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The Jurassic floor of the Bohemian Massif in Moravia – geology and paleogeography

Josef Adámek

Czech Geological Survey, Leitnerova 22, 658 69 Brno, Czech Republic. E-mail: adamek@cgu.cz

Abstract. The lithofacies, paleogeography, and tectonics of the Jurassic sediments were studied in the footwall of the Carpathian Foredeep and outer units of the Carpathian Flysch Belt in southern Moravia. The major lithofacies were correlated and shown in a set of well logs and regional geological cross-sections. The distribution of facies types is demonstrated in their thicknesses and geological structures. Both cross sections and regional maps (structural and thickness maps) include informations based on deep borehole data and seismic investigation. Some remarks refer to petroleum geology.

Key words: autochthonous and parautochthonous Jurassic, NE European Platform, Western Carpathians, geology, lithostratigraphy, tectonics, depositional topography, petroleum geology

Introduction

Jurassic sediments have been known for a long time in the autochthonous sedimentary cover of the SE margin of the European Platform and in the Flysch Belt of the Western Carpathians. In the vicinity of the city of Brno and the Moravian Karst they are known from some outcrops. In the 1940s they were explored in wells situated in the shallow part of the Carpathian Foredeep. But these wells and outcrops documented only partial sections of the carbonate platform facies. In 1959 the first step into deeper parts of the area was made in Lower Austria by the deep well Staatz-1, which documented mainly pelitic sediments as a basinal facies of Malmian age and primarily clastic sediments of the Dogger (Wessely 1988). In the 1970s, these investigations in former Czechoslovakia were connected (like in Austria) to oil and gas exploration. Otherwise, Jurassic rocks have been mentioned in the literature as tectonic klippen in the Pavlovské Vrchy Hills of southern Moravia and in the Waschberg Zone of Lower Austria for more than 170 years. The exploration and scientific activities on both sides of the border resulted in valuable data on the autochthonous Jurassic as well as the character of the Jurassic of the Outer Carpathians. This paper presents a summary of data concerning Jurassic sediments in the area of interest (Fig. 1), with particular focus on their geological setting and development. The author had been interested in the Jurassic sediments during his long professional activity with the company Moravské Naftové Doly a. s., and some previously non-published information were used in this paper.

Method

Lithological profiles controlled by cuttings, cores, paleontological assemblages, and microfacies, compared with standard microfacies by Wilson (1975) and logs from many deep wells and seismic profiles, have been used to study the autochthonous Jurassic. The multidisciplinary data set formed the basis for well log correlation in the area of interest, and was integrated into a 2D seismic interpretation to construct regional geological cross-sections and to generate structural and thickness maps. Drilling and seismic investigation have revealed many facts on the geological structure and development of Jurassic facies as well as the influence of some significant faults.

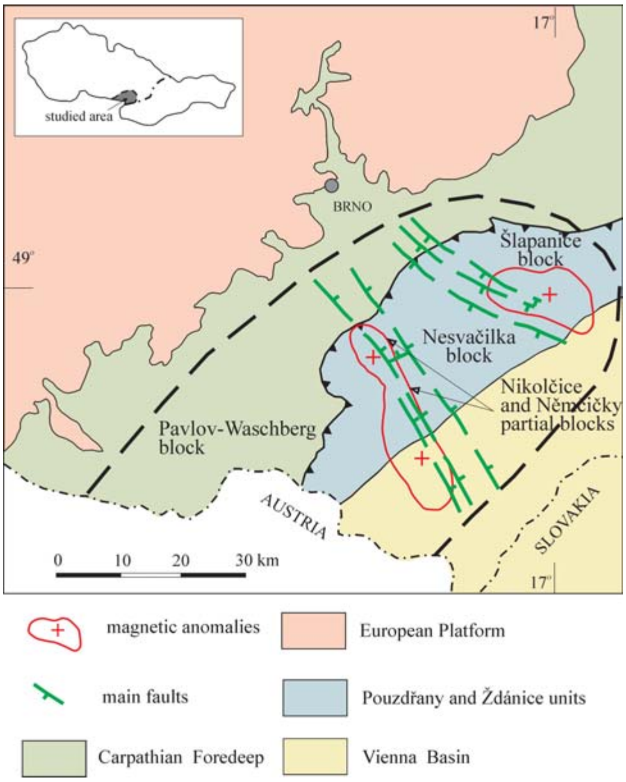

Figure 1. Geological map with individual tectonic blocks.

Geological setting

The geology of the autochthonous and allochthonous Jurassic units of this area has been described by Eliáš (1962, 1969, 1974, 1981, 1984, 1992), Stráník et al. (1968, 1979, 1993), Špička (1976), Vašíček (1980), Adámek (1986, 1990, 2001), Adámek et al. (1980), Eliáš and Wessely (1990), Jiříček (1990), Ciprys et al. (1995), and Wessely (in print).

In this region, the encountered rock complexes belong to three structural levels, the Cadomian, Variscan, and Neoid, all of which are buried below the overthrust flysch complexes of the Western Carpathians. The Cadomian level is composed of metamorphites, granitoids to quartz diorites, and rare ultrabasic rocks. They can be found in the Brunovistulicum unit (Dudek 1980). The Variscan level (?Cambrian, Lower Devonian to Upper Carboniferous) begins with prevailingly red-coloured, coarse-grained clastics. This lithofacies has been identified as the Old Red Sandstone throughout the entire region and, by recent assumption, partly of Lower Cambrian age. Based on micropaleontological data from the Němčičky-3 and -6, and Měnín-1 wells (Jachowitz and Přichystal 1997, Fatka and Vavrdová 1998), middle Devonian deposits overlie the Old Red Sandstones, followed by Lower Carboniferous carbonates. At the onset of Hercynian Orogeny, the carbonate was replaced by the synorogenic flysch sedimentation (Culm), which in the Late Carboniferous was overlain by post-orogenic molasse sediments of the Upper Carboniferous, which are comprised mostly of sandstones containing coal seams (Namurian – A). The Mesozoic Tethyan cycle (Neoid level) began with rifting and deposition of basal, mostly terrigenous, clastic sediments and marine marly shales in the Middle Jurassic (Dogger). This sedimentation was followed by a further transgression of the Tethyan Sea. The development of the Malm is predominantly carbonatic in the shallow depth area, and marly and carbonatic in the basinal facies in a deeper area, continuing to the end of the Jurassic (Malm, Tithonian). The general characteristics of the particular lithostratigraphic units of the Jurassic and their thicknesses are displayed in Fig. 2.

After the Jurassic, the terrain was uplifted and re-peneplaned (except the Pavlov-Waschberg block) up to the Tertiary. A marine transgression locally occurred at the Pavlov-Waschberg block during the end of the Lower Cretaceous. During most of the Lower Cretaceous, the Moravian part of the North European Platform was uplifted and locally eroded, and only rare occurrences of Aptian to Albian rocks are found (Krystek and Samuel 1978, Řehánek 1984). Afterwards, the Middle–Upper Cretaceous sedimentation started. During this major transgression, sedimentation from Turonian to Maastrichtian (Adámek 1986), Turonian to Campanian (Řehánek 1978), or Upper Cenomanian to Lower Campanian continued. During the Laramide Orogeny (Late Cretaceous to Early Paleogene), this area was uplifted and deeply eroded by rivers in the tectonically predisposed Nesvačilka and Vranovice depressions. In both of these depressions most of the Mesozoic sediments were removed. The heavily eroded pre-Tertiary basement in both depressions was gradually filled with sediments during Paleogene. During the orogenic phases in the Early Miocene most of the Paleogene fill in the northwestern shallow parts of both depressions was not tectonically deformed. The distribution of Autochthonous Paleogene deposits is presently much smaller than originally, due to intense denudation and tectonic abrasion during thrusting of the flysch nappes. The Miocene fill of the Carpathian Foredeep was covered by

