14. MAGNETIC-MINERALOGICAL STUDIES OF DSDP SITE 323 CORES

V.I. Bagin, Yu.A. Bogdanov, and T.S. Gendler,
P.P. Shirshov Institute of Oceanology, Academy of Sciences, USSR

INTRODUCTION

Using Mössbauer and rock magnetism methods, samples of cores from DSDP Site 323 were studied in our laboratory to determine some of their magnetic mineralogical and magnetic physical properties as a means of mineral identification and as a means of gaining some insight into the genesis of their iron forms.

Site 323 sediments were sampled from the ocean floor to a hole depth of 701 meters where basalt was encountered. For chronological purposes the description proceeds from the basalt contact up. Our mineralogical studies resolve three depth intervals: (1) typical deep-sea deposits from 701 to 638 meters; (2) terrigenous deposits with a large amount of mineral alteration from 638 to 506 meters; and (3) terrigenous deposits with little mineral alteration from 506 to 0 meters.

ANALYTICAL PROCEDURES

We studied three aspects of the samples from Site 323: Mössbauer effect, magnetic properties at room temperature, and thermomagnetic effects and properties.

Mössbauer Technique

The Mössbauer methods (Wertheim, 1964) were used mostly on the lower portion of the sediment column. The results are summarized in Table 1, and some Mössbauer spectra are shown in Figure 1. Because of the very limited ferromagnetic constitution of these samples, the ferromagnetic fraction was not satisfactorily measured by Mössbauer spectra. All the samples studied by this method have spectra with one small quadrupole doublet with a splitting value of about 0.054 mm/sec and isomer shift (with respect to Co$^{57}$[Pd]) of about +0.18 mm/sec. The doublet peaks are sharp and have components of equal intensity and equal line width. The observed characteristics of these parameters indicate fine superparamagnetic particles of approximately 180Å.

Spectra of the samples from levels higher in the sediment column indicate that iron is mainly contained in the clay minerals either only in the Fe$^{2+}$ state (montmorillonite) or in both the Fe$^{2+}$ and Fe$^{3+}$ states (illite, cronstedtite, chamosite).

Magnetic Properties at Room Temperature

The magnetic investigations at room temperature consisted of the following (see Table 2 for definition of symbols used): Determination of $I_{rs}$ as a function of $H$; a.c. demagnetization of $I_{rs}$; determination of $[He's]$ and $I_{rs}$; and determination of the ratios $I_{rs}/I_{r_{max}}$ and $I_{rs}/I_{r_{max}}$ (Table 1). The first parameter ($I_{rs}$ as a function of $He$) characterizes the relative amounts of paramagnetic, superparamagnetic, single domain, and multidomain grains of iron-containing minerals in the samples (Bagin et al., 1969). The second parameter, $I_{rs}$, characterizes the relative remanent saturation magnetization of the various deposits. The results of room temperature magnetic determinations are given in Table 1.

Curves of $I_{rs}$ as a function of $He$ were two types: normal (Figure 2) and anomalous (Figure 3). For the curves of normal type (the normal type of deposit) the beginning of the saturation plateau ($He's$) varies from 1000 to 3000 oe. For the anomalous type of curve (the anomalous deposit) the beginning of the saturation plateau ($He's$) is greater than 7000 oe. For the normal deposit the average value at the maximum slope ($He's$) is about 250 oe, and for the anomalous deposit the maximum slope ($He's$) is about 1.5 to 2 times greater.

The ratio $I_{rs}/I_{r_{max}}$ varies greatly from sample to sample. The difference between the maximum and the minimum values of the ratio is as much as 1.5 to 2 orders of magnitude. The curves (not shown) for $I_{rs}$ as a function of $H$ are typical for deposits of normal type. One-half of $I_{rs}$ is usually demagnetized at 100 to 150 oe. Only for the anomalous deposits is one-third of $I_{rs}$ not demagnetized at 600 oe. The values of the ratio $I_{rs}/I_{r_{max}}$ vary from 2.7 to 15.0. This means that there is a wide range in grain size of the iron-containing minerals in the deposits.

The results of magnetic investigations at room temperature show that the majority of samples contain magnetic minerals with a moderate value of magnetic hardness. Only for the anomalous deposits were magnetic phases found that require a great coercive field. The large differences between the ratios of $I_{rs}/I_{r_{max}}$ and $I_{rs}/I_{r_{max}}$ in Table 1 only indicate that the deposits contain iron in a number of different forms.

Thermomagnetic Studies

Figure 4 shows curves of $I_{s}/I_{s}$ and $I_{rs}/I_{rs}$ as a function of temperature. The samples fall into five classes:

Class 1. Magnetite and maghemit determine the thermomagnetic curves of this class (Figure 4a, b). The Curie point is about 575°C. Temperature changes cause mineral alterations of maghemit. The Curie points and the curves indicate maghemit.

