Variscan shearing tectonics in the Bohemian Massif

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Abstract

Between Bretonian and Asturian phases by Stille bracketed Variscan (Hercynian) shearing in the Bohemian Massif mossaic of terraines is considered as a result of the dextral lateral movement of the Fenosarmatia and Baltica with respect to Africa. The estimated throw for the Bohemian Masif is approximatelly 400 km and the compatibility of the movement for the whole massif was reached through two principal kinematic events: 1) Sinistral shear on NE-SW strike-slips (Bretonian phase) and 2) dextral shear on the NE-SW strike-slip (Asturian phase). The first event was accompanied by the mafic and ultramafic rock intrusions and leucogranulitic melt generation. The second event preceded and was accompanied by granite batholites intrusions. It is corelated with Culmian basin opening.

Introduction

Use of the stretching lineation and foliation plane attitudes together with their correlation with the geophysical and geological data in the Bohemian Massif (Svoboda et al., 1966) led to the delimitation of the principal shear zones as featured in Fig. 1. The Bohemian Massif is divided by them into a mossaic of blocks with different type of internal deformation corresponding to transpression and/or transtension. Following the fault displacement and the thickness of the shear zone the most important ductile strike-slips are: 1. Bavarian shear zone of the NW-SE direction (BSZ), 2. Elbe-Oder shear zone, NW—SE (ESZ), 3. Moravian shear zone, NNE—SSW (MSZ), 4. Erbendorf-Ohře (Eger) shear zone, ENE—WSW (EOSZ), 5. Central Bohemian shear zone, NE—SW (CBSZ).

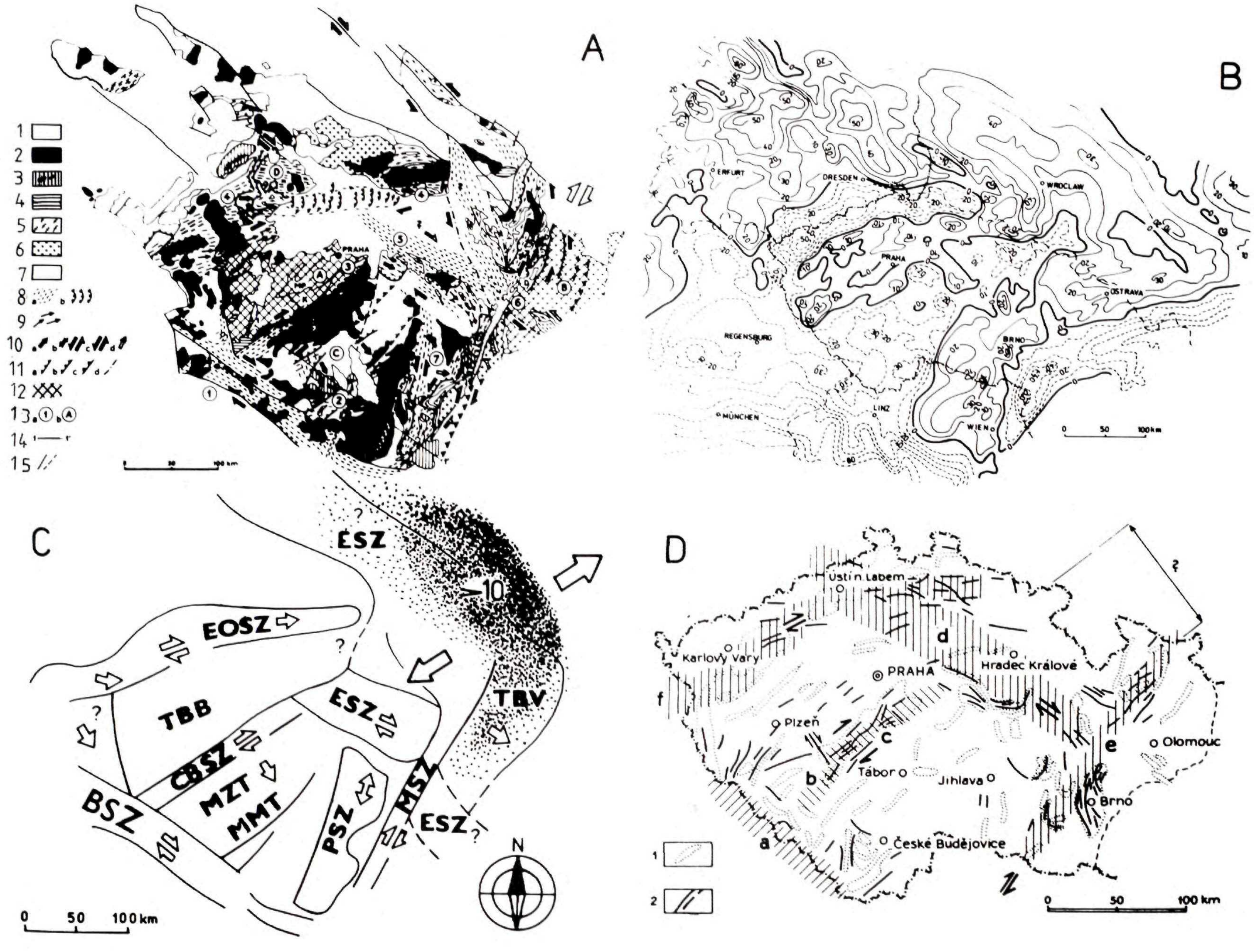
The Central Bohemian and the Erbendorf-Ohře shear zones limit from the SE and NW the transpressional block of Bohemicum. The Moravian shear zone (after the Morava river) delimitates from W the transpressional block with Panafrican basement called here as the Brunovistulian block after the Brunovistulicum by Dudek (1980). The Moldanubian block bounded from all sides by strike-slips is segmented by inner shear zones of strike-slip, thrust and/or normal fault geometries from which the Moldanubian Main thrust seems to be the most im ortant (Rajlich et al., 1986).

