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Geology of the Grand Coulee

Joseph G. McMacken

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STEAMBOAT ROCK

PHOTO BY BROWN

GRAND COULEE DAM
AND
COLUMBIA BASIN IRRIGATION PROJECT

PRICE 25¢

THIRD EDITION

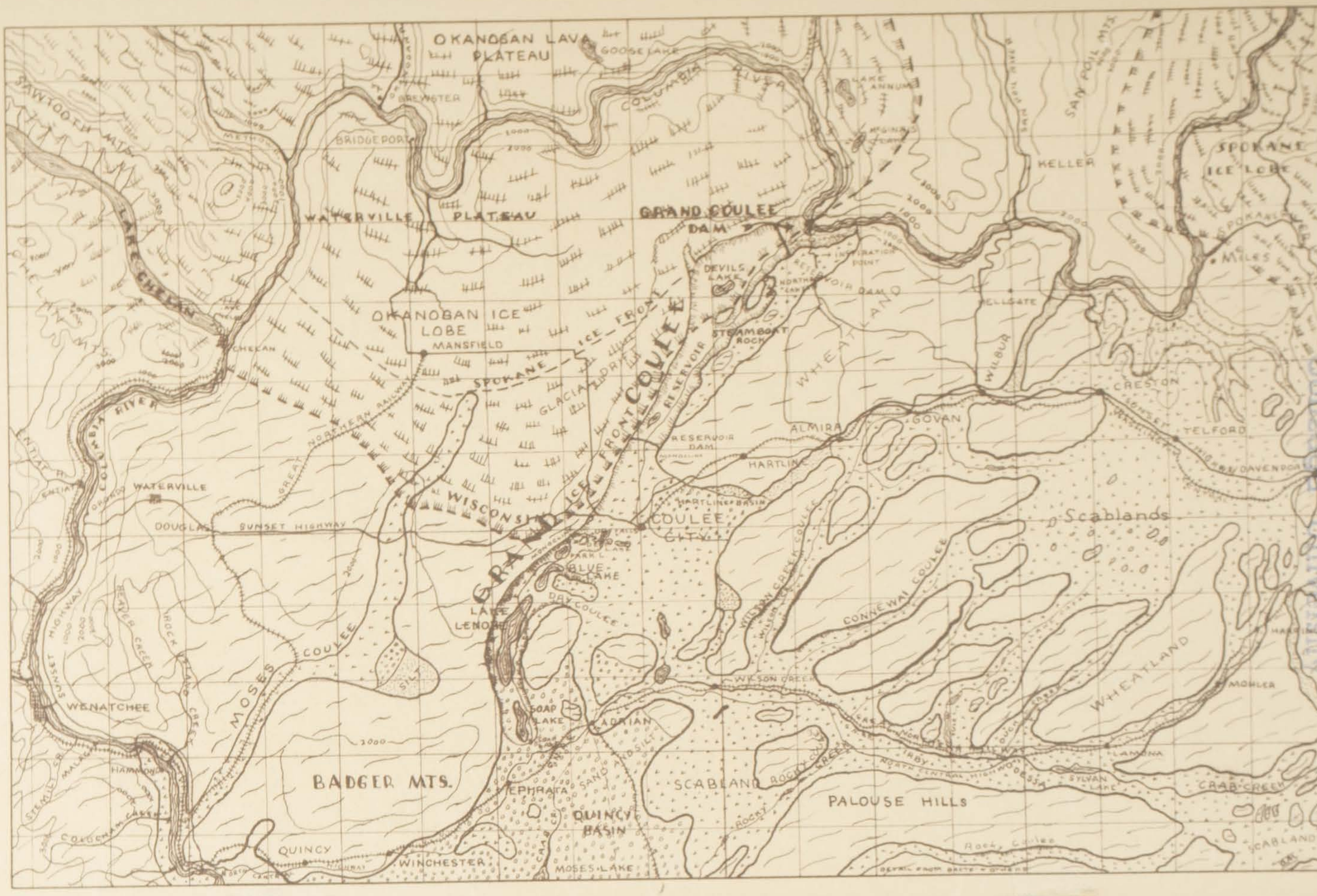


PHOTO BY WALLACE AERIAL SURVEY

DRY FALLS. UPPER COULEE WITH STEAMBOAT ROCK IN UPPER LEFT. WHEATLANDS RIGHT. COULEE CITY RIGHT CENTER. NOTE BATTLESHIP ROCK IN LINE WITH PROJECTION SEPARATING TWO HORSESHOE SCARPS. FALLS LAKE LEFT ALCOVE. CASTLE LAKE SHOWS BELOW COULEE CITY. DEEP LAKE FAILS TO SHOW BELOW IN RIGHT ALCOVE

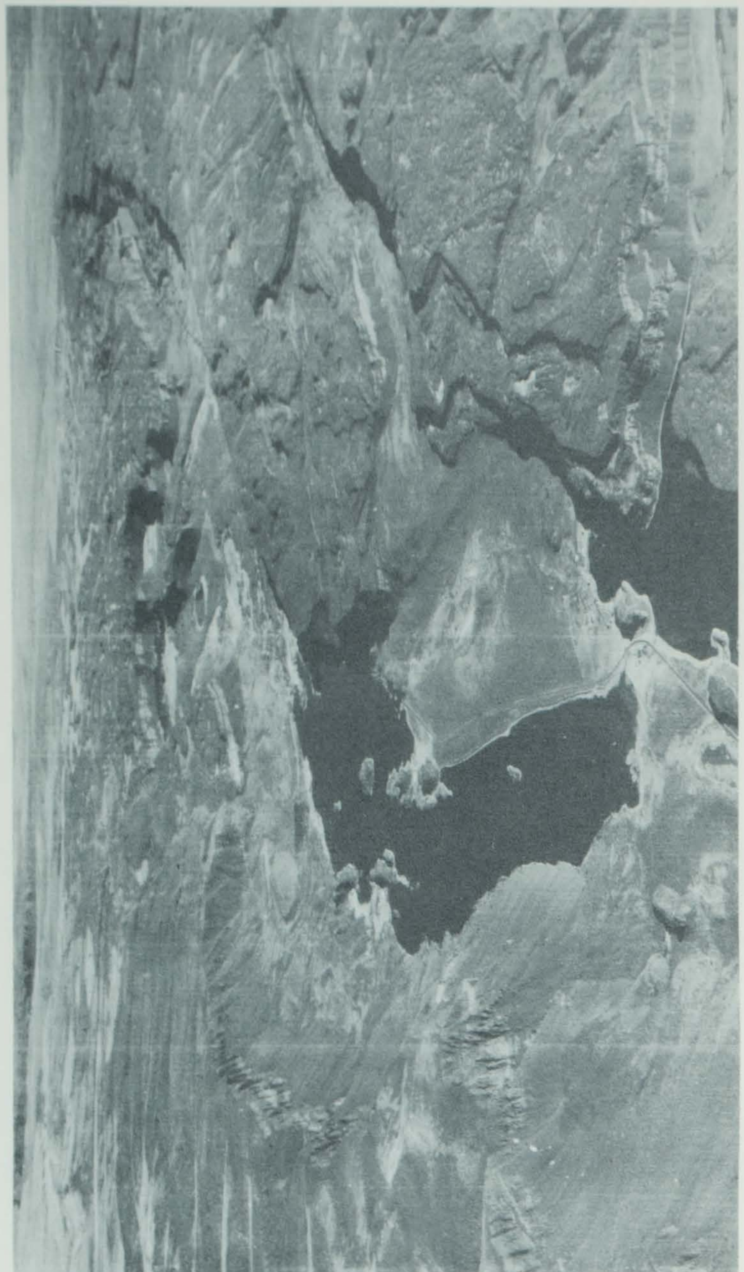


PHOTO BY WALLACE AERIAL SURVEY

GREAT CATARACT GROUP SHOWS IN CENTER. DEEP AND CLEAR LAKES IN RIGHT ALCOVE. FALLS AND PERCH LAKES IN LEFT ALCOVE. PARK LAKE IN CENTER. BLUE LAKE LOWER CENTER WITH JASPER CANYON LEADING TO RIGHT. FOSSIL TREES AND RHINOCEROS CASTS IN LOWER BLUFF HEADING JASPER CANYON.

