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PEBBLES OF SILICEOUS CLASTICS AND SILICEOUS ROCKS IN CONGLOMERATES OF FLYSCH SEQUENCES (ALBIAN, CENOMANIAN) IN VICINITY OF THE POVAŽSKÁ BYSTRICA TOWN, KLAPE UNIT, PIENINY KLIPPEN BELT, WESTERN CARPATHIANS

Otoczaki klastycznych utworów krzemionkowych i skał krzemionkowych w zlepieńcach sekwencji fliszowych (alb, cenoman) w okolicy Považskiej Bystricy, jednostka klapska, pieniński pas skałkowy, Karpaty Zachodnie

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Abstract: Pebbles of siliceous clastic rocks were not particularly petrographically studied so far in the Cretaceous exotic conglomerates of the Western Carpathians. They occur in polymictic conglomerates representing sediments of gravity flows. The pebbles of clastic rocks are known continuously in many places of the Pieniny Klippen Belt (PKB). Their average content in the conglomerates is up to 25%. Analysed were mainly pebbles of sandstones and conglomerates. According to degree of mineralogical maturity, diagenesis and sometimes low degree of metamorphism we infer their pre-Mesozoic age. No fossils were found in the examined rocks. Some of them were turmalinized. Except of clastic sediments, radiolarites, lydites (rarely with silicified plant tissue), and jaspers were identified. According to microscopic study, the siliceous sandstones and conglomerates mostly consist of quartz, feldspars, lithoclasts, heavy minerals and matrix (often chloritic). Their compositons were plotted in triangular diagrams Q-F-L (Quartz, Feldspars, Lithoclasts). The diagrams were compared with the diagrams of similar clastic rocks which are known from the sequences of Tatricum, Veporicum, Hronicum and Gemericum. The diagrams of clastic rocks of the Pieniny Klippen Belt conglomerates are apparently different from those of clastic rocks of the Central and Inner Western Carpathians.

Key words: pebbles of siliceous clastic rocks, silicites, petrography, Cretaceous conglomerates, Pieniny Klippen Belt, Western Carpathians

Treść: Otoczaki egzotykowych skał krzemionkowych Karpat Zachodnich nie były do tej pory obiektem badań petrograficznych. Występują one w kredowych zlepieńcach polimiktycznych spływów grawitacyjnych i znajdywane są w wielu miejscach pienińskiego pasa skałkowego (PKB). Udział tych egzotyków w zlepieńcach może dochodzić do 25%, przy czym niektóre z nich są sturmalinizowane. Analizie poddano głównie otoczaki piaskowców i zlepieńców. Przy braku jakichkolwiek skamieniałości, w nawiązaniu do stopnia mineralogicznej dojrzałości otoczaków, stopnia diagenezy, jak również słabego metamorfizmu autorzy sugerują ich przedmezozoiczny wiek. W oparciu o badania mikroskopowe stwierdzono, że piaskowce i zlepieńce krzemionkowe zawierają głównie kwarc, skalenie, minerały ciężkie i niezidentyfikowane litoklasty, tkwiące w matriksie, często o charakterze chlorytowym. Sporadycznie występują fragmenty radiolarytów, lidytów (rzadko ze skrzemionkowanymi fragmentami flory) i jaspisy. Skład badanych egzotyków przedstawiono na diagramach trójkątnych (Q, F, L). Diagramy te były z kolei porównywane z diagramami sporządzonymi dla podobnych utworów klastycznych znanych z sekwencji Tatricum, Weporicum, Hronicum i Gemericum, co doprowadziło do wniosku, że egzotyki tego typu z PKB są zupełnie różne od utworów klastycznych Karpat Centralnych i Zachodnich.

Słowa kluczowe: otoczaki klastycznych skał krzemionkowych, silicyty, petrografia, zlepieńce kredowe, pieniński pas skałkowy, Karpaty Zachodnie

INTRODUCTION

Petrographic studies of polymictic conglomerates in various units of the Western Carpathians in Slovak territory were carried out by several authors. The main goals of their interes were mainly the conglomerates of the Pieniny Klippen Belt (PKB) – pebbles of limestones, dolostones, volcanic, plutonic and metamorphic rocks, see e.g. Borza (1962), Krivý (1969), Marschalko *et al*. (1976), Mišík *et al*. (1977), Mišík & Sýkora (1981), Šímová & Šamajová (1981), Šímová (1985), Mišík *et al*. (1991), Uher & Pushkarev (1994) and others. Pebbles of Pieniny Klippen Belt conglomerates in Polish territory were analysed by Wieser (1958, 1970), Birkenmajer *et al*. (1990), Tomaś *et al*. (2004) and others.

