THE MAP OF MORPHOSTRUCTURES OF THE CZECH REPUBLIC

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Jaromír Demek, Karel Kirchner, Peter Mackovčin, Petr Slavík: The map of morphostructures of the Czech Republic. Geomorphologia Slovaca et Bohemica, 7, 2007, 1, 5 Figs., 27 refs.

The authors present a map of morphostructures in the territory of the Czech Republic. Morphostructures (GERASIMOV 1946) are terrain types generated by a combination of the neotectonic activity and exogenic processes (mainly climate controlled). Morphostructures exist in a hierarchical arrangement. Individual morpohostructures were delimited by morphostructural analysis using structural geological and hydrogeological information, planation surfaces, morphometric analysis, and analysis of geomorphic nets, river terraces and correlative deposits as key data sources. The map contains the classification and the cartographic presentation of individual types of morphostructures on the territory of Czechia using colours and signs. The authors distinguished 6 megamorphostructures of the 1st order: Bohemian Massif, Moravian-Silesian Terrane, Carpathian Foredeep, Outer Western Carpathians, Pannonian Basin and Silesian Lowland, and a range of morphostructures of the 2nd and 3rd order.

Key Words: Czech Republic, map of morphostructures, morphostructural analysis.

1 INTRODUCTION

The authors worked out the Map of morphostructures of the Czech Republic on a scale 1:1 000 000 within the framework of works focused on the publication of the Atlas of Landscapes in the Czech Republic. Under the term of morphostructures (GERASIMOV 1946) the authors understand relatively distinctive parts (units) of diverse size delimited in the relief, which came to existence through a combination of neotectonic and exogenic processes (climate-controlled processes in particular) on the geological basement including both rocks and the effects of older tectonics (jointing, folding, faulting, etc.). Geomorphologists usually distinguish active and passive morphostructures. Morphostructural evolution of Central Europe in the Paleozoic resulted from several orogenetic stages due to the collision and faulting of Baltica, Laurentia and Gondwana and among them moving terranes such as the exotic terrane of Avalonia and the Bohemian Massif. The Czech territory is situated on the boundary of Eurasian and African lithosperic plates whose movement results not only in vertical but also horizontal movements of morphostructures. With respect to this exposed location of Czechia on the dividing line between the lithospheric plates and regarding the complex history of the relief the map illustrates first of all active morphostructures.

Morphostructures constitute a hierarchical structure from morphostructures of the 1st order (mega-morphostructures) such as the Bohemian Massif, up to low-order morphostructures (micro-morphostructures) such as grabens or anticline crests (BAKER 2007, p.5). Demarcation and classification of morphostructures are both of theoretical significance for explanation of the lithosphere-relief relationships, and of practical importance in prediction the processes of natural disasters threatening the environment of human society.

2 MORPHOSTRUCTURAL ANALYSIS

Morphostructures were demarcated in the map by using morphostructural analysis (MAR) which is a set of methodological procedures of structural geomorpho-

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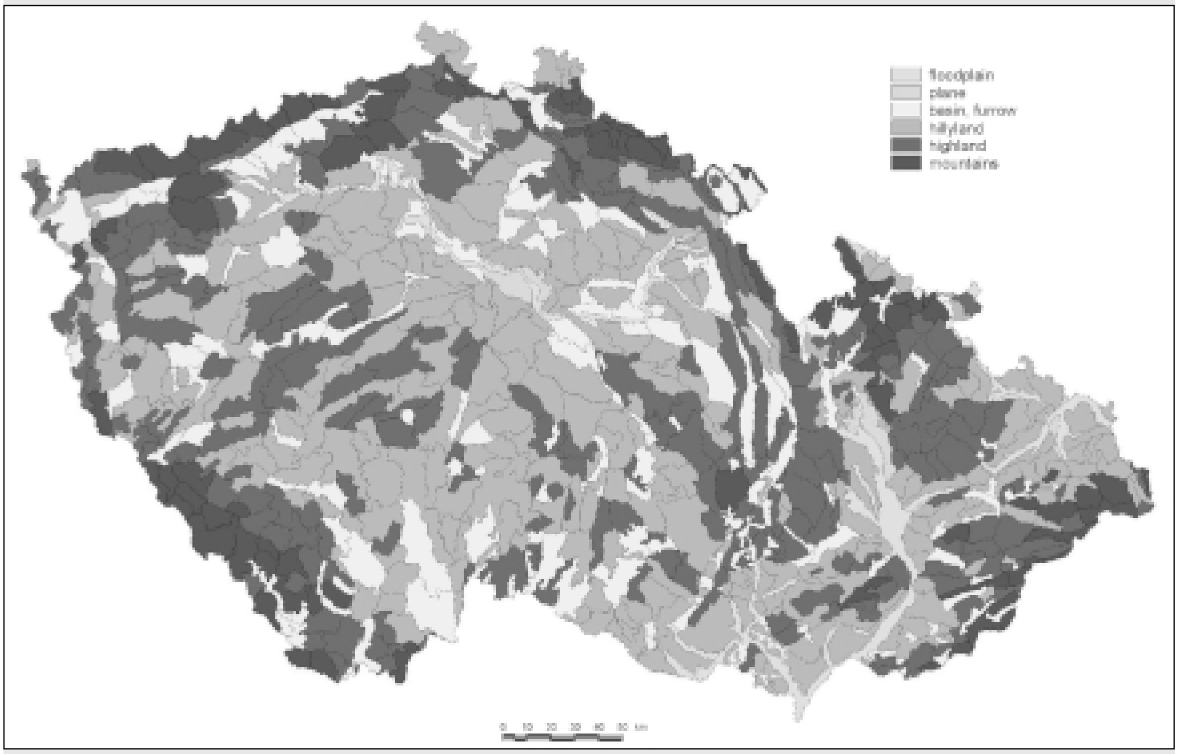

Fig. 1 Morphographical types of relief of the Czech Republic. Compiled by J. DEMEK and P. SLAVÍK

logy, whose aim is to explain direct and indirect links between properties of the existing relief and construction of the Earth interior (esp. lithosphere). Morphostructural analysis uses both geomorphological and non-geomorphological methods (LACIKA 1986). Geomorphological methods of MAR used by the authors in map generation and for the classification of morphostructures were those of field geomorphological research and mapping, morphometrical analysis (**Fig.1**), analysis of geomorphological nets (esp. riverine and valleys patterns), analysis of floodplains and terraces, analysis of longitudinal and transversal terrain profiles, analysis of planation surfaces. Non-geomorphological methods of MAR used by the authors were those of the analysis of structural geological data (esp. the new geological map of Czech Republic 1:500 000 – CHÁB, STRÁNÍK and ELIÁŠ 2007), hydrological and hydrogeological data, analysis of correlate deposits, geodetic and geophysical methods and analysis of remote sensing data.

