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

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With 5 Figures

ČSSR
Bohemian Massif
Crustal Structures
Desná Dome
Gravimetry
Magnetometry

Contents

Zusammenfassung

Anhand von gravimetrischen Daten und Bewegungssinn-Indikatoren wurde großmaßstäbliche variszische Boudinage der proterozoischen Kristallinkruste im nordöstlichen Teil der Böhmischen Masse studiert. Die Zone erfuhr in spätvariszischer Zeit eine großräumige, rechtsseitige Blattverschiebung; durch Transpression und Transtension entstanden Krusten-Boudins. Die morphologischen Aufwölbungen innerhalb der devonischen und unterkarbonen Sedimentbecken werden zum Großteil als Konservierung der ursprünglichen Krustendicke interpretiert. Die duktile Zone lag während der Zeit der Zerrung in einer Tiefe von 4–5 km unterhalb der heutigen Oberfläche. Ihre erhöhte Position wird mit der Zunahme der Metamorphose-Intensität in Verbindung gebracht.

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 basis 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.

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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 regimen described from the Alps from Tauern window by SELVERSTONE (1987) is contemporary with the strike-slip on the Judicarian 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 flyschoid 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

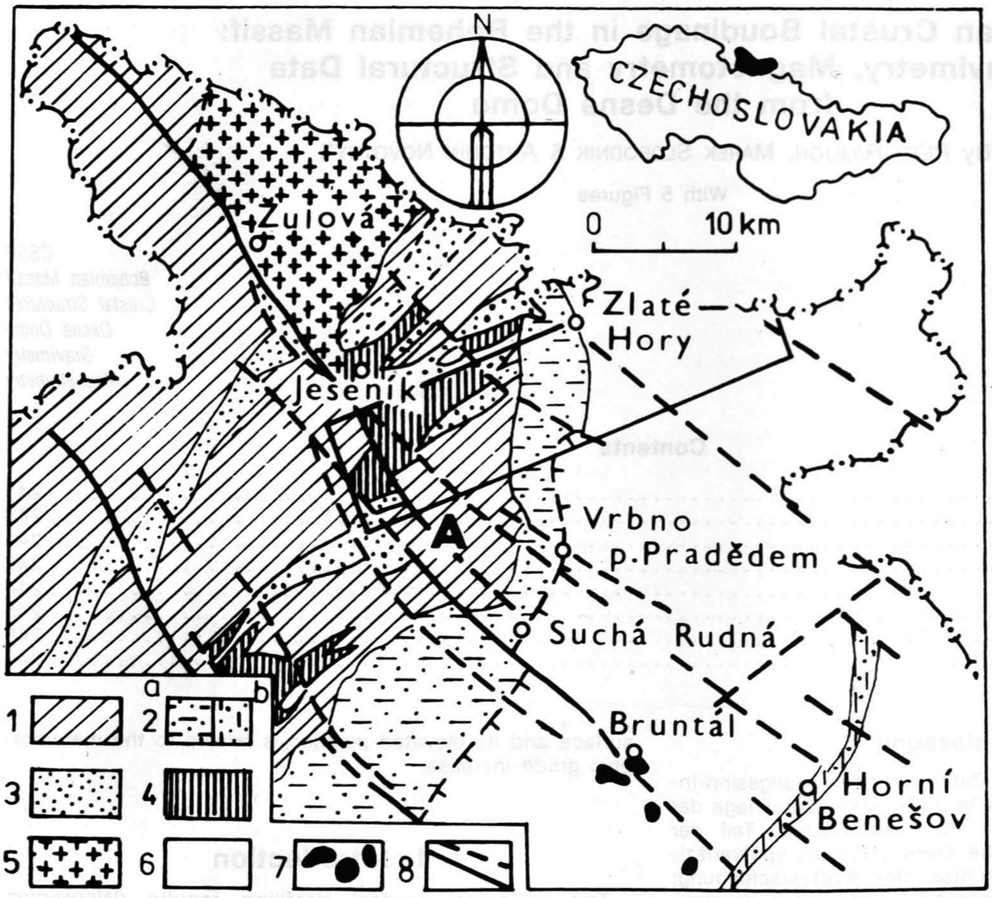

Fig. 1.
Geological setting of the area studied.
1 = Pre-Devonian crystalline rocks (A = Desná Dome); 2 = Devonian volcano-sedimentary rocks (a = Vrbno Group, b = Šternberk-Horní Benšov zone); 3 = Devonian in the high grade metamorphic units; 4 = amphibolite massifs; 5 = Žulová granite (post-Bretonian);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

