Reply to comment by Stamatakis et al. on ‘Early Silurian palaeolatitude of the Springdale Group redbeds of central Newfoundland: a palaeomagnetic determination with a remanence anisotropy test for inclination error’

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Stamatakis et al. raise several objections to our recent palaeomagnetic study of the Springdale Group redbeds of Newfoundland. We discuss their comments below.

In their summary, Stamatakis et al. comment that ‘recent palaeomagnetic results from coeval Silurian sedimentary and volcanic rocks of Newfoundland yield contradictory results, with shallow characteristic directions recorded by the redbeds and steeper characteristic directions recorded by the volcanics’. However, the Newfoundland volcanics that give steeper magnetic inclinations lie stratigraphically beneath the redbeds of the Wigwam Formation (see our Table 2). If one suspects that most of the remanence within bedding has occurred. This is incorrect. It is not the difference between IRM$_x$ and IRM$_y$ that predicts inclination error. The ratio IRM$_0$/IRM$_x$ shows no significant change with increasing field as clearly shown by the linearity of the plot in our Fig. 8(b).

Stamatakis et al. claim that ‘if the graph in Fig. 8(a) is extrapolated to higher fields in the range near haematite saturation, it appears that the increasing difference between the intensity of the IRM$_x$ compared to the IRM$_y$ would lead to the opposite conclusion, i.e. that significant deflection of the remanence within bedding has occurred’. This is incorrect.

Stamatakis et al. suggest that our IRM experiments may mostly be measuring the anisotropy of the coarsest haematite, whereas the natural remanent magnetization (NRM) may mostly be carried by much finer haematite whose anisotropy and inclination error may be much higher. However, the finest haematite in our specimens is likely that whose anisotropy and inclination error may be much higher.

Stamatakis et al. also imply that our ‘tectonic reconstruction (is) based solely on the redbed magnetization’. In fact, we utilize results from redbeds and minor intercalated volcanic rocks of Newfoundland and both redbeds and volcanic rocks of Britain (see our Table 3 and Fig. 10).

IRM EXPERIMENTS

We agree with Stamatakis et al. that there are limitations to the isothermal remanent magnetization (IRM) test that we propose. However, we argue that these limitations are not as serious as these authors imply and believe that the test can be useful with many redbeds to help determine if inclination shallowing has occurred.

(1) Stamatakis et al. state that our maximum applied field of 800 mT is ‘too small to magnetize most of the haematite fraction’ and seem to imply that more than 8000 mT may be required. We argue that 800 mT may well have magnetized more than half of the haematite fraction because Dunlop (1971, Table 5.1, column 8) only required fields from 229 to 821 mT to attain half of saturation IRM in his fine-grained haematite specimens.

Stamatakis et al. claim that ‘the first grains of large size (averaging 0.05 mm judging by microscope examination of polished thin sections of the 10 specimens of our Table 2). If one suspects that most of the NRM in a specimen is carried by much finer detrital grains (which seems more likely in clay-rich sediments that we have avoided), we suggest giving the samples a thermo-remanent magnetization (TRM) at 45$^\circ$ to bedding. Then use the TRM component parallel to bedding (TRM$_p$) and the TRM component perpendicular to bedding (TRM$_n$) in place of IRM$_x$ and IRM$_y$ respectively in our eq. (4).

(2) Stamatakis et al. want us to determine the whole anisotropy of the IRM tensor. We (and Tauxe et al. 1990) found that this was not possible with haematite-bearing rocks because, as we discussed on pp. 647–648, ‘the first direction to which the field was applied tended to acquire a stronger remanence (IRM) than subsequent directions’.

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Fortunately, measuring only in the plane perpendicular to bedding that contains the NRM direction is adequate if one is testing for inclination error due to deposition or compaction.

(3) Only in experiments on clay-rich sediments has it been demonstrated that initial consolidation may cause a significant remanence shallowing that is unaccounted for by the theoretical relation of Jackson et al. (1991). However, ‘we were careful to avoid clay-rich specimens in our collecting’ as we state on p. 649 and as can be seen in the grain diameter estimates in our Table 1.

CONGLOMERATE TEST

Stamatakis et al. conclude that the conglomerate test, although it rules out thermal overprinting of the redbeds, does not exclude chemical remagnetization. We agree. Indeed, we said so on p. 645: ‘This (conglomerate) test also shows that the haematite in the redbeds was probably not thermally remagnetized. However, prefolding chemical remagnetization in the redbeds is not ruled out by this test.’

IMPLICATIONS FOR APPARENT POLAR WANDER

(1) Since they consider inclination shallowing likely in the case of redbeds of Newfoundland, it is surprising that Stamatakis et al. accept the Silurian data from cratonic North America for calculating a reference field. The bulk of the data from the craton is derived from sedimentary rocks (often redbeds) for which no tests for inclination shallowing have been conducted.

(2) In our paper, we mentioned only one controversial aspect of the age of the Dunn Point Formation remanence. There are, however, several reasons to reserve judgement on the age of this remanence. To summarize: (a) the age of the Dunn Point volcanics is poorly constrained radiometrically (Fullagar & Bottino 1968) and could be much older than early Silurian (Hodych & Buchan 1994). Therefore, even if the remanence were known to be primary it would be difficult to use it with confidence for polar wander purposes. (b) The remanence has not been demonstrated primarily on the basis of a palaeomagnetic field test. (c) Sampling sites used in the fold tests are all in steeply to vertically dipping flows where 'interlayered sediments suitable for bedding measurements are rarely available' (Johnson & Van der Voo 1990), perhaps explaining the fact that both positive and inconclusive fold tests have been reported for this unit.

(3) We are unable to comment on the discussion of Stamatakis et al. concerning their Fig. 1(c) since the data contained in it are not referenced and the paper from which it was adapted is not yet published.

CONCLUSIONS

Stamatakis et al. note that our conclusions are ‘difficult to reconcile within the frame work of established continental reconstructions.’ We submit, however, that the present palaeomagnetic data on which continental reconstructions in the Silurian (and more generally in the Early Palaeozoic) are based are often poorly constrained, especially in age (Buchan & Hodych 1993). Hence, it may be premature to consider continental reconstructions as ‘established’ until ages of rock units have been accurately determined and their palaeomagnetic directions are clearly established as primary or secondary.

REFERENCES


