic and rhyolitic flows and agglomerates, the Homestead Formation at the Oxbow contains some minor amounts of pyroclastic and other sedimentary materials. Because of the metamorphism, contrasts between the different rocks are not great. Among the recognized rock types are andesite, andesite tuff, conglomerate (volcanic), dacite, quartz latite, rhyolite, trachyte(?) and associated basic dikes.

All the rocks show about the same degree and intensity of metamorphism. In all rocks plagioclase is either saussuritized or albitized and primary ferromagnesian minerals have been changed to epidote, or epidote and chlorite, or exceptionally actinolite. Veins of epidote are abundant through all rock.

Andesite

Best exposed in some of the old railroad cuts near the north boundary of the area, are massive andesite flows with altered blocky phases. They are composed of dark, amygdaloidal, fine-grained rock studded with small amygdules of quartz, quartz and epidote, and of epidote alone. The rock is otherwise composed of scattered albitized plagioclase phenocrysts in a matrix of smaller albitized plagioclase laths with felted aggregates of tiny needles of actinolite(?) and epidote between the laths. The only unaltered minerals are accessory grains of apatite and zircon.

Andesite tuff

Beds of andesite tuff exposed on Blue Creek at an altitude of 2,500 feet are composed of a dark, fragmental rock, made up chiefly of small fragments of porphyritic andesite of dull reddish to black color. Some of the fragments are composed of wholly crystalline rocks; some contain much dark opaque matter. In some of the fragments the albitized plagioclase laths show a rude parallelism; in other fragments, the laths are unoriented. Some grains of quartz also occur in the rock fragments.

Conglomerate

Conglomeratic beds made up largely of angular fragmental materials compose a minor part of the formation. One typical exposure along the road a short distance below the oxbow loop consists mainly of angular volcanic fragments up to several inches long, ranging in composition from rhyolite to andesite, with minor admixtures of rounded quartz pebbles in a matrix of quartz and altered feldspar, originally a feldspathic sand.

Fig. 5 - Air view of the Oxbow of Snake River taken from the Idaho bank prior to the construction of the Oxbow Dam. The rocks in the foreground belong chiefly to the schist-gneiss unit of the Permian Seven Devils Volcanics. Horizontal beds in background are Columbia River basalt. The large valley in the background is occupied by Pine Creek. Downstream is to the right. P.H. indicates location of new powerhouse. Former powerhouse was just downstream of the new one. Photo by Idaho Power Company.

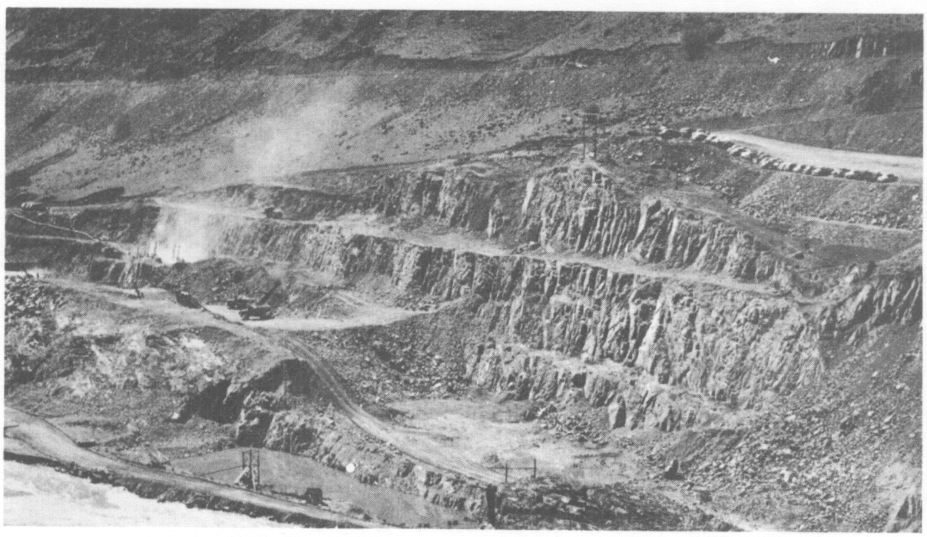

Fig. 6 - Steeply dipping and much fractured gneiss of the schist-gneiss unit in the Seven Devils Volcanics in the Oregon abutment of the Oxbow Dam. Photo by Idaho Power Company.

Dacite

Where exposed on Blue Creek at an altitude of 2,300 feet the dacite is a gray, porphyritic rock with feldspar phenocrysts less than 1 mm. long in a dense aphanitic groundmass. As revealed by the microscope the rock contains some small rock fragments but otherwise is composed chiefly of broken quartz and albitized feldspar grains in and partly corroded by a feldspathic matrix. The texture of the matrix is somewhat variable but suggests welded tuff relationships. The rock contains abundant quartz in the fine grained groundmass.

Quartz latite

Fairly widespread, the quartz latitic flows are composed of light-gray or white to greenish-gray rocks which in general are inconspicuously porphyritic, at least to the unaided eye. The microscope, however, reveals few to numerous phenocrysts of sodic plagioclase and quartz, accompanied by minor amounts of quartz. Some of the quartz phenocrysts are broken; others as well as some of the feldspar grains are corroded and embayed. In some rock most of the quartz occurs as phenocrysts with little in the groundmass. The rock also contains minor amounts of small-grained epidote and chlorite, and locally much limonite, mainly along fractures.

Rhyolite

Flows of light-colored rhyolite are widespread. Most have abundant conspicuous quartz grains and tend to resemble altered grits, but the microscope reveals that the quartz grains as well as numerous grains of sodic plagioclase, most of which are 1 to 2 mm. long, are held in a grayish, microspherulitic groundmass of quartz and potash feldspar.

