GEOLOGICKÝ ZBORNÍK — GEOLOGICA CARPATHICA, 33, 5, BRATISLAVA, OCTOBER 1982, Pp. 635—650

MIROSLAV HARMAN*

SECONDARY ALTERATIONS OF PLAGIOCLASES OF GRANITOID ROCKS OF THE WEST CARPATHIANS

(Figs. 8, Tabs. 2)

Introduction

When we want to consider samples of granitoid rocks of the West Carpathians, used for complex geochemical and petrological investigation from the viewpoint of the degree of weathering, it is necessary to state, that they mostly express the first phases of weathering (in the sense of G. Millot, 1970; I. I. Ginzburg, 1963, K. K. Nikitin, 1968; J. M. Melnik, 1970 and others). The fundamental analysis shows that in granitoid rocks of the West Carpathians besides little exceptions are:

a) Plagioclases always in various degree affected by secondary alterations, according to modal analyses build up 22—68 % rocks.

b) Potassium feldspars, quartz and muscovite are in this phase of weathering usually unaltered.

c) Biotites (2—18 %) remain almost completely unaltered, or are weakly altered (baueritization), most often their structure is weakened by leaching of K cation only.

d) Other dark minerals and accessories form from the standpoint of weathering processes negligible amounts (up to 1 %).

For these reasons is evident that the secondary products of disintegration of plagioclases most optimally characterize the weathering processes of West Carpathian granitoids, as the products of disintegration of other minerals take part in crystallization of secondary minerals to a little extent only. Only in rare cases of intensive exposition of exogenic influences (tectonic metamorphism, K-metasomatism, hydrothermal influences, influence of overlying rocks) more intense disintegration of other primary minerals is taking place, which then partly influence the weathering process.

In valuation of the weathering processes in such a wide group of samples it was necessary to take into consideration also great heterogeneity of petrological types (from leucogranites to tonalites), great difference of genetic types, (mobilization granites, palingenic, subautochthonous, synkinematic, postkinematic types, autometasomatic, injection-metasomatic granites to migmatites, microgranites etc.), as well as various intrusive phases (or crystallization phases) in the individual types (in some places 2 to 3 stages of crystallization of primary minerals) etc.

Solving of this problem was contributed by the possibility to obtain concentrates of feldspar mineral fraction in the microprocessing, elaborated in the separation laboratory of the Slovak Academy of Sciences by M. Žabka. For the purpose of separation of secondary minerals the sample taken from the stage of 4-th separation process was used (M. Žabka, 1982). The sample containing plagioclases, K-feldspars and a small amount of quartz was after washing still dispersed by ultrasound

* RNDr. M. Harman, CSc., Geological Institute of the Slovak Academy of Sciences, Dúbravská cesta 9, 814 73 Bratislava.

2 × 2 min. at 24 kHz, so the secondary minerals were released from disintegrated plagioclases. The washing was decanted and used for analyses. In this process unweathered orthoclases and quartz passed into the decanted sediment only to a very little extent and could be distinguished well in X-ray analysis and electron microscope. (It is necessary to remark that also preparation of monomineral fraction of plagioclases was solved. This fraction is reached by flotation in very acid environment, formed by hydrofluoric acid, which has aggressive effect on clay minerals. With using of this monomineral fraction of plagioclases as basis for obtaining secondary minerals the amount of admixtures of K-feldspars and quartz would be reduced, in the decant, but to the detriment of considerable damaging of crystallinity and morphology of clays, as we found out in the testing series. Therefore we gave up investigation of this fraction).

A negative role in obtaining secondary minerals from disintegrated plagioclases played the fact that for the group of samples investigated in a complex way fresh rocks were taken when possible. But also this way it was possible to obtain from the majority analysable amounts of secondary minerals by the described process.

Method of work and results of mineralogical study

The mineralogical analysis of secondary products was carried out by methods of X-ray analysis (oriented and unoriented preparates, for solving of specific problems of identification of smectites and IM-structures of saturation by glycerine and Na-saturation, for solving of distinguishing of chlorite and kaolinite type minerals, annealing of the preparate to 550 °C), then by methods of electron microscopy (transmission electron microscopy including application of selective solubility and carbonate test, by methods of suspension and fracture replicas and etched surfaces, further electron diffraction as well as scanning electron microscopy), by DTA and TGA methods and to a little extent also with application of the results of chemical silicate analysis.

