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The impact of Outer Western Carpathian nappe tectonics on the recent stress-strain state in the Upper Silesian Coal Basin (Moravosilesian Zone, Bohemian Massif)

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Abstract: The Upper Silesian Coal Basin (USCB) represents a typical foreland basin developed during the Variscan orogenic phase of the Late Carboniferous. Later, during the Alpine orogeny the Outer Western Carpathian nappes were thrust over the post-Variscan foreland, to which the USCB belongs. Due to this complex tectonic history, redistribution of stress fields occurred in the post-Variscan basement. Furthermore, post-Variscan denudation processes probably also contributed to recent stress regimes. Nevertheless, the impact of the West Carpathian orogeny can be regarded as the most significant influence. The in-situ measurement of recent stress fields in deposits of the Karviná Formation of the USCB and structural analysis of the Czech part of the USCB, has focused on verification of the structure and stress interference of the Carpathian nappes and post-Variscan foreland basement. In the southernmost part of the Karviná Subbasin, the easternmost domain of the USCB, situated in the apical zone of the Variscan accretionary wedge, hydrofracturing and overcoring stress measurements have been recorded in coal seams from selected coal mines. The data have been supplemented by interpretation of focal mechanism solutions of mine induced seismic events. Measurements of recent in-situ stress regimes in the Karviná Formation of the USCB indicate a dominant generally NW–SE orientation of the maximum horizontal compression stress. The results demonstrate that the stress-strain regime in the Karviná Formation in the Variscan Upper Carboniferous basement is significantly influenced by the stress field along the Outer Western Carpathian nappes front. Besides improving our understanding of recent regional stress fields within an area of mutual structural-tectonic interference by both the Variscan and Alpine orogenies, the measured data may contribute to more optimal and safer mining activities in the coal basin.

Key words: Variscan orogeny, Outer Western Carpathians, Upper Silesian Coal Basin, paleostress, recent stress fields.

Introduction

The Upper Silesian Coal Basin (USCB) represents the apical domain of the Variscan accretionary wedge (foreland coal-bearing molasse), which is now a part of the epi-Variscan basement (e.g. Grygar & Vavro 1995; Kandarachevová et al. 2009; Grygar & Waclawik 2011; etc.). Its Variscan tectonic pattern was structurally also affected by tectonic loading of the West Carpathian nappes and by sedimentary loading of the West Carpathian Foredeep. Amongst others, these impacts are apparent in the southern part of USCB (referred to as the Karviná Subbasin).

The definition of neotectonics was discussed by more authors (e.g. Hancock & Williams 1986; Karabanov et al. 1994; Hók et al. 2000; etc.), but the Hók et al. (2000) concept of the definition of neotectonics and recent stress-strain fields has been adopted. They consider neotectonic stress in the Western Carpathians to have been brought about by tectonic movements from Pliocene to recent times. Nevertheless, we believe that the definition of neotectonic stress will vary for different localities depending on the local tectonic evolution. Therefore, for neotectonic development of the southern part of the USCB, it is more appropriate to consider the period from the Oligocene to Recent. Consequently, we regard contemporary stress states measured in the coal mines of the USCB as representing the recent stress regime.

In this article, the influence of Alpine tectonics on the structural patterns and in consequence on the recent stress-strain regime in the Variscan basement, including the USCB, is discussed. Discussion is based on *in situ* horizontal stress measurements and their interpretation. The stress measurements were obtained using hydrofractures and what is referred to as the Compact Conical Ended Borehole Overcoring (CCEBO) method, and by interpretation of focal mechanisms of important seismic events induced by the coal mining activity. The main purpose of the research is to reveal, as accurately as possible, recent stress-strain distributions. This would be very useful in guiding coal mining activities in this part of the USCB.

Variscan tectonics of the USCB

The USCB forms an integral part of the Moravosilesian region of the Bohemian Massif (Fig. 1). The USCB corresponds to the West European zones of the sub-Variscan coal-bearing molasse (e.g. Grygar & Vavro 1995; Dopita et al. 1997; etc.). The recent structural framework of the coal-bearing deposits represents only the erosional relicts of an originally more extensive system of partially, more or less connected sedimentary basins located in the zone of the Brunovistulian foreland (see Fig. 1). These Carboniferous coal-bearing formations

