Large-Scale Fold Architecture of the Stronie Formation, the Orlica-Śnieżnik Dome, West Sudetes

Mirosław JASTRZĘBSKI

Institute of Geological Sciences, Polish Academy of Sciences, Podwale 75, 50-449 Wrocław, Poland

The metasedimentary Stronie formation, composed of mica schists and subordinate marbles, quartzites, and metavolcanic rocks, is considered to be the structurally higher part in the core of the Orlica-Śnieżnik Dome (OSD) (e.g. Don et al. 2003). Its lower parts consist of ortho- and paragneisses enclosing several high-pressure eclogite and granulite bodies. A recognisable tectonometamorphic evolution of the Stronie formation began with the E-W subhorizontal shortening and generally upright folding (D1), which led to crustal thickening. As a result of the subsequent gravitational subvertical flattening, the originally steep structural planar surfaces (S1) were deformed to form tight, strongly inclined to recumbent folds F2. In the metapelites, on the microscopic scale, this is documented by the flattened inclusion trails in garnet porphyroblasts and the subhorizontally disposed external axial plane schistosity S2. Chemical zoning of white micas as well as calculations of average P-T conditions carried out by THERMOCALC software show that this event occurred at the temperature peak and decreasing pressure connected with the onset of uplift. Under the peak conditions, the original flat arrangement of metamorphic isograds was developed. Subsequently, the S2 planes were zonally reactivated as S3 foliaton during the top-to-NW(N) shearing (D3). Spatial orientations of the S2||S3 foliations differ over the OSD area, considerably varying even in the neighbouring areas, according to their position within the superposed macroscopic folds F4. On the stereographic projections, poles to the axial plane foliation S2 in NW parts of the Lądek-Śnieżnik and Orlica-Bystrzyca metamorphic units form a pattern of belts of great circles with common girdle axes near 330/15. Poles to the S2 planes, orientations of which were measured in the SW part of the OSD, form locally a belt with the axes at the maximum of 40/40. D4 folding was caused by the NW-SE and NE-SW shortening under low-ductile conditions. Major D4 folds are accompanied by open, upright, concentric mesofolds. In S and E of the OSD the NE-plunging concentric folds dominate, being toward NE replaced by the NW-plunging ones, which conforms to the girdle axes of the foliation belts on the stereographic projections.

In mica schists, the S2 axial plane foliation consists of different mineral assemblages, the distribution of which indicates decreasing metamorphic conditions toward the NW/W. The *garnet-staurolite*–in zone (547–637 °C, 7.5–8.0 kbar) is dipping under the *garnet-staurolite*–out zone (506–532 °C, 5.7–6.7 kbar) in NW part of the Lądek-Śnieżnik Unit and SE part of the Orlica-Bystrzyca Unit and the *biotite-chlorite*–in, *garnet*-out zone at the NW edge of the OSD. Such a pattern of decreasing metamorphic conditions in mica schists is also valid for metamorphic assemblages observed in marbles. Furthermore, the observed pattern of the diopside and tremolite isograds in marbles of the SW part of the OSD is roughly consistent with the boundary between the gneisses of lower structural level and the rocks of the Stronie formation. The major NW-plunging folds F4 have folded not only S2 planes but also metamorphic isograds. Differences in P-T conditions noted over the studied area could be explained by the reorientation of the isotherms around axes plunging similar the NW-SE trending folds. This event occurred at final stages of Variscan consolidation. In the OSD, a domal region was produced with NW/W-ward dipping slopes, at the centre of which the lowest structural level (with HP rocks) has been exposed.

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Neotectonic Rejuvenation of Variscan Structures in Relation to Tracing of Methane Escape: Preliminary Note (Upper Silesian Coal Basin, Moravosilesian Area, Bohemian Massif)