From the viewpoint of morphostructural analysis the territory of the Czech Republic lies on the younger lithosphere of Central and South Europe. The younger lithosphere is partitioned from the old lithosphere of the Baltic shield and the East-European craton by the trans-European suture zone (TESZ) which is a broad and compound zone of terranes accretion (PHARAOH 1999, p.17). The Bohemian Massif in the west of the country is a mosaic of terranes of extremely diverse palaeogeographical origin (FRIEDL et al. 2000) that were mutually consolidated during the Variscan orogeny in the Palaeozoic. Faults bordering the crust of individual terranes are often hidden under younger rocks. After the consolidation of individual terranes the Bohemian Massif and the Moravian-Silesian Terrane were predominantly under platform regime which started to be replaced by neotectonic regime towards the end of the Oligocene.

Variscan Gondwanian terranes joined to the Baltica in the Carboniferous are as follows:

– the extensive Moldanubian Terrane composed of crystalline and deep-seated eruptive rocks in the southern and south-western parts of the Bohemian Massif,
– the Tepla-Barrandian Terrane constituting the core of the Czech Basin , and a part of the Bohemian Cretaceous Basin,
– the Saxon-Thuringian Terrane reaching into the north-western Bohemia (the Crystalline of Krušné hory Mts. and the Ohře Rift),
– the Sudeten Terranes in the north of Bohemia, Moravia and Silesia (CYMERMAN 1999, CYMERMAN, PIASECKI and SESTON 1997).

The Moravian-Silesian Terrane (MST) with the Cadomian Brunovistulicum joining the Bohemian Massif in the east is a palaeoproterozoic (perigondwanian) terrane joined to the Baltica at the end of Ordovician and at the beginning of Silurian. Brunovistulicum was the first morphostructural unit in Central Europe defined as a terrane (NAWROCKI et al. 2004). Brunovistulicum reaches under the Carpathian Foredeep and Alpine nappes of the Outer Western Carpathians. The

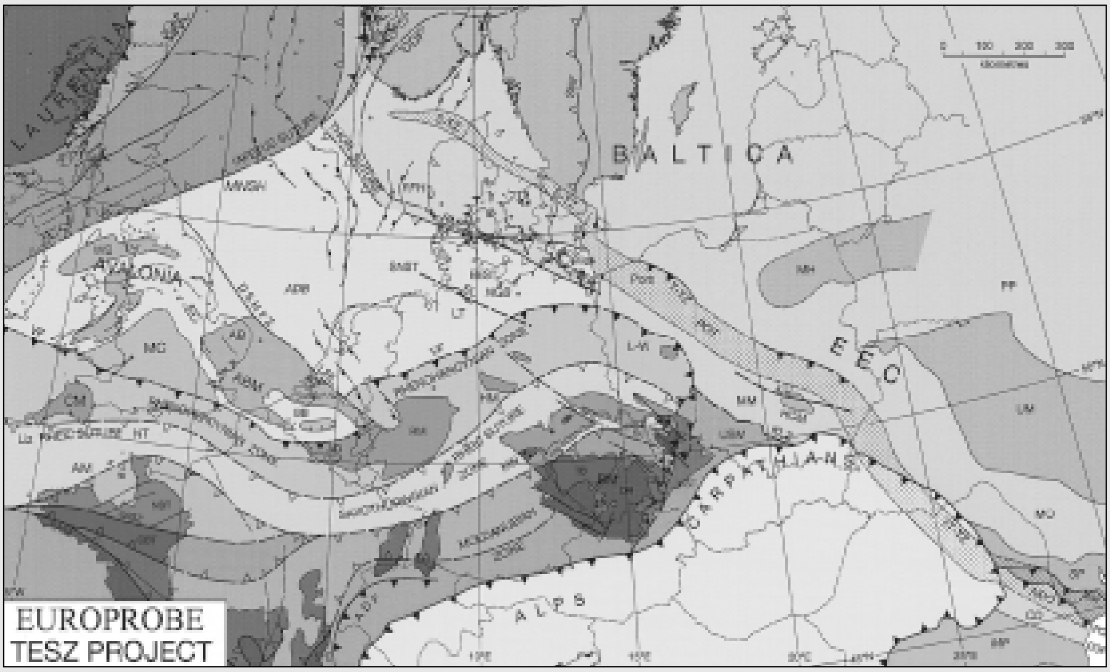

Fig. 2 Terranes in the Czech Republic (PHARAOH 1999)
Legend: BM (Bohemian Massif), MST (Moravian-Silesian Terrane), DR (Drosendorf Unit of the Bohemian Massif), GF (Gföhl Unit of the Bohemian Massif), TB (Tepla-Barrandian Terrane), USM (Upper Silesian Massif), SU (Sudeten terranes), EFZ (Elbe Fault Zone)

junction of Variscan and Alpine orogenies (Alpine front) is later laid onto the original accretion mosaic.

3 Construction of the map of morphostructures

In the construction of the map of morphostructures of the Czech Republic the authors proceeded in six stages according to principles of morphostructural analysis (MAR). The first stage consisted in a morphometrical analysis of the Czech relief. The second stage was analysis of field geomorphological data and analysis of geomorphologic maps. The following third stage included an analysis of structural geological, tectonic and hydrogeological data (esp. the new geological maps of the Czech Republic 1:500 000 – CHÁB, STRÁNÍK and ELIÁŠ 2007). The important fourth stage was an analysis of nets (fault, riverine, valleys) which closely linked with the fifth stage in which the authors analyzed planation surfaces. The sixth stage was to verify the obtained results by analyzing data from remote sensing.

