

Drill Core Orientation using Palaeomagnetism

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Abstract

Palaeomagnetic orientation of drill core from the Sydney-Bowen Basin is feasible. A consistent magnetisation is observed in coal measures in the basin enabling the remanence of an unoriented sample to be utilised to orient the sample. Palaeomagnetic orientation of drill core for fracture analysis has been used successfully in the Sydney-Bowen Basin.

The direction of magnetic remanence in the sediments of the southern Sydney Basin is consistent across a wide area, this direction being north and up. Similarly, the remanence direction observed in Bowen Basin coal measures is consistent from the south (Moura mine) to the north (Goonyella mine) of the basin, and this direction is also north and up. The consistency of the remanence direction is lithology dependent. Fine sandstone and siltstone/mudstone units gave the most reliable results. Coarse sandstones gave inconsistent remanence directions and should not routinely be used for drill core orientation using palaeomagnetism.

A longcore magnetometer constructed by the CSIRO Rock Magnetism Group enables measurement of the remanence of HQ drill core without the need to subsample. The measurement of the remanence of HQ drill core using a longcore magnetometer shows similar results to the remanence measured using laboratory magnetometers indicating that drilling does not alter the NRM. Thus, the noninvasive orientation of drill core by measurement of remanence using a longcore magnetometer is feasible for samples from the Permian coal measures of the Sydney-Bowen Basin. As well, storage of the drill core has no or limited effect on the remanence of the drill core. A small component is sometimes present but is easily removed by AF demagnetisation.

Weathering has a severe effect on the remanence of samples, inhibiting orientation by palaeomagnetism. Weathering can produce hematite/goethite which retains a strong chemical remanent magnetisation and thus dominates the NRM of the sample.

Key words: Drill Core Orientation, Sydney Basin, Bowen Basin, Palaeomagnetism, Longcore Magnetometer.

Introduction

A consistent magnetic remanence present in rocks throughout a region can be utilised to orient drill core from the particular region. Measurement of the remanence of unoriented drill core and the subsequent rotation of this measured remanence to that of the known remanence for the region enables

orientation of the drill core. This paper outlines the research into using palaeomagnetic orientation of drill core from the coal measures of the Sydney-Bowen Basin.

Following the observation of Schmidt and Embleton (1981) that many rocks in southeastern Australia have been severely overprinted magnetically in the Cretaceous, an investigation of the magnetic properties of samples of the Sydney Basin coal measures was carried out (Schmidt and Anderson, 1991; 1992). These studies showed that the sediments possess a consistent magnetic direction and this direction can be used in the orientation of drill core. Following the Sydney Basin study, oriented samples were collected from five collieries in the Bowen Basin. Results show that a consistent remanence direction is present in the coal measures in the basin (Lackie, 1993) and that palaeomagnetic orientation of drill core from the coal measures is feasible.

As an adjunct to the study of the magnetic properties of the coal measures of the Sydney-Bowen Basin a horizontal spinner magnetometer (longcore magnetometer) was constructed to enable measurement of the remanence of drill core without the need to subsample the drill core. This paper compares the remanence measured with a longcore magnetometer to that measured using laboratory magnetometers from drill core samples from the Sydney-Bowen Basin.

