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Partial Melting of Bimineralic Eclogite by Clinopyroxene Breakdown

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The generation of melt during exhumation of UHP–HP metamorphic rocks is an important variable in our full understanding of the fluid–melt-fluid evolution during the subduction cycle and the exhumation mechanism of deeply subducted continental crust (Wang et al., 2020; Sizova et al., 2012). It is generally believed that the partial melting of deeply subducted eclogite is controlled by the mineral assemblage, particularly the presence of any hydrous minerals, and the metamorphic P–T path. Here we report results from the Sulu belt, which was formed by the deep subduction of the passive margin of the Yangtze Craton under the North China Craton, with exhumation occurring during the Mesozoic (240–210 Ma). Recent studies in this belt have shown that phengite-bearing UHP eclogites can develop a solute-rich supercritical fluid or melt along grain boundaries by dehydroxylation of nominally anhydrous minerals during the early stage of decompression and/or trigger partial melting by breakdown of phengite and/or omphacite during the later stage of exhumation (Wang et al., 2014; Wang et al., 2020; Feng et al., 2021). However, the capacity of bimineralic eclogite to melt remains enigmatic due to the anhydrous mineral assemblage, indicating a low primary bulk water content, and the absence of studies reporting evidence of melting.

To determine whether bimineralic eclogite can produce melt during exhumation we undertook a comprehensive study, including petrology, microstructure and geochronology, on a bimineralic eclogite boudin within gneiss from a locality in the northeast of the Sulu belt. The margin of the eclogite boudin is extensively retrogressed, whereas the core is well preserved with distinctive garnet-rich and pyroxene-rich layers. The Ca-rich clinopyroxene in the boudin core exhibits abundant exsolved quartz formed during exhumation. In the pyroxene-rich layers micrometer-scale intergranular pockets composed of euhedral Ca-rich hornblende and Ca-rich plagioclase, and accessory barite and apatite, are interpreted as leucosome. Comparing the calculated bulk composition of the leucosome pockets, which is diorite, with the clinopyroxene, garnet and accessory mineral compositions from the host, suggests that the melt formation is dominated by the breakdown of clinopyroxene rather than garnet or the accessory minerals, based on the trace element characteristics. Symplectitic intergrowths of hornblende and plagioclase occur along boundaries between the garnet-rich and pyroxene-rich layers and extend into both.

LA-ICP–MS analysis of metamorphic zircon from the eclogite with leucosome pockets yields an age range of 230–210 Ma. Ti-in-zircon thermometry yields a wide range of temperatures from 800 to 500°C. By contrast, temperatures calculated from the rock-forming minerals yield 890–830°C (Grt–Cpx thermometry at 3 GPa), 880–820°C (Amp–Pl (from leucosome pocket) thermometry at 1 GPa), and 700–650°C (Amp–Pl (from symplectite) thermometry at 1.0–0.5 GPa). Overall, we interpret the partial melting of the bimineralic eclogite in the northeastern Sulu belt to record breakdown of clinopyroxene during decompression from UHP–HP metamorphic conditions. This represents the first detailed micro-scale study of in situ melting of UHP bimineralic eclogite.