HIGHLIGHTS FROM THE LEME GEOCHRONOLOGY PROJECT

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The current LEME Geochronology Project [full title: Geochronology and models of landscape evolution], grew out of the Paleomagnetic Dating Project that began in LEME 1 in 1995. Eleven years on, paleomagnetic dating remains at the forefront of the project, but is now supplemented by other dating methods including K/Ar and Ar/Ar, cosmogenic isotopes, luminescence, (U-Th)/He, U/Pb and U-series (Fig. 1). Of these, the latter three methods have yet to reach maturity and further work is required to fully test their applications to regolith materials; the other methods may be considered to be "well established".

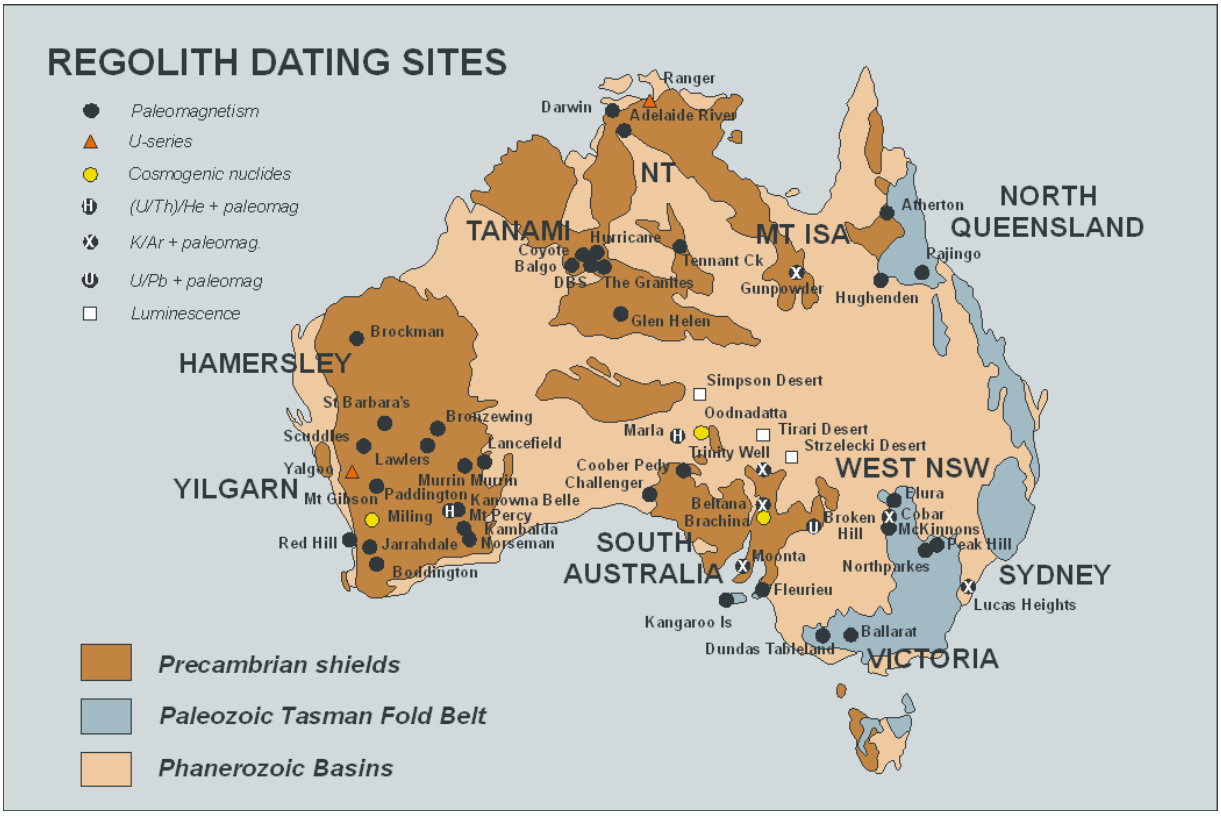


Figure 1. Map showing the distribution of sites from which samples have been dated in the Geochronology Project.

Results from paleomagnetic dating, in particular, demonstrate the great antiquity of Australian regolith, which in places is up to 320 million years old. Furthermore, from results at many sites across the continent, deep oxidative weathering occurred during three major intervals; 0-20 Ma, 60-80 Ma and 320-300 Ma, probably driven by major climatic changes (Pillans 2002). The recognition that past climate must have strongly influenced regolith processes and landforms, spawned a new project early in LEME 2, "History of Aridity".

