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Compression along faults: example from the Bohemian Cretaceous Basin

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Abstract

Effects of horizontal north-south compression of Paleogene age have been found near significant fault lines in sedimentary rocks of the Bohemian Cretaceous Basin. Stress orientation, time relations and similarities with other areas of the Alpine foreland point to direct manifestations of tectonic processes in the Alpine-Carpathian orogenic belt.

Introduction

Hitherto, the majority of faults disturbing sediments in the Bohemian Cretaceous Basin was assumed to represent normal faults and hence even the Saxonian tectonics was considered as a tensional one. Developments in analytical methods investigating slickenside features (Arthaud, 1969; Angelier, Mechler, 1977; Angelier et al., 1982) allowed a more profound treatment of Post-Cretaceous tectonic events in the area in question.

Suitable area for this method is offered by the surroundings of the Lužice Fault. Frequent silicification of Cretaceous sandstone related with tectonic movements preserved frequently slickensides in the area. Similar conditions are near the Středohorský Fault around Česká Lípa, Dubá and Mšeno.

Paleostress orientation analysis along the Lužice Fault in Elbsandsteingebirge Mts., GDR

The Lužice Fault represents a reverse block fault tracing from the Ještěd Mts. foothill to Dresden (Klein, Soukup, 1963). Granite of the Lužice Massif in the Elbsandsteingebirge Mts. is thrown upon Cretaceous sediments along a fault plane tracing the Kirnitzsch river valley toward Hohenstein. Cretaceous sediments southerly from the fault are cropping out in stratigraphic range from the Lower Turonian to Coniacian being mostly represented by the facies of quartz "ashlar" sandstone with argillaceous sandstone intercalations or conglomerate layers (Fig. 1).

In the near surroundings of the fault a zone of several tens to hundreds of meters developed consisting of heavily jointed sandstone containing great amount of silicified belts and siliceous tectonic polishes (Fig. 1). According to Seifert (1932), this is a crushed and subsequently cemented zone made of clasts near the fault planes. The displacement attains here some 400 m (Wagenbreth, 1967). A summarizing result of slickenside surface analysis using methods of Angelier, Mechler (1977) and Angelier et al. (1982) along the Lužice Fault (Lichtenheiner Mühle, Kuhstall) is represented in fig. 2 a. The main component σ_1 of the strain generating the reverse fault had N—S to NNE—SSW orientation. In the dislocation zone itself, the most frequent slickenside orientations are those dipping under medium angles to N as well as antithetic ones dipping under medium angles to S.

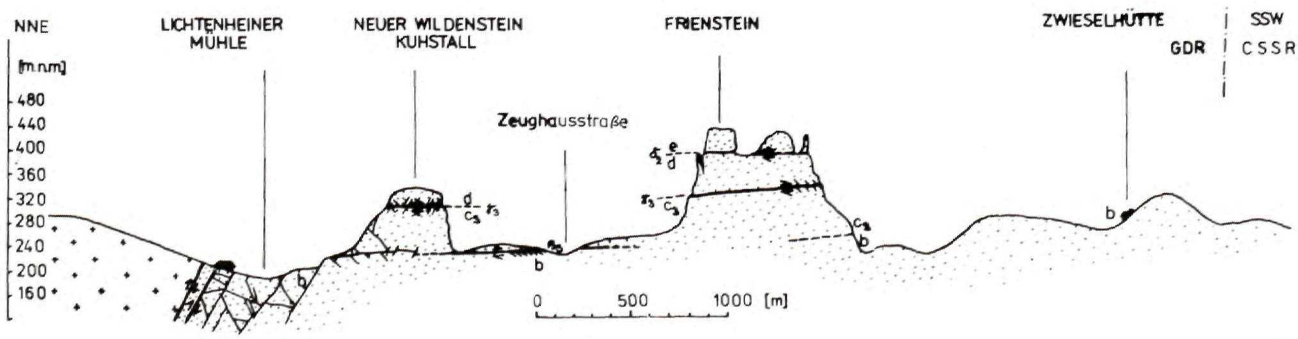

Fig. 1. Geological profile of the Elbsandsteingebirge Mts. between Lichtenheiner Mühle and eastern surroundings of Schmilka (Bad Schandau area).