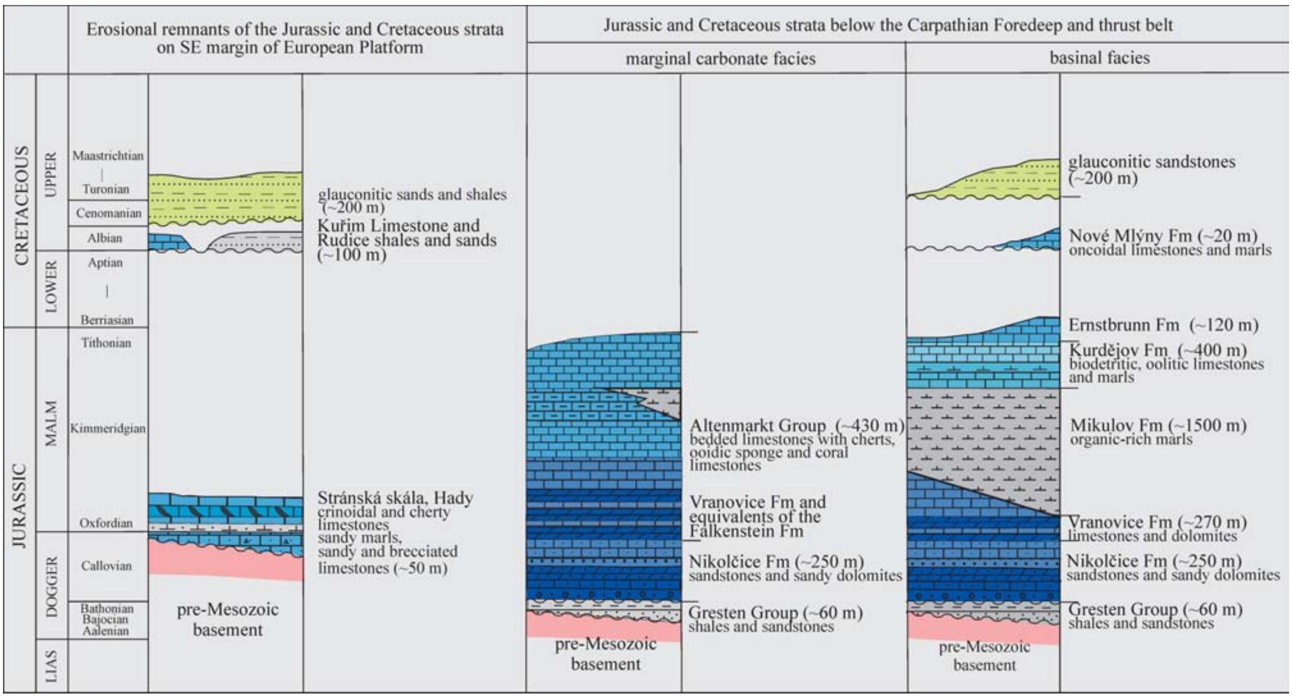

Figure 2. Lithostratigraphic units of the Autochthonous Mesozoic.

overthrust nappes in some parts of the area in front of the flysch. These deposits were preserved to a larger extent, but reduced in thickness under the flysch nappes, primarily on the Nikolčice-Kurdějov horst. The thicknesses of Paleogene, Miocene, and Mesozoic sediments on the Pavlov-Waschberg block were markedly influenced by nappes and were locally incorporated into the basal part of the flysch nappes. The Western Carpathian Flysch Belt comprises the Outer (Menilite-Krosno) group of nappes represented by the Pouzdřany and Ždánice units.

Structural setting

The southeastern margin of the North European Platform (in Czech geological articles often denominated as the southeastern slopes of the Bohemian Massif) in the area of interest was early divided in a transversal direction into two main tectonic blocks: The South Moravian block (subsequently named the Pavlov-Waschberg block) in the SW, and the Central Moravian block in the NE (Chmelík 1969, Špička 1976). The boundary between them was originally considered to be the Nesvačilka depression axis. In the next stage, the individual blocks were established on the basis of the actual knowledge of structural development of the area (Dvořák 1978, Adámek et al. 1980, Adámek 1990, Krejčí et al. 1996). The present article discusses both of the above-mentioned main blocks, as well as the subsequently-formed partial blocks (Fig. 1). These partial blocks, from SW to NE, are: the Nikolčice-Němčičky, the Nesvačilka, and partly the Šlapanice block. Drilling data and geophysical investigations have revealed new facts concerning the fault system separating the main and partial blocks, and have enabled definition of the boundary between the Pavlov-Waschberg and Central Moravian blocks to the SW margin of the Nikolčice-Kurdějov Ridge (Adámek 1990). This ridge made it possible to distinguish partial blocks, such as the shallow Nikolčice and the deep Němčičky block. Interrelations among the blocks were described by Adámek et al. (1980). According to Pícha (1979) the autochthonous Jurassic strata of southern Moravia and northeastern Austria have been confined to a relatively narrow zone of the Carpathian Foreland between Brno and the Danube valley. The area relates to the NW-SE trending rift and modifies the regional depression. Pícha et al. (2005) subsequently defined the depression as the Dyje/Thaya depression.

Jurassic geological development

According to the development of the blocks, the Jurassic sediments lay unconformably on the pre-Mesozoic basement at the Cadomian (Crystalline) or Variscan level (?Cambrian, ?Lower Devonian to Upper Carboniferous). Deposition of Jurassic strata started in the Middle Doggerian (Upper Bajocian–Bathonian) in southern Moravia. These deposits are known in Lower Austria as the Gresten Beds, Gresten Group, or Gresten Formation, formerly in southern Moravia as the Diváky Beds (Eliáš 1974, 1981, Brix et al. 1977, Eliáš and Wessely 1990). Subsequently, the term Gresten Beds was accepted for similar sediments in the southern Moravian area (Adámek 1986, 2001, Řehánek et al. 1996).

In Austria the Gresten Group (except the underlying Porrau Diabase Complex) was subdivided into four members: Lower Quarzarenite Series, Lower Shale Horizon, Upper Quarzarenite Series, and Upper Shale Horizon (Wessely in Brix et al. 1977). The sedimentation was described as a product of combined delta and marine sedimentation of synrift type. The full facies variety is clearly visible in the Austrian territory, but in southern Moravia has not yet been identified. Only an incomplete development with different members of the Gresten Group was found on both of the main tectonic blocks. A more complete succession was found in the Nesvačilka block. The thickness of the sediments varies within tens of metres (at about 60 m on the above-mentioned block). According to information about the Austrian territory (Grün 1984, Sauer et al. 1992, Zimmer and Wessely 1996), there is a distinct SW-NE general drift of tectonic lines in Austria showing a dipping of the fault system towards SE. The thickness of deposits reaches more than 1700 m (in the area of Stockerau). The thickness depends on the position within the deltaic complex and the position within the synsedimentary tilted fault block system. In southern Moravia these sediments have been found locally and incompletely as relatively thin bodies in an uplifted position. A slightly different direction of faulting is found on the Nesvačilka block (Figs 7, 8).

