

Ell, J. 1956. Soil Conditions and Plant Growth. Longmans, Green & Co., New York. 35 pp.  
Greene, F. 1922. Conditions indirectly affecting vertical distribution on desert mountains. Ecology, 3: 269-274.  
Greene, F. 1924. Soil temperature as influenced by altitude and slope exposure. Ecology, 5: 28-136.  
Greene, F. 1927. The physical conditions of a coastal mountain range. Ecology, 8: 398-414.  
Survey Staff. 1960. Soil classification. Soil Conservation Service, U.S. Dept. of Agriculture. Weather Bureau. 1930-1965. Climatological data, Montana Section.  
Wagner, R. H. 1956. Vegetation of the Great Smoky Mountains. Ecol. Mono., 26:81-103.

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## Late Cenozoic Volcanism, St. Joe Valley, Idaho

When the Columbia River basalt flows were extruded from vents in central Washington, they spread eastward into Idaho. As flow overlapped flow, there developed a nearly level constructional plain that extended up major stream valleys that had been eroded into the mountainous terrain of the Idaho Panhandle. Although these streams have subsequently been able to dissect and partially destroy this plain, large areas of the flows remain. At some locations, however, there are present remnants of basaltic flows that appear to have come from a different source. One such location is in the valley of the St. Joe River.

### St. Joe Valley

In northern Idaho the valley of the St. Joe River follows a generally westward course from the Idaho-Montana border to the southern end of Coeur d'Alene Lake, a distance of about 100 miles (Figure 1). Here it turns northward and is drowned beneath Coeur d'Alene Lake for an additional 35 miles. This lake is held in by a dam of glacial outwash at its northern end and is the source of the westward-flowing Spokane River. In addition to almost countless smaller tributaries, the St. Joe Valley is joined by the St. Maries River at the town of St. Maries, and by the Coeur d'Alene River at Harrison, about one-third of the distance north on Coeur d'Alene Lake.

In its upper reaches, the St. Joe Valley is a winding canyon that is flanked by peaks standing as much as 3000 feet above it. Valley sideslopes rise steeply from the narrow valley floor and are generally continuous and unterraced. However, near the town of Herrick, about two-thirds of the distance downstream to the southern end of Coeur d'Alene Lake, the shape of the valley cross-section begins to change. The river remains confined in a narrow canyon with only slight floodplain development and nearby peaks rise 3000-3500 feet higher, but the sideslopes are no longer continuous from water level to ridgecrest. Small valley-side terraces and spur-crest benches are present. These are particularly prominent at or near an elevation of 3200 feet above sea level.

Farther downstream the upper part of the valley gradually widens and a valley-in-valley form is clearly evident. A prominent, nearly flat, though discontinuous surface lies at about 3200 feet, or roughly 1000 feet above the present river floodplain nearby. This surface, although somewhat dissected, is readily recognizable on a topographic map and in the field (Figure 2). Its greatest development is south of the St. Joe River not far upstream from St. Maries. Farther downstream, between St. Maries and the