Sydney Basin

Oriented samples were collected from the drift at the Tahmoor Colliery (Fig. 1) in the southern Sydney Basin. The stratigraphy sampled spanned most of the Narrabeen Group (Coalcliff Sandstone to the Bald Hill Claystone or equivalents) immediately overlying the Bulli Seam. Samples were also collected from the old adit and the rock-pool at Coalcliff (Fig. 1). The natural remanent magnetisation (NRM) for the majority of samples from the Tahmoor drift and from Coalcliff is directed northward and steeply upward (Figs 2a, 3a). Alternating field (AF) demagnetisation of samples (Figs 2b, 3b) shows that the NRM is stable, with little change in direction after demagnetisation of 100 Oe [10 mT]. The mean direction for the samples from Tahmoor has a Declination = 006.0°, an Inclination = -76.4° and an $\alpha_{95} = 1.6^\circ$ (i.e. the oval area within this angular distance of the estimated mean direction contains the true mean direction with 95% confidence). The mean direction for the samples from Coalcliff is Declination = 355.2°, Inclination = -74.4° and $\alpha_{95} = 3.7^\circ$. The mean NRM inclinations are significantly steeper than the present geomagnetic field at Tahmoor/Coalcliff, which has a direction of Declination = 012.4°, Inclination = -65.3°. The NRM is therefore not related to a recent magnetisation but is similar to the Cretaceous overprint reported by Schmidt and

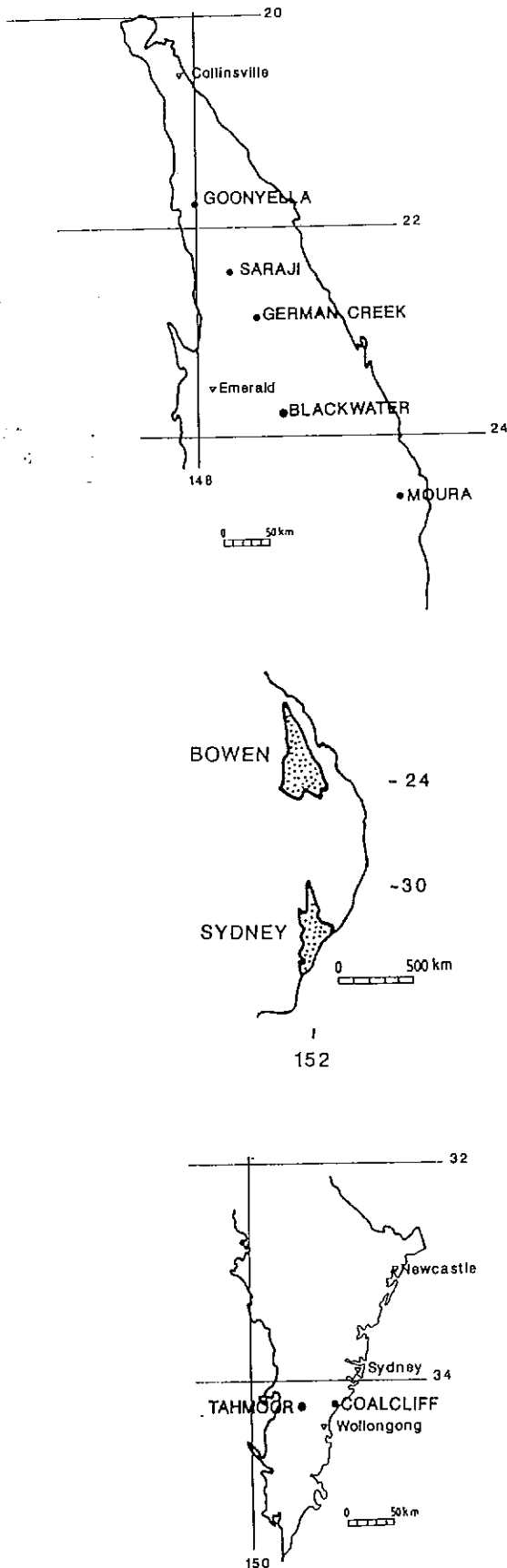


FIGURE 1
 Sketch map of the outcropping Sydney-Bowen Basin showing the collieries at which oriented samples were taken. Collieries sampled in the Bowen Basin were: Moura; Blackwater; German Creek; Saraji; and Goonyella. In the Sydney Basin, the Tahmoor Colliery and the old adit at Coalcliff were sampled.

Embleton (1981). The overall mean declination of the samples from Tahmoor and Coalcliff is 000° (i.e. North). This direction can then be thought of as the palaeomagnetic reference direction for the southern Sydney Basin.