Structures in the wrench zones

Beside the inner transpressional and/or transtensional deformation of the inner part of blocks and/or terrains (Matte, Rajlich, 1988), the structure of the ductile strike-slips and/or wrench zones has particular features such as the development of structural fans (positives or negatives) in the function when the inner deformation of the wrench zone was of the transpressional and/or transtensional character. Thrusts moving paralelly with the strike-slips along flat décollement planes are also common (Fig. 3) and are represented for instance by the Svratka dome thrusts. The thrusting could occur also perpendicularly to the strike-slip trend as it is exemplified by the Eastern border of the Culmian basin in the Moravian shear zone (Fig. 4). These structures were modelled by Emmons (1967) and bear the common name structural fans, flower or palm-tree structures (Ramsay and Huber , 1987). The strongest ductile deformation occur in the places where the level of the flat décollements planes which compensated the strike-slip fault movement on the surface occur (Woodcock, Fisher, 1986) and were exhumed in crustal boudinage-like formes, such as the Kutná Hora crystalline, with pencil gneisses. This development was schematically summarized in Fig. 3. The principal characteristics of the above mentionned shear zones are summarized in Table 1 and more detailed characteristics are published by Rajlich (1987 a, b, c).

Crustal extension

Crustal boudinage (Malavieille, 1987) is a particular feature of several areas and the crystalline cores such as the Desná and Keprník domes represent the best example (Becke, Schuster, 1887), where the Panafrican boudinaged crust is rised among the Devonian and Culmian strata. This occurred through the extensional — normal faulting tectonics on the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TAB. 1
Characteristics of the principal shear zones of the Bohemian Massif

Name	Lenght (km)	Width (km)	Direction	Shear sense indicators	Estimated offset (method)	Metamorphic grade	Accompanying tectonic style
Bavarian shear zone	500	40	NW-SE	D-oblique folds, bent of Kaplice-Rožumberk Group	D 100 km (comparison with Elbe zone)	Amphibolite facies	Uniformly oriented foliations
Elbe-Oder shear zone	500	60	NW-SE	D-displacement of magnetic anomalies S-metamorphic pull--apart domes (Kutná Hora crystalline)	D 120 km — displacement of the NE-SW belt of magnetic anomalies	Upper amphibolite facies	Imbricate structures in flancs, metamorphic pull-apart domes
Moravian shear zone	350	20	NNE-SSW	D-transpression of the Culmian basin, asymmetric structures S-metamorphic pull--apart domes with ENE-WSW stretching lineation	D 100 km, strain analysis, reoriented folds	Amphibolite and granulite facies	Thrusts parallel and perpendicular to the shear zone trend, metamorphic pull-apart domes and sedimentary basins
Erbendorf-Ohře (Eger) shear zone	350	20—30	ENE--WSW	D-transpression of Bohemicum terrane,	D 90 km, offsetting of Elbe shear zone	Amphibolite facies	Imbricate structures in flancs
Central Bohemian shear zone	150	15—20	NE-SW	D-transpression of Bohemicum terrane, asymmetric structures, E-W minette dykes S — ENE-WSW obliques folds of Barrandian, N-S diabase dykes	D 100 km, strain data, mylonitization	Amphibolite facies	Tectonic fan, syntectonic granite intrusion

D — dextral shear sens, S — sinistral shear sens

flancs of domes (Rajlich et al., 1989), Fig. 5, which are formed of the upper-not uniformly stretched Proterozoic crust (1 400—590 m. y. U-Pb age of the Keprník orthogneiss, van Breemen et al., 1982).

