Anisotropy of Magnetic Susceptibility Parameters: Guidelines for their Rational Selection

EDGARDO CAÑÓN-TAPIA

Abstract—Twenty-eight parameters used to characterize measurements of the anisotropy of magnetic susceptibility are compared theoretically in this work by introducing the concept of the field of susceptibility tensors, which allows the representation of parameters as families of lines in a plane. It is demonstrated that the foliation and lineation parameters are but a special case of the shape parameters, implying that the resolution of these two rock fabric elements using AMS measurements alone is more an artifact of the numerical range of definition of some parameters than a quantification of two physically independent features. Also, it is shown that parameters presumably of the same type do not necessarily yield equivalent interpretation of results in a qualitative sense, and therefore, caution should be strongly exercised when parameters are to be selected. Parameters quantifying the degree of anisotropy are, in general, equivalent to each other because of the very small departure observed in natural rocks from the isotropic case. However, a final consideration of the possible ability to differentiate rock types and a convenient range of values allowing expression of the degree of anisotropy in a well-defined percentage are pointed out as the main factors to be considered before selecting one parameter within this class.

Key words: Magnetic susceptibility, AMS parameters, magnetic fabrics, degree of anisotropy.

Introduction

Due to the interest in the determination of the low-field anisotropy of magnetic susceptibility (AMS) because of its value as a petrofabric indicator, numerous anisotropy factors have been proposed. The selection of suitable parameters is one of the most fundamental aspects of any AMS study, yet at present there are no objective criteria for deciding which parameters should be used (see e.g., HROUDA, 1982). In an effort to alleviate this situation, ELLWOOD et al. (1988) suggested some criteria, within an instrumental basis, to select parameters. They pointed out that some methods of measurement favor the use of parameters that include the differences of the principal susceptibilities, while others call for the use of their

1 HIG-SOEST Univ. of Hawaii at Manoa, 2525 Corrca Rd., Honolulu, Hawaii 96822, U.S.A.
ratios (see also HROUDA and JELINEK, 1990). However, they overlooked the fact that most of the available parameters use both ratios and differences of the principal susceptibilities in their definitions and, as will be shown later, given the small departures from the isotropic case that are usually observed in rock specimens, there is no practical difference between both types of parameters. Another important aspect of this problem was also highlighted by ELLWOOD et al. (1988) and TARLING (1983), who mentioned that the actual calculation of different parameters reduces to a simple arithmetical combination of the principal susceptibilities, provided that these can be uniquely determined, and consequently, all of them are interdependent to some extent. Therefore, the need for more structured criteria that can be used to select AMS parameters has not yet been completely satisfied.

In practice, four classes (foliation, lineation, shape and degree of anisotropy) of AMS parameters are used to make quantitative comparisons of the properties that they are supposed to be estimating and, commonly, it has been assumed that the selection of a particular parameter within each of these classes is unimportant (RAHMAN et al., 1975; TARLING, 1983), i.e., it is expected that any two parameters within the same class will yield very similar, if not identical, qualitative results. However, this assumption was never proved, and as will be illustrated later, it was not completely justified in some cases.

In this work, a mathematically oriented point of view was used to make a theoretical comparison among 28 AMS parameters (see Tables 1 and 2), allowing the formalization of the equivalences between some of them. The theoretical comparison was made by introducing a suitable representation of the field of susceptibility tensors, in which parameters could be conveniently expressed as families of lines; constraining the area of interest to the range of expected experimental values proved to be important in the establishment of equivalences. It is important to mention that, with this approach, parameters are examined independently of their physical definition, i.e., whether they were first proposed as measuring magnetic foliation or degree of anisotropy is not important; the emphasis is rather made on some of their mathematical properties such as range of definition and distribution of this range within the field of susceptibility tensors, and also in the qualitative results that are expected from the use of a given parameter. The latter aspect was approached by using actual values of the principal susceptibilities taken from several rock types to test the validity of the theoretical considerations and, ultimately, to justify the suggested reduction to only two different classes of parameters. In any case, the purpose of this work is to offer to the interested reader the opportunity to compare parameters in a more structured and objective manner than possible to date, allowing him (her) to decide which parameters are more convenient for his (her) particular interests.