It is evident from the results of mineralogical analyses that the dominant phase in association of secondary minerals in granitoids is three — layered 10 Å mineral with character of potassium hydromica, interlayered cation is K^+, thus illite. The good structure order of this mineral is confirmed by values of interplanar distances, calculated from diffractograms of various localities, often also the point character of electron diffraction. The mineral dehydroxylates at temperatures typical of illite. Morphologically (in electron microscope) this mineral appears in form of sharply delimited isometric and prismatic tables of 1—6 μm size with sharply delimited borders, often with typically developed interference strips. At some localities a specific development of fine- dispersed form may be recorded (0.5—3 μm), mainly in leucocratic types of granodiorites, as e. g. ZK 50, 54, 68, 55, 44, 23, 41 a. o.), in other places the coarser — dispersed type predominates. This phenomenon provides the possibility to suppose two generations of illite, which differ granulometrically. The fine-dispersed type has a distinctly lower structure order degree (more diffuse lines of electronograms), from comparison of X-ray records of preparates containing the fine--dispersed type, of oriented, water-saturated and ethylene-glycol-saturated, may be concluded that a part of minerals of this type belong to mixed-layered IM-minerals.

A further, but essentially less spread secondary mineral is montmorillonite. This smectite, for its usually very little representation (with the exception in the area of the Tríbeč Mts. and Malé Karpaty Mts.), is more difficult to determine by X-ray method, also by glycerinated X-ray preparates, where it was possible to observe more distinctly the shift of basal reflexes. The presence of smectites can be distinctly confirmed on the basis of their typical morphology in electron microscope. They usually form particles and aggregates of 0.5–5 μm size (according to the degree of desintegration), without regular delimitation with typically vague borders, caused by penetration (of OH groups) into interlayered spaces of the structure lattice. The degree of vagueness of the borders permits to suppose the presence of Ca^{2+} montmorillonites, as can be confirmed also by the results of other measurements, mainly by thermic analysis, showing that this mineral has water bound in two energetic levels, what Na montmorillonites never have. The electron diffraction testifies to a low degree of order of this material.

In small amount (relatively in such an extent as smectites, but in greater variability) the presence of chlorite may be identified. The occurrence of chlorite is usually bound to the presence of K-metasomatism (e. g. the area of the Považský Inovec, Vysoké Tatry or Malá Fatra), or hydrothermal influences, which supply K-ions (Malé Karpaty, Nízke Tatry Mts.). Regarding to the fact that in these cases formation of kaolinite phase is possible (in case of combination of reflexes 14.0 and 7.15 Å), the method of annealing of X-ray sample to 550 °C was applied, which makes possible their distinct separation in X-ray record.

In electron microscope this mineral appears quite distinct in the shape of aggregates, which disintegrate into isometric tabular particles without vague borders of 0.5–8 μm size at the margins. Sometimes indications of radial arrangement of aggregates or typical brush-like formations can be observed. Generally septochlorites may be concluded.

Very rarely minerals of the kaolinite group could be identified by X-ray analysis (Vysoké Tatry, ZK 22 and 23, Malé Karpaty Mts. ZK 5). They are usually connected with larger occurrence of chlorite. For their identification we used the already mentioned heating of sample to 550 °C or dissolution in HCl. In electron microscope this mineral is usually not forming typical pseudohexagonal forms, in one case we found a particle resembling halloysite. Generally it may be said that kaolinite type minerals are not distinctly represented in secondary products of plagioclase weathering of the West Carpathians and their presence is usually bound to processes of autometamorphism.

Abundant is the presence of quartz, which may be identified in secondary products by the methods of X-ray analysis. On the basis of reflexes 4.15, 2.53, 1.64 Å and further it ma by concluded that the majority are formed by high temperature β cristobalite, but less distinct lines of 4,04,2,14 Å a. o. prove that also low-thermal α cristobalite sporadically occurs, which is a product of secondary disintegration of plagioclases. Probably a part of SiO_2 of secondary origin is also found in amorphous form.

The presence of a small amount of calcite may be confirmed unambiguously by methods of X-ray analysis, mainly in more basic types of granodiorites. It is one of typical secondary products of plagioclase disintegration. The typical rhombohedral morphology in electron microscope and sporadically realized carbonate test, mainly in cases of more distinct occurrence (in mylonites), unambiguously confirm its presence. In certain cases (Malé Karpaty Mts.) on the basis of preserved pseudomorphs (typical polysynthetic and cyclic intergrowths) it was possible to prove that the first product of carbonate crystallization was aragonite, which is regarding to the high instability is rapidly recrystallized into calcite, when also still sporadically original aragonite forms have preserved. (M. Harman – J. Derco, 1974, 1976).