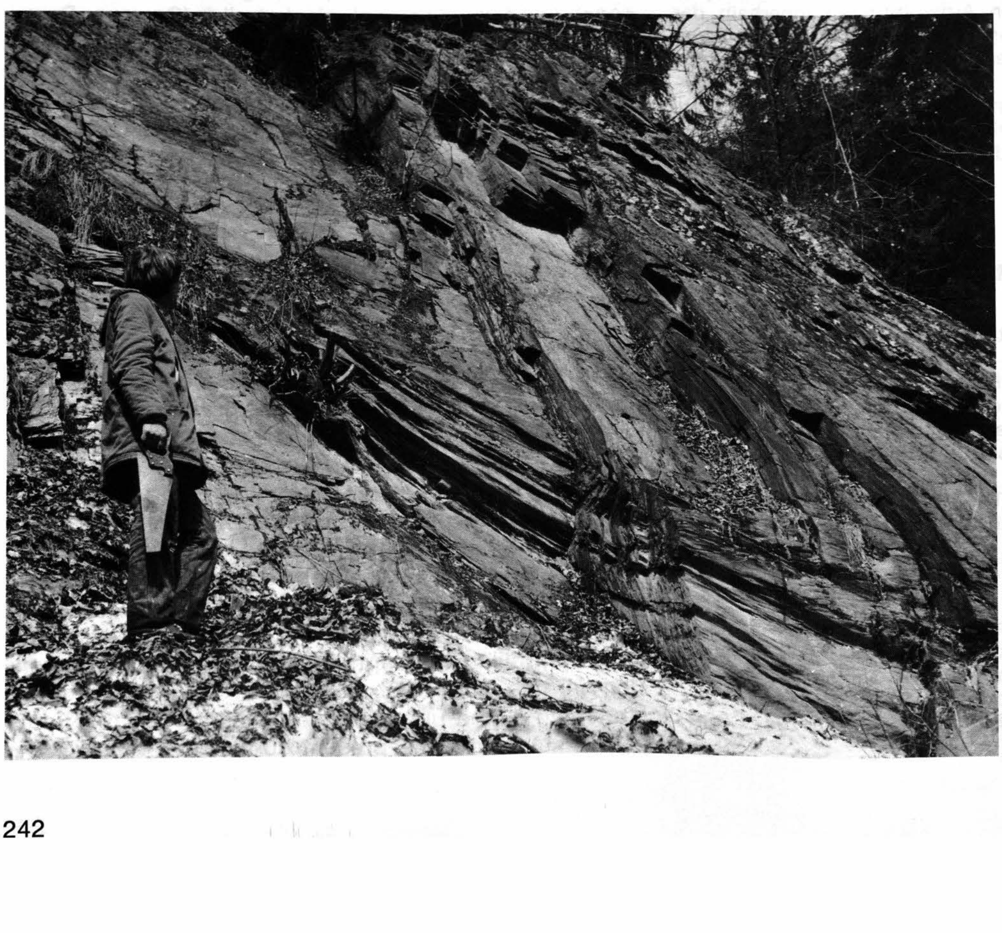

Fig. 2.
F_2 curvilinear asymmetrical folds on the base of the Culmian flyschoid sequence indicating the normal faulting-extension during the Hercynian orogenesis in the region.
Ondřejov quarry.

