The experimental deformation perspective on plate tectonics and the build up of anisotropy

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The plate tectonic model assumes that rigid plates move due to the dragging of the mantle (convection) and to the pull of subducting slabs. These require that the lithosphere is able to transmit stresses laterally, and therefore is rigid, and that the mantle underneath can flow plastically. The recent development of experimental deformation in laboratory at high pressure and temperature (e.g. Griggs, Turner and Heard, 1960), demonstrated both these assumptions.

From the recent compilation of precise GPS measurements for the ILP project on plate movements (Kreemer et al., 2002), it is obvious that most of the deformation is localized into narrow zones on the earth surface. Therefore the new challenging questions are: why does deformation localize? And after localization, why it remains localized? In other words, what are the processes and the factors controlling the localization and its maintenance into narrow zones?

In order to answer these questions a new apparatus was constructed (Paterson and Olgaard, 2000) to reach large shear strain in an internally heated gas medium apparatus, using the torsion technique. The experiments performed on this type of apparatus (e.g. Pieri et al., 2001, Bystricky et al., 2000) demonstrated that a certain amount of weakening is associated to the dynamic recrystallization occurring during deformation. Therefore the deformed rock is weaker than the protolith. Moreover, the building of a strong lattice preferred orientation means that the deformed rock it also acquires a strong anisotropy (mechanical, elastic and of thermal diffusivity). This anisotropy, which is oriented according to the flow, increase the weakness of high strain zones and of orogens because can carry more heat from below than undeformed rocks, increasing the temperature and promoting the deformation.

Both the anisotropy and the weakening associated to dynamic recrystallization are the possible explanation for the maintenance of the deformation into narrow zones.

All the monomineralic rocks that was deformed so far in torsion, deformed homogeneously. On the other hand, 2 phase rocks (or polyphase rocks) always displayed some localization of the deformation, with the formation of shear bands or of discrete shear zones within the samples or only of bands of higher strain. The conclusions that is possible to draw from these high temperature experiments is that the deformation tends to localize spontaneously in heterogeneous material subjected to large shear strain, probably because of alignment of grain boundary, which make grain boundary sliding more efficient. Indeed, in the exposed lower crustal section there is several evidence showing that deformation tends to localize in polyphase or heterogeneous rocks.