COMPLEX STRUCTURE STUDY OF MUTUAL INTERACTION OF ALPINE AND VARISCAN OROGENY USING DIGITAL ELEVATION MODEL MORPHOSTRUCTURAL ANALYSIS (MORAVO–SILESIAN REGION — CZECH REPUBLIC)

R. GRYGAR and J. JELÍNEK

Institute of Geol. Engineering, VŠB – Technical University Ostrava, 17. listopadu, 70833 Ostrava–Poruba, Czech Republic

Abstract: Complex morphostructural and tectonic study of mutual structural interaction Alpine (West Carpathian Belt) and Variscan orogeny (Moravosilesian zone - Bohemian Massif) can be very good applied in Moravosilesian area. Comparative analyses demonstrate good correlation between the individual structural frameworks of separate Pan-African, Variscan and Alpine orogeny. The morphotectonic analysis is based on 3D visualization and interpretation of digital elevation models (DEM) of above-mentioned structural levels (Pan-African, Variscan and Alpine – recent geomorphology). Analyzed digital models of buried Pan-African and Variscan surface have been compiled based on data from drilling and mining activities and data from geophysical seismic survey. Comparative analyses demonstrate, in many aspects, a very good geometrical correlation between the structural frameworks well known also from the mining activities in coalmines of Upper Silesian Coal Basin.

Key words: Digital Elevation Model, morphostructural analysis, tectonic loading, nappes, lithospheric flexure, tilting.

The Moravosilesian zone of the Bohemian Massif is appropriate area, where principles of morphotectonic analysis can be applied for solving specific problems of structural framework and among others polyphase deformation development. The area is unique case due to superposition of three structural levels, corresponding to three orogeny cycles. Lower most Pan-African (Cadomian) Brunovistulian foreland terrane (Fig. 1) conditioned and influenced complex geological and among other deformation development of the next Variscan orogeny and their accretion wedge represented by volcano-sedimentary and carbonate platform formations of Rheno-Hercynian foredeep and Subvariscan foreland coal-bearing basin (Upper Silesian Coal Basin). Finally sequences of the West Carpathian foredeep and the Outer West

Carpathian nappes formed Alpine accretion wedge with opposite NW-ward kinematics. Brunovistulicum (Dudek 1980) as the oldest crustal segment (terrane, microcontinent – Grygar and Vavro, 1995) represents a foreland of both above mentioned accretionary wedges: the older Variscan one with generally top-to-NE kinematics and younger Alpine wedge (Outer Carpathian Belt) with top-to-NW up to N nappes thrusting.

The morphotectonic analysis is based on 3D visualization and interpretation of digital elevation models (DEM) of above-mentioned structural levels (Pan-African, Variscan and Alpine – recent geomorphology). Analyzed digital models of buried Pan-African and Variscan surface have been compiled based on data from drilling and mining activities and data from geophysical seismic survey (Gnojek and Hubatka 2001, Grygar et al. 2002 in press), especially, however, from detailed digitalization of topographic map of 1: 25000 and 1: 50000 scale (exhumed post-Variscan and actual Alpine morphostructures). Models were compiled partially using software Surfer 8.0 (shaded relief) and mainly by ArcInfo 8.1 and Arc View GIS 3.2 - 3D Analyst module visualization capability. The results of these procedures were compared with standard structure and paleostress analysis inferences and also underground structure maps demonstrating some representative structural features of individual seam levels in area of Upper Silesian Coal Basin.

Detailed digitalization of topographic map was done for model of Variscan foredeep (Nízký Jeseník Mts.) with coal-bearing molasse (Upper Silesian Coal Basin) and Alpine Outer West Carpathian Belt. The DEM of the buried pre-Alpine autochthon relief (so called "Carboniferous Buried Mountain") based on the drilling and mining activities data (Aust in Dopita et al. 1997) was compiled in scale 1: 100000 for Czech and Polish part of Upper Silesian Coal Basin. This buried one paleoreliéf was merged with model of westward-uncovered Culm basin exhumed relief of the Nízký Jeseník Mts., to get complex DEM of the pre-Alpine foreland.