Large amount of obtained information was necessary to process by means of GIS and digital cartography to receive its representation and visualization in the form of new map of morphostructures. The map is namely of geoinformation project Landscape Atlas of the Czech Republic elaborated in the GIS milieu. This approach also enabled rapid and first-class cartographic elaboration in the digital form. The whole process of the production of the new map was carried out in the information system ArcView GIS of the firm ESRI in the coordinate system S-42 (Gauss Krüger {Pulkovo 1942). The applied software had not only enough instruments for acquisition of the vector data, its editation and its management, but also due to broad range of symbols fully satisfied authors needs of final visualization of spatial data.

Obtained vector data were stored in the format ArcView Shape file in two layers – first the layer of linear elements for linear objects and second layer of polygons for spatial objects. Both layers had attribute tables for following classification of elements according author's ideas.

In the frame of linear objects authors distinguished 4 types of map's elements:

– axis of anticlines (in the map shown by the red colour),
– axis of synclines (in the map shown by the green colour),
– the head of nappes (in the map shown by the black linear symbol),
– fault scarps (in the map shown by the black linear symbol).

The main part of the elaboration of the new map was the choice of appropriate manner of cartographic interpretation of delimited areal. During the choice of means of expression was necessary to take in the consideration first a large number of morphostructures (totally 53 types) and second 3 types of their hierarchical structure. At the end authors used combination of linear signs and colour raster. This combination enabled to use one main express mean for every hierarchical order as follows:

– Morphostructures of the 1st order - colours
– Morphostructures of the 2nd order – raster (with basic colour marking the 1st order)
– Morphostructures of the 3rd order raster (the type of raster marks the 2nd order and the colour marks the 1st order).

During the cartographical processing author fully used advantages of digital technologies which enables exact adjustment of basic parameters of used hatchings (their spacing, thickness, angle and colour) and raster.

For morphostructures of the 1st order were used shades of yellow, orange and brown colours for the Bohemian Massif and the Moravo-Silesian terran) light-green colour for the Pannonian Basin, light-blue for the Silesian Lowland, shadows of red for the Outer Western Carpathians and blue.-green colour for morphostructures of the Carpathian Foredeep.

Types of linear and signs raster were chosen in the way to evoke character of the given type of relief. In the frame of the 2n hierarchical level thus for horsts were used raster with sharp angles, for domal and fold morphostructures raster with rounded signs for plateaus formed by horizontally bedded sediments horizontally layered cubical raster.

For the marking of the relative elevation of the morphostructures of the 2nd order authors used colour of raster according the principle the higher relative elevation, the darker shadow of the colour.

4 Types of morphostructures in the territory of the Czech Republic

4.1 Morphostructures of the 1st order

The authors distinguished 5 morphostructures of the 1st order in the Czech territory: the Bohemian Massif with the Moravo-Silesian Terrane, the Silesian Lowland, the Carpathian Foredeep, the Outer Western Carpathians and the Pannonian Basin.

4.2 Morphostructures of the 2nd order within the Bohemian Massif and the Moravo-Silesian Terrane

Morphostructures of the 2nd order within the Bohemian Massif and the Moravian-Silesian Terrane are sub-divided into morphostructures of the 3rd order which further split in:

4.2.1 Morphostructures of the 3rd order on the basement

Morphostructures of the 3rd order on the basement are further divided to:

4.2.1.1 Block morphostructures (ZEMAN 1978) forming:

– horsts with the upland relief (e.g. Krkonoše, Králický Sněžník, Hrubý Jeseník, Blanský les Forest, Slavkovský les Forest), highland relief (e.g. Český les Forest, Nízký Jeseník Highland, Drahanská vrchovina Highland, Zábřežská vrchovina Highland), and relief of hilly lands (e.g. Středočeská vrchovina Hilly land and a greater part of the Českomoravská vrchovina Highland),
– grabens without younger filling (e.g. Tachovská brázda Furrow, Liberecká kotlina Basin), with the filling of Permian-Carboniferous (e.g. Boskovická brázda Furrow), with the filling of Cretaceous (e.g. Králický prolom Graben), and with the filling of Neogene (e.g. Chebská pánev Basin, Sokolovská pánev Basin, Hradecká pánev Basin),
– compound systems of horsts and grabens with the highland relief (e.g. in the Bobravská vrchovina Highland),
– inclined blocks with the mountains and highland relief (e.g. Krušné hory Mts.),
– karst morphostructures with the highland relief (e.g. Moravian Karst).

4.2.1.2 Basin morphostructures with the filling of Permian-Carboniferous (e.g. Podkrkonošská pahorkatina Hilly land)

4.2.1.3 Fold-faulted morphostructures further sub-divided to:

– anticlinal (e.g. Zvičínský hřbet Ridge),
– synclinal (e.g. Jihlavsko-sázavská brázda Furrow, South-Bohemian megasyncline),
– megaanticlinal with the mountain relief (e.g. Šumava Mts., Orlické hory Mts.) and with the highland relief (e.g. Strážovská vrchovina Highland),
– limbs of megaanticlines with the highland relief (e.g. Šumavské podhůří Piedmont and a part of the Orlické podhůří Piedmont, Železné hory Mts.) and with the relief of hilly land (e.g. a part of the Orlické podhůří Piedmont),
– Bohemicum (of Teplá-Barrandian Terrane with strong effects of lithology) further divided into highland Bohemicum (e.g. Brdy Highland with a strong effect of rock composition) and Bohemicum of hilly lands (e.g. Pavlíkovská pahorkatina Hilly land),
– circular with the highland relief (e.g. Sedmihoří Highland),
– domes with the mountain relief (e.g. Sýkořská hornatina Mts.) and with the highland relief (e.g. Žďárské vrchy Hills and Nedvědická vrchovina Highland).

4.2.2 Morphostructures of the 3rd order in areas where morphostructures are developed in sedimentary or igneous (especially in neovolcanic) rocks.