The secondary albite regarding to its little occurrence, can be reliably identified only in areas with a high degree of disintegration of plagioclases, or in massifs with manifestations of metasomatism (migmatization). Iron oxides are most often found in areas of strong alteration (mainly where disintegration of biotite took place – e. g. in areas of alkalic metasomatism of Malé Karpaty Mts. granitoids) and intense tectonic metamorphism. Rarely organic substance is found (mainly in hybrid types).

Relations of secondary alterations to individual granitoid massifs of the West Carpathians

The course of secondary alterations of granitoid rocks and mainly of their plagioclases of the West Carpathians has many common features. On the basis of the investigation carried out some characteristic features of the individual areas can be distinguished.

The Malé Karpaty Mts. are characterized by very intense secondary alterations of granitoids. This is conditioned by very intense (in relation to other massifs of the West Carpathians) and unequal exposition of the Alpine tectonic metamorphism and the assumption of local pre-Alpine alteration. To this type autometamorphosed types belong. Distinctly prevailing is the illite-hydromica type of weathering with the possibility of occurrence of two illite generations. Chlorite in relatively larger amounts was identified in the western part of the Bratislava massif (ZK 54, 53) and at the western margin of the Modra massif. In the first case its greater occurrence may be looked for in hydrothermal processes (?) and in the second case in manifestations of K-metasomatism. In spite of that the absence of chlorite may by stated in the autometamorphosed type of Horvátka (ZK 46) where is a distinct portion of montmorillonite in secondary products, similarly as also in the area of abundant occurrence of pegmatites in the area of Železná studnička (ZK 51).

The Považský Inovec and Tríbeč Mts. have two slightly different types of plagioclase weathering. Leucocratic types of ZK 41, 42, 100, 103 are relatively fresh, little affected by tectonic metamorphism, of prevailingly illite weathering with occurrence of a small amount of montmorillonite and secondary albite. Typical hybrid and migmatized granitoids (ZK 17, 64, 15), regarding to the supply of K in the process of metasomatism, have a higher content of illite and more distinct content of chlorite in secondary products. Relatively abundant is also here formation of secondary albite and quartz.

The Veľká Fatra and Malá Fatra Mts. display a distinct illite character of plagioclase weathering with remarkable occurrence of chlorite in the more basic type of tonalite from Smrekovica only (ZK 20). The influence of hydrothermal processes was expressed here by a greater occurrence of illite, secondary quartz and albite only. In the area of Dubná Skala – biotite tonalite (ZK 38) influences of tectonic metamorphism relatively with increased formation of montmorillonite were manifested.

The V y s o k é T a t r y Mts. shows great differences in the degree of weathering of granitoids. The most intensively altered type – biotite granodiorite from the locality Štrbské pleso (ZK 30) displays an intensive formation of illite and chlorite, sporadically little montmorillonite, showing marks of slight autometamorphism. Other basic types (tonalites and muscovite – biotite granodiorites of the Vysoké Tatry Mts. type – ZK 22 and 23) are little disintegrated, illitized with chlorite and with indications of formation of kaolinite minerals, lying near the zone of autometamorphosed types. On the other hand the highly limonitized type ZK 71 (Tatranské Matliare – muscovite – biotite granodiorite) lying in the zone of autometamorphosed granites, macroscopically altered, does not show, when studied by X-ray method, the presence of illite, only a small amount of chlorite, quartz (partly secondary), albite and as accessories perhaps also the presence of minerals of kaolinite group.

The N í z k e T a t r y Mts. are characterized by essentially lower intensity of secondary alterations of plagioclases, which is, however, likewise dominantly illitic. Chlorite occurs more distinctly in areas with precondition of K-metasomatism and near the contact with migmatites (e. g. ZK 3) or in places with exposition of hydrothermal alteration, for example in the area of occurrence of barite veins at the locality Tále – Srdiečko (ZK 68). Indications of formation of montmorillonite are only in the areas of the SW part with eventual indications of autcmetamorphism (ZK 24 and 25).

