GAMMA-RESONANCE SUDIES OF ROCKS NEAR THE EAST (Kingdom Saudi Arabia, Turkey)

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Gamma-resonance studies of the spectra of 57Fe nuclei in rocks of Saudi Arabia and Turkey have been carried out. The presence, phase composition and physico-chemical state of iron atoms in all studied rock samples are shown.

INTRODUCTION

Rock is any mass or aggregate of one or more mineral species or organic matter that are products of natural processes, formed in different ways and at different times in the history of our planet. According to the geological conditions of formation, all rocks are divided into igneous, sedimentary and metamorphic. Igneous rocks are the result of the solidification of natural magma melt, and make up about 65% of the volume of the earth's crust. Depending on the depth of solidification of the melt, they are classified as volcanic and plutonic. Volcanic (effusive) rocks are localized in the earth's crust or on its surface; hypabyssal rocks are formed as a result of the solidification of lava at a shallow depth from the earth's surface. Plutonic (intrusive) rocks are formed as a result of the solidification of magma in the thickness of the earth's crust and upper mantle at various depths. Sedimentary rocks were formed under conditions of low temperatures and pressures as a result of accumulation, transfer and deposition of mineral or organic substances on the surface of the planet. Metamorphic rocks were formed as a result of various natural effects on sedimentary and igneous rocks. They make up 27.4% of the total volume of the earth's crust. It follows that part of the Earth's upper mantle (lithosphere) and the earth's crust consist of formations and rocks of different geology [1].

It is known that up to 1 billion tons of space objects ranging in size from fractions of a millimeter to tens of tons fall on planet Earth every year [2]. According to thermomagnetic measurements, cosmic dust containing particles of metallic iron and nickel is found directly in dusty cosmic clouds, in the atmosphere, in ice and snow, and in precipitation [3-6]. The discoveries of modern astrophysics also indicate the cosmic origin of iron in the planets of the Solar system. Cosmic dust can be detected anywhere in the universe, although its concentration varies markedly from place to place [7, 8].

There are several ways of dust formation in space: - destruction of celestial bodies as a result of collisions of asteroids and larger objects; - explosions of stars, as a result of which their particles scatter through space and create giant clouds of dust; - remnants of formed star systems and planets; - during the formation of a new star. According to its location in the universe, cosmic dust is divided into intergalactic, galactic, interstellar, interplanetary, near-planetary, asteroid, cometary, Kuiper belt dust, etc. Cosmic dust also includes micrometeorites, particles of interplanetary dust that, due to their small mass, do not heat up when passing through the atmosphere and reach the Earth's surface unchanged, which makes the problem of studying cosmic dust very important for understanding the origin of the Solar System. A strong argument in favor of the cosmic origin of iron is the impossibility of iron formation in the bowels of the Solar System and, especially, the Earth, since its formation requires temperatures of tens of millions of degrees, which are reached only in the bowels of giant stars. The composition, structure and conditions of occurrence of rocks depend on the geological processes that form them, occurring inside the earth's crust or on its surface. The mechanism of rock formation can also be different depending on time, place and climatic conditions. The study of the substance of cosmic dust, which includes iron, will contribute to solving many theoretical issues and, first of all, understanding the processes of evolution of cosmic bodies, the Earth and the Solar system as a whole. It follows from the above that the study of rocks has scientific and practical value. They play a significant role in enriching our knowledge of the Earth. Knowing the geological structure of a particular region, the chemical composition of rocks, it is possible to assume what type of fossils will be in its depths. Such branches of geology as volcanology, tectonics and seismology allow us to predict earthquakes and volcanic eruptionsAccording to the cosmic hypothesis, iron fractions in the form of atoms, ions and their compounds should probably be scattered over the entire surface of the planet and found in almost all minerals, rocks, river and sea sediments, which is confirmed by thermomagnetic measurements [3]. Cosmic dust containing particles of metallic iron and nickel is found directly in the Earth's atmosphere, in ice and snow, in sediments. However, the question of the nature of the distribution of iron across the continents and its physicochemical state in various rocks and minerals, as well as the absence of traces of iron in Antarctica, remains unclear [2]. Obviously, if iron was of purely terrestrial origin, it would not be scattered over the entire surface of the land, sea and river sediments of the planet, but would be localized in certain areas of the planet like many other chemical elements. In order to determine the distribution of iron across the planet's continents, we previously used the YAGRS method to study more than 100 rocks and river sediments of different morphology, color, and structure, collected from different areas of the planet (Russia, Europe, Asia, North America, the Middle East), in which iron was found both in free form and as part of various oxides and in various physical and chemical states. In this work, more than 20 rock samples from Saudi Arabia and Turkey have been studied.