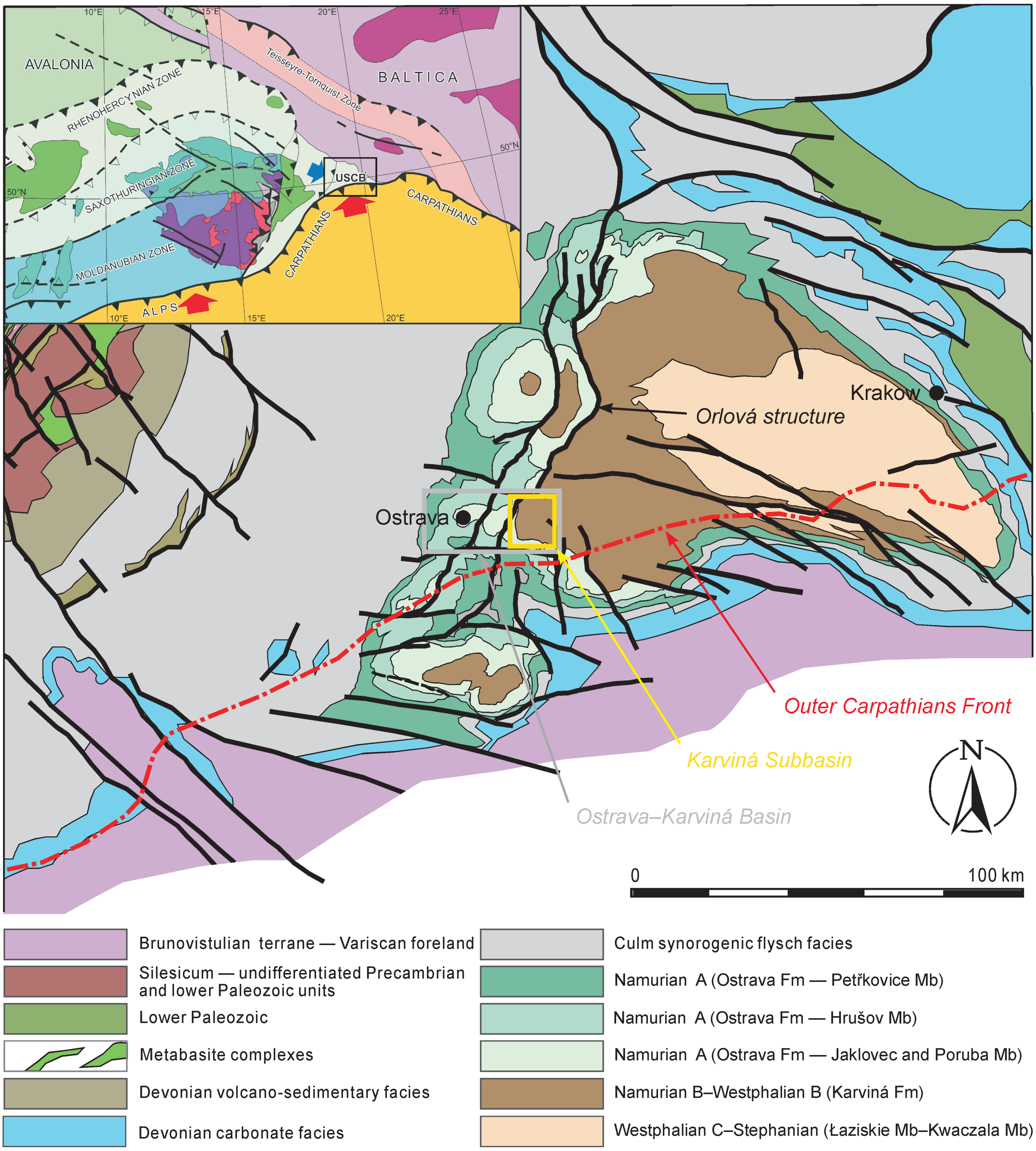

Fig. 1. Simplified pre-Tertiary basement geological map of the USCB in the context of Moravosilesian Zone (sketch map in the upper left corner according to Pharaoh et al. 2000).

have also been identified in deep boreholes close to Němčičky in Southern Moravia. It is most likely a subsurface continuation of the USCB (Dopita et al. 1997).

The structural-tectonic framework of the USCB is reflected in the stress-strain development of the Variscan accretionary wedge in the Moravosilesian region (e.g. Cháb et al. 2010). The basin lies in the apical zone of the Variscan accretionary wedge (defined by Grygar & Vavro 1995) of the Moravosilesian domain. The control of the structural pattern of the pre-Variscan (Cadomian) Brunovistulian foreland (Dudek 1980) on Variscan and Carpathian tectonics played a significant role in the structural development of the basin, character of the stress-strain regime, tectonic style, kinematics and intensity of the deformations. As is evident from the transverse WNW–ESE cross-section (see Fig. 2), the flysch foredeep and coal-bearing molasse of the Moravosilesian area, correspond to a typical accretionary wedge with a general eastward regional vergence during fold-thrust and nappe tectonics. Regarding the known character of their sedimentary development (Kumpera & Martinec 1995; Kandarachevová et al. 2009),