This type of morphostructures is further divided into:

– brachysynclinal morphostructures on the Permian-Carboniferous (e.g. Jestřebí hory Mts. with marginal cuestas and Broumovská kotlina Basin),
– brachysynclinal morphostructures on the Cretaceous (e.g. Polická vrchovina Highland),
– fold-faulted morphostructures on the Permian-Carboniferous with the highland relief (e.g. Manětínská vrchovina Highland) and with the relief of hilly lands (e.g. Kněževeská pahorkatina Highland),
– fold-faulted morphostructures on the Cretaceous anticlinals (e.g. Ridges Libotovský hřbet , Hořický hřbet, Opočenský hřbet, Vraclavský hřbet, Litický hřbet, Hřebečovský hřbet and Kozlovský hřbet),
– fold-faulted morphostructures on the Cretaceous synclinals (e.g. Královédvorská kotlina Basin, Rychnovský úval Graben, Litomyšlský úval Graben, Vysokomýtská kotlina Basin, Ústecká brázda Furrow),
– plateaus morphostructures on the Cretaceous deposits with the highland relief (e.g. Polomené hory Mts., Vyskeřská vrchovina Highland), with the relief of hilly lands (a greater part of the Bohemian Plateau) and with the lowland relief (e.g. Labská niva Floodplain),
– neovolcanic upland morphostructures (Doupovské hory Mts.),
– neovolcanic morphostructures of block character (České středohoří Mts.),
– block morphostructures, horsts formed of Cretaceous sediments with the mountain relief (e.g. Sněžnická hornatina Mts.) and with the highland relief (e.g. Růžovská vrchovina Highland, Džbán Hilly land).

4.3 Morphostructures of the 2nd order in the Silesian Lowland

The epiplatform Silesian Lowland is in the Czech territory predominated by subsiding morphostructures with the relief of hilly lands (e.g. Vidnavská nížina Lowland, Osoblažská nížina Lowland, Hlučínská pahorkatina Hilly land) and with the lowland relief (e.g. Opavsko-moravská niva Floodplain)

4.4 Morphostructures of the 2nd order in the Carpathian Foredeep

The longitudinal depression in Moravia founded at the Paleogene – Neogene boundary during the Savic orogeny in the foreland of the Outer Western Carpathians is predominated by subsiding morphostructures with the relief of hilly lands on low-resistant Neogene and Quaternary deposits of soft superficial forms. Lowland morphostructures are represented by floodplains of larger rivers. In the Dunajovické vrchy Hills there is a dome with the combe (Březská sníženina Depression) bordered by Přední and Zadní Dunajovický hřbet Ridges.

4.5 Morphostructures of the 2nd order in the Outer Western Carpathians

After the consolidation of a considerable part of Europe by Variscan orogenic processes and after coming to existence of the supercontinent of Pangea, fault tectonics and block sinking occurred on the edges of this supercontinent, which were followed by the overthrust of flysch nappes on the south-eastern margin of the platform. The movements of nappes ended essentially in the Badenian. During the Pannonian the nappes were faulted into nappe-faulted morphostructures and some morphostructures of the Outer Western Carpathians gained a montane character. The map distinguishes nappe-faulted morphostructures on flysch, klippen belt morphostructures, intermontane depressions, and morphostructures on uplifted Neogene deposits.

The nappe-faulted morphostructures on flysch are sub-divided into the following morphostructures of the 3rd order:

– with the mountain relief (e.g. Moravian-Silesian Beskids, Javorníky Mts.),
– with the highland relief (e.g. Ždánický les Forest, Chřiby Highland, Hostýnské vrchy Hills, Vsetínské vrchy Hills, White Carpathians),
– With the relief of hilly lands (e.g. Podbeskydská pahorkatina Hilly land, Vizovická pahorkatina Hilly land).

Similarly, the morphostructures on the uplifted Neogene sediments are sub-divided into morphostructures of the 3rd order: with the highland relief (e.g. Orlovická vrchovina Highland) and with the relief of hilly lands (e.g. Tištínská pahorkatina Hilly land).

5 Discussions

5.1 Block structure of the Bohemian Massif and the Moravo-Silesian Terrane

Regarding their location on the boundary of Eurasian and African lithospheric plates and a complex history of individual terranes related to Variscan orogeny the Bohemian Massif and the Moravo-Silesian Terrane are generally characterized by block morphostructure (ZEMAN 1978, ŠTOVÍČKOVÁ 1973). The individual blocks of varying dimensions are separated by a complicated system of both deep-seated and shallow faults.

5.2 Megaanticlines and megasynclines

In addition to the prevailing block structure there are also folds of a large radius (megafolds) occurring in the Bohemian Massif. The concept of undulating megafolds of large amplitude in the Bohemian Massif was developed by J. MOSCHELESOVÁ (1930). Megafolds are flat downwarpings of rocks sized several tens of kilometers having the form of megaanticlines and megasynclines. In the terrain, the ridges often represent megaanticlines and the depressions between them represent megasynclines. While the folds are characteristic of a typical correspondence between the shape and the internal construction, the correspondence is rarely observed in the megafolds. Evolution of a flat vaulting within the old folded or metamorphed structure is usually accompanied by the coming to existence of a novel internal structure of the megafold by faulting into smaller or bigger blocks along the old rejuvenated and newly emerged faults (DEMEK and ZEMAN 1979, p. 266). Megafolds, namely the megaanticlines are frequently disturbed by longitudinal faults. Some megaanticlines even exhibit breaching and development of a graben in their axis (e.g. the graben of Záhorská brázda Furrow in the megaanticline of Orlické hory Mts.). In the morphostructural analysis the megafolds are demarcated on the basis of morphography, analysis of planation surfaces, distribution patterns of old weathering products and river pattern groundplan.

With the map of South Bohemia the authors followed up the work of J. MOSCHELESOVÁ (1930) and A. KOPECKÝ (1989) in distinguishing the Šumava megaanticline. The Šumava megaanticline runs in SE-NW direction its axis approximately copying the state border. It shows an obvious linkage to the Šumava branch of the Central Moldanubian Massif with a permanent ascending tendency due to light granitic rocks surrounded with a heavier mantle. The Šumava megaanticline divides into the following morphostructures (CHÁBERA et al. 1985, p. 104):

– Trojmezný megaanticline along the state border
– Vltavická brázda megasyncline along the upper course of the Vltava River
– Boubín—Želnava – Kleť megaanticline.

