SIRS — Attention has recently been drawn (Weir 1979) to the variation in exposure width of the Moffat Shale belts of the Southern Uplands. This, it has been suggested (op. cit. pp. 175–7), is caused by the exposure of different structural levels of a curved zone as a result of very large-scale open folding on an approximately N-S axial trend: the broad outcrops of shale corresponding to culminations above igneous plutons with the narrower outcrops formed by the exposure of a higher structural level in depressions between plutons. This intriguing idea raises a number of questions, not least the coincidence of depressions with the Cairnsmore of Carsphairn and the Culvennan Fell intrusions. However, of more general significance may be the original variation in the stratigraphic thickness of the Moffat Shale sequences. In most of the inliers true black shale forms only a small proportion of the total thickness, the remainder being composed of siltstone, fine greywacke, chert and lava. The first two of these lithologies probably represent distal turbidite deposits and their thickness may well vary along strike relative to the origins of the depositing turbidity currents. Lava thicknesses will, of course, be very variable laterally and cherts too may be thickly developed in places and absent elsewhere. Thus, for example, of the wide Moffat Shale outcrops shown N of Glenluce (Weir 1979, fig. 2, culmination 1) the northernmost is composed in the main of fine greywacke and does not form a recognizable outcrop on Sheet 3 (Stranraer) of the one-inch Geological Map, and the southernmost contains a large proportion of chert, together with some lavas and intrusive dolerites. It is doubtful whether any valid conclusions can be drawn from a comparison of the exposure width of the latter outcrop with the narrower part of the same shale belt to the NE where, in a sequence several hundred metres thick, up to 20 thin shale horizons are interbedded with siltstones and fine greywackes with only very rare chert (Stone 1980).

The Moffat Shale belts cropping out adjacent to the south-western margin of the Loch Doon pluton contain a high proportion of shale and mudstone and do represent a marked thickening of the shale belt. However, the structural complexity of these outcrops (investigated by recent I.G.S. mapping) indicates that local tectonic thickening may well be involved. Further, there is very little variation in the overall dip along the shale belt from the southermost extremity of the Loch Doon pluton to Glenluce, and certainly nothing like sufficient to produce the variation in thickness as modelled.

Overall I would suggest that there are sufficient local stratigraphic, and probably structural, differences to explain the along-strike variation in the thickness of the Southern Uplands shale belts without recourse to a large-scale folding model.

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SIRS,—Your correspondent highlights an admitted deficiency in the presentation of my paper (Weir 1979). It is, as he points out, abundantly clear from studies in progress, in thesis and in publication, that the majority of outcrops of Moffat Shales are intimately associated with greywackes, and with bedded cherts and lavas where appropriate. Among instances which may be cited are the Leadhills fault zone in the Leadhills-Abington area (B.C. Hepworth, pers. com.); several fault zones in West Nithsdale (Floyd 1975); Clanyard Bay (Watson 1976); and Cairnsmore of Fleet (Cook 1976; Cook and Weir 1980). Indeed, it was to avoid tedious repetition of a cumbrous term such as 'outcrops of Moffat Shales in association with greywackes and other lithologies' that Floyd (1975) employed the term 'Line', implying thereby restriction of Moffat Shales (and stratigraphically associated rock types including cherts, lavas and pyroclastics) to those impressively linear outcrops. This usage dates back to Peach and Horne (1899), and has been extensively adopted with this implication by St. Andrews workers subsequent to Floyd.