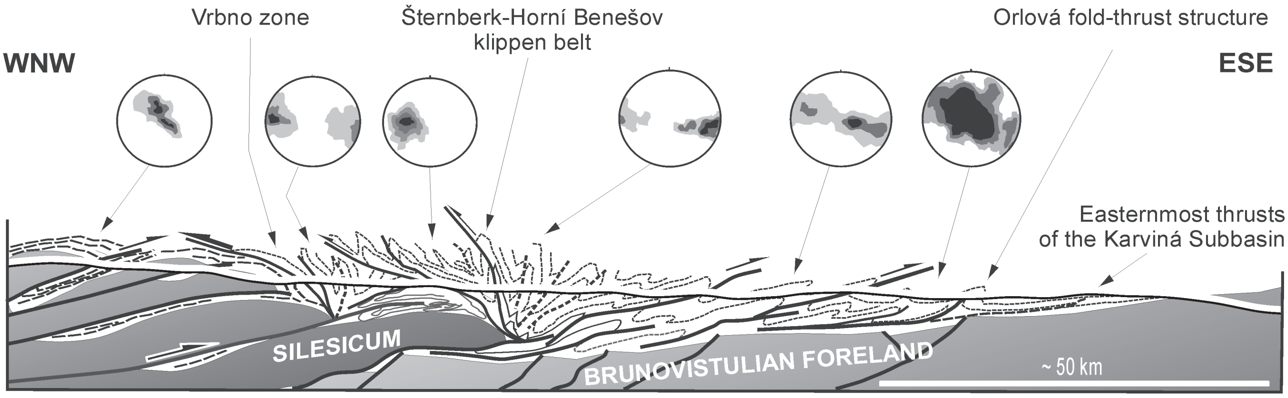

Fig. 2. Schematic structural cross-section across the accretionary wedge of the Moravosilesian Zone. Contour diagrams correspond to poles of bedding and/or main cleavage system.

they present the typical features of a synorogenic accretionary wedge. The stacked pile of Silesicum crystalline nappes (Cháb et al. 2010) in the western domain of the Moravosilesian area (Fig. 2) represents what is referred to as a backstop structure (e.g. Davis et al. 1983; Lallemand et al. 1992; Jamison 1993; etc.). Due to the structural-tectonic activity, more complex tectonic styles participated in the structural pattern of both the flysch foredeep and the foreland basin of the USCB.

The complicated fold-thrust pattern in the western part of the USCB, in comparison with the relatively simple tectonic style of the eastern Karviná Subbasin, has been commented on by Dopita et al. (1997). The distribution of tectonic style is also determined by the character of the Brunovistulian basement and by its regional position in the apical domain of the Variscan accretionary wedge. The USCB is noticeably asymmetrical in both WNW–ESE and NNW–SSE directions. These two polarities, longitudinal and transverse ones, are responsible for its present structural-tectonic framework (e.g. Grygar et al. 1989; Nawrocki 1993).

The Czech part of the USCB could, from the point of view of the longitudinal polarity, be subdivided into two basic structural domains. The boundary line corresponds to the Orlová fault-propagation fold structure (Grygar & Waclawik 2011). Whilst the westerly domains (Ostrava and Petřvald Subbasins) display more complex and complicated tectonic styles, the area to the east of the Orlová structure (Karviná Subbasin) is distinguished by the predominance of transtensional normal fault tectonics. The transverse structural polarity of the NNW–SSE direction is evident from the more complicated tectonic styles in the more northerly parts of the above group of subbasins. The intensity of deformation decreases southwards, due to the variable kinematics and deformation intensity of the Variscan accretionary wedge. Both structural directions are equally important in the general scheme of Variscan regional stress fields (Grygar et al. 1989).

The Orlová structure was previously generally regarded as the easternmost fold-thrust structure of the Moravosilesian Variscan foredeep. On the other hand, the Karviná Subbasin, which lies to the east of the Orlová structure, is in direct contact with the Outer Carpathian nappes. A more detailed picture of the structural tectonic pattern of the Karviná Subbasin is given in Fig. 5. A transtensional paleodynamic regime dominates there. Many of the normal faults are combined with strike-slip movements (transtensional faults, etc.; Grygar et al. 1989).

The Karviná Formation coal seams dip at very low angles, which usually do not exceed 10° to 15°. In the western part, open and gentle fold structures are defined — the Suchá Anticline and Suchá Syncline, both of which are parallel to the Orlová fault-propagation fold structure. Both Suchá fold structures are genetically linked with normal fault kinematics. In the easternmost part of the Karviná Subbasin, the fold structures are not present. The folding is also linked to regional longitudinal faults, which brought about mostly antithetic rotation (tilting) of the fault blocks.

It is evident from the map in Fig. 5, that the framework of the Karviná Subbasin is characterized by longitudinal normal faults striking in a submeridional direction (NNE–SSW to NNW–SSE) and transverse normal faults striking generally W–E (to WNW–ESE). These are mainly steep normal faults (dips 50°–70°). Most of them display evidence of strike-slip kinematics (Danys & Sivek 1976). This is an example of transcurrent dextral strike-slip faulting often with an "en echelon" fault pattern (Grygar et al. 1989; Grygar & Welser 1994). The main genetic role belongs to the submeridional Karviná Graben and its transverse Dětmarovice Graben (see Fig. 3). The Dětmaro-

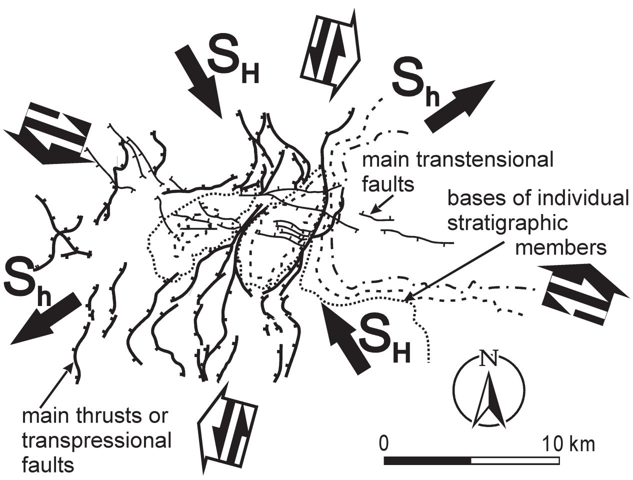

Fig. 3. Variscan stress-strain model of the Czech part of the USCB based on paleostress analysis.

