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MANIFESTATIONS OF CONTACT METAMORPHISM IN THE NW PART OF SLOVENSKÉ STREDOHORIE MTS.

(*Fig. 1–10*)

Abstract: In the NW part of Slovenské stredohorie Mts. manifestations of contact metamorphism were found, as a consequence of active intervention of deep-seated diorite nature masses into the adjacent sedimentary, sedimentogenous and volcanogene environment. In the presented work mainly those features of contact metamorphism are reported, which revealed as typical in this regions, owing to the effects of the intrusion on sedimentary series. This knowledge derives from a present analysis of a deep-drilling and is part of detailed investigations in this region.

Резюме: В СЗ части Словацкого Стредогорья были обнаружены проявления контактного метаморфизма как результат активного воздействия глубинных масс диоритового характера на близлежащие, осадочные, седиментогенные, и вулканогенные условия. В предлагаемой работе автор приводит главным образом те признаки контактного метаморфизма, которые проявились в этой области как типичные в результате воздействия интрузии на осадочные серии. Эти познания исходят из анализов глубинных скважин, проведенных до сих пор и являются частью детального исследования, проходящего в настоящее время.

Introduction

Manifestations of contact metamorphism, thermic, as well as metasomatic, were intensively studied recently, as they may be regarded as direct evidence of processes of qualitative mineral transformation of rocks situated in the proximity of intrusive magmatic bodies, due to the effects of a local thermic field, and thus reflecting thereby also the concrete geological conditions by which they have been induced.

The present state of study of these problems in the West Carpathians can be designated as gradual orientation in the paragenetic analysis of the mineral association, which alone may be regarded at present as basis for the determination of pt conditions of the creation of products of contact-adjacent metamorphism, as well as a basis for eventual selection from the view of economical effectivness.

The manifestations of contact metamorphism in the region of Slovenské stredohorie Mts., namely in its SE tract in the Štiavnické pohorie Mts. were long ago known and are relatively the most abundant, taking into consideration some particular montane complexes of the West Carpathians. A considerable number of occurrences (14 altogether) in the SE part of Slovenské stredohorie Mts. is due also to the relatively wide prospection on this area (fig. 1).

Individual occurrences of the products of contact, thermic and metasomatic alteration in this region are allied to the endo- and exozone of the contact field and reflect (the majority of occurrences) contact-near metasomatic processes. Only sporadic occurrences reveal prevalently thermic contact processes (J. Šalát 1954, F. Zábranský 1969; M. Kodĕra 1960). Contact-metasomatic and thermic transformations in the SE part of Slovenské stredohorie Mts. were induced by a granodiorite-diorite intrusion (as

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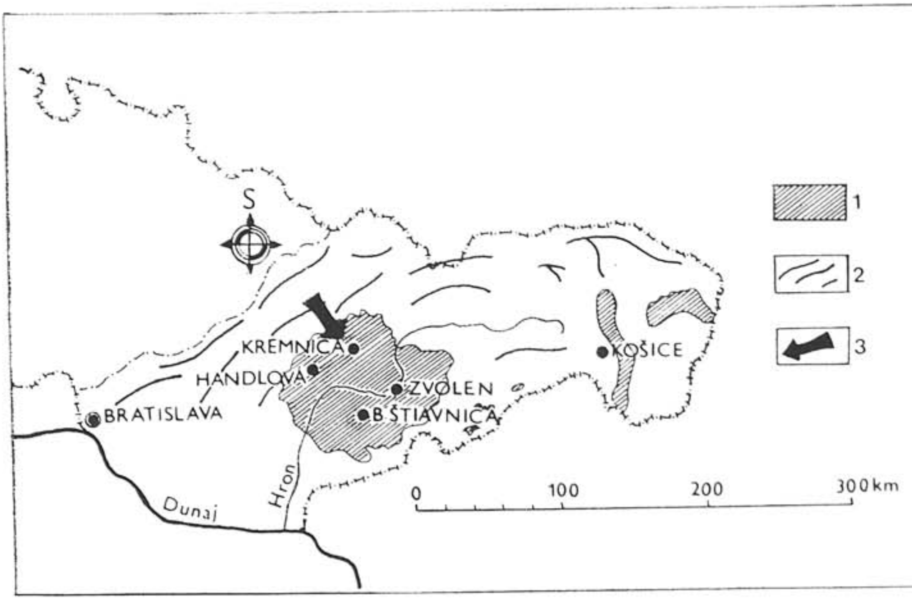