GRAND COULEE OF WASHINGTON [1]

By Prof. Joseph G. McMacken
Lewis and Clark High School, Spokane

The Grand Coulée is, as is well known, a great gash, a thousand feet deep, cut across the even lava-plateau of central Washington, a Titan of chasms carved by the greatly swollen Columbia River when immense continental glaciers blocked its original channel and valley in the Big Bend region. Of all the many abandoned river channels in the Columbia lava plateau the Grand Coulée is the most remarkable and most portentous. It not only contains the greatest "dry falls" in the world, but it represents the greatest example of canyon-excavation by glacial waters in existence. It is one of the seven corrasional wonders of the world.

The Grand Coulée opens from the canyon of the Columbia River, in the northwest corner of Lincoln County, and extends southwest for a distance of 50 miles; ending at Soap Lake where it is made a closed canyon by the gravels of Quincy basin. It is divided into two parts at Coulée City by a break where the western wall subsides and is joined by a broad valley gradually sloping upward for 15 miles to the eastward. This break furnishes the only traffic route across its entire extent. The upper Coulée opens from the deep Columbia canyon at an elevation of 500 feet above the river. At this point the Coulée is three miles wide, gradually widening to nearly five miles at Steamboat Rock, and then narrowing to about $1\frac{1}{2}$ miles, as it opens out on the Hartline basin. Throughout its entire length it is a wide, flat-bottomed canyon with vertical walls of basalt reaching upwards to nearly one thou-

[1] Address before the Northwestern Scientific Association, Spokane meeting, December 27, 1928, accompanied by lantern slides.

MOUTH OF GRAND COULEE SHOWS IN UPPER LEFT CENTER OF PICTURE. TOWNS OF ELMORE, GRAND COULEE, MASON CITY, AND ENGINEERS TOWN LOCATED IN CENTER.

PHOTO BY GUILBERT

sand feet. About one-fourth of the way down the canyon stands the impressive Steamboat rock, a conspicuous enisled mesa, two miles long and half a mile wide, with its top on a level with the general plains surface.

Three miles below Coulée City, the bottom of the canyon makes a sudden drop of over 400 feet, marking the place over which the Columbia River once poured in a mighty cataract. The lower canyon, 20 miles long, extends from here to where it opens out on the Quincy basin. The eastern wall keeps about on the same level as the brink of Dry falls, but the western wall, dropping as a monocline rises to a height in places of over a thousand feet, and may be seen from many miles to the eastward as a black, frowning escarpment. The lower Coulée floor is nearly covered with beautiful, rock-walled lakes. The formation of the Coulée is a part of enormous excavating work done by gigantic floods of the Glacial epochs.

Back in Cretacic times, sea occupied all of central Washington, and extended from the Gulf of California to the Arctic ocean. The old Cascade peneplane formed its western border, while to the east, the old Selkirk range, connecting perhaps with the Blue mountains to the south was washed by its waters. With Miocene times came crustal warpings and continued elevation of the Cascades and adjacent territory. Volcanic activity was initiated, and out of thousands of fissures came prodigious lava-floods. Flood succeeded flood, as revealed in the Coulée walls, until altogether they covered 250,000 square miles, and built up the Columbia lava-plateau to a height of 4,000 feet in places. There is no record of greater lava-floods having ever appeared on the face of the Earth. Rivers were dammed and caused to change their courses. Large lakes were formed by these lava-flows. The Columbia River, flowing southward through the Colville and Chamokane valleys towards Pasco, was dammed and deflected by each succeeding lava-flood until it was made to flow into the Big Bend country, on the border-line between the old granite tract and the lava plain.

The Coulée walls record the history of at least seven floods separated from one another by long intervals of time. Each time the lava-plain must have cooled and weathered into soil. Tree-life slowly crept in from the highlands to the north and west only to be destroyed by a succeeding flood. One of these intervals is recorded on the shores of Blue lake. Here the cutting of the Coulée exposes, below the sixth layer from the top, the remains of a great forest. Here are the casts of big trees on the hollow trunk of one of which six or seven people may stand. Its upper part was destroyed and its charred remains were changed into fossilized wood. The soil on which this ancient forest grew was in many places baked into solid rock which is hard to distinguish from the basalt itself below.

At the end of the lava-floods, which built up the lava-plain to an elevation of 2,400 feet, the Columbia River was flowing in the Big Bend. Many mountain lakes existed in the valleys in the highlands to the north, held in by lava dams.

The period following was one of quiet and erosion. Some local uplifts in the Nespelem range, to the north, probably shifted the Columbia River from the Omak channel south to its present one. The mountain lakes were filled up or drained. The Columbia carved its way down the slope of the old granitic mountains as it excavated its magnificent canyon, 1600 feet deep, marked on the south by perpendicuıar walls of basalt. The lava-plain, partially covered with lœssial and lacustrine deposits weathered into the rolling, mature topography of the Palouse hills with well established drainage-lines.

