NOTE ON THE PYROXENES OF BASALTIC MAGMA.

FREDERICK WALKER.

ABSTRACT. Observations are presented on the pyroxenes of common basaltic magma which are for the most part in agreement with the recent work of H. H. Hess. The effect of volatile constituents on pyroxene crystallisation is stressed.

INTRODUCTION.

BY collating recent data on common basaltic pyroxenes and by adding his own valuable observations Doctor Hess[1] has rendered a great service to petrology. Much light has been thrown on a group of minerals that is of the utmost importance, for average undifferentiated basalt or diabase contains over 40 per cent of modal pyroxene. It is perhaps unlikely that all the conclusions of Doctor Hess will find universal acceptance among petrologists, but they will serve at the very least as an admirable basis for discussion and for further work. This note deals with some of the more controversial points raised by him. It is based on observations made during the past twelve years on diabases and dolerites located in Scotland, the Palisadan region, and South Africa. The African work was carried out in collaboration with Mr. A. Poldervaart, who has in hand a special study of the pyroxenes of the Karroo dolerites. The present writer wishes to emphasize at the outset that he is in agreement with the majority of the conclusions of Doctor Hess.

NOMENCLATURE OF COMMON CLINOPYROXENES.

The nomenclature and classification of the orthopyroxenes present little difficulty and the scheme proposed by Hess and Phillips[2] leaves little to be desired, but the case of the common clinopyroxenes is entirely different. It seems definitely desirable to classify them according to their Wo, En, and Fs content neglecting minor constituents, but it is doubtful whether the present state of our knowledge justifies their grouping according to the triangular diagram of Hess.[3] The chief objection to the diagram is the presence of such a large blank

[1] Hess, H. H.: 1941, Amer. Mineral., 26, 515-535, 573-594.
[2] Hess, H. H., and Phillips, A. H.: 1940, Amer. Mineral., 25, 271-285.
[3] Hess, H. H.: loc. cit., 518.

area in the lower portion. Many pyroxenes of dolerites (for instance those of the Karroo) lie in this blank area. The space allotted to pigeonite will have to be considerably enlarged. Simplification would result by including endiopside with augite. If a separate name is required for pyroxenes in this area, the term magaugite seems preferable.

PIGEONITE-AUGITE RELATIONS.

The pigeonite field in the triangular diagram will no doubt be enlarged as reliable chemical data accumulate. As to the limiting values of the optical properties, the present writer is quite prepared to accept 32° as the maximum value for 2V but considers that the limit should be without reference to the orientation of the optic axial plane. In his experience pigeonites with the optic axial plane parallel to (010) are most frequently found as the margins of strongly zoned augite crystals with which they are in perfect optical continuity and their optic axial angle does not fall much below 32°. They are the result of extreme zoning and show a complete gradation into normal augite. Such pigeonites are ferriferous and lie just below the ferro-augite field of the triangular diagram.

Pigeonites with the optic axial plane perpendicular to (010) are of quite different nature. They may precede augite in the crystallisation of diabase and dolerites or may come after it, but in both cases the boundary between pigeonite and augite is sharply defined under the microscope, indicating a discontinuity. In the first case the mineral is magnesian and may be a reaction product of magnesian olivine or of bronzite. In the second it is ferriferous, being a lime-poor equivalent of ferro-augite, though there seems again to be a distinct discontinuity of composition between the two varieties. The formation of this late pigeonite is probably due to the elimination of most of the lime from the residual liquid. Some of it may be a reaction product of late olivine.

ORDER OF CRYSTALLISATION OF PYROXENES.

The excellent schematic diagrams of Hess[4] throw much light on the order of crystallisation of the various pyroxenes and on their mutual relationship but, as he himself states, there are exceptions to what he considers to be the normal order. The present writer believes that these exceptions are much more numerous than indicated by the data of Hess. In particular the

[4] Hess, H. H.: Op. cit., 585-590.

case of the crystallisation of early orthopyroxene or pigeonite from dolerite calls for comment. Hess[5] states that "igneous rocks of basaltic composition, which show crystallisation of lime-poor pyroxene before augite are exceedingly rare," but this is surely not the case. The crystallisation of orthopyroxene before augite in the very widespread Karroo magma was recorded by Prior[6] for a Natal sill, while further work by Walker and Poldervaart[7] has shown that intrusions in which orthopyroxene or pigeonite precede augite are abundant in all parts of the Karroo province.