The immediately impressive feature of the fault zones, in addition to their considerable lateral extent, is their variability in width, from more than 1 km to about 30 m (Cook 1976; Weir 1979). This variability is most clearly expressed in the Talnotry and Blauirbuies Lines (Cook and Weir 1979), both of which display a WSW-ENE decrease in width. Relationships within a fault zone are most clearly expressed in the Talnotry Line. In its western outcrop W of the Fleet pluton, the line is confined below by a reverse fault inclined NNW at around 45°. Above this, slices of Moffat Shales and overlying greywackes are bounded by steep reverse faults. These slices are obviously schuppen arising from the basal fault as a sole; 14 have been mapped, decreasing eastwards to 3 where intersected by the pluton. E of the pluton the fault zone is reduced to a width of around 500 m, with 3-5 schuppen. The sole hades more steeply, and the hades of the imbricate faults approximate more closely to that of the sole. Comparable relationships are demonstrable in the Blairbuies Line 5 km S, the western outcrop exposing 26 schuppen in a width of 1 km, and the eastern 9 in a width of 700 m.

A second factor crucial to Cook's reasoning is the existence of a regional eastward plunge, away from the pluton, of around 2-3°, exposing successively higher tectonic levels in this direction. Thus, higher tectonic levels appear to be associated with narrower dislocation zones and steeper sole faults.

Fault zones S of the Fleet pluton all display narrow dislocation zones, steep soles and few or no schuppen, with hades approximating to those of the soles. Width decrease is progressive N-S from the Blairbuies Fault, this being taken to imply exposure of correspondingly higher levels of the tectonic profile away from the strikewise diameter of the pluton, which intersects the Blairbuies Line. All these factors support listric geometry, as explained by Price (1977). The comparative constancy of spacing of the more laterally continuous lines, at around 5-8 km (Weir 1979) also supports their propagation as a family of listric faults.

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There are certain complications and inconsistencies. Some arise through the steepening of the faults in NW succession, to the point of actual overturning of the Fardingmullach Line in West Nithsdale (Floyd 1975). This steepening is by late rotation, and is implicit in the mechanism of accretionary prism generation expounded by McKerrow et al. (1977) and Leggett et al. (1979)—as is the generation of a family of listric faults. Moreover, some of the evidence from individual faults is apparently inconsistent. Underground workings in the Leadhills Line suggest that the sole is a reverse fault inclined at 30–40° NNW (Mackay 1959), whereas Hepworth's study immediately E (in progress) indicates a near-vertical hade with the imbricate faults overturned at 60–70° SSE. This observation is more consistent with Floyd's findings. Any intrinsic variation in steepness does not relate to variation in line width. The dislocation zone is wide, and would suggest exposure at a deep level. This is supported by the angular divergence of 20–30° between the sole and the imbrication faults.

Variations in line width are thus considered most probably to be related to variations in depth of exposure of the tectonic profile. On individual lines, these variations must be related either to transverse folding, or to faults with very considerable vertical displacements. Certain transverse faults do cause slight variations in line width, for instance along the Talnotry Fault W of the Fleet pluton and the Fardingmullach Fault in West Nithsdale (cf. Weir 1979, fig. 2). These vertical movements are interpreted as dip-slip components along Main wrench faults, and are most likely to be of local significance (admitting the difficulty of following any structure through the greywacke tracts). Tendency to gradual narrowing of the lines favours folding. Approximate N-S alignment of adjacent and successive wide tracts suggests exposure in plunge culminations. This would imply folding. Coincidence of one such major alignment with the line of the Loch Doon and Fleet plutons suggests their forceful emplacement as a mechanism; it is noteworthy that both intrusions cause conspicuous deviations in strike of the lines. Support is lent by a modest expansion of the Ettrick Valley Line near the Portencorkrie stock in the Rhinns of Galloway, and of the Leadhills Line near the Spango stock NE of Sanquhar. Rank of coalification of graptolites in the Moffat area has been ascribed (Watson 1976) to possible presence of a concealed pluton; its position would coincide approximately with a major expansion of the Ettrick Valley Line, and lesser expansions of fault zones tentatively equated with the Talnotry and Blairbuies Lines. Admittedly the Kirkcowan stock W of Newton Stewart is situated in an alignment of minimum width—how authentic this alignment is may be questioned, as the terrain is curiously poor in exposure.

The evidence in favour of large-scale folding is not conclusive, and not as strong as that for listric faulting, but is at least suggestive.
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