METHOD AND MATERIALS

Registration of gamma-resonance (Mossbauer) spectra of 57Fe nuclei was performed on the MS-1104Em spectrometer in a compressed transmission geometry. The source of gamma radiation was the isotope 57Co(Cr). The spectra were decoded by the Univem-MS program. The samples for the study were finely dispersed rock powders crushed in an agate mortar.

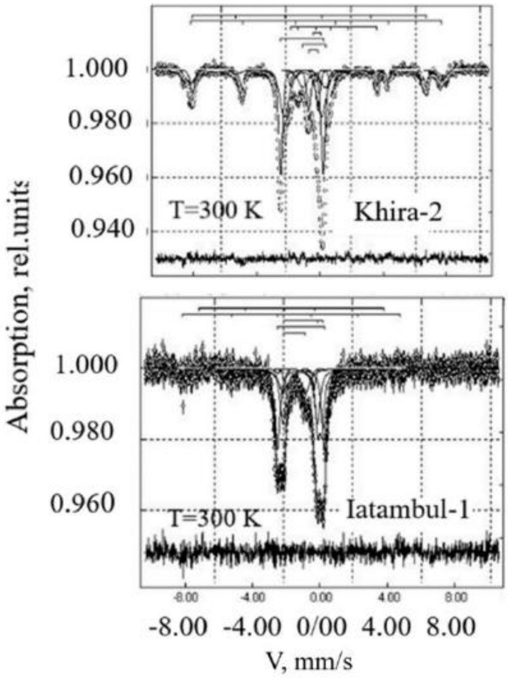

Fig.1. Mössbauer spectra of ^{57}Fe nuclei in the roksof Khira-2 and Istanbul-1 at T=300 K.

Experiment and results Hydrogen, calcium, iron – all of these are present in the space environment, but in such quantities that their detection requires high-precision instruments and corresponding data analysis programs. Nuclear gamma resonance spectroscopy (NGRS), based on the Mössbauer effect, is just such a method. Due to its extremely high sensitivity (ΔE/Eγ=10-13) to short-range effects, the method is one of the most effective nuclear-physical tools for studying both intra-atomic and cooperative phenomena of the condensed state of matter, allows for highly accurate investigation of hyperfine interactions in objects in which iron is a matrix or accessory impurity, characteristic of many rocks. In all the rock samples we studied, iron fractions were found in different oxides and different concentrations. This is consistent with the fact that the rocks were formed in different geological periods (Precambrian, early Paleozoic and middle and late Mesozoic), when cosmic processes had different character and different activity.

Fig. 1 shows the results of model decoding of the spectra of 57Fe nuclei in the rocks of Saudi Arabia (Khira-2) and Turkey (Istanbul-1), which are characteristic of iron nuclei in rocks of different continents. As follows from Fig. 1, the spectrum of the Khira-2 rock sample corresponds to the nuclei of iron atoms in several structurally, magnetically and electrically nonequivalent positions of the heterogeneous crystal lattice of the rock, which consists of different minerals and iron oxides. The shape of the 57Fe spectrum in the Istanbul-1 sample also characterizes the heterogeneity of the sample, in which, however, the iron atoms are in an asymmetric environment of atoms of other elements, but without intra-atomic magnetic fields on their nuclei. Similar and more complex spectra consisting of a superposition of sextets, doublets and singlets were obtained for all samples, the parameters of which are presented in the tables. Some samples exhibited "magnetic activity" and their spectra represented a superposition of several Zeeman sextets.

