

Study of Tectonic Pattern of the Dubňany Seam in the Czech Part of the Vienna Basin

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ABSTRACT: The article deals with tectonic structure of the Czech part of the Vienna Basin. Based on detailed mining and drilling exploration, a tectonic map of the upper Pannonian lignite deposit was reconstructed in the study area. Data were acquired for more than 50 years of exploration. Results of the detailed geological exploration of the deposit have been verified and sorted out according to the reliability. Selected data were used for 3D modelling of the tectonic structure and geological framework of the lignite deposit. The concept of the tectonic history in the Czech part of the Vienna Basin was developed in accordance with modelling the Dubňany and Kyjov seams. In the article, attention is paid to the method of creating tectonic models. The final phase of the tectonic development of this piggy-back basin of pull-apart type combined with graben is described.

KEY WORDS: coal seam, lignite deposit, 3D modelling, pull-apart basin, the Czech part of the Vienna Basin.

Introduction

The tectonic structure of the Czech part of the Vienna Basin in the area of the South Moravian Lignite Coalfield (Fig. 1) was newly clarified in a grant project of the Czech Republic aimed at the application of modern methods of evaluation of coal deposits using an interactive programme system. The basis of modern evaluation of coal deposits is a digital model of the geometry of the seam and its internal attributes. The coal seams from the South Moravian Lignite Coalfield were modelled from the data gained from drilling and mining explorations done for more than 50 years. A new tectonic map was created on the basis of the digital model. The most important area of the coalfield – the Moravian Central Depression – was used as an example of the modelling of the seam floor.

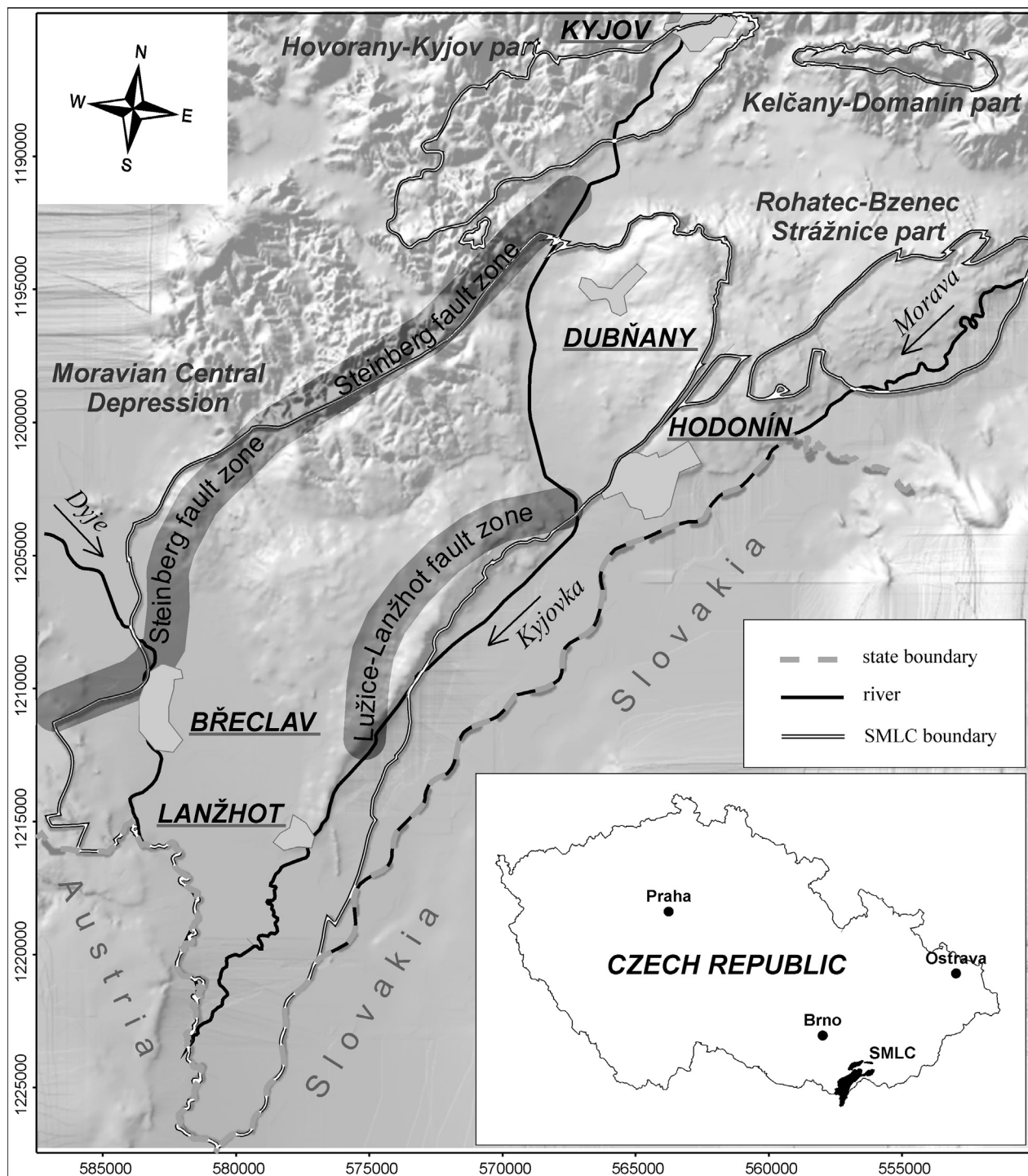
The Vienna Basin is an irregular Neogene rhomboedral depression located in the area of the Czech Republic, Slovakia and Austria. Its length is 150 km and its width varies from 50–60 km. The origin and evolution of the Vienna Basin have not been unambiguously solved. According to the latest conceptions resulting from plate tectonics theory, the basin has been developing from the Eggenburgian to the lower Badenian as a piggy-back basin and from the middle Badenian as a pull-apart basin. According to Kováč and Plašienka (2003), the Eggenburgian opening of depocentres was guided by ENE-WSW-oriented dextral horizontal faults and NW-SE-oriented normal faults. N-S-striking sinistral faults and NE-SW-oriented reverse thrusts participated in forming the tectonic structure. Subduction-collision processes were very important for the area concerned in the Karpatian. The creation of a significant shear zone with the NE-SW orientation resulted from these processes. According to Kováč and Plašienka (2003), the Vienna pull-apart Basin opened in this area. The N-S compressional component of paleostress field was characteristic for this phase of development. The sinistral faults along the Malé Karpaty block and the fronts of the Magura nappes played an important role in the evolution of the Vienna Basin in this period (Fodor 1995). According to Wessely (1986), en echelon faults resulted from strike-slip tectonics. However Jiříček (2002) explains en echelon fault pattern and local curvature of the faults