Almost 150 seismic profiles were measured in E of Moravia and Silesia from 1960s to 1980s. Most of them were concentrated to the SW-ward part of Outer Carpathian Belt. Majority of the seismic activities were focused on the search for hydrocarbons. Interpretation of the seismic survey carried out during previous decades concentrated exclusively on the study of geological sections of sedimentary complexes present in the area under study overlying the Brunovistulian crystalline basement. Determination of the boundary between the sedimentary rocks and the Brunovistulian crystalline basement, which could be mostly shown fairly reliably, was the latest and the most profound task of the previous interpretation. Seismic indications of the Brunovistulian buried surface, together with the results of more

than one hundred boreholes reaching to the basement (see Suk et al.1991), were the basis for the scheme of buried Brunovistulian paleorelief compiled within the project of "Geodynamic model of the relation between the Bohemian Massif and the Western Carpathians" (Hubatka in Krejčí et al. 1998).

All made models of particular structural levels are integrated in context of more general DEM model of recent relief of Bohemian Massif and Western Carpathian system based on GTOPO30 data. The GTOPO30 DEM is set up on basis satellite radar data (SAR - Synthetic Aperture Radar). The data for 30-second GTOPO30 grid are provided by USGS (http://edcdaac.usgs.gov/gtopo30/gtopo30.html).

Comparative analyses demonstrate, in many aspects, a very good geometrical correlation between the structural framework well known from the mining activities in coalmines of the Upper Carboniferous coal-bearing formations and the buried relief of the epi-Variscan platform. Analogously mutual induced relationships can be observed between the morphostructural patterns of the present Epi-Alpine relief of Outer Carpathian belt (Fig. 2) and the structural pattern of the Upper Silesian Coal basin. This reveals significant and so far not well quantified role of the Alpine rejuvenation of the Variscan faults structures (especially a subequatorial faults and shear zones) in the course of nappe thrusting in the time of Alpine orogeny. There is causal genetical interference with tectonic role of pre-Alpine Brunovistulian autochthon, which one induced dynamics and kinematics development of the Outer Carpathians nappes, especially their internal structure framework. Contrariwise above-mentioned pre-Alpine basement was simultaneously modified as a consequence of tectonic loading by Alpine nappes (Fig. 3) and sedimentary loading by foredeep filling. This loading influenced development of a lithospheric flexure of the Alpine foreland and mainly its activation – rifting by subequatorial fault systems. Distinct tilting (bookshelf tectonic) is typical brittle deformation style of rigid Brunovistulian basement that is consequence of brittle crust flexuring.

Morphotectonic analysis utilizing also geophysical data (Hubatka and Gnojek 2001) emphasized fact, that Brunovistulian basement is fractured and vertically differentiated by great fault zones (Fig. 1), firstly of so-called “Sudetic direction” (conjugated system of WNW-ESE and NW-SE striking faults). The prominent one Sudetic tectonic zone (sometimes named “Upper Moravian depression boundary fault”) is induced by SW morphostructural limit of Nízký Jeseník Mts. - outcropping part of Culm basin, which one continues to NW as a Sudetic Inner Fault. Its opposite SE-ward continuation and structural imprint into upper most structure level of the Outer Carpathian nappes realm is also very well confirmed by our

morphostucture analysis. The discussed zone is prominently traceable in residual gravity and magnetic maps (Šalanský 1995, Gnojek – Hubatka 2001 etc.). This tectonic zone constitutes a boundary between two parts of Brunovistulian basement with different paleo-morphostructures. However, Sudetic fault system is not so evident at the NE Silesian part of Brunovistulian area. System of subequatorial (both conjugated strikes WNW-ESE and WSW-ENE) faults – such as Dětmarovice and Beskydy fault zones – is distinctly dominant there.

