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THE NÍZKE TATRY MTS. CRYSTALLINE COMPLEX – NEW FACTS AND INTERPRETATION (WESTERN CARPATHIANS, CZECHOSLOVAKIA)

(9 Figs., 1 Tab.)

Abstract: The Tatric part of the Nízke Tatry crystallinicum is formed by a granitic pluton and metamorphic rocks. Granitoid composition varies within granites – granodiorites – tonalites. The metamorphic rocks are represented here mainly by migmatites and various types of gneisses and amphibolites. Diorites, skarnoids, metaultramafites and other rocks occur here in small amounts. A number of enclaves (diorites, Gar-Bi gneisses) often occur in the granitoids. The results of the investigation of mineral compositions showed great variations in pyroxene, amphibole, garnet and plagioclase compositions. Plagioclases and garnets often have zonal structure. The protolith of the gneisses, Hbl-gneisses and amphibolites was sediments of greywacke type, volcano-sedimentary rocks with an admixture of basic material, and/or less frequent basalts and acid volcanites. Metamorphic conditions were investigated through mineral associations and various thermobarometers. In the southern part of the Ďumbier zone temperature increases, from 550–650° C to 650–750° C or higher, northwards to the Nízke Tatry pluton. The regional metamorphism was earlier than the periplutonic one connected with the granite pluton.

Резюме: Татриная часть кристаллиникума гор Низкие Татры образована гранитовым плутоном и метаморфическими породами. Состав гранитоидов колебает от гранитов до гранодиоритов и тоналитов. Из метаморфических пород здесь находятся главным образом мигматиты, различные типы гнейсов и амфиболитов. Менее здесь встречаются диориты, скарноиды, метаультрамафиты и другие типы пород. В гранитоидах находятся различные типы энклав (диориты, Gar-Bi гнейсы). Изучение состава минералов показало больщие вариации в составе пироксенов, амфиболов, гранатов и плагиоклазов. Плагиоклазы и гранаты часто имеют зональную структуру. Протолитом гнейсов, амфиболовых гнейсов и амфиболитов были незрелые осадки типа граваков, смещанные вулканоосадочные тороды с примесью основного материала, или более редко базальты и кислые вулканиты. Условия метаморфизма изучались на основе минеральных ассоциаций и различных термометров и барометров. Температура в южной части Дюмбиерской зоны повыщается с 550–650 °C до 650–750 °C, или тоже больше в направлении к северу, к Низкотатранскому плутону. Региональный метаморфизм является более древним чем периплутонический, вызванный гранитовым плутоном.

Geology

The Nízke Tatry Mts. are the most extensive mountain range of the Western Carpathians. Due to post-Palaeogene tectonics two types of morphologically uniform crystallinicum were formed here: the Veporic one in the eastern part, and the Tatric in the western part. The western, Ďumbier part, of the mega-anticline of the Nízke Tatry Mts. is characterized by

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a striking asymmetry of the crystallinicum : the northern slopes are mostly formed by granitoids of the Nízke Tatry pluton and the southern ones by metamorphites. In the north, the crystallinicum is submerged under Mesozoic sequences (Fig. 1).

Metamorphic rocks are formed mainly by migmatites of different structural types and biotite gneisses and to a lesser extent by other types of rocks – amphibolites, amphibolic, quartzitic and pyroxenic gneisses, etc. They underwent middle and high degrees of metamorphism at medium pressures. Radiometric dating (e. g. Kantor, 1961; Bojko, 1975) proves the Variscan age of metamorphism. The sedimentation of the original rocks of this metamorphic sequence must have taken place in the Lower Palaeozoic (Čorná – Kamenický, 1976). Findings of Lower Palaeozoic sporomorphs in the schists from narrow tectonic zones amid the gneisses and metamorphites (Molák et al., 1986) incited a broad discussion. Some aspects of the interpretation of these findings have not been thoroughly discussed.

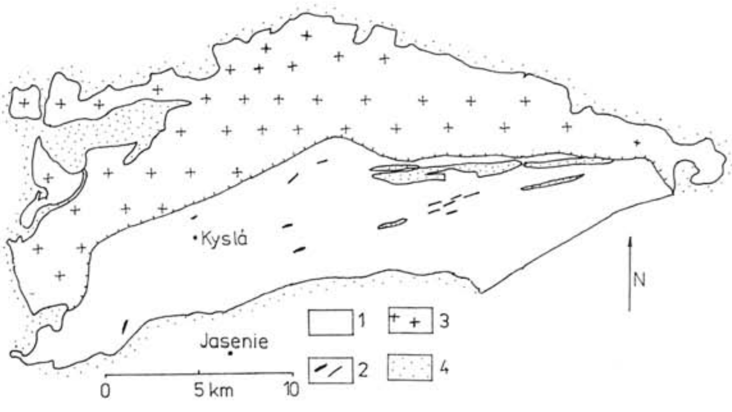

Fig. 1. Sketch of the Tatric part of the Nízke Tatry crystallinicum.
Legend: 1 – migmatites and gneisses; 2 – amphibolites; 3 – granitoids – the Nízke Tatry pluton; 4 – Upper Palaeozoic and Mesozoic as a whole; 5 – the Veporic part of the Nízke Tatry Mts. as a whole.

