Magnetic studies on charnockites of Palni Hills

K RAMASWAMY and N RAMAMURTHY

Department of Physics, Annamalai University, Annamalaiagar 608 101, India

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Abstract. The magnetic properties like coercive force, mean mass susceptibility and relative remanence of some charnockites of Palni Hills, South India collected at different altitudes were measured.

Keywords. Charnockites; coercive force; mean mass susceptibility; relative remanence.

1. Introduction

The study of magnetic behaviour of rocks has evinced keen interest since it throws light on the various features like the constituents, the petrological aspects, the domain structures forming the rock and also the origin and nature of formation. Such studies on the basaltic formation of Deccan traps (Verma *et al* 1974), columnar basalts of Bombay (Radhakrishnamurthy *et al* 1971) and North Pacific deep sea sediments (Johnson *et al* 1975) have been made. One of the interesting formations in South India is the charnockite formations of Tamil Nadu. Systematic studies of the magnetic properties of the charnockite formations of Tamil Nadu area appear to be meagre and this paper attempts to fill this lacuna with special reference to those of Palni Hills.

2. Petrology and location of charnockites

Charnockite is the name given to a series of granitoid rocks of South India found in the hill formations of Nilgiris, Palnis, Shevaroyes and Pallavaram of Tamil Nadu. These rocks are identified as one of the oldest formations in the world (Wadia 1975). The charnockites of South India have been classified as igneous rocks by Ramaswamy and Murthy (1974) from the optical mineralogical studies. Saxena (1977) pointed out that the mineral, chemical and phase equilibrium relationships indicate that these rocks are formed by recrystallization between 600–900° C relatively at shallow depths of 6 to 12 km and there is a possibility of geothermal gradient of 70 to 100° C per km. Further, he suggested that the latest geothermal gradient is around 1300×10^6 years ago.

Palni Hills has a wide distribution of charnockites at various altitudes. The specimens for the study of the magnetic behaviour were collected at 850–2400 m altitude with the help of the Geology Department, Annamalai University.

3. Experimental methods

To study the magnetic behaviour of rock specimens, an apparatus based on the design of Blackett (1956) and modified by Rakshit and Dutt (1971) was constructed.

In this method, the specimen in the form of a rectangular block was allowed to vibrate between the pole pieces of a homogeneous electromagnet. A pair of pick-up coils wound round the pole pieces picked the a.c. voltage generated during the flux delinking, produced by the vibration of the specimen. This a.c. voltage was rectified and measured by an accurate nanoammeter specially constructed for this purpose. The specimen was partially demagnetised using an a.c. field, to remove any stray magnetism existing in the specimen. Varying the current in the electromagnet, the usual current cycle was followed and a hysteresis loop was drawn. Normally all the specimens tended to get saturated around 2500 Oersteds. However, to ensure saturation the field was increased upto 4000 Oersteds. From the hysteresis curves various parameters like the coercive force H_c , remanent magnetisation J_r , saturation magnetisation J_s and mean mass susceptibility χ values were obtained. The induced magnetic moment M (in c.g.s. units) of the specimen was calculated using the relation $M = i \times K$ where $K (= 15.07)$ is the instrument constant obtained from the known parameters of the experimental set-up and i is the current read by the nanoammeter in microamperes.

4. Results and discussion

4.1. Coercive force H_c

The coercive force values of the specimens obtained from the hysteresis curves are shown in table 1. The specimens can be classified into intermediate and acid charnockites on the basis of thin section analysis. Data for grain size and percentage of magnetite, found by means of modal analysis, are also presented in table 1. It is seen that the intermediate rocks appear to have lower values (mean value 240 Oes) for coercive force than the acid rocks (mean value 287 Oes). The coercive force is also found to be inversely proportional to the grain size. The variation is more pronounced in acid rocks compared to the intermediate rocks. A similar pattern has been reported by Nagata (1961) for igneous rocks and by Rakshit (1974) for Rajmahal basalts. Such a behaviour is also consistent with the multidomain structure of magnetite found in these specimens as indicated by modal analysis.

4.2. Susceptibility

The value of mean mass susceptibility has been found to vary from 0.6 to 3×10^{-3} e.m.u./g in the charnockite specimens studied. Nagata (1961), after investigating

Table 1. Coercive force, mean mass susceptibility and other values of some charnockites of Palni Hills.