This horst-like elevation zone (striking WSW-ENE) represents opposite structure to the Main depression in Polish part of the Upper Silesian basin (Jura 2001) is evident in Czech part of buried post-Variscan surface. The tectonic ramps genetically linked to above mentioned elevation zone are logically subparallel with Outer West Carpathian Belt frontline and at the same time most probably conditioned development of main structures of the Other Carpathian nappes. The vertical movement amplitude on these Alpine foreland faults progressively increases from north to south. In Polish part of Upper Silesian coal basin this amplitude corresponds to first10 m (Jura 2001) and increase up to first 100 m in Czech southern part of Alpine foreland, where in most southern known area on sub-Beskydy faults system prove first kilometers vertical movement.

Distinct features (second trend) of Alpine rejuvenation are indicated equally by "radial" originally Variscan based faults. For instance Těšín fault, Orlová fault-propagation-fold structure can be ranged as well as Karviná graben, which is distinctly copied into Alpine structural level. These structures are the main part of dominant trend oriented NNE-SSW resp. NNW-SSE conjugated one.

This work was supported by the GAČR – Grant Agency of the Czech republic (Project #205/01/0480 and #205/00/1182).

References

DOPITA M., et al., 1997. Geologie české části hornoslezské pánve, MŽP ČR, Praha.

DUDEK A., 1980. The crystalline basement block of the outer Carpathians in Moravia: Bruno-Vistulicum. Rozpr. Čs. Akad. Věd, Ř. mat. přír. Věd, 90, 8: p.85, Praha

GNOJEK I., MUTLOVÁ A., DĚDÁČEK K., 2000. Aeromagnetic map of the Czech Republic based on the grid of data 250m x 250 m. Ministry of Enviroment of Czech Republic, Geofyzika Brno.

GNOJEK I., HUBATKA F., 2001. Structure of the Brunovistulian Unit (E part of the Czech Republic) on the basis of seismic and magnetic data. Bull. Czech Geol. Survey, 76, 3: 157-168.

GRYGAR R., VAVRO M., 1995. Evolution of Lugosilesian Orocline (North-eastern periphery of the Bohemian Massif): Kinematics of Variscan deformation. J. Czech Geol. Soc., 40, 1-2: 65-90.

HUBATKA F., GNOJEK I., 2000. Contribution to the Structure of the Crystalline Basement in Eastern Moravia Based on Geomagnetic and Seismic Data. Geolines, Valume 10, Institute of Geology, Academy of Sciences of the Czech Republic, 33.