Granitoids mostly occur on the southern slopes of the Ďumbier part of the Nízke Tatry Mts. Petrographic variety of these rocks reflects the complexity of the processes of their genesis. Apart from the differentiation processes, interaction with metamorphites (hybridization, anatexis) and alteration took place intensively. Besides the classic types of granitoids – those from Ďumbier, Prašivá and Kralička regions – several other types have been distinguished; however, their mutual relations have not been for the most part identified. Granitoids appear to have affected the origin of the most valuable ore deposits on the territory of the Ďumbier part of the Nízke Tatry Mts. – Dúbrava, Magurka, Jasenie, etc.

The allochthonous character of granites in the Nízke Tatry pluton has been known for a longer time (Koutek, 1931); however the relationship of granite to its metamorphic mantle is disputable; there is a rather great variety of views concerning it – from a granitoid overfault onto metamorphites, through a strained granitoid intrusion without any stronger interaction with the environment, to the origin of at least a part of granitoids by anatexis, and/or granitization of the rock of the metamorphic mantle.

There is a considerable amount of radiometric datings of the rocks of the Nízke Tatry pluton of which an absolute majority prove the Variscan age of these rocks (e. g. Kantor, 1959; Cambel et al., 1977; Bagdasaryan et al., 1986).

The most thoroughly examined part of the Nízke Tatry crystallinicum must be that of Jasenie – Kyslá. Bezák and Klinec (1980) distinguished between 5 rock zones in this region running from northeast to southwest. From the north they are:

1. The zone of the Jasenská hoľa hill is made of medium-grained biotitic granitoids with local metamorphite enclaves. In general, it is the Nízke Tatry pluton.
2. The zone of the Zámostská hoľa hill, approximately 1.2 km wide. The largest part of it is made of migmatites with nebulitic structures. Latiborská hoľa granitoids (Lukáčik, 1982) are typical for this zone.
3. The zone of the Špíglová valley, approximately 1.5 km wide. It is mostly made of migmatites with stromatitic and ophtalmitic structures. This is a zone with the most variable rock association and the centre of tungsten mineralization in this region.
4. The zone of the Struhár peak lies on the northern side discordant to the underlying zone of Špíglová valley (Bezák – Klinec 1980). The rock types of the Struhár zone are rather specific – there are typical fine-grained oriented leucocratic rocks of aplitoid shape, migmatites with local paragneiss and amphibolite intercalations here.

Petrography

The Lower Palaeozoic of the Tatric part of the Nízke Tatry Mts. contains the following rock types: *1. granitoids,* 2. *migmatites,* 3. *gneisses,* 4. *amphibolites,* 5. *rocks of special compositions,* structures and textures.

In spite of their low contents they are indispensable to the resolution of how the whole complex was formed. From among such types are: metaultramafites, banded amphibole rocks, Al-rich gneisses from nebulite zone, garnet granitoids, clinopyroxene rocks and skarnoids.

Granitoids

Several types of granitoids have been presented from the Tatric part of the Nízke Tatry Mts. The main rock types are those of Ďumbier and Prašivá that form the largest part of the Nízke Tatry pluton (Koutek, 1931). The former correspond to granodiorites-tonalites, the latter to granites-granodiorites and these are typical for pink K-feldspar phenocrysts. The granites of the Králička type make up a uniform body in migmatites. They are usually altered to a high degree and contain sillimanite (Dupej – Siegl, 1984). They are generally considered anatectic. The granites of the Kotliská area (following Bezák – Klinec, 1983) represent a continuation of the nebulite zone eastwards to the Lomnistá valley. They are fine-grained greyish rocks of sugar-like appearance and usually contain fine (2–3 mm) idiomorphic garnets. There is another type of granitoids, the Latiborská hoľa one (Lukáčik, 1982), which is included in the nebulite zone. Macroscopically the granitoids are even medium- or coarse-grained. Non-homogeneities due to schliers of mafic minerals (biotites and garnets) are frequent. Another typical mineral is sillimanite. Our investigations make us consider the Latiborská hoľa granitoids as anatectic granites and biotite schliers as a complementary material to the composition of the original nebulites (migmatites).

Apart from the given granitoid types there are also various types of aplites, pegmatites and rocks of amphibolic diorite character.

Migmatites

The Tatric part of the Nízke Tatry crystalline complex is an ideal place for migmatite study in the Western Carpathians. Three types of migmatites are dominant here: stromatitic, ophtalmic and nebulitic. The other types occur in lesser amounts. Within the zones that were singled out there are some differences in migmatite compositions and properties. In the zone of Struhár the richest abundance is that of migmatites with fine-grained structures and variable thicknesses of paleosome and neosome. Neosome shows aplitic features and the same grain size as paleosome. Neosome compositions are close to the granite minimum. In the Špíglová zone, mostly stromatitic and ophtalmic migmatites were formed. In stromatites neosome does not differ from paleosome in grain size. In the bands of neosome local swells occur, and the sharp boundaries between individual bands often disappear. The boundaries neosome–paleosome are often obscure. The zone of the Zámostská hoľa hill, i. e. that of nebulitic migmatites, is inevitable for the understanding of the genesis of granites and migmatites. Mainly, this zone is a contact zone of the Nízke Tatry pluton and the metamorphic mantle. The migmatites of the nebulite zone differ from those of the Špíglová and Struhár zones mainly in grain size: they are coarse-grained, and in structure. The relationship between neosome and paleosome is diffuse. Paleosome is often split and spread in the rock. The neosome of nebulitic migmatites is close to, and/or identical to the Latiborská hoľa granites. Following the investigation of structural and textural properties and mineral assemblages we can suppose that in the zone of the Zámostská hoľa hill the limits of ultrametamorphism were exceeded. The temperatures detected on the basis of the study of coexisting minerals were about 750 °C. Metamorphism in the Špíglová and Struhár zones was mostly of isochemical character, with the migmatites from the zone of the Zámostská hoľa hill; on the other hand, we can talk about an open system with an intensive element migration.

