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The stratigraphy separation diagram–an amazing tool for fault analysis

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Abstract: The Stratigraphy Separation Diagram (SSD) is a neglected tool of fault analysis, which allows the interpretation of both fault-surface geometry and the mechanism of faulting. As it needs to evaluate displacement (separation) along the fault under study, this method can be used only in areas with well-documented (tectono)-stratigraphic sequences. The paper presents both some common patterns of SSD and two examples of seemingly similar faults from the Barrandian area (Czech Republic).

Keywords: stratigraphy separation diagram, fault slip, fault blocks, thrusts, Barrandian.

The problem faced is how to confirm or reject equivalency of two faults, with similar strike, known length, tectonic setting and produced repetition of stratigraphic sequence, i.e. how to determine their geometry and mechanism of origin. The stratigraphy separation diagram (SSD) appears to be an ideal, cheap, but neglected tool for this purpose. This contribution analyzes several types of SSDs and interprets two different faults previously thought to be genetically identical.

Slips and separations

SSDs are based on the relationship between the separations of two parts of one horizon displaced along a fault surface. The displacement can be described in terms of two parameters: slip and separation (Reid *et al.*, 1913). By the term "slip" we can understand the relative movement along the fault surface. Two equivalent points on opposite fault walls indicate the two terminal points of the displacement vector termed "net slip" (N in figure 1), which consists of two pairs of components. "Strike slip" is a horizontal component parallel to the fault strike (S in figure 1) and "dip slip" is an inclined component parallel to the fault dip (D in figure 1). "Trace slip" is a component parallel to the trace of bedding on the fault surface (T in figure 1) and paired "perpendicular slip" is perpendicular to it (P in figure 1).

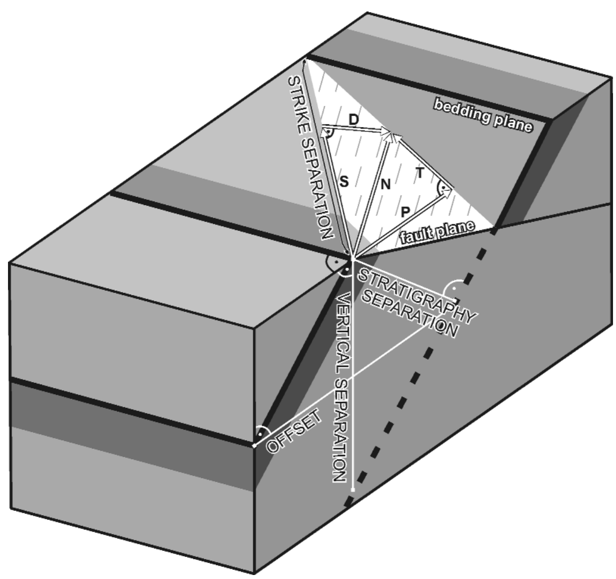


Figure 1. Definition of fault slips and separations using bedding plane disrupted by fault.

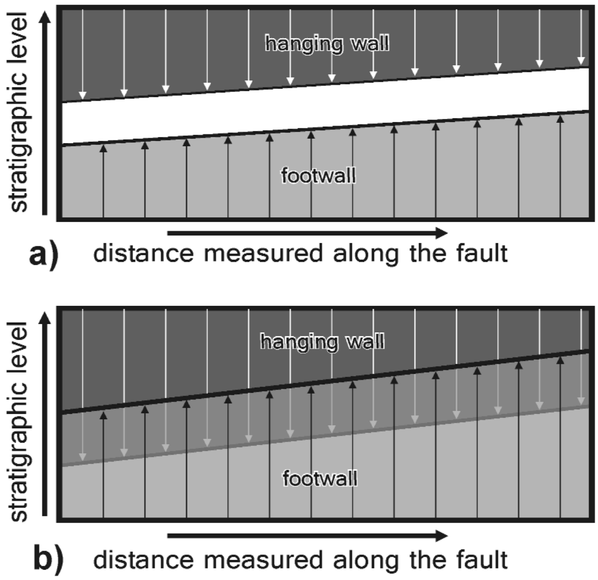


Figure 2. Stratigraphic gap (a) and stratigraphic duplication (b) in stratigraphic separation diagrams.