In the Callovian time a new cycle started that was marked by an unconformable superposition on older sediments and tectonics. As a result of the global eustatic cycle by the Callovian regional transgression, mainly sandstones of the Nikolčice Formation and the corresponding Höflein Formation in Lower Austria were deposited on a regional plain surface. The cycle is characterized by carbonatic influence in the beginning, particularly on the Pavlov-Waschberg block, and by sandstones on the southern part of the Central Moravian block. Thicknesses of the both facies (sandstones and sandy dolomites) in southern Moravia range between 70–250 m. The prevailing terrestrial sedimentation was followed by a further transgression of the Tethyan sea and created a Malmian carbonate platform (Altenmarkt beds, Ladwein 1976), later renamed as the Altenmarkt Group (Eliáš and Wessely 1990) in the shallow northwestern peripheral part. This part developed along a passive continental margin in the west. Another one, the so-called Pavlov carbonate platform (Eliáš 1984) was probably developed on a horst block in the inner part of the Jurassic basin in the Late Jurassic (see the model of the depositional topography on Fig. 3). The upper part of the sediments of this platform was incorporated during the late Alpine deformation and thrusting into the frontal part of the Carpathian thrust belt (Jurassic and Cretaceous sediments of the Pavlovské Vrchy Hills). The surface of the

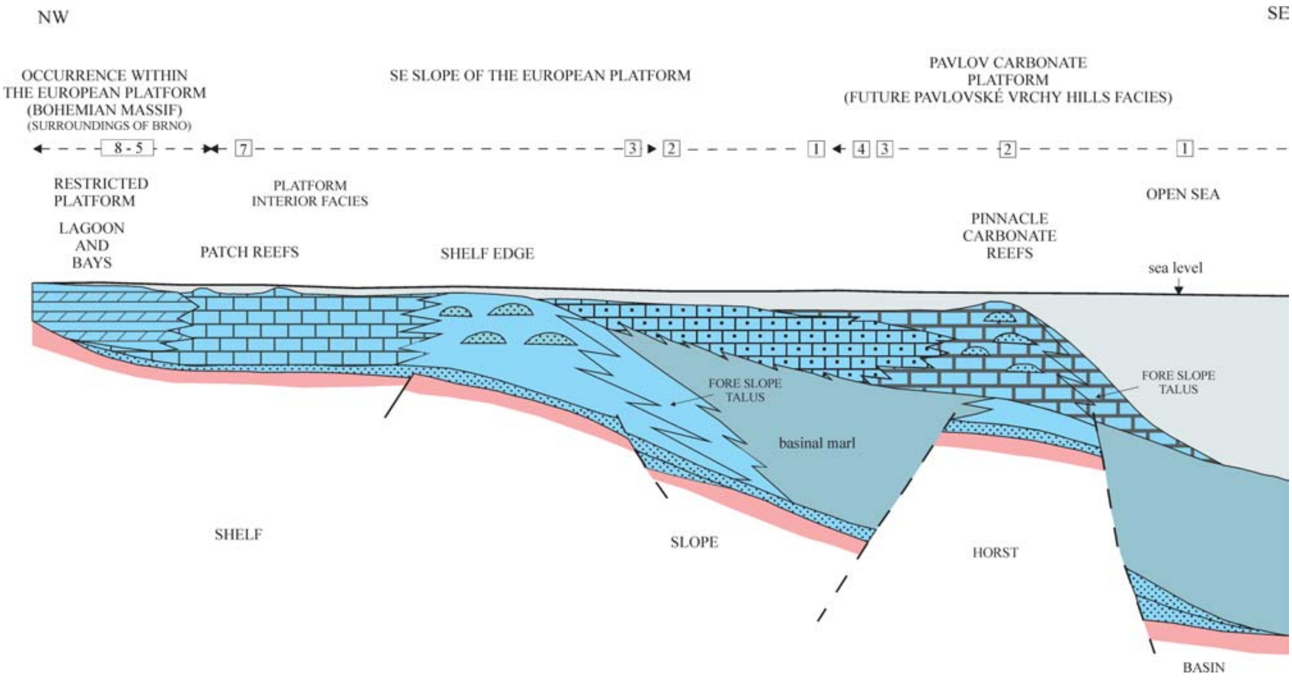

Figure 3. Jurassic on the SE margin of the European Platform – model of the depositional topography (horizontal and vertical dimensions not to scale). 1–8 – standard microfacies by Wilson (1975).

autochthonous Jurassic rocks is exposed only in the vicinity of Brno, and was described by Eliáš (1984). The 430 m thick sequence of the marginal carbonate facies, the Altenmarkt Group, begins with bedded limestones with some chert, grading upwards into bioclastic limestones containing algal-sponge associations and some rare coral patch-reefs. The moderate dip of the slope of the carbonate platform is characteristic of the study area, and, contrary to Lower Austria, does not contain any large reef complexes.

Predominantly marly sediments form a basinal pelitic-carbonatic development that was deposited in a deeper, more restricted marine environment (Kapounek et al. 1967, Stráník et al. 1968, Brix et al. 1977, Eliáš 1981, Adámek 1986, Eliáš and Wessely 1990). Upwards from the bottom the following lithostratigraphical units can be distinguished: Vranovice (limestone and dolomite), Mikulov (marl), Kurdějov (arenite) formations, and finally the Ernstbrunn Formation (limestone). The transitional series of the sediments between the marginal carbonate and the basinal, pelitic-carbonatic development is represented by the equivalent of the Vranovice Formation in Moravia and the Falkenstein Formation in Lower Austria. The Vranovice Formation fringes basinward, and its thickness decreases from 270 m at the front of the marginal carbonate platform (marginal carbonate facies) to only a few tens of metres in the pelitic-carbonatic development (basinal facies) further east. The Mikulov Formation (dark marl) is the most extensive member of the deeper pelitic-carbonatic development. The known thickness is about 2000 m, but often it is tectonically enlarged (Adámek 1986) by duplication (Fig. 6). The Mikulov Formation (marl) gradually passes upwards into the Kurdějov Formation (arenite) as the basin grew shallower. The up to 400 m thick dark to light Kurdějov Formation (arenite) developed from the Mikulov Formation (marl) by an upward transition. The Kurdějov Formation (arenite) consists of various types of detrital limestones alternating with layers of dark marls. The regression resulted in the development of carbonates of the Ernstbrunn Formation (limestone), which is very similar to the external klippen of the Carpathian nappes (Řehánek 1987). The Ernstbrunn Formation, containing the remains of mollusks, algae, and corals, terminated the Malmian sedimentation. Their thickness (known from deep wells) reached about 120 m.

All the individual facies complexes of Jurassic in the Czech territory have been described by Eliáš (1962, 1969, 1974, 1977, 1981) and Řehánek (1977, 1985). A comparison of the Ernstbrunn Formation between wells and outcrops in southern Moravia was published by Řehánek (1987). The description, compilation, and comparison of all of the lithofacies on both sides of the Czech/Austrian border have been presented by Adámek (1985, 1986) and Eliáš and Wessely (1990). Stratigaphy of the autochthonous Jurassic and Cretaceous deposits, their lithostratigraphic units, and their relationships are shown in Fig. 2.

Interpretation

The Jurassic stratigraphy and structure of southern Moravia described in the preceding sections is illustrated in five figures, each of which has two parts: a regional correlation of well logs, and a geological cross section. The regional profiles are based on seismic and well log data. The locations of the regional geology and regional correlations of well log profiles described in text are indicated on the map

(Fig. 10). Well log correlation and subsequent interpretation of the geologic cross sections document the geological development on the profiles with emphasis on the Jurassic strata. Well logs were used to identify the individual Jurassic facies (using spontaneous potential SP and resistivity gradient curve Rag). For the geological interpretation of each of the regional cross sections, the seismic lines were used. For a better understanding of the geological development of the area, the profiles had been situated perpendicular to the main geological features.

Cross sections

Transversal profiles (Figs 4–6) connect the shallow part of the Carpathian Foredeep with the Vienna Basin through the Carpathian Flysch Belt, or they terminate in the Carpathian Flysch. Each of them is about 30 km long, and the wells and seismic lines verify all the profiles. The profiles document both Doggerian and Malmian strata, marginal carbonate and basinal facies, as well as geology in general, including tectonic patterns with dominant normal faults and overthrusts. A well log cross section in the upper part and a regional geological cross section in the lower part of each of the individual figures show the thinning and developing of the Jurassic strata from southeast to northwest, and document the development and facies characteristics of the Jurassic.

