

MASS MAGNETIC SUSCEPTIBILITIES OF
SOME TRIOCTAHEDRAL MICAS

WILLIAM C. HOOD, *Department of Geology, University
of South Florida, Tampa, Florida*

AND

RICHARD L. P. CUSTER, *North Carolina Highway Commission,
Raleigh, North Carolina*

ABSTRACT

Mass magnetic susceptibility values of thirty-eight trioctahedral micas range from 0.74×10^{-6} cgs to 74.84×10^{-6} cgs and are found to be a function of total iron content according to the relationship: $\log K_m = 0.0827 + 1.1435 \log \text{Fe}_2\text{O}_3$. Oxidation state of the iron influences mass magnetic susceptibility less than total iron content, with ferrous iron imparting a slightly higher susceptibility than ferric iron.

INTRODUCTION

Mass magnetic susceptibilities of thirty-eight trioctahedral micas were determined using a Frantz Isodynamic Separator. Comparison of the data to partial chemical analyses indicates clearly that the major controlling factor in determining magnetic susceptibility is the amount of iron present in the mica. The direct relationship verifies Kruglyakova's (1964) results and is established precisely enough that magnetic susceptibility can be used to rapidly estimate total iron content in trioctahedral micas.

EXPERIMENTAL METHODS

Both chemical analyses and mass magnetic susceptibility determinations were made on purified samples of phlogopite, biotite, and lepidomelane micas. Analyses for total iron were made colorimetrically using a Bausch and Lomb Spectronic 20 colorimeter and the method of Shapiro and Brannock (1962). Analyses for FeO were made by the method of Reichen and Fahey (1962). Results for total iron are considered to be precise to $\pm 3\%$ and FeO $\pm 2\%$ of the amount present.

Mass magnetic susceptibilities of micas with particle size of 125 to 250 microns were calculated from measurements made with a Frantz Model L-1 Isodynamic Separator. In most instances a side slope of 15° and a forward slope of 25° was used. For greater precision, the machine was modified by connecting an ammeter with a larger scale in series with the ammeter of the separator. Use of the larger meter allowed amperage to be read directly to 0.01 amperes and estimated to 0.002 amperes. Each sample was inserted into the machine and the current adjusted until the separator split the sample into two equal parts, one more and one less magnetic. Because of the danger of saturation, current values greater than one ampere were not used. When the desired splitting of the sample could not be obtained with a side slope of 15° and currents less than one ampere, side slope was reduced, the current adjusted until splitting was obtained, and the reduced value of side slope was then utilized in calculating mass magnetic susceptibility.

Visual estimation was used to determine the equality point in splitting the samples.

Weighing the splits was found to be unnecessarily time consuming. The amperage needed to split a biotite sample from Raleigh, N. C., was determined by each of six individuals. Values ranged from 0.369 to 0.375 amperes with the mean being 0.372 and the standard deviation 0.002 amperes.

The amperage necessary to split a sample was used to calculate mass magnetic susceptibility according to the following equation (Hess, 1959):

$$K_m = \frac{20 \sin \alpha \times 10^{-6} \text{ cgs}}{I^2}$$

where K_m is mass magnetic susceptibility, α is the angle of side slope, and I is the current in amperes.

RESULTS

The results of chemical analyses and mass magnetic susceptibility determinations show that mass magnetic susceptibility values range from 0.74×10^{-6} cgs for a phlogopite with 1.30 percent Fe_2O_3 to 74.84×10^{-6} cgs for a biotite with 33.81 percent Fe_2O_3 . This range in values agrees well with those reported by other workers (Rosenblum, 1958; Povarennykh, 1964; Kruglyakova, 1964) although some of the values for phlogopites are lower than those previously reported.

The log of mass magnetic susceptibility is a function of log of total iron content (Fig. 1). The data appear to fall along a straight line, the equation for which, determined by least squares analysis, is:

$$\log K_m = 0.0827 + 1.1435 \log \text{Fe}_2\text{O}_3$$

where K_m is mass magnetic susceptibility and Fe_2O_3 is total iron content. For practical laboratory purposes, a more usable form of this equation is obtained by converting K_m back to current necessary to split the sample into two equal parts. The equation then becomes, for a side slope of 15° :

$$\log I = 0.3156 - 0.5718 \log \text{Fe}_2\text{O}_3$$

where I is the current (in amperes) needed to split the sample and Fe_2O_3 is total iron content. A convenient way to use the equation is to plot the line on semilogarithmic coordinates with current on the semilog axis. This curve, the experimentally determined points, and the data given by Kruglyakova (1964) are shown in Figure 2. It indicates the determination of current needed to split a mica sample can be used as a simple and rapid method for estimating the total iron content of a trioctahedral mica.

