L4 Subdivision of the Archean

< Superior 2.5 Gy, Kaapvaal 3.1 Gy first craton; low heat flow, “reefs”, archons >

... it is wrong always, everywhere, and for any one, to believe anything upon insufficient evidence.
—William Kingdon Clifford (1845-1879) who would have evidentialism as a rule of morality.[1]

By the end of the Archean, plate tectonics had assembled several microcontinents. The unraveling of the geologic history of Archean greenstone belts is greatly aided by a careful consideration of zircon and titanite U-Pb isotopic ages.

Continents are different from island arcs because their interiors stabilize as cratons long enough for granitic batholiths in them to become unroofed by erosion and from this source large quantities of quartz sand can accumulate peripherally on them.[2]

Proterozoic platform and marginal miogeoclinal quartz-rich sediments are separated by a profound nonconformity upon rocks of the Superior province. This is a large fragment now in North America of a once Archean continent. In exposed rocks of the Superior province, micas that last crystallized, and which at near surface low temperatures ceased to be permeable to argon, have a statistical median radiometric K-Ar age of 2.5 Gy. This age is used by the USGS and the GSC to define for North America the end of the Archean Eon.[3]

A world average for the end Archean orogenies is 2.6 Ga. However, not involved in the end Archean orogenies, are still surviving fragments of earlier Archean continents.

The oldest extensive platform rocks are found in the Witwatersrand and the Pongolo basins of the Kaapvaal shield, southern Africa (***Figure L4.1***). Outpourings, present there, of vast volumes of plateau basalts (Venterdorp volcanics total thickness to as much as 3000 meters) could record conditions that led to tensional breakup 2.7 Ga of this first evident continent. Venterdorp volcanics are interlayered at their base with the upper part of a placer-gold bearing braided river deltaic platform sequence (the upper Witwatersrand supergroup) of vast volume. Its area measuring more than 40,000 square kilometers and to a maximum thickness of 8 kilometers, indicates a craton receiving sediments in a foreland to a compressional orogenic belt. Sedimentary gold and uranium in quartz-pebble conglomerates had earlier accumulated in graywackes and shales. The presence of the conglomerates, symmetrical rippled (some double-crested recording ebb and flow) sands, and mudcracked muds indicates an intertidal rather than the deepwater deposition usual for graywackes. The craton at this earlier time is interpreted to have had a passive margin. Volcanics dated 2.9-3.1 Gy, included as layers in rift quartzarenites (Dominion reef), fix a minimum age for the craton.[4]

Kaapvaal platform rocks are, by the present subdivision of Precambrian time, Late Archean in age. Kaapvaal shield rocks are typical of Archean greenstone and granite-gneiss belts. Had the boundary between the Proterozoic and Archean been established in this locale, it would have the age 3.1 Gy when the Kaapvaal craton stabilized.[5]

Archean cratonic roots

Continental lithosphere is thicker than oceanic lithosphere. The continental lithosphere is thickest where structural provinces of Archean age exist in the shield. In those cratonic terranes, seismic studies record an increase in velocities of P-waves to depths of 200 km and lateral variations of velocities of S-waves to depths of 400 km. Density features resolved by seismic tomography above 325 km are mostly composition related, unless igneous activity is a factor, and those below are temperature related, unless plate subduction, present or ancient, is a factor.

Diamond erupting kimberlite volcanoes regardless of age of intrusion are restricted, in their known locations, to the platforms and shields of continents underlain by Archean lithosphere (Clifford’s rule, [6] that is T. N. Clifford's and not W. K. Clifford's!). Temperature-sensitive mineral inclusions in diamonds provide evidence that low temperature is a persistent characteristic of the lithosphere of shields even where the rocks are 3 Gy.

Heat flow through cratonic terranes is less than it is through younger continental crust, and the heat-flow difference at the boundary of the two is sharp. This is explained by Andrew A. Nyblade as owing less to a compositional difference and more to the greater lithosphere thickness of the Archean cratonic terrains. Mantle heat flow is deflected by mantle convection around their "deep keels." [7]

The composition of a deep-keeled ancient structural province, be it a *proton* (which name is a contraction of Proterozoic Eon and craton) or an *archon* (which name is a contraction of Archean Eon and craton),[8] is inferred to be a refractory (high melting temperature), magnesium enriched, residue rock from which has been extracted either iron-rich oceanic basalt, now elsewhere, or the overlying continental crust.[9]

The present temperature profile of archons has a lesser gradient than the rapidly steepening profile to higher temperature with depth, that must have existed at the time of their formation.

Where the craton keels have been hotspot heated in the post-Archean, anorogenic kimberlite volcanic eruptions have brought up diamonds (and noticeable, and easily panned for, high specieifc-gravity indicator minerals: metallic-black chromite and ilmenite, black-red garnet, and bright-green diopside and olivine). Tin-uranium deposits of anorogenic volcanic origin in Archean terrains find a similar explanation. ❑

Figure L4.1 [10] Found in southern Africa today are extensive, little deformed, Late Archean platform sediments. The Witwatersrand Basin sediments, top down, grade from mostly quartzarenites (quartzites) to mostly muds (phyllites, slates, quartz-schists and banded ironstones). The enormous extent and uniform thickness of individual beds, which also prove the existence of a craton, is known because auriferous "reefs" (quartz-conglomerate stringers, which occur at various levels), have been prospected, and are mined, for placer gold and uranium. These sediments record 300 million years of accumulation that began 2.7 Ga. The Witwatersrand succession is separated by an unconformity from the underlying 2.7 to 3 Gy Pongolo Basin supergroup comprised mostly of pillowed lava (amygdaloidal andesite) flows but which also includes layers of sands (quartzites) and muds (phyllites) with features (mud cracks) that indicate a shoaling, continental-shelf environment of deposition.[11]

Corroborating the placer origin of the reef gold is its 3 Gy age indicated by its rhenium-osmium content (^{187}Rh decays to ^{187}Os with a half-life of 45 Gy) as reported by Jason Kirk in 2002.[12]

The supercrustal Witwatersrand and Pongolo accumulated on an erosion surface cut across an Early Archean granite-gneiss and greenstone belts that date 3.1 to 3.5 Gy.