In the southern part of the area (Fig. 4) the Gresten and Nikolčice formations of the Dogger are poorly developed in wells and hardly distinguished on seismic profiles. The cross section passes the western margin of the Jurassic with the marginal carbonate facies (Novosedly-1 and Březí-1 wells) through the Březí-2, Nový Přerov-2 and Mikulov-1 wells with basinal facies. The Sedlec-1 well represents the deeper part. The geological cross section illustrates the regional tilting of the eastern slope of the Bohemian Massif. In the shallow part of the profile, younger post-Jurassic, antithetic and basinward-directed normal faults are expected. Earlier faults, such as in the Dolní Dunajovice gas field, are also documented. In the deeper parts normal significant synthetic faults are expected.

The NNW part of the profile on Fig. 5 crosses the Vranovice depression, filled by Paleogene sediments, and continues through the Carpathian Flysch Belt to Vienna Basin (easternmost part of the profile). Except for the eastern slope of regional tilting, one can see the dominant younger faulting of the Jurassic (similar to that in Fig. 4). The profile passes the Pasohlávky-1 and Mušov-3G wells (both of which contain thermal water, Adámek and Michalíček 1990). It crosses the northern part of the Dolní Dunajovice gas field, which has been converted into an underground gas storage facility (Dunajovice-17 well), and continues to the deeper part of the region (Strachotín-2 and Bulhary-1 wells).

The profile situated on the Nikolčice-Kurdějov horst (Fig. 6) connects the shallow part of the Carpathian Foredeep with the so-called Měnín Hill, which consists of Paleozoic sediments. It then passes the marginal carbonate platform of the Jurassic (shallow Měnín Counterflush Cf wells and Nikolčice-4 well), and reaches the basinal deeper part of the Jurassic development below the flysch nappes (Nikolčice-6, 1A, 2A, Němčičky-5, 2, 1 and Kobylí-1 wells). From the view of the geological development of the separate blocks the profile is situated in the southern part of the Central Moravian block. The structural extension related to Dogger rifting is recognized in the shallow part of the area – on the Nikolčice partial blocks. The Cadomian level, composed of granitoid rocks, was encountered only in the Nikolčice block. Because of the great thickness of the overlying sediments it has not been reached by drilling in the deeper parts of the area, as in the Němčičky block. The tectonic style of the area is a bit different than on both previous transversal profiles (Figs 5, 6).

All transversal profiles document the different kind of sedimentary cover of the Dogger and Malm. But except for the Doggerian tectonics, all the Jurassic complexes of sediments are disturbed by normal-synthetic fault steps down to the subthrust floor. There are also a few significant normal-antithetic faults (faults systems) in the shallow part of the Carpathian Foredeep, some of which are of importance from the hydrogeological, hydrodynamic, and petroleum perspective (Adámek 1977, 1978, 1985, 1986, Polesňák and Adámek 1983, 1986). The faults were formed as a result of thrust loading over the foreland in the Neogene. Their mechanism and pattern, and their significance for hydrocarbon accumulation, have been described by Harding and Tuminas (1989).

Longitudinal regional correlation profiles of well logs, and geologic cross sections (Figs 7, 8), pass through the Pavlov-Waschberg block region in the SW part. The central parts of profiles pass through the Nikolčice–Kurdějov horst and the Nesvačilka depression, and continue to the Ždánice high (Šlapanice or Uhřice individual fault blocks). This means that the profile connects both main regional blocks in the area of interest: the Pavlov-Waschberg and Central Moravian blocks. Studies permit the determination the southwestern margin of the Variscan area of sedimentation preserved on the Nikolčice-Kurdějov horst, and the identification of the structure of this region near the limits of the Variscan tectogene. NW-SE striking tectonic elements in this region subdivide the whole area between the Pavlov-Waschberg block and the Ždánice high into numerous step-like blocks with faults that evidently disturb the Variscan level and the lower part of Jurassic sediments. The profile in Fig. 7 was situated in the deeper part of the Carpathian Flysch Belt, while the profile in Fig. 8 was situated in the shallow part of the area (Carpathian Foredeep and the frontal part of Carpathian Flysch Belt). The cross sections illustrate the geological and tectonic pattern on the profiles, and the tectonic style of both main blocks (Pavlov-Waschberg and Central Moravian blocks) and the individual-partial blocks.

The profile situated in the deeper southeastern part of the area (Fig. 7) passes the marginal part of the Vienna Basin (Nové Mlýny-2 well), the Pálava Hills (Nové Mlýny-3 well) with the Nikolčice-Kurdějov horst and the Uhřice

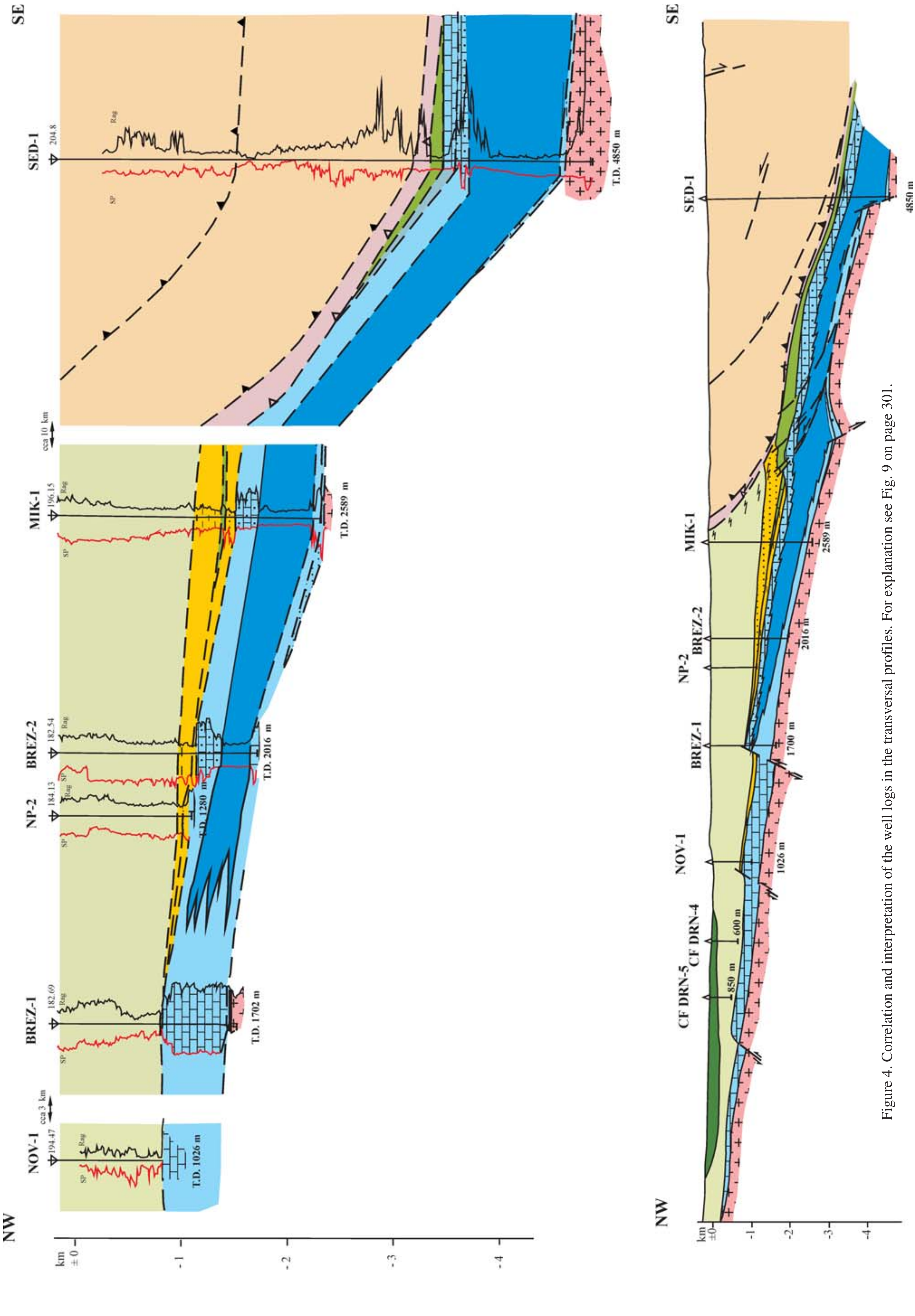

Figure 4. Correlation and interpretation of the well logs in the transversal profiles. For explanation see Fig. 9 on page 301.