by a gradual opening of the centre of the Vienna Basin from south to north along the Steinberg fault and the opposite Lužice-Lanžhot fault complex during the lower Badenian up to the middle Badenian. Normal faults with the NNW-SSE to NW-SE orientation played the main role in the opening of the depression in the middle Miocene (Kováč, Hók 1993). The results of the paleostress analysis by Nemčok et al. (1989) prove the compression in the NE-SW orientation. Kováč and Hók (1993) do not exclude the activation of sinistral faults with N-S and NNE-SSW orientation or the activation of dextral faults with the orientation of WSW-ENE. The Vienna pull-apart Basin consists of a system of ridges and grabens separated by prominent faults with a considerable displacement amplitude (Kováč, Plašienka 2003).

The Moravian Central Depression is a graben in the central part of the Vienna Basin. The Dubňany Seam is developed in its area to a length of about 40 km and a width from 8 to 15 km. The limitation of the seam is mainly tectonic but it can be also formed by outcrops buried by Quaternary sediments. To the northwest, the seam is limited by the Steinberg and Schratzenberg fault complex and to the southeast by the Lužice-Lanžhot fault complex. Some associated faults of both complexes are antithetic and form subgrabens. The central part of the depression is slightly faulted. The Dubňany Seam has an asymmetric synclinal form with the axis of the syncline close to the eastern margin. There are partial depressions and elevations on the axis; the maximal depth of the seam floor is 315 m (–120 metres above the sea level). The dip of the seam in the western part of the depression is smaller (1–3° to the southeast); in the eastern part it reaches 3 to 5° to the northwest (Honěk et al. 2001).

