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CLIMATIC CHANGES, MAGNETIC INTENSITY VARIATIONS AND FLUCTUATIONS OF THE ECCENTRICITY OF THE EARTH'S ORBIT DURING THE PAST 2,000,000 YEARS AND A MECHANISM WHICH MAY BE RESPONSIBLE FOR THE RELATIONSHIP – A DISCUSSION

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1. Introduction

In several papers Wollin et al. [1–3] have suggested that a relationship exists between climate, intensity of the earth's magnetic field, and the eccentricity of the earth's orbit. Using data from deep-sea cores, they noted that natural remanence intensity was low during warm climatic intervals over the past 2 Ma and inferred a qualitative visual correlation with the orbital eccentricity of the earth.

We maintain that no connection is evident between climate and paleointensity of the magnetic field. The result in Wollin et al. [1–3] is due to a failure to remove the effect of varying magnetic material input, which is largely climatically controlled. We present evidence from a North Atlantic core that no connection between climate and paleointensity exists over the interval 60,000–127,000 years B.P. and we stress the necessity for careful attention to details of the magnetic character of the sediments in interpreting marine sedimentary paleomagnetic data.

2. Paleointensity and climate

Worldwide fluctuations in the oxygen isotopic composition of Quaternary foraminifers are associated with the interglacial-glacial cycle of alternating warm and cold intervals [4]. Similar variations in sediment lithology, carbonate content, foraminiferal species abundance, and mineralogy also are seen, especially in the North Atlantic Ocean [5–7]. Ruddiman and McIntyre [6] showed that the fluxes of biogenic and terrigenous material vary by factors of 2 to 3 depending on climatic conditions. Terrigenous input is high during glacial times in all sediment size fractions, while biogenic production is low. Since the magnetic minerals that record the ancient behavior of the earth's magnetic field are contained within the terrigenous fraction, some method of correction is necessary in order to isolate the geomagnetic field intensity.

There is currently no way to obtain absolute paleointensity from sediments, as there is for igneous rocks using thermal techniques [8]. At best a relative paleointensity can be measured by normalising the natural remanent magnetisation (NRM) to some extensive magnetic property of the sediment. Various investigators have used isothermal remanent magnetisation (IRM), bulk susceptibility, and anhysteretic remanent magnetisation (ARM) for this purpose. Johnson et al. [9] argued that both IRM and susceptibility overemphasize the contributions from large multidomain grains. Levi and Banerjee [10] showed that ARM often reproduces the coercive force spectrum of sediments and can serve as a compensating quantity. To use the ARM normalization

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method careful alternating field demagnetisation-remagnetisation studies on many samples are necessary to prove that the coercive force spectra for the NRM and ARM are similar.

Wollin et al. [1–3] mainly used partially demagnetized NRM measurements as an indicator of magnetic field intensity, usually using data from published work. Most of the results they reference were acquired for magnetostratigraphic purposes and did not include systematic magnetic property studies. One of their references [9] did include some ARM work, but only one set of partially demagnetized NRM measurements (core TT28-22) was normalised to ARM. The other curve reproduced in [2] was ARM only (core TT28–14). We believe that Wollin et al. [1–3] have not established that magnetic mineral content variations are unimportant and that their magnetic intensity index is a true measure of geomagnetic behavior. In fact the high correlation of an ARM curve with the orbital eccentricity in [2] suggests that magnetic fraction variations are dominant.

3. Discussion

Fig. 1 shows an example of a relative paleointensity measurement from core 19 of cruise 94 of the "Atlantis II" collected near 56°N, 29°30'W on the eastern flank of the Reykjanes Ridge. The faunal stratigraphy, from counts of the water mass assemblages of Ruddiman and McIntyre [6], show the prominent Termination I (13,000 years B.P.) at 110 cm and Termination II (127,000 years B.P.) at 725 cm. Pronounced warm intervals include oxygen isotope stage 5e inferred at 605–720 cm and the Barbados I event near 400 cm. The ice-rafted ash layers I and II mapped by Ruddiman and Glover [11] appear at 90 and 310 cm.

The magnetic measurements involved a 12-step alternating field demagnetisation-remagnetisation program on samples spaced 2.5 cm apart. All of the samples were stably magnetised, with a median demagnetising field of 300 Oe and a directional change of 5–7° over the 0–600 Oe range of peak AF. About 20% of the magnetisation remained after the 600 Oe treatment. The ARM was imparted in a 0.2-Oe coaxial steady field and a 600-Oe peak alternating field. The NRM and ARM demagnetisation curves are