In contrast to slip, the term "separation" means the real distance between two parts of one bed surface disrupted by the fault. The separation is produced only by perpendicular slip and any length of the trace slip has no effect on separation. It is possible to measure several types of separation depending on the observed direction, i.e. "vertical separation" measured in the vertical direction, "offset" in the horizontal plane at right angles to the strike of the bed, "strike separation" in the fault strike direction and "dip separation" in the fault dip direction. Note that the value of the strike slip and strike separation are different (Fig. 1). SSD construction needs to quantify "stratigraphic separation" as the perpendicular distance between two parts of one disrupted bed surface. Knowing the local stratigraphic scale, we can easily determine the stratigraphic separation combining the stratigraphic levels of both fault walls.

Stratigraphy separation diagrams

SSDs plot the stratigraphic level of both fault walls against the distance along the fault surface (Woodward, 1987; Wilkerson *et al.*, 2002; among others). In this way, the two lines in the diagram represent the stratigraphic levels of two fault walls. There are two possibilities for their relative position: if the line representing the stratigraphic level of the hanging wall is situated above the footwall line, there is a clear stratigraphic gap in the SSD (Fig. 2a) and, vice versa, if the footwall line is above the hanging wall, there is stratigraphic duplication along the fault (Fig. 2b).

After SSD construction, we can interpret the fault geometry. A constant value of stratigraphic separation between fault walls is typical for translatory fault blocks (Figs. 3a and 3c). Sudden changes in stratigraphic levels identically affect both lines in SSD and indicate cutting by younger transversal fault (Fig. 3b). Parallel waves on lines in SSD mark older folds cut by the fault under study (Fig. 3c). It is significant that synclines are represented by convex arches (upward) and anticlines by concave ones (downward). Completely different patterns in SSD are produced by faults with flat-ramp-flat geometry. Typical steps (ramps) appear in a distinct position on both fault wall lines, while long horizontal sections mark flats (décollements). Recognition of various ramp types has been discussed by Wilkerson *et al.* (2002).

Examples

The Barrandian, the area under study, is situated in central Bohemia, Czech Republic. Since the early 18th century, paleontologists have focused their interest on this area because of the large number of localities rich in fossils. The result of this intensive paleontological research is that we have at our disposal detailed stratigraphy and good stratigraphic maps of this area. Two faults under study (the

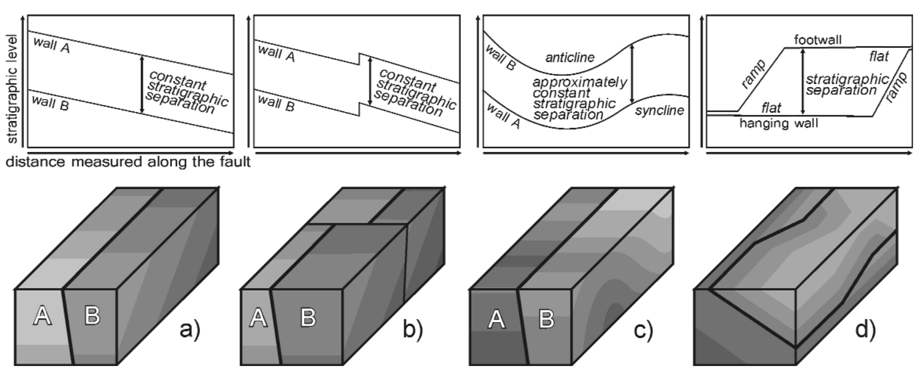


Figure 3. Interpretation of different patterns in stratigraphy separation diagrams: (a) translatory block fault, (b) old translatory block fault cut by younger transversal fault, (c) translatory block fault crosscutting older fold structure, (d) thrust fault with flat-ramp-flat-geometry.