Problems

So far, there is no unified opinion of the evolution and tectonic structure of the Vienna Basin. In the last few years, geologists' opinions of the evolution of the Vienna Basin have been developing very much (e.g. Janoschek 1942, Buday 1960, Mahel 1961, Němec 1973, Pícha et al. 1971, Kováč, Hók 1993, Kováč



■ Fig. 1. The digital terrain model of recent relief with schematic map of the South Moravian Lignite Coalfield (SMLC).

and Plašienka 2003, Strauss et al. 2006). The tectonic structure and the evolution of the Vienna Basin is globally solved from the point of view of the collision of the Alpine orogeny with the southeast margin of the Bohemian Massif. However, tectonic relations of individual faults at the opening of the basin have not been explained yet. Nowadays the Vienna Basin has a rhombic form which has become a motive for the search for its genesis considering theoretical presumptions.

While modelling the tectonic structure of lignite deposit in the Moravian Central Depression it is necessary to take into consideration the spatial evolution of the whole Vienna Basin and the evolution of its main faults. While thinking about the detailed model of tectonic structure of particular lignite deposit it is not possible to take into account the existence and the geometry of faults only according to the contemporary valid theory of origin of the Vienna Basin. The aforementioned dis-

crepancy is a result of different views of deposit and regional geologists on the tectonic situation and importance of individual faults. The majority of regionally important faults is not formed by one fault plane but by a fault complex with a width of several tens to several hundreds up to thousands of meters in which there are a lot of partial, more or less parallel faults. In regional geology, the whole fault belt (fracture zone) is usually generalized into one main fault. However, knowledge of detailed tectonic structure of deposit is important for the deposit and mining geology.

Data

The data about the seams and surrounding rock mass were gained from coal mines and from deposit drilling exploration which was done in the South Moravian Lignite Coalfield in several stages (Honěk et al. 2001). More than 2500 drills from the period of 1952 to 1990 were used for the creation of digital tectonic model of the whole coalfield.

The drills were divided into three groups according to types and reliability of data (Fig. 2). The first group is formed by lignite deposit drills drilled in the period from 1950's to 1990's. They can be divided into two subgroups. The first one is formed by the drills drilled up to the year 1970. Later in the text, these drills are referred to as "the old ones". The later drills are referred to as "the new ones". The density of the drills was 250×500 m to 250×250 m in the mining areas and their surroundings. In the southern part of the Moravian Central Depression the density of drills was even $2,000 \times 2,000$ m.

The disadvantage of most of the old drills was the way of drilling – the counterflush type (CF). The fragments of rocks and coal were transported by hollow drill-rods using counterflush. Their gravitation separation occurred during this process. The surfaces of seams and their intercalations were determined with reduced accuracy in the range of 0.5–1 m. The information from the old drills has reduced reliability in comparison with the data from the new drills. Nevertheless, the old drills appear more significant than the new ones – the number and the extent of the area in which they were drilled are much higher.

In new core lignite deposit drills from the 1970's and 1980's, the seam floor is defined exactly using geophysical logging. Considering the extent of the provided analyses, the new drills give the most reliable and the biggest file of information from the South Moravian Lignite Coalfield. Unfortunately, the new drills do not cover such a large area as the old ones. Most of the new drills were drilled in the central and southern parts of the Moravian Central Depression during the Hodonín-Břeclav exploration project and in the eastern part of the depression while exploration of the Hodonín I Coalfield.

The second group is formed by the boreholes drilled during oil exploration. They were drilled using the CF-rigs from the 1930's to 1950's. The density of these drills is uneven and their reliability is significantly reduced. The data about these drills were gained from the revision report (Krejčí et al. 1975) made before the beginning of the new deposit lignite exploration in the 1970's in the central and southern parts of the Moravian Central Depression. The accuracy of the determination of the seam floor is from 2–3 m in this group.

The third group is formed by various other drills. Information about these drills was gained from archive materials. The reliability of data from these drills is low; nevertheless, the data were used while modelling the seam floor mainly in the western and the southernmost parts of the Moravian Central Depression where there are no lignite deposit drills.

