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Palaeomagnetism and Magnetic Anisotropy of Proterozoic Banded-iron Formations and Iron Ores of the Hamersley Basin, Western Australia

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Abstract

The deflection of post-folding remanence towards the bedding plane by high magnetic anisotropy can produce an apparent synfolding signature, with best agreement between directions from different fold limbs after partial unfolding. The effect of magnetic anisotropy of banded-iron formations on measured remanence inclinations and inferred palaeolatitudes can lead to large errors in calculated palaeopoles for intermediate to moderately high palaeolatitudes but is minor for low palaeolatitudes. Anisotropy also causes cones of confidence to be underestimated, due to compression of the range of inclinations. Therefore high anisotropy can not only bias estimated palaeofield directions and cause underestimation of errors, but can also mislead interpretation of the relative timing of remanence acquisition.

Key words: Palaeomagnetism, Magnetic anisotropy, Banded-iron formations, iron ores, Hamersley Basin, Proterozoic

Introduction

Rock magnetic properties and palaeomagnetism of weakly metamorphosed banded-iron formations (BIFs) of the Lower Proterozoic Hamersley Group, Western Australia, and Proterozoic BIF-derived iron ores have been investigated. The BIF units sampled here are slightly younger than 2500 Ma. At Paraburdoo, Mount Tom Price and Mount Newman iron ore formation was completed before 1850 Ma. The stratigraphy and chronology of the Hamersley Basin are summarised in Fig. 1.

Sampling and Rock Magnetism

Sampling was mainly from the Mount Tom Price and Paraburdoo mining areas and for the first time a palaeomagnetic fold test on fresh (unweathered and unaltered) samples has allowed the nature of the remanence of the BIFs to be clarified. The remanence is carried by late diagenetic/low grade metamorphic magnetite after primary haematite. It is prefolding and is unlikely to be greatly affected by the high anisotropy because the palaeofield inclination was genuinely low, as discussed below.

Determination of palaeofield directions from measured remanence directions is complicated by self-demagnetization effects in strongly magnetic, highly anisotropic BIF specimens. We have presented a method for correcting measured directions for the effects of self-demagnetization and anisotropy (Schmidt and Clark,1993). For typical BIFs, the effect of magnetic anisotropy on measured remanence inclinations and inferred palaeolatitudes is minor for low palaeolatitudes, but can lead to large errors in calculated palaeopoles for intermediate to moderately steep palaeolatitudes. Anisotropy also causes cones of confidence to be underestimated, due to compression of the range of inclinations. In principle, deflection of post-folding remanence towards the bedding plane by high magnetic anisotropy can produce an apparent synfolding signature, with best agreement between directions from different fold limbs after partial unfolding. Thus high anisotropy can not only bias estimated palaeofield directions and cause underestimation of errors, but can also mislead interpretation of the relative timing of remanence acquisition. The anisotropy of anhysteretic remanent magnetization (ARM) probably yields an upper limit to the anisotropy of the chemical remanent magnetization (CRM) carried by the BIFs. Figure 2 shows cleaned remanence directions from Paraburdoo BIFs, with respect to the palaeohorizontal. In Fig. 2a these directions are uncorrected for anisotropy and have a flattened distribution, reflecting deflection towards the bedding plane. In Fig. 2b the measured ARM anisotropy has been used to correct the directions, producing a vertically elongated distribution that suggests overcorrection. From the anisotropy of ARM, a maximum inclination deflection of 9° is suggested for the sampled BIFs. This corresponds to less than 5° change of palaeolatitude.

Palaeomagnetism

The palaeomagnetic pole position calculated for BIFs at Paraburdoo is 40.9°S, 225.0°E (dp = 2.9°, dm = 5.8°) after tilt correction, but without correction for anisotropy (thus the errors are slightly underestimated). Other pole positions reported include those from flat lying BIFs from Wittenoom at 36.4°S, 218.9°E (dp = 4.6°, dm = 9.1°), from Mount Tom Price iron ore at 37.4°S, 220.3°E (dp = 5.7°, dm = 11.3°) and from Paraburdoo ore at 36.4°S, 209.9°E (dp = 4.7°, dm = 8.8°). The poles from the BIFs, the Paraburdoo ore and the part of the Tom Price deposit that was sampled in this study are indistinguishable from each other and from the Mount Jope Volcanics overprint pole.