The crustal extension is also a particular feature of the development of the Bohemian Massif in later Variscan stage. The important extension which amounts up to 130 % of the original width was found in the Moravian shear zone (Fig. 4) and up to 120% and more stretching can be supposed in the extended area of the Moldanubian and Central Bohemian plutons (Fig. 2). The granite intrusions are directly related to this phase as it can be deduced from the small scale tectonic structures related to migmatization (Rajlich et al., 1986) and/or deformation of the Low Paleozoic-Upper Proterozoic granites (Klečka et al., 1986). The model of Wickham and Oxburgh (1985) for the rift setting of the metamorphism can be evoked here and the granites were probably created through the fusion inside the principal — extensional décollement plane (Fig. 6).

Chronology of the principal Variscan kinematic events

Comparing shearing sense, geochronology of metamorphism (van Breemen et al., 1982; Maluski.

◀ Fig. 1. A — Principal shear zones of the Bohemian Massif (Rajlich, 1987 a, b). 1 — platform cover, 2 — Variscan granites, 3 — granulites with inclusions of ultramaphic rocks, 4 — larger bodies of maphic and ultramaphic rocks, 5 — orthogneisses, 6 — Cadomian granites, 7 — domains of the Variscan tectogenesis, 8a — stretching lineation attitude, 8b — thrusts hidden under platform cover, 9 — direction and sense of tectonic transport in imbricate zones, 10a — direction of tectonical transport in larger thrusted units, 10b — strike-slip sense in wrench shear zones — Westphalian stage, 10c — strike-slip sense in Givetian phase of shearing, 10d — thrust sense in the early Variscan (Givetian?) stage of shearing, 11a — thrusts, 11b — thrusts inferred from the geophysical study, 11c — early Variscan thrusts, 11d — limit between NW — SE and N-S stretching lineation attitude on the junction of Elbe and Moravian shear zones. B — Generalized gravity map of Central Europe (Imbrmajer, 1981). C — Areal delimitation of the principal shear zones and blocks (terraines) of the Bohemian Massif, dotted — area of intense Devonian and Culmian subsidence. D — Magnetic anomaly map (Šalanský, 1983) with shear sense on the most important shear zones, a — Bavarian shear zone, b, c — Central Bohemian shear zone, d — Elbe shear zone, e — Moravian shear zone, f — Erbendorf-Ohře (Eger) shear zone. The interrogation mark denotes the displacement of maphic rocks (magnetic anomalies, Bernard et al., 1983; Krs, 1988) in the Bohemian Massif.