Gneisses

Gneisses from intercalations of metre- or decametre-size in nearly all zones. The most common types of gneisses are: biotitic, amphibolic, muscovite-biotitic, biotite-amphibolic, muscovite-quartzitic.

Following the results of our study we can assume, that the character of gneisses is, above all, a reflection of lithology, i. e. the composition of the primary rocks – sediments from which they originated. The major problem of the genesis of gneisses is the reason for their being intact in the migmatite zone. The likely reasons are the following: unsuitable chemical composition of the protolith or unsuitable structural predisposition. The former is considered verified enough with the gneisses with elevated admixtures of basic tuffitic material and likely with quartzitic gneisses (Pitoňák – Spišiak, 1988).

Amphibolites

Amphibolites belong to the major rock types of the Nízke Tatry crystallinicum. They are closely associated with various gneiss types. Amphibolites are mostly massive, medium- or fine-grained, and locally oriented. With regard to modal composition we can distinguish between several types of amphibolites:
amphibolites s. s., biotite amphibolites, garnet amphibolites, epidote amphibolites, pyroxene amphibolites.

Rocks of special composition

These rocks are minor in the Nízke Tatry crystallinicum but, on the other hand, they are of great importance to the genesis of the whole complex.

Banded amphibolic rocks

– are a specific rock type of the Nízke Tatry crystallinicum. From the petrographical point of view, they are bands of variable thickness and composition, irregularly alternating (Fig. 2). The composition and thickness is kept within a great length (several tens of metres). The bands are:

– light quartz-feldspar bands. These usually contain quartz, plagioclase (An_{20}), K-feldspar and sometimes biotite. Drop shaped exsolutions of quartz in plagioclase and poikilic textures can be observed frequently.

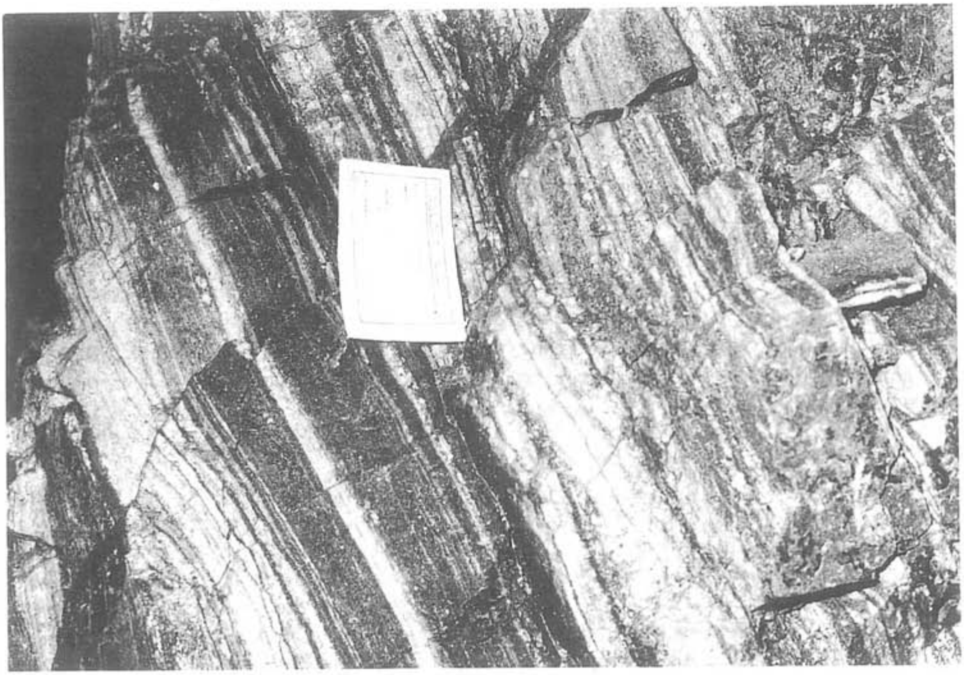

Fig. 2. Banded amphibolic rocks (gneisses), Jasenie–Kyslá, gallery Nr. 4, M. p. 48, scale 7 × 10 cm.

– quartz-garnet bands – these are rare;

– dark quartz-plagioclase-biotite-amphibole bands with variable composition. They differ mainly in modal amphibole abundance. Thicker bands show the character even of amphibolites. Plagioclase basicity varies within An_{30}–An_{35};

– dark quartz-plagioclase-biotite bands. The most common mineral is biotite, modal contents of which are up to 50 per cent. In these bands plagioclase basicity varies within An_{35}–An_{45}. The elevated basicity is due to the absence of calcium in biotite structure and its occurence in plagioclase.

In some places between the bands, lenses of amphibolic rocks of centimeter or decimeter size can be seen. These are medium to coarse-grained and often show the features of diorites.

The origin of individual bands – rocks structure, is the most discussed problem. There are three possible origins:

– light bands are injections of acid material in the original basic rocks;

– light and dark bands are a product of metamorphic differentiation;

– light and dark bands reflect the original protolith composition and metamorphic processes made these differences greater, thus, banding is a reflection of the original structure.

