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Identification of magnetic coercivity components in natural substances using Max Unmix web-application

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Abstract

Identification of magnetic minerals in rocks and other natural substances (sediments, ashes, soils, etc.) is important in Earth sciences. Such identification often uses a measurement of the IRM (isothermal remanent magnetization) acquisition curve that in turn provides the coercivity spectrum of the sample. In this study, MAX Unmix web-based application was used to unmix the coercivity spectrum of 13 natural samples to obtain their coercivity components. Digitized IRM acquisition data were inputted into the application, then adjusted specific parameters to obtain a best-fit coercivity spectrum revealing coercivity components. As a result, two to three components are generally identified for each sample. MAX Unmix application is highly recommended in future studies requiring the identification of magnetic minerals in natural substances.

1. Introduction

Magnetic methods are often used in Earth sciences, including volcanology and environmental studies. In such studies, magnetic methods are used to identify natural substances' magnetic mineralogy and granulometry (rocks, sediments, ashes, etc.). These identifications are often complicated as magnetic particles in natural substances are heterogeneous. One way to identify the magnetic properties of a natural substance is through its magnetic coercivity. In rock magnetism, it is common to decipher the magnetic coercivity spectrums or components through the shape of isothermal remanent magnetization (IRM) acquisition curve [1]. Such curves are subjected to statistical analyses known collectively as the unmixing process. Several computer software could be used in the unmixing process. However, some are outdated or require expensive licensure [2–4]. A web application for unmixing magnetic coercivity distribution was recently released and termed MAX Unmix [5]. This web application is available at the following site: http://www.irm.umn.edu/maxunmix. In this study, MAX Unmix was tested in IRM acquisition curves of natural substances that include volcanic lavas, volcanic ashes, lake sediments as well as soils and fly ashes. In all cases, MAX Unmix provided the coercivity components that could then be used to differentiate one sample or substance from the other. MAX Unmix has shown versatility and might be adopted as a standard practice in rock magnetism.

2. Experimental Methods

IRM acquisition curves were acquired from the literatures and the previous works of senior author and his former students. If the digital data were not available, the IRM acquisition curves were digitized from printed literature using WebPlotDigitizer, a web-based application (https://automeris.io/WebPlotDigitizer/) that could be used to extract data from plots, images, and maps. Table 1 shows the description of the 13 samples used in this study, while Figure 1 shows the typical IRM acquisition curves. The digitized IRM acquisition curves were then entered into the MAX Unmix application. MAX Unmix application then issued a raw coercivity spectrum for each sample. Figure 2 shows the typical raw coercivity spectrum for the samples in this study. The operator then adjusted three parameters (mean coercivity, dispersion, and relative proportion) to obtain the components of the coercivity spectrum. The adjustment or curve fitting was conducted by a trial-and-error approach until a best-fit coercivity spectrum was obtained.

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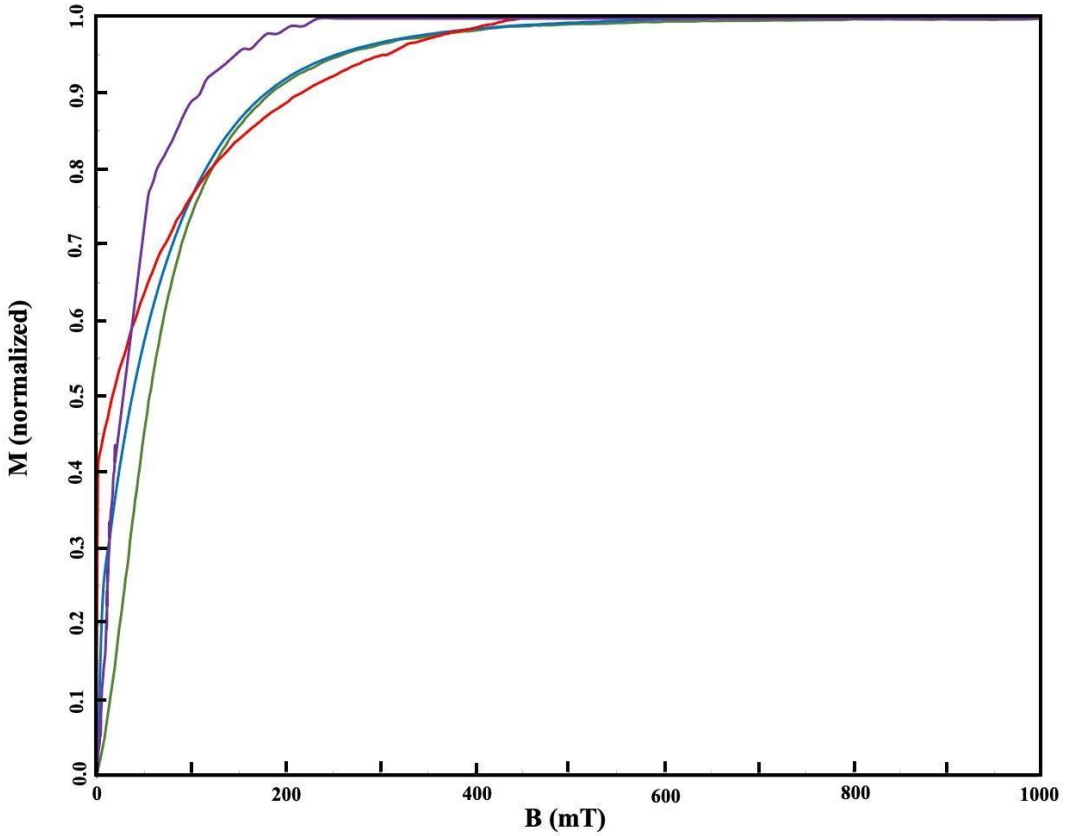


