MAGNETOSTRATIGRAPHY

A Summary

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Introduction

Magnetostratigraphy is the element of stratigraphy that deals with the magnetic characteristics of rock units[1], obtained by measuring the direction and intensity of magnetism in rocks of different ages. The magnetic characteristic most often used, however, is the polarity of magnetic remanence. The polarity is said to be "normal" (north-seeking magnetization gives a northern hemisphere pole, as today) or "reverse" (north-seeking magnetism gives a southern pole). The polarity is established from isolating of the primary remanent magnetism of the sample, using paleomagnetic investigation [2&3].

Magnetostratigraphy defines the sequence of geomagnetic polarity reversals recorded during deposition of a geological formation. This approach can be a very valuable technique for the subsurface correlation of marine and continental sequences and is the only correlation technique which is independent of any facies control. It provides an important complement to biostratigraphy for core correlating and dating. In general the rock magnetic stratigraphy involves the utilization of magnetic properties of sediments and sedimentary rocks as a means of (1) stratigraphic correlation, (2) identification of sediment sources and transport mechanism, (3) characterization/detection of paleoenvironmental change[4].

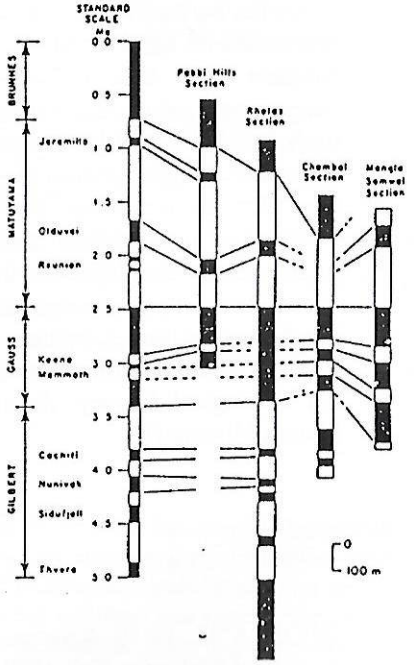


Figure 1. An example of magnetostratigraphic correlation of local reversal sequences in four composite sections, with the standard sequence at left.[15]

Background Theory

Since geomagnetic reversals are globally synchronous events, they provide a powerful supplement to conventional biostratigraphic data. Significant improvements in resolution result, especially for biostratigraphically - impov-

erished sequences. Dating is achieved by correlating the observed polarity sequence with the magnetic polarity timescale. The technique has the potential to be applied to all parts of the stratigraphic section, which were laid down during a time interval when the Earth's magnetic field periodically reversed. The technique can be applied to all sedimentary and bedded volcanic rocks which contain primary magnetic iron oxide or sulfide minerals which have not suffered tectonic, thermal and or chemical effects during their post-depositional history, as these would have removed the primary (depositional) remanent magnetization[3].

Sample Preparation and Laboratory Procedures

In the laboratory, paleomagnetic investigation should be applied on standard 25mm core plugs, or in some circumstances they can be made on the core sections[2] or fresh outcrop samples. In the case of sediment cores, rock magnetic methods are generally conducted on subsamples from sediment cores often collected as 8-cm^3 plastic cubes[4]. Many laboratory equipments are made of non-magnetic materials to avoid post-sampling magnetization. Although well lithified sediments are easier to handle and work with, poorly consolidated sediments can still produce good results, particularly if they are fine grained.

It is necessary to first restore core pieces into their original in-situ positions with respect to North and the vertical, before interpret spatial data from cores (such as directions of sedimentary structures or fracture planes). This is the process of core re-orientation. Paleomagnetic re-orientation is achieved by measuring and analyzing the remanent magnetism of the sample. The mean direction of remanent magnetism for a given interval of core defines the direction of geographic North relative to a scribed orientation line. Incremental demagnetization analysis is used to isolate different components of magnetism in the rock, which define present-day North and paleo-North at the time of rock formation. These components may be used separately or together for core re-orientation. Measurement of remanent magnetizations of samples are performed by using either a spinner magnetometer or super conducting rock magnetometer, depending on the magnetization intensities. Magnetic susceptibilities are measured with a agnetic susceptibility meter. The two routine "cleaning" techniques used are alternating field demagnetization and thermal demagnetization to isolate characteristic remanent magnetizations (ChRM)[5]. An alternating field demagnetization (AFD) current controller (Fig.2) is used for the alternating field demagnetization and thermal demagnetizer is used for thermal demagnetization.

Advantage

The paleomagnetic method has the particular advantage that measurements are made on samples from the core itself, rather than requiring specialized and expensive downhole tools. Consequently, it can be applied to virtually all cores, regardless of the