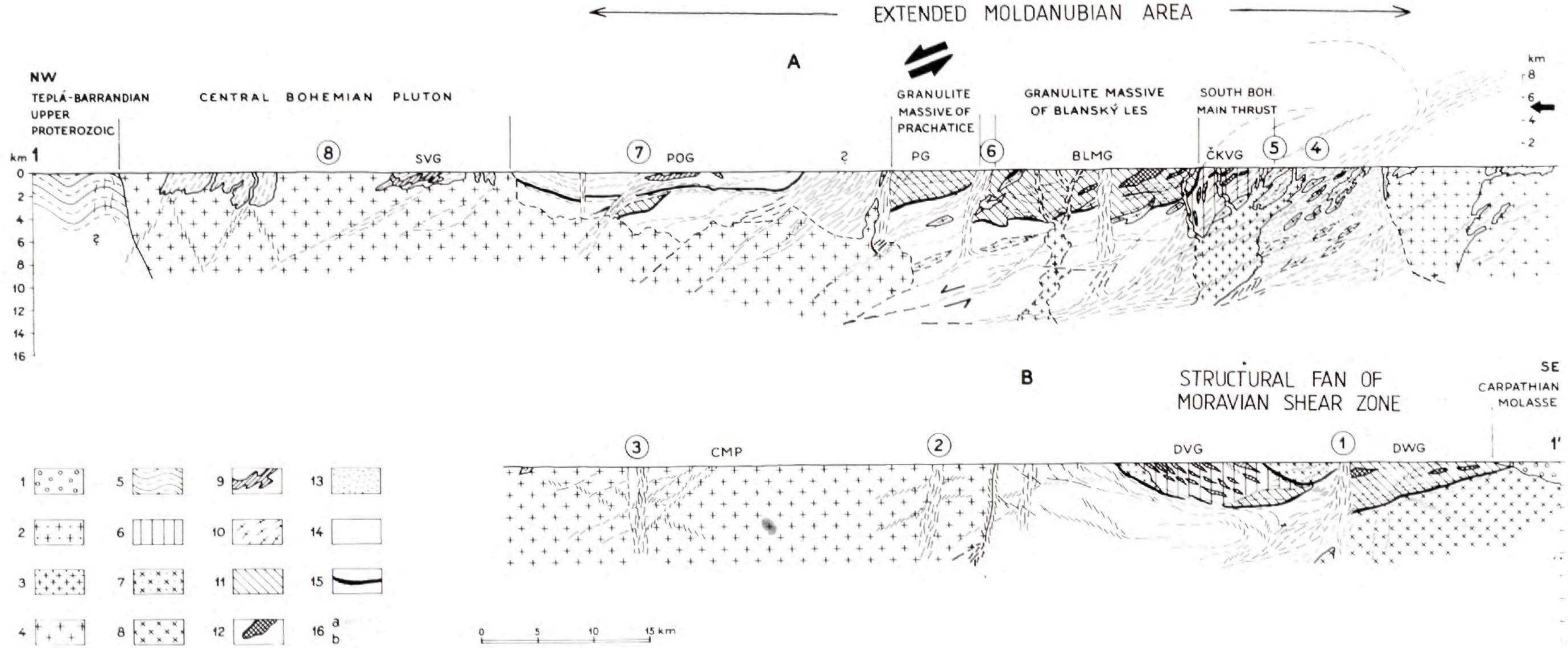

Fig. 2. Cross-section through the Moldanubian area: 1 — sediments of the Carpathian molasse, 2 — Mrákotín type (331 m. y. $^{39}Ar/^{40}Ar$, Maluski, unpublished data) granite of the Central Moldanubian pluton, 3 — Variscan granites and aplites, often sheared (304 m. y., U-Pb dating, Wendt et al., 1988), 4 — granites of the Main Variscan intrusive phase (330 m. y., van Breemen et al., 1982), 5 — folded Upper Proterozoic sediments, 6 — paragneisses with varied intercalations, 7 — Biteš orthogneiss, 8 — Brno, Upper Cadomian granite massif, 9 — presumably Paleozoic limestones, 10 — orthogneisses, 11 — granulites (370—340 m. y., U-Pb see text), 12 — ultramaphic inclusions in the granulites, 13 — retrogressed rocks and muscovitization, 14 — pre Variscan metamorphites (1 800 m. y.?), 15 — assumed principal décollement plane of the early Variscan thrusts, 16 a, b — Variscan shear zones. Numbers in circles: 1 — Moravian shear zone, 2 — Přibyslav shear zone, 3 — inner shear zones of the Central Moldanubian pluton, 4 — Kaplice-Rožumberk unit of retrogressed rocks in the Main Moldanubian thrust, 5 — main thrust plane of Moldanubian thrust, 6 — Lhenice shear zone, 7 — Protivín shear zone, 8 — Central Bohemian shear belt, SVG — Sušice Varied Group, POG — Podolsko Varied Group, ČKVG — Český Krumlov Varied Group, CMP — Central Moldanubian pluton, DVG — Diendorfer Varied Group, DWG — Dunkelsteiner Wald granulite.

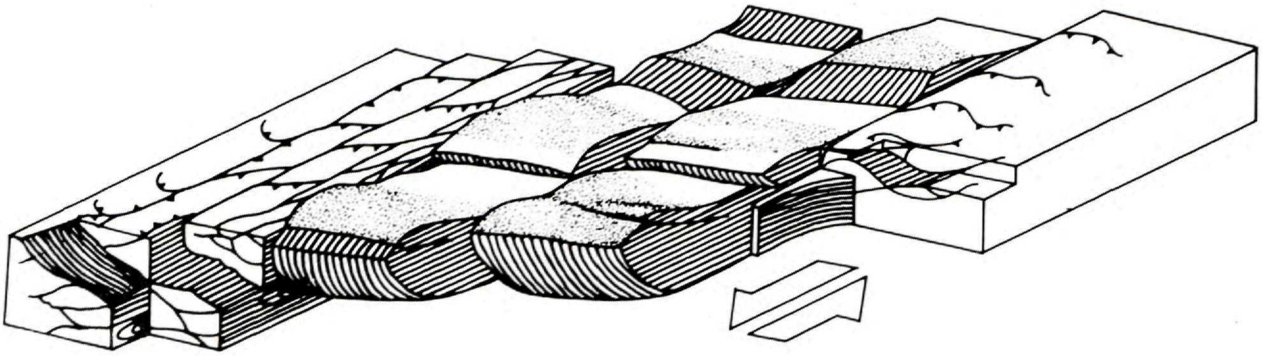

Fig. 3. Cartoon summarizing the tectonic style of strike-slip and/or wrench tectonic in the Bohemian Massif.

