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TO THE PROBLEMS OF ALTERATIONS OF CENTRAL SLOVAKIAN NEOVOLCANITES

(Fig. 1—14)

A b s t r a c t: In the paper a geological characterization of alterations of neovolcanites is presented in dependence upon the structure of the volcanic complex, within the area of the Kremnica ore field. Clay minerals of argillitized zones are especially studied in detail. For ore localizing textures the association of mica clays, kaolinite is characteristic. Montmorillonitization is of the character of mass alteration in stratigraphically higher parts of the volcanic complex.

Introduction

From the standpoint of study of alterations of neovolcanites the region of the Slovakian Midmountains has provided for classical examples for solution of this problem since long ago. Since the time when the fundamental work by F. R i c h t h o f f e n (1860) had been written several authors dealt with problems of alteration of the neovolcanites. From the latest period there are especially the works by M. B ö h m e r (1961, 1966), who studied alterations of neovolcanites in relation to ore veins of the gold-silver formation in the ore field of Kremnica and the works by J. F o r g á č (1966) and V. R a d z o (1967) concerning the ore field of Štiavnica-Hodruša in relation to ore veins of the polymetallic formation. On the basis of up to present knowledge it may be supposed that alterations of the West Carpathian neovolcanites generally depend upon the volcanological development of the region and its consolidation in the post-volcanic period and upon metallogenetic development showing corresponding tendencies of development in the individual volcanic ranges of Central Slovakia. The regularities found out at the individual localities are therefore of wide validity. The presented paper is regionally based on the conditions found in the ore field of Kremnica and attention is especially paid to investigation of clay minerals, which have up to now been studied least in mineral associations of altered neovolcanites.

Brief Characterization of Geological and Deposit Conditions of the Ore Field of Kremnica with Distinguished Types of Neovolcanite Alteration

The ore veins of Kremnica are the most typical representative of the gold-silver formation which belongs to the most widely spread types of hydrothermal ore mineralization in the neovolcanites of the Slovakian Midmountains.

The ore field is partly exposed in an erosion window in the centre of the Mountains of Kremnické pohorie, where on the surface regionally propylitized pyroxenic andesites of Upper Tortonian age appear, in the scheme of succession further pyroxene-amphibolic andesites and pyroxenic andesites $\pm$ amphibolite and biotite with prevailing effusive forms, abundantly accompanied by pyroclastic rocks, follow. Biotite-amphibolic andesites of Sarmatian age with typical extrusive forms incoherently border the central part of the mountain range. Acid volcanism is represented by extrusions of Sarmatian rhyolites bordering the central part from the south and north, present in the central

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part in the ore field in the form of subvolcanic to hypabyssal dykes. In the centre of the ore field also diorite porphyrites occur, being of uncertain position in the succession, however older than the rhyolites.

The first data of the substratum of the neovolcanites in the ore field could have been obtained in the present period only, when structural borehole encountered carbonate-schistose complex of Middle Malmian-Kimmeridgian age, 800 m deep. Ore localizing dislocations in this complex are highly aquiferous with thermal waters of deep circulation, the catchment area of which are exposures of the Mesozoic at the circumference of the volcanites of the Mountains of Kremnické pohorie. The mentioned structural borhole encountered in carbonate rocks a hot spring of the yield of 2700 l/min and temperature of 47 °C. These hydrogeological data are to take into consideration because such a hydrogeological regimen existed in this area since the end of the Miocene and according to all signs essentially influenced the character of hydrothermal activity, especially in the sense that hydrothermal solutions were of mixed character, besides the juvenile constituent there was also a great share of vadose waters of deep circulation.

The commencement of the ore mineralization process followed the protrusion of rhyolite dykes, which together with ore-bearing veins are paragenetically dependent upon the acid deep-seated magmatic source. We distinguish in the development of ore veins the older stage of Au, Ag, and the younger of Sb.

Fig. 1 presents a typical cross section through the ore field of Kremnica with both vein systems of Kremnica, the system of the Schrämmen and Gold Vein. In the profile the regional extension of alterations of the volcanic complex is delimited. The boreholes KR-1 and KR-2 confirmed the assumption that hydrothermal alterations and a part of the vein structures, the Gold Vein in this profile, are present in covered position under younger volcanites. Hydrothermal alterations gradually die away in the upper members of the volcanic complex. The boreholes KR-1 and KR-2 served for the study of the character of alterations in marginal parts of the ore field and in the neighbourhood of the uppermost parts of the vein structures, formed by opal and lowthermal chalcedony-carbonate veinstone.

Fig. 2 presents typical cases of hydrothermal alterations of the volcanic complex in dependence upon its structure.

1. Altered zone near the dislocations.

2. Alterations of the volcanic complex with stratovolcanic structure, when as a consequence of circulation along strata of higher porosity the alterations of volcanites acquire a „stratiform" character. On the surface relics of massive lavas remain, predominantly altered at the contacts and along joints.

3. The complex of pyroclastic rocks or volcanic breccias pierced by subvolcanic bodies is also selectively hydrothermally altered. In all the cases hypogene alterations in the surficial zone were intensified by supergene alteration as a consequence of the action of meteoric waters.

The alterations of neovolcanites can be divided into regional or mass alterations affecting extensively volcanic complexes and arround fissures alterations.

Regional alterations are caused by solutions of the pores of various genesis, acting in the pores and closed small joint systems of various geneses. To this type of alterations those of propylitization in narrower of the word belong, formed by the association of minerals: carbonate, chlorite, pyrite and smaller amounts of clay minerals. In higher parts of the volcanic complex montmorillonite is of the leading position at this type of alteration.