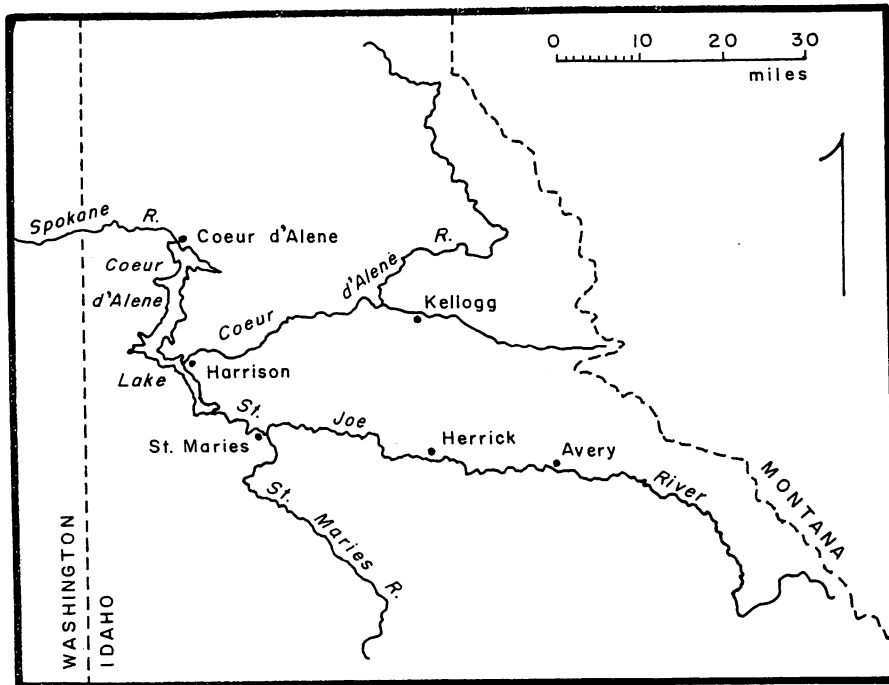


Figure 1. Map of a portion of northern Idaho showing locations of major streams.

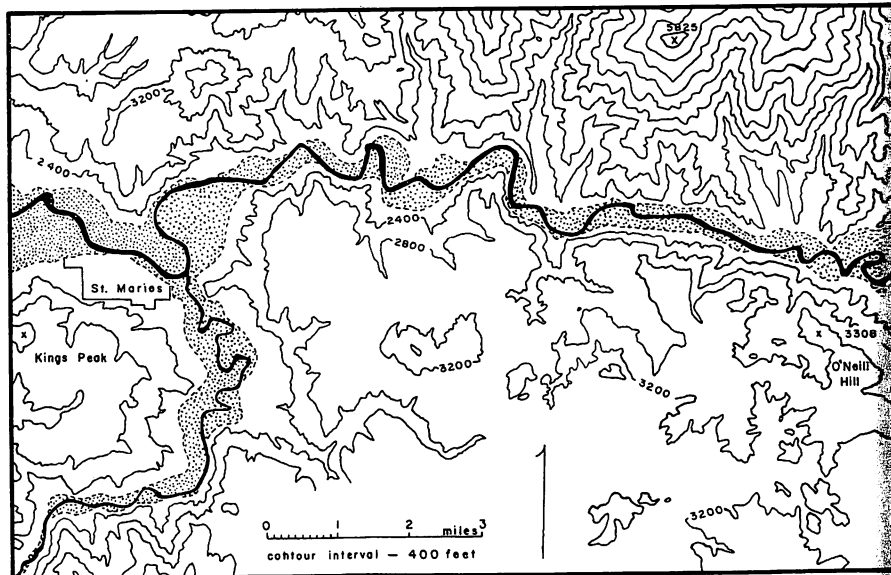


Figure 2. Topographic map of lower St. Joe River and main area underlain by St. Joe Valley Basalt. Stippling indicates extent of modern floodplain. (Contours from USGS quadrangles.)

southern end of Coeur d'Alene Lake, terraces and flat-topped spur remnants are less extensive. Along both sides of the lake there is widespread development of a nearly level surface. This surface, however, is at a notably lower elevation. Harrison Flats (Figure 3) constitute the outstanding part on the eastern side of the lake. The

