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MAGMATIC ROCK FORMATIONS IN THE WEST CARPATHIANS AND THEIR METAMORPHIC EFFECTS

Abstract: The problem of plutono-magmatic sources of metamorphism of schistose rocks of the West Carpathian crystalline is discussed in the work. Variscan or Variscan—Caledonian granite plutonism is regarded as most important. It is stated that neither Precambrian rocks nor Precambrian magmato-orogenic cysles have so far been proved in the modern relief of the West Carpathians. Even in the Caledonian era no separate orogenic processes of Caledonian folding have been confirmed, or at least they cannot be distinguished from Variscan ones. Geochronological data indicate (Rb-Sr isochrone method determined the age of 360—395 m. y.) that already at the boundary of the Devonian and the Silurian, there began supply of thermal energy. Therefore the Variscan granitoid plutonism intensively developed as early as in the Lower and Middle Devonian and the individual intrusive stages of the granite magmatism gradually ascended as younger differentiates of various petrological character. Besides the principal types of the Variscan granitoids also Gemeric granitoids have to be regarded as an independent granitoid formation. Their different ages have not been confirmed geochronologically with certainty (Carboniferous—Permian—Jurassic—Cretaceous). In comparison with the principal types of the Variscan granitoids of the West Carpathians, they represent geochemically different and variable types, but not all leucocratic, relatively younger granitoid apophyses belong to the formation of Gemeric granitoids. As regards metamorphism of the crystalline, metamorphic effects of rock types other than granitods are insignificant.

Резюме: В статьи дискутируется о плутонически-магматических источниках метаморфизма сланцевидных пород кристаллиникума Западных Карпат. Самым важным считают автори варисцийский, или варисцийско-каледонский гранитный плутонизм. Констатируется что до сих пор не удалось в настоящем релиефе Западных Карпат подтвердить докембрийские породы ни докембрийские магматические орогенические цикли, но в каледонской эре тоже небыли определены самостоятельные орогенические процессы каледонской складчатости или их нельзя отличить от варисцийских. Геохронологические данные определенные Rb-Sr методом (360—395 м. лет) указывают что в каледонской эре на границы или в конце силурского периода начал приток тепловой энергии. Поэтому варисцийский плутонизм развивался интенсивно уже в нижнем и среднем девоне и отделные интрузивные фазы гранитного магматизма постепенно выступали как дифференциаты различного петрологического характера.

Самостоятельной формацией гранитоидов должно считать кроме основных типов варисцийских гранитоидов тоже гемеридные гранитоиды, различный возраст которых был геохронологически подтвержден (карбон-пермь-юра-мел). В сравнении с основными типами варисцийских гранитоидов Западных Карпат они являются геохимически отличными и изменчивыми, но не все лейкократовые, сравнительно более молодые гранитоидные апофизы во вепоридах принадлежат к формации гемеридных гранитоидов. Метаморфическое действие других типов пород кроме гранитоидов кристаллиникума с точки зрения метаморфизма кристаллиникума являются незначительными.

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At present deep-seated metamorphic processes of Variscan magmatic-orogenic cycle are regarded as the main source of metamorphic processes. They are closely associated with the development of granite plutonism, which has various manifestations taking place in different depth horizons during a longer time span (im excess of 100 m.y.) (B a g d a s a r y a n et al., 1982, 1983, 1986; B i b i k o v a et al., 1988; C a m b e l et al., 1988). The Variscan granitoids were formed and/or intruded in several stages of the orogene development. They ascend closer to the surface in various stages of differentiation and consequently in various time and development stages. The basic and most common variety of the granitoids that underwent differentiation is biotite granodiorites to tonalites, from which more leucocratic differentiates, mainly muscovite-biotite and biotite granodiorites and/or muscovite-biotite granites, pegmatites. and aplites are derived. Minor amounts of dioritic and gabbroid rock types are formed locally. Most geologists regard the West Carpathian granitoids as middle to upper crustal products formed by the anatexis of Paleozoic and/or Upper Proterozoic detritic sediments often of graywacke character intercalated with clayey and clayey-quartzy to sandy sediments and rarely also with marly or more carbonatic rocks. The sediments locally contain also organic matter, sometimes considerably concentrated giving rise to black shales. These sedimentary rocks alternate with effusions of basic magmas, mostly of tholeiite character, accompanied by tuffs and tuffites and in places also by ultrabasic rocks. The protolith character of the sediments has been described in detail H o v o r k a (1974, 1979, 1982).

