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ZEOLITES IN NEOGENE VOLCANOCLASTICS OF SLOVAKIA

(Fig. 1—18)

Abstract: Authogenic zeolites — clinoptilolite and mordenite are main rock-forming minerals of some acid volcanoclastics in neovolcanics of Middle and East Slovakia. Using of scanning electron microscope made possible to observe mineral associations and texture of altered formerly glassy volcanoclastics, besides morphology and dimensions of crystallized zeolite aggregates.

Резюме: Из анализов экзотик мелового флиша Пиенид и по двиляются существенными породообразующими минералами некоторых кислых вулканокластик в неовулканитах средней и восточной Словакии. Использование сканирующего электронного микроскопа кроме морфологии и размеров кристаллизованных зеолитовых агрегатов предоставило возможность исследовать минеральные ассоциации и структуры измененных, первично стеклоподобных вулканокластик.

Introduction

Zeolites-hydrated alusilicates of the alkalis and alkaline earths have been known for two centuries already and they have always been an object of raised interest of numerous mineralogists and chemists because of their specific properties.

The first works on zeolites refer to exclusively well crystallized individuals and their aggregates, which frequently form a filler of cavities and veins of igneous, mainly basaltoid rocks. On the basis of these occurrences the opinion, that zeolites are products of post-magmatic hydrothermal activity, was wide spread for a long time.

In spite of the fact, that J. Muray and A. F. Renard (in A. A. Sheppard, 1975) described a phillipsite from the deep-marine sediments already in 1891, only in the last three decades, in the connection with the development of modern methods of investigation, the fact, that zeolites are frequently main rock-forming mineral of metamorphosed, but especially sedimentary rocks of various lithogenesis and age, was found out. In the nature there are about 35 mineral species of zeolites known, which originated in wide span of physical-chemical and thermodynamic conditions not only by the effect of hydrothermal solutions, but also under the conditions of metamorphosis, diagenesis and pedogenesis.

In contradistinction to the first works, refering to zeolites from igneous rocks, in the present on a world-wide scale, the investigation is orientated above all to zeolites occurring in sedimentary and sedimentary-volcanogenic formations, because they represent raw materials of great potential economic significance in many cases. (F. A. Mumpton, 1973; R. A. Munson — R. A. Sheppard, 1974; R. A. Sheppard, 1971; 1975 and others.)

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In spite of the fact, that 15 various zeolite minerals were found in sedimentary rocks till now, many of them do not form bigger concentrations, respectively they have not got convenient qualities, necessary for practical using.

From the mentioned below, most frequent and spread zeolites in sedimentary rocks only clinoptilolite, mordenite, chabazite and erionite are of practical significance. They are noted for high thermal and chemical stability besides good adsorption qualities. (R. A. Sheppard, 1975).

Analcite	$NaAlSi_2O_6 . H_2O$
Chabazite	$(CaNa_2)Al_2Si_4O_{12} . 6H_2O$
Clinoptilolite	$(Na_2K_2Ca)_3Al_6Si_{30}O_{72} . 24H_2O$
Erionite	$(Na_2K_2Ca)_{4,5}Al_9Si_{27}O_{72} . 27H_2O$
Ferrierite	$(K, Na_2)\ (Mg, Ca)_2Al_6Si_{30}O_{72} . 18H_2O$
Heulandite	$(Ca,Na_2)_4Al_8Si_{28}O_{72} . 24H_2O$
Laumontite	$Ca_4Al_8Si_{16}O_{48} . 16H_2O$
Mordenite	$(Na_2K_2Ca)Al_2Si_{10}O_{24} . 7H_2O$
Phillipsite	$(K_2Na_2Ca)_2Al_4Si_{12}O_{32} . 12H_2O$

In spite of frequent occurrence of zeolites in various geological conditions, extensive investigations of the last period prove unambiguously, that the most convenient conditions for their origin are being formed in volcanogenic–sedimentary type of lithogenesis. (R. L. Hay, 1966; F. A. Mumpton, 1960, 1973, 1975; G. J. Butuzova, 1964; A. G. Kossovskaja, 1975; R. A. Sheppard, 1975; H. Minato – M. Utada, 1971; W. R. Reynolds, 1970; A. S. Michajlov – A. I. Krinari, 1970; V. A. Supryčev, 1977 and many others).

The demonstration of that fact is, that all up to now known, economically significant concentrations of zeolites bind to young (Cretaceous and Neogene) effusive – sedimentary rocks. Their position and extent form advantageous deposit conditions. In these formations frequently occur portly, 100 and more meters thick positions of almost monomineral zeolite rocks, which petrographic denomination in literature is not united. B. Alexiev a E. G. Djuorova (1974) refering to the works of other authors (E. E. Senderov – N. I. Chitarov, S. Deffeys) proposed classification for rocks, where zeolites are rock-forming minerals. They suggested denotation "zeolitites" for rocks with the content of zeolites over 50%. Depending on many factors in zeolitized volcanoclastics there commonly occur two, respectively more zeolites with changeable quantity of fresh volcanic glass, cristobalite, montmorillonite, potassium feldspars and other authigenic minerals.

