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ALTERNATING FIELD DEMAGNETIZATION OF ROCKS, AND THE PROBLEM OF GYROMAGNETIC REMANENCE

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Alternating field (a.f.) demagnetization has proved to be a very reliable technique for separating the magnetization components of rock samples. The method is subject to errors caused by either imperfection of the technique or by intrinsic properties of a rock. Recently, Stephenson [1,2] introduced the term gyroremanent magnetization (GRM) for a disturbing remanent magnetization that can be acquired by magnetic material during tumbling or stationary a.f. demagnetization. The implications for the routine a.f. demagnetization of anisotropic rock samples seemed to be very serious. Here, however, a method is presented on how to avoid the effect of GRM on results obtained from stationary a.f. demagnetization.

1. Introduction

Since the early days of palaeomagnetic research, two fundamental different methods of a.f. demagnetization have been used: the stationary method and the tumbling method. In the stationary demagnetization method, developed by As and Zijderveld [3], a sample is demagnetized along three orthogonal axes and subsequently the remanent magnetization is measured. During the demagnetization procedure there is no movement of the sample relative to the alternating field.

Ideally, the magnetic moments unblocked by an applied peak field will be aligned oppositely in equal amounts along the three orthogonal axes when the alternating field is reduced from its peak value to zero. In the tumbling demagnetization method, first published by Creer [4], the sample spins around two or more axes in presence of an alternating magnetic field. Ideally, the unblocked magnetic moments will be oriented at random when the field is reduced to zero. It was recognized [5,6] that for both methods disturbing magnetizations related to intrinsic properties of a rock, can be introduced during the demagnetization process. For the tumbling demagnetization method such an unwanted magnetization was named rotational remanent magnetization (RRM) and a way of correcting for it was given [7]. Stephenson [1] has explained RRM in terms of the gyromagnetic effect and also pointed out [2] that in a strongly anisotropic magnetic material a remanent magnetization can be introduced if the position of the specimen relative to the alternating field is stationary. He suggests that this too could be of gyroremanent origin.

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2. The extended stationary a.f. demagnetization method

The occurrence of a disturbing magnetization during the stationary a.f. demagnetization of certain rocks has been known for some time. Although at the time its origin was obscure, a method of correcting for it was developed [6], and an origin related to anisotropy was suggested [8]. The first observation of such a disturbing remanent magnetization was made on Permian rhyolites from the Bolzano area in Italy [6]. With routine stationary a.f. demagnetization (demagnetization with the *X*, *Y* and *Z* directions parallel to the coil axis and measurement of the total remanent vector of the specimen afterwards) it was found that the remanent magnetization first decreased but then increased after demagnetization in successively higher fields. If plotted on an orthogonal projection diagram [9] (Fig. 1a) the remanent magnetization moves away from the origin for higher alternating fields. A more detailed investigation of the rock followed. At each demagnetization step a sample was first treated as usual with respectively the *X*, *Y* and *Z* axis parallel to the coil axis. Then after the specimen was again demagnetized at the same peak field with the *X*-axis parallel to the coil axis, the total remanent magnetization was measured. The latter procedure was repeated with respectively *Y* and *Z* parallel to the coil axis. The results of these measurements are shown in Fig. 2. The open symbols in each of the diagrams give the intensities of the remanent magnetizations parallel to the coil axis where the closed symbols represent the remanent magnetization perpendicular to the coil axis. If at each demagnetization step the open symbols from each of the three diagrams are used to calculate the remanent magnetization, the resulting demagnetization diagram differs from the original one (Fig. 1b). The direction of the characteristic magnetization obtained from Fig. 1b agrees with the characteristic directions of other rocks from the same area which do not show the disturbing magnetization.