Tahmoor

In 1992, palaeomagnetic orientation was done on twenty drill core samples from eight drill holes in the Tahmoor area to orientate faults and fractures which were observed in the drill core. One of the drill holes studied is TNC14, which is just

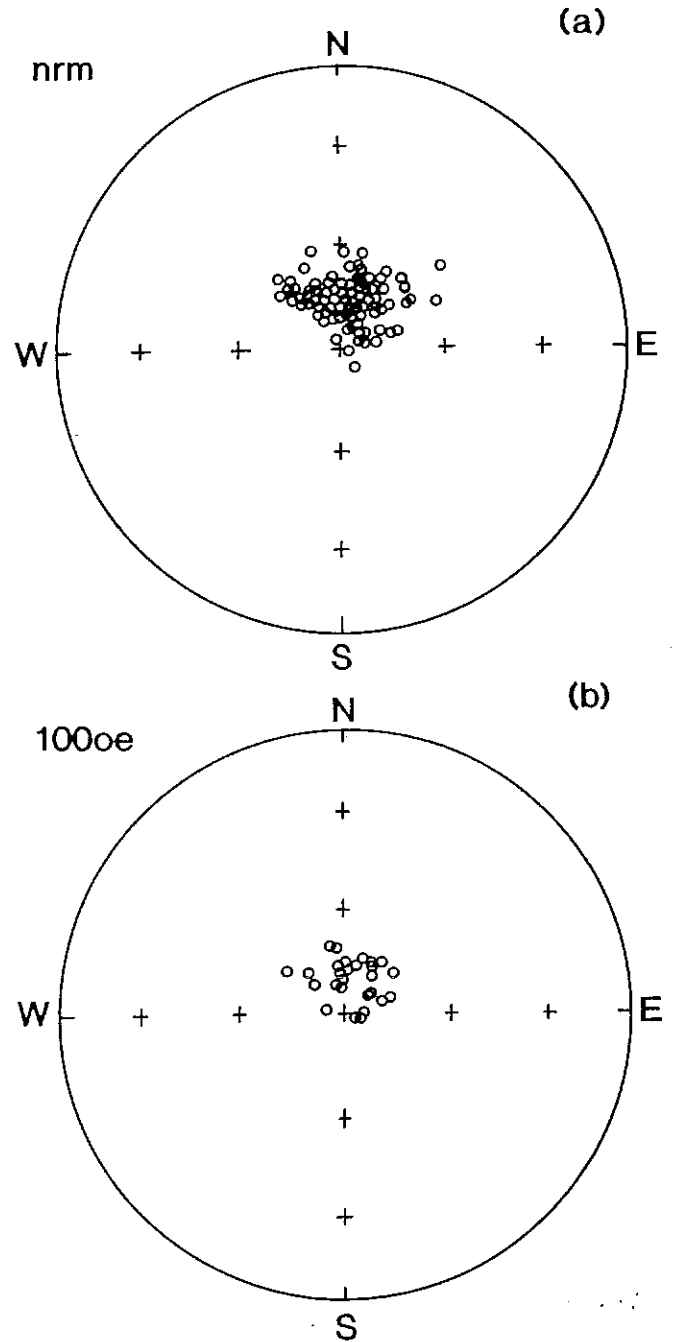


FIGURE 2
 Equal area plots of the remanence of specimens from Tahmoor. (a) NRM. (b) After AF demagnetisation of 100 Oe [10 mT]. Closed (open) symbols indicate lower (upper) hemisphere. Note the stability of the remanence which does not change direction after AF demagnetisation of 100 Oe [10 mT].

