Želetice Group: Very low-grade Palaeozoic sequence at the base of Moravicum, Czech Republic

Želetická skupina: velmi nízce metamorfovaná paleozoická sekvence na bázi Moravika

(3 figs, 5 tabs)

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We define a new very low-grade metamorphic unit – Želetice Group – that crops out in the northern termination of the Moravian Dyje window and in the central part of the Svratka window in the hanging wall of the Devonian Lažánky-Heroltice limestones and below the biotite-bearing phylites of the Pernegg-Upper Lukov-Bílý Potok Groups. A part of the Želetice Group in the Dyje window was earlier called Porphyroid Group (Preclik 1926b). The newly defined unit consists of greywackes, slates, metatuffites and sericite-chlorite-bearing marbles. This unit was so far considered as a lower part of the Pernegg-Upper Lukov-Bílý Potok Groups. However, Želetice Group differs from the overlying complexes by different lithology and considerably lower metamorphic overprinting. Pebbles of Devonian Lažánky-Heroltice limestones found in the metagreywackes define the lower age limit as Devonian. The age of cooling of the whole Moravian nappe pile c. 330–325 Ma ago (Dallmeyer *et al.* 1994) implies the minimum age of this Group. Our data indicate that an important Palaeozoic sequence overlays the Brunovistulian basement, apart of well-known Devonian limestones and siliciclastics, prior its collision with the Moravicum and Moldanubicum.

Key words: Moravicum; Želetice Group; marbles; metapelites**;** low-grade metamorphism; Bohemian Massif

1. Introduction

Preclik (1926a, b) mapped in the northern part of the Dyje window a complex of very low-grade metapelites, marbles and metavolcanics – porphyroids. He separated this complex from westward situated, slightly higher-grade Inner Phyllites, and named this complex as Porphyroids. He considered this Group to be Devonian in age because of similarity of limestones in this unit to the Devonian limestones in the Moravian Karst. Likewise, Suess (1912), i.e. before Preclik, noted that the metasediments in the Inner Phyllite zone are not uniform over the entire area. The metapelites and carbonate rocks, cropping out in the lower (eastern) part of the phyllite zone in the northern termination of the Dyje window, differ considerably from the majority of phyllites by their very low degree of metamorphic overprinting. The geological map 1 : 50 000, sheet 34-11 Znojmo (Matějovská *et al.* 1988), covering the northern termination of Dyje window, indicates the differences between the western and eastern parts of the Inner Phyllites in the northern termination of the Dyje window. The eastern part is formed by "greywacke gneiss" (Matějovská *et al.* 1988) with sericite + chlorite, whereas the western part contains phyllite with biotite. However, the Preclik's idea that an additional unit crops out in this area, between the Brunovistulicum and Moravicum, was abandoned in the literature of the last decades. We tried to verify the concept of Preclik (1926a, b) by a detailed documentation and study of sporadic and weathered outcrops in this area. The situation of petrologically studied localities is shown in Fig. 2, results are summarized in Tables 2–5. Because we have found that the carbonate rocks are better preserved than the metapelites, we studied the marbles using cathodoluminescence and electron microprobe to find out potential differences in their composition and grade of metamorphism. We have correlated the geological situation and structure observed in the Dyje window with relations in the Svratka window, situated further to the North.

2. Geological setting

Three major units form the crystalline basement at the eastern margin of the Bohemian Massif (Fig. 1). From the basement to the hanging-wall units (E-W section) they include the Brunovistulicum (Dudek 1980), Moravicum and Moldanubicum (Suess 1912). All three units are in tectonic contacts. Moravicum is thrust over Brunovistulicum (Jaroš – Mísař 1976), and Moravicum itself is overthrust by Moldanubicum (Suess 1912). Some Devonian limestones are sandwiched between the Brunovistulicum and Moravicum indicating the Variscan age of the tectonic processes. The significant role of the Variscan tectonics was confirmed by geochronological data, indicating a Lower Carboniferous age of the main tectonic phase (Dallmeyer 1994). Moravicum forms two windows (Fig. 1). The northern one is named Svratka (Schwarzawa, Suess 1912), whereas the southern one as Dyje (Thaya) window. The Dyje window could be more precisely classified as a half-window; the eastern part of the window is mostly covered by Tertiary and Quaternary sediments. Only rather small outcrops – Miroslav Horst, Krhovice crystalline and crystalline rocks by Frauendorf (Fig. 1) represent the eastern parts of the window (Höck – Leichmann 1993). Dirnhofer (1996) and Riegler (2000) described a much larger areal extent of the eastern flank of the window from deep boreholes in this area.

The structure of both windows is similar in general. The basement is formed by Brunovistulicum in both cases. Brunovistulicum consists mainly of Precambrian granitoids