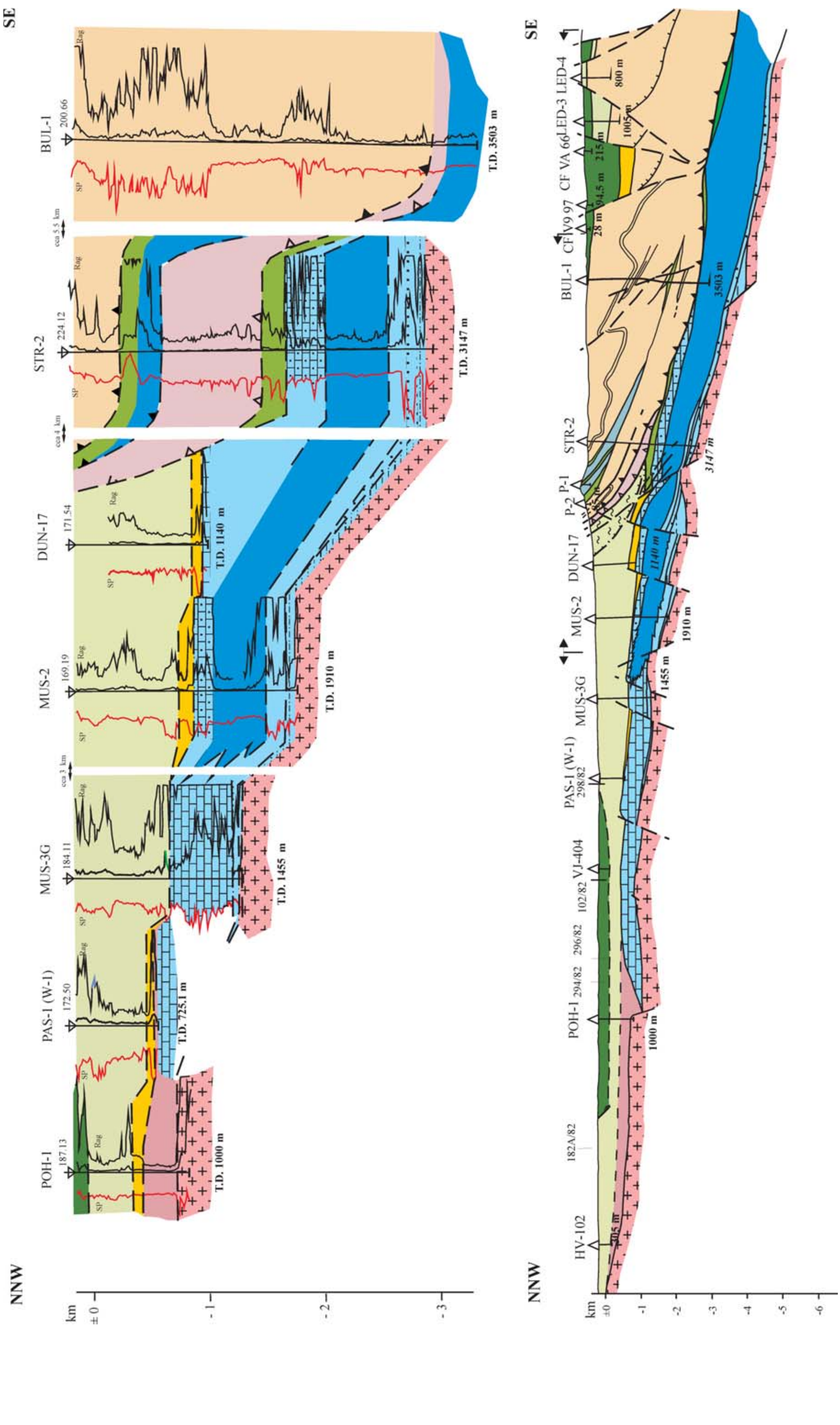

Figure 5. Correlation and interpretation of the well logs in the transversal profiles. For explanation see Fig. 9 on page 301.

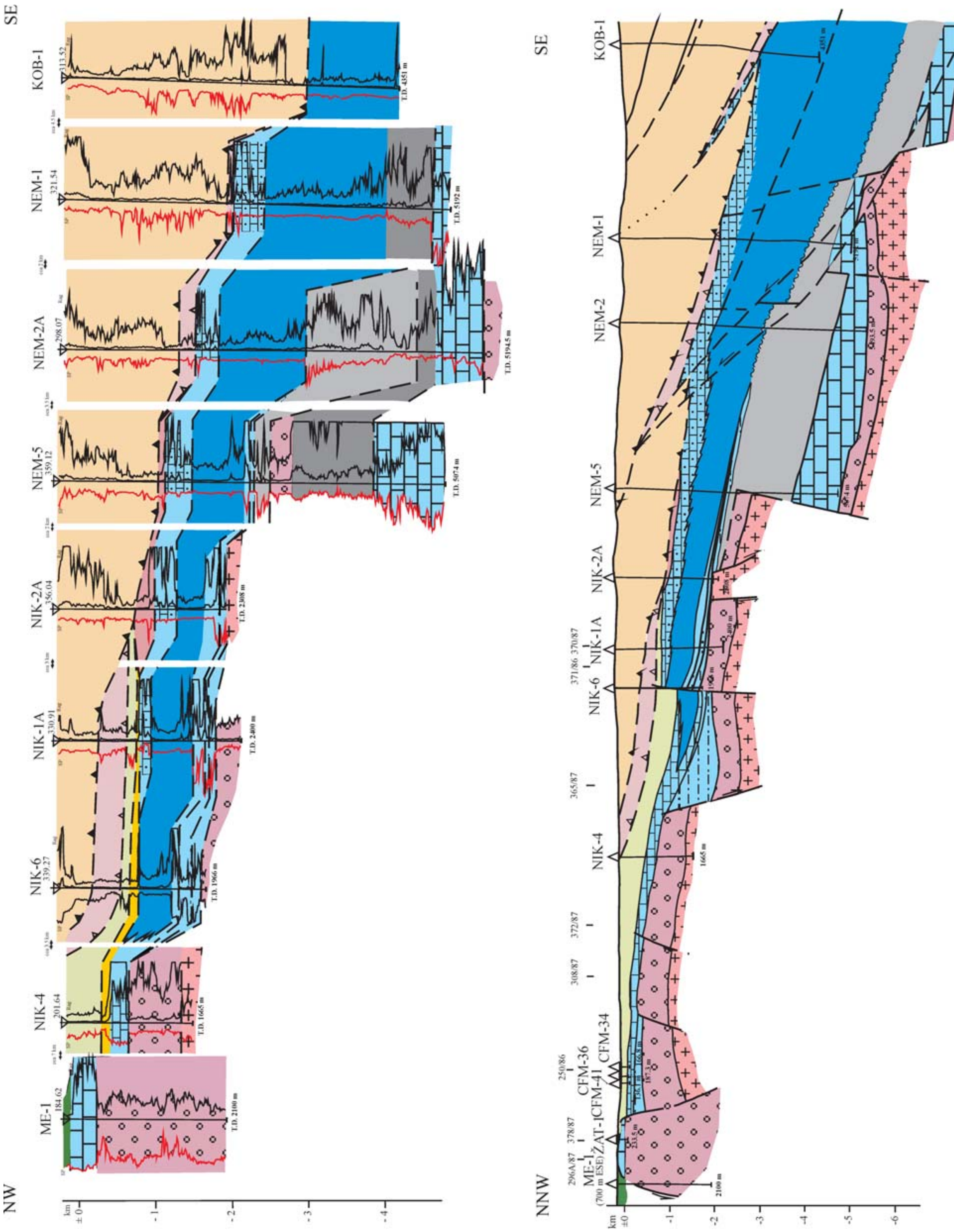

Figure 6. Correlation and interpretation of the well logs in the transversal profiles. For explanation see Fig. 9 on page 301.

