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Original paper

Pre-Late Carboniferous geology along the contact of the Saxothuringian and Teplá–Barrandian zones in the area covered by younger sediments and volcanics (western Bohemian Massif, Czech Republic)

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The boundary between the Saxothuringian and the Teplá–Barrandian zones at the western margin of the Bohemian Massif represents an important tectonic suture of the Central European Variscides. However, most of this boundary is covered by Late Carboniferous and younger sedimentary and volcanic rocks, which prevent direct observation of particular geological units. We present a compilation of geological and depth measurement data from 12,134 exploration boreholes that reached the basement of the volcanic and sedimentary infill in the area of the Eger Graben in the north-western Bohemia, and correlate covered geological units with those exposed on the present-day surface. The resulting compilation reveals the relief of the sedimentary basins basement and interprets the real extent of the basement geological units in the western part of the Bohemian Massif. It also shows the position of the contact between units with the Saxothuringian and the Teplá–Barrandian affinities and suggests the boundary between rocks with Devonian metamorphic record and those metamorphosed during the Early Carboniferous period of the Variscan tectonometamorphic cycle.

Keywords: Bohemian Massif, Saxothuringian Zone, Teplá–Barrandian Zone, suture, Central European Variscides
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1. Introduction

The contact between the Saxothuringian and the Teplá–Barrandian zones in the Bohemian Massif (Fig. 1) has been recognized long time ago as one of the tectonic sutures in the Central European Variscides (Kossmat 1927; Matte 1986; Franke 1989, 2000; Matte et al. 1990; Pharaoh 1999). The significance of this collisional boundary was later emphasized in numerous studies on exhumation of high-pressure rocks, which appear on both sides of the suture zone (Franke 1984; Krohe 1996; Matte 1998; Klápová et al. 1998; O'Brien 2000; Franke and Stein 2000; Willner et al. 2000; Konopásek et al. 2001; Konopásek and Schulmann 2005). However, all the tectonic interpretations are hampered by the fact that most of the transition zone between the Saxothuringian and the Teplá–Barrandian zones is covered by Late Carboniferous and Permian basin fills, Cretaceous sediments and Tertiary volcanic and sedimentary rocks of the Eger Graben (Fig. 2). Thus, with an exception of a narrow corridor in the area northwest of the Mariánské Lázně Complex (Fig. 2), the rocks along the Saxothuringian/Teplá–Barrandian suture in the western part of the Bohemian Massif cannot be studied directly and all the data necessary for interpretation of tectonic processes must

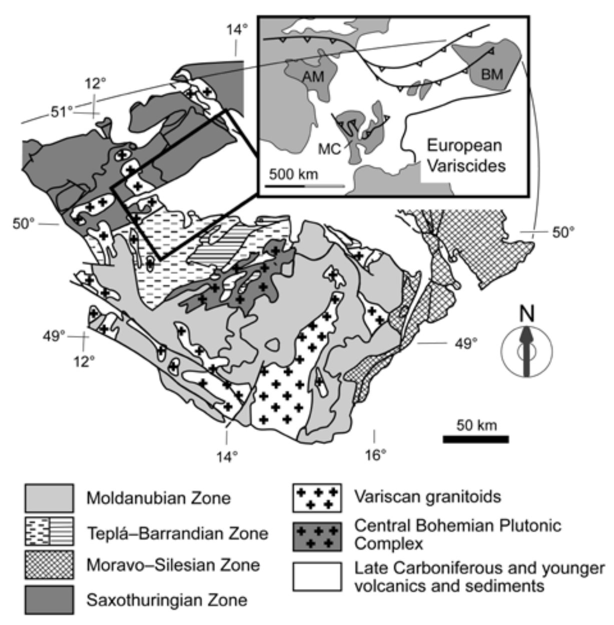

Fig. 1 Simplified geological map with major tectonic units of the Bohemian Massif. The upper inset shows the location of the Bohemian (BM) and two of the other massifs (MC – French Massif Central; AM – Armorican Massif) in the European Variscides. The area discussed in the text is represented by a black rectangle.