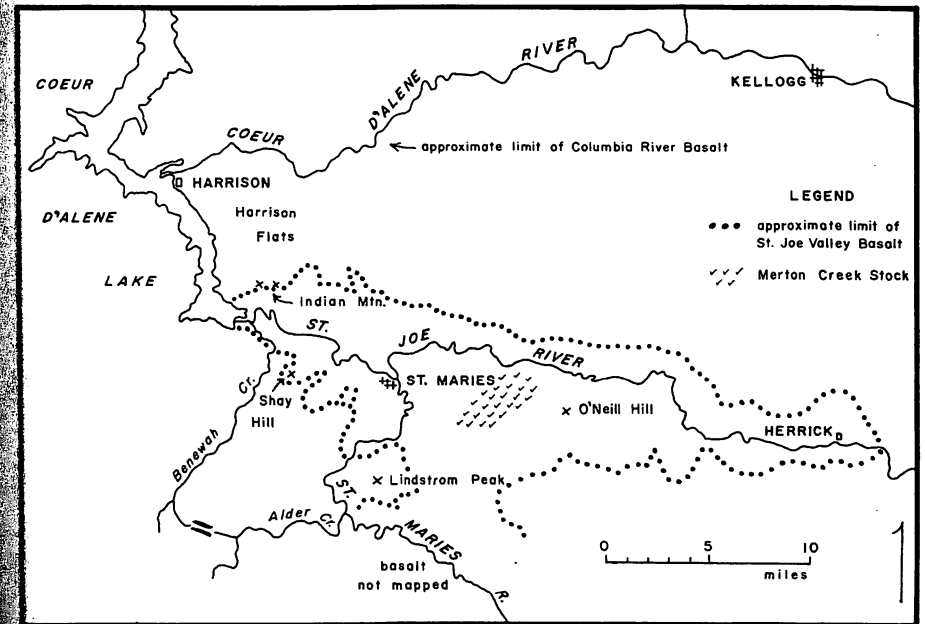


Figure 3. Extent of St. Joe Valley Basalt, location of Merton Creek Stock, and limit of Columbia River Basalt.

elevation of this surface is about 2800 feet, or only 700 feet above the lake level where the valley of the St. Joe River is now drowned.

Previous mapping by Anderson (1927, 1940) of the areas flanking both sides of Coeur d'Alene Lake delineated extensive occurrences of basaltic lava capping uneven topography eroded on much older metamorphic and intrusive igneous rocks prior to the volcanic activity. Along much of the lakeshore, this basalt is mapped as outcropping down to lake level. Anderson states that the flows reached maximum elevations of 2500-2700 feet, but his map shows that basalt is present throughout the extent of Harrison Flats, and over an even larger area on the western side of the lake. Topographic maps published since Anderson's work was completed show that both of these areas have maximum elevations of about 2800 feet.

Occurrences of this basalt along the shores of the southern third of Coeur d'Alene Lake and in the lower reaches of the Coeur d'Alene River valley were mapped in detail by Johns (1961). He found that the maximum elevation of the flows is nearly constant at about 2800 feet and that they directly underlie constructional plains such as Harrison Flats.

In the vicinity of St. Maries, in the extreme southeastern corner of his map area, Johns found scattered small exposures of basaltic lava as high as 3000 feet. He called attention to the problem posed by these higher-level occurrences, but further study of this aspect was beyond the scope of his investigation. Lower flows in the St. Maries area had previously been briefly described by Kirkham (1926) in relation to water-supply problems.

The presence of a few scattered exposures of basalt flows on both sides of the St. Joe River near Herrick, 22 miles upstream from St. Maries, was mapped by Pardee (1911) and by Umpleby and Jones (1923). Wagner (1949) mapped these occurrences in slightly greater detail, stating that they are located at about the 3500-foot contour and cap small areas on spurs. Anderson (1928) noted the presence of similar outcrops closer to St. Maries. Intermittent studies made between 1959 and 1962 by the present writer in the St. Joe Valley downstream from Avery have resulted in the delineation of extensive occurrences of basaltic lavas at elevations up to 3350 feet.

#### Extent of High-Level Lavas

Extending eastward from St. Maries for about 15 miles on the southern side of the St. Joe River is a broad, nearly flat area slightly dissected by a few major streams (Figure 2). Throughout most of this area the surface is directly underlain by basalt; in some places near the eastern end, the basalt is capped by a veneer of gravel consisting of pebbles and cobbles of quartzite. At scattered localities erosional windows through the basalt expose underlying Precambrian rocks. At other places small hills of the older rocks were surrounded but not covered by the lava flows. In most instances the rocks exposed in these windows and step-tops are argillites or quartzites of the Precambrian Belt Series. West of the center of this area, however, there are numerous exposures of quartz monzonite (unpublished thin section identification by M. E. Bickford). These are probably parts of a small stock similar to the Herrick Stock located about 15 miles farther east. This stock was named the Merton Creek Stock (Dort, 1962a) because exposures of the quartz monzonite are located within the drainage basin of that creek. It is estimated that its area of outcrop is about five square miles (Figure 3).

The elevation of the upper surface of the basalt, some of which is vesicular and most of which shows columnar or blocky jointing, is generally above 3200 feet. The apparent maximum elevation at which basalt is present within the area studied in the field is on top of O'Neill Hill at an elevation of about 3350 feet. This hill is located 10 miles east of St. Maries and one mile south of the St. Joe River. Interpretation of new topographic maps suggests that basalt may be present on a broad dome reaching an elevation of 3398 feet three miles south of O'Neill Hill, but no field check was made at this locality.

