



Apparent contradiction between tectonics and deposition in overturned strata — a case study from the “Moravian Culm” (Czech Republic)

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An apparent contradiction between structural and sedimentological indications commonly used for discrimination of the overturned and non-overturned beds during geological mapping was found at Paršovice, a site situated in the easternmost part of the European Variscides. An outcrop of folded Lower Carboniferous siliciclastic rocks of the “Culm facies” lies on the NE margin of the Bohemian Massif, in the SE part of the Maleník Block (Moravia, Czech Republic). Flute casts in the steep overturned limb of a tectonic fold demonstrate the normal stratigraphic polarity of the bed. At the same site, a slump-related isoclinal fold was found. The apparent contradiction between structural (relation of cleavage and bedding) and sedimentological (flute casts on bed soles) indications is explained by a combination of successive phases of slump- and tectonically-related folding.

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INTRODUCTION

The area studied is situated at the easternmost margin of European Variscides and, notably, lies at right angles to the trend of the main belt of Rhenohercynicum (Southern Wales–Germany–Southern Poland). The basement belongs to the Brunovistulicum.

The stratigraphic polarity of sedimentary layers is an important property that is interpreted as recorded during geological mapping. Various indicators of the stratigraphic polarity of beds (normal *versus* overturned position) are used in practice. Flute casts occurring at the bottoms of thick sandstone beds belong among the common sedimentological indicators. Another indicator is known as “normal graded bedding” when sandstone in one bed fines upwards. In folded strata, structural indicators are commonly used. The relationship between axial cleavage and bedding represents a widely used indicator for discrimination of overturned *versus* non-overturned fold limbs (for instance Ramsay and Huber, 1987). Generally there are always steeper dips of strata than those of cleavage within the overturned limb of a fold. When the dip of cleavage is steeper

(or dips in the opposite direction) than that of bedding, this typically indicates the non-overturned limb of a fold.

During geological mapping on the NE margin of the Bohemian Massif, an apparent contradiction between structural and sedimentological indications of the stratigraphic polarity of the strata was found at Paršovice, situated in the SE part of the Maleník Block (Fig. 1). The aim of this article is to explain this apparent contradiction, and to point out its wider significance.

STRUCTURAL AND SEDIMENTOLOGICAL OBSERVATIONS

Upper Viséan deposits of the Culm facies are exposed at Paršovice. During the Variscan orogeny, the strata were folded by kilometre-scale asymmetrical folds of eastward vergency. The fold axes are predominantly NNE–SSW, and cleavage planes predominantly dip to the WNW (Kumpera, 1983; Dvořák, 1994; Grygar and Vavro, 1995; Havíř *et al.*, 2003).

In the central part of the quarry face, the antiform of a tectonic fold verging to the east is present (Fig. 2). The fold axis is sub-horizontal and its orientation is NE–SW (plunge of axis

