Metamorphic evolution and tectonic implications of the Qianlishan-Zhuozishan complex, westernmost part of the Paleoproterozoic Khondalite Belt in the Western Block of the North China Craton

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A major advance has been made in understanding the Paleoproterozoic amalgamation of the North China Craton at ~1.85 Ga following recognition of two Paleoproterozoic continent-continent collisional belts, named the Trans-North China Orogen and Khondalite Belt[1-2]. In the last few years, extensive work has been done on the Trans-North China Orogen[3-5], but few investigations have been carried on the Khondalite Belt in the Western Block, which has hindered the further understanding the tectonic amalgamation of the Yinshan and Ordos Terranes and the formation of the Western Block. In this study, we present metamorphic data for the khondalites in the Qianlishan-Zhuozishan Complex in the westernmost part of the Paleoproterozoic Khondalite Belt, which places rigorous constraints on the evolution of the belt and amalgamation of the Western Block. The Qianlishan-Zhuozishan Complex is composed predominantly of S-type granites and supracrustal rocks, including Al-rich gneisses, quartzites, marbles and calc-silicate rocks, collectively called khondalite series in the Chinese literature. Petrographic studies show that the Al-rich gneisses from the Qianlishan-Zhuozishan Complex underwent four distinct metamorphic stages. M1 is represented by quartz + plagioclase + muscovite + biotite + garnet core, forming at 550-650°C and 6-8 Kbar. The M2 stage formed sillimanite, garnet, cordierite, K-feldspar, plagioclase and quartz at the T-P conditions of 750-800°C and 6-7 kbar. It was then followed by the M3 stage that represents the formation of cordierite coronas surrounding garnet, indicating a nearly isothermal decompression. Finally, the rock experienced a retrogressive stage (M4) represented by the appearance of andalusite and late muscovite. These mineral assemblages and their approximate P-T estimates define a clockwise P-T path involving nearly isothermal decompression for the Qianlishan-Zhuozishan Complex, supporting the recently proposed model that the Western Block formed by the collision between the Yinshan and Ordos Terranes along the Paleoproterozoic Khondalite Belt.

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The source and distribution of volatile elements on Hadean Earth

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The Earth's atmosphere is an integrated product of planetary evolution processes that reflects the chemistry of the contributing materials (precursors) and the energy supplied. According to astrophysical models, potential precursors that could have delivered significant quantity of water or hydrogen to the primitive Earth include the solar nebula, comets and carbonaceous chondrite-like materials of different sizes (planetary embryos, micrometeorites and IDPs). The comparative study of H, N and C isotopic compositions between those potential precursors and the Earth suggests that a major source of highly volatile elements is carbonaceous chondrite-like material (e.g. Marty and Yokochi, 2006). As such components cannot be the major building blocks of the Earth, however, the mode and timing of their supply as well as the possible events having affected the water and other volatile elements need to be constrained in order to understand the evolution of the primitive Earth's surface environment. In this context, noble gases are advantageous tracers of physical processes and their time scales given that they are chemically inert and that several radiogenic isotopes of appropriate production rates exist.

Xenon isotopes indeed provide an exceptional set of chronological tracers: ^{129}Xe was produced by the now extinct β-decay of ^{129}I ($T_{1/2}$= 15.7 Myr), and $^{131\text{-}136}$Xe were produced by the spontaneous fission of ^{238}U ($T_{1/2}$= 4.45 Gyr) and now extinct ^{244}Pu ($T_{1/2}$= 82 Myr). As the respective proportions of ^{244}Pu and ^{238}U fissions to $^{131\text{-}136}$Xe isotopes are poorly constrained due to the similar relative yields, we determined the proportions of ^{244}Pu and ^{238}U fission derived ^{136}Xe according to the relative abundances of ^{4}He-^{21} Ne-^{136}Xe, for a set of new noble gas data obtained for Kola plume (Russia) samples (Yokochi and Marty, 2005). The ^{244}Pu contribution of mantle plume-related component is estimated to be 33-60 % of total fission ^{136}Xe. This value is significantly lower than what is expected for a chondritic reservoir (96 %), and is similar to the previously proposed best estimate for the MORB mantle (32 ± 10 %). This result implies that the whole mantle was subject to degassing after the decay of ^{244}Pu, over the entire Hadean. In line with this result, a model age of the atmosphere based on the ratio of radiogenic ^{129}Xe/^{40}Ar suggests that the atmosphere was subject to hydrodynamic loss over 150 Myr after solar system formation, much longer than previous model estimates using xenon isotopes alone.

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