Sediments, also with high content of zeolites, usually do not macroscopically differ from tuffs, tuffites, sandstones, and other sedimentary rocks. Small dimensions of the majority of zeolites in the range of 0,01–0,003 mm, low index of refraction, respectively low birefringence cause the possibility of their transformation with cristobalite, opal, respectively with devitrificated volcanic glass, and that is why they frequently remain unnoticed, being microscopically studied in polarizing microscope. Finding out and identification of zeolite minerals in sedimentary rocks is based above all on using X-ray analysis with diffractographic technique and on the complex of other physical – chemical methods.

In the present to study minutely crystalline zeolite aggregates in the changed sedimentary—volcanogenic rocks, but especially for good distinguishing ability a scanning electron microscope is successfully used.

Occurrences of zeolites in volcanoclastics of Slovakia

In Czechoslovakia only a couple of years ago rich concentrations of authigenic zeolites in some acid neogene volcanoclastics of East and Middle Slovakia were found out. (E. Šamajová – I. Kraus, 1976, 1977; E. Šamajová, 1977.)

Evaluation of transformation grade of original rock and so its practical significance requires using of specific methods at the petrographic—mineralogic study. On the basis of X-ray, thermic, chemical analysis and optical study was found out, that clinoptilolite and mordenite—zeolites with high content of Si – form basic component of observed volcanoclastics. Mineralogical characteristic of mentioned zeolites and the petrography of altered rhyodacite and rhyolite volcanoclastics is mentioned more in detail in the previous works.

In the region of eastslovakian neogene basin from up to the present time found out indices of zeolite mineralization, the most significant occurrence as regards both extent and content of utility component related on shallow-water, marine detrital – volcanogenic series of strata of upper part of lower badenian, especially on the position of rhyodacite, so called Hrabovec – tuffite.

The position of tuffite, from which abandoned quarries discover about 40 meters, near municipality of Nižný Hrabovec and Kučín (district of Vranov nad Topľou), reaches thickness of about 100 m and strike length of 7 km (J. Slavík et al., 1967). Authigenic clinoptilolite which originated by transformation of glassy vocanic ash probably during diagenesis of rhyodacite tuffite, is basic rock-forming mineral of the rock. Insignificant quantity of mordenite occur in the quarry near Kučín, which is situated about 1 km NW from Nižný Hrabovec. Crystalloclasts of quartz, medium-acid plagioclases, some of biotite occur in the basic clinoptilolite mass. On the average their content does not exceed 20%. The presence of finely dispersive low-temperature cristobalite was X-ray graphically proved too.

In the region of middleslovakian neovolcanics acid volcanoclastics were the study object. They rise in the SW border of Kremnické pohorie Mts., and are analogies of Hrabovec – rhyodacite tuffite by their petrochemical character (J. Slavík et al., 1967; J. Lexa, 1969).

Rhyolite and rhyodacite tuffs and tuffites are constituents of volcanogenic complex, which is the product of the III. rhyolite phase (M. Kuthan, 1963). On the basis of palynologic discoveries (M. Ciesarik – E. Planderová, 1965; V. Konečný – G. P. Bagdasarjan – D. Vass, 1969) and of stating of absolute age, they are classified on the boundary-line of upper Sarmatian and Panonian. Volcanoclastics, which have the character of tuff-breccias and pumiceous flows, somewhere passing to the positions with more sorted out volcanogenic material, settled in smaller limnic basins and on the dry land.

Besides expressive processes of bentonitization, to a small extent also kaolinization (I. Kraus – J. Zuberec, 1976), which affect mentioned volcanoclastics, it is possible to determine more continuous zone approximately of EW

direction between Jastrabá skala (elevation point 684) and Paseka (elevation point 585) with prevailing zeolite mineralization.

Intensity of transformation, spreading of zeolites and mineral associations are changeable in the observed stripe. It is mostly connected with the textural variability of volcanoclastics.

Especially intensive zeolitization of rhyolite tuff-breccias shows in the cut of rail-way line between stations Bartošova Lehôtka and Stará Kremnička. Texture of the rock is lithocrystallovitroclastic Except the original glassy material, which was dominating component of tuff-breccias, zeolitization affects also crystalloclasts of plagioclases to a great extent.

The main rock-forming minerals are clinoptilolite and mordenite in the close association with cristobalite. (E. Šamajová – K. Kraus, 1976, 1977). The same high content of authigenic zeolites was found out in the medium–grained tuffs in the surroundings of elevation point Paseka, where in contradistinction to previous occurrence, expressively prevails clinoptilolite. In spite of it, in the surface exposures of rhyolite tuff-breccias in the cut of brooks Rudnice on the basis of mineralogic study they found out, that zeolites concentrate in fine-grained light-green mass, while angular 1–5 cm long fragments of white pumice are being transformed by montmorillonite and kaolinite.

