30 YEARS OF DIAMONDS IN CANADA
8-12 July 2024 • Yellowknife
12th International Kimberlite Conference Extended Abstract No. 12IKC-51, 2024

Formation and evolution of the subcontinental lithospheric mantle beneath accretionary orogenic belts: implications for the birth of future cratons

Yuchen Liu[1], Gongcheng Tian[1], Yong Xu[1], James M. Scott[2], Jingao Liu[1]*
1. China University of Geosciences, Beijing 100083, China
2. Department of Geology, University of Otago, Dunedin 9054, New Zealand

Introduction

Cratons are the oldest tectonic units on Earth. It was demonstrated that thick lithospheric roots with low density and high viscosity played a major role in the long-term stability of cratons (Jordan, 1978; Lee et al., 2011; Wang et al., 2014). Rather than being innate, the chemical compositions and structures of lithospheric roots attributing to stabilization were gradually established over the course of later geological processes (Lee and Chin, 2023). Studying younger continental terranes seems favorable for understanding how the stable cratonic lithosphere evolves. Here a comprehensive elemental and Re-Os isotopic study of minerals and whole rocks has been conducted on 103 mantle peridotite xenoliths collected from the Xing'an and Songnen block of the western Xing'an Mongolia Orogenic Belt (XMOB).

Results and discussion

Chemical compositions of most XMOB peridotites reflect varying degrees of melt extraction (4-25 %), whereas higher degrees of hydrous melting (~30 %) appear in a few residues with refractory compositions and low densities similar to cratonic counterparts (Fig. 1).

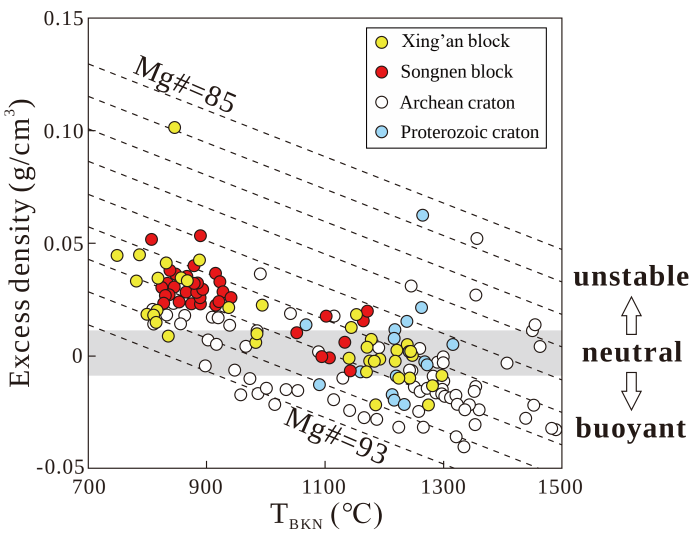

Fig. 1. Excess density versus T_{BKN} for peridotites. The data of Xing'an and Songnen block are from this study. Data of Archean and Proterozoic cratons are derived from publications.

The pressure-temperature conditions of 1.24-2.49 GPa and 821-1074 °C for spinel-facies peridotites yield surface heat fluxes of ~55-70 mW/m^2, corresponding to lithospheric thickness up to 125 km. Geothermobarometry and geophysical observations indicate at least 30 km thicker in lithospheric relative to the eastern XMOB (Fig. 2).

