PALEOMAGNETIC DATING OF WEATHERED REGOLITH AT NORTHPARKES MINE, NSW.

BRAD PILLANS[1], ERIC TONUI[1] & MART IDNURM[2]

[1]*Cooperative Research Centre for Landscape Evolution & Mineral Exploration, Australian National University, Canberra, ACT, 0200*
[2]*Australian Geological Survey Organisation, GPO Box 378, Canberra, ACT, 2601*

ABSTRACT

Paleomagnetic samples were collected from deeply weathered regolith which overlies the Late Ordovician porphyry copper-gold orebody at Northparkes mine. The origin of the magnetisation of the samples is inferred to be chemical, acquired during weathering. Well defined intermediate and high temperature remanence components were isolated in 27 specimens of in situ weathered bedrock (saprolite), and yield a combined mean pole position of 51.2°S, 81.4°E (A_{95} = 3.6°). This pole is consistent with a Paleozoic, possibly early or mid Carboniferous, age for weathering. Remanence directions in overlying mottled, clay-rich valley fill (?) sediments, although more scattered, are broadly consistent with a Cainozoic age for weathering. We conclude that weathering of the regolith has been an on-going, although not necessarily continuous, process at Northparkes since the late Paleozoic.

Key words: Paleomagnetism, regolith, dating, Northparkes

INTRODUCTION

The ages of weathered, non-fossiliferous regolith materials are notoriously difficult to determine in Australia. Dating methods such as radiocarbon, luminescence and U-series disequilibrium are generally limited to the past few hundred thousand years, while techniques such as K/Ar and electron spin resonance are only applicable to mineral phases that are rare in regolith sequences. However, because of the common occurrence of secondary iron-rich minerals, the techniques of paleomagnetism have wide application in regolith studies [For a general introduction to the techniques and applications of paleomagnetism, readers are referred to Butler (1992)]. In this study paleomagnetism is used in an attempt to establish a chronological framework for weathered regolith materials at Northparkes mine.

Northparkes is a porphyry copper-gold deposit related to Late Ordovician quartz monzonite intrusions, dated by $^{40}Ar/^{39}Ar$ and U-Pb methods at 439 Ma (Perkins et al. 1990). The deposit is overlain by up to 30 m of intensely weathered regolith, which is well exposed in two open-cast pits (E22 and E27). In both pits, transported sediments unconformably overlie in situ weathered bedrock saprolite. The transported sediments fill broad depressions up to 400 m wide and 25 m deep which have little or no expression in the modern landscape. They consist of mottled clay-rich materials composed dominantly of kaolinite, with secondary dolomite, silica and hematite. The high degree of weathering of the transported sediments makes interpretation of their depositional environment extremely difficult, but we tentatively refer to them as valley fill sediments, probably partly colluvial and partly alluvial.

SAMPLES AND RESULTS

A total of eighty-five oriented paleomagnetic samples were collected from nine sites: four sites in saprolite and five sites in the valley fill sediments (Table 1). At each site, the wall of the pit was cut back to expose a fresh, moist sub-vertical face. Small cube-shaped pedestals were carved with a sharp knife, onto which 6 cm^3 plastic boxes were carefully fitted. Before removal from the face, samples were oriented with a Brunton compass and inclinometer, and the directions corrected for local magnetic declination.

All samples were measured on a two-axis ScT cryogenic magnetometer at the joint AGSO/ANU Paleomagnetic Laboratory, Black Mountain, Canberra. Both thermal and alternating field demagnetisations were carried out stepwise on the samples to isolate the Characteristic Remanent Magnetisation (ChRM). From their strongly weathered character, we conclude that the ChRM in the

TABLE 1: *Paleomagnetic sampling sites, Northparkes mine*

SITE NO.	PIT	SAMPLE NOS.	DESCRIPTION	PROFILE NO.*
PM-01	E22	NPK-01 to 06	Pink-weathered saprolite	7-8
PM-02	E22	NPK-07 to 09 NPK-46 to 63	Pink-weathered saprolite	7
PM-03	E22	NPK-10 to 15	Megamottle zone	5
PM-04	E22	NPK-16 to 21	Megamottle zone (base)	3-4
PM-05	E27	NPK-22 to 24	Pink-weathered saprolite	10
PM-06	E27	NPK-25 to 30 NPK-64 to 73	Megamottle zone (top)	5-6
PM-07	E27	NPK-31 to 36	Earthy megamottle zone	3
PM-08	E27	NPK-37 to 39	Pink-weathered saprolite	2
PM-09	E27	NPK-40 to 45 NPK-74 to 85	Mottled clay, base valley fill	?