Jan JELÍNEK and Radomír GRYGAR

VŠB-TU Ostrava, 17. listopadu, 708 33 Ostrava, Czech Republic

The Moravosilesian zone of the Bohemian Massif consists of two accretion wedges (Variscan and Alpine) lay above pan-African Brunovistulian terrane (microcontinent). The older Variscan allochton was thrusted top-to-E up to SE and younger Alpine wedge in opposite direction top-to-NW up to N. The covered part of Variscan basement (first of all represented by Upper Silesian Coal Basin – USCB) was influenced by a sedimentary loading of Inner Carpathian molasses and Outher Badenian molasses, just as by tectonic

movement of an accretion wedge during the period of Alpine orogeny. The coincident sedimentary and tectonic loading influenced development of a lithospheric flexure of Alpine foreland and mainly a rifting activation of subequatorial fault systems. The distinct tilting (block rotation linked to bookshelf tectonic) is typical brittle deformation of rigid Brunovistulian basement that followed genesis of asymmetric lithospheric flexure of Alpine foreland (Grygar and Jelínek 2002). The movement of Alpine nappes over the basement initiated significant rejuvenation of older Variscan structures. A lot of reactivated Variscan faults of USCB were imprinted through Outer Carpathian nappes to recent relief.

Research project focused on detection of features and extent of Variscan structures to recent relief in Moravosilesian area is resolved at present. Results of the study (manifestation of tectonic pattern in relief) will be helpful for localization of faults in the recent relief and paleorelief of the USCB as well as for specification of continuation of significant Sudetic faults SE-ward under Carpathian nappes to area of USCB. Alpine tectogeny reactivated Variscan tectonic zones which could be potential natural zones of methane's escape. In the fifties Petránek (1954) pointed out a possibility to escape of methane's escape up to relief along reactivated Variscan structures. His early ideas about the influence of young Tertiary tectonics on structure-tectonical conditions of Variscan accretion wedge of the USCB have been overlooked.

The selected methodical procedure included the morphostructural analysis of digital elevation models supplemented with representative morphometrical analysis (the slope aspect, the aspect of slope-orientation, the digital determination of topolineaments, the drainage basin elongation ratio, etc.), structure-paleodynamic analysis and some methods of remote sensing. The morphostructural analysis of studied area is based on 3D visual comparison between interpretation of digital elevation models (DEM) of particular structural levels and results of structural-tectonic mapping. Analyzed digital models were compiled on basis of data from drilling and mining activities and data from detailed digitalization of topographic maps. The wide possibilities of computing 3D visualisation facilitate illustrative display of DEM of particular structural levels and much easier qualitative analysis of the three-dimensional structural manifestation of tectonic deformations between Variscan and Alpine DEM. Rightness of results was verified by structure field research, which included brittle faults paleodynamic analysis of coal mining data and complex structure analysis. The final structure framework was confronted with tectonic maps and also underground structure maps for representative structure and seam levels of the USCB.

The comparative analyses demonstrate in many aspects a neotectonic rejuvenation of pre-Alpine relief linked to development of a lithospheric flexure of Alpine foreland and mainly a rifting activation of subequatorial fault systems. The Dětmarovice Tectonic Zone with vertical amplitude of movement about 1000 m on partial faults represents the most evidently reactivated subequatorial fault system (direction WNW-ESE to WSW-ENE) in the north of the Czech part of the USCB (Grygar and Jelínek 2002). This shear zone connects the west of Orlová structure with the fault systems of the same direction in the western part of the USCB and continues as a Jeseníky Marginal Fault as far as Opava town. The intrusions of neovolcanites and the occurrence of mineral water rich in CO_2 (Dopita et al. 1997) along this tectonic zone are an evidence of the Neoidic geodynamic activities. Good examples of Neoidic activities of the Dětmarovice shear zone is bend of Odra's riverbed to the east. The Dětmarovice Tectonic Zone together with the Bludovice Tectonic Zone, Orlová Fault-propagation-Fold Structure, Michálkovice Structure, Těšín Fault and Karviná Graben are morphologically so evident in paleorelief of USBC that they are distinctly imprinted to Alpine structural level into recent relief.

The Alpine sedimentary and topographic loading of epi-Variscan platform by Carpathian nappes activated not only subequatorial pre-Alpine faults but also a genesis of new structures at direction ENE-WSW to NE-SW. Neoidic genesis of normal slip faults and tension depressions of Morava Gate Graben was supported by results of comparative morphotectonic and paleodynamic analysis. Their genesis is also related to development of lithospheric flexure of Alpine foreland.