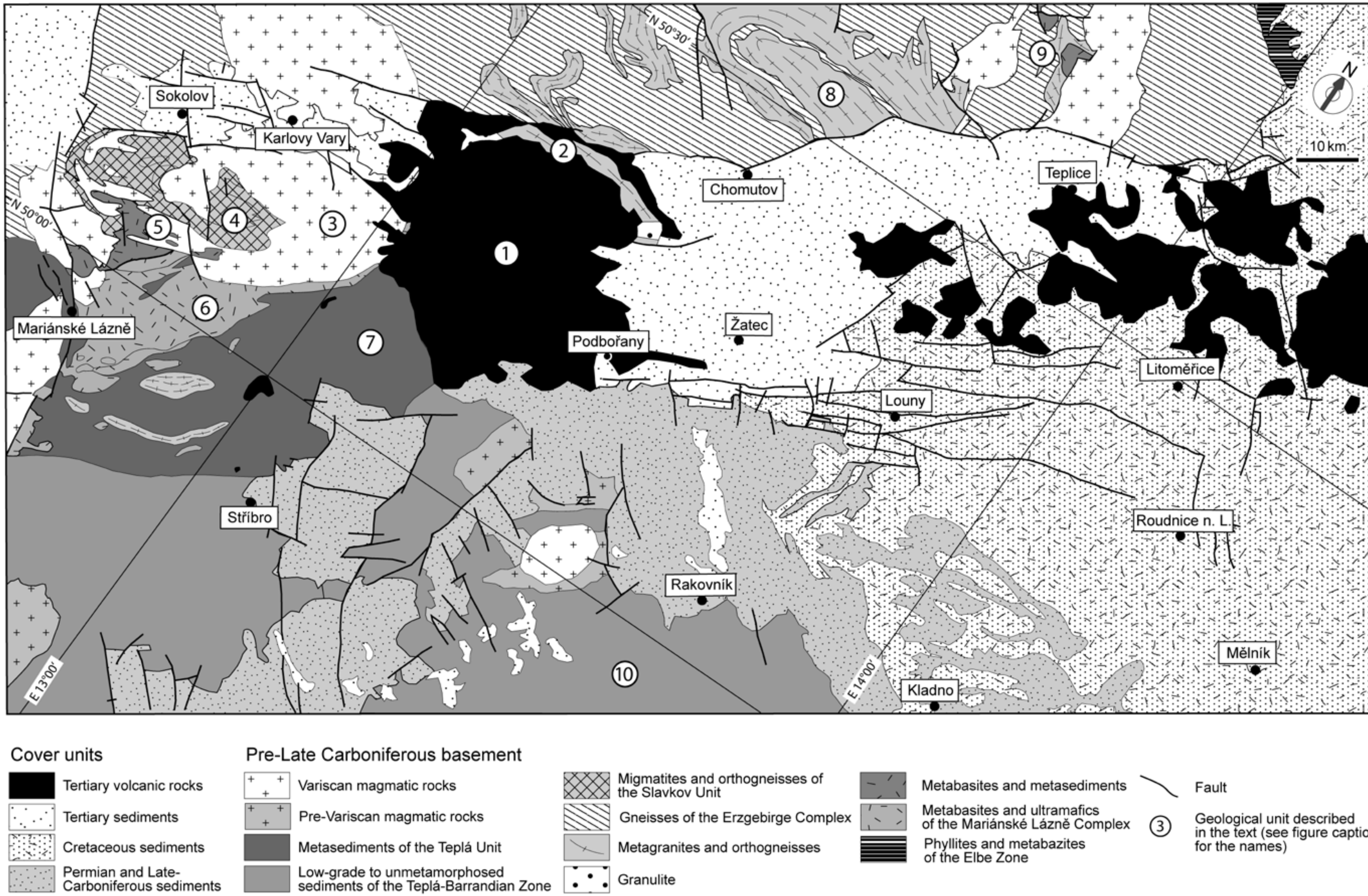

Fig. 2 Geological map of the northwestern part of the Bohemian Massif (for location see Fig. 1) with post-Lower Carboniferous cover of volcanic and sedimentary rocks (simplified after Cháb et al. 2007). Numbered geological units mentioned in the text are as follows: (1) Doupov Volcanic Complex, (2) Eger Unit, (3) Nejdek–Eibenstock Pluton, (4) Slavkov Unit, (5) Kladská Unit, (6) Mariánské Lázně Complex, (7) Teplá Crystalline Unit, (8) Sv. Kateřina/Reitzenhein structure, (9) Altenberg Block, (10) Barrandian Complex.

be extrapolated from observations in geological units exposed in more distal parts of the Saxothuringian and the Teplá–Barrandian zones.

Chaloupský (1973) published the first summary of available information about the basement underneath the Bohemian Cretaceous Basin in which he used a large database of exploration borehole data. His synthesis, which also partly covered the area of the Saxothuringian/Teplá–Barrandian boundary, was based on lithological correlations with exposed pre-Cretaceous rocks of the Bohemian Massif. At the same time, geophysical and geological observations in the Eger Graben area led to a formal definition of the surface demonstration of the Saxothuringian/Teplá–Barrandian boundary, which was then designated as the "Litoměřice deep fault" (Šťovíčková 1973). Gravimetric survey along this fault zone has revealed a chain of positive gravity anomalies and a steep gravity gradient towards the northwest indicating the boundary between low-density rocks of the Saxothuringian Zone and high-density rocks of the Teplá–Barrandian Zone (Šťovíčková 1973; Blížkovský et al. 1994; Švancara et al. 2008; Sedlák et al. 2009). Seismic survey in the area of the Saxothuringian/Teplá–Barrandian boundary by Plomerová et al. (2007) and Babuška et al. (2008) has shown differences in orientation of the mantle fabric in these large-scale zones and led to delimitation of their contact in the mantle lithosphere. The position of this boundary in the mantle was later correlated with surface geology by Babuška et al. (2007) and Babuška and Plomerová (2008). Recently, a new compilation of pre-Mesozoic geology of the Bohemian Cretaceous Basin basement was published by Uličný et al. (2009a). Their map also covers the area of the Eger Graben, but does not show the crystalline basement below the Carboniferous and Permian sediments.

We present a compilation of the data from 12,134 boreholes that reached the base of the Late Carboniferous–Cretaceous–Tertiary infill of sedimentary basins in the area southeast of the Krušné hory (Erzgebirge) Mountains. For the compilation of geological information we used archived drill cores owned by the company Diamo a.s. and the cores stored at the Czech Geological Survey. All the drill site coordinates and geological descriptions of the core samples, as well as depth measurements and geophysical data collected from boreholes during exploration drilling, are deposited at the Czech Geological Survey – Geofond (see *http://www.geofond.cz/mapsphere/EEARTH/*). As an additional source of data in regions with low density of borehole data we used seismic reflection profiles of Chudomel et al. (1983). Details on early results of this work can be found in the report by Mlčoch et al. (2001).

Macroscopic and microscopic study of archive samples and samples from occasional basement exposures within the volcanosedimentary complexes permitted their lithological correlation with uncovered basement exposed at the western margin of the Bohemian Massif, namely the Erzgebirge Complex with the Eger Unit and the Kladská and Slavkov units that are all traditionally considered as a part of the Saxothuringian Zone, and the Mariánské Lázně Complex and the Teplá Crystalline Unit that are interpreted as marginal geological units of the Teplá–Barrandian Zone (Fig. 2). The resulting geological map was linked with existing geological maps of the surface exposures of the pre-Late Carboniferous basement (Fig. 3). Moreover, depth measurements in the boreholes permitted a reconstruction of the present-day surface of the basement and revealed the tectonic importance of fault structures in the development of the Late Carboniferous to Tertiary sedimentary basins.