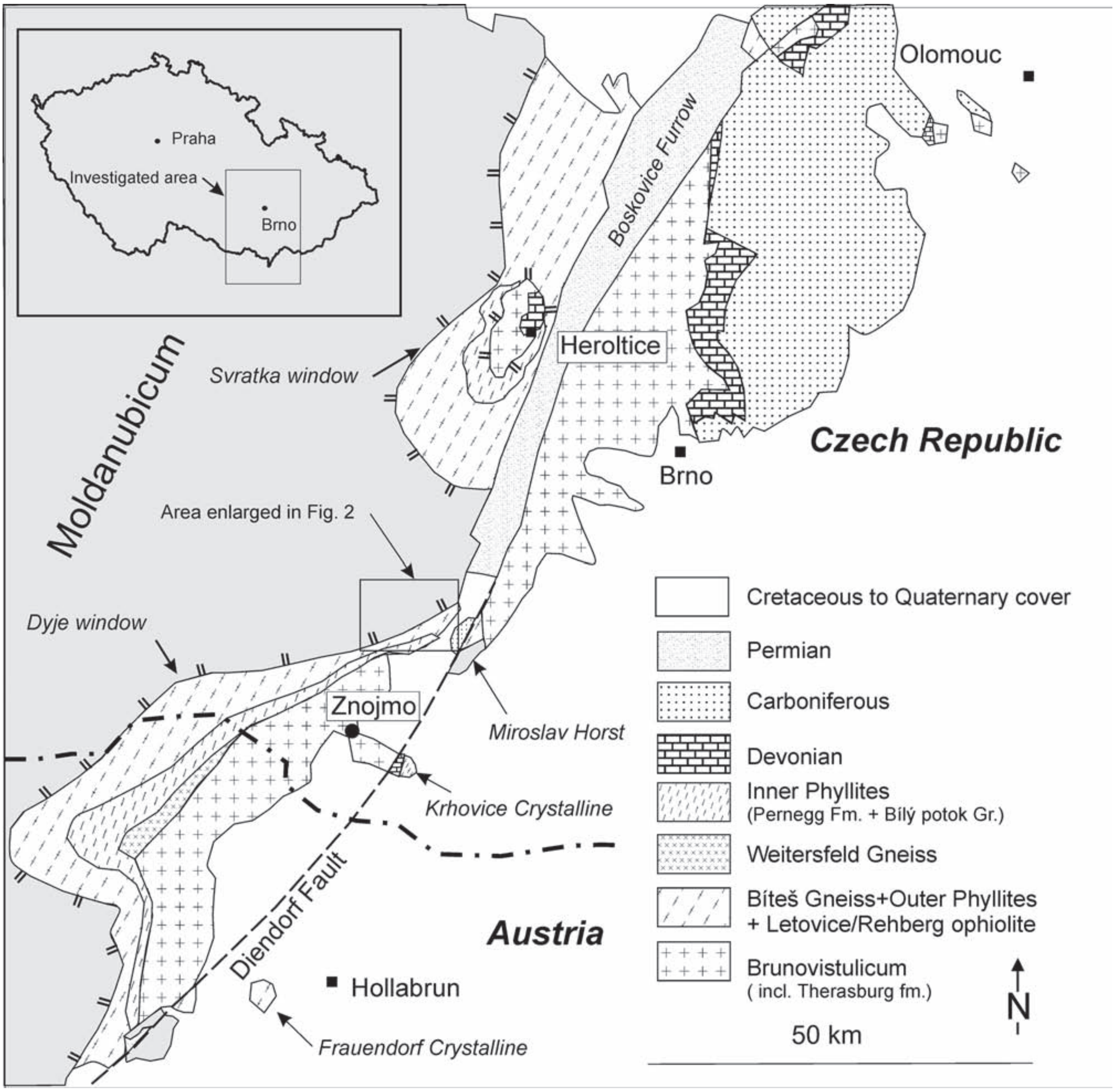


Fig. 1 Simplified geological map of the eastern margin of the Bohemian Massif modified from the Geological map 1: 500 000

(van Breemen *et al.* 1982), older ophiolites (Finger *et al.* 2000), and relics of metamorphic mantle. Devonian limestones as well as siliciclastic sediments formed primary sedimentary envelope on the Brunovistulicum. They are now sandwiched between Brunovistulicum and Moravicum in the Svratka window as Lažánky-Heroltice limestones. (Svoboda – Prantl 1951, Jaroš – Mísař 1976). The presence of palaeontologically proved Devonian sediments is not known from the Dyje window. Anyhow, some limestones crop out between Brunovistulicum and Moravicum in the northern termination of Dyje window by Kadov (Fig. 2). The occurrence of deformed Devonian limestones permits to distinguish clearly the basement and Variscan nappes in the Svratka Window, whereas a similar clear separation is difficult in the Dyje window.

The lowermost Moravian unit was originally named Inner Phyllites (Innere Phylite, Suess 1912). Höck (1975) divided the Inner Phyllites in Austria into two parts. The lower unit – Therasburg Formation (lower Lukov Unit in the Czech literature, Batík 1984) consists of metapelites, gneisses, and quartzites. The upper unit – Pernegg Formation (upper Lukov Unit) is composed of metapelites and marbles. The lithological equivalent of Pernegg Fm. in the Svratka window is locally termed Bílý Potok Group, whereas an equivalent of Therasburg Fm. is known from the Svratka window as Deblín Group (Jaroš – Mísař 1976, Mísař 1994). The detailed division of the Inner Phyllites and correlation of individual units in both windows is shown schematically below.

Svratka window	**Dyje window**	
	Czech Republic	Austria
Deblin Group	lower Lukov unit	Therasburg Fm.
Bílý Potok Group	upper Lukov unit	Pernegg Formation

