J Geophys (1987) 61:64–66

Journal of Geophysics

Palaeomagnetism of sedimentary rocks of the uppermost Cretaceous from the oases of Dakhla and Kharga in the Western Desert of Egypt

S. Saradeth, H. Soffel, and A. Schult

Institut für Allgemeine und Angewandte Geophysik, Universität München, Theresienstrasse 41, D-8000 München 2, Federal Republic of Germany

Abstract. In the Western Desert of Egypt two profiles have been sampled at the Cretaceous-Tertiary boundary: one at Gebel Gifata near the Dakhla Oasis (29.0° E, 25.5° N) and the other at the Abutatur phosphate mine in the vicinity of Kharga Oasis (30.5° E, 25.5° N). The rock sequences, consisting mainly of limestones and shales, were found to be extremely weakly magnetized. A complete sampling along profiles across the Cretaceous-Tertiary boundary was not possible because many parts of the profiles were covered with debris. The presence of goethite also made many rocks unsuitable for a palaeomagnetic study. However, seven profile sections without goethite (six with normal and one with reversed polarity), all from the Gebel Gifata near the Dakhla Oasis, yielded a mean characteristic remanence direction of $D=357.6°$ E, $I=32.0°$, from which a virtual geomagnetic pole position at 224.7° E, 81.5° N, $A=8.5°$ could be calculated. This pole position is in good agreement with other Upper Cretaceous – Lower Tertiary poles of Egypt (Schult et al., 1981).

Key words: Cretaceous-Tertiary boundary – Palaeomagnetism – Africa – Apparent polar wander path

Introduction

The Cretaceous-Tertiary boundary has become a subject of increasing interest for many disciplines in the geosciences because of the suspected impact of a large meteorite at this period with fatal consequences for life on earth (Silver and Schultz, 1982). Sedimentary sequences of that age interval have been carefully studied in the meantime by various groups of geoscientists, also with regard to the structure of the geomagnetic field. The reversal pattern of the geomagnetic field around the Cretaceous-Tertiary boundary (Alvarez and Lowrie, 1978) shows some characteristic features which can be used for the determination of the age of sedimentary piles, provided that a complete sampling is possible.

In connection with the Special Research Project No. 69 of the Technical University of Berlin we have been able to take samples at two profiles from the Cretaceous-Tertiary boundary in the Dakhla and Kharga Oases in the Western Desert in Egypt for such a palaeomagnetic and magnetostratigraphic study.

Sampling

The stratigraphy of the sampling sites has been studied by Barthel and Herrmann-Degen (1981). The series consists mainly of limestones (Tarawan and Kurkur formation of Lower Paleocene age) and shales (Dakhla shale) ranging in age from the Lower Paleocene into the Campanian, with some economically interesting phosphate horizons in the Campanian. The Cretaceous-Tertiary boundary is believed to coincide with the so-called Bir-Abu-Munqar horizon. Many parts of the profiles were either not accessible or covered with debris, or were otherwise not suitable for sampling (material which was too soft or too fractured, so that not even hand samples could be taken). The oriented cores were drilled with portable core drilling machines at distances of about 0.5 m. In the Dakhla and Kharga area, 484 and 187 cores, respectively, have been sampled, each core yielding 1–3 cylindrical specimens 2.5 cm in diameter and 2.3 cm in length.

Rock magnetic measurements

The magnetic susceptibility X of the rocks was measured first with a Kappabridge (Jelinek, 1973) in order to find ways for their classification and characterization. Most of the specimens of the Dakhla profile (about 80%) are weakly paramagnetic ($X>0$), indicating at least some iron content in the limestones and the shales. The remaining 20% were found to be diamagnetic ($X<0$); predominantly limestones. Most of the specimens from the Kharga profile (about 60%) are diamagnetic as well. From the diamagnetism of many specimens, an extremely low iron content can be expected which is estimated to be less than a few 100 ppm. The remaining specimens from this profile were found to be weakly paramagnetic. The low iron content of many specimens from both profiles indicates a poor quality of these rocks for any palaeomagnetic measurement. As it turned out later, only the predominantly paramagnetic shales of the Gebel Gifata site (Dakhla Oasis) gave reasonably reliable palaeomagnetic results in some parts. More details about the rock magnetic properties of the samples can be taken from an internal report (Saradeth et al. 1986).