The original sediments deposited prior of the Variscan metamorphism and/or before the metamorphosis that began already in the Caledonian era do not attain metamorphic facies higher than green-schist. Biotite or micas, except for clastogene ones, indicate a beginning progressive metamorphosis associated with the supply of energy and heating of sediments which began during the Variscan and/or Variscan—Caledonian endogene processes.

The Caledonian tectonic-orogenic stages or sedimentation processes, according to earlier views due to the denudation of hypothetical Caledonian mountains, have not been distinctly identified in the West Carpathian area, yet. That is how it should be in accordance with the views on the development of orogens and geosynclines. It is noteworthy that the Variscan orogenic phenomena and tectonic structures cannot be distinguished from the Caledonian ones in the West Carpathians. Therefore any attempts to identify independent Caledonian parts of the West Carpathian crystalline besides the Variscan orogeny are futile, foredoomed to failure and belong into the realm of fantasy and old-fashioned thinking. On the basis of some recent geochronological data we can only state that as early as in the Caledonian era, possibly at the end of the Silurian and in the Devonian, there began effects of heat energy ascending that already in this period heated up rocks, which can be regarded as a preparatory stage of the colossal Variscan orogeny. This is suggested by geochronological dating of granitoid rocks by Rb/Sr isochrone analysis (about 380—390 m.y.).

We have neither geological nor radiochronological evidence of the presence of the pre-Paleozoic Cadomian and/or Baikalian folding. Similarly, no expected changes in the sedimentation and sediment character have been found. The evidence of a high-thermal regional metamorphosis associated with Pre-

cambrian synkinematic migmatitization and granitization, as stated by Maheľ (1986), Máška—Zoubek (1961), J. Kamenický (1967) and others could not have confirmed geochronologically the Precambrian age of these rocks (Krist—Krivý, 1985).

According to present-day views on geological and geochronological data, Precambrian metamorphic rocks are unlikely to occur in larger quantities on the present relief of the West Carpathian crystalline. There is no other geological evidence. On the contrary, the presence of the Paleozoic has been proved palynologically in many places of the supposed Precambrian (Čorná, 1968; Čorná in Cambel—Čorná, 1974; Čorná—Kamenický, 1976; Planderová, in Cambel—Planderová, 1985 and other works of Čorná and Planderová; Klinec — Planderová — Miko, 1975; Klinec — Planderová, 1981).

It is noteworthy that as late as in 1936 Zoubek (1936) regards the West Carpathian crystalline as Variscan and only in 1958 he submitted a hypothesis about its Precambrian age.* Nevertheless, this hypothesis has not been confirmed by geochronological and radiometric data obtained so far, nor there is a reliable geological evidence.

In order to summarize and evaluate all sources metamorphic processes in the West Carpathian area on the basis of real data, the following facts are given:

1. *The pre-Variscan metamorphosis* is characterized by low-temperature, anchimetamorphic stage and by metamorphosis attaining at most chlorite facies, usually without the presence of biotite. It is necessary to distinguish, however, whether such rocks is not a product of tectonometamorphosis and diaphtoresis of higher metamorphosed sequences. In the West Carpathian crystalline this rock type affected by progressive metamorphic processes to a minimum extent can be found only in the Spišsko-gemerské rudohorie Mts.

