

Magnetoacoustic Emission of Magnetite Ores of Complex Genesis

I. I. Glukhikh, V. S. Ivanchenko, and Corresponding Member of the RAS V. I. Utkin

Received August 4, 2006

DOI: 10.1134/S1028334X07020420

The first measurements of magnetoacoustic emission (MAE) of natural ferrimagnetics were carried out in a magnetite monocrystal of nearly stoichiometric composition [1]. The present paper is devoted to the results of the study of MAE properties of magnetite ores formed in magmatic, metasomatic, and metamorphic processes. Such ores occur in the Evstyunin deposit (Middle Urals) [2]. The MAE properties of magnetite ores from this deposit indicate the presence of several generations (stages) of their formation. Massive ores demonstrate the most prominent distinctions. The presence of sulfide mineralization is reflected in specific features (asymmetry) of MAE curves if pyrrhotite is developed. In addition, the asymmetry of MAE curves is an indicator of differences in the general magnetization of ferrimagnetics.

The Evstyunin deposit is located in the Tagil Trough, which is characterized by an abundance of gabbroid and basaltoid complexes. The deposit is a member of the subformation of Ti-poor magnetite ores confined to the western outer contact of the Tagil syenite-diorite massif [3]. The enclosing rocks are composed of pyroxene-plagioclase rocks and hornfels related to the dynamometamorphism of volcanosedimentary sequences of the Tagil Trough under the influence of hot basalts and ultrabasites of the Ural Platinum Belt. Deposits of this type are characterized by insignificant development of garnet-epidote skarns that are superimposed on metasomatites with Ti-poor magnetite ores. Ore mineralization is represented by numerous stratiform and lenticular bodies that are conformable with the banding of the enclosing rocks [3].

Ore samples for the MAE measurements were taken from the Novo-Evstyunin ore-bearing zone. According to V.D. Rudnitskii and K.B. Aleshin, this zone is located in a thick sequence of intensely metamorphosed acid volcanic rocks that give way to basic rocks downward the dip. Orebody 21 is confined to a thick

sequence of metamorphosed acid rocks. The magnetite mineralization is developed in metamorphic patchy-banded andesite-dacite rocks formed after volcanosedimentary rocks. Orebody 22 is located among pyroxene-plagioclase rocks of the basic composition. This orebody includes interlayers of garnet and pyroxene-garnet skarns and epidotites.

Ores of the Evstyunin deposit can be divided into several types in terms of mineral assemblages, textural-structural features, and properties of magnetite [4]. The plagioclase-pyroxenite magnetite ore is the major type, whereas the skarn (pyroxene-garnet-magnetite) ore is subordinate. The deposit also contains epidotized plagioclase-pyroxene-magnetite ores. The ores are divided into the following structural varieties: massive ore (magnetite >70%), high-grade patchy-banded ore (magnetite 40–70%), low-grade disseminate ore (magnetite 20–40%), and mineralized rocks (magnetite <20%). Based on the magnetite content, the ores are divided into two varieties. The high-temperature Ti-poor magnetite is typical of plagioclase-pyroxenite-magnetite ores, whereas magnetite of the skarn stage is typical of pyroxene-garnet-magnetite ores.

The disseminated ores and mineralized rocks contain Ti-poor magnetite characterized by the universal presence of hatched-laminar inclusions (ilmenite and spinel) and minimum values of coercibility. This variety represents a young magnetite generation formed at high temperatures in the course of postmagmatic metasomatic processes after the emplacement of syenite-diorite plutons. The Ti-poor magnetite occurs in all ore types [3, 4].

The patchy ore contains titanomagnetite with typical exsolution textures. This ore variety is characterized by a low Curie temperature (560–570°C) and high coercibility. Titanomagnetite of this ore represents the earliest generation with formation conditions nearly similar to those of the magmatic ore [3].