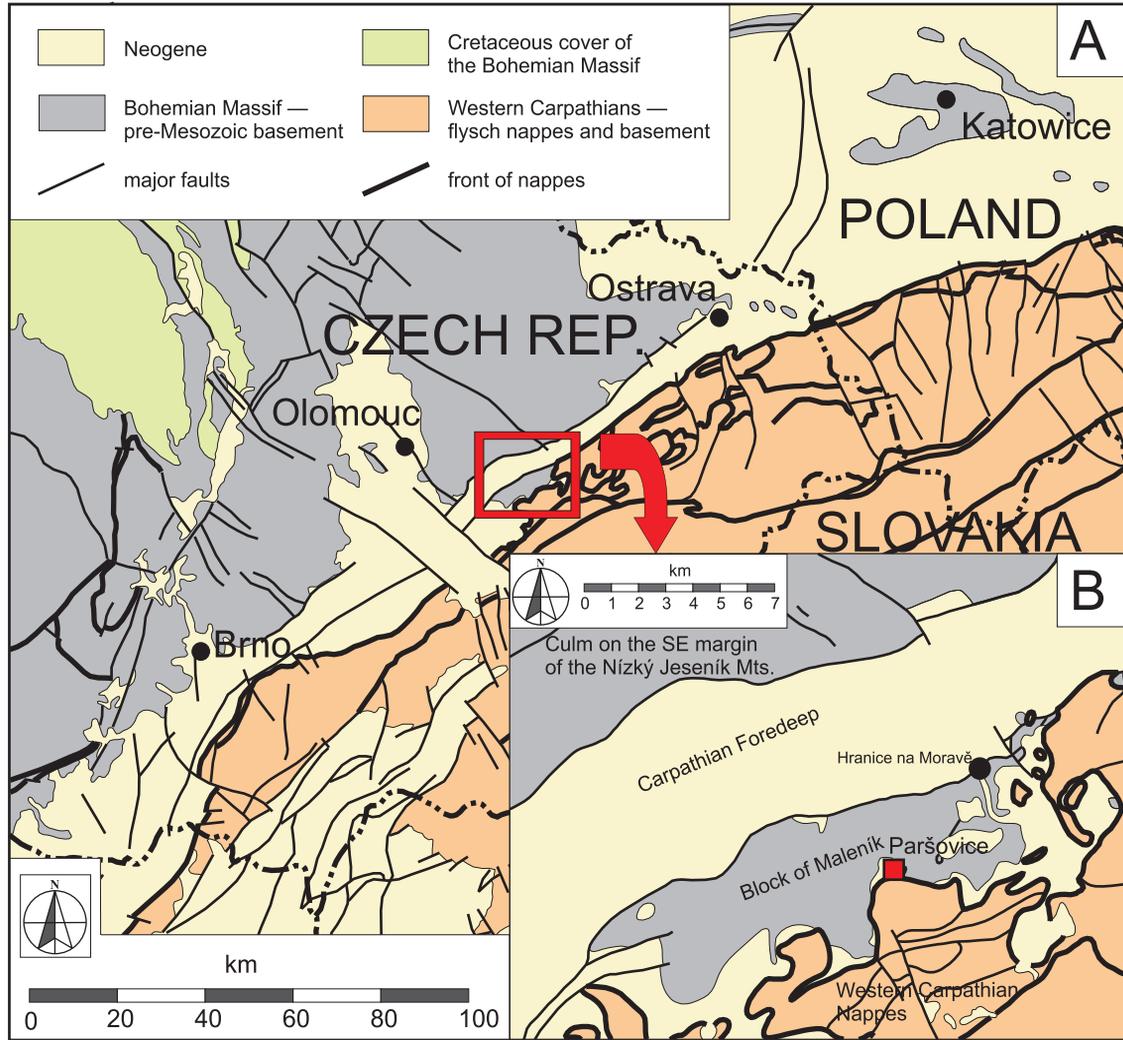


Fig. 1. Geological scheme and situation of Paršovice

A — location of the Maleník Block, where the Paršovice locality is situated, on the eastern margin of the Bohemian Massif (geological map compiled and modified after Kodym *et al.*, 1967 and Mahel', 1973); **B** — location of the Paršovice locality in the Maleník Block (geological map after Roth, 1990, simplified)