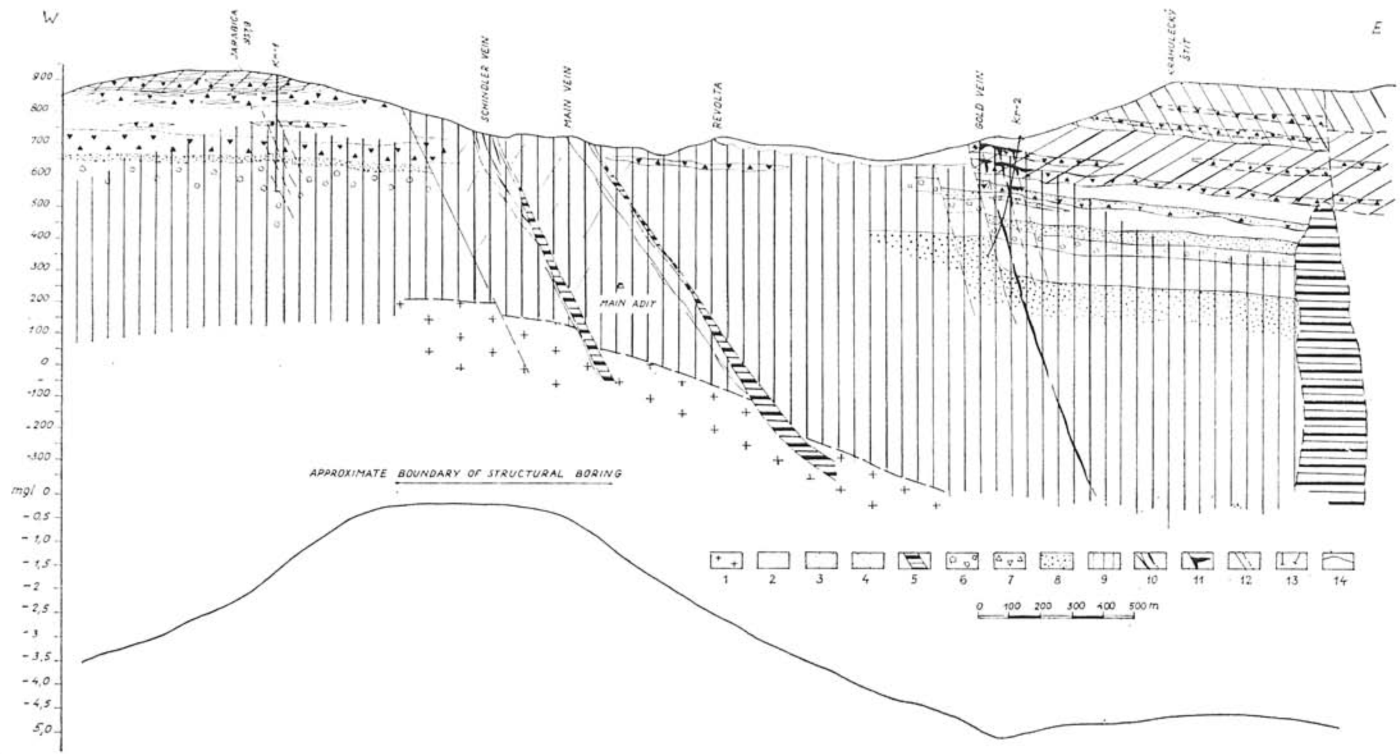

Fig. 1. Typical cross section through the ore field of Kremnica. 1 — Substratum of the neovolcanites on the whole: Miocene hypabyssal intrusive rocks and Mesozoic carbonate -shaly rocks, 2 — older pyroxenic andesites, 3 — pyroxeneamphibolic andesites, 4 — pyroxenic andesites with accessory amphibole and biotite, 5 — rhyolites, 6 — tuffaceous lavas, 7 — agglomerates, 8 — tuffs, 9 — regional alteration of volcanites with greater intensity of alteration, structural sings are wiped off, 10 — gold-bearing quartz veins, 11 — veiny and stratified layers of opalites, 12 — dislocations, 13 — prospection holes, 14 — gravimetric profile of Bouguer anomaly.

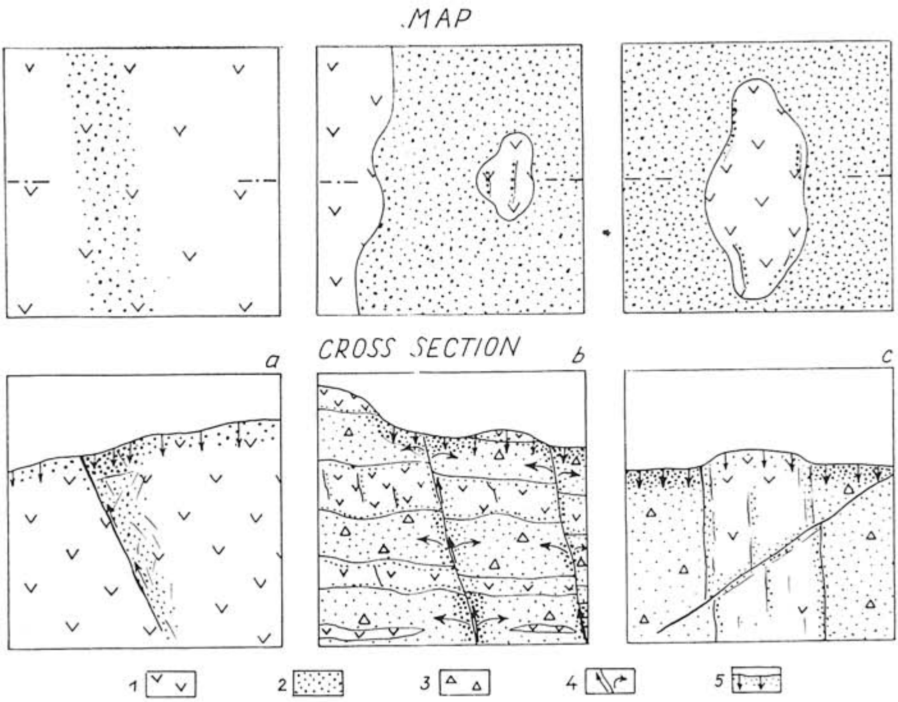

Fig. 2. 1 — Solid volcanic rocks — lava flows, volcanic bodies, 2 — altered volcanites, 3 — volcanites with higher porosity — pyroclastic rocks, tectonic and volcanic breccias, 4 — directions of circulation of ascending solutions, 5 — meteoric waters.

Arround-fissures alterations originate around open circulation systems of hydrotherms. As a rule several zones can be distinguished there:

1. Zone of silification adjoining to the ore vein, which from clay minerals contains mica clay.

2. Zone of mica clay with admixture of kaolinite and swelling chlorite with content of K_2O reaching up to 7—8 %, the content of Na_2O reaching only one tenth of per cent.

3. Zone of adularization, especially typical of the higher parts of ore veins, with content of K_2O up to 9—10 % and content of Na_2O lowered to one tenth of per cent.

4. Zone of chloritization that gradually passes into regionally propylitized andesites. In volcanites lying in stratigraphically higher position montmorillonite is present in this external zone instead of chlorite.

The lateral order of the zones of altered volcanites is also reflected in their vertical distribution. The mentioned zones have the following optimum of development beginning from the upper parts of the vents: the level of montomorillonitization, substituted by chloritization in greater depth, the level of adularization and mica clay.

Using of borings in the marginal parts of the ore field, where ore-bearing structures gradually wedge ont towards the surface and consequently are covered under the younger members of volcanites, made possible to study the types of alterations, which were carried away by denudation in the central part of the ore field. The level with maximum extension of montmorillonitization is especially concerned there. Those types of alterations belonging to the inner zones could have been studied best near the ore veins in the centre of the ore field on the contrary. In associations of secondary minerals of the altered zones least studied are till now clay minerals, especially in zones 1, 2 and 4, therefore we mainly focused on detailed mineralogical study of clay minerals of these zones mentioned in the following part of this paper.