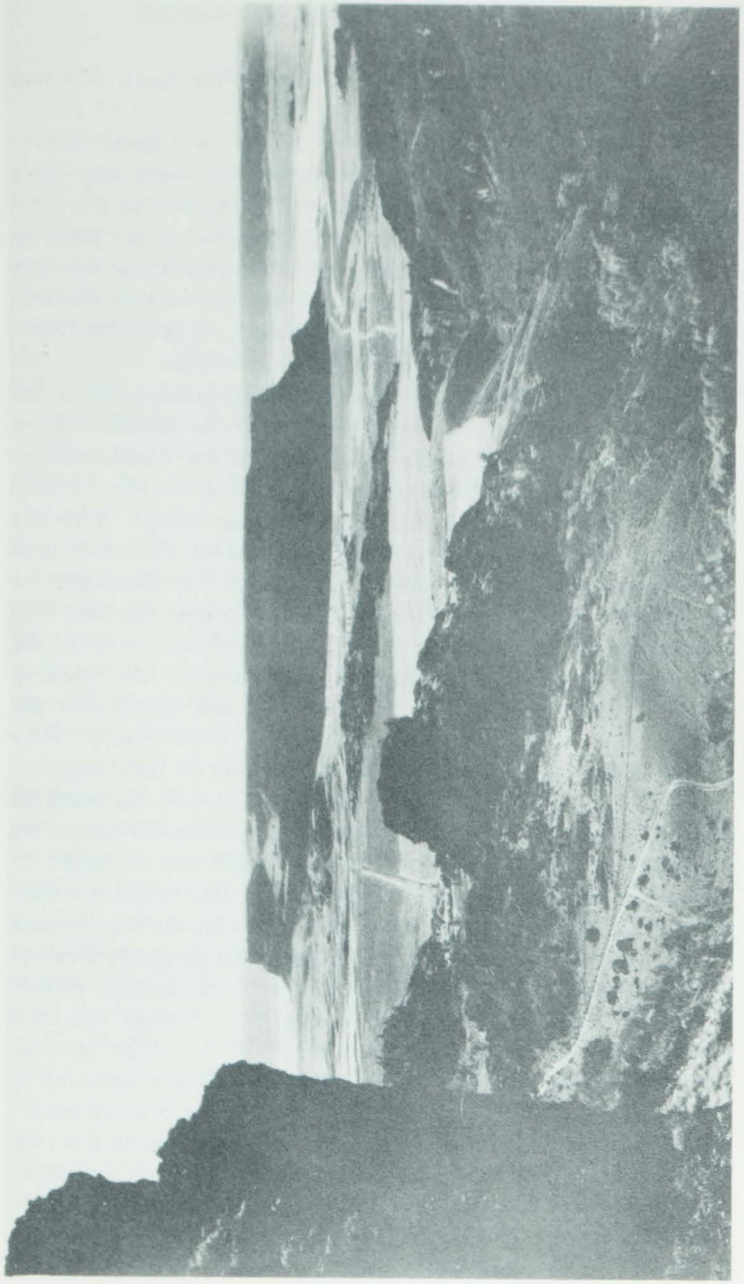
At the close of Pliocene time the Cascades were finally warped into position and the highlands to the north elevated. The lava-plateau was changed in many particulars. The western edge was raised several thousand feet, and the area near Pasco depressed a thousand feet or more to produce a gradual slope southward of 20 to 30 feet to the mile. Local warpings gave birth to a prominent fold, from Waterville to Rockford, the Spokane divide, which crosses the Coulée about four miles south of Steamboat rock. Two monoclines appeared to the south. One four miles north of Coulée City, seen plainly at the end of the east wall of the upper Coulée, sloped south eastward, and another, west of Coulée City is exposed on the west wall on the descent of the road down into the lower Coulée. These, together with a fold a little more than half way down the lower Coulée, formed the structural depression, or sag, of the Hartline basin. The western end of the lower fold warped higher to the west to produce the Badger mountains. Another monocline formed at the end of the lower Coulée.

Similar warpings to the south produced the Frenchman hills and the Quincy structural-basin.

Then comes the excavation of the Coulée by Glacial waters. At least three advances of the Cordilleran ice-sheets may have contributed to the cutting of the Coulée. Of the work of the Kansan Ice little is known. It is doubtful if it reached so far south as the Columbia River in the Coulée region. In two places only has its work been recognized: one near Cheney, reported by Pardee; and another northeast of Reardan, near Hite, reported by Bretz. Its work in the Coulée region is yet to be determined.

The melting ice, from the ever spreading glaciers, filled the rivers with sediments in volumes too great to be carried. Rivers overflowed their banks in effort to dispose of the Glacial waters. Great lobes of the ice extended down the Spokane, Colville, Columbia, San Poil, Methow, Chelan, and Okanogan valleys. Virtually the entire Columbia basin was occupied except the small area between Hellgate and the head of the Coulée. The Okanogan ice lobe filled up the Columbia valley, and pushed across the river into Douglas county, to the west of Grand Coulée. This ice dammed the Glacial floods pouring down the Columbia canyon. They quickly filled the unoccupied portions of the canyon and flowed over the divide along the east edge of the ice-dam to the south. They flooded an area ten miles wide, and no less than 50 feet deep.

As the Glacial floods poured over the anticline to the south of Steamboat rock they began the excavation of the Coulée. This flood, on a gradient of 20 to 30 feet to the mile, was an engine of tremendous excavating power. Here on this fold began a waterfall, a hundred feet or more in height, that worked its way through the divide backward towards the Columbia at about the level of the top of Steamboat rock. These yellow floods, as they poured southward, swept off the loose covering of Palouse soil, and tumbled over the monoclinal fold nearly 800 feet high into the Hartline structural basin. Here, where the Coulée narrows to about two miles, began the formation of one of the greatest waterfalls of all ages. After excavating its way a short distance up the Coulée it must have been two miles wide and 800 feet in height, with the flood of a hundred Niagaras. It operated for a period of time long enough to cut its way back nearly 30 miles to the Columbia. Eight miles before reaching the old Columbia valley,



STEAMBOAT ROCK FROM PRECIPICE OVERLOOKING MOUTH OF NORTHRUP CANYON WHICH ONCE STOOD AS A GOAT ISLAND TO DIVIDE TWO MIGHTY CATARACTS OVER 4 MILES WIDE AND 800 FEET HIGH.

PHOTO BY GUILBERT

it widened to nearly four miles, and dividing as it cut its way backward it left a Goat island, two and one-half miles long, a half-mile wide, and 800 feet high. Its layers of basalt look like the decks of a mighty vessel, hence, the name Steamboat rock. The white sands at its base remind one of the sea; and as one travels up the Coulée it seems to recede along the opposite Coulée wall to the south thus completing the illusion. Here on either side of Steamboat rock must have roared a once mighty twin-falls, each half 800 feet high and two miles wide.

A mile or two above Steamboat rock, the receding falls encountered a ridge of granite 500 feet high. This resisted the erosion of the falling waters, and this section was carved into one of the rugged and spectacular parts of the Coulée proper. Here small channels cut into the granite. Monadnocks of every size and shape were left. Several are capped with black basalt. The granite ridge loses itself in the east wall of the Coulée. Here there is direct contact between the granite and basalt. It indicates the long period of erosion to bare the granite before the oncoming of the lava.

As the divided Glacial waters were cutting backwards to form Steamboat rock, the eastern branch again divided to cut out one of the most spectacular sections of the Coulée. Here a water-fall, a half-mile wide and 800 feet high, when the Glacial waters were at flood, cut its way for a distance of three miles in a northeasterly direction. Two miles from the Coulée it divided into two branches and a half mile further the left scarp divided again. As the Glacial floods diminished in amount the channels gradually narrowed, so that their ends today are marked by scarps and pot-holes. A small lake in one of the pot-holes rests peacefully as a reminder of the ancient floods. The walls of Northup canyon, rising perpendicular over 800 feet from the narrow floor, seem to press in on all sides. It gives a feeling of depth and height not felt in the wider main Coulée.