to the north of the Tahmoor Colliery. With this drill hole, a steep fracture was of interest and a fiducial line was marked in a down dip direction on a sample in which the fracture is present. The results of the longcore magnetometer measurement of the remanence of a sample of drill core (~436 m) are shown in Fig. 4. The relative declination results are very consistent with a mean declination of 266° with reference to the fiducial mark. The drill core sample was subsequently subsampled and the remanence of these subsamples was measured using a more sensitive cryogenic magnetometer. Samples were then AF demagnetised to check the stability of the remanence. The NRM directions of the subsamples are very consistent (Fig. 5a) with a mean direction

of relative declination of 254°. This direction is in good agreement with the longcore result. AF demagnetisation of specimens shows (Fig. 5b) that the NRM direction is stable with no change in direction after demagnetisation of 100 Oe [10 mT]. The resultant direction of the fiducial mark after rotation of the measured declination to the palaeomagnetic reference direction is 106°. This indicates that the dip of the fractures is to the east. The strike of these fractures (N/S) is similar to faults observed from seismic studies of the area.

Bowen Basin

Oriented samples were collected from five collieries in the Bowen Basin (Fig. 1). The collieries were: Moura; Blackwater; German Creek (southern); Saraji; and Goonyella. Samples were taken from the Moranbah, Rangal and Baralaba Coal Measures, as well as the German Creek Formation. The lithologies sampled ranged from mudstones to coarse-grained sandstones. Samples were taken from the floors and roofs of seams, as well as from sediments away from the seams.

The NRM directions of all specimens, excluding coarse-grained sandstones, from the five collieries are plotted in Fig. 6. The consistency of the directions is excellent, with the dominant NRM direction being northerly and up. This remanence direction is observed from the south (Moura) to the north (Goonyella) of the basin and thus can be used as a palaeomagnetic reference direction for coal measures within the basin. Fine-grained sandstones and siltstone/mudstone units gave the most reliable results. Coarse sandstones gave inconsistent results and should not be used routinely for drill core orientation.

German Creek

Drill core samples were obtained from the German Creek Colliery in order to compare remanence results obtained from