The Šumava megaanticline is delimited by faults both in the north-west and south-east. Similarly, the Mt. Vítkův kámen (1035.5 m a.s.l.) is limited towards the megasyncline of the Vltavická brázda by a fault scarp (ČECH 1956). The Lhenická brázda Furrow delimited by high-reaching fault scarps represents a transversal trough morphostructure. The north-eastern limb of the Šumava megaanticline forms the Šumavské podhůří Piedmont descending towards the megasyncline of South-Bohemian depressions. Pediments developed along water courses copying the limb inclination (KUNSKÝ 1938). The megasyncline of South-Bohemian depressions whose axis runs approximately from the town of Horažďovice in the west through Strakonice to the town of České Budějovice in the east and further on to the south towards the town of České Velenice is an old subsided area that has been recurrently sedimentation area since the Cretaceous. The megasyncline is accompanied by longitudinal and transversal faults, too. Old tropical weathering products are preserved in

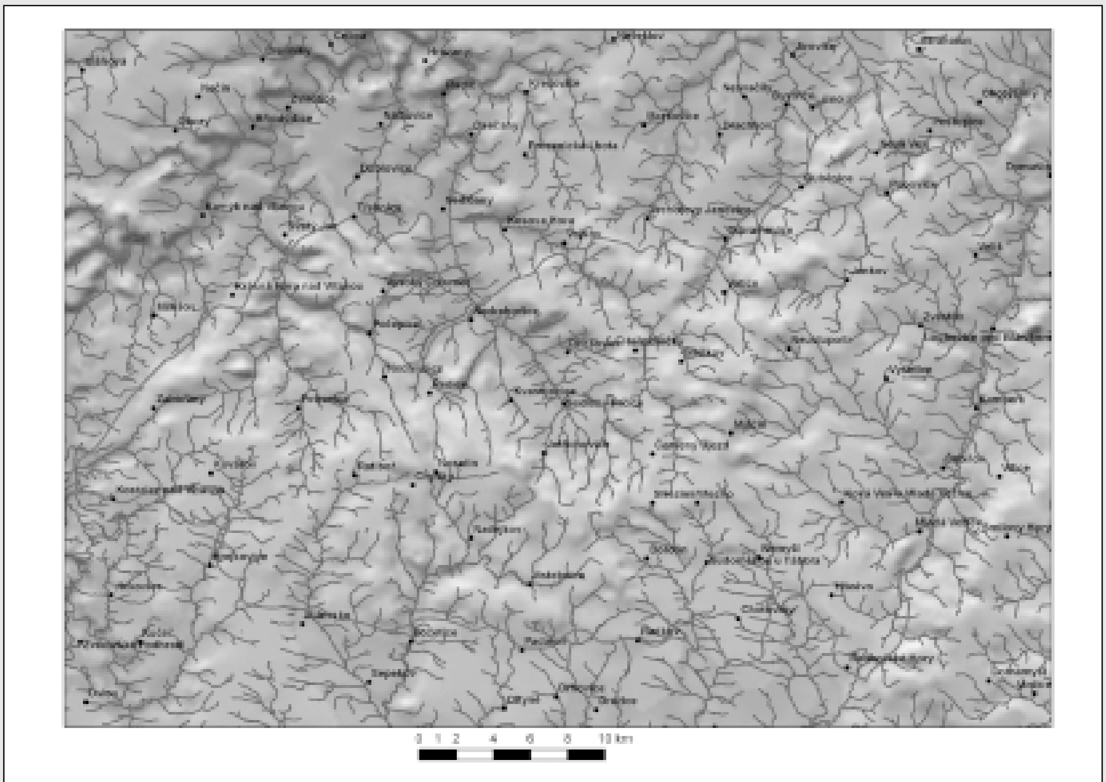

Fig. 3 Meganticline of the Central Bohemian threshold (compiled by M. HAVLÍČEK)

the crystalline bedrock underlying younger Cretaceous, Neogene and Quaternary sediments.

The axis of the Central Bohemian threshold megaanticline (DĚDINA 1930) runs approximately from the spot height of Zběžnice (608.4 m a.s.l.) in the west through the Javorová skála Rock (722.8 m a.s.l.) to Hill Mezivratí (713.3 m a.s.l.) in the east. The course of the megaanticline shows well in the river pattern groundplan. Megaanticline vaulting in the neotectonic stage of relief development resulted in the coming to existence of Central Bohemian Divide, a bending of the Lužnice River from the S-N to NE-SW direction (MOSCHELESOVÁ 1930, p. 155), and an arching of the Vltava River course to the west. In the district of Jindřichův Hradec the Javořice megaanticline rises on the main European Divide (MOSCHELESOVÁ 1930, p. 156) which represents the highest-reaching domed parts of the Bohemian-Moravian Highland in the Novobystřická vrchovina Highland and Jihlavské vrchy Hills. Its axis runs from the Austrian-Czech border in the Southwest to the highest point of the Bohemian-Moravian Highland – the Javořice Mt. in the Northeast. The megaanticline is disturbed by faults as well (e.g. faults of the Rudolecký prolom Graben)

The southern part of Jihlava megasyncline runs approximately parallel to the axis of the Javořice megaanticline. The megasyncline starts in the south as a depression of the Dačická kotlina Basin and its axis follows towards the town of Jihlava and continues as a Jihlava-Sázava Furrow to the town of Havlíčkův Brod. Parallel to the megasyncline axis runs the Přibyslav deep-seated fault (MÍSAŘ et al. 1983, p. 29).

