

Analysis of Mount Etna's volcanic rocks

Katarína Sedlačková¹, Jozef Sitek¹, Patrik Novák¹, Július Dekan¹

In this work we have analysed the basalt rocks from the area of Mount Etna using ⁵⁷Fe Mössbauer spectroscopy (MS), X-ray diffraction (XRD) and X-ray fluorescence analysis (XRF). Mössbauer spectroscopy was used to identify and to quantify the content and the magnetic nature of the iron-bearing minerals in the lava samples. Magnetite, olivine, pyroxene, hornblende, hematite and goethite of different relative abundances were found in the investigated samples. X-ray diffraction supported the structural analysis and determined the phases not visible by MS, like albite and calcite. X-ray fluorescence was employed to provide compositional analysis of the studied samples. The used methods showed qualitatively similar composition of the investigated rock samples, even though they also disclosed the quantitative differences in phase proportions agreeing with observed sample coloration. Identified compositional variations may result from the different processes during basalt formation and/or unequal weathering history.

Keywords: Mount Etna, volcano rock, basalt, lava, Mössbauer spectroscopy, X-ray diffraction, X-ray fluorescence

1 Introduction

Basalt rocks forms when lava reaches the Earth's surface at a volcano or mid ocean ridge. The lava is between 1100 to 1250°C when it gets to the surface. It cools quickly, within a few days or a couple weeks, forming solid rocks. Very thick lava flows may take many years to become completely solid. Basalt is an extrusive igneous rock that is very dark in colour. It is the most common type of rock in the Earth's crust and it makes up most of the ocean floor. Basalt is usually composed of minerals such as feldspar (predominantly plagioclase), quartz, pyroxene (augite, pigeonite), olivine, hornblende and magnetite. The mineral composition of volcanic rocks is often difficult to determine due to their very fine grain size. The basalt usually exhibits dark grey to black colour due to a high content of pyroxene minerals. Light-coloured basalts occur when the content of plagioclase or quartz is higher.

In this work we have analysed the basalt rock from the area of Mount Etna, which is the highest active volcano in Europe and one of the most active and most intensely monitored on Earth [1]. ⁵⁷Fe Mössbauer spectroscopy counts to effective fingerprinting techniques enabling to identify different types of basaltic volcanic rocks because of the abundance of iron in the dominant rock components [2]. Mössbauer spectroscopy was therefore used as the crucial analytic technique to determine different iron-bearing minerals and to yield information about the amount of iron at a particular site or in a particular oxidation state. Besides Mössbauer spectroscopy method, X-ray diffraction (XRD) technique and X-ray fluorescence

(XRF) analysis were employed to support and to complement the results yielded by Mössbauer spectroscopy.

2 Sampling and analytical methods

Investigated samples were collected in the area of Craters Silvestri of Mount Etna in Sicily in 2017. The Craters Silvestri are two inactive craters formed as a result of the Mount Etna eruption of 1892. Photographs in Fig. 1 taken during terrain inspection are showing terrain appearance and demonstrating occurrence of basaltic rocks of different colours (different shades of red, brown and black colour).

Images of four samples, hereafter named sample #1, #2, #3 and #4, selected for analysis are presented in Fig. 2. Samples of different colours were chosen for comparative purposes.

Mössbauer spectra were recorded at room temperature (RT) using a Wissel Mössbauer spectrometer with the ⁵⁷Co(Rh) source in transmission geometry and evaluated using the CONFIT program [3]. In the fitting procedure, hyperfine parameters including isomer shift (IS), quadrupole splitting (QS), internal hyperfine magnetic field (B_{hf}) and the relative absorption area (A_{rel}) of the individual spectral components were acquired. The accuracy of the reported values is about 0.04 mm/s for the isomer shift and quadrupole splitting, 0.5 T for the hyperfine field and about 2% for the relative absorption area.