2. Lithological characterization of geological units identified at the base of Late Carboniferous to Tertiary sedimentary and volcanic sequences

2.1. The Saxothuringian Zone

The Erzgebirge Complex shows, in its eastern part, a large orthogneiss body of the Sv. Kateřina/Reitzenhein structure (Fig. 2), which represents the structurally lowermost part of the rock sequence (Mlčoch and Schulmann 1992; Rötzler et al. 1998; Konopásek et al. 2001). Orthogneisses of the Sv. Kateřina/Reitzenhein structure are characterized by medium-temperature solid-state deformation ranging in intensity from metagranites to mylonites (Mlčoch and Schulmann 1992; Schulmann et al. 1996). The overlying metasedimentary sequence contains relicts of high-pressure/low- to medium-temperature metamorphism, corresponding to an amphibolite/eclogite-facies transition (Rötzler et al. 1998; Konopásek 1998). Konopásek and Schulmann (2005) recognized two groups of orthogneiss bodies in the Erzgebirge Complex which are, in contrast to the Sv. Kateřina/Reitzenhein orthogneiss, overlying the high-pressure metasediments. These allochthonous bodies were subdivided into two groups according to their metamorphic conditions. The Lower Crystalline Nappe consists of medium-temperature orthogneisses without any evidence for partial melting, resembling those of the Sv. Kateřina/Reitzenhein structure. These orthogneisses are associated with bodies of medium-temperature mafic eclogites (Schmädicke et al. 1992; Klápová et al. 1998; Konopásek et al. 2001). The Upper Crystalline Nappe is represented by the Eger Unit (Fig. 2) and some other orthogneiss bodies in both Czech and German parts of the central Erzgebirge (Konopásek and Schulmann 2005), where they are associated with high-temperature mafic eclogites (Schmädicke et al. 1992; Mlčoch et al. in press). Characteristic feature of the Upper Nappe is the dominant high-temperature metamorphism developed in felsic lithologies that had mostly igneous protoliths. It consists of high-temperature orthogneisses showing various stages of anatexis (Zulauf et al. 2002; Závada et al. 2007), granulitic gneisses and felsic granulites with subordinate migmatitic metasediments (Hradecký et al. 2000). The only surface outcrops of the Eger Unit emerge from the cover Tertiary volcanic rocks in the form of an erosive window in the Ohře River valley northeast of Karlovy Vary (Fig. 2).

In borehole samples, the identification of rocks of the Erzgebirge Complex (Fig. 3) is based on the following features: 1) Orthogneisses of the Sv. Kateřina/Reitzenhein structure form direct spatial continuation of this dome known from the present-day surface. 2) Orthogneisses overlying the metasedimentary sequence represent direct continuation of allochthonous bodies west of Chomutov (Fig. 3) described by Konopásek et al. (2001) and Konopásek and Schulmann (2005). They are represented by several varieties ranging from coarse-grained types to fine-grained gneisses characterized by equigranular granulitic texture. Orthogneisses of the Lower and Upper Crystalline nappes are not distinguished in the map (Fig. 3) and we only show the granulite-bearing belt in the centre of the unit and another body of granulites that is today completely hidden below younger volcano-sedimentary formations (Kopecký and Sattran 1966; Kotková 1993). 3) Metasedimentary rocks of the Erzgebirge Complex are in most cases represented by biotite–muscovite–plagioclase ± garnet gneisses or micaschists lacking the typical medium-temperature/medium-pressure mineral assemblages with staurolite or staurolite + kyanite. 4) Northeast of the Sv. Kateřina/Reitzenhein structure, the rock sequence is dominated by feldspar-rich muscovite–biotite gneisses that are correlated with the "grey gneisses" cropping out in the northeastern part of the Erzgebirge Mts. 5) Occasional granitoid intrusions are surrounded by gneisses of the Erzgebirge Complex.

2.1.1. The low-grade belt

Rare exposures of low-grade rocks crop out from beneath the post-orogenic cover in the form of isolated windows in the area between Karlovy Vary and Litoměřice (Fig. 2). These rocks are represented by fine-grained phyllites, graphite-bearing quartzites and subordinate low- to medium-grade amphibolites (Sattran and Váně 1964; Mlčoch 2003). Corresponding rock association can also be seen as small denudation relicts in the Altenberg Block north–northwest of Teplice (Fig. 2) where it is interpreted as allochthonous body emplaced on top of the Erzgebirge Complex (Pietzsch 1914; Cháb et al. 2007).

Metabasites of the low-grade belt are fine-grained and bear the mineral assemblage amphibole–epidote–plagioclase–ilmenite ± biotite ± quartz. Fine-grained schists of this unit are usually composed of a muscovite–biotite ± chlorite–plagioclase–quartz assemblage with occasional small relicts of garnet.

2.2. The Teplá–Barrandian Zone

2.2.1. Metabasites of the Mariánské Lázně Complex

Apart from the main body of the Mariánské Lázně Complex, equivalent rock types represented by migmatitic and banded amphibolites, serpentinites and eclogites crop out at the western flank of the Tertiary Doupov Volcanic Complex (Fig. 2) and the same rock assemblage occurs as xenoliths in the Doupov Complex volcanics. Continuation and spatial extent of the Mariánské Lázně Complex further to the northeast was inferred from the geophysical data (see references in Vrána and Štědrá 1997) and also confirmed by several boreholes.

2.2.2. The Teplá Crystalline Unit

The surface exposure of the Teplá Unit (Fig. 2) is represented mostly by medium-grade metasediments with well-developed Barrovian metamorphic zones (Žáček and Cháb 1993) and associated with small bodies of Cambrian granitoids (Dörr et al. 1998). A major feature serving as a basis for identification of the Teplá Unit metasediments and their discrimination from the gneisses and micaschists of the Erzgebirge Complex is the presence of Barrovian mineral assemblages with biotite, garnet, staurolite and kyanite.

Borehole samples of the Teplá Unit metasediments usually represent muscovite–biotite micaschists with occasional garnet porphyroblasts. Some of the samples are intensely deformed giving the rock a mylonitic appearance. The characteristic microscopic feature is the presence of two garnet generations and coarse-grained aggregates of kyanite crystals.