* See Tonui (1998) for details

samples is a chemical remanent magnetisation acquired during weathering of both the in situ and transported regolith materials. Resultant paleomagnetic ages thus relate to the times of weathering, not the times of deposition of the sediments or the cooling of the orebody and host rocks. In many samples, demagnetisation revealed multi-component magnetic directions which were analysed by Principal Component Analysis (Kirschvink 1980).

Natural Remanent Magnetisation (NRM) directions (i.e. prior to demagnetisation) were scattered, with a general tendency to cluster around the present geomagnetic field direction at the site. In some of the samples this direction is consistent with contemporary (e.g. mining related) weathering. Of the nine sampled sites, only four yielded statistically reliable remanence directions.

Eleven samples from, or just beneath, the base of the valley fill sediments at Site PM-09 yielded very similar, stable magnetic directions (Fig. 1). The resultant pole position (Table 2) is consistent with a Miocene age of magnetisation (=weathering). However, such an age is inconclusive because:

1. All directions have the same (normal) polarity, which is unusual for a prolonged (>1 Ma) period of magnetisation in the Tertiary.
2. The directional grouping is very tight (Fig. 1), suggesting that remanence acquisition occurred over a brief interval of time (<1 ka).
3. The mean direction (declination 9.0°, inclination -60.7° - see Table 2) closely resembles that of the present geomagnetic field at Northparkes (declination 11.3°, inclination -64.2,°), and both have normal polarities.

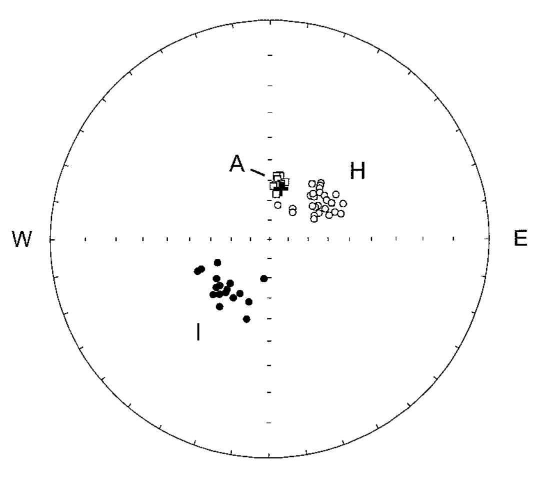

Figure 1: *I and H remanence component directions for the Northparkes saprolite (circles), and directions from the base of the valley fill, A (squares). Filled (open) symbols indicate reverse (normal) polarity directions. Cross shows present geomagnetic field direction. Equal angle projection.*

With progressive demagnetisation, samples from three sites in the saprolite, and one site in the valley fill sediments revealed a reverse polarity component, indicating remanence acquisition during weathering prior to the Brunhes/Matuyama polarity transition (0.78 Ma) - see Pillans & Bourman (1996) for further discussion. However, samples from the weathered valley fill sediments generally yielded scattered directions. Six samples from the megamottle zone at Site PM-06 yielded a pole position with a large angular uncertainty (radius of 95% confidence circle 14°; Table 2) broadly consistent with remanence acquisition during Cainozoic weathering, but results from the other four sites were too inconsistent to calculate pole positions.