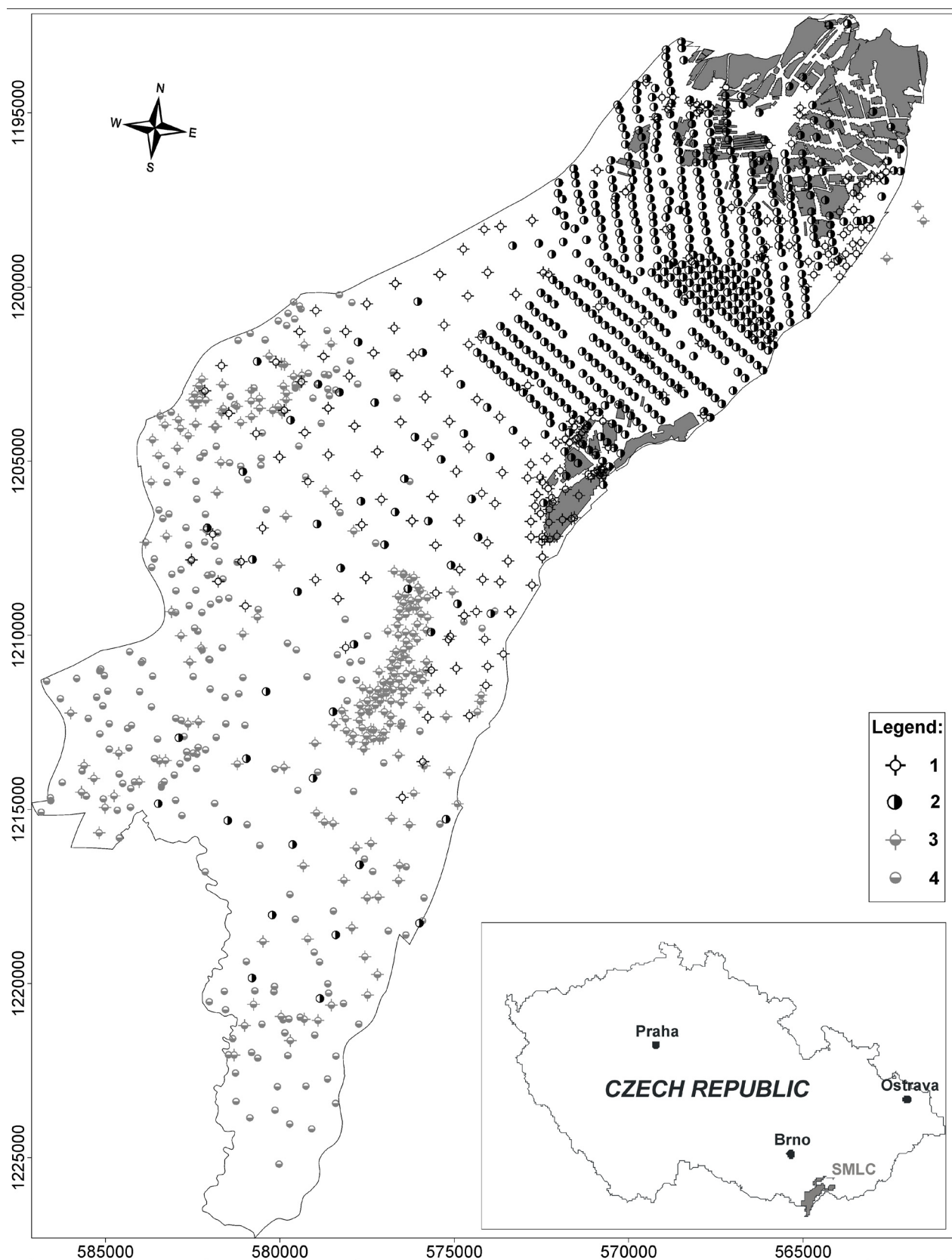
Methodology

The aim of the digital modelling of the Dubňany seam floor in the Moravian Central Depression was to create a model depicting a real surface of the seam floor with the highest accuracy. The model was formed with respect to proved tectonic fractures. The accuracy of the final digital model depends on the accuracy of the input data, their density and the type of the interpolation algorithm used. Verification of the input data from drills was the first step in the creation of the digital model of the Dubňany seam floor. The actual modelling of the seam floor was done with the software system Surfer, 8.01 version. The Cross Validation method was used for the selection of the most suitable interpolation method. The minimum curvature method was defined as the most suitable interpolation method.