vice Graben is part of a major structure of higher regional order — the Dětmarovice Shear Zone (Grygar et al. 1989). The main regional tectonic zones (Dětmarovice Shear Zone and Karviná Graben) split up the Karviná Subbasin into four blocks with different vertical structural positions and different internal structural frameworks (Grygar et al. 1989 — see Fig. 5).

Apart from what is referred to as the Central Thrust (see Fig. 5), no other thrust structures have been identified in the Dětmarovice Shear Zone. However, during extension of mining to lower stratigraphic levels in the easternmost part of the Karviná Subbasin, new thrust systems structures and corresponding ductile deformation structures were discovered (Grygar et al. 1998; Ptáček 1999; Waclawik 2009; Grygar & Waclawik 2011). Amplitudes of the above very flat, mostly intraformational thrusts give rise to vertical magnitudes of up to 20–30 meters. This system of recently discovered thrust structures (referred to as the Eastern Thrusts — Waclawik 2009; Grygar & Waclawik 2011) generally strike NE–SW (Fig. 5). This thrust system represents the most easterly thrusting of the Variscan accretionary wedge of the Moravosilesian Zone as a whole.

Alpine tectonics of the Outer Western Carpathians

In the Late Cretaceous, a major foreland basin system developed in the Outer Carpathian zone, dominated by siliciclastic shelf, and deep-water flysch sedimentation formed in the Outer Carpathian zone. The Inner and Outer Western Carpathians are separated by the Pieniny Klippen Belt suture zone (e.g. Golonka & Pícha 2006). The Outer Western Carpathians are composed of Jurassic to Miocene mostly flysch deposits, which built up into several nappes. As is evident from Fig. 6, during the Paleogene and Neogene they were thrust as an accretionary wedge over the European foreland of consolidated Variscan and pre-Variscan Brunovistulian basement, overlain by Miocene deposits within the Carpathian Foredeep (e.g. Plašienka et al. 1991; Plašienka 1997, 1999; Golonka & Picha 2006; etc.).

The Outer Western Carpathians belt represents the immediate contact of the Alpine orogeny with the most easterly part of the Bohemian Massif. The thin-skinned type of Alpine accretionary wedge of the Outer Carpathian flysch belt consists of numerous tectonostratigraphic units (e.g. Oszczypko 1998; Šefara et al. 1998). The most external units, the Menilite-Krosno Group are characterized by a Late Cretaceous to Late Eocene succession of variegated shales, Early Oligocene menilitic silicites, and the Late Oligocene to Early Miocene Krosno-type flysch (Mahel' 1991). The structural tectonic pattern of the Outer Western Carpathians belt represents the typical structure of an accretionary wedge (e.g. Oszczypko 1998). The Subsilesian and Silesian Units may be better classified as a continuation of the Alpine molasse into the territory of northeastern Moravia. Thick Late Cretaceous to Eocene deep-water flysch deposits characterize the internal Magura Unit, which, during the sedimentation, was separated from the external units by the Silesian Ridge. The Magura Unit, also referred to as the Magura Group of Nappes, is correlated with the Rhenodanubian Flysch of the Alps (Eliáš et al. 1990).

Generally top-to-NW movement of the nappes of the Outer Carpathians over the Variscan basement (Bohemian Massif including the Brunovistulian Pan-African basement) commenced probably in the Oligocene and continued in the early Tortonian (Menčík et al. 1983; Bielik et al. 2002; Golonka & Picha 2006). As a consequence, superposition and reactivation of Variscan fault patterns of the Variscan foreland basement, including the USCB terrane, also took place.

Stress-strain model of the USCB

A paleostress analysis, based on a complex structural-tectonic analysis and slickenside measurements on thrust faults, resulted in our interpretation of a WNW–ESE to NW–SE orientation of maximum compression (Grygar et al. 1989; Grygar & Vavro 1995; Havíř 2001). This conclusion is also based on structural and paleostress investigations of thrust-fold structures in the eastern domain of the Variscan flysch foredeep (Culm facies of Hradec-Kyjovice Formation in the stratigraphic footwall of the coal-bearing Ostrava Formation) westwards of the western limit of the USCB (see Fig. 1). Typical out-of-sequence thrust structures were observed not only in the above Moravosilesian flysch domain, but also in the Upper Silesian Coal Basin, controlled by widespread sedimentary bedding parallel (intrafolial) shearing (for "progressive easy-slip thrusting" see Gayer et al. 1991). Čížek & Tomek (1991), on the basis of drilling and seismic profiling of the eastern part of the flysch foredeep, recognized detachment and thrusting between Culm facies and Devonian limestone facies in the cover of the Brunovistulian foreland. Similar kilometer scale thrusts were identified and documented in detail in the Czech part of the Karviná Subbasin of the USCB (Grygar et al. 1989; Grygar & Waclawik 2011).

