CONCERNING BASALTIC GLASS

RICHARD E. FULLER, *University of Washington.*

EVIDENCE OF THE SYNGENETIC ALTERATION OF SIDEROMELANE

In the western portion of the Columbia River Plateau, a number of basaltic flows show evidence of aqueous chilling. A variety of results have been achieved dependent on the depth of the water and the fluidity of the lava.[1] Whether it caused granulation or the formation of ellipsoidal masses, the lava, which came in contact with the water, has invariably been chilled to the transparent variety of basaltic glass known as sideromelane. This substance has been largely altered to palagonite, a hydrated mineraloid. In the past this alteration has been attributed[2] chiefly to later agencies. In a previously published petrographic description of the sideromelane and palagonite of this region it was stated, however, that field evidence "strongly indicates that the palagonitization of these tuffs was effected by the steam generated in the quenching of the extruded material."[3] Strong testimony to this statement may be observed at two localities.

On the eastern wall of the Columbia River valley at about three miles south of the mouth of Moses Coulee, a steep straight cliff exposes for nearly a mile the chilled basal phase of a very fluid flow which advanced into shallow water gradually building at its margin a breccia formed largely of granulated glass enclosing ellipsoidal masses. This heterogeneous basal phase accumulated with well-defined foreset bedding, which is here shown in an ideal cross-section. The bedding dips to the north and thereby indicates that the flow advanced from the south. Traced northward the overlying massive lava, which had flowed over its chilled base almost as if on dry land, thins out and the breccia, while still retaining its uniform thickness, ceases abruptly with an inclination parallel to the dip of the foreset bedding. Normal to this slope rises the columnar jointing of a later flow without any indication of intense chilling.

[1] R. E. Fuller, The Aqueous Chilling of Basaltic Lava on the Columbia River Plateau: *Am. Jour. Sci.*, vol. **XXI,** pp. 281–300.

[2] R. Bunsen, Beitrag zur Kenntniss des Islandischen Tuffgebirges: *Annal. Chem. u. Pharm.*, vol. **LXI,** p. 279, 1847; W. S. von Waltershausen, Ueber die submarinen Ausbrüche in der Tertiär-Formation des Val di Noto im Vergleich mit verwandten Erscheinungen am Aetna: *Gött. Stud.*, p. 400, **1845;** M. A. Peacock, The Petrology of Iceland, Preface and Part 1—The Basic Tuff: *Trans. Roy. Soc. Edinburgh*, vol. **LV,** pp. 70–71, 1926.

[3] M. A. Peacock and R. E. Fuller, Chlorophaeite, Sideromelane and Palagonite from the Columbia River Plateau: *Am. Mineralogist*, vol. **13,** p. 376, 1928.

Near the northern end of the flow, the breccia is unaltered and remains as a porous mass of broken fragments of black vitreous sideromelane, which is finely to coarsely vesicular.[4] This material is locally cemented with calcite. Palagonitization is encountered fairly sharply at the base of the exposure about a hundred yards south of the margin of the flow. As seen from a distance the line of demarcation between the yellowish breccia and the dark one cuts diagonally across the foreset bedding with a still lower dip to the north.

The coincidence of this lack of alteration with the end of the flow strongly suggests the palagonitization of the breccia to be syngenetic with the advance of the lava. Two factors are considered by the writer to be responsible for this phenomenon. With the gradual diminution of the advancing lava, the water at the contact would have been less intensely heated. At the same time, the thinning of the capping flow would have facilitated the escape of steam. Although these two factors would explain the progressive decrease in alteration towards the nose of the flow, the reason for the sharp contact between the two facies is problematical.

Additional evidence of syngenetic alteration may be observed in the valley of Douglas Creek at about half a mile from Moses Coulee. Here, massive palagonitic breccias are intermingled with micaceous sediments, which in part remain as angular blocks. The relation is attributed to the advance of very fluid basalt into a lake containing partially consolidated sediments. In this instance the quantity of water was sufficient to completely quench the flow.[5]

Although the granulated sideromelane of the massive breccia is almost completely altered to palagonite, the glass embedded in the sediments or in contact with the blocks of sandstone is perfectly fresh. The sediments are considered by the writer to have protected the fragments from the intense steam action both by coating them and by reducing their temperature. The latter factor probably is far the more important.

