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ST. MICHAEL'S,
ST. AGNES BEACON,
CORNWALL.

CORRESPONDENCE

ULTRABASIC PILLOW LAVAS FROM CYPRUS

SIR,—In his letter (*Geol. Mag.*, 1958, xcv, 436) Mr. D. W. Bishopp refers to the Diabase of Cyprus and expresses the view that it is composed of a series of highly folded lava flows and states that he would welcome knowledge of any argument counter to this theory. During the original reconnaissance of the Troodos Mountains, when detailed mapping had only been done over limited areas, it seemed reasonable to assume that the diabase sheets were altered lavas. Further work, however, more particularly round the margin of the Diabase has accumulated evidence which would suggest that at least a large proportion of the formation is an intrusive rock. It is therefore proposed, in this letter, to describe in general terms some of the evidence favouring this conclusion.

The clue to the origin of the Diabase is to be found in its similarity to the Basal Group of the Pillow Lava Series. It can be shown that the Basal Group is largely composed of multiple dykes; these dykes, in many areas, are indistinguishable from diabase sheets. The following brief description of the Basal Group and its relationships with the Diabase may therefore contribute towards the solution to the problem.

The Basal Group of the Pillow Lava Series is a transitional formation between the Diabase and the overlying Lower and Upper Pillow Lavas. It is distinguished from the Diabase by the inclusion within its outcrop of occasional pillowed exposures and from the Lower and Upper Pillow Lavas by its

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super-abundance of dykes. The dykes of the Basal Group vary from 2 feet to 10 feet in thickness and range in composition from slightly altered andesite or basalt to diabase. The pillowed exposures, which occur as narrow screens between the dykes, are usually about 10 feet wide, but screens 50 feet in width have been noted. Their composition is similar to the enclosing dykes. The screens are separated from one another by distances ranging from a few feet to over a quarter of a mile measured across the strike. It is obvious from the discordance in dip between these pillow lavas and the enclosing rock that the latter is of an intrusive nature and occurs as a series of multiple dykes. The dykes and the sheets in the adjacent Diabase are concordant but, within the Basal Group, a dyke series may cut across an earlier series at acute angles.

As the Diabase is approached, the dykes of the Basal Group lose their vesicularity, and gradually take on the characteristics and composition of diabase sheets. Namely, the dykes become hard and indurated and subsidiary jointing running parallel to their walls is developed. (Hence the sheets varying in thickness from " a few centimetres to a metre or so in thickness " referred to by Mr. Bishopp.) It is thus a matter of great difficulty to draw a boundary between the Diabase and the Basal Group. This difficulty was appreciated by J. M. Carr (*Ann. Rept.*, 1955, p. 27) when he described portions of the Diabase as being identical with that of the exceptionally thick and numerous multiple dykes of the basal portion of the Pillow Lava Series. L. M. Bear (*Ann. Rept.*, 1955, p. 30) said of the Basal Group that " . . . . its most striking feature is its similarity to the diabase and there is no evidence to dispute that it is largely diabasic material within which occur subordinate lava types ".

The general picture is that in the Pillow Lava Series, dykes become increasingly abundant as the Diabase is approached until, in the Basal Group, they constitute as much as 90 per cent of the rock. Correspondingly the pillow lava screens become narrower and less frequent until in the Diabase they are no longer present. It is therefore possible that the Diabase is a series of intrusive sheets which, over a long period of time, were successively injected and acted as feeders to the overlying lava flows. The generally non-vesicular nature of the Diabase in the interior of the massif passing upwards into vesicular Basal Group dykes is consistent with an intrusive origin, the gas phase only being released as the magma reached higher levels in the crust.

A difficulty in accepting an extrusive origin for the Diabase is that diagnostic characteristics such as vesicularity, prominently chilled and uneven slaggy surfaces, by which a subaerial lava flow may be recognized, are lacking.