An example of a rhyolite flow lacking such quartz grains, is exposed at the 2,500-contour on Blue Creek. This rock is lighter colored than the grit-like flows and contains only a few inconspicuous grains of quartz and feldspar in a white, dense, chert-like groundmass consisting of devitrified glass.

Trachyte(?)

Where exposed on the east side of the river a short distance below the oxbow loop, the trachyte(?) is a very fine-grained rock, which shows a tendency to split into thin plates. Under the microscope it is revealed as a porphyritic lava with scattered phenocrysts of highly altered plagioclase and with grains of epidote pseudomorphous after former ferromagnesian minerals. The rock has an altered feldspathic groundmass in which the borders of the feldspar grains are not sharply defined. These grains lack the polysynthetic twinning of plagioclase.

Basic dikes

Small, scarce, unmapped, generally highly altered basic dikes a few feet thick occur. Fine grained, black rock from such a dike on Blue Creek at the

2,180-foot contour is cut by numerous small veins of epidote, and is so altered that even under the microscope its original character other than that of a basic igneous rock is uncertain. Original feldspars have been completely altered to aggregates of zoisite, sericite, and epidote, with some albite and quartz. The dark minerals have been converted largely to actinolite which has also penetrated much of the saussuritized feldspar.

Rock from another dike north of the oxbow loop is more coarsely crystalline and is dark greenish gray. It was composed originally of about half light and dark minerals; but all dark minerals have been converted to epidote and chlorite, and the plagioclase has been albitized, although the twinning lines, spaced as far apart as in labradorite, have been retained. As in other dikes, magnetite is relatively abundant.

A rock near Indian Creek superficially resembles an altered quartzite. The rock is moderately coarse grained and has a dull-greenish color caused by the presence of altered ferromagnesian minerals. It is composed largely of altered plagioclase and lobate quartz in which are contained remnants of a rock, possibly a silicified volcanic. The rock contains much sericite and some epidote and chlorite. Any ferromagnesian minerals have been obliterated by the alteration. The plagioclase is heavily saussuritized. The rock has a quartz dioritic composition.

Schist-gneiss unit

Separated from the metavolcanic and sedimentary rocks by faults, the schist-gneiss unit comprises the rock of the oxbow loop and the canyon above. It is most widely exposed in the northeastern half of the loop, in the canyon of Indian Creek, and in the canyon wall southeast of the loop (Fig. 2).

The unit shows the effects of more intense deformation and metamorphism than does the rest of the formation. It has some remnant flows of rhyolite and beds of tuffaceous rocks but for the most part is dominantly schistose to gneissic and apparently is derived from tuffaceous rocks.

Excluding the minor intercalations of metarhyolite and other rocks, the unit is composed dominantly of schistose rocks and subordinately of gneisses. Much of the schist appears to have been impregnated with variable amounts of feldspar. As mineralogic evidence of its greater degree of metamorphism, the epidote-chlorite alteration has been succeeded by an actinolite type of alteration which characterizes the unit as a whole. The rocks of the unit may be classed as actinolite schist and gneiss. If structural interpretations are correct, the unit must be at least 4,500 feet thick.

Actinolite schist

Although the actinolite schists occur throughout the unit, they are most conspicuously exposed in the sharp bend of the oxbow at and near the mouth of Indian Creek (Fig. 8). There the foliation is vertical and the schist, which

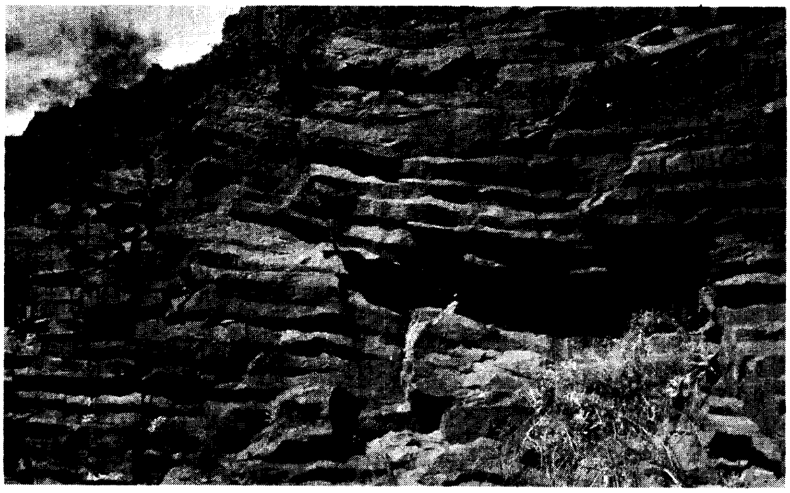

Fig. 7 - Curved, nearly horizontal, columnar jointing in Columbia River basalt at the mouth of Pine Creek. Such horizontal columns usually develop along the steep valley wall contact of the lower flows which occur as valley fills. Photo by H. T. Stearns.