XRD measurements were recorded using the diffractometer D8 Advance with Cu anode. All measurements

Slovak University of Technology, Faculty of Electrical Engineering and Information Technology, Institute of Nuclear and Physical Engineering, Ilkovičova 3, 812 19 Bratislava, Slovakia, katarina.sedlackova@stuba.sk, jozef.sitek@stuba.sk, patrik.novak@stuba.sk, julius.dekan@stuba.sk



Fig. 1. Photographs from sampled terrain of Craters Silvestri



Fig. 2. Rock samples collected at Mount Etna site (Craters Silvestri)

were performed in $\theta/2\theta$ geometry with a divergence slit of 0.6 mm and an antiscatter slit of 5.5 mm. A parallel plate collimator with an angular acceptance of 0.2° was inserted in the incidence and diffracted beam paths. Diffraction patterns were analysed using EVA software with implemented ICDD database PDF-2 (release 2015) for qualitative phase analysis [4].

Main constituent elements of volcano rocks were determined by X-ray fluorescence (XRF) analysis. X-ray fluorescence spectra were taken using Amptek Experimenters XRF Kit consisting of miniature X-ray tube (Mini-X) and complete X-ray spectrometer (X-123). The X-123 spectrometer contains Si-PIN detector (size 6 mm^2 , thickness $500\ \mu\text{m}$) with energy resolution of about 145 eV FWHM at 5.9 keV [5], preamplifier, digital pulse processor and multichannel analyser. The XRF spectra were measured on the samples positioned at 45° with respect to the X-ray beam direction and 45° to the detector. The X-ray tube working voltage was 25 kV and the measurements were performed in air at RT. The XRF spectra were analysed using Amptek ADMCA program [6].

Samples for Mössbauer spectroscopy and X-ray diffraction analysis were prepared in powder form by scraping from the surface of the selected rock pieces to obtain representative of the bulk composition. For X-ray fluorescence analysis we utilize its advantageous capability to analyse bulk samples non-destructively, without the necessity of their further mechanical or chemical prepara-

tion. The extent to which XRF results represent the bulk composition of samples is given by the critical penetration depth. For samples of basaltic composition, 99% of the observed XRF signal originates from the depth roughly between 30 and 1000 μm , depending on the element analysed [7].

3 Results and discussion

3.1 Mössbauer spectroscopy

Mössbauer spectra of investigated volcano rock samples consist of many overlapping subspectra. In order to distinguish between them correctly, a fitting model based on the superposition of magnetic and non-magnetic components was applied. Mössbauer spectra of basalt rocks samples can usually be analysed employing non-magnetic components assigned to ferrous iron ions, Fe^{2+} , in pyroxene $(\text{Mg,Fe,Ca})\text{SiO}_3$ and olivine $(\text{Mg,Fe})_2\text{SiO}_4$, and to a ferric iron component, Fe^{3+} , that is difficult to assign to any specific mineral species [8]. It is often classified as hornblende $(\text{Ca,K,Na})_{2-3}(\text{Mg,Fe}^{2+},\text{Fe}^{3+},\text{Al})_5(\text{Si,Al})_8\text{O}_{22}(\text{OH})_2$, which is used as a general field term to refer to a dark amphibole, an important group of inosilicate rock-forming minerals occurring in igneous and metamorphic rocks [9]. Magnetic components identified in the spectra include predominantly the iron oxides of spinel-type magnetite,