Fig. 1. Scheme of the situation of Slovenské stredohorie Mts. in the central, southern part of the West Carpathian arc in the scale 1:50 000 000. 1. — Tertiary volcanism in the West Carpathians. 2. — Pretertiary and Paleogene mountain formations of the West Carpathians. 3. — Occurence of contact metamorphism.

indicated by these authors) on carbonate and carbonate-magnesium, sedimentary Mesozoic series, sporadically on the Permian. Some occurences of products of contact metamorphism were produced by massive apophyses of a granodiorite intrusion of porphyric development — by granodiorite porphyry. Owing to their presence in close connection with them, they were interpreted as such in the sense of these authors.

Nevertheless, the occurence of hypabyssal dyke and vein bodies was known long ago, in the NW part of Slovenské stredohorie Mts. in Kremnické pohorie Mts. manifestations of contact metamorphism were not known. Recently in the course of intensive prospection work and investigations, products of contact, thermic and metasomatic alteration were established in this region (M. Böhmer 1973, M. Šímová 1973) in the deep-seated basement beneath the mass of surface and subsurface volcanism. In the presented work some features of contact metamorphism are dealt with, determined so far by macro- and microanalysis of a drilling bored in the central part of Kremnické pohorie Mts.

Approximate data on the geological structure of the NW part of Slovenské Stredohorie Mts.

Approximate data on the geological structure of the NW part of Slovenské stredohorie Mts. already confirm that a region variegated and complicated from geological and tectonical point of view, is concerned.

The NW section of Slovenské stredohorie Mts., the region of Kremnické pohorie Mts., is built on the top by products of post-Tortonian volcanism. The initial most ancient stages of this volcanism produced according to F. Fiala 1961, andesite lavas, the younger stages rhyolite and rhyodacite lavas and during the youngest stages originated in much smaller amounts than in the latter phases basaltoide and basanitoide lavas.

On surface levels the volcanic facies dominates. From mining works and several drillings bored in the central part of Kremnické pohorie Mts. it is known (M. Böhmer 1971), that also the subvolcanic facies of acid and intermediate character participates in the structure of Kremnické pohorie Mts. represented by a series of vein and dyke bodies of diorite and granodiorite nature. Their explicit close relationship to the volcanic facies does not follow from the petrostructural features, as well as from the mineral associations of these complexes, also owing to lack of present investigations. The interrelation of the diorite and granodiorite bodies is not explicit. A number of signs like the tectonic alliance, the position, the natural relations, the postmagmatic neomineralization, the eventual active contact with the encompassing environment of these vein and dyke bodies, confirm or indicate a close connection with the magmatic facies acting in subsurface levels of the volcanics.

Under the mass of young volcanic rocks inclusively the mentioned volcanic bodies, as it is recorded by (O. Fusán — M. Kuthán — S. Ďuratný — J. Plančár — L. Zbořil 1968), geophysical data indicate, a „Malachov part" of the Malachov—Lieskovec elevation with general NW—SE trending ridge of complicated spatial and temporary development, conditioned and influenced by Sudetic, Alpine and younger tectonic systems. The ridge of this elevation was cut in various depth levels from 200 to 600 metres. It is cropping out north of Zvolen near Lieskovec (c. D.). The Veporides, their Envelope unit in the scope of the Triassic—Jurassic—Low Cretaceous and the Choč nappe are assumed to participate likely on the structure of this complicated ridge. According to the cited authors the postalpine formations and the central West Carpathian Eocene cannot been eliminated.