Isolated patches of basalt cap smaller benches and spur crests on both sides of the St. Joe River as far east as 17 miles upstream from O'Neill Hill and also downstream from St. Maries and the southern end of Coeur d'Alene Lake. Gravel-capped basalt is present on a broad spur crest at an elevation of 3200 feet at Herrick. Four miles west of the lava is gravel-capped at an elevation of 3100 feet on the northern side of the river, and reaches to about 3300 feet on the southern side directly across the inner canyon. Basalt is also exposed down to river level on both sides of the inner canyon

and slightly interfingers with beds of cobble to pebble gravel and some finer sediment.

On the northern side of the inner canyon, across from O'Neill Hill, basalt caps a small spur-end knob at an elevation of about 3000 feet and is partly veneered with gravel. A little lava and extensive gravel deposits are present on a spur three miles west at and below 3200 feet. Lava and associated gravel are also present just below 3200 feet on the next three spurs farther west.

West and northwest of St. Maries town, basalt is present south of the St. Joe River to an elevation of about 3000 feet on Shay Hill. Yet only one mile farther northwest, exposures of Belt Series strata extended from lake level at the southernmost tip of Coeur d'Alene Lake to peaks having elevations of 3600-4000 feet. Furthermore, on the northern side of the St. Joe Valley, lava is exposed at about 3000 feet three miles north of St. Maries, as recorded originally by Johns (1961). Farther northwest, however, the maximum elevation of basalt exposures decreases abruptly so that on the southern slopes of Indian Mountain, five miles northwest of St. Maries, the upper surface has an elevation of only 2600 feet. This declining surface (Figure 4) is

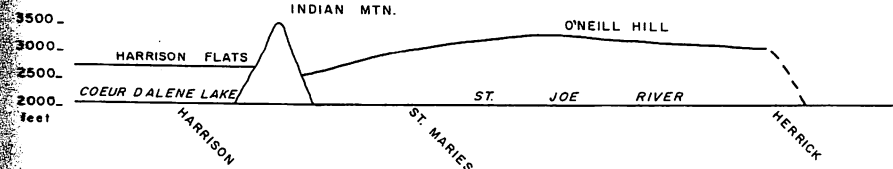


Figure 4. Profile showing former extent of St. Joe Valley Basalt and discordant elevations of this unit and Columbia River Basalt against Precambrian rocks of Indian Mountain.

separated from the 2800-foot basalt surface of Harrison Flats on the northern slopes of Indian Mountain by a continuous exposure of Belt rocks extending from the top of the mountain down to lake level.

#### Source of High-Level Lavas

Previous investigators in this region (Anderson, 1928; Kirkham, 1926; Pardee, 1911; Wagner, 1949) recorded the presence of basalt along the St. Joe River and assumed that it was part of the Columbia River Basalt. The Columbia River flows are believed to have originated from swarms of feeder dikes, some of which may have been located near Spokane (Campbell, 1950; Pardee and Bryan, 1926). From these, and perhaps other, undiscovered sources in this area, flows spread eastward to abut and partially submerge the lower slopes of mountainous terrain in Idaho. The upper surface of the final flows was probably nearly horizontal, except at the distal end where a relatively steep slope would have been present facing in a general easterly direction away from the source of the flows (Bond, 1963; Fuller, 1950; Johns, 1961). It was not until new topographic maps became available and detailed field studies were begun by the present author that it was recognized that the upper surface of the basalts in the lower St. Joe Valley slope in a general westerly direction toward the supposed source of the lava.

It is therefore necessary to explain not only why the upper surface of the basalt, which attains elevations exceeding 3300 feet east of St. Maries, declines westward

in a direction opposite to the direction of flow of the Columbia River Basalt (to a low of 2600 feet), but also why there is a marked discordance between this sloping "St. Joe Surface" on the southern side of Indian Mountain and the horizontal, 2800-foot "Harrison Flats Surface" on the northern side of the mountain. Four alternative hypotheses may be considered. (1) All of the basalts are of the same age and the eastern termination has been warped upward, or the western part warped downward. (2) The basalts are all of the same age and the eastern part was faulted upward, or the western part was faulted downward. (3) The higher, eastern flows are of the same age as the lower, western flows, but they were extruded from a local source at an elevation higher than that of the vents to the west. (4) The higher, eastern flows are neither the same units nor the same age as the lower, western flows.