The V e p o r i d e s and Č i e r n a h o r a are characterized by a great variety of analysed granitoids from leucogranites through orthogneisses to tonalite. The distinct type of illitic weathering of plagioclases is evident also here. More acid types are tending to formation of a small amount of montmorillonite with weathering (ZK 7, 6, 19), more basic types and types with distinct autometamorphism (ZK 66), or tectonic metamorphism are characterized (ZK 83) by more intensive formation of chlorite, albite and secondary quartz, what is connected with generally more extensive alteration of rocks, when also other primary minerals (e. g. biotite) were subject to more intensive disintegration (ZK 83).

The G e m e r i d e s are similarly as the Veporides characterized by a great variety of petrological and genetic types of granitoids. On the whole (according to selection of samples, which were available) can be stated a higher illitization of plagioclases together with formation of chlorite in leucocratic type affected by tectonic metamorphism (ZK 16, and 13), at the last type with manifestations of autometamorphism and slight indication of formation of smectite. The type ZK 33 (Hnilec leucogranite), besides illization of primary plagioclases, shows relatively more intensive development of albite. The sample ZK 61 (muscovite leucogranite from Čučma) is relatively fresh. The presence of hydrothermal influences, besides common illitization and formation of little amount of secondary kalcite, was not distinctly manifested.

The B r a n i s k o represents more intensive chloritization together with formation of illite. The rock (ZK 55) is leucocratic, of aplite-pegmatite character, unequally disintegrated near the contact with amphibolites.

Discussion and conclusions

In weathering of feldspars of the West Carpathian granitoid rocks 3 more or less contemporaneuos processes may be distinguished:

a) disintegration of the structure of maternal mineral with contemporaneous releasing of fundamental building units of original structure.

b) removal and migration of released components from the phase boundary.

c) rebuilding of the remnant of original structure by formation of new mineral, which is already more or less in equilibrium with the reaction environment.

According to Jackson et al. (1948) the weathering process is influenced by intensive and extensive factors. Among intensive factors the temperature, velocity of circulation of solutions, chemical properties of solutions, their oxidation-reduction potential and biological activity belong. From these factors the chemical properties of solutions are the most important. Under conditions of natural weathering are the solutions, which come into contact with feldspar minerals. They are actually weak acids, according to C. W. Correns (1962), G. W. Morey and W. T. Chen (1956) the greatest activity show the first dissociation degrees of the carbonic acid (HCO_3^-). This solution may be also enriched in various ions, as e. g. in hydrothermal solutions. To the extensive factors playing an important role in weathering processes the petrographic character of primary rocks and the specific surface of the particles of the solid phase belong. The most important factor from these extensive factors is under conditions of the West Carpathians the intense Alpine tectonic metamorphism, which forms conditions favourable for attacking of surficial parts of minerals affected by cataclasis, but also reduces their structural stability.

The mechanism of plagioclase disintegration in the weathering processes can be partly observed by polarisation microscope or optimally by scanning electron microscope. On the basis of our study we could distinguish three types of weathering:

1. Weathering — formation of secondary minerals in fissures of plagioclases situated in various directions to cleavibility or lamellation. This type of weathering is usually in rocks affected by tectonic metamorphism.

2. Weathering parallel with lamellae (so called selective). In this type an unequal disintegration with formation of secondary minerals in lamellae of plagioclases of various basicity can be distinguished. In extreme cases one lamella is completely decomposed and altered into secondary minerals, whilst the adjoining, sharply bordered, is completely intact.

3. Weathering in isolated "nests" independently on joints or lamellation of plagioclases. This type of weathering is relatively scarce, has not been described in literature yet and is a specific manifestation of autometamorphism.

These three types of plagioclase weathering are demonstrated on the pictures from scanning electron microscope 1—8.

The physical and chemical sides of weathering are mutually connected. In the weathering process are structural changes, in which the character of fundamental cations, their mobility, capacity of exchange, mainly, however, their distribution in the original structure play a decisive role.

Fig. 1. Weathering of plagioclase – origin of secondary minerals transversely to lamellation. Tonalite – plagiogranite, Harmónia, quarry in the Žliabok brook. Scanning el. microscope, 4000 x.

Fig. 2. Selective weathering of plagioclase lamellae. Biotite granodiorite of Prašivá type, (Sopotnica – Hronov). Scanning el. microscope, magnif. 14 000 x.

