Structural Model for the Columbia River Basalt Near Riggins, Idaho

by

P. R. Hooper

ABSTRACT

Imnaha Basalt and Grande Ronde Basalt (R₁) of the Columbia River Basalt Group form a small synclinal basin immediately west of Riggins, Idaho. The displacement of the margins of the basalt outcrop, of the synclinal axis, and of a dike of Saddle Mountains (?) Basalt define a pattern best explained by a model of west-northwest to east-southeast and north-northwest to south-southeast dextral strike-slip faults and east-northeast to west-southwest sinistral strike-slip faults. The development of the syncline, downthrow on the east side of the easterly dipping Riggins fault, and the strike-slip displacement are regarded as broadly contemporaneous. Regional implications of significant west-northwest strike-slip movement in the Riggins area and the possible displacement of the Columbia River dike swarm by such a movement farther west is noted.

INTRODUCTION

The Riggins 30-minute quadrangle includes parts of the western margin of the Idaho batholith and the eastern edge of the Columbia River basalt province, as mapped and described by Hamilton (1962, 1963a, 1963b, 1969, 1976; Onasch, 1977). The marginal facies of the batholith include the Riggins Group, a highly metamorphosed and sheared sequence, thrust westward over the Seven Devils Group on the Rapid River thrust (Hamilton, 1963a). The Seven Devils Group is an island arc assemblage of Permian-Triassic age thought to have been accreted to the North American Plate in late Permian to Cretaceous time (Hamilton, 1976; Davis and others, 1978). In the Riggins area the suture zone between the accreted island arc and the earlier western boundary of the North American Plate corresponds to a broad synformal trough that extends from the Clearwater embayment in the north through Meadows Valley and the Payette Valley to the south. Isolated outcrops of Columbia River basalt are exposed in this trough between the Clearwater and Weiser embayments (see Figure 1 in Camp and others, 1982 this volume).

Reconnaissance mapping of the small areas of basalt near Riggins, undertaken by the writer during 1980, was designed to locate the stratigraphic divisions of the Columbia River basalt recognized in the main part of the Columbia Plateau (Swanson and others, 1979). The most obvious stratigraphic horizon in the Riggins area is the contact between the coarse phyrstic Imnaha Basalt and the overlying aphyric flows of the Grande Ronde Basalt. The contact is easily traced across the area west of Riggins (Figure 1). Whereas the present work is significantly less comprehensive than that of Hamilton, mapping the contact has made it possible to clarify the type and sequence of deformation which has affected the basalt in the last 17 million years.

STRATIGRAPHY AND STRUCTURE

Two main outcrops of basalt are present (Hamilton, 1969). The slightly larger outcrop occurs along the bottom and sides of the Little Salmon River canyon, 3 to 35 kilometers south of Riggins. This is composed almost entirely of Imnaha Basalt (Ti) with one or two flows of Grande Ronde Basalt (Tgr₁) forming only the highest exposures west of the canyon. The smaller basalt outcrop, the subject of this paper, lies immediately west of Riggins (Figure 1) and is some 17 kilometers long from north to south and 8 kilometers wide. It includes 500 meters of Imnaha Basalt (Ti) conformably overlain by 335 meters of Grande Ronde Basalt of the oldest magne-

Figure 1. Geologic map of the Columbia River basalt near Riggins, Idaho.
Figure 2. Structural model of the Columbia River basalt near Riggins, Idaho.
At least thirteen individual flows of Imnaha Basalt are present in this outcrop. All but the lowest one have been correlated with flow types recognized in the Snake, Imnaha, and lower Salmon River canyons (Hooper and others, 1979; Hooper and others, in preparation), and they lie in the same stratigraphic sequence (Table I). The easily recognizable highest flows in the type Imnaha Basalt area, however, the Fall Creek, Log Creek, and associated American Bar types, are missing from the Riggins area.

The contact between Imnaha and Grande Ronde Basalts is recognizable in the field, and its disposition clarifies the structural history. The flows form a gentle synclinal basin elongated north-south. They consistently dip inward from the contact with the surrounding pre-Tertiary metamorphic rocks. The dip increases as the contact is approached (Figure I), and small sympathetic normal faults commonly occur near the contact. On the east side, the base of the basalt sequence is clearly unconformable; the lava appears to have filled a deep valley, and younger flows overlap the valley side to the east. The west side of the basalt outcrop is bounded by the

Table 1. Major element analyses of Columbia River basalt west of Riggins, Idaho. (Analyses by XRF, normalized on a weight percent volatile-free basis with FeO set at 2.00%).