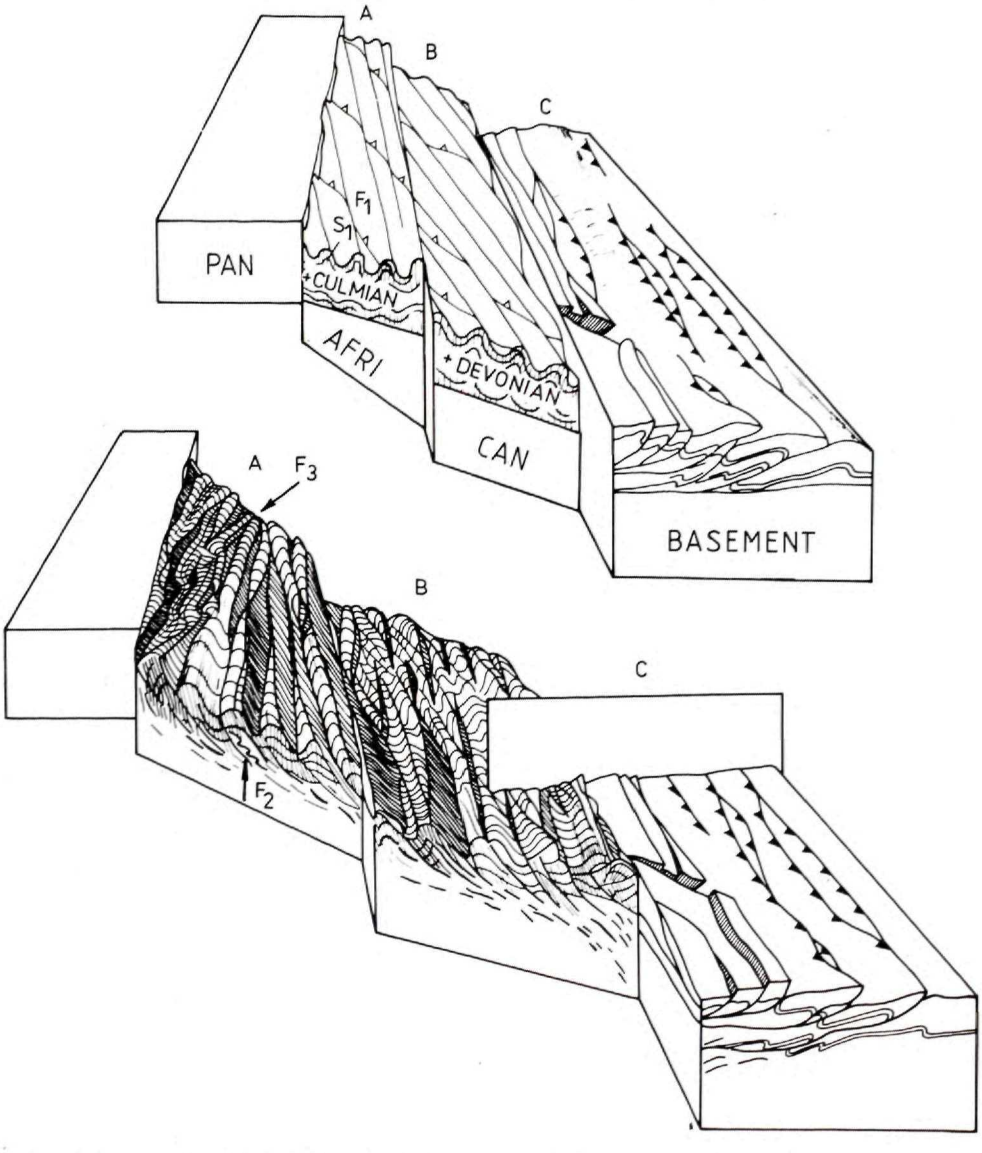

Fig. 4. Transpressional followed by transtensional tectonic development of the Moravian shear zone.

unpublished data; Wendt et al., 1988), granites and stratigraphical constraints, two bulk kinematical phases are discernible in the Bohemian Massif (Fig. 7). The first phase of the sinistral movement on the NE-SW faults began in the Low Givetian (360—370 m. y.) and was accompanied by the folding and regression in the Barrandian area (Srbsko strata) and by maphic and intermediary rocks intrusions.