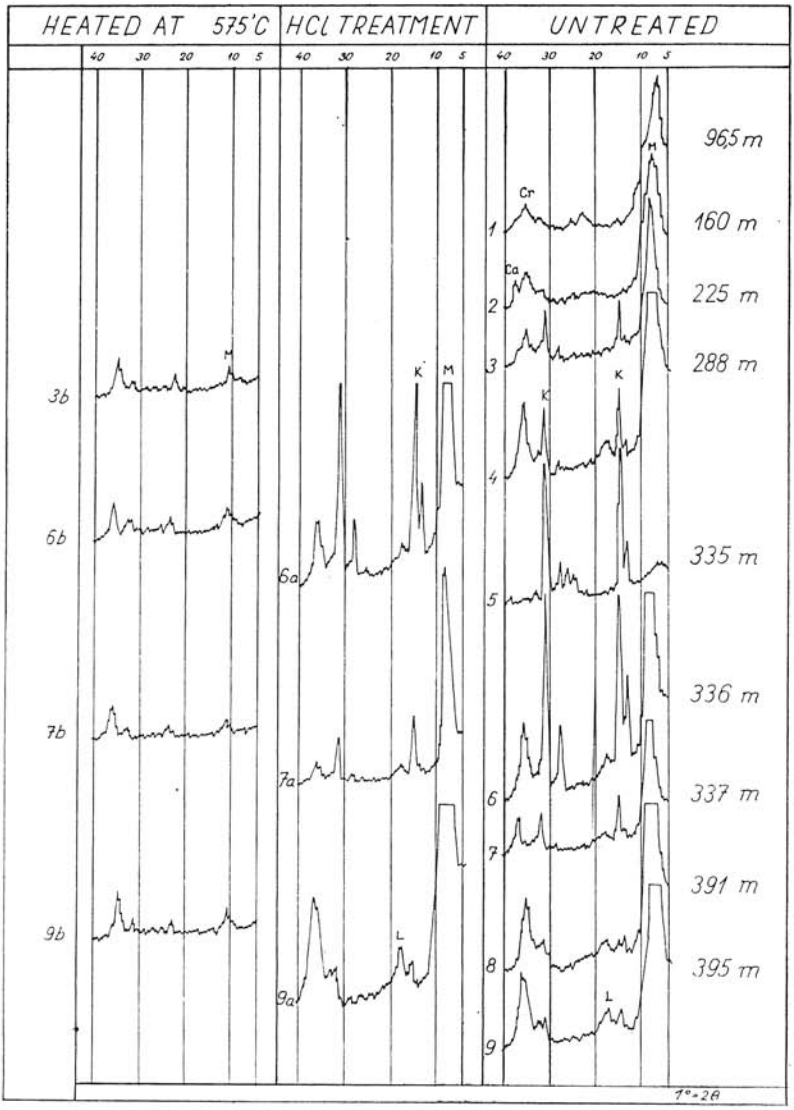

Fig. 3. X-ray record of clay minerals in the marginal part of the ore field of Kremnica. Diffractograph GON-3, FeK radiation, 40 kV, 15 mA, diaphragms 2′, shift 2°/min., T — 4. M — montmorillonite, K — kaolinite, L — lepidocrocite, Ca — calcite, Cr — cristobalite.

Clay Minerals in the Marginal Part of the Ore Field of Kremnica

The character of alterations leading to the formation of clay minerals in the marginal parts of the ore field of Kremnica was studied in pyroxenic-amphibolic, pyroxenic andesites and tuffites in the boreholes KR-1 and KR-2.

The mostly wide spread clay mineral is montmorillonite (fig. 3, tab. 1). Finding of kaolinite to be present in higher concentration, especially where intense ore mineralization represented by vein quartz, carbonates, rarely pyrite, was taking place, is very important. It is a sample from the depth of 288 m. The studied clay forms the filling in the tectonically disrupted zone and accompanies a veinlet of quartz and carbonates 20 cm thick. A second place, even more important from this standpoint, is the interval of 334—354 m with silicified andesite, vein quartz, carbonates and pyrite present. The whole section is intensely argillitized and bleached. Reticulated veinlets of snow-white clay mineral, 1—3 mm thick, in the groundmass of argillitized andesites are especially characteristic. The supposition of pure kaolinite to be concerned has been confirmed as the sample from the depth of 335 m proves. The presence of kaolinite can be also observed in microphotograph made by aid of electron microscope (fig. 4).

On the basis of X-ray identification we found out some data in the boring KR-2, concernig mainly montmorillonite. The position of basal spacings varies in a wide range from 12.6 to 15.1 Å. It is generally known that montmorillonite with basal spacing of 12.4 contains only one layer of water molecule in the interlayer space. According to C. E. Weawer (1956) with montmorillonite containing onevalent cations in the interlayer space usually the basal spacings of 12.4 Å appears. It is interesting

Table 1. Chemical Analyses of Montmorillonites from the Marginal Part of the Ore Field of Kremnica. Analyst Ing. J. Polakovičová

	KR-1/240 m	KR-2/96.5 m	KR-2/395 m
SiO_2	53,05	53,29	47,36
Al_2O_3	13,43	15,69	19,41
TiO_2	0,50	0,43	0,98
Fe_2O_3	6,31	8,47	5,12
FeO	0,97	0,40	0,77
MnO	0,12	0,04	0,02
CaO	3,30	2,34	2,34
MgO	3,20	3,74	3,15
K_2O	0,20	0,31	1,03
Na_2O	1,06	0,54	4,63
Loss by drying 110 °C	9,74	9,14	6,56
Loss by annealing 110—900 °C	8,18	6,17	8,76
P_2O_5	0,04	0,08	0,09
Sum	100,10 %	100,64 %	100,22 %
Molecular ratio	6,85	5,88	4,23