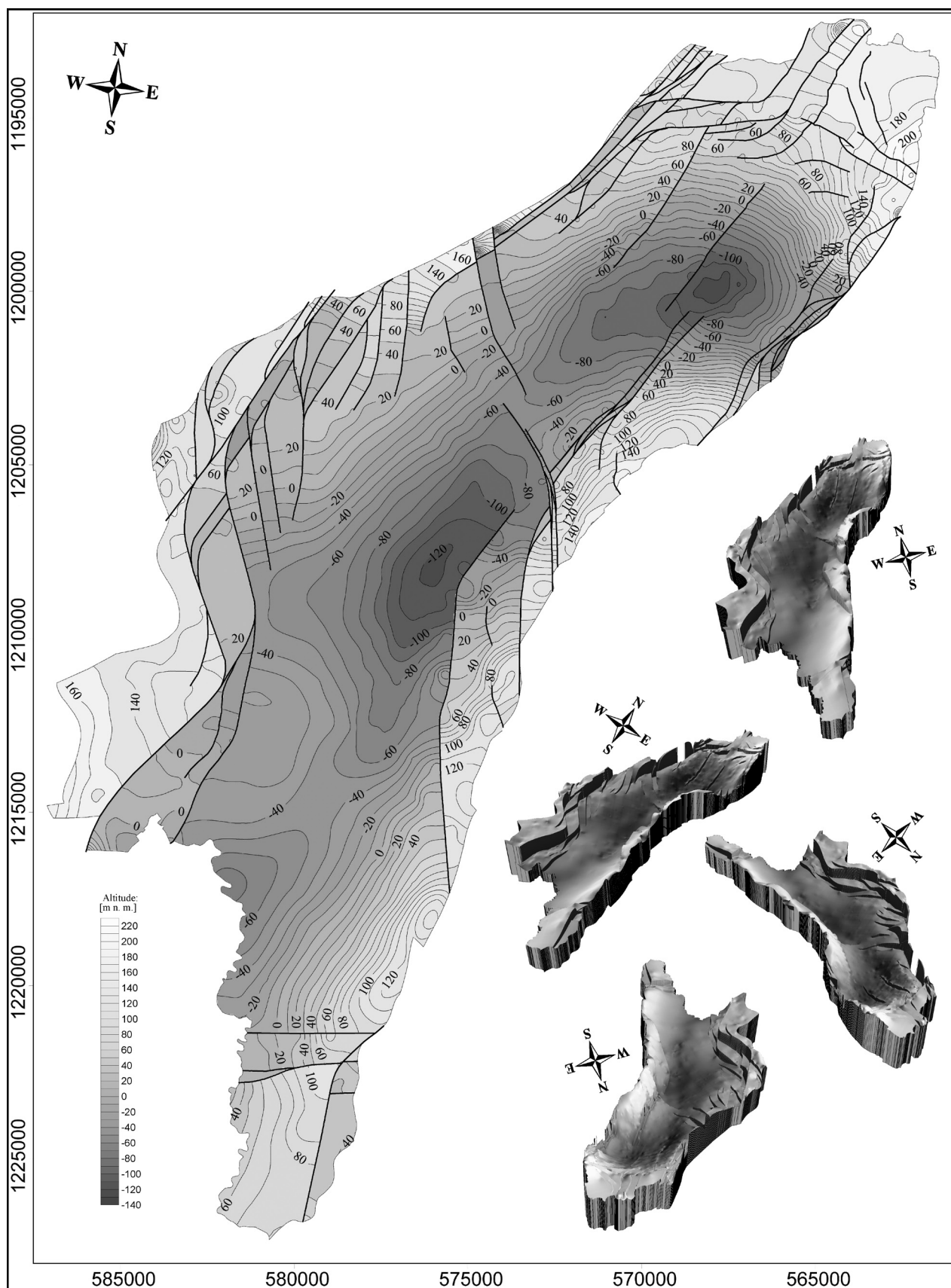
A non-tectonic model was created in the first phase of the modelling of the seam floor. This model was tested by selected morphotectonic analyses such as gradient analysis, analysis of the first and the second directional derivative, elevation analysis and shaded relief model analysis. The definition of morphological lineaments was the result of morphotectonic analysis. The morphological lineaments indicated the existence and the nature of possible tectonic fractures. The interpretation method of morphological lineaments was taken from Jelínek's study (2004). The gained result was compared to the gravimetric map of Bouger anomalies and to the geologists' opinions of the structure of the Vienna Basin. The final conception of the tectonic failure of the modelled seam floor was put as faults into the calculation of the model in the second phase. To simplify it, the faults were modelled as vertical ones. In the South Moravian Lignite Coalfield, it was found out by mining activities that the horizontal displacement on the faults is minimal.

Some tectonic blocks were modelled in the first set up model in a very unlikely way. Therefore, a process of making the model more accurate followed. The elevations of the seam floor among surrounding drills were compared section by section. Using this comparison, the inaccuracies in the definition of the seam floor were revealed in some cases. Such drills were excluded from further processing. Position of individual faults in the model was corrected using the aforementioned method. Subsequently, the conception of the individual faults was corrected and the faults were put into the calculation of a new tectonic model.

