Eoarchean tectono-metamorphic signatures recorded on the Isua Supracrustal Belt

Anthony Ramírez-Salazar¹, Thomas Mueller¹, Sandra Piazolo¹, Alexander Webb², Christoph Hauzenberger³, Jiawei Zuo², Peter Haproff⁴, Jason Harvey¹, and Callum Charlton¹

¹University of Leeds, Institute of Geophysics and Tectonics, Leeds, United Kingdom of Great Britain and Northern Ireland (eears@leeds.ac.uk)
²Department of Earth Sciences and Laboratory for Space Research, University of Hong Kong, Pokfulam Road, Hong Kong, China
³Department of Earth Sciences, University of Graz, Universitätsplatz 2, A-8010 Graz, Austria
⁴Department of Earth and Ocean Sciences, University of North Carolina Wilmington, 601 South College Road Wilmington, NC 28403, USA

The Eoarchean Isua Supracrustal Belt (ISB) is one of the few locations where it is possible to study the tectono-metamorphic evolution of a young planet. The ISB is thought to represent metavolcano-sedimentary units from two different embryotic continental segments/terranes associated with two large TTG bodies of contrasting crystallization age. Until recently, geochemical and metamorphic signatures have been interpreted to be consistent with a subduction-collision event, thereby matching Earth’s active ‘horizontal’ tectonic regime. This interpretation is often cited as evidence that plate tectonics has operated since the Early Archean. New structural, field, isotopic and geochemical data, however, suggest that the ISB is rather a continuous volcano-sedimentary sequence with a rock record that could be explained by ‘vertical’ tectonic models involving extensive volcanic resurfacing and single-plate tectonics. In this work, we present metamorphic data retrieved from a new set of samples from the eastern ISB to evaluate the two contrasting hypotheses. Throughout the ISB, two major Archean medium grade metamorphic events ($M_1$, $M_2$) can be identified, overprinted partially by near-pervasive low-temperature retrogression. The pre-Ameralik dykes ($≈ 3500$ Ma) event $M_1$, is characterized by a strong foliation and typically lineation that plunge towards the southeast with development of amphibolite facies assemblages, with common appearance of syn-tectonic garnet and amphibole porphyroblasts. Phase equilibria modelling, classic and isopleth geothermobarometry show that $M_1$ evolved as a nearly isothermal prograde metamorphism that culminated in an amphibolite facies peak ($0.65$ GPa and $550-580$ °C) common to the entire belt. $M_2$, probably Neoarchean in age, is identified by the frequent appearance of post-tectonic garnet rims with estimated lower grade conditions. Low temperature retrogression is widespread along the ISB, however, it seems more penetrative in the northern area occurring as garnet pseudomorphism and retrograde chlorite commonly mimicking the foliation by replacing biotite, with some samples showing complete chloritization. We argue that the retrogression textures could be responsible for the apparent zones of lower metamorphism previously reported as prograde, a conclusion also supported by our geothermobarometric data, and that the tectonic...
models supported by previous interpretations need to be revised. The isothermal prograde path as well as the high geothermal gradient associated with peak conditions (≈ 900 °C/GPa) is consistent with vertical tectonics models during the Eoarchean. This interpretation is in agreement with global data analysis that suggest non-uniformitarian geodynamics in the Early Archean, as well as the viability of early vertical tectonics on the other terrestrial bodies of our solar system. It follows that studies like this can shed light on not just the cooling of early Earth, but also on the cooling of terrestrial planets universally.