2.2.3. The Barrandian Complex

Rocks of the Barrandian Complex (Fig. 2) are represented by low-grade metasediments in its western part and unmetamorphosed Proterozoic–Lower Palaeozoic sedimentary sequence in the east. The Proterozoic (meta-) sedimentary sequence is intruded by bodies of Cambrian and Devonian granites (Venera et al. 2000; Dörr et al. 2002; Žák et al. in press). Core samples of the Proterozoic metasediments from the Barrandian Complex are

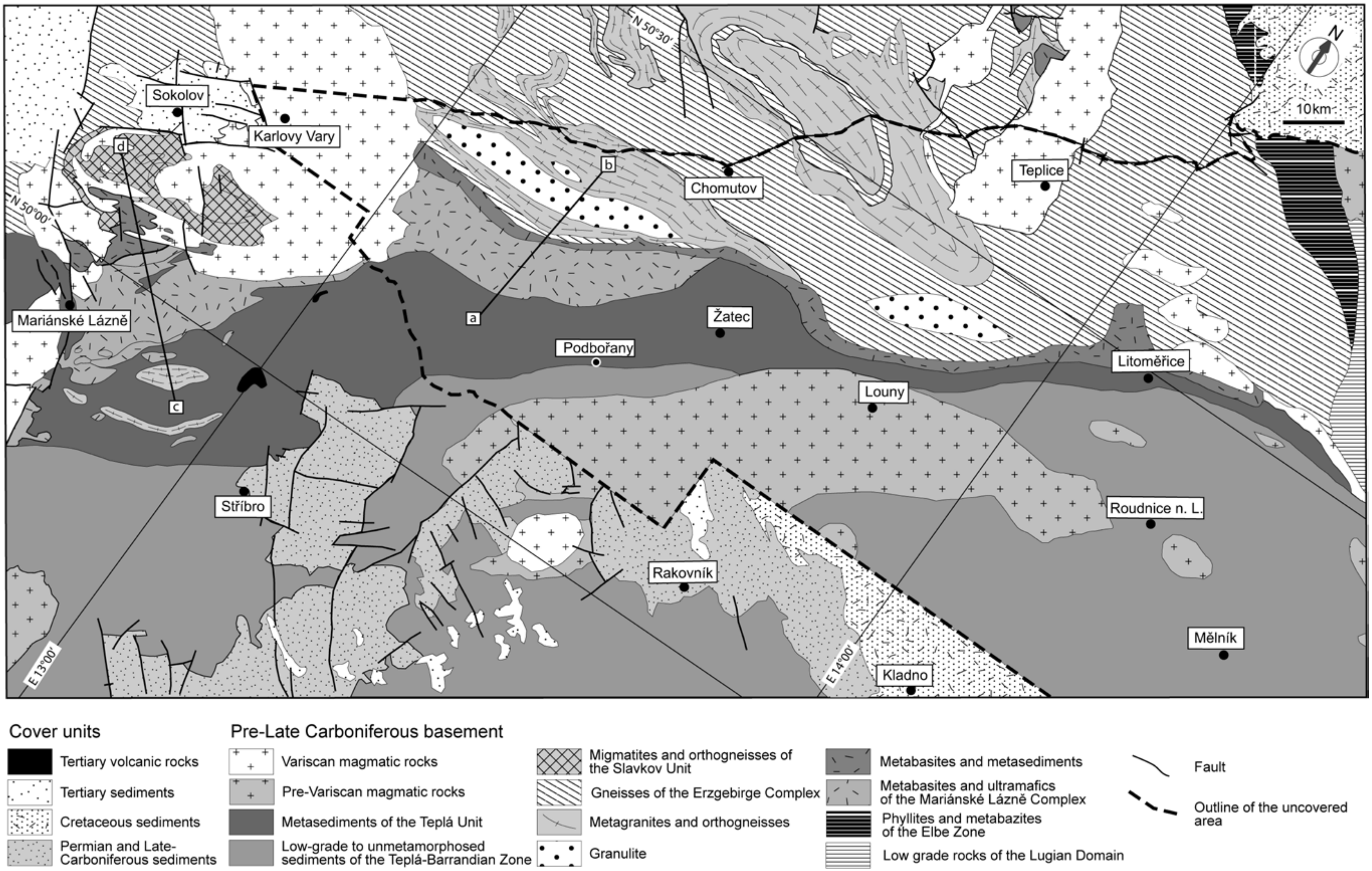

Fig. 3 Geological map of the pre-Late Carboniferous basement in the northwestern part of the Bohemian Massif. The area that is presently hidden below younger sedimentary and volcanic rocks is delimited by the bold dashed line. Tectonic significance of the geological units along the lines a–b and c–d is described in the text.

represented by fine-grained chlorite–sericite phyllites with occasional presence of low-grade metabasites. A large part of this unit in the presented map (Fig. 3) involves the granitoid body of the Louny Pluton (Mísař et al. 1983), the spatial extent of which was interpreted from the gravity data (Kopecký et al. 1997) and its presence confirmed by several boreholes.

3. Morphology of the basement beneath the volcanic and sedimentary sequences

Apart from the geological map, depth data from the boreholes were used for the construction of a 3D model of the crystalline basement morphology (Fig. 4) with a resolution higher than it was known from the previous studies (Chaloupský 1973). The sedimentary cover of the crystalline basement is formed by three independent systems of sedimentary basins.

The lowermost system is represented by the post-orogenic infill of extensional to transtensional Carboniferous to Permian basins that largely follow the trend of the Teplá–Barrandian – Saxothuringian suture (e.g. Jindřich 1971; Malkovský 1987; Pašek and Urban 1990; Uličný et al. 2002, 2009a). As discussed e.g. in Uličný et al. (2009a), opening of this basin system was related to NE–SW trending extensional faults. The axis of the Bohemian Cretaceous Basin follows the NW–SE striking Elbe Fault System (e.g., Uličný et al. 2009b) and cuts across the underlying Late Palaeozoic basins. However, the Elbe Fault System affected the Late Palaeozoic basins' geometry already during the Permian (Uličný et al. 2002, 2009b). The uppermost system of sedimentary basins is represented by Oligocene–Miocene infill of the Eger Rift. Špičáková et al. (2000) and Rajchl et al. (2009) have demonstrated that early opening of this basin system was governed by NNE–SSW to N–S extension oblique to the rift axis. According to these authors, major faulting occurred at a post-depositional stage and overprinted the early E–W trending faults by NE–SW trending major bounding faults.

