Variscan Crustal Boudinage in the Bohemian Massif: Gravimetry, Magnetometry and Structural Data from the Desná Dome

By Petr Rajlich, Marek Slobodník & Antonín Novotný

With 5 Figures

Contents

Zusammenfassung ................................................................. 241
Abstract ................................................................. 241
1. Introduction .................................................... 241
2. Geological Setting .................................................... 242
3. Methods of the Study ........................................................ 244
4. Discussion ............................................................... 245
5. Conclusions ............................................................... 246
References ................................................................. 246

Zusammenfassung

Abstract
Gravity data and kinematical sense indicators were used for the study of the Variscan crustal scale boudinage of the Proterozoic crystalline crust in the NE part of the Bohemian Massif. The zone underwent to the large scale dextral strike-slip in the late Variscan stage and the crustal boudins originated in the transpression and transtension tectonics. The morphological elevation of domes among the Devonian and Culmian sedimentary basin is in greater part due to the preservation of the original crustal thickness. The ductile level in the time of extension occurred at the depth of 4–5 km below the present surface and its elevated position is related to the metamorphic grade increase.

1. Introduction

The reflexion crustal profiling results (Wernicke, 1981) and following geological studies (Coward, Dewey & Hancock, 1987) show that the crustal extension can be an important part of the kinematics of an orogenic zone. Several authors (for instance Malavieille, 1987) suppose that firstly the thickening of the continental crust occurred and was later followed by the gravitational collapse. The extensional regime described from the Alps from Tauern window by Selverstone (1987) is contemporary with the strike-slip on the Jurassic line. This problematic is thus interesting not only from the point of view of the timing of extension in the orogeny, but also from the point of view of its relation to the kinematics of the orogenic zone. Gravity interpretation of the Desná dome shape together with the structural studies from the Northern part of the Moravian shear zone show that extensional structures - crustal boudinage - are there related to the longer tectonic activity beginning with the sedimentation of the Devonian, with the intrusion of the Givetian volcanics and terminated by the Westphalian strike-slip. They can thus be related to the progressively developing wrench zone. Crustal boudinage from the Moravian shear zone is also a proof of the temperature conditions controlling the depth of the uniform crustal extension in this zone, which led to the inhomogeneous stretching in the upper parts of the crust to the depth of 4–5 km below the present surface.
2. Geological setting

The Eastern part of the Bohemian Massif is bounded by the important NNE–SSW striking ductile wrench zone with combined transpression and transtension deformation style originated during the Middle Visean up to Upper Westphalian orogenesis. The transpression and transtension related structures are well visible in the fyschoid sediments ranging in age from Frasnian up to Lower Westphalian. Three generations of folds can be observed here i.e. the upright of flower-like fanning $F_1$ folds with axial planar cleavage, with axes reoriented from their former position at 45° to the zone boundary to the present 15–20° position. The younger

Fig. 1. Geological setting of the area studied.
1 = Pre-Devonian crystalline rocks (A = Desná Dome); 2 = Devonian volcano-sedimentary rocks (a = Vrbno Group, b = Sternberk-Horní Benšov zone); 3 = Devonian in the high grade metamorphic units; 4 = amphibolite massifs; 5 = Žulová granite (post-Brétonian); 6 = Culmian flysch; 7 = neovolcanites (basalts and associated pyroclastic rocks); 8 = main fault line.

Fig. 2. $F_2$ curvilinear asymmetrical folds on the base of the Culmian fyschoid sequence indicating the normal faulting-extension during the Hercynian orogenesis in the region. Ondřejov quarry.
Fig. 3.
Geological map of the area studies, modified from FEDULOVÁ et al. (1987), HETTLER et al. (1975), DVOŘÁK et al. (1979) and BRSSINOV et al. (1972).
\( F_2 \) folds generation (fig. 2) occurred in the continuous dextral strike-slip. Their N–S direction and subhorizontal fold axial planes are indicative of the normal faulting-extensional component of the kinematics. The \( F_3 \) upright or to SE inclined \( F_3 \) folds of the NE–SW and E–W direction arranged into the NE–SW zones have the position of Riedel shears.

The Desná dome (fig. 1) which occurs on the western border of the wrench zone represents the core of the pre-Devonian crystalline rocks i.e. mainly gneisses, blastomylonites and metagranitoids with the sporadically preserved remnants of the Devonian quartzites on top of it. The analogous orthogneisses from the Keprník dome yielded the zircons of the 1400–950 m.y. age (Van Breemen et al., 1982). The vault is rimmed from W, N and E by the Devonian series i.e. mainly quartzites and phyllites in the NE and NW part also by the included Devonian volcanites (fig. 1 and 3) of the tholeiitic composition (Patocka, 1987; Soucek, 1981). The dimension of the metamorphic core is 10 km in the NE (longer axis) direction and 6 km in the NW direction (fig. 1). Following to the surface outcrops the dip of the eastern flank is 40–60° under the Culmian and Devonian sediments, 30° to the NE and western flank is formed by the flower structure of Devonian rocks in the strike-slip of the Kouty zone – the important gravity gradient (Čuta et al., 1964). The main stretching lineation directions are NE–SW (60°) in the metamorphic core complexes and N–S on its eastern border. The inner structure of the vault is therefore more or less discordant with respect to its envelope. New data concerning interpretation of its development are supplied by the detailed gravimetry and by the whole kinematics of the Variscan orogene in the Bohemian Massif (Rajlich, 1987).