Class 2. These thermomagnetic curves (Figure 4c, d) are typical for deep-sea deposits. The curves are indicative of the presence of nonstoichiometrical hematite and hydroxides of iron.

1Translated in part from Russian.
Class 3. The thermomagnetic curves (Figure 4e, f) are characteristic of iron oxide forms, and they are typical for nonstoichiometrical hematite.

Classes 4 and 5. It is presumed that the curves of Figures 4g, h, i are likely to be determined by temperature transitions of cronstedite. The 525°C temperature corresponds to the beginning of the temperature transition of cronstedite as revealed by differential thermal analysis.

MAGNETIC-MINERALOLOGICAL DEPTH ZONATION OF SITE 323

Interval 701 to 638 Meters; Typical Deep Sea Deposits

The magnetic-mineralogical data delineate three zones in this interval.

Zone A, 701 to 675 meters: Samples 16-1, 57-62 cm; 16-4, 83-94 cm; 18-2, 80-86 cm; 18-3, 130-139 cm; 18-4, 115-124 cm. The thermomagnetic and other magnetic characteristics are typical of deep-sea deposits. The iron is mostly contained in the super-paramagnetic grains of αFeOOH. The ferromagnetic fraction contains the nonstoichiometrical hematite.

Zone B, 675 to 660 meters: Samples 15-3, 29-36 cm; 15-4, 54-63 cm; 15-5, 89-98 cm; 15-6, 19-26 cm. The thermomagnetic data are typical for highly altered terrigenous deposits. The iron is contained in non-stoichiometrical hematite. The hydroxide iron forms are less common here than in Zone A.

Zone C, 660 to 638 meters: Samples 13-6, 145-150 cm; 14-2, 1-8 cm, 128-135 cm; 15-1, 52-60 cm; 15-2, 91-100 cm. Zone C is similar to Zone A.

Interval 638 to 506 Meters; Terrigenous Deposits With Highly Altered Minerals

We used Samples 10-1, 113-122 cm; 10-2, 75-85 cm; 10-3, 106-114 cm; 11-2, 137-148 cm; 13-1, 246-250 cm. The magnetic properties of the deposits are similar to those of Zone B at 675 to 660 meters below the sea floor. Cronstedite is
MAGNETIC-MINERALOGICAL STUDIES OF CORES

TABLE 2

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ir&lt;sub&gt;s&lt;/sub&gt;</td>
<td>remaining Ir&lt;sub&gt;s&lt;/sub&gt;&lt;sub&gt;0&lt;/sub&gt; at a particular temperature as the</td>
</tr>
<tr>
<td></td>
<td>sample is heated or cooled</td>
</tr>
<tr>
<td>Ir&lt;sub&gt;s&lt;/sub&gt;&lt;sub&gt;0&lt;/sub&gt;</td>
<td>initial saturation remanence</td>
</tr>
<tr>
<td>Ir&lt;sub&gt;s&lt;/sub&gt;&lt;sub&gt;max&lt;/sub&gt;</td>
<td>maximum value of Ir&lt;sub&gt;s&lt;/sub&gt;&lt;sub&gt;0&lt;/sub&gt; for given collection of samples</td>
</tr>
<tr>
<td>I&lt;sub&gt;s&lt;/sub&gt;</td>
<td>magnetization in a strong field at a particular temperature</td>
</tr>
<tr>
<td>I&lt;sub&gt;s&lt;/sub&gt;&lt;sub&gt;0&lt;/sub&gt;</td>
<td>initial saturation magnetization</td>
</tr>
<tr>
<td>I&lt;sub&gt;r&lt;/sub&gt;</td>
<td>normal remanence</td>
</tr>
<tr>
<td>I&lt;sub&gt;r&lt;/sub&gt;&lt;sub&gt;max&lt;/sub&gt;</td>
<td>maximum normal remanence for each sample</td>
</tr>
<tr>
<td>H&lt;sub&gt;e&lt;/sub&gt;</td>
<td>artificial magnetic field to which a sample is subjected</td>
</tr>
<tr>
<td>H&lt;sub&gt;d&lt;/sub&gt;</td>
<td>reverse d.c. magnetic field required for complete demagnetization of Ir&lt;sub&gt;s&lt;/sub&gt;&lt;sub&gt;0&lt;/sub&gt;</td>
</tr>
<tr>
<td>H&lt;sub&gt;es&lt;/sub&gt;</td>
<td>minimum amount of magnetic field required to reach the beginning of the saturation plateau (Figure 2)</td>
</tr>
<tr>
<td>H&lt;sub&gt;es&lt;/sub&gt;</td>
<td>The magnetic field at a point of maximum rate of change of I&lt;sub&gt;r&lt;/sub&gt;/I&lt;sub&gt;r&lt;/sub&gt;&lt;sub&gt;max&lt;/sub&gt; on the I&lt;sub&gt;r&lt;/sub&gt;/I&lt;sub&gt;r&lt;/sub&gt;&lt;sub&gt;max&lt;/sub&gt; versus H&lt;sub&gt;e&lt;/sub&gt; curve of Figure 2</td>
</tr>
<tr>
<td>oe</td>
<td>oersteds</td>
</tr>
<tr>
<td>H</td>
<td>a.c. field</td>
</tr>
<tr>
<td>a.c.</td>
<td>alternating current</td>
</tr>
<tr>
<td>d.c.</td>
<td>direct current</td>
</tr>
<tr>
<td>I&lt;sub&gt;s1&lt;/sub&gt;</td>
<td>I&lt;sub&gt;s&lt;/sub&gt;&lt;sub&gt;0&lt;/sub&gt;</td>
</tr>
<tr>
<td>I&lt;sub&gt;s2&lt;/sub&gt;</td>
<td>saturation magnetization at 20°C after first heating</td>
</tr>
<tr>
<td>w</td>
<td>approximately equal to</td>
</tr>
<tr>
<td>H(0% Ir&lt;sub&gt;s&lt;/sub&gt;&lt;sub&gt;0&lt;/sub&gt;)</td>
<td>median destructive a.c. field</td>
</tr>
</tbody>
</table>

