PAULOPOST STILBITE IN THE CAMAS LAND SILL, CHELAN COUNTY, WASHINGTON

WALTER M. CHAPPELL, *University of Washington.*

INTRODUCTION

The Camas Land sill of gabbro and diabase is located in the southern part of Chelan County, Washington, about 10 miles northeast of Blewett Pass and 15 miles west and slightly north of Wenatchee. It is roughly of spoon-like shape, conforming to a synclinal fold the axis of which trends northwest–southeast.[1] The dimensions of the basin-like body are $3\frac{1}{2} \times 1\frac{3}{4}$ miles and, on account of its shape, the term lopolith may be applicable.[2] From the standpoint of its mode of intrusion it might even be classed as a phacolith. The thickness varies from about 50 feet at one point on the south side to 500 feet or more on the west and northwest. Conformity with the arkosic sandstones and minor conglomerates and shales of the Eocene Swauk formation is imperfect in several places, notably along the northeast margin where the magma of the main body cuts across the sedimentary beds to connect with a thin outlying sheet intruded along a lower horizon. Lack of conformity in the main body is negligible when it is considered that the invaded rock is predominantly massive arkose. The intrusion is thought to have occurred in the Eocene epoch, subsequent to folding and partial erosional beveling of the Swauk formation; it is regarded as one of the manifestations of the vulcanism which gave rise to the Teanaway basaltic flows and dikes occurring extensively south of Mt. Stuart on the southern flanks of the Wenatchee Mountains. Following intrusion of the Camas Land sill, erosion cut deeply into the poorly consolidated sediments, wearing into relief that portion of the area protected by the relatively resistant igneous rock (see Fig. 1). Hence Camas Land is now a topographic eminence bounded by a marginal rampart formed by the upturned edges of the intrusive. It preserves however, a part of the valley of a superimposed stream which successfully carved deep notches in the southern and western parts of the rim before capture of its headwaters by a smaller stream working headward in the readily-yielding sedimentary formation.[3]

---

[1] Smith, G. O., *U. S. Geol. Survey Geol. Atlas, Mt. Stuart folio,* No. 106, **1904.**

[2] Grout, F. F., The lopolith; an igneous form exemplified by the Duluth gabbro: *Am. Jour. Sci.*, 4th ser., Vol. **46,** pp. 516–522, 1918.

[3] Smith, G. O., and Curtis, G. C., Camasland; a valley remnant: *Bull. Geol. Soc. Am.*, Vol. **II**, pp. 217–222, 1900.

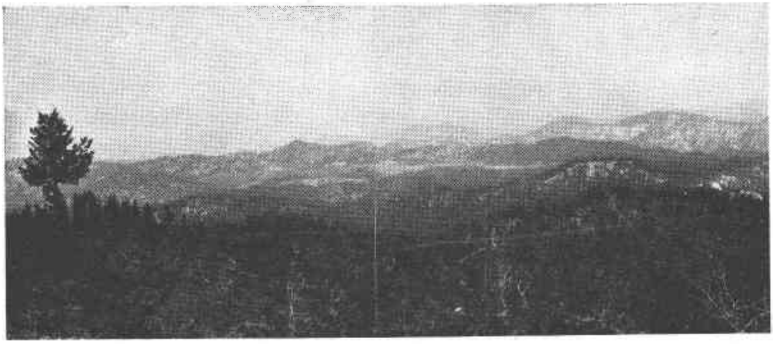

FIG. 1. A view (looking northeast) of Camas Land from Tiptop, a prominent peak 4813 feet in elevation which is about 1300 feet above and 2 miles distant from the marginal rim.

The present work on paulopost action and its effects was undertaken on the suggestion of G. E. Goodspeed of the University of Washington. The author gratefully acknowledges his helpful suggestions and criticisms.

OUTLINE OF THE PETROGRAPHY

Megascopically the coarse-textured portions of the sill are gray to slightly purple with visible crystals of plagioclase and augite; the fine-textured parts are dark gray to black, commonly showing on the weathered surface a mottling characteristic of many diabases.

Several closely related rock types are represented in the intrusive body. Gabbro, the predominant rock, makes up approximately 75 per cent; in the order of their abundance, diabase, olivine diabase, and olivine gabbro make up the rest of it. Quartz-bearing modifications occur in those parts of the sill where paulopost action was most prevalent. Plagioclase feldspar, quantitatively the most important mineral constituent, varies from calcic labradorite (An 65, Ab 35) to oligoclase with a preponderance of the former. Zoned crystals within this range of variation are numerous. In the diabase, plagioclase is of early generation with large crystals of augite built around it to form the characteristic diabasic or ophitic texture. In the thicker and coarser-textured portions of the sill, predominately gabbro, the augite crystals average from two to six millimeters in length; the plagioclase averages up to eight millimeters. Magnetite, some of it titaniferous, occurs as euhedral grains of early crystallization but more of it appears as irregular masses surrounding the feldspar and mafics. Olivine is locally an important mineral constituent, especially near the rarely exposed lower contact and in the small outlier to the northeast of the main intrusive. Approximately 40 per cent of the augite is of the variety pigeonite, distinguishable by its small optic angle. Typical Camas Land gabbro, exclusive of the paulopost minerals, contains 73 per cent plagioclase, 26 per cent augite and pigeonite, 1 per cent magnetite. Both enstatite and hypersthene are present in the sill but are seen in comparatively few sections. With high magnification needles of apatite are seen to cross the non-opaque minerals at random. Quartz when present is associated with stilbite in the interstices. Calcite has a similar occurrence locally where paulopost action was greatest.

