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WESTERN CARPATHIANS IN THE TERRITORY OF THE CZECH REPUBLIC

Petr SKUPIEN & Zdeněk VAŠÍČEK

Institute of Geological Engineering, VŠB – Technical University;
17. listopadu, 708 33 Ostrava-Poruba, Czech Republic;
e-mail: petr.skupien@vsb.cz, zdenek.vasicek@vsb.cz

INTRODUCTION

The Outer Western Carpathians represent the most external zone of the Western Carpathian mountain chain. In its present form, the Outer Carpathians consist of the Outer Group of Nappes divided from the lowest to the highest into the Subsilesian, Silesian, and Fore-Magura units and the Magura Group of Nappes divided into the Rača, Bílé Karpaty, and Bystrica units. The whole nappe allochthon is thrusted over the Miocene sediments of the Carpathian Foredeep more than 60 km (Picha *et al.* 2006). During the Mesozoic, the Outer Western Carpathians domain rimmed southeast margin of the North-European Platform. This domain was separated by the Penninic Oceanic Branch from the Central Carpathian – Alpine microcontinent, associated with the Adriatic microcontinental assemblage since the Cimmerian collision.

Late Jurassic subsidence enhanced deposition in several troughs (from south to north the Magura-, the Silesian- and the Subsilesian basins) separated by ridges. During Early Cretaceous, black shale dysoxic sedimentation with local submarine clastic fans embraced almost all Outer Carpathian basins. Slow and uniform sedimentation of green and black shale took place during the Albian-Cenomanian, followed by sedimentation of red and variegated shale under well-oxygenated conditions in the Upper Cretaceous. Locally more than 6 km thick flysch deposits are typical of the Outer Carpathian sedimentary sequences.

The Silesian unit is a part of the flysch zone of the Outer Western Carpathians representing the complex of allochtonous nappes. Three subunits (facies) are preserved in the present-day structure of the Silesian Unit (Picha *et al.* 2006), i.e. the Godula subunit (basinal setting), the Baška subunit (frontal slope setting) and the Kelč subunit (continental slope setting).

VENDRYNĚ

Vendryně Formation (Fig. 1) is oldest known strata of the Godula subunit (Těšín Nappe). Originally is known as the Lower Těšín Member (Teschen in German; Cieszyn in Polish). Recently was renamed to the Vendryně Formation (Eliáš *et al.* 2003). Vendryně Formation is represented by dark-brown calcareous shales with occasional thin beds of siltstones, limestones and olistholits. The pelitic and chemical material is thought to be derived from the wider surroundings of the landmass (platform of the Boheman Massif) with a subdued relief. Slump conglomerates (debris flows) with clasts of limestones (Ropice horizon of Menčík *et al.* 1983) occur in the upper part of the formation. Vašíček (1972a, b) assigned the Vendryně Formation, about 350÷600 m thick, to the Oxfordian to Tithonian and possibly to the Berriasian(?) age. Upper part of the Vendryně Formation contains large amounts of dinoflagellates and foraminifera linings. Dinoflagellate cysts belong to the Late Tithonian to Early Berriasian (Skupien 2003).

Fig. 1. Vendryně Formation, right bank of Olše River near Vendryně

Fig. 1. Formacja wędryńska, prawy brzeg Olzy koło Vendryně

BAŠKA

Rocky bottom of the Ostravice River near Baška village exposes higher (Upper Barremian) part of the Hradiště Formation. Dark-grey marlstones and siltstones are penetrated and metamorphosed by intruding rocks of so-called teschenite association. A teschenite pyroxenite

exposure more than 100 m long occurs in the river bed and both the banks of the Ostravice River. The exposure contains almost 2 m thick layers of dark grey calcareous claystones of the Těšín-Hradiště Formation, locally metamorphosed along the contact with teschenite. Fragments of ammonites and small gastropods occur in one of the claystone layers. *Partschiceras infundibulum* (d'Orb.) and *Costidiscus rakusi* Uhlig are the best-preserved ammonites. The latter species indicate deposits at the Early/Late Barremian boundary (Vašíček *et al.* 2004).

In the beds immediately underlying the igneous rocks, there is exposed a thrust plane separating the Silesian Nappe from structurally lower Subsilesian Nappe. Mandelstones with cavity diameters to 15 cm as maximum, filled by calcite, analcime and harmotome, occur locally near the contacts with the sediments.