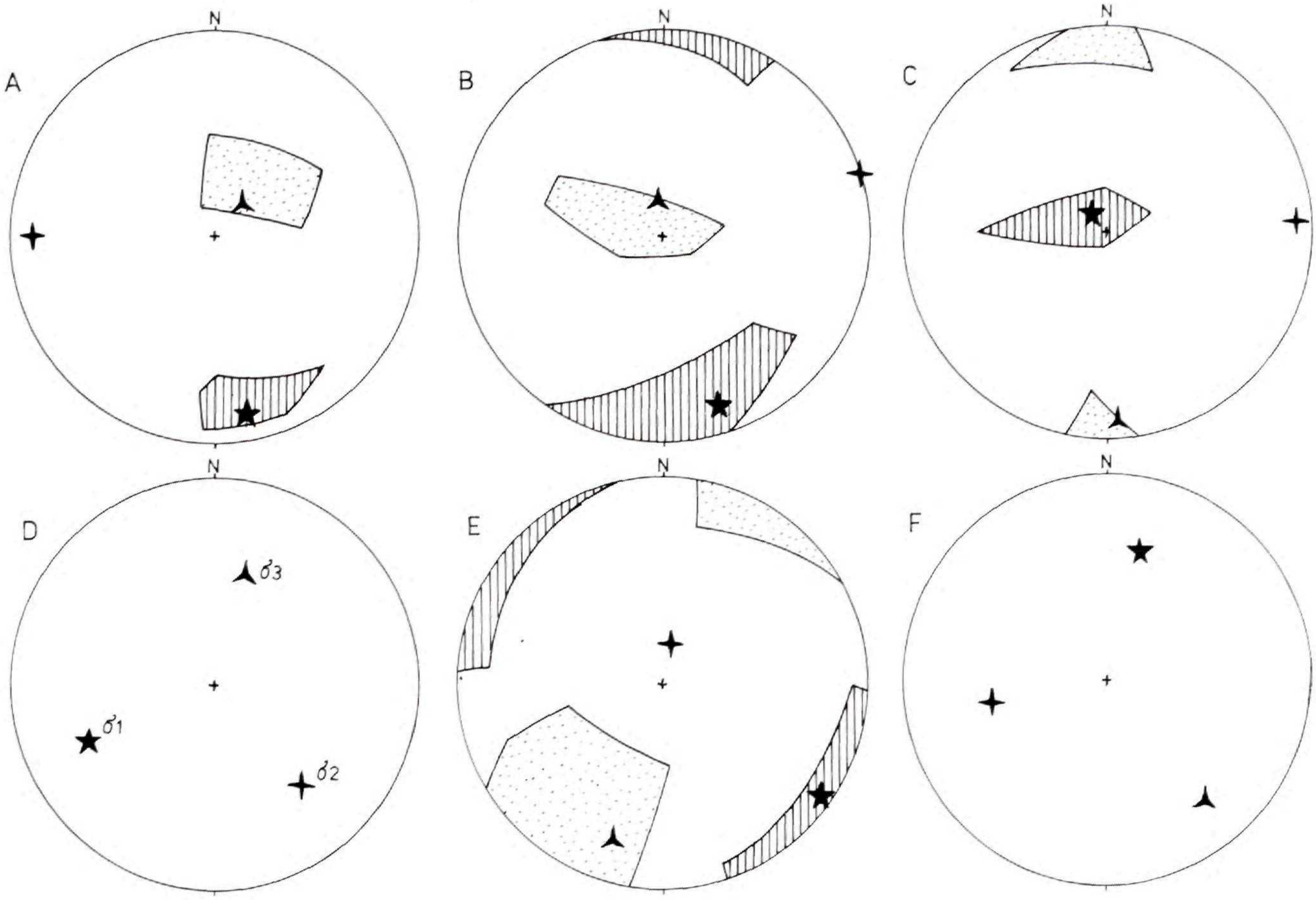

Fig. 2. Orientation of main axes of stress tensor in central parts of the Bohemian Cretaceous Basin. A — Lichtenheiner Mühle. B — Suché skály (α). C — Suché skály (β). D — Suché skály (γ). E — Suché skály (δ). F — Schneideberg near Dubá.