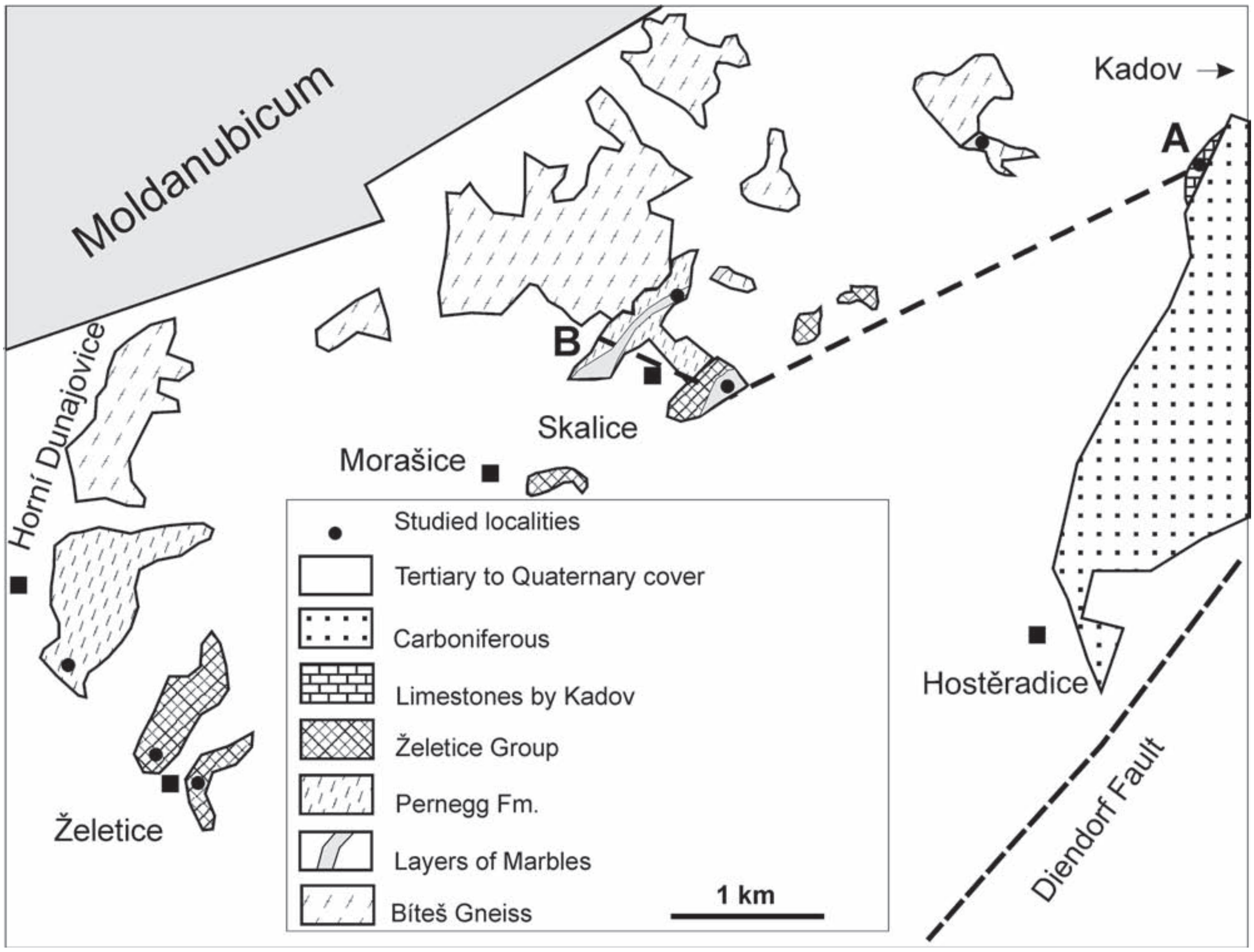


Fig. 2 Schematic map of the northern termination of the Dyje window. Compiled using maps of Matějovská *et al.* (1988) and Preclik (1926 b)

With regard to the occurrence of palaeontologically proved Devonian sediments (Svoboda – Prantl 1951) between Deblín and Bílý Potok Group in the Svratka window, the original interpretation by Suess (1912) of the Inner Phyllites as the lowermost Moravian unit must be corrected. The lower part of the Inner Phyllites (Deblín, lower Lukov, and Therasburg Fm.) must be considered as parts of the Brunovistulian basement, because these units are covered, at least in the Svratka window, by Devonian limestones. Similarly, observed intrusion relation between Precambrian Brunovistulian granites and Therasburg-Deblin Formation forming the mantle of the intrusion (Höck – Leichmann 1993) confirms the correctness of such interpretation. Only the upper part of the Inner Phylites – Pernegg Formation, and its equivalents – upper Lukov and Bílý Potok unit – form the lowermost Moravian nappe. We will use the term Pernegg Fm. as a joint designation for this unit in both windows, as originally proposed by Höck (1975).

Bíteš Gneiss is the next higher Moravian unit. These strongly deformed granitic gneisses overlay tectonically the Pernegg Formation. Bíteš Gneiss itself is overlain by a unit, which was originally named Outer Phyllites. The Olešnice Group in the Svratka Window and the Vranov Unit in the Dyje window are the names for this unit in the present terminology. The Letovice-Rehberg ophiolite (Höck *et al.* 1997, Leichmann 2003) rimmed at several places in the hanging wall the Outer Phyllites, forming a border zone between Moravicum and tectonically higher Moldanubicum.

The eastern margin of the Bohemian Massif shows a characteristic inverted metamorphic zonation. The tectonically highest unit – the Moldanubikum – exhibits the highest metamorphic conditions in upper amphibolite – granulite and locally eclogite facies (Franke 2000, Henk *et al.* 2000). Moravicum is generally characterized by lower amphibolite to greenschist facies, whereas Brunovistulicum is affected in its westernmost part by a very strong brittle to ductile deformation mainly. The metamorphic evolution of Moravicum, mainly of Pernegg Fm., was subject of many studies: Frasl (1970), Höck (1975, 1995), Höck *et al*. (1991), Bernoroider (1989), Batík (1984, 1999), Kachlík (1989), Pivnička (1995), Tomek *et al.* (1995), Štipská – Schulmann (1995), and Štipská (1999). The metamorphism is inversional, but the pT conditions decrease not only from hanging wall (West) to the base (East), but towards the South and North as well. This is a result of exhumation of a large-scale fold structure with the maximum uplift in the centre of the window, and a less intensive exhumation on the North, West and South (Tomek *et al.* 1995, Štipská 1999).

As we noticed already in the introduction, the geological structure in the northernmost part of the Dyje window deviates slightly from the general situation. Fig. 2 brings a detailed scheme of this area. If we follow the SW-NE profile indicated on the map by a broken line (B-A), we start in the marbles of the Pernegg Fm. Below these marbles the metapelites of Pernegg Fm. crop out. This is a common Moravian situation, which could be documented on several profiles across both the Dyje and Svratka windows. But below the Pernegg metapelites, another layer of marbles crops out, which has at the bottom metasedimentary rocks again (cf. Suess 1912). This lower body of marbles + metasediments cropping out below the Pernegg Fm. was described by Preclik (1926 b) as porphyroids. Tertiary and Quaternary sediments cover the eastern continuation of the profile. However, farther to the east, small outcrops of deformed limestones come up from the Tertiary sediments. These limestones are in tectonic contact with Lower Carboniferous greywackes in the East. The limestones are lithologically very similar to the Devonian Lažánky-Heroltice limestones in the Svratka window, but no fossil record is reported here.

A similar section was documented in the centre of the Svratka window, on the right bank of the Svratka river, close to the Heroltice village (Fig. 1). The sequence of metapelites and metagreywackes were documented below the marbles and biotite phyllites of the Bílý Potok Group (= Pernegg Fm.), and in the hanging wall of Devonian limestones.

3. Methods

The marbles were studied using hot cathode HC2-LM microscope. The accelerating voltage was 14 kV, and the current density10 mA/mm^2. Photographic documentation was taken with Olympus digital camera. The selected samples were consequently analyzed using microprobe Cameca SX100 in the wavelength-dispersion mode with beam diameter of 3–5 mm, accelerating voltage of 15 kV, and sample current of 40 nA. Wollastonite (Ca), oxides (Si, Al, Ti, Fe, Mn, Ba) and chlorides (Na, K, Cl) were used as standards. Data were reduced using the ZAF-4 corrections. Part of analyses (No 2 , Table 3; Nos 4–9, Table 5) was performed on the CamScan 4DV instrument with EDX AN 10 000 analyzer, in the energy-dispersion mode (beam diameter 1 mm and accelerating voltage of 20 kV). The chemical composition of the rock samples was determined by wet methods, Analyst P. Kadlec at the Department of Geological Sciences, Masaryk University, Brno.