Discussion and Conclusions

The magnetization of the BIFs was probably acquired during burial metamorphism of the Hamersley Group, soon before the main folding and uplift event in the southern part of the

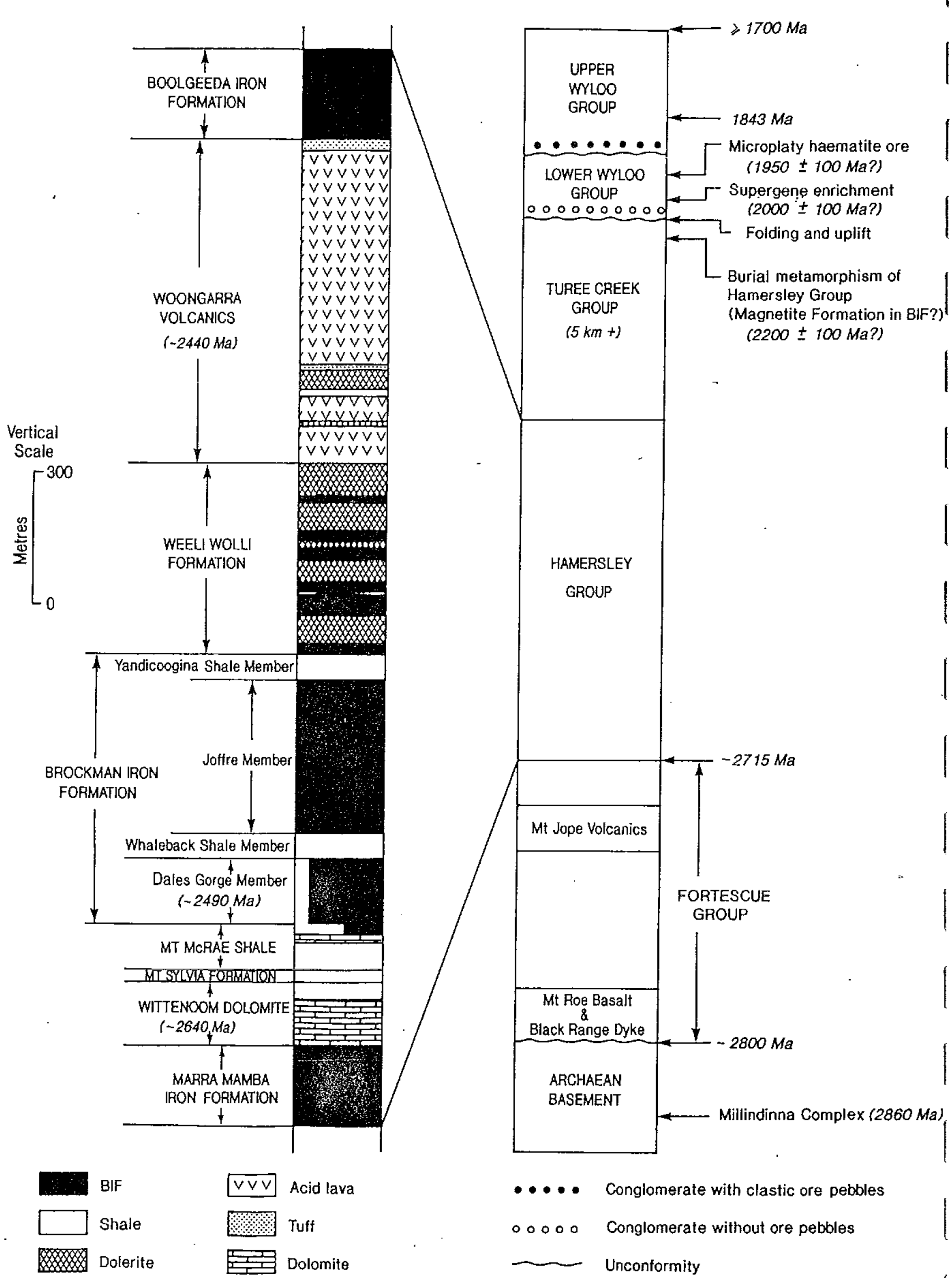

FIGURE 1
Stratigraphy and key geological events of the Hamersley Basin, including detailed stratigraphy of the Hamersley Group. This paper discusses results from the Dales Gorge and Joffre Members, although the results are equally applicable to other BIFs.

Hamersley Province. This tectonic event exposed magnetite-rich BIFs to near-surface oxidizing conditions, producing extensive martite-goethite orebodies and also appears to have produced the syn-folding overprint magnetization recorded by the Mount Jope Volcanics of the underlying Fortescue Group. Figure 3 shows positions of palaeomagnetic poles from this study, together with previously documented poles of similar age.

From stratigraphic considerations and other geological evidence discussed by Morris (1985), the ages of magnetization are tentatively interpreted as ~2200±100 Ma for the BIFs, ~2000±100 Ma for the supergene enrichment of BIF to martite-goethite ore, recorded by the Paraburdoo and Mount Tom Price orebodies, and ~1950±100 Ma for the metamorphic martite-microplaty haematite ore, recorded as an overprint by the Tom Price orebody and as the only surviving magnetisation of the Mount Newman orebody.