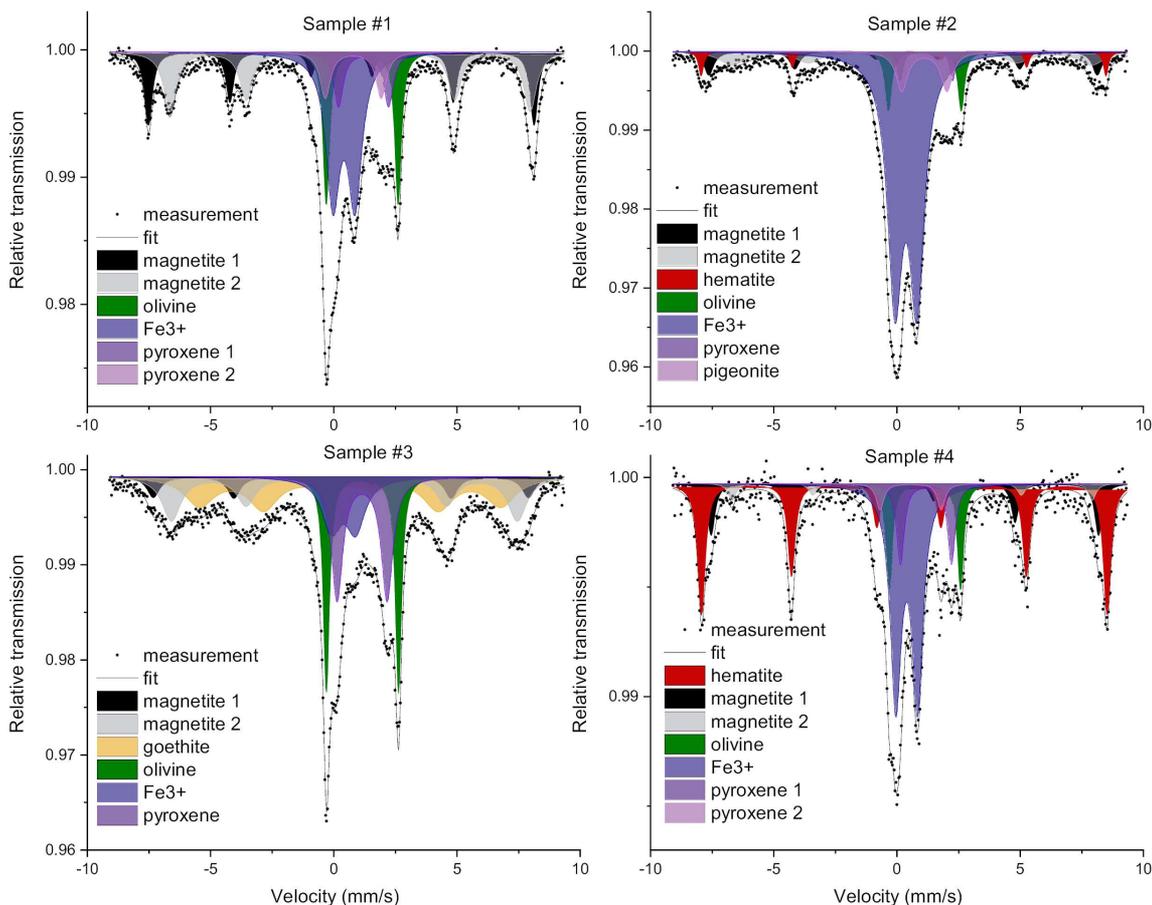


Fig. 3. Mössbauer spectra of the samples #1, #2, #3 and #4

Fe_3O_4 , and the rhombohedral hematite, $\alpha\text{-Fe}_2\text{O}_3$. Orthorhombic iron oxyhydroxide goethite, $\alpha\text{-FeO}(\text{OH})$, which is the common weathering product of iron-bearing minerals, was also found in the Mössbauer spectrum of one of the investigated samples. Goethite is commonly formed as a result of oxidation process in the weathering environment, but its occurrence may be also associated with hydrothermal processes during the basalt rock formation [9].

Basalt rocks are natural materials, where different impurities often enter the iron oxide structures (eg titanium in magnetite structure forming titanomagnetite). This may cause the hyperfine parameters modification and/or creation of several additional components in the spectra. Broadening of spectral features due to the iron atoms having different number of different types of ions at nearest neighbours was also reported [8].

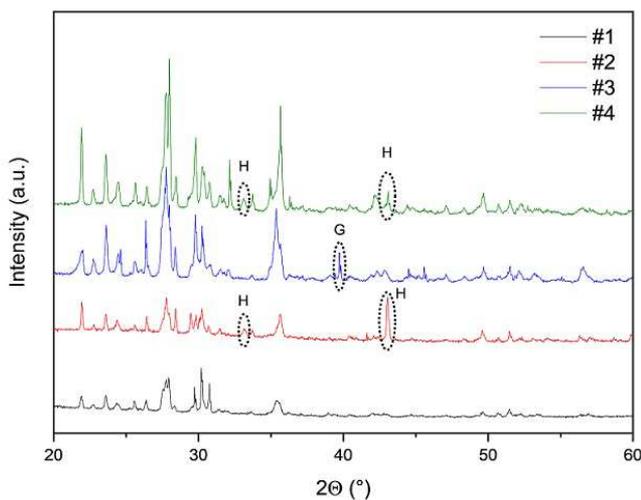
The Mössbauer spectra of the samples collected at room temperature are shown in Fig. 3 and the corresponding parameters of the spectra are listed in Tab. 1. The evaluation process of the Mössbauer spectra approved the presence of magnetic and non-magnetic components. The first magnetic component represented by two Zeeman sextets with hyperfine magnetic field of about 45 T and 49 T can be attributed to magnetite and the second magnetic component described by one sextet with higher hyperfine magnetic field ($B_{\text{hf}} \sim 51$ T) cor-

