Read at the Annual Conference of the Ussher Society, January 1997

THE PETROGRAPHY OF THE FREMINGTON DYKE

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Roberts, C.L. 1997. The Petrography of the Fremington Dyke.
Proceedings of the Ussher Society, **9,** 182-187.

The Fremington dyke displays at least a two-stage emplacement history. The larger inner portion is multi-xenolithic with both sedimentary and igneous xenoliths, although buchite structures complicate precise definition. An isotopic age of 292.4 ± 7.1 Ma obtained by the Ar/Ar dating method indicates that the dyke is broadly coeval with the Exeter Volcanic Series, but that it also just predates many of the Cornubian granites. The dyke may also be contemporaneous with the Carmenellis granite at 293.1 ± 1.3 Ma and the weakly-megacrystic facies of the Dartmoor granite at 285.3 ± 0.8 Ma.

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INTRODUCTION

The Fremington dyke has been compared to the minette or mica traps of Cornwall by Dewey (1910), who indicated a close resemblance between many of the dyke features at Fremington and characteristics in some dykes in the Exeter Trap Series. Dewey (1910) also reported positive evidence to place the dyke after the intrusion of the granite masses and thus inferred a Permian age, but did not elaborate on the nature of the evidence. Hawkes (1985) described the dyke as an autolytic (i.e. containing xenoliths of itself) kersantite lamprophyre consisting of pseudomorphed olivine crystals set in a fine-grained matrix of plagioclase feldspar, biotite,