Formation is teschenite association represents dikes, veins, lavas, pillow lavas (Fig. 2), and pyroclastic rocks of the teschenite rift-related submarine alkalic, calc-alkalic, and basic volcanism. Šmíd (1962) and Šmíd & Menčík (in Menčík *et al.* 1983) distinguished three groups of volcanic rocks: picrites, teschenites, and monchiquites. Hovorka & Spišiak (1988) associated the teschenite volcanism with a short-term rifting of the continental crust. Dostal & Owen (1998) pointed to similarities of these rocks to basalts, basanites, and nephelinites derived from the upper mantle. The volcanic activity peaked during the deposition of the lower part of the Hradiště Formation in the Early Berriasian to Early Barremian time, although teschenite volcanic rocks are sporadically found also in the underlying Těšín Limestone and the Vendryně Formation.

Fig. 2. Pillow lavas on the left bank of the Ostravice River near Baška village

Fig. 2. Lawy poduszkowe na lewym brzegu Ostrawicy koło wsi Baška

Ostravice; Frýdlant tectonic window (southern margin)
Tectonic contact of the Ždánice-Subsilesian Unit with the Silesian Unit

A gently dipping nappe plane between the Ždánice-Subsilesian Unit and the hanging wall Silesian Unit (Fig. 3), represented by the partial Godula Nappe, is exposed in the Ostravice River bed incised into early Holocene gravels at the community of Ostravice.

The Ždánice-Subsilesian Unit, represented by the middle portion (of Maastrichtian age here) of the Frýdek Formation, is exposed in the northern part of the outcrop. It is formed by grey silty calcareous claystones with subordinate laminae or thin beds of white-grey fine- to very fine-grained calcareous subgreywackes.

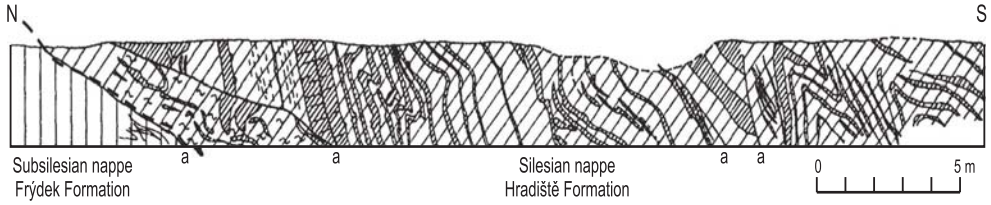

Fig. 3. Tectonic contact of the Ždánice-Subsilesian Unit with the Silesian Unit

Fig. 3. Kontakt tektoniczny jednostki żdanicko-podśląskiej z jednostką śląską

Fig. 4. Těšín-Hradiště Formation on the right bank of the Ostravice River near Ostravice

Fig. 4. Formacja cieszyńsko-grodziska na prawym brzegu Ostrawicy koło Ostrawicy

The base of the Godula Nappe of the Silesian Unit is formed by tectonically intensively deformed Hradiště Formation (Hauterivian, Fig. 4) in flysch development, disharmonically

folded into chevron folds with vertical to horizontal axial planes. The lower parts of the turbidites, usually tens of centimetres thick, are composed of blue-grey, medium- to very fine-grained calcareous subgreywacke passing into grey to black-grey claystones with variable $CaCO_3$ content (distal turbidites with T_{b-e} and T_{a-e} intervals). Bases of subgreywacke beds bear frequent flute casts and sole marks. The sediments can be classified as distal turbidites deposited in a reducing alkaline environment.

The Hradiště Formation passes upwards into dark non-calcareous pelites of the Veřovice Formation (Middle to Upper Aptian) and spotted pelites of the Lhoty Formation (Albian), exposed in the right cut-bank of the Ostravice River further upstream, beyond the rapids.

Štramberk, Kotouč Quarry, Silesian Unit, Baška development, Hradiště Formation and Baška Formation (Upper Jurassic to Upper Cretaceous)

Sedimentation in the Baška Development (subunit), which was defined by Matějka & Roth (1949, 1955), is delimited in extent to a relatively small area of Palkovice Hills between Frýdek and Nový Jičín. Initial sedimentation is connected with the carbonate platform that was situated on the Baška Cordillera (elevation). The Štramberk Limestone was deposited there. The Štramberk Limestone was defined by Hohenegger (1849). Nevertheless, he did not state any type locality. Opinions about the time span occupied by it differ in detail. Most frequently, the Tithonian is stated. According to Houša (in Houša & Vašíček 2005) the sedimentation of Štramberk Limestone could begin in the uppermost Kimmeridgian and end in the Lower Berriasian (calpionellid Remaniella Subzone). Limestones of the Štramberk-type are white-grey limestones deposited in different settings of the carbonate platform and reef complex. Biogenic and sparitic limestones come from the core of the reef (biosparites, intrasparites and intrabiosparites, a.o.).