The stress-strain model of the Variscan orogeny is presented in Fig. 3. It was derived by a complex structural-tectonic analysis of the USCB, and corresponds to the late Variscan deformation phase of the USCB. The directions of the principal horizontal axes of the generalized regional strain ellipsoid are marked. The positive signs represent compressional quadrants (approximately NW–SE direction), which have resulted in structurally higher, uplifted segments of the Ostrava and Karviná Subbasins. The larger complex arrows describe the relative perpendicular movements of constituent segments and simultaneously strike-slip movement sense on the conjugate shear zones. The diagram confirms the different stages of deformation within the Dětmarovice Shear Zone (strike direction approximately WNW–ESE) and deformation in the southern part of the Ostrava Subbasin. Almost the same dirrections of maximum compression were confirmed by interpretation of recent earthquakes located on the neotectonically rejuvenated fault systems in the eastern part of the Sudetes (Špaček et al. 2006).

Stress-strain model of the Outer Carpathians

In the region of the Karviná Subbasin, neither direct nor indirect recent stress measurements have been recorded from the foredeep of the Outer Western Carpathians at the immediate contact with the Bohemian Massif. The directions of paleostress fields may be interpreted from analyses of the main compressive forces in the partial Godula Nappe in the Beskydy Mts (Menčík et al. 1983). The directions of the main compressive forces for Tortonian and late Tortonian folding events are documented in Fig. 4. Whilst Tortonian directions of maximal horizontal compression were interpreted as NW–SE, based on paleostress analyses in the Godula Nappe (Menčík et al. 1983), the direction of maximal horizontal compression in the late Tortonian was rotated to a N–S direction. Menčík et al. (1983) asserted that the NW–SE direction was not influenced by elevations in the post-Variscan autochthonous basement, but were controlled by synsedimentary movements. The direction of the late Tortonian stage of the Alpine orogeny, exhibits a dominant northward direction of thrusting (see Fig. 4).

The compilation map of recent stress fields, published by Hók et al. (2000), presents stress measurements from a variety of other authors in addition to the original measurements of horizontal stress. Furthermore, the results of Polish interpretation of stress fields in the Outer Western Carpathians are also quoted (Hók et al. 2000). The paleostress development of the Alps and Outer Western Carpathians is discussed by more authors (e.g. Zuchiewicz 1994; Peresson & Decker 1997; Márton & Fodor 2003). On the basis of the available data, the direction of maximum horizontal compressional deformation in the Polish part of the Outer Western Carpathian belt is roughly N–S, whereas in the western part of the zone of collision with the Bohemian Massif, this direction has rotated to an approximately NW–SE direction (Fig. 4).

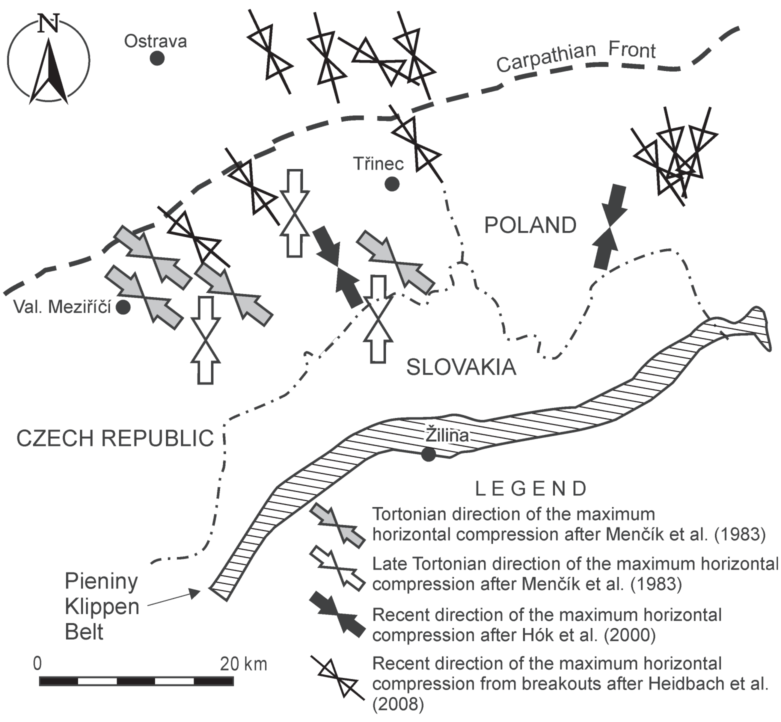

Fig. 4. Compilation map of horizontal stresses measured and/or interpreted in the Outer Western Carpathian area.

Horizontal stress directions in the northern part of the Outer Western Carpathians are published in the World Stress Map (Heidbach et al. 2009). The results represent the data gained from borehole breakout analyses of variable quality. All quoted results of horizontal stress measurements or interpretations are shown in the compilation map in Fig. 4. Apart from the directions interpreted by Menčík et al. (1983) for the late Tortonian stage of the Alpine orogeny, they generally correspond to each other.