blocks on the SW slope of the Ždánice high. The profile was verified by wells and seismic lines, and crosses the Vranovice and Nesvačilka depressions filled with autochthonous Paleogene deposits. All the area is overthrusted by flysch nappes (Pouzdřany and Ždánice units). The Jurassic sediments are mostly preserved on the Waschberg-Pavlov block, the Nikolčice-Kurdějov horst, and partly on the Šlapanice block. The geologic cross section illustrates the trends on the flanks of the Nikolčice-Kurdějov horst as well as on SW slope of the Ždánice high (Uhřice blocks). In the central, axial parts of the Vranovice and the Nesvačilka depressions we do not expect (based on well logs and seis-

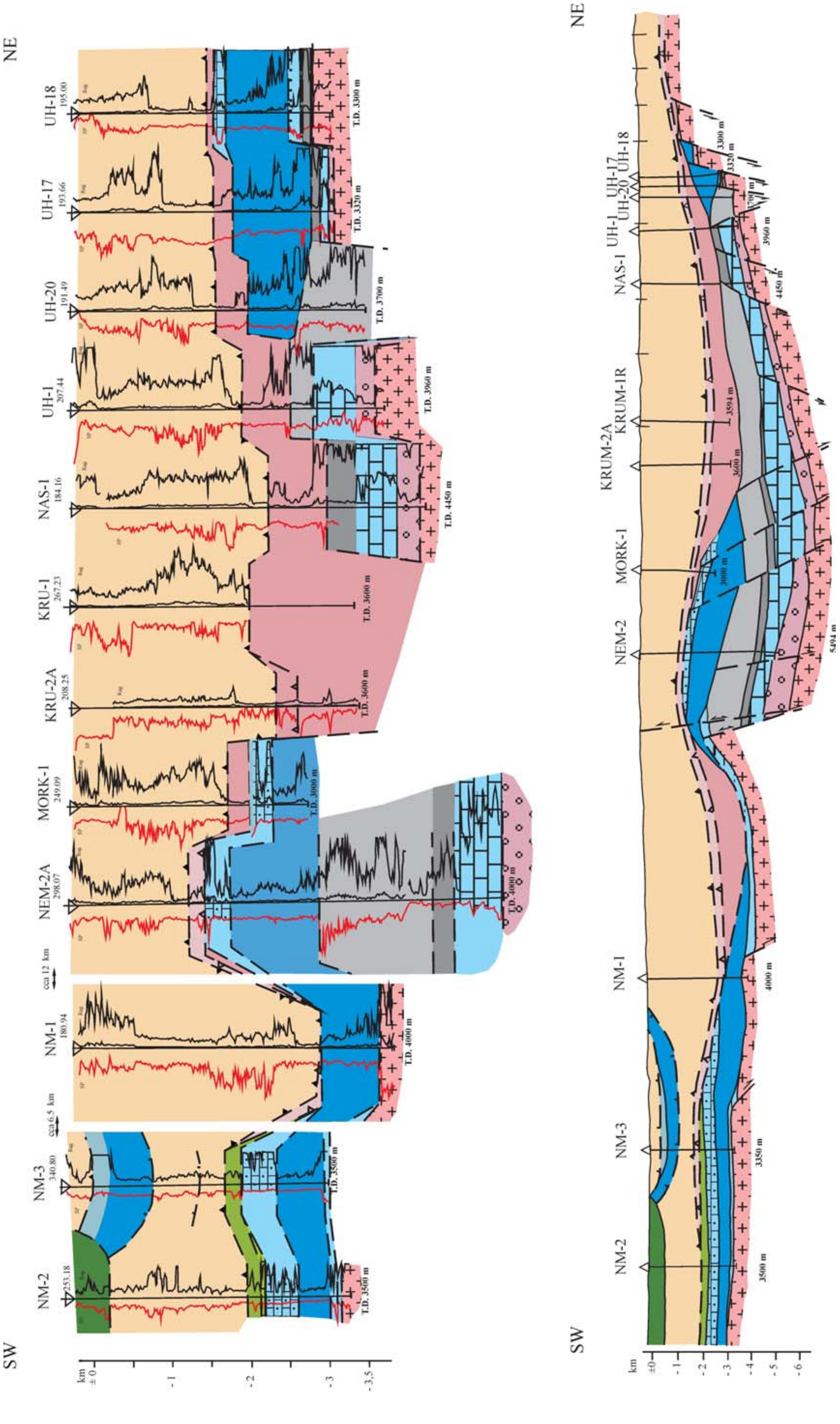

Figure 7. Correlation and interpretation of the well logs in the transversal profiles. For explanation see Fig. 9 on page 301.