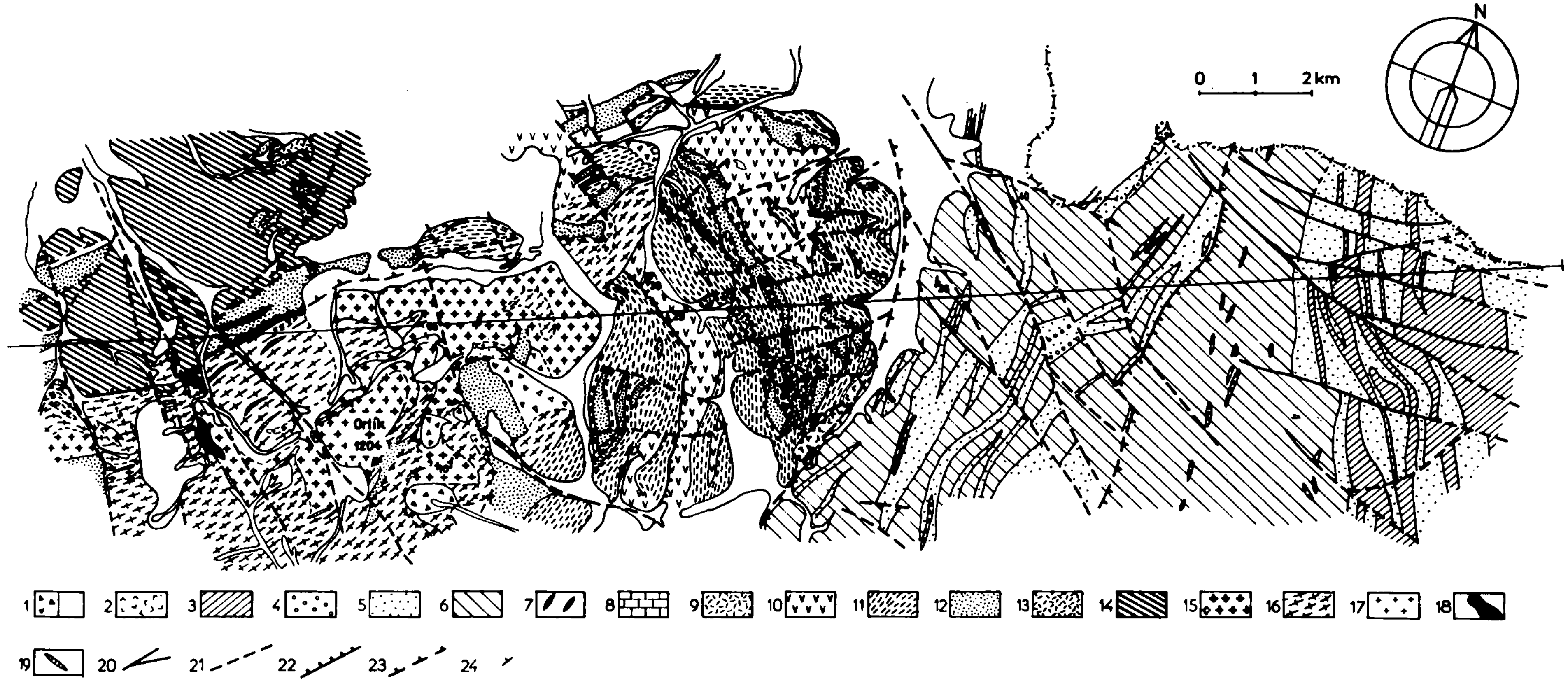

Fig. 3.
Geological map of the area studies, modified from FEDIUKOVÁ et al (1987), HETTLER et al. (1975), DVOŘÁK et al. (1979) and BUSSINOV et al. (1972).
1 = Quaternary deposits; 2 = fossil weathering products; 3 = Culmian shales, slates and siltstones; 4 = conglomerates; 5 = graywackes; 6 = siltstones and shales; 7 = lamprophyr dykes (dotted = occurrences in blocks); 8 = marbles; 9 = acid volcanics; 10 = mafic volcanics; 11 = metasediments; 12 = quartzites; 13 = marbles with terrigeneous components; 14 = amphibolites; 15 = sheared granites; 16 = granite and migmatite mylonites; 17 = sheared pegmatites; 18 = micaschists and biotitic paragneisses; 19 = quartz veins; 20 = faults; 21 = supposed faults; 22 = normal faults; 23 = supposed normal faults; 24 = strike and dip of the foliations.

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 (PATOČKA, 1987; SOUČEK, 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 ist 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 (BECKE & 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 Horní 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.