Fig. 3. Selective weathering of plagioclase lamellae. Biotite-muscovite granodiorite, Železná studnička – Bratislava. Scanning el. microscope, magnif. 4000 x.

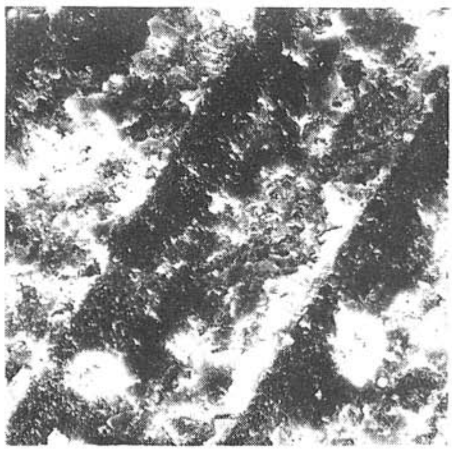

Fig. 4. Commencing stages of plagioclase weathering in form of "nests". Leucocratic hydro- (auto) metamorphosed granite, gamekeeper's cottage Horvátka, Borinka. Scanning el. microscope, magnif. 4000 x.

In plagioclase structures $(Si, Al)O_4^{4-}$ tetrahedrons are connected with all four oxygens into uninterrupted three-dimensional configuration. The negative charge formed by substitution of Al for Si in the tetrahedrons is compensated by alkalic cations and Ca, which are mobile under conditions of weathering, so that the disintegration of feldspars begins with their leaching. The released

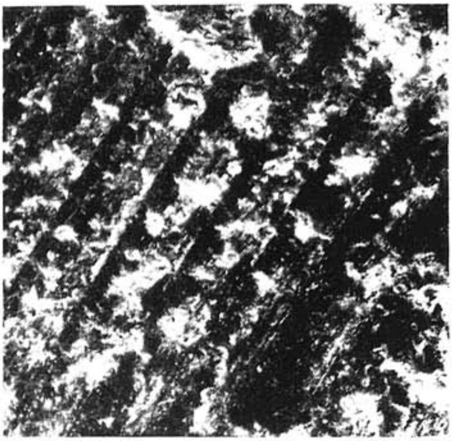

Fig. 5. Commencing stages of plagioclase weathering in form of "nests". Leucocratic hydro- (auto) metamorphosed granite, gamekeeper's cottage Horvátka, Borinka. Scanning el. microscope, magnif. 1200 x.

Fig. 6. Detail of "nest" of secondary minerals. Leucocratic hydro- (auto) metamorphosed granite, gamekeeper' cottage Horvátka, Borinka. Scanning el. microscope, magnif. 10 000 x.

chains of SiO_4^{4-} tetrahedrons are fixing a part of Al, or Mg^{2+}, when chlorite or montmorillonite originate, or K^+, when illite forms. Under conditions of the West Carpathian granitoid rocks, when almost simultaneously, although to a little extent leaching of K^+ and Mg^{2+} from biotites, takes place, optimum conditions of formation of three-layered mineral-illite are easily reached. But also in the case of intact biotite it can be reckoned with the share of K-component in the basic part of plagioclases. This is testified by the chemical analyses of separated plagioclases (L. Kamenický – J. Macek – E. Martíni, 1980), according to which the content of K_2O varies in plagioclases from 0.77–5.02 %, the average value for samples from the West Carpathians is 1.5–2 %, whilst in orthoclases it varies around 13 % on an average. So we have reasons to suppose that K^+ forms isomorphous substitution also in the structure of primary plagioclase. This is testified, for instance, by weathering of plagioclases in "nests", which are isolated from the surrounding environment (autometamorphosed type of granodiorite from the area of Horvátka in the Malé Karpaty Mts., ZK 49 – Figs. 4–8). Further on, under conditions of the West Carpathians metasomatism is a frequent phenomenon, which is the precondition of K^+-supply already under conditions of crystallization of primary minerals and thus of fixation of thision in the plagioclase structure. So we can really suppose, that in agreement with the valid schemes after primary releasing of Ca and Na ions unbalance of charge is in the primary plagioclase structure-cations compensating Si–Al (Mg) groupings are coordination-wrapped by Si–Al cations. Solid solutions of amorphous SiO_x and AlO_x phases originate, which are fixing the least mobile K^+ cation, which is compensating the unbalance of charge and formation of illite structure is possible. This process is made possible by the presence of K^+ in the lattice of feldspar mineral,

