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A STUDY ON THE SAND OF FLAMING MOUNTAIN

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ABSTRACT

A sand sample collected at the foot of Flaming Mountain was studied further. On the basis of the change in the relative intensity after heat treatment, one of the sextets observed in its Mössbauer spectrum at liquid nitrogen temperature was ascribed to goethite. This result provides a useful information on the geological history of the region where the mountain is located.

Keywords: Mössbauer spectroscopy Sand of flaming mountain

1 INTRODUCTION

Sand samples were collected at the foot of Flaming Mountain located in Turpan Basin of the Xinjiang Uighur Autonomous Region of China where the climate is extremely dry and hot in summer. The sand is brownish red, and the name of the mountain originates from this colour.

In a preliminary Mössbauer study[1], we found two sextets of magnetic components at 80 K besides two doublets of paramagnetic Fe^{3+} and Fe^{2+}. One of the sextets with the larger splitting was assigned to hematite ($\alpha-Fe_2O_3$) particles of small sizes, but the interpretation of the other, which is not observed at room temperature, remained ambiguous. According to its smaller magnetic splitting and a larger linewidth at 80 K it can be assignable to hematite, but with much smaller particle sizes or with a certain diamagnetic impurity. An alternative interpretaion for this component is that it represents goethite ($\alpha-FeOOH$). In this work, we study the sand further in order to understand its composition in detail.

2 EXPERIMENTAL

The ground sand of Flaming Mountain was heated at various temperatures from

473 K to 623 K in order to see whether the component with the smaller magnetic splitting is goethite or not. The measurement of Mössbauer spectra was carried out at room and liquid nitrogen temperature using a conventional spectrometer. The thickness of the samples was 40mg/cm^2. The original sand of the large size was measured by the conversion electron Mössbauer spectra (CEMS) to study the difference of composition between the surface and interior.

The elemental analysis for the sand sample was performed by proton-induced X-ray emission (PIXE) and Rutherford backscattering (RBS) on a 2×1 MV Tandem.

3 RESULTS AND DISCUSSION

The Mössbauer spectrum of the sample of Flaming Mountain at 80 K is shown in Fig.1 (*A*). The spectrum at RT consists of a sextet with hyperfine magnetic field B_{hf} of $4.06\times 10^7 \pm 3.98\times 10^5$A/m (510± 5 Oe), along with paramagnetic doublets of Fe^{3+} and Fe^{2+}. However, the magnetic component is decomposed into two sextets with $4.22\times 10^7 \pm 3.98\times 10^5$ A/m (530± 5 kOe) and $3.90\times 10^7 \pm 3.98\times 10^5$ A/m (490± 5 kOe) at 80 K, respectively, as can be seen in Fig.1. The electric quadrupole sphitting, defined as the splitting between the first and second peaks minus that between the fifth and sixth is positive at both room and liquid nitrogen temperatures. Positive quadrupole sphitting below the Morin temperature (263 K) for the larger magnetic splitting is, as before, attributed to small size of hematite particles in the sample[2].

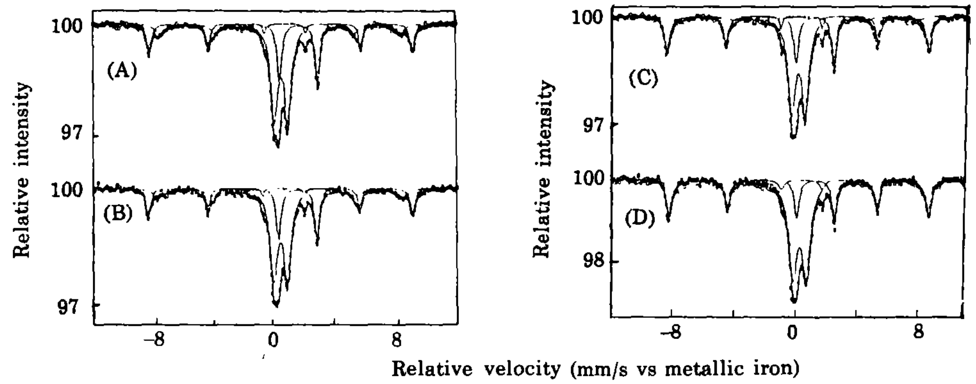

Fig.1 Mössbauer spectra of a sand sample of Flaming Mountain

(*A*) With no heat treatment (*B*) After heating at 473 K for 4 h

(*C*) After heating at 523 K for 4 h (*D*) After heating at 573 K for 4 h

Fig.1 (*B*– *D*) shows the Mossbauer spectra after heating in air at 473 K, 523 K and 573 K, measured at 80 K. It clearly shows that the intensities of the sextet with the smaller magnetic splitting decrease with the increase of heating temperature. Fig.2 shows the relative intensities of the sextets as a function of heating temperature. We found from the two curves in Fig.2 that the component with the smaller magnetic splitting transformed into that with larger one. The former disappeared completely from the Mössbauer spectra after annealing at 573 K, and the latter correspondingly increased. This result along with the value B_{hf} indicates that the former can be assigned to goethite of small sizes, because goethite can be dehydrated to hematite. But the transition temperature observed is lower than that of pure bulk goethite to hematite[3]. Their small sizes and the much lower anisotropy energy density, which affects the relaxation time of small particles exponentially, of goethite than hematite can explain why no sextet corresponding to this component was observed at RT.