The study in the scanning electron microscope

Existing knowledges about authigenic zeolitization of some acid volcanoclastics of Slovakia were completed by the study of morphological and structural changes of originally hyaline rocks in the scanning electron microscope JSM-03 in Dionýz Štúr Institute of Geology in Bratislava. (operators: K. Šebor and M. Švec). About 120 electron microphotographs from 30 preparations were scanned altogether. The study was done on the natural fracture planes, metallized by Au. Besides the samples representing zeolitized volcanoclastics of East and Middle Slovakia, the samples of clinoptilolite and mordenite zeolitites from Cuba, Bulgaria and Ukraine were used for comparing.

Identifying zeolites in the changed volcanoclastics we compared occurring crystalline forms on the one hand with morphology of their analogues, which are known from cavities and veins of igneous rocks, on the other hand with forms of minute crystals of zeolites, which F. J. Butuzova, 1964; V. Alexijev – G. Kirov, 1969; R. A. Sheppard – A. J. Gude, 1973; R. A. Sheppard, 1975; A. G. Kossovskaja, 1975 and others described from sedimentary–volcanogenic formations.

The results of the study of various mineral species of zeolitized volcanoclastics from some world localities in the scanning electron microscope, published by F. A. Mumpton and W. C. Ormsby, 1976, provided especially convenient and objective comparative material.

Evaluating of the objects, scanned in the scanning electron microscope, in particular the results of X-ray phasie analysis, which in the most cases provides sufficiently reliable informations on presence of separate zeolites, respectivelly of other minerals, were taken into consideration.

Clinoptilolite, on the basis of knowledge of above mentioned authors, often forms in sedimentary and sedimentary-volcanogenic rocks aggregates of well crystallized, tabular crystals of some micrometers length and of 1–2 micro-

meters thickness with expressive monoclinic symmetry. Tabular, more or less elongated, clinoptilolite crystals of various thickness are noted for a usually expressive developed plane 010, according to which minerals of heulandite structural group have perfect cleavage. Clinoptilolite, in contradistinction to heulandite, crystals of which are elongated in the direction of crystallographic axis "a", form crystalline individuals elongated along the axis "c" (W. A. Deer – K. A. Howie – J. Zussman, 1966).

V. Alexiev and G. Kirov (1969) on the basic of the study in electron microscope found out in oligocene sediments – NE of Bulgaria – three morphologic forms of crystals oc clinoptilolite, which are schematically represented in the Fig. 1.

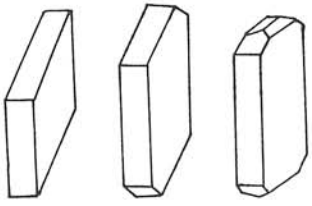

Fig. 1. Forms of crystals of clinoptilolite from oligocene sediments of NE Bulgaria (B. Alexiev – G. Kirov, 1969).

Fig. 2. Scanning electron microphotograph of fine-grained clinoptilolite zeolite from the quarry near Nižný Hrabovec.

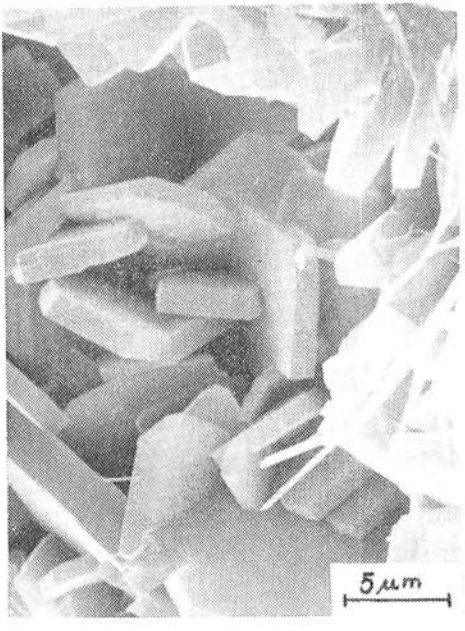

Fig. 3. Scanning electron microphotograph of idiomorphic crystals of clinoptilolite with spicules of mordenite from the guarry near Kučín.

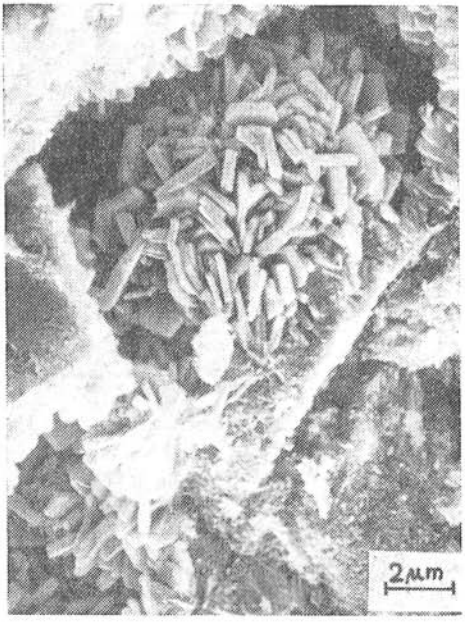

Fig. 4. Scanning electron microphotograph of minutely crystallized aggregate of clinoptilolite from the quarry near Kučín.