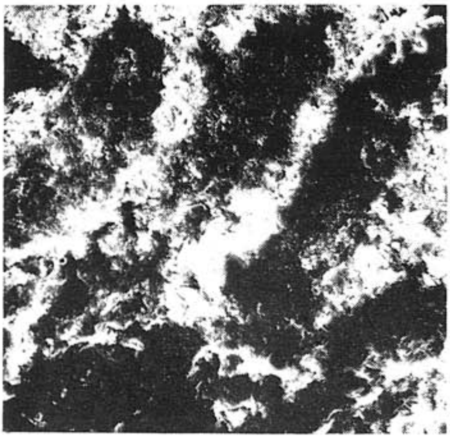

Fig. 7. Advanced stage of plagioclase weathering of hydro- (auto) metamorphosed type of granite, gamekeeper's cottage Horvátka, Borinka. Scanning el. microscope, magnif. 800 x.

Fig. 8. Detail of high degree of plagioclase weathering of hydro- (auto) metamorphosed type of granodiorite, formation of illite, probably also of secondary muscovite, (leaf- shaped forms), albite, quartz (isometric forms) and carbonates (forms resembling nail development). Leucocratic hydro- (auto) metamorphosed granite, gamekeeper's cottage Horvátka, Borinka. Scanning el. microscope, magnif. 14 000 x.

moderate climatic conditions, intermediate reactions of the environment and corresponding factor of time (W. H. Huang and W. D. Keller, 1972 a. o.).

In the more advanced phase of weathering, mainly in types affected by tectonic metamorphism of wider extent, where evident disintegration of biotite is taking place (in form of releasing of Mg^{2+} and Fe^{2+} ions – so called baueritization) and under conditions of more intensive circulation of solutions the action of H^+ ion is evident, which easily penetrates into the disturbed structures of primary minerals and releases alkalies, a preferred product of secondary alterations is montmorillonite. This process has not become prevalent under conditions of weathering of the West Carpathian granitoids and is of local importance only. It is typomorphous for secondary products of mylonites only (M. Harman et al., 1974, 1976).

A part of the disintegrated plagioclases is evidently chloritized. Formation of chlorite is together with montmorillonite bound to rock types with more basic feldspars, in which fixation of K^+ is possible or as a consequence of its surplus in rock caused by K-metasomatism, injection metasomatism or hydrothermal influences. This opinion is also confirmed by the decrease of its occurrence in areas of autometamorphism.

The accessory and sporadical occurrence of minerals from the kaolinite group can be substantiated in isolated cases by the local presence of more acid environment, which could have been a consequence of hydrothermal processes, or on the other hand in isolated environment within the decomposed feldspars where circulation was at minimum level. This environment, however, was not typical for weathering of plagioclases from West Carpathian granitoids, as also the low structure order of kaolinite testifies.

According to the opinions of I. I. Ginzburg (1963), K. K. Nikitin (1968), G. Millot (1970), J. K. Melnik (1970) and others, however, the kaolinite type of weathering is most typical for weathering of granitoid rocks. To this final stage the weathering process must undergo several phases. According to these authors in the first two phases leaching and hydratation take place, the last two phases are characterized by termination of leaching and hydrolysis. Mineralogically the first two phases are characterized by sericitization (so called zone of hydromicas), the last by formation of kaolinite phase. According to this scheme the weathering process of granitoid rocks of the West Carpathians could be ranged to the second, in local cases (Malé Karpaty Mts.), to the third degree. The secondary alterations of plagioclases of West Carpathian granitoids thus did not reach the stage of formation of kaolinite group minerals. This may be explained by two alternatives:

a) The environment of the West Carpathians, contrary to that of the Bohemian massif, underwent especially since the Carpathian orogeny a more dynamic development (superimposed processes). Because of formation of thick weathering crust there were no suitable conditions regarding to intensive denudation. But also in places where weathering crust formed to a limited extent on granitoids (Malé Karpaty Mts.), kaolinization is still not typically developed.

b) A much more shorter time factor for development of processes of secondary alterations in the West Carpathians on the contrary to the Bohemian massif, where conditions had been stabilized already for a long time.

We suppose that with this substantiation the present-day stage of the wethering process of the West Carpathian granitoids and its qualitative – mineralogical difference from secondary products of granitoid weathering of the Bohemian massif may be explained.