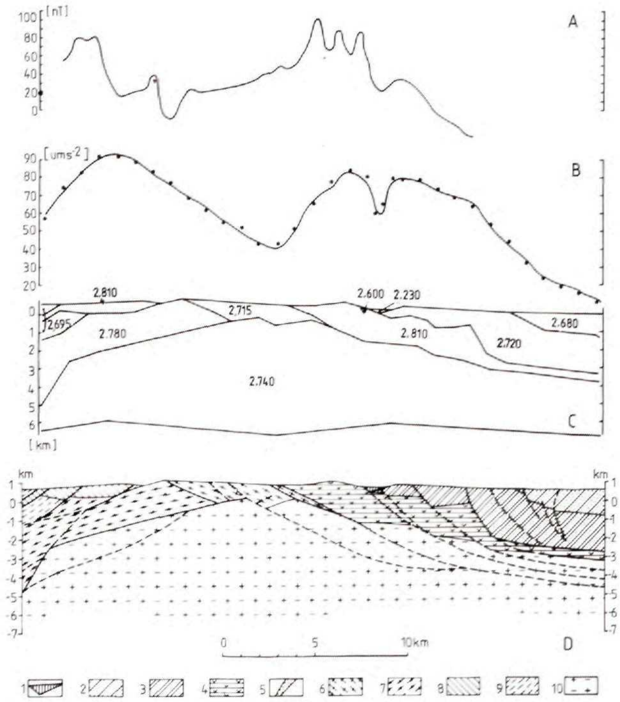

Fig. 5. Example of crustal boudinage in Moravian shear zone (NE-SW section through the Desná dome; Rajlich et al., 1989). A — magnetometry curve, B — gravity — observed curve and calculated gravity values (dotts) according to modelled densities and shape of bodies, C — density model, D — tectonic interpretation; 1 — Quaternary and Tertiary unconsolided sediments, 2 — graywackes and shales (Lower Viséan, Horní Benešov beds), 3 — slates and graywackes (Frasnian — Famenian, Andělská Hora beds), 4 — Quartzites and phyllites with inclusions of maphic volcanics (Siegenian-Gedinian), 5 — Lower Devonian quartzites, 6 — mylonitized granites and migmatites, 7 — paragneisses and maphic volcanics, 8 — Devonian amphibolites, 9 — orthogneisses and paragneisses, 10 — Panafrican crust.

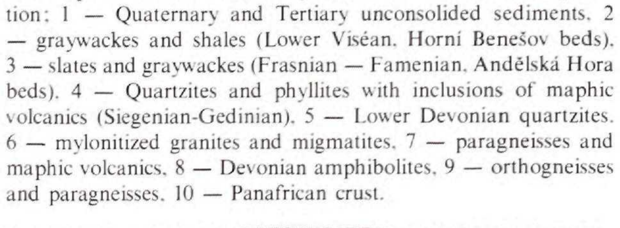

Fig. 6. Probable tectonic setting of Variscan granites in the Bohemian massif on the oblique décollement zone. Drawn with use of the model by Wernicke (1985).

Pull-apart basins were formed in the NNE-SSW striking Moravian zone and they have grown up to Tournaisian. The later right-hand movement on the NNE-SSW Moravian zone was concomitant with the crustal extension in the Moldanubian especially between the Central Bohemian and Moldanubian plutons. The Carboniferous flysh sediments were folded in the same time. The main phase of the extensional tectonics in Moldanubian preceded the 336 m. y. old intrusions of durbachites (melanocratic syenodiorites) and undeformed Variscan granites in this area. It continued to move up to Middle Westphalian as it can be deduced from the

