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SHORT NOTE

A simple, alternative presentation of paleomagnetic demagnetization data

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RESUMEN

La mayoría de los artículos de investigación en paleomagnetismo y magnetismo de rocas publicados desde 1967, usan diagramas de componentes vectoriales (conocidos como diagramas de Zijderfeld) para describir e investigar la estabilidad direccional y la intensidad del decaimiento de la magnetización remanente durante la demagnetización en el laboratorio. Por consiguiente, el entendimiento del paleomagnetismo moderno requiere de la comprensión clara de esta técnica de gráficas. Desafortunadamente, el diagrama de Zijderfeld no es fácilmente comprensible para gran parte de la comunidad geocientífica. Además, no es posible leer directamente los ángulos de declinación e inclinación en el diagrama. Se propone aquí una simple presentación de los datos de demagnetización. Este diagrama alternativo expone la información esencial que contienen actualmente los diagramas estereográficos y las curvas de intensidad normalizada. Es también eficaz para la presentación de datos de paleointensidad con el método de Thellier.

PALABRAS CLAVE: Paleomagnetismo, diagrama de Zijderfeld.

ABSTRACT

Most research articles on paleomagnetism and rock-magnetism published since 1967 use vector component diagrams (known as Zijderfeld diagrams) to describe and investigate the directional stability and intensity decay of remanent magnetization during standard laboratory demagnetization. The understanding of modern paleomagnetism, therefore, requires the clear comprehension of this graphical technique. Unfortunately the Zijderfeld diagram is not readily comprehensible, for much of the geoscience community. Furthermore, it is not possible to directly read the declination and inclination angles on the diagram. A simple presentation of demagnetization data is proposed. This alternative diagram displays the essential information currently contained in stereographic diagrams and normalized intensity plots. It is also effective for presentation of Thellier paleointensity data.

KEY WORDS: Paleomagnetism, Zijderfeld diagram.

INTRODUCTION

The orthogonal projection (Zijderfeld diagram) is used to visualize the progressive demagnetization of remanent magnetization during stepwise thermal or alternating field (AF) demagnetization. This method has the advantage compared to early proposed stereographic projection that the intensity of magnetization is incorporated in the diagram; on the other hand, two curves are required.

Some typical examples of stepwise demagnetization are shown on Figures 1 to 3. In the upper part of each figure, the natural remanent magnetization (NRM) vector is placed at the origin of the Cartesian coordinate system. The tip of the vector is projected on the horizontal and vertical planes, indicating magnetic declination and apparent inclination respectively. The distance of each data point from the origin is proportional to the intensity of NRM. The NRM vector is decomposed into its north (N), east (E) and vertical (Z) components

$$N_i = \text{NRM}_i \cos(I_i) \cos(D_i)$$

$$E_i = \text{NRM}_i \cos(I_i) \sin(D_i) \quad (1)$$

$$Z_i = \text{NRM}_i \sin(I_i)$$

where NRM_i is the intensity of natural remanent magnetization and I_i and D_i are the inclination and declination of NRM_i . The Zijderfeld diagram in its classical form indicates only the apparent inclination. True inclination is given by

$$\tan(I) = \tan(I_{app}) \left| \cos(D) \right| \quad (2)$$

DESCRIPTION OF NEW DIAGRAM

Some inconveniences might be noted when using the Zijderfeld diagram: (1) is relatively complex, especially for the non-paleomagnetic geoscience community, (2) it does not yield directly the numerical values of the declination and inclination. The values of the angles are needed from tables

