of the slower phase-determining components and the time were such that the sizes of the quenched equilibrium systems were quite small.

The presence of the bimineralic core zone complicates any analysis of the data because no simple relation between concentration and chemical potential should be expected in this zone. The occurrence of three phase assemblages and the data for the actinolite and biotite zones indicates that at least three independent extensive parameters such as Mg, Al, Fe are necessary to describe the observed sequence from core to biotite rock. Matthews' emphasis on the importance of variations in Mg by itself (p. 28, ll, 14-15, and p. 32, l. 17) is not warranted. The small variations of one variable, e.g. concentration of Al, may be more critical in determining the stability of a phase at a given point than the large variations of another, e.g. concentration of Mg. Variations between these three variables, while other parameters remain essentially constant, are sufficient to determine the presence or absence of chlorite (q.v. 32, l. 18). However, the influence of variations in other parameters (e.g. Si?) are not excluded.

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THE GEOLOGICAL INTERPRETATION OF POTASSIUM-ARGON AGES OF METAMORPHIC ROCKS FROM THE SCOTTISH CALEDONIDES

Sirs,—Harper (1967 p. 56) comments on the origin of the Strathspey Pegmatite Complex and suggests that it formed as a result of partial remelting of the metasediments during a high temperature peak of Dalradian metamorphism. This misleading hypothesis probably arises as a result of the limited descriptions of the complex currently available (Read 1915, p. 44; Anderson 1947, pp. 105-6, 111, 1956, pp. 21-34). Miller and Brown (1965a, p. 120) referred to this complex as an 'Older Granite' but meant to imply an association in time with $F_3$ metamorphism and not a migmatitic origin (Smith 1965, p. 463; Miller and Brown 1965b, p. 558).

Recent detailed mapping of this area has indicated a much more complex
geological history (Smith 1968) than was previously recognised. Three phases of deformation have affected the Moinian and Dalradian rocks of Upper Strathspey. Major and minor Early recumbent folds trending north-east, associated with regional axial plane schistosity, are deformed by Late Main asymmetric folds, with steeply dipping axial planes trending north-east, and by strain slip cleavage. Late Oblique minor open folds also affect the metasediments. These folds have been compared (Smith 1968, Table 2) with the $F_1$, $F_3$ and $F_4$ folds described from the Iltay Dalradians by Rast (1963).

It is difficult to distinguish the individual episodes of metamorphism which have affected these coarse grained metasediments, as it is elsewhere in the Highlands. However, evidence of a rise into the sillimanite-almandine sub-facies during and after the Early phase of deformation followed by a period of Late Main syntectonic retrogressive metamorphism in the quartz-albite-epidote-biotite sub-facies, has been observed. The first recrystallisation is accompanied by migmatisation which ceases prior to the advent of the Late syntectonic metamorphism.

New observations on the Strathspey Pegmatite Complex show that it comprises a central core of heterogenous granitic rocks approximately 6 miles long by 4 miles wide trending north-east. It is surrounded by metasediments penetrated by large numbers of minor bodies of pegmatite, aplite and granite. These minor apophyses are most abundant in a zone about half a mile wide around the central core and their numbers diminish rapidly at greater distances. The mapped boundary of the granite core marks a fairly rapid transition from rocks comprising mainly granite to those in which metasediment is predominant. The complex comprises mainly muscovite-biotite-granodiorite which commonly grades into aplite granite or porphyritic and uniform pegmatite with no distinct margins between the various rock types. In addition the granitic rocks are commonly cut by discrete veins of pegmatite, aplite and quartz. Large numbers of metasedimentary enclaves occur in the central core varying in size from maximum diameter measured in inches up to rafts several hundred yards long and over one hundred feet in thickness.

Various structural observations indicate that the granite core and its associated minor apophyses are intrusive in origin (Smith 1965). The age of this intrusive event relative to the structural history of the area can be shown by the fact that minor representatives of the Late Oblique folds occur in metasedimentary enclaves within the granite, though some reorientation of these structures has taken place, probably as a result of magmatic flow.