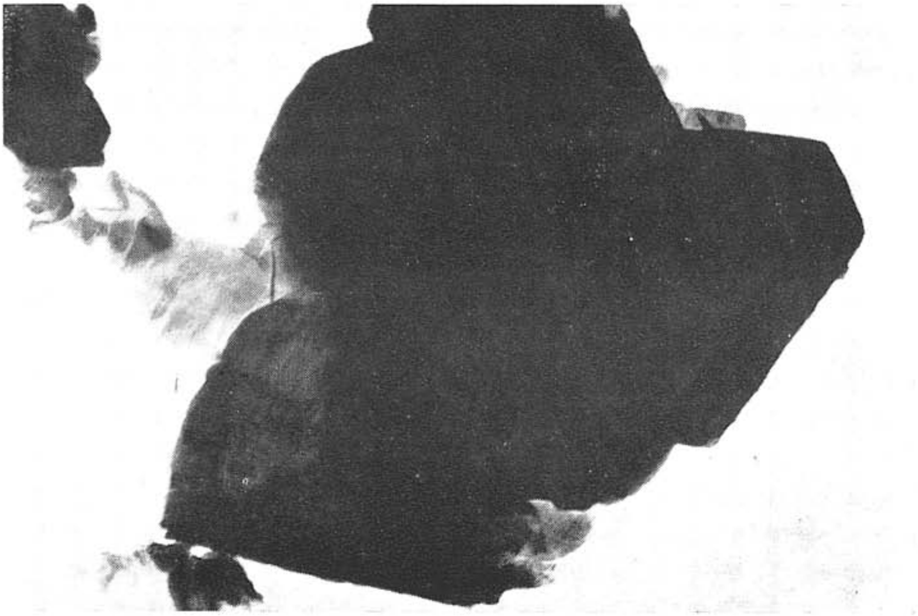

Fig. 4. Kaolinite from the marginal part of the ore field of Kremnica. Borehole KR-2 335 m. Magnif. 18 000 ×. All the microphotographs (figs. 4—11) were prepared under table electron microscope Tesla BS 242 by H. Gerthofferová. The preparations were prepared by suspensation method.

that in the chemical analysis of the sample from the depth of 395 m a conspicuously high content of Na_2O (4.63 %) was found. That would point to the presence of Na montmorillonite.

On the basis of optical study the chloritization in fine-grained aggregates of argillitized andesites could not have been excluded. This is the reason why we looked for the presence of chlorites by X-ray methods. The samples were trated with two-normal HCl at the temperature of 95 °C for a half an hour, further we hated them at 575° for a half an hour and at the same time we treated them with glycerol. In the composition of the studied samples (fig. 3) no changes occurred with action of HCl. The basal spacings of 7.1 and 3.57 Å remained preserved, only their intensity increased slightly. The basal spacings of 12.6—15.1 Å belonging to three-layer expanded mineral has not changed. With heating the samples at the temperature of 575 °C the structure of the expanded mineral is getting disturbed, as it is manifested in the shift of the basal spacings to 9.6 Å. At same time its intensity decreases rapidly. This fact shows the basal spacings of 12.6—15.1 Å exclusively to belong to montmorillonite.

The chemical composition of the clay constituent in the fraction less than 2 micrometres we studied in the boreholes KR-1 and KR-2 at montmorillonite only. We did not succeed in separating out the required amount of pure kaolinite forming thin veinlets in decomposed andesite.

We calculated the following crystallochemical formulas according to W. P. Kelley (1955) from the samples KR-1/240 and KR-2/96.5:

KR-1/240

$[Si_{7.93}\,Al_{0.07}]^{IV}$ $[Al_{2,29}\,Fe^{+3}_{0,71}\,Fe^{+2}_{0,24}\,Mg_{0,71}]^{VI}$ $[Ca_{0,53}\,Na_{0,31}\,K_{0,04}]^{XII}$ $O_{20}\,(OH)_4$

KR-22/96.5

$[Si_{7,66}\,Al_{0,34}]^{IV}$ $[Al_{2,32}\,Fe^{+3}_{0,92}\,Fe^{+2}_{0,05}\,Mg_{0,80}]^{VI}$ $[Ca_{0,36}\,Na_{0,15}\,K_{0,05}]^{XII}$ $O_{20}\,(OH)_4$

The studied montmorillonites are characterized by low substitution of Al for Si in tetrahedral coordination, as reflected in the high Si: Al ratio value. The sample KR-2/395 contains admixture of kaolinites, what to a considerable degree could misrepresent the calculated values, therefore we do not mention the crystallochemical formula.

Clay Minerals in the Central Part of the Ore Field of Kremnica

In order to be able to compare the mineralogical character of altered andesites in the marginal parts with alterations in immediate neighbourhood of the ore veins of Kremnica we carried out detailed mineralogical study of the argillitized zone in close proximity of Au-Sb mineralization. Sampling we avoided the filling of tectonic dislocations (tectonic clay), where clay minerals are not found at the original place of formation, that's why they do not provide for a reliable picture of the actual character of alteration in the place of sampling. We studied argillitized rocks directly in the vein system and close neighbourhood of the ore veins.

The results obtained till now on the basis of DTA, X-ray methods, study under electron microscope and chemical analysis confirm especially mica clay, kaolinite and

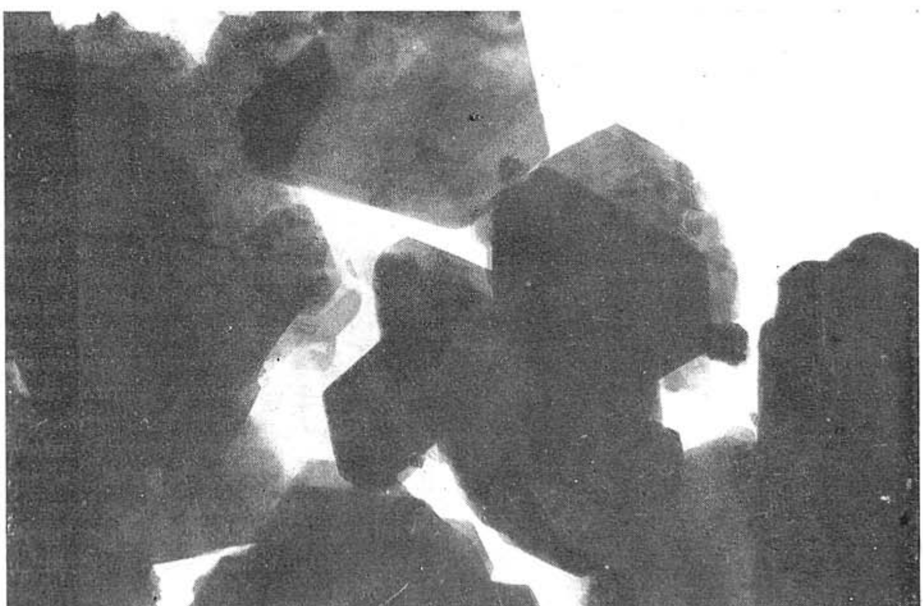

Fig. 5. Kaolinite, Václav adit, sample 5, Magnif. 30 000 ×.

Fig. 6. Hydromuscovite 1M, Ferdinant pit, V. horizon, sample 1. Magnif. 20 000 ×.