Fig. 1. The typical digitized IRM acquisition curves used in this study. Red curve represents volcanic lavas (IJ-1), green curve represents volcanic ashes (Bromo), blue curve represents lake sediments (TOW9-4-125), and purple curve represents fly-ash (KTPS ASH)

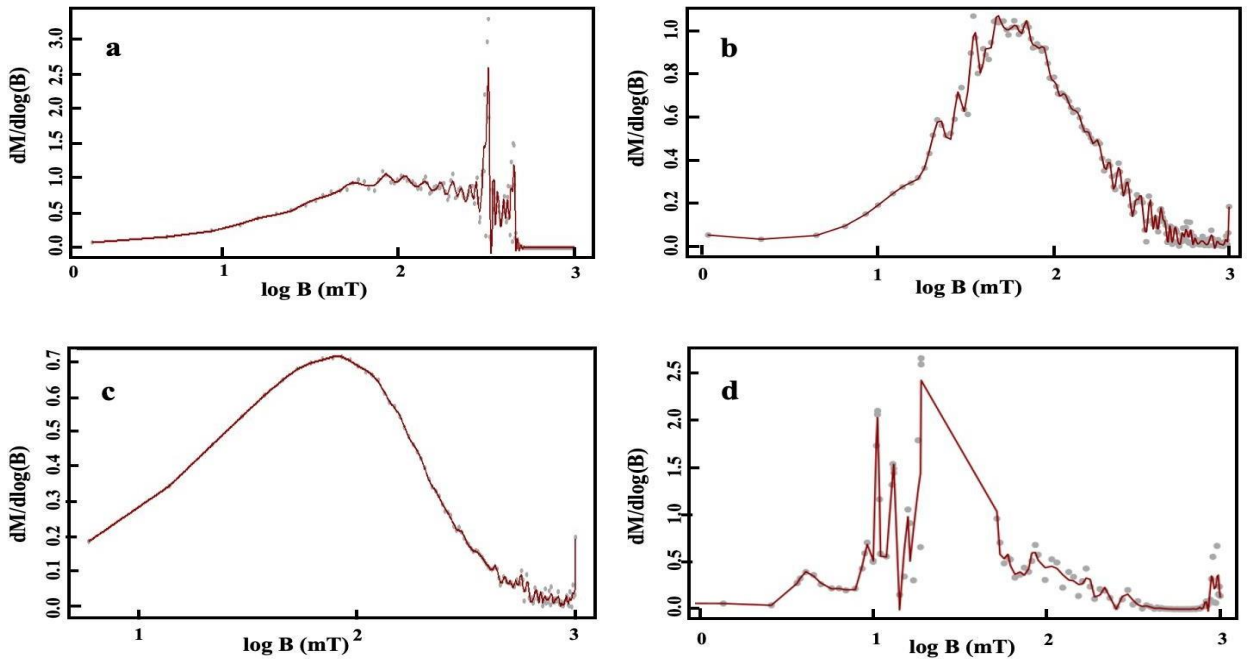


Fig. 2. The typical raw coercivity spectrum issued by MAX Unmix prior to adjustment or curve-fitting process. (a). volcanic lavas (IJ-1), (b) volcanic ashes (Bromo), (c) lake sediments (TOW9-4-125) and (d) fly-ash (KTPS ASH

3. Results and Discussion

Figure 3 shows the coercivity models issued by MAX Unmix for the typical samples used in this study. In most cases, there are two coercivity components except for the volcanic ashes (Bromo), which have three components. Table 1 shows the coercivity components in the 13 samples in this study. As shown in Figure 3, except for fly ashes, all the models are in good agreement with the coercivity components. However, the model for fly ashes is not as good as that for other samples, likely due to its relatively poor quality of digitized IRM curve (see Figure 1). Identification of two or more coercivity instruments in the sample or a group of samples is invaluable in characterizing the properties of such sample(s). For instance, in the case of volcanic ashes, the recent Bromo ash is clearly distinguishable from its older counterparts (Widodaren of 1.8 kyr and Segorowedi of 33 kyr). See [7] for details of the volcanic ashes. Similar analyses could be drawn for other samples. Differences in coercivity components or spectrum in natural samples might be due to variation in magnetic mineralogy as well as in the magnetic domain. In natural samples, the predominant magnetic minerals are iron-bearing minerals that occur as iron oxides, iron oxyhydroxides, or iron sulphides [10]. Each mineral has its distinctive coercivity spectrum. Moreover, for each mineral, its coercivity spectrum might also be affected by its magnetic domain. For example, samples containing predominantly single-domain (SD) grains would have higher coercivity than those containing multi-domain (MD) grains. Variation of magnetic mineralogy and magnetic domain in natural samples is not a simple manner as it might be controlled by the source(s) as well as by the processes experienced by the sample such as diagenesis [10]. Availability of MAX Unmix and other software that would allow identification of coercivity components and spectrum in natural samples is invaluable in PREM (paleo-, rock-, and environmental magnetism).