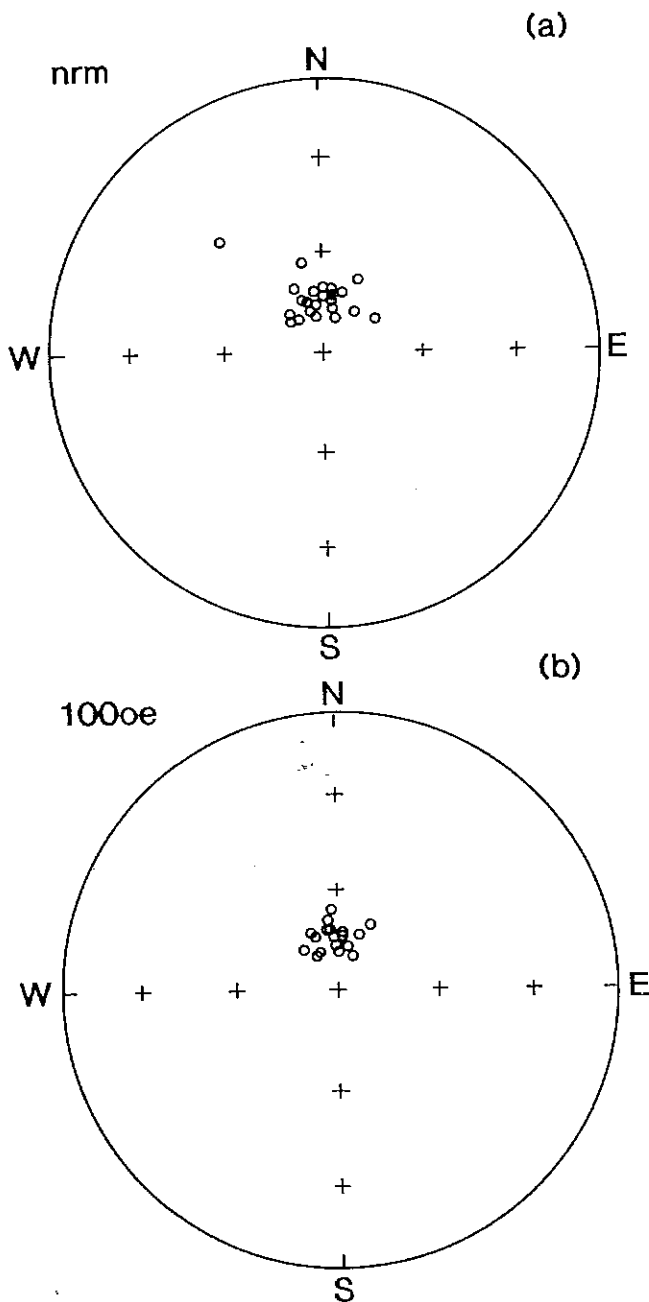


FIGURE 3
Equal area plots of the remanence of specimens from Coalcliff. (a) NRM. (b) After AF demagnetisation of 100 Oe [10 mT]. Closed (open) symbols indicate lower (upper) hemisphere. Note the stability of the remanence which does not change direction after AF demagnetisation of 100 Oe [10 mT].

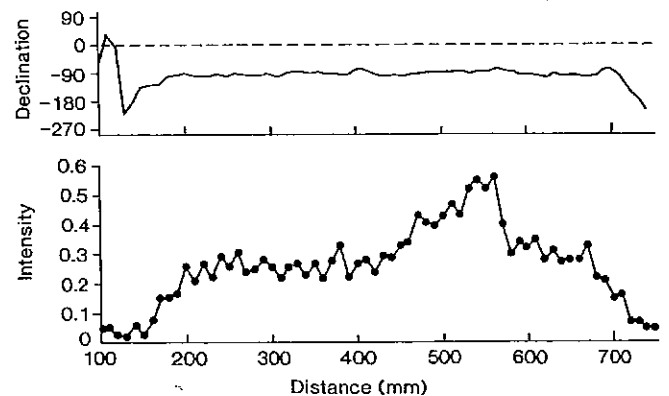


FIGURE 4
Results of longcore magnetometer measurements on a drill core sample from drill hole TNC14 at Tahmoor. Upper plot shows the variation of declination along the core, with 0° indicating the reference line on the core. Lower plot shows the variation of magnetic intensity along the core. Unit of intensity is μG [mA/m]. The ends of the core are at 180 mm and 700 mm. The mean relative declination of the core is 266° with a standard error of 1° and a precision parameter of 58. Note, the sample intensity ranges from 0.2 μG to 0.6 μG and the declination is very consistent along the length of the sample.

the longcore magnetometer with those obtained from the cryogenic magnetometer. Samples were taken from three drill holes and were all fine- to medium-grained sandstones. The results from one of the drill holes (DDH98) are presented here. The longcore magnetometer results for sample DDH98A show a consistent relative declination (Fig. 7) with a mean of 11° with respect to a marked reference line. The NRM of subsamples taken from sample DDH98A show a tight grouping of relative declination with a mean of 010° (Fig. 8).

This mean direction coincides with the longcore mean direction. Thus the remanence of the drill core has not been affected by the drilling process and measurement of the NRM of drill core with the longcore magnetometer will allow reliable orientation of drill core. AF demagnetisation of the subsamples showed that the NRM direction is stable.