Of the 46 points plotted, eight have magnetic susceptibilities that are distinctly lower than the general trend. Of these, seven have Fe_2O_3 to FeO ratios greater than 1.75. Conversely, of the eleven samples that have ratios greater than 1.75, only four are not significantly lower than the general trend. This seems to indicate that the oxidation state of the iron

exerts some control over mass magnetic susceptibility, with micas having high Fe_2O_3 to FeO ratios generally having lower mass magnetic susceptibilities, other things being equal, than those with low Fe_2O_3 to FeO ratios.

To test this hypothesis, approximately 0.5 g of each of five samples was placed in 20 ml of 30 percent hydrogen peroxide and heated at 70°C

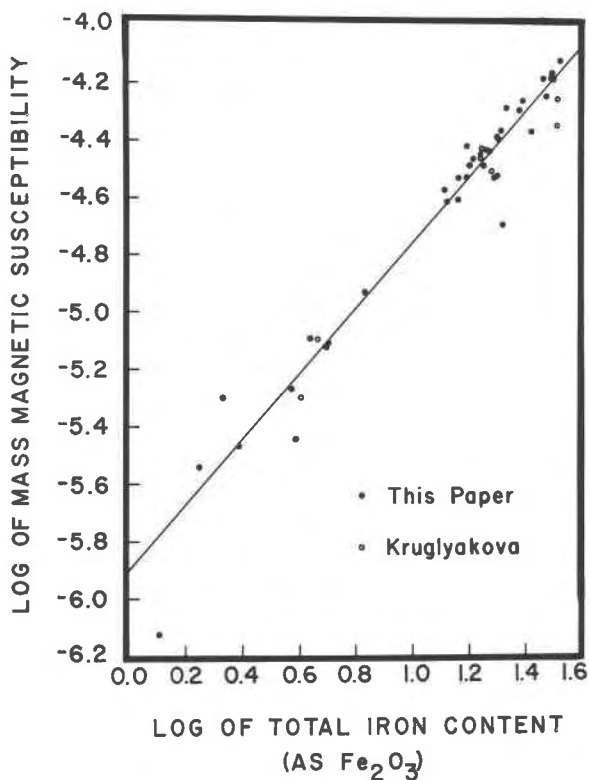


FIG. 1. Log of mass magnetic susceptibility as a function of log of total iron content.

until dry in an attempt to oxidize some of the ferrous iron and determine if there was any change in mass magnetic susceptibility. The treatment resulted in a distinct color change in the micas, with the colors becoming lighter and taking on silvery or golden tones.

Three of the five samples decreased in K_m , one increased, and one remained constant (Table 1). The one that remained constant was low in total iron content with a relatively high Fe_2O_3 to FeO ratio and was slightly above the general trend before treatment; therefore, it is not

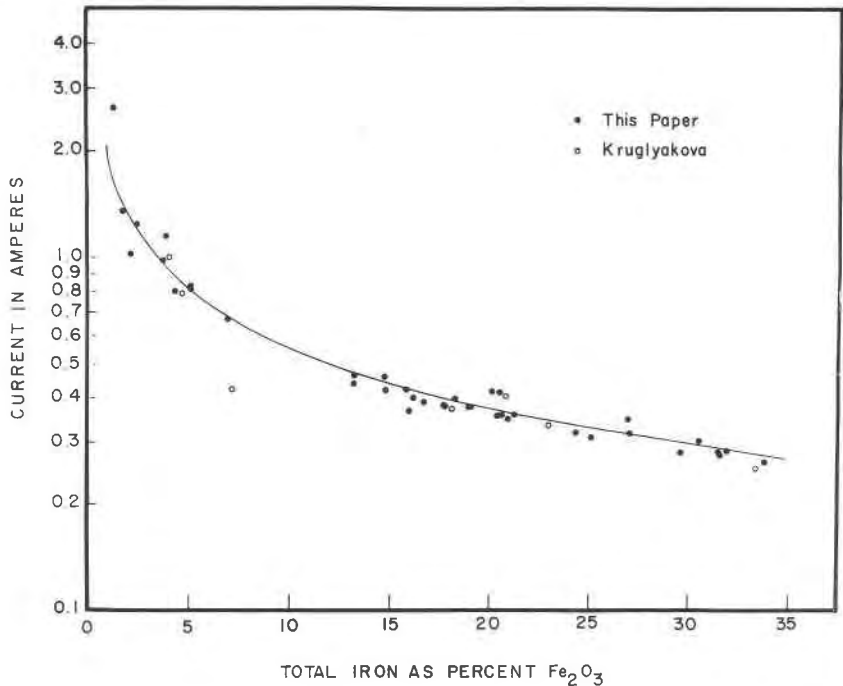


FIG. 2. Current necessary to split a mica sample into two equal parts as a function of total iron content.

surprising that no change occurred. We cannot explain the slight increase of K_m in sample number 12. The remaining three samples decreased in K_m , indicating that the relative amounts of Fe^{3+} and Fe^{2+} probably do play a role in determining the mass magnetic susceptibilities of trioctahedral micas.