responds to hematite. In the Mössbauer spectrum of the sample #3 also a sextet with lower B_{hf} of about 38 T was unveiled, which can be assigned to goethite. The non-magnetic fraction of the Mössbauer spectra was evaluated as superposition of a couple of doublets with different quadrupole splittings. The doublet with the highest QS of 2.9 mm/s and IS of 1.1–1.2 mm/s is characteristic for olivine. The doublets with lower values of QS between 1.8 and 2.5 mm/s and IS of 0.5–1.2 mm/s can be attributed to pyroxene (eg augite $(\text{Ca},\text{Na})(\text{Mg},\text{Fe},\text{Al},\text{Ti})(\text{Si},\text{Al})_2\text{O}_6$ or pigeonite $(\text{Ca},\text{Mg},\text{Fe})(\text{Mg},\text{Fe})\text{Si}_2\text{O}_6$). Components of both olivine and pyroxene represent iron in the form of Fe^{2+} . The last subspectrum employed to describe the non-magnetic phase was a doublet with a quadrupole splitting of about 0.9 mm/s and an isomer shift of ca 0.4 mm/s typical for oxidized Fe^{3+} iron ions in octahedral coordination (hornblende). From the overall spectral area of ferrous and ferric subspectra, the ratio of $\text{Fe}^{2+}/\text{Fe}^{3+}$ can be determined, which can yield information about iron oxidation with the progress of basaltic magma differentiation [10].

As obvious from Fig. 3, the shapes of Mössbauer spectra are very different at the first sight, which indicates marked compositional variations of the investigated samples. Spectrum of the sample #1 shows comparable abundance of the magnetic and non-magnetic components, whereby in the central (non-magnetic) region, the com-

Table 1. Parameters of Mössbauer spectra of the samples #1, #2, #3 and #4. IS values are quoted with respect to $\alpha\text{-Fe}$

		A_{rel} (%)	IS (mm/s)	QS (mm/s)	B_{hf} (T)	Γ (mm/s)
Sample #1	Magnetite 1	17	0.31	-0.01	48.6	0.38
	Magnetite 2	24	0.67	-0.02	45.4	0.62
	Olivine	15	1.15	2.92	-	0.32
	Pyroxene 1	8	1.21	2.03	-	0.47
	Pyroxene 2	7	0.79	2.27	-	
	Fe^{3+}	30	0.41	0.89	-	0.69
Sample #2	Magnetite 1	8	0.33	-0.17	49.0	0.48
	Magnetite 2	12	0.62	-0.04	45.3	1.21
	Hematite	4	0.39	-0.25	51.0	0.24
	Olivine	6	1.13	2.96	-	0.31
	Pyroxene 1	3	1.19	2.13	-	0.26
	Pyroxene 2	8	1.11	1.83	-	0.57
	Fe^{3+}	59	0.36	0.89	-	0.73
Sample #3	Magnetite 1	8	0.32	-0.06	47.3	0.62
	Magnetite 2	20	0.50	-0.08	43.60	0.92
	Goethite	26	0.68	-0.03	38.0	1.45
	Olivine	17	1.16	2.93	-	0.30
	Pyroxene	18	1.15	2.03	-	0.57
	Fe^{3+}	12	0.40	0.98	-	0.93
Sample #4	Magnetite 1	12	0.28	0.08	48.8	0.37
	Magnetite 2	4	0.71	-0.20	45.4	0.37
	Hematite	29	0.39	-0.19	51.1	0.37
	Olivine	10	1.13	2.90	-	0.31
	Pyroxene 1	9	1.18	2.07	-	0.37
	Pyroxene 2	3	0.52	2.48	-	0.37
	Fe^{3+}	34	0.39	0.88	-	0.54