Another sample (DDH98B) from this drill hole did not show consistent longcore magnetometer results but showed inconsistent declination results and variable intensities (Fig. 9). The NRM of subsamples taken from the drill core show

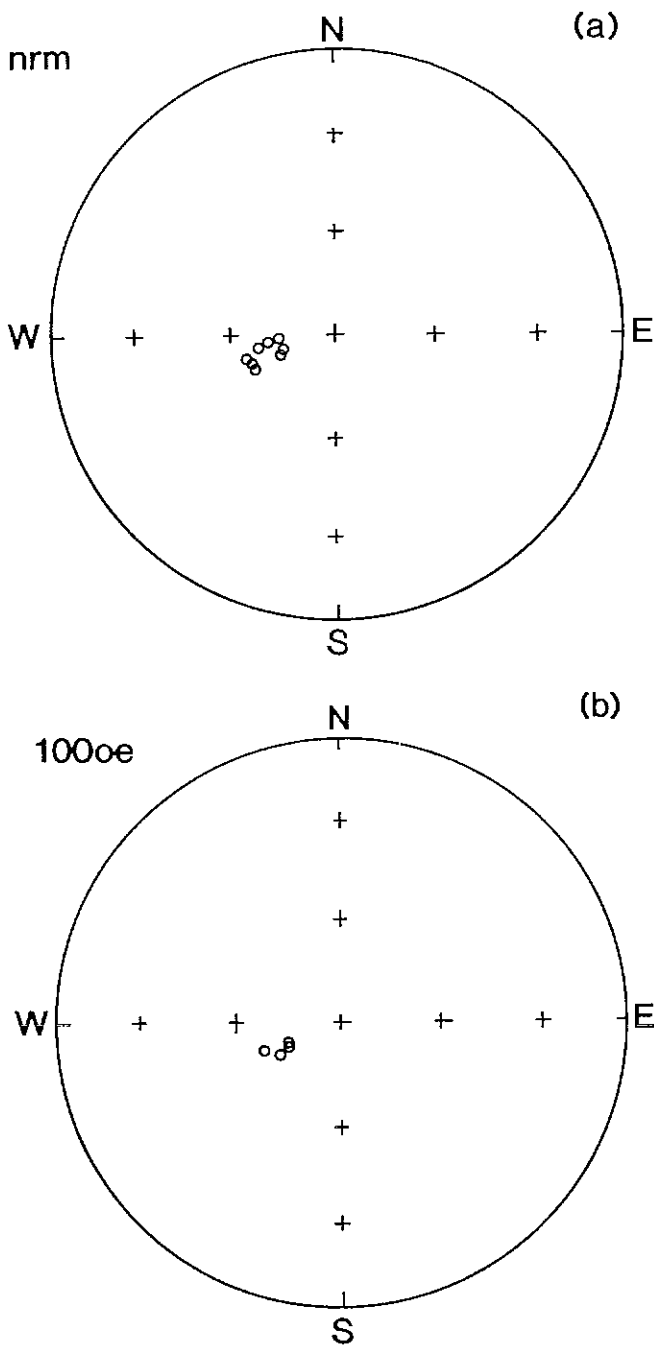


FIGURE 5 Equal area plots of the remanence of subsamples from the drill core sample from drill hole TNC14. Closed (open) symbols indicate lower (upper) hemisphere. Note the stability of the remanence which does not change direction after AF demagnetisation of 100 Oe [10 mT]. Compare the mean relative declination (254°) with the mean declination measured with the longcore magnetometer (Fig. 4).