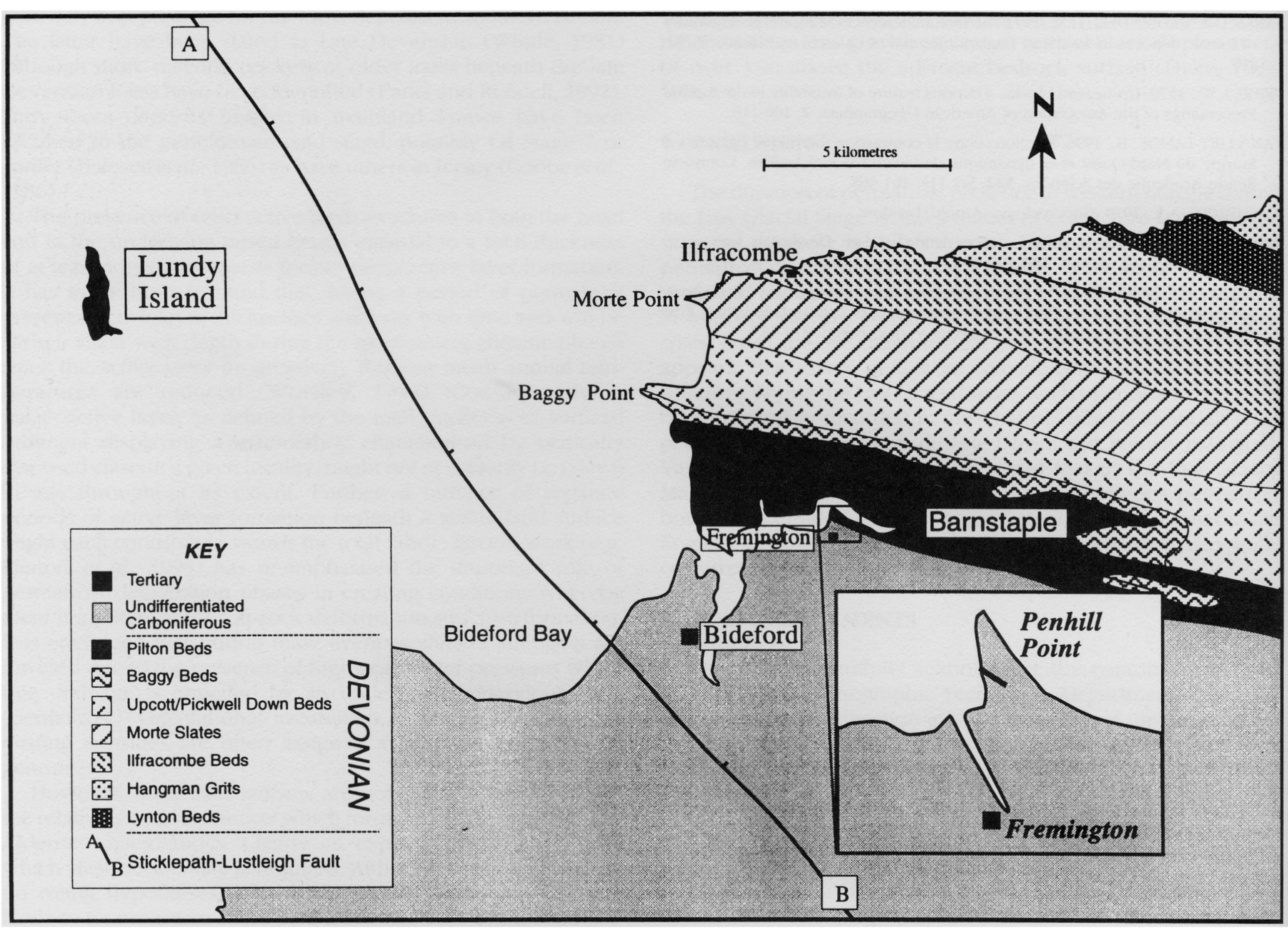

Figure 1: The simplified geology of North Devon. The Fremington dyke is shown within the inset.

secondary chlorite and calcite. Hawkes (1985) also noted the occurrence of mineral aggregates of quartz and chlorite or calcite and quartz, sometimes eroded out to produce cavities in the weathered parts of the dyke.

However, apart from these two descriptions, little else has been published on the Fremington dyke. This paper introduces new petrological observations and an Ar-Ar date for the dyke.

Figure 2: Photograph of the northern aspect of the dyke. The hammer head is positioned on the contact with host sediments, whilst the base of the hammer shaft marks the boundary between inner and outer components in the dyke.

FIELD RELATIONS

The dyke was intruded into the transitional Devonian/Carboniferous Pilton Shale Group on the foreshore of Penhill Point in the River Taw estuary (Figure 1). As the intrusion has broadly concordant relationships with the host sediments, which strike 106° and dip 42° to the south-west, it has more of a sill-like form at this locality. This may have important implications for the nature and types of scavenged host sediments which compromise the xenoliths in the dyke. The degree of contact metamorphism in the host sediments is limited to a zone about 2-3 mm in thickness and marked by a change in colour from pale brown to a dark blue/black. Dyke margins are relatively straight.

The dyke itself has been weathered to varying degrees and contains at least two discrete components. An outer fine-grained phase about 12 cm thick on both northern and southern aspects of the dyke has been completely altered to give a light rusty brown colour. A 10-15 mm thick chilled margin in this phase enclosing bands of vesicles (< 1 mm in diameter) parallel to dyke margins suggests a degree of mantle de-gassing during emplacement at relatively high crustal levels. There are no phenocrysts or xenoliths in these two segments of the dyke.

The central part of the dyke divides the outer phase and presents a distinct morphology with a blocky appearance and a multi-xenolithic fabric (Figure 2). The contact between both parts of the dyke is not chilled, which implies that both the outer and inner phases of dyke emplacement were temporally relatively close. Vesicles and calcite-filled amygdales accompany xenoliths and a grey-hearted core to the blocks is revealed by thick weathered exfoliating crusts with a rusty-brown colour.