On the basis of our studies we would like to present some facts concerning the genesis of the rocks under study:

1) Against the injection of acid material in the originally basic rocks are:

– the preservation of very thin dark bands (approximately 2 mm) between two light bands and their great orientation length;

– orientation of thin bands (biotite ribbons, etc.);

– the composition of some light bands – quartz + garnet, and/or anchimonomineral garnet bands;

– frequent multiple alternations of thin bands of variable compositions;

– the presence of fine lenses of amphibolic rocks flowing around by the light and dark bands.

2) The processes of metamorphic differentiation have not been studied in detail yet. Following our investigations, we cannot neglect the possibility of metamorphic differentiation in this region, though it must have taken place only under restricted conditions. From the geochemical viewpoint, the light and dark bands have very different chemical compositions

3) The third way is supported by several geological as well as petrographical and mineralogical data, e.g. gradual transition of banded rocks to amphibolites with the increasing number of bands, or identical composition of amphiboles from dark bands, lenses in banded rocks and those from host rocks.

Al-rich gneisses

This group of rocks is comprised of enclaves, and/or smaller layers of biotite-garnet gneisses from the zone of the Zámostská hoľa hill. They are rather strictly limited and often separated by a several-centimetre leucocratic quartz-plagioclase-garnet fringe. The composition of the enclaves and their microscopic character are very close to each other. They consist of quartz, plagioclase and biotite. Garnet is typical here. Apatite, allanite and sphene occur in accessory amounts. With regard to their mineral and chemical compositions we take these rocks as a metamorphosed equivalent of clayey, and/or marly sediments. The original presumably continuous layer of rocks was disintegrated during metamorphic and tectonic processes. The rocks have specific chemical compositions – high contents of Al_2O_3, P_2O_5 and CaO, similarly specific are the compositions of rockforming minerals (see mineralogical part) as well.

Skarnoids

These rock types have not been identified in the Tatric crystallinicum yet. Pyroxene gneisses presented by Koutek (1931) and Miko et al. (1977) could be classified with similar rock types. The term skarnoid is used to prevent terminological problems with terms "skarn", "erlan", "tactite". Our investigations suggest that they are rocks of skarn type in their composition (hedenbergite – Fe-Ca garnet), but were formed by regional metamorphism of originally marly, and/or carbonate rocks.

Metaultramafites

These rocks have been presented from a bearing in the Tatric crystallinicum for the first time. They form lenticular bodies and layers in the zone of Špíglová. They are strongly altered and from among primary minerals only chromites have survived in many cases. They were described in detail in a paper by Spišiak et al. (1988).

Among other specific rock types there are garnet granitoids and clinopyroxene granitoids. They occur in the zone of the Zámostská hoľa hill and they may represent rocks similar to Al-rich gneisses.

Mineralogy

We have examined the composition of the essential rockforming minerals from all the rock types with an electron microprobe. Besides the compositions of individual minerals, the zonality was also studied. All the analyses were published in Pitoňák – Spišiak (1989). Some of the results are briefly summarized in the following:

Pyroxenes were found in two rock types: skarnoids and clinopyroxene granitoids. According to IMA classification (Morimoto et al., 1988) clinopyroxenes from skarnoids (sample J-172) correspond to hedenbergites and those from granitoids (J-143) to diopsides (Fig. 3).

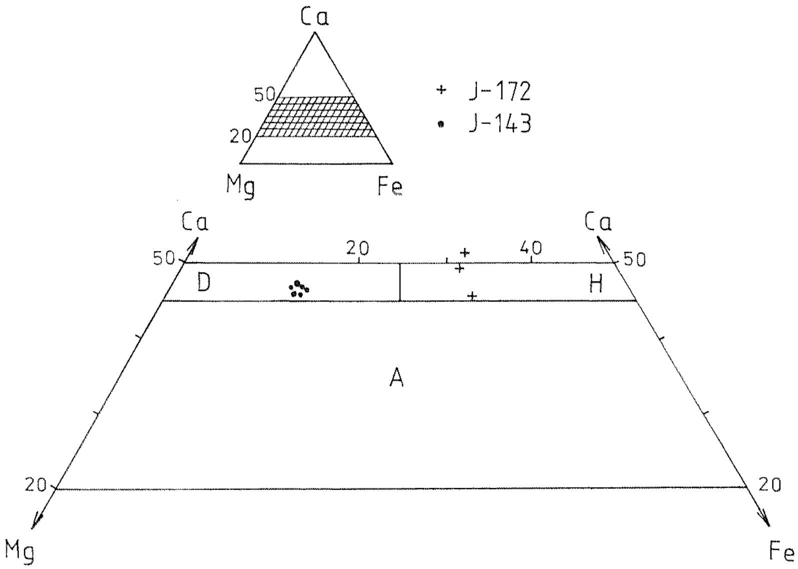

Fig. 3. Classification diagram of clinopyroxenes (according to Morimoto et al., 1988) D – diopside, H – hedenbergite, A – augite.

