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Tectonic sliding within the Moinian Loch Eil Division near Kinlocheil, W. Inverness-shire: comment

Sirs—Strachan (1982) sub-divided the Loch Eil Division psammites (Johnstone et al. 1969) of the Kinlocheil area into a series of mappable units, and produced a welcome refinement of the stratigraphy in this area. He argued that both the impersistence of some units, and the apparent stratigraphic repetitions, are the result of tectonic sliding, on the grounds that the stratigraphy determined south of Loch Eil (the ‘type’ stratigraphy) was also the original stratigraphy north of Loch Eil. My mapping along the Glenfinnan/Loch Eil Division junction, between Glenfinnan and Glen Affric, confirms Strachan’s view that there is a more complex stratigraphy in this zone than that proposed by Johnstone et al. (1969), and shows, moreover, that there is a lateral variation in the lithostratigraphy. However, poor exposure in the area where the ‘type’ stratigraphy is defined (Strachan 1982, pp. 189–90) means that control on the lateral persistence of units is there less precise than in the well exposed Na h-Uamhachan/Gulvain area (Strachan 1982, fig 1) where complex sliding is invoked to explain lateral changes. Hence it might have been appropriate to use the sequence in the northern area to interpret the southern area. In the light of the new field observations I have reservations about the interpretation of the Kinlochcil area as a zone of sliding. Lithostratigraphic, metamorphic fabric and geometrical evidence argue against the published conclusions.

Detailed re-examination of the area suggests that there are no suitable field criteria for distinguishing the lithologies of the Basal Psammites from those of the Glen Garvan Psammites; beds within the Kinlocheil Cross-Bedded Quartzites are also commonly indistinguishable from beds within these two formations, e.g. the eastern slope of Druim Fearna [NM 96 77] consists of locally cross-bedded psammites with little or no quartzite. Poor exposure south of Loch Eil means that here the lateral persistence of the Kinlocheil Banded Quartzites cannot be proved, and their distribution north of Loch Eil suggests that while they are a distinctive lithology, they are not a unique lithostratigraphic formation. In the Na h-Uamhachan area (Strachan 1982, fig. 1), north of Loch Eil, quartzites identical to the Kinlocheil Banded Quartzites occur within a unit designated the Gulvain Psammitic Gneisses (Glenfinnan Division). These quartzites occur interbanded with gneissose psammite on a metre scale, and as a lens, mappable at 1:10 000 scale [NM 975 849]. The latter occurs within in situ psammitic gneisses to the north of the slides shown by Strachan; it might be better interpreted as a small sedimentary

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intercalation of silicious sediment within the more quartzofeldspathic, now gneissose psammites. The impersistence of the Kinlochel Banded Quartzites, and the similarity of lithologies within the Basal Psammites, Kinlochel Cross-Bedded Quartzites and Glen Garvan Psammites, casts doubt on the necessity of a tectonic 'cut-out' beneath Loch Eil, (Strachan 1982, fig. 1) to explain the absence of Kinlochel Cross-bedded Quartzites, and an apparent cut-down through stratigraphy of the Kinlochel Banded Quartzites, north of Loch Eil.

As well as the interbanding of psammitic gneisses and banded quartzites, psammites identical to the Basal and Glen Garvan Psammites also occur within the Gulvain Psammitic Gneisses. Conversely, psammitic gneisses occur within the Kinlochel Banded Quartzites, interbanded with the quartzites [NM 9794 8417]. Thus psammites, psammitic gneisses and banded quartzites occur in both Glenfinnan and Loch Eil divisions sensu Strachan. A 3 km band of Gulvain Psammitic Gneisses, 'slid' into Loch Eil Division rocks, (Strachan 1982, fig. 1) passes east and west into a similar thickness of Basal Psammites which cannot confidently be distinguished from the Psammitic Gneisses. The Basal Psammites are locally gneissose and the Psammitic Gneisses are commonly quartzitic or non-gneissose: I would suggest that this is a continuous band of psammitite, the local development of a gneissosity reflecting the more feldspathic bands present.

Strachan (1982) used the term 'slide' in the sense of Hutton (1979). Hutton's definition includes the development of a 'zone of high strain'. Where the 'Kinlochel slide' is exposed at Cala na Creige [NM 963 804] there are no indications of fault rocks, brittle or ductile, and preservation of massive bedforms and sedimentary structures is indicative rather of a zone of low strain. There seems to be no reason to regard Cala na Creige as anything other than a sedimentary passage from dominantly psammitic (quartzo-feldspathic) into dominantly quartzitic rocks.