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¹ Squaw Creek  
² Papoose Creek  
³ average analysis of sample numbers given  
⁴ flow types from P. R. Hooper, W. D. Klock, C. R. Knowles, and S. P. Reidel, in preparation
Riggins fault (Hamilton, 1969) which has been traced north to Whitebird and has a downthrow to the east of over 600 meters (Hooper, in Swanson and others, 1981). In the Riggins area the fault plane dips to the east at angles as low as 45 degrees and is accompanied by many parallel faults within the basalt which juxtapose Imnaha Basalt against Grande Ronde Basalt in many places. The easterly dip of the flows increases to as much as 35 degrees as the Riggins fault is approached, at which point the less competent flow tops are sometimes used as small fault planes.

The whole basalt outcrop is cut by small faults, and the systematic orientation of the creek suggests many more. Observed faultss include a set of northwest-southeast faults in the north part of the outcrop at the head of Bean Creek (Figure 1). Vertical displacement with downthrow to the southeast is evident. Vertical cliffs form the east side of the ridge between Bean Creek and the Salmon River canyon and result from major N. 10° W.-trending planes of shattered rock, apparently dipping west at about 70 degrees. No displacement along the zones was observed. Another fault of similar trend near the middle of the basalt outcrop shows significant vertical displacement with the downthrow to the east, and a part of Race Creek follows the same trend (Figure 1). Less direct evidence of faulting can be found in the stepped nature of the northwest and southeast boundaries of the basalt outcrop and in the apparent displacement of the axis of the syncline and of a well-defined dike (Figure 2). In many places, these apparent displacements lie along west-northwest to east-southeast-trending valleys, and all suggest dextral strike-slip movement. Another dominant drainage direction has an east-northeast to west-southwest trend.

Hamilton's map (1969) shows three sharp steps in the northwest part of the basalt boundary with 90 degree reentrant angles occurring across Kessler Creek, West Fork of Race Creek, and Bean Creek. Whereas exposures are notably poor in the critical areas and more detailed work is required to draw the contact precisely. the writer's current mapping has confirmed this unusual form. The most obvious explanation is a set of faults with west-northwest trends parallel to the valleys along which a component of dextral strike-slip movement has occurred. Evidence in support of this explanation can be found in the displacement of the axis of the syncline (Figure 1). Hamilton (1969) drew this axis as a sinuous line, and because the syncline is a shallow one, the exact position of the axis is not easy to define. Nevertheless, it is quite clear in the field that the axis is offset across the West Fork of Race Creek and Kessler Creek and that the size of the offset is approximately that required to displace the basalt contact by dextral strike-slip (Figure 2).

Additional evidence of dextral strike-slip movement occurs further south between Squaw Creek and Papoose Creek. A prominent peak, the Squaw triangulation station on the north side of Squaw Creek, is a deeply dissected volcanic vent composed predominantly of pyroclastic and lahar materials dipping and thinning away from a central point capped by a thin lava flow. A roadcut in Squaw Creek below the vent reveals a wide dike with prominent and unusual cooling joints (Figure 3). Chemical analyses of the flow and the dike reveal a similar chemical composition which is distinguishable from either Imnaha or Grande Ronde chemical types (Table 1). The vent is later than the Grande Ronde Basalt on which it stands and appears to lie on or near the axis of the basalt syncline. Its chemical composition most closely resembles that of the Sprague Lake and Lewiston Orchards flow of northeast Washington (Wright and others, 1980).

Another dike outcrop of similar width, vertical dip, petrography, and chemical composition and with the same unusual joint pattern occurs on the north side of Papoose Creek. No other dike of the Columbia River Basalt Group has been observed in this area, and the evidence strongly suggests that they are two parts of the same feeder dike. As the two exposures are clearly not on trend, the explanation must lie in en echelon emplacement or in the presence of a dextral strike-slip fault. Of the many dikes of Columbia River basalt this writer has mapped, only a few display en echelon emplacement, in which the separation is a few meters at most. Thus, it is probable that a plane of strike-slip movement of between 1 and 2 kilometers is present. Topographic expression of such a fault plane is not obvious; however, a west-northwest line connecting local evidence of faulting west of Squaw Peak and passing through saddles in the ridge between Squaw and Papoose Creeks may be the trace of the fault. In this southern part of the basalt outcrop the predominant drainage trend is east-northeast to west-southwest (upper Squaw Creek and Papoose Creek); the synclinal axis is displaced to the east along this drainage, and on the south side it plunges gently northward from the southern contact (Figure 1). A plausible but as yet unverified model to account for these trends and displacements includes a second set of strike-slip faults with sinistral displacement in the east-northeast to west-southwest direction (Figure 2).

