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Microstructural evidences of garnet plasticity in the continental crust. New example from south Madagascar

Karim Malamoud (1), Jean-Emmanuel Martelat (1), Patrick Cordier (2), Karel Schulmann (3), and Jean-Marc Lardeaux (4)

(1) OSUG Laboratoire de Géodynamique des Chaînes alpines UMR 5025, Université Grenoble, France, (2) Unité Matériaux et Transformations UMR 8207, Université Lille 1, France, (3) Centre de Géochimie de la Surface, UMR 7516, Université Strasbourg, France, (4) Laboratoire des Sciences de la Terre, UMR 6526, Université Sophia Antipolis, France

Garnet mechanical behaviour is of great importance to understand the rheological evolution of rocks within the mantle and the lower crust. Well-constrained natural examples of plastically deformed garnets are scarce; consequently their identification and the physical parameters controlling their occurrence are still debated.

In southern Madagascar, a granulitic metamorphic event has developed during a late Panafrican – Cambrian, east-west shortening (570 Ma). This has led to the development of vertical transpressive shear zones. Within these zones, we identified variations in garnet microstructure following the deformation sequence. In order to understand this evolution, we carried out a thorough microstructural description of samples using the following techniques: optical microscopy and SEM imaging, EBSD technique (localized lattice-preferred orientation), TEM for dislocation density, EMP for chemical analyses, as well as crystal size distribution, statistic grain boundary and shapes analyses (Lexa et al., 2005).

The hand samples were quartzites or two-feldspars quartzo- feldsphatic rocks bearing 10 modal percent of garnet. As strain increases, various garnet textures were observed: Type 1) millimetre-sized rounded garnets bearing two types of inclusions, i.e. elongated quartz ribbons and well oriented sillimanite parallel to the lineation; Type 2) elliptic very elongated and lobed garnets (1 to 8 aspect ratio); Type 3) smaller elongated pinch and swell garnets (1 to 3 aspect ratio); and finally Type 4) rounded small garnets (300 microns in diameter).

Type 1 textures are due to multiple nucleation garnets and coalescence controlled by aluminous aggregates (biotite and sillimanite). As strain increases, these large skeleton garnets start to re-crystallise preferentially at the tip of lenticular quartz inclusions, giving Type 2 very elongated garnets with unique CPO. The latter then continues to re-crystallise by sub-grain rotation as underlined by the CPO in situ measurements of new re-orientated grains (Type 3). In the type 4, few large garnets remain and only smaller-sized rounded garnets are left. In these highly deformed rocks, fine sillimanite needles are locally preserved and tilted with respect to the main foliation. All garnets from Type 2 to 4 textures are chemically homogeneous.

Data from garnets, quartz, and feldspars are compared for each microstructural type and progressive deformation. The observed microstructures are in accordance with garnet ductility coeval with the deformation of quartz K-feldspar and plagioclase and showing mixing of all phases (random distribution) as well as constant grain size (average diameter 200 microns). Our analyses show that under the high-temperature and dry conditions (850°C) all phases are mechanically active. This indicates convergence of strength minerals marked by contrasting (laboratory derived) rheologies.

Lexa, O., Štípská, P., Schulmann, K., Baratoux, L., Kröner, A., 2005. Contrasting textural record of two distinct metamorphic events of similar P-T conditions and different durations. Journal of Metamorphic Geology 23. 649-666. http://petrol.natur.cuni.cz/∼ondro/polylx:home