GEOLOGICAL SURVEY RESEARCH 1963

Short Papers in Geology and Hydrology

Articles 1–59

GEOLOGICAL SURVEY PROFESSIONAL PAPER 475–B

Article 36

PARADISE DEBRIS FLOW AT MOUNT RAINIER, WASHINGTON

By DWIGHT R. CRANDELL, Denver, Colo.

Abstract.—The Paradise debris flow blankets the Paradise Park area on the south flank of Mount Rainier. It is roughly correlative in age with the 4,800-year-old Osceola Mudflow on the northeast flank of the volcano; both probably originated as debris avalanches from a former summit of Mount Rainier volcano.

Studies of surficial deposits in Mount Rainier National Park have revealed an unconsolidated till-like deposit of Recent age on the south flank of Mount Rainier volcano. This deposit is inferred to be a debris flow that originated in an avalanche from the upper slopes or summit of the volcano. Because it veneers a rather wide area at Paradise Park and Paradise Valley (fig. 36.1), it is referred to as the Paradise debris flow.

Description.—The debris flow consists of angular and subangular rock fragments as large as 8 feet in diameter in a purplish-gray matrix of sand, silt, and clay, which oxidizes to yellowish brown. The rock fragments are nearly all andesite from Mount Rainier volcano, but a few are of granodiorite that crops out in the upper Nisqually River valley. The debris flow is 1 to 5 feet thick in most outcrops, but a thickness of as much as 15 feet is not uncommon. Owing to its thinness, the debris flow rarely forms constructional topography, but simply veneers ridges, knobs, and depressions in older material (fig. 36.2). At Reflection Lakes, however, the debris flow is thick enough to form a hummocky surface, and the lakes occupy closed depressions in it.

Distribution and volume.—The Paradise debris flow forms a blanket that is almost continuous in an area bounded on the north and east by Panorama Point and Mazama Ridge, and on the west by late Recent moraines that extend along the east side of Nisqually Glacier. Southward, the debris flow crops out discontinuously down the Nisqually River valley. It has been recognized as far downstream as the mouth of Tahoma Creek, about 4 miles downvalley from Longmire, and it may be one of several debris flows that occur in the valley as far downstream as National, 13 miles below Longmire.

A large lobe of the debris flow overlies glacial drift of late Wisconsin age in the Reflection Lakes area. The flow entered the Reflection Lakes depression through a saddle at an altitude of between 5,100 and 5,200 feet in Mazama Ridge that is about 300 feet above the floor of the adjacent Paradise Valley.

The debris flow occurs at a higher altitude at Paradise Park than it does on the opposite side of the Nisqually River valley. Whereas the deposit is at an altitude of as much as 6,600 feet near Panorama Point, it is not present on a late Wisconsin cirque floor at an altitude of about 5,900 feet on the valley wall directly opposite.

Outcrops along the Entrance Road half a mile east of Ricksecker Point indicate the maximum depth of the debris flow while it was in motion. There, at an altitude of about 4,300 feet, remnants of the Paradise deposit lie about 800 feet above the present floor of the Paradise River valley. The deposit is not found above about 4,250 feet at Ricksecker Point itself. Thus, while the debris flow was moving, its surface sloped westward in the Paradise River valley.

The volume of the debris flow preserved upstream from Longmire probably is not more than about 30 million cubic yards. An estimate of its volume while flowing, based on heights it reached on valley sides and on the probability that the fluid material was draining from one area while the crest was still passing points farther downstream, is 400 to 500 million cubic yards.

Remnants of the deposit that are preserved high on valley sides are not believed to be erosional remnants of a fill that solidified in the valley to that height. Rather, they are interpreted as veneers left after the crest and most of the flow had moved downvalley. The postglacial age of the deposit indicates that its remarkable height on valley walls is not the result of the debris flow having moved on the surface of glacial ice in the valley.

Age and origin.—At Paradise Park the debris flow is separated from till of late Wisconsin age and older bedrock by colluvial deposits and ash layers that include ash layer O (Crandell and others, 1962), which is

ART. 36 *IN* U.S. GEOL. SURVEY PROF. PAPER 475–B, PAGES B135–B139. 1963.