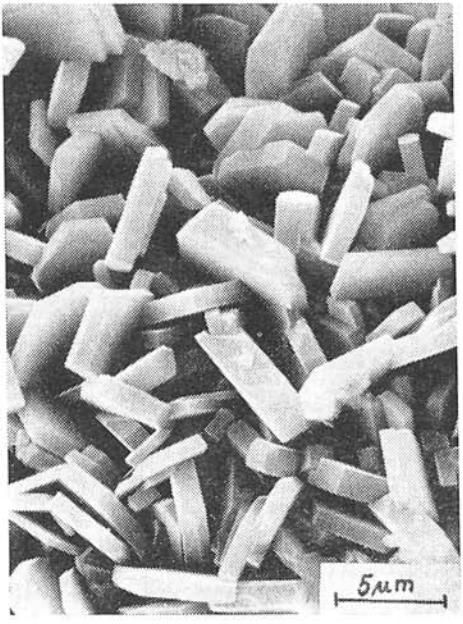

Fig. 5. Scanning electron microphotograph of idiomorphic crystals of clinoptilolite from more coarse-grained tuff from Bulgaria (Rodopy).

In spite of this fact in some zeolitized volcanoclastics, where was stated high content of clinoptilolite by combination of various mineralogic methods, the rock in the scanning electron microscope appears as grained aggregate, sometimes with the indications of tabular jointing. Very fine-grained or even pelitic clinoptilolite zeolites from the quarry near Nižný Hrabovec (Fig. 2) are of this character as well as macroscopically almost the same clinoptilolite volcanoclastics from Cuba (province Las Villas).

In spite of this fact in the partially coarse-grained more pumiceous development of zeolitized rhyodacite tuffite, which in the quarry near Kučín forms upper part of the same position, relatively big (to 5 micrometers), tabular, perfectly developed crystals of clinoptilolite occur in microcavities, somewhere commonly with like needle mordenite. (Fig. 3). More minutely crystallized aggregates of clinoptilolite of 1 micrometer size were sporadically observed in finergrained development of tuffite in the lower part of the quarry (Fig. 4). We met with analogous idiomorphic development of crystals of clinoptilolite in the samples of zeolitized tuffs of medium granularity from Bulgaria (Rodopy) – Fig. 5.

From the mentioned observing is evident, that dimensions of fragments of volcanic glass and texture of original rock besides other factors expressively influences development of crystalline forms of authigenic zeolites.

This dependence was also acknowledged at the study of zeolitized rhyolite and rhyodacite tuff-breccias in the middle Slovak neovolcanics.

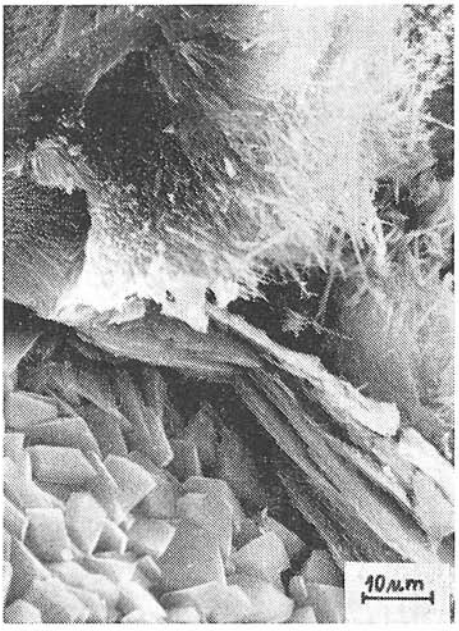

Fig. 6. Scanning electron microphotograph of aggregate of tabular clinoptilolite crystals and of fine fibrous mordenite from Bartošova Lehôtka.

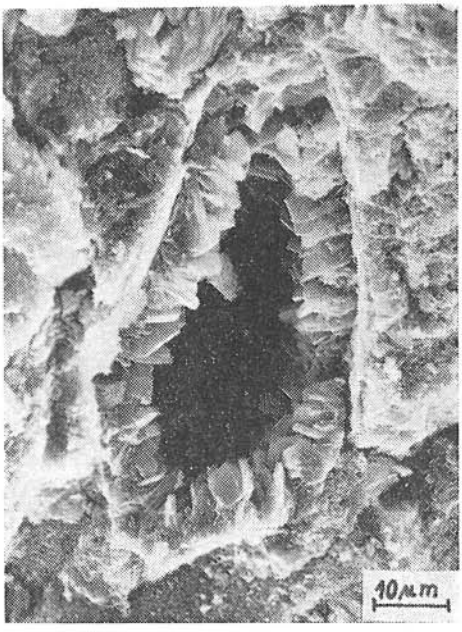

Fig. 7. Scanning electron microphotograph of druse of clinoptilolite in the zeolitized rhyolite tuff from Bartošova Lehôtka

In contradistinction to Hrabovec—clinoptilolite tuffite common occurrence of clinoptilolite and mordenite with variable mutual substitution (Fig. 6) is characteristic of zeolitized acid volcanoclastics of SW border of Kremnické pohorie Mts. Almost idiomorphic crystals of clinoptilolite usually border microfractures in a rock, respectivelly drusily grow into cavities (Fig. 7), or fill them up. On the surface of clinoptilolite crystals somewhere occur thin needles, sometimes fibers of mordenite. (Fig. 8).