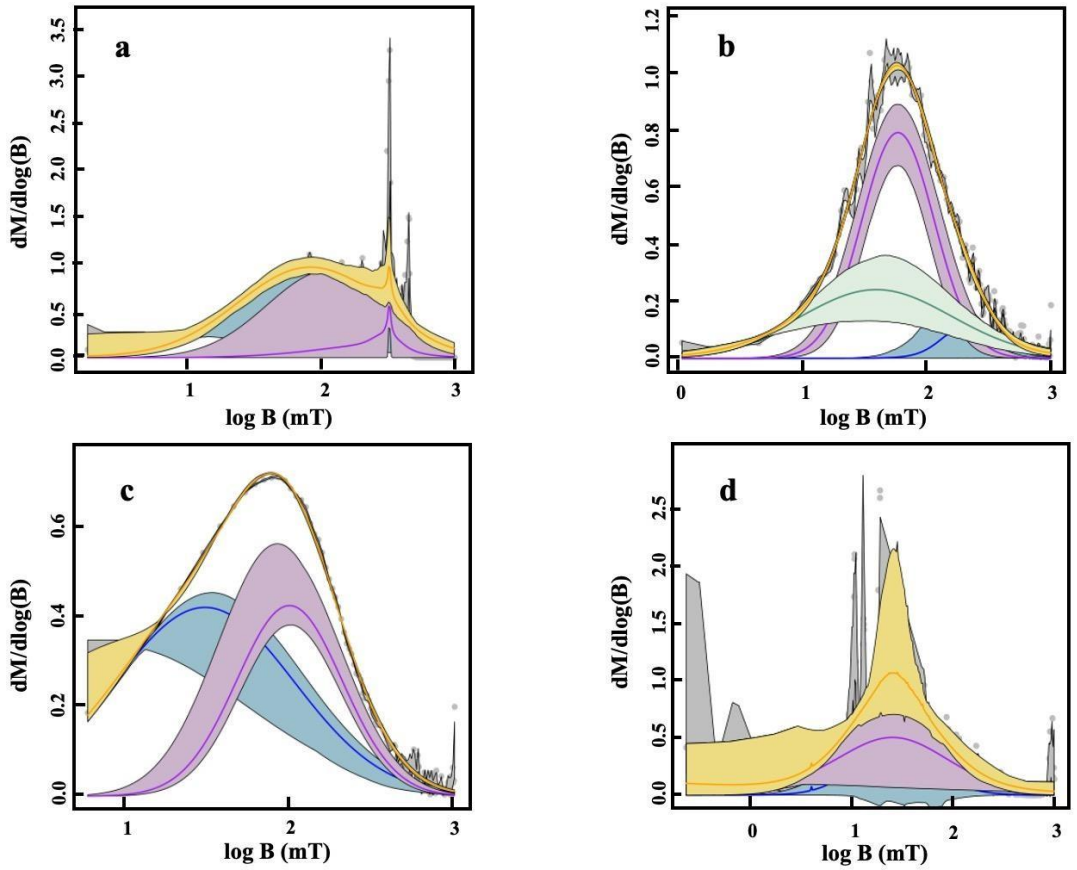


Fig. 3. Coercivity models issued by MAX Unmix after adjustment or curve-fitting process. (a). volcanic lavas (IJ-1), (b) volcanic ashes (Bromo), (c) lake sediments (TOW9-4-125) and (d) fly-ash (KTPS ASH). Blue lines represent the first coercivity component, purple lines the second coercivity component, and green lines the third coercivity component. The yellow lines represent the best-fit coercivity model or spectrum based on the data shown in grey lines. All data, except for the fly ash show good fit between the model and the data. See text for explanation.

4. Conclusions

We have presented the results of our evaluation on the use of MAX Unmix web-based application in identifying magnetic coercivity components in 13 natural samples that include volcanic lavas, volcanic ashes, lake sediments, soils, and fly-ash MAX Unmix could generally identify 2 to 3 components in each sample. When compared with original reports or publications (from which the IRM acquisition curves were obtained), these components, in turn, belong to either different magnetic minerals or different magnetic-grain sizes. Due to its accessibility and versatility, MAX Unmix is highly recommended to future studies requiring the identification of magnetic minerals in natural substances.

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