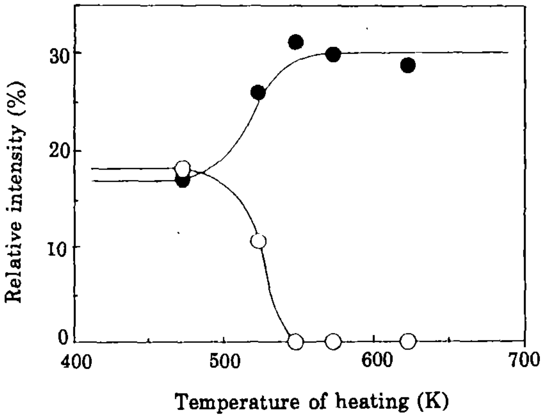

Fig.2 The relative intensities of the two sextets as a function of the heating temperature

• : sextet with larger splitting

O: sextet with smaller splitting

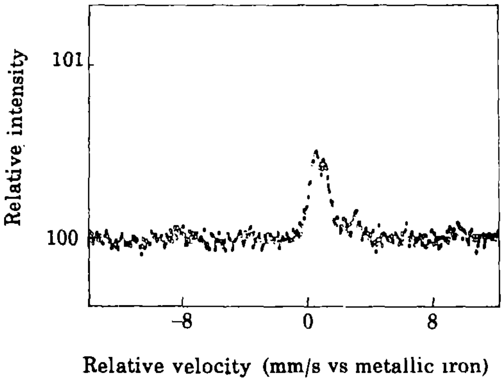

Fig.3 The CEMS of the untreated sand

Assuming the reduction of B_{hf} only by the particle size, the size of the hematite, as compared with the results of Kündig *et al.*[2], is about 18 nm. The size of goethite derived from the blocking temperature which is assumed to be RT, is about 16.4 nm, taking the anisotropy energy density of $1.56\times 10^{-3}\,\mathrm{J/cm^3}$.[4] So the sizes of both components are approximately the same. Unfortunately, similar field-reducing is also caused by isomorphous substitutions which are commonly encountered in hematite and goethite in the natural sand. Well documented in that respect is the case of Al. Al can be substituted up to an extent of about 33 at. % and 30 at. % for Fe in goethite and hematite, respectively. An average field reduction of about 1.1×10^5 A/m (1.4 kOe) at 80 K and 6.4×10^4 A/m (0.8 kOe) at RT per at. % Al for goethite and hematite has been respectively derived[5]. Based on the observed reduction values and the relationships between the average B_{hf} and the Al content, about 10 at. % Al content can be roughly obtained for the goethite and hematite fractions of the present sand sample. We observed, in the sand, Al (8.5 wt. %) with a total content about twice that of Fe (4.7 wt. %) along with Mn (0.1 wt. %), Ti (0.4 wt. %) and Ca (5.1 wt. %) by PIXE and RBS. But, most of the impurities are considered not to be contained in the goethite and hematite fractions. We can not determine the real sizes of those two kinds of particles and impurity content because these two factors give rise to the same effect that reduce both B_{hf} and Morin temperature. However, the extent of reduction in B_{hf} ($<2\%$ at 80 K) strongly points to a low Al- substitution with small sizes of the sand.

The CEMS of the untreated sand is shown in Fig.3. The relative intensity of the doublet of Fe^{2+} is seen to be much smaller than that in the absorption spectrum of the bulk sand (Fig.1(*A*)). This observation shows that the oxidation of Fe^{2+} in the surface layers is proceeding much faster than in the bulk, as is expected.

Coexistence of hematite and goethite in the sand may give us useful information on the climate of this region in the remote past. In soils, goethite is usually formed as a weathering product of Fe^{2+} silicates. So, it means the climate of Flaming Mountain in the past geological era was not so dry and hot as nowadays. Probably, it was a lake or marshland. This idea is proved recently by Chinese geologist[6]. It was said that 2.5 hundred million years ago this region was a sea, during past 2.5- 0.65 hundred million years it was a lake or marshland, since 0.65 hundred million years it has gradually become dry from wet. So, the Mössbauer characterization of iron oxides and hydroxides in the sand is also a very useful method for geology.

The powder sand with a diameter of about 40 μ m after grinding can not be separated by both magnetic and heavy liquid methods, and 91 % of original sand can be attracted by a Sm- Co magnet.

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