Data on the extension, the quality and quantity of these units are so far not available or uncompletely only.

According to O. Fusán et al. (1968) these geophysical data indicate in the basement of the volcanic complex an extensive intrusion reaching from Handlová to the underlying of Javorie, to the easternmost part of Slovenské stredohorie Mts. These authors assign to this intrusion the Hodruša—Vyhne granodiorite from Štiavnické pohorie Mts. and the Lieskovec granite cropping out in the area of Zvolen.

The centre of the „Kremnica ore field" as it was denominated by M. Böhmer (1971), with its endogenous mineralization is related to the volcanic, subvolcanic and hypabyssal facies, lying above the Malachov section of the Malachov—Lieskovec ridge.

Into this suggested and only partly proved complicated structure of the central parts of Kremnické pohorie Mts., several deep-drillings have been situated and realized during the last years. The deepest one bored so far in this area pierces the intrusion and its contact aureole.

The contact aureole of Kremnica

The up to present deepest drilling in the NW part of Slovenské stredohorie Mts., situated 2 km NNW from Kremnica, the drilling Kr-3, pierces according to M. Böhmer (1973) and M. Šímová (1973) in surface levels a 280—300 m thick bed of pyroxene, hypersthene-diopside andesites and their explosive equivalents (on effusion basis). In their subposition the drilling penetrates trough several massive vein and dyke bodies of pyroxene, quartz-free diorite of „pseudoophitic" crystallization sequence (with idiomorphic andesines An_{49-53} and interstitial uralitized diopsides), and series of altered sedimentary and metasedimentary rocks in a total range of 1100 metres up to a depth of 1300—1400 m.

In the deepest reached levels from 1765—1779 metres the diorite intrusion was cut in a scope of 14 m.

The intrusion-adjacent medium in a width of appr. 60 m displays features of the intensive acting thermic effect of the diorite intrusion. In this part a great number of contact hornfelses, crystalline limestones and quartzites were found by M. Šimová (1973) already by the initial analysis of the drill.

It could be determined that the intrusion-adjacent environment close and far off the intrusion suffered by recrystallization and neomineralization. Relics were observed sporadically in the recrystallized and neomineralized medium with partly preserved textures of clastic and blastic rocks of the sandstone and paraschist type. These relics already authorize us to speak about the metamorphism of „sedimentary and metasedimentary" or „sedimentary and sedimentogenous" series, as this has been stated above. These relics are neither so numerous, nor explicit in order to serve as basis for considerations on the pre-contact nature of the intrusion-adjacent rocks, or their series. In any case they are the impulse for their investigation, eventually also in close proximity.

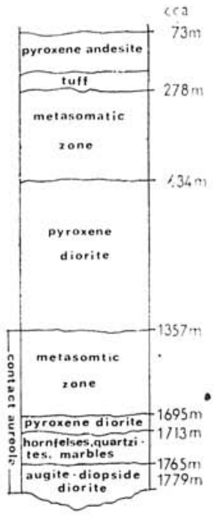
The zone of hornfelses, crystalline limestones and quartzites, as well as the intersected zone of the intrusion are penetrated by a dense net of craks of various thickness. Their mineralization appears very unhomogenous: of high- and low-temperature range, ore and non-metalic mineralization in places related only to joints, sometimes penetrating gently into already contact-metamorphosed spaces around the joints. On some sites the mineralization is peculiar (anizotropical andradite-grossularite crystalline and compact vein filling), in places of an intensity overlapping the products of contact thermic transformation to such an extent, that these may easily be disregarded by microanalysis, and naturally, by macroanalysis.

There is no doubt that these phenomena are in connection with contact-metasomatic high- and low-temperature processes, skarn-forming processes including. Neither by their extent, nor by the content are these features negligeable and the whole area is going to be specially studied from this point of view.

