THE FORMATION OF IDDINGSITE

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Introduction

In their comprehensive paper on the origin, occurrence, composition and physical properties of the mineral iddingsite, $MgO \cdot Fe_2O_3 \cdot 3SiO_2 \cdot 4H_2O$, Ross and Shannon (5) concluded that iddingsite is not a product of weathering, but is a deuteric mineral derived during the final cooling of the lavas in which it occurs by a reaction between gases, water, and olivine, under oxidizing conditions. They claimed further, that "the magma must have come to rest before iddingsite formed, for though it is a very brittle mineral, it is never fractured or distorted by flow."

Late Formation of Iddingsite

This claim is confirmed by the manner of occurrence of iddingsite in basalts from two Victorian localities, Lady Julia Percy Island (4), and the Colac District (6).

At Lady Julia Percy Island, near Portland, a bed of "boulder tuff," about 30 feet thick, occurs at the base of six flows of olivine basalt, the upper five of which contain abundant iddingsitized olivine.

The boulders of the tuff consist of a core of dense crystalline basalt grading outwards into a margin of tachylyte. In thin section the tachylyte is seen to consist of a light greenish-brown glass, in which are set numerous small, and a few large, crystals of olivine, and scattered laths of basic plagioclase (Ab_{35}). The olivine crystals, especially the larger ones, are much corroded, but the olivine is fresh and unaltered.

Towards the interiors of the boulders, where crystallization has been more or less complete, the olivine crystals are rimmed with iddingsite. The iddingsite is clearly not a weathering product, nor could it have formed previous to the extrusion of the lava boulders. Rapid escape of gases from the magma, and sudden chilling of the surface of the boulders, preserved the olivine unaltered in the tachylyte margins. This freezing of the rim, however, retained some water within the central part of the boulders, and also slowed the rate of cooling of the interior, making iddingsitization possible.

Thin selvages of tachylyte frequently form a "skin" to basalt flows in the Colac district (6). The tachylytes are identical with that just described from Lady Julia Percy Island. They consist of corroded phenocrysts of unaltered olivine, and scattered laths of labradorite, set in a light brown, or sometimes black, glass, Where, however, the tachylyte begins to grade into a more crystalline basalt, iddingsite appears irregularly in the cracks, and at the rims of the olivine crystals. In certain of the crystalline lavas it is a common mineral constituent. Here again, the iddingsite was formed during the consolidation of the lava, but subsequent to its extrusion, and after it had come to rest.

In both instances it is clear that the magma was at a relatively high temperature when extruded, since pyroxene, although a common phenocryst constituent of the crystalline lavas, had scarcely commenced to crystallize out of the tachylyte.

EARLIER FORMATION OF IDDINGSITE

Where, however, the magma had cooled to a somewhat lower temperature before extrusion, the iddingsite seems to have formed at a slightly earlier stage, viz., during the actual process of extrusion, and before the lava came to rest.

Thus at the summits of many of the centres of eruption of the Newer Volcanic basalts of Victoria, highly glassy, but not tachylytic, rocks are found. These consist of numerous fine laths of plagioclase, with phenocrysts of augite and iddingsitized olivine, set in a dense dark glassy base. The darkness of the glass is due to the presence in it of innumerable globulites of iron oxide. These rocks are, moreover, finely, but highly

FIG. 1

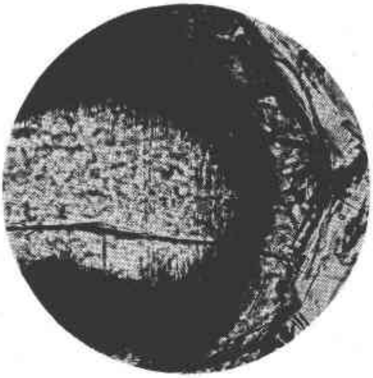

FIG. 2

FIG. 1. Iddingsite round a core of embayed olivine, with a margin of later olivine. The later olivine tends to have an idiomorphic outline, which is in part masked by a number of small grains of augite, which are moulded on the olivine. Ordinary light, ×18.

FIG. 2. Magnified view of the olivine crystal shown in figure 1. The junction between the iddingsite and the core olivine is fibrous, denoting a reaction, while the junction with the outer olivine is sharp, suggesting a cessation of iddingsite-forming conditions and a return to olivine precipitation. The idiomorphic outline of the outer olivine is clearly shown. The contraction cracks in the olivine have formed subsequent to development of iddingsite. Ordinary light, ×146.

vesicular, testifying to the presence and easy escape of an abundance of gases.

Two observations indicate that the iddingsite was formed before consolidation was complete:— (1) rims of augite surrounding iddingsitized olivine crystals, and (2) zones of fresh olivine, often idiomorphic in outline, enclosing embayed and iddingsitized olivine phenocrysts (Figs. 1 and 2).

Ross and Shannon (5) described "large phenocrysts (of olivine) completely altered to iddingsite while small groundmass olivines of a later generation show little alteration," and "cores of iddingsite surrounded by fresh olivine." They concluded from this "that the alteration was partly dependent upon the zonal variations in the original olivine," iddingsite only forming in the presence of olivine of a certain limited chemical composition.