The morphostructural interpretation of Železné hory Mts. is questionable. The Železné hory Mts. are usually explained as a wedge block inclined to Northeast. However, the authors attached themselves to the interpretation of hydrogeologists (HERČÍK, HERMANN and VALEČKA 1999, p. 72) claiming that the Železné hory Mts. represent a limb of the Železné hory Mts. anticline (megaanticline) breached by the Železné hory Mts. fault. The fault of Železné hory Mts. disturbed the Cretaceous cover of the Železné hory Mts. only after the rise of asymmetrical folds of the Dlouhá mez syncline (megasyncline?) and the megaanticline of Železné hory Mts. Although the Cretaceous sediments of the Dlouhá mez syncline end at the fish pond of Velké Dářko, the synclinal downwarping can be tracked up to the Crystalline of the Bohemian-Moravian Highland. In the continuation of the Železné hory Mts. fault to the Southeast of the Dlouhá mez syncline some blocks of Cretaceous sediments sunk into the crystalline rocks into a depth of 100-200 m were found (PRACHAŘ and AMBROŽ 1971). B. ZAHÁLKA (1954) defined the faulted fold of Orlické hory Mts. which is –according to the current knowledge- a megaanticline with the subsided blocks of Cretaceous sediments and breached by the faulted system of Orlickozáhorská brázda Furrow. The bend of Cretaceous sediments during the uplift of megaanticline is well noticeable for instance from along the road running from the town of Nové Město nad Metují to Náchod. The south-western limb of the megaanticline is formed by the Podorlická pahorkatina Hilly land.

5.3 Fold morphostructures of the Bohemian Plateau

Fold morphostructures in which – unlike in megafolds- there is a correspondence between the relief and the attitude of rocks are well noticeable within the Cretaceous sediments of the Bohemian Plateau. The map illustrates the system of fold morphostructures northwards of the Jílovice dislocation, which are conspicuously shown in the relief. Axes of the fold morphostructures turn from the Sudeten direction (NW-SE) to the NW-SE up to N-S. The relief is characterized by conspicuous anticlinal ridges designated as the Hořický hřbet Ridge (Hořice anticline disrupted by Mlázovice fault), Zvičinský hřbet Ridge (Zvičín anticline dislocated in the north by Zvičín fault), Libotovský hřbet Ridge (Libotov anticline), Opočenský hřbet Ridge (Opočno anticline), Kozlovský hřbet Ridge (Potštejn anticline), Litický hřbet Ridge (Litice anticline) and Vraclavský hřbet Ridge (flat Vraclav anticline). Steeper trough limbs of anticlinal ridges are largely disturbed by faults and are therefore defined as fold-faulted morphostructures on the Cretaceous deposits.

Synclinal depressions between the anticlinal ridges are for example the Miletínský úval Graben (Miletín syncline between Hořice and Zvičín anticlines), Královedvorská kotlina Basin (Králův Dvůr syncline), Rychnovský úval Graben, Ústecká brázda Furrow (Ústí syncline disturbed by Semanin fault), and Litomyšlský úval Graben (Vysoké Mýto syncline between Potštejn and Vraclav anticlines in the south-eastern continuation of the geomorphologically less pronounced Hradec syncline).

5.4 Domes

Domes are large circular or oval morphostructures, a fairly symmetrical upfolds in which all the beds dip away from a central point. Recognizing characteristic in humid areas is a network of radial water courses. If the rising dome is cut by a sufficiently watery course, it may cut through the dome during a slow lift and give rise to antecedent graben. In the further development a central depression may come to existence due to erosion called combe. **Fig. 4** shows the map of the plug dome of Sýkořská hornatina Mts. in the Bohemian-Moravian Highland. The dome core is formed by the Bíteš orthogneiss of Moravicum. There is a conspicuous radial river pattern developed on the dome.

The map of morphostructures of the Czech Republic also illustrates the dome of Dunajovické vrchy Hills in the Dyjsko-svratecký úval Graben. In the dome formed by Neogene sediments there is a central Březská sníženina Depression (Combe) bordered by asym-

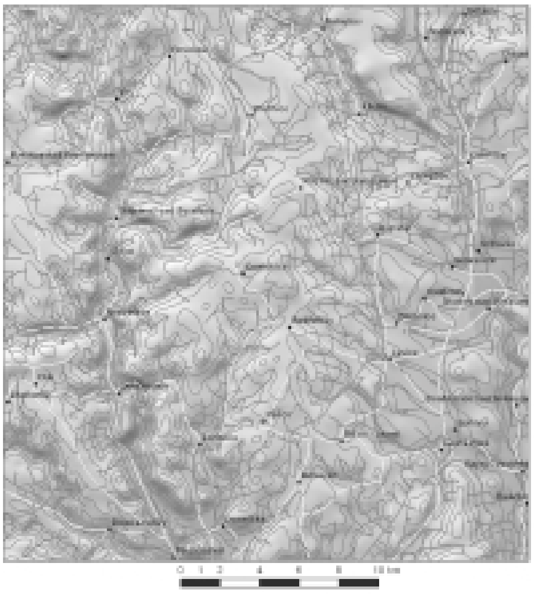

Fig.4 Dome of the Sýkořská hornatina Mts. (compiled by M. HAVLÍČEK)

metrical structural ridges (Přední and Zadní Dunajovický hřbet Ridges). The ridges fall by steeper scarps into the combe and by milder slopes they incline to the outside.

5.5 Fold-faulted structures of the Bohemicum

Already J. HROMÁDKA (1956) distinguished a geomorphologically different area in central and south-western Bohemia, which he called the Poberounská soustava System. The morphostructural foundation of the Poberounská soustava System is formed by old Neoproterozoic and Palaeozoic folded and faulted rocks of the Teplá-Barrandian Terrane. The territory differs from other geomorphological systems of the Bohemian Massif by more pronounced structural control by rock properties and by the attitude of the rocks onto the relief. Earth crust stability of this part of the Bohemian Massif during the neotectonic stage appears to be testified by an extensive occurrence of pediments (pediment country westwards of Prague). This opinion is however contradicted by essential river pattern changes during the neotectonic period (e.g. the Berounka River course changing first from the east to the west and then in the opposite direction from the west to the east) as well as by numerous former Neogene through-flown lakes with lacustrine sediments giving the evidence of neotectonic movements.