In the presented model of the crystalline basement morphology (Fig. 4), faults with large displacement are the most prominent, regardless of their strike or time of main activity: the NE–SW faults active as normal faults mainly during the Late Palaeozoic, NW–SE trending faults of the Elbe Fault System and, to some extent, E–W trending extensional faults. The greatest displacement occurred during the Late Palaeozoic along the NE–SW normal faults that bound individual Carboniferous–Permian basins, which can be inferred from the thickness of their infill (Pešek et al. 1998) that highly exceeds the thickness of overlying Cretaceous (Malkovský et al. 1974) and Tertiary (Malkovský 1985) sediments.

From the course of the most prominent fault structures in the presented 3D model of the crystalline basement morphology can be inferred that the Carboniferous to Permian sediments can be seen as an infill of three particular sedimentary basins, the position of which only partly overlaps with those defined by Holub and Pešek (1992). They are the Žatec Basin (western part of the Kladno–Rakovník Basin *sensu* Holub and Pešek 1992), the Roudnice Basin (central and eastern part of the Kladno–Rakovník Basin and the Mšeno–Roudnice Basin *sensu* Holub and Pešek 1992), and the Česká Kamenice Basin (Pešek et al. 1998). Holub and Pešek (1992) pointed out that their classification of Carboniferous to Permian sedimentary basins in this area is based on traditional names of coal mining districts and does not reflect the tectonosedimentary evolution. We suggest that the Žatec, Roudnice and Česká Kamenice basins are the main Late Palaeozoic structures, each of them with a distinct evolution (Mlčoch and Martínek 2002; Fig. 4). The Česká Kamenice and Roudnice basins are separated by a ridge structure along which occasional outcrops of the crystalline basement appear.

4. Discussion

4.1. Spatial extent of individual geological units

The distribution of the studied boreholes and basement outcrops at the surface (Fig. 5) shows that the best resolution of the map is reached for the basement of Cretaceous–Tertiary infill of the Eger Graben. For this reason, the extent of the Erzgebirge parautochthonous schists and gneisses, continuation of allochthonous orthogneisses and granulites and of the Sv. Kateřina/Reitzenhein structure in the central Erzgebirge, as well as the outline of the Variscan granitoid plutons are considered as a reliable picture of the subcrop on the presented map scale. On the other hand, low number of boreholes in the southern and southeastern part of the covered area may cast some doubt on the reliability of the presumed extent of some geological units. In such case, auxiliary data were used for the best possible delimitation of the subcropping units.

The areal extent of the Mariánské Lázně Complex under the cover formations is mostly inferred from the gravity survey (see gravity map and corresponding references in Vrána and Štědrá 1997). However, as discussed above, apart from several borehole data and occasional outcrops, there are also mafic xenoliths belonging to this unit enclosed in rocks of the Tertiary Doupov Volcanic Complex.

There is only a limited number of boreholes that reached the "low-grade belt" (Fig. 5). Although there are