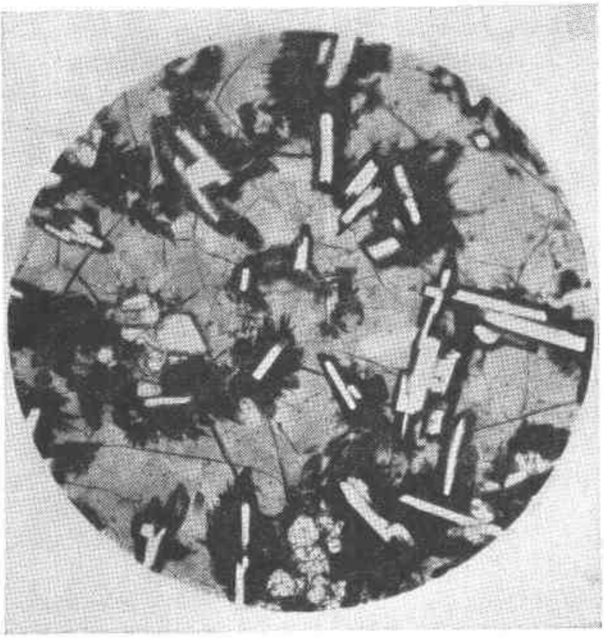
Transition from Sideromelane to Tachylyte in the Chilled Basal Facies of the Flows

The pillows are invariably coated with black vitreous sideromelane which in thin section is a pale olive-buff. At the outer margin,

[4] A petrographic description of a typical specimen of this rock has been previously described, M. A. Peacock and R. E. Fuller, *op. cit.*, p. 370.

[5] R. E. Fuller, *op. cit.*, pp. 295–298.

the glass, which exhibits a rough conchoidal fracture, is traversed by a net work of contractional cracks forming irregular polygons, the smallest of which are about 1 cm. in diameter. At a depth of about 1 to 2 cm., these joints end abruptly at an irregular crack that roughly parallels the surface. Below this the glass develops a finer system of contractional cracks, which divides it into smaller units averaging approximately .5 mm. across. With this change the fracture becomes minutely hackly although it still retains a pitch-like lustre.



Photomicrograph showing the dark brown substance forming in sideromelane around crystals of labradorite and pyroxene at about 4 cm. from the surface of a basaltic ellipsoid. Note both the characteristic feathery outline of the dark precipitate and and the local gradational relation to the enclosing glass. X 98.

The rate of cooling varies even in individual pillows depending largely on the proximity of the major joint cracks, but at a depth of about 4 cm. the rock as a rule begins to lose it hackly fracture and extreme vitreous appearance. Here a thin section shows a dark brown semi-opaque substance with a rather feathery outline forming in the glass around the microscopic crystals of feldspar and pyroxene. (See figure.) Traced inwards from the surface of these pillows the dark masses become more opaque and increase in concentration, until the sideromelane survives only as small isolated patches and then disappears leaving the crystals of plagioclase and pyroxene in an opaque ground.

In this transitional zone, which has a depth of about 1 cm., the sideromelane may be observed to become slightly grayish in reflected light. The brown substance, which is isotropic is very variable in its degree of translucence. In part its boundary appears gradational to the sideromelane and the small joint cracks may locally be traced directly across it. More often it shows a clean cut outline with flamboyant marginal projections, which taper to a rounded or pointed end. Many of the latter are distinctly curved. These projections, which range from .003 to .015 in width, locally attain a length of 0.1 mm.

The brownish material has a higher index of refraction than the sideromelane, but the writer did not succeed in isolating it in order to determine its numerical value. Its formation, however, is definitely a transitional step in the development of an opaque ground composed of dustlike particles and thin needles of magnetite in a grayish ground. This heterogeniety is considered by the writer to be characteristic of tachylyte for it is identical in appearance to the fresh glassy margin of several dikes, when examined microscopically in reflected light.

Although both the color and petrographic relations of the brown substance suggest that it is the initial step in the formation of magnetite, it is not magnetic and must have undergone considerable molecular concentration with further crystallization. Presumably it represents globulites, cumulites and crystalites of magnetite which Harker[6] has previously described in basaltic glass. His description, however, applied to a type that would be here classed as a transitional facies, for he states that it consists of a brown or yellow glass densely charged with a separation of magnetite.

The gradational increase in the precipitation of the iron oxide emphasizes the distinction between transparent sideromelane, which has suffered ultrarapid chilling, and the more familiar opaque tachylyte, which has formed beneath an insulating layer of glass. In contrast to these types, the final mesotasis of crystalline basalt is not uncommonly formed of a fairly transparent light brown glass. The clarity of this slow cooling variety is presumably due to the previous separation of magnetite.

[6] Alfred Harker, *Petrology for Students*, Cambridge **1923**, p. 190.