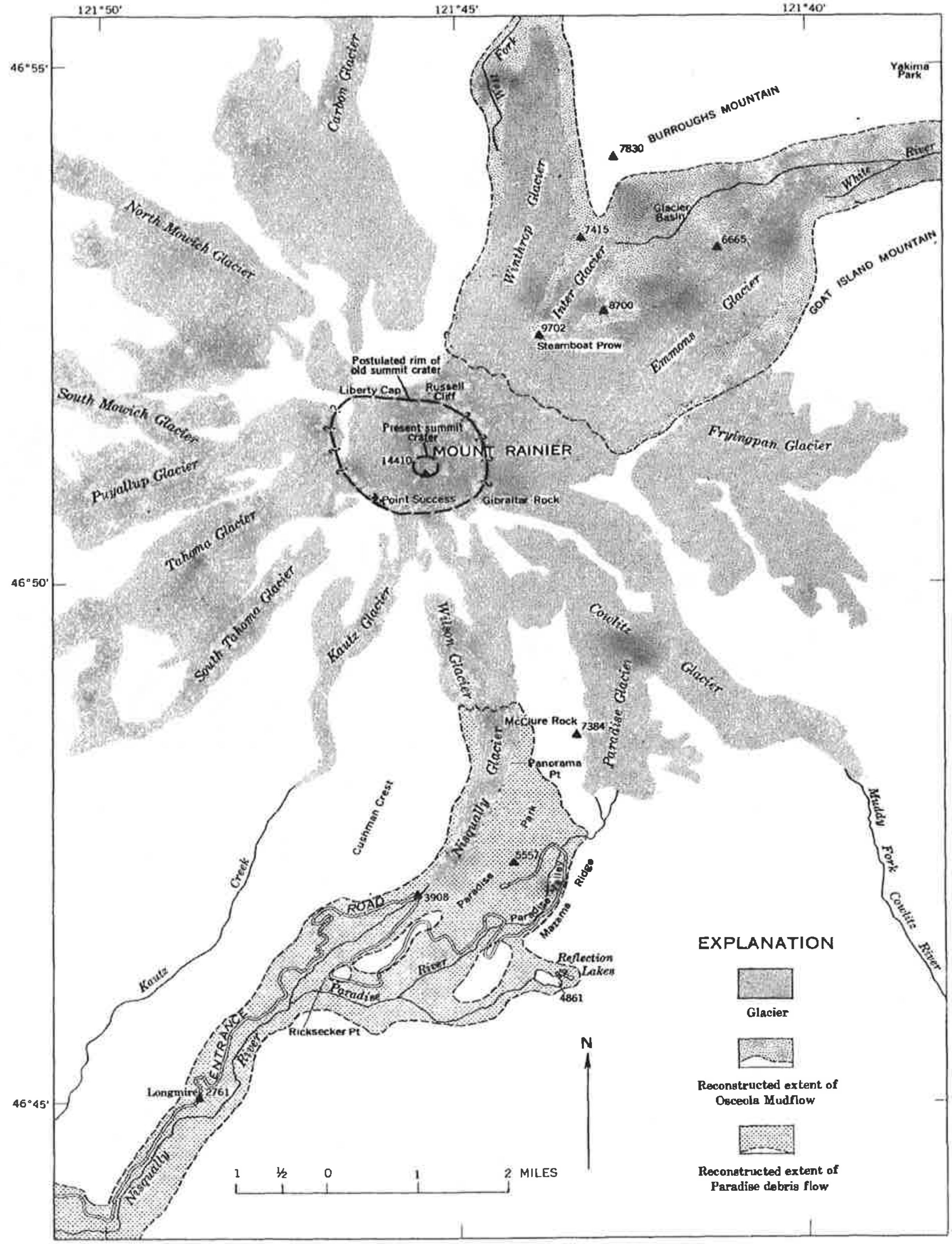

FIGURE 36.1.—Reconstructed areal extent of Paradise debris flow on south side of Mount Rainier, and Osceola Mudflow on north side. Glacier margins are those surveyed in 1910–13; many small glaciers are not shown.

FIGURE 36.2.—Paradise debris flow veneering till of late Wisconsin age at Paradise Lodge parking lot. Highest point in view is Point Success; Gibraltar Rock is at upper right. Nisqually Glacier heads in summit snowfield adjacent to Gibraltar Rock; Wilson Glacier is to the left.

thought to be about 6,500 years old. The debris flow is overlain at most places by ash layer Y, which probably is about 3,200 years old. In a road cut at the west abutment of the Entrance Road bridge across the Nisqually River, carbon collected from a layer between ash layer Y and the debris flow has an age of 4,000±250 years (W–1116) (Crandell and others, 1962).