The frequency of such surfaces decreases with the growing distance from the fault and silicification preserves only along surfaces running parallel to bedding planes and the immediate surroundings. The N—S compression related with reverse faulting resulted here in shift-faulting within horizontally bedded sandstone (Fig. 1). Thrust surfaces generated along mechanically weaker intercalations with higher clay contents or in pronouncedly different mechanical texture than the surrounding rocks. These surfaces are separating several tens of meters thick quartz arenite layers devoid of deformational traces. The amount of displacement was not stated. Frequent and even silicified Riedel's shear surfaces point to the motion of the hanging wall to the south.

The Elbsandsteingebirge Mts. are characterized by the presence of so called "ashlar" jointing i. e. by two mutually perpendicular joint systems of subvertical orientation. Their orientations are almost the same in the entire area. The N—S trending joints are frequently open tension gashes whereas the E—W trending ones are more closed and, near to the thrust planes, point to connections with Riedel's shear surfaces. Probably, also the joint system developed here as the result of the same compression.

Effects of compressional tectonic phase along the Lužice Fault have already been studied in the Elbsandsteingebirge area (Seifert, 1932). The analysis of nivelled surfaces preceeding basalt eruptions disclosed the earlier age of reverse faults than is the age of basalt bodies (Wagenbreth, 1967). A subsequent tensional phase caused there only small normal faulting in the northerly blocks.

Paleostress orientation analysis of the eastern Lužice Fault along the margin of the Bohemian Cretaceous Basin between Malá Skála and Rovensko p. T.

The oldermost structural element in the area is a flexure creating margin to the Bohemian Cretaceous Basin between Malá Skála and Rovensko pod Troskami (Fig. 3a). The Korycany sandstone reveals here dips between 20°—40° and the middle limb of the flexure is sheared along with the upthrow of the NE block. The dip angle gradually increases and its orientations change northerly from Koberovy. Coin-