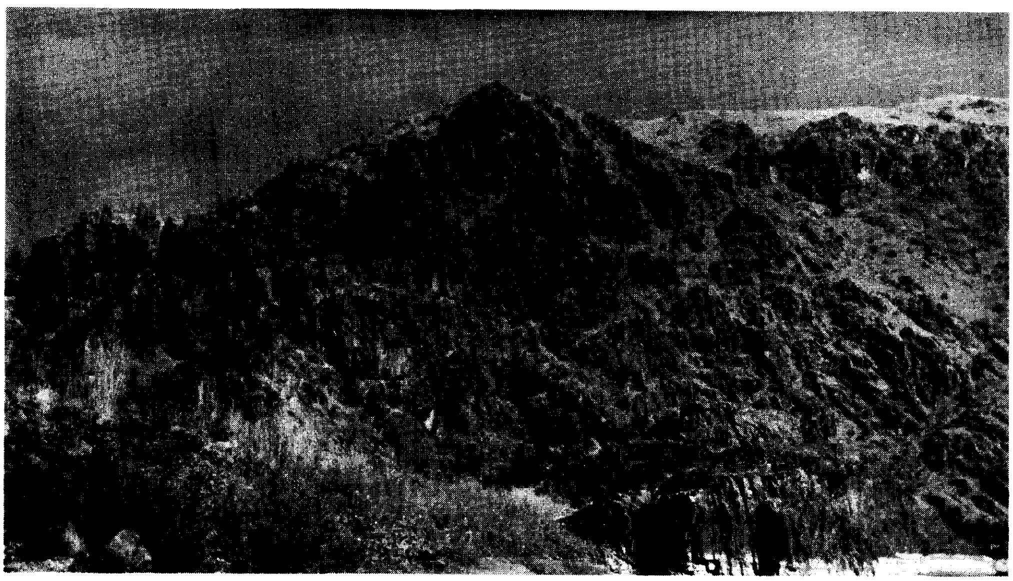

Fig. 8 - Outcrop of vertical beds of actinolite schist in the schist-gneiss unit of the Seven Devils Volcanics at the mouth of Indian Creek. Photo by H. T. Stearns.

measures 2,000 feet thick, has been differentially eroded in such a way that bands stand out like dark dikes. Despite its foliation, the rock is hard and in the river has been polished to a high gloss.

The schist is dark greenish-gray, fine-grained, and in addition to abundant actinolite contains quartz and minor chlorite, epidote (locally abundant in spots), magnetite, and pyrite. Most of the actinolite penetrates the quartz and chlorite as needles, but some of it forms porphyroblasts which crowd aside the foliation planes.

In places the schist has hard nodules which on exposed surfaces resemble metamorphosed pebbles, but which on close inspection prove to be small pods or thin lenses of quartz and altered plagioclase.

Gneiss

Most of the gneiss occurs as intercalations in the schist south of the sharp bend of the oxbow loop, particularly in the rocks within the loop and less abundantly in the rocks across the river near Scorpion Creek. Those within the loop are in thin beds (Fig. 6), and those across the river occur as lumps or knotlike masses in the schist. The gneiss is most conspicuous and widespread in the vicinity of bodies of quartz diorite. Because of its feldspathic nature, the gneiss is lighter colored than the schist. The layers of lighter-colored rock average about 18 inches thick, exceptionally as much as 12 feet thick, and terminate by transition into schist or by mergence with irregular, intrusive-like masses of quartz diorite.

Most of the basic rocks in the unit have become schistose. One outcrop across the river from the mouth of Scorpion Creek is composed largely of alined actinolite and of saussuritization products of the original feldspars.

JURASSIC(?) INTRUSIVE ROCKS

General features

Small bodies of granular intrusive rocks are restricted to the belt of schist-gneiss rock. These granular intrusives include a few dikes of hornblendite and larger and more numerous, irregular bodies of quartz diorite. Those mapped along Snake River are now submerged in the Oxbow Reservoir. Because their emplacement followed deformation of the metavolcanic and sedimentary rocks, they are commonly regarded as products of the orogeny of Late Jurassic time.

Hornblendite

A specimen from a 2-foot dike that cuts the schist at the loop is dark greenish-black, has small recognizable grains of hornblende and a lustrous appearance. The microscope reveals that the rock is composed largely of pale greenish-brown hornblende which forms well-shaped, often twinned crystals of random orientation. Some of the crystals are partly fringed with minute actinolite needles, but most of the hornblende, which composes more than three-fourths of the rock, appears to be primary. Other minerals include quartz, an unidentified feldspar, chlorite, and some accessory apatite. These occupy the interstices between the hornblende crystals.

Quartz diorite

The bodies of quartz diorite are aligned in a northeasterly direction along the belt of schistose rocks. Except for three bodies along the southeast side of the oxbow loop (Fig. 2), they were not mapped. These bodies tend to merge with the bordering rock and consequently their boundaries are not sharply defined. Some of the outcrops resemble masses of feldspathic metamorphic rock rather than bodies of intrusive igneous rock.

The rocks in these bodies show minor textural and mineralogic differences, but all are granitoid and of quartz dioritic composition. They are of medium to rather coarse grain size and are usually intricately fractured, locally crushed, and cut by veins of epidote. All rocks are altered and greenish.

The rocks are composed of plagioclase, hornblende, biotite, and quartz with accessory apatite, zircon, sphene, and magnetite, but alteration has generally been so extensive that no primary minerals can be identified by the unaided eye. Hornblende and biotite may be recognized in a few of the larger bodies where alteration has been least complete; quartz is generally conspicuous. Plagioclase is either extensively saussuritized, and so loaded with alteration products, or else is completely albitized. The hornblende is usually partly to completely altered to epidote and the biotite, to chlorite. Plagioclase formed one-half to two-thirds of the original rock; hornblende and biotite 15 to 20 percent and the quartz most of the remainder.

Quartz is much recrystallized into granular aggregates. Large lobate grains of quartz penetrate well-shaped crystals of plagioclase, and enclose plagioclase and granular quartz.

PRE-COLUMBIA RIVER BASALT UNCONFORMITY

The little deformed Columbia River Basalt lies upon a deeply eroded and deeply weathered surface cut in the older rocks (Fig. 10). The pre-basalt mantle of decomposed rock remains intact beneath the uneroded cover of younger rocks.

The fossil soil upon which the basalt accumulated has not been mapped, although some thick remnants assigned to it were uncovered by test pits well away from the basaltic cover. This old soil is chiefly yellow sandy loam, unlike any soil formed since the Miocene basalts were laid down. Some of it has layers of hill wash which contain fragments of unmetamorphosed silicic volcanic rock unrelated to the Seven Devils Volcanics.