According to the up to present results of microanalysis, to the suggested evidence for the active effect of the diorite intrusion belongs also the biotitization of a diorite vein, in the distance of 60 m from the intrusion and of a cordierite-bearing rock group in 400 m distance of the intrusion, with relics of sedimentary and metasedimentary rocks, analoguous to those found in deeper positions nearer to the intrusion. These rock series far off the intrusion are similarly affected by post-contact processes and cordierite in them is either relict or highly sericitized (pinitized) (fig. 2).

The total extension of the contact aureole in the region of Kremnica exceeds inclusively the endo- and exozone several 100 m.

The endozone cut approx. in 15 m size, is marked by the well preserved magmatic character of augite-diopside diorite of dinstinct abyssal development of the augite, $c/\gamma = 45°$, (1—2 cm phenocrysts) and by hypabyssall development of diopside and andesine An_{53}. The augite individuals are corroded and show reaction rims of uralitized diopside and magnetite. The diopside and the feldspar portion is more or less intensively replaced (this replacement is waning out towards depth and in the rock predominate primary magmatic diopsides and andesines) by interstitial with regard to



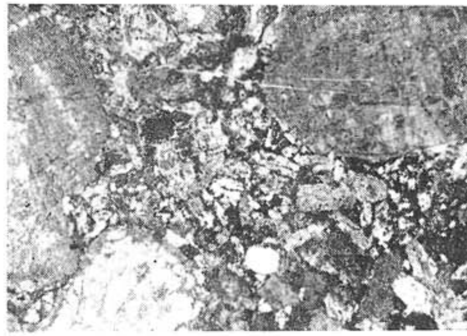


Fig. 3. Augite-diopside diorite from marginal parts of the intrusion, 2 km NW of Kremnica, from 1779,60 m depth. Magnif. 12 X. x nicols. Photo L. O s v a l d.

Fig. 2. Scheme of the section through the contact aureole according to the drilling Kr-3. bored 2 km NW of Kremnica.

augite grainy isotropic grossularite-andradite, scapolite, magnetite, pyrite and zoisite. The augite interspaces are locally filled up with calcite, sericite, pyrite and magnetite and the rock gained the character of a „contact-adjacent porphyric breccia" (fig. 3 and 4). Even this mineral association of the endozone together with the petrotextural features of diorite confirm that also in the marginal parts of the intrusion several successive separate isolated or overlapping contact metasomatic processes were active in a wider temperature range (fig. 3, 4, 5).

In turn contact metasomatic character dominates in the exozone and the products of contact metamorphism were strongly replaced.

By special selection of samples from the drill ore for microanalysis it was possible to identify several groups of mineral associations of hornfelses:

garnet-diopside hornfels with wollastonite
pleonaste-periclase-brucite hornfels
periclase-brucite hornfels
spinel, diopside hornfels.

Garnet-diopside hornfels with wollastonite was identified in close vicinity of the intrusion, in the form of narrow stripes. It is of typical hornfels texture, its granularity does not exceed 1 mm. Garnet is of the grossularite-andradite typen is somewhat higher than 1,70, mainly isotropic, reacting rarely in polarizing light. Short-columnar diopside crystals show $c/\gamma = 36—39°$. In minute up to fibrous crystals wollastonite is unconspicuous (macroscopically it is more striking). In some particular grains of hornfels appear vesuvian-idiocrase and along the hornfels stripes numerous crystals of the epidote-zoisite group, inclining by their optical properties to zoisite, in places also interstitial calcite was found. These, however, are not of contact-thermic origin and their replacing tendency is striking.

Pleonaste-periclase-brucite hornfels is a white to yelloish fine-crystalline rock of greasy luster. Owing to its granularity it is impossible to distinguish in this hornfels the minerals macroscopically (this being the case also with other hornfelses). Its texture is conspicuously granoblastic. Periclase appears in isometric, rhombic and tetragonal-

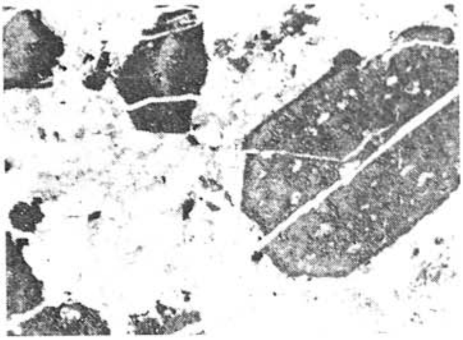


Fig. 4. Augite-diopside diorite from marginal parts of the intrusion. 2 km NW of Kremnica, 1779.60 m depth. Magnif. 43 X. x nicols. Photo L. O s v a l d.

