

Archaean growth structures in the Pilbara, Australia (extended abstract)

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Faults and folds, active during sedimentation, progressively induce thickness differences, unconformities and onlapping contacts in the stratigraphic record. Such growth structures, therefore, contain a special record of the relationship between sedimentation and deformation at the earth surface and at shallow crustal levels. The analysis of this kind of relationships applied to the earliest stages of crustal development of the earth forms part of a research project in the early Archaean of the Pilbara, sponsored by the Dr. Schürmann Foundation. Two examples are discussed (Figure 1; Nijman et al. 1998a, b).

The North Pole Chert, in the lower part of the Warrawoona Group (Figure 2), is famous for its remains of about 3.5-Ga-old stromatolites (Dunlop et al. 1978; Buick & Dunlop 1990). Though thoroughly investigated paleontologically and petrographically, the area had never been mapped in detail. Combined structural and sedimentologic analysis reveals that synsedimentary tensional growth faults controlled the thickness and facies distribution of the North Pole Chert, and the concurrence of primary and secondary chert, synsedimentary growth of huge barite mounds and barite-chert veins.

Both stratigraphically and with respect to the provenance of its sandstone component, the North Pole Chert was related to felsic volcanism in an otherwise completely basalt-dominated subaqueous volcanic environment. The listric normal growth faults were induced by moderate uplift, coincident with felsic volcanism. Swarms of chert-barite veins arose from the growth-fault planes and created hydrothermal vents in the shallow, sedimentary basin formed by collapse due to the faulting. Ba, Si and sulphide emanated from these vents into a stratified tide-influenced water body, only about 50m deep. Subsequently, the faults and the sediments they controlled, were affected by low-angle thrusting and doming of the lower Archaean rock suite above the North Pole Batholith, one of the granitoid complexes

that characterize the geologic scene of the Pilbara (Figure 1).

The second example concerns the 3.3-Ga transition of the volcanic assemblage of the lower Archaean Warrawoona Group to the mid-Archaean clastic sediments of the Gorge Creek Group in the east-striking Coppin Gap Greenstone Belt (Figures 1, 2). Arrays of tensile growth faults ('1' in Figure 2) in a 3.46-Ga-old suite of felsic volcanics, arenites and cherts belonging to the Warrawoona Group are quite similar to that of the North Pole, though oriented differently and associated to huge accumulations of megabreccia composed of felsic volcanic agglomerate. Basal detachments to the normal faults and similar other shear zones ('2' in Figure 2) climb eastwards through the lower Archaean rock suite along ramps and flats. Tectono-stratigraphic relationships in footwall and hangingwall, and deformation patterns in shear zones generally reflect crustal shortening with east vergence along most of the earlier low-angle tensile fault zones, a clear indication of inversion tectonics. Although definite geochronologic proof has to be awaited, large-scale repetition of the early Archaean stratigraphic column seems to have taken place (Figure 2). Low-angle thrusting interfered with and gave way to interbatholith compression. Intrusion of a 3.31-Ga-old granite body sets a minimum age to the thrust event and hence to the inversion of tensile to compressive structures.

Relief formed by this complicated deformation was progressively and syntectonically filled with conglomerate (alluvial fans) and sandstone (alluvial fans and coastal quartz arenites) of Gorge Creek Group (\pm 3.3 Ga) affinity. Stacked unconformities and depocentre shifts reveal a history of differential uplift of the adjacent intrusive domains and of interbatholith folding ('3' in Figure 2), interfering with the thrust event. Conversely, the unfolding of the unconformities allowed the reconstruction of the preceding east-verging low-angle thrust geometry and normal fault arrays.