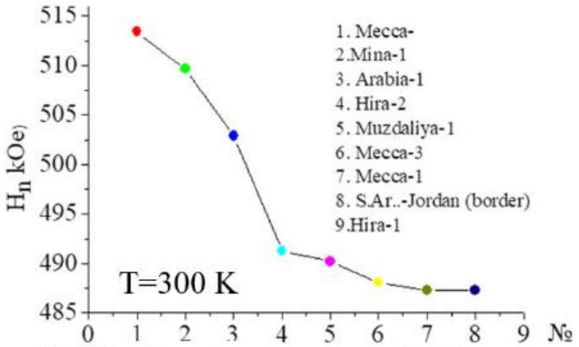

Fig. 2. Hyperfine magnetic fields on ^{57}Fe cores in rocks from Saudi Arabia

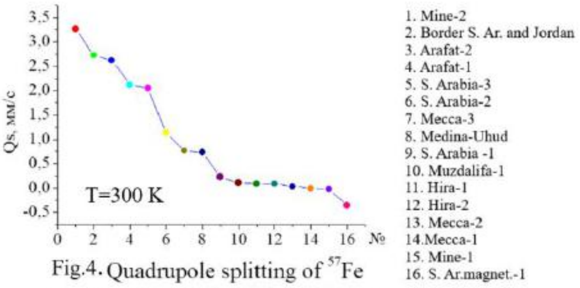

Fig.4. Quadrupole splitting of ^{57}Fe core spectra in rocks of Saudi Arabia

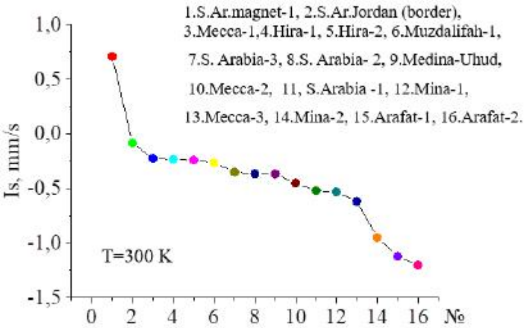

Fig.3. Isomeric shifts in the spectra of 57Fe nuclei in rocks of Saudi Arabia

Table 1.

Parameters of the 67Fe nuclei spectra in the studied rock samples of Saudi Arabia.

#@#	Sample	Component	Is, mm/s	Qs, mm/s	G, mm/s	S, %
	Arafat -1	Doublet	- 1.1206	2.1144	0.5445	17.46
	S.Ar. Arafat -2	Doublet	-1.1298	2.6174	0.2993	17.46
	S.Ar. Arafat -3	Doublet	-1.1322	2.4556	0.5268	43.81
	S.Arabia-1	Doublet	-1.1562	2.0634	0.3818	45.86.
	S.Arabia-3	Doublet	-1.1481	2.0798	0.3768	43.68
	S.Arabia -2	Doublet	-1.1459	2.0800	0.3501	31.19
	S.Arabia -4_	Doublet	-0.3671	1.1331	0.1746	7.82
	S.Arabia -5	Doublet	-0.3504	2.0471	0.3113	86.13
	S.Ar. Mecca-1	Doublet	-1.1269	2.7465	0.6111	25.32
	S.Ar. Mecca-2	Doublet	-0.2714	0.6429	0.3143	13.98
	S.Ar. Mecca-3	Doublet	-1.1457	2.5674	0.3488	44.46
	S.Ar. Mine-1.	Doublet	-1.1423	2.0582	0.3249	41.88
	S.Ar.Mine-1	Doublet	-1.1431	2.0678	0.3015	36.93
	S.Ar.-magnetic-1_	Doublet	1.1259	2.2094	0.6090	59.94
	S.Ar.-magnetic-3	Doublet	1.1213	2.2076	0.6371	51.28
	S.Ar.-magnetic-2	Doublet	1.1357	2.1538	0.6111	66.61
	S.Ar.-magnetic-	Component	1.1389	2.1640	0.3647	45.6
	S.Ar. Medina-Uhud	Doublet	-0.3682	0.7361	0.3476	12.42
	Jordan-S.Arabia	Doublet	-1.0819	2.7232	0.2716	19.20
	S.Ar. Muzdalifa -1	Doublet	-1.1525	2.0870	0.4794	50.78
	S.Ar. Hira 1	Doublet	-1.1502	2.7290	0.3101	24.36
	S.Ar. Hira 2	Doublet	-1.1516	2.6012	0.4121	39.40
	S.Ar.Mina-2	Doublet	-0.9495	3.2581	0.1939	4.03
	Antalya (Akdeniz)	Doublet	-1.59	-0.18	0.17	4.79
	Istanbul-1	Doublet	-0.06	2.08	0.18	13.65
	Istanbul-2	Doublet	-1.10	1.95	0.31	24.01