Fabrics within bands of pelitic gneiss in Loch Eil Division rocks, e.g. [NM 9830 8443], indicate that the metamorphic peak was MS1, coeval with sliding, and not MS2 as stated by Strachan (1982, p 195). Migmatitic quartzo-feldspathic segregations and the S1 fabric are clearly folded by D2 folds. As the S2 crenulation tightens, so the segregations are progressively transposed (reworked) to constitute an axial planar, apparently penetrative S2 fabric. Thus the segregations, associated with the metamorphic peak, are clearly pre-D2 and can be seen to lie within S1 where D2 strain is low. Comparison of the fabrics of the Kinlochel 'slide zone' with those of the syn-metamorphic Sgurr Beag slide (Rathbone and Harris 1979; Powell et al. 1981), shows that the high ductile strains and blastomylonites typical of the Sgurr Beag slide, are notably absent from the Kinlochel 'slide zone'.

The model for the development of the Kinlochel slide zone (Strachan 1982, pp 187 and 200) requires that a monocline present to the south of Loch Eil must be D1 in age and hence coeval with sliding. However, on Druim Fearna (op. cit. fig. 1) the monocline clearly folds an earlier penetrative fabric and, hence, cannot be a D1 structure. This monocline faces and overturns east, and since according to Strachan
D1 minor folds overturn west (being D1 structures they must also face west), it seems more likely that the monocline is associated with the easterly facing event of the Beinn an Tuim synform generation (op. cit. fig. 1).

Finally, the model proposed (op. cit. fig. 3), for the sequential development of the slides, must be called into question. This shows westerly directed thrusting/sliding, and therefore can have nothing to do with the easterly overturning monocline. The sequence of slides envisaged in the model obeys none of the standard thrust zone propagation models (e.g. Elliott and Johnson 1980), and thus the mechanics of its development are difficult to envisage. Given the low ductile strains identified in the Kinlocheil slide zone, it should be possible to use the good stratigraphic control in the area to construct restored cross-sections in the manner of Elliott and Johnson (1980) to test the feasibility of this model.

Lacking any evidence to the contrary it seems safer to regard the Kinlocheil area as part of the transition zone from typical Glenfinnan Division striped/pelitic lithology, into typical Loch Eil Division psammitic lithology. This interpretation is consistent with my own observations of lateral and vertical stratigraphic changes in the Loch Quoich and Loch Arkaig areas, and with a similar transition zone between Glenfinnan and Loch Eil Division lithologies in Ardgour (Drs. M. Stoker and A. L. Harris, pers. com.)

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Alan M. Roberts

Jane Herdman Laboratories of Geology,
P.O. Box 147,
The University,
Liverpool.
L69 3BX.

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TECTONIC SLIDING WITHIN THE MOINIAN LOCH EIL DIVISION NEAR KINLOCHEIL, W INVERNESS-SHIRE: REPLY

Sirs—Although broadly supporting the contention that the Loch Eil Division Moine of the Kinlocheil area may be subdivided into a series of lithostratigraphic units (Strachan 1982a), Roberts (1983) disagrees with aspects of the published structural interpretation of the area.

Roberts questions the existence of a tectonic break in the area immediately to the north of Loch Eil on several grounds. He considers that the level of exposure south of Loch Eil is not sufficiently adequate to allow the erection of a 'type' stratigraphy, and in particular to prove the lateral persistence of the Kinlocheil Banded Quartzites, and implies that the observed distribution of lithological units might be better explained by a series of fortuitous facies changes within the unexposed ground between Druim Fearna and Kinlocheil.

The suggestion that the level of exposure south of Loch Eil is significantly less than that north of Loch Eil is clearly refuted by an examination of my field maps: this demonstrates that there are c. 75 exposures per km² south of Loch Eil, and that the area north of Loch Eil is only marginally better exposed at c. 80 exposures per km². The level of exposure south of Loch Eil is thus entirely sufficient, both to enable the construction of a 'type' stratigraphy, and to prove the lateral persistence of the Kinlocheil Banded Quartzites which are regularly exposed along strike [e.g. NM 964 767, NM 948 754 and NM 944 745] at least as far south as the Cona River. There are no systematic facies changes within any of the lithostratigraphic units with respect to the unexposed ground between Druim Fearna and Kinlocheil, and in particular the Kinlocheil Cross-Bedded Quartzites maintain their dominantly quartzitic character throughout their mapped extent. It is also important to note that the Basal Psammites, Kinlocheil Banded Quartzites and Glen Garvan Psammites all maintain a relatively constant thickness throughout the Loch Eil area. It therefore seems more likely that the absence of the Kinlocheil Cross-Bedded Quartzites north of Loch Eil is due to tectonism rather than lateral facies changes.