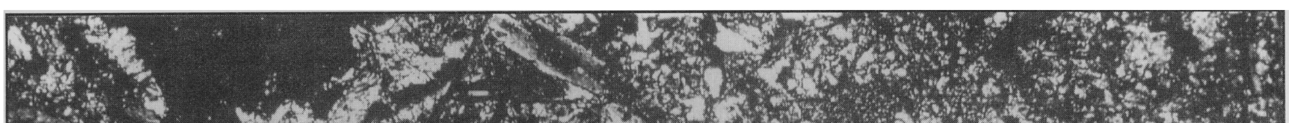

Figure 3a: Dyke under XPL, width = 3 mm. a) Plagioclase laths set in a weathered matrix of plagioclase and pyroxene.

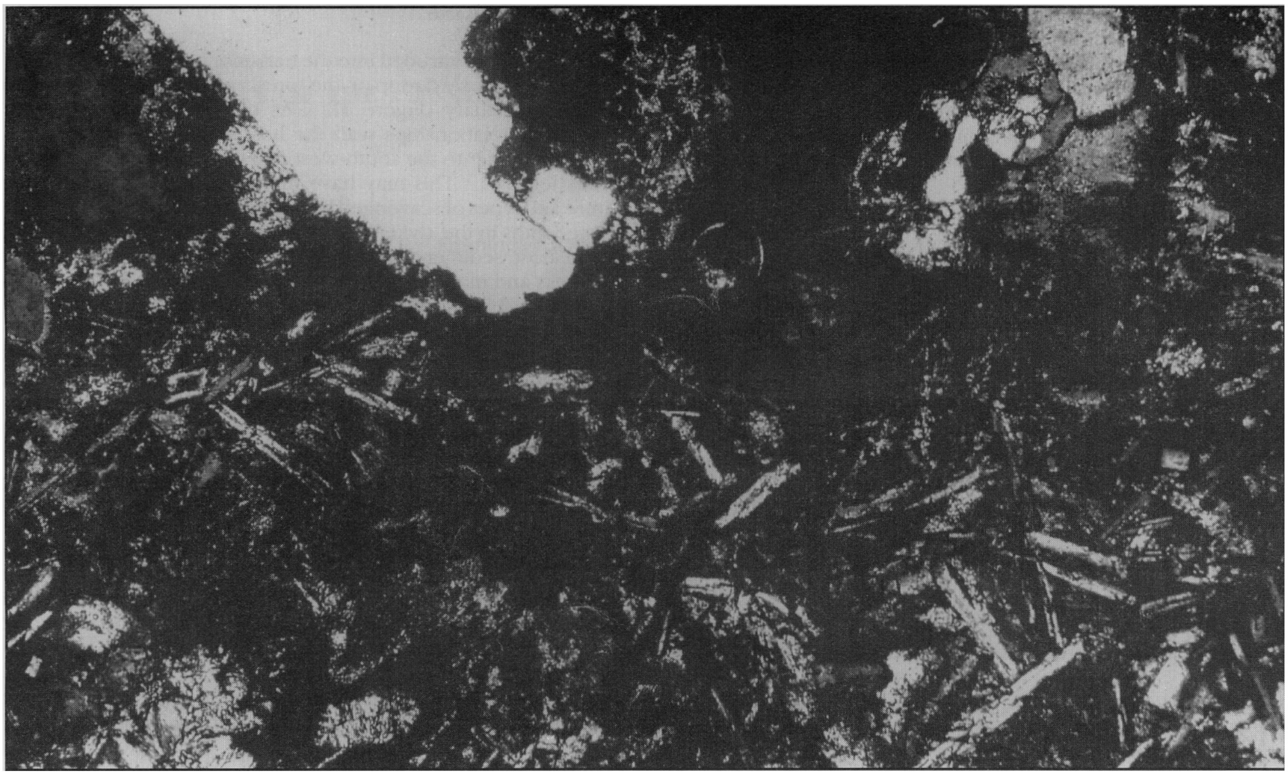

Figure 3b: Skeletal and swallow-tail structures in feldspar to indicate rapid quenching.