Figure 2 shows the maximum values of hyperfine magnetic fields on 57Fe nuclei in rock samples where iron was probably contained mainly in magnetite and tetite. As can be seen from the figure, even a small area of one country contains rocks from different geological periods, which probably had their own physicochemical and geological features. Figures 3 and 4 show the dependences of isomer shifts and quadrupole splittings of the spectra of iron nuclei, characterizing the electron charge density on iron nuclei and their environment geometry. The phase composition of the rocks includes mainly FeOOH+FeOnH (goethite), Fe_2O_3 (hematite) and Fe_3O_4 (magnetite). According to the isomer shifts, the valence of Fe in the samples corresponds to all possible valence states of iron in oxides and other compounds.

It is known that iron exhibits variable valence (although the most stable compounds are divalent and trivalent iron). With oxygen, iron forms oxide (II) FeO, oxide (III) Fe_2O_3 and oxide (II, III) Fe_3O_4 (a compound of FeO with Fe_2O_3, which has a spinel structure). In humid air at normal temperatures, iron is covered with loose rust (Fe_2O_3 nH_2O). The results of our research also showed the presence of iron in the indicated oxides, including in free metallic form, but only in one sample - S. Arabia-2. The results we obtained complement previous studies and serve as another argument in favor of the cosmic origin of iron on earth, which has a powerful force and benefit for people [10].

Table 2.

Parameters of the spectra of 67Fe nuclei in the studied rock samples of Turkey.

Sample	Hn, kOe	Is, mm/s	Qs, mm/s	G, mm/s	S, %
Antalya (Acdeniz)	400	-1.59	-0.18	0.17	4.79
Istanbul-1	-	-0.06	2.08	0.18	13.65
Istanbul-2	-	-1.10	1.95	0.31	24.01

Table 3.

Phase composition of the studied samples

Sample	phase composition	contentб %
S.Ar. Mine-1	FeOOH+FeOnH (goethite) Fe_2O_3 (hematite) Fe_3O_4 (magnetite)	95.3 ± 4.7 1.7 ±1.7 3.0 ±3.0.
S.Ar. Mine-1	FeOOH+FeOnH Fe_2O_3 Fe_3O_4	99.4 ± 0.6 0.1 ± 0.1 0.5 +/- 0.5.
S.Ar.Mina-2	FeOOH+FeOnH Fe_2O_3 Fe_3O_4	94.5 ± 5 .5 2.1 ±2.1 3.4 ± 3.4
S.Arabia - 3	FeOOH+FeOnH Fe_2O_3 Fe_3O_4 Fe (iron)	22.4 ±22.4 1.0 ±1.0 76.0 ±24.0 0.6 ± 0.6
S.Arabia -5	FeOOH+FeOnH Fe_3O_4 FeO	90.4±9.6 0.4±0.4 9.2±9.2.
S.Ar.-magnetic-1	FeOOH+FeOnH Fe_3O_4	35.6±4.8 64.4 ± 4.8
S.Ar. Khira-20	FeOOH+FeOnH	100.0 ± 0.0.
Muzdalifaa- 1	FeOOH+FeOnH Fe_2O_3 Fe_3O_4	97.1 ± 2.9 1.9 ±1.9 1.0 ± 1.0
Mecca-3	FeOOH+ FeOnH	100.0± 0.0
Mecca-1	FeOOH+FeOnH Fe_2O_3 Fe_3O_4	98.4 ± 1.6 0.5 ± 0.5 1.1 ± 1.1
S.Ar, Khira-1	FeOOH+FeOnH FeO	99.8 ±0.2 0..2 ± 0.2
Mecca-2	FeOOH+FeOnH Fe_2O_3 Fe_3O_4	66.4 ± 0.9 33.5 +/- 0.8 0.1 +/- 0.1

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