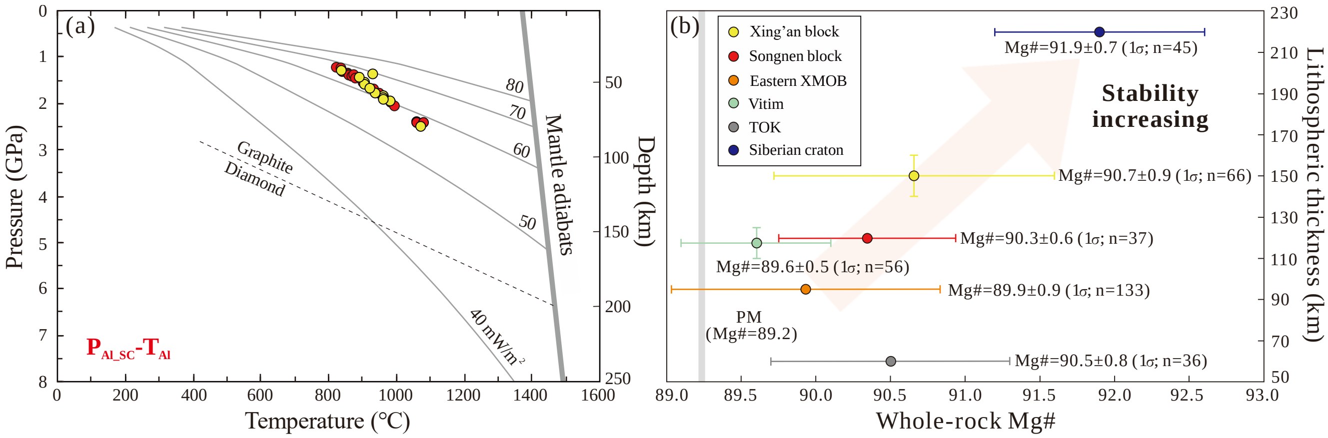

Fig. 2. (a) The temperature and pressure for the XMOB spinel-facies peridotites. (b) Whole-rock Mg# of peridotites from different localities and their corresponding lithospheric thickness. Mg# of Xing'an and Songnen block are from this study. Mg# of other terranes and lithosphere thickness are from publications.

The peridotites with Neoproterozoic and Mesoproterozoic Re-depletion Os model ages match temporally with overlying crust, while Archean-aged ones represent mantle fragments derived from heterogeneous asthenosphere or recycled adjacent cratons (Fig. 3). During the Mesoproterozoic to Neoproterozoic, the mixture of ancient fragments and ambient mantle experienced initial melting at spreading centers. With further hydrous re-melting of mantle residues and thickening of the lithosphere, these newly formed blocks were further lateral accreted during the Phanerozoic (Fig. 4).

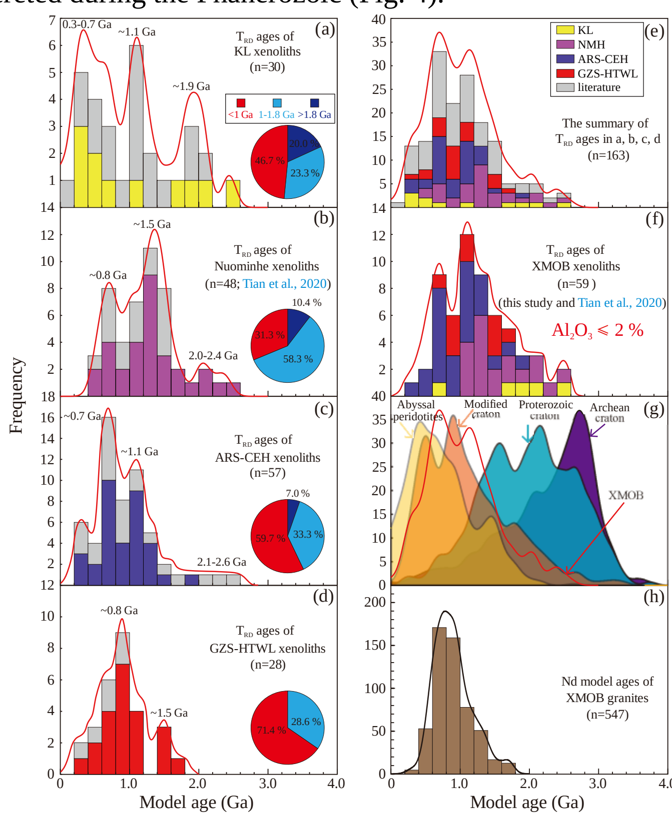

Fig. 3. Histograms of Re depletion model age (T_{RD}) and Nd model age in XMOB. (a-e) T_{RD} ages of the XMOB peridotites. Data in grey and purple column are from publications. (f) T_{RD} ages of refractory XMOB peridotites (Al_2O_3 ≤ 2 %). (g) T_{RD} ages of mantle peridotites from global tectonic settings (from publications). (h) Nd model ages of XMOB granites (from publications).