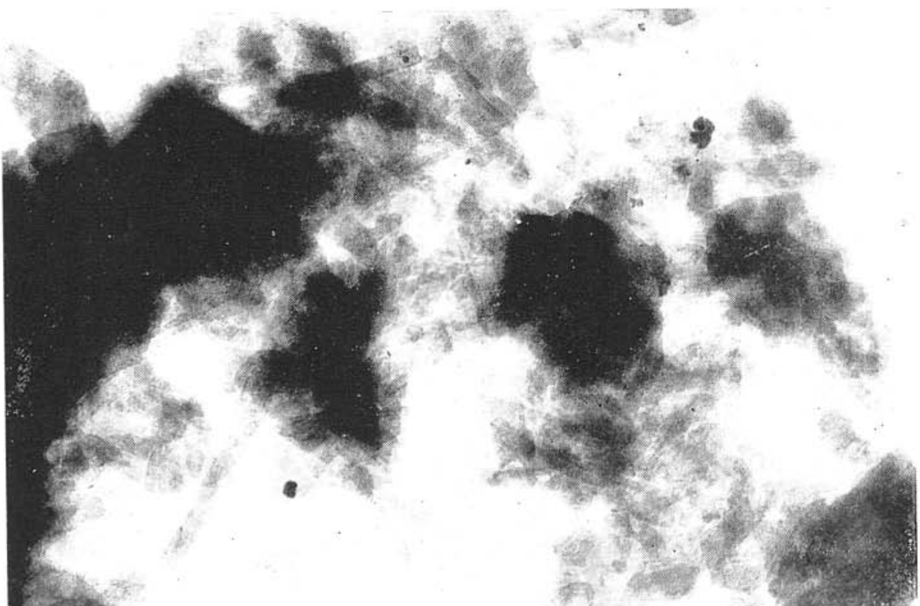

Fig. 7. Hydromuscovite 3T, outcrop of the Schrämen Vein on the Mt. Šturec, sample 2. Magnif. 20 000 ×.

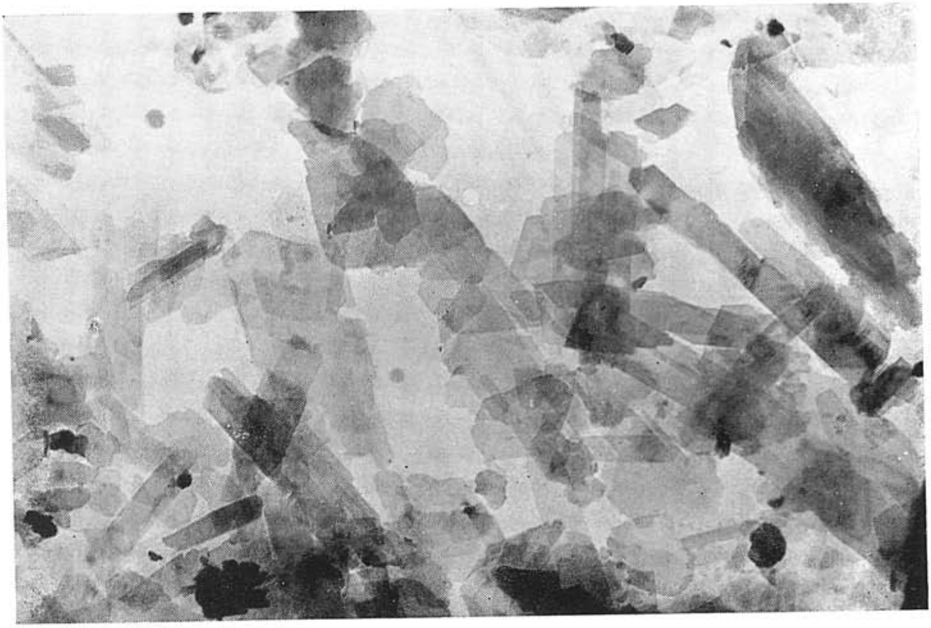

Fig. 8. Interstratifield structure of illite with expanded three layer clay mineral. Ferdinand pit, IV. horizon, sample 9. Magnif. 18 000 ×.

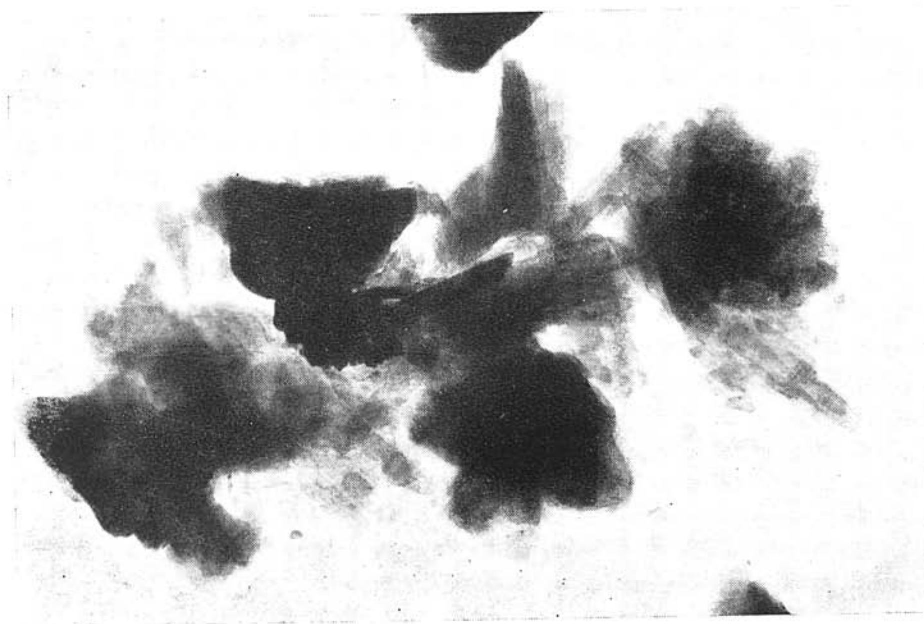

Fig. 9. Interstratified structure of illite with expended three layer clay mineral and swelling chlorite. Ferdinand pit, II. horizon, sample 8. Magnif. 16 000 ×.

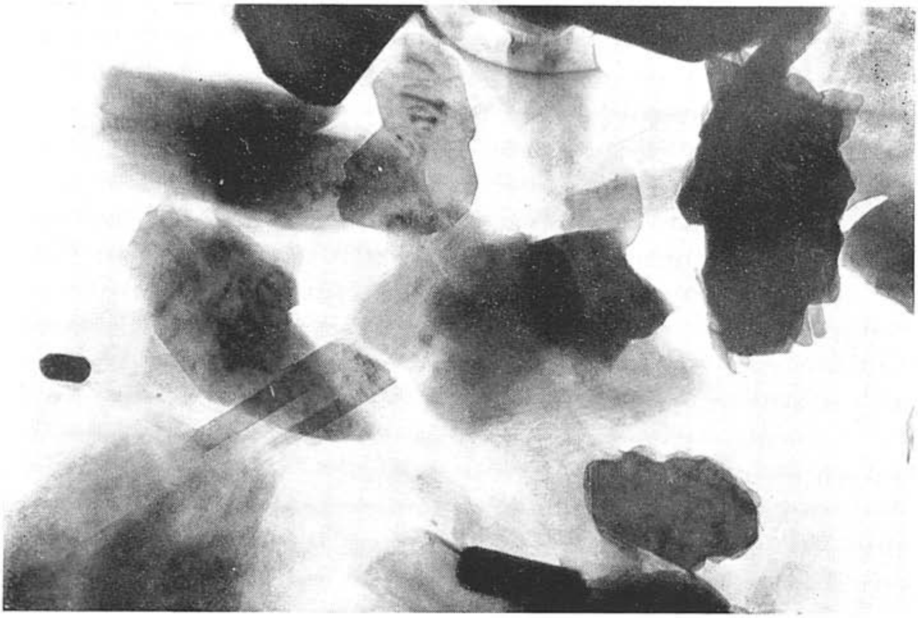

Fig. 10. Kaolinite, mica clays, swelling chlorite. Ferdinand pit, II. horizon, sample 11. Magnif. 18 000 ×.