According to Dunlop (1972), the acquisition of Isothermal Remanent Magnetization (IRM) with increasing intensity of the magnetic field gives indications for the ferrimagnetic mineralogy. Figure 1 shows some typical IRM-acquisition curves. Magnetite and hematite are only rarely present (Fig. 1a), whereas goethite (Fig. 1b) was found to be

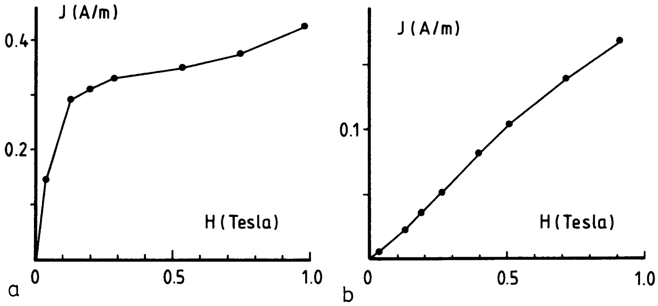

Fig. 1a, b. Isothermal remanence acquisition curves in fields up to 1 T for **a** a sample containing mostly magnetite (with some hematite) and **b** a sample containing goethite as magnetic mineral

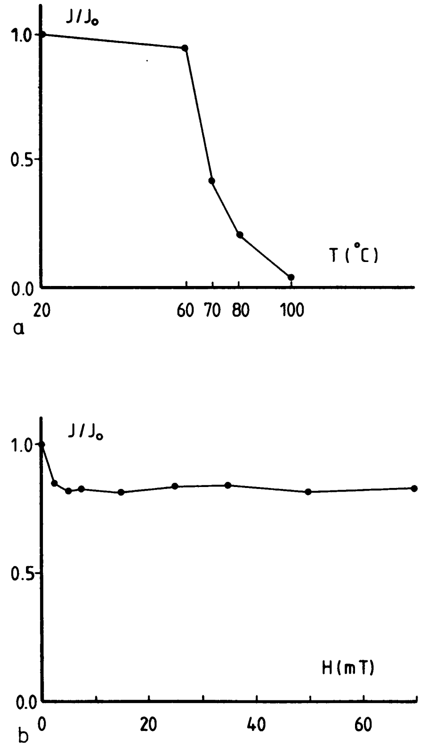

Fig. 3a, b. Variation of NRM intensity of samples containing goethite during **a** thermal and **b** alternating-field demagnetization

the dominant ferrimagnetic mineral in many rocks. This is also revealed in the thermal demagnetization and alternating-field demagnetization curves, which are discussed in a later section. Goethite is an iron-oxide mineral which is formed during weathering from other iron oxides (predominantly magnetite). The presence of goethite in rocks is always regarded as indicative of a complete or partial loss of any primary remanent magnetization in favour of a secondary remanence of uncertain age.

Palaeomagnetic measurements

Due to the low iron content of many rock specimens, a rather low intensity of the remanent magnetization could be expected. The measurements were carried out with the cryogenic magnetometer at the University of Bochum. The sensitivity of the available instrument was $1–2 \times 10^{-7}$ Gauss or $1–2 \times 10^{-4}$ A/m. Even with this instrument it was not possible to measure the Natural Remanent Magnetization (NRM) of all specimens. This is in agreement with the results of the susceptibility measurements which showed that most specimens of this profile are diamagnetic with an obviously extremely low iron content. The specimens of the Dakhla profile were found to have much higher NRM intensities. This is in agreement with the higher abundance of specimens with a paramagmetic susceptibility in this collection.