Along with the above mentioned rocks, pebbles of siliciclastic rocks and silicites occur in the conglomerates of the Pieniny Klippen Belt. These were, however, not examined in detail so far. This paper brings the first detailed information on the composition of these rocks and compares them with composition of siliciclastics in some units of the Central and Inner Western Carpathians. The aim of our research was to fill this gap in pebble analysis of the Pieniny Klippen Belt conglomerates. The paper represents an introduction to petrographic analysis of siliciclastic and siliceous pebbles.

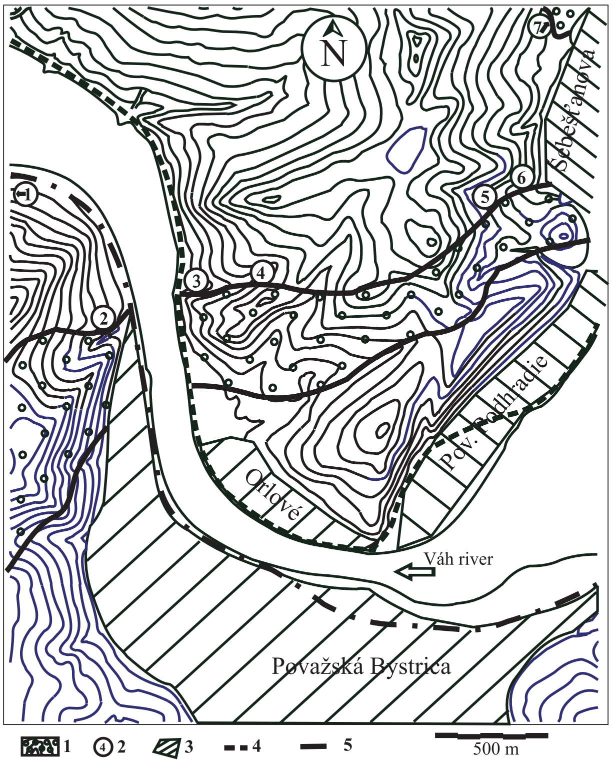

Fig. 1. Cretaceous exotic-bearing unit in vicinity of Považská Bystrica. Explanations: 1 – bodies of conglomerates in flysch sequence of Klape Unit, 2 – localities, 3 – settlement, 4 – road, 5 – railway

The conglomerates are distributed in lens-shape bodies scattered along the entire Pieniny Klippen Belt area. At the examined localities, in the vicinity of Považská Bystrica, they belong to the Klape Unit. They are part of the Albian-Cenomanian turbidite sequence. According to unpublished data (Mišík & Sýkora, personal communication), contents of the siliciclastic and siliceous pebbles was from 1–3% up to 17–25%. The pebbles were collected at the outcrops 1–7 (see Fig. 1) and evaluated according to their lithotypes, i.e. conglomerates, coarse-grained sandstones, medium-grained sandstones, fine-grained sandstones, silicites and other rocks.

Percentual ratio of components were gathered by planimetric analysis. In the clastic rocks, no primary sedimentary textures were found; rarely, parallel lamination was observed. Colour of the clastic rocks was grey, dark grey to greenish-grey; other lithotypes were reddish-grey. The silicites are fine-grained, with grey, greyish-black to red colour.

PETROGRAPHY

Conglomerate pebbles

Conglomeratic rocks (Fig. 2A) were classified according to Kukal (1985). They are represented by quartzose (consisting of quarz clasts) and oligomictic orthoconglomerates. The rocks are slightly tectonically disrupted, which is caused by overall tectonic overprint of the conglomerate bodies in which the pebbles occur. However, a slight metamorphic overprint of the pebbles is primary. The grain size varies from 0.2 to 5 mm, rarely up to 1 cm and more. The grains are angular to subangular, locally with sutured boundaries. Cataclastic effects are common in the grains. The most abundant is grey and pink, mostly undulose vein quartz, less numerous are β-quartz grains. Locally, quartz grains with subparallel lamellae were found (Fig. 2B). Quartz with similar texture is typical for shock metamorphism in the places of meteoritic impacts (see Carter, In: French & Short 1968). Phyllites and metasandstones are the most common lithoclasts rarely also marble lithoclasts with authigenic feldspars are present (Fig. 3E). Less frequent are feldspar grains, which are commonly sericitized. Accessoric grains of tourmaline, apatite, zircon, rutile and chlorite can be found, too. Matrix of the conglomerates is quartz-chlorite-sericitic. According to Dickinson (1970) it can be named as epimatrix. The percentages of the main components are listed in Table 1.