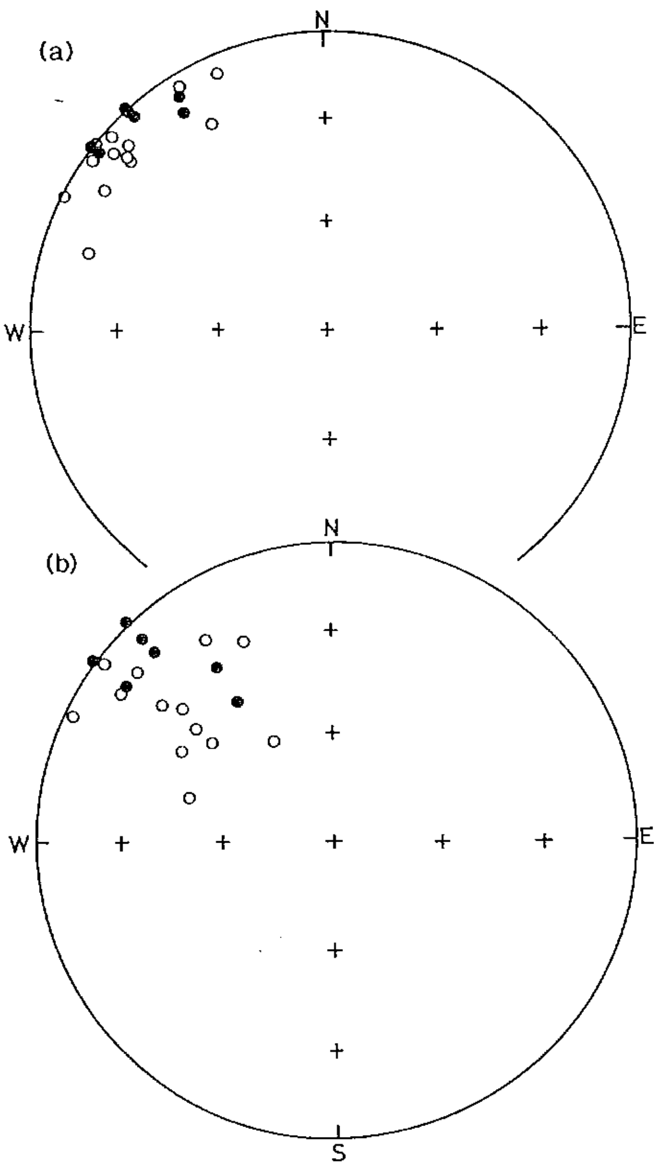

FIGURE 2
Equal-area stereographic projections showing a) cleaned bedding-corrected magnetization directions from BIF at Paraburdoo as measured (note some inclinations are positive and the distribution is flattened), and b) same directions as a) but corrected for anisotropy using anisotropy of ARM as an analogue for anisotropy of CRM (note this over-corrects and smears the distribution vertically).

Acknowledgements

Over the past decade many individuals have contributed to our understanding of the magnetic properties of BIFs. We especially wish to acknowledge Bob Smith (CRAE) and Bill Burns (Hamersley Exploration) for access to proprietary information.

References

Embleton, B.J.J., (1978), 'The palaeomagnetism of 2400 m.y. old rocks from the Australian Pilbara Craton and its relation to Archaean-Proterozoic tectonics'. *Precamb. Res.*, 6, 275-291.
Evans, M.E., (1968), 'Magnetization of dykes: A study of the palaeomagnetism of the Widgiemooltha Dike Suite, Western Australia'. *J. Geophys. Res.*, 73, 3261-3270.
Giddings, J.W., (1976), 'Precambrian palaeomagnetism in Australia I: Basic dykes and volcanics from the Yilgarn Block'. *Tectonophysics*, **30**, 91-108.