This result is rather surprising, because the magnetic susceptibility of

TABLE 1. OXIDATION EXPERIMENTS ON SOME MICAS

Sample No.	Total Iron	FeO	Ratio	K_m Before Oxidation $\times 10^{-6}$ cgs	K_m After Oxidation $\times 10^{-6}$ cgs
2	1.81	1.14	1.6	2.84	2.84
12	14.77	9.79	1.5	24.57	25.37
17	20.50	4.69	4.4	29.90	27.68
26	20.66	17.19	1.2	40.38	37.51
32	25.10	18.97	1.3	54.21	48.83

ions is directly proportional to the number of unpaired electrons they contain. Thus, Fe^{3+} with five unpaired electrons should impart a greater magnetic susceptibility to a mica than a corresponding amount of Fe^{2+} with four unpaired electrons. A possible explanation of this anomalous situation can be made using Povarennykh's (1964) ideas concerning the influence of chemical bond types on magnetic susceptibility. Povarennykh argues that Fe^{2+} in six-fold coordination with oxygen, having a bond that is 69 percent ionic in character, would have no directed bonds and hence have four unpaired electrons. When Fe^{2+} changes to Fe^{3+} in the mica, the iron should retain the six-fold coordination but should become more covalent (the bond between Fe^{3+} and oxygen is only about 54 percent ionic). This increase in covalency should result in a tendency to pair the shared electrons. If it were 100 percent covalent, there would be only one paired electron; however, if it is only 46 percent covalent, there should be approximately three unpaired electrons. The magnetic moment of an ion is given by the equation $\mu_{\text{eff}} = (n(n+2))^{1/2}$ Bohr magnetons, where n is the number of unpaired electrons. The ratio of $\mu_{\text{Fe}^{2+}}$ to $\mu_{\text{Fe}^{3+}}$ in a biotite would be

$$\frac{[n_{\text{Fe}^{2+}}(n_{\text{Fe}^{2+}} + 2)]^{1/2}}{[n_{\text{Fe}^{3+}}(n_{\text{Fe}^{3+}} + 2)]^{1/2}}$$

Considering the partly covalent nature of the Fe^{3+} to oxygen and bond substituting values for n , this becomes

$$\frac{(4(4 + 2))^{1/2}}{(3(3 + 2))^{1/2}} = \frac{\sqrt{24}}{\sqrt{15}} = 1.26,$$

indicating that the magnetic moment of Fe^{2+} in the mica structure should be about 1.26 times greater than that of Fe^{3+} . Therefore, the mass magnetic susceptibility of trioctahedral micas will not only depend upon how much iron is present, but, other things being equal, also upon the relative amounts of iron in the ferrous and ferric states. The close fit of the empirical data to the calculated line indicates, however, that this latter factor is of only minor importance.

In summary, the main controlling factor in mass magnetic susceptibility of trioctahedral micas is total iron content and a determination of this property can be used as a rapid semiquantitative method for determination of total iron in these micas. Although the relative amounts of ferrous and ferric iron influences mass magnetic susceptibility, the effect is minor and hence the results for most samples are still satisfactory.

ACKNOWLEDGMENTS

We would like to thank Michael Phillips, David Havener, Ronald Chase, and James Allen who supplied some of the micas used in this study. David Vogler and Aaron Rust assisted greatly in the chemical analyses and Mickey Head, James Goetz, and Sandra Riggs helped determine mass magnetic susceptibilities. Stanley Wimberley critically read the manuscript and suggested several changes.

REFERENCES

- HESS, H. H. (1959) *Notes on operation of Frantz Isodynamic Magnetic Separator*. (Pam.) S. G. Frantz Co., Inc., Trenton, N. J.
- KRUGLYAKOVA, G. I. (1964) On the magnetic properties of minerals. In M. H. Battey and S. I. Tomkeieff, (Ed.) *Aspects of Theoretical Mineralogy in the U.S.S.R.*, Pergamon Press, Oxford, 435-450.
- POVARENENYKH, A. S. (1964) On the magnetic properties of minerals. In M. H. Battey and S. I. Tomkeieff (Ed.), *Aspects of Theoretical Mineralogy in the U.S.S.R.*, Pergamon Press, Oxford, 451-463.
- REICHEN, L. E. AND J. J. FAHEY (1962) An improved method for the determination of FeO in rocks and minerals including garnet. *U.S. Geol. Surv. Bull.* 1144-B, 1-5.
- ROSENBLUM, S. (1958) Magnetic susceptibilities of minerals in the Frantz Isodynamic Magnetic Separator. *Amer. Mineral.* 43, 170-173.
- SHAPIRO, L. AND W. W. BRANNOCK (1963) Rapid analysis of silicate, carbonate, and phosphate rocks. *U. S. Geol. Surv. Bull.* 1144-A, 1-56.

Manuscript received, March 7, 1967; accepted for publication, July 3, 1967.