4. Results

The following sequence was documented in both windows (Table 1)

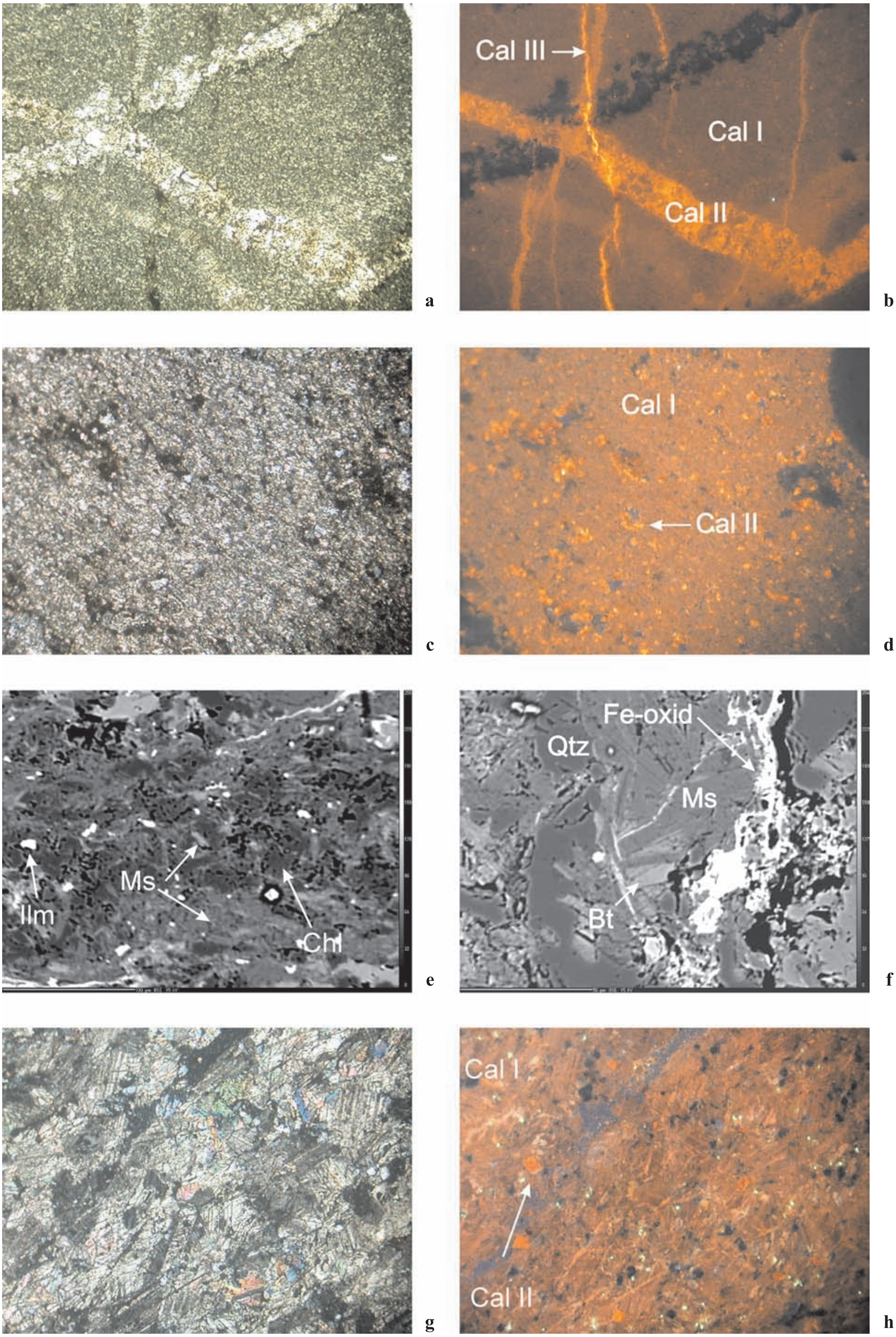
Table 1 Lithological sequence observed in both windows listed from the basement to the top.

Dyje window	Svratka window
Crystalline basement: Brunovistulicum	Crystalline basement: Brunovistulicum
Limestones near Kadov Želetice Group Slates+metagreywackes+ chlorite-sericite-bearing marbles (former Porphyroid Group)	Lažánky-Heroltice limestones Želetice Group Slates+metagreywackes+ metatuffites
Pernegg-Upper Lukov Unit biotite phyllites + biotite-bearing marbles	Upper part of the Bílý Potok Group biotite phyllites + biotite-bearing marbles
Bíteš Gneiss	Bíteš Gneiss

4.1 Lažánky-Heroltice and Kadov limestones

These marbles crop out below the low-grade sequence (Želetice Group) in both windows. The limestones near Kadov (Dyje window) form an isolated outcrop WSW of the Kadov village. These limestones are not accompanied by other sedimentary rocks. They are in a tectonic contact with Lower Carboniferous greywackes only (Fig. 2). The studied limestones are light grey, very fine-grained massive rocks. They are penetrated by very abundant thin calcite veins. The very fine-grained matrix exhibits dull brown-orange CL (Fig. 3a, b). This fabric is probably of deformation origin (Špaček *et al.* 2001). Stylolites were

Fig. 3 ⇒
a – Deformed limestone, Kadov, crossed polars, width of the photograph is 3 mm,
b – CL photograph, deformed limestone, the same area as on Photo 1. Kadov. Three generations of calcite veins differ in their CL. Width of the photograph is 3 mm,
c – Fine-grained marble Skalice, Želetice Fm., crossed polars. Width of the photograph is 3 mm.
d – CL photograph, fine-grained marble, the same area as in Photo 3, Skalice, Želetice Fm. Grains of calcite II with bright orange CL in a matrix calcite I. Width of the photograph is 3 mm,
e – BSE image, Marble, Skalice, Želetice Fm. Chlorite-phengite nest in marble. Width of the photograph is 0.3 mm.
f – BSE image, Marble, Skalice, Pernegg Fm. Muskovite-biotite intergrowth. Width of the photograph is 0.15 mm.
g – Marble, Skalice, Pernegg Fm, coarse-grained calcite, crossed polars. Width of the photograph is 3 mm,
h – CL photograph, Marble, Skalice, Pernegg Fm, the same area as in Photo 7. The sample is dominated by calcite I with dull orange CL, calcite II exhibits bright orange CL. Width of the photograph is 3 mm.