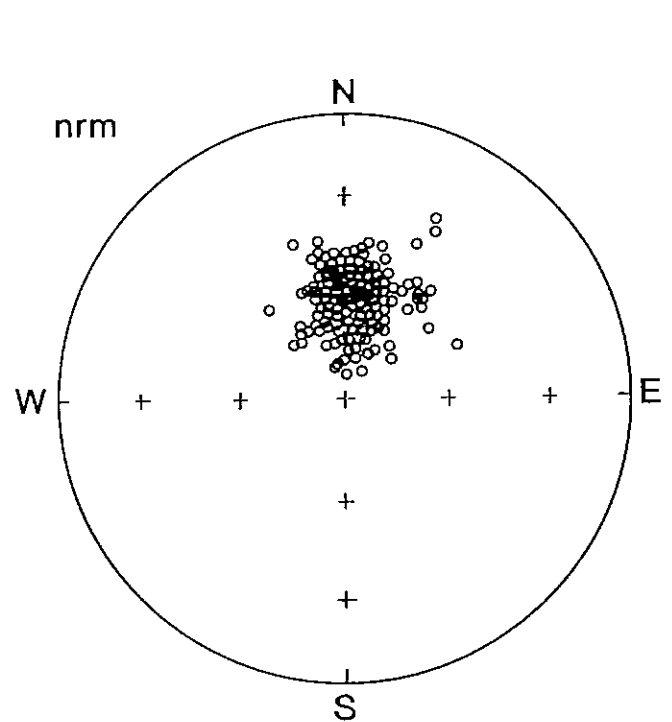


FIGURE 6 Equal area plot of the NRM of specimens from the five collieries sampled in the Bowen Basin. Closed (open) symbols indicate lower (upper) hemisphere. Note the excellent grouping of the directions around north. Samples from coarse-grained lithologies have not been included in the plot nor have those samples whose orientation was not accurately determined when the sample was originally obtained.

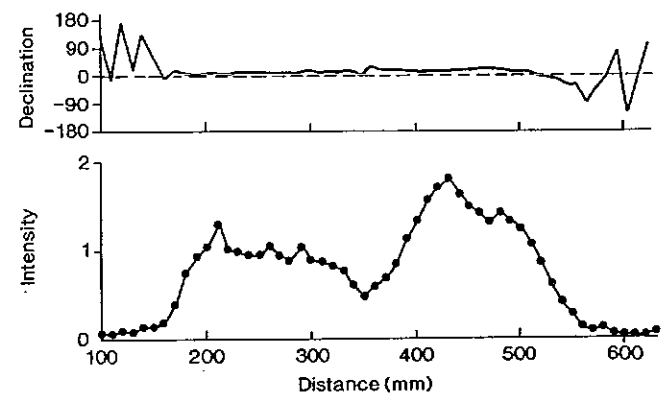


FIGURE 7 Results of longcore magnetometer measurements on a drill core sample (98A) from drill hole DDH98 at German Creek. The ends of the core are at 200 mm and 500 mm. The relative declination is consistent over the length of the core, with a mean relative declination of 11°, which has a standard error of 1° and precision parameter of 137. The intensity varies from ~0.6 μG [mA/m] up to ~1.8 μG [mA/m]. See Fig. 4 for an explanation of the plots.

a similar relative declination to that observed with the longcore magnetometer. The declinations vary from south to west through north, as is observed with the longcore result. The ends of the drill core sample show much higher ($> 1.5 \mu\text{G}$ [mA/m]) intensities than the centre section of the core ($\sim 0.3 \mu\text{G}$ [mA/m]). The ends of the core are fractures which show the orange coloured stain of weathering. The large intensity increases are the result of goethitic/hematitic weathering from the fractures. AF demagnetisation of weathered and non-weathered subsamples indicated that the remanence of the

weathered subsamples is held by hematite or goethite while magnetite is present in the non-weathered subsamples. The weathering has produced a chemical remanent magnetisation (CRM) in goethite/hematite, which is dominating or even has totally replaced the previous remanence. Obviously weathered samples cannot be used for palaeomagnetic orientation.

Conclusions

Palaeomagnetic orientation of drill core from the Sydney-Bowen Basin is feasible. A consistent magnetisation is observed in coal measures in the basins (Figs 2, 3, 6), thus enabling the remanence of an unoriented sample to be utilised to orient the sample. Palaeomagnetic orientation of drill core for fracture analysis has been used successfully in the Sydney-Bowen Basin.

There is good agreement between longcore magnetometer results and cryogenic magnetometer results (compare Figs 4 and 5, 7 and 8). Thus measurement of the NRM of drill core with the longcore magnetometer will allow reliable non-invasive orientation of drill core, both recent and old.

It has been found that the finer grained lithologies (medium-grained sandstones or less) are best for drill core orientation. Coarse-grained sandstones may give inconsistent results, although some examples have displayed excellent results.

