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The origin of oriented mineral inclusions in garnet/clinopyroxene of UHP rocks: Insight from the TEM study

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The phase formed by a solid-state exsolution process generally occurs as oriented lamellae, plates, needles, or short prisms with definite crystal forms and follows specific crystallographic orientation relations (CORs) with the host mineral to reduce the kinetic barriers for nucleation and growth and also to minimize the interfacial and the strain energy. Accordingly, oriented inclusions to be categorized as exsolution products must be ascertained by rigorous crystallographic, energetics and mass balance examinations. Oriented mineral inclusions are known to occur in garnet and clinopyroxene of various ultra-high pressure (UHP) rock types, e.g. garnet peridotite, eclogites, metapelites, and gneisses, and are usually considered to be the exsolution products upon P-T decreasing and have been taken as important UHP indicators. Our TEM study in the past few years, however, showed that the geneses of such tiny oriented inclusions within UHP garnet/clinopyroxene are rather complicated. They could occur either as single-phase inclusions or multiple-phase inclusion pockets with specific phase-assemblage, following either single or multiple CORs, or even without any specific COR with the mineral host. These observations, along with the energetic and mass balance considerations, do suggest that these tiny oriented inclusions in UHP garnet/clinopyroxene might have various petrogenetic origins, including solid-state exsolution, co-precipitation, cleaving-infiltration-healing, and metasomatic alteration. Only through very detailed petrographic, chemical and crystallographic studies as demonstrated in our previous studies of the kokchetavite-bearing multiple-phase needles/prisms in clinopyroxene (Hwang et al., 2004; 2013a), the rutile needles in garnet (Hwang et al., 2007, 2014; Proyer et., 2013), the ilmenite/spinel plates in clinopyroxene of garnet pyroxenite (Hwang et al., 2011), the orthopyroxene blades in peridotite garnet (Zhang et al., 2011; Hwang et al., 2013b), can the true origins of such oriented inclusions in UHP minerals be deciphered.

Hwang et al., 2004. *Contrib. Mineral. Petrol.*, **148**, 380?389. Hwang et al., 2007. *J. Metamorph. Geol.*, **25**, 349-362. Hwang et al., 2011, *Contrib. Mineral. Petrol.*, **161**, 901-920. Hwang et al., 2013a. *J. Asian Earth Sci.*, **63**, 56-69. Hwang et al., 2013b. *J. Metamorph. Geol.*, **31**, 113?130. Hwang et al., 2014. *J. Metamorph. Geol.*, DOI: 10.1111/jmg.12119. Proyer et al., 2013. *Contrib. Mineral. Petrol.*, **166**, 211-234. Zhang et al., 2011. *J. Metamorph. Geol.*, **29**, 741?751.

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