**Fig. 4.** X-ray diffraction pattern of samples #1, #2, #3 and #4. The most apparent differences are marked correspondingly, *ie* H – hematite, G – goethite

ponents attributed to Fe^{3+} and olivine are both manifested similarly significantly. Spectrum of the sample #2 shows pronounced central part describing predominantly a Fe^{3+} phase. Less abundant magnetically splitted com-

ponents comprise beside magnetite also hematite, which can be responsible for the orange-red colour of this sample. Magnetic components of the sample #3 are manifested by apparently broadened lines, which were fitted by several broadened sextets. Two of them ($B_{\text{hf}} \sim 43$ T and $B_{\text{hf}} \sim 46$ T) can be attributed to magnetite, whereby some deviations of the Mössbauer parameters from their values typical for the pure magnetite phase are plausible due to the above described effect of impurities. The last sextet with markedly lower B_{hf} of about 38 T was assigned to goethite. Magnetic phases with higher values of B_{hf} over 50 T (*eg* hematite) are obviously not present in the spectrum. The central part of the spectra demonstrates pronounced abundance of two doublets: the first one with high quadrupole splitting representing olivine and the second one with lower quadrupole splitting value describing pyroxene. Spectrum of the sample #4 differs from the spectra of the other investigated samples mainly by the significant contribution of the magnetic component assigned to hematite, whose occurrence corresponds again with the red-brown colouring of the sample. Central part of the spectra is comparatively noticeable and comprises a mixture of non-magnetic phases with prevailing Fe^{3+} phase contribution.

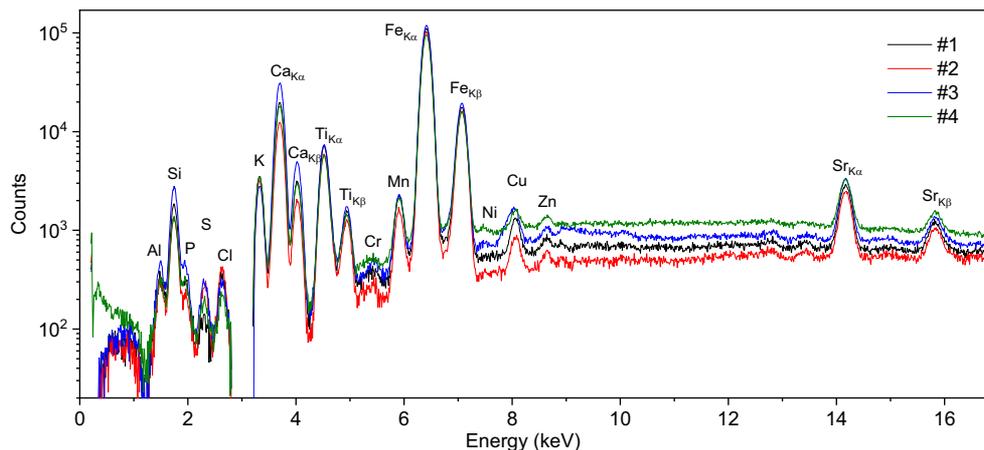


Fig. 5. XRF spectra of samples #1, #2, #3 and #4

Table 2. Relative concentrations of compounds identified by XRD for samples #1, #2, #3 and #4 from semi-quantitative analysis, uncertainty 10 %

Sample	Albite	Pigeonite	Pyroxene	Olivine	Magnetite	Iron (III) silicon oxide	Calcite	Hematite	Goethite
#1	64	14.2	7.8	4.3	4.4	3.7	1.6	0	0
#2	59	10.8	5.7	5.3	5.8	3	5.1	5.3	0
#3	29.7	15.9	7.9	16.6	3.9	3.3	8.3	0	14.4
#4	31.2	16.8	8.3	17.5	4.1	3.5	8.7	9.9	0

Table 3. Relative element concentrations for samples #1, #2, #3 and #4, uncertainty 5-30 %