In spite of the fact, that up to the present time from zeolitized volcanoclastics from Slovakia were not acquired isolated crystals of clinoptilolite for more precise determination of crystallographic dates, its morphology, sufficiently objective from scanning electron microphotographs indicates the presence of analogous crystalline forms, which were described by B. Alexiev and G. Kirov, 1969 from oligocene sediments of NE Bulgaria.

Mordenite, which is orthorhombic, in the changed volcanoclastics usually makes up needle — like crystals, frequently spherulitically arranged, respectivelly very fine and long fibers.

In keeping with observing of F. A. Mumpton and W. C. Ormsby (1976) it is necessary to mention, that in some, especially fine-grained volcanoclastics, where X-ray analysis acknowledged high content of mordenite (zeolitized tuffs from Cuba — province Oriente) its characteristic fibrous and needle — like morphologic forms did not show at the study in the scanning microscope.

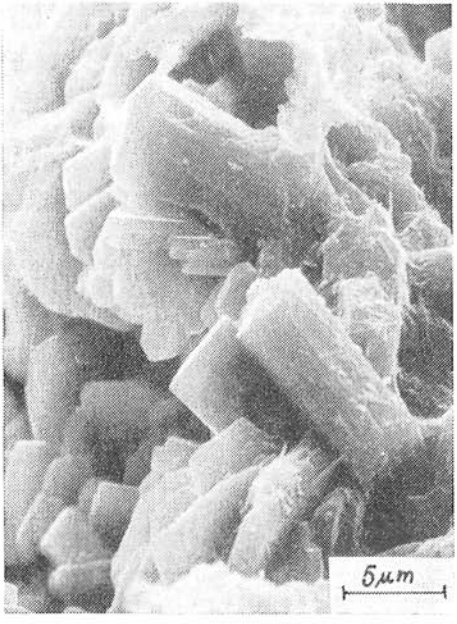

Fig. 8. Scanning electron microphotograph of tabular crystals of clinoptilolite with fine fibers of mordenite from Bartošova Lehôtka.

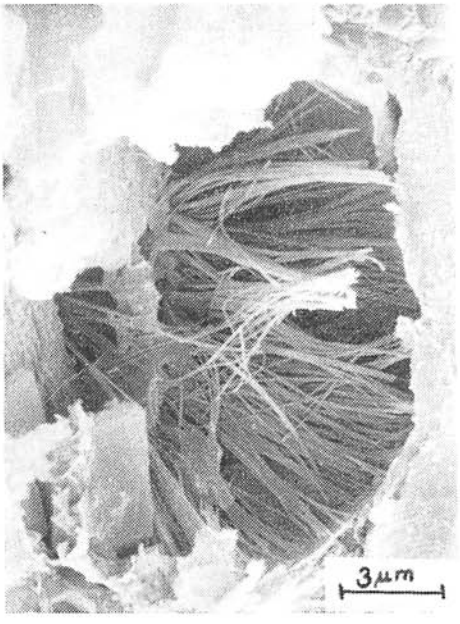

Fig. 9. Scanning electron microphotograph of mordenite, growing in the cavities of clinoptilolite zeolite from the quarry near Nižný Hrabovec.

It is obvious from our up to now study of zeolitized volcanoclastics from Slovakia, that mordenite in a high degree occurs especially in pumiceous, brecciated, respectively with hydrothermal activity interfered volcanoclastics. In pelitic clinoptilolite zeolite from the quarry near Nižný Hrabovec were in scanning electron microscope very scarcely observed fine fibrous formations, probably of mordenite, growing in the cavities of changed tuffite (Fig. 9). Relatively more frequent is occurrence of mordenite in the quarry near Kučín, proved by X-ray analysis. Mordenite forms somewhere white about 1 mm thick liners on the joint planes of light-green clinoptilolite zeolite. Except this, heightened content of mordenite and cristobalite was found out in grey—white about 1—2 cm thick bands, which locally occur in the mentioned tuffite. Mordenite in contradistinction to other occurrences forms shorter sheafy formations of very fine fibers, as scanning electron microphotograph proves (Fig. 10).

To the new discoveries of bigger concentrations of mordenite in eastslovakian neovolcanics belong pumiceous rhyolite tuffs with expressive vesiculous texture in locality Veľká Tŕňa (district of Trebišov). Thickness of tuff position, the age of which is stated on the boundary-line between upper Badenian and Sarmatian, is 10—100 m (J. Slávik et al., 1967). Fragments of pumice some mm to 5 cm in size are changed into montmorillonite. More fine-grained grey—white, originally glassy material of putty mass is transformed into a tangle of fine, some decades micrometers long mordenite fibers, of which characteristic, often reticulate texture is evident from scanning electron micrographs. (Fig. 11).