COLUMBIA RIVER BASALT (MIOCENE)

The Columbia River Basalt is represented locally not only by flows but also by tuff breccia and by basaltic dikes which served as feeders to the flows and bedded pyroclastic materials.

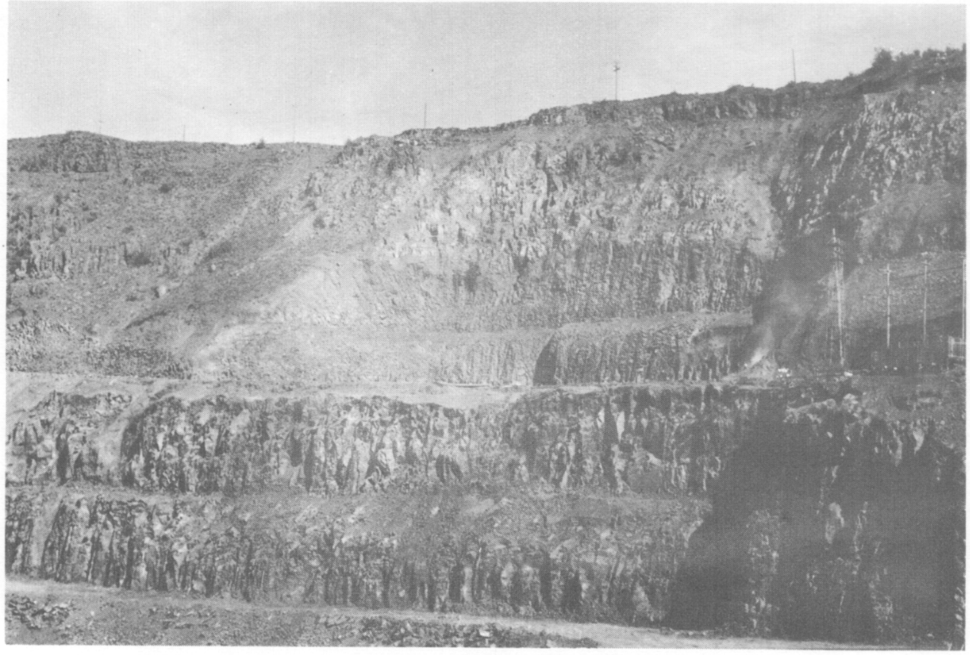

Fig. 9 - Columnar jointed basalt flows exposed in the downstream side of the Oxbow ridge at the site of the new powerhouse. The lowest flow exposed is Flow No. 1 in Table 1. Photo by Idaho Power Company.

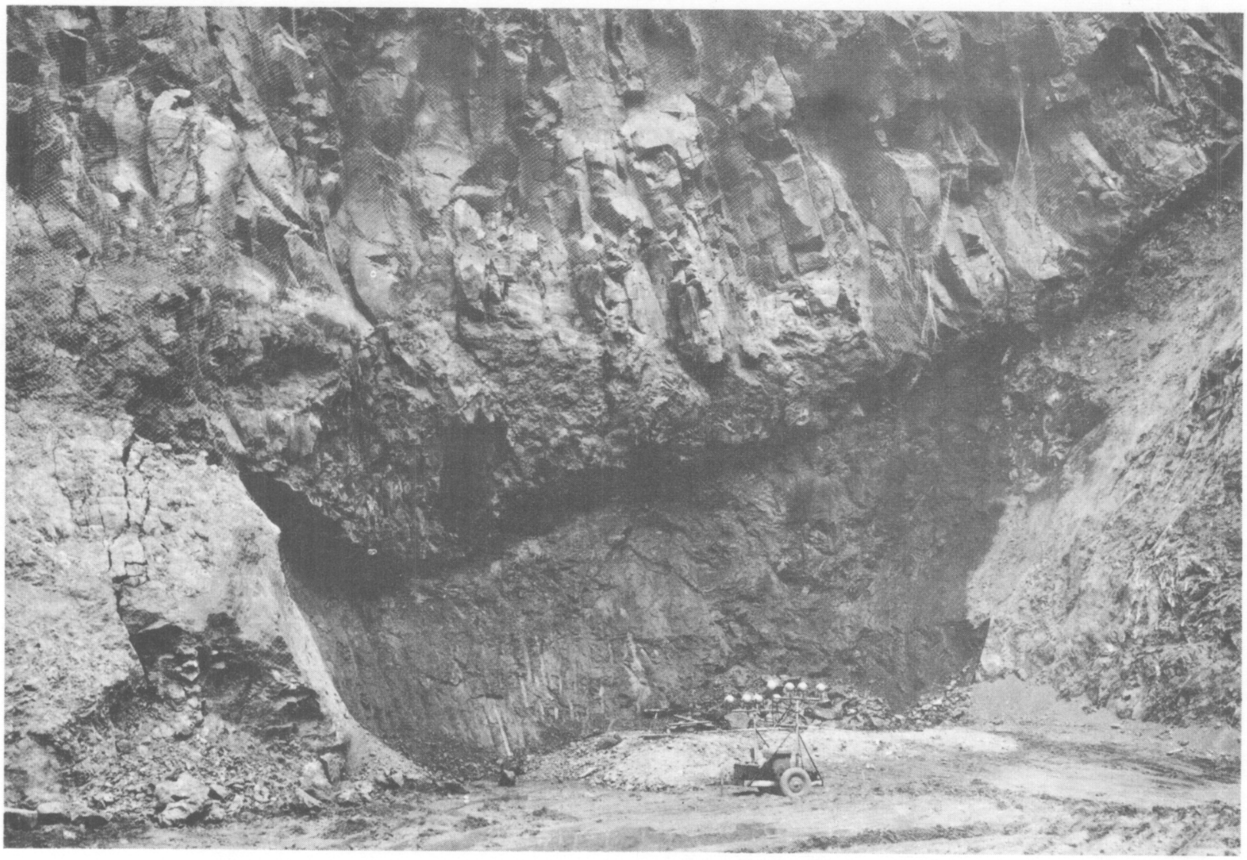

Fig. 10 - Erosional unconformity between the Columbia River basalt (above) and weathered diorite (below) at intake of power tunnels on the upstream side of the Oxbow ridge. A thin bed of basaltic tuff breccia lies at the base of the basalt. Photo by Idaho Power Company.