Below I outline some of the highlights of the Geochronology Project and its forerunner, the Paleomagnetic Dating Project. Overviews of Australian regolith geochronology are given in Pillans (1998, 2005).

LACHLAN FOLD BELT

First results were obtained from Northparkes mine, where Eric Tonui was undertaking his PhD fieldwork (Tonui 1998). Oxidized saprolite yielded a surprisingly old paleomagnetic age of ~320 Ma (Pillans *et al*. 1999), which when combined with apatite fission track data, indicated episodes of kilometre-scale burial and denudation (O'Sullivan et al 2000). Interestingly, recently published K/Ar ages from Jenolan Caves (Osborne *et al*. 2006) support this regional story.

Further paleomagnetic dating has been undertaken by Martin Smith (2001; 2006) at McKinnons, Elura, New Cobar and Peak Hill mines, yielding generally younger (Cenozoic and Mesozoic) ages.

YILGARN

An early focus in the Geochronology Project was paleomagnetic dating of regolith in the Yilgarn. Sampling was undertaken in open pit mines, which provided excellent, deep exposures. Initially it was hoped to be able date the widespread, so called "lateritic residuum", however, this generally proved unsuitable for paleomagnetic dating. On the other hand, oxidized saprolite, up to 100 m below the surface, turned out to be an ideal medium, and revealed a long history of weathering dating back, in some instances, to pre-Cenozoic times. Some early results were published in Anand & Paine (2002, Table 16). These and later results clearly showed that deep oxidation had preferentially occurred during two major episodes – around 60 Ma, and during the last 12 Ma. There is also evidence of an earlier deep oxidation episode at ~300-315 Ma at Laverton (Lancefield mine) and Meekatharra (St Barbara's mine), and another at ~180 Ma at Kalgoorlie (Mt Percy). The result from Lancefield is particularly interesting because the oxidation occurs in a tillite which is overlain by shale of early Permian age (Eyles & de Broekert 2001). The paleomagnetic weathering age indicates that the tillite must be latest Carboniferous or older.

Recent studies (e.g. Pigeon *et al*. 2004; Heim *et al*. 2006) have demonstrated the potential for dating iron nodules in Western Australia using the (U-Th)/He method. Mark Paine (formerly Curtin University) and Martin Smith (ANU) have pioneered this technique in LEME.

LUCAS HEIGHTS

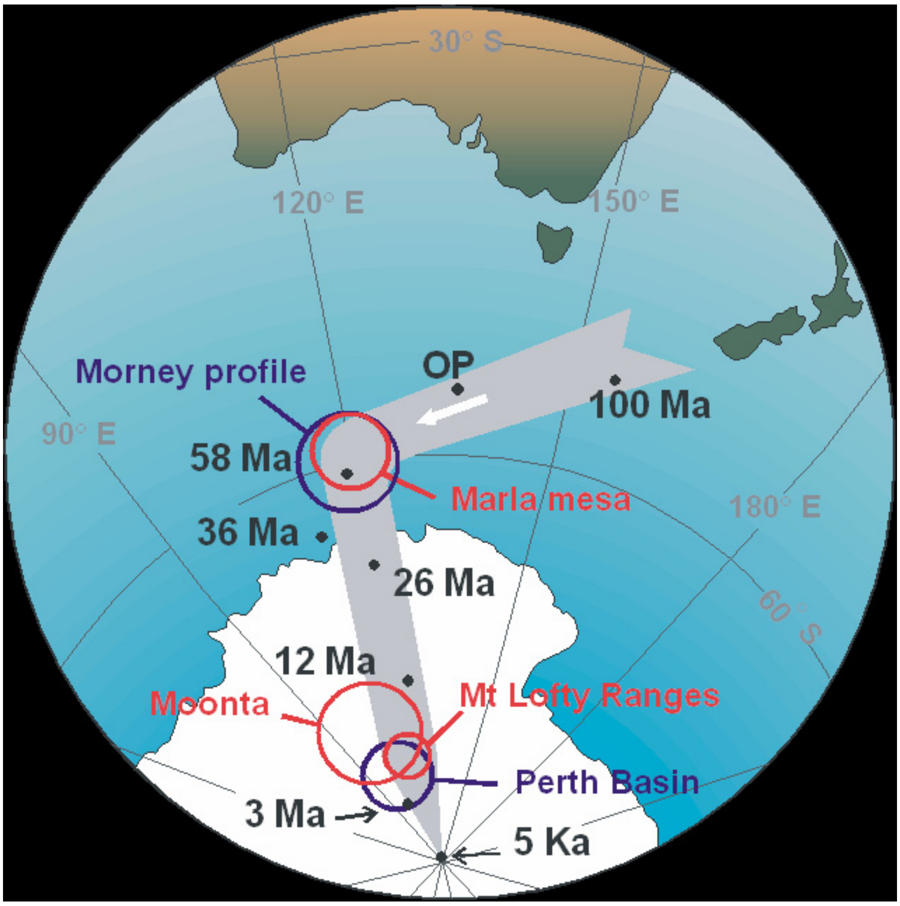
In July 2002 I was asked to assist in determining the timing of last movement of two faults on the site of the replacement research reactor (RRR) at Lucas Heights in Sydney. The steeply dipping faults could be traced for more than 100m across the RRR excavation. The eastern strand was a normal fault with a dip separation of 1-1.3 m, while the western strand was a reverse fault with a dip separation of 0.25-0.3 m. The key issue was to assess the seismic hazard posed by the faults.