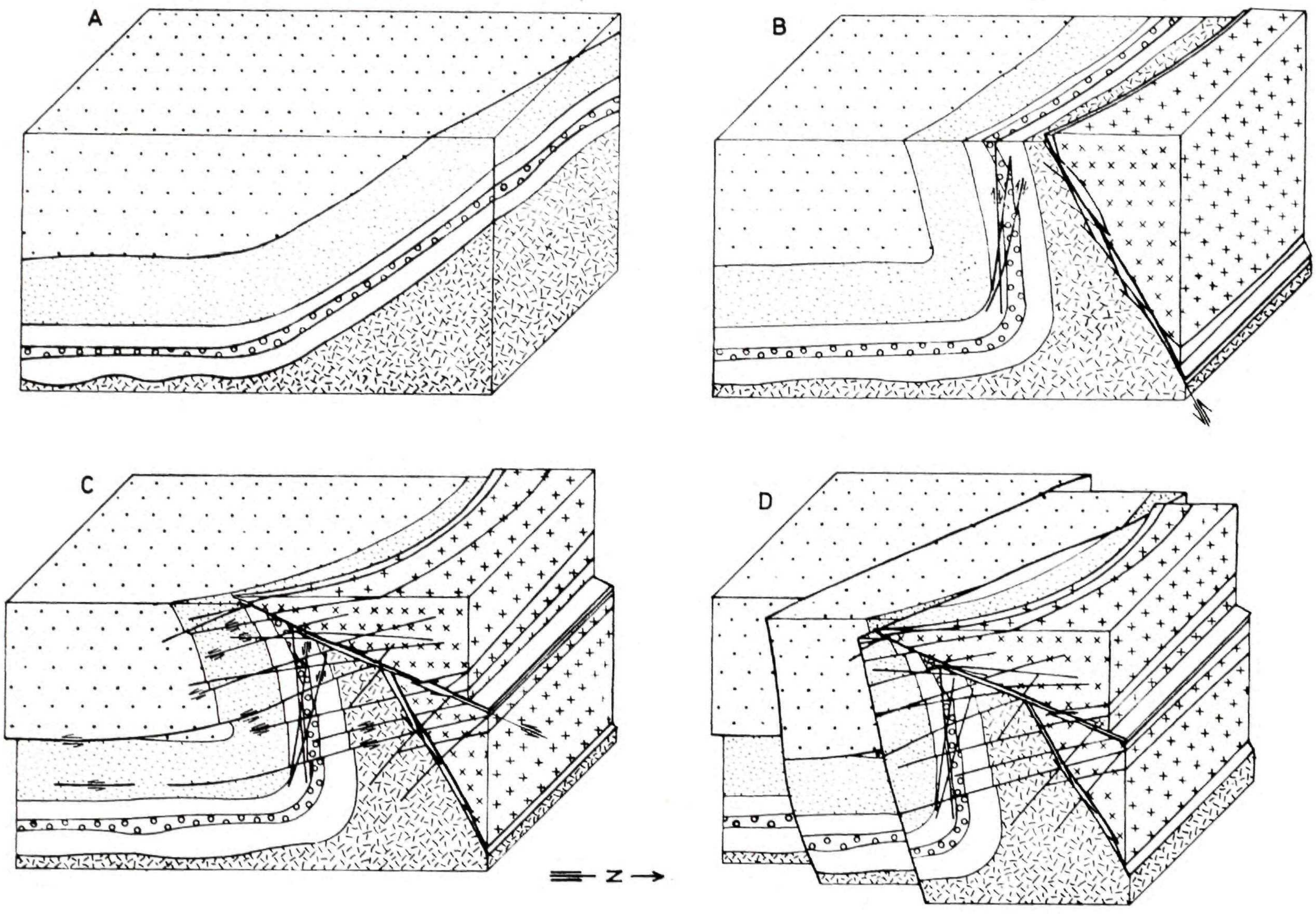

Fig. 3. Structural development of the margin of the Bohemian Cretaceous Basin near Malá Skála. A — flexure stage, B — phase α, C — phase β, D — phase δ of north-eastern segment.

cidence of both features indicates a common source what is the influence of the Lužice Fault running in about 300 m distance (Coubal, 1989).

Structures of the Cretaceous along the Lužice Fault are well expressed e. g. in the Suché skály area NE from Turnov. Slickenside analysis revealed in this area the following partial tectonic events:

Phase α. Gradual approaching of the flexure and the Lužice Fault results in the rearrangement of bedding planes from average 230/30 into 355/50 (dip plane orientation and angle) within the immediate surroundings of the Lužice Fault. The feature points to the upthrow of the northern block along the fault plane dipping under medium angle to the N. Slickenside analysis of the phase (Fig. 2b) revealed subhorizontal N—S compression and the resulting reverse fault induced dragging of beds in the footwall (Fig. 3b). During increasing bending of single beds a creep developed along bedding surfaces together with shearing of the southerly blocks with the compressed nucleus of the bending (Fig. 3b).

Phase β. During the next phase the σ_1 and σ_3 strains became inversed (Fig. 2c). Upthrow of the northerly block along low angle surface occurred along the Lužice Fault (Fig. 3c). The phase appeared within Korycany sandstone by development of dense Riedel's shear surfaces represented by southerly dipping low-angle silicified zones and tectonic polishes crossing obliquely to normally to the erected bedding surfaces. In subhorizontaly lying Middle Turonian to Coniacian sediments (Jizera and Břežany Fms.) this phase resulted in southward shift-faulting affecting few kilometres from the fault. Thrust surfaces there are also silicified and related with Riedel's shear surfaces (e. g. the Sokol hill).

Southerly from the Lužice Fault the margin of the Bohemian Cretaceous Basin gradually deviates and also the influence of related tectonic phases α and β gradually disappear. A more distinct further phase may be revealed by slickenside analysis in the Suché skály area.

Phase γ. The maximum strain component is dipping at various angles to SW and the minimum one to NNE (Fig. 2d). Mostly faults of NE—SW to ENE—WSW strike became activated in this phase as oblique slip faults with transversal segmentation of the Cenomanian sandstone belt along the NE margin of the Bohemian Cretaceous Basin. The largest shift attaining 1 km occurred along the Kozákov Fault.

