

Rare-earth and trace element characteristics of pseudomorphs after lawsonite in Tlc-Grt-Cld schists of Makbal Complex

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Lawsonite [CaAl₂Si₂O₇(OH)₂.H₂O] is a critical hydrous mineral that formed at high-pressure (HP) and low-temperature (LT) metamorphic conditions in oceanic subduction zones. It can be stable in a wide pressure-temperature (P-T) range with reaching ultrahigh-pressure (UHP) conditions (up to 300 km depth) as suggested by experimental data (Pawley, 1994; Schmidt, 1995) and thermodynamic modeling (Clarke et al., 2006; Wei & Powell, 2006). However, most of natural occurrences of lawsonite and its pseudomorphs are reported mainly from the blueschist facies metamorphic rocks and their presence in a HP-UHP eclogite-facies rocks is rare (Tsuji-mori et al., 2006). Lawsonite pseudomorph is identified because of their square to lozenge shape and its breakdown products (mainly epidote, paragonite, chlorite, kyanite). Despite such reports, the reactions behind the formation of lawsonite pseudomorph are not clearly resolved, and in fact, the origin of Ep + Pg + Chl assemblages after lawsonite is debated (Shelly & Bossiere, 1999).

We present a potential way to confirm the previous existence of lawsonite using trace element compositions of the clinozoisite in the multiphase solid inclusions (MSI) of clinozoisite + paragonite + chlorite in garnets of talc-garnet-chloritoid (Tlc-Grt-Cld) schists in Makbal complex. Lawsonite can contain considerable amounts of trace and rare-earth elements (REE) and therefore the pseudomorph minerals (especially epidote/clinozoisite) may inherit the trace element pattern after lawsonite (Spandler et al., 2003). With this scenario in mind, we have performed LA-ICP-MS trace element analysis on the clinozoisite in MSI. The outline of MSI (up to 0.1 mm in size) shows idiomorphic-prismatic shapes and mainly consist of Czo +/- Pg +/- Qtz +/- Ky +/- Mrg, Czo + Pg +/- Chl and Czo + Cld +/- Pg +/- Chl. The estimated/reconstructed bulk compositions of MSI indicate that MSI can be originated from former lawsonite, which can be stable under peak UHP stage.

The trace element compositions of clinozoisite in MSI of clinozoisite + paragonite + chlorite and host garnet were analyzed in-situ on polished thin-sections using LA-ICP-MS at Kyoto University. The spot size was 35 micrometer. The acquisition time for background and samples were 60 sec and 180 sec, respectively. NIST610 and BCR2G glasses are used as external standard, whereas 44Ca as internal standard. Iolite software package is used for data reduction (Paton et al., 2011).

The results show low Sr (710-880 ppm) and moderate contents for LREEs (49-76 ppm for La). The sample/chondrite and sample/primitive mantle normalized diagrams show that trace and REE pattern of clinozoisite in our study is very similar to lawsonite pattern previously reported worldwide (Spandler et al., 2003; El Korh et al., 2009; Martin et al., 2011).

This new data suggest that lawsonite was stable along with garnet, chloritoid, talc and glaucophane at peak-UHP stage and it was decomposed to Czo + Qtz +/- Ky +/- Pg +/- Chl during the isothermal decompression, overstepping the following mineral reactions, such as Lws = Zo + Ky + Qtz + H₂O, Gln + Lws = Zo + Pg + Chl + H₂O and Grt + Lws = Zo + Cld + H₂O. According to petrogenetic grid for NCKFMASH system (Wei & Powell, 2006), these mineral reactions combined with Carp = Tlc/Chl + Ky and Cld = Grt + Ky reactions define the P-T conditions for lawsonite decomposition as 16-22 kbar and 510-590 °C. The micro-cracks radiating from MSI may imply the possible pathway of fluids released due to the breakdown of lawsonite during decompression.

We suggest that the identifying trace element compositions of constituent minerals of MSI that regarded as pseudomorphs after lawsonite can be effective tool in confirmation of the previous existence of lawsonite.

Keywords: lawsonite, trace elements, UHP metamorphism, Makbal, Kyrgyzstan