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## MÖSSBAUER SPECTROSCOPIC STUDIES OF REFERENCE SAMPLES OF ICELANDIC IGNEOUS ROCKS

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Résumé.- On a enregistré les spectres Mössbauer de huit échantillons de roches, entre 80K et 300K. Les échantillons ont été sélectionnés comme matériaux de référence géochimique et sont typiques de la pétrographie de l'Islande. Les analyses par effet Mössbauer et par voie chimique sont comparées, en particulier le rapport  $Fe^{3+}/Fe^{2+}$  qui apparaît plus faible par effet Mössbauer.

Abstract.- Mössbauer spectra of eight rock samples have been measured at 80K and 300K. The samples, originally selected as geochemical reference material, represent the regional petrographic pattern of Iceland. The mineral compositions extracted from the spectra are compared with the results of chemical analysis. The ferric-ferrous ratio calculated from these two methods is also compared and for all the samples the ratio from Mössbauer data is lower.

1. Introduction.- Mössbauer spectra of igneous rock samples can give additional information about the character of their iron content. Spectra of eight rock samples covering the compositional range of Icelandic igneous rocks have been measured at 80K and 300K. Being a part of the N-Atlantic rift system, Iceland is characterized by the production of tholeiitic magma along the volcanically active fissure swarms of the rift zones bisecting the island [1]. The rift zones are dominated by abyssal type tholeiites (sample B-THO) with clinopyroxene, magnesian olivine and titanomagnetite, frequently showing ilmenite exsolution, as the principal iron bearing minerals. Intermediate and silicic rocks are formed in the most active centers of the rift zone. The iron mineralogy of the intermediate rocks (icelandite, I-ICE and dacite, I-DAC) is typically minor clinopyroxene and resorbed olivine along with titanomagnetite. The tholeiitic obsidian A-THO, is classified as an entirely glassy rock. Outside the rift zone of Iceland magmas with alkaline affinities are produced, here represented by Fe-Ti basalt, B-ALK, and alkaline rhyolitic obsidian, A-ALK. The basalt shows microphenocrysts of clinopyroxene, ilmenite and titanomagnetite, but the only iron bearing mineral of the obsidian is crystallites of alkaline pyroxene. Two plutonic rocks, a ferrogabbro, B-GAB, and granophyre, A-GRA, closely resembling the composition of B-ALK and A-ALK respectively were studied for comparison.

2. Experimental.- The rock samples were ground to 200 MESH and samples of 50 mg/cm<sup>2</sup> were measured with a conventional constant acceleration spectro-

meter using <sup>57</sup>Co in Rh as a source. The spectra at 300K, showing mainly the paramagnetic part, are shown on figure 1. For further investigation of the magnetic minerals and for extracting various data on mineral composition, spectra at higher speed interval and at 80K were obtained.

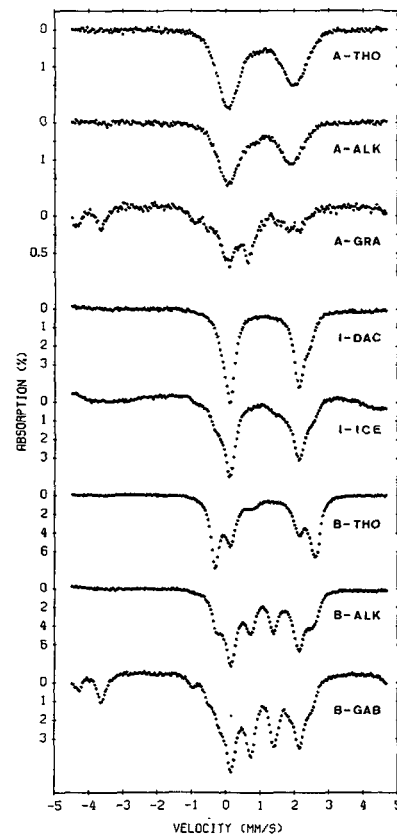


Fig. 1 : Mössbauer spectra of reference samples, at 300K.