Tuff breccia

Tuff breccia occurs as a basal member as well as intercalations between the flows. The basal member is exposed beneath the basaltic flows both above and below the oxbow loop and to limited extent within the loop itself where it locally is underlain by a bed of basalt (Fig. 2). The tuff-breccia member ranges from a few feet to 200 feet thick, reaching its greatest thickness close to vents near Copperfield and upriver near the mouth of Warm Spring Creek where an eroded vent complex is exposed (Fig. 2).

Except for one bed, the intercalated tuffs are too thin to map. The mappable bed crops out in the canyon wall on the southeast side of Pine Creek 200 feet above the river and across the river on the Idaho side opposite the Oxbow tunnels (Fig. 2). The exposure along Pine Creek is cut off by the Powerhouse fault. The tuff interbedded with the basalt layers high in the canyon walls is in discontinuous bands a few inches to two feet thick.

The basal tuff breccia forms a strong, massive, little-jointed bed that stands well and affords good foundations for heavy structures. The rock is composed largely of basaltic cinders but near the powerhouse contains blocks of amygdaloidal basalt up to one foot across, torn from the underlying flow. The tuff is chiefly firefountain debris from nearby vents, but the presence locally of coarse breccia fragments in the tuff indicates considerable force in some of the explosions.

The interbedded tuff is also composed of basaltic cinders but is without coarse admixtures. The thick cinder bed south of Copperfield indicates proximity to a vent. In the upper Blue Creek drainage beyond the map area, the basaltic tuff in one place contains an interstratified four-foot interbed of white sediment; at another place, it changes into thinly laminated tuffaceous shale. There are also thin-bedded carbonaceous shales with abundant fossil leaves on the weathered surface of the Seven Devils Volcanics and also in depressions on the top of a hummocky pahoehoe flow.

Flows

The flows of Columbia River Basalt comprise the most widely exposed rock in the area, forming the rock of the upper canyon walls and in some places the lower walls also (Fig. 2). The river has cut through the lowermost flow so that a nearly complete section of the basalt is exposed in the Oregon wall from river level to canyon rim, 3,000 feet vertically.

The lower flows are unusually thick flows with large joint columns and thin compacted clinker tops typical of pooled lavas, but upper flows are thinner bedded and contain much more clinker. Apparently the early flows ponded in basins and canyons, but once the terrain had been smoothed so that the lava could flow unimpeded, it spread widely into thinner sheets and solidified as more normal flows with the usual amount of clinker.

Some of the flows are pahoehoe but most are aa. All are vesicular with vesicles particularly abundant near tops, less so near bottoms. Pillow lavas occur in three exposures---one behind the present powerhouse, another behind the former powerhouse, and the third in the old railroad tunnel (Fig. 4). These pillows indicate local contact of hot lava with moisture. The pillow lava behind the present powerhouse forms a nearly vertical band 50 feet wide. The pillows are from six to 12 inches across with baked carbonaceous shale in the interstices. The vertical columns in the basalt curve toward the pillow lava and become horizontal, like the exposure shown in Figure 7, indicating a cooling contact. Chunks of clay eight inches across are contained in the massive basalt. Apparently, the lava plowed up mud adjacent to a steep valley wall. The pillow lava behind the former powerhouse borders the same lava flow and rises steeply, which suggests another valley-wall contact.

Five flows of basalt crop out in the oxbow loop and each is readily identified by its megascopic characteristics. A sixth flow was cut in drilling below river level. The flows range from very fine-grained to coarse porphyritic basalts with feldspar and augite phenocrysts. They are typical ponded basalts. Five of the flows are shown in Figure 9. Their characteristics are summarized in the following table:

<u>Stratigraphic Sequence in the Oxbow Ridge</u>

Flow (No.)	Thickness (feet)	Description
Top of Section		
7	190+	Fine-grained massive black basalt with scarce feldspar crystals 1/4 in. long. Forms hill under triangulation station F. Top eroded. Top at 2,315 ft.; bottom, 2,125 ft.
6	100	Augite-feldspar porphyritic basalt forming cap of plateau east of road. Bottom of flow varies between 2,005 and 2,020 ft.
5	80±	Feldspar porphyritic basalt. Bottom at 1,930± ft.
4	50±	Fine-grained blue basalt. Bottom at 1,880± ft. Thin lenses of carbonaceous tuff in places along its base.
3	190±	Augite-feldspar porphyritic basalt with irregular bottom and in places containing interbedded contemporaneous tuff, indicating nearby vent. Rests on older basaltic tuff, ancient soil, and metamorphics at upstream end of diversion tunnel, and on tuff and flow 6 on downstream end. Bottom at 1,700± ft.

-	65±	Hard, black basaltic tuff composed chiefly of vesicular and amygdaloidal lapilli of highly variable thickness. Bottom at 1,635± ft.
2	50±	Fine-grained, vesicular and amygdaloidal nonporphyritic basalt. Not exposed at surface but found below river level in drill holes at powerhouse. May be vesicular top of valley-filling basalt flow No. 7.
1	300±	Dense, coarse-grained columnar basalt with scattered feldspar phenocrysts filling an ancient valley cut in the pre-Tertiary rocks near the Oxbow powerplant. Drill hole 63 did not penetrate flow at 1,598 ft.
-	0-25	Soil and hillwash lying on weathered metamorphics and buried by the lava flows.