The first two suggestions may be considered together. It is known that the central part of the Columbia Plateau overlies a deep basin which has been filled with a thick succession of basaltic flows. Indeed, the bottom of the lavas is now below sea level. The regional subsidence that formed this basin is believed to have been a result of and to have occurred during the extrusions (Lindgren, 1900; Mackin, 1961; Russell, 1901). Waters (1961) demonstrated that some subsidence of the central basin occurred after cessation of the main period of extrusive activity because some flows now dip gently toward their sources. However, this regional warping is not sufficient to account for the relatively abrupt decrease in elevation of the upper surface of the St. Joe basalt.

In west-central Idaho, between Boise and Grangeville, there has been described (Anderson, 1934; Capps, 1941; Hamilton, 1962) a belt of structural deformation which essentially coincides with the western border zone of the Idaho batholith. In this belt there are folds, westerly-tilted fault blocks, and westerly-dipping monoclines. All of these features strike approximately north-south. The age of this deformation is later than that of extrusion of the Columbia River Basalt because the flows are warped and offset, in some instances through vertical distances of several hundred to a thousand feet. On the basis of geomorphic evidence and similarity with areas to the south and west, it is believed that the faulting occurred in Pliocene and early Pleistocene time.

In the Clearwater Embayment, extending some 50 miles north of Grangeville to within about 40 miles of the lower St. Joe area, two sets of faults trend toward the northeast and northwest respectively. Stratigraphic evidence (Bond, 1963) indicates that deformation occurred during and especially after the main period of Columbia River volcanic activity ended. Local evidence is lacking, but an age of late Pliocene or Pleistocene is supported by Bond on the basis of freshness of scarps, stage of erosional development, and similarity to other areas.

No evidence of Pliocene or younger structural deformation has been recognized in the region around Coeur d'Alene Lake and the St. Joe River. Although the only detailed mapping that has been completed in this area is that by Johns (1961), there appears to be no geomorphic evidence of postlava folds, monoclines, or faults that could explain the westward decline in elevation of the lava surface in the lower reaches of the St. Joe Valley and the abrupt junction of the St. Joe Surface with the general Harrison Flats Surface at the southern end of Coeur d'Alene Lake. The best explana-

tion of the field relationships is that the two levels of basalt came from separate and distinct sources at differing elevations.

The higher lava surfaces upstream from St. Maries can be explained as being at or near the source or sources of those flows. The generally decreasing elevation in a westerly, down-valley direction shows the direction of movement of the flows. The discordant junction at Indian Mountain (Figure 4) marks the location where the advancing front of flows from the east met the eroded front of flows from the west, thus clearly indicating two ages of volcanic activity instead of simultaneous extrusion from different vents. For convenience of discussion, these units can be referred to as the Columbia River Basalt, a name already well established, and the St. Joe Valley Basalt, respectively.

It apparently is not easily possible to test this hypothesis of the presence of different lava groups on the basis of brief study of the mineralogy or petrology of the rocks. It has been shown by Johns (1961) that there is considerable variation between units of the Columbia River Basalt along the eastern margin of their extent, and even marked variation within units. Extensive detailed mapping, such as that accomplished by Waters (1961) and Bond (1963) in other areas, might permit such distinction to be made, but none was attempted in connection with the project reported here.

The zone of abrupt decrease in elevation of the St. Joe Surface northwest of St. Maries marks the location of the downstream end or snout of the St. Joe Valley Basalt. There is a similar abrupt decrease in elevation of the front of the Columbia River Basalt that flowed upstream into the Coeur d'Alene River Valley near Harrison (Figure 3). The seemingly abrupt front of the Columbia River Basalt at Indian Mountain may be more apparent than real. It is possible that some of the lava exposed at low levels upstream along either the St. Joe or St. Maries rivers may belong to this unit. However, elevations of the highest flows in each area exceed 2800 feet and therefore indicate extrusion from local sources. The upstream termination of the St. Joe Valley Basalt formed an abrupt face near Herrick.