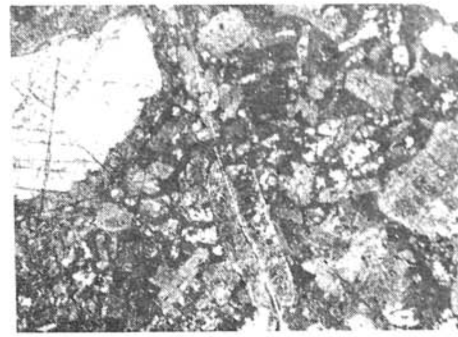


Fig. 5. Augite-diopside diorite from the marginal parts of the intrusion. 2 km NW of Kremnica, 1765.30 m. Magnif. 11 X. x nicols. Photo L. O s v a l d.

like sections of 1—2 mm sizes. It was identified only in isotropis form with n somewhat lower than 1.70. Many transparent grainlets show submicroscopical pigmentation. A part of the grains is replaced by microscopical up to submicroscopical brucite flakes. Brucite is fine-flaky, $^1/_2$—1 mm in size, under the microscope reminding micaceous crystals, transparent, with dense, parallel cleavage cracks on the vertical faces, showing parallel extinction. In maximal brightness it has variegated interference colours of brownisch tints and bronze luster. The base planes have no cleavage cracks, the interference colours are grey, sometimes of undulatory extinction, another time it does not react to polarized light. On these planes it displays reliably monoaxial positive o. s. These crystals appear in aggregates and also in individual grains, the latter in striking tetragonal shapes. Brucite flakes replacing periclase are smaller in size, those occuring in veinlets penetrating through these and other hornfelses are much larger, 2—5 mm, with analoguous characteristics.

Pleonaste appears mostly in 1—2 mm isometric grains. Its relief is high and the cleavage cracks are conspicously unoriented. It is of green colour.

Periclase-brucite hornfels a bimineralic association the mineral properties analoguous

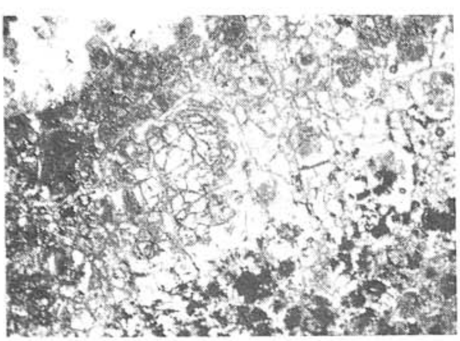


Fig. 6. Pleonaste-periclase-brucite hornfels. 2 km NW of Kremnica, 1773.50 m depth. Magnif. 43 X. x nicols. Photo L. O s v a l d.

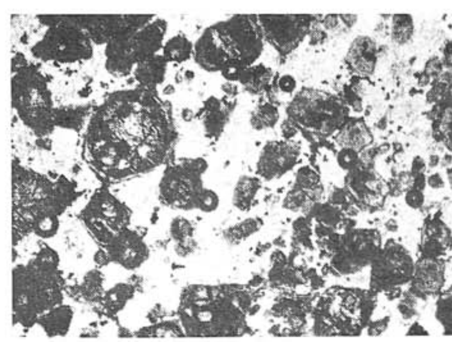


Fig. 7. Pleonaste-periclase-brucite hornfels. 2 km NW of Kremnica, 1773.50 m depth. Magnif. 43 X. x nicols. Photo L. O s v a l d.