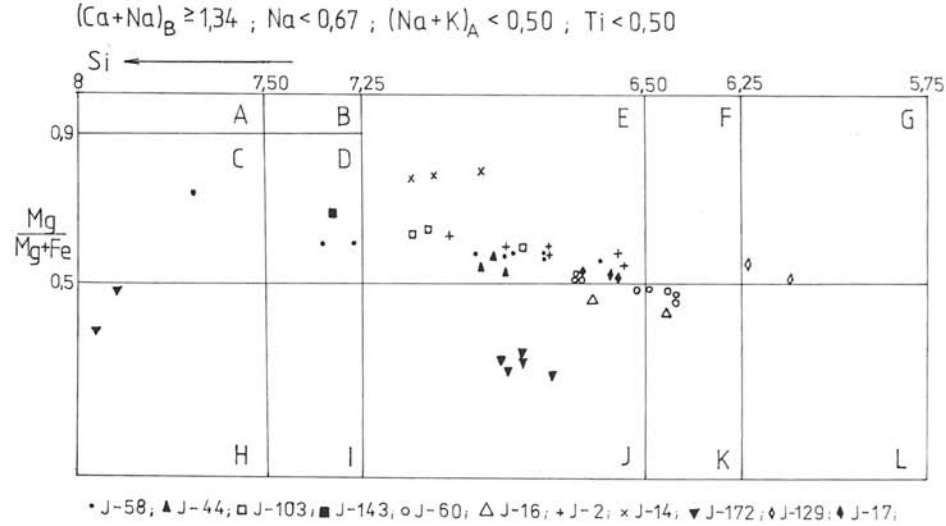

Fig. 4. Classification diagram of calcic amphiboles (L e a k e , 1978).
Fields: A – tremolite, B – tremolitic hornblende, C – actinolite, D – actinolitic hornblende, E – magnesio-hornblende, F – tschermakitic hornblende, G – tschermakite, H – ferro-actinolite, I – ferro-actinolitic hornblende, J ferro-hornblende, K – ferro-tschermakitic hornblende, L – ferro--tschermakite.

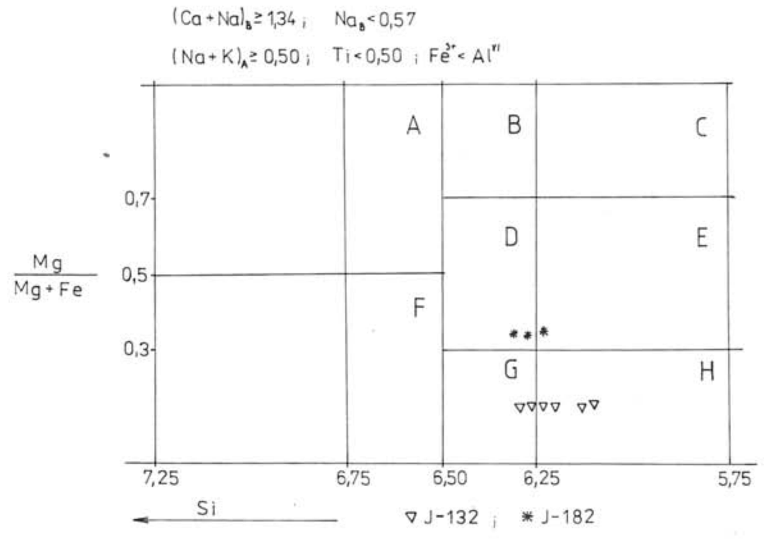

Fig. 5. Classification diagram of calcic amphiboles (L e a k e , 1978).
Fields: A – edenitic hornblende, B – pargasitic hornblende, C – pargasite, D – ferroan pargasitic hornblende, E – ferroan pargasite, F – ferro-edenitic horblende, G – ferro-pargasitic hornblende, H – ferro-pargasite.

Amphiboles. With regard to rock type, optical properties and chemical composition we distinguished between several types of amphiboles (Figs. 4, 5):
– amphiboles from amphibolic gneisses and amphibolites (samples J-14, J-16, J-17, J-2, J-44, J-58, J-60, J-103). They show green or brown-green pleochroism and according to IMA classification (Leake, 1978) correspond to Mg-hornblende, or they lie close to Fe-hornblende field. Apart from these, in amphibolites there are also younger spicular actinolitic hornblendes, and/or actinolites.
– amphiboles from skarnoids (J-172) have blue-green pleochroism and are rich in Fe and poor in Mg. In the classification diagram (Fig. 4) they lie in Fe-hornblende field and are shifted in the direction of low Mg/Mg+Fe ratio. Like amphibolites, skarnoids contain newly-formed spicular amphiboles corresponding to Fe-actinolite.
– amphiboles from garnet-amphibole gneisses from the zone of Struhár, and migmatized amphibolites from the zone of Špíglová represent a specific amphibole type. The former are pronouncedly pleochroic, blue-green amphiboles. They are both characteristic for high Fe, Al and alkaline elements contents. In the classification diagram of amphiboles (Fig. 5) they lie in the field of Fe-pargasitic hornblendes (garnet-amphibole gneisses, J-132) and/or that of pargasites and pargasitic hornblendes with low Fe-contents (migmatized amphibolites, J-172).
– another type of amphiboles is tremolite from altered ultramafites (Spišiak et al. 1988).

Garnets. Like amphiboles, also garnets from various rock types differ in their chemical compositions. Our investigations support that garnet composition depend mostly on the rock composition. On the basis of optical properties and chemical composition of garnets we classified several types:

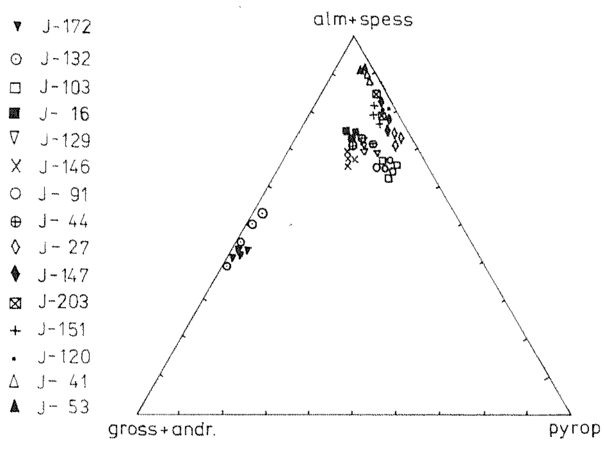

Fig. 6. Ternary diagram of alm+spess : pyrope : gross+andr for garnets. For samples symbols see the text.

