Paleozoikum

DEVONIAN SEDIMENTARY ROCKS TECTONICALLY INCORPORATED INTO THE BRNO MASSIF, EASTERN MARGIN OF THE BOHEMIAN MASSIF

Devonské sedimentární horniny tektonicky začleněné do brněnského masivu, východní okraj Českého masivu

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Abstrakt
Devonská klastika severního okolí Brna jsou součástí sj. orientované zóny Babího lomu, která probíhá středem brněnského masivu. I když devon tvoří zdánlivě samostatný relikt, byly na jižním svahu kopce Strážná (369 m n. m.) nalezeny klíčové informace pro řešení stavby celé zóny Babího lomu: 1) Horninový sled devonských klastik je na dané lokalitě dostatečně variabilní (břidlice, prachovce, pískovce, křemenné a petromiktní slepence), což umožňuje dobře rozpoznat vrstevnatost i směr do nadloží. 2) Vrstevnatost devonských hornin se v z. části reliktu uklání k V a směrem na V se překlápí přes vertikální orientaci do pozice překocené s úklonem k Z. 3) Omezení devonských hornin je z části primární – transgresivní (na JZ s reliktním fosilním zvětráním podloží), z části tektonické (východní a sz. omezení). Uvedená pozorování lze v kombinaci se strukturně geologickými informacemi z okolí vysvětlit následující interpretací: 1) Devonské vrstvy tvoří překocenou vrásu. S největší pravděpodobností se jedná o antiklinálu s osní plochou ukloněnou k Z. 2) Vrásová stavba vznikla zřejmě v důsledku deformace vlekem podél násunového zlomu a tvoří spodní část tektonické šupiny. 3) Svrchní část této šupiny reprezentují horniny hřbetu Babího lomu. Následné křehké postižení vedlo k rozdělení struktury a posunutí částí do různých úrovní za vzniku dnešního obrazu geologické stavby.

Abstract
The Devonian clastic rocks in the northern vicinity of Brno are a segment of the north-south oriented Babí lom zone, cutting central part of the Brno Massif. Although the Devonian rocks form a seemingly isolated relict, the area of southern slope of Strážná hill (369 m a. s. l.) south of Lelekovice gives us key information for understanding the whole Babí lom zone structure: 1) The Devonian sediments are lithologically variable, with shale, siltstones, sandstones, and quartzitic conglomerates, which enables us to recognize bedding and younging. 2) Bedding changes its orientation: it is dipping towards the east in the west, vertical in the middle, and overturned with dip towards the west in the east. 3) The Devonian rocks are limited partially primarily with transgressive boundary (in the SW with relict of fossil weathering) and partially tectonically (in the E and NW). These facts can be interpreted by the following explanation: 1) The Devonian beds form a recumbent fold, which is most likely an anticline with axial surface dipping towards the west. 2) The fold structure probably originated by dragging alongside a thrust fault and is a lower part of a tectonic sheet. 3) The Babí lom ridge may represent an upper part of the sheet. A segmentation of the structure is a result of subsequent brittle faulting.

Introduction

The locality under study is a part of the Brno Massif (Brunovistulicum), which is comprised of two different granitoid regions separated by the Metabasite zone (Weiss in Svoboda et al. 1964, p. 328; Hanžl, Melichar 1997). The Eastern granitoid zone is typical by Královo pole granodiorite with characteristic columnar biotite crystals (Mitrenga, Rejl 1993). Metabasite zone is accompanied by a discontinuous belt of Devonian clastic rocks named Babí lom zone (Dvořák 1963a). This north-south oriented zone starts near Šebrov in the north and continues through Lelekovice to Žlutý kopec [Yellow hill] and Červený kopec [Red hill] in the city of Brno (Fig. 1).

The Devonian clastic rocks of the Babí lom zone consist mainly of different-size grained conglomerates, sandstones, arkose, and siltstones. Small occurrences of highly strained limestone were found west of Lelekovice village. The clastic sediments have red-violet color. Intercalation of strong conglomerates and soft sandstones and siltstones leads to zonal geomorphology with rocky ridges separated by smooth terrain. Petrography of Babí lom zone clastic rocks was described by Zádrapa (1962) and sedimentary interpretation by Wojewoda et al. (2015). The age of these sedimentary rocks was considered to be lower Devonian (Zapletal 1931–1932). The Givetian age of limestone from Lelekovice was biostratigraphically documented by Hladil (1991). An identically oriented bedding of the limestone and of the clastic rocks of Babí lom locality as well as the overall development of the Devonian in Moravia can indicate Devonian, pre-Givetian age of the clastic rocks with some degree of certainty.