Fig. 11. Mica clay and kaolinite. Ferdinand pit, IV. horizon, sample 12. Magnif. 18 000 ×.

swelling chlorite to be present from clay minerals (figs. 4—11). In surficial outcrops of the Schrämen Vein on the Šturec jarosite was found. With more detailed identification of mica clay we found out hydromuscovite 1 M and 3 T polytype to be concerned. To a considerable degree also randomly interstratified illite with expanded three layer mineral is present. The mica clays most frequently contain admixture of kaolinite in variable amount. More rarely monomineralic concentrations of mica clays are present and only scarcelly we find pure monomineralic kaolinite.

Identification of Mica Clays

In the terminology of mica clay a considerable disagreement is still evident. The term „illite" was used first by R. E. Grim, R. H. Bray, W. F. Brindley (1937) as general designation for clay minerals, which are concentrated in soils. Later the individual varieties of mica clay started to be gradually differentiated and designated with various terms. According to the opinion of some authors the term „illite" should be restricted to the type locality only or used as general term for the clay mineral with basal spacings of 10 Å only, which is not being studied more in detail from the structural and chemical aspect. G. Brown (1955) submitted the suggestion to substitute illite with the term „hydrous mica" with differentiation of the dioctahedral and trisoctahedral type. As intermediate stage between muscovite and hydrous mica of dioctahedral type the term „hydromuscovite" is currently used. The criteria for accurate distinguishing of the individual varieties of mica clay minerals seem however se far not be exactly limited and frequently misunderstanding occurs.

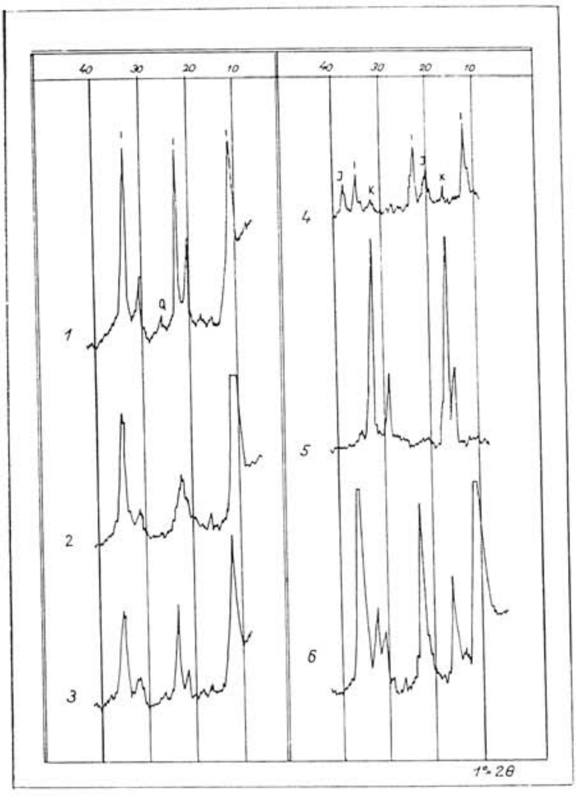

Fig. 12. X-ray record of clay minerals from the central part of the ore field of Kremnica. Diffractograph GON 3, FeK radiation, 40 kV, 15 mA, diaphragms 10′, shift 2°/min. T — 4. I — mica clay, K — kaolinite, J — jarosite, Q — quartz.

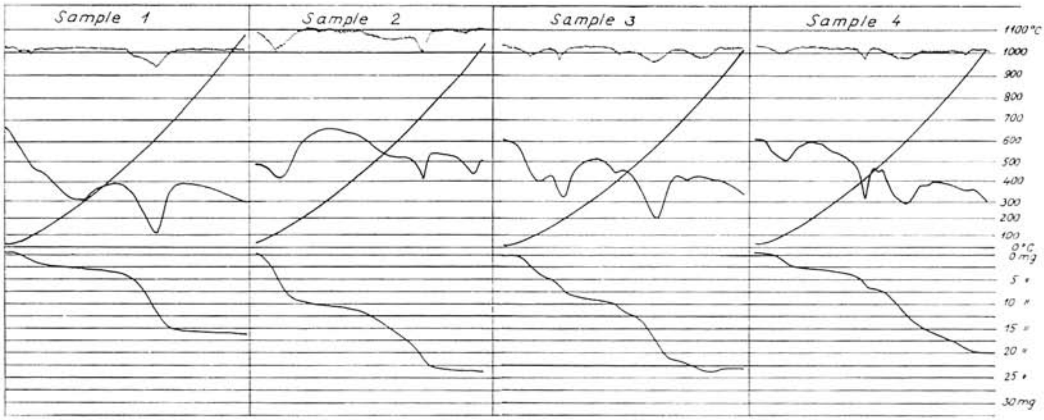

Fig. 13. DTA curves of clay minerals from the central part of the ore field of Kremnica. Sample 1, hydromuscovite 1M. Sample 2, hydromuscovite 3T. Sample 3, interstratified structure of illite with expanded three layer clay mineral. Sample 4, jarosite with mica clay and kaolinite.

For the identification of mica clay itself precise finding out of the content of interlayer and OH water is of considerable importance. In this way the thermoanalytic apparatus of the system of F. and J. Pavlík, L. Erdey (derivatograph) provided for valuable aid. We analysed samples of the fraction less than 2 micrometres. Samples 1,2 and 3 were found out by X-ray methods to be monomineralic, with the exception of the presence of quartz in sample 1. Sample 4 contains jarosite besides kaolinite and mica clay (fig. 12).

