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Metamorphic processes in the Eoarchaean: evidence from the 3.7-3.8 Ga Isua Greenstone Belt

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The rocks of the Isua Greenstone belt in west Greenland represent the world's largest and best preserved suite of Eoarchaean (3.7-3.8 Ga) meta-volcanic and meta-sedimentary rocks. As such they represent an important region in which to obtain evidence of geodynamic processes in the early Earth. This region however has also become a 'battleground' of competing ideas, not least the tectonic setting in which these rocks might have formed. For example Furnes et al. [1] have argued that, in part, this suite represents a former ophiolite, whereas others have argued from the presence of boninitic lavas for an arc affinity for these metavolcanic rocks [2].

Unravelling the deformation and metamorphic history of this area is not trivial. Geological mapping and detailed U-Pb zircon chronology shows that the rocks of the Isua Greenstone belt comprise two structural packages of different ages. A 3.8 Ga suite of metavolcanic and metasedimentary rocks intruded by 3.8 Ga tonalitic gneisses making up the outer, southerly arc of the greenstone belt was juxtaposed against a younger, northerly 3.7 Ga suite associated with 3.7 Ga tonalitic gneisses. The two packages were assembled at about 3.66 Ga [3] and both are metamorphosed to amphibolite facies. Later 3.65-3.6 Ga deformation of the younger suite has given rise to a number of separate, shear-zone bounded units in the younger, northern terrane [3].

Detailed mapping of garnet textures and compositions in pelitic lithologies reveals a complex sequence of garnet growth chronologies with up to three episodes of garnet growth and in detail variations between the different domains of the greenstone belt [4,5]. The older, southern terrane is least well characterised with respect to metamorphic grade. There are three episodes of garnet growth and garnet-biotite temperatures are up to 590°C. Metamorphic pressures are not well constrained. In the northern terrain three episodes of garnet growth can be recognised and peak garnet-biotite temperatures are up to 610°C. However in the northwestern subdomain only two phases of garnet growth are recorded and peak garnet biotite temperatures are up to 650°C. Kyanite but not sillimanite is recorded in this terrane suggesting a minimum pressure of ca 7 kb. In the northeastern subdomain only a single phase of garnet growth is recorded and calculated P-T conditions are 470°C, 4 kb [6] although these rocks are part of a prograde sequence with temperatures rising to 550 °C. A further constraint on metamorphic conditions is the absence of partial melting in felsic lithologies. Garnet geochronology indicates that garnet growth was at 3.74-3.7 Ga [4] although it is possible that the latest garnet growth episode was at 3.63 Ga [7] synchronous with titanite in the tonalitic gneisses.

The Isua metasediments record thermal gradients from ca. 3.7 Ga which plot in the 'higher T/P gradient than normal' category of Brown [8], indicative either of higher mantle heat flow in the early Archaean, or of their structural location between two magmatic/tonalitic massifs. There is no evidence for high pressure metamorphism analogous to that found associated with modern subduction zones.

References:

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