The studied area itself lies in the southern vicinity of Lelekovice in the southern part of the Strážná hill (altitude 369 m), where a segment of Devonian clastic rocks was discovered. Geometry and tectonic interpretation of this small relic is the aim of this work.

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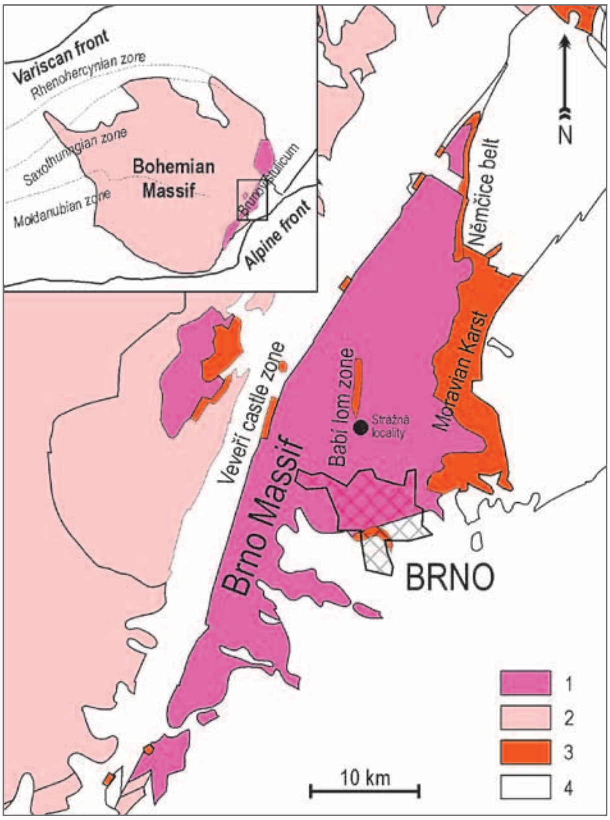

Fig. 1: Schematic geological map of the Brno Massif. 1 – Brunovistulicum; 2 – Other crystalline units; 3 – Devonian; 4 – Post Devonian units.

Strain relations of the Brno Massif and Devonian sedimentary rocks

Rocks of the Brno Massif were strained during the Variscan orogeny. Geometry of the deformation is well visible at contacts with the Devonian rocks, which could be found in 3 zones: (1) Veveří castle zone at the western edge of Brno Massif, (2) central Babí lom zone and (3) at the eastern contact with the Moravian Karst (Dvořák 1963a), especially in its northern part called the Němčice belt (Kettner, Chlupáč 1962).

Structure of the Babí lom zone was first shown by Gerlich (1932), who concluded that the Devonian limestone has been overthrusted by the Metabasite zone. Zapletal (1931–1932, p. 94) recognized that the Devonian rocks are not an erosional relic of a graben, but slices incorporated into the Brno Massif granitoids along reverse faults. Dvořák (1963b) considered the Babí lom zone as a compressed syncline, which has been overthrusted by Brno Massif rocks from both western and eastern sides. Hladil (1991) referred to the limestone as a large "boudin".

Based on stylolites and quartz veins orientation analysis, Roupec (1994) was able to distinguish two east–west compression phases during the Variscan orogeny. Similar results were found by Hroza (2003) based on paleostress analysis of faults in the Eastern granitoid zone. Hanžl and Melichar (1997) considered the Devonian rocks in the Brno Massif as evidence of the Variscan thrusting, which was apparently proved by a seismic profile (Hanžl et al. 1999). Contrary to the prevailing opinion about thrust tectonics, Železný and Melichar (2002) described a local brittle-ductile normal faulting at the boundary of the Metabazite and the Eastern granitoid zones.