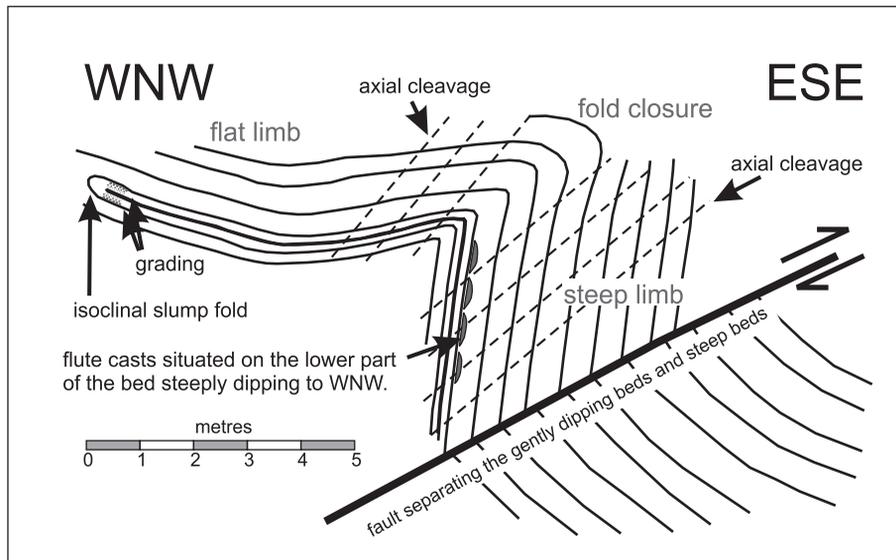


Fig. 2. Scheme of the observed configuration at Paršovice

37/4). The western fold limb is flat, the eastern limb is steep and overturned. In the flat limb, the cleavage planes have a higher angle of dip than has the bedding. This relationship between axial cleavage and bedding indicates a non-overturned limb. In the steep limb, the cleavage planes have lower angle of dip than the bedding. Thus, the relationship between axial cleavage and bedding is consistent with the observed overturning of the steep fold limb (see Ramsay and Huber, 1987) and corresponds to the observed geometry of the tectonic fold. Nevertheless, flute casts demonstrating a normal (“non-overturned”) stratigraphic polarity were observed on the lower (eastern) bedding planes in the steep overturned limb of the tectonic fold. This means that, “non-overturned” stratigraphic polarity was found in the overturned fold limb (see Fig. 2). This observation represents an apparent contradiction between the structural (relationship between cleavage and bedding) and sedimentological (position and shape of the flute casts) indications commonly used for discrimination of overturned *versus* non-overturned beds.

An important phenomenon was observed in the western part of the site. In the flat limb of the tectonic fold, an isoclinal slump fold was found (Fig. 2). Similar slump textures were observed by Dvořák (1987) in the Drahaný Culm facies deposits near Šošůvka (Drahaný Upland) in the SE part of the Bohemian Massif. The graded bedding of the greywacke bed demonstrates the normal stratigraphic polarity of the lower limb and the overturned stratigraphic polarity of the upper limb in the case of isoclinal slump fold at Paršovice. The overturned limb of the slump structure continues across the hinge of the tectonic fold.

In the eastern part of the site, gently dipping bedding was observed (the angle of dip is lower than 10°). Westwards, close to the central area where the steep fold limb dipping to WNW is exposed, the angle of dip increases and bedding dips moderately to the ESE. There is a sharp boundary formed by a narrow zone between the eastern area of strata gently to moderately dipping to the ESE (the angle of dip varies from 7 to 40°) and the central area of steep beds dipping to the WNW (angle of dip varies from 69 to 80°). We suggest that a west-dipping fault separates these two areas.

INTERPRETATION

We infer the following succession of steps (events) explaining the observed configuration at Paršovice (Fig. 3):

1. Deposition of the sediment and formation of the flute casts on the lower part of the deposited layers. The position of the flute casts indicates normal stratigraphic polarity.

2. Formation of the slump structure represented by the isoclinal non-tectonic fold. The upper limb of

the isoclinal fold is overturned to the east (Fig. 4). The position of the flute casts indicates a negative stratigraphical polarity in the upper limb of the slump structure.

Steps (1) and (2) took place in a soft, non-consolidated state of the sediment followed by diagenesis. The further history comprised:

3. The Variscan folding of the Culm facies deposits. The tectonic antiform with its steep overturned eastern limb recently exposed at the Paršovice quarry was formed. In the steep limb of the tectonic fold, the upper limb of the slump texture was secondarily overturned. That is why the position of the flute casts indicates a normal stratigraphic position, in spite of the fact that they are situated in the overturned limb of the tectonic fold (Figs. 2 and 5).

4. Faulting in the steep fold limb. The movement along the fault cutting the steep limb completes the scenario that was recently observed at the exposure.

The relationship between axial cleavage and bedding correctly indicates the overturning of the steep limb of the tectonic fold. The strata were overturned only once during the tectonic deformation connected with the Variscan folding. But in the upper limb of the slump structure, the strata had been already overturned before tectonic deformation, during slumping on the inclined slope of the Culm basin. Thus, the strata including the formed flute casts were overturned twice in this part of the slump structure and that is why the position of the flute casts correctly indicates the normal stratigraphic polarity of these layers.