Base of section

Some of the flows at the Oxbow are amygdaloidal. This is especially true of the basalt under the powerhouse where the vesicles are filled with zeolites (chiefly heulandite, according to Prof. Andrei Isotoff of Idaho State College), and by lesser amounts of chalcedony and opal. Vesicles in the pillow lavas are also filled with zeolites. A considerable number of fissures and vesicles contain iron pyrite.

One of the most unusual features of lava flow No. 3 is the presence of seams of glass up to two inches thick along joints. Because every fracture surface is coated with black glass, the blasted basalt resembles piles of coal. Drill cores indicate that the glass penetrated the flow through hairline cracks as well as larger openings, even filling cracks in feldspar phenocrysts (Howard Coombs, University of Washington, written communication). This glass had to make its way into the lava flow after the lava had solidified and fractured, probably while the rock was still hot. The glass in the flow penetrated from two nearby glassy dikes, but it is difficult to conceive how the magma could have penetrated the rock in such highly fluid fashion (Stearns, 1961).

The rock in all the flows is much the same in mineral content and composition. Such differences as may exist reflect differences in the rate of cooling and whether or not intratelluric crystals were floated up in the magma and trapped as phenocrystic grains in the lava rock. The flows are composed of siliceous basalts, like the Yakima flows of the Columbia River basalt described by Waters (1961, p. 588-604). However, the highly porphyritic basalts in Oxbow ridge fit his Picture Gorge basalts better than the Yakima basalts which are mostly aphanitic.

In the flows that were studied in thin section the rock is dark gray to black, is conspicuously porphyritic, with small, widely scattered crystals of labradorite up to 1/4 inch long. Smaller phenocrysts of augite are less common. The matrix is aphanitic. The groundmass is composed largely of labradorite and augite with appreciable amounts of magnetite tubes and ilmenite plates and variable amounts of brownish glass. Some of the phenocrystic plagioclase shows oscillatory zoning, but the plagioclase that composes the matrix is unzoned and forms small, well-shaped laths, with small grains of augite or glass in the interstices between the laths.

Basalt dikes

The 15 dikes mapped in the area (Fig. 2) as well as a few others later seen from the air, feeders to the lava flows, are composed of fresh, unaltered rock in marked contrast to the altered basic dikes related to and associated with the Seven Devils Volcanics. These basaltic dikes range from a few inches to 30 feet thick. Most of them show prominent cross jointing; a few show platy jointing close to their borders. All of them are bordered by glass selvages from 1/4 inch to 1/2 inch thick. Two of the dikes in the powerhouse area are composed entirely of glass. These two glassy dikes are six to eight feet wide, but thin rapidly upward. They can be traced through two lava flows and a tuff bed. Drilling in the area revealed numerous glassy dike stringers or dikelets a few inches thick, offshoots of these two glassy dikes. The glass is the same as that which permeated the lava flows in the powerhouse area.

The dikes are generally nonporphyritic but a few carry large augite and feldspar phenocrysts. Their rock is not so dark as the rock in the flows and is usually gray to brownish-gray and is fine grained. In thin sections there is little to distinguish the rock from that of the flows, except that glass is absent except in the two dikes described above, and in its place are scattered grains of accessory quartz. The essential minerals are augite and labradorite; and the minor minerals are magnetite (with lesser ilmenite), quartz, and needles of apatite. The quartz is interstitial with respect to the plagioclase and other minerals.

Basaltic dikes like those at the Oxbow are numerous throughout the surrounding region as this general region was a major source of the fissure eruptions that laid down the vast floods of Columbia River basalt in the adjacent parts of Oregon, Washington, and Idaho. At the Oxbow most of the lava apparently issued with mild firefountaining indicated by local accumulation of cinders. Since the cinder deposits are of limited extent, most of the lava flows must have formed inconspicuous lava domes or issued from fissure vents.

QUATERNARY DEPOSITS

General features

Surficial deposits of Quaternary age include bouldery terrace alluvium of Pleistocene age and streams and river alluvium as well as talus debris of Recent age. Because of some differences between the river deposits and those made by the tributary streams, the two are mapped and discussed separately. Patterned ground, probably of periglacial origin, caps the Oxbow ridge (Malde, 1964). Three patches of tufa are exposed at the mouth of Warm Springs Creek, deposits by a warm spring rising through buried limestone (Fig. 2).

Pleistocene deposits

Terrace alluvium

Terrace remnants scattered at intervals along the Snake River canyon as much as 200 feet above the river (Fig 2) are strewn with well-waterworn boulders. Where exposed in an excavation opposite the diversion tunnel (Idaho side), the terrace material contains much fine gravel and sand as well as scattered boulders. Stearns (1962, p. 386) considers that these deposits were laid down during a single catastrophic flood when ancient Lake Bonneville overflowed into the Snake River drainage.

Recent deposits

Talus

Extensive talus slopes are widespread along the river and in places on the upper canyon sides (Fig. 2). These occur at the base of basaltic cliffs and at the foot of massive outcrops of the older rocks; hence they are composed of two different kinds of materials. The talus at the foot of basaltic cliffs contains considerable clay and fines washed from the high weathered areas above. An attempt was made to utilize these fines for core material in the dam but the fines were not sufficiently abundant to separate economically and so core material had to be obtained from the exhumed fossil soils and decayed older rock remaining in small flats and basins high on the canyon slopes.