Weathering has a severe effect on the remanence of samples inhibiting orientation by palaeomagnetism. Weathering can produce hematite/goethite which retains a strong chemical remanent magnetisation and thus dominates the NRM of the sample.

Storage of drill core has no or limited effect on the remanence of the drill core. A small component is sometimes present but is easily removed by AF demagnetisation. The actual drilling of the core does not affect the remanence of the core.

The age of the remanence of the coal measures in the Sydney Basin is Cretaceous. The age of the remanence of the coal measures in the Bowen Basin is possibly Cretaceous. This is the current focus of our research.

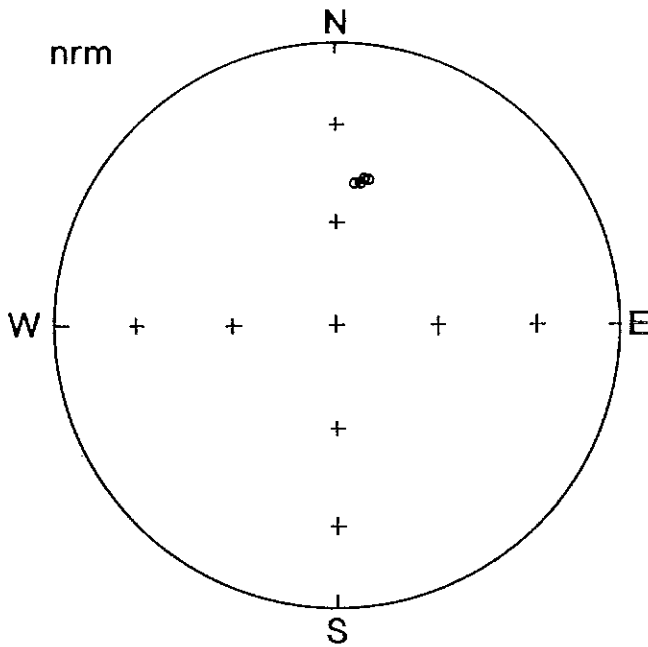


FIGURE 8
Equal area plots of the NRM of subsamples from the drill core sample from drill hole DDH98A at German Creek. Closed (open) symbols indicate lower (upper) hemisphere. Compare the mean relative declination (10°) with that shown by the longcore magnetometer result shown in Fig. 7.

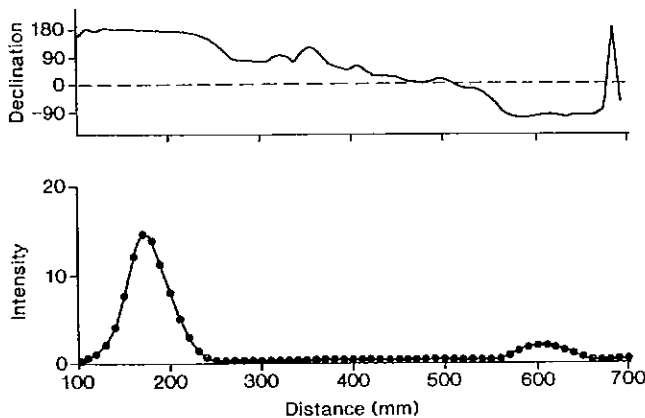


FIGURE 9
Results of longcore magnetometer measurements on a drill core sample (98B) from drill hole DDH98 at German Creek. The ends of the core are at 160 mm and 610 mm. The declinations vary from south at the bottom of the core (left side of plot) to west at the top of the core through north in the centre of the core. The ends of the sample show much higher ($> 1.5 \mu\text{G}$ [mA/m]) intensities than the centre section of the core ($\sim 0.3 \mu\text{G}$ [mA/m]). This sample shows the severe effect that weathering can have on the remanence of samples. See Fig. 4 for an explanation of the plots.

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