In this connection also the question of sericite should be mentioned. In petrographical descriptions of alterations of West Carpathian plagioclases, on the basis of optical study every alteration of plagioclases is usually described as "sericitization". As sericite fine-grained hydromica is usually described, closer to muscovite, on the basis of optical, chemical and structural properties. In our investigation we carried out X-ray, DTA and electron microscopic analyses of specially separated secondary products, designated as sericite. We have come to conclusions, which may be summarized briefly into several points:

a) X-ray and electron diffraction analyses mostly indicate a moderately shifted line 10 Å toward lower values, more intensive lines 4.28, 4.45, 1.48, 1.29 Å, diffusion lines in the sphere 2.86–2.98 Å and in the sphere 1.67 Å, what is typical of illites (on the contrary to muscovite, mostly 1M and $2M_1$, which has distinct sharp lines 5.02, 4.52, 2.12, 2.56, 1.95 Å and diffusion lines in the sphere 2.13–2.38 and 1.35 Å). Very well developed is the sharp line 2.58 Å, characteristic of modification 1Md, to which the greater majority of illites belong. The sharp lines of diffractograms, frequent point reflexes testify to a good order of the mineral. These characteristics are in oriented X-ray preparates typical of illite, are not changing with the effect of ethyleneglycol and glycerine, neither by annealing to 550 °C (besides occasionally increasing intensity of line 3.33 Å).

b) DTA curves with distinct endotherms at 120, 560 and 900 °C, at about 930 °C the exothermic reaction, are characteristic of illite.

c) The investigated mineral is characterized by high dispersiveness, the electron microscopic analysis confirms the size of particles on an average of 1.5–3 μm. (Secondary muscovite forms essentially larger particles, which can be identified well petrographically.)

d) The geochemical factors — sufficient water, a small content of K^+ in plagioclases and almost total absence of hydrothermal influences in the majority of granites, are unambiguously more optimum for formation of illite.

On the basis of these factors we suppose that the essential component of fine-dispersive secondary minerals, forming by disintegration of plagioclases of West Carpathian granitoids, is illite. A process characteristic of feldspar disintegration is so not sericitization but argillization of illite type.

Some petrographers, on the basis of the study under polarization microscope, describe the occurrence of epidote in granitoids of the West Carpathians, mainly in connection with the process of saussuritization of feldspars. In our investigation we have not identified epidote as product of secondary alteration of feldspars in any case. For this reason we tend to the opinion that epidote in granitoids is either primarily a magmatic mineral, where together with allanite it forms an isomorphous order in the stage of primary magmatic crystallization differentiation (J. Gbelský, 1980 a. o.), or is a product of post-magmatic processes, mainly hydrothermal, when it usually forms particular small veins.

According to the results obtained these dependences of optimum origin of secondary minerals (x = frequency of occurrence) may be compiled for granitoids of the West Carpathians) — Tab. 1, 2.

Translated by J. Pevný
Review by I. KRAUS

Manuscript received April 20, 1982

Table 1

Dependences of optimum origin of secondary minerals

Secondary mineral	Weathering processes	Tectonic metamorphism	Autometamorphism	Hydrothermal alterations	Migmatization K-metasomatism	Preferred type of rock
Illite	xxx	xx	xxx	x (?)	x	
Montmorillonite	xx	xxx	x (?)			acid types
Chlorite	xx		x	xx	xxx	basic types
Kaolinite	x			x (?)		
IM structures	x	x	x	x (?)		
Sericite (muskovite)	x (?)			x	x	
Albite	xx	x	x		x	
Kalcite	x	x	x			
Quartz	x				x	acid types
Epidote				x		
Limonite	x	x				basic types

Table 2

Frequency of occurrence of secondary minerals in plagioclases of the West Carpathians

Location	Bas. plag. in % An	Kaol.	Hall.	Montm.	IM str.	Illite	Chlor.	Quartz (+ sec.)	Albite	Kalcite	Remark
Malé Karp. ZK 5	uncert.	x o				xxx ooo	—	xx o	x	x	
ZK 48	12—16			x oo		xx oo		x		xx	
ZK 49	uncert.			x o		xxx ooo		x	x	x o	hydro-auto metamorphism
ZK 50	20—24			x	?	xxx oo		x		xx	
ZK 51	18—24		o?	o		xx oo	x o	x		x	
ZK 53	18—23	o		x o	?	xxx ooo		x		x	
ZK 54	uncert.			o		xxx ooo	xx o	xx o	x	x	hydrotherm. influences
ZK 60	22—28					xx oo	x o	x	x	x	
17/63	uncert.			o	?	xx oo	x o				samples from collections of J. Veselský
19/63	uncert.			x o	x	xxx oo		x	x		—„—
26/63	uncert.			x		xxx ooo			x	x	—„—
28/63 (ZK 49?/	uncert.			o		xxx ooo		x o			—„—
50/63	uncert.			x o	x	xx oo			x	x	—„—
56/63	uncert.			x		x o		x o	x		—„—