The following chemical analysis of the Camas Land gabbro, by Dr. H. N. Stokes, is taken from the folio:

SiO_2	51.98
Al_2O_3	15.99
Fe_2O_3	3.10
FeO	5.88
MgO	5.09
CaO	9.68
Na_2O	2.71
K_2O	0.81
H_2O at 110°	0.48
H_2O above 110°	2.08
TiO_2	1.71
P_2O_5	0.31
MnO	0.10
Li_2O	trace
S	0.01

STILBITE PROPERTIES AND MODE OF OCCURRENCE

The most notable fact brought out by this study is the prevalence of the zeolite mineral stilbite which not only occurs interstitially but likewise penetrates the plagioclase as irregular blebs. This is noted as characteristic of most specimens of the intrusive, the black fine-textured more quickly chilled bottom facies excepted. Stilbite is especially prevalent in those parts of the sill having least thickness and is most common along the northeastern margin. The folio makes no statement of the presence of this mineral but mention is made of an undetermined mineral "probably orthoclase." In thin section the resemblance of the stilbite to orthoclase is striking, hence, since no orthoclase could be found in a large number of sections, the mineral previously noted was most likely stilbite. The chemical analysis indicates no extraordinary percentage of potash for a gabbro, but it does show the presence of a fairly large quantity of chemically combined water, apparently from stilbite.

In thin section the stilbite appears in irregular masses with wavy extinction; frequently it is in optical units which show good cleavage and nearly parallel extinction. Between crossed nicols its maximum yellow and orange interference colors contrast strongly with the gray and white of the plagioclase. The properties as determined are as follows: $\alpha=1.487$, $\beta=1.498$, $\gamma=1.50$; $2V=48°$; $X \wedge c=7°$; optically negative; good $\{010\}$ and imperfect $\{100\}$ cleavages.

Origin of the Stilbite

The fact that stilbite and small amounts of quartz occur interstitially indicates that both are final products of crystallization. Furthermore, it is apparent that in the last stages of crystallization

Fig. 2

Fig. 3

Fig. 2. Photomicrograph of gabbro, showing on the right a large crystal of labradorite in extinction position with blebs of stilbite (white); at the center a lath of oligoclase which has more successfully resisted paulopost action; near the center myrmekitic intergrowth of plagioclase (dark) and stilbite with larger masses of stilbite (white) above and below; at upper left the basal section of a quartz crystal. ×43.

Fig. 3. Photomicrograph of gabbro with a mass of stilbite at the center (white) and myrmekitic plagioclase and stilbite above it. Plagioclase is seen as rounded remnants and shreds in crystallographic continuity with each other and with the parent plagioclase crystal immediately above. ×43.

the residual liquids have caused a partial resolution of plagioclase crystals, frequently producing irregular blebs and veinlets along fracture lines as shown in Fig. 2. It is likewise clear that much of the interstitial stilbite is not filling existing interspaces between earlier crystals but occupies space made for it by active solution of plagioclase, a process which likewise produced a myrmekitic intergrowth of plagioclase, stilbite, and sometimes quartz. Again this process of resolution has been so complete that along a border irregular shreds having simultaneous extinction are the only remaining evidence that feldspar has been displaced (see Fig. 3). This process affects all of the plagioclase but is selective in that the more calcic varieties suffer most. Other minerals likewise have yielded to this action. Olivine is replaced wholly or in part by serpentine, especially the brown variety bowlingite. Augite, pigeonite, and other mafic minerals occasionally show a border of chloritic alteration products.

Because of the very small size of the Camas Land stilbite crystals no chemical analyses were made but comprehensive analyses of this mineral by Winchell indicate that there is little variation in composition and that the precise formula is nearly $Na_3Ca_9Al_{21}Si_{59}O_{160} \cdot 60H_2O$.[4] Since most of the plagioclase has a composition which may be designated as calcic labradorite it is evident that the zeolite partially replacing it is, except for the water of hydration and additional silica, similar in composition to the replaced labradorite. This, coupled with the fact that quartz often occurs with the stilbite but of earlier generation indicates the residual solutions to have been of siliceous and aqueous content. The occurrence of calcite suggests that carbon dioxide may likewise have had a part in the reaction and zeolitization. These residual solutions of the last stage of magmatic activity were, until arrested by cooling, actively dissolving the plagioclase by penetrating along cracks and contemporaneously depositing quartz and stilbite.

---

[4] Winchell, A. N., A new theory of the composition of the zeolites, Part III: *Am. Mineralogist*, Vol. **10**, p. 151, 1925.