Goldschmidt 2000
September 3rd–8th, 2000
Oxford, UK.

Journal of Conference Abstracts
Volume 5(2), 455

Submerged Early Archean Flood Volcanism: Geochemical and Geological Evidence from the Pilbara Craton, Australia

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Exceptionally preserved early Archaean supracrustal rocks are common in the Pilbara Craton, although there have been surprisingly few detailed geochemical studies of them. In the Pilgangoora Belt, the ~3.52Ga Coonterunah Group was intruded by ~3.50 to ~3.47 Ga Carlindi granitoids, and the combined terrain was uplifted and eroded to form an erosional unconformity. This is the oldest-known evidence for emergent continental crust. The uppermost units of the regionally extensive ~3.46 Ga Warrawoona Group were deposited onto the unconformity. In the North Pole Dome, ~10 km of the Warrawoona Group are exposed, of which the upper ~3 km correlates lithologically and geochemically with the Warrawoona Group in the Pilgangoora Belt. The lower part of the North Pole succession, therefore, must have been deposited while the Coonterunah-Carlindi terrain was emergent. These two successions provide critical constraints for determining the tectonic setting of the Pilbara greenstone belts.

The whole-rock composition of the Coonterunah and Warrawoona basalts is remarkably similar, with a crustal geochemical signature overprinting a background depleted mantle composition; N-MORB-normalised enrichment of LILE, Th, U and LREE greater than Ta, Nb, P, Zr, Y and M-HREE. Such compositional similarities suggest that all the basalts were formed by the same petrogenetic processes. Stratigraphic, geological and geochemical characteristics indicate that the basalts assimilated up to 25% evolved crustal material, which was not associated with subduction-related mantle enrichment. Moreover, small compositional differences between basalts can be readily explained by various degrees of assimilation and fractional crystallisation. All the basalts, therefore, are interpreted to have erupted onto continental basement. The least contaminated and least evolved basalts show that the mantle source was as depleted or even more depleted in incompatible elements than the present mantle. This interpretation is consistent with Nd and Hf isotopic studies.

Evidence from both greenstone belts can be used to define some criteria which must be satisfied by proposed tectonic setting models. These include, 1) eruption onto continental basement, 2) derivation from a mantle with a generally uniform (depleted) composition, 3) eruption of thick basaltic successions with only minor komatiitic and felsic volcanism, 4) no stratigraphic trends of basalt composition, 5) coeval granitoid emplacement 6) emergence of the Coonterunah-Carlindi terrain, 7) persistent shallow subaqueous to subaerial eruption of the Warrawoona Group, 8) extensional setting for the Warrawoona Group, 9) very low-grade metamorphism throughout the Warrawoona volcanic pile and 10) minor regional deformation. Some derived constraints are that the potential mantle temperature was ~1400ºC, partial melting was shallow and did not involve garnet, and that the pre-Warrawoona basement must have been significantly extended and thinned during deposition of the Warrawoona succession to maintain shallow subaqueous to subaerial conditions. These criteria preclude many of the possible tectonic settings for greenstone development. The favoured model for the Pilbara is a setting similar to Phanerozoic continental flood basalt provinces, but differing from recent analogues in that it was deposited onto submerged basement. The base-level of deposition was most likely controlled by the thickness of the continental basement and the rates of extension and eruption.