Discovery and Initial Documentation of the Archean Shangying Eclogitic Garnet-Pyroxenite, North China Craton

Timothy Kusky[1], Lu Wang [1], Wenbin Ning[1], Bo Huang[1]

[1] State Key Lab of Geological Processes and Mineral Resources, Center for Global Tectonics, School of Earth Sciences, China University of Geosciences, Wuhan, 4300074, China

Earlier this year, we reported a late Archean orogenic eclogitic garnet pyroxenite at Shangying, China, preserved as a block in a 2.52-2.53 Ga ophiolitic mélange of China's North China Craton (NCC). The tectonic block records pre-2.47 Ga peak eclogite-facies metamorphic conditions of 792–890°C/19.8–24.5 kbar, corresponding to metamorphic T/P ratios of 323.3–449.5°C/GPa and geothermal gradients of 9.5–13.2°C/km, the lowest of any recorded Archean metamorphic geothermal gradient. Since this discovery is, at present, the world's oldest recognized (*i.e., not yet disputed*) eclogite facies fragment of oceanic MORB crust, we here present a short history of exploration, mapping, and laboratory analyses that led to the discovery, which was not a random find, but the result of two decades of intense work defining different parts of this ancient orogen. Lessons we learned from this experience may help others in the search for even older remnants of Earth's earliest oceanic crust and reveal further details about the geodynamics and thermal regime of the Archean. The next oldest recognized orogenic eclogites include those in the 2.1-Ga Kasai Block of the Congo Craton, the 2.09-Ga Eburnian–Trans-Amazonian orogen of Cameroon, the 1.9- to 2.0 Ga Ubendian–Usagaran Belt of Tanzania, the 1.8-Ga Trans-Hudson orogen, and 1.9 Ga eclogitization of Archean rocks in the Belomoran massif of the Fennoscandian Shield. (Ning et al., 2022).

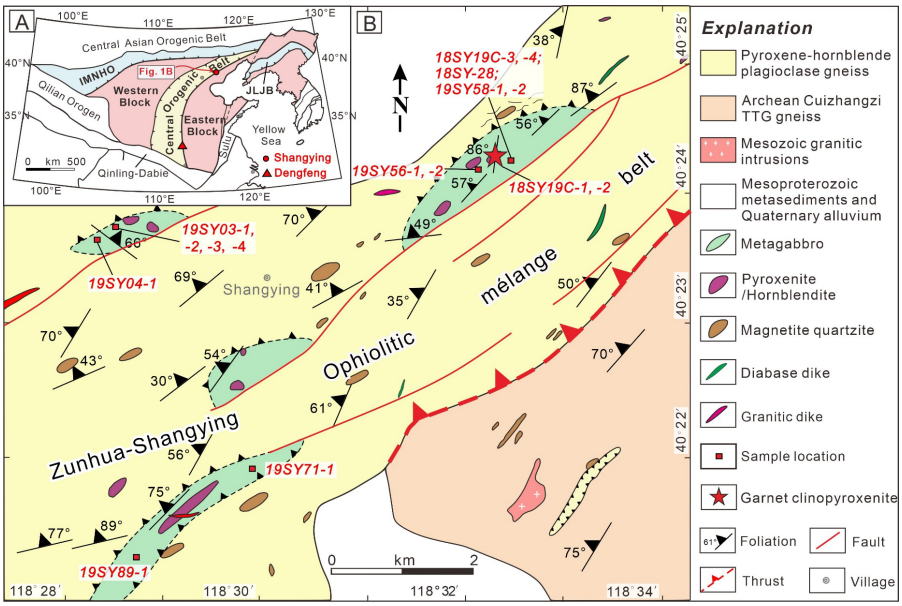

Figure 1- Maps of the North China Craton and the Shangying area. Garnet clinopyroxenites occur as layers and pods in metagabbro blocks scattered in the Archean Zunhua-Shangying ophiolitic mélange (Ning et al., 2022).