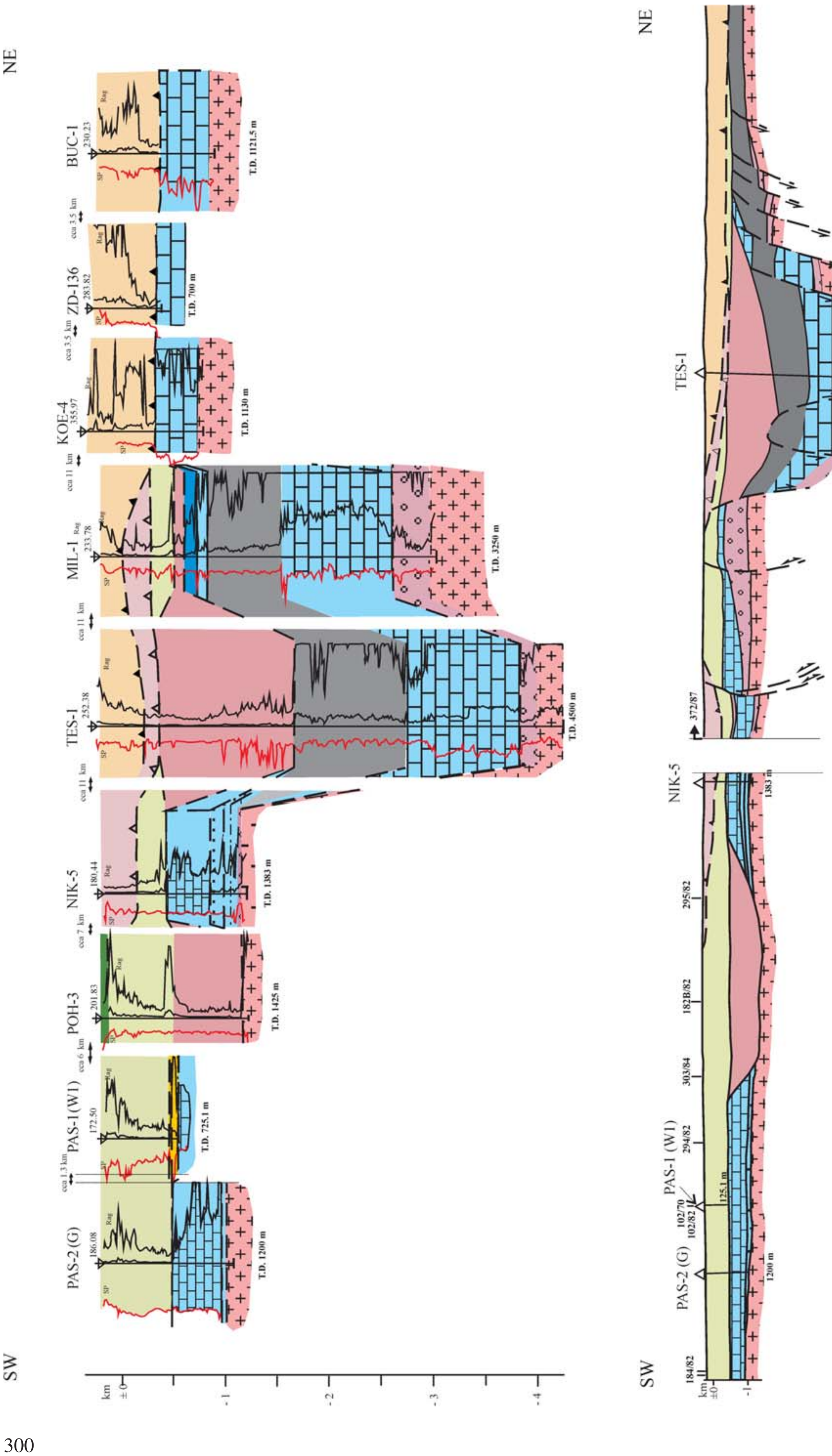

Figure 8. Correlation and interpretation of the well logs in the transversal profiles. For explanation see Fig. 9 on page 301.

mic investigations) almost any thickening of Jurassic sediments, which have been largely removed by long-term erosion in both depressions. On the SW slope of the Ždánice high they were left as remnants in tectonically limited blocks on the downthrown blocks (NE part of the profile), or due to the inversion on individual, partial, upthrown blocks.

The profile (Fig. 8) in the shallow northwestern part of the area passes the part of Carpathian Foredeep (Pasohlávky-1, 2G wells) with the Nikolčice-Kurdějov horst (Nikolčice-5 well), crosses the Vranovice and the Nesvačilka depressions, and ends on the SW flank of the Ždánice high. This profile was verified in the above-mentioned wells, and generally documents the marginal carbonate platform. The thickness of the Jurassic sediments reaches about 500 m. According to the profile in Fig. 7, the development of both Paleogene depressions was similar. In contrast to the profile situated in the deeper part of the area (Fig. 7), erosion has clearly been the dominant controlling mechanism for the Vranovice depression.

Structurae and isochore maps

The structural contour map of the top of the pre-Tertiary relief (Fig. 10) shows essential features and structural elements. The contour interval is 100 m in the shallow part and 200 m in the deepest part of the area. Elevation is indicated in metres above sea level. The NW-SE trend of the regional tilting of the individual blocks (Vranovice, Nesvačilka and Nikolčice-Kurdějov high) is evident, as well as a relatively gradual slope in the deeper part of the area to the southeast. The roughly NW-SE trending depressed zones are the most prominent elements within the pre-Tertiary relief, and the map displays their deepening towards the SE. In the largest part of the area of the Vranovice depression, and partly in the area of the Nesvačilka depression, the Jurassic sediments were largely removed by deep but selective erosion. Thus, the crystalline basement and the Lower Carboniferous Culm or sediments of Dogger age form the pre-Tertiary relief. Only remnants exist on tectonically limited blocks, namely on the SW slope of the Nesvačilka depression (Figs 7, 8).

Isochore map

The Jurassic isochore map (Fig. 11) clearly shows the thicknesses of both Jurassic developments in the area of interest, except the non-depositional area in the Vranovice and the Nesvačilka depressions. While the deposition on the Pavlov-Waschberg block is symmetric, that on the Nikolčice-Kurdějov high and the Nesvačilka depression is distinctly asymmetric due to the different tectonic development of these blocks. Thicknesses reach up to 1100 m on the Pavlov-Waschberg block, 2000 m on the Nikolčice-Kurdějov high, and at about 500 m on the Uhřice block. The Jurassic sediments of the marginal carbonate platform have been identified as remains, while the thickness of the basinal facies (Mikulov marls) increases eastward under the flysch nappes. The continuation of the Ju-

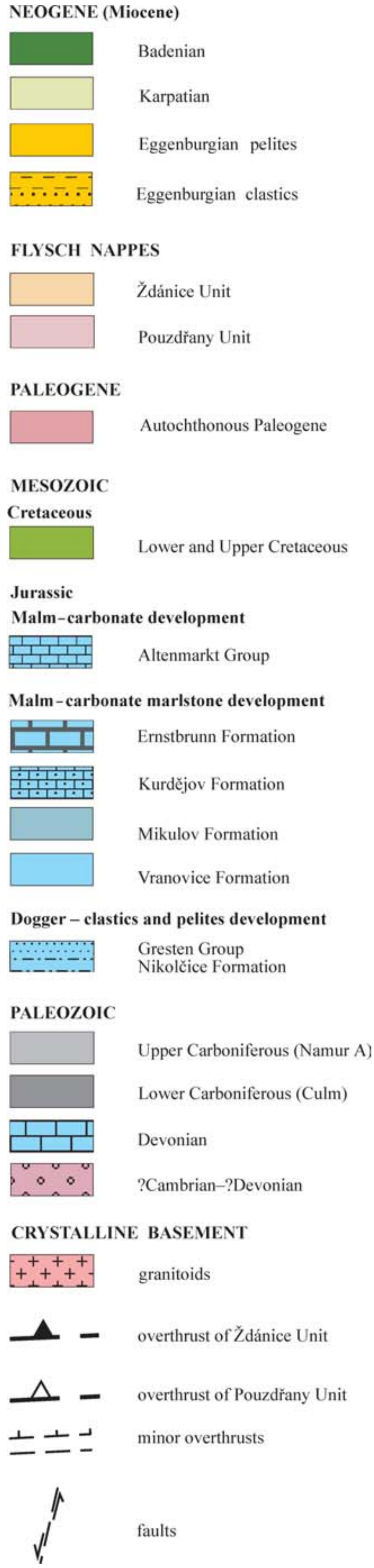

Figure 9. Explanations for Figs 4–8.