Prague and the Tachlovice faults) crosscut the northeastern limb of the large Prague Synform, which consists of Lower Paleozoic sediments (Ordovician to Devonian) and which was formed during the Variscan Orogeny (Fig. 4). The faults under consideration are almost parallel and strike in an ENE-WSW direction. Two oblique, but practically longitudinal SSDs were constructed using detailed geological maps to show the geometry of the fault surfaces (Fig. 5).

The Prague Fault was described as early as the 19th century by Krejci and Feistmantel (1885) because of the eye-catching stratigraphic separation along it. It is at least 60 km in length, dipping nearly vertically in the solitary outcrop. As the Prague Fault seems to be younger than thrusts (e.g. Tachlovice Fault, Ockov Fault), we use tectonostratigraphic levels for SSD construction instead of true stratigraphic ones. SSD shows waves with nearly constant stratigraphic separation along the greater part of the fault (~1600 m), which is typical for block faults crosscutting older folds. Considering stratigraphic separation, vertical fault striation and average inclination of bedding (~40°), the net slip along the Prague Fault could be estimated to be approximately 2500 m. The middle blocks situated a fixed stratigraphic distance from marginal walls indicate two-stage movement along the fault. One part of the fault in the Rudna surroundings is distinct from the considered pattern. Variable stratigraphic separation recognized here is still problematic. It may be interpreted as a zone of intersection with another, still unknown fault.

