direction with a steep dip on both sides, NNW-ESE to NW-SE direction with a steep dip to the ENE, and NW-SE with a steep dip on both sides

Disintegrated rocks were also found in zones some meters thick, in Mesozoic sedimentary suites. Claystones and marlstones weathered to clay of medium to high plasticity. Dolomites disintegrated into pebble and sand. Open gaps and caverns up to 1 m were found in carbonates.

Crystalline as well as sedimentary rocks are much jointed, often with striation of sub-horizontal to vertical dip. Sub-horizontal striation of NWN-SES direction was found even in limnic limestones of Upper Miocene age (Panonian) in the vicinity of the eastern pilot tunnel mouth. This indicates that horizontal tectonic movement took place at the end of the Miocene.

Concentrated inflow of ground water took place from fault zones as well as joints in granitic rocks with a yield up to more than 40 l per second. Fault zones were water bearing in their marginal parts. The central part of some fault zones is filled with clay gauge up to 1 m thick. Clay filling is also found in cracks in fault zones.

Multi-Stage Variscan Evolution of the Central Sudetes – Structural Evidence from the Kłodzko Metamorphic Unit

Stanisław MAZUR

Institute of Geological Sciences, University of Wrocław, Pl. Maxa Borna 9, 50-204 Wrocław, Poland

The Sudetes display numerous features indicating the Late Devonian/Early Carboniferous age of their tectono-metamorphic evolution (e.g. recent review in Aleksandrowski et al. 2000). This time range is constrained, among others, by Carboniferous cooling ages of several metamorphic complexes, Carboniferous late- to post-orogenic plutonism and by a continuous basinal sedimentation until the Late Devonian or Early Carboniferous. However, these pieces of evidence seem to contradict the occurrence of the so-called pre-Upper Devonian unconformity in the Kłodzko unit, originally recognized by Bederke (1924). Folded and metamorphosed metamorphic series in that area are unconformably overlain by basal conglomerate and Late Devonian limestone. Since the work of Bederke, the unconformity has been frequently interpreted in favour of the Caledonian orogeny in the Sudetes (e.g. Bederke 1929; Don 1990; Oliver et al. 1993). Nevertheless, the Early Palaeozoic/Early Devonian tectonism in the Kłodzko unit was discredited by new palaeontological evidence indicating the Late Givetian age of the metamorphosed limestone from that area (Hladil et al. 1999). Consequently, the ages of folding and metamorphism in the Kłodzko unit seem to be restricted to a narrow time span of ca 10 Ma between the Late Givetian and Late Frasnian.

Metamorphic rocks of the Kłodzko unit below the angular unconformity, experienced three main deformation events D_1-D_3. Two following deformations, D_4-D_5 , were subsequently imposed both on the metamorphic basement of the Kłodzko unit and on the Late Devonian – Early Carboniferous sedimentary succession of the adjacent Bardo basin. The Devonian part of the structural evolution which took place between the Late Givetian and Late Frasnian involved: (1) top-to-WNW D_1 thrusting, (2) compressional D_2 folding due to NNE-SSW shortening and (3) dextral strike-slip displacement D_3 confined to WNW-ESE trending shear zone hundreds of metres wide. The first event in most cases took place under the amphibolite facies conditions and was followed by the latter two accompanied by greenschist grade metamorphism. The post-Devonian deformation sequence comprised: (4) WNW-ESE sinistral strike-slip shear D_4 associated with the emplacement of the late-tectonic Złoty Stok granite and (5) intense D_5 folding of the Bardo basin and of the adjacent part of the Kłodzko unit produced by NNE-SSW compression. The first deformation event D_1 formed the general structure of the Kłodzko unit representing a pile of thrust sheets characterized by tectonic inversion of the metamorphic grade. The whole stack rests on the essentially unmetamorphosed Nowa Ruda ophiolite and is overlain by a younger sedimentary succession of the Bardo basin.

Structural evolution of the Kłodzko unit started already in the early Late Devonian and was terminated by uplift and erosion in the latest Devonian followed by a period of basinal sedimentation in Early Carboniferous. The second deformation paroxysm took place at the end of Early Carboniferous times and was roughly coeval with the emplacement of the Złoty Stok granite. Consequently, the Variscan evolution of the Kłodzko unit seems to be split into two time intervals separated by short-duration phase of extension and sedimentation. Outside the Kłodzko unit in the central Sudetes, the first orogenic event can be correlated with deformation and uplift of the Góry Sowie massif as well as with the emplacement of the Sudetic ophiolites. The second one corresponds to the deformation and metamorphism of the Orlica-Śnieżnik dome. Both domains of the central Sudetes showing different timing of the Variscan convergence (i.e., Góry Sowie/Kłodzko and Orlica-Śnieżnik domains) are now juxtaposed along the late-orogenic sinistral Skrzynka shear zone. Despite of their present proximity, they appear to represent fragments of different collision zones successively involved in the Variscan accretion of the Sudetes. Hence, the complex structural history of the Kłodzko unit does not support a continuous continental convergence lasting from the Devonian to Early Carboniferous but a discontinuous evolution model. In the latter model the already exhumed Devonian collisional belt was folded once again during the Early Carboniferous event.

References

ALEKSANROWSKI P., KRYZA R., MAZUR S., PIN C. and ZALASIEWICZ J. A., 2000. The Polish Sudetes: Caledonian or Variscan? *Transactions of the Royal Society of Edinburgh: Earth Sciences*, 90: 127-146.

