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Measurement of magnetic susceptibility of Rajmahal traps

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सार – चुम्बकीय प्रवृति का मापन करने के लिए आवश्यक उपकरण बनाया गया। उत्तरी भारत में राजमहल चोरगढा की औसत चुम्बकीय प्रवृति 0.554×10^{-3} वि०चु०ई०/घ०से० आकलित की गई है जोकि विश्व के अन्य क्षेत्रों जैसे जापान और ग्रेट ब्रिटेन के असिताश्मों की तुलना में कम है। इसमें चुम्बकीय प्रवृति पर उष्मा के प्रभावों का भी अध्ययन किया गया है और देखा गया है कि तापमान में वृद्धि के साथ-साथ चुम्बकीय प्रवृति भी सामान्यतया बढ़ती है।

ABSTRACT. Necessary apparatus for the measurement of magnetic susceptibility was built up. The average magnetic suceptibility of the Rajmahal traps in eastern India is estimated to be 0.554×10^{-3} emu/cc and is thus low compared to basalt from other areas of the world such as Japan and Great Britain. Heating effect on magnetic susceptibility has been studied. Generally the susceptibility increases with the increase of temperature.

1. Introduction

There has been hardly any attempt till 1964 to measure the susceptibilities of Rajmahal traps lying in the eastern part of India. The present work has been taken up in 1964 to augment the existing scientific knowledge about these traps. Rock samples were collected from an area of mean Lat. 25.1 deg. N and Long. 87.7 deg. E. Previously susceptibility of rocks was measured in fields of 10 Oe or more but Nagata (1953) and others showed that magnetic susceptibility of igneous rocks determined in the magnetizing field greater than the total earth's field (0.50 Oe) are most useful for geophysical purposes. Keeping the above consideration in view, a susceptibility apparatus was built up in the laboratory which is based upon the design suggested by Bruckshaw & Robertson (1948) and Bruckshaw & Vincenz (1954). The principle employed is the inductive method of measuring the magnetic susceptibility of rock specimens in a weak field.

2. Data

The rock specimen in the form of cylinder (2 cm length and 2 cm diameter) is magnetized by induction by a small uniform alternating field. This produces an alternating e.m.f. in a balanced pick up coil system. The e.m.f. is proportional to the induced magnetization and is measured on a potentiometer fed by an e.m.f. proportional to the magnetizing field. Hence the balance on the potentiometer is a measure of the ratio of the induced moment to the field, *i.e.*, a measure of KV, where K is the volume susceptibility and V is the volume of the specimen.

Fig. 1 shows the circuit diagram. The coils H, H of a Helmholtz system carry an alternating current of 0.4 amp at 40 c/s from an oscillator fed by a stabilized voltage, to produce an uniform magnetizing field of 0.5 Oe over the specimen S. The pick up system consists of 2 coils, P_1 main coil consisting of 21500 turns of S.W.G. 44 enamelled copper wire and P_2 compensating coil consisting of 22000 turns of similar wire, joined in series opposition. It is fixed co-axially inside the Helmholtz coil consisting of 20 turns of S.W.G. 26 of enamelled copper wire in each coil. With no specimen in the holder, the total e.m.f. in the pick up system is small, since the exciting field induces almost equal but opposite e.m.f. in P_1 and P_2 When a rock specimen is inserted, it induces a larger e.m.f. in the nearer coil P_1 and a

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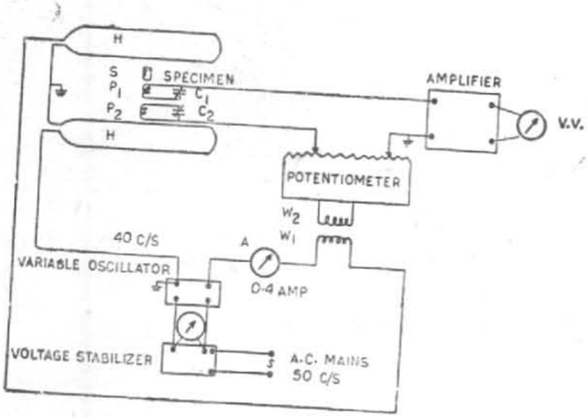

Fig. 1. Circuit diagram of susceptibility apparatus

smaller opposite e.m.f. in the more distant coil P_2. The result is a differential e.m.f. in the pick up which is measured on a potentiometer fed by an a.c. e.m.f. from the oscillator by mutual coupling between the coils W_1 and W_2 consisting 30 turns of wire each having mutual inductance of 1.187 microhenries. After amplification by a four stage low noise amplifier the balance is detected by a vacuum tube voltmeter. C_1 and C_2 are two small variable condensers 50 picofarad each, which give a variation in the phase of the P.D. across the coils P_1 and P_2 and so facilitate balancing.

If H is the instantaneous value of the magnetizing field, K the volume susceptibility, and V the volume of the specimen, the induced moment is $K.V.H.$, neglecting the effects of demagnetization. The flux linked with the pick up system is then $F.K.V.H.$, where F depends on the geometry of the coils and the specimen. The differential e.m.f. e is given by : $e = jWFKVH = jWFKVci$ where j is called the operator of the rotating vector indicating that the magnetic flux leading the differential e.m.f. by 90 deg., W is the angular frequency of the energizing current i and c the constant of the Helmholtz system. If M is the mutual inductance between the coils W_1 and W_2, R the total resistance in the potentiometer circuit which equals 22 ohms and r the resistance tapping the balance, then $e = jWMir/R$ the small self inductance of W_2 being neglected. Hence

$$jWFKVci = jWMir/R$$

or $KV = Br$, where $B = M/cFR$ is called the constant of the equipment.

