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

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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)

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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}

diminishes all normal stresses and thus facilitates the block movement.

Thrust planes of Carpathian superficial nappes are often accompanied by the so-called “rauhwackes”, which represent basal cataclastic mass formed in a course of nappe movement. As in many similar cases in Alps, Appenines or Pyrenees also these rocks bear evidences for principal importance of hot overpressured fluid incidental to their formation. Fluid inclusions were preserved in synkinematically crystallised authigenic quartz and feldspar from basal rauhwackes of the Muráň nappe, which are believed to contain the authentic fluid facilitating the movement of the nappe. Results of the fluid inclusions investigation support the hypothesis of Hubert and Rubey and on the other hand indicate certain new mechanical difficulties.

Fluid inclusions were investigated by means of optical microthermometry using a Linkam THM600 heating/freezing stage. Chemical composition was determined from eutectic temperature of the solution and melting temperature of the gaseous phase. Concentration of NaCl eq. was calculated from dissolution temperature of halite (= final homogenisation) using equation of Sterner et al. 1988. Pressures at homogenisation were estimated from the isochores of the systems H_2O-NaCl (Brown and Lamb 1989, Bodnar 1994), H_2O-NaCl-CO_2 (Bowers and Helgeson 1983) and CO_2 (Sterner and Pitzer 1994).

Trapped aqueous fluid is highly concentrated solution of NaCl, KCl, $CaCl_2$, $MgCl_2$ and $CaSO_4$ (up to 53 wt% NaCl eq.), containing up to 5 mole % of CO_2 and a small amount of additional gas compound, probably CH_4. Inclusions of this type sometimes coexist with inclusions of pure CO_2 or solid inclusions of halite. Their presence points to a heterogeneous trapping and is also key to the genetic classification of inclusions into 3 groups with different mode of trapping:

Group 1. Aqueous 3–4 phase inclusions containing brine, vapour bubble and 1–2 crystals of salt (halite ± sylvite). These inclusions have been trapped in 1-phase field. Homogenization temperatures (T_h): 250–450 °C, represent minimum possible trapping temperatures. Pressures at T_h are 0,9–5,3 kbar.

Group 2. Aqueous inclusions of the group 1 coexisting with inclusions of pure halite. Fluid was heterogenized prior to trapping, precipitation of halite possibly resulted from cooling of homogenous fluid. T_h: 360–407 °C, represent true trapping temperatures. Pressures at T_h: 0,8–3,1 kbar.

Group 3. Aqueous inclusions of the group 1 coexisting with inclusions of liquid CO_2. Fluid was heterogenized prior to trapping, admixing of CO_2 phase occurred due to the drop of pressure. T_h (of brine inclusions): 430–437 °C, pressure at T_h (derived from density of CO_2 inclusions): 3–4,5 kbar. These are the most reliable pressure data.

Usual practice is to convert inclusion fluid pressure to the depth of burial – this would result in 3–15 km of overburden. In our case, however, the paleo-depth is known: stratigraphically based estimates range between 1–3 km, which is also in good agreement with very weak metamorphic overprint of the Muráň nappe. Consequently, pressure data are not related to the lithostatic load and must be interpreted to reflect a fluid overpressure, varying from lithostatic (p_{lit}) to highly supralithostatic – ca. $5 \times p_{lit}$. Such overpressure below a nappe block is mechanically unstable and cannot be maintained for a long time. Despite this, its duration was long enough to allow for growing quartz crystals (1–2 mm in diameter), containing the fluid inclusions under study. Possible explanation is that the extreme overpressure acted locally in isolated domains. Overheating of pore fluids, resulting from friction in the basal thrusting plane, is regarded as a primary reason for the pressure increase. Relatively wide span of pressures points to a dynamic regime with pressure fluctuations. These were possibly caused by failures of the overlying carbonatic block and fluid leak-off along the ruptures.

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Interpretation of the Fault Network of the Western Bohemian Region Based on the Digital Model of the Relief DMR2 and Gravimetric Maps

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Western Bohemia and the adjacent area of SE Saxony and NE Bavaria represent a region with enhanced seismicity in the form of reoccurring earthquake swarms. Interdisciplinary studies carried out in this region aim at linking geological and geophysical data to understand distribution of the epicentres and causes of the seismicity. A new insight in the tectonic structure of the area is