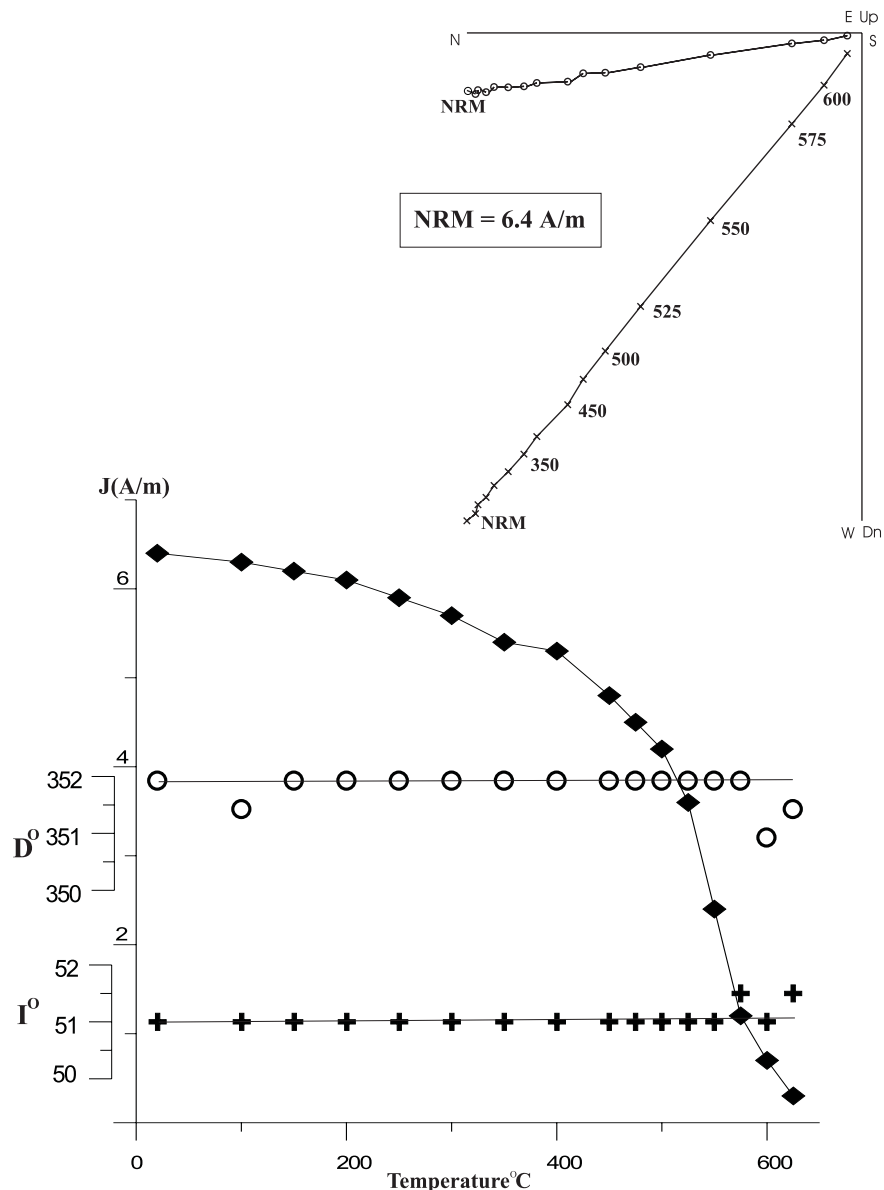


Fig. 1. Standard thermal demagnetization obtained on an andesite sample with simple one component NRM (from Goguitchaichvili *et al.*, 1997). Upper part - Zijderveld diagram, the numbers refer to the temperatures in °C, \circ projection onto the horizontal plane, \times projection into the vertical plan; Lower part, alternative presentation (see text). (+) Inclination, (o) Declination. (♦) NRM intensity.

or the associated stereographic projection must be given; (3) it does not provide the unblocking temperature or alternating field spectra. Associated demagnetization curves need to be given, in order to estimate the MDT (median destructive temperature) and MDF (median destructive field).

A proposed simple presentation is shown on the lower parts of Figures 1 to 3. Demagnetization curves and associated paleodirections obtained after each heating step are presented in a single diagram. Any straight lines through the origin of the Zijderveld diagram define a characteristic mag-

netization component. They are represented by horizontal declination and inclination segments in our proposed diagram. This new presentation (1) is very simple to understand for people who are unfamiliar with paleomagnetism, (2) allows the numerical values of inclination and declination as well as their stability during treatments to be retrieved directly, (3) it yields information about the intensity (unblocking temperature or AF spectra, MDTs and MDFs) directly from the remanence decay curves.