Phase δ. The Malá Skála area together with the southerly rock tower areas (e. g. the Klokočské skály) are deformed by high-angle faults trending NNW—SSE and inducing horizontal slips (Fig. 3d). Strain orientation is indicated by fig. 2e. The faults running roughly parallel to the Bohemian Cretaceous Basin margin obliquely dissect the structures originated during phases α and β within the Malá skála area. Mutual relations of phases γ and δ are difficult to establish however boths are subsequent to α and β ones (Coubal, 1989).

Paleostress orientation analysis along the Středohorský Fault in wider surroundings of Česká Lípa and Dubá

A thrust of Coniacian sandstone over flyschoid facies of the same age was uncovered in Lasvice village near Zákupy. Movement striae on polishes do not occur there but the frequent Riedel's shear surfaces and dragging of beds near the fault indicate N—S transport direction of the hanging wall. Similar deformations are present in excavations at the northern margin of Česká Lípa. Within an about 100 m broad zone, low-angle thrust planes are strongly folded by folds attaining several tens of metres size with limbs dipping by up to 70°. The N—S trending fold axes show E—W orientation of the principal stress during this late phase.

Subhorizontal polishes are preserved near to the stratigraphic top of the Jizera sandstone in several dm thick silicified belts parallel to bedding surfaces on the Schneideberg hill E from Dubá or on the Bezvel hill near Katusice. Slickensides on polishes reveal N—S to NW—SE orientation and the respective principal stress attitudes are represented by fig. 2f. Frequent crushed zones of subhorizontal orientation are mentioned together with polishes by Doležal (1976) from drillings into Cretaceous sediments of the Strážský block unit.

Discussion

Post-Cretaceous space reduction of the basin is also evidenced by deuteric bending of flexure orientation creating the northeastern margin of the Bohemian Cretaceous Basin between Rovensko pod Troskami and Koberovy. This rearrangement of orientation changed the original NW—SE trend into a WNW—ESE one. Further deformation phases are superponed over this first one. Deformations reflecting an E—W principal stress orientation could be discerned near Česká Lípa, Malá Skála, Mochov and elsewhere. Even a tension phase showing NE—SW orientation of the relative tension manifested in the central parts of the Bohemian Cretaceous Basin.

The lack of younger sediments hinders more accurate geological dating of the N—S compressional phase. With respect to the lack of respective deformations within young volcanic bodies of the Elbsandsteingebirge Mts. or near Dubá, the relative