PETROGRAPHY

All thin sections were taken from the freshest parts of the inner dykes to minimize the optical effects of weathering. The majority of the dyke fabric is largely aphanitic and overall felsic in composition, composed of simply twinned oligoclase laths (Figure 3a) set in a weathered matrix that was probably dominated by mafic minerals minus biotite. In other places, plagioclase laths border on labradorite in composition and demonstrate both skeletal and swallow-tail morphologies indicating that the magma was rapidly quenched (Figure 3b). Such variation in plagioclase composition within the fabric may indicate at least a two phase emplacement history for the inner component. Alternatively, the variable plagioclase composition could reflect the mixing of melts from different sources but subsequently homogenized into one intrusive event.

Also, a large number of plagioclase phenocrysts varying from labradorite to oligoclase in composition are held by the matrix. Although some of the phenocrysts are relatively fresh, none demonstrate zonation and all are either sub-rounded or partially resorbed to some degree (Figures 4a and 4b). Rarer pseudomorphed olivine phenocrysts have been replaced by chlorite and calcite (Figure 5). The matrix also contains patches of acicular biotite in random orientation (Figure 6). It is unclear how such patches relate to the rest of the dyke.

However, the most intriguing aspect of the dyke concerns the composition of the included xenoliths. Most xenoliths are sedimentary in origin and have undergone low grade metamorphism. Compositions are dominated by well rounded to sub-rounded quartz grains veneered by chlorite, possibly replacing silt or clay fractions in the xenolith (Figure 7a). Conversely, some xenoliths are composed of fresh plagioclase crystals and quartz (Figures 7b and 7c). Grain/grain boundaries in this case are separated by devitrified glass, revealing a

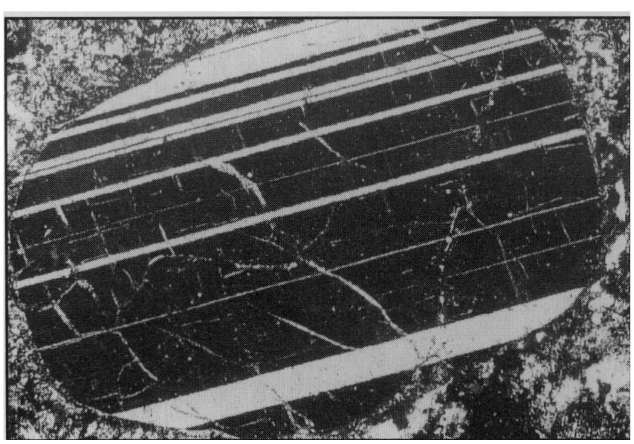

Figure 4a: Plagioclase phenocrysts under XPL, width = 3 mm. a) Large rounded phenocryst, composition An_{24}.

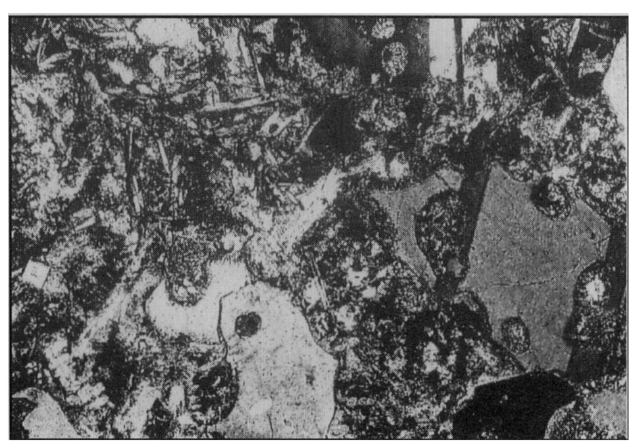

Figure 4b: Partially resorbed phenocrysts with rare skeletal structures in smaller grains.