When multicomponent magnetization is present, the secondary component **A** (Figure 2) forms a linear path on the

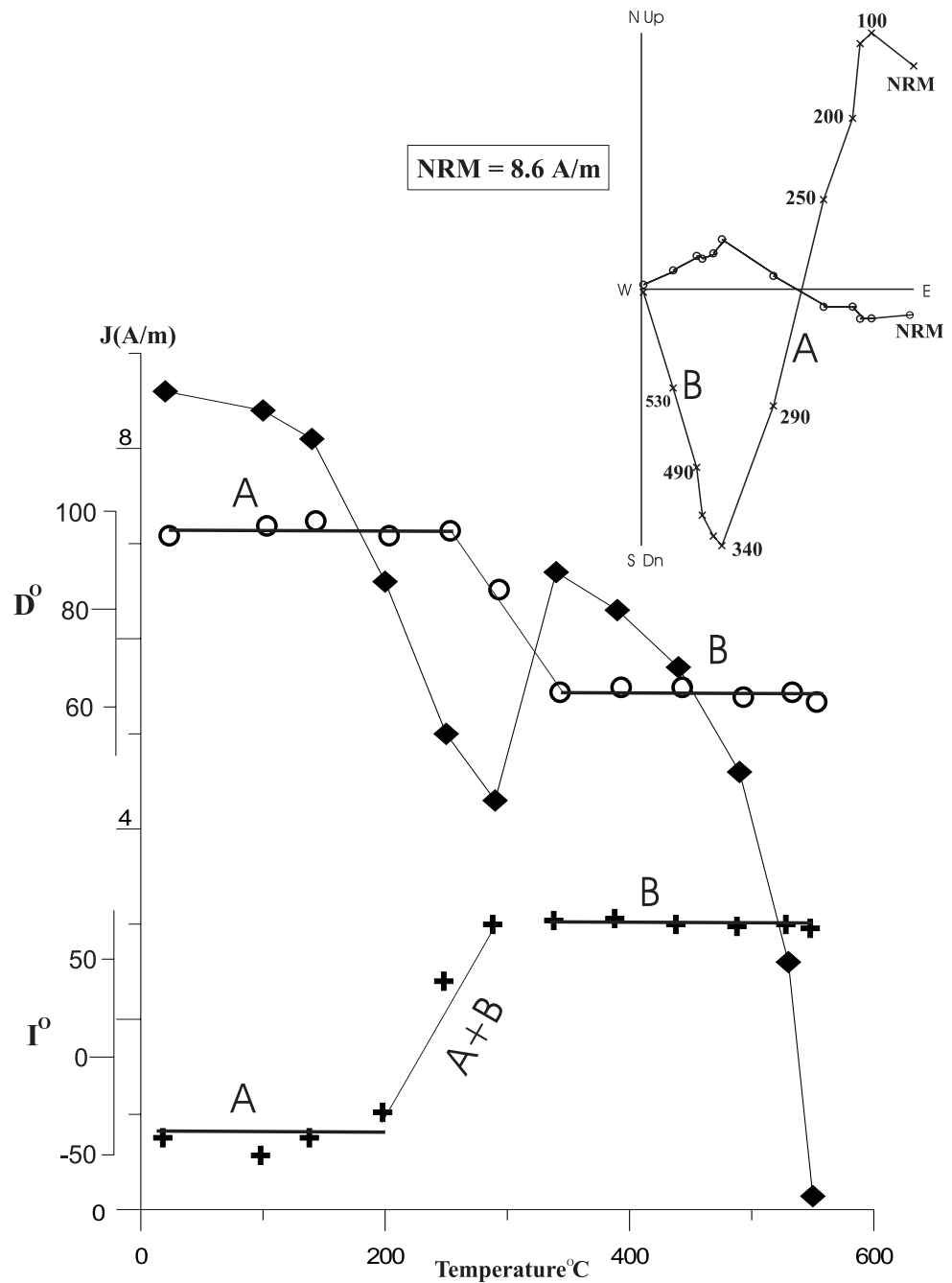


Fig. 2. Example of standard thermal demagnetization obtained on a basaltic sample with a multicomponent magnetization (from Goguitchaichvili *et al.*, 1999a). Notation as in Figure 1.

Zijderveld diagram, but it does not point to the origin because the direction changes during stepwise demagnetization as both **A** and **B** components are present. Thus, every point of component **A** in the Zijderveld diagram corresponds in fact to a mixture of **A** and **B** components and pure secondary magnetization directions cannot be found. The 'second-

ary' component is divided into two different segments in our proposed presentation (Figure 2, lower part). During the early steps of demagnetization (NRM to 200°C), primary magnetization (**B**) is present, but the remanence may be dominated by secondary magnetization (**A**). At higher demagnetization steps the primary component will contribute largely to the