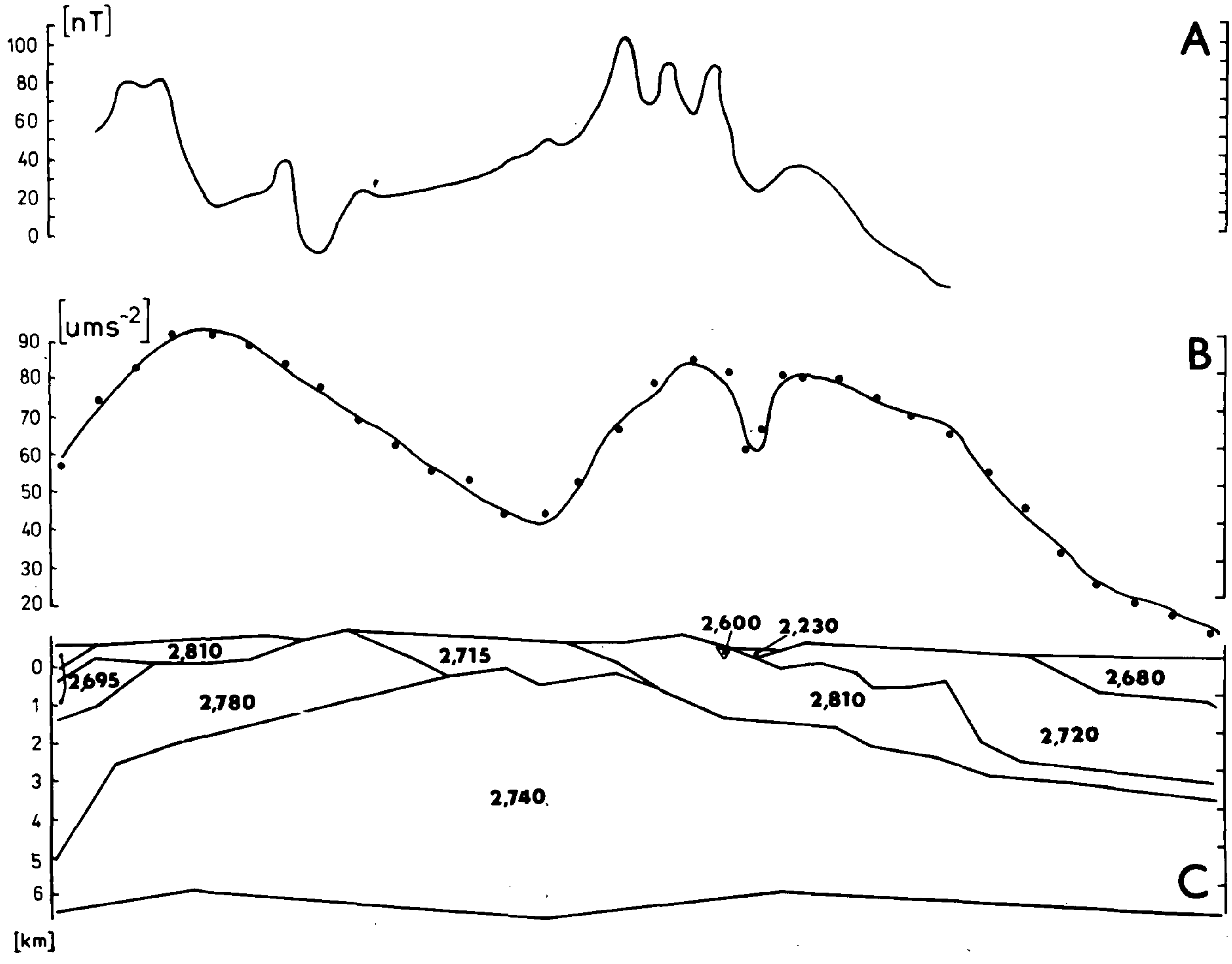

Fig. 4.
Geophysical data and resulting density model of the Desná dome.
A = magnetometry; B = gravimetry – observed curve and calculated gravity values (dots) according to the modelled densities and shape of the bodies; C = density model.

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 ŠVANCARA (1984). The entry values were the measured gravity values, the differential densities collected by DAŇKO et al. (1978) and the set of polygon (X, Z) coordinates describing the surface shape of geological bodies in the profile, and data on their length perpendicularly to the cross-section. The gravity data are from the map of the complete Bouguer anomalies (IBRMAJER, 1965). The interpretation of structures in the cross-section was verified with the aid of Δ-T magnetic curve using the data of GNOJEK & DĚDÁČEK (1980).