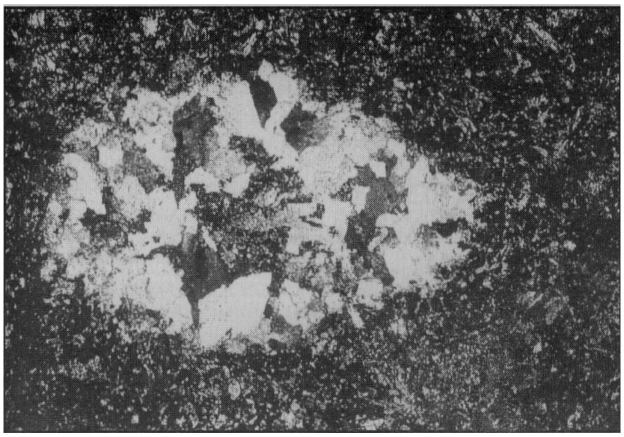

Figure 5. Olivine phenocryst replaced by chlorite and calcite. XPL, width = 1.5 mm.

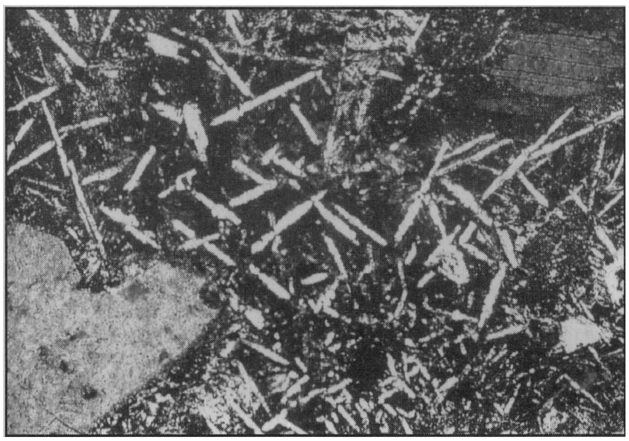

Figure 6 Random orientation of acicular biotite. XPL, width = 1.5 mm.

buchite structure that complicates distinction between a sedimentary or igneous origin. Fresh plagioclase is not exclusive to igneous rocks, but the angularity of some crystals (Figure 7c) argues against a sedimentary origin.

AR/AR DATING OF THE DYKES

Argon dating of plagioclase crystals using the laser ablation method has revealed new information on age relationships in the Fremington dyke. A best-fit isochron mixing line for a plagioclase phenocryst reveals a $^{40}Ar/^{39}Ar$ ratio for the radiogenic endmember of 37.679± 0.209 (Figure 8), which corresponds to an isotopic age of 353.8 ± 4.3 Ma. However this is artificially old, as the composition of the trapped $^{40}Ar/^{36}Ar$ component (231.4 ± 6.4) is lower than present day atmospheric composition of 295.5 (McDougall and Harrison, 1988) and probably indicates some argon loss. When the analysed trapped component is anchored close to the present day $^{40}Ar/^{36}Ar$ component, an isotopic age of 292.4 ± 7.1 Ma is obtained. Therefore, the Fremington dyke is broadly coeval with basic lava flows, dykes (291 ± 6 Ma; Miller *et al.,* 1962 and Thorpe *et al.,* 1986) and lamprophyres (average 291 Ma; Hawkes, 1982) of the Exeter Volcanic Series in South and mid-Devon (ages determined by whole rock K/Ar analyses). Given the error limits in the isotopic age introduced here, the dyke may also be coeval with the Carnmenellis pluton at 293.1 ± 1.3 Ma or the weakly-megacrystic facies of the Dartmoor granite at 285.3 ± 0.8 Ma (Clark *et at,* 1993).