The data obtained by aid of DTA show the mineral with randomly interstratified structure to have besides the endothermic peak by 560 °C slight endothermic reaction developed by 720 °C, similarly as sárospatakite of R. E. Grim, W. F. Bradley, G. Brown (1951). (Fig. 13, sample 3). The basal spacings of the studied interstratified structure of illite and expanded three layer mineral of 10,36 Å shifts to 9,62 Å after treatment with glycerol (fig. 14). On the basis of the data of differential-thermic and X-ray methods we state that the studied mineral is similar to sárospatakite or so called „illite" from Füzerradvany. K. Melka, E. Slánsky (1958) consider the „illite" from Füzerradvany as interstratified structure of illite-montmorillonite with insignificant portion of montmorillonite. We can say with certainty about the studied randomly interstratified structure that besides illite three layer expanded clay mineral has share in its composition. Till now we have not found out with certainty it montmorillonite or expanded chlorite is concerned. G. Brown, D. M. C. MacEwan (1950) calculated the curves showing the shift of basal spacings in randomly interstratified structures in dependence upon the representation of the original constituents. On the basis of these data we came to the conclusion that the amount of the three layer expanded clay mineral is less than 20 %.

Another important aspect in the study of mica clay is the determination of polymorphism. H. S. Yoder, H. P. Eugster (1955) found out the alteration of 1 M polytype into 2 M_1 taking place at the remperature of 200—350 °C and pressure of

1054 kg/cm² on the basis of experimental work. The conclusion is generally drawn from this fact that 2 M_1 polytype first of all originates at higher temperature. The conditions, under which polytypes of mica clay originate, have not been definitively clarified as yet. B. Velde (1965) experimentally obtained muscovite 2 M_1 already at the temperature of 125 °C. The works by C. E. Weawer (1959) also show 2 M_1 polytype to originate with diagenesis, thus at relatively very low temperature. In this connection the information of A. A. Levinson (1955) is interesting that 1 M and

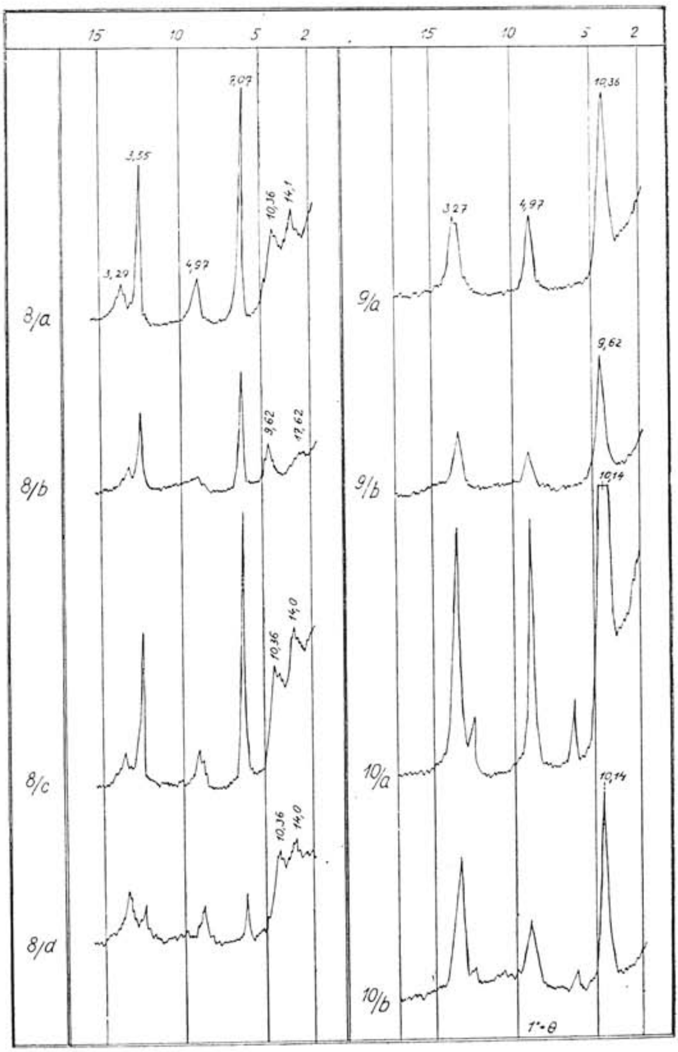

Fig. 14. Roentgenographic record of clay minerals from the central part of the ore field of Kremnica. Diffractograph Philips-Müller, Cu radiation, Ni filter, diaphragms 1°—0, 1°—1°. T — S. a — untreated, b — glycerol, c — heated at 450 °C, d — heated at 600 °C.

3 T polytypes are not found in sedimentary series. 2 M_1 and 1 M_d polytypes are usually bound to sediments only to the contrary.

The data obtained by aid of the derivatograph (fig. 13) show sample 2 to have endothermic peak at 720 °C (tab. 2). A course of the DTA curve corresponding to that of sample 2 is mentioned by R. C. Mackenzie, G. F. Walker, R. Hart (1949) for illite 3 T from Balatter in Scotland. Comparing powders of mica clay from Kremnica with 1 M and 2 M_1 polytype prepared synthetically in tab. 3 we found out 1 M and 3 T polytype manifested in mica clay in Kremnica. According to H. S. Yoder, H. P. Eugster (1955) for 3 T polymorphism the basal spacings of 3.87 and 2.88 Å are characteristic. The line 2.87 is present in sample 2 simultaneously with the line 3.83 Å. We did not find dolomite in the studied by means of the manometric method (J. Turan 1965) since in the reverse case the line 2.87 Å would belong to this mineral.

The third important moment in the study of mica clay is knowledge of the chemism. For total characterization of clay minerals present in the argillitized zone in the neighbourhood of the ore veins of Kremnica I also mention the analysis of kaolinite:

From chemical analysis 1 (tab. 4) we calculated the following crystallochemical formula according to G. Brown, K. Norrish (1952):

$[Si_{6,80}\,Al_{1,20}]^{IV}\ [Al_{3,23}\,Fe^{+3}_{0,31}\,Fe^{+2}_{0,08}\,Mg_{0,34}]^{VI}\ [K_{1,23}\,Ca_{0,08}\,Na_{0,05}\,H_3O_{0,24}]^{XII}\ O_{20}\,(OH)_4$

Identification of Swelling Chlorite

The basal spacings of three layer expanded mineral 14.12 Å and after treatment with glycerol 17.62 Å (fig. 14) are found in parts 4—7 m distant from the vein system. With heating up to 450 and 600 °C for a half an hour the position of the basal spacings does not change, what excludes the presence of montmorillonite and proves the presence of swelling chlorite.