Cal III
Cal I
Cal II
a
b
Cal I
Cal II
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d
Ms
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Chl
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Fe-oxid
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Cal I
Cal II
g
h

observed commonly. Rounded quartz grains occur as a minor component only. No metamorphic micas or other minerals could be documented here. A much larger body of limestones, belonging to the Devonian Lažánky-Heroltice limestones, crops out in the hanging-wall of the Brunovistulian basement (Deblín Group) in the Svratka window. The limestones in the Svratka window are lithologically heterogeneous. However, the strong deformation, a similar tectonic position, and the absence of any newly formed metamorphic minerals are common attributes connecting the Lažánky-Heroltice limestones (Svratka window) with limestones from Kadov (Dyje window).

4.2 Želetice Group

Metagreywackes, slates, tuffites, and chlorite-sericite-bearing marbles are the essential rock types recognized within this unit. In the northernmost part of the Dyje window this sequence was originally named as the Porphyroid Group (Preclik 1926 b). Best outcrops in the Dyje window are situated in the eastern part of the Želetice village, in the road cut south of Morašice village and on the hill in Skalice village. A similar low-grade sequence was mapped in the central part Svratka window (map sheet 24-32 Brno). The outcrop situation here is even less informative than in the Dyje window. We were able to document only a W – E oriented profile approximately 150 m long, from the lowermost Devonian limestones across low-grade metagreywackes and metatuffites (Želetice Group) to biotite phyllites of the Bílý Potok Group (Pernegg Fm.) along a creek approximately 500 m southeast of the Heroltice village (Fig. 1). However, sericite-chlorite phyllites were not mapped here as a separate unit, they were classified with a lower part of the Bílý Potok Group.

Metagreywackes

Metagreywackes were found in both windows. In the Dyje window the best exposure is an old quarry near Želetice, where Preclik (1926 b) described porphyroids. In the Svratka window they were documented in the hanging wall of the Devonian Lažánky-Heroltice limestones southeast of the Heroltice village, below the typical biotite-bearing phyllites of the Bílý Potok Group.

The metagreywackes from both windows are massive rocks. Colours vary from grey to greenish-grey or brownish-grey if weathered. Modal analyses are listed in Table 2 (Nos 1–3). The very fine-grained (~ 0.02 mm), recrystallized matrix is composed of metamorphic Fe- and Mg-rich white mica (Table 3, No. 1, Table 5 Nos 1, 2), chlorite, and carbonate. Quartz and plagioclase represent the detritic component in the matrix. Schistosity was observed only in deformed samples, where white mica starts to form discontinuous strips. Detritic plagioclase, quartz, K-feldspar (Table 5, No. 3), biotite, and fragments of granitoids, and recrystallized limestones were found as clasts in the matrix. The size of the fragments is 0.6 mm on average, and doesn't exceed 3 mm. The plagioclase clasts are not well rounded; lath-shaped crystals are also observed. Some plagioclase grains exhibit oscillatory zoning in cathodoluminescence, indicating its magmatic origin. Apart from common sericite, which is alteration product, acicular apatite was found as inclusions in some plagioclase grains. The grain size and angularity of quartz fragments is very similar to that of plagioclase fragments. In the more deformed parts of the rock, quartz forms elongated lenses, while plagioclase is crushed at its rims. Up to 3 mm long fragments of subhedral dark-brown biotite are frequently bent and curved by deformation and replaced by chlorite at their rims. K-feldspar forms semi-angular, unaltered grains. Aggregates of K-feldspar + pla-

Table 2 Modal analysis. Metasediments from Želetice and Pernegg Fm.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Qtz	33.1	44.5	20.0	31.2	35.4	18.0	30.0	26.0	29.0	22.0	26.5	9.8	49.0	45.0
Pl	25.1	14.7	45.0	1.5	4.7	24.0	10.0	6.0	12.3	18.0	0.6	30.6	3.0	–
Kf	0.2	2.0	1.0	0.2	0.2	0.2	–	–	–	–	–	0.1	1.0	–
Ms	31.1	19.3	15.0	29.5	20.6	35.0	30.0	33.0	12.0	2.0	33.1	4.6	28.0	28.0
Chl	5.7	10.3	10.0	22.7	22.4	19.0	21.0	26.0	7.0	29.5	15.0	25.3	10.0	12.0
Bt	1.1	–	–	–	–	–	–	–	0.3	–	18.2	6.9	4.0	11.0
Tur	–	–	–	1.2	0.2	–	–	1.0	–	–	1.6	0.3	1.0	1.0
Hbl	–	–	–	–	–	–	–	–	3.3	10.0	–	–	–	–
Cal	2.1	4.3	–	–	–	–	–	–	4.1	5.0	–	–	–	–
Ep+pmp	–	3.4	2.0	–	3.5	–	–	–	32.0	13.0	–	–	–	–
Opq	1.6	1.5	7.0	13.7	13.1	4.0	9.0	7.0	0.3	0.5	4.9	9.8	4.0	3.0

1–10 – Želetice Group. 1, 2 – metagreywackes, Svratka window, Heroltice; 3 – metagreywacke -Dyje window Želetice; 4, 5 – slates, Svratka window Heroltice; 6–8 – slates – Dyje window, Želetice; 9, 10 – metatuffites, Svratka window, Heroltice. 11–14 – Pernegg Formation; 11, 12 – biotite phylites, Svratka window, Heroltice; 13, 14 – biotite phylites, Dyje window, Horní Dunajovice

Table 3 Representative analyses of rock forming minerals. Metasediments and marbles from the Dyje Window.