Sandstone pebbles

In the sandstone pebbles, the matrix also diagenetically turned to epimatrix. Classification of Pettijohn (1973) was used to distinguish the main types. Following Petránek (1963) and Konta (1972) methodology, the sandstones can be divided into three groups, according to their grain size: coarse, medium- to fine-grained. In the first stage of evaluation, only grey and dark grey sandstone pebbles were examined; the reddish-grey of the clastic sediments will be evaluated in the next stages.

Coarse-grained sandstones: quartzwackes (Fig. 2C), quartz meta-wackes and arkosic wackes. The grains are predominantly slightly rounded, often with sutured contact boundaries and affected by cataclasis.

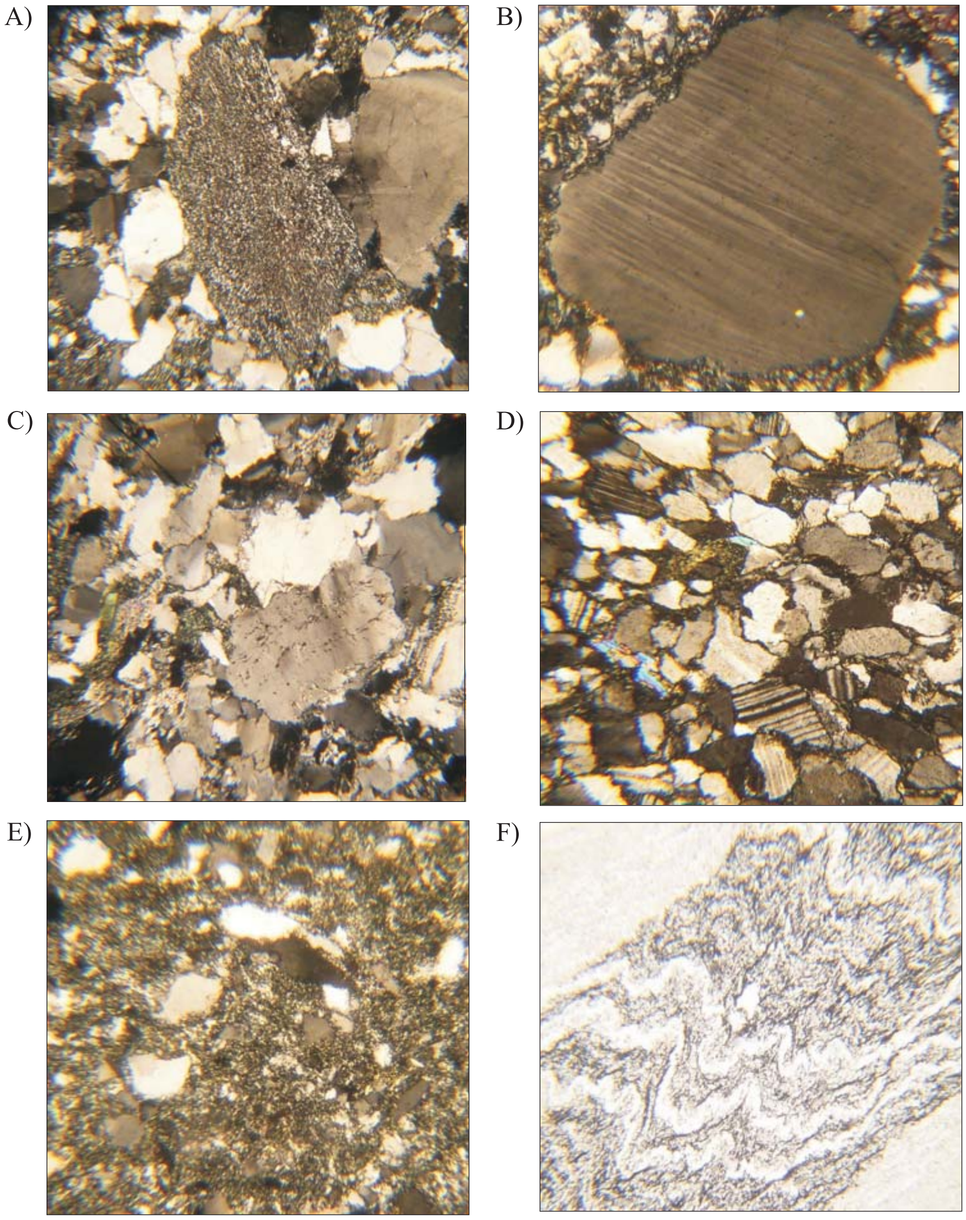

Fig. 2. A) Conglomerate with rock fragment of silicite with fine-grained texture. Crossed polars, mag.: 27× (Loc. Považský hrad 2); B) Quartz grain with signs of shock deformation (relatively common in the thin sections). Crossed polars, mag.: 107× (Loc. Považský hrad 