In Scotland and Northern England the same is the case with the late Palaeozoic quartz-dolerites and tholeiites. According to Hess "there is a slight suggestion in Holmes[8] description" (of the Whin Sill and associated intrusions) "that the hypersthene started to crystallise ahead of the augite but this point is not at all clear." Yet in the paragraph referred to Holmes writes: "Hypersthene (H) appears first followed by hypersthene-augite (A) (pigeonite), which in turn is followed by the less magnesian pyroxene B (augite)." The same relations have been recorded for many of the corresponding rocks of Scotland [Flett[9] and Walker[10]].

EXSOLUTION OF AUGITE FROM ORTHOPYROXENE.

According to the observations of Hess,[11] in diabases and dolerites hypersthene commences to exsolve plates or globules of augite when a molecular ratio MgO:FeO near 70:30 has been reached. In norites and gabbros the same phenomenon takes place when the corresponding ratio reaches approximately 73:27. The present writer believes, however, that exsolution may take place at ratios approaching 80:20. In several of the Karroo sills unzoned bronzite crystals of about this composition show unmistakable exsolution blebs (Walker and Poldervaart[12]). It seems also possible if nothing more than the temperature of inversion from pigeonite to hypersthene may be modified by differences of physical and chemical environment. In these same Karroo sills, which are only very slightly differ-

[5] Hess, H. H.: Op. cit., 528.
[6] Prior, G. T.: 1910, Ann. Natal Museum, 2, 138.
[7] Walker, F., and Poldervaart, A.: 1941, Trans. Geol. Soc. S. Af., 44, 137.
[8] Holmes, A.: 1928, Min. Mag., 21, 507.
[9] Flett, J. S.: 1910, Mem. Geol. Survey, Scotland, Edinburgh District, 304.
[10] Walker, F.: 1935, Min. Mag., 24, 140-142.
[11] Hess, H. H.: Op. cit., 529.
[12] Walker, F., and Poldervaart, A.: Op. cit., 132-134.

entiated, the upper portions contain early pigeonite and the lower portions early orthopyroxene, the two minerals bearing a complementary relationship. This may well be due to the lowering of the inversion point, owing to a concentration of volatiles at higher levels in the sill. It is also possible the volatile constituents of mafic magmas may affect the solubility of Wo in orthopyroxene and that the abnormally active Karroo magma therefore tends to exsolve augite from a more magnesian orthopyroxene.

The early hypersthene of the relatively inactive Scottish dolerites though considerably richer in iron is quite free from exsolved plates or blebs.

In future investigations of pyroxenes more attention might be paid with advantage to the volatile content of the magmas involved. Recent workers seem to have been unaware of the highly interesting observations of Guimarães[13] in this connexion. His conclusions, which relate to the basaltic rocks of Northern and Central Brazil, have been epitomized: "Nous avons décrit dans un de nos dernières travaux le *processus* de hypersthénisation qui ont souffert les roches à charactère basaltique en des conditions speciales.

En plus nous avons montré que ce *processus* s'annonce par la variation des propriétés optiques du pyroxène: nous citerons commes examples la diminution de l'angle des axes optiques et la rotation de leur plan autour de Z.

Presque tous les stades de transformation de l'augite en diopside magnésien et hypersthène ont été observés dans un même massif rocheux et notamment dans une seule préparation microscopique.

Nous avons également vérifié que la lamellation selon (001) lorsqu'elle est très fine et accompagnée d'une diminution remarquable de la valeur de la biréfringence (en sections parallèles à ZX) est un indice de commencement d'hypersthénisation."

The final conclusions of Hess, worded with commendable caution, remain unaffected by these remarks. If, as one hopes, they are accepted by the majority of mineralogists and amplified by further work they will represent a very considerable clearing in the jungle of petrology.

The writer takes pleasure in acknowledging the kindness of Dr. A. L. du Toit in giving him access to the Brazilian literature.

[13] Guimarães, D.: 1933, Servico Geologico, Minas Geraes, Mon. 1, 43-64.

University of Cape Town,
Cape Town, So. Africa.