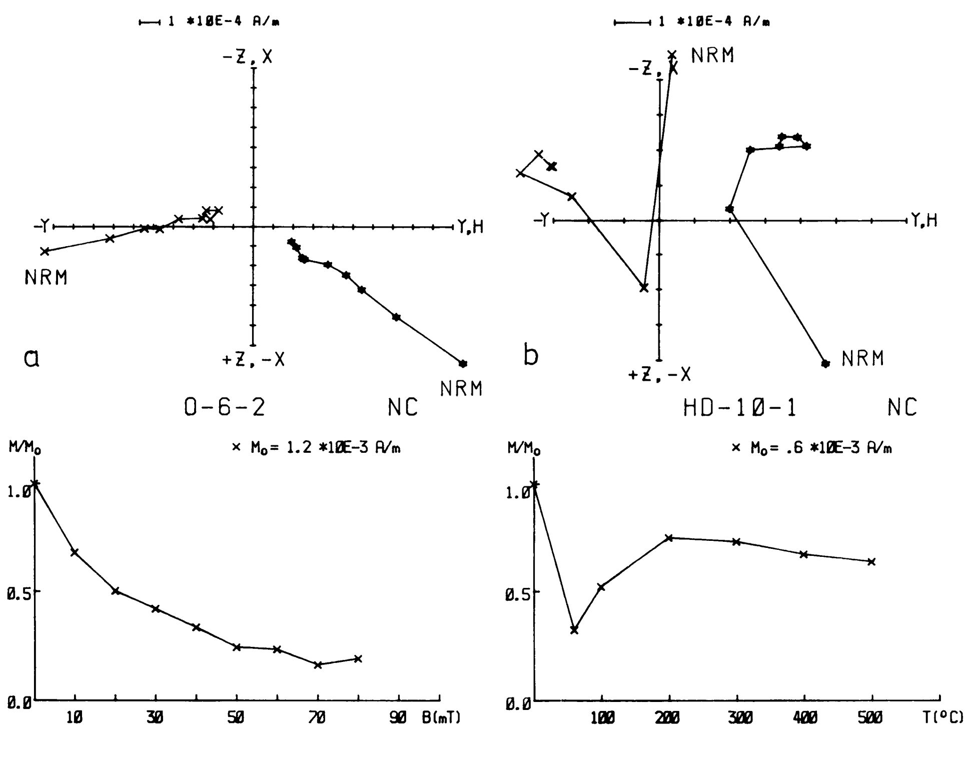

Fig. 2a, b. Vector and intensity diagrams showing the change of magnetization with respect to an internal coordinate system during demagnetization. *Crosses:* projection onto the horizontal *x–y* plane; *stars:* projection onto a vertical *H–z* plane. **a** AF demagnetization of sample number 0-6-2 with both normal NRM and CARM. **b** TH demagnetization of sample number HD-10-1 with normal NRM and reversed CARM

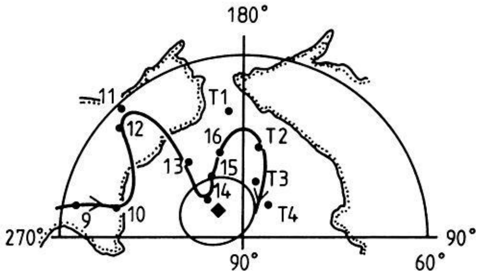

Fig. 4. Cretaceous and Tertiary polar wander path and pole positions of Africa. See also Schult et al. (1981) for numbers of poles and references. *Diamond with oval of confidence:* pole position of this paper for the Cretaceous-Tertiary boundary

Table 1. Mean remanence directions of the seven profile sections from Gebel Gifata (Dakhla Oasis) where reliable remanence directions could be obtained. The sections are arranged with age increasing from $N=1$ to $N=7$. M: Middle to Lower Maastrichtian; C: Upper to Middle Campanian; n = number of specimens; N = number of the section; d, D: declination in °E; i, I: inclination; k: precision parameter; $\alpha(95)$, $A(95)$: radius of the 95% confidence circle; DP, DM: errors of the virtual geomagnetic pole position in degrees

Section number	n	d (°E)	i (°)	$\alpha(95)$ (°)	k	Longitude (°E)	Latitude (°N)
1 (M)	8	355.7	32.3	5.2	113.2	236.9	81.1
2 (M)	30	359.9	33.6	5.1	27.1	210.5	82.8
3 (M)	26	357.9	44.4	6.1	22.2	316.8	88.0
4 (M)	9	5.6	33.6	14.0	14.5	172.3	81.1
5 (M)	24	5.4	19.0	4.2	51.0	190.4	73.4
6 (M)	7	349.6	41.0	35.3	3.9	289.6	80.3
7 (C)[a]	22	168.8	−18.8	3.7	70.7	245.3	70.9

Mean of the sites:

N	D (°E)	I (°)	$A(95)$ (°)	k	Longitude (°E)	Latitude (°N)	DP (°)	DM (°)
7	357.6	32.0	8.5	50.4	225.0	81.5	5.4	9.6

[a] A reversed section which was inverted to normal polarity for the computation of the mean remanence direction and pole position