#### Geomorphic History

The difference in age of the two groups of lava flows is borne out and emphasized by a comparison of the shapes of the valleys of the Coeur d'Alene and St. Joe rivers in their middle and lower reaches and by geomorphic interpretation of the contrasts. The Coeur d'Alene River valley, eroded in strata of the Precambrian Belt Series, is broad and flat-bottomed. The river meanders across a wide floodplain, which certainly required a considerable length of time for its development. In contrast, the St. Joe Valley, eroded in the same Belt Series rocks by a somewhat larger stream, is narrow and steep-sided. Floodplain development is limited to the lowest reaches, and even there meanders are not freely formed. The processes of valley widening have clearly not had as long to work.

Outpourings of the Columbia River Basalt in Washington gradually built the lava surface higher until outlying ridges of the prelava topography near Spokane were submerged (Pardee and Bryan, 1926). Later flows in this sequence were then able to extend eastward to the foothills of the mountain region in Idaho. South of Spokane there may have been no such outlying ridges to block the lavas and flows may have

advanced eastward earlier. In any event the advancing flow fronts undoubtedly caused simultaneous ponding of both the ancestral St. Joe and Coeur d'Alene rivers. Anderson (1927) has suggested that prior to the volcanic activity, drainage may have been to the west and southwest from a point near Harrison. Ultimately, obstruction by the lavas forced the streams to turn northward along the lava front and seek an exit to the northwest, flow toward the south being effectively blocked by hilly terrain.

As soon as outpouring of the Columbia River lavas ceased in this region, drainage became firmly established on the surfaces of the last flows to reach the foothills of the Idaho mountains. This composite surface has been referred to in this report as the "Harrison Flats Surface." Many tens of miles to the north and west, the Columbia River began to downcut and erode a canyon in the recently extruded lavas. Migrating upstream, a wave of downcutting in turn caused progressive rejuvenation of the ancestral Spokane River, which then permitted renewed incision by the Coeur d'Alene and St. Joe rivers. Both streams were, therefore, rejuvenated and enabled to resume downcutting through the marginal lavas at essentially the same time.

During the interval between the final extrusions of lava and arrival of the headward-migrating wave of rejuvenation, however, these streams were effectively held at the new base level of the Harrison Flats Surface. Being unable to erode downward, they meandered back and forth on the surface of the lava and the sediment filling the valleys upstream from the lava terminus. Valley sidewalls were trimmed back and low spurs truncated, resulting in considerable widening of the valley floor.

After that rejuvenation began, the Coeur d'Alene River eroded a canyon in the lava plugging its lowest reaches and flushed out much of the sand and cobble to boulder gravel accumulated behind the lava dam. This downcutting proceeded at a pace determined by the gradual lowering of the temporary base level on the basalts down-stream, and some of the stream's energy potential was expended in further widening of the valley. The cycle was finally interrupted by glacial blockage of drainage (Anderson, 1927; Dort, 1962a), and Coeur d'Alene Lake was formed, drowning the lower reaches of the valley. The new lake constituted a raised temporary local base level. Aggradation, caused by the locally decreased gradient, both filled in the head of the long, narrow arm of the lake and worked upstream as well, creating an even wider valley-floor flat, now dotted with small lakes situated between the valley sides and natural levees along the river.

For a time the St. Joe River acted in the same manner as the Coeur d'Alene. Incision by the river gradually lowered the lava threshold below the constructional Harrison Flats Surface, upstream gravel fill was removed, and valley widening resumed. However, erosion was temporarily stopped a second time by the outpouring of new lavas from local sources within the St. Joe Valley. Because the main vents were located on the southern part of the broad valley floor eroded by the St. Joe River before rejuvenation permitted incision below the Harrison Flats Surface, these new lavas flowed northward to the northern side of the valley (after first filling the new canyon formed by the rejuvenation), and then downvalley to the west. The northward slope of the lava surface forced the river against the northern wall of its valley.

The valley was again blocked by lava that extended from the present location of the southern end of Coeur d'Alene Lake (not then in existence) to a point at least

30 miles upvalley, and the river deposited gravel and sand behind the new lava dam. Deepening and widening of the floor of St. Joe Valley could not be continued until this new blockade had been breached. While the St. Joe River was re-excavating its valley for a second time, the Coeur d'Alene River was able to continue widening its valley floor. The great disparity in valley-floor widths is a direct consequence of these contrasting valley histories.