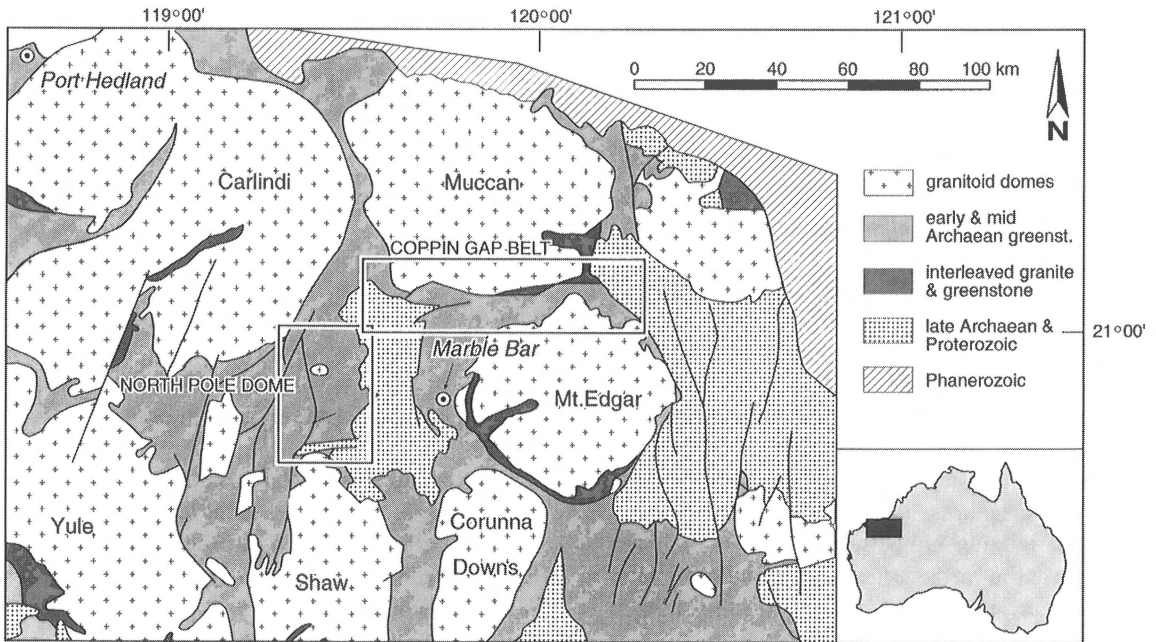


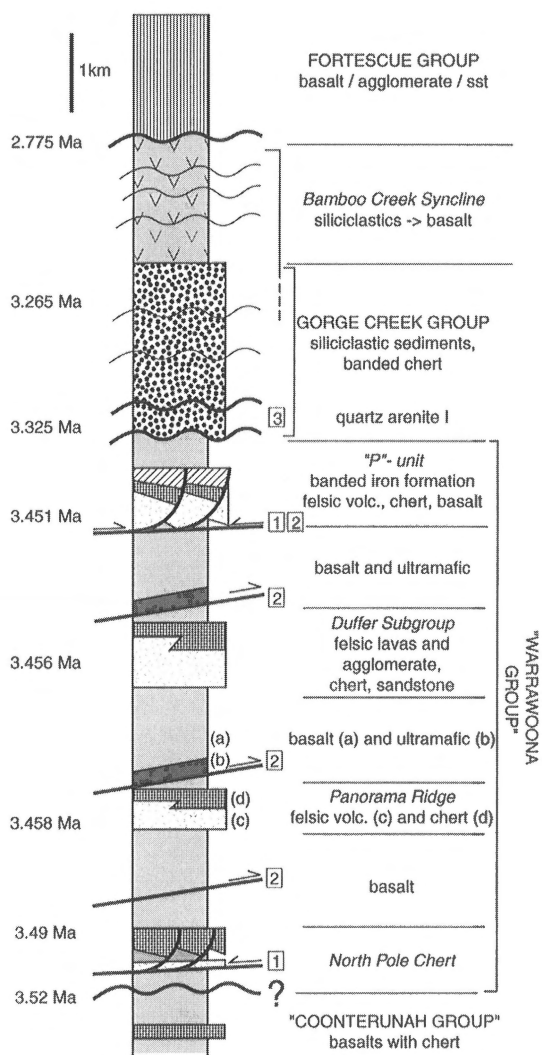
Figure 1. Geographic and geologic setting of the North Pole Dome and Coppins Gap Greenstone Belt in the Pilbara, northwest Australia.