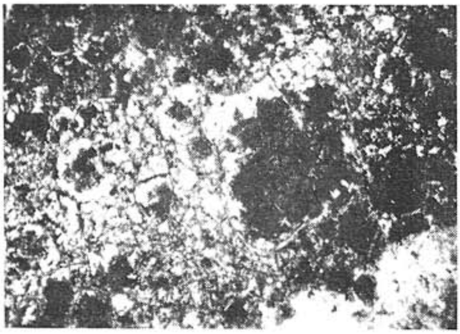


Fig. 8. Pleonaste-periclase-brucite hornfels. 2 km NW of Kremnica. 1773,50 m depth. Magnif. 43 X. x nicols. Photo L. O s v a l d.

Fig. 9. Pleonaste-periclase-brucite hornfels with contact-adjacent metasomatic mineralization and a brucite veinlet. 2 km NW of Kremnica. 1773,50 m depth. Magnif. 43 X. x nicols. Photo L. O s v a l d.

to those of the former hornfels. On the enclosed figures they are partly metasomatically replaced (fig. 6. 7. 8. 9. 10).

Spinel-diopside hornfels. Bimineralic „lenses" were found on several sites, approx. in the same depth level as the above mentioned hornfelses with periclase, brucite and pleonaste. Spinel is in them strikingly transparent (with regard to diopside), $n = 1.76$. Diopside shows analoguous optical characteristics as the former hornfelses.

I do not deal in this work with the mineralization of the contact metasomatic stage (marginally only as ore and non-metallic mineralization), as it is the aim of this work to give fundamental data on the manifestation of contact metamorphism in a region, where so far it was not known, and secondly, because its diversity, succession and alliance to a certain environment or zone is so complex that it requires an analysis in broader context. Thus, it would be precocious to make definitive conclusions on the basis of the up to present investigated material.

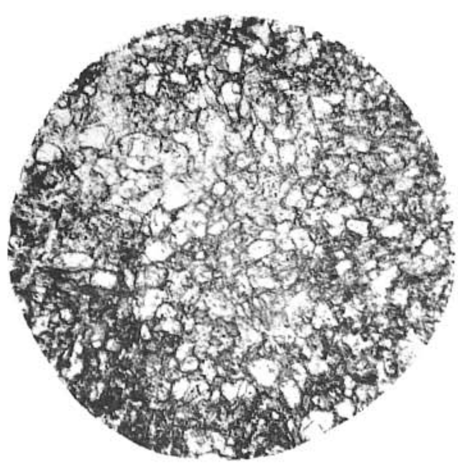


Fig. 10. Garnet-diopside hornfels. 2 km NW of Kremnica. 1779 m depth. Magnif. 64,5 X. x nicols. Photo L. O s v a l d.

Interpretation

The data given on the features of contact metamorphism in the NW part of Slovenské stredohorie Mts. can be interpreted as follows:

1. In the deep-seated basement of the centre of the NW part of Slovenské stredohorie Mts. a contact aureole of several 100 m size is extending on the contact of the diorite intrusion and the intrusion-adjacent series.

2. In the time of its action on the adjacent medium the diorite intrusion has been already a partly shaped mass. Considering the present knowledge on massive intrusive bodies inducing intensive recrystallization, while dykes or veins reveal only unsubstantial effects, massive bodies and laccoliths give raise to a more intensive contact metamorphism by their apical parts than by the basal ones. In this sense the diorite intrusion should not represent on this site its apical part, neither the highest degree of metamorphism. It may be assumed in closer or more distant environment and in turn we can suggest the subsidence of the intrusion surface towards its more basal parts, where untransformed intrusion-adjacent series or their waning out could be expected.

3. The character of the products of contact-thermic metamorphism is distinctly calcareous-magnesian and magnesian. This is an important notion for their interpretation as products not only recrystallized, but with a variegated mineral association .thus contact-neomineralized.

