CORRESPONDENCE

THE EDITOR,

British Antarctic Survey Bulletin

SIR,

Banded Gabbros of West Graham Land

Banded gabbros have been described from the west coast of Graham Land between Anvers Island (lat. 64°S.) and Marguerite Bay (lat. 67°S.) by Adie (1955), Hooper (1962), Goldring (1962) and Curtis (1960). The latest study of the banded gabbros on the Anagram Islands by Fraser (1964) has re-emphasized that this banding is always steeply inclined and is caused by a variation in the pyroxene/plagioclase ratio without an initial difference in the chemical compositions of these minerals. The bands are narrow, typically a few centimetres wide, and may be accompanied by orientated schlieren and an igneous lamination in which the 010 faces of the plagioclase crystals are parallel to the banding. To this Fraser has added convincing evidence of the intrusion of the magma in a number of pulses. He has also been able to demonstrate an alignment of the long axes of the plagioclase crystals (previously noted by Goldring) in a horizontal position.

It appears to be generally agreed by the workers concerned that this is a fluxion banding (Wager and Deer, 1939), formed during the intrusion of the gabbro magma and that it should not be confused with the gabbro layering formed in an essentially horizontal position by the settling of crystals under the influence of gravity.

Fraser's assumption that the direction of magma flow is parallel to the direction of the long axis of the plagioclase seems to be unjustified for two reasons. The gabbro intrusions are relatively small in size, with the banding parallel to steep contacts. By analogy with other orogenic provinces, they are likely to have possessed a boss form. If this is correct, the magma must have flowed in a more or less vertical direction. Secondly, the little information that is available concerning the orientation of the longest axes of feldspar crystals during magma flow in intrusive bodies is inconclusive (Brothers, 1964, p. 255).

If it is reasonably assumed that plagioclase crystals were elongated parallel to their *c*-axes during growth, then Brothers's (1964) work shows that in the allivalites of Rhum the longest axes are perpendicular to the current direction, while in the banded trough structures of the Skaergaard intrusion the longest axes are parallel to the direction of flow. Orientation of the longest axes of plagioclase cannot, therefore, at present be used to determine the direction of flow. It can only be suggested that, for the general reasons given above, the flow direction was likely to have been near vertical. A more detailed study of mineral orientation is required to ascertain whether Fraser's observations apply all round the margins of a gabbro boss.

In discussing the origin of the banding, Fraser has not considered the banding in gabbro dykes within the gabbros, as recorded by Goldring (1962, p. 34). Some of these bands contain large crystals of plagioclase and augite elongated perpendicular to the banding. The bands are parallel to the margins of the dykes which are unchilled, have a similar mineralogy to the gabbros and which may be better considered as a late magmatic pulse into earlier semi-consolidated gabbro. The intimate association of normal fluxion banding with bands in which large crystals are developed at right-angles to the banding is well known from the "Border Group" of the Skaergaard intrusion (the perpendicular feldspar rock (Wager and Deer, 1939)).

More recently, Taubeneck and Poldervaart (1960; see also Poldervaart and Taubeneck (1960)) have described two types of banding which are intimately associated in the Willow Lake intrusion. The first is a fine banding, roughly parallel to steep contacts, caused by rapid alternations of the pyroxene/plagioclase ratio and which appears to be identical to the structures in both the San Marcos gabbro (Miller, 1938) and the west Graham Land gabbros. The second type contains large crystals elongated perpendicular to the banding. The two types appear parallel throughout the intrusion (Taubeneck and Poldervaart, 1960, fig. 4) but the second type is most strikingly developed in unique zones, which outline the funnel shape of the intrusion, and in gabbro dykes within the intrusion.

The terms chosen by Taubeneck and Poldervaart to describe these two types of banding, namely "*rhythmic layering of the Skaergaard type*" and "*rhythmic layering of the Willow Lake type*", respectively, are unfortunate. The term "layering" implies an originally horizontal attitude, which from their own evidence seems most unlikely and is known not to have been the case in the San Marcos gabbro and the Graham Land gabbros. Also, *Skaergaard type* invites comparison with the "Layered Series" of the Skaergaard intrusion, with which it has little in common. While one hesitates to propose new terms, particular structures such as those described need some label and I would suggest the terms *normal rhythmic banding* and *rhythmic banding of the Willow Lake type* (in which large crystals are elongated perpendicular to the banding), respectively. Both types would come under the general heading of fluxion banding as used by Wager and Deer for the "Border Group" of the Skaergaard intrusion.

Having demonstrated that the banding is due to flow rather than crystal settling under the influence of gravity, Fraser suggests that the banding was a result of the intrusion of a heterogeneous magma under pressure, although he admits difficulty in explaining the anorthosite bands by this mechanism. The suggestion of a heterogeneous magma was first made by Hooper (1962, p. 37), but in view of the presence of *rhythmic banding of the Willow Lake type* as observed by Goldring (1962) and the striking similarity of these features to those of the Willow Lake intrusion, this explanation is no longer tenable. Indeed rhythmic banding of the Willow Lake type strongly suggests at least some magmatic pulses of purely liquid magma. A heterogeneous magma is also an unconvincing explanation for the very delicate repetitions of pyroxene- and feldspar-rich bands.

Two additional mechanisms for rhythmic banding have been suggested. Yoder (1954) has shown that rapid fluctuations in the water pressure during intrusion of a crystallizing magma could produce this effect, with or without crystal settling. Such a mechanism might explain the banded gabbros described by Wells (1954; 1962), in which the bands are steeply inclined and steepening towards the centres of the intrusions. Later tilting is absent in both cases, yet a density stratification is clearly apparent. Taubeneck and Poldervaart (1960) have suggested undercooling. In the banded gabbros of the Anagram Islands as illustrated by Fraser (1964, see especially fig. 8), undercooling would be a convenient explanation for the much stronger banding near the outer margin of each successive pulse, where the new magma came into contact with the slightly cooler, semi-consolidated gabbro already in place.

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21 December 1964

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Dr. Hooper has cited evidence to show that the orientation of the longest axes of plagioclases is not a reliable criterion for determining the direction of magmatic flow. While this is clearly true in the general case, it should be pointed out that the interpretation placed on the orientated plagioclases in the banded gabbros of the Anagram Islands was not made without reference to the pseudosedimentary structures exhibited by the banding, although this was not stated in the original paper (Fraser, 1964). Several of these structures, particularly those shown in figs. 5 and 8, are much more readily explained in terms of horizontal flow rather than vertical flow. This, of course, does not preclude vertical movement of magma at some places within the gabbro mass but conclusive evidence of this has not been recorded. More intensive field work would be required to fill in these details.

It is very unlikely that the banding in the gabbros of the Anagram Islands is rhythmic banding of the Willow Lake type. In spite of the apparent similarities in the structures developed in the gabbros of the Anagram Islands and the Willow Lake intrusion, there are in fact significant differences in detail indicating differences in origin. For example, the minor folds in the Willow Lake intrusion have apices pointing downward (Taubeneck and Poldervaart, 1960, p. 1300), whereas in the Anagram Islands this is not the case (cf. Fraser, 1964, fig. 5). A much more important difference is that in the gabbros of the Anagram Islands there is an absence of the texture which characterizes the banding of the Willow Lake type, viz. crystal elongation at high angles to the banding. Consequently, undercooling, which Taubeneck and Poldervaart (1960, p. 1316) believe to be the cause of the banding and the distinctive texture, does not appear to be the explanation for the stronger banding near the contact with the preceding phase as suggested by Hooper. Differential flowage in a heterogeneous magma is therefore not to be entirely discounted.

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