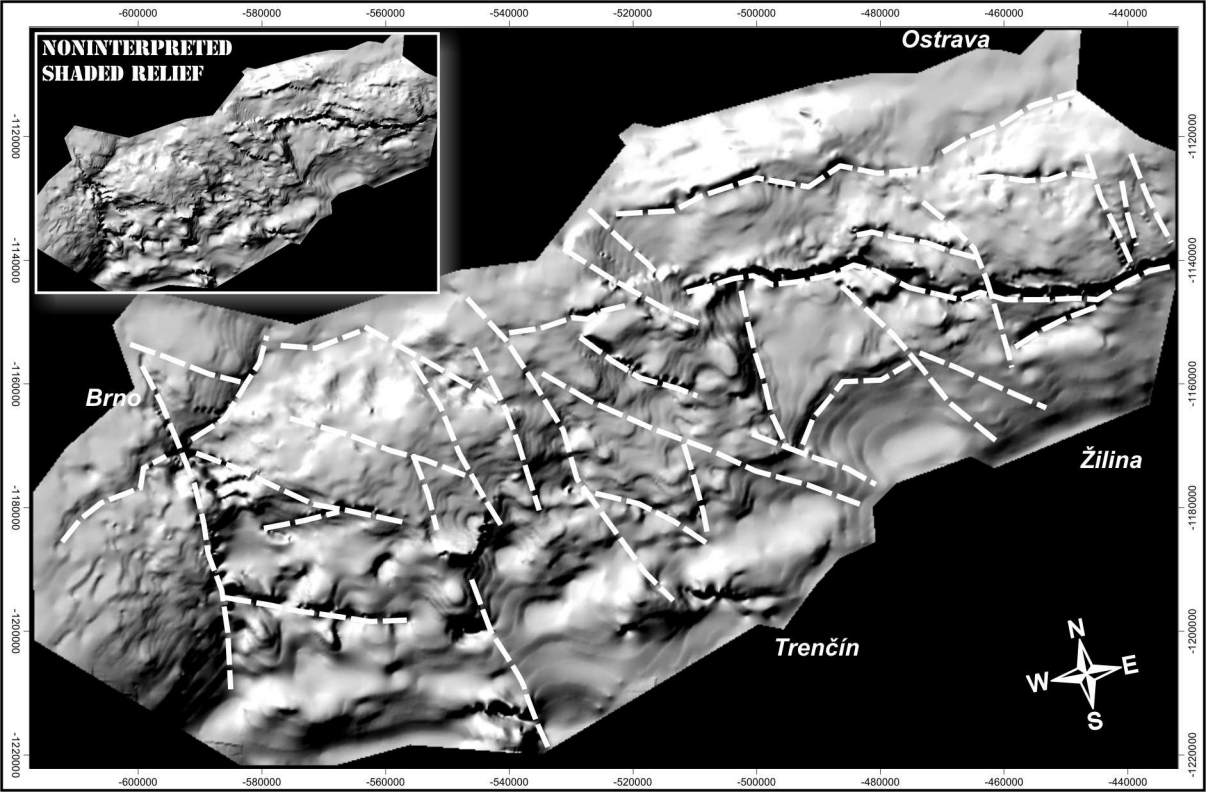
JURA J., 2001. Morphotectonika I ewolucja różnowiekowej niezgodności w stropie utworów karbonu Górnośląskiego Zagłębia Węglowego. Wydaw. Uniw. Śląsk. Katowice, 176 pp.