Identification of Jarosite

Another mineral, important from the genetic standpoint, we have found in the argillitized zone near the ore veins, is jarosite. It is found together with kaolinite and mica clay, especially in surficial outcrops of the ore veins. In this sense sample 4, fig. 12 and 14, is typical, coming from the surficial outcrop of the Schrämen Vein on the Mount of Šturec. The DTA curve agrees very well vith the curves of jarosites mentioned in the works by J. L. Kulp, A. H. Adler (1950) and J. Jarkovský, B. Číčel (1959). It is characterized by two intense endothermic and one exothermic deviation. The endothermic deviations with peaks at 425 °C and 735 °C signalize the disintegration

Table 2. Peaks of Endothermic Reactions and Loss of Weight in Mica Clay

	Nb. 1		Nb. 2		Nb. 3		
	I. min.	II. min.	I. min.	II. min.	I. min.	II. min.	III. min.
DTA	260 °C	610 °C	110 °C	720 °C	100—200 °C	560 °C	720 °C
TG	1,45 %	5,20 %	3,50 %	4,66 %	3,80 %		5,40 %

Table 3. Powders of Mica Clay from Kremnica

$2M_1$		1M		Nb. 1 1M		Nb. 2 3T		Nb. 3 1M	
d	I	d	I	d	I	d	I	d	I
10,01	100	10,00	60	—	—	—	—	—	—
5,02	55	5,01	30	—	—	—	—	—	—
4,48	55	4,48	80	4,43	VS	4,44	VS	4,45	VS
4,46	65	—	—	—	—	—	—	—	—
4,39	14	—	—	—	—	—	—	—	—
4,30	21	4,34	15	—	—	—	—	—	—
4,11	14	4,10	10	—	—	—	—	—	—
3,97	12	—	—	—	—	—	—	—	—
3,89	37	—	—	—	—	—	—	—	—
—	—	—	—	—	—	3,83	S	—	—
3,74	32	—	—	—	—	—	—	—	—
—	—	3,65	40	3,62	S	3,62	S	3,66	S
3,50	44	—	—	—	—	—	—	—	—
3,35	100	3,34	70	3,30	VS	3,32	VS	3,32	VS
—	—	—	—	—	—	3,25	VW	—	—
3,21	47	—	—	—	—	—	—	—	—
—	—	3,07	35	3,06	S	3,09	S	3,04	S
2,87	35	—	—	—	—	2,87	S	—	—
2,80	22	—	—	—	—	—	—	—	—
—	—	2,68	10	—	—	—	—	—	—
2,59	50	—	—	—	—	—	—	—	—
2,58	45	2,57	35	—	—	—	—	—	—
2,56	90	2,55	60	2,53	VS	2,55	VS	2,56	VS
—	—	2,44	10	2,43	VW	2,44	VW	2,44	VW
—	—	2,39	5	—	—	—	—	2,39	VW
—	—	2,36	5	2,36	VW	2,37	VW	—	—
—	—	2,24	10	—	—	2,23	VW	2,24	VW
—	—	2,21	5	2,19	VW	—	—	—	—
—	—	2,11	15	2,11	VW	2,12	VW	2,13	VW
—	—	2,00	5	—	—	—	—	—	—
—	—	2,01	30	—	—	2,02	VW	1,99	VW
—	—	1,95	5	1,97	VW	1,96	VW	—	—
—	—	1,71	2	—	—	—	—	—	—
—	—	1,67	10	—	—	1,68	VW	1,68	VW
—	—	1,63	10	1,63	VW	1,63	VW	1,63	VW

$2M_1$ — synthetically prepared polytype (Yoder, Eugster 1955). 1M — synthetically prepared polytype (Warshaw 1960). Working conditions Mikrometa 1, Chirana, CuK_α radiation, diaphragm $^1/_2$, time of exposure 6–12 hours diameter of chamber 57 mm, VS — very strong, S — strong, VW — very weak.

of the structure of jarosite. The exotherm at 475 °C indicates crystallization of Fe_2O_3 from amorphous mass. In X-ray identification in oriented preparations jarosite has basal spacings at 5.9 and 3.06 Å.

Conclusion

On the basis of mineralogical study of clay minerals in the ore field of Kremnica we found two mineral assemblages to be present.

1. In the marginal parts of the ore field and also in stratigraphically higher members of the volcanic complex montmorillonite was found to be the most widely spread

Table 4

	No 1	No 2	No 3	No 4	No 5
SiO_2	51,44	54,56	51,20	50,10	45,79
Al_2O_3	28,43	26,70	22,75	25,12	35,50
TiO_2	0,14	—	1,65	0,50	0,09
Fe_2O_3	3,12	0,79	6,59	5,12	2,20
FeO	0,74	—	0,85	1,52	0,67
MnO	—	—	—	—	—
CaO	0,59	1,91	0,43	0,35	0,47
MgO	1,25	1,61	2,87	3,93	0,59
Na_2O	0,22	—	0,34	0,05	0,35
K_2O	7,32	8,23	8,10	6,93	1,09
P_2O_5	0,04	—	—	—	0,02
V_2O_5	—	—	0,18	—	—
Loss by drying 110 °C	1,69	—	—	—	0,45
H_2O^-	—	1,11	—	—	—
Loss by annealing 110—900 °C	5,39	—	—	—	12,89
H_2O^+	—	4,77	5,52	7,18	—
Sum	100,87 %	99,68 %	100,48 %	100,80 %	100,11 %
Molecular ratio $SiO_2 : Al_2O_3$	3,13	3,47	3,76	3,39	—

No 1 — hydromuscovite 1M, Kremnica, No 2 — hydromuscovite $1M \gg 2M_1$ F. Novák, F. Kupka (1960), No 3 — illite 1M, F. Novák, J. Vtělenský (1960), No 4 — illite $2M_1$, R. E. Grim, R. H. Bray, W. F. Bradley (1937), No 5 — kaolinite, Kremnica. Samples 1 and 5 were analysed by J. Polakovičová.

mineral. This mineral is also very abundant in other areas of the Central Slovakian neovolcanites, alteration of which is of regional character.

2. In close proximity to the ore veins or ore locating structures mica clay is present. At distance of several metres from the vein already a more varied assemblage of clay minerals is present — mica clay, kaolinite, swelling chlorite and interstratified structure of illite with expanded three layer mineral. This mineral assemblage appears in zonal order around ore locating dislocations. It is evidently of hypogene genesis.

Analogous results are mentioned by R. Sales, Ch. Meyer from the deposit of Butte (in C. F. Park, P. A. Mak-Dormid 1966), where in argillitized quartzy monzonites they delimited the zone of kaolinization adjacent to the vein and the outer wide zone of montmorillonite.

As a consequence of hypergene processes in volcanites altered hydrothermally still kaolinite associated with jarosite originates.

Montmorillonite may arise in hydrothermal way, by the effect of slightly acid carbonic solutions (S. J. Naboko 1965), as we also suppose to be the case for the ore field of Kremnica. Spreading of montmorillonitization in wide areas of the neovolcanites, outside the ore fields, however, also indicates the possibility of formation by the action of descending waters.

Up to present results show that it is just the study of clay minerals in altered neovolcanites that to a significant degree may help in solution of the genesis and to delimit those parts in extensive altered areas, which may be important from the standpoint of ore-bearing.

Translated by J. Pevný.

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