CORRESPONDENCE

The age of the volcanic rocks in the Woo Dale borehole, Derbyshire

SIR – The highly altered character of the volcanic rocks which were encountered in the lower part of the Woo Dale borehole (Cope, 1973), situated about 5 km E of Buxton in North Derbyshire, has until recently defied attempts to obtain a meaningful radiometric age for these rocks.

These altered rocks were encountered at a depth of 275.60 m beneath a 2 m thick mantle of blue, green and grey pyritous breccia containing angular fragments of limestone, lava and pyroclastics. The lower limit of this breccia is somewhat difficult to define because there is a downward gradation through a thickness of 4–5 m into relatively fresh purple and purplish-brown tuffs, which were encountered at a depth of 279 m. This upper 7 m of the volcanic sequence, because of its altered nature as well as its obvious close relationship to the underlying volcanic rocks, is interpreted as a deep weathered zone of the volcanic pile brought about at some time subsequent to eruption but prior to the onset of limestone sedimentation.

The stratigraphical relationships of the volcanic rocks, based upon borehole cores only 0.04 m in diameter, leave their precise age uncertain. Their minimum age must be approximately that of the immediately overlying limestones. The lowest 30 m of these limestones were tentatively assigned to the top of the Tournaisian (Cope, 1973) or possibly to the higher part of the Courceyan Stage in the revised nomenclature for the Dinantian (George *et al.* 1976).

Professor R. Conil has examined thin-sections of the cores from this part of the borehole, and is of the opinion that, on the evidence of the foraminifera, these beds are to be assigned to the lowest Viséan and that the Tournaisian is not represented (pers. comm.). Nevertheless, the presence of *Dainella* including *D. fleronensis* (Conil & Lys) would not be inconsistent with these lowest beds of limestone representing the uppermost Courceyan. This would therefore be the approximate minimum age for the upper part of the volcanic rocks. Their maximum age is very much an open question on stratigraphical grounds. There is clearly a marked break between the volcanic rocks and the succeeding limestones which is marked by a polygenetic breccia and a deeply weathered zone at the top of the volcanic pile. Evidently, the late-Courceyan sea transgressed an old land-surface composed of volcanic rocks undergoing tropical weathering. Such a state of affairs is quite unknown in the Dinantian lava flows and bedded pyroclastic rocks which are exposed in North Derbyshire. Moreover, the Woo Dale volcanic rocks are petrologically distinct from any Lower Carboniferous lavas and pyroclastic rocks known in Great Britain. There is evidence too in the borehole cores that the Dinantian limestones rest with marked unconformity upon the volcanic rocks, for whilst the former are virtually horizontal the latter show dips of the order of 40°.

The most that can be said on stratigraphical grounds is that such evidence is undeniably in favour of a pre-Carboniferous age for the volcanic rocks.

Of the thickness of 33 m of volcanic rocks proved by the borehole, the upper part to a depth of 302 m consists of a variety of tuffs which are largely sericitized and silicified; from a depth of 302 m to the bottom of the hole at 312 m are fine-grained porcellanous-looking lavas in which there is a distinct flow-banding indicating a dip of about 40°. These lavas are sub-alkaline in character and approach sodic-dacites or sodic-rhyolites. A detailed account of their petrology and geochemistry is in course of preparation.

Samples of lavas from the lowest part of the borehole were submitted, through the kind offices of Sir Kingsley Dunham, F.R.S., to Dr N. J. Snelling of the Isotope Geology Unit of the Institute of Geological Sciences for possible K/Ar dating.

The rocks turned out to be ill-suited to accurate dating because they appear to have experienced a large but variable amount of argon loss. Five of the samples were selected for whole-rock analysis, and this was carried out by Mr C. E. Rundle and Mrs M. Brook. Potassium was determined by flame photometry using a lithium internal standard, whilst argon was determined by standard gas extraction and isotope-dilution techniques using an enriched ^{38}Argon tracer. The results are shown in Table 1.

The wide spread of ages obtained probably reflects the different amounts of argon loss due to the presence of non-retentive alteration products. Because of the very altered state of the lavas and the lack of any correlation between calculated ages and potassium content, which might suggest the presence of excess argon, it is assumed that the calculated ages shown below are minimum estimates.

It is suggested that the greatest calculated age (sample 292.8 m) most closely approaches the true age of

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Table 1

Sample (Depth, m)	K (%)	N^1/g Rg.^{40}Ar	Apparent age (Ma)
279.5	1.429	22.0937	359±6
280.2	1.740	24.9326	335±5
281.2	1.236	10.8314	212±3
292.8	1.652	27.4166	383±6
293.1	2.133	18.2646	208±3

$\lambda^{\beta} = 4.962 \times 10/\text{yr}$, $\lambda^{e} = 0.581 \times 10/\text{yr}$, $^{40}\text{K/K} = 0.01167$ atom. %.
Errors quoted are the standard error on the mean and are an estimate of analytical precision only.

formation, and consequently that the lavas are probably older than 383 Ma, i.e. they are of Devonian age or older.

It was not possible to assess the amount of argon loss experienced by this sample, and consequently the result does not preclude the possibility of an Ordovician age for these rocks, quite a feasibility in the light of rocks of this age having been shown to underlie the Dinantian in the Eyam borehole which lies about 11 km ENE of Woo Dale (Dunham, 1973). Furthermore, the data do not preclude the possibility of a Precambrian age for the lavas as was tentatively suggested initially (Cope, 1949), a view which has been challenged by Le Bas who favoured a Lower Carboniferous age (Le Bas, 1972).

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