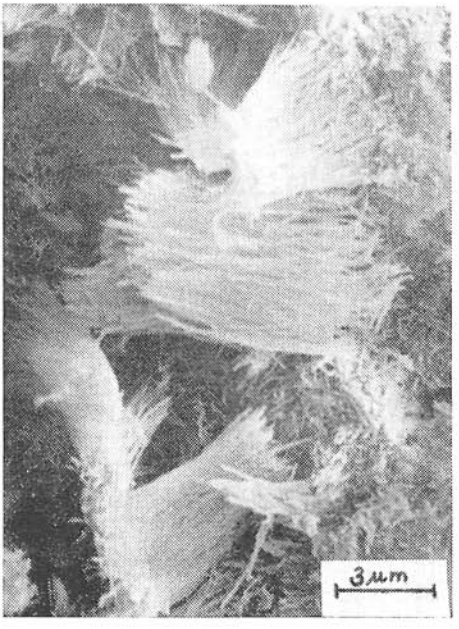

Fig. 10. Scanning electron microphotograph of sheafy formations of mordenite from clinoptilolite zeolite from the quarry near Kučín.

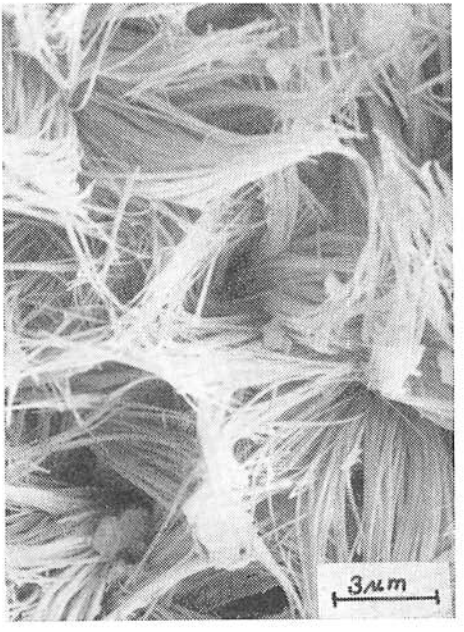

Fig. 11. Scanning electron microphotograph of mordenite zeolitite from the locality of Veľká Tŕňa (Eastern Slovakia).

The presence of mordenite was acknowledged by X-ray analysis. Clinoptilolite was not observed on the locality. From the other minerals quartz, plagioclases, biotite and cristobalite are present in a tuff.

Clinoptilolite and mordenite are the basic rock-forming minerals of zeolitized acid volcanoclastics of SW border of Kremnické pohorie Mts., as it was already mentioned above. Their mutual substitution is considerably changeable and somewhere, as X-ray analysis and observing in scanning electron microscope proved, mordenite expressively prevails over clinoptilolite, respectively forms almost monomineral concentrations. Constant accompanying mineral of mentioned zeolites is low-temperature cristobalite found out radiometrically. Minute spherical formations consisting of fine tables observed in scanning electron microscope correspond to forms of lussatite – cristobalite with low crystallinity, (Fig. 12) which M. Marková described from limnoquartzites of Žiarska kotlina basin (1978).

Mordenite, except radiated aggregates, which are analogy of needle – like forms of mordenite of hydrothermal origin, found out on the joint of andesite in the central Vihorlat (E. Šamajová, 1977) frequently makes up a tangle of some micrometers long, bent fibers, or transforms minute fragments of volcanic glass from edges. (Fig. 13, 14, 15, 16).

F. A. Mumpton, 1960; B. Alexiev – E. G. Djorova, 1976; D. P. Koutin – Korrea – A. Brito – Rochas, 1976 and other mention the possibility of transformation of clinoptilolite to mordenite. From the observing

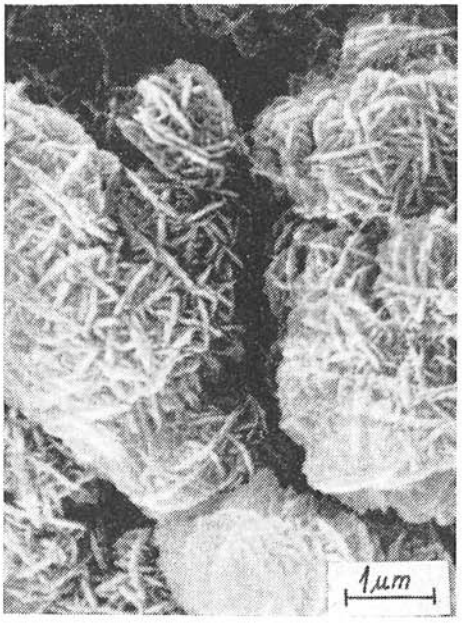

Fig. 12. Scanning electron microphotograph of lussatite — cristobalite from Bartošova Lehôtka.