With no record of historical record of seismicity or surface fault rupture, the only obvious constraint on the history of fault movement was that they offset Triassic age Hawksbury Sandstone. In other words at least one faulting event had occurred in the last 200 million years –hardly a close constraint. However, in the south wall of the excavation a layer of iron oxide was draped across, but not cut by the faults. Samples of the iron oxide layer were taken for paleomagnetic measurements, and showed that the layer had reverse polarity which must have been acquired prior to the last reversal of the Earth's magnetic field (the Matuyama/Bruhnes reversal dated at ~0.78 Ma). Thus the last fault movement occurred at least 0.78 million years ago. Indeed, the paleomagnetic pole position indicated an age of > 5 Ma (Pillans 2003), which was considered sufficiently long ago for the risk of future fault movement to be negligible, and for approval to be given to proceed with construction. The RRR will be commissioned in early 2007.

SOUTH AUSTRALIA

Following on from paleomagnetic studies of Pleistocene sections near Adelaide (Pillans & Bourman 1996, 2001), further paleomagnetic sampling was undertaken of deeply oxidized rocks in the Mount Lofty Ranges and at Moonta copper mine on Yorke Peninsula. Ages from both areas were late Cenozoic (Figure 2), as are K/Ar ages on alunite clays from Moonta (J. Dunlap pers. comm. 2005).

Figure 2. A. Marla mesa, a ferricrete-capped mesa in northern South Australia, from which a paleomagnetic weathering age of ~60 Ma has been obtained.



B. Paleomagnetic poles (95% confidence circles) for sites in South Australia, compared with two well established poles from SW Queensland (Morney Profile) and Perth Basin (WA) – data from Idnurm & Senior (1978) and Schmidt & Embleton (1976), respectively.

Further north, a ferricrete-capped mesa near Marla has become something of a reference locality – see Figure 2. Paleomagnetic samples from the ferricrete yield a well-defined pole with an age of ~60 Ma, indistinguishable from the regionally extensive Morney Profile in SW Queensland (Idnurm & Senior 1978). Preliminary (U-Th)/He ages (Smith 2006) on the ferricrete are slightly younger (~50 Ma), but are uncorrected for He diffusion losses.

At Beltana, in the Flinders Ranges, there has been much speculation about the origin of the willemite (Zn_2SiO_4) ore – is it supergene or hypogene? In 2001 I collected samples of coronadite associated with the willemite, which yielded a K/Ar age of 435±5 Ma (Groves *et al*. 2003). The age of the coronadite, together with fluid inclusion studies that indicate temperatures of formation in the range 50-150°C, clearly support a hypogene origin (Groves *et al*. 2003).

NORTHERN TERRITORY

Prior to LEME, little was known about the age of regolith in the Northern Territory, with one notable exception - a K/Ar dating study of supergene manganese deposits on Groote Eylandt by Dammer *et al*. (1996). However, in 2003, Juan-Pablo Bernal completed a PhD study on the Ranger uranium mine (Bernal 2003), demonstrating that U-series dating was feasible on goethitic pisoliths less than 0.5 million years old.

Recently, two LEME projects (NT Regolith, and Tanami projects) provided the opportunity to carry out reconnaissance paleomagnetic dating on samples from a wide range of sites (Pillans & Craig 2005). Current detailed work in the Tanami region indicates that the deep oxidation extends back to ~320 Ma, and that the area has been continuously subaerially exposed for at least 100 Ma, and perhaps longer.

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