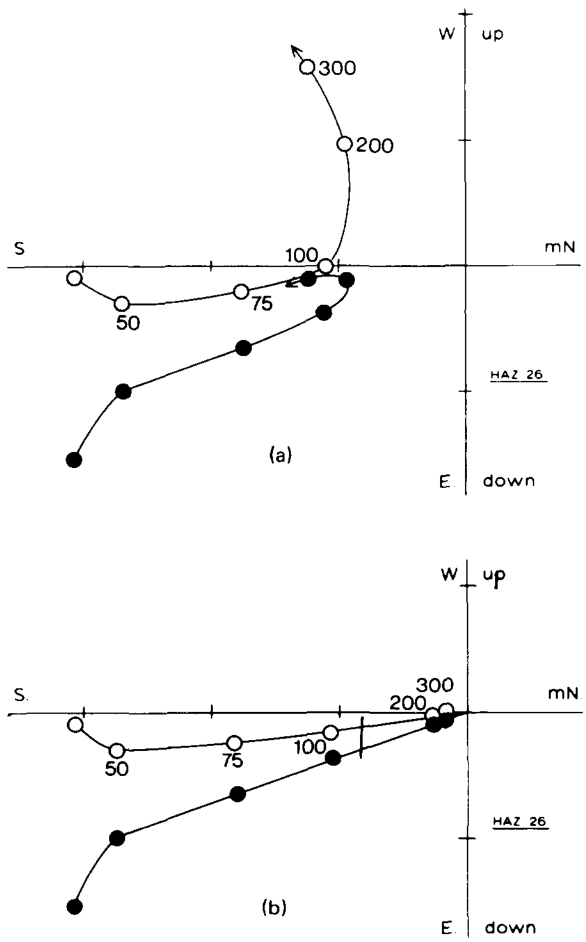
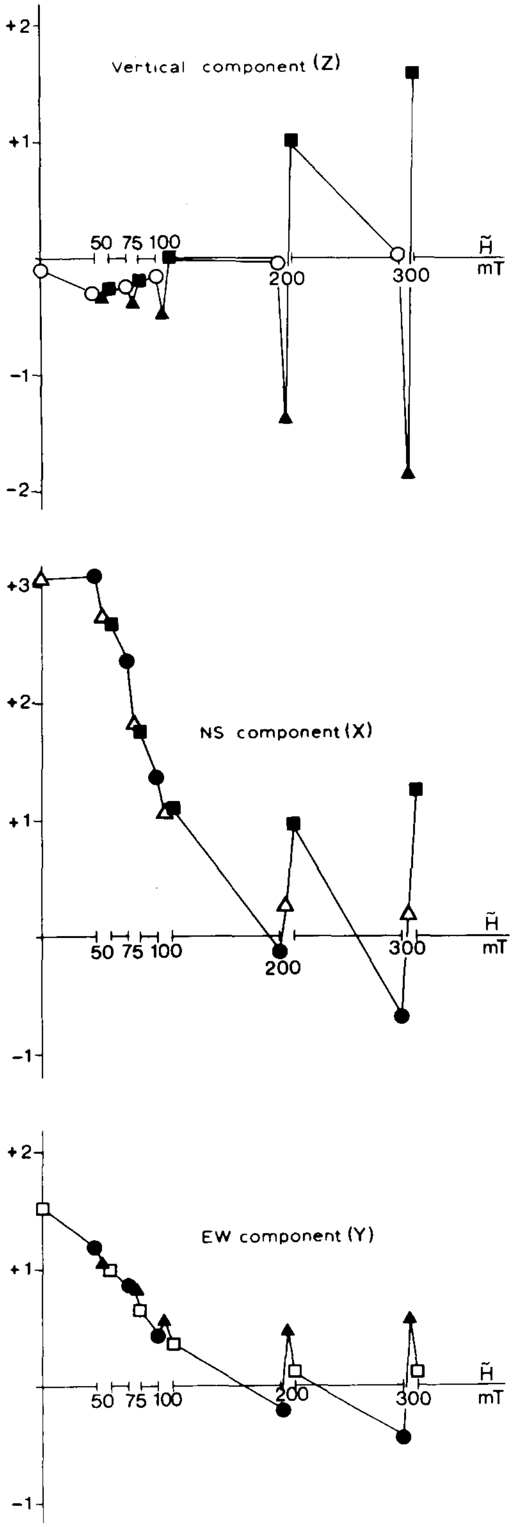


Fig. 1. Orthogonal projection diagrams of alternating field demagnetization results from a Permian rhyolite. (a) When routine a.f. demagnetization method is applied to the specimen. (b) When each of the three orthogonal directions of the specimen demagnetized and measured separately at each a.f. demagnetization step.

3. Discussion

Several experiments were done to identify the nature of the disturbing magnetization. Its properties can be summarized as follows: (1) its direction is always found perpendicular to the axis of the demagnetization coil axis; (2) there is no measurable effect parallel to the coil axis; (3) the effect increases with increasing alternating magnetic fields; (4) it is an intrinsic property of the rock; (5) it occurs both in igneous and sedimentary rocks [10]; (6) although the disturbing magnetization is most pronounced for high alternating fields, it can already be noticed for alternating fields as low as 40 mT. In a first attempt to explain the phenomenon, Dankers [8] argued that the disturbing effect is probably caused by rotation



of the unblocked magnetic moments of anisotropic grains from the alternating magnetic field direction to a direction of easy magnetization of the grain during reduction of the alternating field to zero. In that model the disturbing magnetizations perpendicular to the a.f. coil axis occur if the directions of easy magnetization in the rock are not symmetrical around the direction of the alternating field. Such a situation can occur for instance if the rock anisotropy has a trigonal symmetry.

According to Stephenson [2] a disturbing magnetization can also be introduced by direct equivalent magnetic field of gyromagnetic origin caused by relaxation of unblocked magnetic moments from the alternating field direction towards the easy magnetic direction, and oriented perpendicular to the alternating field. His observations made on an anisotropic sample made of pieces of magnetic recording tape are in excellent agreement with the observations on the Permian rhyolite presented here. It shows that if his interpretation is correct, gyromagnetic remanence can be a measureable effect in rocks. For palaeomagnetic research it is very important that from Stephenson's [2] experiments it can be concluded that the disturbing magnetization does not occur in the direction of the demagnetization coil axis. It means that the method of demagnetizing and measuring each X, Y and Z component separately at each demagnetization step, as used successfully in the Utrecht Palaeomagnetic Laboratory for many years on empirical grounds gives indeed results that are not affected by the disturbing remanent magnetization.

Conclusively it can be said that when using the stationary a.f. demagnetization method disturbing

Fig. 2. Change of the three orthogonal components of the natural remanent magnetization of a Permian rhyolite (HAZ 26) during alternating field demagnetization in five steps up to 300 mT. At each alternating field intensity (50, 75, 100, 200, 300 mT) the sample was demagnetized three times and completely measured after each treatment. Open symbols denote intensities in the direction parallel to the coil axis and full symbols measurements perpendicular to the coil axis. Circles indicate results after demagnetization of the sample with the Z-axis parallel to the coil axis, triangles after demagnetization with the X-axis parallel to the coil axis and squares after demagnetization with the Y-axis parallel to the coil axis.

magnetizations can be recognized and can be separated from the NRM demagnetization results by following a special procedure. At the same time information is obtained about the high field anisotropy of the rock, which probably can be useful for the geological interpretation of the genesis of the rock.

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