2); C) Coarse-grained sandstone – quartz wacke. Crossed polars, mag.: 26× (Loc. Šebešťanová 4); D) Medium-grained sandstone – arkosic wacke. Crossed polars, mag.: 40× (Loc. Orlové 23); E) Fine-grained sandstone – quartz wacke. Crossed polars, mag.: 51× (Loc. Orlové 23); F) Ductile deformation in dark-grey silicite. Crossed polars, mag.: 39× (Loc. Orlové-Lesná cesta)

A) B) C) D) E) F)

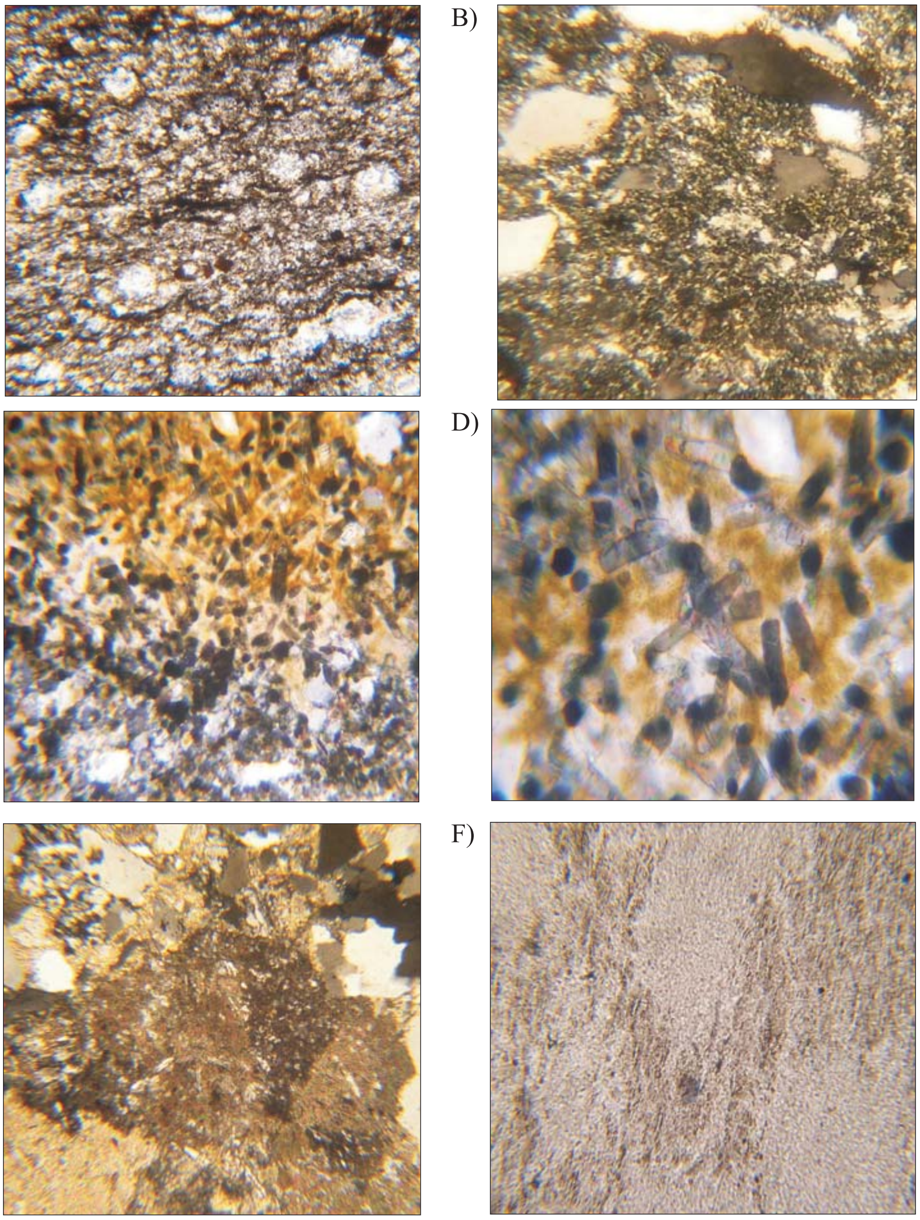

Fig. 3. A) Imperfectly preserved radiolarians in dark-grey radiolarite. Crossed polars, mag.: 31× (Loc. Orlové 21); B) Quartz wacke, quartz grains in epimatrix. Crossed polars, mag.: 70× (Loc. Šebešťanová 23); C) Turmalinized sediment with relics of clastic grains. Crossed polars, mag.: 110× (Loc. Orlové-Lesná cesta); D) Detail of turmalines. Crossed polars, mag.: 213× (Loc. Orlové-Lesná cesta); E) Marble lithoclast in conglomerate pebble. Crossed polars, mag.: 56× (Loc. Orlové 24); F) Remnants of silicified plant tissue in dark-grey silicite. Parallel polars, mag.: 33× (Loc. Šebešťanová 5)