Stream alluvium

Some bouldery alluvium extends up the larger stream canyons tributary to the Snake River, but most of the stream alluvium is concentrated at the mouths of the tributary canyons where it spreads out as alluvial cones and fans bordering the river (Fig. 2). The stream alluvium is composed of boulders and poorly sorted sands and gravels deposited under torrential conditions, where stream velocity was checked at river level. The materials of these deposits are chiefly basaltic, having been derived from rocks within individual drainage basins.

River alluvium

The recent deposits of the Snake River consist of extensive cobble, gravel, and sand bars below the high water mark. Such alluvial deposits occur discontinuously along the river with the largest and most extensive exposures along the north side of the oxbow loop (Fig. 2). The large gravel bar on the Oregon bank just below the oxbow was the source of all the aggregate for the Brownlee and Oxbow dams. The gravel had a rather uniform size of minus three inches and was excellent aggregate, except for a deficiency in fines that was met by mixing with mill tailings from the Cornucopia mine in the nearby Wallowa Mountains. The gravel is generally composed of pebbles of basaltic composition, but the sand is commonly quartz, derived from the granitic terranes in the upriver tributary Boise and Payette River drainages.

STRUCTURES IN THE METAVOLCANIC ROCKS

FOLDS

The older volcanic rocks appear to form a northeast-trending, complexly faulted syncline whose axis is along the belt of schistic-gneissic rocks a short distance southeast of and roughly parallel to the oxbow loop (Fig. 2). Southeast of the axis the rocks of the schist-gneiss unit dip 70°NW to 85°NW, and on the northwest side dip as steeply to the southeast. Because folded rocks were not actually seen on the axis, the structure can be interpreted otherwise. Near and parallel to Indian Creek the general synclinal structure is interrupted by a faulted block of vertically dipping schistose beds which may represent either a tightly compressed anticline or anticline and syncline whose axes are about parallel to that of the major syncline. These vertical beds are in fault contact with the metavolcanics whose beds generally dip about 85°SE and appear to form the northwest limb of the faulted syncline. This relation to the supposed syncline may be partly confirmed by the presence of andesitic flows similar to those near Homestead about four miles upriver from the Oxbow.

FAULTS

The older volcanics have been extensively faulted. Some of the more prominent faults are shown on the map (Fig. 2), but the many hundreds of smaller ones that were observed have been omitted. The trend of the major faults is northeast, roughly parallel to the folding, but many of the minor faults strike northwest. The most notable faults are those which bound the block of vertically-dipping schists which extends across the end of the Oxbow ridge and up Indian Creek. The one on the northwest side of the block, which has brought the tightly compressed schistose beds against the somewhat less deformed beds of the Seven Devils Volcanics, may dip steeply southeast; the fault of the southeast side of the block may likewise dip steeply southeast. The displacement along these faults has not been determined but is probably considerable. A mapped fault of northwest trend apparently cuts off the block of schistose rocks near the end of the oxbow loop.

The older rocks are everywhere shattered and crushed by minor faults. Some 100 minor and 12 significant faults were exposed in the Idaho spillway of the dam, all too closely spaced to be shown on the geologic map. Most of the faults there exposed had strikes of N30°-60°W and dips of 40°-85°SW and NE. A few had strikes ranging from N5°E to N65°E, and nearly vertical dips.

STRUCTURES IN THE COLUMBIA RIVER BASALT

FOLDS

With minor exceptions, the flows of Columbia River basalt are everywhere nearly horizontal. Just west of the oxbow ridge the flows are tilted a few degrees to the south. Again near the mouth of Indian Creek in the Idaho bank the flows depart from the horizontal and appear to form a gentle syncline with flanking dips of 5° to 10° (Fig. 2), but the small local fold appears to be related to drag along the large post-basalt faults. Tilting of the flows in this area appears to be related to faulting rather than to any general folding. However, the Brownlee dam 11 miles upstream was built in the bottom of a broad syncline in the basalts; and farther southeast folding is common in the basalts.

FAULTS

Because they disturb the otherwise essentially horizontal layers of Columbia River basalt, the major post-basalt faults are very obvious, but the minor faults, closely spaced and numerous, are detectable only in fresh excavations, or in clean outcrops.

The Powerhouse No. 1 fault, so named because of its exposure at the now demolished powerhouse built in 1910, is the major fault in the mapped area (Fig. 2). Where exposed in a road to a borrow pit 1.1 miles up Blue Creek (road not shown on map), the fault forms a wide crushed zone bordered by narrow downdropped wedges of basalt and tuff. It there strikes N45°E and dips 85°SE. The fault is also well exposed in the abandoned railroad tunnel, where, as shown in Figure 4, it forms a crush zone 300 feet wide containing two bands of gouge and breccia, each 100 feet wide. On the southeast side of the bend of the oxbow, the fault has a measured downthrow of 415 feet.

A branch of the Powerhouse fault, designated as the Powerhouse No. 2 fault, is exposed on the downstream side of the outlet of the old diversion tunnel. It has a downthrow of 50 feet on the east.

Twenty-one faults cross the oxbow ridge in a distance of 900 feet northeast of the road crossing. All strike nearly due north, parallel to the five basalt dikes in the same area. Many more faults are probably concealed beneath the overburden on the remainder of the ridge. These faults have vertical displacements of a few inches to a few feet, but some have considerable horizontal movement. These faults are too closely spaced to be shown on Figure 1.

SUMMARY AND CONCLUSIONS

Aside from its conspicuous topographic aspect, the Oxbow has other features of general interest. Its older group of metavolcanic and sedimentary rocks differ considerably from the Seven Devils Volcanics farther downstream below Homestead and from the contained fossils nearby, is known to be of Permian (Phosphoria) age. The metavolcanics and sediments nearby, belong in the lower part of the Seven Devils Volcanics which are known elsewhere to contain rocks as young as Jurassic (Anderson and Wagner, 1952, p. 4-10). A thick succession of schistose-gneissic rocks were mapped separately. They appear to represent a unit of more intensely metamorphosed, originally chiefly tuffaceous rocks within the Seven Devils Volcanics. Their greater metamorphism reflects their occurrence along a zone of more intense deformation, marked by complex faulting and tight folding. This zone of marked structural weakness facilitated and directed intrusion of quartz diorite.