Table I

Norm of Fe-minerals "CIPW"	Fe-minerals in Mössbauer spectra.	A-THO		A-ALK		A-GRA		I-DAC		I-ICE		B-THO		B-ALK		B-GAB	
		"CI"	MS	"CI"	MS	"CI"	MS	"CI"	MS	"CI"	MS	"CI"	MS	"CI"	MS	"CI"	MS
Fs	/Pyroxene(FeII)	42	(84)	49	(66)		(19)	58	51	30	32	35	35	37	40		29
Hm + Ac	/Pyroxene(FeIII)		(16)	43	(13)	29	(31)		0				10		3	16	11
Mt	/Magnetic min.	52			22	60	50	29	35	55	58	34	4	38	32	61	39
Il	/Ilmenite	6		8		11		13	2	15		8	2	26	16	23	17
Fa	/Olivine		0		0		0		12		10	23	49		9		4
Qz (quartz in norm)		34		25		32		22		9		0		2		4	
Ferric ratio, $\frac{\text{Fe(III)}}{\text{Fe(II)}+\text{Fe(III)}}$		.35	.14	.43	.31	.69	.64	.20	.16	.37	.29	.22	.13	.25	.19	.57	.37

The total error,  $\pm 2$  in the percentage figures in MS-column and  $\pm 1$  in the CI-column.

Due to lack of space none of these spectra are shown. The spectra were fitted by computer with constraints on equal area for Lorentzian lines of the quadrupole splitting. Known parameters of magnetite, ilmenite, olivine, pyroxene and amorphous silicates /2,3,4/ were often used as constraints in estimating the mineral composition of the samples but in all cases the f-factors were set equal.

3. Results and discussion.- Table I shows the results from the chemical analysis and area fits of the Mössbauer spectra (MS) on a comparable form. In order to make the chemical analysis comparable to area percentages obtained from the MS, shown in column "MS", the normative Fe-mineral composition (CIPW-norms) was recalculated as a percentage of the total number of iron atoms and these figures are shown in column "CI". In the first row normative Fs (ferrosilite,  $\text{Fe}_2\text{SiO}_3$ ) is compared with the ferrous part of pyroxene obtained from the MS. In the second row values of Hm (hematite) and Ac (acmite,  $\text{Na}_2\text{O} \cdot \text{Fe}_2\text{O}_3 \cdot 4\text{SiO}_2$ ), the only pure Fe(III) normative minerals, are compared with the ferric part of the pyroxene in MS. The third row shows the magnetite in norm compared with the spectral part showing magnetic splitting, usually some mixture of titanomagnetites, although in one case, B-GAB, the spectra show pure magnetite. The strength of the magnetic field measured at 80K reaches the values of 485 to 510 kOe for the various samples. Row 4 shows Il (ilmenite in norm) and the spectral part of the ilmenite mineral. When comparing the information given by the two methods, row 3 and 4 should be observed together. In norm calculation titanomagnetite will be divided between Mt and Il, but above 66K ilmenite can easily be separated from tita-

nomagnetite in the MS. Row 5 compares Fa (fayalite in norm) with olivine observed in MS and row 6 shows the normative Qz (quartz) of the rock samples for general information on their chemistry. It has been impossible to resolve the paramagnetic part of the MS in different minerals for the first three samples, A-THO, A-ALK and A-GRA. The obsidian glasses, A-THO and A-ALK fits to the same parameters which were obtained for amorphous rock /3/, but the granophyre, A-GRA shows a different structure. In these cases the area was only resolved into ferrous and ferric part and the values are given in parenthesis in the first and the second row, indicating no relation with pyroxene. The last row shows the ratio of Fe(III) to the total amount of iron, calculated from the CIPW-norms and from area in the Mössbauer spectra. For all the samples, the Mössbauer spectra show a lower ratio. The discrepancy is largest for the amorphous A-THO and the holocrystalline plutonic sample, B-GAB. This may be interpreted as some oxidation occurring in the chemical analysis. In calculating the MS ferric ratio for samples showing a clear evidence of titanomagnetite (I-ICE, I-DAC and B-ALK), 50% of the excess of Ti according to the norms, is estimated to be found in solid solution.

4. Conclusion.- The Mössbauer spectra give a clear picture of the actual iron mineralogy of the specimens outlined above and is superior to other methods in the study of glassy rocks. A point of special interest is the Mössbauer spectra of the iron in titanium oxides, exemplified by detection of ilmenite in the sample I-DAC, where ore microscopy failed to detect its presence, and observation of continuous solid solution series of titanomagnetite in sample I-ICE.

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