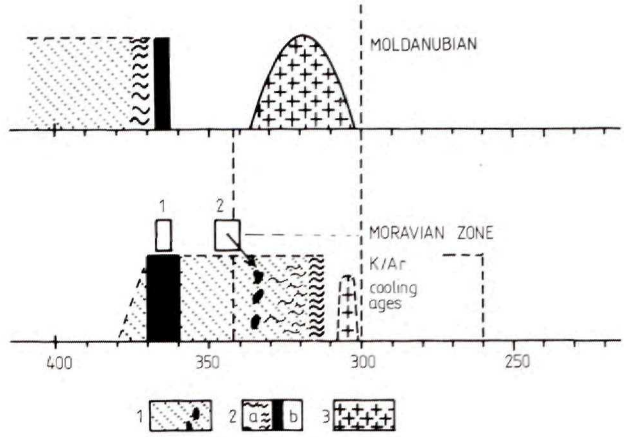

Fig. 7. Correlative diagram of tectonometamorphic and magmatic evolution in the Moldanubian block-terrane and Moravian shear zone. 1 — sedimentation, black spots occurrence of granulite pebbles, 2a — folding, b — mafic intrusions, 3 — granites. Numbers in picture: 1 — time of the leucogranulitic melt derivation, 2 — time of the granulitic mineral assemblage metamorphism.

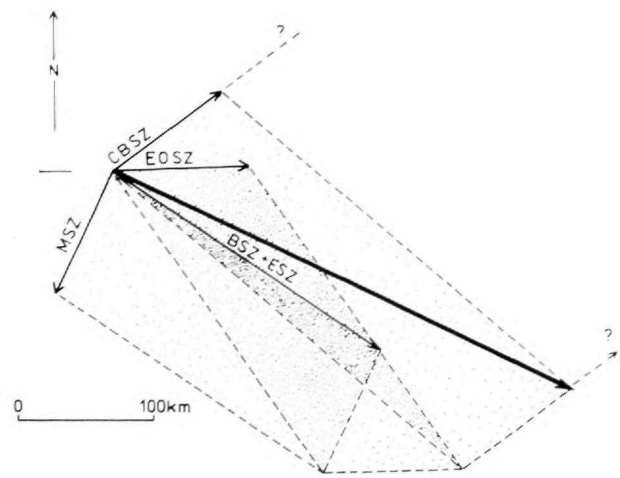

Fig. 8. Resulting vector product for the estimated displacement on the principal shear zones of the Bohemian Massif.

304 m. y. (U-Pb) old sheared granites (Wendt et al., 1988) in the normal faulting stage of the Main Moldanubian thrust. E-W minette dykes of the Central Bohemian pluton are direct evidence of the dextral shear sense in later stage of the granite emplacement (Rajlich, 1988 a, b, c).

The first stage of shearing led also to the fusion and leucogranulitic melt formation as it was found in the Southern Bohemian granulites (Wendt et al., 1988) and to the tectonic intermixing of ultramaphic rocks and Gföhl gneiss (Medaris, Misař, unpublished data; Misař, Urban, 1988). The onsetting of the granulite metamorphism or the closing stage of the granulite mineral assemblage growth was now dated