The coarse, unsorted texture of the Paradise deposit could be explained by several modes of origin. Some likely ways in which debris of this nature could be deposited are by a glacier, by local sliding and flowage of weathered ash and rock debris, by direct falling of material explosively erupted by the volcano, and by avalanching from high on the flank or from the summit of the volcano. Avalanching is the most probable origin; evidence that seems to rule against other origins is presented below.

A wide range in particle size in the debris flow suggests the possibility that it is glacial drift deposited by Nisqually Glacier when it was thicker and broader than at present. However, the presence of ash layer O (Crandell and others, 1962) at the ground surface immediately beyond late Recent moraines of Nisqually and Paradise Glaciers indicates that the glaciers have not extended beyond these moraines in about the last 6,500 years. In addition, distribution of the debris flow suggests that it was not formed by Nisqually or Paradise Glaciers, because in order for these glaciers to have covered Paradise Park and Paradise Valley, they also would have covered areas where the debris flow is not present.

The debris flow also somewhat resembles colluvium that could be formed by local sliding and flowage of rock debris mixed with volcanic ash. Occurrence of the debris flow as a veneer on some ridgetops, as well as on valley floors and slopes between, rules against this origin, as does the restriction of the deposit to the areas immediately adjacent to the Nisqually and Paradise River valleys.

That the Paradise deposit might have resulted from an explosive eruption of Mount Rainier seemingly is denied by its distribution. Ejection of rubble from high on the south side of the volcano in an explosion sufficiently violent to have covered Paradise Park and Paradise Valley with debris would also have left deposits in the area upslope from Panorama Point.

The absence of any topographic evidence of a source for the deposit near McClure Rock suggests that the debris flow originated high on the volcano in the form of a debris avalanche. Such an avalanche would have accelerated rapidly as it traveled down Nisqually Glacier. At a point west of McClure Rock, the top of the east valley wall becomes low enough to have permitted a large avalanche to surmount it. Owing to the steep slopes bounding the west sides of Wilson and Nisqually Glaciers, and to the arcuate path of the avalanche, the debris was not deposited very high on the west wall of the Nisqually River valley opposite Paradise Park. Absence of the deposit on Mazama Ridge is best explained by lack of either momentum or thickness sufficient for the avalanche to surmount the ridge.

The avalanche could have been either wet or dry when it covered the Paradise area; in either condition it probably would have had sufficient momentum to flow over topographic obstacles. Even if it started dry, it probably soon became wet in transit and then formed a debris flow.

Possible correlation and common source of Paradise debris flow and Osceola Mudflow.—The Paradise debris flow is lithologically similar although less clayey than the 4,800-year-old Osceola Mudflow in the West Fork and White River valleys on the northeast side of Mount Rainier (Crandell and Waldron, 1956). The Osceola moved 45 miles down the White River valley and spread into the Puget Sound lowland in a lobe 20 miles long and as much as 10 miles wide. An investigation of the mudflow in the lowland suggests an average thickness of about 20 feet and a volume of perhaps as much as 1.3 billion cubic yards (Crandell, 1963).

From its distribution at Mount Rainier, Crandell and Waldron (1956) concluded that the Osceola Mudflow had an eruptive source in a vent or vents high on the volcano, but neither an exact source nor mode of origin was proposed. Subsequently, Crandell (1963) suggested that the mudflow originated in one or more phreatic explosions that ejected clay-rich debris formed within the volcano by hydrothermal alteration of wallrock along old conduits and fissures. It was thought that as this material settled on the flanks of Mount Rainier, it moved on downslope as a mudflow.

The highest outcrop of the Osceola thus far recognized is at the 9,700-foot summit of Steamboat Prow, but it must have originated somewhere above this point, for it flowed over Steamboat Prow into Glacier Basin, apparently as a debris avalanche.

If the Paradise debris flow and Osceola Mudflow originated as debris avalanches high on the volcano, a source area of large volume is required, and it seems likely that the missing summit of Mount Rainier might in some way be involved.

Russell (1898) first pointed out that the present summit of Mount Rainier consists of the higher of two cones built within a large crater, the rim of which is preserved at Point Success and between Liberty Cap and Russell Cliff. High points on this older crater rim indicate that the summit of the volcano was removed above an altitude of about 14,000 feet. The old summit crater had a diameter of about 1.25 miles, measured from Liberty Cap to Point Success. Its formation was attributed both by Russell and by Matthes (1914) to explosive decapitation of the volcano, but Coombs (1936) proposed that the shape of the old summit area resulted from "* * * intermittent explosive activity, probably breaching first one side of the crater and then the other." He also suggested that the old crater subsequently had been modified by glacial erosion.