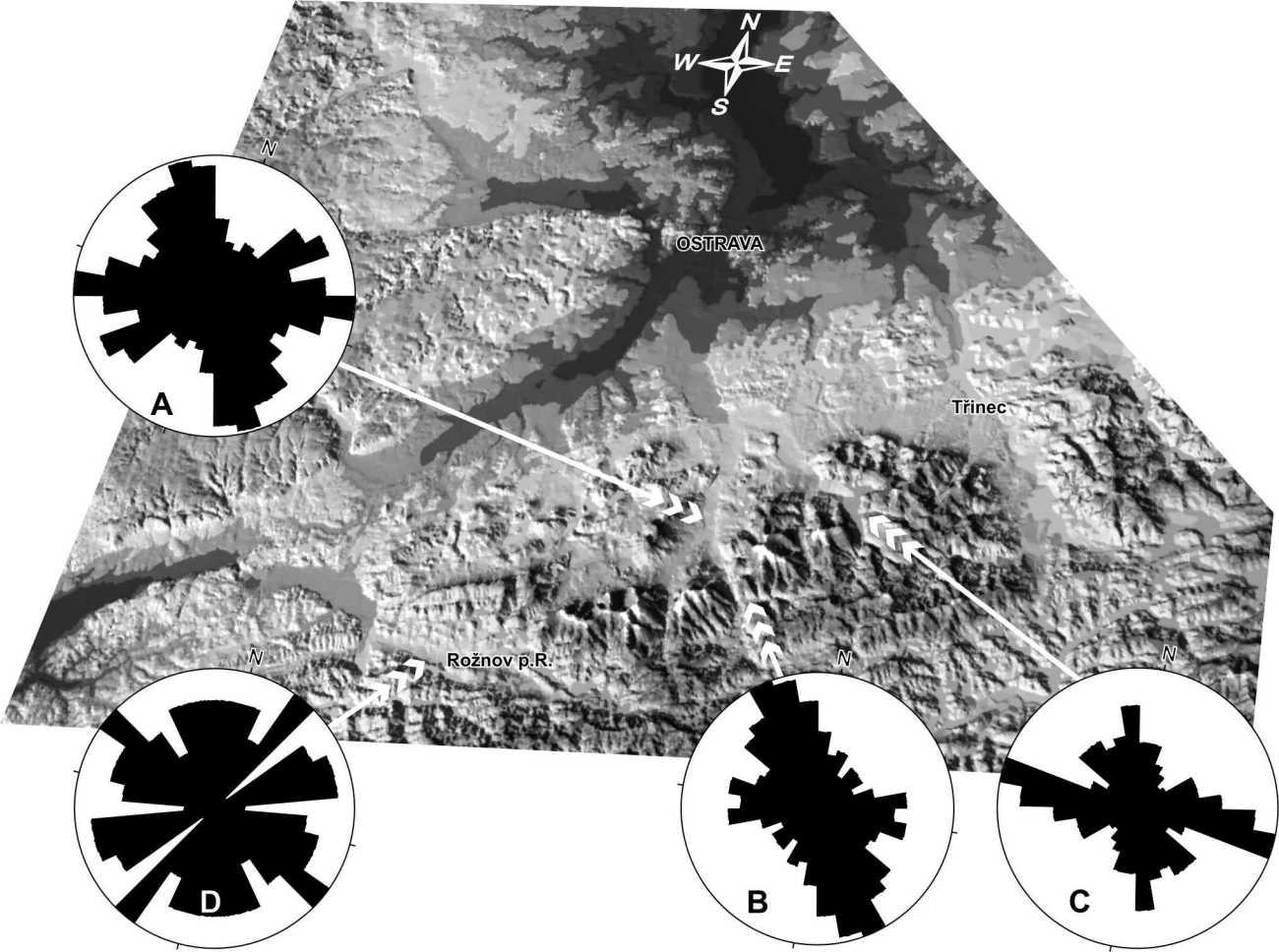
KREJČÍ O., MÜLLER P., FRANCŮ J., 1998. Geodynamic model of the contact of the Bohemian massif and Western Carpathians – geophysical chapter by Hubatka F., Sedlák J., Ondra P. (1997): Geofyzikální práce na na úkolu VaV/630/1/97. (in Czech) – manuscript, Geofyzika Brno, Czech Geol. Surv. Branch Brno.
ŠALANSKÝ K., 1995. Magnetic map of the Czech Republic, 1:500000. Czech Geol. Surv., Praha.