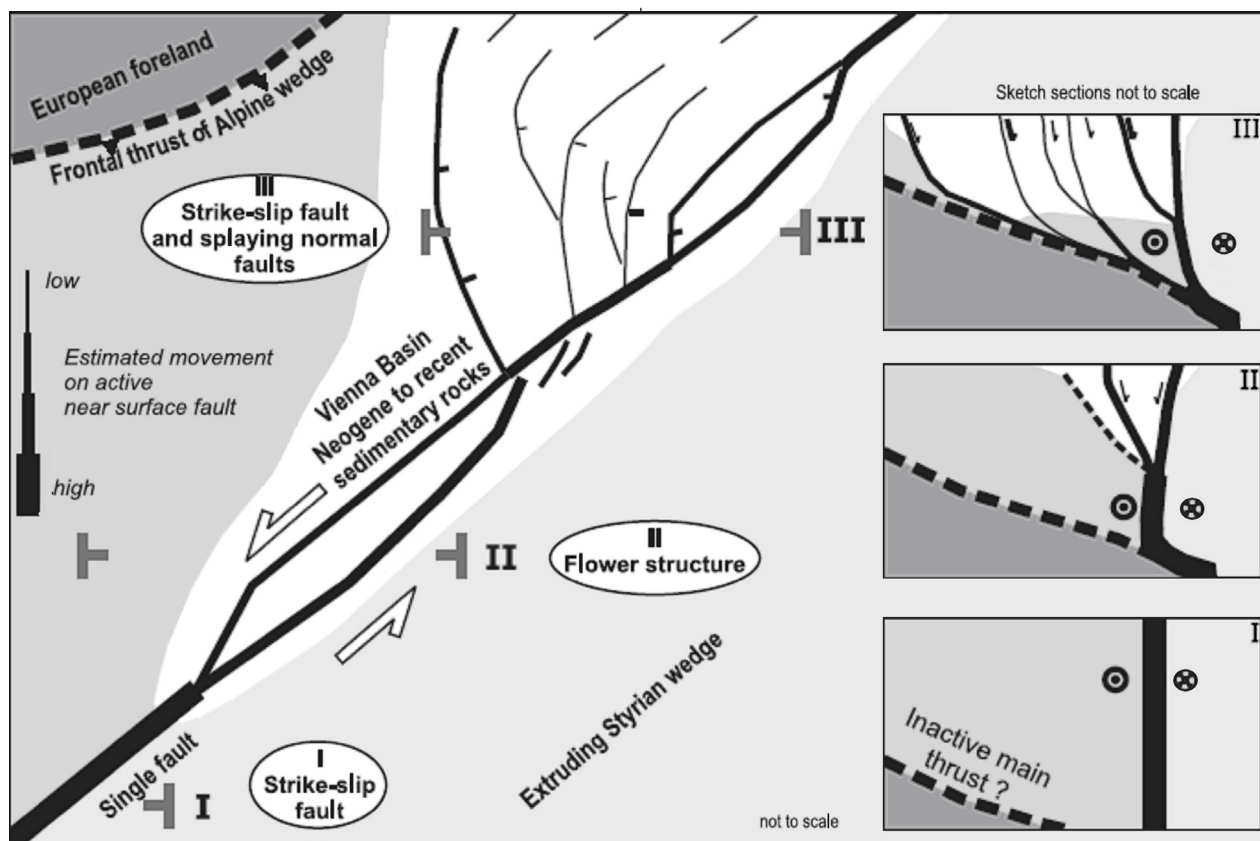
The gained model was displayed in the 3D view. The faults and their segments were classified into three categories according to their importance in the model or according to the fault throw. The first class was formed by faults with a fault throw higher than 30 m, the second one by faults with a fault throw from 5 to 30 metres and the third one by faults with a fault throw under 5 metres. The method divided the individual fault segments according to their importance. Subsequently, the seam floor was remodelled, a new model was drawn, the positions of



■ **Fig. 2.** Drills used for modelling of the Dubňany Seam floor in the Moravian Central Depression. Location of the South Moravian Lignite Coalfield in the bottom right corner. 1 – the lignite deposit drills from 1970's and 1980's, 2 – the lignite deposit drills from 1950's, 3 – other drills from the report Krejčí et al. (1975), 4 – other drills from archive documentation; grey polygon – mined out area.



