with a small " knoll " feature projecting from the Malvernian surface through the shale layer. There was no indication of " neptunian dykes ".

In the " Sycamore tree " quarry at West Malvern an undeformed horizon of laminated siltstone occurs as a persistent band within the more fossiliferous portion of the Upper Llandoverian conglomerate close to the Malvernian contact. A dip measurement gave a reading of 60 degrees in a westerly direction. This suggests the possibility of a closely similar relationship to that which exists in the South Malverns.

These two exposures indicate that at least *two* unfaulted contacts between the Pre-Cambrian and Upper Llandoverian exist on the western flanks of the Malverns ; and in the absence of other exposures of the contact zone to confirm, or disprove, the general unconformable relationship suggested, I incline to agree with Ziegler that the absence of pre-Upper Llandoverian strata along the Malvern line north of Gullet Quarry is due to pre-Upper Llandoverian positive movement resulting in erosion and non-deposition. Field-mapping south of the Gullet Quarry indicates that the positive movement along the Malvern line took place after the deposition of the Upper Cambrian and was accompanied by faulting, the effects of which tend to be obscured by the Upper Llandoverian transgression ; more especially by the latest phase (C_5 zone) which finally submerged the Malvern marine ridge.

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CONDITIONS IN THE METAMORPHIC CALEDONIDES DURING THE PERIOD OF LATE OROGENIC COOLING

SIR,—Dr. J. Watson (*Geol. Mag.*, 101, No. 5, 457–465) has made the interesting suggestion that the thermal pattern of the metamorphic Caledonides was retained until Newer Granite times and may thus account for variations in the character and contact effects of the Caledonian granites and their associated minor intrusives. From the pattern of Rb-Sr and K-Ar dates obtained from the Moine and Dalradian rocks, Dr. Watson concludes that a central region, coinciding very approximately with the " thermal anticline " of Kennedy, cooled to a particular stage at 400–420 m.y. while the more peripheral regions had reached the same stage some 40 m.y. earlier. If attention is confined to K-Ar ages on micas, so that variation in the diffusion rates of daughter products is minimized, a rather different pattern emerges, which invites an alternative interpretation of the Newer Granite phenomena.

Over 150 K-Ar ages on Moine and Dalradian micas have now been published. Very strong maxima occur between 420 and 430 m.y. in the frequency distribution for the Moines, and between 420 and 440 m.y. in the Dalradian (Brown, Miller, Soper, and York, in preparation). The possible significance of these maxima is fully discussed in the above paper ; the interpretation which I favour is that the Dalradian rocks, occupying a generally higher tectonic level than the Moines, cooled through the temperature range of partial argon loss to that of complete argon retention some 10 m.y. before the Moines, following a metamorphic " event " which had affected both Series more or less synchronously. This implies a much shorter period of late-orogenic cooling than envisaged by Dr. Watson. Further, it has been suggested by Hurley *et al.* (1962) that radiogenic argon is not retained in the mica lattice above temperatures in the range 100°–200° C. Various lines of geological evidence seem to indicate that this figure is somewhat low. Even so, if the interior parts of the orogen (as now exposed) had cooled below the temperatures of greenschist facies metamorphism at about 420 m.y. it is difficult to envisage that a temperature gradient towards the peripheral areas, sufficient to account for the variations in Newer Granite contact phenomena, could be maintained until the granites arrived some 20 m.y. later.

A more important factor may be depth of emplacement. If the area of low K-Ar ages and high metamorphism does represent a deeper level in the orogen than the peripheral regions, it is reasonable to conclude that the intrusions now exposed in this central area were emplaced under greater hydrostatic stress and in an environment favouring slower heat dissipation than intrusions of a similar age in the marginal regions. Retention of volatiles and slow cooling in the central area could account for the presence of fringing migmatite and pegmatite complexes around the larger granites, the absence of chilling in appinitic bodies, the occurrence of aplites rather than porphyrites and perhaps also the asymmetry of contact effects of certain complexes. In certain cases both factors may have been important : the Rogart complex in South-east Sutherland, which has a markedly asymmetrical contact migmatite (facing the thermal " high ") has yielded K-Ar ages of 424 and 416 m.y. (Brown *et al.*, 1965). This complex is apparently an early manifestation of Newer Granite activity and may thus have been emplaced at a period when the crustal temperature on opposite sides of the intrusion still differed sufficiently to influence the contact effects.

Dr. Watson has emphasized the importance of lateral variations in crustal conditions, as well as changes in time, as a factor influencing the mode of emplacement of granitic bodies. The Newer Granites were emplaced during a period of rapid late-orogenic uplift, erosion, and " molasse " sedimentation ; it is scarcely surprising that in relatively small areas, where the order of emplacement of successive members of a granite suite can be determined (geologically—Glen Coe, Donegal, or radiometrically—the Lake District : Brown, Miller, and Soper, 1964), the later intrusions appear to have been emplaced under a thinner cover. Considering the metamorphic belt as a whole, although radiometric evidence is incomplete, it is evident that the majority of Newer Granites were emplaced in Lower and early Middle Old Red Sandstone times. This is a relatively short period, particularly in comparison with the time occupied by the preceding metamorphisms. As Dr. Watson has shown, variations in the mode of emplacement can be related to position within the fold belt. I suggest that an important factor influencing this variation was depth of emplacement and that in spite of a presumed high geothermal gradient at this period the influence of a residual thermal pattern may have been secondary.

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