Metamorphic CO_2 production in scapolite-bearing calc-silicate rocks from the upper Greater Himalayan Sequence (eastern Nepal Himalaya)

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The “long-term carbon cycle” operates over millions of years and involves the slow exchange of carbon between rocks and the surficial system; the volume of CO_2 involved in these processes is still far from being constrained. So far, the degassing flux was mainly estimated based on the flux emitted by volcanoes in different geodynamic contexts, and additionally include carbon from the mantle and carbon degassed from subduction zones. This estimated flux does not take into account CO_2 derived from orogenic zones, where organic rich sediments and limestone may be buried at depths at which CO_2 is formed by metamorphic reactions. However, recent studies suggest that metamorphic degassing from active collisional orogens supplies a significant fraction of the global solid-Earth derived CO_2 to the atmosphere, thus playing a fundamental role, even in today’s Earth’s carbon cycle (Gaillardet and Galy, 2008; Evans, 2011; Skelton, 2011).

In order to test if calc-silicate rocks may act as metamorphic CO_2-source rocks, a petrologic study of K-feldspar + scapolite -bearing calc-silicate rocks from eastern Nepal Himalaya has been performed. These rocks are hosted in anatectic kyanite-sillimanite- bearing gneisses (i.e. Barun Gneiss, see Groppo et al., 2012) and often occur as tens to hundreds of meter thick, folded or boudinated, levels occasionally associated to layers of impure marbles. The transition between the hosting paragneiss and the calc-silicate granofels is generally gradual and is characterized by the progressive disappearance of biotite, the appearance of clinopyroxene and the modal increase of plagioclase. This suggest that calc-silicate rocks derive from former marly intercalations within a thick sedimentary sequence.

Mineral assemblage consists of K-feldspar + clinopyroxene + scapolite + calcite + plagioclase + quartz ± zoisite (Fig. 1a, b), and later epidote and green amphibole. Clinopyroxene often shows oriented inclusions of phlogopite + scapolite + calcite ± muscovite ± quartz (Fig. 1e), whereas zoisite includes scapolite + quartz + calcite + Na-rich plagioclase (Fig. 1c, d) and is intergrown with K-feldspar and Ca-rich plagioclase. Clinopyroxene is often partially replaced by later green Ca-amphibole ± epidote, whereas scapolite is locally partially replaced by symplectitic aggregates of plagioclase + calcite (Fig. 1f). In addition to the ubiquitous titanite, a strongly pleochroic allanite and a bluish to colourless tourmaline (Fig. 1a) locally occur, whereas graphite is always absent.

The K-feldspar + scapolite -bearing calc-silicate rocks can be modelled in the NKCMAS-CO_2-H_2O system, including plagioclase and scapolite solid solutions, in addition to the fluid of variable composition. The results of petrologic modelling suggest that most of the key-microstructures in the studied rocks correspond to invariant assemblages in the classical T-XCO_2 grids. In such a complex system, the use of mixed-volatile phase diagram projections (in which the volatile composition of the system is projected onto the P–T coordinate frame: Connolly and Trommsdorff, 1991; Castelli et al., 2007; Groppo et al., 2013), is the best approach for simultaneously considering the effects of the three variables P, T and X_{fluid} on phase relations; fluid-present univariant curves in a mixed-volatile P–T projection correspond to invariant points in the correspondent isobaric T–XCO_2 sections.

Preliminary petrologic data demonstrates that K-feldspar + scapolite -bearing calc-silicate rocks may act as CO_2-source during prograde heating, releasing internal-derived CO_2-rich fluids (XCO_2=0.5-0.6) through clinopyroxene, K-feldspar and zoisite -forming, and scapolite -consuming, reactions such as:
Qtz + Cal + Mu + Scp = Zo + Pl + Kfs + F
Qtz + Phl + Scp + Zo + Cal = Cpx + Kfs + Pl + F
Mu + Scp + Phl + Qtz + Zo = Cpx + Kfs + Pl + F

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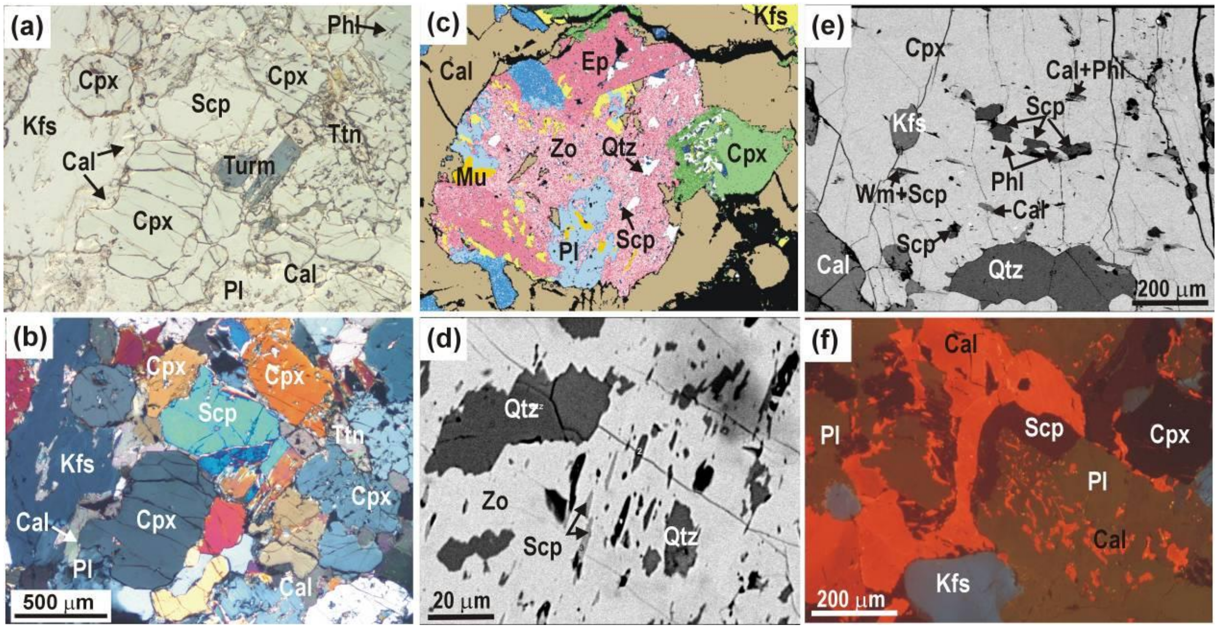

Figure 1. (a,b) Representative microstructure (a: Plane Polarized Light; b: Cross Polarized Light) of the K-feldspar + scapolite -bearing calc-silicate rocks. Note the oriented phlogopite inclusions in the up-right clinopyroxene. (c) Compositioal map of a zoisite crystal including quartz, scapolite muscovite and Na-rich plagioclase and intergrown with K-feldspar. (d) Detail of oriented scapolite and quartz inclusions within zoisite (BSE image). (e) Detail of oriented scapolite + phlogopite + calcite + muscovite inclusions within clinopyroxene (BSE image). (f) Detail of a plagioclase + calcite symplectitic aggregate partially replacing scapolite in the rock matrix (CL image).

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