The Štramberk Limestone in a classical form occurs in several quarries (Fig. 5) in the immediate vicinity of the town of Štramberk in the shape of large carbonate blocks, smaller blocks, breccias and conglomerates. Opinions about the setting and position of the Limestone in the Silesian Unit have been controversial up to now. Matějka & Roth (1955), Frajová-Eliášová (1962), Houša (1976) and Menčík *et al.* (1983) interpret carbonate blocks as tectonic klippen separated from the carbonate platform in the course of Silesian Nappe overthrust. According to Eliáš & Stráník (1963), Eliáš (1979), Eliáš & Eliášová (1984, 1986), large and also smaller blocks were formed by the disintegration of the platform and redeposition of limestones into younger deposits at the foot of slope of the Baška ridge. None of the mentioned theories, however, explains completely the chaotic character of limestone-bearing deposits in the Štramberk area.

As stated by Picha *et al.* (2006) (in Picha & Golonka 2006), the truth lies somewhere in between both opinions. The Štramberk carbonate platform rimmed by coral reefs was a source of clastics and debris. Gravitational slides and turbidite currents transported smaller and also larger blocks and fragments from the rim (edge) of platform as far as the foot of the adjacent basin. On the other hand, in the course of later tectonic transport, large tectonic pieces of carbonate platform were separated from softer, less competent rocks situated on the slopes of the platform. The result is a melange in which larger blocks from the carbonate platform have