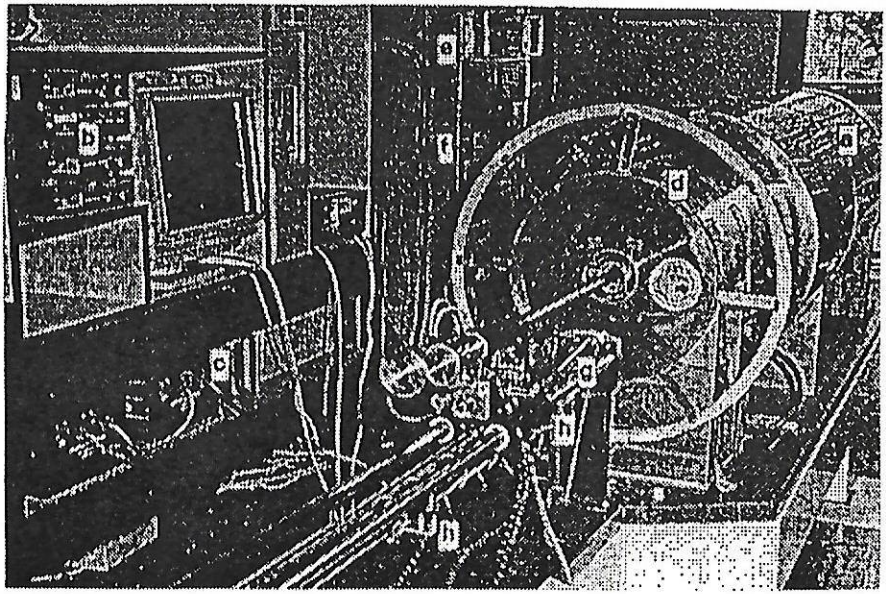


Figure 2. Figure 1. Overview of the atuomated AFD system. a. magnetometer, b. magnetic field sensor signal display and processing electronics, c. stepper-motor controller for trsnlation and rotation of samples in the measurement and AF-coil positions, d. AF-coil sets, e. AF generation and control electronics, f. bias coils supply, g. sample-holder support bridge, h. optosensors[14].

drilling technique used or the type or quality of downhole survey data available. For barren interval where biostratigraphy data are not available this method will be one of the most useful technique. Since the polarity extent globally, long distance correlations become possible.

Limitation

This method so far can not be used if the sediments have been heated up to high enough temperature for a long enough period of time. This condition make the primary remanent magnetization wholly unblocked and overprinted by a thermoviscous remanent magnetization. Where the sediments have suffered diagenetic effect, which have resulted in the dissolution of the detrital magnetic minerals by aggressive reducing fluids, then this can result in the loss of primary magnetizations. If the stratigraphic interval has no magnetic polarity variation (Earth's magnetic field was stable), no correlation can be made base on this method. Tectonic deformation can also create problem when resulting in reorientation of magnetic minerals or perma-

nent deformation of magnetic mineral lattice fabrics and associated distortion of their magnetization. Therefore to avoid these condition, the determination of the relaxation time spectrum of samples, usually by determining their present range of blocking temperatures or coercivity are fundamental to all paleomagnetic investigation[6]. Besides that, collecting of samples should be wholly free from weathering product and the natural dip of the all outcrop must be measured to applied the field tests of paleomagnetic stability[7].

Application

Published magnetostratigraphic studies in Indonesia are limited due to rather complicated analyses procedure and relatively expensive. Some publications which show the application of magnetostratigraphy are as follow:

* Magnetostratigraphy has been applied in Bandung area, West Java by Edy Sunardi to establish the stratigraphy of the volcanic rocks for the last 4 Ma. This study revealed the first comprehensive establishment of the magnetic polarity stratigraphy of volcanic rocks in Indonesia. An extended abstract of this study can be read in this volume (Edy Sunardi also published his paper together with R. P. Koesoemadinata in the 26th IAGI Meeting in 1997 [5]).

* Paleomagnetic investigation of Plio-Pleistocene formations in Sangiran and Mojokerto, Java was carried out to date stratigraphic levels of Phithecanthropus fossils. Secular variation records of paleomagnetic field direction from the two areas show very consistent changes with some prominent features. The record for the past 3 million years obtained in Sangiran revises the magnetostratigraphy of earlier investigations and reveals stratigraphic levels of polarity boundaries and events. Based on correlation of the secular variation record of Mojokerto with that of Sangiran, magnetostratigraphy of Pleistocene formations in Mojokerto was established. The stratigraphic zone of Pithecanthropus in Sangiran ranges from the lower boundary of Jaramillo event to the Brunhes/Matuyama boundary, and the stratigraphic level of Homo modjokertensis lies at the lower border of Jaramillo event. Magnetochronologically it dates from about 0.73 - 0.97 m.y. for Sangiran and about 0.97 m.y. for Mojokerto[8].

* Paleomagnetic study of the northern arm of Sulawesi, support a clockwise rotational motion of the northern arm of Sulawesi. The 90° rotation occured after the Eocene/Early Miocene period. The pole of rotation was located at the eastern end of the northern arm, near Menado. The rotational motion ceased before the volcanic activity was renewed at the Plio-Pleistocene. This paleomagnetic study allow to construct the evolution of Sulawesi[9].

* None of oil industry example in Indonesia can be found in common publication so far. But various technique including a newly emerging technique which will be of general interest to the oil industry can be studied from the Geological Society Special Publication No. 98[10], this publication explores the applicability and potential of paleomagnetic techniques to hydrocarbon exploration and production[6]. Therefore, this potential paleomagnetic applications awaiting the sedimentary geologist

willing to explore these new paleomagnetic tool[11]. This method, however, has proved the ability to build a stratigraphic framework and undertaking facies analysis in barren sediments.

Conclusion

Magnetostratigraphy which simply defined as stratigraphy based on magnetic polarity recorded in the rock is useful for barren interval (interval with no fossil dating) correlation. This method is not really popular as this method is relatively new and rather complicated procedures required. However, this technique has been applied in Indonesia.

Recommendation

Pilot project with universities are suggested once they established the laboratory. University of Padjajaran for example will set up paleomagnetic laboratory with Japan university graduate experts. Contact Edy Sunardi for detail[12]. GRDC / PPPG has also some experts in paleomagnetic study and Bambang Dwiyanto, M.Sc. is the contact person[13].

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