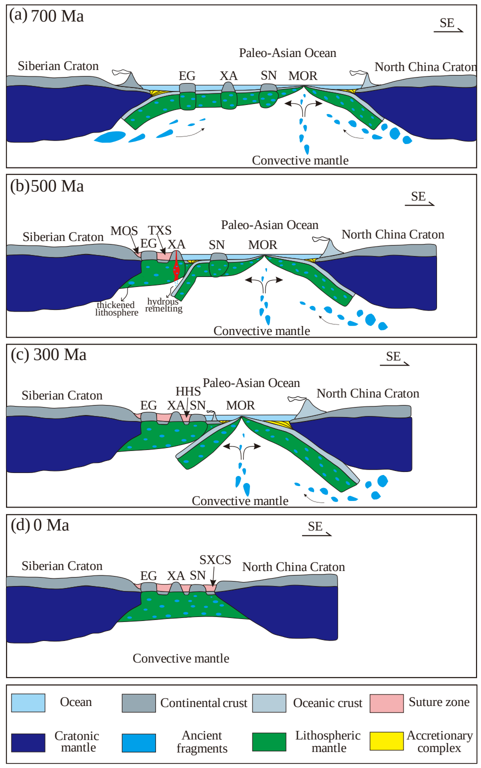

Fig. 4. Schematic cartoons illustrating the evolution of subcontinental lithospheric mantle (SCLM) in the western XMOB. (a) The formation of multiple microcontinental blocks occurred prior to 700 Ma. (b, c) Collision of blocks during the Paleozoic. (d) The lithospheric structure of the present XMOB.

Conclusions

Chemical compositions of peridotite xenoliths imply that the lithospheric mantle beneath the western XMOB experienced varying degrees of melting extraction (4-30 %). The extreme Os heterogeneity in the SCLM indicates a composite structure of building blocks with different evolutionary histories. The temporal consistency in crust and underlying SCLM with Neoproterozoic and Mesoproterozoic formation ages likely suggests a genetic link, while Archean-aged peridotites likely represent mantle fragments derived from heterogeneous asthenosphere or recycled cratonic roots. Phanerozoic orogenic convergence was responsible to laterally accrete these blocks of which the lithospheric mantle had experienced decompressional melting at spreading centers. The resultant addition of refractory peridotites, exhibiting compositional buoyancy similar to Archean and Proterozoic cratons, regulates the density profile of the newly formed lithospheric mantle. During accretionary orogeny, this composite lithosphere experienced lateral compression and thickening, as revealed by the geothermobarometry of spinel-facies peridotites and geophysical observations. The investigation on chemical compositions and structure of juvenile continents confirms the beneficial role of accretionary orogeny in suturing the pre-existing continental nuclei, as well as promoting the long-term stability of continents and laying the foundation of forming potential cratons.

References

Jordan TH (1978) Composition and development of the continental tectosphere. Nature 274(5671): 544-548.

Lee CTA, Chin EJ (2023) Cratonization and a journey of healing: From weakness to strength. Earth and Planetary Science Letters 624: 118439.

Lee CTA, Luffi P, Chin EJ (2011) Building and destroying continental mantle. Annual Review of Earth and Planetary Sciences 39(1): 59-90.

Wang H, van Hunen J, Pearson DG, Allen MB (2014) Craton stability and longevity: The roles of composition-dependent rheology and buoyancy. Earth and Planetary Science Letters 391(1): 224-233.