As subducting slabs descend into the mantle, increasing pressures and temperatures lead to the progressive breakdown of hydrous mineral phases and the release of water-rich subduction-zone fluids (Schmidt and Poli, 1998; John et al., 2012). These fluids control many significant geological events in convergent plate margins, such as metasomatism and partial melting of the mantle wedge (Tatsumi, 2005; Scambelluri et al., 2006), generation of arc magmas (Peacock, 1990; McCulloch and Gamble, 1991), production of ore deposits (Sun et al., 2004), and intermediate- deep earthquakes (Davies, 1999; Hack et al., 2003). In addition, subduction-zone fluids are the dominant medium to transfer elements from the subducting slab to the overlying mantle wedge (Manning, 2004; Hermann et al., 2006). Therefore, knowledge regarding the dehydration of hydrous minerals in subducting slabs is fundamental to understand these geological processes in subduction zones (Philippot and Selverstone, 1991; Bebout, 2007). Natural eclogites and enclosed HP veins in HP-UHP metamorphic terranes are the direct exhumed products of deeply subducted slabs, and thus record important information on dehydration processes of basaltic system in subducting slabs (Gao and Klemd, 2001; Hermann et al., 2006). Therefore, knowledge regarding the dehydration of hydrous minerals in subducting slabs is fundamental to understand these geological processes in subduction zones (Philippot and Selverstone, 1991; Bebout, 2007). Natural eclogites and enclosed HP veins in HP-UHP metamorphic terranes are the direct exhumed products of deeply subducted slabs, and thus record important information on dehydration processes of basaltic system in subducting slabs (Gao and Klemd, 2001; Hermann et al., 2006).

Lawsonite [CaAl₂Si₂O₇(OH)₂·H₂O] is an significant metamorphic mineral that is stable at LT and HP-UHP conditions in subducting metabasites. This mineral is of particular importance because that (1) it is a main vehicle for transporting water (~11.5 wt.% H₂O content in its crystal structure) from the subducting slab into the deep mantle (Schmidt and Poli, 1998); (2) it typically forms in a relatively cold subduction zone and is an indicator of LT metamorphism (Pawley, 1994; Schmidt and Poli, 1994; Okamoto and Maruyama, 1999); (3) it is the dominant host of LILE (Sr, Pb) and LREE (Tribuzio et al., 1996; Spandler et al., 2003; Usui et al., 2006; Martin et al., 2011). Therefore, the presence of lawsonite in eclogite provides vital constraints on the P-T trajectory, geothermal gradients, exhumation rate, fluid/melt flux and element recycling in deep subduction zones (Spandler et al., 2003; Zack et al., 2004; Davis and Whitney, 2006; Tsujimori et al., 2006; Whitney and Davis, 2006; Wei and Clarke, 2011). However, lawsonite is extremely sensitive to temperature increase and local deformation (fluid infiltration) during exhumation (Whitney and Davis, 2006), and it generally decomposes quickly once the metamorphic P–T conditions are out of its stability field. Consequently, it is very difficult to detect the previous existence of lawsonite and detailed fluid-element actions in lawsonite-absent eclogites.

The Ganghe lawsonite pseudomorph-bearing UHP eclogite in the Dabie UHP terrane (eastern China) provides an excellent opportunity to investigate the dehydration of lawsonite eclogite, UHP fluid evolution and trace-element mobilization (Guo et al., 2012, 2013). Major-element and trace-element distributions in multi-stage minerals were examined in the Ganghe UHP eclogite. The whole-rock Sr and LREEs are mainly dominated by epidote; other minerals (garnet, omphacite, quartz, kyanite, barroisite, phengite and accessory minerals) play a very limited role in the Sr and LREEs budgets. Two stages of epidote, which have significant different Sr and LREEs contents, were recognized in the eclogite (Guo et al., 2013): (1) Epidote porphyroblasts (Ep-P), which are suspected to be the pseudomorphic mineral after lawsonite, contain very high Sr (7200 to 10300 ppm) and LREEs. (2) An earlier-stage epidote (Ep-In), which occurs as inclusions in matrix omphacite, or in omphacite inclusions in Ep-P, has much lower Sr (990 to 1890 ppm) and LREEs contents. In-situ Sr isotope analyses indicated that both stages of epidote have same Sr isotopic composition, which are obviously different with those of gneisses (wallrock of eclogite).
indicates that the components of late-stage Ep-P are mainly inherited from earlier-stage minerals rather than derived from external sources by infiltration. Therefore, there should be mass balance for each component between both metamorphic stages. However, all of the existing early-stage minerals predating the pseudomorphic minerals have very low contents of Sr and LREEs, and the total amounts of these elements in the early-stage minerals do not balance those in the pseudomorphic minerals. This indicates that a missing Ca- Al-, Sr- and LREE-rich mineral, which was previously in equilibrium with the early-stage minerals, likely existed in the Ganghe eclogite. Based on the mineral geochemistry and phase equilibria modelling, we confirm that the missing mineral cannot be anything but lawsonite. Examining the mass (im)balance of Sr and LREEs between multi-stage HP-UHP epidote can be used as a potential method to confirm the previous existence of lawsonite in lawsonite-absent eclogite.

Phase equilibria modeling indicate that UHP lawsonite broke down at 2.8-3.0 GPa and 650-680 °C in the Ganghe eclogite (Guo et al., 2012). The released UHP fluid flows into the low-pressure fractures induced by volume shrinkage during the dehydration of eclogite. The released UHP aqueous fluid reacted with the eclogite and dissolved kyanite, coesite, epidote, omphacite, rutile, zircon and apatite. This leads to significant transfers of SiO₂, Al₂O₃, CaO, FeO, Na₂O, TiO₂, P₂O₅, LILE (Sr and Pb), REE and HFSE (Nb, Ta, Zr, Hf) from eclogite into the UHP fluid (vein). The solubilities of these minerals and relevant element mobilities gradually increase toward the fluid due to the increase of fluid/eclogite ratios. Mass-balance calculations (using the method of Guo et al., 2009) suggest that trace elements have significantly different mobilities during the UHP fluid-eclogite interaction (Guo et al., 2012). LILE and LREE show very high loss (-88% for Sr, -51% for Pb and -70% for La) in the eclogite near the vein (< 8 cm). The losing degrees of HFSE (-15% for Nb) and HREE (-33% for Y) are significant lower than the LILE and LREE. Highly fluid-mobile elements (Cs, Rb, K and Ba) were gained in the eclogite by consuming the interstitial fluid after veining. The data above indicate that significant amounts of trace elements can be transported through mineral dissolution and precipitation into the HP-UHP subduction-zone fluids and thus deep mantle at P-T conditions that are directly related to the slab-mantle-arc mass transfer.

**Key words:** lawsonite, eclogite, epidote, subduction-zone fluid, trace element, Dabie UHP terrane

**References**