Fig. 13. Scanning electron microphotograph of monomineral aggregates of radiated mordenite from Bartošova Lehôtka.

of mentioned authors results the fact, that this transformation takes place especially owing to tectonic activity, accompanied by low-temperature hydrothermal activity, respectively in the proximity of the contact zones with younger, vein bodies.

With regard to geological construction of the studied region (the proximity of Kremnické hory field) and total character of changes of acid volcanoclastics, it is necessary this possibility of transformation is taken into consideration. For the time being we have not sufficient number of criterions for unambiguous judgement, whether mordenite originated directly from glassy component of volcanoclastics or secondarily, to the detriment of clinoptilolite. From boundaries of grains passing mordenitization of volcanic glass, observed in electron microscope (Fig. 15) without using of diffraction does not solve the question.

Slightly rounded edges of crystals of clinoptilolite with thin needles of mordenite on its surface, which can be seen in scanning electron microphotograph (Fig. 17) give evidence for lowering of stability of clinoptilolite.

Frequent common occurrence of clinoptilolite and mordenite in the changed volcanoclastics stated in numerous localities, is however, at the same time an evidence, that borders of stability of these zeolite minerals coincide to a certain extent.

F. A. Mumpton and W. C. Ormsby (1976) called attention to the possibility of transformation of mordenite and erionite at identification on the basis of morphologic study of zeolitized volcanoclastics. Erionite forms analo-

Fig. 14. Scanning electron microphotograph of fibers of mordenite with minute tables of cristobalite behind from Bartošova Lehôtka.

Fig. 15. Scanning electron microphotograph of fine-fibrous mordenite along a joint and on the edges of fragments of volcanic glass from Bartošova Lehôtka.

gous, although in the majority of cases thicker needles, sometimes with distinct hexagonal sections. Besides the fact, that common occurrence of mordenite and erionite is exceptional, this problem is unambiguously solved by X-ray analysis, which gives different diffractional characteristics.

Comments to genesis

In spite of the fact, today generally admitted, that in the majority of cases mother material, from which authigenic zeolites originated, was grained volcanic glass able to react with water solutions, still the mechanismus of this transformation is not unambiguously explained. F. A. Mumpton (1973) took as an example the study of zeolitized volcanoclastics from the localities originated in different lithologic conditions in the west part of USA and pointed to the possibility of using of scanning electron microscope also when solving some genetic questions. Occurring mineral associations, texture and morphologic changes of zeolites at the detailed study of bigger sets of samples, provide valuable evidences for explaining of the way of transformation of original amorphous volcanic glass in well crystallized zeolite minerals.

Mentioned author (1973) on the basis of present knowledge, acquired by synthesis of zeolites and their recent origin, indicated the scheme (figure 18) of 5 basic ways of reactions, which can be used at the transformation.

Fig. 16. Scanning electron microphotograph of mordenite reticulately replacing fragments of pumice from Bartošova Lehôtka.

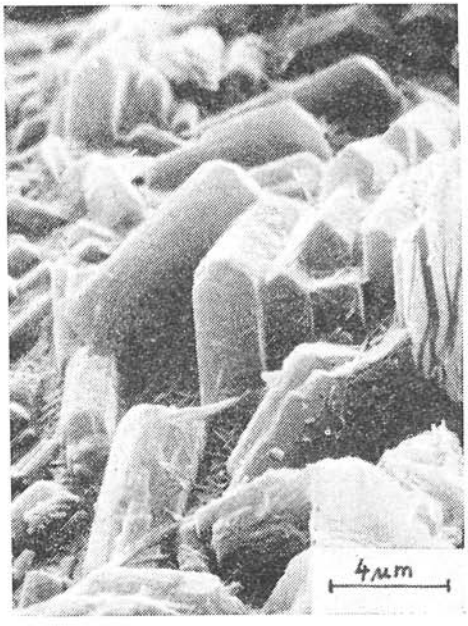

Fig. 17. Scanning electron microphotograph of clinoptilolite with fine spicules of mordenite on the planes of crystals from the locality of Rudnica.

From the scheme results, that zeolites can originate by crystallization from solutions as well as from hydrated gelmeter material, direct ly or by interstage through some of mentioned forms. The fifth supposed possibility — direct overcrystallization of original volcanic glass to zeolite is considered to be less probable.

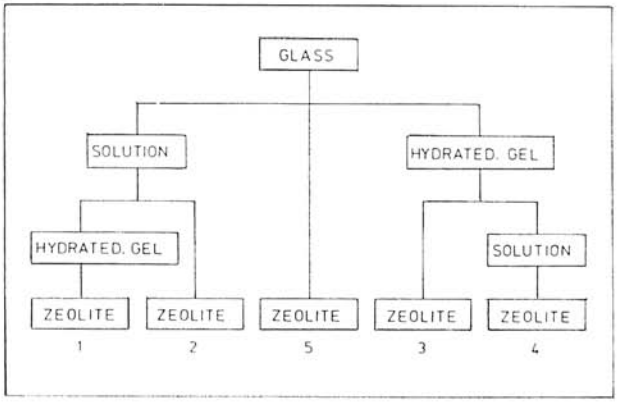

Fig. 18. The scheme of possibilities of ways of growing of zeolites from original volcanic glass (F. A. Mumpton, 1973).

