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A study of anhysteretic remanent magnetization with the variation of A. C. and D. C. fields on Rajmahal basalts

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ABSTRACT. Anhysteretic Remanent Magnetization is produced in a rock specimen when an alternating field, sufficient to cause saturation, is applied and reduced to zero in the presence of a constant direct field. The ARM produced increase with the increase of A. C. field range when the D. C. field is kept constant and reaches a saturation value. The saturation value is different for different specimens and increases as the coercive force increases. The ARM developed in various specimens with the variation of D. C. field, when the maximum alternating field intensity is constant, is a linear function of a small D. C. field.

1. Introduction

Permanent magnetization in the direction of the prevailing geomagnetic field has been found to be acquired by certain rocks. The rocks have been found to retain the magnetization over geological ages. The natural magnetisn possessed by rock specimens is called natural remanent magnetization (N.R.M.). The intensities of magnetization of rocks are much lower than those of iron alloys as the rocks contain a small fraction of iron materials. Clegg *et al.* (1958), McDougall and McElhinny (1970) a d Klootwijk (1971) have also studied about the remanent magnetization of Rajmahal traps. The Rajmahal traps consist mainly of basaltic and pitch stone trap flows. Everitt (1961), Patton and Fitch (1962) and Larson and others (1969) studied about the ARM of rock specimens and prepared samples. The experime tal results discussed in the present paper were obtained at steady field intensities between 0.20oe. to 7.57oe.

2. Experiment

At first attempts were made to study the variation of ARM for the same value of the D.C. field but for different ranges of A.C. field on different rock specimens. A rock spec men of 2 cm length and 2 cm diameter was demagnetized in all the three directions n the usual way in the zero field by applying an A.C. field of 880.0 (peak) oersteds and gradually and uniformly reduced to zero in 4 minutes with a variac. The demagnetizing coil system was designed by the author (Rakshit 1972). The specimen was held in the on-centre position of the Astatic Magnetometer constructed by Mahaseth (1968), and the value of the small moment, still retained, was measured. A current of 1.4 amp was passed through the horizontal pair of coils of the Helmholtz system from a storage cell. The direction of current through the system was such that the field produced was in the direction of Earth's vertical component producing a total field of 4.93 oe. An A.C. current was passed through the solenoid. The rock specimen was placed inside the demagnetizing coil so that the middle point of the specimen was at the centre of the coil system with its Z-direction along the axis of the solenoid when both the fields were on' and the horizontal componer t of the Earth's field had been eliminated by passing the suitable current from a storage cell through the vertical pair of coils of the Helmholtz system. The A.C. field was taken slowly a d steadily reduced to zero. The specimen was taken out and was placed again in the on- centre position of the Asatic Magnetometer. The amount of ARM developed was measured. The starting value of the demagnetizing field was then gradually increased, in steps, in the presence of the constant D.C. field and the process repeated. The specimen was placed in such a way that the direction of magnetization was always the same. Several specimens, T_{32} T_{42}, T_{54}, T_{59}, M_{117} and B_{156} were taken and observations were made. The value of ARM developed was plotted against the A. C. field as represented in Fig. 1. The experiment was similar to Patton a d Fitch (1962) on samples of magnetite and basalt. The values of the A.C. field, when the ARM developed in the various specimens is saturated, as obtained from Fig. 1, and the values of the remanent coercive force are given in Table 1. The coercivities of the specimens were measured by the experimental arrangement by Rakshit and Dutt (1971).