When the Glacial floods poured into the Hartline basin, they found the pre-Glacial drainage-outlet to the southwest, formed by the structural sag, all too small to carry away the waters. They flooded back into the basin to form a lake covering over fifty square miles. Here the waters dropped their loads of silt, sands, and gravel to fill the basin to a depth of several hundred feet. The

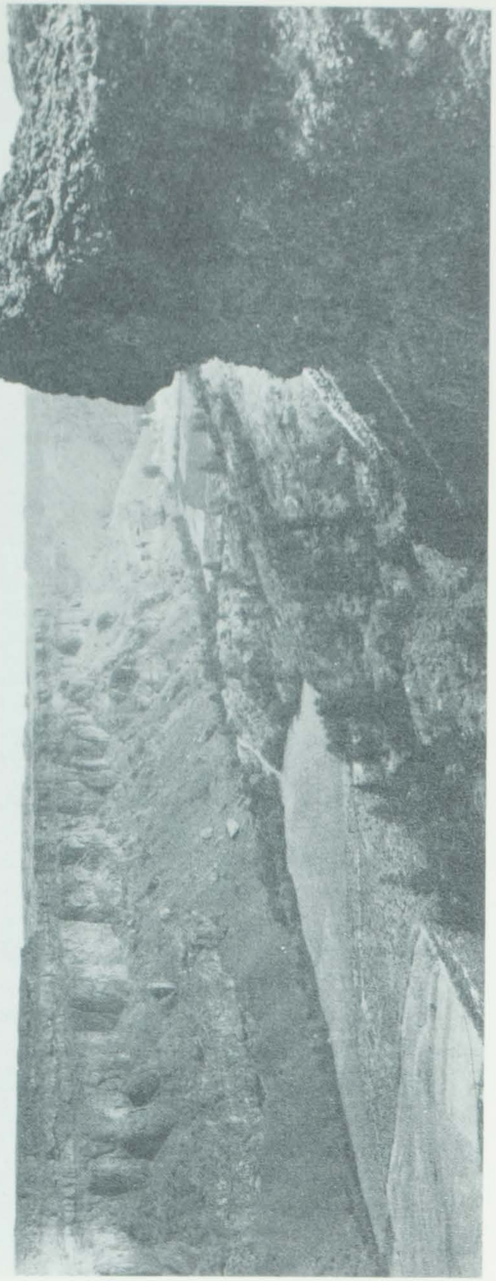


PHOTO BY LIBBY

NORTHRUP CANYON ONE OF MANY SIDE CANYONS OF THE COULEE IS MORE SPECTACULAR THAN MAIN COULEE DUE TO ITS NARROWNESS. CUT BY A RETREATING WATER FALL.

lake lasted until the Glacial floods cut channels wide and deep enough to carry off the flood-waters of summer. The last of the Glacial waters removed nearly all of the gravel near the vicinity of Coulée City and there left characteristic scablands.

The cutting of the lower Coulée in many ways is of greater interest than that of the upper Coulée. Here the Glacial waters spread into a number of anatamosing channels, due to the presence of the narrow outlet of the Hartline basin to the south which was filled to overflowing. The floods were so enormous that they flooded across the rock fold there over a width of 13 miles. They rushed down the south slope of the anticline to produce water-falls and rapids that carved out the most rugged, the wildest and most spectacular of all the abandoned channels of the scablands. The falls cut through the folds and dug deep into the layers of basalt below. They carved out channels in every direction, dividing here, uniting there, until one finds it easy to lose one's self in the maze. Hundreds of depressions, great pot-holes, monadnocks rising on every hand, mark a region of tremendous erosional activity cut by the yellow sand-laden waters. They left on their retreat Spring coulée, Deadman draw, and Dry coulée, the latter, for five or six miles from where it opens to the east from the main Coulée at the lower end of Blue Lake, runs eastward parallel to the divide until it finally opens southward into the Quincy basin.

The final stage in the early cutting of the Coulée occurred when the flood-waters poured down the monoclinal fold sloping southward into Crab Creek and the Quincy basin. Here began waterfalls that excavated the lower Coulée. At the lower end of Soap lake began the inception of Dry falls, two miles wide and at least 400 feet high.

The Glacial floods were, of course, seasonal in volume. As spring came and melting began on the surface of the great ice-fields, brooks and then rivers began to flow off the surface to augment that issuing from beneath caused by ground-heat and the ice-pressure. The lower channels were soon filled and began to be cut deeper. When melting was at its maximum all the higher channels were filled to over-flowing, and further excavated. As the colder seasons of the year came on the floods again diminished in amount, and, gradually shrinking to the main channels, in time cut these deep enough to carry the diminishing floods near the close of the Glacial epoch. In the latter part of the epoch only the lower, main channels were occupied, as is indicated by the narrowing canyon-walls below the old scarps remaining.

The down-cutting of the Grand Coulée represents enormous excavation and removal of ground-up basalt. The Palouse soil was removed from an area of at least 100 square miles, and the rocks below cut and carved into the main Coulée with its many side-canyons. In the upper Coulée area fully 20 cubic miles were removed. At least a similar amount was cut from the lower Coulée and side-canyons. No less than forty cubic miles of material were carried southward of which only a small part was left in the Hartline basin. At least twenty-five cubic miles of material found lodgement in the Quincy structural basin. Here the Glacial floods again confined by the narrow outlet of Crab Creek to the east of Frenchman hills, spread until they formed an immense lake covering the basin area of 250 square miles. Here gravels and sand and silts were deposited to a depth of 500 feet. This lake had four outlets, three to the west, opening into the Columbia valley, and the original Crab Creek outlet, to the east of Frenchman hills. This lake existed until the Drumhellar channels were excavated over an area ten miles wide and deep enough to drain it at least partially during the low-waters of winter.

Lake Quincy is a portion of the lake described as Lake Lewis in a previous paper by the author entitled "Lake Lewis and the Flood-waters of the Okanogan Ice-sheet." Lake Quincy, together with Hartline lake, connected with the flooded basins of Pasco, and Willamette valley, when the Glacial floods were at their height, and combined to form Lewis lake.

It of course took considerable time for the falls to cut their way the lengths of the lower and upper Coulées. Allowing 20 feet a year the floods excavated and sculptured for a period of approximately 6,000 years. It may have been somewhat less, since the successive layers of basalt separated by erosion planes with layers of soil, together with the loose basaltic columns, lent themselves admirably to rapid-disintegration. The falls cutting back along the erosion-lines readily under-cut the basaltic columns by removing the clay. The suction of the rushing, falling waters was ample enough to pluck the columns easily from the scarps of the Coulée-walls. The waters flooded over the anticlinal to north at an eleva-

tion of 2,500 feet. They dropped over 1,500 feet before they entered the Quincy structural basin. Eliminating the up-gradients due to the folds and the steep monoclinal, the gradient averaged more than 30 feet to the mile. Today, above Dry falls, the gradient for several miles is in excess of 80 feet to the mile.

When, at last, the climate grew warmer the great ice-sheet began to melt rapidly and to retreat northward. The lakes to the south diminished in size, and, as the Glacial floods subsided, they finally were completely drained, and their bottoms traversed by streams. Many stranded bergs melted to leave their loads of boulders to litter the lake-bottom and Coulée-floor. With the removal of the ice-dams the Spokane-Columbia drainage to the east resumed its former course, and, for a time at least, found its outlet through the Coulée. The waters from the retreating ice, coming down the Okanogan valley, in time removed the gravels from the Columbia basin below the mouth of the Coulée, allowing the river to assume its old channel to the sea. This may not have been as long and serious an undertaking as might be imagined since the ice-filled section may not have been filled with gravel up to the 1800-foot level, as is indicated in the unoccupied sections of the canyon. After filling the canyon the ice would be forced over the lower section, and only the melting at the bottom would deposit sediment. The writer has recently had an opportunity to examine the terraces in this section in proof of this hypothesis.