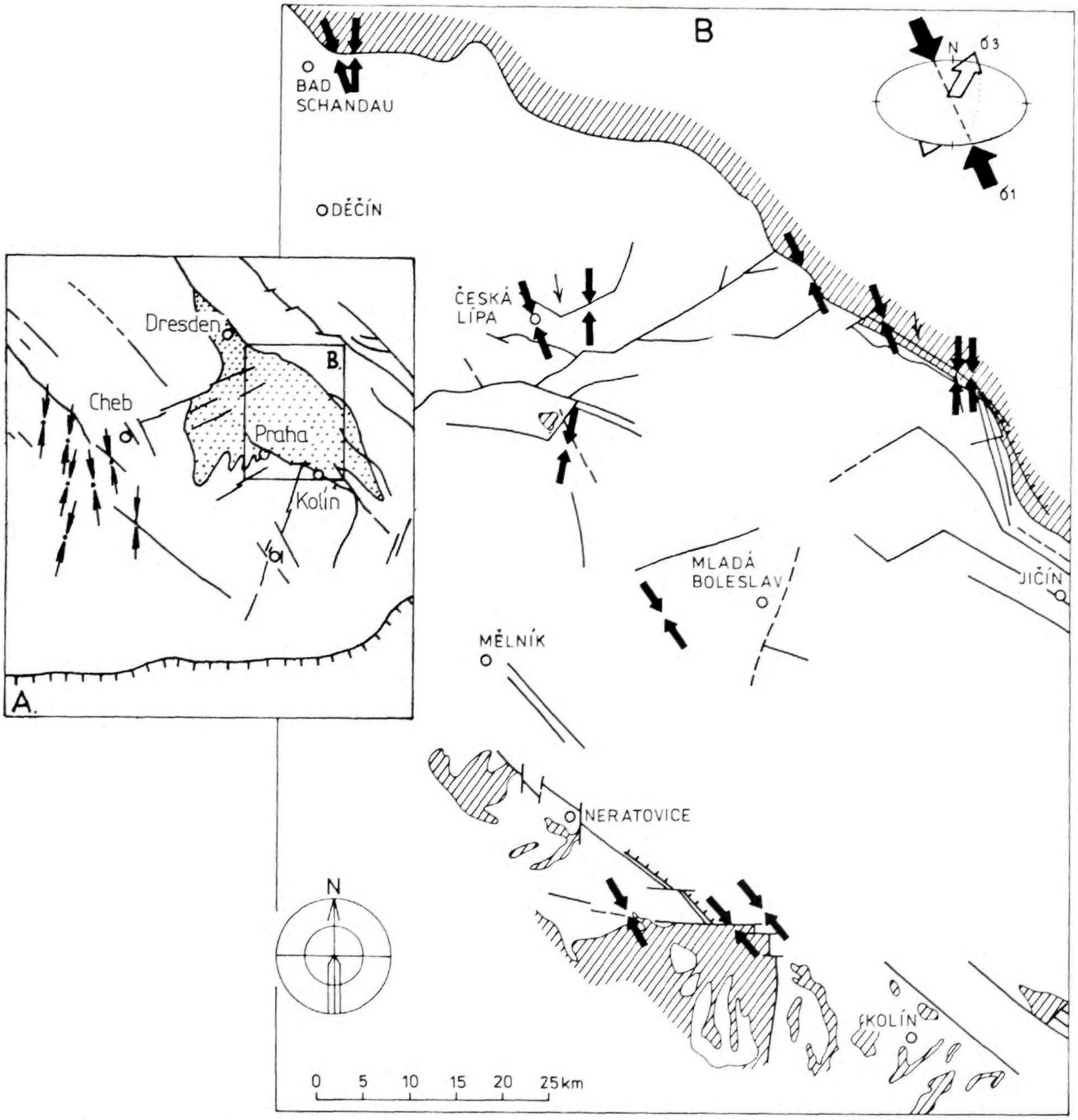

Fig. 4. Reconstruction of principal stress orientations. A — Upper Eocene along the western margin of the Bohemian Massif (according to Bergerat, 1987), B — during phase in the central part of the Bohemian Cretaceous Basin.

age is about Paleogene. Mutual interactions of tectonic events within the Alpine-Carpathian orogenic belt and its foreland have been already postulated and chronologically compared by Malkovský (1971). Bergerat (1987) submitted reconstructions of paleostress orientations for the Alpine foreland between the Pyrenees and the Bohemian Massif. The phase of N—S compression is assumed by her as one of the most important deformations dated Upper Eocene. The respective age is Middle Paleocene to Lower Eocene according to Ziegler (1987). Eocene to Lower Oligocene compression in the Alpine foreland representing the Pyrenean phase has been postulated by Roth and Procházková (1988).

Effects of N—S compression discovered in the central part of the Bohemian Cretaceous Basin may be interpreted as proof of tectonic processes in the Alpine-Carpathian orogenic belt influencing the foreland made of the Bohemian Massif.

Conclusion

Tectonic features indicating strong N—S compression in certain stages of Saxonian tectonics are preserved in many places in central parts of the Bohemian Cretaceous Basin (Fig. 4). The principal stress orientation is in most localities a horizontal one. Detailed investigations into deformations along the Lužice Fault in the Malá Skála area disclosed that this tectonic process was composed of several subsequent partial events. Compression mainly manifested along large faults of E—W and NE—SE strike, where the tectonically weakened basement did not retain the acting strain. Cretaceous sediments in the near vicinity of faults have been dissected by thrusts whereas in distances reaching several kilometers the more competent rocks underwent shift-faulting due to the N—S space reductions.

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