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General Discussion

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General discussion

A. Nicolas (*Laboratoire de Tectonophysique, Université de Nantes, France*). In this general discussion, I would like to discuss briefly the problem of metamorphism and granitic magmatism associated with shear zones, a topic that has not been addressed during this meeting.

Major vertical shear zones, because they correspond to large relative displacements (commonly hundreds of kilometres), must be at depth in continuity with some flat-lying decoupling level for obvious continuity requirements. Two such levels can coincide with the presumably ductile lower continental crust, and with the top of the asthenosphere. Thus major shear zones may be rooting either into the deep continental crust, recording crustal relative displacements or into the asthenosphere, thus recording lithospheric displacements as in the case of the San Andreas Fault or the Alpine Fault of New Zealand.

On the other hand, shear zones are or are not the loci of metamorphism and of crustal magmatism. Cases have been described where these activities are clearly related to the tectonism in the shear zone. Metamorphic zonations are then parallel to the shear zone trend and the metamorphic degree increases symetrically toward the axis of the shear zone, eventually leading to syn-kinematic partial melting and granite injections along this axis (Nicolas *et al.* 1977; Bossière 1985). Such thermal activity has been ascribed to shear heating (Nicolas *et al.* 1977), an interpretation disputed on the ground that shear heating, when the chosen boundary condition is constant velocity, is a self-regulated process becoming inefficient close to the melting point (Turcotte & Oxburgh 1968). The thermal effect is alternatively explained by the pre-existence of a thermal alignment which, as a weak zone, predetermines the emplacement of the shear zone itself (Poirier *et al.* 1979). I doubt that this explanation can be generalized to all shear zones where a thermal effect is described, in particular when this effect is related to a late activity of a pre-existing shear zone, as in the South Armorican shear zone (Diot *et al.* 1983).

Fleitout & Froidevaux 1980) have proposed a thermo-mechanical model to avoid these difficulties. They show that for a lithospheric shear zone, shear heating was able to raise the temperature to 10^3 K in the stronger mantle lithosphere. In a long-lived shear zone like San Andreas, this heat is progressively conducted into the overlying crustal formations, where it triggers partial melting and thus produces the metamorphic and magmatic effects that are now observed along the shear zone in deeply eroded terranes.

It is conjectured here that the occurrence of a metamorphic–magmatic activity associated with a shear zone could distinguish lithospheric shear zones from crustal ones. Only in lithospheric shear zones can metamorphic zonation and syntectonic granitic intrusions develop, owing to the effect of shear heating in mantle formations followed by heat conduction into the crust. In crustal shear zones, shear heating is not able to raise substantially the temperature and therefore to induce melting, except locally when it generates pseudotachylite, probably in relation to seismic events. Therefore crustal shear zones would be devoid of significant thermal effects.

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J. G. Spray (*Department of Earth Sciences, Cambridge University*). The role of shear heating in generating metamorphic anomalies within and around major deep-seated fault zones is clearly a subject that deserves more detailed attention, but is one that has not been considered at this meeting. While we know that stick-slip fault behaviour can locally generate melts (pseudotachylytes) within the upper 15 km of the crust during seismic events, provided fault velocities and shear stresses are sufficiently high, it remains unclear exactly how viable the process of shear heating is within the lower levels of the crust where movement occurs predominantly by aseismic creep. Under these conditions short-duration, high-velocity fault movement does not occur, and instead displacement must occur at plate tectonic rates. If shear stresses are unlikely to exceed 1 kbar† then this suggests that the effects of shear heating would be negligible. However, provided relative movement is maintained for geologically long periods (i.e. up to 10 Ma), it is possible for shear heating to contribute to a local steepening of the temperature gradient by up to a few hundred degrees centigrade as a result thermal conduction away from the shear interface. As we know, this probably occurs in the slip zone on a descending slab during subduction and, in a similar manner, is certainly likely to boost temperatures within large continental faults.

† 1 bar = 10^5 Pa.

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