Alpine reactivation of Variscan radial faults (direction NNW--SSE up to NNE-SSW) is another example of fault rejuvenation of buried Variscan relief and their imprint on recent georelief. A typical example is zone of Jablunkov Morphological Depression, which is associated with Těšín Fault. Its structural imprint to Outer Carpathian nappes genetically conditioned formation of the most conspicuous radial structure in recent relief of Beskydy Mts. Morphological features of DEM of recent relief showed that the Těšín fault is connected NNW-ward to Odra tectonic zone.

Up-to-date in-situ stress measurements (e.g. Staš et al. 1996, Schenk et al. 2004) in the contact zone of both Variscan and Alpine orogeny (Moravosilesian area) support consideration of continued Alpine tectogenesis paleostress field, characterized by the nearly same position of the main global compression stress $\sigma 1$ oriented NNW-SSE up to NW-SE. This fact indicates continuation of neodynamic stress field up to recent time.

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P-T Conditions and an Extent of the First Alpine Deformation Event Recorded in the Vepor Unit, West Carpathians

Petr JEŘÁBEK[1], Shah Wali FARYAD[1], Karel SCHULMANN[2], Ondrej LEXA[2] and Lucie TAJČMANOVÁ[1]

[1] Institute of Petrology and Structural Geology, Charles University, Albertov 6, 128 43, Praha 2, Czech Republic
[2] Ecole et Observatoire des Sciences de la Terre, Universite Louis Pasteur Strasbourg, 5 rue Rene Descartes, F-67084 Strasbourg Cedex, France

The Vepor unit composed of Variscan basement and Late Palaeozoic to Mesozoic cover sequences is one of the major crustal segments incorporated into the Alpine structure of the Central West Carpathians. Two Alpine deformation events are recorded in this unit. The first one is characterized by the presence of sub-horizontal mylonitic fabric with E-W trending stretching lineation related to formation of vast mid-crustal shear zone. The second one, responsible for kinking and folding of earlier fabrics in the weaker lithologies preferentially, resulted from subsequent oblique convergence with the Gemer unit in the south.

Based on our recent field and petrological studies of migmatites and gneisses from the Kralova Hola massif in the north of the Vepor unit, three metamorpic events can be distinguished. The first event, characterised by the presence of garnet and staurolite, is regional metamorphic event, most probably of Variscan age. The second event led to the formation of garnet and andalusite and could relate to Variscan granite formation. There is a sharp compositional change in garnet between Ca-rich core formed during regional metamorphism and relatively Ca-poor rim related to contact metamorphism. The last event, characterised by the presence of garnet and chloritoid, is believed to represent regional Alpine metamorphism that was coincident with the first Alpine deformation event. The Alpine garnet is again rich in grossulare content. Thermodynamic modelling in the Vertex program was used to estimate P-T conditions of the Alpine metamorphism for the gneiss from the Kralova Hola massif. The results of this method indicated P-T conditions 0.5–0.6 GPa and 450–500 °C. Similar P-T conditions were obtained for the metasediments of the Slatvina formation in the south of the Vepor unit (0.6 GPa and 500 °C, using Vertex) and for the orthogeneisses form the central part of the Vepor unit (0.5–0.7 GPa and 450–500 °C, using THERMOCALC). Detailed investigation of quartz microstructure carried out on orthogneisses of the entire Vepor unit includes recrystallized grain size measurements and the CPO (crystal preferred orientation) measurements. The recrystallized quartz grain size determination was performed automatically from a set of micrographs using the Lazy Grain Boundary macro in the Scion program. This analysis covering most of the Vepor unit area revealed only small variations in the mean grain size with slight increase towards the west. The quartz CPO measurements produced by using the EBSD (electron back-scatter diffraction) and the CIP (computer-integrated polarization microscopy) methods indicated operation of basal <a>, rhomb and prism <a> slip systems.

The results of microstructural analyses correspond well with our temperature estimates and therefore can be used as complementary method for evaluation of regional extent of the metamorphic conditions during the first Alpine deformation. We argue that the first Alpine deformation recorded in basement of the Vepor unit occurred in similar metamorphic conditions during vertical shortening of buoyant Veporic crust. The last stages of exhumation of the Vepor unit as well as differences in pressure estimates in the interior of the Vepor unit could be explained by subsequent convergence with the Gemer unit in the south and the Fatric unit in the north.