Sample	Relative concentration (%)												
	Fe	Ca	Si	Al	Ti	K	Sr	Mn	Cl	S	Cu	P	Cr
#1	48.3	19.4	15.9	6.4	4.7	2.9	0.7	0.7	0.4	0.2	0.2	0.2	0.1
#2	52.5	14.5	14.1	8.6	4.5	3.1	0.7	0.5	0.6	0.5	0.1	0.3	0.0
#3	40.6	23.9	19.3	8.8	3.7	1.7	0.6	0.5	0.2	0.3	0.2	0.2	0.0
#4	48.4	20.7	13.6	7.5	4.3	3.1	0.8	0.7	0.3	0.2	0.2	0.2	0.1

It has to be emphasized, that the relative abundances of the individual iron phases are strongly dependent on the fitting procedure, where the choice of the line width parameter (Γ) is one of the most critical point. Therefore, it is important to find an appropriate model for the set of evaluated samples to minimize this effect. In case of very different sample composition within a set it is, however, often very difficult to meet this requirement.

3.2 X-ray diffraction analysis

As the method of Mössbauer spectroscopy provide detailed information exclusively on iron-bearing phases, we have performed additional analysis using X-ray diffraction to determine phase composition of the samples independently from the content of iron. From XRD analysis of diffraction patterns (Fig. 4) the presence of several crystalline phases was recognised. The main compounds found in the XRD patterns of all studied samples were albite, pigeonite, pyroxene, olivine, magnetite, iron sil-

icon oxide and calcite. As can be seen, except of iron containing minerals we have identified albite and calcite. Albite ($\text{NaAlSi}_3\text{O}_8$) is a plagioclase feldspar mineral frequently found in rocks of originally basaltic composition and it is often considered associated with other minerals, like hornblende. Development of calcite (CaCO_3) realizes as the mafic minerals recrystallise. Calcite is also commonly formed in the process of weathering in which readily water-soluble calcium cations are released and rapidly bind CO_2 from the atmosphere forming stable carbonate minerals like CaCO_3 [11].

Table 2 lists the relative abundancies attributed to the individual compounds calculated using semi-quantitative analysis [12, 13]. In the semi-quantitative XRD method the intensity received by sample analysis is compared to known intensity and information found in a database distributed by the International Centre for Diffraction Data (ICDD) [14]. This database contains intensity data from several different mineral phases which makes semi-quantitative determination in a sample fast and easy.

Commonly, the intensity of the diffraction peak of minerals not only contributes to the quantity of various phases. Therefore, this method is less accurate, but can provide a rough estimation.

The most apparent compositional deviations were observed for the samples #2 and #4 as compared to the samples #1 and #3, where the expected hematite phase was determined. XRD analysis also confirmed presence of goethite in the sample #3. The observed differences are marked in the pertinent diffraction patterns in Fig. 4. They are in a good agreement with results from Mössbauer spectroscopy.

3.3 X-ray fluorescence

XRF analysis is one of the few techniques capable of analysing samples both non-destructively and in situ, and in consequence, offers unique analytical opportunities as compared with other techniques for elemental analysis. On the other hand, XRF results are limited because the basalts were studied as bulk rock samples and therefore not entirely uniform in the analysis depth.

Figure 5 shows the background corrected and interference free XRF spectra of the samples #1, #2, #3 and #4. Concerning qualitative analysis, the used instrumentation system allows identifying elements with atomic number 11 and higher (above Na). XRF analysis of the presented spectra disclosed presence of the following elements: Fe, Ca, Si, Al, Ti, K, Sr, Mn, Cl, S, Cu, P, Cr and marginally Mg.

The samples were subjected to semi-quantitative analysis to inspect the differences in their elemental composition. To quantify the compositional variations, the relative abundance of an element with respect to the other identified elements was calculated from the measured intensity of the corresponding XRF spectra peaks. The detection efficiency and the fluorescence yield were taken into account during evaluation procedure. The values of the relative elements concentrations quoted in Tab. 3, denote in this sense a rough estimation of the relative proportion of an individual element concentration serving for comparison purposes among studied samples. As obvious, the relative abundances of the identified elements have similar tendency for all studied basalt rocks. All samples show the highest concentration of iron, whereas the elements like calcium, silicon, aluminium, titanium and potassium proved to be significant in this order.

