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Exhumation history of the North Dabie UHP terrain, central China and REE behavior during retrograde metamorphism: Evidence from three episodic growths of metamorphic zircon and REE zoning of garnet in granulite

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A combined study of mineral inclusions, SIMS U-Pb dating and in situ trace element analyses of zircons and coexisting minerals from a high-pressure (HP) granulite in the North Dabie Terrain (NDT) of Dabie-Sulu ultrahigh-pressure metamorphic (UHPM) belt, east China, provides insight into the exhumation history of NDT and rare earth element (REE) behavior during retrograde metamorphism. Besides inherited cores and one magmatic rim, zircon grains separated from the HP granulite record three episodic metamorphic ages: (1) weighted mean age of 225.0 $\pm$ 2.2 Ma recorded by zircon domains with Rt + Grt + Cpx + F-Ap + Aln inclusions and flat HREE patterns without negative Eu anomaly, indicating eclogite-facies metamorphic time of NDT; (2) weighted mean age of 213.2 $\pm$ 2.1 Ma given by zircon domains with Pl + Cpx + Grt + Qtz + Ap inclusions and rather flat HREE patterns with negative Eu anomaly, recording granulite-facies retrograde metamorphic time of NDT; (3) weighted mean age of 200 $\pm$ 2 Ma recorded by zircon domains with Amp + Pl + Qtz + Ap inclusions and steep HREE patterns with remarkable negative Eu anomaly, indicating amphibolite-facies retrograde metamorphic time of NDT.

Garnet in granulite shows compositional zoning with decrease of REE (especially HREE) contents from core to rim and change of Eu anomaly from negative to positive. This feature together with the rather flat HREE patterns and low REE contents of granulite-facies metamorphic zircons suggest that granulite-facies metamorphism of NDT occurred in a closed system with only internal fluid activity. Change from negative to positive Eu anomaly in garnet rims may suggest that the granulite-facies retrograde metamorphism could be subdivided into two stages. The first is symplectite stage with lower fO_2 during initial exhumation, in which Eu is preferably partitioned into Ca-rich plagioclase in symplectite resulting in negative Eu anomaly in garnet core and newest formed garnet. The later is recrystallization stage at lower crustal level with higher fO_2, in which the recrystallized Na-rich plagioclase with relatively lower Eu anomaly was in equilibrium with garnet rims resulting in positive Eu anomaly for overgrown garnets. Calculated HREE partition coefficients between granulite-facies metamorphic zircons and the accompanying garnet out rims agree with equilibrium $D_{HREE(Zrn/Grt)}$ defined experimentally, suggesting a chemical equilibrium between the garnet rim and granulite-facies metamorphic zircons. Positive correlation between Zr and Yb of garnet out rims suggests that this chemical equilibrium was built up in their crystallization, which further confirms the interpretation of 213.2 $\pm$ 2.1 Ma as granulite-facies metamorphic recrystallization time. Steep HREE patterns and significant elevated REE contents of amphibolite-facies zircons suggest that the amphibolite-facies metamorphism occurred in an open system and external fluid carried more REE into this system. This REE-enriched external fluid can also modify the REE contents of clinopyroxene relics.

Three episodic Triassic metamorphic ages of the granulite together with their corresponding metamorphic phases defines a cooling P-T-t path, which clearly shows that NDT experienced UHP metamorphism contemporary with South Dabie UHPM Terrain around 226-225 Ma followed by the first uplifting process during 225 Ma to 213 Ma. NDT stayed at lower crustal level and underwent granulite-facies retrograde metamorphism till 213 Ma, and then was uplifted to mid-crust level with amphibolite-facies retrograde metamorphism about 200 Ma. A tectonic model explaining the exhumation history of NDT is also proposed.