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Research Advances

Multistage Metamorphic Evolution and *P-T-t* Path of High-*T* Eclogite from the North Dabie Complex Zone during Continental Subduction and Exhumation

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Objective

High-*T* eclogites from the North Dabie complex zone (NDZ), central China underwent a complex metamorphic evolution involved in ultrahigh-pressure (UHP) and high-pressure eclogite-facies metamorphism, and subsequent granulite-facies overprinting and amphibolite-facies retrogression during the Mesozoic continental deep subduction and exhumation. As a consequence, the eclogites were strongly affected by multiple decompression and re-crystallization processes during exhumation. Some eclogites have even been wholly transformed to garnet granulite, or garnet amphibolite, or even garnet-absent amphibolite. In these strongly retrogressed eclogites, nearly all omphacites are transformed/decomposed into symplectites consisted of diopsidic clinopyroxene, plagioclase, hypersthene and hornblende, except for rare relics included in garnet or zircon. Since the eclogites are strongly retrogressed, their peak-mineral assemblages and compositions are rarely preserved, thus making the estimation of the peak *P-T* conditions challenging. Furthermore, the Cretaceous partial melting and migmatization greatly affected the preservation of earlier minerals and identification of related metamorphic stages for the eclogites. In this context, it is thus generally difficult, using conventional geothermometers, to precisely constrain the actual metamorphic *P-T* conditions experienced by the eclogites during the various stages of their evolution. Therefore, the *P-T-t* paths of the eclogites in the NDZ are rare and have been a matter of discussion for long. Nevertheless this information is essential for a robust understanding of the genetic and evolutionary processes among three eclogite-bearing slices (i.e. NDZ, CDZ-Central Dabie mid-T/UHP metamorphic zone and SDZ-South Dabie low-*T* eclogite zone), and exhumation mechanism of the UHP rocks in the Dabie orogen.

Methods

This study carried out an integrated petrological and geochronological investigation of the eclogites from the Luotian dome in the NDZ. The analytical methods include conventional thin-section observations and thermobarometric estimations, pseudosection approach/ thermodynamic modeling, Ti-in-zircon and Zr-in-rutile thermometer, and zircon SHRIMP U-Pb and related mineral Sr-Nd-Pb-Ar isotope dating.

Results

Based on the above investigations, the evolutional processes for the high-T eclogites from the NDZ at least comprise eight metamorphic stages during continental subduction and exhumation (Fig. 1) as follows: (i) Stage 1, a prograde increase in both P and T from ~650°C /1.2 GPa up to > 750°C /> 2.0 GPa at 237 ± 4 Ma; (ii) Stage 2, UHP metamorphic peak, corresponding to diamond eclogite-facies metamorphism with *P* and *T* conditions of 5–7 GPa and 881−1080 °C at 226 ± 2 Ma; (iii) Stage 3, quartz eclogite-facies metamorphism with P and T conditions of ~2.0 GPa and 901−1028°C at 214 ± 2 Ma; (iv) Stages 4-6, granulite-facies metamorphic overprinting at 207 ± 4 Ma, characterized by post-eclogite decompression resulted in omphacite decomposition to three successive diopside + plagioclase, diopside + plagioclase + hypersthene and diopside + plagioclase + hypersthene + amphibole symplectite stages with *P* and *T* conditions of (1.6−1.98 GPa)/(899−987° C), (1.1−1.3 GPa)/(850−890° C) and (0.8−1.0 GPa)/(850−930° C), respectively; (v) Stage 7, high amphibolite-facies metamorphism with *P* and *T* conditions of 0.7−0.8 GPa and 720−770°C at 198 ± 8 Ma;

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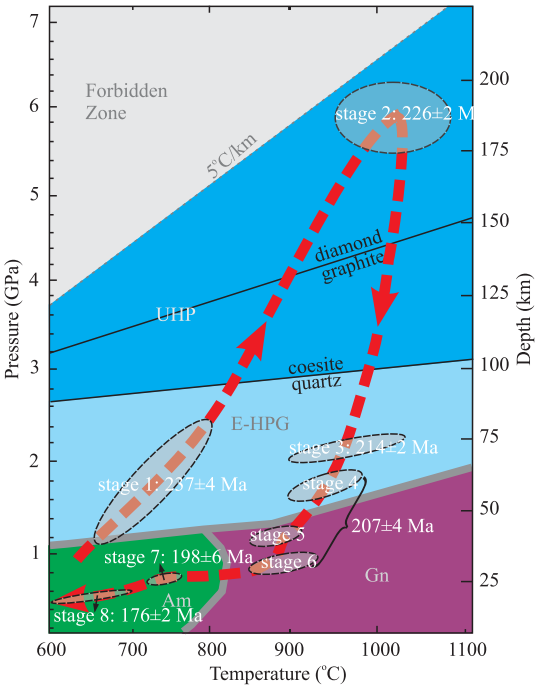

Fig. 1. A complete *P–T–t* path from subduction to exhumation for the NDZ eclogites in the Dabie orogen.

P–T regimes assigned to various metamorphic types: Am, amphibolite facies; Gn, granulite facies; E-HPG, eclogite–high-pressure granulite facies; UHP, ultrahigh pressure metamorphism.

(vi) Stage 8, low amphibolite-facies metamorphism with *P* and *T* conditions of 0.5–0.6 GPa and 600–700°C at 176 ± 2 Ma. Therefore, apart from the high peak temperatures, the eclogites in the NDZ kept their temperatures >850 °C for a long-lived evolution during exhumation from the mantle to lower crustal depths. That is to say, the rocks underwent a nearly isothermal HT decompression process from UHP eclogite- to granulite-facies conditions. Considering the weighted mean ages of UHP metamorphism (226 Ma) and HP eclogite-facies retrogression (214 Ma), the exhumation from mantle depths to crustal depths of ca. 2.0 GPa must have been completed within about 12 Ma. This implies that about 60 km of exhumation should have occurred within about 12 Ma, leading to an average exhumation rate of 0.5 cm/a. A comparatively lower exhumation rate of ~0.4 cm/a characterized the following evolution from HP eclogite-facies (214 Ma) to granulite-facies (207 Ma) conditions, corresponding to nearly isothermal exhumation at very high temperature (>850 °C) from pressures of 2.0 to 1.0 GPa. Thus, the rapid exhumation rate of the initial stage of exhumation was followed by a comparatively slower exhumation rate at HT conditions, which led to significant decompression melting at 207 ± 4 Ma. The protracted HT evolution experienced by the NDZ eclogites may explain why UHP relicts are rarely preserved in these eclogites and in the associated rocks from the NDZ.

In addition, plagioclase and hypersthene symplectitic intergrowths along the crack of a porphyroblastic amphibole from strongly retrograded eclogite indicates a late granulite-facies overprinting, resulted from the Cretaceous post-collision mountain root removal and consequent asthenosphere upwelling and heat input. As a consequence, it led to widespread heating melting and migmatization in the NDZ at ~130 Ma.

Conclusion

The obtained results for the first time provide unambiguous evidence of a long-lived HT (>850 °C) evolution with a near-isothermal decompression path from mantle depths to lower-crustal levels, and most importantly allow precisely constraining a complete prograde, peak and retrograde *P-T-t* path involved in eight metamorphic stages for the NDZ slice in the Dabie orogen during the Mesozoic continental subduction and exhumation. The detailed clockwise *P-T-t* trajectory of the NDZ shed new light on formation and exhumation of the UHP metamorphic belt in the Dabie orogen.

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