3. Methods of the study

The structure of the Desná dome (Beck et Schuster, 1887) was solved in the gravity cross-section of the NE–SW direction, which means partly obliquely to the N–S structures trend. In the cross-section (fig. 3) occur successively from NE towards the SW: The Horni Benešov polymictic grauwackes, Andělská Hora shales and grauwackes, Devonian quartzites, maphic and subordinately acid volcanics and further to the west the crystalline basement such as paragneisses and metagranites with blastomylonites (Fišera et al., 1982). The cross-section ends on the NW border in the amphibolites and sediments of the Devonian.

![Graphs and charts related to geophysical data and resulting density model of the Desná dome.](image)

A = magnetometry; B = gravimetry – observed curve and calculated gravity values (dots) according to the modelled densities and shape of the bodies; C = density model.
The quantitative direct solution was calculated with use of the interactive procedure. On the display the parameters of the geological model were changed operatively with respect to the dimensions and differential densities of the bodies in the geological model (fig. 4), minimalising the differences between calculated and measured curves. The theoretical background for the algorithm was given by RASMUSSEN & PEDERSON (1979), the program was compiled by ŠVANGARA (1984). The entry values were the measured gravity values, the differential densities collected by DÁRKÓ et al. (1978) and the set of polygon (X, Z) coordinates describing the surface shape of geological bodies in the profile. The gravity data are from the map of the complete Bouguer anomalies (IBRMÁJer, 1965). The interpretation of structures in the cross-section was verified with the aid of Δ-T magnetic curve using the data of GNOJEK & ŘEĎÁČEK (1980).

4. Discussion

The calculated model is outlined on the fig. 4 and the partly triangular shape of the basement (gneisses, metagranitoïds and blastomylonites) is characteristic. The basement upper boundary displays the step-like subsidence against the overlying metasedimentary units. The body of lesser densities (2.715) on the top of the dome corresponds to the rocks similar to the basement but with greater part of younger pegmatites and of metamorphites. The body of greater densities on the western boundary of the vault (2.780) is from the point of view of the density nearly identical with underlying rocks what can be caused by greater amount of amphibolites and paragneisses. Similar stepwise boundary as the underlying units has also the volcanogenic Devonian (2.810) against the Culmian strata. There is a striking increase of the thickness of the Devonian closer to the NE boundary of the Desná dome. This tendency is not so clearly visible in the case of Culmian flysch which overlay the Devonian. It has firstly the reduced thickness which then becomes thicker in the direction of the East. The amphibolite body from the western part of the area has the rather constant thickness close to 500-600 m.

This shape characteristics was interpreted in the tectonic profile (fig. 5) using the observation of tectonic transport sense of small structures and especially of the folds F2 (fig. 2). To the kinematical solution of the shape of density bodies in the cross-section corresponds best the intense normal faulting-extensional tectonics cutting of the flanks of the core of the dome along the ductile normal faults with the variable dip between 0 to 70° in overlying sedimentary units. This kinematical plan corresponds well to the indicators of tectonical transport direction found on the outcrops of the area. The normal faults occur on the East as well as on the West of the Desná dome, forming in the western part a negative fan. Following from the gravity model interpretation they become horizontal in the depth of 4 through 5 km and this ductile-brittle level transition closer to the former surface was influenced by the elevated temperature gradient (DvOůK & WOLF, 1979) as can be deduced from the comparison with the commonly occurring depth at 6-10 km (JACKSON, 1987). This observation is also in agreement with the described most intense growth of metamorphic mineral porphyroblasts in the closing stage of the F2 folds formation (CHAB et al., 1986).

The conspicuous change of the thicknesses of the Devonian in the area on the NE termination of the Desná dome can be interpreted as the formation of the pull-apart basins in the time of sedimentation of the Devonian before the Frasnian and Famennian. The trough is filled mostly by the maphic volcanics and the most intense activity corresponds mostly to Givetian (SUK et al., 1984). We feel that the greater sediment thickness accumulation is mostly caused by the left-hand strike-slip movement on the basement faults of NNE-SSW direction (DvOůK, 1985) in the Variscan orogen. The pull-apart basins of NW–SE direction on pre-existing faults crossed by the M-C zones (RAMSAY & HUBER, 1987) correspond best to this tectonics. The sedimentary basins of the same NW–SE axis and with...
rapid changes of thicknesses in the NE–SW direction are typical for the whole area of the Moravo–Silesian shear zone and were studied thoroughly on the Drahany Upland by Dvořák (1973). The ductile structure of low angle normal faults of this stage is conserved as NE–SW stretching lineation in mylonites of the Desná dome, oblique to the N–S trend of lineations in the Culmian and on its boundary. On the NE end of the gravity profile the parameters of the model change in such a sense that there occurs a boundary with rocks of lower densities than studied in the model. It corresponds also to the change of dip of foliation and we suppose that another structural fan propagates himself in this area.

5. Conclusions

The crystalline rock domes with the envelope of the Devonian units on the NE part of the Bohemian Massif were formed through the crustal scale boudinage of the Proterozoic crystalline basement of the Devonian and Culmian basins. This occurred through the extensional-normal faulting tectonics on the flanks of domes formed of the upper – not uniformly stretched Proterozoic crust above the more uniformly stretched one in the Devonian and Culmian and on its boundary. On the NE end of the gravity profile the parameters of the model change in such a sense that there occurs a boundary with rocks of lower densities than studied in the model. It corresponds also to the change of dip of foliation and we suppose that another structural fan propagates himself in this area.

References