The Veveří castle zone (or Čebínka zone) consists of small discontinuous sheets, which have been dislocated by the marginal fault zone of the Boskovice furrow that complicates its interpretation (Bábek et al. 1995; Špaček et al. 2002). On the other hand, brittle-ductile structures associated with thrust shear zones and drag folds were discovered at the eastern margin of the Brno Massif in the Němčice belt (Melichar, Kalvoda 1997) as well as in southern part of the Moravian Karst (Rez et al. 2011).

Methods

A field work took place in autumn 2016 and spring 2017, which yielded three key outcrops (localities). Their locations are given in figure 5. Directional data were recorded in dip notation and processed in the StaTect software. The data were plotted in the Lambert equal-area azimuthal projection on the lower hemisphere.

Results

Bedding was recognized by lithological changes among several types of sandstones, conglomerates and laminated siltstones. Bedding is usually N–S striking and more-or-less steeply dipping (Fig. 2). Overturning of bedding was discovered on locality #2 (Fig. 3), where its dip direction is changing from west to east: beds are moderately to steeply dipping to the east in the western part of the road cut (S 78°/65°, Fig. 4a), subvertical orientation is typical for the central part and dip direction to the west (S 261°/80°) was found in the east. Facing of the sedimentary rocks was recognized on locality #1, where

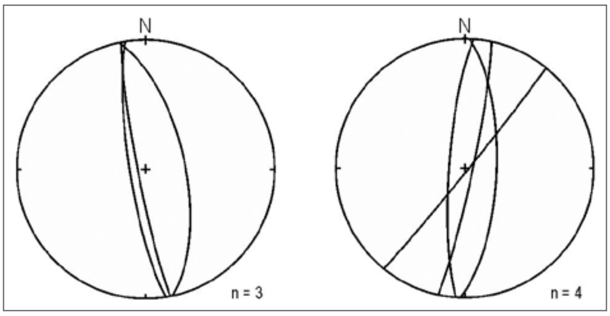

Fig. 2: Orientation of bedding (left) and cleavage planes (right). A Lambert equal-area azimuthal projection on the lower hemisphere.

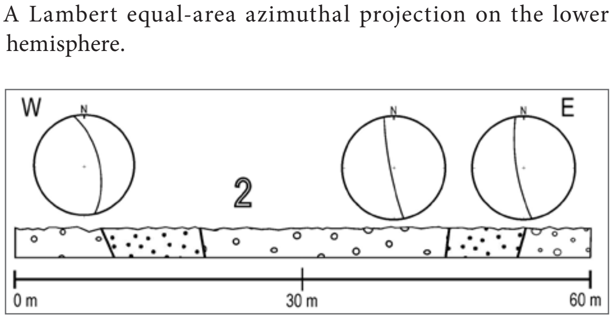

Fig. 3: A changing of bedding orientation from normal at the west to overturned at the east, roadcut south of Lelekovice, locality #2. Key: dots – sandstone and siltstone; circles – conglomerates.