– the first group is represented by the garnets from skarnoids (J-172) and garnet-amphibole gneisses from the zone of Struhár (J-132). These are characteristic for high grossular and low pyrope contents. In the ternary diagram (Fig. 6) these garnets form a separate field. We point out that Fe^{3+} contents were not stated in the analyses and for this reason, the andradite component may be considerably lowered.

– the second, relatively independent group is represented by the garnets from the banded amphibolic rocks (J-16, J-103) from the zone of Špíglová, and those of the atoll type from the garnet-amphibole gneisses of the Struhár zone (J-129). Similar compositions were found with the garnets from more basic Al-richer gneisses from the zone of the Zámostská hoľa hill (J-44, J-146). This group is typical for lower contents of grossular component and, as opposed to the first type, increased contents of pyrope and almandine components. The individual types differ from each other in the contents of spessartine component.
– the third group appears to have the lowest contents of grossular component and is comprised of more leucocratic Al-rich gneisses (J-151) and garnet granitoids from the zone of the Zámostská hoľa hill (J-27, J-147, J-203), and garnet-biotite gneisses from the Špíglová zone (J-91, J-120).
– the last independent type is represented by the garnets from the gneisses of the Struhár zone (J-41, J-53). They have high contents of almandine and spessartine components and low contents of grossular and pyrope ones.

With garnets from the Nízke Tatry crystallinicum all types of zonality were found. They are reflected in geotectonic development and metamorphic conditions in individual zones. The garnets from the zone of the Zámostská hoľa hill are, in general, zoneless, or slightly zonal. The low zonality may be a result of high temperatures at the origin of the rocks of this zone. With the garnets from the gneisses of the Struhár zone, normal zonality was found, i. e. the increase of Fe and Mg contents and decrease of that of Mn from core to rim. The cases of a specific type of zonality, when a sudden and irregular change of the composition within one grain sets in, are observed in the garnets from skarnoids. Here, within one garnet grain it is possible to distinguish at least two separate, chemically different phases (more detailed results of garnet study are presented in Pitoňák – Spišiak, 1989).

Biotites. Biotites from various rock types were also studied in detail; however, their compositions are not as variable as those of the other minerals. They were, in general, nonzonal however often strongly altered. Concerning the highest TiO_2 contents, the biotites from Al-rich gneisses and migmatized amphibolites were the richest. A considerable difference between the biotites from the gneisses and the migmatites from the Špíglová zone was found. Detailed results of biotite study are presented in Pitoňák – Spišiak (1989).

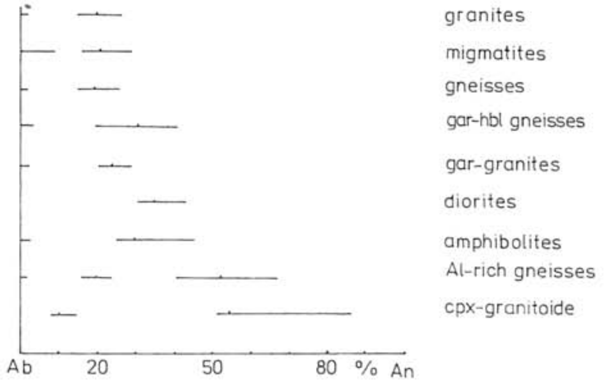

Fig. 7. The composition of plagioclases from various rock types of the Nízke Tatry crystallinicum.

Plagioclases. Plagioclases from all rock types were studied. The compositions were detected on the basis of optical investigation and electron microprobe analyses. The results correlated well. Plagioclases in rocks show great variability in composition (Fig. 7). Besides medium-basic and basic plagioclases there are also acid, usually younger, ones. Plagioclase zonality is for the most part unclear in metamorphic rocks. The garnet-amphibole gneisses from the Struhár zone are an exception; here, the rims are richer in anorthite component than the core. Anorthite component occurs in very high contents in the plagioclases from Al-rich gneisses and clinopyroxene granitoids from the zone of the Zámostská hoľa hill (more than 50 per cent). In these rocks, plagioclase basicity is supposed to be affected by specific protolith composition.

Geochemistry

Geochemical examination was carried out on the basis of 191 silicate and 74 spectral analyses of the rocks from the Ďumbier part of the Nízke Tatry crystallinicum. A certain number of analyses was taken over. The complete analytical material is given in Pitoňák – Spišiak (1989). Tab. 1 presents basic statistical data on the contents of major elements in some rock groups.