■ Fig. 3. Sketch tectonic map of the Dubňany seam floor in the Moravian Central Depression (modelled without usage of auxiliary data points). 3D view in the bottom right corner (vertically exaggerated 15×).



■ Fig. 4. Schematic sketch map of southern to central Vienna Basin and cross-sections illustrating active kinematics and partitioning of deformation along the Vienna Basin Transfer Fault entering the basin from the south (Hinsch et al. 2005).

individual tectonic blocks were re-evaluated and the positions of individual faults were modified when necessary. The described method kept repeating until most tectonic blocks and positions of faults corresponded to the overall idea. The final stage included the usage of auxiliary points, which helped to correct modelled seam base surface in the areas with insufficient drill data.

Discussion

The modelled Dubňany seam floor in the Moravian Central Depression (Fig. 3) reflects the idea about its tectonic structure interpreted on the basis of about 2,500 drills. The exact data about the tectonic structure exist only in the areas proved by mining activities in the northern part and some parts in the eastern area.

A considerable tectonic failure of the Dubňany Seam in the area of the fault belt of the Steinberg fault was found out by modelling. To the north of Břeclav, the Steinberg and Schrattenberg fault systems become one. The important strike-slip faults with a fault throw of over 100 m branch into the individual faults which bend and further, they branch into smaller faults. The fault throw on these normal faults reaches values of tens of metres. In consequence of the normal kinematics of the faults, the tectonic blocks form step-shaped pattern and dip in the NE direction into the open space of the pull-apart basin. The partial normal faults are understood as associated faults of the Steinberg fault complex of strike-slip kinematics which are characterized by strike-slip

and splaying normal faults of the third type. This type is described by Hinsch et al. (2005) as a system of arch-bent interconnected faults decreasing their dip towards the depth (Fig. 4: type III). Hinsch et al. (2005) described these bent vertical faults in the Vienna Basin on the basis of the results of 3D reflection seismic mapping.

Some associated faults are antithetic and create subgrabens. These associated faults probably have strike-slip as well as normal components because the blocks limited by them are rotated towards the general nature of the seam in the Moravian Central Depression.

The south-eastern limitation of the Moravian Central Depression is formed by the Lužice-Lanžhot fault complex. This fault complex is formed by several prominent en echelon faults which are linked together by the arch-bent faults with the N-S to NE-SW orientations. The results are in harmony with Wessely's theory (2006) on en echelon fault pattern and the depocentres in the Vienna Basin and their bent nature. To the southwest the faults are branched into partial fractures with a fault throw of tens of metres. The resulting blocks dip towards the basin. This phenomenon is explained by Hinsch et al. (2005) as "negative flower structures" of the second type. The faults are steeper and, unlike the third type, do not form complicated structures. Similar strike slip faults were described by Strauss et al. (2006). The Brodský fault with the NNW-SSE orientation disturbs the Lužice-Lanžhot fault complex. It is a relatively narrow fault belt with a width of approximately 150 m which was penetrated by several drills. The fault throw on this fault is decreasing to the

north until it ceases to exist in the intersection with the axis of the basin. A similar, but not so prominent fault can be found in the southern part of the Lanžhot fault. The axis of the basin seems to be dislocated on both faults. The existence of similar faults in the basin was confirmed by Holzel and Wagreeich (2006) who studied active faults in the Miocene on the basis of 3D seismics.

Conclusions

The created tectonic map is a new interpretation of the tectonic structure of the Moravian Central Depression. It is based on the data from approximately 2,500 drills and mining documentation. The correctness of the supposed interpretation of the tectonic structure of the Moravian Central Depression depends not only on the correctness and density of the input data but also on the accuracy of the model. The position of faults is defined exactly in the northern part where there was a dense network of reliable drills with the depth of the seam floor defined exactly and where tectonic field maps are available. The aforementioned faults are mainly faults with a fault throw exceeding the value of 20 m. A lower level of accuracy of the tectonic map is in the middle and southern parts of the area where deposit drills were available only in a rare network and it was necessary to complete them with oil drills which are less accurate. However, it is possible to say that the accuracy of the new conception on the tectonic structure of the Moravian Central Depression is much higher than in the case of general opinions of regional geologists exploring the whole Vienna Basin.

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