4. Discussion

The calculated model is outlined on the fig. 4 and the partly triangular shape of the basement (gneisses, metagranitoids 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 flysh 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 F_2 (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 flancs 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 (DVOŘÁK & 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 F_2 folds formation (CHÁB 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 (DVOŘÁK, 1985) in the Variscan orogen. The pull-apart basins of NW–SE direction on pre-existing faults crossed by the N–S ones (RAMSAY & HUBER, 1987) correspond best to this tectonics. The sedimentary basins of the same NW–SE axis and with

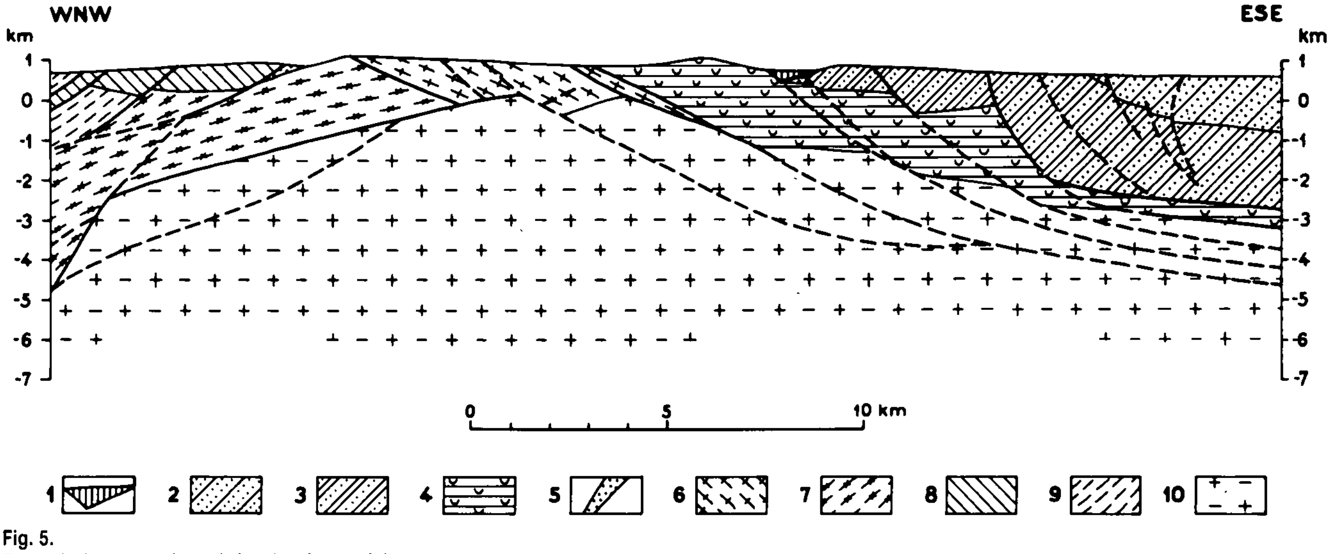

Fig. 5.
Tectonic interpretation of the density model.
1 = Quaternary and Tertiary sediments; 2 = graywackes and shales (Lower Viséan, Horní Benešov beds); 3 = shales and graywackes (Frasnian–Famenian, Andělská Hora beds); 4 = Quartzites, phyllites and mafic volcanics (Siegenian–Gedinian); 5 = Lower Devonian quartzites; 6 = mylonitized granites and migmatites; 7 = paragneisses and mafic volcanics; 8 = amphibolites; 9 = orthogneisses and paragneisses; 10 = Pre-Devonian crust (granites, paragneisses etc.).

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 flancs of domes formed of the upper – not uniformly stretched Proterozoic crust above the more uniformly stretched one during the intense sedimentation of the Devonian (Givetian) when the narrow pull-apart basins on the pre-existing NW–SE faults were formed and further in the Westphalian phase during the change of the transpression to the transtension kinematics in the dextral strike-slip. In this manner the inversion structures originated as relics of more or less preserved original thickness of the Proterozoic crust bounded from all sides by normal faults. Their morphologic elevation among the Devonian and Culmian sedimentary basins is in greater part due to this preservation of original thickness. It follows also from our study that the crustal extension has occurred on the early stage of the orogen evolution due to the wrench style tectonics of the whole zone.

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