Forum

Porphyroblast rotation versus non-rotation: Conflict resolution: COMMENT

COMMENT: doi: 10.1130/G30299C.1

Gordon Lister and Marnie Forster
Research School of Earth Sciences, The Australian National University, Canberra, NSW 0200, Australia

Fay et al. (2008, p. 307) state that: "no porphyroblast rotation occurs during ductile deformation relative to spatial coordinates" and that "porphyroblasts can now be routinely used to access lengthy structural and/or metamorphic histories destroyed in the matrix by reactivation such as movement directions, shear senses, and extended pressure-temperature-time paths." They thus imply that rotation of a porphyroblast can be considered in terms of an arbitrarily defined spatial coordinate system. However, since in some spatial coordinate systems, the Earth rotates, so do porphyroblasts. This makes no sense. Delving further, it becomes evident that in fact the frame of reference considered is a geographical coordinate system, and that a central plank to the theory of "gyrostasis" is the notion that in some way porphyroblasts can "feel" the orientation of a far distant continent (e.g., Bell et al. [1995, p. 500], claim that "porphyroblasts from the European Alps… reflect the movement of the African Plate relative to Europe").

We would argue otherwise. Porphyroblasts are encased in flowing rock at the time of their growth, and they will thus respond to rotation of a material frame to which they are anchored. Porphyroblasts that grow within tabular microlithons may appear not to have been rotated (much) with respect to another, because the microlithons themselves have suffered little relative rotation. Other examples where porphyroblasts do not rotate (much) with respect to each other can be ascribed to the fact that similar matrix strains have been achieved, with similar patterns of strain localization and flow. The same (or very similar) motions have been imposed, with similar outcomes. There is nothing remarkable in such observations, except to marvel that extrapolations based on the theory of continuum mechanics should be so consistent.

Porphyroblasts also respond passively to later imposed movements, although adherents to the theory of gyrostasis invariably neglect such aspects. Along with the encasing rock mass, porphyroblasts are consistently rotated by the later buckling and folding that is common to almost all orogens. Such movements routinely affect earlier-formed metamorphic schist and gneiss fabrics in their entirety, including porphyroblasts formed at an earlier stage of the geological history.

A second flawed concept adhered to by proponents of the theory of gyrostasis is the assertion that all foliations are in fact shear foliations. The key word to look for here is the term "reactivation" (in the sense used by Fay et al., 2008). Adherents to the theory of gyrostasis disallow the well-recognized and well-documented phenomenon of horizontal shortening in a fold belt due to buckling of relatively strong competent layers. Their counter-claim is that, in fact, all folds are "shear folds" (with shearing taking place on planes of zero resolved-shear-stress, orthogonal to the direction of bulk compression). They impose a progressive-bulk-inhomogeneous-shear model (in many cases inappropriately). In consequence, adherents to the theory of gyrostasis (e.g., Fay et al., 2008) are obliged to introduce concepts such as "reactivation," which in their usage is a geometric manipulation that is specifically designed to address an inadequacy of their model assumptions. In all cases this is unnecessary, for the phenomena in question can be rationally and logically explained by the effects of flexural flow during buckling, with deformation focused in the relatively weak incompetent layers. There is no need to call on any aspect of the theory of gyrostasis to explain such observations.

A third flawed concept is the assertion that reactivation consistently and pervasively eliminates all evidence of (numerous) past microfolding events in matrix foliations. The process of reactivation (as defined by Bell et al., 1995) is required because they need to explain the absence of crenulations in locations where the models that they advocate would otherwise require their existence. The more credible alternative is that, in most cases, crenulations are not present in these locations because they did not ever form in the locations. For example, in folded psammo-pelite beds defined by graded turbidite sequences, the transitional zone between a competent psammite and an incompetent pelite often marks the zone where nucleation of axial-plane crenulation cleavages can be observed. The progressive evolution of such crenulations (with amplitude increasing as sand content decreases) makes it clear that the reason that crenulations did not form immediately adjacent to the competent layer is quite simple. The competent bed (and the adjacent transitional zone) is relatively strong in comparison to the adjacent weaker-flowing pelite layers. There is thus no need to postulate a process solely for the purpose eliminating all microstructural traces of previously formed crenulations. It is evident that those crenulations did not exist in the first place.

The models advocated by Fay et al. (2008) require adherence to one or more statements of doctrine, as outlined above. These contrast to views that attract little debate, because they define the mainstream of modern theory as to the structural evolution of deformed and metamorphosed tectonites: 1) material frameworks can be defined that allow explanation of observed microstructures, including the variation in the orientation of inclusion trails in porphyroblasts, and 2) many folds are the result of shortening accommodated by the buckling of relatively competent lithologies (e.g., in the psammitic layers of a turbidite sequence). These strong layers drive flow in the relatively weak (and thus accommodating) incompetent lithologies in between the buckling competent layers (e.g., in crenulating pelitic layers, where the strongest axial-plane cleavages result). Finally, we note that similar fold geometries such as those that led to models advocated by Bell et al. (1995) have been shown largely illusory, and/or the result of strains later more uniformly imposed upon the rock mass after the initial buckling produced parallel folds. There is no reason to require the existence of earlier-formed foliations that are now uncrenulated because an undocumented (and largely imaginary) process has eliminated all evidence. The absence of evidence has never been proof of the existence of an otherwise non-testable phenomenon. There is thus no conflict to be resolved, except in the minds of those proponents of a world view that allows planets to rotate, but not porphyroblasts.

REFERENCES CITED

Bell, T.H., Forde, A., and Wang, J., 1995, A new indicator of movement direction during orogenesis: measurement technique and application to the Alps: Terra Nova, v. 7, p. 500–508, doi: 10.1111/j.1365-3121.1995.tb00551.x.

Fay, C., Bell, T.H., and, Hobbs, B.E., 2008, Porphyroblast rotation versus nonrotation: Conflict resolution: Geology, v. 36, p. 307–310, doi: 10.1130/624499A.1.