2. *The Variscan or Variscan—Caledonian*** progressive metamorphosis includes various degrees of the intensity as well as types of metamorphosis from chlorite facies through the formation of gneisses and migmatites to ultrametamorphosis of different manifestation. Here we place palingenic manifestations of solidification to differentiation of melt formed by anatexis. These metamorphic types were either regional metamorphic processes affecting large regions or the metamorphosis concentrated around some intrusive bodies and/ /or their promontories. The periplutonic regional metamorphosis thus formed with isometamorphic zones of various thickness and evident alteration zoning of the schist mantle depending on the distance from the intrusive source (e.g. Malé Karpaty Mts.) The metamorphic degree has been determined by means of the metamorphic mineral association (Korikovsky et al., 1984, 1985; Korikovsky — Putiš, 1986). In places where granitoids intruded into a

* Materials of KBGA, 4th congress 1958, Kijev 1960.

** The author sometimes introduces also the term Variscan—Caledonian metamorphism regarding radiometrically determined age of granitoid and metamorphic rocks of about 400 m. y., i. e. energy supply is presupposed already in the Upper Silurian or on the Silurian/Devonian boundary.

setting of low thermodynamic conditions, usualy by the ascending of the magma into younger, stratigraphically higher horizons, there originate contact-metamorphic phenomena with typical contact minerals — andalusite, cordierite etc. and hornfels rock texture (Malé Karpaty., Veporides).

Variscan and/or Variscan—Caledonian granitoids forming the *main formation* of the West Carpathian granitoids are represented by tonalites, mono- to two-mica granodiorites, two-mica to mono-mica granites, pegmatites and aplites. Metamorphic effects due to other rock types, e.g. basic gabbroid rocks and ultrabasic bodies, are insignificant in comparison with those of the granitoid rocks.

3. Special attention has to be paid to the so-called Gemeric Granites which are regarded as the source of siderite and polymetallic mineralization in the Spišsko-gemerské rudohorie Mts. and on the basis of K/Ar geochronologic measurements were considered Neoid (Cretaceous). Recent Rb-Sr isochrone analyses, however, have determined their Permian to Carboniferous, exceptionally Jurassic to Cretaceous age (K o v a c h et al., 1979, 1986). The problem is still unresolved. Results of Jurassic—Cretaceous determination may be considered as secondary ones, affected by younger geological events.

These granites surely have a different geochemical composition and therefore we place them into an *independent younger formation of Gemeric granitoids*. Some leucocrate vein rocks of the Veporicum may also belong into this formation. These rocks contain more fluids and elements such as B, Sn, W, Li, Be, rare earths. Also this youngest Late Variscan (Permian to Upper Carboniferous) formation probably still belongs to Variscan plutonic processes and gives rise to contact metamorphosis of Carboniferous and Permian sediments in the Veporic area. In several places of the Gemericum, drilling has discovered zoning and gradation of metamorphic degree, downward or toward larger massifs of Gemeric (?) granitoids. It is noteworthy that so-called Permian porphyries in the Ľubietová area have not been investigated geochronologically, yet and may have been derived from synchronous Upper Paleozoic Variscan magmatism.

4. *An independet formation* is represented by hypabyssal to abyssal bodies in the Central Slovakian Neogene volcanic area, i.e. the so-called Hodruša volcanic-plutonic Neogene granitoid complex (nowadays designated as the Hodruša-Štiavnica intrusive complex) which, mainly in the vicinity of Hodruša town, gave rise to skarn deposits at the contact with Mesozoic rocks (Š a l á t, 1954). The contact metamorphosis of the Mesozoic rocks often accompanied by manifestation of mineralization was caused by acid granitoid hypabyssal to abyssal differentiates (R o z l o ž n í k — Š a l á t, 1963, 1973) in the Hodruša area. They are of Neogene age and R o z l o ž n í k (1979) regards them as banatitetype rocks.