	1	2	3	4	5	6	7	8	9
SiO_2	48.2	45.6	48.4	46.7	37.8	37.8	26.6	nd	nd
TiO_2	1.0	0.4	0.3	0.5	1.4	1.4	nd	nd	nd
Al_2O_3	20.0	33.9	31.7	34.3	17.4	18.0	21.4	nd	nd
FeO	10.8	2.3	2.0	0.3	18.4	17.3	23.2	1.3	0.4
MgO	5.2	0.6	2.0	2.0	11.8	11.8	16.5	0.7	1.1
CaO	nd	nd	0.1	0.4	0.1	0.1	nd	54.2	54.7
K_2O	12.2	10.2	11.0	10.1	8.77	9.2	0.1	nd	nd
Na_2O	nd	0.7	0.1	0.3	0.08	0.1	nd	nd	nd
F	nd	nd	0.3	nd	1.3	1.2	0.1	nd	nd
Tot	97.4	93.7	95.6	94.6	95.9	96.9	87.9	56.2	56.2
Si	3.359	3.101	3.223	3.110	2.825	2.816	2.757		
Ti	0.052	0.020	0.015	0.025	0.080	0.078			
Al 3+	1.643	2.717	2.488	2.692	1.531	1.580	2.614		
Fe	0.629	0.131	0.111	0.017	1.148	1.078	2.011	0.018	0.006
Mg	0.540	0.061	0.199	0.199	1.310	1.310	2.549	0.017	0.027
Ca			0.007	0.029	0.009	0.008		0.965	0.967
K	1.085	0.885	0.935	0.858	0.835	0.874	0.013		
Na		0.092	0.013	0.039	0.010	0.014			
F			0.063		0.315	0.283	0.033		

1 – white mica from metagreywacke, Želetice Group, Želetice
2 – white mica from biotite-bearing phyllite, Pernegg Fm., Horní Dunajovice
3 – white mica from marble, Želetice Group, Skalice
4 – white mica from marble, Pernegg Fm., Skalice
5 – biotite from marble, Pernegg Fm., Skalice
6 – biotite from marble, Pernegg Fm., Skalice
7 – chlorite from marble, Želetice Group, Skalice
8 – carbonate from marble, Želetice Group, Skalice
9 – carbonate from marble, Pernegg Fm., Skalice

gioclase, and plagioclase + quartz were observed as well. Euhedral zircon is a typical accessory mineral. It shows characteristic internal magmatic zoning. The clasts of carbonates were found in greywackes in the Svratka window. Despite of a small size of the fragments (up to 3 mm), the similarity with underlying Devonian limestones is evident.

The chemical composition of the greywacke (Table 4, analysis No. 2) with SiO_2 content ~ 62 wt.%, Al_2O_3 15.6 %, and $\sum$ alk 6.6 % is close to granodiorite. The elevated CaO content is explained by the presence of carbonate clasts. The mineralogical composition of the clasts, mainly the presence of magmatic plagioclase, K-feldspar, Pl+Qtz and Kf+Qtz fragments, biotite, euhedral zircon, and acicular apatite, together with the chemical composition, indicate that the greywackes were derived from a nearby plutonic or volcanic body, probably of a granitic- granodioritic composition. The greywackes were found at the same locality near Želetice, where Preclik (1926b) described porphyroids. Because the mineral composition and chemistry of our metagreywacke is very close to those of porphyroids as described by Preclik (Table 4, analysis No. 3), we assume that the greywackes described here are equivalent to Preclik's porphyroids. The only difference is in the labeling of the rock, resulting from a different interpretation of primary and secondary structures.

Slates

These rocks occur in both the windows. They are grey, laminated rocks with a dim, silvery luster on the foliation planes. The mineral composition is mostly identical to the greywacke matrix – phengite, chlorite, quartz, carbonate, and plagioclase (Table 2, Nos 4–8). A gradual transition between both rock types was documented in many places. Relics of aleuritic structure are preserved in the undeformed domains, while in the deformed parts mica and quartz are aligned in strips.

Tuffites

The tuffites are fine-grained, greyish-green colored rocks, which occur as several decimetres to metres thick layers in the greywackes in the Svratka window. The fine- to very-fine-grained recrystallized matrix consists mainly of epidote and quartz. Plagioclase, carbonate, chlorite, white mica, and titanite are minor compo-

Table 4 Representative whole-rock chemical analyses.

	1	2	3
SiO_2	54.32	61.91	64.48
TiO_2	1.05	0.57	0.65
Al_2O_3	17.47	15.63	16.75
Fe_2O_3	2.30	2.45	2.54
FeO	5.06	3.01	1.92
MnO	0.11	0.10	0.03
MgO	4.50	2.13	2.33
CaO	5.55	2.96	2.74
K_2O	2.60	3.77	2.59
Na_2O	2.83	2.92	3.20
P_2O_5	0.23	0.20	0.17
CO_2	1.29	1.93	1.42
H_2O	2.15	1.98	1.00
Tot.	99.64	99.73	100.00

1 – Metatuffite, Heroltice
2 – Metagreywacke, Heroltice
3 – Porphyroide, Želetice, (Preclik 1926 b)

Table 5 Representative analyses of rock forming minerals. Metasediments from the Svratka Window.

	1	2	3	4	5	6	7	8	9
SiO_2	48.2	45.4	62.5	45.6	35.6	26.3	62.7	36.8	37.9
TiO_2	1.0	0.6	0.4	0.4	1.4	nd	nd	nd	nd
Al_2O_3	20.0	28.1	18.1	33.9	19.1	24.9	24.0	21.3	21.7
FeO	10.8	7.1	0.8	2.3	23.0	31.6	0.2	26.1	26.0
MnO	nd	0.2	nd	nd	nd	0.3	nd	5.1	4.8
MgO	5.2	4.1	nd	0.6	8.4	10.9	nd	0.5	0.7
CaO	nd	nd	0.5	nd	nd	nd	4.7	9.3	9.3
K_2O	12.2	10.8	15.9	10.2	8.1	0.1	0.1	nd	nd
Na_2O	nd	nd	nd	0.7	nd	nd	9.1	nd	nd
Cl	nd	nd	nd	nd	0.8	nd	nd	nd	nd
Tot	97.4	96.3	98.2	93.7	96.4	94.1	100.8	99.1	100.4
Si	3.359	3.112	2.960	3.101	2.720	2.637	2.757	2.982	3.012
Ti	0.052	0.031	0.014	0.020	0.080				
Al	1.643	2.270	1.010	2.717	1.720	2.943	1.244	2.034	2.033
Fe	0.629	0.407	0.032	0.131	1.469	2.650	0.007	1.768	1.728
Mn		0.012				0.025		0.350	0.323
Mg	0.540	0.419		0.061	0.957	1.629		0.060	0.083
Ca			0.025				0.221	0.807	0.792
K	1.085	0.944	0.961	0.855	0.789	0.013	0.006		
Na				0.092			0.776		
Cl					0.104				

