DYNAMIC REMANENT MAGNETIZATION AND THE EFFECT OF IMPACTS ON THE REMANENT MAGNETIZATION OF STRONGLY MAGNETIC ROCKS

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Fig. 1

Figure 1: Fig. 1

Abstract

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DYNAMIC REMANENT MAGNETIZATION AND THE EFFECT OF IMPACTS ON THE REMANENT MAGNETIZATION OF STRONGLY MAGNETIC ROCKS

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Dynamic remanent magnetization I_{rd} arises in specimens of magnetites and magnetic rocks under the action of impacts in the presence of an external constant magnetic field ([1]). Dynamic magnetization was first obtained by Domen ([2]) on specimens of soft iron and steel.

Experiments with specimens of magnetite, pyrrhotite, gabbro, serpentinite, diorite, granite, bauxite, and other rocks showed that all the rocks studied acquire in the terrestrial magnetic field an I_{rd} that varies in magnitude but is quite measurable ([3]). As an example, let us consider the creation of I_{rd} by impacts in a specimen of magnetite from the Lisakovsk deposit (Fig. 1). Similar curves were obtained for magnetites from many deposits of the Urals and Kazakhstan, and also for other magnetic rocks.

Fig. 1. Creation and destruction of dynamic magnetization in a specimen of Lisakovsk magnetite.
1—3—growth (1) and decrease (2, 3) of I_{rd} as a function of the number of impacts. Curve 3 was obtained after the specimen had been held in an unmagnetized state for 2 months; 4—change of I_{rd} as a function of the energy imparted to the specimen by impacts; 5—change of I_{rd} with time.

Dynamic magnetization was created in the specimen (a cube with side 30 mm) in the terrestrial field of 0.5 Oe by impacts of bronze weights of 0.68 and 1.36 kg, falling freely from heights of 7 and 13 cm. Before the start of the experiment the specimen was brought to the zero magnetic state by demagnetization in a nonmagnetic space with the aid of an alternating magnetic field decreasing in amplitude ([1]). As the number of impacts increases (weight 1.36 kg, height 13 cm), I_{rd} shows a tendency toward saturation. The magnitude of the saturation dynamic magnetization I_{rdS} in the terrestrial field for magnetite is of the order of 0.03-0.04 cgs/cm^3. The direction of the dynamic magnetization coincides with that of the acting field and does not depend on the direction of the impacts. The increase of I_{rd} (Fig. 1, 1) under the action of impact energy E (kg · m) is described, to a first approximation, by the empirical formula

$$I_{rd} = I_{rdS}\left(1 - e^{-b\sqrt{E}}\right).$$

In the initial part of the curve, up to an energy of the order of 6 kg · m, when the energy is plotted on a logarithmic scale, the dependence of I_{rd} on the impact energy

is a straight line (Fig. 1, 4) $I_{rd} = A + D\lg E$, where b, A, and D are constant coefficients. (In constructing the experimental curve $I_{rd} = f(\lg E)$, the loss of energy during impacts was not taken into account.)

Samples with the remanent magnetization obtained in this way were subjected to various demagnetizing effects in order to determine its stability. It turned out that, in a nonmagnetic space, I_{rd} is demagnetized by an alternating field of the order of 80-120 Oe (Figs. 2 and 3). The dynamic magnetization of magnetite is compensated by normal magnetization obtained in fields of 7-12 Oe (the destructive field H_c'). Heating to 350-400° in a zero magnetic field completely destroys I_{rd}. Demagnetization by impacts in a nonmagnetic space showed that after 50 impacts there still remains 10-20% of the initial value of I_{rd}, obtained in the Earth' s field by fifty such impacts. Consequently, as in the case of a constant magnetic field, the magnetization with respect to impacts exhibits hysteresis (Fig. 1, 1, 2). Holding in a nonmagnetic space decreases the dynamic magnetization: in 2 months the I_{rd} of magnetite decreased by 24% of its initial value.

Fig. 2. Demagnetization of remanent magnetizations in a magnetite sample in a nonmagnetic space by an alternating magnetic field (1-6) and by impacts (7-12).
1—$I_{rt} = 0.030$; 2—$I_n = 0.022$; 3—$I_{ri} = 0.023$; 4—$I_{rv} = 0.014$; 5—$I_{rd} = 0.023$; 6—$I_{rn} = 0.030$; 7—$I_{rt} = 0.031$; 8—$I_{ri} = 0.030$; 9—$I_n = 0.022$; 10—$I_{rv} = 0.014$; 11—$I_{rd} = 0.023$; 12—$I_{rn} = 0.026$ cgs/cm^3

The decrease of dynamic magnetization with time in a zero field at room temperature for the same magnetite sample, as a function of the logarithm of time, is represented by a straight line (Fig. 1, 5), which is described by the formula $I_{rd} = B - \tau_d \lg t$, where B and τ_d are constant coefficients. Extrapolation of this dependence, obtained for this magnetite over 2 months in the laboratory, to a long interval of time makes it possible to find that, under unchanged conditions, about 10,000 years will be required to decrease I_{rd} by 50%, and about 10^8 years to decrease it by 75%. Demagnetization by impacts of the dynamic

Fig. 3

Figure 2: Fig. 3

magnetization of the same sample aged with time showed that the stability of I_{rd} had become higher (Fig. 1, 3).