Our team began work in the North China Craton in 2000, initially as a partnership between Tim Kusky of USA and Jianghai Li of PKU (China). During this time, we defined the Central Orogenic Belt (COB) as an Archean orogen, using

Archean structural and tectonic features to define its boundaries, including the transition from an autochthonous to para-autochthonous passive margin-foreland basin sequence on the Eastern Block, to allochthonous units of the orogen, including accreted arcs, fore-arc sequences, and ophiolitic fragments. All of these tectonic units were affected by two deformation and metamorphic events, one at *ca.* 2.5 Ga, and a later high-grade event at *ca.* 1.85 Ga, that affected nearly all rocks of the craton, and we related to the NCC joining the Columbia Supercontinent through a collision with Siberia along the cratons' northern margin. Our proposal that some of the mafic/ultramafic units in mélange and gneissic belts were ophiolitic was initially controversial and met with some hostility from Chinese colleagues (Kusky & Zhai, 2012), but subsequent documentation of all components of classical Penrose-type ophiolites (Kusky et al., 2020), convinced most of the community of their ophiolitic origin. Multiple isotopic systems demonstrated the late Archean age of all components, and that the crustal sequence was compositionally and temporally related to (*i.e.,* derived from) the depleted mantle harzburgites (Ning et al., 2022). Through detailed field work, and student PhD and MSc projects, we continued mapping and delineation of tectonic units and history of the plate-scale 1600-km long COB, documenting numerous key-indicators for the operation of modern-style plate tectonics resulting from the late Archean arc/continent collision. These include the Archean passive margin overlain by Archean-Paleoproterozoic foreland basin sequences, a frontal mélange/accretionary wedge sector of the orogen thrust over the autochthon, ophiolitic fragments with UHP chromite (chenmingite) and UHP mineral inclusions in chromitites, accreted arcs with ages from 2.7-2.52 Ga, spatially- and temporally-linked paired metamorphism, clockwise PTt paths, subduction initiation sequences, and far-travelled sheath-folded sub-horizontal nappes of fore-arc accretionary complexes, interpreted to have formed by closure of a 3500 km wide ocean, similar in width, length, and life-span to modern ocean basins.

Documentation of these orogenic zones, and compilation of existing metamorphic data led us to further map and document the diverse set of ophiolitic blocks in the linear Zunhua-Shangying segment of the COB. During mapping for the PhD work of Wenbin Ning, we returned to the Shangying area for further analysis of the structural geology, petrology, and metamorphic history of blocks in the ophiolitic mélange, resulting in the new map (Fig.1), and the discovery in the field of the Shangying eclogitic garnet pyroxenite (Ning et al., 2022). The eclogitic garnet pyroxenite forms remnant igneous layers in part of the oceanic layered gabbro complex, preserved in some of the blocks as cm-to m-scale layering of leucogabbro, thin layers of anorthosite, melanogabbro, eclogitic garnet pyroxenite, pyroxenite, with intrusive leucogabbros and trondhjemites. The garnet pyroxenites are present in several of the mapped ophiolitic blocks in the area (Fig. 1), and on-going work is aimed at further constraining the PTt evolution of these various blocks, and obtaining a deeper understanding of Archean subduction thermal and geodynamic regimes.

Kusky, T.M., Zhai, M.G., 2012. The Neoarchean ophiolite in the North China Craton: Early Precambrian plate tectonics and scientific debate, *Journal of Earth Science* 23, 277-284.

Kusky, T. M., Wang, J.P., Wang, L., Huang, B., Ning, W.B., Fu, D., Peng, H.T., Deng, H., Polat, A., Zhong, Y.T., Shi, G.Z. 2020. Mélanges through time: Life cycle of the world's largest Archean mélange compared with Mesozoic and Paleozoic subduction-accretion-collision mélanges. *Earth Science Reviews* 209, 103303.

Ning, W. B., Kusky, M.T., Wang, L., Huang, B., 2022. Archean eclogite-facies oceanic crust indicates modern-style plate tectonics. P*roceedings of the National Academy of Sciences of the United States of America*, https://doi.org/10.1073/pnas.2117529119.