The four sites in saprolite generally yielded more consistent remanence directions than those in the valley fill sediments. Principal component analysis of twenty seven samples from Sites PM-01 and PM-02, in pinkish weathered saprolite, yielded well defined intermediate (I) and high (H) temperature antiparallel remanence components (Fig. 1) with a combined mean pole position of 51.2°S, 81.4°E (A95 = 3.6°) - Table 2. This pole (NPK) plots considerably west of the Australian Cainozoic Apparent Polar Wander Path (APWP) and appears to lie on the Paleozoic APWP (Fig. 2). Two versions of the mid to late Paleozoic APWP from Lackie & Schmidt (1993) and Klootwijk (1996) respectively are shown in Figure 2. The Northparkes pole is consistent with either a middle Carboniferous age (Lackie & Schmidt APWP) or a late Carboniferous to early Permian age (Klootwijk APWP). However, the latter is ruled out by the normal polarity of the H remanence as against the reverse polarity of the late Carboniferous - late Permian geomagnetic field, unless the magnetisation has recorded a previously unknown normal polarity interval within that period.

Table 2. *Summary of paleomagnetic results from Northparkes Mine*

Component	N	Remanence Direction Dec (deg)	Inc (deg)	k	α95 (deg)	Pole Position Lat (°S)	Long (°E)	K	A95 (deg)
					Site PM-02 (Saprolite)				
Intermediate	17	41.4	-56.3	58.6	4.7	56.3	77.3	31.5	6.5
High	27	52.6	-58.8	87.8	3.0	48.0	83.5	48.4	4.0
Combined (I + H)	44	48.1	-58.0	67.7	2.6	51.2	81.4	36.6	3.6
					Site PM-06 (Valley fill)				
High	6	349.3	-61.1	47.6	9.8	187.1	77.1	23.0	14.3
					Site PM-09 (Base of valley fill)				
High	11	9.0	-60.7	628.6	1.8	111.8	78.7	389.	2.3

Notes: N = number of specimens; K and k = precision parameters; α95 and A95 = semi-angles of 95% confidence cones.

The pole NPK was calculated on the assumption that the remanence directions do not need substantial tectonic corrections, as suggested by vertical to subvertical orientation of the pipe-like monzonite intrusives (Jones 1985) that host the Northparkes orebody However, if the orientation evidence of the intrusives is discounted as inconclusive, the possiblity exists that the pole belongs to an entirely different part of the APWP, with its proximity to the Carboniferous segment being merely fortuitous

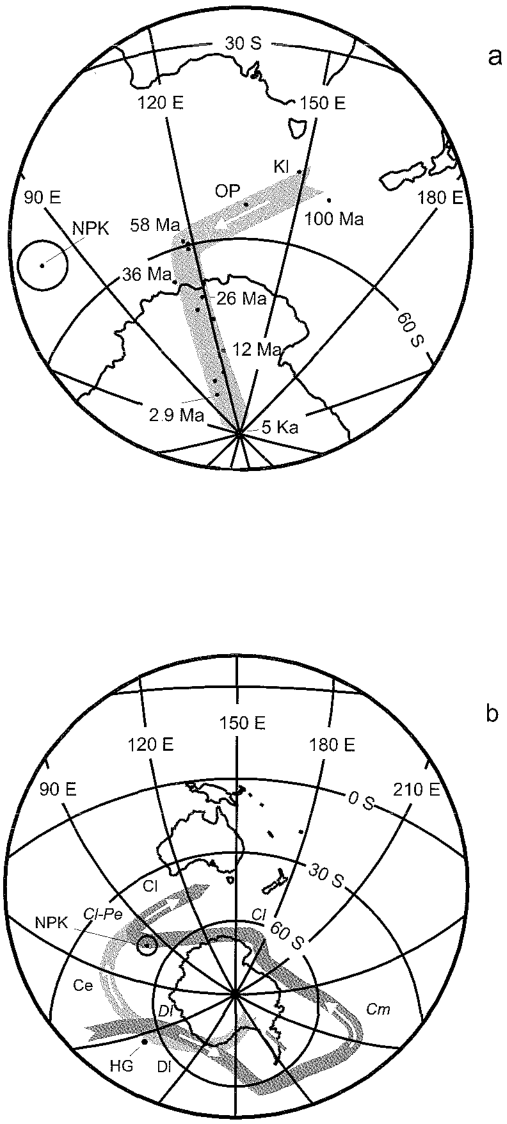

Figure 2. *Comparison of pole position (NPK) from saprolite at Northparkes mine with a the Australian Cainozoic apparent polar wander path (after Idnurm 1994) and b alternative Paleozoic apparent polar wander paths of Lackie & Schmidt (1993) [pale stipple, non-italicised symbols] and Klootwijk (1996) [dark stipple, italicised symbols] HG = pole from late Devonian Hervey Group (Li et al 1988)*