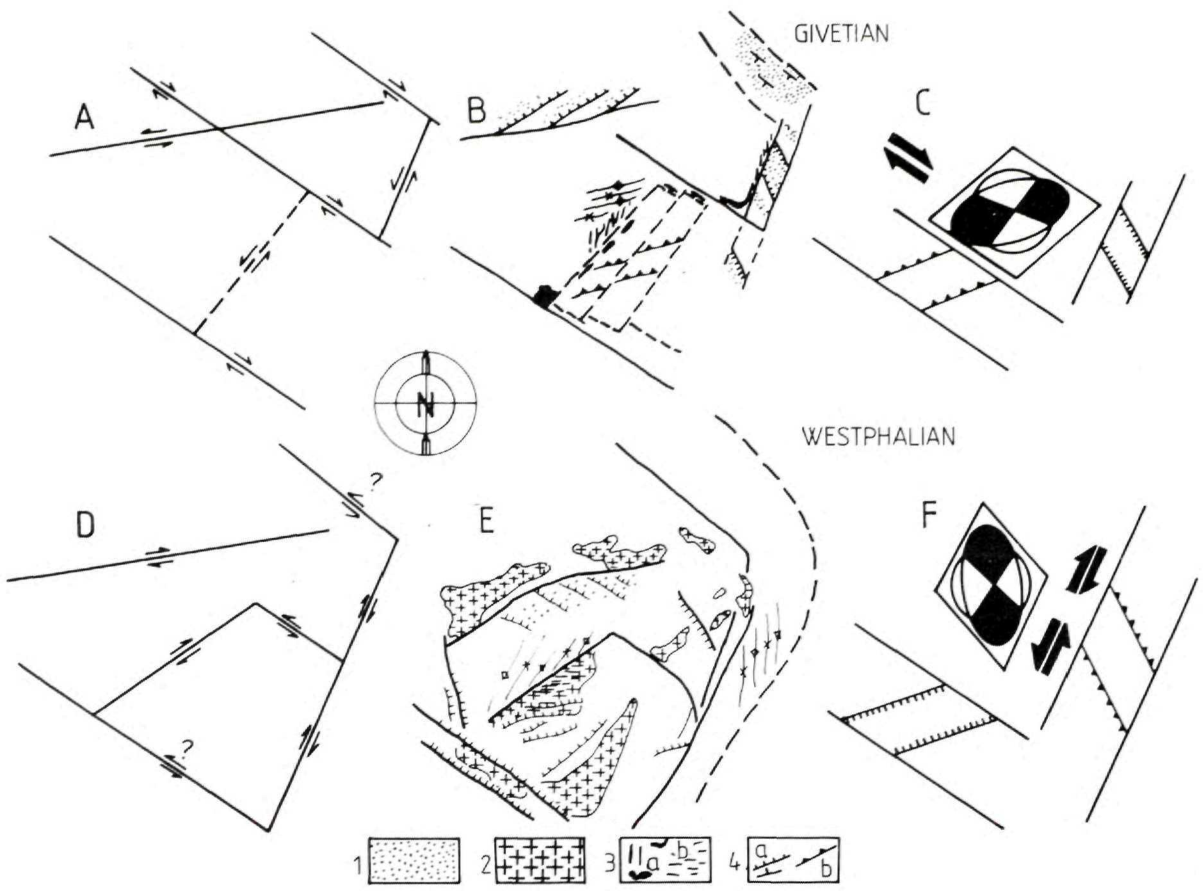

Fig. 9. Diagramatic representation of principal shearing kinematics in Bohemian Massif. 1 — sedimentary basins, 2 — granites, 3a — mafic rocks intrusions, 3b — minettes, 4a — normal faults, 4b — thrusts. A — shearing sense on the NW-SE and NE-SW shear zones during Acadian — first Variscan stage, B — folds, thrust and pull-apart basins attitude, C — transpression and transtension sectors attitude in the Acadian shearing stage, D — NE-SW shear zones dominated shearing sense in the Asturian stage, E — fold, normal faults and granite batholites attitude in the Asturian stage, F — transpression and transtension sectors attitude in the Asturian shearing stage.

unequivocally in the Bohemian Massif as a 338—348 m. y. old event (van Breemen et al., 1982; Wendt et al., 1988; Aftalion et al., 1988). Rapid uplift of granulites through the thrusting and/or extension in the Moravian zone is documented by the presence of their pebbles in the Lower Viséan conglomerates (Dvořák et al., 1985). The metamorphism lasted than up to Lower Permian following to the K/Ar cooling ages from muscovites and biotites from the Jeseníky area (Melková, unpublished data).

Relation of the Variscan shearing in Bohemian Massif to global tectonics

The outlined kinematics in the shear zones of the Bohemian Massif can be used for the testing of various aspects of the Variscan plate tectonics in Central Europe. Estimated movement on the shear zones and their attitude yield the vector product of the principal movement as featured in Fig. 8. According to this construction, the principal kinematical direction is 116°.

Estimated translation of the Northern area with respect to the Southern one between which the Bohemian Massif has moved is 378 km. No less important Late Variscan — Permian translation (Arthaud, Matte, 1977) is included. The 26° deviation of the resulting vector from the principal kinematic axe which is expected to be E-W for the European Variscides (ENE—WSW dextral shear of Moroccan High Atlas, Rajlich, 1985; Variscan Pyrenees, South Armorican shear zone, Jegouzo, 1979; Appalachians and European Variscides, Arthaud, Matte, 1977; Badham, 1982; Mísař, Urban, 1988), can be explained by: 1. the presence of undetected NE-SW shears inside the Moldanubian and inside the Saxothuringian, 2. by passive rotation of the shear zone strikes during Variscan development and during Alpine orogeny. The bulk translation for the

E-W trend with undetected NE-SW strike-slip would amount to 600 km.

Conclusions

The kinematical analysis of the principal shear zones of the Bohemian Massif reveals the prominent role of the wrench tectonics in the Variscan orogeny. The compatibility of the deformation in the whole area was reached through the thrusting and transpression and/or transtension and extension within the wrench zones and/or within the block (terraines) separated by strike-slips. Two total kinematical phases of the Givetian and Westphalian age (Bretonian and Asturian phases of Stille) can be separated in the principal shear zones and they occurred in the progressive dextral translation of the Baltica and Fenosarmatia with respect to Africa.

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