Methods and results of recent stress measurements

For the purposes of our project, three different methods were used. The hydrofracturing method is one the most commonly used methods for delineating recent stresses in the Ostrava-Karviná Coal Field. Measurement of the stress tensor by utilization of special conical gauge probes was a second method employed, and the third method involved the interpretation of focal mechanisms of seismic events monitored by the Regional Seismic Network of the Czech part of the USCB.

Hydrofracturing is a borehole test method used for stress state assessment in rock masses in the vicinity of boreholes (e.g. Amadei & Stephansson 1997; Nakamura et al. 1999; Haimson & Cornet 2003; etc). The non-deformed section of a borehole (commonly 30 m deep) is chosen and two rubber packers are pressurized so that they adhere to the walls. Water is pumped into the sealed up section, and pressure is gradually raised until a fracture is initiated in the wall of borehole. The orientation of the fracture is obtained by use of oriented packers, which are imprinted on the borehole wall by the newly initiated fractures. Values of breakdown pressure, reopening pressure and shut-in pressure are recorded, so that measurements of the horizontal components of the principal stresses can be calculated. The technique is based on similar methods depending on the geomechanical conditions in the vicinity of the borehole.

Recently, measurements of stress tensor changes have been obtained using special conical gauge probes. These probes were developed by the Institute of Geonics AS CR (Staš et al. 2005) on the basis of theoretical and practical experience gained from using the Compact Conical End Borehole Overcoring (CCBO) method (Obara & Sugawara 2003). This method of long term monitoring of stress tensor changes by CCBM (Compact Conical-ended Borehole Monitoring) is derived from a compact conical ended borehole overcoring method. By omission of the overcoring phase (which results in destruction of the measured point for the next measurement during standard CCBO) a long term probe life is achieved. This allows us to measure a stress tensor change in relation to a reference stress state. Our apparatus is constructed for 76 mm diameter boreholes, where the bottom of the borehole is shaped with an apical angle of 60° by the special conical drill bits. The probe is water-proof and uses 6 pairs of mutually perpendicular gauge sensors placed with a standard configuration on the conical surface. The apparatus is developed with two variants: for overcoring (CCBO), and for long term monitoring (CCBM). Measurement of deformation on every gauge and A/D data processing are controlled by a microcomputer inside the probe. Digital data can be stored either in the internal memory of the probe when in autonomous mode, or can be sent to an external control unit.

The maximum and minimum horizontal components of recent principal stresses (S_H and S_h), have been measured in 28 localities in the region of interest since 1994 using the hydrofracturing method (e.g. Amadei & Stephansson 1997; Haimson & Cornet 2003; etc). However only 25 were suitable for the purposes of interpretation of horizontal stress components. The other boreholes were deformed and closed for the probe. The measurements were recorded at a depth of 600–800 m beneath the surface in the Karviná Subbasin. Eight new hydrofrac measurements were obtained at the same depth during 2008 and 2009 (see Fig. 5). The first group of measurements in 2008 was obtained in localities next to the main Variscan tectonic structures. Although most of the measured strain directions could be influenced by local stress fields in the vicinity of mine workings, the interpreted stress directions are close to published Variscan kinematic directions (Grygar & Vavro 1995). For example, the maximum horizontal stress direction (S_H), interpreted from the 2008 measurements between the Stonava and Albrechtice faults, corresponds to the maximum horizontal stress direction (S_H) of the Variscan kinematic model. In the follow-up stage, stress measurements have been obtained at different distances from the faults and finally in the central parts of tectonic blocks in a relatively unfractured rock. Compilation of all hydrofrac measurements and interpreted compression directions are shown in Fig. 5. On the diagram, indicated by different arrows, are horizontal stress measurements using the new CCBO or CCBM method (Staš et al. 2006), described above.