Sl. No.	Specimen No.	Coercive force H_c (Oe)	Mean mass susceptibility $\chi \times 10^3$ (e.m.u/g)	Relative remanence R	Saturation magnetisation J_s (e.m.u/c.c.)	Remanent magnetisation J_r (e.m.u/c.c.)	Grain size of magnetite (microns)	Percentage of magnetite	Density (g/c.c.)
1.	25	242	1.33	0.38	2.48	0.98	4.24	5.63	2.56
2.	113	250	1.22	0.24	2.76	0.95	4.42	5.56	2.69
3.	12	200	0.77	0.29	2.43	0.68	6.83	3.33	2.75
4.	91	203	2.11	0.31	5.95	1.82	8.06	9.4	2.67
5.	73	167	2.98	0.23	8.24	1.79	12.76	10.88	2.93
6.	123	285	2.12	0.37	3.90	1.65		*8.0 (8.6)	2.78
7.	93	300	1.99	0.42	5.07	2.13		*7.8 (8.1)	2.75
8.	111	350	0.61	0.28	2.31	0.66	5.44	7.07	2.59
9.	33	233	1.30	0.23	4.04	0.94	10.09	5.4	2.70
10.	14	234	0.71	0.19	2.50	0.48	9.87	3.35	2.63
11.	148	252	0.89	0.24	2.24	0.54	8.32	2.31	2.77
12.	99	250	1.83	0.22	5.79	1.25	8.07	7.30	2.56
13.	195	258	1.39	0.25	3.27	0.82	6.8	5.1	2.70
14.	5	335	0.84	0.24	4.85	1.14		*3.8 (3.5)	2.64
15.	11C	338	1.17	0.33	4.04	1.31		*4.5 (4.72)	2.61
16.	95	375	2.28	0.42	4.82	2.03		*8.91 (9.0)	3.01
17.	10	240	1.23	0.22	5.42	1.20		*4.72 (4.80)	2.71
18*.	6	253	2.5	0.34	3.68	1.25		*9.9 (10.5)	2.58

Specimens 1 to 7 belong to intermediate charnockites and 8 to 17 belong to acid charnockites.

Specimen 18* is identified as basic charnockite (Vellore, Kottayam Dt., Kerala)

*Obtained from modal analysis.

() Predicted from the χ Vs % curve (figure 1).

a number of specimens, concluded that in volcanic rocks, χ is usually in the range from 10^{-4} to 10^2 e.m.u./c.c., in plutonic igneous rocks 10^{-4} to 5×10^{-3} e.m.u./c.c., in metamorphic rocks from 10^{-5} to 3×10^{-4} e.m.u./c.c. and in sedimentary rocks below 10^{-5} e.m.u./c.c. Our values are well within the ranges quoted by Nagata for igneous rocks and this suggests that these rocks may be of igneous origin, as proposed by Ramaswamy and Murthy (1974).

It is a known fact that the susceptibility depends on the percentage of magnetite present in a specimen. An attempt is made to correlate the percentage of magnetite with the χ -values. A linear relationship of the form $\chi = (2.43 \pm 0.20) \times 10^{-2} C_{Mt}$ is found to exist (figure 1). Here, C_{Mt} is the norm or theoretically calculated percentage of magnetite. Such a relationship was reported by Nagata (1961) in the case of igneous rocks. For some specimens, the predicted values agree well with the values obtained from the modal analysis (table 1). It is seen from figure 1 that some points are spread from the median line. This spread may be attributed to the fact that the susceptibility is strongly influenced by the size and shape of the grains as well as by their internal stress at the time of formation of the rock (Kato 1940; Balakrishna and Vijayaraghava 1963).

4.3. Relative remanence R or J_r/J_s ratio

Relative remanence R i.e. the ratio of remanent magnetisation J_r to the peak intensity of magnetisation J_s for each specimen was calculated and the values given in table 1 indicate that all specimens exhibit R values less than 0.5. One noteworthy feature is that the intermediate charnockite specimens have an average R value of 0.33 while acid specimens have a value around 0.26.

Figure 1. Relation between mass susceptibility and percentage of magnetite.

Figure 2. Variation of J_r/J_s with the coercive force H_c .

Many authors have discussed the R value in terms of domain structures (Stoner and Wohlfarth 1948; Neel 1955; Johnson *et al* 1975; Radhakrishnamurthy *et al* 1978). They have stated that R value close to 0.5 indicates single domain grains in rock specimens. Johnson *et al* (1975) after investigating the magnetic behaviour of some specimens from North Pacific deep sea reported that since these specimens show a value less than 0.5, multidomain structures are common in these specimens. Radhakrishnamurthy *et al* (1978) made granulometric analysis of a number of basalt specimens and concluded that R values less than 0.5 indicate a mixture of S-D and M-D grains while R values close to 0.5 indicate the presence of a large percentage of S-D grains.

It may be inferred from the magnitude of R values that all specimens have a mixture of S-D and M-D grains and that the intermediate rocks (mean $R = 0.33$) have more predominance of S-D grains than the acid rocks (mean $R = 0.26$).

Relative remanence is found to show a linear variation with the coercive force (figure 2). A similar relationship was reported by Nagata (1961).

5. Conclusions

The mean value of the coercive force for the charnockites of Palni Hills is found to be equal to 260 Oersteds. J_r/J_s is less than 0.50; this indicates that charnockites contain mixture of S-D and M-D structure of magnetite crystals.

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