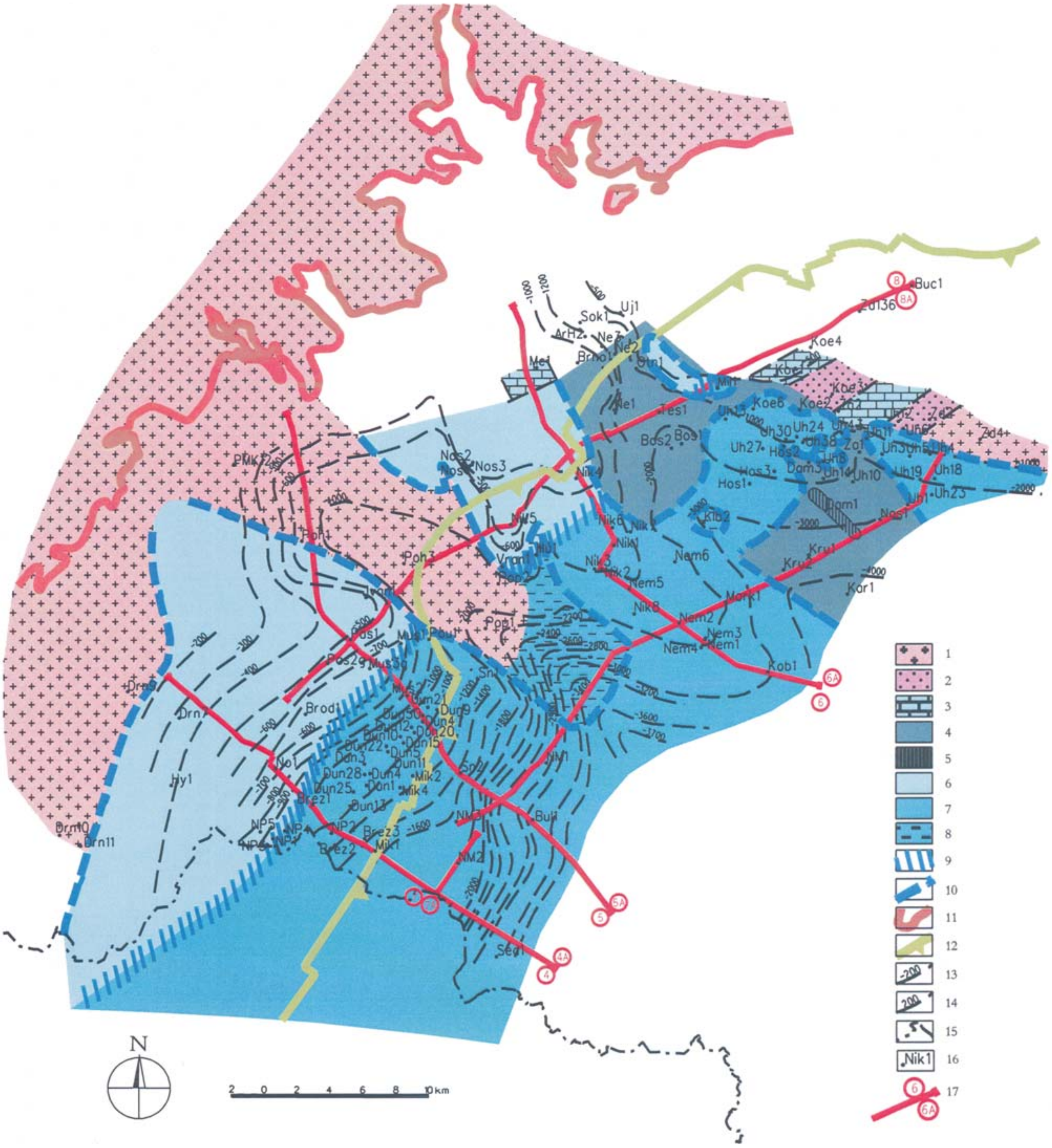

Figure 10. Structure contour map on the pre-Tertiary basement and situation of wells.
1 – Crystalline and Paleozoic basement, 2 – Paleozoic (?Cambrian–?Old-Red), 3 – Devonian, 4 – Lower Carboniferous, 5 – Upper Carboniferous with coal, 6 – Jurassic, carbonate platform, 7 – Jurassic, basinal development, 8 – Gresten Group and Nikolčice Formation, 9 – Mušov, transition zone of Jurassic facies, 10 – extension of Jurassic sediments, 11 – outcrop of Crystalline and Paleozoic basement, 12 – Carpathian thrust front, 13 – contours, 14 – isochors, 15 – state border, 16 – selected wells, 17 – direction of profiles.

rassic sediments to the Bohemian Massif (to the NW) and to the Western Carpathians (to the SE) is not depicted. Marginal carbonates, basinal facies, and the transition zone between both Jurassic developments are depicted on this map, and the transition zone is indicated by a dashed line. The transition zone named as the Mušov Zone (Adámek 1974, 1977) represents the changing of the facies in the seismic image between both main facies developments, which, together with normal faulting, plays a very important role from the petroleum perspective. The marginal carbonate platform seems to be an open hydrogeological structure, while the basinal facies (pelitic-carbonatic development), is closed and of interest for petroleum exploration (Polesňák and Adámek 1983, 1986).

Figure 11. Isochore map of Malmian sediments and facies distribution.

Petroleum geology

Reservoir rocks

In the study area, the most important reservoir rocks are the Gresten Group (Dogger sandstone facies), the Nikolčice Formation (Callovian sandstones and sandy dolomites), and the Vranovice Formation (Oxfordian limestones and dolomites). In these lithostratigraphic units the most important hydrocarbon reservoirs are situated not only in southern Moravia (Dambořice, Žarošice and Uhřice – south oil fields), but also in Lower Austria (Höflein). Within the Gresten sandstone facies, the values of porosity in the Dambořice oil field range between 15–25 %, while their permeability ranges from 100 to 1000 (8000) md (Kostelníček and Thonová 1994). In the Höflein field, the Höflein and Gresten lithostratigraphic units are stated as the gass-bearing strata. For the Höflein Formation (analogous to the dolomitic development of the Nikolčice Formation in southern Moravia), porosity values reach 25.4 % and permeability values vary between 131–1119 md. In the Gresten Sandstone underlying the Höflein fields, the Höflein Formation porosity and permeability values are 21.2 % and 516–3236 md, respectively (Grün 1984, Sauer et al. 1992, Zimmer and Wessely 1996).

Source rocks

The Mikulov Formation (marl facies) buried under the flysch units is indicated as the prominent hydrocarbon source rocks based on a series of geochemical studies (Ladwein 1988, Franců et al. 1996, Pícha and Peters 1998). The total TOC values recognized within the Mikulov Formation vary between 0.2–10 % with an average value of 1.9 %. Marl of the Mikulov Formation is considered to be the principal hydrocarbon source not only for the hydrocarbon deposits in the Vienna Miocene sedimentary fill, but also for its foreland in southern Moravia and adjacent regions (Pícha 1966, Krejčí et al. 1994, Ciprys et al. 1995, Franců et al. 1996, Zimmer and Wessely 1996). The source rock potential of the Mikulov Formation evidently increases eastward under the flysch nappes. There were found indications of noncommercial hydrocarbon accumulations in the area of interest and adjacent areas in all the potential sedimentary sequences. We suppose that the hydrocarbon indications confirm the idea of young Miocene migration processes, and hence of possible subsequent hydrocarbon filling of the potential traps. Practically all of the hydrocarbons could have been generated after the overthrusting of the flysch nappes. Migration processes took place both laterally and vertically. Migration pathways within fractured rocks along the young or older Miocene reactivated fault systems had great importance.

Sealing

The pelitic facies of Jurassic (Mikulov Formation) are generally considered as the sealing horizon for the older Dogger and Malm (Gresten-Group sandstone facies, Nikolčice and Vranovice formations). Besides lateral facies changes, normal faults played an important sealing role, depending on their displacement and the thickness of the facies.

Conclusions

In this article, an interpretation of the Jurassic strata under the Miocene sediments of the Carpathian Foredeep and the flysch nappes in the southwestern part of the Carpathians is presented. The cross sections document in detail the Doggerian and Malmian sediments, carbonatic and basinal facies, as well as geology in general, including tectonic patterns with dominant normal faults and overthrusts. The development of both the Doggerian and the Malmian sediments was different. From the petroleum perspective, the Doggerian clastics are important reservoir rocks for the whole Jurassic strata. A model for the distribution of the Malmian facies was demonstrated. The moderately dipping slope of the carbonate platform is characteristic of the study area. The longitudinal profiles exhibit the southwestern margin of the Variscan area with different structural features of the Jurassic on the Pavlov-Waschberg and the SW part of Central Moravian blocks. Isopachs and facies maps show the extent of Malmian sediments by means of seismic and well data. The structural contour map displays the essential features and structural elements of the pre-Tertiary relief. The isochore map shows the thicknesses of both of the Jurassic developments and the non-depositional areas in the Vranovice and the Nesvačilka grabens.

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