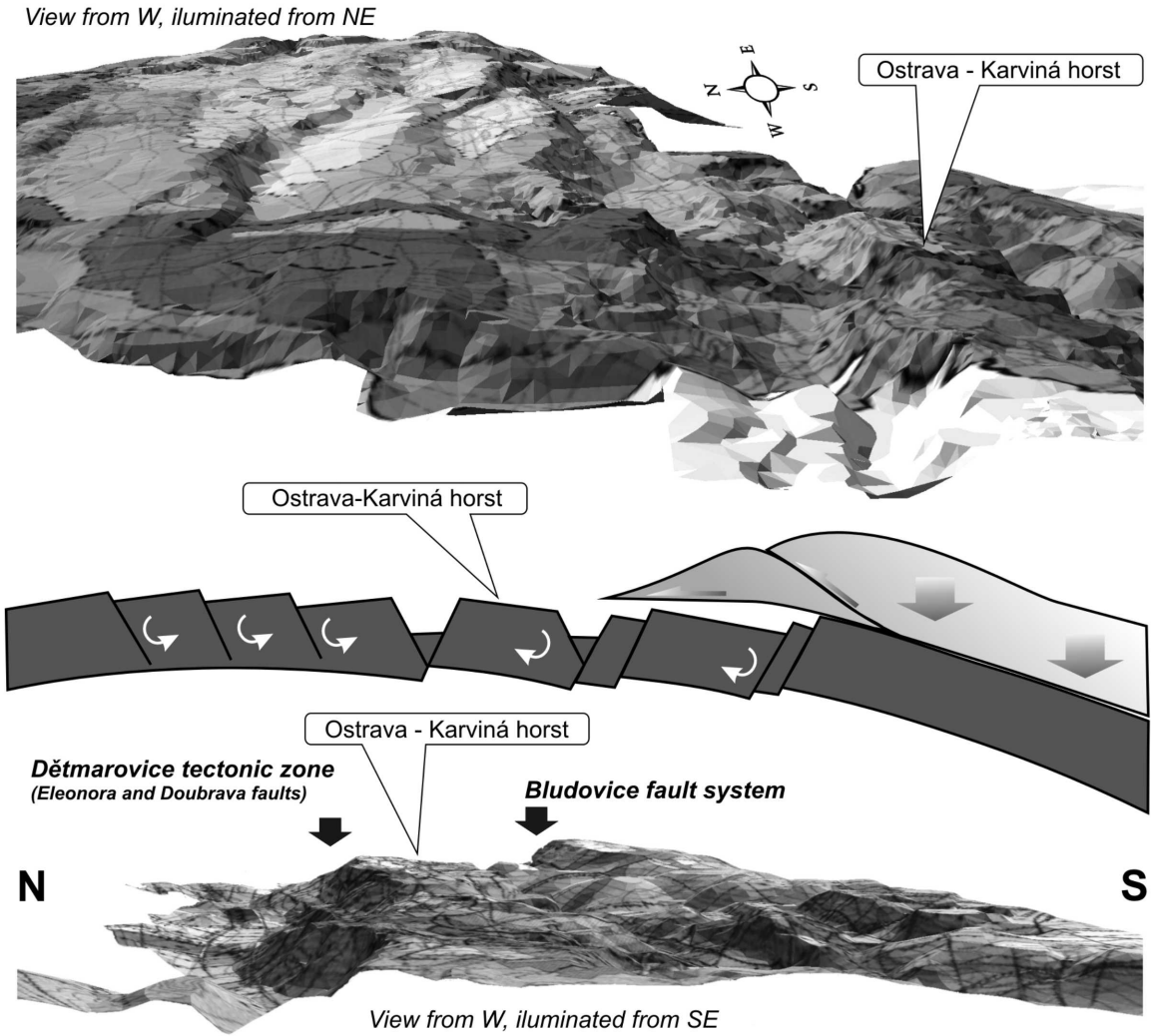
Fig. 1. Digital elevation model – DEM (shaded relief illuminated from the NW, compiled on geophysical and boreholes data according to Hubatka 1997) of buried Brunovistulian (Pre-Variscan) basement with interpreted main fault systems.

Fig. 2. DEM (shaded relief illuminated from SW) of Moravskoslezské Beskydy Mts. (Outer West Carpathian Belt) and adjacent areas with rose diagrams of brittle mesoscopic deformation structures (fault and joints systems from Beskydy Mts. area – Silesian ans Subsilesian nappes). Conjugated subequatorial systems WNW-ESE and WSW-ENE), so as radial NNW-SSE up to Sudetic system NW-SE are evident on all rose diagram and recent morphostructure (DEM).

Fig. 3. Schematic interpretation and genesis of lithospheric flexure with consequent brittle block tilling - schematic cross section of Alpine foreland, due to tectonic loading by Alpine nappes. 3D view DEM corresponds to northern Polish part of pre-Alpine basement (upper) and the same for southern Czech part (lower). Both together illustratively document antithetic block tilting along main subequatorial faults systems of Alpine foreland.


NONINTERPRETED
SHADED RELIEF
Ostrava
Brno
Žilina
Trenčín
N
W
E
S
-600000
-580000
-560000
-540000
-520000
-500000
-480000
-460000
-440000
-1120000
-1140000
-1160000
-1180000
-1200000
-1220000


N
W
E
S
OSTRAVA
Třinec
Rožnov p.R.
N
A
N
D
N
B
N
C


View from W, iluminated from NE
E
N
W
S
Ostrava - Karviná horst
Ostrava-Karviná horst
Ostrava - Karviná horst
Dětmarovice tectonic zone
(Eleonora and Doubrava faults)
Bludovice fault system
N
S
View from W, iluminated from SE