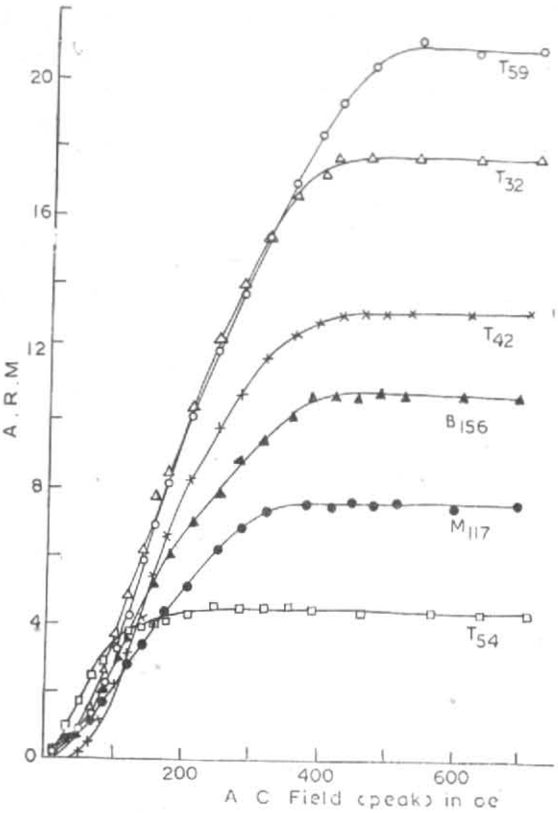

Fig. 1

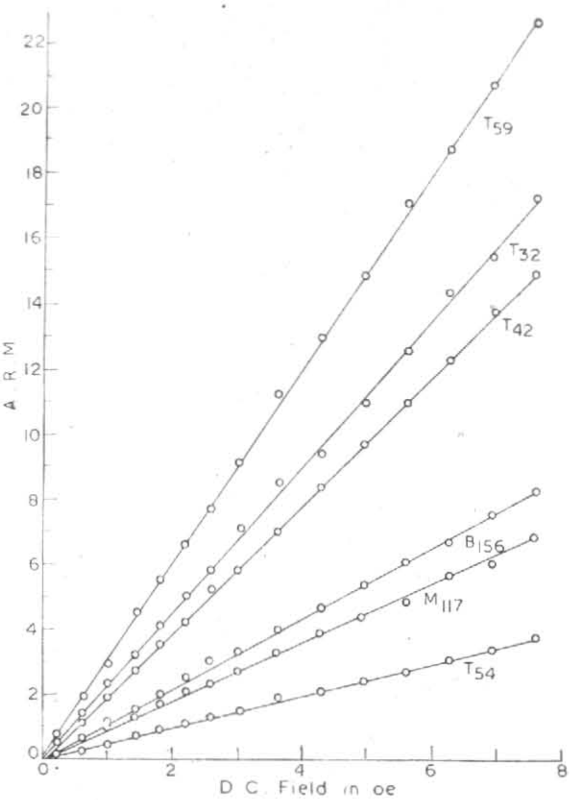

Fig. 2

TABLE 1

Specimen No.	T_{32}	T_{42}	T_{54}	T_{59}	M_{117}	B_{156}
A. C. field for saturation value of ARM as obtained from Fig. 1 in oersteds	460·0	425·5	282·5	580·0	345·0	380·5
Remanent coercive force in oersteds	155·6	132·5	60·6	164·7	83·7	98·4

The second experiment for the study of ARM produced in a rock specimen with the variation of D.C. field for the same A.C. field range was performed. A similar rock specimen, as that of the previous experiment, was also demagnetized in all the three directions by the process described above. An A. C. field of 247.3 oe was produced in the demagnetizing oil by passing a current of 1.4 amp. through it. The specimen, fixed to the specimen holder, was placed inside the solenoid with its Z-direction coinciding with the vertical. The A.C. field was gradually and steadily decreased from 247.3 oe to zero in 3 minutes in the presence of a D.C. field. The holder with the specimen was withdrawn from the solenoid and both the fields were switched off. The moment, developed due to the ARM produced in the specimen, was measured by the Astatic Magnetometer. The D.C.field was increased in small steps and the ARM produced on the specimen for the same range of the A.C. field was measured. The specimen was held in such a way that the effect of the field was always additive. Thus ARM was produced in specimens T_{32}, T_{42}, T_{54}, T_{59}, M_{117} and B_{156}. Fig. 2 is a plot of ARM *versus* the D.C. field and is a straight line. The ARM about proportional to the D.C. field. Patton & Fitch (1962) also got a linear relation for a sample of basalt.

3. Result

It has been found from Fig.1 that as the A.C. field range increases the ARM produced also increases, reaching a saturation value at a certain field. The saturation values for different specimens are different. A specimen with coercivity is being saturated in the lower range of A.C. field than a specimen with high coercivity. With low range of the field the particles with low values of coercivity only contribute to the ARM. As the field increases the value of ARM also increases due to the presence of grains with higher coercive force. When the field has increased sufficiently, saturation value of ARM is attained. A further increase of the filed does not develop any more moment. The saturation value for all the specimens is not the same. Table 1 shows that, in general, the saturation value of ARM increases with remanent coercive force. Rocks which have higher coercive forces develop higher ARM.

Fig 2. represents the relation of ARM produced in different specimens with the variation of D.C. and is linear, but the slope of different straight lines is not the same. Specimen having greater slope has developed more anhysteretic moment than a specimen with lesser slope for the same value of the D.C. field. As the D.C. field increases, the value of ARM developed also increases and is about proportional to the D.C. field. The intensity of the ARM developed increases with the coercive force of the specimen for the same value of the D.C. field.