The history of the St. Maries River also has been profoundly affected by this local volcanic activity. This river follows a generally northwesterly course for most of its length. In its lower reaches, however, it bends farther into the west, then jogs several miles in a northeasterly direction before joining the St. Joe River (Figure 1). It is possible, perhaps even probable, that the original course of this river followed a nearly straight course from its headwater reaches to its confluence with the St. Joe. This course, which would have gone east of Lindstrom Peak (Figure 3), would have been followed before extrusion of the Columbia River Basalt, and would have undergone the same sequence of blockage by lava and then rejuvenation that affected the St. Joe River.

Later, when the St. Joe Valley Basalt advanced from vents to the northeast, the lower reaches of the ancestral St. Maries River were completely covered. The river was then forced westward by the lava front. The presence of scattered deposits of stream gravel indicates that for a short time drainage escaped westward through a broad low in the divide between Alder and Benewah creeks, but either through simultaneous overflow toward the north or by piracy from the north, the present course of the river became established on the western side of Lindstrom Peak.

#### Age of St. Joe Valley Basalt

After extrusion of the Columbia River Basalt ceased, streams flowing from the Idaho mountains onto the surfaces of the youngest flows (collectively comprising the Harrison Flats Surface) were unable to re-excavate their valleys until a wave of rejuvenation migrated upstream from the canyon-cutting Columbia. The lower reaches of the major streams were held at the level of this surface through a period of time long enough to permit cutting of broad valley-floor flats. The trimming back of low spurs and truncation of minor hills was especially marked along the lower St. Joe River near St. Maries, where a flat about six miles wide was developed.

Once rejuvenation began, the St. Joe was barely able to incise a narrow valley to a depth of approximately 1000 feet below the upstream equivalent of the Harrison Flats Surface before most of this new valley was filled and then covered by the St. Joe Valley Basalt. Since that event, there has been time only sufficient for the St. Joe River to remove most of the lava plug occupying the previous narrow valley.

A much greater length of time must have been required for the wave of rejuvenation to work many tens of miles up low-gradient streams on the upper surface of the Columbia River Basalt than would have been necessary for the vigorous St. Joe River to cut through the relatively small plug of younger lava in its valley. On the basis of strictly geomorphic evidence, it appears that the St. Joe Valley Basalt is markedly younger than the Columbia River Basalt. Inasmuch as extrusion of the Columbia River Basalt was mainly a Miocene event, apparently ending in early Pliocene time

(Pardee and Bryan, 1926; Waters, 1961; Bond, 1963), it may be estimated that extrusion of the St. Joe Valley Basalt occurred in latest Pliocene or, more likely, early Pleistocene time. Assignment of this age to the St. Joe Valley Basalt is re-enforced by the assignments of similar ages to similar young lavas by several workers in nearby areas.

The presence of younger lavas at various locations around the margins of the Columbia River Basalt is well known. Plio-Pleistocene volcanic activity was exceedingly widespread in the Cascade Range and the plateau area of central Oregon. At Lewiston, Idaho, 70 miles south-southwest of St. Maries, Lupter and Warren (1942) identified a deep canyon, named by them the Asotin Canyon, eroded into the Columbia River Basalt by the Snake River as a consequence of regional deformation and stream rejuvenation near the end of Pliocene time. Subsequent local eruption filled this canyon with a lava plug at least 850 feet thick before erosion of the present valley took place. These authors suggested that erosion of Asotin Canyon was initiated by the same general episode of deformation that uplifted the Plio-Pleistocene Ringold formation in central Washington. On this basis they assign an early Pleistocene age to the lavas that plugged Asotin Canyon. This conclusion was later accepted by Hollenbaugh (1959) after further study in the area.

In a region extending to within 20 miles south of St. Maries, Tullis (1944) found extensive occurrences of lava that in part occupies valleys eroded in the Columbia River Basalt and in part outcrops at elevations as much as 250 feet higher than the uppermost Columbia River flows, apparently in the vicinity of local vents. He believed these higher lavas to be of Pliocene or younger age. Later, after making a detailed study of the stratigraphy and structure of volcanic rocks in the entire Clearwater Embayment, Bond (1963) reiterated the probable Pliocene or Pleistocene age of the youngest lavas that occupy valleys eroded in the Columbia River Basalt.

