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P–T–t evolution of the Wutai–Hengshan area, North China Craton: insights from phase equilibria and geochronology of garnet amphibolites

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Garnet amphibolites can provide valuable insights into geological processes of orogenic belts, but their metamorphic evolution is still poorly understood. Garnet amphibolites from the Wutai–Hengshan area of the North China Craton mainly consist of garnet, hornblende, plagioclase, quartz, rutile and ilmenite, with or without sphene and epidote. Four samples were selected in a south–north profile from the lower Wutai Subgroup to the south Hengshan Complex, for elucidating the characteristics of metamorphic evolution. For the sample from the lower Wutai Subgroup, garnet exhibits obvious two-stage growth zoning characteristic of pyrope (Xpy) increasing but grossular (Xgr) decreasing outwards in the core and both Xpy and Xgr increasing outwards in the rim. Phase modelling using THERMOCALC suggests that the garnet cores were formed by chlorite breakdown over 7–9 kbar at 530–600 °C, and rims grew from hornblende and epidote breakdown over 9.5–11.5 kbar at 600–670 °C. The isopleths of the minimum An content in plagioclase and maximum Xpy in garnet in the P–T pseudosection were used to constrain the peak P–T condition, which is ~11.5 kbar/670 °C. The modelled peak assemblage garnet + hornblende + epidote + plagioclase + rutile + quartz matches well the observed one. Plagioclase–hornblende coronae around garnet indicate post-peak decompression and fluid ingress. For the samples from the south Hengshan Complex, garnet zoning weakens gradually, reflecting modifications during decompression of the rocks. Using the same approach, these rocks are inferred to have suprasolidus peak conditions that increase northwards from 11.5 kbar/745 °C, 12.5 kbar/780 °C to 13 kbar/800 °C. The modelled peak assemblages involve diopside, garnet, hornblende, plagioclase, rutile and quartz, yet diopside is not observed petrographically. The post-peak decompression is characterized by diopside + garnet + quartz + melt = hornblende + plagioclase, causing the peak diopside to be consumed and garnet compositions to be largely modified. U–Pb dating indicates that zircons in the Wutai sample record a protolith age of *c*. 2.50 Ga and a metamorphic age of *c*. 1.95 Ga, while zircons in the Hengshan samples record metamorphic ages of *c*. 1.92 Ga. The *c*. 1.95 Ga age is interpreted to represent the pre-peak or peak metamorphic stage and the ages of c. 1.92 Ga represent the cooling stage of the rocks. Garnet amphibolites and other rocks in the Wutai–Hengshan area share similar clockwise P–T morphologies and metamorphic P–T arrays with an apparent thermal gradient of 15–17 °C/km at their peak pressure stage. They may represent metamorphic products at different crustal depths in one orogenic event including a main thickening stage at c. 1.95 Ga and a prolonged exhumation and cooling after 1.92 Ga.