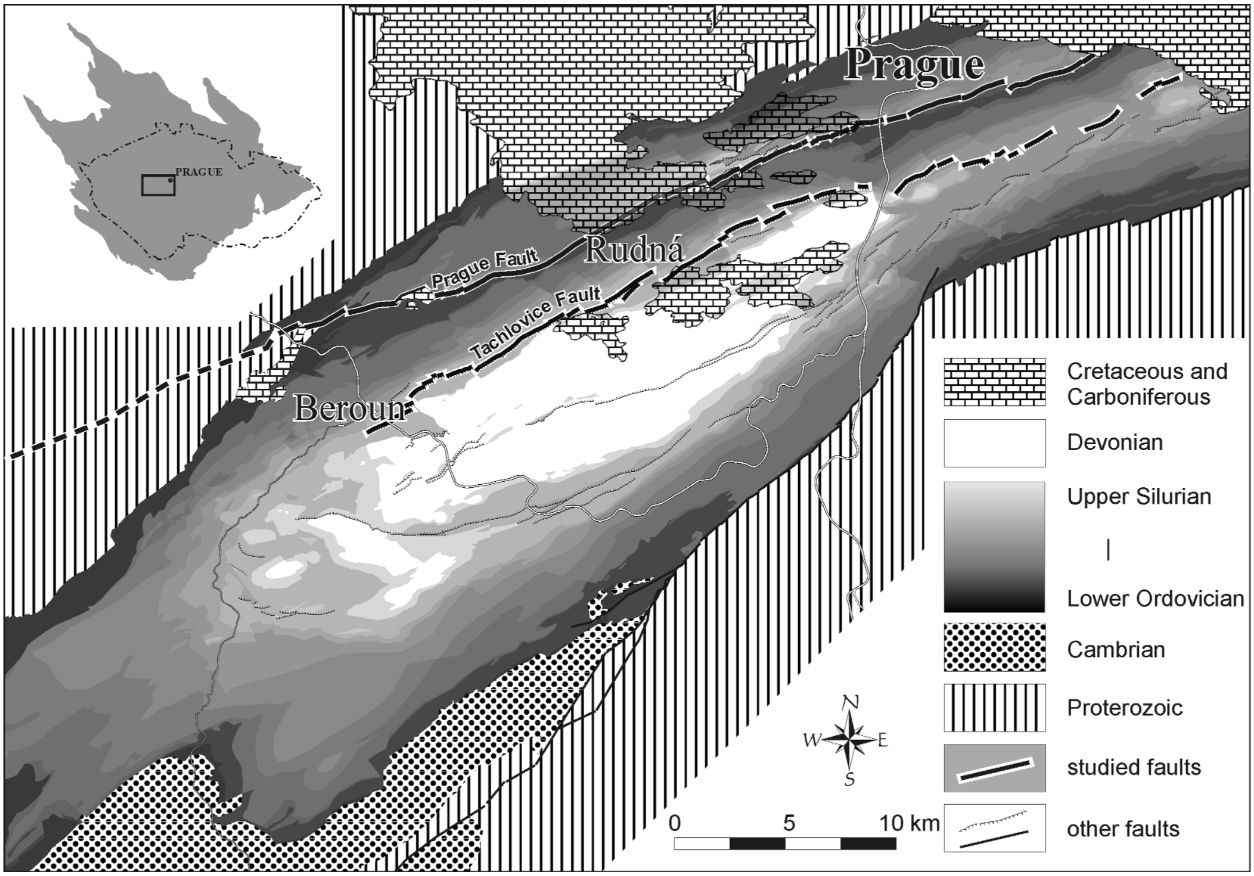
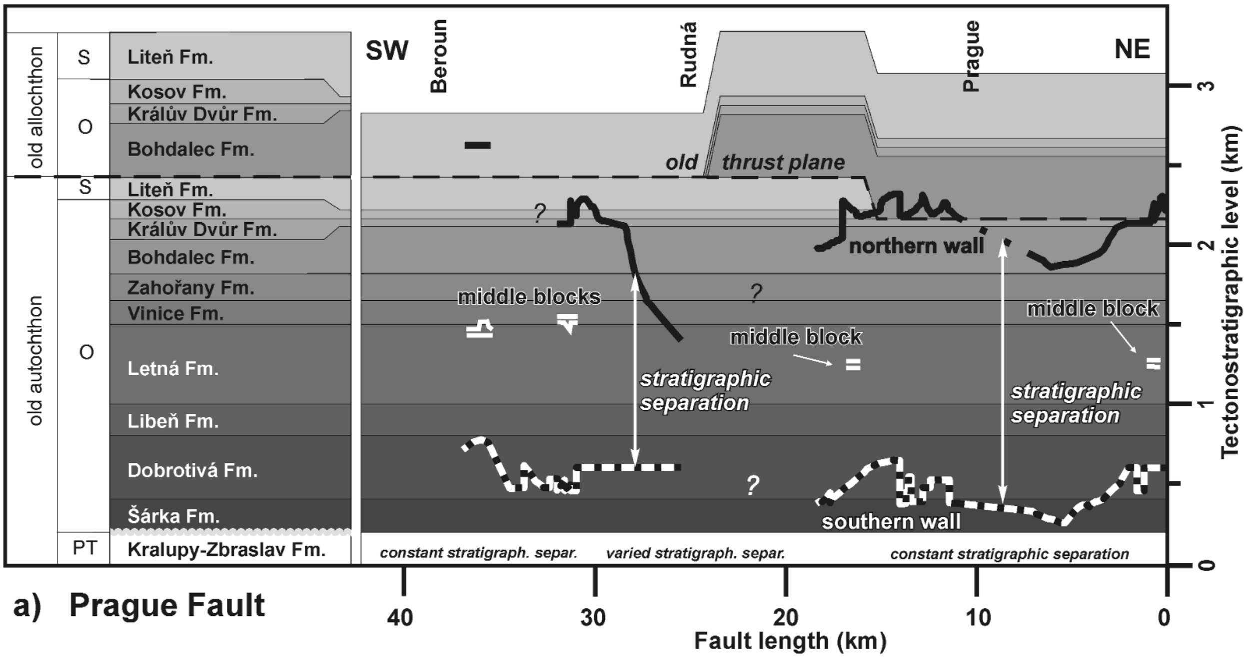


Figure 4. Schematic map of the Prague Synform with the two faults under study.