Comparing the magnesium hornfelses of the investigated region with the results of experimental works of A. J. Cvetkov (1949) who gained periclase and brucite by heating of dolomite we can explain the genesis of periclase in the periclase-brucite hornfels association which is differentiated as a thermic association of contact metamorphism by dedolomitization of dolomites and Ca—Mg limestones:

$$CaMg(CO_3)_2 = CaCO_3 + MgO + CO_2$$

and the formation of brucite in this association by hydratatian following this dedolomitization:

$$MgO + H_2O = Mg(OH)_2$$

In the sense of this comparison brucite whose hydrothermal origin in the studied hornfelses is not evidenced, would not be explained sufficiently. G. Turner (1951) reports unhydrothermal brucite as common in the facies of pyroxene hornfelses.

The formation of spinel in magnesium hornfelses can be explained by Al admixture in dolomites or in calcareousmagnesian limestones:

$$CaMg(CO_3)_2 + Al_2O_3 = MgAl_2O_4 + CaCO_3 + CO_2$$

The cited experimental works report on the formation of spinel and diopside ev. forsterite with simultaneous presence of Al and Si in dolomites.

The sedimetary series into which the diorite mass has been intruding were of calcareous-magnesium up to dolomite character, enriched locally in Si colloids (opal or quartz), in places with argillaceous and marly layers.

Sedimentary series which gave raise to calcareous silicate hornfelses with grossularite, had the character of calcareous sediments enriched in clayey and marly constituents.

4. The thermal regim in the course of a phase of contact metamorphism indicates the

process of periclase genesis. Considering the experimental works of A. J. Cvetkov (1949), the dissociation of calcite is starting at 860 °C and that of magnesite at 610—620 °C. Pressure increase raises and the presence of light volatile compounds decreases the temperature of dissociation. Therefore the dissociation of the Mg component in carbonate with the formation of periclase and the recrystallization of the Ca carbonate sets in. In addition periclase reacts with water and is affected by brucitization.

Even if we do not accept this knowledge as a whole, the majority of the hornfels minerals originated by contact metamorphism (spinel, pyroxenes, wollastonite), lets us suggest that contact metamorphism took place under the conditions of the pyroxene hornfels facies.

Explaining at least marginally the relation between the diorite intrusion and the superponed diorite veins and dykes, the diorite intrusion is younger than the diorite vein, the biotitization of which may be regarded as the product of contact metamorphism. The relation of the diorite intrusion to the other veins and to the huge pyroxene diorite dyke, as well as to the roof lavas of the pyroxene andesite is evidently successive and the subject of further investigations.

6. The relation of the intrusion to the metamorphosed sedimentary series of calcareous-magnesium up to dolomite nature with clay intercalations, marly and colloid Si beds indicates that a „neointrusion" is concerned. This problem will be studied separately on petrogenetic characteristics and textural features of the diorite intrusion, the diorite veins and dykes and on the effusive equivalents of the diorite magma, on pyroxene andesites occuring in this region.

Conclusion

By the analysis of the deep-drill Kr-3, bored in the central part of Kremnické pohorie Mts. an intrusion of augite-diopside diorite has been cut and on its contact with the intrusion-adjacent medium a contact aureole of several 100 m size war found. The aureole displays endo- and exozonal thermic and metasomatic development. Contact-thermic metasomatism conditioned the development of hornfelses, crystalline limestones and quartzites. From hornfelses typical for this region and for the region of the West Carpathians were differentianed magnesium-calcareous and magnesium types of garnet-diopside hornfelses, periclase-brucite hornfels, pleonaste-periclase-brucite hornfels, spinel-diopside hornfels and others.

The endo- and exocontact zone is penetrated by a dense net of joints with unhomogenous and variegated mineral filling, likely allied with the contact-adjacent metasomatic and skarnforming processes. Their features are relatively intensive and overlap in places the products of thermic metamorphism.

To manifestations of contact metamorphism belongs also the biotite zone the biotitized vein diopside diorite and the cordierite zone in the periphery part of the aureole.

The present knowledge on the nature of contact metamorphism and its interpretation follow from the macro- and microscopic study of the bore core, of the deepest drill in this region. Research is still going on in detailed paragenetic analysis.

Translated by L. MINÁRIKOVÁ.

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