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Self-Reversal above Room Temperature due to N-Type Magnetization in Basalt

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Self-reversal due to Néel's N-type spontaneous magnetization versus temperature has been reported for some alkali basalts by Schult (1965, 1968), Nishida and Sasajima (1974) and for a basalt from the ocean floor by Sasajima and Nishida (1974). The ferrimagnetic mineral component of these rocks was titanomaghemite. In all cases reported the compensation temperature (temperature at which self-reversal of remanence takes place) was below room temperature. In small parts of a hand specimen obtained from an alkali basalt of Miocene Age (Steinberg at Meensen near Göttingen) also compensation temperatures above room temperature have been observed.

The outer zone of this hand specimen (about 10 cm diameter) appears reddish brown due to weathering, the inner zone is dark grey. From the oriented hand specimen several cylindrical samples were cut, each about 0.5 to 1 cm^3. On these samples the direction of the natural (NRM) and characteristic (CARM, after about 150 Oe AF cleaning) remanent magnetization was measured and the temperature dependence of CARM (accuracy about 5%) between $-196°$ C and $+100°$ C (accuracy about 3%). Then the samples (partly) were crushed and the magnetic phase was enriched to about 80 weight % with a hand magnet. On the separated material x-ray powder photographs were taken and the spontaneous magnetization (accuracy 5%) versus temperature was measured between $-196°$ C and the Curie temperature in fields up to 14 KOe. On some basalt samples also the temperature dependence of an artificial thermoremanent magnetization (TRM) was measured. TRM was produced by heating the samples shortly to about 250° C (to above the Curie temperature) by submerging in hot oil and then cooling down to 20° C in a field of about 0.4 Oe.

The direction of NRM and CARM (after AF cleaning with about 150 Oe) at room temperature was reversed with respect to the present Earth's magnetic field for most samples in agreement with other samples from the same locality. Some samples from the outer (weathered) zone of the hand specimen however

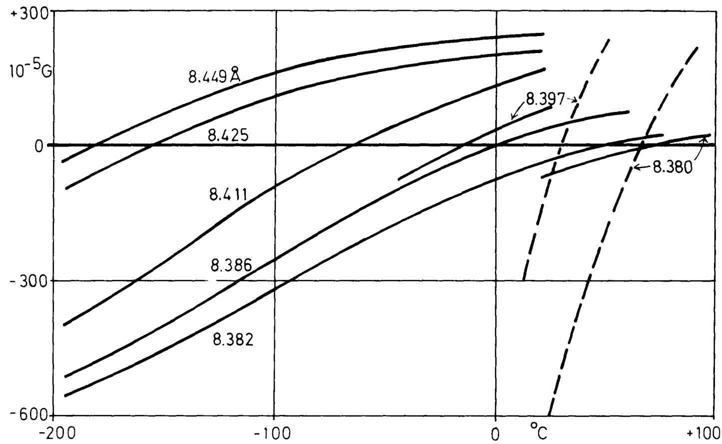

Fig. 1. Temperature dependence of CARM (continuous curves) and TRM (dashed curves) for several basalt samples from the hand specimen from Steinberg at Meensen near Göttingen. The lattice constants of the titanomaghemites in the basalt samples is given as parameter

have normal remanent magnetization with a direction of CARM antiparallel to that of the reversed samples. The temperature dependence of CARM (Fig. 1) shows that all samples undergo self-reversal: Samples with normal remanent magnetization at room temperature show self-reversal above room temperature and samples with reversed remanent magnetization below room temperature. – Also the artificially produced TRM shows self-reversal, sometimes at a temperature a little higher than the CARM (see Fig. 1).

The spontaneous magnetization versus temperature curves ($I_s(T)$) for samples with compensation temperatures T_k below about 0° C are N-type curves similar to those sometimes observed in basaltic rocks (Fig. 2). $I_s(T)$ does not vanish completely but has only a minimum at T_k because the material is not homogeneous. The $I_s(T)$ curves for samples with T_k above room temperature have no minimum but only a small hump below the Curie temperature and seem to approach the Q′-type (Schult, 1971). But these apparent Q′-type curves are "hybrid" N-type curves because the remanence clearly shows self-reversal.

The x-ray powder photographs of the separated material from all samples only shows lines responsible for a cubic spinel phase i.e. titanomaghemites in agreement with microscopic observations. The respective lattice constants are given in Fig. 1 and 2 as parameter. A microprobe analysis on two samples yielded the following compositions (calculated for stoichiometric titanomagnetite) with the respective lattice constants (accuracy 0.002 Å):

$Fe_{2.19}Ti_{0.69}Al_{0.02}Mg_{0.1}O_4$ (8.449 Å),

$Fe_{2.12}Ti_{0.65}Al_{0.12}Mg_{0.11}O_4$ (8.382 Å).

With the aid of the O'Reilly and Readman (1971) diagram an oxidation parameter $z \approx 0.4$ for the first analyzed sample and $z \approx 0.7$ for the second sample was estimated. (This estimation is only tentative because of appreciable Al and Mg content of the titanomaghemites.) The oxidation parameters of the

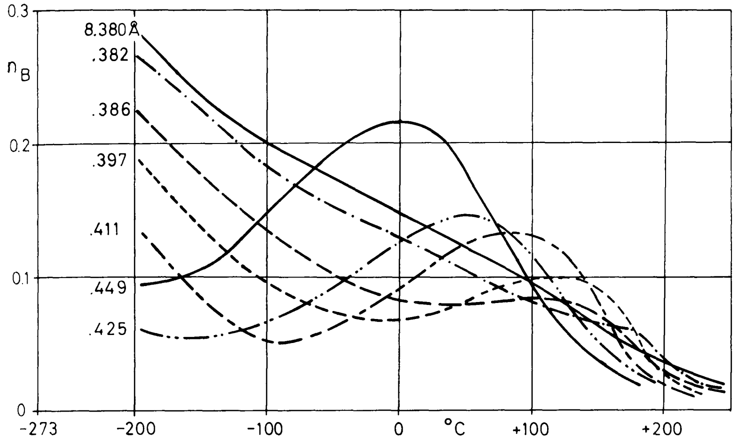

Fig. 2. Temperature dependence of spontaneous magnetization (in Bohr magnetons per formula unit titanomaghemite) measured on separated material from the same samples as in Fig. 1 with their respective lattice constants

other samples are probably between these two extreme values of z, because the two analyzed samples have (nearly) the extreme values in lattice constant and Curie temperature.—In the hand specimen the lattice parameter decreases from the centre to the surface and the Curie temperature increases. It can be assumed therefore that all samples have undergone low temperature oxidation most pronounced near the surface of the hand specimen. From Fig. 2 follows that with decreasing lattice parameter (i.e. increasing oxidation parameter) the spontaneous magnetization at 0° K and the compensation temperature increase. This can be explained by increasing ratio of the sublattice magnetizations at 0° K I_A/I_B (A for tetrahedral, B for octahedral sublattice) with $I_A/I_B > 1$ (Schult, 1971). It may be possible that with further low temperature oxidation the compensation temperature increases further until it equals the Curie temperature thus producing an irreversible self-reversal of remanent magnetization. For this process the Al and Mg content probably is also important. This will be discussed in a more detailed paper.

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