From the previous it is evident, that the way of origin of zeolites in glassy volcanoclastics at diagenesis or by the effect of hydrothermal solutions is in the basic features the same is played. Mutual acting of diffusive solutions with components of mother rock plays the primary role. Mineral associations of authigenic zeolites and of accompanying alumosilicates, however, depend on chemical composition, texture (size of grains, permeability) and age of mother rocks, on chemismus of capillary solutions, pH environment and other factors (R. L. Hay, 1966).

Intensive zeolitization of rhyodacite tuffite in the wide surroundings of Nižný Hrabovec on the basis of geological position and of character of mineralization represents volcanogenic-sedimentary deposit type, which originated during diagenesis of sediment. Zeolitized rhyodacite tuffite represents a rock with well sorted out, very finegrained material, which was being settled in extensive, relatively shallow-water marine basin. Mutual acting of capillary solutions with homogeneous mother rock in fixed physical-chemical conditions, made possible the origin of stable, almost monomineral clinoptilolite mineralization. Manifestations of zeolitization of rhyolite and rhyodacite tuff-breccias in the Sw border of Kremnické pohorie Mts. differ from zeolitized Hrabovec — tuffite by various intensity of zeolitization, by dislocating of zeolites as well as by mineral associations. Zeolites are represented by mordenite and clinoptilolite. This fact is connected with different texture of compared volcanoclastics, deposited in freshwater basins in the proximity of volcanic centers and with the conditions of origin as well. With the regard to the development of total volcanogenic complex of Kremnické pohorie Mts. it is probable, that in the transformation of studied volcanoclastics except possible diagenetic processes hydrothermal solutions took their part.

Conclusion

Different morphology of individual mineral species of authigenic zeolites conveniently completed X-ray analysis at their identification. Knowledges, acquired by the study in scanning electron microscope at the same time gave precision to the conception about the character of transformation of acid, essentially glassy volcanoclastics into rocks with high content of clinoptilolite and mordenite, which, using of polarising microscope, were unperceivable. This method is convenient not only for observing of morphology and dimensions of minutely crystalline zeolite aggregates, but also for study of paragenetic and structural relations of authigenic minerals originated at diagenesis, respectively owing to other secondary changes of alumosilicate rocks. Structure of zeolite aggregates in the changed volcanoclastics influence also economic value of zeolite raw material at its other modification. (F. A. Mumpton — W. C. Ormsby, 1975).

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REVIEW

MÁRIA FÖLDVÁRI–VOGL, DrSc.: THEORY AND PRACTICE OF REGIONAL GEOCHEMICAL EXPLORATION, AKADÉMIAI KIADÓ, BUDAPEST, 1978, 272 p.

The book "Theory and practice of regional geochemical exploration" contains rich experiences of the prominent hungarian author – Maria Földvári – Vogl and her working team at the finding out and exploring of rare elements in various geological regions of Hungary. The author divided the book into two main parts. In the first one there are stated theoretical bases according to which every effective exploration at the finding out of rare elements should be operated. The second part of practical meaning is a survey on concentration of separate rare elements and other microelements and their most frequent forms of occurrence.

In the book there are mentioned data about contents of rare elements in various rocks of Hungary as well as numerous informations about concentration of investigated elements including ore elements according to data in the world literature. Literary data in the number of 690 are summed up at the end of the book, from them 233 quotations of basic geochemical literature and 457 quotations concerning the investigated elements. In the book there are stated dates about these elements: Li, Be, B, F, Rb, Cs, Nb, Ta, Zr, Hf, Mo, Re, Sn, W, Sc, Tr, Th, U, Cu, Ag, An, Zn, Cd, Hg, Ga, In, Tl, Ge, Pb, As, Sb, Br, Se, Te, V, Cr, Ni, Co, Pt – metals.

Besides the data about concentration of the above mentioned elements, informations of economic meaning are stated too, i. e. about production of rare elements, about their values in world markets etc.

In the book there are stated the brief data about regional – geochemical methods including analytic determination of elements and their statistic elaboration. The question of distribution type of elements is discussed too, but only the data on arithmetic mean are stated. We suppose, that besides arithmetic mean also data on geometric mean, which is representative mean value of content of a given microelement with the distribution close to the lognormal type, would have been purposeful to state.

The book "Theory and practice of regional geochemical exploration" is a monographic work, which fills up the gap of given problems in the geochemical literature. Not only rich theoretical and practical experiences and extensive scientific material of the author and her team, but also numerous data from the world literature are interpreted in this book.

The book, in spite of its brief elaboration, is a representative work, which can be recommended not only to specialists in the branch of regional geochemistry, but also to other geochemists of theoretical and practical direction, further to students of geochemistry and to all workers mainly in applied geochemical exploration.

It contains an amount of data, which can be useful in pedagogic process at teaching geochemists.

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