4 Conclusion

Investigation of basalt rock samples from Mount Etna volcano has been performed using combination of three different analytical techniques proving their qualitatively similar compositions resembling to those observed for many Etnean lavas. Structural analysis disclosed, however, significant compositional variations between samples collected from the same site. The observed differences correspond very well with samples colouring and point at

non-identical conditions during their formation (pressure, temperature) and/or to unlike weathering conditions (duration, humidity). Additionally, subsequent remelting and remobilization of basaltic magmas can be also responsible for a wide variety of melt compositions of volcanic rocks [15].

The crucial analytical method of Mössbauer spectroscopy identified the iron-bearing minerals like magnetite, pyroxene, olivine and hornblende (Fe^{3+} phase) to be the most abundant. Exposed surfaces of basalts weather relatively rapidly due to oxidation of iron-rich minerals into hematite or other iron oxides (or hydroxides). Hematite is staining the rock a brown to rust-red colour and it was disclosed by MS correspondingly in both orange-red-coloured samples. Occurrence of goethite in one sample also reflect the weathering process and/or conditions of basalt formation. Mössbauer spectra in spite of their complexity yielded information about individual phase abundances and thereby also indicated differences in magnetic and non-magnetic phase ratios. The method of X-ray diffraction confirmed the presence of the above listed iron-bearing phases specifying additionally the presence of pigeonite. XRD method completed the phase analysis by revealing other minerals not visible by MS, like albite and calcite. Structural examination of the samples has been fulfilled by X-ray fluorescence in terms of elemental analysis. The main constituent elements of all studied samples were identified as Fe, Ca, Si, Al, Ti and K in this order. The elements enter the individual phase structures in a very complex ways and therefore it is difficult to find meaningful correlation between the elemental concentration and the phase composition.

REFERENCES

- [1] S. Mollo, G. Lanzafame, M. Masotta, G. Iezzi, C. Ferlito and P. Scarlato, "Cooling History of a Dike as Revealed by Mineral Chemistry: A Case study from Mt. Etna Volcano", *Chemical Geology*, vol. 288, no. 1-2, pp. 39–52, 2011, 10.1016/j.chemgeo.2011.06.016.
- [2] J. Sitek, K. Sedlačková and J. Dekan, "Analysis of Volcano Rocks from Canary Islands", *Applied Physics of Condensed Matter*, Štrbské Pleso, 2013, pp. 66–69.
- [3] T. Žák and Y. Jirásková, "CONFIT: Mössbauer spectra fitting program", *Surface and Interface Analysis*, vol. 38, no. 4, pp. 710–714, 2006, 10.1002/sia.2285.
- [4] "DIFFRAC.EVA", Bruker.com, 2021, <https://www.bruker.com/en/products-and-solutions/diffractometers-and-scattering-systems/x-ray-diffractometers/diffrac-suite-software/diffrac-eva.html>. [Accessed: 25-Feb-2021].
- [5] "X-123 Complete X-Ray Spectrometer with Si-PIN Detector – Amptek – X-Ray Detectors and Electronics", Amptek.com, 2021, <https://www.amptek.com/products/x-ray-detectors/si-pin-x-ray-detectors-for-xrf/x-123-complete-x-ray-spectrometer-with-si-pin-detector>, [Accessed: 25-Feb-2021].
- [6] "MCA8000A Multichannel Analyzer Software Downloads - Amptek - X-Ray Detectors and Electronics", Amptek.com, 2021, <https://www.amptek.com/internal-products/mca8000a-multichannel-analyzer-software-downloads>. [Accessed: 25-Feb-2021].
- [7] P. Potts, O. Williams-Thorpe and P. Webb, "The Bulk Analysis of Silicate Rocks by Portable X-Ray Fluorescence: Effect of