The most common are undulose quartz grains; feldspars are commonly strongly sericitized. Other clasts from up to 5% of the components. Lithoclasts are represented by quartzose and chloritic phyllites, together with schistose metamorphic quartz coming from low-grade metamorphic rocks. Sporadically, well-rounded clastic tourmalines and zircons occur in the sandstone pebbles. The clasts are poorly size-sorted. The average grain size is about 0.65 mm; rarely up to 0.8 mm (Tab. 1).

Table 1

Main components of the investigated rocks [%]

Group	Conglomerates			Coarse-grained sandstones				
Thin-section	2	3b	18787	4	7	23811	21418	23454
Quartz	77.6	64.7	64.1	95.3	94.7	93.6	89.7	95.0
Feldspars	13.2	12.3	9.4	–	2.2	4.7	4.3	3.6
Lithoclasts	9.2	23	26.5	4.7	2.9	1.7	6.0	1.4
Matrix	34.8	46.4	34.3	15.0	37.4	45.7	34.9	28.8
Heavy min.	–	–	–	0.7	0.1	1.2	–	0.8
Chlorite	–	–	–	–	0.2	–	–	–

Group	Medium-grained sandstones							
Thin-section	23814	20453	20454	20459	19319	23444	23452	20448
Quartz	96.0	95.3	85.5	67.4	84.8	75.8	91.9	79.2
Feldspars	1.1	1.2	10.0	30.9	3.7	24.2	3.8	9.2
Lithoclasts	2.9	3.5	4.5	1.7	11.5	–	4.3	11.6
Matrix	46.9	47.7	22.1	33.4	31.7	37.0	46.4	35.0
Heavy min.	0.8	1.0	0.6	–	1.0	1.0	0.8	–
Chlorite	0.1	–	–	–	2.7	–	0.4	–

Group	Fine-grained sandstones									
Thin-section	20462	6	23808	23815	23405	23453	21265	21267	21451	PB 1
Quartz	67.4	95.6	93.3	70.9	94.6	97.0	98.8	99.0	64.4	64.3
Feldspars	30.9	1.0	5.2	–	1.9	1.5	0.5	–	35.6	35.7
Lithoclasts	1.7	3.4	1.5	29.1	3.5	1.5	0.7	1.0	–	–
Matrix	33.4	70.5	49.6	48.0	57.5	25.0	59.0	57.2	47.2	37.3
Heavy min.	–	–	–	0.5	–	1.0	0.5	0.8	–	1.0
Chlorite	–	–	–	–	0.2	–	–	–	–	5.8

Medium-grained sandstones: the group contains quartzwackes, feldspatitic greywackes, lithic greywackes and arkosic wackes (Fig. 2D). They are poorly to moderately size-sorted; the size varies between 0.2 and 0.45 mm. The quartz grains are mostly slightly rounded and undulose. In this group of sandstones, feldspars are more frequent than in the other groups; they are dominated by plagioclases. The feldspars are commonly sericitized. Relatively frequent are light micas. Heavy minerals are rare; they are mostly represented by zircon and tourmaline. The epimatrix is fine-grained, of brown to greenish-brown colour (see Tab. 1).

Fine-grained sandstones: they are represented by quartzwackes (Fig. 2E), arkosic wackes, lithic graywackes and arkosic arenites. They are relatively well size-sorted; the grain size is below 0.2 mm. The grain margins are often corroded. Feldspars are strongly sericitized. Rare heavy minerals are represented by zircon, tourmaline and rutile. The samples are typical by possessing considerable quantity of epimatrix, without original texture and composition. In the pebbles of fine-grained sandstones, the matrix contains numerous epigenetic newly-formed tourmalines. Together with tourmaline, the epimatrix is mostly formed by chlorite and sericite (Tab. 1).

The tourmalinization of the examined samples is connected with the changes in the original rocks. The tourmaline forms isolated needles, sheafs and nests (Fig. 3C, D). Its crystals often cut epimatrix together with quartz sand grains. The tourmalinization in some samples reached relatively high degree; such rocks may be rank among tourmalinites (schorl rocks). These rocks were not identified in the conglomerates of the Pieniny Klippen Belt so far.