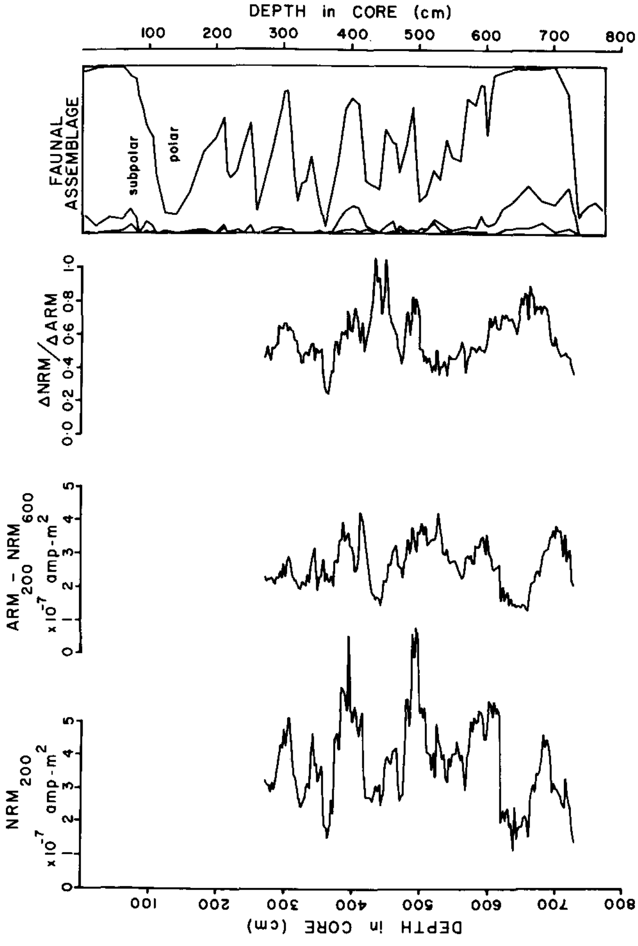

Fig. 1. Paleomagnetic and faunal data from AII94 core 19, comparing NRM intensity after 200 Oe AF demagnetisation, ARM intensity after 200 Oe AF demagnetisation and with the residual NRM vector removed, relative paleointensity by ARM normalisation, and faunal assemblages [6]. The faunal data are a cumulative percentage read from right (0%) to left (100%), with a high percentage of the polar assemblage indicating a cold climate. See text for details of the magnetic treatment and the stratigraphic control.

quite similar, indicating that ARM is a good normalising parameter for relative paleointensity.

The NRM intensity curve of Fig. 1, demagnetised to 200 Oe, shows a prominent low in stage 5e near 650 cm. Fluctuations up-core correlate with climate only in a gross sense, with lower NRM intensity during warmer periods. The ARM curve, also demagnetised to 200 Oe and with the residual NRM vector removed, varies markedly with the climatic cycle, apparently reflecting the changing input rate of terrigenous material. The paleointensity curve was derived by vector subtracting the 200 and 300 Oe NRM and ARM measurements and taking their ratio. The 200–300 Oe range was chosen because it lies in the middle of a wider range where the NRM and ARM coercive force spectra are very similar. A broad high in the paleointensity is seen through stage 5e, a low is seen in the colder interval up-core, and no peak is seen near the Barbados I warming. No obvious correlation with climate is apparent. The sharply changing nature of the NRM curve probably does not reflect true geomagnetic behavior, as suggested by the much smoother normalized magnetisation curve.

We are presently examining the ARM normalisation method in five deep-sea cores from the Iceland Basin, all taken within a $\frac{1}{2}°$ by $\frac{1}{2}°$ area, to see whether any statistically significant relative intensity information exists among them. The analysis will be quantitative. However, even the qualitative discussion presented here does indicate the need for caution in interpreting magnetic intensity data from sediments.

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References

1 G. Wollin, W.B.F. Ryan and D.B. Ericson, Climatic changes, magnetic field intensity variations, and fluctuations of the eccentricity of the earth's orbit during the past 2,000,000 years and a mechanism which may be responsible for the relationship, Earth Planet. Sci. Lett. 41 (1978) 395–397.

2 G. Wollin, W.B.F. Ryan, D.B. Ericson and J.H. Foster, Paleoclimate, paleomagnetism, and the eccentricity of the earth's orbit, Geophys. Res. Lett. 4 (1977) 267–270.

3 G. Wollin, D.B. Ericson, W.B.F. Ryan and J.H. Foster, Magnetism of the earth and climatic changes, Earth Planet. Sci. Lett. 12 (1971) 175–183.

4 W.S. Broecker and J. van Donk, Insolation changes, ice volumes, and the ^{18}O record in deep-sea sediments, Rev. Geophys. Space Phys. 8 (1970) 169–198.

5 W.F. Ruddiman, Pleistocene sedimentation in the equatorial Atlantic: stratigraphy and faunal paleoclimatology, Geol. Soc. Am. Bull. 82 (1971) 283–302.

6 W.F. Ruddiman and A. McIntyre, Northeast Atlantic paleoclimatic changes over the past 600,000 years, Geol. Soc. Am. Mem. 145 (1976) 111–146.

7 W.F. Ruddiman, North Atlantic ice-rafting: a major change at 75,000 years before the present, Science 196 (1977) 1208–1211.

8 R.S. Coe and C.S. Gromme, A comparison of three methods of determining geomagnetic paleointensities, J. Geomagn. Geoelectr. 25 (1973) 415–435.

9 H.P. Johnson, H. Kinoshita and R.T. Merrill, Rock magnetism and paleomagnetism of some North Pacific deep-sea sediments, Geol. Soc. Am. Bull. 86 (1975) 412–420.

10 S. Levi and S.K. Banerjee, On the possibility of obtaining relative paleointensities from lake sediments, Earth Planet. Sci. Lett. 29 (1976) 219–226.

11 W.F. Ruddiman and L.K. Glover, Vertical mixing of ice-rafted volcanic ash in North Atlantic sediments, Geol. Soc. Am. Bull. 83 (1972) 2817–2836.