Granitoids. Geochemistry of the granitoid rocks of the Nízke Tatry pluton has been known quite well from the works by Cambel – Petrík – Vilinovič (1985), Hovorka – Spišiak (1982) and others. The knowledge of the geochemistry of the granitoids from the Nízke Tatry pluton can be summarized as follows: the granitoids under study mostly have peraluminous character, peraluminosity index is dropping towards more basic rock types. Peraluminous granitoids contain Al-minerals, such as Al_2SiO_5 modifications, muscovite, biotite, cordierite, garnet, etc. These mineralogical criteria are fulfilled mainly in the case of the Latiborská hoľa and Králička types as well as those of the Kotliská region (sillimanite, garnet). Nearly all the types are abundant in muscovite and apparently biotite. We can say, that with the increasing degree of differentiation in granitoids only SiO_2 and K_2O contents increase, those of Na_2O are relatively constant. This suggests that K_2O/Na_2O ratio is increasing to the degree of differentiation. The data on the likely source protolith of the Western Carpathians granitoids (including those of the Nízke Tatry pluton) show that the most likely protolith is crustal metasedimentary material mixed with a certain amount of magmatic material of mantle origin (Hovorka, 1979, 1980; Cambel – Petrík – Vilinovič, 1985). According to I/S classification (White – Chappel, 1977) the granitoids of the Nízke Tatry pluton represent a transitional type, only those from the Latiborská hoľa and Králička regions belong to S-type. According to Bagdasaryan et al. (1985) the initial Sr ratio for the Ďumbier type is 0.7079 and for the Králička one but also a part of the Ďumbier granitoids 0.7157. The given ratios correspond to crustal re-cyclical material of mixed character with dominant sediment and lower contents of basic rocks of mantle origin. We have tried to solve the questionable granitoid having been originated from the metamorphites of the Nízke Tatry crystallinicum. We have taken into consideration the following: the granitoids of the Nízke Tatry pluton are mostly formed by more basic granitoid types – granodiorites or even tonalites and the chemical composition of this more basic rock types appears to correspond to the primary magma the best. Applying various statistical methods (e. g. Fig. 8) we have found, that there is no simple correspondence between the chemical compositions of the crystallinicum granitoids and metamorphites. Gneisses and migmatites, as opposed to granodiorites and tonalites as the dominant rocks of the crystallinicum, have higher Ti, Fe, Mn, Mg and lower Na contents and moreover, the latter are Ca depleted. The considered admixture of basic mantle rocks in the protolith explains CaO abundance in granitoids when compared with migmatites, however, it would increase the abundance of mafic elements and the lack of Na_2O. These considerations show that the idea of simple correspondence of the chemical composition of the hypothetical magma originated by metamorphite and granitoid magma anatexis was wrong. Such an interpretation of granitoid genesis requires a complex of succesive processes – restite separation, intensive migration of alkaline elements, and/or other elements from the external source, etc.

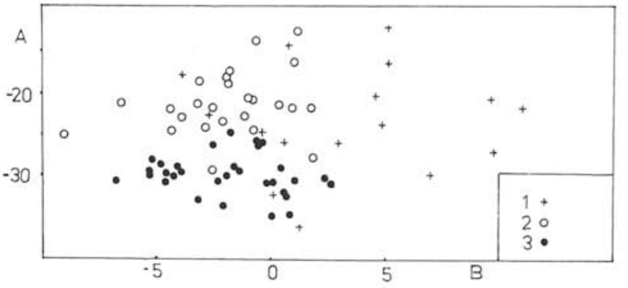

Fig. 8. Discrimination diagram. A – the values of the discrimination function migmatites : granitoids; B – the values of the discrimination function gneisses : migmatites.
1 – gneisses; 2 – granitoids; 3 – migmatites.

Migmatites. The migmatites of the Nízke Tatry crystallinicum can be generally considered as rather similar to the gneisses, although in several parameters they appear to be on the boundary between the gneisses and granitoids of the Nízke Tatry pluton. Peraluminosity index of the migmatites is rougly the same as that of paragneisses. Na_2O/K_2O ratios are higher in migmatites than in gneisses and are closer to those in granitoids. When comparing the average chemical compositions of stromatites and paragneisses (Tab. 1), we find that gneisses are more variable. Some slight statistical differences can be observed only in CaO contents and reversed Na_2O/K_2O ratio. Ophtalmites, as opposed to gneisses, have higher SiO_2 and lower CaO, MgO contents and again, the reversed Na_2O/K_2O ratio. The origin of K-feldspar loops has been considered as a result of elevated contents, and/or penetration of K_2O into ophtalmites. Even a simple comparison of stromatites and ophtalmites (Tab. 1) shows that there are no greater statistical differences in the contents of alkaline elements between these rock types. As it was proved by a discrimination analysis stromatites, as opposed to ophtalmites, have elevated Fe, Mg, Ti and lowered Si contents. Discrimination quality was high.

Paragneisses. When compared with granitoid rocks, the paragneisses show a higher peraluminosity index and a lower K_2O/Na_2O ratio. Na contents are higher than those of K. With their chemical compositions the paragneisses are on the boundary between amphibolic rocks on the one hand, and migmatites and granitoids on the other. Their variable composition is a reflection of the protolith – a mixture of terrigenous and basic volcanogenous materials in various ratios (Pitoňák – Spišiak, 1988). The highest SiO_2 contents are found in quartzite gneisses the protolith of which represents the most mature sediments – sandstones in the region under study. Several authors investigated the protoliths of the gneisses of the Nízke Tatry crystallinicum by various geochemical methods (Hovorka, 1975; Pitoňák, 1985; Krist – Miko – Krištín, 1988). The results were equal. The character of most paragneisses of the Nízke Tatry crystallinicum corresponded to greywackes and subgreywackes which explains to a certain degree a rather rare occurrence of Al_2SiO_5 mineral modifications in the gneisses of the studied area. Pure clayey protolith seldom occurs in this