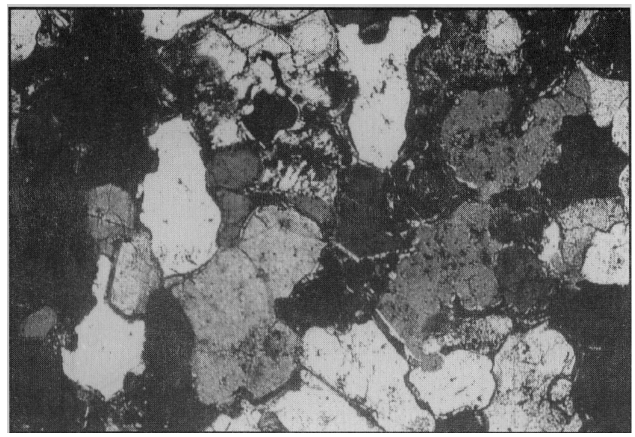

Figure 7: Xenolithic inclusions in the dyke under XPL, width = 1.5 mm. a) Rounded to subrounded quartz grains with some chlorite replacement. b) and c) Plagioclase and quartz grains with devitrified glass around grain/grain boundaries indicating possible buchite structures.

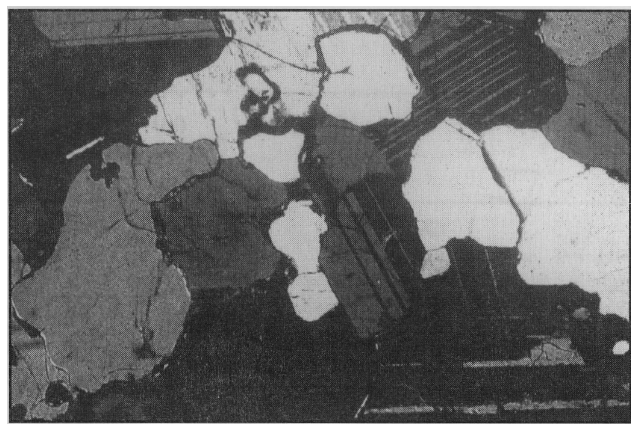

Figure 7b.

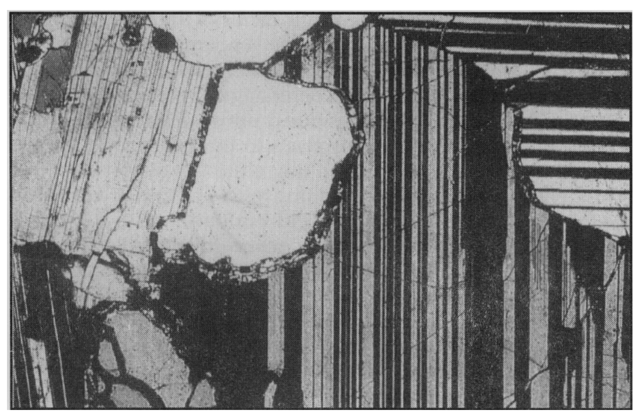

Figure 7c.

DISCUSSION

Although most of the xenolithic material is clearly sedimentary, some clasts may be igneous in origin. This does not necessarily indicate a previously unrecognized plutonic body in North Devon. Tunbridge (1976, 1978) noted exotic, angular igneous clasts in the conglomerates within the Rawn's Formation of the Hangman Grits (Upper Devonian) cropping out along the North Devon coastline near to Lynton. This rock formation is significantly older than the Pilton