The Tachlovice Fault defined by Svoboda and Prantl (1948) is the second fault under study. This fault is at least 40 km long in strike and dips moderately to the SE. SSD shows the Tachlovice Fault as a typical thrust fault with flat-ramp-flat geometry (Fig. 5), which is in contradiction to its previous interpretation as a synsedimentary fault (Chlupac *et al.*, 1998). Flats of hanging wall are situated in the Silurian Liten Fm (black shales) in the SW part and in the Ordovician Bohdalec Fm (gray shales) in the northeastern part.



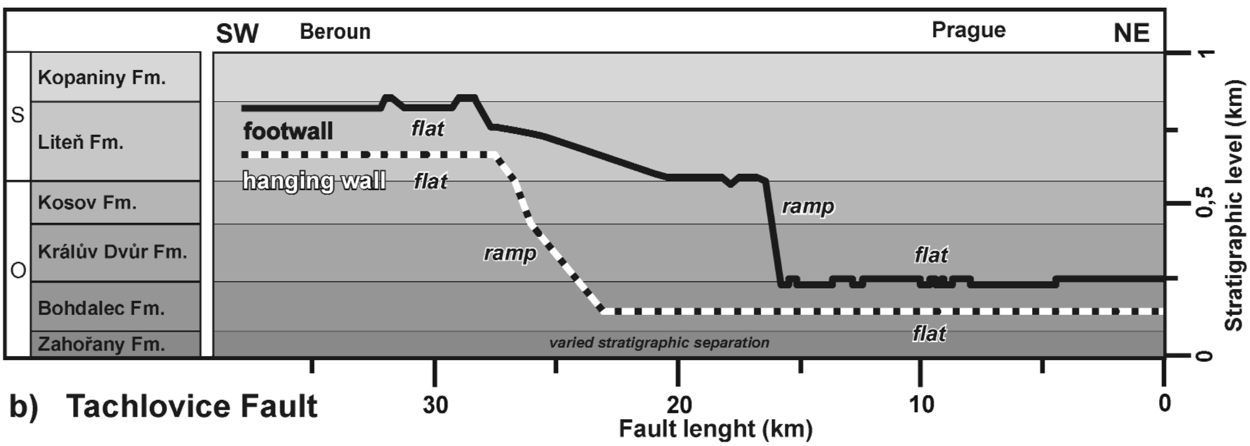


Figure 5. Stratigraphy separation diagrams of the Prague Fault (a) and the Tachlovice Fault (b). Key: PT: Proterozoic, O: Ordovician, S: Silurian.

Ramps intersect Kosov (sandstones) and adjacent formations (approximately 400 m in thickness for a distance of less than 5 km). The footwall displays a very similar pattern but one flat in the northeastern part is set to Kraluv Dvur Fm (gray shales) instead of to a hanging wall of lower Bohdalec Fm.

Conclusions

Although both the Prague and the Tachlovice faults seem to be of the same nature (the same strike, remarkable stratigraphic separation, similar localization in the Prague Synform), the SSDs of the faults demonstrate different features of fault surface geometry and consequently very distinct mechanisms of origin. The Tachlovice Fault is one of the main thrusts in the Prague Synform with flat-ramp-flat geometry producing fault-related folding while the Prague Fault was formed later, after folding, and belongs to a group of block translatory faults. Consequently, stratigraphic separation diagrams demonstrate their applicability and effectiveness as tools for the tectonic analysis of faults. Detailed stratigraphy and good geological maps are important requirements for the use of SSDs, but when these are available, this method is economical, simple and effective. We could even say, amazing.

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