A significant obstacle to a model including a set of major west-northwest to east-southeast dextral strike-slip faults is the obvious failure of the faults to cross...
the entire basalt outcrop. The West Fork of Race Creek, Kessler Creek, and indeed both upper Squaw Creek and Papoose Creek are sharply truncated at their eastern ends by a north-northwest-trending valley (Figure 1), to the east of which the west-northwest to east-southeast trend is not present. The lower reaches of both Race Creek and Squaw Creek do, however, display a west-northwest to east-southeast orientation with evidence of dextral strike-slip displacement of the basalt contact (Figure 1). Clearly, if these are the same dextral strike-slip faults that displace the northwest basalt contact, they must themselves have been displaced by strike-slip movement either along the north-northwest trend (dextral) or along the east-northeast to west-southwest trend (sinistral). On the evidence available from this reconnaissance field work, no unique solution is possible. One model is suggested in Figure 2 in which the syncline formed first and was followed by the Saddle Mountains Basalt vent along its axis and then by the west-northwest to east-southeast dextral strike-slip faults that were later displaced by both the north-northwest to south-southeast and east-northeast to west-southwest strike-slip movements. The normal, approximately north-south, Riggins fault was the last event. Such a time sequence is probably misleading. For example, there is almost certainly some association between the development of the syncline and the uplift along the Riggins fault, which clearly increased the dip on the western limb of the syncline. It also seems inevitable that, in a deformation pattern such as illustrated in Figure 2, the movement in one plane must be accompanied by movement in the other planes, resulting in an overall east-west extension and north-south shortening. The apparent time sequence most probably represents the order of the most recent movements in each direction.

DISCUSSION

The north-south suture zone along the western margin of the Idaho batholith has been tectonically active in the last 17 million years. The Stites basin, a northern extension of this zone in the Clearwater embayment, was active during early Grande Ronde Basalt eruption (Camp, 1981), and the thickness of both Imnaha and lower Grande Ronde (Trg) Basalt units near Riggins suggests that this area was already a topographic low separating the batholith from the Seven Devils Mountains at the time of their eruption. Since Grande Ronde time, both the Seven Devils Mountains and the Nez Perce plateau on the west have risen relative to the suture zone primarily by vertical movement along the Riggins fault (Camp and Hooper, 1981). The north-south syncline displayed by the basalt near Riggins is probably a result of the drag caused by this movement.

The deformation model proposed (Figure 2) to explain the present features of the basalt involves west-northwest to east-southeast dextral, east-northeast to west-southwest sinistral, and north-northwest to south-southeast dextral strike-slip movement. Of these, the dextral faults appear to show the greatest displacement. The total effect is a shortening in a north-south direction, an extension in the east-west direction, and a distortion of an originally north-south or north-northwest to south-southeast long axis of the outcrop into a north-northeast to south-southwest long axis and a possible slight rotation of the synclinal axis in a clockwise direction.

Evidence of strike-slip displacement in the southeast part of the Columbia River basalt province has been presented by Ross (1978), Price and others (1973), and Shubat (1979), but the horizontal disposition of the flows has made it difficult to ascertain the number and significance of such faults in the southeast part of the Columbia Plateau. More recently, dextral strike-slip movement close to the Olympic-Wallowa lineament has been postulated by Farooqui (1980), Kienle and Hamill (1980), and Gehrels and others (1980). Hooper and Camp (1981) have suggested that the Olympic-Wallowa lineament marks a rough boundary separating an area to the southwest, where dextral shear predominates, from an area to the northeast where the shear component is less evident but where north-south shortening and east-west extension have resulted in north-northwest basalt feeder dikes and east-west folds modified
locally by older basement structures. The basalt outcrop west of Riggins provides evidence of an unusually detailed deformation pattern well to the northeast of the eastern extension of the Olympic-Wallowa lineament. It is clear that the structural development of this critical zone needs more detailed study.

The probability of more extensive west-northwest to east-southeast dextral strike-slip movement in this area than had hitherto been proposed may have some interesting consequences in interpreting the evolution of the Columbia Plateau to the north and west. For example, the concentrations of feeder dikes at the mouth of the Grande Ronde River and at Cornucopia, Oregon, are significantly greater than in adjacent areas. Yet these two concentrations are not on trend with each other. The relatively few dikes in the deeply eroded Imnaha and Snake River canyons make it clear that this is not simply a matter of more dikes occurring in the more deeply dissected areas. Although Taubenbeck (1970) and Swanson and others (1979) have emphasized the presence of dikes outside the Grande Ronde and Cornucopia swarms, yet the greater concentration of dikes within these originally named swarms has become increasingly apparent with more detailed mapping. It is interesting to speculate that dextral strike-slip movement within a broad zone that includes the extension of the Olympic-Wallowa lineament, with a cumulative effect of about 35 kilometers (20 miles) of displacement, would place the two areas of maximum dike concentration in line with each other.

ACKNOWLEDGMENTS

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REFERENCES