BEDERKE E., 1924. Das Devon in Schlesien und das Alter Sudetenfaltung. *Fortschr. Geol. Paläont.*, 7: 1-50.

BEDERKE E., 1929. Die varistische Tectonik der mittleren Sudeten. *Fortschritte der Geologie und Paläeontologie*, 23: 429-524.

DON J., 1990. The differences in Paleozoic facies-structural evolution of the West Sudetes. *N. Jb. Geol. Paläont., Abh.*, 179: 307-328.

HLADIL J., MAZUR S., GALLE A. and EBERT J., 1999: Revised age of the Mały Bożków limestone in the Kłodzko metamorphic unit (Early Givetian, late Middle Devonian): implications for the geology of the Sudetes. *N. Jb. Geol. Paläont., Abh.*, 211(3): 329-353.

OLIVER G. J. H., CORFU F. and KROGH T. E., 1993. U-Pb ages from SW Poland: evidence for a Caledonian suture zone between Baltica and Gondwana. *J. Geol. Soc. London,* 150: 355-369.

Case Study of the Cone-in-cone Structure Based on Czech and Crimean Samples

Rostislav MELICHAR[1] and Yuriy D. SHKOVIRA[2]

[1] *Department of Geology and Paleontology, Faculty of Science, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic*

[2] *Department of Geology and Hydrogeology, Faculty of Geology and Geography, Dnepropetrovsk State University, prospekt Karla Marxsa 36, Dnepropetrovsk, Ukraine*

Cone-in-cone is a small-scale structure in sediments, mainly in shales and slates containing some amount of carbonate (or gypsum). The usual plane bedding cleavage changes to conical, making a series of cones packed inside of each other. Hard cones consisting of fibrous carbonate (or other minerals) are commonly separated by a narrow clay film. The surface of this clay film is always ribbed transversely (semi-annular depressions and ridges filled with clay) and often fluted or grooved lengthways (polished surface). Cone-in-cone structures are either made up of rims of concretions or separated layers.

The samples studied were concretion rims from Ordovician shales in the Barrandian (Vokovice, Prague, Czech Republic) and cone-in-cone layers from Triassic-Jurassic shales in the Crimean complex (from the area around Bakhchisaray, Crimea, Ukraine). Some other samples were from the Czech Republic – Silurian sediments (Barrandian, Králův Dvůr), Devonian (Stínava-Chabičov Fm., Stínava), Paleogene pelosiderites (West Carpathians, Frenštát pod Radhoštěm) – and from other European localities as well. Based on these samples, the following facts were ascertained:

- The cone-in-cone structure is usually developed in a shale complex composed of insoluble minerals within the cone-in-cone structure and in its surroundings seems to be similar.
- Cone-in-cone structures are always developed at contact with competent body and the cone apex is always oriented toward a competent material (the hard center of concretion, sandstone bed, etc.).
- The apical angle of a cone changes during its evolution (from wide to sharp).
- Carbonate fibres in cones are parallel to cone axes and parallel to fibres of associated fibrous veins (beef structure), e.g. the direction of extension.
- The sense of shear on clay films indicates the sliding of the cone core outwards, the sense of shear in small transversal clay ridges is compatible and indicates the same direction of extension as the fibres (e.g. parallel to cone axes).

The origin of cone-in-cones depends on bedding cleavage and the crystallization of carbonate or other soluble minerals. The first (or the most exterior) small carbonate vein is usually parallel to a bedding cleavage. The presence of different mechanics on both sides creates instability and the origin of cone nucleus. One cone series is made by dozens of these veins. Some volumetric overpress is created during the growth of older veins. This stress forms young veins and cones into a final shape with sharper and sharper apical angles. The geometry of cones indicates a rotational geometry of the strain ellipsoid with the longest axes oriented perpendicular to the surface of the nearest competent body. If the cone-in-cone structure is developed along competent bed, the marginal cones are asymmetrical (extension is not perpendicular to a competent surface) and narrow shear zone is formed on the contact. The sense of shear indicates the radial movement of the growing cone-in-cone layer in comparison to competent base.

This model presents cone-in-cone structure as a compression equivalent of columnar structure or mud cracks (volumetric extension) with asymmetry determined by the mechanic asymmetry of the two sides. Using this model, it is clear why it is not possible to distinguish either the direction towards the superincumbent bed or the directions of the tectonic stresses base on orientation of the cone apex.

Is there any Mechanical Paradox in Thin-Skinned Thrusting? A Case Study from the Muráň Nappe (Central Western Carpathians)

Rastislav MILOVSKÝ[1], Vratislav HURAI[2] and Dušan PLAŠIENKA[3]

[1] *Geological Institute of Slovak Academy of Sciences, Severná 5, 974 01 Banská Bystrica, Slovakia*

[2] *Geological Survey of Slovak Republic, Mlynská dolina 1, 817 04 Bratislava, Slovakia*

[3] *Geological Institute of Slovak Academy of Sciences, Dúbravská 9, 842 26 Bratislava, Slovakia*

Mechanisms of thin-skinned thrusting belong to frequently discussed questions since the thrusts were recognised in nature. Most satisfying explanation of this phenomenon is offered in articles by Hubert & Rubey and Rubey and Hubert (1959) where the authors consider the mechanical effect of the fluid on the basal nappe plane: since the pressure in fluid acts isotropically, p_{fluid}