To transfer NPK onto the Tertiary APWP requires a tilt correction of >25° However, the tilting would need to have occurred during the Tertiary, which is unlikely considering the tectonic quiescence of the Parkes region in that period Therefore, a Tertiary paleomagnetic weathering age for the saprolite is ruled out The only major post-Ordovician deformations that have been recognised in the Parkes region are associated with the Tabberabberan Orogeny, which ended in the mid Devonian, and the early to mid Carboniferous Kanimblan Orogeny The Kanimblan Orogeny was preceded by erosion and deposition of continental sediments, including red beds, the sediments being represented in the Parkes region by the Hervey Group Deep weathering was, therefore, possible during that period However, it is unlikely that the saprolite formed at that time: to transfer NPK to the paleomagnetic pole for the Hervey Group (Li et al 1988) requires a tilt correction of ca 45° towards 190° - a direction that is inconsistent with the dominant NS fold trend in the Hervey Group in the Parkes region (Li et al 1988) The pole NPK is, however, compatible with the early Carboniferous APWP of Lackie & Schmidt (1993), requiring a tilt correction of 25° towards 070°

DISCUSSION

From the paleomagnetic results we infer that weathering of regolith at Northparkes mine has been an on-going process, although not necessarily continuous, since at least Paleozoic time Regional geology of the Northparkes area (e g Clarke & Sherwin 1990) suggests that that the area has probably been subaerially exposed since the late Devonian Fluvial sandstone and conglomerate beds of possible Mesozoic age (Clarke & Sherwin 1990) occur to the west of Northparkes mine, but otherwise the stratigraphic record of post-Devonian times is almost entirely unknown in the area Interpretation of apatite fission-track data in the Bathurst area, some 100 km east of Northparkes Mine, suggests kilometre-scale uplift and erosion in the mid-Cretaceous, with the amounts possibly decreasing westwards (O'Sullivan *et al* 1995) If Northparkes underwent subaerial weathering in early or mid Carboniferous times, it seems implausible that the area was buried under kilometre thickness of sediment, later to be exhumed to within perhaps a few tens of metres of the Carboniferous ground-surface

The time of deposition of the valley fill sediments at Northparkes must predate the time of weathering (Cainozoic) of the sediments and postdate the truncated saprolite (Paleozoic age) beneath The valley fill sediments may relate to a system of N-S trending valleys that predate the formation of the Canobolas Divide, which was formed by downwarping of the Murray Basin. The divide was already in existence prior to 12 Ma, as evidenced by K/Ar dated lavas which flowed down valleys to the north, south and west, and may have formed by downwarping of the Murray Basin prior to the middle Eocene (Ollier & Pain 1994), i e prior to 45 Ma The paleomagnetic ages from Northparkes Mine are therefore consistent with other evidence for the age of the Canobolas Divide

Unequivocal pre-Late Cretaceous ages for weathering profiles in southeastern Australia have not previously been reported using paleomagnetic techniques: The oldest reported paleomagnetic ages for weathering profiles appear to be for the Late Cretaceous-Early Tertiary Morney profile in southwest Queensland (Idnurm & Senior 1978) and Late Cretaceous-Early Tertiary profiles in the New England region (Schmidt & Ollier 1988) Stratigraphic (Daily et al. 1974) and oxygen isotopic evidence (Bird & Chivas 1989) support a pre-mid Jurassic age for a lateritic profile on Kangaroo Island, whereas paleomagnetic results (Schmidt et al. 1976) suggest a late Cainozoic age Based on isotopic data from kaolinite-rich weathering profiles throughout Australia, Bird & Chivas (1989) concluded that a number of profiles with low $\delta^{18}O$ compositions (< 15 ‰) represent remnants of a once extensive regolith cover that formed in a much cooler climate than has prevailed since the late Cretaceous Oxygen isotope analysis of kaolinite from Northparkes regolith materials is planned to test our paleomagnetic age estimates