Idnurm, M. and Giddings, J.W., (1988), 'Australian Precambrian polar wander: A review'. *Precamb. Res.*, **40/41**, 61-88.
McElhinny, M.W. and Evans, M.E., (1976), 'Palaeomagnetic results from the Hart Dolerite of the Kimberley Block, Australia'. *Precamb. Res.*, **3**, 231-241.
Morris, R.C., (1985), 'Genesis of iron-ore in banded iron-formation by supergene and supergene-metamorphic processes — a conceptual model'. pp 73-235, *in*, Wolf, K.H. (Ed.), Handbook of Strata-Bound and Stratiform Ore Deposits **13. Elsevier, Amsterdam.**
Porath, H. and Chamalaun, F.H. (1968). 'Palaeomagnetism of Australian haematite ore bodies, II, Western Australia'. *Geophys. J. R. Astr. Soc.*, **15**, 253-264.
Schmidt, P.W. and Clark, D.A., (1993), 'Palaeomagnetism and magnetic anisotropy of Proterozoic banded-iron formations and iron ores of the Hamersley Basin, Western Australia. *Precamb. Res.*, in press.
Schmidt, P.W. and Embleton, B.J.J., (1985), 'Pre-folding and overprint magnetic signatures in Precambrian (~2.9-2.7 Ga) igneous rocks from the Pilbara Craton and Hamersley Basin, N.W. Australia'. *J. Geophys. Res.*, **90**, 2967-2984.