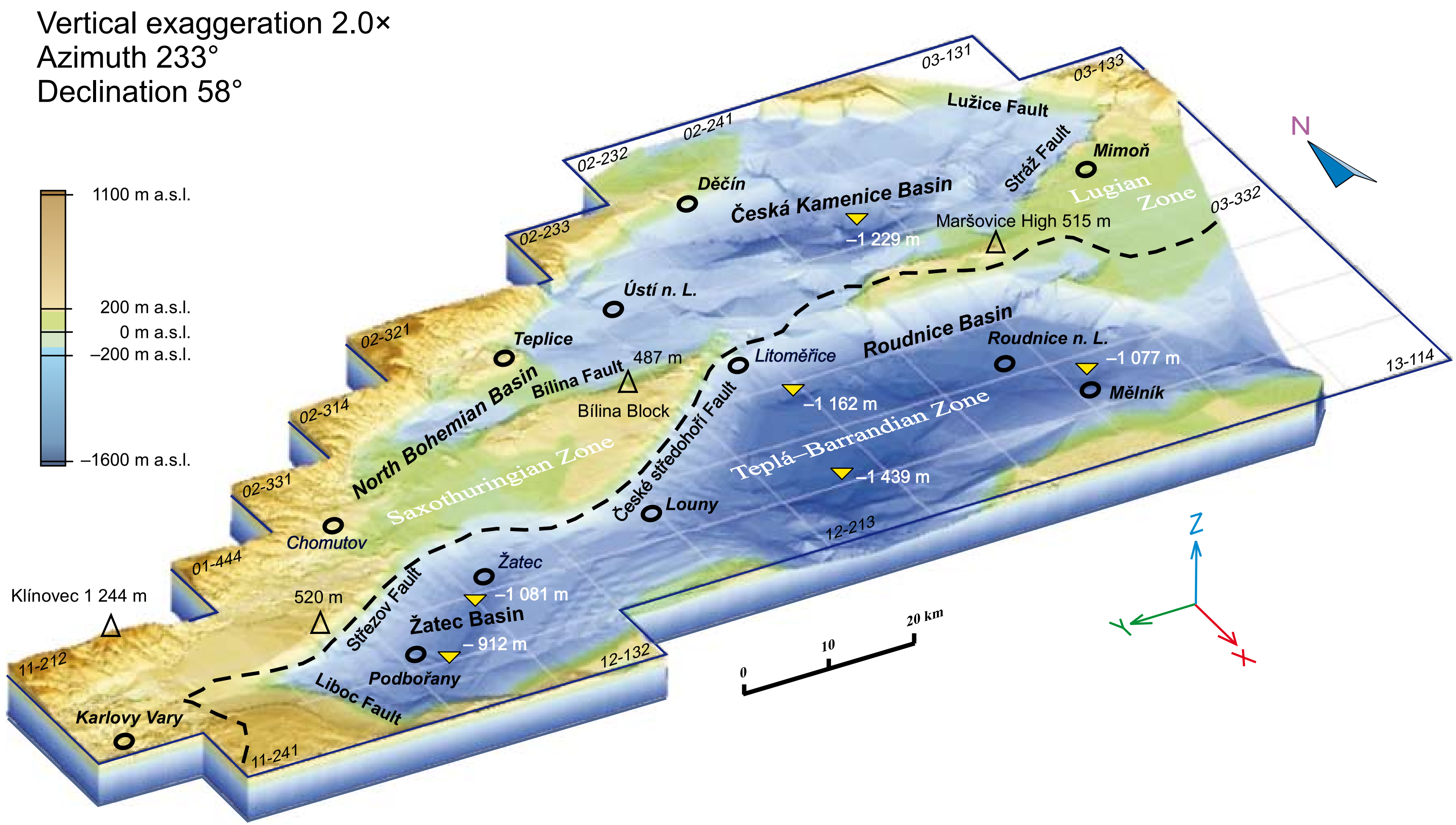

Fig. 4 Block-diagram compiled from the depth measurements in studied exploration boreholes showing relief of the pre-Late Carboniferous basement. Dashed line shows the inferred north-western geological limit of the Teplá–Barrandian Zone. Numbers in XX-XXX format are numbers of selected 1:25 000 topographic map sheets.

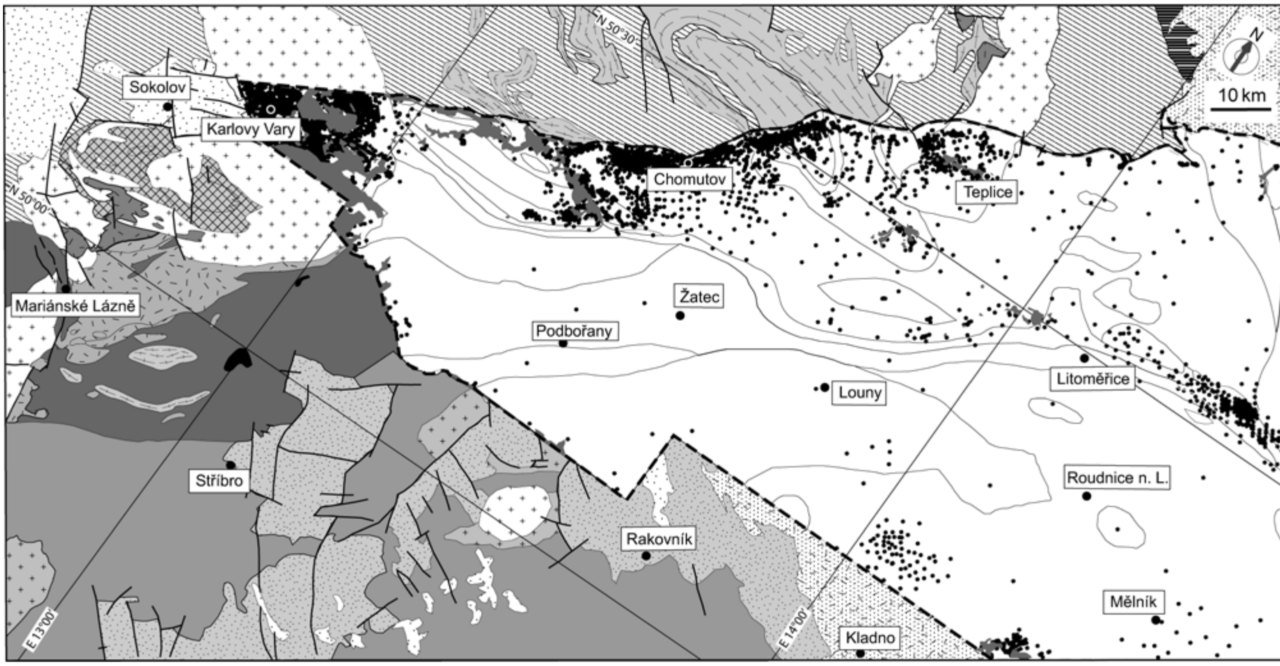

Fig. 5 Distribution of natural outcrops (grey polygons in the area delimited by the bold dashed line) and of the studied boreholes (black dots) in the area covered by the geological map of pre-Late Carboniferous basement units presented in Fig. 3. Geological units and various rock types of the pre-Late Carboniferous basement are only shown as outlines.

localities where this unit is exposed on the present-day surface and its regular presence along the margin of the Teplá–Barrandian Zone suggests that this belt could be continuous, its uninterrupted course cannot be proven with existing data. Similar is the situation with the borehole data for the continuation of the Teplá Crystalline Unit. Because the amphibolite-facies metasediments with Barrovian mineral assemblages occur along the entire exposed margin of the Teplá–Barrandian Zone (Vejnar 1982; Žáček and Cháb 1993; Zulauf 1997), except its contact with the Central Bohemian Plutonic Complex, we interpret the continuation of the Teplá Unit as an uninterrupted belt flanking the entire northwestern margin of the Teplá–Barrandian Zone.

There is a large number of boreholes in low-grade to unmetamorphosed schists of the Barrandian Complex, but they are usually concentrated in clusters. Such distribution of data cannot exclude the possibility that some other rock types (especially granitoids or metabasites) can also be present within this unit.