1, 2 – white mica from metagreywacke, Želetice Group, Heroltice
3 – K-feldspar from metagreywacke, Želetice Group, Heroltice
4 – white mica from garnet-bearing phyllite (Bílý potok Group)
5 – biotite from garnet-bearing phyllite (Bílý potok Group)
6 – chlorite from garnet-bearing phyllite (Bílý potok Group)
7 – plagioclase from garnet-bearing phyllite (Bílý potok Group)
8 – garnet, core from garnet-bearing phyllite (Bílý potok Group)
9 – garnet rim from garnet-bearing phyllites (Bílý potok Group)

nents. Relics of pumpellyite were observed rarely in some epidote grains in the matrix. Green to brown amphibole, biotite, plagioclase, and epidote were found as up to 1.2 mm long clasts in the matrix (Table 2, Nos 9, 10). The amphiboles form euhedral, green-colored grains with brown relics in the central parts. The amphiboles are frequently replaced by chlorite, epidote, carbonate, and white mica at their rims and along cleavages. Plagioclase usually forms slightly rounded grains, rarely occurs as tabular, euhedral, zoned crystals. It is mostly fresh, only rarely is replaced by prehnite. Brown biotite forms deformed books with rims occasionally replaced by chlorite. Amphibole, biotite and plagioclase therefore represent with a high probability detrital primary magmatic minerals, later partly overprinted by metamorphic recrystallization.

The chemical composition (Table 4, No. 1) was probably influenced by sedimentary admixture, which is expressed by the presence of carbonates and white mica. Therefore, the contents of CaO (5.55 wt.%), Al_2O_3 (17.47 wt.%), and K_2O (2.6 wt.%) might be somewhat elevated. However, the high content of MgO (4.5 wt.%), TiO_2 (1.05 wt.%), FeO_{tot} (7.1 wt.%), intermediate SiO_2 (54.32 wt.%), and the presence of amphibole, point most probably to an andesitic protholith.

Chlorite-sericite-bearing marbles

Marbles were found in the Dyje window only, in the Skalice village (Fig. 2). They form a main layer up to 50 m thick and a few thinner layers, mainly in slates. All the layers are parallel with regional schistosity. Marbles are fine-grained, grey rocks with well-developed planar fabric. They are rather homogeneous if observed in transmitted light. CL study indicates two types of calcite. The prevailing calcite (I) forms very small anhedral dark dull orange grains if observed in CL. A younger calcite (II) with bright orange CL forms thin veins cutting the carbonate (I) or forms rarely larger separate grains distributed sporadically in calcite (I) (Fig. 3c, d) The prevailing calcite with dark dull CL is slightly enriched in FeO (around 1.3 wt. %, Table 3, No. 8). Quartz, chlorite and white mica are the most important silicate components of the rock. Quartz forms rounded grains, evenly distributed in the rock. Chlorite and white mica form nest-like aggregates (Fig. 3e). The white mica is muscovite with a high phengite component (Table 3, No. 3), chlorite corresponds to clinochlore (Table 3, No. 7). Note that no reaction product, such as biotite, appears at the contact between muscovite and chlorite.

4.3 Pernegg Formation (= upper Lukov unit, Bílý Potok Group)

Biotite-bearing phyllites and biotite-bearing marbles are typical members of this unit in both windows. The marbles described below, come from the northern termination of Dyje window near the Skalice village, analyses of metapelites come from both windows.

Biotite-bearing phyllites

The biotite-bearing phyllites occur in the hanging wall of the Želetice Group in both windows. The mineral composition is listed in Table 2 (Nos 11–14). The following principal differences, if compared with metasediments of the Želetice Group, are noted:

(a) Presence of metamorphic biotite (Table 5, No. 5). Biotite forms layers together with white mica, which alternate with quartz-feldspar layers.
(b) White mica is coarser-grained and has a different composition with lower SiO_2, FeO and MgO and significantly higher Al_2O_3 (Table 3, No. 2; Table 5, No. 4).

(c) Plagioclase is homogeneous if observed in transmitted light, CL, and back-scattered electron images.
(d) No relics of sedimentary structures were observed in these rocks.

These metapelites grade to calc-silicate schist and marbles in their upper part.

Biotite-bearing marbles

Marbles in the Lukov Unit were recently described by Houzar – Leichmann (2003) and Houzar et al (2004). Marbles from the profile studied near the Skalice village in the Dyje window are coarse- to fine-grained, white to grey coloured foliated rocks. Coarse-grained marbles with calcite grains up to 3 mm prevail over fine-grained marbles that form thin layers parallel with the regional foliation.

Two calcite generations were observed using CL method (Fig. 3g, h). Dull orange calcite (1) forming equant grains prevails over bright orange calcite (II), which rims or fills the space among grains of calcite (I). Calcite (I) contains 0.5 wt. % FeO on average (Table 3, No. 9). Quartz, plagioclase, white mica and biotite are the most important minor components. Quartz and plagioclase (Ab_{98}) are randomly dispersed in the rock, micas form thin strips. Biotite is flogopite-annite solid solution with XFe (0.45–0.46, Table 3, Nos 5, 6) with fluorine content up to 1.3 wt.%. White mica is muscovite (Table 3, No. 4) containing 0.21–0.26 wt.% F. Biotite is partly replaced by chlorite (Fig. 3f).

5. Discussion and conclusions

Our observations indicate, in accordance with the opinion of Suess (1912) and Preclik (1926a, b), that the metasediments cropping out between the Precambrian basement and the Bíteš gneiss in both Moravian windows are not uniform with respect to their lithology, metamorphic evolution, and probably in their age. Especially the profile in the northernmost part of the Dyje window clearly documents these features.

The hanging-wall metasedimentary sequences are resting here on limestones that are characterized by very strong deformation, but almost lack any thermal overprinting. No newly formed metamorphic minerals, or recrystallization of calcite matrix was observed here. These limestones could be compared with Devonian Lažánky-Heroltice limestone occurring in the hanging wall of the Brunovistulian basement in the Svratka window (Špaček *et al.* 2001).