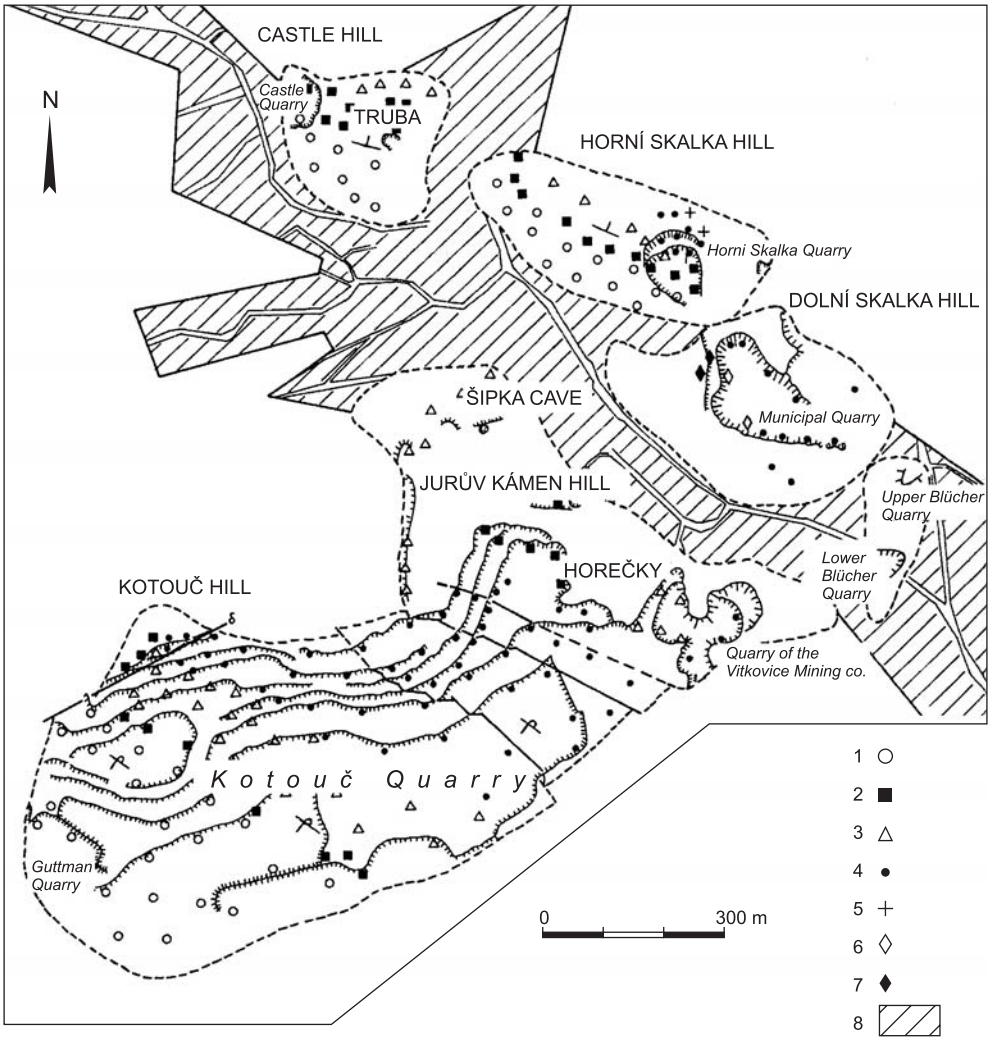

Fig. 5. A map of the main limestone bodies in the vicinity of Štramberk, with the positions of principal quarries and calpionellid zonation (from Houša 1990, revised Houša & Vašíček 2005). 1 – limestone without calpionellids; 2 – *Chitinoidella* Zone; 3 – *Crassicollaria* Zone; 4 – *Calpionella alpina* Subzone; 5 – *Remaniella ferasini* Subzone; 6 – *Calpionella elliptica* Subzone; 7 – *Calpionellopsis simplex* Subzone; 8 – town of Štramberk

Fig. 5. Mapa głównych bloków wapieni w okolicy Štramberku z pozycją kamieniołomów i zonacją kalpionellową (z Houša 1990, zrewidowane przez Houša & Vašíček 2005). 1 – wapienie bez kalpionelli; 2 – *poziom Chitinoidella*; 3 – poziom *Crassicollaria*; 4 – podpoziom *Calpionella alpina*; 5 – podpoziom *Remaniella ferasini*; 6 – podpozim *Calpionella elliptica*; 7 – podpoziom *Calpionellopsis simplex*; 8 – Štramberk

the characters of klippen. Smaller blocks and debris correspond to foot clastic sediments that developed especially in the Lower and the lower part of Upper Cretaceous.

According to historical sources, the Štramberk Limestone of high technological quality (contents of $CaCO_3 > 95\%$, $MgO < 1\%$) has been systematically quarried since the beginning of the 17th century.

Houša (1975, 1990) and also Houša in Houša & Vašíček (2005) proved that after the ending of sedimentation of Štramberk Limestone in the Štramberk area, the sedimentation of Lower Cretaceous carbonates still continued intermittently (Fig. 6). This is proved by calpionellids and ammonites. Of these Lower Cretaceous carbonates, the Kopřivnice Limestone is the most famous. Suess (1858) described it under the name Kalke von Nesseldorf (German name of Kopřivnice). The type locality is the upper Blücher quarry between Štramberk and Kopřivnice. The Kopřivnice Limestone contains, in addition to abundant brachiopods and echinoderms, Upper Valanginian ammonites (Houša & Vašíček 2005). Limestones of the Kopřivnice type are brown-red and red micrites, clayey micrites, biomicrites, intrabiomicrites, intramicrites *etc*.

In the period between the sedimentation of Štramberk Limestone and Kopřivnice Limestone, the Olivetská hora Limestone was deposited. However, later Houša (in Houša & Vašíček 2005) refused the mentioned lithostratigraphic unit and replaced it by two new stratal members, i.e. Čupek Formation and Gloriet Formation. The former Formation occupies the Middle to the lower part of Upper Berriasian (calpionellid Elliptica to Simplex Subzones), the Gloriet Formation then the Lower Valanginian to the lower part of Upper Valanginian (ammonite Pertransiens to Verrucosum Zones).

Besides these carbonate deposits, other local Lower Cretaceous lithostratigraphic units are also known from the Štramberk area. To them e.g. black-grey claystones and siltstones containing ammonites of Valanginian (preserved usually as pyrite moulds) up to the Lower Hauterivian (Houša & Vašíček 2005) belong. Houša connects them with the name of Plaňava Formation. In addition to them, still other similar dark grey or green-grey deposits exist that are usually of Albian to Cenomanian age (Svobodová *et al.* 2002, 2003, 2004).