The retreating waters left the Coulée much as it is today. Its floor stood fifty feet higher than it does now. This, in part, is told by the deposit of shells seen in the excavation at the side of the new highway along the east side of Park lake. These were left on the shore-line of one of the lakes that must have dotted the old Coulée floor. As the climate had changed to a semi-arid condition, due to the then recent elevation of the Cascades, erosion did little during the inter-glacial stage to change the topography of the Coulée. Dry falls probably stood as a scarp three miles below its present location, where the road leaves the upper floor to descend into the lower Coulée. This is indicated by the widening canyon at this point.

Then, for long, nothing occurred to mar the quietness of Coulée-walls. Again the climate changed to that of another Glacial epoch. The glaciers in their retreat near the tops of the mountains began at least their third advance. Again they pushed southward towards the Spokane and Columbia valleys only to reach them at one point. The Okanogan lobe of this Wisconsin ice pushed its way across the Columbia, again diverting its waters into the Grand Coulée. It pushed farther south than the Spokane Ice, to near the brink of Dry falls. It forced its way into the upper Coulée as far as Steamboat rock, as shown by the striations on its western edge. It forced the waters to flow through the eastern channel with a western bank of ice.

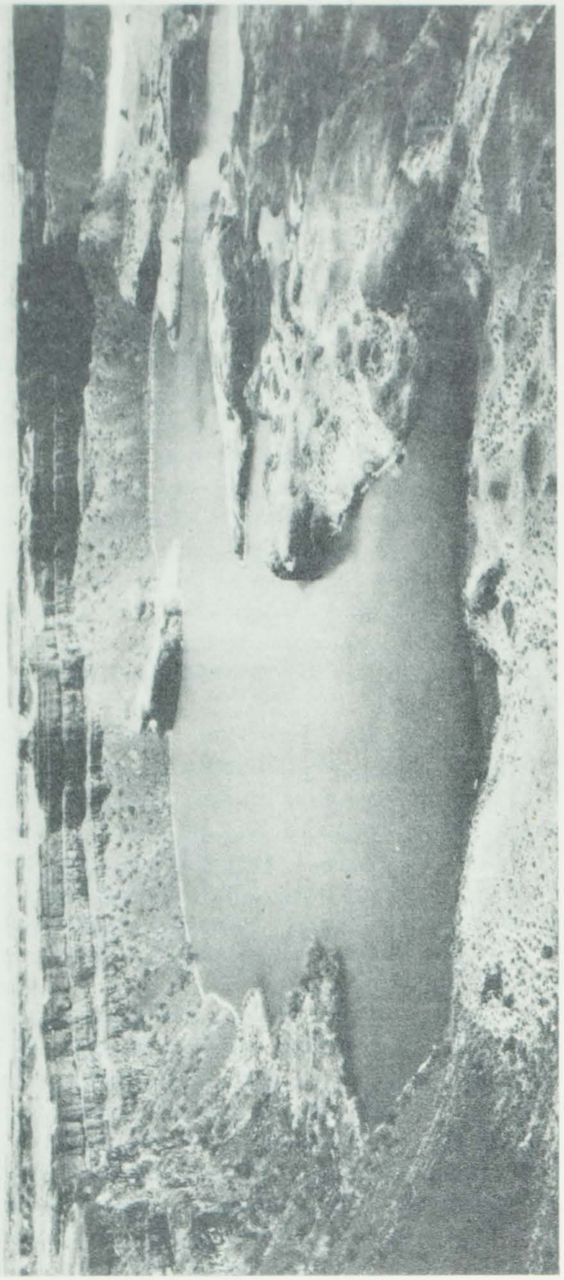
The ice was of less thickness and volume than the Spokane ice-sheet. The Glacial floods were of diminished volume and excavating power. Although the Grand Coulée was the only one of the ancient channels opening from the Spokane ice-front into the scablands to be occupied, the main Coulée was large enough to carry these immense, but not so gigantic, floods as those of the Spokane ice-age, although they consisted of all the waters from the ice-front as far east as the Rocky Mountains. The Okanogan drainage was diverted mostly through Moses Coulée, and the Columbia drainage to the west. The fact that Grand Coulée, together with Moses Coulée, were the only old channels to be occupied, is explained by Professor Bretz on the basis of the height of the talus-slopes on the Coulée walls. In Grand Coulée they extend about two-fifths the height of the walls, while in the older channels to the east they reach from three-fifths to four-fifths up, indicating a much older age. He has worked out the relative time-intervals between the Glacial epochs, and the Present by the volume of the talus and the cliff-surfaces exposed.

With the Wisconsin Glacial floods deflected to the Grand Coulée, Dry falls came into being again and started to retreat up the Coulée some three miles to its present scarp. None of the eastward channels opening out of the lower Coulée were occupied. The waters did little to change its topography, except to deepen the bottom of the Coulée, and to excavate the lower Coulée about three miles farther northeast. In the Quincy basin they lowered the old channels southward. In the lower Coulée the waters scoured out and lowered the level of the rock-walled lakes. The retreating falls divided near their present location and sculptured out Battleship rock. The falling waters ground deep to leave Perch and Deep lakes nestling at the foot of the falls. In the upper Coulée the

channel was deepened and widened to the east of Steamboat rock, and made more rugged. The absence of a large gravel bar at the mouth of Northup canyon may indicate that it was for a time occupied. The more resistant granite outcrop to the north and east of Steamboat rock had left this channel at the close of the Spokane epoch at a higher elevation. With the retreat of the ice the waters were diverted to the west channel to further deepen it, leaving Devils lake, and one or two smaller bodies of water where it scoured deeper. From the Glacial ice-bank and dam great blocks of ice broke loose to float as bergs down the channel. As the waters diminished these stranded on the margin and bottom to melt and leave huge boulders to litter the Coulée floor. As the ice-dam melted, and the waters began to revert to this former channel, large quantities of sand and silt were left to fill the level stretch in the bed. A large gravel-bar was left to partially block the entrance to a small, short, scarp-ended canyon on the east wall about the midway between Steamboat rock and the Hartline sag indicating the great depth of the waters. The part of the Columbia-canyon not occupied by the ice was again filled to the 1200-foot level with gravels indicated by the gravel-terraces at that level remaining today.

This relation would be lacking if I did not take time to describe briefly the chief scenic attraction of the Coulée, the Dry falls. Here operated one of the greatest water-falls of all geological history. It is not hard to visualize the scene when the diverted waters of the glacially swollen Columbia River, over three miles wide and from 50 to 300 feet deep, poured its mighty flood over the brink of the precipice. Niagara falls are a pigmy in comparison, with drop of only 165 feet. The power of Columbia waters was at least that of a 100 Niagaras.

Today, of course, all is silent. One stands on the dry, frowning brink of the Coulée chasm and gazes hundreds of feet down upon the placid lakes nestling in the pot-holes ground out of the solid rock at the foot of the one-time falls. The scarp rises from the lakes below as a perpendicular wall built tier upon tier by at least seven distinct lava-flows. The irregular brink divides into a number of horseshoe falls receding here and again extending. Below the center rises a goat-island, Battleship rock, telling of a time when the excavated waters had divided into a double falls. The



DRY FALLS 3.5 MILES WIDE AND 417 FEET HIGH SHOWS SEVEN LAVA FLOODS IN ITS ESCARPMENT. ITS FALLING WATER WOULD HAVE MADE A HUNDRED NIAGARAS. FALLS LAKE FILLING POT HOLE AT BOTTOM. ALLIGATOR HEAD.