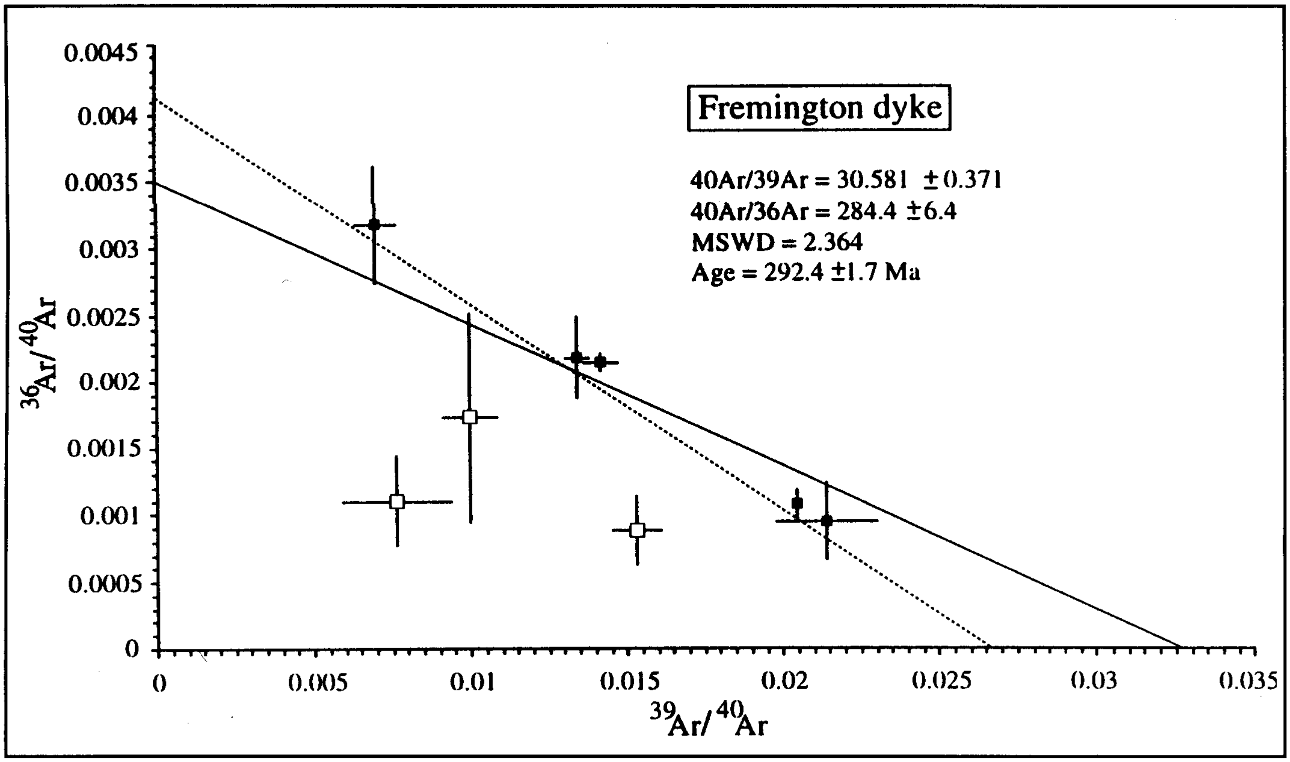

Figure 8: Ar/Ar age determination for the Fremington dyke. Black and white filled squares (with error bars) represent analyses obtained from two different feldspar crystals. Only isotopic compositions obtained from one feldspar (black squares) have been used here to calculate the age. The other feldspar (white squares) may have suffered argon loss due to excessive weathering. The dashed line represents the best fit regression line for the five black data points, but the $^{36}Ar/^{40}Ar$ ratio is above the ambient atmospheric ratio (0.0035) to indicate that derived age is false. The solid black line represents the best fit regression isochron when the $^{36}Ar/^{40}Ar$ ratio is set at atmospheric composition. The age is calculated from the $^{39}Ar/^{40}Ar$ ratio along the x-axis using the standard formula derived by McDougall and Harrison (1988).

Shales and stratigraphically just over 4,000 m below the Fremington dyke outcrop.

Assuming that the conglomeratic facies of the Rawn's Formation does extend southwards to the Fremington area (which cannot be confirmed from borehole information), the inclusion of igneous clasts from the conglomerate layers within the Fremington dyke must be considered unusual, as there must be relatively few suitable igneous clasts to be scavenged form the sediments in the first place. In any case, this model implies a considerable amount of cross-cutting relationships (at least 4,000m) for which there is no direct field evidence.

Alternatively, igneous xenoliths observed in thin section may indeed be derived from a hidden igneous intrusion somewhere in North Devon. As the dyke just pre-dates most of the Cornubian granites or at least is contemporaneous with the Carnmenellis and parts of the Dartmoor granites, such a hidden igneous body may represent one of the earliest magmatic phases associated with pre-orogenic basic-acid volcanic systems. It is possible that a small igneous intrusion could remain unobserved by geophysical modelling if it had low bulk susceptibility or minimal density contrast with its host rocks.