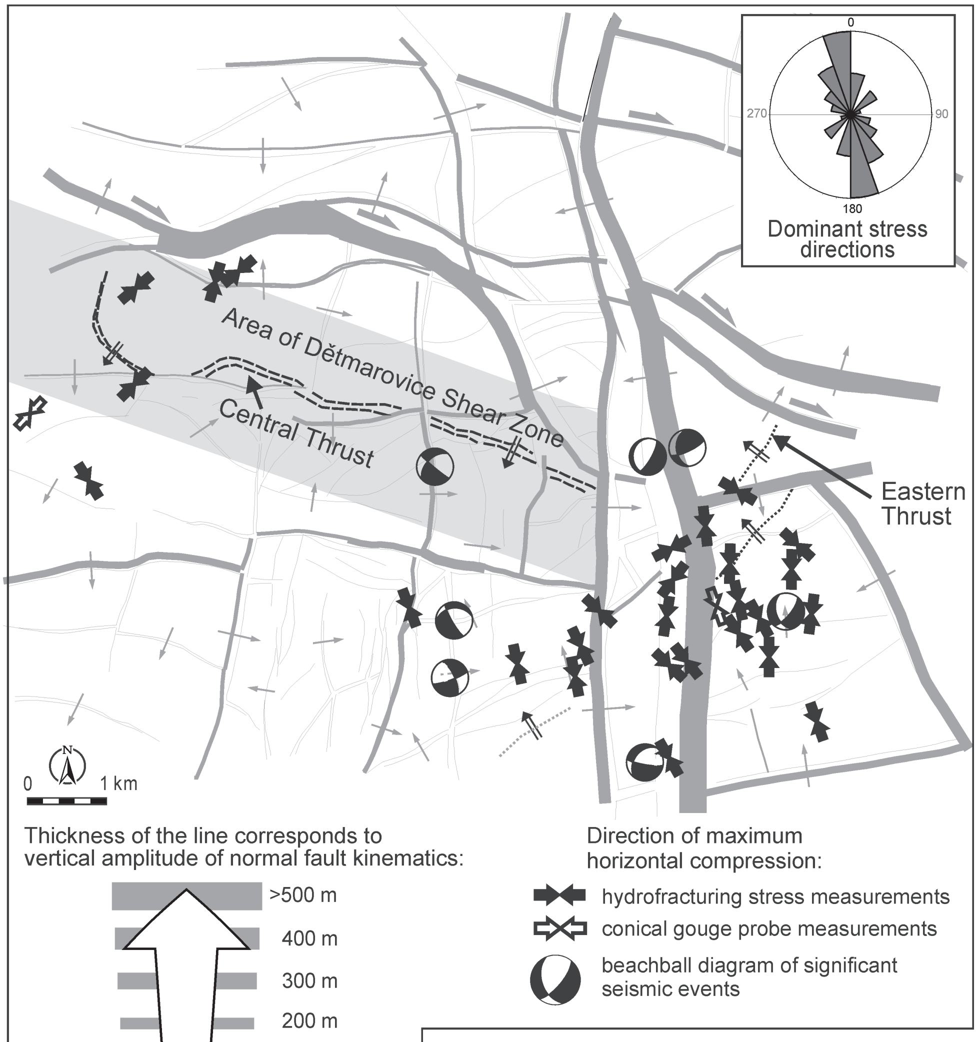

Fig. 5. Compressional components of horizontal stresses derived from hydrofrac, conical gauge probe measurements and "beach ball" diagrams of analysed seismic events with the main Variscan faults of the Karviná Subbasin in the background.

Interpretation of focal mechanisms of seismic events, monitored in USCB, is based on the principal seismic moment tensor inversion method (e.g. Aki & Richards 1980; Lund 2000; Stec 2009; etc.). The seismic events with high energy emissions were analysed.

More than 250 seismic events of magnitude from 1.2 to 2.3 (of energy 10^3 J to 10^6 J) were monitored in the easternmost part of the Karviná Subbasin in 2008 and as many as 190 in 2009. Analyses of the focal mechanism for each seismic event significantly expanded the information on local stress fields in the vicinity of excavated coal seams. The first results indicated that interpreted stress-strain directions in some cases replicated the assumed horizontal components S_H and S_h. Nevertheless, focal mechanism interpretations demonstrate considerable variability of the compressive component of the horizontal stresses (Fig. 5). We consider this to reflect the importance of stresses induced by mining.

The influence of the Alpine orogeny on the southeastern part of the Upper Silesian Coal Basin

As stated in the preamble, it is crucial that we understand the neotectonic development of stress fields and principally the recent stress regime, which is most probably influenced by the Alpine orogeny. Earlier workers (e.g. Roth et al. 1962) assumed that the Bohemian Massif, representing the Alpine foreland, played an important role in relation to the Carpathian nappes and their internal structural development. On the other hand, Hók et al. (2000) consider the influence of the Carpathian nappes on the structural tectonic framework of the Variscan basement unlikely. According to them, in the Tertiary, the Variscan basement was already consolidated.

Teper & Sagan (1995) considered the influence of the loading of the Variscan basement by the Outer Carpathian nappes, and the influence of the stress fields along their front. This influence is most intense in the southern part of the USCB and decreases to the north. The impact of the sedimentary loading was simultaneously enhanced by the Miocene sedimentary filling of the sub-Variscan autochthon. As already stated, Miocene sediments overstepped the eroded Carboniferous surface during the Karpatian. The thickness of the sedimentary filling oscillated and reached up to 1000 meters. According to Teper & Sagan (1995), the maximum horizontal stress component rotated from the original E–W direction to a N–S direction, a principal direction of the Carpathian overthrusting, and subsequently to the contemporary approximately NE–SW direction. It is necessary to point out, that the entire neotectonic stress-strain interpretation of Teper & Sagan (1995) was based on focal mechanism solutions of the seismic events induced by mining. The interpretations are, no doubt, very interesting, but we consider, based on our experiences with the interpretation of seismicity in the Karviná Subbasin, that their relevance to the entire USCB is limited.