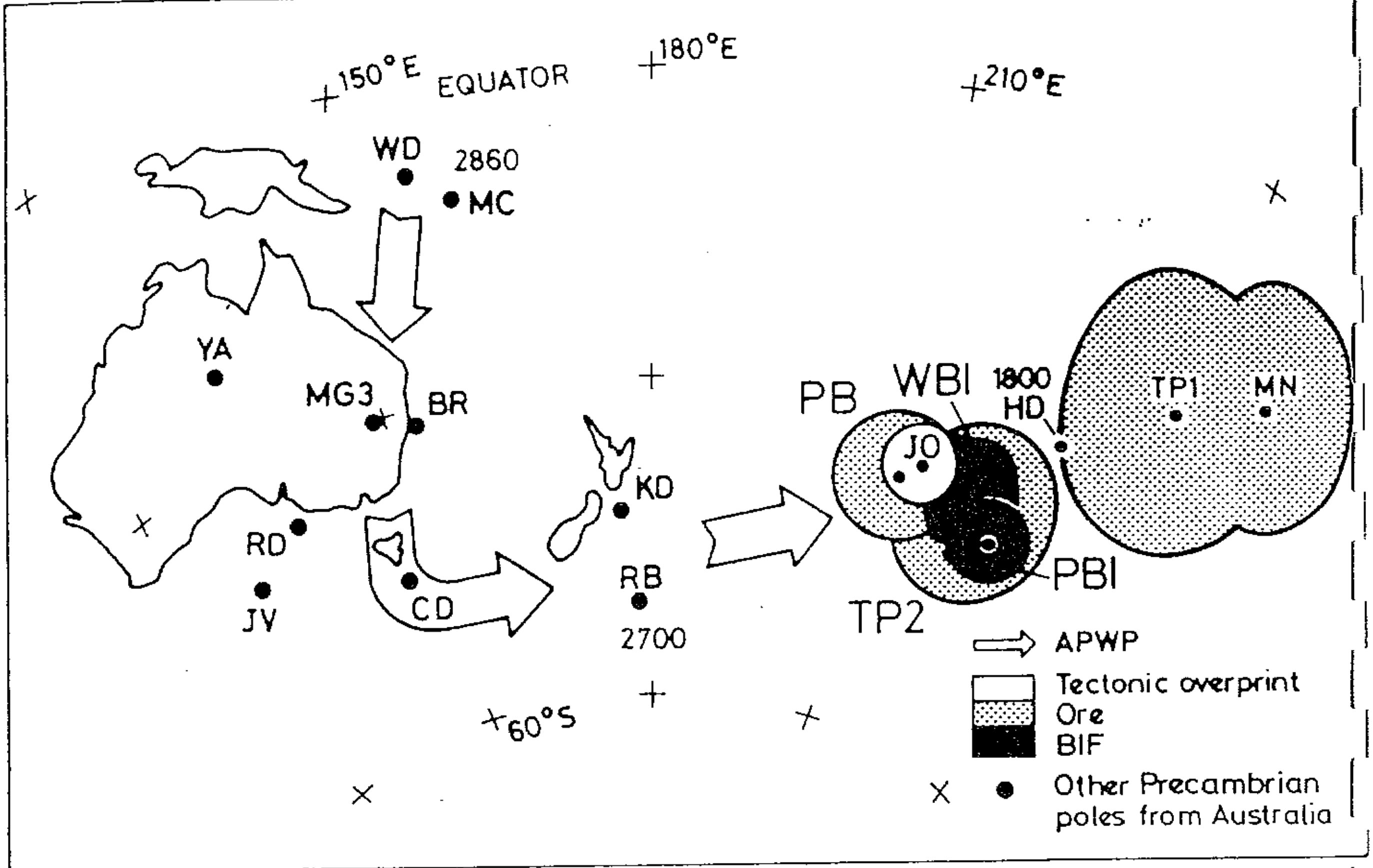

FIGURE 3
APWP showing poles from this study and related poles. Pole mnemonics are PBI and WBI, Paraburdoo and Wittenoom banded iron formations (BIFs) respectively, PB and TP2, Paraburdoo and Mount Tom Price iron ore/oxidized BIF respectively. Other mnemonics are those used by Idnurm and Giddings (1988), WD — Widgiemooltha dyke (Evans, 1968), MC — Millindinna Complex, JV — Mount Jope Volcanics, RB — Mount Roe Basalt and JO — Mount Jope Volcanics syn-folding overprint (Schmidt and Embleton, 1985), YA — Yilgarn A dykes and RD — Ravensthorpe dyke (Giddings, 1976), MG3 — Mount Goldsworthy 3, KD — Koolyanobbing Dowd's Hill, TP1 — Mount Tom Price iron ore and MN — Mount Newman iron ore (Porath and Chamalaun, 1968), BR — Black Range dyke and CD — Cajuput dyke (Embleton, 1978), HD — Hart Dolerite (McElhinny and Evans, 1976).