#### Acknowledgments

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#### Literature Cited

- Anderson, A. L. 1927. Some Miocene and Pleistocene drainage changes in northern Idaho. Idaho Bur. Mines and Geol., Pamph. 18, 29 p.
- \_\_\_\_\_. 1928. A geological reconnaissance in the St. Maries Region, Idaho. Idaho Bur. Mines and Geol., Pamph. 30, 22 p.
- \_\_\_\_\_. 1934. A preliminary report on recent block faulting in Idaho. Northwest Sci., 8:17-28.
- \_\_\_\_\_. 1940. Geology and metalliferous deposits of Kootenai County, Idaho. Idaho Bur. Mines and Geol., Pamph. 53, 67 p.
- Bond, J. G. 1963. Geology of the Clearwater Embayment. Idaho Bur. Mines and Geol., Pamph. 128, 83 p.
- Calkins, F. C. 1909. A geological reconnaissance in northern Idaho and northwestern Montana. U.S. Geol. Surv., Bull. 384, 112 p.
- Campbell, C. D. 1950. Petrology of the Columbia River Basalts: Present status and ideas for future work. Northwest Sci., 24:74-83.
- Capps, S. R. 1941. Faulting in western Idaho and its relation to the high placer deposits. Idaho Bur. Mines and Geol., Pamph. 56, 20 p.
- Dort, W., Jr. 1962a. Late Tertiary volcanism, St. Joe Valley, Idaho. Northwest Sci., 35:155-156.

- \_\_\_\_\_. 1962b. Glaciation of the Coeur d'Alene District, Idaho. Bull. Geol. Soc. Am., 73:889-906.
- Fuller, R. E. 1950. Structural features in the Columbia River Basalt. Northwest Sci., 24:65-73.
- Hamilton, W. 1962. Late Cenozoic structure of west-central Idaho. Bull. Geol. Soc. Am., 73:511-515.
- Hollenbaugh, K. M. 1959. Geology of Lewiston and vicinity, Nez Perce County, Idaho. Unpub. M.S. thesis, Univ. of Idaho.
- Johns, W. S. 1961. Pre-lava geomorphology of the lower Coeur d'Alene and St. Joe River valleys, Kootenai and Benewah Counties, northern Idaho. Unpub. M.S. thesis, Univ. of Kansas.
- Kirkham, V. R. D. 1926. Ground water for municipal supply at St. Maries, Idaho. Idaho Bur. Mines and Geol., Pamph. 17, 11 p.
- Lindgren, W. 1900. The gold and silver veins of Silver City, De Lamar and other mining districts in Idaho. U.S. Geol. Surv., 20th Ann. Rept., Part 3:65-256.
- Lupter, R. L., and W. C. Warren. 1942. The Asotine stage of the Snake River Canyon near Lewiston, Idaho. J. Geol., 50:866-881.
- Mackin, J. H. 1961. A stratigraphic section in the Yakima Basalt and the Ellensburg formation in south-central Washington. Wash. Div. Mines and Geol., Rept. Inv. 19, 45 p.
- Pardee, J. T. 1911. Geology and mineralization of the upper St. Joe River basin, Idaho. U.S. Geol. Surv., Bull. 470:39-61.
- Pardee, J. T., and K. Bryan. 1926. Geology of the Latah formation in relation to the lavas of Columbia Plateau near Spokane, Washington. U.S. Geol., Prof. Paper 140-A:1-16.
- Russell, I. C. 1901. Geology and water resources of Nez Perce County, Idaho. U.S. Geol. Surv., Water Supply Paper 53-54, 141 p.
- Tullis, E. L. 1944. Contributions to the geology of Latah County, Idaho. Bull. Geol. Soc. Am., 55:131-164.
- Umpelby, J. B., and E. L. Jones, Jr. 1923. Geology and ore deposits of Shoshone County, Idaho. U.S. Geol. Surv., Bull. 732, 156 p.
- Wagner, W. R. 1949. The geology of part of the south slope of the St. Joe Mountains, Shoshone County, Idaho. Idaho Bur. Mines and Geol., Pamph. 82, 48 p.
- Waters, A. C. 1961. Stratigraphic and lithologic variations in the Columbia River Basalt. Am. Jour. Sci., 259:583-611.
- White, W. S. 1960. The Keweenawan lavas of Lake Superior, an example of flood basalts. Am. Jour. Sci., 258-A:367-374.

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