1. continuation of Tab. 2

Location	Bas. plag. in % An	Kaol.	Hall.	Montm.	IM str.	Illite	Chlor.	Quartz (+ sec.)	Albite	Kalcite	Remark
Vys. Tatry ZK 22	22	x				x oo	x	x		?	near-automet.
ZK 23	20—22	x		?	?	x		xx	x		—,,—
ZK 30	30—36	?		x o		xxx ooo	xx o	x	x		
ZK 40	28—32			?		x	?	x	x	?	very fresh rock
ZK 47	18—22					o	? o	x		x	—,,—
ZK 71	20—22					?	x	xx oo	x		autometamorph.? limonitiz.
Níz. Tatry ZK 3	2—3					x o	xx o	x			K-metasom.
ZK 4	18—27					xx o		x	x		
ZK 24	18—24			x		x o		xx	xx		
ZK 25	10—18			x?		xx		x	x	x	automet. — K-feldspars
ZK 68	17—20			?		x o	xx o	xx	x		
Pov. Inovec ZK 17	12—16			?	?	x o		xx	xx		migmatite
ZK 15	20—28			x		xx oo	x	x	xx		directed
ZK 64	16—18					xx o	x o	xx	x		migmatit.-hybr. gr.

2. continuation of Tab. 2

Location	Bas. plag. in % An	Kaol.	Hall.	Montm.	IM str.	Illite	Chlor.	Quartz (+ sec.)	Albite	Kalcite	Remark
Veporidy ZK 2	9–15			x?		x	x o		xx		
ZK 7	uncert.			x o		xx o	xx oo	x	x	x	
ZK 10	26–29					xx oo	x	x	x	x	
ZK 6	12–18					x o	x? o	x	x	?	orthogneiss
ZK 9	34 ?			x		xx oo		xx o	x	?	
ZK 19	30–36			x o		x o		x			
ZK 58	10–12					xx o	x o	x	xx	x	
ZK 66	30 ?					x o	x	xx o	x		autometamorph. type
ZK 67	34–40			x		x o	x o	x	x		directed
ZK 83	uncert.					xx oo	xx o	x	x	?	strongly direct-ed
Gemeridy ZK 13	22–28			x		xx o	xx oo	x			slight meta-morphism
ZK 16	uncert.			?		xx o	x	xx	x		very directed
ZK 33	uncert.			?		xx oo	?	x	xx		autometamorph.
ZK 61	16–18				?	xx o		x		x	

3. continuation of Tab. 2

Location	Bas. plag. in % An	Kaol.	Hall.	Montm.	IM str.	Illite	Chlor.	Quartz (+ sec.)	Albite	Kalcite	Remark
Veľ. Fatra ZK 22	24—30	?		? o		xx oo	xx o	x	x	xx	
ZK 44	22—28					xxx ooo	o	x	xx		hydrotherm. f. (barite)
Malá Fatra ZK 21	18—28			?		x o		x	x		very fresh
ZK 38	28—34			x o		xx o	? o	x	x		near migm.
ZK 59	26—29					xx o	x o	xx o	?	?	
ZK 97	28—32					xx oo	x o	xx oo	x		automet.?
ZK 98	28—30	x				x o	x	x			—„—
Tríbeč ZK 41	10—12	?		x		xx o	?	x o	x	?	
ZK 42	10—14			x o		xx o	?	x	x	?	directed
ZK 100	8—12			x		x o		x o	xx	x	
ZK 103	uncert.	?		x		x o	x o	x	xx		
Branisko ZK 55	8—12					x o	xx o	x	x	?	
Čierna hora ZK 11	28—30					x o		x			

Explanations: x, xx, xxx / o, oo, ooo } frequency of occurrence;
x X-ray and DTA methods; o electron microscopy methods.