This interpretation is supported by a study of the contact between the Basal Psammites and Kinlocheil Banded Quartzites north of Loch Eil. I reiterate that this contact is sharp and, contrary to the opinion of Roberts, do not consider that there is any indication of a sedimentary passage between the two units. The contact is associated with highly attenuated D1 isoclines and sheared quartzites at Kinlocheil (Strachan 1982a, p. 195), and locally developed 'flaggy' zones and a thin tectonic schist at Cala na Creige (Strachan 1982b, p. 62). These features rather suggest that

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this contact is a syn-metamorphic displacement; in this context I believe that usage of the term ‘tectonic slide’ is entirely justified. Roberts’ comparison between the fabrics of the Kinlocheil slide zone and those of the Squurr Beag Slide is not particularly meaningful since the two structures are manifestly of different origin and scale. Thus whilst successive workers have demonstrated that the Squurr Beag Slide is a major dislocation of regional extent (Tanner et al. 1970) the Kinlocheil slide zone is, in my view, only likely to be a relatively localised dislocation (decollement?) near the contact between the Glenfinnan and Loch Eil Divisions. It would therefore be somewhat surprising if there were to be any comparison between the intensity and scale of deformation related to these structures.

With reference to the Na h-Uamhachan area Roberts further suggests that gneisses interpreted as allochthonous Glenfinnan - Division (Strachan 1982a, b) should be more correctly assigned to the Loch Eil Division. Careful examination of the well exposed ground on Na h-Uamhachan will, however, demonstrate that these gneisses are both lithologically and structurally distinct from adjacent Loch Eil Division units, from which they are separated by sharp tectonised contacts, but similar in all respects to the northerly unit of the Gulvain Psammitic Gneisses which has well-developed gradational contacts with the Druim Na Saille Pelites of the Glenfinnan Division. Both the units termed ‘Gulvain Psammitic Gneisses’ (Strachan 1982a, fig 1) contain a substantially higher proportion of interbanded pelitic material than do any Loch Eil Division units, numerous thin amphibolite bands and white pure quartzites which are compositionally distinct from the less well-sorted more feldspathic quartzites characteristic of the Loch Eil Division. Furthermore, both autochthonous and allochthonous Gulvain Psammitic Gneisses contain a distinctive suite of highly attenuated tight to isoclinal folds which deform the dominant planar fabric within these units. These structures are present in both gneissose [NM 977 845] and non-gneissose lithologies [NM 986 851] and appear to pre-date the regional D_2 folding. Structures of a similar style and orientation are, however, completely absent from adjacent Loch Eil Division units (Fig. 1) (Strachan 1982b, p. 98). This suggests that these gneisses are also structurally distinct from the Loch Eil Division and reinforces the interpretation that the southerly unit is allochthonous Glenfinnan Division.

I would consider that the most likely explanation of the ‘steep belt’ south of Loch Eil is that it reflects a deeper-seated ‘ramp’ structure (cf. Strachan 1982a, p. 198) formed during a complex progressive D_1 deformation involving recumbent folding and westerly-directed sliding/thrusting. Since D_2 minor folds consistently
verge to the west between the Glen Garvan synform and Callop [NM 924 788] there seems little possibility that the monoclinal structure depicted in Strachan (1982a, figs 2 and 3) is a D2 antiform as suggested by Roberts. My model for the development of tectonic slides in the Kinlocheil area envisages that slides dominantly develop at progressively deeper structural levels in the direction of thrust direction and I cannot agree that this is necessarily at variance with any of the published "standard thrust zone propagation models".

It is apparent from the text of my paper (Strachan 1982a, p. 195) that I was relying on the work of Dalziel (1966) and Dalziel and Brown (1965) with respect to the timing of peak metamorphism within the Loch Eil Division which, according to these authors is broadly MS 2. It seems likely, however, that the metamorphic peak within the Loch Eil Division is, in fact, MS 1 (Strachan 1982b) and was responsible for the growth of pyroxene-biotite and hornblende-biotite assemblages in calc-silicates, fibrolite in semi-pelitic schists, and also, as correctly pointed out by Roberts, the local development of migmatitic segregations in the Na h-Uamhachan area. The presence of migmatic segregations and fibrolite axial planar to D2 folds with interlimb angles of 50°–60° would, however, suggest that
MS 2 was at least locally of equivalent metamorphic grade to MS 1. Most structural texts indicate that 'transposition' is a structural process associated with very tight to isoclinal folding (interlimb angles of less than 10°–15°), and since most D 2 folds only rarely have interlimb angles of this order it seems unlikely that there has been any widespread transposition of MS 1 fabrics as suggested by Roberts.

In conclusion, whilst I thank Roberts for his comments, I see no reason to substantially alter the published interpretation of the structural geology of the Kinlocheil area. There is no convincing evidence to support the hypothesis that the Glenfinnan and Loch Eil Division of this area are linked by a transition zone, and I suggest that Roberts has confused a metamorphic transition with a sedimentary transition. All the available evidence would seem to support the conclusion that the Kinlocheil area is the site of tectonic sliding adjacent to the contact between the Glenfinnan and Loch Eil Division Moine.

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Department of Geology and Physical Sciences
Oxford Polytechnic
Headington
Oxford OX3 03P

R. A. Strachan

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