The lit-par-lit migmatites and ‘permeation’ gneisses are distributed through the country rocks in a series of bands bearing no constant relationship to the main granite boundary, and indeed are much more widespread than the minor apophyses of the granite already described. It is suspected that these bands are related to Early major folds but no positive proof of this has yet been found. Quartzofeldspathic augen are aligned with the axes of Early folds. Late lineations
and minor folds are superimposed on the migmatites. A few replacive pegmatites of the same generation as the migmatites occur in the area mainly as concordant pods but also as irregular discordant patches. These rocks are part of a regional migmatite complex extending north-east into the area of Grantown-on-Spey (Johnstone 1966, Fig. 19).

It has been noted above, however, that the granite core of the Pegmatite Complex contains metasedimentary enclaves with preserved Late Oblique folds. Thus in Upper Strathspey the time relationships between the formation of regional migmatites and the Strathspey Pegmatite Complex can be clearly demonstrated. The former were the result of high grade metamorphism which took place before the Late Main (F₃) folding and the latter was intruded after the Late Oblique (F₄) deformation.

The new evidence can be used to test the validity of both the 'slow cooling' and 'overprinting' hypotheses (Harper 1967, pp. 47-8) to explain the age pattern found in Upper Strathspey. The mean age determined on biotites from the Monadhliath Schists is 428 m.y. and from the Central Highland Granulites it is 432 m.y. (Brown et al. 1965, p. 130; Miller and Brown 1965a, Table 2a; Smith 1965, p. 462; Harper 1967, Table 1). The mean age of the Strathspey Complex is 427 m.y. (Miller and Brown 1965, Table 2d; Harper 1967, Table 2) excluding the Dalchully Granite 393 m.y. (Miller and Brown 1965a, Table 4) which is considered to be part of the Strathspey Complex on geological grounds (Smith 1965, p. 462). The dates on the metamorphic rocks could be explained either as the result of complete overprinting of earlier events by the strong Late Main retrogressive metamorphism reported (see Miller and Brown 1965b, p. 558) or equally well by slow cooling at greater depths in the tectogene. However, it has been shown that the Late Oblique (F₄) folding intervenes between the retrogressive metamorphism and granite intrusion which both yield similar radiometric ages. In addition to the interval for folding, further time is required for the granite to cool to temperatures at which radiogenic argon can accumulate. This evidence appears to favour the slow cooling hypothesis rather than overprinting in which retrogressive metamorphism and granite intrusion would need to be more or less synchronous. Until, however, fuller geological information is available for all rocks which have been dated it seems unlikely that an entirely satisfactory explanation for age patterns in the Caledonides will be forthcoming.

REFERENCES


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Sirs,—Dr Smith has a great deal of new and interesting information on the Strathspey Pegmatite and Migmatite Complex. Although I have stated that the whole complex was probably formed by partial melting of metasediments during the high temperature peak of Dalradian metamorphism, Smith’s latest evidence would suggest that only the *migmatites* formed during the high temperature metamorphic peak between F₁ and F₃; the *pegmatites* were intruded later, after F₄. This new evidence strengthens the slow cooling hypothesis, for similar K-Ar ages have been obtained from both the migmatites (432-428 m.y.) and the pegmatites (427 m.y.). Clearly, regional cooling and initiation of radiogenic argon retention in the whole migmatite-pegmatite complex occurred around 430 m.y. ago. The K-Ar ages do not resolve the different times of structural emplacement.

If the pegmatites were, however, emplaced *during* the time of regional uplift and cooling of the metamorphosed Dalradian complex, their K-Ar ages would be much closer estimates of the real time of pegmatite emplacement. The Strathspey Pegmatite Complex and the Crarae porphyry sill in the S.W. Highlands might in this case be temporal correlatives.

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