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Retrograde carbon sequestration in orogenic complexes: a case study from the Chinese Southwestern Tianshan

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The interaction between ascending carbonic fluids and rocks at shallow depths in orogenic systems plays an important role in carbon flux regulation. In subduction zones, most works have focused on processes related to carbon release from the subducting slab or sequestration via high-pressure (HP) carbonation of mafic or ultramafic lithologies. A significant fraction of the carbonic fluids released by deep metamorphic reactions can also reach orogenic complexes and react with crustal and exhumed metamorphic rocks. However, the amount of fluid-mediated carbonation that may take place at crustal depths in orogenic complexes is still poorly constrained.

We report the occurrence of retrograde mafic eclogites and metasomatic marbles in UHP units in the Chinese Tianshan orogenic belt. The mafic eclogites recorded two successive, superimposed metamorphic–metasomatic stages: graphite precipitation along fractures and veins at eclogite facies (Stage#1) and pervasive rock carbonation (i.e., Stage#2: silicate dissolution and carbonate precipitation) at retrograde amphibolite to greenschist facies. This work focuses on Stage#2 carbonation, which consists of the transformation of Stage#1 graphite-bearing eclogites into carbonate + paragonite (± zoisite) + quartz. We present field, microstructural, petrological, and geochemical results of carbonic fluid–rock interactions affecting exhumed mafic eclogites. These results are supported by thermodynamic modeling for low-pressure carbonation of mafic eclogite obtained by means of EQ3/6 and the Deep Earth Water model. Carbon and oxygen isotopic data and thermodynamic modeling suggest an external metasedimentary source for the Stage#2 carbonation. This deep carbon sequestration event can be referred to retrograde, greenschist-facies conditions at about 10 kbar and 450 °C, and redox conditions similar or more oxidized than the quartz–fayalite–magnetite (QFM) buffer. Our findings provide new insights into the reactivity of metastable, exhumed metamafic rocks with ascending carbonic fluids in orogenic systems. We conclude that retrograde, fluid-mediated rock carbonation can significantly impact on carbon fluxes from active collisional belts.