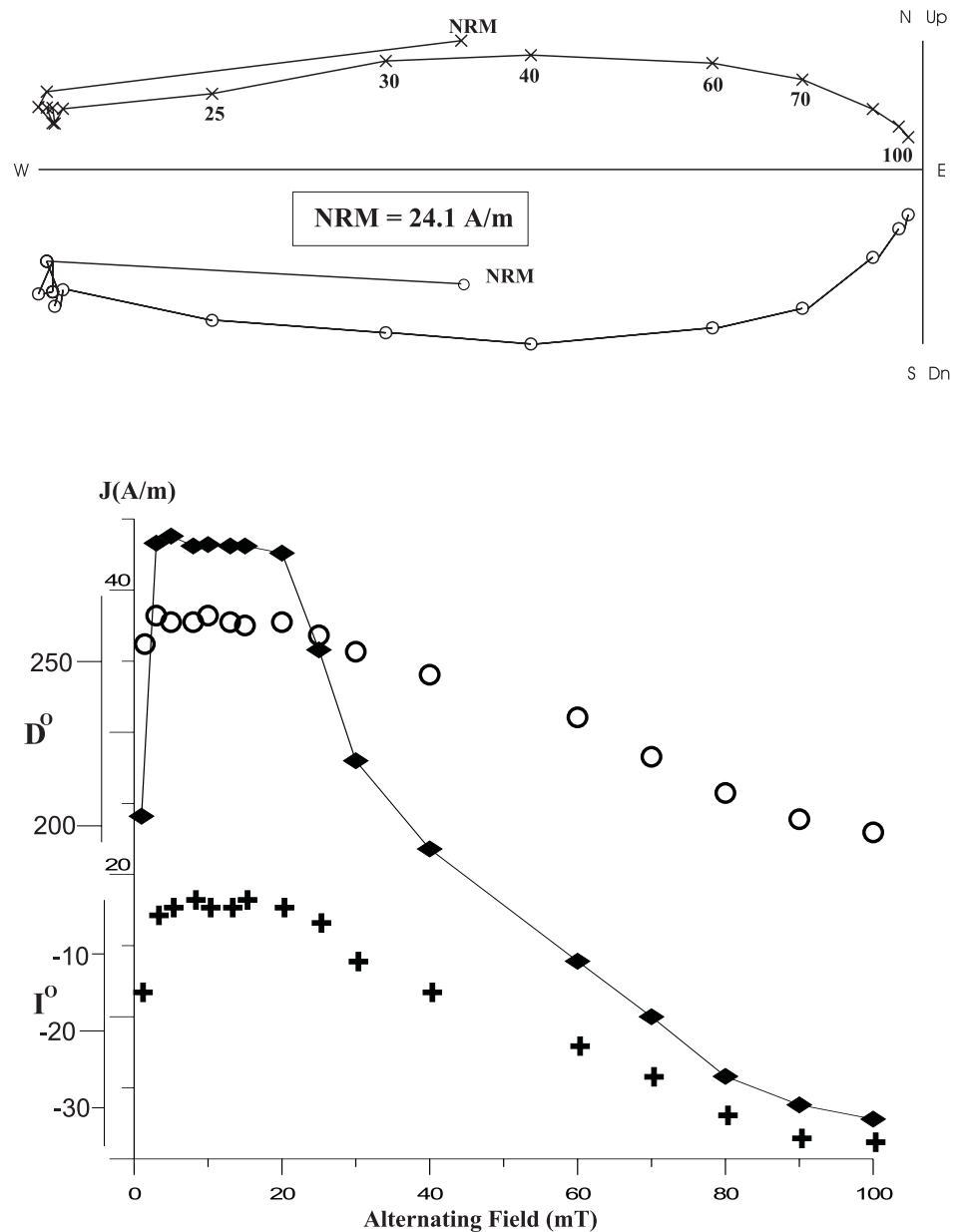


Fig. 3. Example of standard alternating field demagnetization obtained on a basaltic sample (from Soler, 1997), affected by lightning. Notation as in Figure 1.

total magnetization and the NRM values between 200° and 340°C correspond to some intermediate value (A+B in Figure 2). Thus, a better visualization of the directions is obtained.

The new presentation may also be used as a tool for absolute geomagnetic intensity determination. The upper part of Figure 4 shows Thellier paleointensity plots (Thellier and Thellier, 1959) with the associated Zijderveld diagram, which helps to check direction changes during heating in a magnetic field. For our proposed presentation (Figure 4, lower part) it

becomes possible to incorporate NRM demagnetization and thermoremanent magnetization (TRM) acquisition curves.

