Variations in magnetization intensity of ocean floor basalts

A REPORT by Bleil and Petersen[1] analyses data collected on 3,500 basalt samples retrieved from the ocean floor. The authors could account for the observed patterns of marine magnetic anomalies merely on the basis of a simple mechanism of low-temperature oxidation of titanomagnetite grains in basalts and consequent changes in the intensity of magnetization. The facts and figures given in the paper appear convincing if taken at their face value, as does any cross-checking if limited to the references cited therein. However, for a critical reader who is also a researcher in rock magnetism, the presentation betrays a one-sided and oversimplified approach. I wish to substantiate this remark by the following points.

(1) Although the average bulk composition of the magnetic grains of oceanic basalts may correspond to that given by the authors, it is over-optimistic to consider that all marine basalts causing the magnetic anomalies consist of a single specific member of the titanomagnetite solid solution series and its oxidation products. To cite one extreme example, Murthy *et al.*[2] have shown that a peridotite sample from Leg 37 contained almost pure magnetite as inferred from the magnetic properties.

(2) The oxidation parameter z, which the authors considered as the key factor, is not a directly measurable quantity but is derived from two others, one often being the Curie temperature which itself cannot be determined for basalts uniquely[3]. Moreover, basalts often indicate more than one Curie temperature[2]. Although z is a highly favoured parameter among a significant school of rock magnetists, its uniqueness and significance as applicable to basalts become questionable if only this school gives a minimum consideration to the facts mentioned below.

(3) Studies on the magnetic domain state aspects of titanomagnetites[4,5] indicated quite a complex behaviour for these minerals and hence the compositional features of the grains derivable from chemical and X-ray analyses on the one hand and from magnetic techniques on the other, could differ widely. Certain magnetic properties like Rayleigh loops (hysteresis loops in a field of 10 Oe) shown by basalts could be explained only by invoking superparamagnetic behaviour for some of the magnetic grains present in the samples[6]. The values of intensity of natural remanent magnetization and susceptibility will be highly sensitive to temperature if the basalts concerned show Rayleigh loops, and the issues raised by Deutsch and Pätzold[7] cannot be ignored in a model for magnetic anomaly interpretation.

In September 1979, the Rayleigh loops of several oceanic basalt samples from Petersen's collection were photographed in his own laboratory when I was visiting him and we discussed their implications at that time. It is surprising that the impact of such observable properties were not mentioned in their paper[1]

C. RADHAKRISHNAMURTY
Tata Institute of Fundamental Research, Bombay 400005, India

1. Bleil, U. & Petersen, N. *Nature* **301**, 384-388 (1983).
2. Murthy, G. S., Deutsch, E. R. & Pätzold, R. R. *J. geophys. Res.* **81**, 4199-4206 (1976).
3. Radhakrishnamurty, C., Deutsch, E. R. & Murthy, G. S. *J. Geophys.* **45**, 433-446 (1979).
4. Radhakrishnamurty, E. *et al. Phys. Earth planet. Inter.* **26**, 37-46 (1981).
5. Radhakrishnamurty, C. *et al. Phys. Earth planet. Inter.* **30**, 281-290 (1982).
6. Neel, L. *C. r. hebd. Seanc. Acad. Sci., Paris* **270**, 1125-1130 (1970).
7. Deutsch, E. R. & Pätzold, R. R. *J. geophys. Res.* **81**, 4188-4198 (1976).

BLEIL AND PETERSEN REPLY—We agree with Radhakrishnamurty that our explanation of the temporal variation of magnetization intensity of oceanic basalts[1] is necessarily a simplification of the mechanism underlying this phenomenon. However, we cannot agree with particular points which he raised against our arguments.

(1) Our data refer to the uppermost 500–1,000 m of oceanic basalt, which are directly accessible due to the drillings of the Deep Sea Drilling Project. Analyses of the magnetic mineral components contained in these rocks (predominantly mid-ocean ridge basalt (MORB)) show a surprising uniformity in composition, in correspondence to the uniformity of the overall geochemistry of the rocks. We are well aware that at greater depths, below seismic layer 2A, the magnetic mineral component is likely to be different from that described in our paper. An example of this kind is the peridotite sample cited by Radhakrishnamurty. A possible contribution of such deep-seated sources to the marine magnetic anomaly pattern will consequently show a different temporal magnetization variation, compared with that proposed in our model. It must be kept in mind, however, that the main portion of magnetic sources is located within the uppermost 500–1,000 m of the oceanic crust[2] which is MORB of essentially uniform composition.

(2) In evaluating age trends of the magnetic properties of oceanic basalts, it is not a prime question which parameter is chosen as reference, as long as this parameter can be defined uniquely. In our case, this parameter was the Curie temperature, which was transformed to the titanomagnetite oxidation parameter z using the relationship derived by Petersen *et al.*[3]. The latter relationship is based on chemical analysis of titanomagnetite extracted from ocean floor basalts. It is not correct to say that Curie temperatures of oceanic basalts cannot be determined uniquely. For such a statement the number of ambiguous Curie temperature analyses has to be seen against the total number of Curie temperature analyses carried out on ocean floor basalts, most of which are unambiguous (see, for example, refs 4–7).

(3) Radhakrishnamurty contends in his third point that the domain state of the magnetic minerals rather than their ferrimagnetic structure—as proposed by us—is the cause for the described temporal variation of magnetization intensity. That could be due either to superparamagnetism that develops in the magnetic minerals in the course of seafloor alteration (as proposed originally by Butler[8]), or to an effect of enhanced induced magnetization at slightly elevated temperatures by the Hopkinson effect, as proposed by Deutsch and Pätzold[9]. However, a comparison of our Figs 2, 3 and 5 (ref. 1) shows that for a rock of a certain oxidation state, the magnetization minimum will be the same for both remanent and saturation magnetization. This observation strongly contradicts Radhakrishnamurty's suggestion. If a systematic variation of the domain state of the magnetic minerals were responsible for the observed trend, it should not be seen in the saturation magnetization.

U. BLEIL
Institut für Geophysik, Ruhr-Universität, Bochum, FRG

N. PETERSEN
Institut für Allgemeine und Angewandte Geophysik, Universität München, Munich, FRG

1. Bleil, U. & Petersen, N. *Nature* **301**, 384-388 (1983).
2. Schouten, H. & Denham, C. R. *Am. geophys. Un. Maurice Ewing Ser.* **2**, 151-159 (1979).
3. Petersen, N., Eisenach, P. & Bleil, U. *Am. geophys. Un. Maurice Ewing Ser.* **2**, 210-229 (1979).
4. Schaeffer, R. M. & Schwarz, E. J. *Can. J. Earth Sci.* **7**, 268-273 (1970).
5. Lowrie, W., Lövlie, R. & Opdyke, N. D. *J. geophys. Res.* **78**, 7647-7660 (1973).
6. Murthy, G. S., Deutsch, E. R. & Pätzold, R. R. *J. geophys. Res.* **81**, 4199-4206 (1976).
7. Grommé, S. & Mankinen, E. A. *Init. Rep. DSDP* **34**, 485-494 (1976).
8. Butler, R. F. *J. geophys. Res.* **78**, 6868-6876 (1973).
9. Deutsch, E. R. & Pätzold, R. R. *J. geophys. Res.* **81**, 4188-4198 (1976).

0028-0836/83/440092—01$01.00