Our view, based on the structural and morphotectonic investigation of the mutual interaction of the Alpine and Variscan orogenies in the USCB area, has been presented previously (Grygar & Jelínek 2003). Three structural levels are developed in the USCB area. The analyses demonstrate a good correlation between the structural framework in Variscan structures, observed relatively precisely by measurements in the coal mines and the Brunovistulian basement, and simultaneously help us to explain the mutual relationships between the structural pattern of the USCB and the present-day epi-Alpine relief of the Outer Carpathian belt. The Alpine reactivation of the Variscan fault structures was also very significant (see Fig. 6). There is a causal genetic coincidence with the tectonic role of both the post-Variscan and Brunovistulian foreland. It influenced the dynamics, kinematics and internal structures of the Carpathian nappes. Contemporaneously, the Carpathian Foreland was modified due to tectonic loading by the Outer Carpathian nappes and the sedimentary loading of the Carpathian Foredeep sedimentary fill (Fig. 6). This loading influenced the development of a lithospheric flexure of the Alpine Foreland and consequently rejuvenation of the Variscan, initially by reactivation of subequatorial, fault systems (Fig. 6).

Conclusions

Measurements of recent in-situ stress regimes in the Karviná rocks formation of the USCB using the hydrofrac method

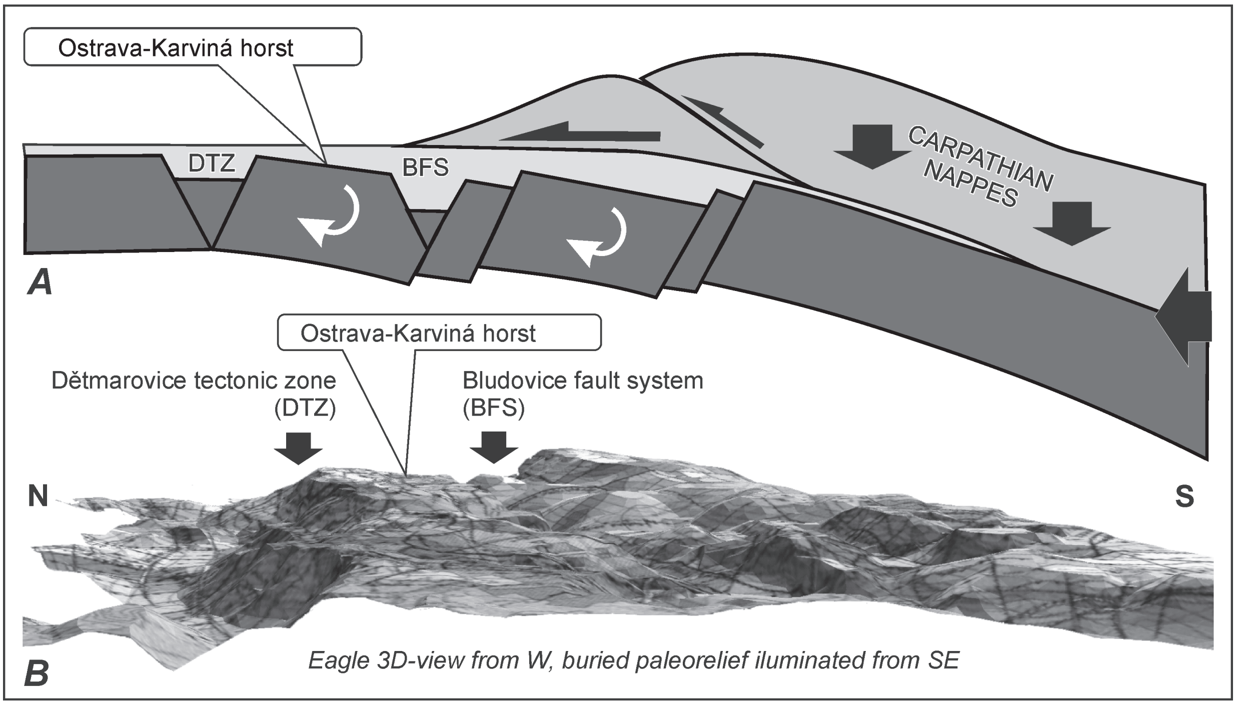

Fig. 6. Schematic interpretation of (**A**) lithospheric flexure and consequent tilting of the epi-Variscan foreland due to tectonic loading by Alpine nappes and (**B**) 3D-model of buried paleorelief of the Czech part of the USCB.

presented here, indicate a dominant generally NW–SE orientation of the maximum horizontal compressional stress (Fig. 5). The results demonstrate that the stress-strain regime in the Karviná Formation in the Variscan Upper Carboniferous basement is significantly influenced by the stress field distributed along the Outer Western Carpathian nappes front. The relations and mutual interference of the tectonic patterns of both the post-Variscan basement and the Outer Carpathian nappes, however, is open to discussion due to the fact that both the Variscan (WNW–ESE to NW–SE) and Alpine (NW–SE to NNW–SSE) maximum compressional stresses are similarly oriented (see Fig. 1). In our opinion, there is little doubt that the most significant control on the stress regime within the collision domain of the epi-Variscan foreland and Outer Western Carpathians since Oligocene times, has come from the West Carpathian orogenic system. Anyway the recent stress state in the Karviná Subbasin, based on the in situ measurements, is influenced by the stress fields of the Outer Western Carpathian nappes front.

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