PHOTO BY GUILBERT

Battleship rises to the level of the canyon-walls, and is half a mile long and several hundred feet wide. As one looks along the broken escarpment to the opposite wall, in its somewhat hazy outline, over-three miles away, the scarp seems to shrink, but one only needs to climb from the Coulée floor below to fully realize the great depth to which the falling waters once plunged.

The walls of the Coulée reveal the happenings of many ages past. The fossil beds in the clays, at the head of the Coulée, tell story of the lava-formed lakes, and of a flora of other days. Fine remains of the ginco, the maiden-hair fern-tree, which now grows only in the Orient and is called the Sacred Tree of China, have been uncovered. Sequoias, similar to those now growing in California, flourished here at one time. Fossilized leaves of 20 varieties of oak, as well as leaves of the elm, yew, cypress, sweet-gum, and the trees of the fig family, have been unearthed.

The old granitic landscape uncovered, relates the story of the earliest events of geologic history. Steamboat rock tells of twin falls so prodigious as to stretch the imagination. The boulder strewn coulée-floor tells of the ice ages and glacial dams so necessary to explain the origin of the Coulée. The perpendicular walls rising layer upon layer tell of a scene so spectacular in its achievements that the story of the Valley of Ten Thousand Smokes in Alaska, leaves much to the imagination yet to be comprehended. The folds and structural sags tell of the shrinking of the Earth's circumference due to the loss of its life-giving interior heat. Dry falls stands as a silent reminder of the manner in which the Coulée is excavated by the retreating water-falls. The rock-walled lakes from Perch and Deep, at the foot of Dry falls, including Park, Blue, Leonore, and finally Soap lake, at the lower end, tell of the unequal erosions of its falling rushing waters. The ancient fossil trees on the shores of Blue lake picture a semi-tropical, forest-clad landscape growing mid lava-flood periods millions of years ago. The gravel-filled basins and scablands and channels bordering the main Coulée show the enormous volume and wide extent of the Glacial floods.

Recapitulating the events as they appear at the height of the tremendous Spokane floods, we may picture to the north, so far as eye can reach, a vast, illimitable ice-sheet, above which only the tallest mountain peaks project, as islands out of the sea. The

VIEW OF PARK LAKE WITH ISLANDS FROM TOP OF ROAD LEADING INTO LOWER COULEE. BLUE LAKE IN THE DISTANCE. ISLANDS SHOW MONOCLINAL FOLD DIPPING INTO LAKE EASTWARD.

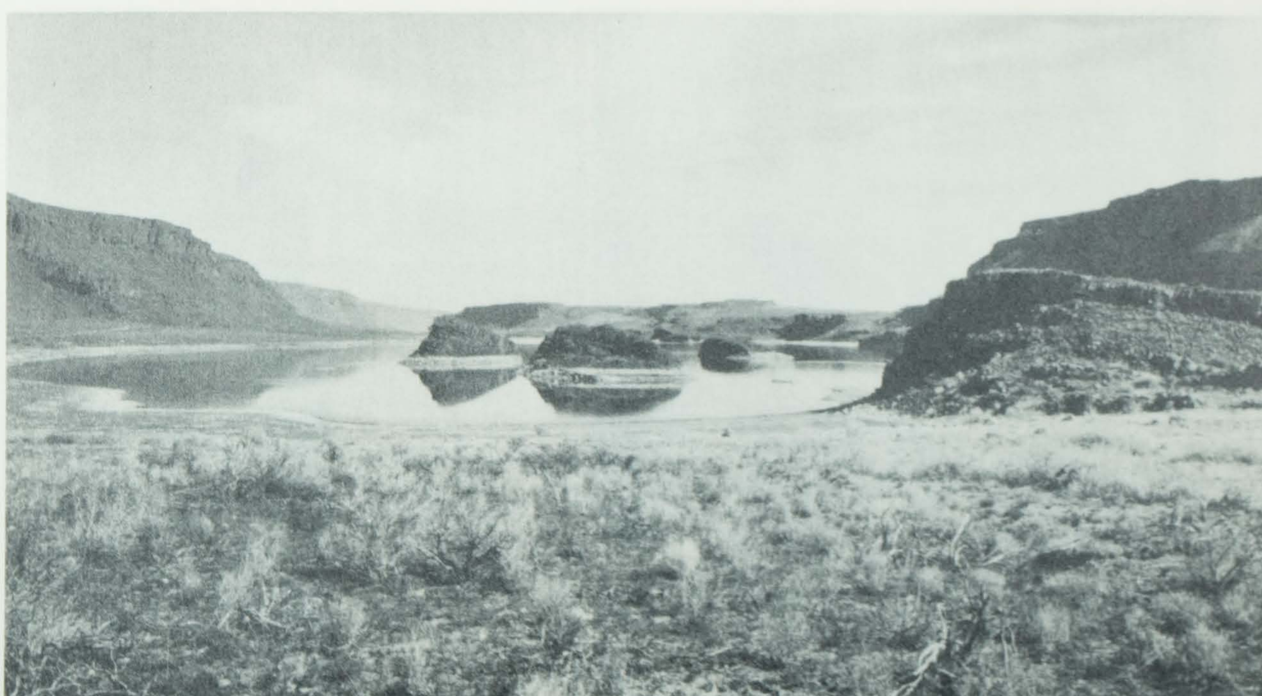
PHOTO BY GUILBERT

BLUE LAKE LOOKING SOUTH. WALLS ON RIGHT TOWER 1000 FEET. BREAK IN LEFT WALLS OPENS INTO DRY COULEE. REMAINS OF FOSSIL FOREST EXIST ON EAST WALL.

PHOTO BY BROWN

BLUE LAKE LOOKING NORTH. GRAND COULEE WITH ALL ITS SOMBERNESS HAS MUCH OF RUGGED BEAUTY. A PERFECT REFLECTION.

PHOTO BY GUILBERT



LAKE LENORE LOOKING NORTH FROM ISLAND. SMALL ISLANDS AND BOTH WALLS SHOW SLOPING MONOCLINAL FOLD ALONG WHICH THE LOWER COULEE WAS CUT.

PHOTO BY GUILBERT

AERIAL SCENE FROM INSPIRATION POINT LOOKING NORTH DOWN RIVER, SHOWING MOUTH OF COULEE IN LOWER LEFT. THIS PICTURE WAS TAKEN BEFORE DAM CONSTRUCTION WAS STARTED. NOTE ARROWS SHOWING LOCATION OF DAM.
PHOTO BY WALLACE

SOAP LAKE AT LOWER END OF COULEE. EASTERN WALL SHOWN SUBSIDING INTO LEVEL FILL OF QUINCY BASIN. TOWN OF SOAP LAKE IN DISTANCE.
PHOTO BY DeLONG

Columbia River canyon, dammed by glaciers on the east and on the west, is filled to overflowing by the glacial rivers emerging from underneath and from off the ice-sheet. Boulder-laden icebergs breaking from the faces if the ice-dams to east and west float slowly in the yellow, silt-laden waters to the outlet at the head of the Coulée, here to quicken their speed as they entered the five-mile wide opening to the south. Gaining speed they divided at a great goat island to plunge over two gigantic horse-shoe falls each two miles and more wide and 800 feet high, to break with deafening roar upon the rocks below. A subordinate flood diverges to the east, and dividing into three streams each a quarter of a mile wide, drop over as many scarps a thousand feet down into Northup canyon, later to join the main flood two miles below. For twenty miles these floods swirl southward to partly slacken their speed as they entered the Hartline basin, there to divide as they emerged to the south, part to seeth and tumble as it encounters the Monadnock, rock-channeled ruggedness of the Frenchman draw, with falls of many widths and depths, part to follow the main channel, two miles wide, to again plunge over another mighty scarp, 400 feet, or more, to the floor of the lower coulée, finally emerge and lose their rapid motion in the placid berg-spotted waters of the Quincy basin.