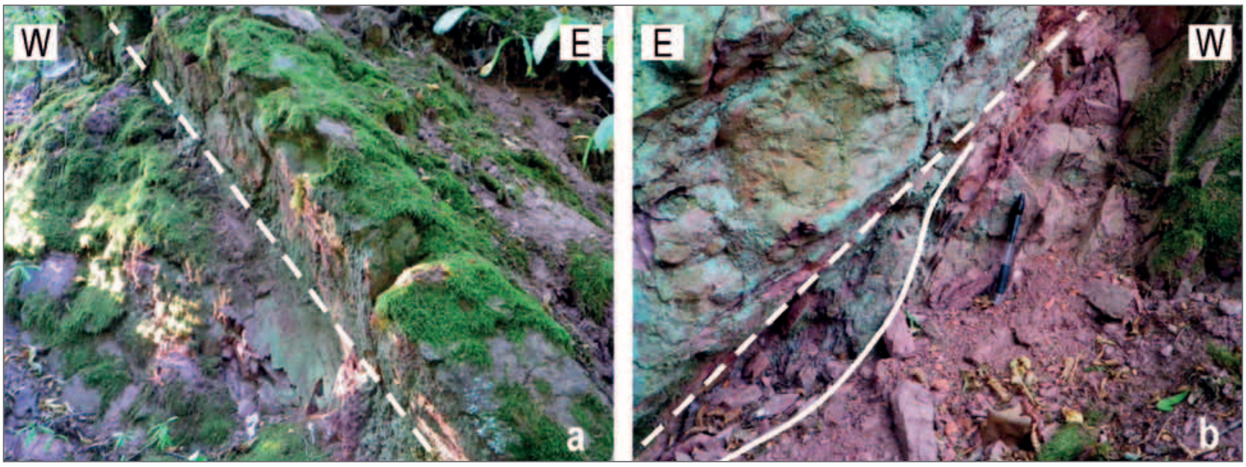

Fig. 4: Sedimentary structures in the Devonian sedimentary rocks: a – bedding well visible on contact (dashed line) between soft sandstones and hard conglomerates, locality #2; b – sedimentary channel (white full line) cut off (dashed line) by conglomerate bed (top-left) indicates younging to the east, locality #1.

channel indicating younging to the east was discovered (Fig. 4b). Strain in the siltstone is documented by cleavage slightly oblique to primary lamination. The cleavage is steep and north-south striking (Fig. 2).

Devonian rocks have an unusual triangle shape delimited by 3 different geological boundaries (see Fig. 5): (1) The southwest one is parallel to a small ridge of the Devonian conglomerate that is well visible both in the field and map (Fig. 5). Granodiorite (Královo pole type) with typical columnar biotite (locality #3) underlies the Devonian rocks. Just under the Devonian, the granodiorite is strongly laterized resulting into reddish hue similar to the Devonian clastic rocks. (2) The eastern limit of the Devonian is more-or-less parallel to the steep bedding in the east. Tectonic nature of this boundary was found on locality #1, where the Devonian rocks and the granodiorite are cut by a steep N–S striking fault. (3) The Northwest border is marked by a sudden ending of the conglomerate ridges and by linear morphological depression in the field.

Discussion and conclusions

As it was described above, the Devonian rocks in the southern vicinity of Lelekovice form a tectonic block limited at the east by a subvertical N–S oriented fault. Its kinematic is unknown even though we could estimate that the western block is fallen down, corresponding to the observation made by Železný and Melichar (2002). NW boundary is probably also formed by a fault. Both existence of the fault at NW and its strike are deduced only from geomorphological indications: the rock outcrop of the Devonian conglomerate ridge is suddenly cut and replaced by the Brno Massif rocks. The boundary is followed by a distinct depression in the field.

We can deduce a transgressive character of the southwest boundary as it is parallel to the bedding trace in the map. This interpretation is supported by fossil laterization of underlying reddish granodiorite on locality #3. The fossil weathering should be of Devonian age as it is situated on the Quaternary-aged hillside and we might exclude upper Paleozoic or Mesozoic ages of this alteration. This interpretation is in accordance with the younging towards east on locality #1. This conformity is important for selection of a possible tectonic model of the area.

As the bedding changes its orientation, we can think about large fold geometry at the area. The orientation of subvertical beds found on locality #2 is evidence for a recumbent fold, whose overturned limb is dipping to the west. An axial surface of the fold can't be horizontal as the bedding changes its dip in the horizontal direction (cf. Fig. 6a); so the axial surface should dip either towards the east (Fig. 6b) or towards the west (Fig. 6c). Combining dip direction of axial surface and younging towards the east we can presume two possible solutions