5. *The oldest but pre-orogeny geosynclinical formation* of igneous rocks in the crystalline is represented by magmatic manifestations of volcano-sedimentary sequences of the pre-Variscan geosyncline (Cambro — Silurian to Devonian in age). In the Spišsko-gemerské rudohorie Mts. these sequences are represented by considerable effusions and/or hypabyssal formations of rhyolites and dacites (porphyroid formation), or in other places by the predominantly younger so-called Rakovec Group of basic igneous rocks. In the central zone of the West Carpathians, similar acid derivatives are metamorphosed to a different

degree and are represented by the so-called Muráň Granite-Gneisses which are products of a special acid magmatism that took place also in the Central West Carpathians, i. e. in the Core moutain area, and Veporicum. The products of this acid magmatic activity in the Centralides and Veporicum were metamorphosed in the Variscan era, but which is important in took place almost throughout the West Carpathian crystalline. The magmatism has been studied mainly by Hovorka that, in the Veporic area, has determined its Paleozoic age (Hovorka, 1986). It includes also rocks of the Veporic part of the Nízke Tatry Mts., Ľubietová Orthogneisses, so-called leptinites of the Kráľova hoľa crystalline and other occurrences (Krist, 1977, 1979). In contrast to these rocks of the central zone characterized by alterations due to Variscan metamorphosis, Gemeric dacites and rhyolites (of the Porphyroid series) are predominantly only dynamometamorphosed and only in deeper horizons or in the vicinity of the Gemeric granitoids they are affected by plutonic manifestations of progressive metamorphosis. The problems of these rocks have been studied by numerous authors, mainly Bajaník, Hovorka, Grecula, Maheľ and others, but this paper is not aimed to deal with them.

In other places of the Tatraveporicum and Gemericum, the Variscan magmatism metamorphosed also various basic effusive and hypabyssal magmatic derivatives altered to amphibolites, gabbro-amphibolites, hornblendites, metadiabases, metatuffs (Dobšiná area and Klátov Group of metamorphic rocks), and carbonatic rocks forming intercalations in the metabasic rocks were altered to erlans (Hovorka et al., in press, Spišiak et al., in press). Similar erlans occur also in the Malé Karpaty Mts. (Cambel, 1954; Šimová–Šamajová, 1979; Cambel—Korikovsky et al., 1989). This category of igneous geosynclinal rocks of Paleozoic age (Cambro — Silurian to Lower Devonian) represents a formation which, as regards its metamorphic effects upon the surrounding rocks, is of little importance and is overshadowed by younger Devonian — Carboniferous (Variscan) granite plutonism.

Of special importance are researches carried out by S. Korikovsky and some of this co-workers. They deal with retrograde alterations of rocks and Alpine tectonic-metamorphic manifestations (Cambel—Korikovsky et al., 1986). These researches have undermined the opinions of Vrána (1964, 1980) that the Alpine orogeny, which apart from the Variscan is the second positively proved orogeny in the West Carpathian area, gave rise to metamorphic rocks of higher thermodynamic metamorphic conditions. The researches have proved that the metamorphosis was retrograde Variscan and distinguished it from the Alpine metamorphosis, the progressive development of which did not exceed chlorite facies intensity.

It may be concluded that, according to present-day views on the tectonic structure of the West Carpathians, combinations of Variscan and Alpine tectonics have produced hypotheses about different degrees and forms of allochthonous and very complex tectonic and nappe structure of the crystalline (which concerns also nappes of the extensive West Carpathian granitoid massifs). According to these views, the position of the individual crystalline complexes and units in the West Carpathian crystalline cannot be regarded as original. Hypotheses of individual authors as well as concepts of the geological structure of the mountains are often so contradicting that they cannot be united and generalized. This is due to the fact that little attention is paid to laboratory research results

and also because of the lack of structural drillholes which could be useful in explaining the results of geophysical investigations by the identification of rocks forming physical boundaries and thus to support the interpretations of geologists-tectonists that suffer from insufficient fundamental informations for their statements.