Grand Coulée, with all the somberness and solemnity of its massive walls, has much scenic beauty. Its perpendicular walls of basalt rise from the level Coulée floor below, tier upon tier, each one of which having its row of basaltic columns, to import to it the appearance of a cyclopean masonry laid by Master hand.

In closing let me show you by pictures something of Grand Coulée's scenic grandure and beauty and something of its geological story.

BIRD'S-EYE VIEW OF COLUMBIA BASIN PROJECT

GRAND COULEE DAM
and
COLUMBIA BASIN IRRIGATION PROJECT

The Grand Coulee Dam and Irrigation Project, when completed, will be one of the largest in the world and will help solve the problems of cheap power and unemployment. It will furnish homes and work for over 100,000 people directly, and indirectly to hundreds of thousands more.

Grand Coulee Dam will hold back the rushing waters of the largest power stream on the American continent. The high dam, when completed, will create an artificial lake 385 feet deep at the dam, an average of .8 miles wide, and extending up the Columbia River 150 miles to the Canadian boundary. The dam will raise the waters of the Columbia River 354 feet, from normal low water level, and will be the highest spillway dam in the world. To hold back the enormous pressure of the impounded waters, the dam will be one of tremendous proportions. Its length will extend across the river 4,300 feet, or nearly a mile. From bed rock to top, it will rise 550 feet above the lowest point of bed rock and will be 500 feet thick at the base, and narrow to a thickness of 30 feet at the top. This will be wide enough to contain a 24-foot roadway and enough room left to place and operate the massive gates of the spillways. The dam will contain 11,500,000 cubic yards of concrete and require 12,600,000 barrels of cement.

The power stations will be located on both sides of the river below the dam and have a total length of 1,300 feet, with a width of 78 feet. Water will be led through 18 giant

PANORAMIC VIEW OF GRAND COULEE DAM CONSTRUCTION. UPPER PLATE SHOWS WEST SIDE WITH ENGINEERS TOWN IN BACKGROUND.
LOWER PLATE SHOWS EAST SIDE CONSTRUCTION WITH MASON CITY IN BACKGROUND.

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steel pipes 18 feet in diameter to 18 powerful turbines each generating 140,000 horsepower, a combined total of 2,520,000 installed horsepower. The pull of these turbines would equal the combined pull of 1,260,000 teams of horses, extending a distance of over 5,000 miles, or nearly twice the distance from Los Angeles to New York. It will furnish a continuous output of 1,225,000 horsepower, the largest power plant in the world. It will be over two and one-half times the size of the Muscle Shoals dam, nearly twice the size of the Boulder Dam, and will be equal to all the combined plants at Niagara Falls.

The Columbia Irrigation Project, as now surveyed, covers 1,200,000 acres, the largest in the United States. It consists of fertile soils of sands and silts in the Quincy and Pasco basins deposited by the glacial floods from the material ground out from the Grand Coulee. For proper irrigation, this land will require 3.25 acre feet per year or, in other words, 39 inches of rainfall per growing season. To furnish this volume of water, a total of 12 powerful pumps will be installed above the dam on the west side. Each unit will require a 62,500-horsepower motor that will raise 1,600 cubic feet of water per second, through pipes 11½ feet in diameter leading to a canal nearly two miles in length to the Grand Coulee Reservoir. The average lift will be 310 feet and require a total of 625,000 horsepower.

The reservoir in the Upper Coulee will be 23 miles long and 2 to 5 miles wide and will be confined by two dams, one at either end of the Coulee. Steamboat Rock will rise as an island in this artificial lake. The reservoir will store 340,000 acre-feet of water. From the lower dam a canal 11 miles long will extend southward where it will divide into two parts, one leading west to the Quincy basin and the other south and east to the Pasco section. These canals will divide and subdivide until they furnish water for each acre of soil.

Excavation for the dam is nearly completed and the pouring of cement is under way. One needs to see the gigantic machinery at work to fully realize the magnitude of the undertaking. Steamshovels, trucks, cranes, motors,

cement mixing plant, conveyor belts, and coffer dams are all of giant proportions. It is well worth a trip across a continent to see these giants at work building the world's largest dam. The mammoth dam is employing 4,500 men directly, and indirectly over 5,500, besides the thousands employed throughout the United States furnishing material used in its construction. It will require at least 8 years to construct, at an estimated cost of $175,000,000, and the total cost of the Columbia Basin Project will be $383,000,000, and require some 40 years for completion.

The Grand Coulee dam will stand at almost the exact spot where the mammoth glacial dam of ice once stood. The dam, when completed, will be a monument to the greatest skill of the hydraulic engineers, though a pigmy in comparison to the dams of glacial ice.

Look with me, if you will, from Inspiration Point and in your imagination see the enormous rivers of ice as they moved down the Okanogan valley to fill the 1800-foot Columbia Canyon and pushed up and over the canyon wall to spread across the Waterville Plateau. This gigantic ice barrier extended southward along the western coulee wall as far as the eye can reach and stretched northward for miles until lost in the distance against the rising peaks of the Okanogan Mountains. It towered upwards above the present river level to a total height of over 1800 feet, and would have made at least 50 Grand Coulee dams.

Although we give freely all due praise to the skill of the engineers and the minds of men that have conceived the present project, yet we must bow our heads in reverence to the tremendous excavating power of Nature's floods that excavated the magnificent canyon of the Columbia and to the titanic rivers of ice that reached down from the north like a mighty hand to seize the river in its icy grasp to dam and divert its floods long enough to sculpture one of the world's wonders, The Grand Coulee.