In the Štramberk area, block accumulations form three major groups of bodies:

a) Western part of Kotouč Hill. Block accumulations reach a thickness of over 400 m (before their extraction in the Kotouč Quarry) and show an uninterrupted stratal succession from the uppermost Jurassic (Tithonian) to the Cenomanian to Lower Turonian. These accumulations in the so-called Kotouč development gradually pass laterally and upwards into different stratigraphic units of the Hradiště Formation. The Kotouč development is dominated by black-grey calcareous claystones, locally accompanied by beds of the Chlebovice Member conglomerates several centimetres to 1 m thick.
b) Massif of the so-called Skalky and Zámecký vrch Hill. Several independent bodies of block accumulations are separated from one another by sediments of continental rise to basinal successions of the Baška subunit. These accumulations include the body of breccia with red and green-grey Kopřivnice Limestone in the so-called Blűcher Quarry. This is overlain by extensive block accumulations with light Štramberk Limestone exposed in the abandoned Municipal Quarry.
c) Southern slope of Bílá hora Hill. Several smaller slump bodies (e.g., the so-called Váňa Stone), partly passing into the Chlebovice Member conglomerates.

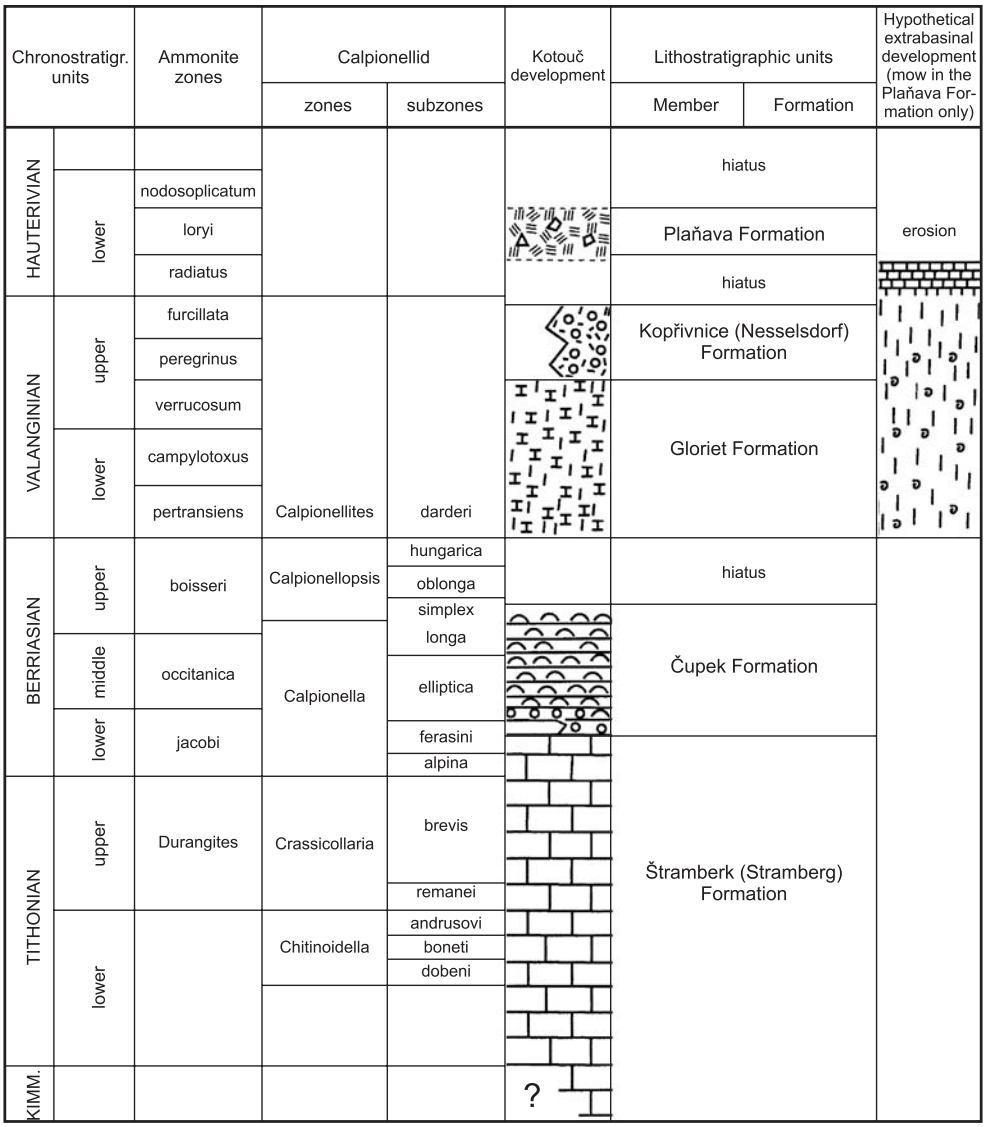

Fig. 6. Stratigraphic units in the region of Štramberk segment of the Baška elevation in the Tithonian and older part of the Early Cretaceous (Houša & Vašíček 2005)