Conclusion

On the basis of published results and new knowledge on thermodynamic researches of the West Carpathian metamorphic rocks as well as on the basis of geochronology of individual geological processes, the submitted work deals with the principal sources of metamorphic activity in individual regions and magmato-orogenic cycles.

1. The author essentially regards near-surface schistose rocks of the crystalline as Paleozoic. Nevertheless, he does not rule out also possible occurrence of a limited amount of Upper Proterozoic rocks in the West Carpathians, but these have not been proved in the modern relief.

2. As the main source of progressive metamorphism the author considers Variscan granite plutonism. Granitoid magmas ascending into higher crustal horizons form, in several mountain ranges, more or less intensive metamorphic zoning in schists around a plutonic metamorphic source often represented by granite intrusions and/or mobilized migmatites. In the extreme case, periplutonic abyssal contact metamorphism of regional extent or contact metamorphism with a typical contact mineral association take place.

3. New geochronological data indicate Variscan age of granitoids which did not solidify in the late orogenic stage of the development of the Variscan orogeny (Lower and Middle Carboniferous) as it was previously assumed, but in the initial one (approximately 360—395 m. y.) and therefore the author supposes that metamorphic manifestations and formation of some part of granite magmatic melt could have taken place as early as at the beginning of the incipient Variscan orogeny or also at the Silurian/Devonian boundary or at the end of the Silurian when thermal energy was introduced. The author regards this period as a preparatory stage of gigantic Variscan orogenic and plutogenic processes. There is no evidence so far of the existence of independent manifestations of the Caledonian orogeny in the West Carpathian area or these manifestations have not been distinguished from Variscan tectonics on the modern relief.

4. In accordance with earlier views the author distinguishes the formation of rocks metamorphosed in the pre-Variscan era or in the Lower Palaeozoic (Lower Paleozoic geosynclinal sediments interlaced with extrusive-hypabyssal products of acid or basic volcanism). Metamorphism due to this magmatism is insignificant and nowhere exceeds the green-schist facies.

5. Of prime importance is Variscan progressive metamorphism caused by granite plutonism. It has various manifestations and intensity according to the depth of zones in which these processes took place and according to the character of the processes as well as periods when intruding magma, differentiated to various extent and differently metamorphosing surrounding schists, ascended. The Variscan metamorphism affects nearly all zones and horizons of the West

Carpathian crystalline and its various lithologic (including Devonian limestones), lithofacial and magmatogene derivatives.

6. As a special formation the author distinguishes granitoids of the Spišsko-gemerské rudohorie Mts. whose age has not been proved unequivocally (we have not zircon analyses) (Upper Carboniferous, Permian, Jurassic?, Cretaceous?) and which form periplutonic or contact aureoles in the Gemeric crystalline. Partly analogical younger rocks occur in the Veporic crystalline, too. The Gemeric schist crystalline composed of different lithological types is locally metamorphosed also by the Variscan granitoid plutonism.

7. The author is of the opinion that the Alpine progressive metamorphism does not exceed chlorite metamorphic facies and only due to Variscan plutonic manifestations schists are metamorphosed into a higher grade. There exists no high-temperature Alpine metamorphism. High-temperature mineral association in crystalline rocks (so called diapthoric mica schists) represents manifestations of retrograde metamorphism which took place in the last stages of plutonic and/or Variscan tectonic processes. These processes may be naturally combined with Alpine tectonometamorphic ones.

8. The author states that the present views on the tectonic structure of the West Carpathian crystalline are based upon insufficient amount of evidence and consequently the views on the structure and tectonics are often considerably contradictory, especially as regards the extent and character of the allochthonity of the West Carpathian crystalline. That is why it is impossible to form a comprehensive united scheme.

There is a special shortage of check drillholes which could confirm supposed structures, and also some exact measurements carried out in the field as well as laboratories.

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