Massive ores are composed of the most diverse minerals, such as Ti-poor magnetite, skarn magnetite, and recrystallized magnetite. The patchy magnetite of the skarn stage is characterized by a normal Curie temperature (573–575°C) and moderate coercibility. This

Institute of Geophysics, Ural Division, Russian Academy of Sciences, ul. Amundsena 100, Yekaterinburg, 620016 Russia; e-mail: voutkin@002.ru

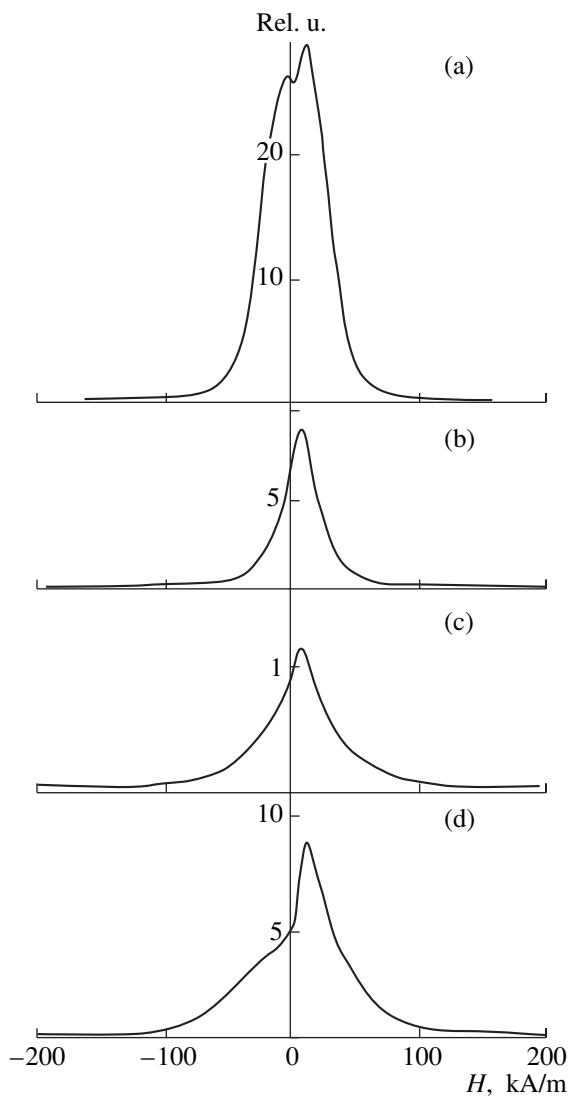


Fig. 1. Typical curves of magnetoacoustic emission of various ore types in the Evstyunin deposit. Ore types: (a) massive, (b) high-grade patchy, (c) low-grade disseminated, (d) sulfide (pyrrhotite).

magnetite is a product of the moderate-temperature contact-metasomatic ore deposition. In general, the massive ores are probably related to recrystallization (crushing, skarnization, and sulfide mineralization) of older ores. Magnetite of this ore has maximum coercibility at a normal Curie temperature (575°C). The figure presents the typical MAE curves for various ore types. The MAE value was measured according to the method described in [1] using the following informative parameters (table): magnetizing field H_{\max} characterized by the maximum MAE value; range of magnetizing field characterized by MAE processes; MAE amplitude; and general shape of the MAE curve.

Analysis of the data obtained shows that the Ti-poor high-temperature magnetite from the mineralized rocks and the low-grade disseminated ores are virtually simi-

lar. The presence of magnetite exsolution textures can be related to higher H_{\max} values relative to pure magnetite [1]. Titanomagnetite of patchy ores with lower Curie temperatures [4] is identified by intensification of the MAE signal and depletion in H_{\max} . Intensification of the MAE signal can primarily be related to enrichment in the content of ferrimagnetics. Depletion in H_{\max} can be caused by the higher homogeneity of the magnetite matrix, although magnetite in the ore has a higher coercibility [4]. The MAE curve of massive magnetite ores is distinguished by the presence of two peaks (Fig. 1a). This is probably related to the superimposition of magnetoacoustic emission of genetically different magnetites. The peak in the magnetization field of 8.0–14.2 kA/m is related to magnetoacoustic emissions of the high-temperature (Ti-poor) and primary magnetite generations [4] (Fig. 1b). Grains of the high-temperature variety with exsolution textures are present in the groundmass. The second peak recorded in the field ranging from –8.0 to +3.2 kA/m is presumably related to the MAE of recrystallized (nearly stoichiometric) magnetite grains of the skarn stage (Fig. 1c). The MAE signal of massive ores is sufficiently intense and similar to the signal recorded in magnetite crystal [1]. The presence of several magnetite generations and the high coercibility of massive ores can be related to expansion of the MAE field.