Fig. 6. Tytońskie i wczesnokredowe jednostki stratygraficzne grzbietu Baška w rejonie Štramberku (Houša & Vašíček 2005)

Picha *et al.* (2006) included all local Cretaceous deposits and local lithostratigraphic units in the area of Štramberk under the name Kotouč Facies. In the original version, the Kotouč development was however defined, namely by Eliáš & Stráník (1963), as dark grey to black-grey pelitic deposits of variable sand content with layers of tilloid conglomerates, and

others. At present, the Kotouč Facies represents all the above-mentioned (carbonate, pelitic, conglomerate) specific Cretaceous deposits linked prevailingly to the area of Štramberk. In the normal development of Baška subunit, the Kotouč Facies corresponds to the Hradiště Formation and the Baška Formation.

From paleogeographic viewpoint, the block accumulations form a part of the succession of the continental rise facies of the Baška Development below the hypothetical Baška cordillera. They include slumps, slides, fallen blocks (olistholiths), rarely also turbidites (especially proximal), the material of which comes – along with the allodapic limestones of the Baška Formation – from both the carbonate platform (Malm to Coniacian) and the reef complex (Malm/Lower Cretaceous boundary) on the Baška cordillera and its slopes. The intervals between gravity flows were characterized by hemipelagite deposition. Redeposition occurred from the latest Jurassic to the Late Cretaceous. Lateral and vertical transitions of these block accumulations into the ambient sediments did not confirm the classical idea that they pose tectonic klippen incorporated into the Silesian Unit.

The Baška Formation occurs abundantly in the Baška subunit, including the Štramberk area. The Baška Formation (originally Baschker Sandstein) was defined by Hohenegger (1861) according to the Baška village near Frýdek. To the present-day conception of Formation, the definition of Matějka & Roth (1949) corresponds. The Baška Formation has most oftenly the nature of medium to coarsely rhythmic flysch. Many sandstones contain not sharply delimited thin layers of brownish or blue-grey cherts parallel to bedding. Furthermore, allodapic sandstones and greenish grey claystones are there in the rhythms. According to the foraminifer assemblages (Hanzlíková & Roth 1963), in the lower part also inoceramid bivalves (Vašíček 1977), the Formation corresponds stratigraphically to the higher part of Middle Albian to the Lower Cenomanian. The thickness of Baška Formation is estimated at about 250÷350 m.

A significant part, more specifically a separate lithostratigraphic unit of noncarbonate deposits in the higher part of Lower Cretaceous of Kotouč facies is the Chlebovice Member, sometimes also Chlebovice Conglomerate. For the first time, it was described by Hohenegger (1861) as Chlebovice Member. The name is derived from the Chlebovice village near Frýdek. The mentioned conglomerates and sandstones occur not only in the Štramberk area, but also in other localities of the Silesian Unit. In the pebble-, cobble- and boulder-sized material and blocks, the Štramberk Limestone dominates. It was Hohenegger (1861) who recognized early that in the conglomerate layers outside the Štramberk area occurred the deposits of dual age: older (usually or probably Hauterivian) which are in the lower part of Hradiště Formation (in the Czech territory e.g. localities of St. Ignatius Hill, Janovice, Sedliště, Těrlicko, Soběšovice, Hradiště, Koňákov, Stanislavice, Chotěbuz) and younger (higher Albian to Cenomanian) confined to the Baška subunit (e.g. localities of Chlebovice, Tichá, Vlčovice, Hukvaldy, Rychaltice, Palkovice). Hohenegger (1861) included these occurrences of redeposited Štramberk Limestone generally under the name "exotic occurrences of Štramberk Limestone".

The Ždánice-Subsilesian Unit in the Štramberk area is underlain by the Karpatian sediments, covering the post-Variscan relief modelled in the rocks of the coal-bearing Carboniferous Ostrava Formation. The lower portion of the Karpatian stratal succession contains basal clastics of favourable aquifer properties, sealed by class ("Schlieren"). These clastics host smalt-stale deposits of natural gas, partly derived from the footwall of the Carpathian nappes and partly accumulated during natural degassing of Carboniferous coal-bearing strata.

An underground gas storage of Štramberk was installed at average depth of 550 m under the surface of these small, now exploited gas deposits (Příbor-south).

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