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Deformation of the Songshugou ophiolite in the Qinling orogen

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The Qinling orogen, middle part of the China Central Orogenic Belt, is well documented that was constructed by multiple convergences and subsequent collisions between the North China and South China Blocks mainly based on geochemistry and geochronology of ophiolites, magmatic rocks as well as sedimentary reconstruction. However, this model is lack of constraints from deformation of subduction/collision. The Songshugou ophiolite outcropped to the north of the Shangdan suture zone represents fragments of oceanic crust and upper mantle. Previous works have revealed that the ophiolite was formed at an ocean ridge and then emplaced in the northern Qinling belt. Hence, deformation of the ophiolite would provide constraints for the rifting and subduction processes.

The ophiolite consists chiefly of metamorphosed mafic and ultramafic rocks. The ultramafic rocks contain coarse dunite, dunitic mylonite and harzburgite, with minor diopsidite veins. The mafic rocks are mainly amphibolite, garnet amphibolite and amphibole schist, which are considered to be eclogite facies and retrograde metamorphosed oceanic crust. Amphibole grains in the mafic rocks exhibit a strong shape-preferred orientation parallel to the foliation, which is also parallel to the lithologic contacts between mafic and ultramafic rocks.

Electron backscattered diffraction (EBSD) analyses show strong olivine crystallographic preferred orientations (CPO) in dunite including A-, B-, and C-types formed by (010)[100], (010)[001] and (100)[001] dislocation slip systems, respectively. A-type CPO suggests high temperature plastic deformation in the upper mantle. In comparison, B-type may be restricted to regions with significantly high water content and high differential stress, and C-type may also be formed in wet condition with lower differential stress. Additionally, the dunite evolved into amphibolite facies metamorphism with mineral assemblages of olivine + talc + anthophyllite. Assuming a pressure of 1.5 GPa, which corresponds to equilibration in the spinel stability field, application of the olivine-spinel thermometer (Ballhaus et al., 1991) suggests temperature of 622 $\pm$ 22 °C.

Amphibole schists display well-developed amphibole CPO with [100], [010] and [001] axes concentrate parallel to Z-, Y- and X-directions, respectively. The strong CPO of amphiboles could be interpreted as anisotropic growth and passive rigid-body rotation under various different stresses rather than results of dislocation creep. The Hbl + Pl thermometer (Holland and Blundy, 1994) constrains the equilibrium temperature to be 640 $\pm$ 34 °C for the amphibolite facies metamorphism.

Zircons in light-color from the amphibolite with Th/U<0.1 and depletion of HREE yield a U-Pb age of 504 $\pm$ 10 Ma, representing the metamorphic age of eclogite. In comparison, the zircons in dark-color from amphibolite showing flat HREE patterns and negative abnormal of Eu give a U-Pb age of 489 $\pm$ 5.2 Ma, constraining the time of retrograde metamorphism of eclogite.

Together with field investigation and regional geology, our new data propose that the A-type olivine CPO was formed in oceanic upper mantle with the spreading of Shangdan ocean before ca. 514 Ma. At ca. 504 Ma, the deep subduction of oceanic lithosphere endured eclogite facies metamorphism and induced B-type olivine CPO. Up to ca. 489 Ma, obduction of the fragments of metamorphosed oceanic lithosphere resulted in the C-type olivine CPO in dunite and amphibole CPO in the retrograded metamorphic eclogite.