In the Victorian basalts one finds, not infrequently, crystals such as that portrayed in figure 1, in which is shown an irregular shaped core of olivine partially replaced by a concentric rim of iddingsite, while outside this is a further rim of olivine with a partially idiomorphic outline (Fig. 2), more or less surrounded by grains of augite. The shape of the iddingsite zone is such as to indicate that it does not replace a well defined zone of olivine of particular composition, but is concentric with the shape of a corroded olivine crystal. Moreover, as figure 2 shows, the junction between the core olivine and the iddingsite is fibrous, denoting reaction, while the junction between the iddingsite and the outer olivine is sharp, pointing to a sudden cessation of reaction, and a reversal to olivine precipitation. This is a common feature in those Victorian basalts which contain iddingsite.

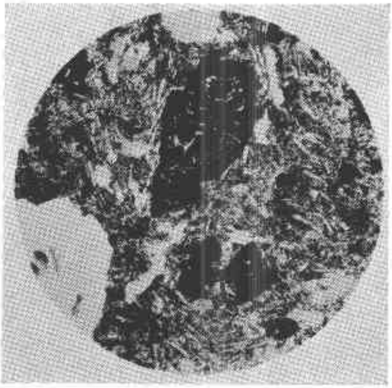

Fig. 3. Pseudomorph of iron ore after iddingsite, itself a pseudomorph after olivine. Ordinary light, ×26

The formation of iddingsite is a process of oxidation and hydration:

$$2(Mg,Fe)O \cdot SiO_2 \rightarrow MgO \cdot Fe_2O_3 \cdot 3SiO_2 \cdot 4H_2O$$

In some instances, however, the action has gone further, and a rim of iron oxide has formed on the outer margin of the iddingsite. Eventually all of the original olivine vanishes, and the iddingsite which had formed a rim about it is completely replaced by magnetite (Fig. 3):

$$MgO \cdot Fe_2O_3 \cdot 3SiO_2 \cdot 4H_2O \rightarrow FeO \cdot Fe_2O_3$$

Goodchild (3) states that the reaction:

$$H_2O + 2FeO \rightleftharpoons H_2 + Fe_2O_3$$

is a delicately balanced, isothermal reaction. Since water vapour does not dissociate at atmospheric pressures, even at 2,000°C. it is probable that such a system is stable under the conditions which exist during and immediately prior to extrusion. In the presence of sufficient water vapour, and with the removal of Fe_2O_3 from further reaction, the process would develop in the left to right direction. With escape of water vapour, this action would come to a stop, and the right to left reaction might set in. Hence it is suggested that the formation of iddingsite would cease soon after the extrusion of the lava, since at that period the water vapour would have escaped.

It seems, therefore, that in such magmas as reach a sufficiently low temperature before extrusion, the iddingsite would develop during the rising of the magma towards extrusion, when as it neared, and passed through the vent, the mineralisers would be most concentrated. Aurousseau (1) has come to somewhat similar conclusions from his examination of the nepheline basanite of Sandy Bay, Tasmania. He writes . . . "these facts suggest that the iddingsite is the result of oxidizing processes that acted rapidly on the olivine, during the liberation of copious volatile phases at the time of extrusion."

It is essential for the formation of iddingsite that the magma should not only be rich in water vapour, but that it should have differentiated in such a manner as to give rise to an iron-rich final fluid. It is characteristic of the Victorian basalts that those rich in iddingsite possess such iron-rich glasses, while in those from which the iron oxides had completely crystallized, no iddingsite formed, although chemically the rocks might be identical (2). In the "non-iddingsitized" basalts the olivine remains fresh, or is altered to serpentine.

The presence or absence of iron oxide globules in the glass is probably controlled by the temperature of extrusion, a low temperature of extrusion providing conditions favouring the completer crystallization of the glass, and so reducing the amount of iron oxide in the volatiles. Only rarely has iddingsite been observed accompanying iron ores which have crystallized at an early stage.

Conclusions

It is concluded, therefore, that iddingsite forms during, or after, extrusion, according to the temperature of the magma at the time of extrusion; and that if the magma has cooled sufficiently before extrusion not enough iron oxides are left in the residual volatiles for iddingsite to be formed.

References

1. Aurousseau, M., *Proc. Lin. Soc. N. S. W.*, vol. **51**, 4, p. 617, 1926.
2. Edwards, A. B., Tertiary volcanic rocks of central Victoria: Abstract No. 1322, *Geol. Soc. London*, Feb. 10th, **1937.**
3. Goodchild, W. H., *Mining Magazine*, p. 26, **1918.**
4. McIvor, E., *Proc. Roy. Soc. Victoria*, n.s., vol. **49**, 2, p. 344, 1937.
5. Ross, C. S., and Shannon, E. V., The origin, occurrence, composition and physical properties of the mineral iddingsite: *Proc. U. S. Nat. Mus.*, vol. **67**, pp. 1–19, 1925.
6. Skeats, E. W., and James, A. V. G.: *Proc. Roy. Soc. Victoria*, n.s., vol. **49**, 2, pp. 250–51, 1937.