Flooding of the deeply weathered and dissected erosion surface carved in the metavolcanic and sedimentary rocks by flows of Columbia River basalt led to pooling of the lower flows, causing them to be thicker than those that later spread out after a smooth lava floor had been established. At several places lava that entered water developed pillows. Minor explosive activity accompanied some of the extrusions but much of the lava issued quietly from fissures, which are marked by basaltic dikes. Firefountaining and explosions at two local vents were responsible for an outward thinning basal bed of massive tuff breccia.

The basaltic lavas are siliceous and contain appreciable matrix glass. They appear to be equivalent to the Yakima basalt that forms the upper group of flows of Columbia River basalt (Waters, 1961, p. 588-604). Feeder dikes contain glass selvages but are otherwise composed of quartz-bearing basalt, the quartz showing the same relations to the matrix minerals in the dikes as does the glass in the flows. Of special interest are the two unique glassy dikes that intrude the lower basalts and inject glass into cracks in adjacent rocks, even into cracks of microscopic size. Such penetration of the nearby flows with glass along minute fractures is one of the most notable and least understood features of the area.

As for the more pertinent topographic features, the prominent northeast-trending post-basalt (Powerhouse) fault was responsible for the southwest (barbed) course of Indian Creek and for the northeast-directed course of Pine Creek. The same fault assisted by northeast-trending structures in the older rocks has also had a profound role in the formation of the oxbow loop. Excavations revealed horizontal movement along many of the lesser faults.

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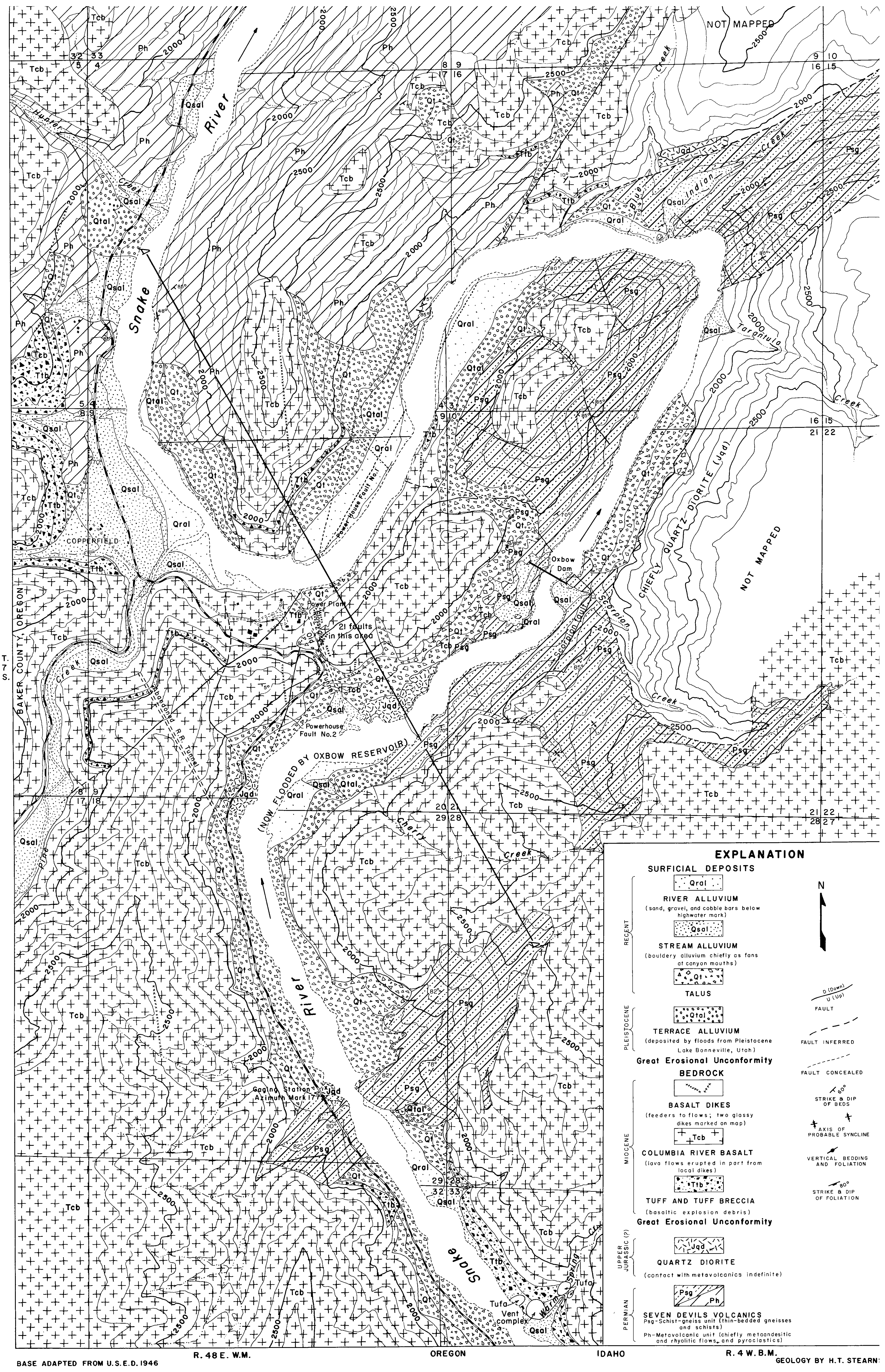

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