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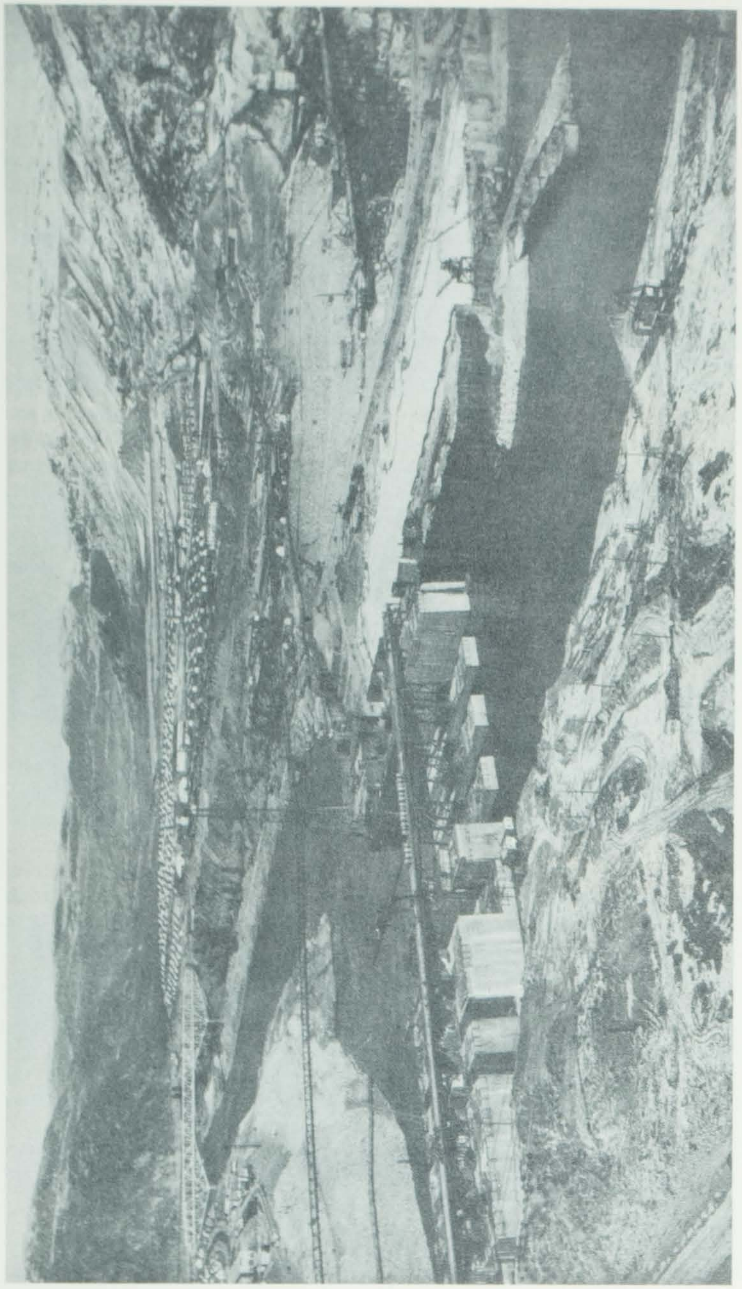
1933 . . . . State of Washington appropriated $377,000 for preliminary survey by Columbia Basin Commission. Grand Coulee Dam and Power Plant included under Public Works program. $63,000,000 allotted for first stages of construction. Mr. F. A. Banks appointed as construction engineer in charge. Thousands of feet of core drilling showed granite foundation to be a "natural." Excavation of bedrock overburden commenced by steam shovels and trucks.

1934 . . . . Government engineers' town planned and streets graded. United States highway bridge started. Contract for construction of foundation of dam and power plant awarded to Mason-Walsh-Atkinson-Kier Co. President Roosevelt and party inspected damsite. Mason City, contractors' camp, finished after 90 days of work. Railroad, highway grade, and power lines from Coulee City completed.

1935 . . . . West side coffer dam completed in March. Conveyor belt carrying 1.3 tons per second of excavated material to Rattlesnake Canyon put in use. Sand and gravel washing plant, conveyor belt, and gravel storage plants finished. Low-dam plan abandoned and contractors ordered to place amount of concrete contained in contract in base of high-dam. Bedrock uncovered. Suspension bridge for sand and gravel conveyor to mixer completed. Highway bridge opened to traffic. Two trestles, with tracks for cement cars, and with cranes for dumping concrete, built over foundation. Cement storage plant and pipe line to mixer completed. All operations of bringing sand, gravel, cement, water, and determining of mixture done by pressing electrical buttons. First concrete placed in dam in Block 40 on December 6th by Governor Martin. Concrete poured in large interlocking blocks. Cracking will be prevented by installing over 2,000 miles of one-inch water pipe in concrete for circulating cold water to remove heat liberated by setting cement.

1936 . . . . East side cofferdam and cement mixer completed. East side excavation continued. Slumping into excavation stopped by freezing area with refrigeration plant. Cofferdams for diverting river started across river from each end of east cofferdam to connect with west foundation. Cribs of timber prepared, floated into place, and sunk to river bottom by filling with gravel and rock. Interlocking steel piling driven to bedrock around cribs. River diverted in November, 1936, to flow through slits over west side foundation. Water pumped out between cofferdams and excavation started.

1937 . . . . Cement poured on east side. Trestles will be connected across river to pour center section. As spillway section in center rises, three parallel, horizontal rows of 20 tunnels, each 8½ feet in diameter, will be constructed through dam. Gates in these will regulate flow downstream in low-water periods. As dam rises, temporary gates will close slits carrying river flow to other slits higher up. Closing gates in tunnels will cause reservoir to fill. A few weeks later will see water flowing through turbines and over the gigantic spillways. Grand Coulee power will be ready to serve mankind.



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COLUMBIA RIVER DIVERTED. VIEW FROM WEST BANK SHOWS DIVERTED RIVER FLOWING THROUGH SLITS IN FOUNDATION. NORTH AND SOUTH COFFER DAMS SHUT OFF THE OLD RIVER BED. THE WATER IN OLD RIVER BED WILL BE PUMPED OUT AND OVERBURDEN EXCAVATED. TWO EAST TRESTLES WILL BE EXTENDED TO POUR CEMENT IN OLD RIVER BED. WEST SIDE COFFER DAM IS BEING DISMANTLED

DATA COLUMBIA BASIN PROJECT

GENERAL INFORMATION	
Project of Public Works Department	
Contractor: Mason-Walsh-Atkinson-Kier Co.	
Engineer in charge of work for the U. S. Bureau of Reclamation, Frank A. Banks	
GRAND COULEE DAM	
Length at Crest	4,300 ft.
Length of Spillway	1,650 ft.
Height above low water	374 ft.
Height above bedrock	550 ft.
Power head at low water	354.6 ft.
Thickness at base	500 ft.
Thickness at top	30 ft.
Excavation	18,000,000 cu. yds.
Concrete	11,500,000 cu. yds.
Cost of dam and power plant	$175,000,000
COLUMBIA RIVER RESERVOIR	
Length of lake created	151 miles
Elevation above sea level	1,292 ft.
Acre-feet of storage	5,028,000
GRAND COULEE RESERVOIR AND CANALS	
Length of reservoir	23 miles
Length of main canals	13 miles
Elevation of water surface above sea level	1,570 ft.
Acre-feet storage	329,000
POWER PLANT AND COST OF POWER	
Number of turbines	18
Horsepower of turbines	140,000
Total installed horse power	2,520,000
Continuous output	1,225,000
Cost in mills of generating per kilowatt hour, prime	1.14
Secondary	.5
Increased power down stream to Snake River	100%
PUMPING PLANT	
Average pumping lift	310 ft.
Number of 1600 second feet pumps	10
Horsepower required for pumping	660,000
RECLAMATION PROJECT	
Acres to be irrigated	1,200,000
Cost of reclamation work	$208,265,000
Total cost of dam, power plant, and reclamation	$383,265,000
Net cost per acre to farmers	$88.00
Total annual charges per acre	$5.39
BENEFITS FROM PROJECT	
Homes and work for	100,000
Increased taxable project values	$217,484,300
Increase population in the Northwest	1,403,000
Annual return for products of Columbia Basin	$110,000,000
Increase N. W. taxable wealth	$3,000,000,000
Carloads of supplies required by population	200,000