



Mesoarchaean granulite facies metamorphism in the Vredefort Dome, South Africa – roots of a rapidly-exhumed transpressional magmatic arc terrane

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The Kaapvaal craton of southern Africa contains arguably the most complete Archaean geological record on Earth. The eastern and central parts of the craton were created by the amalgamation of a series of greenstone-TTG associations between ~3.6 and 3.1 Ga, after which the craton grew laterally by accretion of new terranes along its northern and western margins whilst the central parts of the craton became dominated by a series of large basins that accumulated up to 15 km of sediments and volcanics that have undergone only limited subsequent disturbance. The 3.1 Ga consolidation event manifests itself over large parts of the craton in voluminous, regionally-extensive, ca. 3120-3105 Ma granitoid magmatism. The oldest of the major basinal sequences, the 3074 ± 6 Ma Dominion Group, places a minimum age constraint on the consolidation of the cratonic root. In the central parts of the craton, however, a fortuitous large meteorite impact strike at 2023 Ma has exhumed and rotated on-end a 25-30 km-thick section of the Archaean Basement Complex (ABC) and overlying supracrustal strata in the 90-km-wide Vredefort Dome. The ABC rocks exposed in the core of the dome comprise scattered greenstone fragments (pelitic and greywacke sediments, ironstones, komatiitic to tholeiitic lavas) enveloped by trondhjemitic and granodioritic gneisses and granites. Metamorphic grade typically ranges from upper amphibolite to granulite facies, with peak conditions in the metapelites of 7.1-7.7 kbar, 870-885 °C. THERMOCALC phase equilibria modeling of metapelites and metagreywackes has revealed a tight clockwise P-T path for this metamorphism.

In the southeastern part of the ABC, however, a 1-km-wide mylonite zone separates the high-grade rocks from greenschist-facies (~ 400 °C) metavolcanics. Kinematic indicators support an extensional origin for this shear zone. Field evidence indicates that the metamorphic peak in both the high-grade and low-grade rocks was achieved during development of an intense NW-trending S3 fabric interpreted as the product of dextral transpressional tectonics, which followed the development of a composite S1-S2 subhorizontal fabric. SHRIMP single zircon U-Pb dating indicates that the metamorphic peak occurred at 3080-3090 Ma. In contrast to other areas in the craton, the oldest TTG magmas are only 3120 Ma.

The combined structural, metamorphic, geochemical and geochronological data suggest a juvenile island arc setting for the Vredefort ABC rocks along the southwestern edge of the proto-Kaapvaal craton. Oblique east- to northeast-ward directed collision of the arc with the craton led to crustal thickening, partial melting and emplacement of 3100-3080 Ma granites and granodiorites and high-grade metamorphism. This was followed immediately by collapse of the thickened crust leading to rapid exhumation of the midcrustal rocks by ~ 14 km prior to the deposition of the rift-related Dominion Group within 10 Myr of the metamorphic peak.