Tourmalinic rocks in the Western Carpathians, in the units south of the Pieniny Klippen Belt, are known from primary and secondary occurrences. The tourmalinites form thin intercalations in phyllites of the Nízke Tatry Mts (Miko & Hovorka 1978 and as filling of quartz veinlets in mica schists within the Muráň Gneisses – Hovorka *et al*. 1987). Tourmalinites are also known from granites of the Gemeric Unit (e.g. Broska *et al*. 1998) and in hydrothermal veins of these Unit. Tourmalinic lithoclasts occur in Permian sediments in the Veporic Ľubietová Group (Vozárová 1979) and in the Lower Triassic quartzites of the Tatric Unit (see Mišík & Jablonský 1978, 2000, Uher 1999). Vozárová *et al*. (2003) described tourmaline-enriched laminae in the Lower Triassic quartzitic sediments from the Tatric Unit of the Tribeč Mts too. In the Veporic units, tourmalinites occur as a part of crystalline basement. Mutual comparison of tourmalinic rocks in the Western Carpathians and their eventual paleogeographic relationship was not proved yet.

Pebbles of silicites

Microscopic investigations revealed 18 samples of silicites among the studied material. They were mainly represented by ductile deformed (folded) lydites (Fig. 2F) of dark grey to black colour (10 samples). In most of the lydites, "ptygmatitic folds" of quartz are observable. All of them contain opaque pigmentation. No organic remnants were identified in thin sections. The only exception was a pebble of greyish-black silicite, consisting of fine-crystalline quartz aggregate, with calcite rhombohedra and fragments of plant tissue (Fig. 3F). These rocks are similar to the lydites known from the Lower Paleozoic successions of the Inner Western Carpathians (Gemeric Zone) and to the silicites occurring as clasts in the Lower Triassic quartzites of the Tatric Unit in the Central Western Carpathians.

Rarely, pebbles of reddish to dark grey radiolarites were found. They contain frequent calcitic veinlets. The radiolarians are poorly preserved (Fig. 3A). Attempts to extract the microfauna by dissolving the rock in hydrofluoric acid were unsuccessful. Hence, their stratigraphic rank is yet unknown (Fig. 3A). Some radiolarite clasts underwent ductile deformation. Macroscopically the radiolarites are similar to jaspers of hydrothermal origin (from volcanic rocks), which were also identified in the conglomerates.

Among the silicites, spongolites occur rarely. They contain numerous diagenetic carbonate rhombohedra. In the rock, longitudinal and transversal cross-sections of silicisponge spicules are visible (their age may be Mesozoic).

Two samples of silicites are represented by fine-grained metaquartzites with chlorite and developed foliation.

Pebbles of other rocks

To this groups belong the rocks which were indistinguishable during the field sampling and they are relatively scarce in the conglomerates, but interesting from the provenance point of view. Volcanic breccia with rock clasts of various textures – products of intermediate volcanism belongs here. The clasts in the breccia often contain tiny amigdales. Feldspar clasts are common in the breccia too. The matrix is siliceous. Other sample represents limestone with numerous authigenic feldspars originated due to higher degree of diagenesis. Local authigenic plagioclases prevail over the calcareous matrix.

COMPARISON OF THE COMPOSITION OF THE ANALYSED CLASTIC ROCKS WITH CLASTICS OF THE CENTRAL AND INNER WESTERN CARPATHIANS

The analysed clastic rocks in the Pieniny Klippen Belt conglomerates are characterized by high amount of quartz and relatively lower abundance of feldspars (mostly plagioclases) and lithoclasts. The lithoclasts come generally from the environments of low-grade metamorphism – chloritic, sericitic and quartz phyllites (rare marbles were found in conglomerates). The matrix, mostly formed by chlorite and sericite, represents epimatrix (Fig. 3B), i.e. the rocks underwent higher degree of diagenesis. Typical feature of the fine-grained sandstones is common turmalinization of the matrix (Fig. 3C, D). There is no evidence about the age of the analysed clastics; we suppose their Paleozoic age.

Pebbles of Mesozoic sediments, mainly limestones, in identical conglomerates of the Pieniny Klippen Belt do not show signs of higher degree of diagenesis; only very rarely they contain authigenic quartz and feldspar grains (see Mišík & Sýkora 1981, Mišík *et al.* 1991). Values of the conodont alteration index (CAI) in the Triassic pebbles do not exceed the degree 2 (Mišík *et al.* 1977). Therefore, we assume that the siliciclastic rocks are pre-Mesozoic.