Table 1

Basic statistical data on the contents of major elements in some rock group

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5
paragneisses (11)											
x	66.93	0.77	14.85		4.66	0.08	1.80	2.87	2.82	2.21	0.16
s.d.	3.22	0.41	1.04		1.40	0.04	0.92	0.92	1.30	0.81	0.06
amphibolites (9)											
x	47.90	2.49	14.50	2.28	8.42	0.17	6.36	6.97	1.99	1.95	0.33
s.d.	4.81	0.91	0.80	0.85	1.55	0.05	1.60	2.32	0.53	0.79	0.13
Hbl-gneisses (11)											
x	54.24	2.02	14.10	1.76	7.59	0.15	5.65	6.59	1.81	2.04	0.22
s.d.	3.04	1.14	1.62	0.85	1.89	0.04	2.35	1.75	0.79	0.85	0.13
granodiorites + tonalites (22)											
x	67.40	0.48	15.29	1.47	2.32	0.06	1.69	2.71	3.59	2.98	0.17
s.d.	2.19	0.18	0.78	0.90	1.15	0.02	0.60	0.52	0.51	0.68	1.71
acid granitoids (30)											
x	72.05	0.23	14.47	0.75	1.24	0.04	0.72	1.32	3.18	4.27	0.17
s.d.	3.47	0.21	1.14	0.53	1.00	0.05	0.44	0.81	1.22	0.09	0.15
stromatites (11)											
x	66.89	0.70	14.56	1.00	3.74	0.06	1.77	1.94	2.42	3.64	0.16
s.d.	2.13	0.14	0.60	0.44	0.71	0.03	0.48	0.49	0.51	0.68	0.08
ophtalmites (6)											
x	70.30	0.45	14.04	1.21	2.53	0.04	1.08	1.63	2.85	3.65	0.16
s.d.	0.82	0.13	0.48	1.05	0.67	0.00	0.24	0.33	0.44	1.28	0.01
Al-rich gneisses (8)											
x	58.06	1.08	17.51		6.30	0.12	3.02	5.30	2.61	2.68	0.58
s.d.	3.19	0.24	1.97		0.77	0.03	1.01	0.89	0.96	0.59	0.18

area. The best representatives of the metamorphites originated from such or similar protolith are Al-rich gneisses. These rocks have specific chemical compositions, in particular high Al, Ca and P contents, which are reflected in mineralogical compositions: basic plagioclases, high amounts of accessories, especially apatite with typical pleochroic cores.

Metamorphism

PT conditions of metamorphism were studied from the compositions of rock-forming minerals and the distribution mainly of Fe and Mg between coexisting mineral phases. Mineral associations were studied in detail, too. On the whole, progressive and regressive metamorphisms can be distinguished between. Available geochronological data give us evidence on progressive metamorphism having taken place in Variscan orogene. There are varying opinions on the age of regressive metamorphism. Several authors count it for a regressive branch of Variscan metamorphism and the others for Alpine diaphtoresis. The detected mineral associations correspond to the biotite-muscovite-gneiss facies following the facies classification by Korikovsky (1979). For this facies there are temperatures from 580 to 630° C and pressures from 3.5 to 5.5 kbar. In the region of the Zámostská hoľa hill the facies passes to the sillimanite–biotite–orthoclase one. Similarly, various thermobarometers (Perchuk, 1967; Perchuk et al., 1983; Thompson, 1976; Ferry–Spear, 1978; Hodges–Spear, 1982; Ganguly–Saxena, 1984; Indares–Martignole, 1985; Ghent et al., 1979; Koziol–Newton, 1987) were used for the determining of temperatures and pressures. Pressures varied within 4 and 7 kbar with the maximum about 5 kbar. Temperature conditions correspond to the mineral associations quite well. In the southern part temperatures increase from 550–650 °C to 650–750 °C or higher in the zone of the Zámostská hoľa hill, i. e. towards the Nízke Tatry pluton. Due to low and discontinuous metamorphite occurrence no zonality was observed in the north of the Nízke Tatry Mts. The results of the individual thermometers were often considerably different. Fig. 9 illustrates the results taken from one sample. The obtained results show, that the regional metamorphism was earlier than granite penetration into the present layers and a younger thermal metamorphism was superposed as an effect of the granite intrusion. Regressive metamorphism was superposed on these two relatively separate (though closely connected) processes.

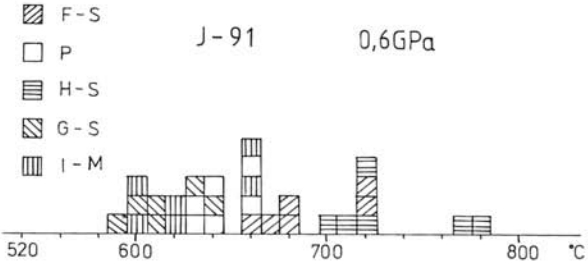

Fig. 9. Temperature comparison according to various thermometers for Gar – Bi pair. Sample J-91, F-S = Ferry–Spear, 1978; P = Perchuk et al., 1983; H-S = Hodges–Spear, 1982; G-S = Ganguly–Saxena, 1984; I-M = Idares–Martignole, 1985. Temperatures are calculated at a pressure of 0.6 GPa.

Progressive metamorphic rocks of the greenschist facies as well have been described in the Tatric part of the Nízke Tatry crystallinicum. They are most spread in the southern part of the Nízke Tatry Mts., in the region of the Biela voda valley (P e c h o et al., 1983; M o l á k et al., 1989). As the genesis of these rocks has not been clarified enough yet and they may also be tectonically and hydrothermally altered higher-grade metamorphic rocks, we have not considered them as a low-grade metamorphic facies of the rocks.

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