4.2. Correlation of exposed and covered geological units along the Saxothuringian – Teplá–Barrandian boundary

The presented compilation of the borehole data shows several important features of the Saxothuringian – Teplá–Barrandian boundary that are directly comparable with its exposed part in western Bohemia. The mafic and ultramafic rocks of the Mariánské Lázně Complex flank approximately a half of the northwestern margin of the Teplá–Barrandian Zone. Immediately SE of the Mariánské Lázně Complex and then further to the NE, the northwestern flank of the Teplá–Barrandian Zone is represented entirely by medium- to high-grade micaschists of the Teplá Crystalline Unit, which towards the east rapidly pass into the low-grade schists. While the transition of the kyanite–sillimanite micaschists of the Teplá Crystalline Unit into migmatitic amphibolites of the Mariánské Lázně Complex can be viewed as a normal, although tectonically reduced, metamorphic gradient, there is a sharp metamorphic discontinuity along the northwestern flank of the Mariánské Lázně Complex, which is bordered by a "low-grade belt" composed of medium- to low-grade metasediments and metabasites (see geological units along the line a–b in Fig. 3).

Another abrupt metamorphic transition exists to the northwest of this "low-grade belt", where it passes into a narrow belt of medium-grade gneisses, which are then in direct contact with granulite-facies mylonitic orthogneisses and migmatites of the uppermost unit of the Erzgebirge allochthon. Such sequence of metabasites, metasediments and orthogneisses is also preserved in the Altenberg Block north of Teplice (Fig. 2) and interpreted as a tectonically emplaced rock assemblage (Pietzsch 1914; Hoth et al. 1995; Schovánek et al. 2004; Cháb et al. 2007).

This collection of geological units with different lithological content and contrasting metamorphic grades is equivalent to the rock succession further to the southwest in the area of the only exposed segment of the Teplá–Barrandian – Saxothuringian boundary (line c–d in Fig. 3). In the north-western tip of the Teplá–Barrandian Zone, kyanite–sillimanite metasediments of the Teplá Crystalline Unit pass into migmatitic metabasites, eclogites and ultramafic rocks of the Mariánské Lázně Complex (Žáček and Cháb 1993). In the footwall there is an assemblage of low- to medium-grade metabasites and metasediments (the Kladská Unit – Kachlík 1993) of a lithological and metamorphic character different from the overlying Mariánské Lázně Complex. The discontinuity in metamorphic grade was interpreted by Kachlík (1993) as an evidence of thrusting of the Teplá–Barrandian Zone over the Saxothuringian Belt. Further to the northwest and towards the footwall, there is another sharp metamorphic boundary, along which the above-mentioned low- to medium-grade metamorphic rocks pass into the high-grade migmatitic orthogneisses and cordierite-bearing migmatites (the Slavkov Unit – Mísař et al. 1983).

From the tectonometamorphic point of view, the assemblage of geological units and their mutual position is almost identical in both the exposed and covered parts of the discussed area. However, the presented geological map shows an apparent lateral offset between the outcropping and buried parts of the Mariánské Lázně Complex and the "low–grade belt" (Fig. 3). This offset occurs in the area of the Jáchymov Fault that was intruded by the Nejdek–Eibenstock Pluton.

The tectonometamorphic patterns suggest that going from the SE to the NW, there seems to be an increasing metamorphic grade from metasediments and orthogneisses of the Teplá Crystalline Unit towards the north-western edge of the mafic Mariánské Lázně Complex. This gradual increase in metamorphic grade is sharply interrupted by the presence of the "low-grade belt" and the high-grade metamorphic rocks reappear as migmatitic metasediments, orthogneisses and granulites of the Erzgebirge allochthon or the Slavkov Unit.

4.3. Age of metamorphism along the Saxothuringian – Teplá–Barrandian suture

Existing geochronological data (Fig. 6) from the above-described geological units suggest two well separated tectonic events along the Saxothuringian – Teplá–Barrandian boundary, at *c.* 400–360 Ma and *c.* 345–330 Ma. Beard et al. (1995) determined the Sm–Nd age of eclogite-facies metamorphism in the Mariánské Lázně Complex at 367 ± 4 or 377 ± 7 Ma. Exhumation of the mafic rocks was dated using the U–Pb method by analyzing zircons from amphibolites migmatitized to various extents during decompression. Bowes and Aftalion (1991) and Timmermann et al. (2004) obtained a similar age of ~360 Ma for the decompression melting event. The K–Ar and Ar–Ar amphibole cooling ages show a rather large spread between 397 and 370 Ma (Kreuzer et al. 1992; Dallmeyer and Urban 1998; Bowes et al. 2002).

Very little is known about the "low-grade belt" that flanks the northwestern margin of the Teplá–Barrandian Zone and there is no geochronological information from scarce outcrops emerging from the Cretaceous–Tertiary rocks of the Eger Graben. Several authors (Zoubek et al. 1963; Sattran and Váně 1964) interpreted the protolith age of these rocks as Palaeozoic, but this estimate is based purely on lithological correlation with rocks of that age exposed in low-grade units of the German part of the Erzgebirge. We have suggested an affinity of this belt to the low-grade unit underlying the mafic–ultramafic rocks of the exposed part of the Mariánské Lázně Complex. Metamorphic amphiboles of this low-grade unit were dated by Kreuzer et al. (1992) at 362 ± 8 Ma, although it is not certain whether this age is valid for the entire "low-grade belt".

The adjacent migmatitic Erzgebirge allochthon shows exclusively Early Carboniferous ages of metamorphism. Granulite bodies in the Eger Unit were dated by Kotková et al. (1996) at 339 ± 1.5 or 346 ± 14 Ma using zircon and rutile geochronology and similar ages were obtained from granulite-facies rocks in the German part of the Erzgebirge Mts. (Kröner and Willner 1998; Tichomirowa et al. 2005). Zulauf et al. (2002) dated monazites and muscovites (U–Pb and Ar–Ar method, respectively) from migmatitic orthogneisses of this unit and reported the same ages (within error) of 342 ± 1 Ma and 341 ± 4 Ma, respectively. Further to the northwest, the mica cooling ages from metamorphic rocks in the Erzgebirge Complex show mostly ~340 Ma but they become slightly younger in the area of the Nejdek–Eibenstock Pluton and in the northern part of the Sv. Kateřina/Reitzenhein structure (Werner and Lippolt 2000). These data in combination with presented geological map suggest that the "chronometamorphic" boundary between the areas of Devonian and Early Carboniferous metamorphism could be represented by the transition from the low-grade metamorphic units underlying the Mariánské Lázně Complex and the medium-grade metasediments of the Teplá Unit into the units bearing granulite-facies orthogneisses, migmatites and granulites (Fig. 6).