The heterogeneity of structures within the dyke implies a complex petrogenetic evolution or even a staged emplacement history. However, a puzzling feature of the plagioclase phenocrysts in particular is that they do not display outer zonation rims to indicate chemical change, which would normally be expected in an evolving magma chamber or during differential cooling from that magma. As the phenocrysts have been partially resorbed, it may be that the once present outer rims have been destroyed, so that crystals now display an apparent homogenous texture. Alternatively, there may have been some degree of magma mixing from different sources. If magmas have not evolved, it is tempting to hypothesize more than one magma chamber to explain the variation in structures.

CONCLUSIONS

1. An Ar/Ar isotopic age for the Fremington dyke dates it as 292.4 ± 7.1 Ma, which indicates that it just pre-dates the bulk of the Cornubian granites but is also coeval with the Exeter Volcanic Series, Carnmenellis granite and parts of the Dartmoor granite.
2. Skeletal and swallow-tail structures in plagioclase feldspars indicate quenching of magma to accompany conventional cooling rates. Plagioclase phenocrysts indicate an earlier (and deeper?) crystallization phase.
3. The dyke has at least a two-stage emplacement history with inner and outer phases.
4. Sedimentary and igneous xenoliths are incorporated within the inner part of the dyke, but buchite structures complicate definition. Devitrified glass has replaced some grain/grain boundaries.
5. Igneous xenoliths may have been derived from a previously unrecognized igneous body in North Devon that potentially just pre-dates the neighbouring granites.

REFERENCES

CLARK, A.H., CHEN, Y., FARRAR, E., WASTENEYS, A.H.P., STIMAC, J.A. HODGSON, M.J., WILLIS-RICHARDS, J. and BROMLEY, A.V. 1993. The Cornubian Sn-Cu (As, W) Metallogenic Province: product of a 30 my. history of discrete and concomitant anatectic, intrusive and hydrothermal events. *Proceedings of the Ussher Society*, **8,** 112-116.

DEWEY, H. 1910. Notes on some igneous rocks from North Devon. *Proceedings of the Geologists' Association,* **21,** 429-434.
HAWKES, J.R. 1982. The Dartmoor granite and later volcanic rocks. In: The geology of Devon. Eds. DURRANCE, E.M. and LAMING, D.J.C., *University of Exeter,* Exeter, 85-116.
HAWKES, J.R. 1985. Igneous rocks. In: Geology of the Country around Ilfracombe and Barnstaple. Eds. EDMONDS, E.A., WHITTAKER, A. and WILLIAMS, B.J., *Memoir of the British Geological Survey,* Sheets 277 and 293, 57.
McDOUGALL, I. and HARRISON, T.M. 1988. Geochronology and thermochronology by the $^{40}Ar/^{39}Ar$ method. *Oxford monographs on Geology and Geophysics,* **No. 9,** Oxford University Press, Oxford. 212 pp.
MILLER, J.A., SHIBATA, K. and MUNRO, M. 1962. The potassium-argon age of the lava of Killerton Park near Exeter. *Geophysical Journal of the Royal Astronomical Society,* **6,** 394-396.
THORPE, R.S., COSGROVE, M.E. and VAN CALSTEREN, P.W.C. 1986. Rare-earth elements, Sr- and Nd- isotopic evidence for petrogenesis of Permian basaltic and K-rich volcanic rocks from southwest England. *Mineralogical Magazine,* **52,** 481-490.
TUNBRIDGE, I.P. 1976. Notes on the Hangman Sandstones (Middle Devonian) of North Devon. *Proceedings of the Ussher Society,* **3,** 339.
TUNBRIDGE, I.P. 1978. Mid-Devonian tectonics and sedimentation in the Bristol Channel area. *Journal of the Geological Society of London,* **143,** 107-116.