3. Calibration of the equipment

The calibration was done by employing a coil, consisting of 80 turns of S.W.G. 40 copper wire, wound over an ebonite cube, carrying a known fraction α of the alternating current i flowing through the Helmholtz coils.

The induced e.m.f. in the pick up coils, using the same symbols as before is given by

$$e = jWFni\alpha V'$$

where V' is the vloume of the coil and n the number of turns per centimeter. If the potentiometer reading to balance is r ohms then

$$e = jWFni\alpha V' = MjWir/R$$

or

$$B = n\alpha V'/cr$$
$$= 0.002762 \text{ (in our case)}$$

4. Experimental procedure

The exciting field of 0.5 Oe (R.M.S.) was produced by passing 0.4 amp (R.M.S.) current through the Helmholtz coil. Balance was then obtained for no specimen in the holder. Next the specimen was inserted in the holder vertically and balance was again adjusted on the potentiometer. Another balance point was determined when the specimen was placed up side down (inverted) in the holder. The mean of these two readings was considered for calculation of susceptibility from the formula :

$$K = Br/V$$

5. Results

In Table 1 are given the magnetic susceptibilities of Tin Pahar lower flow rock specimens of Rajmahal traps. In all 56 specimens were studied. The average susceptibility of specimens from Tin Pahar is found to be 0.554×10^{-3} emu/cc.

Some rock specimens were heated to 190 deg. C and their susceptibilities were then measured, three of them were further heated to 900 deg. C and cooled to room temperature and their susceptibilities were also measured. They are given in Table 2.

Often the magnetite content of rocks is non-uniformly distributed. Hence from some of the

(a)

(b)

(c)

Fig. 2. Thin section study of representative of various areas (a) Tin Pahar (T_5); (b) Ambadiha (A_{113}) & (c) Banskhola (B_{160})

TABLE 1

Magnetic susceptibilities of Tin Pahar flow rock specimen of Rajmahal traps

Specimen No.	Kx10^3 emu/cc	Specimen No.	Kx10^3 emu/cc
T_3	0.448	T_{34}	0.653
T_5	0.618	T_{35}	0.896
T_{14}	0.615	T_{37}	0.666
T_{17}	0.660	T_{38}	0.820
T_{18}	0.647	T_{41}	0.654
T_{22}	0.510	T_{42}	0.511
T_{32}	0.658	T_{45}	0.762
T_{33}	0.755		

TABLE 2

Susceptibilities of heated rock specimen

Specimen No.	Kx10^3 emu/cc before heating	Kx10^3 emu/cc after heating to 190 deg. C	Kx10^3 emu/cc after heating to 900 deg. C
M_{131}	0.642	0.545	1.055
Tal_{87}	0.446	0.506	
T_{64}	0.376	0.367	
T_{34}	0.653	0.506	
B_{155}	0.439	0.501	0.633
A_{143}	1.027	1.160	1.643

TABLE 3

Sample of two Banskhola cores of rocks of non-uniform magnetic content

Specimen No.	Ist specimen Kx10^3 emu/cc	2nd specimen Kx10^3 emu/cc
B_{152}	0.483	0.331
B_{153}	0.589	0.580
B_{154}	0.297	0.268
B_{158}	0.446	0.406
B_{159}	0.341	0.437
B_{160}	0.457	0.323

cores of Banskhola two specimens were prepared. The results from such specimens are given in Table 3.

Thin sections as shown in Fig. 2, of representative specimens of the various areas were studied. The result of a typical specimen from Tin Pahar is given below :

Sp. No. T_6

Fine grained porphyritic rock with some porphyroblast of plagioclase. Mineral constituents estimated are as follows :

Augite	55 to 60%
Plagioclase	30 to 35%
Magnetite	3 to 5%

Palagonite is also present.

6. Discussion

Almost all the Rajmahal trap rocks are fine grained basalt except the rocks from Taljhari which are pitch stone. That the magnetic minerals responsible for the magnetic susceptibilities are mostly magnetite, is confirmed by studies of their thin section.

The varying values of susceptibility shown in Table 1 can be attributed to nonuniform distribution of magnetite in the body of the rock mass. Here the variation lies between 2 to 10 %. Even in the same sample the distribution of magnetite content is greatly nonuniform. Table 3 shows the variation in susceptibilities within the same sample.

From Table 2 it is found that heating to 190 deg. C of the rock specimen resulted in increase of the susceptibility values except of course for specimens from Maharajpur and Tin Pahar. This increase has been suggested by Bruckshaw and Vincenz (1954), Dutta (1955) to be due to the production of new ferromagnetic materials or to changes in the lattice of the existing magnetic constituents, probably the latter in view of the low temperature involved.

Table 2 also shows a further increase in the susceptibility values on heating the three specimens to over 900 deg. C and cooled to room temperature. It may be due to the production of new ferromagnetic materials as suggested earlier.

We find in general that Rajmahal trap rocks have a comparatively low value of susceptibility (0.554×10^{-3} emu/cc) and as such the magnetite content is also small. Also Nagata's (1953) results of olivine basalts from Huri, Hoei crater Japan give a value of the order of 2.25×10^{-3} which is also higher than our rocks.

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References

Bruckshaw, J. M. and Robertson, E. I., 1948, *J. Sci. Inst.*, **25**, 444-446.

Bruckshaw, J. M. and Vincenz, S. A., 1954, *Manual of Royal Astronomical Society Geophysical supplement*, 6, 579-589.

Dutta, S. K., 1955, Ph.D. Thesis, University of London.

Nagata, T., 1953, *Rock Magnetism*, Maruzen Co., Ist. Ed.