4. Discussion

A ferromagnetic material acquires Anhysteretic Remanent Magnetization (ARM) when subjected to an A.C. (alternating) field and a small D.C. (steady) field. Upon removal of both the A.C. and D.C. fields, the remanent magnetization is much intense than it would have been in the presence of D.C. field alone. Many rocks contain a large number of ferrimagnetic grains each consisting of at least one domain. Rajmahal basalts, so far tested, are all found to be multidomains (Rakshit 1975). Every domain or subregion can be characterised by a particular coercivity h_c. If a steady magnetic field larger than h_c of a particular subregion is applied, the magnetization of the subregion will be aligned in the direction of the field. By the application of A.C. field only, the magnetization of the domains becomes haphazard and the intensity also decreases. Minimum intensity is an inherent property of these basalts and is due to the presence of multi domain particles. The minimum intensity will always be present and may be the cause of random scatter. Hence complete demagnetization is not possible. But when a D.C. field is applied simultaneously with the decreasing A.C. field the difference between the resultant positive field and the resultant negative field is twice the applied D.C. field. Magnetization of the material changes as the effective field varies. The effective field is the resultant of a constant D.C. field and an alternating A.C. field. If a rock is subjected to the simultaneous action of a steady D.C. field (h) and a decreasing A.C. field (peak) (H), then the subregions whose coercivity is smaller than $(H+h)$ will be aligned in the direction of the applied field h. The number of domains aligned with the effective field is determined by the value of the effective field and the distribution of domain energy barriers. All the domains whose energy barriers to magnetization are less than the energy supplied by the effective field are thus aligned, while those with higher energy barriers remain unaffected. On the reversed part of the cycle, the resultant maximum field will be $(H-h)$ and some of the domains which were aligned by the positive maximum field will not be reversed because the resultant negative field less than the resultant positive field by twice the applied D.C. field. If the A.C. field is reduced to zero and subsequently the D.C. field is removed, the subregions which were aligned in the direction of h will provide an anhysteretic remanent magnetization, *i.e.*, ARM. The ARM, thus produced, will be greater than the I.R.M. produced by the same D.C. field only. When the alternating field is reduced to zero over a time corresponding to many cycles, domains aligned with positive resultant field (direction of the applied D.C. field) will gradually accumulate and upon removal of the steady field, the domains so aligned constitute remanent magnetization. Here the magnetization is produced by the domain-wall movement because the effective magnetising field is generally low.

When the A.C. field range is increased for a constant D.C. field, we find that the ARM produced in a specimen increases with the increase of A.C. field range (Fig. 1). For a particular A.C. field range, particles with coercive forces of that range are effective in magnetizing the specimen, and the domain-boundary movement takes place. When the A.C. field range increases, grains with higher coercive force are then operative as the effective field range increases and more and more domains are rotated. Hence magnetism is developed in the specimen. With the further increase of A.C. field range more and more domains contribute to the magnetism of the specimen. Below the turning point of the curve, Barkhausen jump takes place and above it rotation of the domains takes place along the direction of the effective magnetizing field. But with the sufficient increase of the field all the domains are rotated in the direction of the magnetizing field. When the rotation of domains has taken place, no further magnetism can be developed even though the A.C. field range increases. Here the domains are saturated and the rotation is complete.

While studying the variation of ARM with D.C. field for the same A.C. field range, it has been found that the relation between the ARM and the D.C. field is linear for a basalt (Fig. 2). The variation of D.C. field was small (0.2 oe. to 7.57 oe.) for a constant A.C. field range. As the D.C. field increases, the effective magnetizing field also increases by double the applied D.C. field, hence the ARM produced on the specimen also increases and we have a straight line graph. Due to small effective field the magnetism produced is by domain-wall movement. The magnetism of the specimen increases as the magnetism developed in the domains increases. Had there been much larger D.C. field, the domains would have been saturated and there would have been rotation of magnetization of domains in the direction of the D.C. field. In this process the grains having coercive forces lying within the positive and negative effective fields, are responsible for the magnetization of the specimen. The domains or subregions whose coercivity lies between the positive and negative values of the resultant field, will be fixed. With the increase of range more and more domains are fixed producing greater value of ARM. Rocks which have higher coercive forces and hence smaller grain size, develop higher ARM than others, others things remaining constant.

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