5.6 Neovolcanic morphostructures

Neovolcanic morphostructures lying at the Ohře rift were classified by the authors into two basic types. The first of them is the massive compound neovolcanic morphostructure of Doupovské hory Mts., which has arisen by neovolcanic activity from numerous volcanic chimneys in a circular arrangement. The second type is the block morphostructure of České středohoří (Bohemian Middle Mountains) where the Cretaceous rocks underlying neovolcanic structures are faulted into blocks that were uplifted or subsided in a different way. The two morphostructures experienced extensive erosion in the Pliocene and Quaternary, which essentially changed their shape.

5.7 Flysch morphostructures of the Outer Western Carpathians

Delimitation of morphostructures in the Outer West Carpathians is complicated by their complex geological structure and geomorphological development (CHLUPÁČ et al. 2002). This about 70 km wide belt of flysch of Mesozoic and Paleozoic age forms thrust nappes, which were folded and overthrusted on the NW foreland during the Upper Paleogene a Miocene. Magura group of nappes formed during Pyrenees and Helvetian phases of orogenic movements during Eocene and Oligocene. Folding and formation of nappes of the outer Flysch zone came during the Savian (Oligocene/Miocene/ and Styrian (Lower Miocene) orogenetic movements. During the Savian Orogenesis formed the Carpathian Foredeep. Flysch nappes were overthrusted over deposits of the Carpathian Foredeep (especially over deposit of Carpathian age), which partly became a part of nappes. The head of the Helvetian form of the Magura nappe served as source area of the back part of the Ždánice nappe. The Magura group of nappes was further overthrusted on the foreland during the Savian and Styrian movements. Partial Magura nappes (Whitecarpathian, Bystrica and Račany nappe) are therefore older and their relief developed in earlier time then relief of outer nappes (e.g. Ždánice nappe). Origin of nappes was accompanied by a tectonic uplift, erosion a deposition in foreland basins (IVAN, KIRCHNER and KREJČÍ 2000). Formation of nappes and their overthrust over foreland after the end of Young Styrian movements formed basic morphostructural features of the Outer Western Carpathians. Partial morphostructural features are given by faulting, lithology and by structural properties of flysch complexes.

Features of cross fault segmentation are lower in the direction NW –SE and in the longitudinal direction from SW to NE. Parallel with the growing elevation from SW to NE are growing litho logical contrasts. The boundary form tectonic depressions of the Upper Moravian Graben and its prolongation to the SE called Fryštácká brázda Furrow. In the part situated to the SE from this line prevail lithological and structural factors. The Ždánice and partly Magura nappes in the southern and central Moravia are faulted and divided into blocks. The example is young heterogeneous elevation of the Středomoravské Karpaty (Central Moravian Carpathians) which divided due to rotation carpatho-pannonian blocks and origin of the Vienna Basin (HUBATKA and KREJČÍ 1996) and the Upper Moravian Graben. The elevation of Central Moravian Carpathians is surrounded on all sides by the lower relief and is cut by horizontal movement which is younger and is identical with overthrust of the Magura nappe. In the SW part of the elevation runs fault in the Trkmanka river valley (CZUDEK 1986) cutting the Čejčská kotlina Basin.

The structural control and the relationship to morphostructures are apparent in the NE and N Moravia and Silesia. The differences in the rock resistance in combination with complex tectonics expressed in the formation if high structural slopes and wide and differently deep intermontane basins mostly structurally controlled (e.g. Rožnovská brázda Furrow). Other intermontane basins in the Podbeskydská pahorkatina Hilly land (e.g. Furrows Frenštátská brázda, Třinecká brázda) originated due to erosion of less resistant rocks mostly of Subsilesian nappe. Klippen structures are structurally controlled by exposures of very resistant rock in the frame of flysch complexes (e.g. Pavlovské vrchy Hills).

It is necessary to mention domal uplift of the Moravskoslezské Beskydy Mts. caused by overthrust of partial rigid Godula nappe on non-stable Subsilesian units and sediments of Carpathian age, which forms gravitational minimum. Thanks to the uplift came to forms of gravitational tectonics and destruction of mountain ridges of the Moravskoslezské Beskydy Mts. (KREJČÍ, HUBATKA and ŠVANCARA 2004, HRADECKÝ and PÁNEK 2004).

6 Conclusions

Based on the morphostructural analysis the authors defined a hierarchical structure of morphostructures in the Czech Republic, expressing it for the first time cartographically.

References

BAKER, V.C. (2007). *Introduction: regional landform analysis.* http://daac.gsfc.nasa.gov/geomorphology/GEO_1/GEO_CHAPTER_1.shtml

CYMERMAN, Z. (1999). Terranes and Terrane Boundaries in the Sudetes. *Geolines* (Praha), 8, Praha, 15-16.

CYMERMAN, Z., PIASECKI, M.A.J., SESTON R. (1997). Terranes and terranes boundaries in the Sudetes, northeast Bohemian Massif. *Geological Magazin* 134, 5,717-725.

CZUDEK, T. (1986). Významná morfotektonická linie Středomoravských Karpat. In: Hrádek, M., Kirchner, K., Květ, R., eds.: Geomorfologie – výzkum a aplikace. *Sborník prac12,* ČSAV Brno. 59-60.

DEMEK, J., ZEMAN, J. (1979). *Typy reliéfu Země.* Academia, Praha, 1-328.

DĚDINA , V. (1930). Přírodní povaha Československa a morfologický vývoj Českého masivu. In: *Československá vlastivěda, Díl I. Příroda,* Sfinx, Praha, 14-46.