- Sample Mineralogy in Relation to the Size of the Excited Volume”, *Geostandards and Geoanalytical Research*, vol. 21, no. 1, pp. 29–41, 1997, 10.1111/j.1751-908x.1997.tb00529.x.
- [8] H. Gunnlaugsson *et al*, “Mössbauer Spectroscopy of Magnetic Minerals in Basalt on Earth and Mars”, *Hyperfine Interactions*, vol. 182, no. 1-3, pp. 87–101, 2008, 10.1007/s10751-008-9714-9.
- [9] D. Malczewski, M. Jeleń, J. Żaba, A. Blachowski, K. Ruebenbauer and M. Dziurawicz, “Identification of Iron-Bearing Minerals in Basalts and Pillow Lavas of the Kaczawa Mountains using ^{57}Fe Mössbauer spectroscopy”, *Nukleonika*, vol. 62, no. 2, pp. 145–148, 2017, 10.1515/nuka-2017-0021.
- [10] N. Bakun-Czubarow, J. Milczarski, J. Gałazka-Friedman, K. Szlachta and S. Forder, “Mössbauer Studies of Volhynian Basalts” *Acta Physica Polonica A*, vol. 119, no. 1, pp. 7–9, 2011, 10.12693/aphyspola.119.7.
- [11] B. McGrail *et al*, “Potential for Carbon Dioxide Sequestration in Flood Basalts”, *Journal of Geophysical Research: Solid Earth*, vol. 111, no. 12, p. n/a-n/a, 2006, 10.1029/2005jb004169.
- [12] M. Bugarčić *et al*, “Application of Raw Volcanic Rock Found in Etna Valley as an Adsorbent of Chromates, Arsenates and Selenates”, *Metallurgical and Materials Engineering*, vol. 24, no. 2, pp. 133–144, 2018, 10.30544/366.
- [13] J. Martín-Ramos, J. Daz-Hernández, A. Cambeses, J. Scarrow and A. López-Galindo, “Pathways for Quantitative Analysis by X-Ray Diffraction, An Introduction to the Study of Mineralogy”, *Cumhur Aydinalp, IntechOpen*, 2012, <https://www.intechopen.com/books/an-introduction-to-the-study-of-mineralogy/pathways-for-quantitative-analysis-by-x-ray-diffraction>.
- [14] I. Madsen, N. Scarlett, L. Cranswick and T. Lwin, “Outcomes of the International Union of Crystallography Commission on Powder Diffraction Round Robin on Quantitative Phase Analysis: samples lato 1h”, *Journal of Applied Crystallography*, vol. 34, no. 4, pp. 409–426, 2001, 10.1107/s0021889801007476.
- [15] J. BARCLAY, “A Hornblende Basalt from Western Mexico: Water-saturated Phase Relations Constrain a Pressure-Temperature Window of Eruptibility”, *Journal of Petrology*, vol. 45, no. 3, pp. 485–506, 2004, 10.1093/petrology/egg091.

Received 12 February 2021

Katarína Sedláčková (Ing, PhD), born in 1977 in Piešťany, Slovakia, received her PhD. degree in Electrotechnology and Materials from the Slovak University of Technology in Bratislava in 2005. She is currently employed as assistant at the Institute of Nuclear and Physical Engineering. Her research activities are focused on detectors of ionizing radiation (Monte Carlo-simulations of particle transport) and on the use of spectroscopic methods in physical engineering (XRF, Mössbauer spectroscopy).

Jozef Sitek (Prof, Ing, DrSc), born in Zahorska Ves, Slovakia in 1944, graduated from the Faculty of Electrical Engineering, Slovak University of Technology, in 1966. He received his PhD. degree in Applied Physics in 1974 and a DrSc. degree in Physics of Condensed Matter in 1994. At present, he is Professor of Physical Engineering at the Institute of Nuclear and Physical Engineering, Faculty of Electrical Engineering and Information Technology.

Patrik Novák (Ing, PhD) born in 1987 in Ružomberok, Slovakia. He is currently a researcher at the Institute of Nuclear and Physical Engineering. He has expertise in studying properties of materials by X-ray diffraction. His dissertation thesis discussed about analysis of residual stresses in thin films by grazing incidence X-ray diffraction. He finished his master’s degree at the Slovak University of Technology (2012) in physical engineering. He gained professional experience at the Slovak Academy of Sciences and the Center for Nanodiagnostics.

Július Dekan (Ing, PhD) born in 1980 in Bratislava, Slovakia, graduated from the Faculty of Electrical Engineering and Information Technology, Slovak University of Technology in Bratislava in branch Electromaterial Engineering and received the PhD degree in Physical Engineering in 2010. Since 2008 he has worked as a researcher at the Institute of Nuclear and Physical Engineering of Faculty of Electrical Engineering and Information Technology.