The MAE curve recorded for the sample with the pyrrhotite-rich magnetic fraction (Fig. 1d, pyrrhotite >90%) shows a sharp asymmetry of the left side. The maximum on the right side of the curve is probably related to the Ti-poor magnetite or primary titanomagnetite. The maximum of the MAE curve, which provokes the curve asymmetry and is related to pyrrhotite, is located at –16 kA/m. The MAE field in this case is as high as 208 kA/m. The left side of the MAE curve for some samples of other magnetite types also shows a similar asymmetry of different degrees.

The MAE value of magnetite makes it possible to assess the general magnetization of all generations of this mineral. The presence of the MAE peak in the zero magnetization field of the magnetite crystal corresponds to the symmetric position of the narrow hysteresis curve of magnetization. An increase in the coercibility and a shift of the hysteresis curve center to the region of positive magnetization values lead to the shift of the MAE maximum, because the magnetization field increases along the ascending loop of hysteresis. The presence of MAE in the negative magnetization field can be caused by magnetization along the descending loop of hysteresis and, hence, the opposite sign of magnetization for the entire magnetite generation considered above.

Thus, the MAE value of magnetite ores of the Evstyunin deposit reflects the presence of magmatic, metasomatic, and metamorphic generations (stages) of their formation. The MAE values are most contrasting in massive ores characterized by the manifestation of

Parameters of the magnetoacoustic emission of various ore types in the Evstyunin deposit

Ore type	Informative MAE parameters, average for three orebodies					Magnetic properties (based on [4])		Genesis of magnetite
	$H_{\max 1}$, kA/m	$H_{\max 2}$, kA/m	Significant range, kA/m	Ampli- tude, rel. u.	Asym- metry	T_{Ci} , °C	H_{av} , kA/m	
Mineralized rocks	7.7	–	111	3.4	Present	575	1.0	High-temperature metasomatic
Low-grade disseminated	8.0	–	86	1.7	Absent	574	1.2	High-temperature metasomatic
High-grade patchy	7.3	–	118	8.4	Present	573	1.7	Primary magmatic
Massive	10.5	–0.2	120	28.0	Present	575	2.3	Skarn metasomatic, recrystal- lized, sulfide mineralization stage
Pyrrhotite	11.2	–16	208	8.5	Present	–	–	Sulfide mineralization stage

all the processes mentioned above. The presence of pyrrhotite-bearing sulfide mineralization is reflected in specific features (asymmetry) of MAE curves. In addition, the MAE patterns indicate differences in the general magnetization trend of various generations of natural ferrimagnetics.

ACKNOWLEDGMENTS

The authors thank K.B. Aleshin for assistance in the choice of samples, Corresponding Member of the RAS E.S. Gorkunov for consultations, and Academician of the RAS N.P. Yushkin for supporting our work.

REFERENCES

1. I. I. Glukhikh and V. S. Ivanchenko, [Dokl. Earth Sci. **361A**, 769 (1998) [Dokl. Akad. Nauk **361**, 375 (1998)].
2. *Skarn–Magnetite Formations of the Urals (Middle and Southern Urals)*, Ed. by V. I. Smirnov and A. M. Dymkin (Ural. Otd. Akad. Nauk SSSR, Sverdlovsk, 1989) [in Russian].
3. V. G. Fominykh, Dokl. Akad. Nauk SSSR **261**, 1209 (1981).
4. I. I. Glukhikh, V. S. Ivanchenko, T. M. Koshkina, et al., *Typomorphism of Magnetites in the Evstyunin and Lagernyi Iron Ore Deposits of the Tagil–Kushva Region* (Ural. Otd. Akad. Nauk SSSR, Sverdlovsk, 1989) [in Russian].