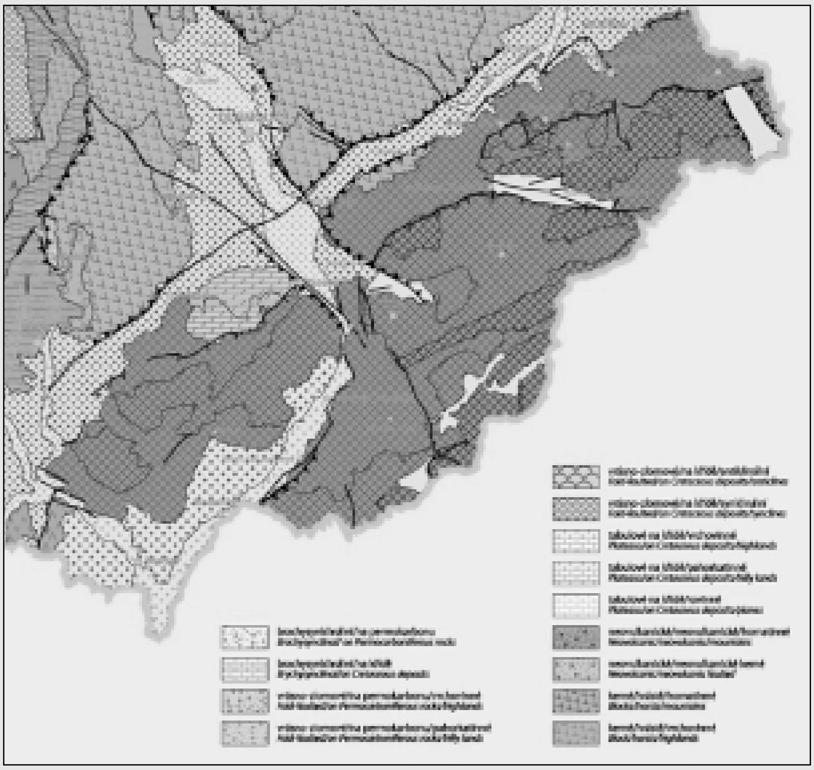

Fig. 5 Example of Map of Morphostructures of the Czech Republic (Section)

FRIEDL, G. ET AL. (2000). Deducing the ancestry of terranes: SHRIMP evidence for South America – derived Gondwana fragments in central Europe. *Geology,* November 2000, 28, 11, Geological Society of America, 1035-1038.

GERASIMOV, I. P. (1946). Opyt geologičeskogo strojenija SSSR. *Problemy fizičeskoj geografii,* 12, Moskva – Leningrad. 33-46.

GERASIMOV, I.P., MĚŠČERJAKOV, J.A. (1967). *Reljef Zemli (morfostruktura i morfoskulptura).* Nauka, Moskva, 1-311.

HERČÍK, F., HERMANN, Z., VALEČKA, J. (1999). *Hydrogeologie České křídové pánve.* Český geologický ústav, Praha, 1-115.

HRADECKÝ, J., PÁNEK, T. (2004). Geomorphology of the Flysch Carpathians: morphostructural polygenesis and dynamic development of the georelief (on the example of the Western Beskydy Mts., the Czech Republic). In: Drbohlav, D., Kalvoda, J., Voženílek, V., eds.: *Czech Geography at the Dawn of the Millenium.* Czech Geographic Society, Palacký University, Olomouc, 41–68.

HROMÁDKA, J. (1956). Orografické třídění Československé republiky. *Sborník Československé společnosti zeměpisné,* LXI (3 a 4), Praha ,161-180 and 265-299.

HUBATKA, F., KREJČÍ, O. (1996). A contribution to the pull-apart theory of the origin of the Vienna basin on an analysis of geological profiles and reflection-seismic data. *Exploration Geophysics, Remote Sensing and Environment,* 3 (1), Brno, 2-4.

CHÁB, J., STRÁNÍK, Z., ELIÁŠ, M. (2007). *Geologická mapa České republiky 1: 500 000 (Geological map of the Czech Republic 1: 500 000).* Česká geologická služba, Praha.

CHÁBERA, S. a kol. (1985). *Jihočeská vlastivěda. Neživá příroda.* Jihočeské nakladatelství, České Budějovice, 1-270.

CHLUPÁČ, I., BRZOBOHATÝ, R., KOVANDA, J., STRÁNÍK, Z. (2002). *Geologická minulost České republiky.* Academia, Praha, 1-436.

IVAN, A., KIRCHNER, K., KREJČÍ, O. (2000). K poznání morfostrukturních rysů reliéfu moravské části Západních Karpat a Panonské pánve. *Geografický časopis,* 52, 4, Bratislava, 221-230.

KOPECKÝ, A. (1983). Neotektonický vývoj a stavba šumavské horské soustavy. *Sborník geologických věd, Antropozoikum,* 15, Praha, 71-59,

KOPECKÝ, A. (1989). *Mapa mladších tektonických struktur Českého masivu 1 : 500 000.* Ústřední ústav geologický. Praha, 1-18.

KREJČÍ , O., HUBATKA, F., ŠVANCARA, J. (2004). Gravitational spreading of the elevated mountain ridges in the Moravian-Silesian Beskids. *Acta Geodyn. Geomater.* 1(3), 135, Praha 97-109.

LACIKA, J. (1986). Klasifikácia metód morfoštruktúrnej analýzy reliéfu. in: Hrádek, M., Kirchner, K., Květ R., eds. (1986). *Geomorfologie - výskum a aplikace.* Sborník prací, 12, Geografický ústav ČSAV Brno, 36-38.

MÍSAŘ a kol. (1983). *Geologie ČSSR I. Český masív.* SPN Praha, 1-333.

MOSCHELESOVÁ, J. (1930). Vlnité prohyby o velké amplitudě v jižních Čechách. *Sborník Československé společnosti zeměpisné,* 36, Praha, 155-158,

PHARAOH , T.C. (1999). Paleozoic terranes and their lithospheric boundaries within the Tran-European Suture Zone (TESZ): a review. *Tectonophysics*, 314, 1-3, 17-41.

PRACHAŘ, L., AMBROŽ, F. (1971). Tektonická kra křídy zakleslá 200 m hluboko v moldanubiku. *Věstník Ústř. Ústavu geologického, Geol.* 46, 3, Praha, 157-161.

ŠŤOVÍČKOVÁ, N. (1973). *Hlubinná zlomová tektonika a její vztah k endogenním geologickým procesům.* Academia, Praha, 1-198.

ZAHÁLKA, B. (1954). Tektonická skizza východočeské křídy. *Sborník ÚÚG XXI* , (1), Praha, 359-363.

ZEMAN, J. (1978). Deep-seated faults structures on the Bohemian Massif. *Sborník geologických věd,* 31, Praha,155-182.