4.4. The Saxothuringian – Teplá–Barrandian boundary

Our evaluation of the borehole data shows continuation of various geological units along the Saxothuringian –

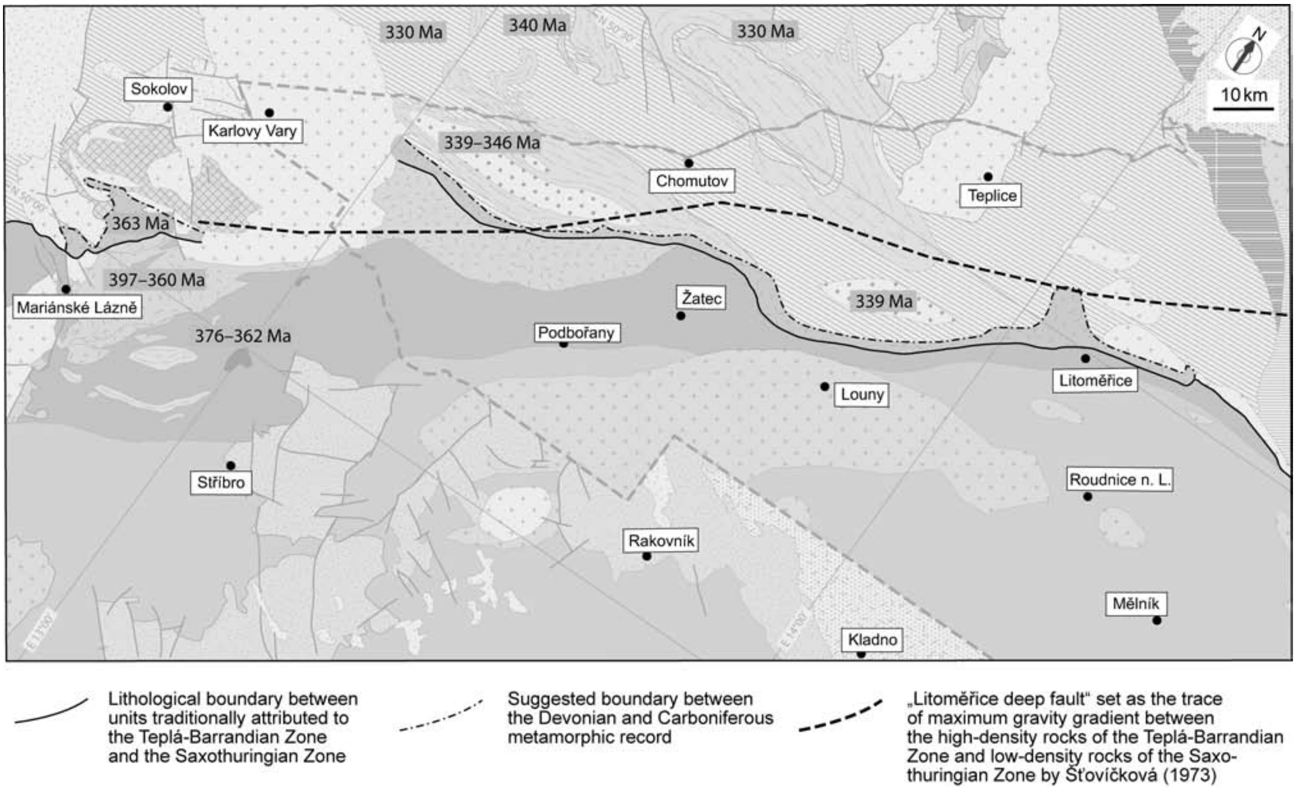

Fig. 6 Delimitation of geological (solid line) and geophysical (dashed line) boundary between units with an affinity to the Saxothuringian and the Teplá–Barrandian zones. Distribution of metamorphic ages of particular geological units in the study area suggests a "chronometamorphic" boundary (dot-and-dash line) between the Devonian and Carboniferous metamorphic record.

Teplá–Barrandian suture below the Late Carboniferous to Tertiary volcanosedimentary cover and thus allows the determination of the geological boundary between units that were traditionally attributed to the Saxothuringian Zone and those interpreted as a part of the Teplá–Barrandian Zone (Fig. 6). Comparison of the geophysical and the borehole data shows that the gravity boundary is shifted towards the northwest with respect to the actual geological boundary (Fig. 6; see also Švancara et al. 2008) suggesting an apparent presence of denser Teplá–Barrandian rocks below the covered part of the eastern margin of the Saxothuringian Zone. Similar shift was reported by Babuška et al. (2007) for the mantle lithosphere and attributed to its detachment from the rigid upper crust.

Existing metamorphic and geochronological data from outcropping equivalents of the covered geological units in the area of the Eger Graben suggest a complex assemblage of crustal segments metamorphosed at various depths and temperature regimes in two well-constrained and non-overlapping temporal periods of the Variscan orogeny. Although there are several models attempting to explain Variscan tectonometamorphic evolution of the Erzgebirge Complex (Matte 1998; O'Brien 2000; Willner et al. 2000, 2002; Konopásek and Schulmann 2005; Babuška et al. 2010), the tectonic evolution between the Devonian exhumation of the high-grade Teplá–Barrandian margin and the Carboniferous collision involving exhumation of Lower Carboniferous diamond-bearing rocks, mafic eclogites and high-pressure granulites remains unclear. The apparent complexity in geological and temporal evolution of the western margin of the Bohemian Massif suggests that any acceptable model of its tectonic evolution must also involve critical evaluation of structural, petrological and geochronological record in small-scale units along the Saxothuringian – Teplá–Barrandian boundary.

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