CONCLUSION

The observation carried out at Paršovice shows that the indicators which are commonly used for discrimination of the

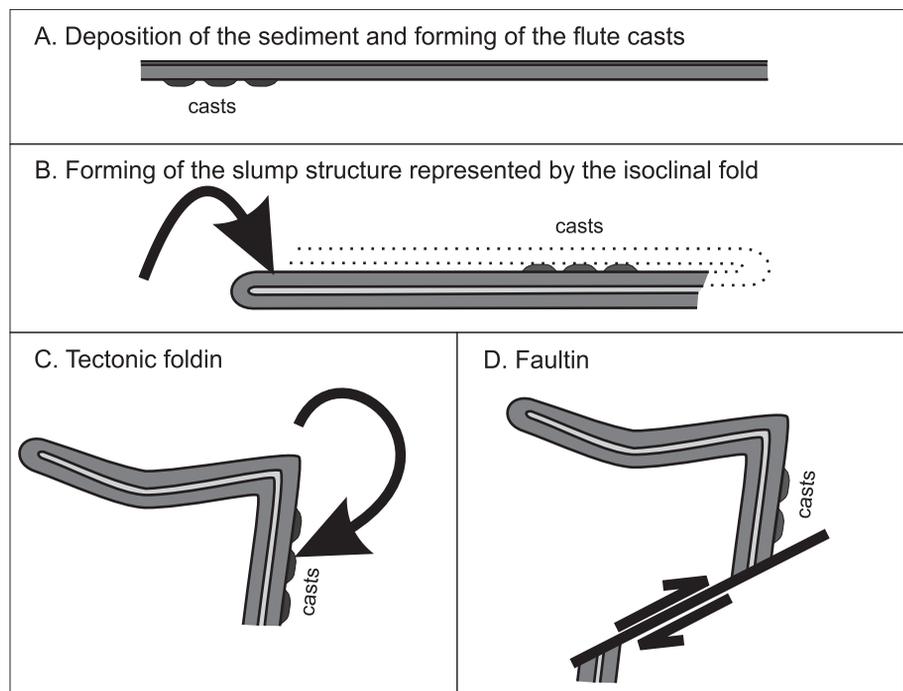


Fig. 3. The scheme of the succession of events explaining the main steps of formation of the observed configuration at Paršovice



Fig. 4. A slump structure in coarse-grained greywackes with graded bedding

overturned *versus* non-overturned beds during geological mapping can sometimes exhibit apparent contradiction. The cause of this apparent contradiction can be the combination of a slump structure and the tectonic structure as follows from the interpretation above. Such a combination should be borne in mind when interpreting indicators of the stratigraphic polarity, particularly so in territories where both tectonic (cleavage, folding) and slump phenomena occur, for instance in the Culm

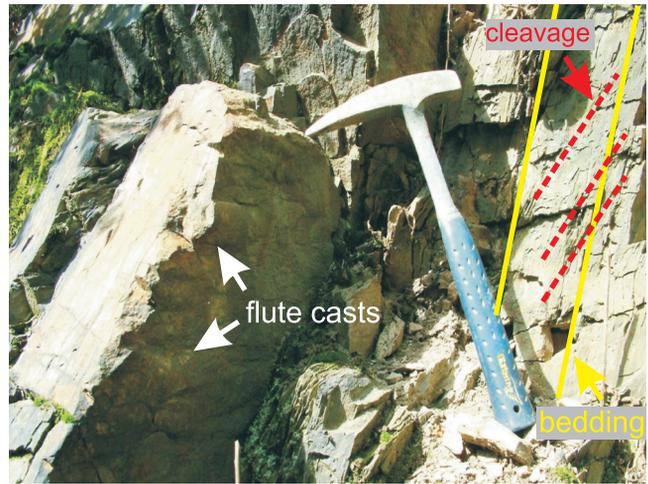


Fig. 5. Flute casts at bottom of a bedding plane in the steep limb of a fold. Note the relation between cleavage and bedding

basin situated at the eastern margin of the Bohemian Massif. The distinguishing of slump structures from tectonic folds has been recently described by Debacker *et al.* (2001) from the Lower Palaeozoic Anglo-Brabant fold belt.

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