The contention that the structure of the Diabase is due to folding is open to question. The structural pattern of the Basal Group dykes, except where they have been disturbed by faulting, is precisely the same as that of the Diabase sheets. Moreover, characteristic features of fold tectonics such as cleavage and schistosity, which may be expected in a highly folded series of competent rocks, are also lacking. The alteration in the Diabase is not of such a type as to suggest dynamic metamorphism nor in the bulk of the outcrop is the alteration so intense that lava flow characteristics would be obliterated. The Diabase is apparently the hydrothermally altered equivalent of the basic dykes of the Pillow Lava Series. The hydrothermal solutions had their source in the basic plutonic rocks by which the Diabase is intruded.

Faulting is particularly prevalent along the northern flank of the Troodos Mountains and has been caused by north–south compression during Tertiary and earlier times. Marked deflection of Diabase sheets terminating in faults can be demonstrated in the field and locally horizontal dips are present. But in the interior of the range no actual " turn over " on the axis of an anticline or syncline has been observed either by myself or, to my knowledge, by my former colleagues in the Cyprus Geological Survey. The writer therefore believes that the dips of Diabase sheets, except where they have been affected by subsequent faulting, represent the original inclinations of successive dykes.

Mr. Bishopp's reference to the strike of the Diabase lining up with the Red Sea direction is particularly apt. In a recent paper R. W. Girdler (1958) interprets high positive gravity anomalies occurring down the centre of the

Red Sea as being due to the intrusion along a crack in the earth's crust of a large basic mass 40 miles wide. It is conceivable that this basic mass may be represented in Cyprus by the Diabase and was intruded, during a period of regional crustal tension, by successive injection of magma along a gradually widening crack.

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R. A. M. WILSON.

GEOLOGICAL SURVEY DEPARTMENT,
BRITISH TERRITORIES IN BORNEO,
JESSELTON, NORTH BORNEO.

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TOURNAISIAN BEDS IN RAVENSTONEDALE AND DUBLIN

SIR,—In a recent memoir on Lower Carboniferous palaeogeography, Professor T. N. George (1958) claims that no rocks older than Viséan are present in Northern England and Scotland nor in County Dublin. For his argument the Ravenstonedale area of the North-West Province is critical, since as he states (1958, p. 241), " the occurrence of Tournaisian rocks elsewhere in the north of England and in Scotland has rested on correlation with the Ravenstonedale sequence."

The beds which have been attributed at Ravenstonedale to the Tournaisian belong to the *Solenopora-* (recte *Pseudochaetetes*) and *gregaria*-subzones above the Shap Conglomerate horizon and the Pinskey Gill Beds below it. In Garwood's vertical section (1913, fig. 2, p. 452) the base of C_2 is drawn at the *Thysanophyllum pseudovermiculare*-band in the *gregaria*-subzone. Professor George appears to have been unaware that I have already (1950, pp. 125, 128–9) advocated lowering this boundary broadly to the base of the algal phase at that of the *gregaria*-subzone, which latter I regard as wholly Viséan. I welcome Professor George's additional arguments (1958, pp. 240–1) for this. (Whether Tournaisian Lower C_2 is present or recognizable in Ravenstonedale is an interesting but, for present purposes, unessential question.)

For the underlying *Solenopora*-subzone the sole positive evidence adduced for a Viséan age is the presence of *Composita* aff. *ficoides* and *Pustula pyxidiformis*. Vaughan (1905, p. 245 and pl. xxix) shows the species-group of " *Seminula* " *ficoides* already appearing at the top of Z_2 in the Bristol area. As for *Pustula pyxidiformis*, Demanet (1958, pp. 123, 126, 130) reports it from $Tn_{3a,\ b,\ \text{and}\ c}$ of Tournai. Garwood (1913, p. 460) records *Spirifer tornacensis* (as *Spirifer clathratus*) from Ravenstonedale and this is one of Professor George's definitive Tournaisian species, but to which he makes no reference in connection with this area. Dr. W. H. C. Ramsbottom kindly informs me that one at least of Garwood's Ravenstonedale *Schellwienella crenistria* is close to, and may well be *Schellwienella aspis*, which is Vaughan's *Orthotetes crenistria* mut Z; and that another is, or is close to, *Schuchertella wexfordensis* (" *Orthotetes crenistria* mut C "). Both species are common together in the Tournaisian of South-East Ireland.