The hanging-wall sequence comprises slates, metagreywackes and marbles. This sequence was first recognized by Preclik (1926 b) and named, according to Preclik's opinion, after the most typical rock, as the Porphyroid Group. Our new observations indicate that the supposed porphyroids should be named correctly as metagreywacke. The mineral composition of these greywackes indicates most probably their volcanoclastic origin. Contrary to Preclik (1926b), we interpret their structures as dominantly primary sedimentary, with a later metamorphic overprinting. Consequently, the denomination of the rock series according to the presumably typical rock – porphyroid – is not applicable. The groups or formations in the Moravicum are usually labeled according to local names. Because Preclik described the "porhyroids" from the Želetice village we propose to name the whole sequence as the Želetice Group. A detailed regional delimitation of this group is difficult, mainly because of close macroscopic similarity of phyllites of the Pernegg Fm. and metasediments of the Želetice Group. The fresh samples could be identified by the presence or absence of biotite. However, biotite in rocks of the Pernegg Fm. is commonly partly replaced by secondary chlorite, and consequently, the weathered samples are very similar to each other.

Marbles in the Želetice Group contain an admixture of very fine-grained white mica and chlorite, forming small nests in the carbonate matrix. Chlorite and white micas are in contact commonly, but no metamorphic biotite was detected. The metamorphic overprinting seems to be a very low-grade one, below the biotite stability field (Yardley 1989, Bucher – Frey 1994). The same feature was observed in slates and greywackes – no newly formed biotite appears, although all necessary components for the biotite-forming reaction, i.e., white mica, chlorite and detritic K-feldspars are present. White micas both from marbles and metasediments are enriched in the phengite component. A similar sequence was mapped in the Svratka window, in the hanging wall of Devonian Lažánky-Heroltice limestones. However, the low-grade metasediments in the Svratka window differ lithologically from those in the Dyje window. Marbles were not documented here, although metatuffites occur in addition to metagreywackes and slates. Metamorphic overprinting is of the same type as in the Dyje window – below the stability field of biotite. Fragments of primary magmatic biotite found in metatuffites and in some greywackes are, similarly to amphibole, partly replaced by chlorite. This feature indicates again, that biotite was not stable during the metamorphic event affecting the rocks after their deposition. The presence of incompletely consumed pumpellyite and prehnite relics in the metatuffites, as well as the high content of phengite component in white mica corresponding probably to chlorite zone with rather incomplete recrystallization of detrital grains. This estimate is in good agreement with the conclusion reported by Ulrich (2000), who estimated the maximum temperature in the underlying Devonian carbonates in the Svratka window at 300 °C.

The overlying metasediments and marbles of the Pernegg Fm. contain metamorphic biotite, and are therefore regarded as higher-grade rocks. The content of phengite component in white mica from metapelites and marbles in the Pernegg Fm. is lower in comparison with that in the Želetice Group (Table 3). Marbles in the Pernegg Formation are more coarse-grained then those from the underlying Želetice Group. All these facts prove the higher grade of metamorphism in the Pernegg Fm.

The age of the Pernegg Fm. was estimated, based on the Sr isotopic data from the marbles in the Dyje window, as Upper Proterozoic (Frank *et al.* 1992), similarly to overlaying Bíteš Gneiss (Friedl *et al.* 2000). The age of the structurally lower Želetice Group is evidently different. The low-grade metasediments are exposed in the Svratka Window directly in the hanging wall of palaeontologically proven, strongly deformed, Devonian (Givetian – Frasnian) limestones (Hladil 1989, Bosák 1983). The metagreywackes from this Group contain clasts that are microscopically well comparable with the underlying Devonian Lažánky-Heroltice limestones. The metagreywackes and whole Želetice Group seem to be therefore younger than Devonian Lažánky-Heroltice limestones. The Givetian-Frasnian is therefore the lower limit for their age. The main tectonic event in the Moravicum was immediately followed by rapid cooling and exhumation of the whole nappe pile by c. 330–325 Ma ago (Dallmeyer *et al.* 1994). Because the rocks of the Želetice Group are incorporated in the Moravian nappe pile, the sedimentation and volcanic activity within the Želetice Group occured most probably between Frasnien and Visean (370–330 Ma). The lower degree of metamorphic overprinting indicates that the Želetice Group didn't undergo the main phase of Moravian metamorphism in greenschist to amphibolite facies. The Želetice Group was affected only by a low-grade overprinting and deformation connected probably with the nappe emplacement. This indicates that the Želetice Group, together with Devonian Lažánky-Herololtice limestones, was overthrust by the Moravian nappe pile later, probably during the main tectonic phase connected with the mentioned nappe emplacement.

In conclusion, our data indicate that apart of fairly known Devonian Lažánky-Heroltice limestones and associated slightly metamorphosed red siliciclastic sediments, another probably volcanosedimentary sequence was deposited on the Brunovistulian basement prior to its collision with Moravicum and Moldanubicum. It is highly probable that the whole sequence was strongly reduced and dismembered during the emplacement of the Variscan nappes because it is situated directly below the main thrust plane.

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Želetická skupina: velmi nízce metamorfovaná paleozoická sekvence na bázi Moravika

V předložené práci je definována velmi nízce metamorfovaná jednotka – želetická skupina, která vystupuje v severním zakončení dyjské klenby moravika a rovněž v centrální části okna svrateckého. Tam leží v nadloží lažánecko-heroltických a v podloží skupiny Bílého Potoka. Část želetické skupiny byla dříve v dyjské klenbě popsána jako skupina porfyroidová (Preclik 1926b). Tato nově popsaná skupina je složena z metadrob, břidlic, metatufitů a chlotiticko-sericitických mramorů. Tato jednotka byla dosud přiřazována, s výjimkou zmíněné práce Preclikovi ke skupině Bílého potoka v klenbě svratecké a ke skupině lukovské v klenbě dyjské. Od těchto skupin se ale odlišuje zejména svým nižším metamorfním postižením. Nález valounů podložních lažánecko-heroltických vápenců v metadrobách určuje spodní věkouvou hranici do devonu, doba chladnutí celého příkrovového komplexu moravika (Dallmeyer *et al.* 1994) limituje svrchní hranici stáří celé skupiny na ca 330–325 Ma. Tyto údaje indikují, že basement brunovistulikua byl, kromě devonských vápenců a podložních siliciklastických sedimentů, pokryt ještě dalšími paleozoickými formacemi, které byly při následné kolizi s moravikem a moldanubikem velmi slabě metamorfovány a včleněny do šupinovité stavby oblasti.