ACKNOWLEDGMENTS

We are pleased to acknowledge the support of North Limited in funding this research, and for their permission to publish our results We thank Colin Pain and Chris Klootwijk for reviewing the manuscript MI publishes with the permission of the Executive Director, AGSO

REFERENCES

BIRD, M. I & CHIVAS, A R. 1989 Stable-istope geochronology of the Australian regolith *Geochimica et Cosmochimica Acta* **53**, 3239-3256.

BUTLER, R F. 1992 *Paleomagnetism. magnetic domains to geologic terranes.* Blackwell, Boston, 319pp

CLARKE, I & SHERWIN, L. (eds.). 1990 Geological setting of gold and copper deposits in the Parkes area, New South Wales *Records of the Geological Survey of New South Wales* **23**, 196 pp

DAILY, B , TWIDALE, C R & MILNES, A. R. 1974. The age of the lateritized summit surface on Kangaroo Island and adjacent areas of South Australia *Journal of the Geological Society of Australia* **21,** 387-392.

IDNURM, M. 1994. New Late Eocene pole for Australia, time-averaging of remanence directions, and palaeogeographic reference systems *Geophysical Journal International* **117**, 827-833

IDNURM, M. & SENIOR, B. 1978 Palaeomagnetic dating of weathered profiles in the Eromanga Basin, Queensland Palaeogeography, *Palaeoclimatology, Palaeoecology* **24**, 263-277

JONES, G J 1985 The Goonumbla porphyry copper deposits, New South Wales *Economic Geology* **80**, 591-613

KIRSCHVINK, J. L 1980 The least-squares line and plane and analysis of palaeomagnetic data *Geophysical Journal of the Royal Astronomical Society* **45**, 699-718

KLOOTWIJK, C 1996 Phanerozoic configuration of Greater Australia: evolution of the North West Shelf Part Two *AGSO Record* **1996/52**

LACKIE, M A. & SCHMIDT, P. W 1993. Remagnetisation of strata during the Hunter-Bowen Orogeny *Exploration Geophysics* **24**, 269-274.

LI, Z X, SCHMIDT, P. W & EMBLETON, B. J. J 1988. Palaeomagnetism of the Hervey Group, Central New South Wales and its tectonic implications *Tectonics,* **7,** 351-367

OLLIER, C D & PAIN, C F 1994. Landscape evolution and tectonics in southeastern Australia. *AGSO Journal of Australian Geology & Geophysics* **15,** 335-345

O'SULLIVAN, P B., KOHN, B P., FOSTER, D A., GLEADOW, A J W 1995 Fission track data from the Bathurst Batholith: evidence for rapid mid-Cretaceous uplift and erosion within the eastern highlands of Australia. *Australian Journal of Earth Sciences* **42**, 597-607.

PERKINS, C , McDOUGALL, I , CLAOUE-LONG, J & HEITHERSAY, P S 1990 40Ar/39Ar and U-Pb geochronology of the Goonumbla porphyry Cu-Au deposits, New South Wales, Australia *Economic Geology* **85**, 1808-1824

PILLANS, B & BOURMAN, R 1996. The Brunhes/Matuyama polarity transition (0 78 Ma) as a chronostratigraphic marker in Australian regolith studies. *AGSO Journal of Australian Geology & Geophysics* **16**, 289-294.

SCHMIDT, P W., CURREY, D T. & OLLIER, C D 1976. Sub-basaltic weathering, damsites, palaeomagnetism, and the age of lateritization *Journal of the Geological Society of Australia* **23**, 367-370.

SCHMIDT, P W & OLLIER, C D 1988 Palaeomagnetic dating of Late Cretaceous to Early Tertiary weathering in New England, N S.W., Australia *Earth-Science Reviews,* **25**, 363-371

TONUI, E 1998 Unpublished PhD thesis, Australian National University