When comparing compositions of clastic rocks of pebbles and those of Gemeric, Veporic and Tatric zones (e.g. Fejdiová 1977, Vozárová & Vozár 1988, Vozárová 1990), (see Tab. 1) there are no analogies (taking into account the recent stage of knowledge).

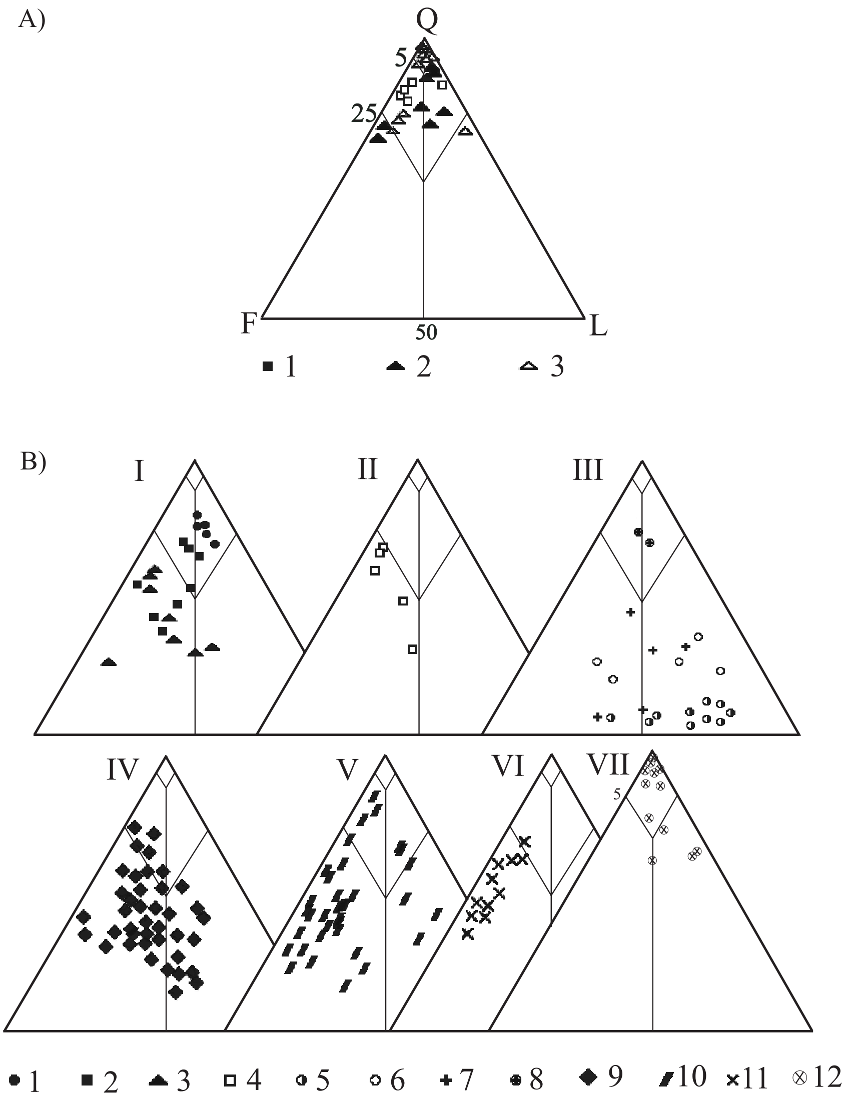

Fig. 4. Classification diagram of groups of the conglomerate sandstone pebbles (A): 1 – coarse-grained sandstones, 2 – medium-grained sandstones, 3 – fine-grained sandstones. Classification diagram of siliciclastic rocks from the Inner West Carpathians (acc. Vozárová & Vozár 1988) and the Tatric cover units (acc. Fejdiová 1971) (B): I: Carboniferous sandstones of Zemplinicum; 1 – Luhyňa Formation, 2 – Tŕňa Formation, 3 – Kašov Formation; II: 4 – Permian sandstones of Zemplinicum – Cejkov Formation; III: Carboniferous conglomerates of Gemericum, Rudňany Formation; 5 – basement consisting of Rakovec Group complexes, basal part, 6 – upper part, 7 – basement consisting of Črmeľ Group complexes, basal part, 8 – upper part; IV: 9 – Permian sandstones of Hronicum – Malužiná Formation; V: 10 – Permian sandstones of the North Veporicum; VI: 11 – Permian sandstones of Tatricum; VII: 12 – classification diagram of siliciclastic rocks – cover units of the Central Western Carpathians

The Paleozoic (Carboniferous) clastic sediments of Gemeric Zone have generally higher ratio of lithoclasts and lower volume of matrix (Vozárová 1990). The lithoclasts are mostly represented by volcanic rocks which are missing in the pebbles of the Pieniny Klippen Belt (as well as clasts of high-grade metamorphics). In Paleozoic rocks of Zemplinic Zone there is an increased ratio of micas, but some similarity is in dominance of plagioclases over K-feldspars.