Fiske and others (1963) conclude that the missing upper part of Mount Rainier represented the loss of a volume of rock of more than 800 million cubic yards. They point out that if the summit of the volcano had been removed in a violent explosion, explosion breccias should be found around the flanks. As these were not recognized, they conclude that the summit was removed either by vertical subsidence into underlying magma, by outward slumping and flowage of solfatarized and softened rock in the central part of the volcano, or by headward glacial erosion into a weak core.

The estimated volume of the Osceola and Paradise deposits requires a source area of at least 1.7 billion cubic yards. If it is assumed that the missing summit cone had a basal diameter of 2,200 yards and a height of 500 yards, it would have had a volume of between 600 and 700 million cubic yards. If the cone had a summit crater, as suggested by Coombs (1936), the estimated volume of the summit cone should be reduced accordingly, perhaps by a fourth or a third. In addition to removal of the volcano above an altitude of about 14,000 feet, it seems likely that the east crater wall also was destroyed, and a huge cirque-shaped depression was formed which opened to the east between Gibraltar

Rock and Russell Cliff. The floor of this depression may have been as much as 1,500 feet below the high points on the rim at Liberty Cap and Point Success. Although an estimate of the size of this postulated depression is hardly more than a guess, the depression may have contained as much as a billion cubic yards of material. Fiske and others (1963) point out that the young cone that forms the present summit of the volcano was built on the eastern rim of the old summit crater; thus, this cone has largely filled the wide low breach inferred to have been present in the eastern rim.

I propose that the former summit of Mount Rainier was removed principally by very large avalanches that originated in hydrothermally altered and weakened rocks. The avalanches were probably caused by phreatic explosions of the volcano, but could have been caused by earthquakes or even slope failures due to oversteepening by glacial erosion. An avalanche descending the south slope of the volcano was confined by the high sides of the Nisqually River valley until it reached a point west of McClure Rock, where it flowed over the east valley wall, veneered Paradise Park and Paradise Valley, and extended downvalley as a debris flow. The Osceola Mudflow probably originated in a comparable avalanche or several nearly contemporaneous avalanches from the summit of the volcano and moved into the valleys of West Fork and White River.

If parts of the avalanches on the northeast side of the volcano were initially dry, dust rolling up from them may have been deposited on adjacent upland surfaces, accounting for the layer regarded as an air-laid facies of the Osceola Mudflow (Crandell and Waldron, 1956).

A mudflow or debris flow comparable in age to the Paradise and Osceola deposits has not been seen in the Carbon or Cowlitz River valleys; the valleys heading in Tahoma, Puyallup, and North and South Mowich Glaciers have not yet been investigated. The absence of such a deposit in the Carbon River valley is consistent with the presence of a high, unbroken rim of the old summit crater between Liberty Cap and Russell Cliff, and its absence in the Cowlitz River valley may have resulted from a predominantly northeastward movement of avalanches on the east side of the volcano. The valley of Tahoma Creek downstream from South Tahoma Glacier contains a debris flow of large volume that postdates ash layer Y, and thus is less than about 3,200 years old. This debris flow perhaps was formed by an avalanche derived from the western part of the former summit.

REFERENCES

Coombs, H. A., 1936, The geology of Mount Rainier National Park: Washington Univ. Pubs. in Geology, v. 3, no. 2, p. 131–212.

Crandell, D. R., 1963, Surficial geology and geomorphology of the Lake Tapps quadrangle, Washington: U.S. Geol. Survey Prof. Paper 388–A. [In press]

Crandell, D. R., Mullineaux, D. R., Miller, R. D., and Rubin, Meyer, 1962, Pyroclastic deposits of Recent age at Mount Rainier, Washington: Art. 138 *in* U.S. Geol. Survey Prof. Paper 450–D, p. D64–D68.

Crandell, D. R., and Waldron, H. H., 1956, A Recent volcanic mudflow of exceptional dimensions from Mount Rainier, Washington: Am. Jour. Sci., v. 254, p. 349–362.

Fiske, R. S., Hopson, C. A., and Waters, A. C., 1963, Geology of Mount Rainier National Park, Washington: U.S. Geol. Survey Prof. Paper 444. [In press]

Matthes, F. E., 1914, Mount Rainier and its glaciers: Washington, U.S. Dept. Interior, 48 p.

Russell, I. C., 1898, Glaciers of Mount Rainier: U.S. Geol. Survey Ann. Rept. 18, pt. 2, p. 349–415.

680231 O—63——10