likely present in Sample 10-1, 113-122 cm. Samples 10-1, 113-122 cm and 10-2, 75-82 cm correspond to the intermediate zone (638 to 506 m) in the terrigenous deposits. Hematite is found in the samples from 638 to 506 meters.

**Interval 506 to 0 Meters; Terrigenous Deposits With Little Alteration of Minerals**

Based upon magnetic-mineralogical characteristics, this interval can be divided into many zones. For simplicity we divided the interval into three groups of magnetic-mineralogical characteristics regardless of the sample's depth in the interval 506 to 0 meters.

Group 1: Samples 1-1, 50-60 cm; 1-3, 78-88 cm; 3-1, 88-94 cm; 4-2. The ferromagnetic fraction consists of low-temperature oxidation magnetite (magnetite and maghemite). The material of these samples was likely derived from pre-existing rocks, with little mineralogical alteration during transportation.

Group 2: Sample 3-2, 61-70 cm. In contrast to the samples of Group 1, magnetite and maghemite were not found. Only nonstoichiometric hematite was found here, which may indicate a highly oxidizing regime at the time of the material's formation.

Group 3: Samples 1-1, 140-150 cm; 1-2, 37-43 cm; 1-4, 118-127 cm; 7-2, 105-110 cm; 7-3, 18-24 cm; 8-1, 120-121 cm. According to the literature (Betekhtin, 1950), cronstedtite formation occurs soon after deposition. The low values of remanent saturation magnetization and high values of the ratio I<sub>s</sub><sub>0</sub>/I<sub>r</sub><sub>s</sub><sub>0</sub> require that the iron is mainly contained in paramagnetic silicate minerals.

**REFERENCES**


Figure 3. A plot typical of anomalous samples of $I_r/I_{r_{\text{max}}}$ as a function of the magnetic field. Note the positions of $H_{es}$ and $H_{es}'$.

Figure 4a. A plot of the saturation magnetization in a 5000 oe field as a function of progressive and regressive temperature for class 1 samples. Note the difference between the heating curve and the cooling curve due to mineral alteration during heating.

Figure 4b. Remanence magnetization of class 1 samples as a function of temperature for progressive heating and then for progressive cooling.

Figure 4c. A plot of the saturation magnetization in a 5000-oe field as a function of progressive and regressive temperature for class 2 samples. Note the differences between the heating curve and the cooling curve due to mineral alteration during heating.
Figure 4d. Remanence magnetization of class 2 samples as a function of temperature for progressive heating then for progressive cooling.

Figure 4e. A plot of the saturation magnetization in a 5000-oe field as a function of progressive and regressive temperature for class 3 samples. Note the differences between the heating curve and the cooling curve due to mineral alteration during heating.

Figure 4f. Remanence magnetization of class 3 samples as a function of temperature for progressive heating and then for progressive cooling.

Figure 4g. A plot of the saturation magnetization in a 5000-oe field as a function of progressive and regressive temperature for class 4 samples. Note the differences between the heating curve and the cooling curve due to mineral alteration during heating.
Figure 4h. Remanence magnetization of class 4 samples as a function of temperature for progressive heating and then for progressive cooling.

Figure 4i. A plot of the saturation magnetization in a 5000-oe field as a function of progressive and regressive temperature for class 5 samples. Note the differences between the heating curve and the cooling curve due to mineral alteration during heating.