Pilot specimens from both profiles have been studied with alternating-field (AF) and thermal (TH) demagnetization experiments in order to determine the stability of the NRM and to get some information about the magnetic mineralogy. Figure 2 gives some examples for AF and TH demagnetization experiments (vector diagrams) for specimens presumably containing magnetite and/or hematite as the main ferrimagnetic minerals. Figure 2a represents a specimen with both normal NRM and Characteristic Remanence CARM, whereas Fig. 2b is a specimen with normal NRM and reversed CARM. Part of the specimens exhibited AF and TH demagnetization behaviour, which is typical for rocks with goethite as the main carrier of remanent magnetization. Figure 3a (TH) and 3b (AF) show the extreme stability of goethite during alternating-field demagnetization and the low Curie temperature and blocking temperatures of goethite (less than 100° C) during thermal demagnetization.

Despite the large sample collection it was only possible to determine the CARM directions of a limited number of specimens and sections in the profiles from the Gebel Gifata (Dakhla Oasis). The mean CARM data are listed in Table 1 together with the mean CARM direction for the entire collection. Normal and reversed polarities have been observed, all grouping quite well. The results of the seven sections are arranged with respect to their age, with age increasing from top to bottom. Sections 1–6 are of Middle to Lower Maastrichtian, section number 7 is presumably of Upper to Middle Campanian age.

Interpretation and conclusions

From the mean CARM direction ($D=357.6°$, $I=32.0°$) and from the mean geographic coordinates of the sampling area (25.5° N, 29.0° E), a virtual geomagnetic pole (VGP) position at 81.5° N, 224.7° E, $A=8.5°$ was determined which is plotted in Fig. 4 (diamond) together with its oval of confidence and other North African pole positions [see Schult et al. (1981) for the exact pole positions and references]. Within the limits of error there is good agreement with the Lower Tertiary and Upper Cretaceous pole positions for North Africa. The small number of polarity determinations makes a correlation with the polarity time scale for the Uppermost Cretaceous impossible, so that the profiles cannot be compared with the Upper Cretaceous-Lower Tertiary polarity time scale as initially planned.

Acknowledgements. We thank Dipl. Geol. W. Herrmann-Degen from the Technical University of Berlin for his support in the field work, and Prof. Dr. U. Bleil, then at the University of Bochum and now at the University of Bremen, for his help and the use of the palaeomagnetic equipment of his laboratory. The financial support of the Deutsche Forschungsgemeinschaft, especially of the Special Research Project (Sonderforschungsbereich) 69, is kindly acknowledged.

References

Alvarez, W., Lowrie, W.: Upper Cretaceous palaeomagnetic stratigraphy at Moria (Umbrian Apennines, Italy): verification of the Gubbio section. Geophys. J.R. Astron. Soc. **55**, 1–17, 1978

Barthel, K.W., Herrmann-Degen, W.: Late Cretaceous and Early Tertiary stratigraphy in the Great Sand Sea and its SE margins (Farafra and Dakhla Oases) SW Desert, Egypt. Mitt. Bayer. Staatsslg. Paläont. Hist. Geol. **21**, 141–182, 1981

Dunlop, D.J.: Magnetic mineralogy of unheated and heated red sediments by coercivity spectrum analysis. Geophy. J.R. Astron. Soc. **27**, 37–55, 1972

Jelinek, V.: Precision a.c. bridge set for measuring magnetic susceptibility of rocks and its anisotropy. Studia Geophys. Geod. **17**, 36–47, 1973

Saradeth, S., Schurr, K., Soffel, H., Schult, A., Hussain, A.G.: Palaeomagnetic measurements and magnetostratigraphy of sedimentary rocks at the Cretaceous-Tertiary boundary from the oases of Dakhla and Kharga in the Western Desert of Egypt. Münchner Geophys. Mitt., Münchner Univers. Schriften, 1, 49–60, 1986. ISSN 0931-2145

Schult, A., Hussain, A.G., Soffel, H.C.: Palaeomagnetism of Upper Cretaceous volcanics and Nubian sandstone of Wadi Natash, S.E. Egypt and implications for the polar wander path for Africa in the Mesozoic. J. Geophys. **50**, 16–22, 1981

Silver, L.T., Schultz, P.H. (eds.): Geological implications of impacts of large asteroids and comets on earth. Geol. Soc. Amer., Special Paper No. 190, 1–528, 1982

Received July 25, 1986; revised version November 17, 1986
Accepted November 26, 1986