Similar differences are valid for Permian clastic rocks of Veporic, Zemplinic, Hronic and Gemeric zones. The Permian sadstones of the Tatric and north Veporic zones are characterized by relatively high percentage of feldspars, with dominance of K-feldspars over plagioclases. The both petrofacies differ only by higher amount of volcanic clasts or metamorphic clasts in higher parts of the Ľubietová Group.

The Lower Triassic sediments of the Tatric Zone (Malé Karpaty Mts, High Tatra Mts) are mostly quartz-arenites – see Figure 4B – VII (compare with Fejdiová 1977). Their quartz grains are both mono- and polycrystalline and well size-sorted. The volumes of matrix and cements is usually below 1%. In the sediments of the cover units, the feldspars are mostly represented by K-feldspars, which are sometimes slightly sericitized. Lithic fragments consist mostly of effusive and phyllitic rocks. Percentage of the lithoclasts is relatively low (maximum 10%). The accessoric minerals also point to the differences between siliciclastics of the Pieniny Klippen Belt and the Tatric Zone. In the Tatric cover units, zircon, rutile and apatite are rare, whereas they are relatively common in the PKB siliciclastic pebbles. Tourmaline represents an ubiquitous accessoric mineral both in the Tatric cover units and in the PKB pebbles. On the contrary, biotite is relatively abundanty in the Tatric cover units but it is almost missing in the PKB pebbles (detritic muscovite is more numerous).

The Paleozoic clastic rocks of Gemeric, Zemplinic, Veporic and Hronic units, as well as Triassic Tatric sediments, are not tourmalinized (see above). Pebbles of tourmalinized rocks are, however, known from the Veporic Permian sediments (Vozárová 1979) and Tatric Triassic (Mišík & Jablonský 1978, 2000).

If comparing the ternary diagrams of the Upper Paleozoic petrofacies it is obvious that the marks are concentrated mainly in the central parts of the diagrams, eventually in the zones with predominance of quartz or feldspars. The diagrams of the PKB pebbles show that these are strongly dominated by quartz grains, which is different from the above mentioned units. The PKB samples containing higher amount of feldspars or lithoclasts are exceptional.

CONCLUSIONS

The degree of matrix diagenesis, formation of new minerals, similar roundness of the quartz grains, their undulosity are very similar in all samples; similarly, as the identical location of the analysed samples in ternary diagrams, they indicate that the investigated rocks came from one source area and most probably they have common provenance.

As concluded from the mentioned analyses, the provenance of the siliciclastic pebbles in the Cretaceous conglomerates from the vicinity of Považská Bystrica is not identical with provenance of similar rocks in other units of the Western Carpathians. They are not identical with any of the recently known rocks, therefore they can be considered as exotic. Some similarities with other units were indicated only exceptionally, only in some features (e.g. amount of detritic mica, lithoclasts of low-grade metamorphics etc.).

In some samples, the quartz contents are similar with the clastics in the Tatric Zone; however, characters of the matrix and lithoclasts are different. Some similarities were observed with Zemplinic Paleozoic rocks in predominance of plagioclases over the K-feldspars. The dark-grey to black-grey lydites, occurring in the conglomerates of the Klape Unit are visually similar to those in the Inner Western Carpathians (Gemeric Zone). They are also similar to black lydite pebbles from the Lúžna Formation (Mišík & Jablonský 1978, 2000). However, petrography of the black silicites from the Western Carpathians was not treated in detail in literature. Therefore, our observations could not be compared with published data. The dark-grey radiolarite pebbles in the PKB conglomerates do not have any equivalents in other units of the Western Carpathians. The red radiolarites are known from the Mesozoic successions.

As a source of exotic material, so called Exotic Ridge (Andrusov Ridge) is inferred. It represents an elevated part of an accretionary wedge moving allong Central Western Carpathians. The direct record of this ridge are pebbles of freshwater and fluviomarine limestones (see Mišík & Sýkora 1981). From the adjacent sedimentary zones, no similar rocks are known. It is supposed, that the exotic ridge was subducted under the Central Western Carpathians. Plašienka (1996) situated the source of exotics to Gemeric and Veporic areas. However he did not treat it as a source of exotic clastics, because in the Middle Jurassic, it was buried deeply under the Exotic Units.

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