Complex Metamorphic Zonation of the Thaya Window: Result of Buckling and Gravitational Collapse of Imbricated Nappe Sequence

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The nappe pile in the southern Thaya window shows an inverted metamorphic zonation ranging from biotite to sillimanite zones. For explanation of the inverted metamorphic zonation in this region a model of imbrication of metamorphic zones associated with their passive deformation was suggested. Whatever the mechanism of inversion, the metamorphic isograds should be subparallel to lithotectonic boundaries in trend and often also in dip. However, the straight NNE trending mineral zones cut the regional structures in the south and in the north. The evolution of inverted metamorphic zonation implies that the oblique angular relationship between metamorphic zones and lithotectonic boundaries appearing in the present erosional section must be produced by a later post-peak effect. We suggest a model involving folding of Moravian nappes that is supported by the following structural and metamorphic evidence:

1) The stretching lineations exhibit a constant SW-NE direction while the foliation planes follow the S shape of the western part of the Thaya window. The synmetamorphic kinematic indicators show top to the NE thrust movements in the southerly dipping dip-slip domain in the south, dextral movements in the western strike slip domain and normal fault movements in the northern termination of the Thaya window. This suggests that the early kinematics are refolded by a large scale antiformal fold with an axis gently dipping to the west.
2) If the nappe sequence with previously developed inverse metamorphic zonation is folded and subsequently cut by a horizontal section the high grade rocks occur in the hinge zone and lower grade rocks in the limb regions. Consequently, the metamorphic zones cut obliquely the individual lithotectonic boundaries so that the metamorphic grade increases towards the hinge zone.

From the observations presented above, we can conclude, that the structure of the Thaya window could be viewed as a large scale antiform with wavelength of 40 - 45 km. Thermal, rheological and fold calculations document and explain mechanism of folding of large scale crystalline nappes. The basic assumption for the model is that the nappes were transported upwards sufficiently rapidly to retain the temperature necessary for their viscous behaviour.

We suggest that in the depth of 15 km of the exhumation path starts the buckling of the Moravian nappe pile and that its wavelength is controlled by the Bíteš orthogneiss because: 1) the Bíteš orthogneiss is the thickest competent layer, 2) the viscosities of the Bíteš and the Weitersfeld orthogneiss became equal and, 3) the viscosity of medium embedding the Bíteš orthogneiss (underlying and overlying metasediments) became homogeneous. Calculated fold wavelength of 38 km is in good agreement with observed wavelength of the Thaya antiform 40 - 45 km.

The depth 15 km of initiation of folding roughly coincides with the depth estimate of 18 km for the burial of the autochthonous Thaya granite. At this depth the autochthonous Thaya granite acted as a buttress which inhibited further nappe thrusting and enhanced buckling of the multilayer system.

The style of folding of the Moravian nappes multilayer sequence is controlled by relatively low ductility contrast ($\mu_{albite}/\mu_{quartz}$) and moderate ratio of incompetent to competent layers. As the competent layers of Bíteš and Weitersfeld orthogneiss lie close to each other, then harmonic fold assemblage is developed.

A relatively low viscosity contrast could be responsible for an important modification of the fold geometry leading to thickening of both competent and incompetent layers in the hinge zone and thinning in the fold limbs. The flattening of megafold limbs is well documented by a similar fold geometry and also by finite strain studies which show oblate strain ellipsoids in limb regions and plane strain fabrics in fold hinge.

The folding of crustal nappes along inclined surface is responsible for a rapid elevation of the fold hinge to supracrustal levels due to horizontal shortening. The overlying thick nappe of Moldanubian migmatites cannot be folded and is therefore affected by extensional faulting along fold limbs. This huge extensional to transtensional faults transport high grade Moldanubian rocks at the direct contact with medium grade Moravian nappes. Extensional faulting also affects the Moravian units and results in reduction of their thickness in the northern and southern parts of the window. The extensional faulting is accompanied by the development of medium-scale gravitational folds in highly anisotropic parts of Moravian nappes and do not affect the whole crustal multilayer.