The examples shown in Figures 1 to 4 suggest that the new presentation of paleomagnetic data may be friendlier and more informative than the original Zijderveld diagram. It allows a direct reading of declination and inclination. Finally, the new diagram includes the demagnetization curve and the TRM acquisition curve, for the case of Thellier experiments.

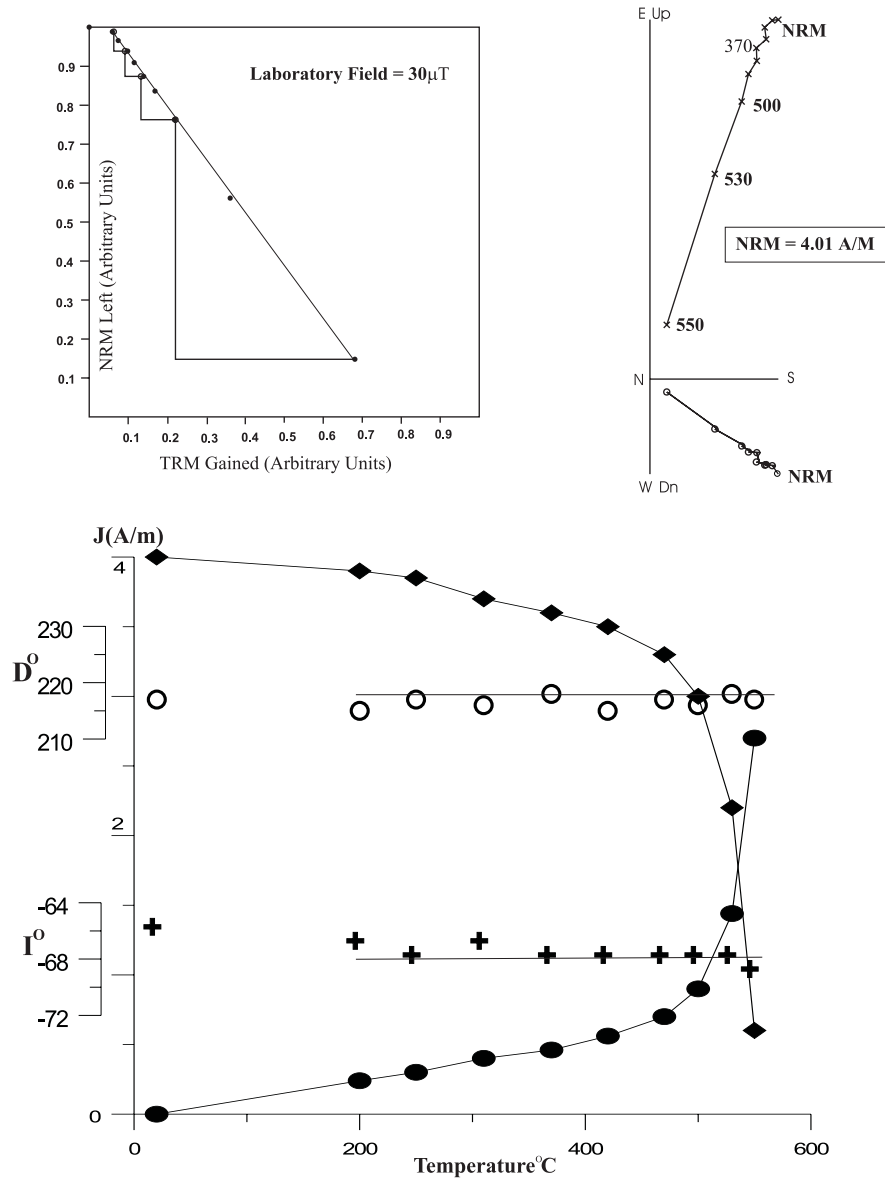


Fig. 4. Example of Thellier paleointensity determination for a hyaloclastite (Goguitchaichvili *et al.*, 1999b). Upper part NRM-TRM plot and associated Zijdeveld diagram; the numbers refer to temperatures in $^\circ\text{C}$, \circ projection into the vertical plane, \times projection on the horizontal plane; Lower part, alternative presentation with incorporation of TRM acquisition curve. (+) Inclination, (o) Declination, (\diamond) NRM left, (\bullet) TRM gained.

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