PALEOMAGNETISM: A TOOL FOR OROCLINAL ROTATION

While viewing a globe, one can readily see the multitude of mountain belts that have an arcuate geometry. Oroclines can simply be defined as any orogen that exhibits this curved nature in map view. However, the deformational history of many oroclines remains a mystery as to how they developed their “bent” geometry. One possible solution is the rotation of a “less-bent” or even linear orogenic belt about a vertical-axis causing the present-day orientation. During the past four decades, studies have shown that paleomagnetism is the best, and many times the only, manner by which these rotations can be studied. Often, these rotations have astounding implications for the geodynamic behavior of a collisional terrane or, at a larger scale, a continent.

During the mid-1950’s, suitable equipment and statistical methods had developed enough to test ideas that had been brewing in the scientific community since the times of Wegener about paleomagnetism and its uses for continental drift (Merrill, et al, 1998). Also around this time, Carey (1955) first coined the term orocline as any “bent” orogenic belt that originally had a linear geometry, though the more modern definition of the word includes any arcuate shaped orogen, despite the deformational history (Eldredge, 1985). Coincidentally, when it was submitted, Carey’s now well-regarded paper was originally rejected by the Geological Society of Australia (Ford, 2004) as this was prior to the acceptance of plate tectonics and oroclines implied a tectonic mechanism. As the continental drift concept blossomed and eventually transcended into plate tectonics during the 1960's, the mechanism by which oroclines could form became much clearer.

Since the widespread acceptance of plate tectonics, many of the world's fold-thrust belts have been extensively studied for rotations through paleomagnetism. Prior to studying a fold-thrust belt for oroclinal rotation, four criteria must be met. These include a systematic change in the trend of fold-axes, well documented geographic and geologic data for the region, reference declinations for rocks of different ages must be available, and the suitability of the remnant magnetization (Eldredge, 1985). The suitability of the remnant magnetization would entail a rock suite to pass reliability criteria, such as the fold test, the conglomerate test or the baked contact test. This proves to be difficult in deformed terranes as secondary magnetization often develop post orogenically, causing a failure of these tests.

If the preliminary criteria are met, samples can be collected from various sites along the trend of the fold axes. Once the proper demagnetization techniques have been applied for each rock type and declinations and inclinations have been determined, a linear regression technique can be applied to resolve the issue of whether the orogen in question is indeed an orocline. In the method described by Eldredge et al (1985), rather than causing a more complex situation by using dual polarities (the virtual geomagnetic poles lie in the northern and southern hemispheres), a uniform polarity is used. The declinations observed (D_o) are normalized by subtracting them ($D_r - D_o$) from a reference declination (chosen on the basis of local paleopoles, the average of the VGP's or another value that remains constant throughout the process) giving values that will be either positive or negative. Positive values will correspond to a counterclockwise rotation about a vertical axis and negative values correspond to clockwise rotations.

Declination, however, is not the only concern in this scenario. Strike trends must also be normalized through a similar process as the declinations. The reference strike is assumed to be that of the average strikes. The sign of the strike trends is not as important as those in the declinations.

When both strikes and declinations have been subtracted from their corresponding reference, they are plotted against each other, where the values of (S_r – S_o) plot on the abscissa (x-axis) and (D_r-D_o) values on the ordinate (y-axis). A regression line will then be plotted through the data. From the plot, three possible scenarios arise. The first is that a positive regression occurs with R (slope)~1, which indicates true oroclinal rotation (Weil, 2001). The second is that the data approach the ordinate, indicating rotation has occurred in small thrusts sheets within a linear orogenic belt. The last situation has the data approaching the abscissa, where the belt was originally arcuate and no “tightening” has occurred since (Eldredge, 1985).

Weil (2001) defined oroclines in three separate categories: primary arcs, true oroclines and partial oroclines. Primary arcs form during the original orogenic development and would therefore show no paleomagnetic rotation. True oroclines occur within Carey’s original definition in that they were once linear and then developed a secondary arcuate geometry. Such orogens would certainly exhibit a large spread in declination when applying paleomagnetic techniques. Partial oroclines are those that have both primary and secondary rotational histories.

Other than paleomagnetism, there are few ways in which to test for oroclinal rotation. One possible way is utilizing ductile fabrics across a fault zone, as Little & Mortimer (2001) did in a study of the New Zealand Orocline. However, these data are not as simple to assess the exact arc forming history as the paleomagnetic data, and therefore are not favored. Although there are drawbacks, such as the common occurrence of remagnetization in deformed areas, paleomagnetism remains the primary tool to study the orocline hypothesis.

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APPENDIX

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