Some conclusions and considerations

- The early tensile growth structures are not unidirectional, and are apparently unrelated to the geometry of batholith doming. Felsic volcanic events appear to overlap with extensional growth faulting. Combined with the extensive hydrothermal veining and venting this supports a model of subaqueous caldera collapse allowing barite-silica precipitation comparable to that of white smokers. At present the association of barite and silica with bimodal volcanism is known from submarine calderas in relatively deep (back)arc settings of the west Pacific (Ishibashi & Urabe 1995). The huge barite mounds, similar in appearance to the Miocene gypsum mounds of the Mediterranean, were primary deposits, providing clasts to diamictite layers that occur in the onlapping basin fill. The North Pole Chert, however, was deposited in a shallow-water environment. Questions arise as to temperature gradient, depth of heat source, water temperature and composition.
- Fault inversion took place on those pre-existing tensional faults favourably oriented with respect to the easterly vergence of the subsequent thrust system. Piggybacks formed primary relief. In places ductile and intensely foliated, chemically and mineralogically altered shear zones occurred only a few hundred metres below the land surface. Again, what sort of temperature gradient prevailed?
- The syndimentary tectonic slicing of the early to mid-Archaean suite places uncertainty on the validity of the existing stratigraphic correlations, which now need further geochronologic work to resolve. Till now, tectonic disturbance of the scale observed, has been largely ignored in reconstructions of the early Archaean sedimentary environments of the Pilbara, and references to arc settings (Eriksson et al. 1994) are therefore premature.
- If intense tectonic slicing and stratigraphic repetition existed in the lower Archaean Warrawoona Group, the basaltic upper crust was relatively thin for the time interval of 200 Ma involved (3.5–3.3 Ga). Hinterlands were low, probably as a result of episodic restricted uplift of a crust insufficiently strong to support major relief features (Vlaar 1986). A relation of tensile faulting with orogenic collapse cannot be assessed. With the 3.3-Ga-old inversion from tensile deformation to thrusting and interbatholith compression, substantial primary relief caused the first major influx of siliciclastics from nearby sources (alluvial fans), reworked in coastal deposystems (quartz arenites).

References

- Buick, R. & J.S.R. Dunlop 1990 Evaporitic sediments of early Archean age from the Warrawoona Group, North Pole, W.A. – *Sedimentology* 37: 247–277
- Dunlop, J.S.R., M.D. Muir, V.A. Milne & D.I. Groves 1978 A new microfossil assemblage from the Archean of Western Australia – *Nature* 274: 676–678
- Eriksson K.A., B. Krapez & P.W. Fralick 1994 Sedimentology of Archean greenstone belts: signatures of tectonic evolution – *Earth Sci. Rev.* 37: 1–88
- Ishibashi, J. & T. Urabe 1995 Hydrothermal activity related to arc-backarc magmatism in the western Pacific. In: Taylor, B. (ed.): Backarc basins, Tectonism and Magmatism. Plenum Press, New York: 451–495
- Nijman, W., C.H. de Bruijne & M. Valkering 1998a Growth fault control of Early Archean cherts, barite mounds and chert-barite veins, North Pole Dome, Eastern Pilbara, W. Australia – *Precamb. Res.* (in press)
- Nijman, W., B.J.A. Willigers & A. Krikke 1998b Tensile and compressive growth structures: relationships between sedimentation, deformation and granite intrusion in the Archean Coppin Gap Greenstone Belt, Eastern Pilbara, W. Australia – *Precamb. Res.* (in press)
- Vlaar, N. 1986 Archean global dynamics – *Geol. Mijnbouw* 65: 91–101



- 1 syn-Warrawoona Group tensile growth faults
- 2 3.3 Ga major thrust event, partly inverting previous normal faults
- 3 interbatholith folding interfering with 2

Figure 2. Tentative and schematic stratigraphic column of the Archean of the East Pilbara, incorporating syndimentary tectonic events based on data from the North Pole Dome and Coppin Gap Belt (modified after Figure 3 in Nijman et al. 1998a).