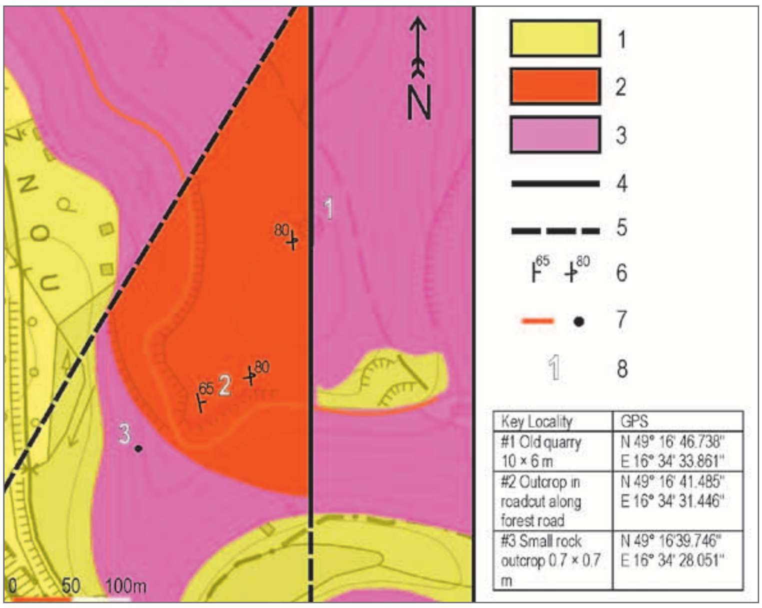

Fig. 5: Schematic geological map of the Devonian rocks south of the Strážná hill-top near Lelekovice village. 1 – Quaternary; 2 – Devonian; 3 – Granodiorite; 4 – Fault; 5 – Fault (questionable); 6 – Bedding; 7 – Localities; 8 – Key locality.

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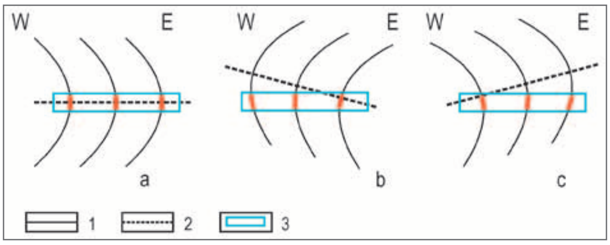

Fig. 6: Schematic cross-sections showing possible interpretations of large fold structure of the area with different inclinations of fold axial surface: a – subhorizontal axial surface; b, c – two possibilities for inclined axial surface. 1 – Foliation; 2 – Axial surface; 3 – Outcrop frame on locality #2.

of the problem: either the axial surface dips to the east and the fold is a syncline (Fig. 6b), or it dips to the west and the fold should be an anticline (Fig. 6c). Considering similar folded boundaries between the Brno Massif and the Devonian rocks (Melichar, Kalvoda 1997; Rez et al. 2011), where axial surfaces of large drag folds dip to the west, the anticline fold seems to be more plausible.

Considering discontinuous sigmoidal pattern of the Devonian rocks in the geological map, regional fold axis inclination to the north, and the structural geometry described within this study, we can accept the similar tectonic model recognized in the Němčice belt by Melichar and Kalvoda (1997) for this area as well. In this model, Devonian rocks overlaying granitoids of the Brno Massif are cut by brittle-ductile thrust shear zones, which form tectonic sheets with typical sigmoidal structure (see Fig. 7): lower recumbent anticline (≈ this work) is changed by middle limb with the lowest dip of the bedding (≈ outcrop in Lelekovice village) and by recumbent syncline on the top (≈ Babí lom ridge). After folding, the sheet was segmented by steep faults forming the fault block assemblage observable today.

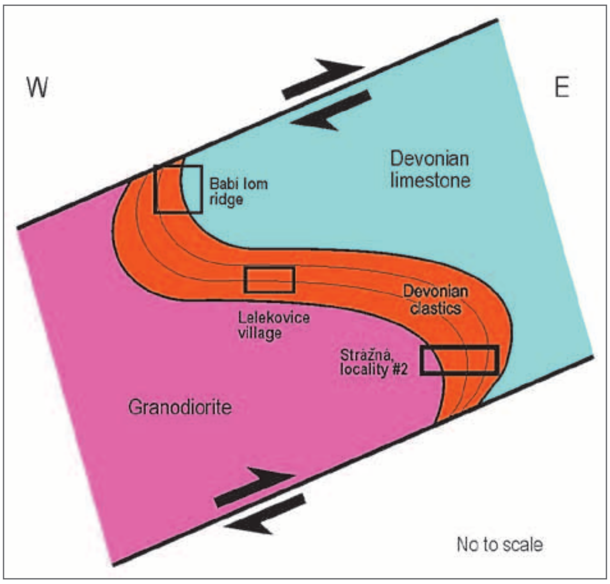

Fig. 7: Model of a cross-section of the large-scale tectonic sheet with lower and upper thrusts developed at the locality and at adjacent areas. Localities with outcropped Devonian rocks are indicated by rectangles. Young brittle faults are not considered.

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