Special experiments were carried out in order to compare the demagnetization of the principal known types of remanent magnetization by impacts and by an alternating field. All samples (cubes with a side of 30 mm) were first brought to the zero magnetic state, and then, in the Earth' s magnetic field, always in one and the same direction, they were successively given magnetizations approximately equal in magnitude: ideal (I_{ri}), dynamic (I_{rd}), normal (I_{rn}), and thermoremanent (I_{rt}). The exception is viscous magnetization (I_{rv}), whose value for magnetite in the Earth' s field at normal temperature over 1 month was equal to 0.014 cgs/cm^3. The comparison was made for various magnetic rocks and magnetites from a number of deposits. The curves of demagnetization of the principal magnetizations of magnetite and diorite porphyrite (the sample was taken from the host rocks of the Lisakovsk deposit) by an alternating field, and the analogous curves for the same samples obtained during demagnetization by impacts (load 0.68 kg, height 7 cm) in a zero field, are shown in Figs. 2 and 3. The character of demagnetization of I_{rt},

I_{ri}, I_n, I_{rv}, I_{rd}, I_{rn} are the same for the magnetite and porphyrite samples both in an alternating magnetic field and under impact, although under the experimental conditions only the normal magnetization is completely demagnetized by impacts.

Thus, tests of the stability of dynamic remanent magnetization using the principal demagnetizing effects (alternating and constant magnetic fields, temperature, impacts, and time) showed that I_{rd} is significantly more stable than I_{rn}, comparable in stability to I_{rv}, and for some samples also to I_{ri}, and less stable than I_{rt}.

It is possible that, with further refinement of the technique, dynamic effects may be used as one of the criteria for evaluating the magnetic stability of the remanent magnetization of rock samples.

Fig. 3. Same as Fig. 2, for diorite porphyrite. In an alternating magnetic field: 1 $-I_{rt} = 0.032$; 2 $-I_{ri} = 0.020$; 3 $-I_n = 0.018$; 4 $-I_{rd} = 0.019$; 5 $-I_{rn} = 0.020$. By impacts: 6 $-I_{rt} = 0.030$; 7 $-I_{ri} = 0.019$; 8 $-I_n = 0.018$; 9 $-I_{rd} = 0.018$; 10 $-I_{rn} = 0.022$ cgs/cm^3.

Mineralogical analysis showed that the magnetite sample is a medium-grained magnetite; the grains are mainly isometric in shape, with a diameter of 0.4-0.7 mm. In isolated cases hematite develops along the edges of the magnetite grains. In the diorite porphyrite, the main ore mineral is magnetite, along the edges of whose grains hematite is developed (magnetite grain diameter 0.1-0.4

mm).

The principal magnetic characteristics of the described samples are:

	χ, cgs/cm^3	I_n, cgs/cm^3	I_S, cgs/cm^3	H'^{**}_c, oersted	H'_{cS}, oersted
Magnetite	0.28	0.022	218	12	68
Diorite porphyrite	0.052	0.018	52	19	97

Thus, in the presence of a constant external magnetic field, impacts and, consequently, all other processes that produce elastic compressions and extensions in the sample must lead to the appearance of dynamic remanent magnetization.

If the obtained dependence of I_{rd} on time proves valid for geological time intervals, then I_{rd} once produced in nature will be preserved for a sufficiently long time. This means that almost every I_n contains its own fraction of I_{rd}, which is of substantial importance for paleomagnetic studies.

In the process of sampling and treating samples, the natural remanent magnetization of magnetically unstable, mechanically strong samples containing large grains of magnetite (diameter greater than 0.2 mm) is strongly distorted because of the appearance of dynamic magnetization and the destruction of the natural remanent magnetization ([3], [4]), whereas in stable samples containing hematite, ilmenohematite, or finely dispersed magnetite as the principal magnetic component, the change in I_n and the formation of I_{rd} under the action of impacts during sampling and treatment are insignificant and practically do not distort either the magnitude or the direction of the natural remanent magnetization.

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Note: Figure translations are in progress. See original paper for figures.