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The geometrical relationship between the stretching lineation and the movement direction of shear zones: Discussion

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IN A recent paper, Lin & Williams (1992) emphasized the difference between the plunge of stretching lineations on *S*-surfaces and that of the movement direction in shear zones, and discussed its implications for interpretation of shear zone kinematics. They further showed that, knowing the strike of a shear zone, the orientation of the *S*-surface and of the stretching lineation, it is possible to determine the dip of the shear zone and the movement direction along it. They applied this technique to the D_1 deformation increment documented by Robert (1989) along the eastern segment of the Cadillac tectonic zone (CTZ) and they proposed an alternative interpretation. This major fault zone extends over 200 km of strike length in an E–W direction, parallel to contacts between major lithologic units.

The D_1 increment of deformation along the CTZ was interpreted by Robert (1989) as transpressional, involving a significant component of shortening across the CTZ, accompanied by localized dip-slip movements, and a minor component of dextral transcurrent shear. This interpretation was proposed to reconcile the obliquity of S_1 to the shear zone boundaries and other asymmetric features, observed in plan but not in cross-section, and the contained steeply E-plunging elongation lineation. Lin & Williams (1992), considering that the obliquity of foliation to shear zones boundaries observed in plan view is *apparent*, used the orientation of S_1 and the stretching lineation to infer a southern dip of 60°. With a note of caution, they proposed that D_1 deformation along the CTZ recorded reverse oblique movements (south over north) with a minor dextral component.

Alternative interpretations of the deformational history of the CTZ are welcome because the internal structure of the CTZ is very complex and challenges conventional shear zone analysis. However, as will be discussed below, the interpretation proposed by Lin & Williams (1992) is not consistent with the available data. I also take this opportunity to present additional observations that bear on the interpretation of the CTZ.

BOUNDARIES OF THE CTZ AND OBLIQUITY OF S_1

Any interpretation of the D_1 deformation must address the geometric relationship between the boundaries of the CTZ and the S_1 foliation within it. The boundaries of the CTZ are marked by a sharp increase in strain (Robert 1989, fig. 4a) and are easily defined on surface and underground exposures, as well as in drill core. As a result of examination of a large number of outcrops and drill holes, the orientation of the CTZ has actually been *mapped* in three dimensions. In the study area, the north and south boundaries of the CTZ coincide with the contacts of laterally continuous lithological units; the CTZ strikes between 090° and 110° and it is known from drilling to dip on average 80° to the north down to a depth of 300 m, as illustrated on cross-sections presented in Robert *et al.* (1990, figs. 3 and 7). A steep northerly dip of the CTZ is also consistent with the dip deduced from deep seismic profiles in the Noranda district, 100 km to the west (Green *et al.* 1990).

The intense S_1 foliation within the CTZ strikes on average E–W and dips steeply to the north (80–85°). In detail, however, it has a more northerly strike than the envelope of the CTZ, making an angle of 10–20° in strike, with a subparallel dip. Thus, the angular relationship between the S_1 foliation and the CTZ only exists in map view, *not in cross-section view*. Similarly, asymmetric features such as S-shaped conglomerate pebbles and bookshelf textures (figs. 4C & F, respectively, in Robert 1989), are only observed in plan view, not in cross-section.

Clearly, the dip of 80° to the north of the CTZ and the obliquity in strike of the foliation are not compatible with the proposed interpretation of Lin & Williams (1992) that the CTZ is a reverse-dextral shear zone dipping 60° to the south. Perhaps they have been misled in their interpretation by the fact that only the trace (strike) of the CTZ was shown in fig. 5 of Robert (1989) for the sake of clarity.

The dextral transcurrent shearing required by the obliquity of S_1 foliation in plan view only is difficult to reconcile with the steeply E-plunging stretching lineation in S_1 and subparallel sheath folds. Dextral transpression, as proposed by Robert (1989) is one way to resolve this paradox. Another possibility is considered below.

EFFECTS OF D_2 DEFORMATION

Within the CTZ, the D_2 increment of deformation has produced mesoscopic to map scale Z-shaped folds with variable but commonly steep plunges. These F_2 folds are interpreted to indicate dextral transcurrent shearing (Robert 1989).

The obliquity in strike of S_1 to the boundaries of the CTZ may also be the product of D_2 deformation. It is possible that the current strike of the S_1 foliation reflects that of the limbs of tight F_2 folds, which would strike more northerly than the envelope of the shear zone and that of lithological units (fig. 10D in Robert 1989). Re-examination of two exposures of the boundary of the CTZ shows that S_1 foliation strikes at 110° and is *parallel* to the local boundary of the CTZ. This suggests that, as previously considered by Robert (1989), the obliquity in strike of the S_1 foliation to the trace of the CTZ is the result of *imbrication and asymmetric folding* during D_2. It also indicates that the S_1 foliation was parallel to the shear zone boundaries, prior to D_2.

The asymmetric shape of the conglomerate pebbles, foliation fish and local bookshelf textures were considered by Robert (1989) to indicate a dextral shearing component during D_1, hence the preferred dextral transpression model. However Hanmer & Passchier (1991) have recently suggested that some of these asymmetric features may not be reliable shear-sense indicators. If this is the case, or if one downplays the importance of these features, there is no longer clear evidence for dextral shearing during D_1, and no requirement to invoke dextral transpression.

As a result, the D_1 increment of deformation along the CTZ could be reinterpreted to be an oblique- to dip-slip shearing event based on the steeply plunging stretching lineations and sheath folds. The sense of shear cannot be established with certainty from the single vergence determination from non-cylindrical to sheath folds reported by Robert (1989). Such an isolated observation has no statistical significance and it is not known if the vergence was determined from the long limb of a mesoscopic fold or the short limb of a larger one.

CONCLUSIONS

It is concluded that the technique proposed by Lin & Williams (1992) to determine the dip and movement direction of shear zones should be applied with caution to complex shear zones involving the interplay of pure shear and simple shear, as well as superimposed increments of deformation. The CTZ *does* dip 80° to the north, not 60° to the south as predicted by their technique. Additional observations suggest that the D_1 deformation could have only involved oblique- to dip-slip shearing, of as yet undetermined sense of shear.

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