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Metamorphic evolution of the Helanshan Complex, westernmost part of the Khondalite Belt in the Western Block of the North China Craton

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The Paleoproterozoic amalgamation of the Western and Eastern Blocks along the Trans-North China Orogen to form the coherent basement of the North China Craton has been well studied in the last decade, but little is known about the history of the interiors of the Western and Eastern Blocks. New data show that the Western Block formed by the amalgamation of the Yinshan Terrane in the north and the Ordos Terrane in the south along an older Paleoproterozoic collisional belt, named the Khondalite Belt. However, the timing and tectonic nature of this collisional event remains unclear. As the westernmost segment of the Khondalite Belt, the Helanshan Complex is a potential area to study the tectonothermal evolution of the the Khondalite Belt.

The Helanshan Complex consists mainly of Paleoproterozoic graphite-bearing Al-rich schists and gneisses, marble, calc-silicate rocks and associated large volumes of S-type granites. They were highly deformed and had experienced several stages of metamorphism. Microstructrual analysis and metamorphic reaction relations show that the Al-rich garnet-sillimanite-cordierite gneisses underwent four major metamorphic stages. The M1 assemblage is represented by inclusions found in the garnet poikiloblast, including quartz, plagioclase and biotite. In some of the rocks, sillimanite pseudomorph after kyanite can be found. Therefore, the complete assemblage of M1 is quartz + plagioclase + biotite + kyanite. The M2 stage is defined by growths of matrix minerals quartz, plagioclase, K-feldspar, biotite, cordierite and sillimanite and garnet porphyroblasts. M3 is represented by the reaction rim of cordierite formed around the garnet porphyroblast. The final stage, M4, is represented by muscovite and sericite, and occasionally, andalusite, overprinting the major foliation in the rock.

A metamorphic P-T path can be roughly reconstructed based on the above the mineral assemblages and their P-T conditions. The M1 assemblages formed under lower amphibolite facies, and thus the temperature of this stage would range between 550-650˚C; and the polymorphic transition of the kyanite into sillimanite indicates temperature rises from M1 to M2 stage. Therefore the M1 stage represents the prograde metamorphism. In the M2 stage (peak metamorphism), the assemblage of quartz + corderite + garnet + sillimanite+ biotite + K-feldspar should have formed under medium-low granulite facies conditions, with temperature roughly at 750-850˚C and pressure at 5-8 kbar. The appearance of the cordierite corona around garnet grain indicates a major decompression happened at the M3 stage, whose P-T conditions cannot be quantitatively estimated but its pressure generally should be lower than 5 kbar. Following the M3 stage is the retrogressive stage (M4). The polymorphic transition of sillimanite to andalusite clearly shows that the P-T condition has reached the andalusite stability field. Thus, temperature is dropping from M3 to M4. Taken together, these mineral assemblages and their P-T estimates define a clockwise P-T path involving decompression which indicate that the Helanshan Complex underwent initial crustal thickening and subsequent exhumation, accommodating a collisional environment, supporting the recently-proposed model that the Khondalite Belt represents a collisional Belt along which the Yinshan and Ordos Terranes amalgamated to form the Western Block in the Paleoproterozoic.

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