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Circular and Lozenge Structure of the Bohemian Massif

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10 Text-Figures

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Inhalt

Kreis- und rautenförmige Strukturen der Böhmischen Masse

Zusammenfassung

Ein Innenbecken mit runden Umrissen in einer Seehöhe zwischen 200 und 500 m und eine als Parallelogramm geformte gebirgige Umrahmung sind die morphologischen Hauptformen der Böhmischen Masse. Das Parallelogramm und die Kreisstruktur sind sichtbar auf Satellitenaufnahmen und durch die Hauptstörungen und sedimentären Becken nachgezeichnet. Die Wiederholung dieser geometrischen Konfiguration aus der Zeit der panafrikanischen Gebirgsbildung spricht für eine Entstehung der Kreisstruktur im Mittel- oder Unterproterozoikum. Die innere kreisförmige tektonische Struktur weist außerdem auf die Anwesenheit eines harten, konsolidierten Körpers in der tieferen Kruste der Böhmischen Massifs hin.

Abstract

The principal geometrical features of the Bohemian Massif are the inner circular depression of varying altitudes between 200–500 metres above the sea level, and the surrounding higher, sometimes mountainous area of the lozenge-form. This lozenge and circular structure visible on the space photographs is materialised by the composite network of the prominent bounding faults and of the crossing elements. The repetition of the geometrical configuration up from the Panafrican orogeny suggests the Middle to Lower Proterozoic origin and stiffened character of the lower crust.

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1. Introduction

The circular structures although economically important through their control of the distribution of ore deposits (SAOUL, 1978) and very often present in the Earth's crust (NORMAN, 1984) range among the most enigmatic structures on Earth.

To take the challenge of their study is often the way into the dark past of the geological evolution of the Earth. Soon also we meet the other problem which is the impossibility to obtain the circular structure from the dynamic processes in the Earth's crust leading to lateral compression. Some mostly unknown vertical agents must be taken into consideration. The statement of the circular structure present in the crust constrains thus the movements on the inner faults and because of its preserved geometry puts the overall limits on the extent of the crustal deformation especially if the structure occurs inside the later mobile belt.

But unavoidably the study of the planets of the solar system has taught us that the circular structures are the principal forms of their surfaces (HOYLE, 1975; WILHELMS, 1987; and numerous other citations). Surely no plate tectonics occurred there but the Earth could not escape the same fate in its earlier history.

I attempted to shed more light on one of such conspicuous circular structures. It is located inside of the topographically rising prominent horst of the Bohemian Massif in Central Europe, between 12° and 18°E longitude and between 48°10' and 51°30' northern latitude.

2. Historical Survey of Geological Research

Surging from the complete sedimentary envelope of the Mesozoic and Cainozoic rocks the length of the lozenge shaped Neogene horst of the Bohemian Massif is approximately 480–540 km in the E–W direction and 360–390 km in the N–S direction. The verified stratigraphical extent of rocks is in the range from the Quaternary to Middle Proterozoic granites which intrude the older formation of unknown age. One dated orthogneiss yielded the intrusive age of 2 b.y. and the Archean neodym residence time in the molten source (WENDT et al., 1988). The Archean residence time for ore lead age is also provided by the ore lead isotopic analyses using the model of AMOV (1983a,b) (RAJLICH et al., 1993) and these data indicate the probable Archean age of the crust of the Bohemian Massif.

The geological development of comparable Palaeozoic series (KREBS, 1977; ZOUBEK et al., 1988), existing geochronological data (VAN BREEMEN et al., 1982) and for instance the paleomagnetism (KRS, 1982) demonstrate that the structure shared the same Phanerozoic history similar to other parts of Hercynian Europe. There are e.g. 2 b.y. old paragneisses, widespread calc-alkaline and alkaline magmatism and granites frequently of I-type of Cadomian age and Variscan shearing events followed by the formation of large granitic batholiths.

The Bohemian Massif obtained its name from E. SUESS (1885, 1888, 1901, 1909). Based on the previous extensive surveying from the second half of the last century the first synthesis from F.E. SUESS (1926) considered it as the Variscan equivalent of the Alpine Mountains formed between Europe and Africa. Important SE oriented thrust tectonics in the SE part of the structure was clearly demonstrated by him (F.E. SUESS, 1898). The nappe tectonics was currently used by many geologists from this time (PRECLIK, 1927; SCHEUMANN, 1939; KETTNER, 1949) mostly within the dynamic concept of the Earth's contraction.

The geologists working in the Bohemian Massif at the beginning of the 20th century also quickly realised that the Massif shared the same geological fate as the remaining Variscan Europe. The junction of different units from the Bohemian Massif to the other extensive outcrops resulted in the distinction of the Variscan orogenic mountain belt in Europe and its inner division which differ slightly by different authors, especially in the meaning they gave or they give to the mobility of the inner units. The first to provide such zonation synthesis was KOSSMAT (1927) and STILLE (1924) who considered also the differing mobility of the belts giving to the central belt of the Moldanubian the meaning of the stable median horst.

During the period between 1960–1980 ideas of mostly vertical movements along the so called deep seated faults in the frame of geosynclinal theory propagated among the Czech geologists. They evoked it in order to explain the folding observed in sedimentary cover rocks. The folding mechanism was supposed to be exercised by the lateral push as the result of the rising basement horsts, granite diapirs or by simple presence of deep seated faults (POKORNY and STOVICKOVA, 1980; SKVOR, 1970; ZEMAN, 1978; SUK, 1979; WEISS, 1977). The delineation of the faults was mostly done on the base of gravimetry and magnetics. Using the geological reasoning the geologists advocated the Archean age of the Moldanubian or of its highest metamorphosed rocks (granulites). The available K/Ar data were explained as the Variscan overprint.

The optical effect exerted by the folds and their ubiquity in the deformed units of the Bohemian Massif made them one of the first objects attracting the geologist's attention. The erroneous identification of the fold axes with the b-axis of the tectonic cross as well as the observation of folds in the superficial units led to the conclusion that their axes are perpendicular to the main direction of the tectonical transport (perpendicular to the a axis). The most cross sections through the folded units should be accentuated as the main tectonic transport the direction perpendicular to the fold axes (KETTNER, 1950; CHALOUPSKY et al., 1989). In the same time the importance of the uniaxial flattening in the ductile domains was exaggerated (RAJLICH, 1974). The stretching lineations associated with the high strain which are indicative of the tectonic transport direction (NICOLAS, 1984; WILSON, 1961) were considered to be orthogonal to the ductile flow direction because they are parallel to the fold axes (BENES, 1964). The knowledge from the superficial domains was transferred to the ductile domains and into the crystalline terrains and biased their tectonic interpretation.

The presumption of the origin of folds in the pure or simple shear geometry with axes perpendicular to the main tectonic transport direction was included into the plate tectonic concept and into the zonation of the Mts. range of the European Variscides. The structures of this orogeny were presented only "in the cross-section" and in this way the cross-sectional thinking (the movement occurs in the cross-sectional plane perpendicularly to the fold axis or to the presupposed subduction zone) is maintained by its adherents.

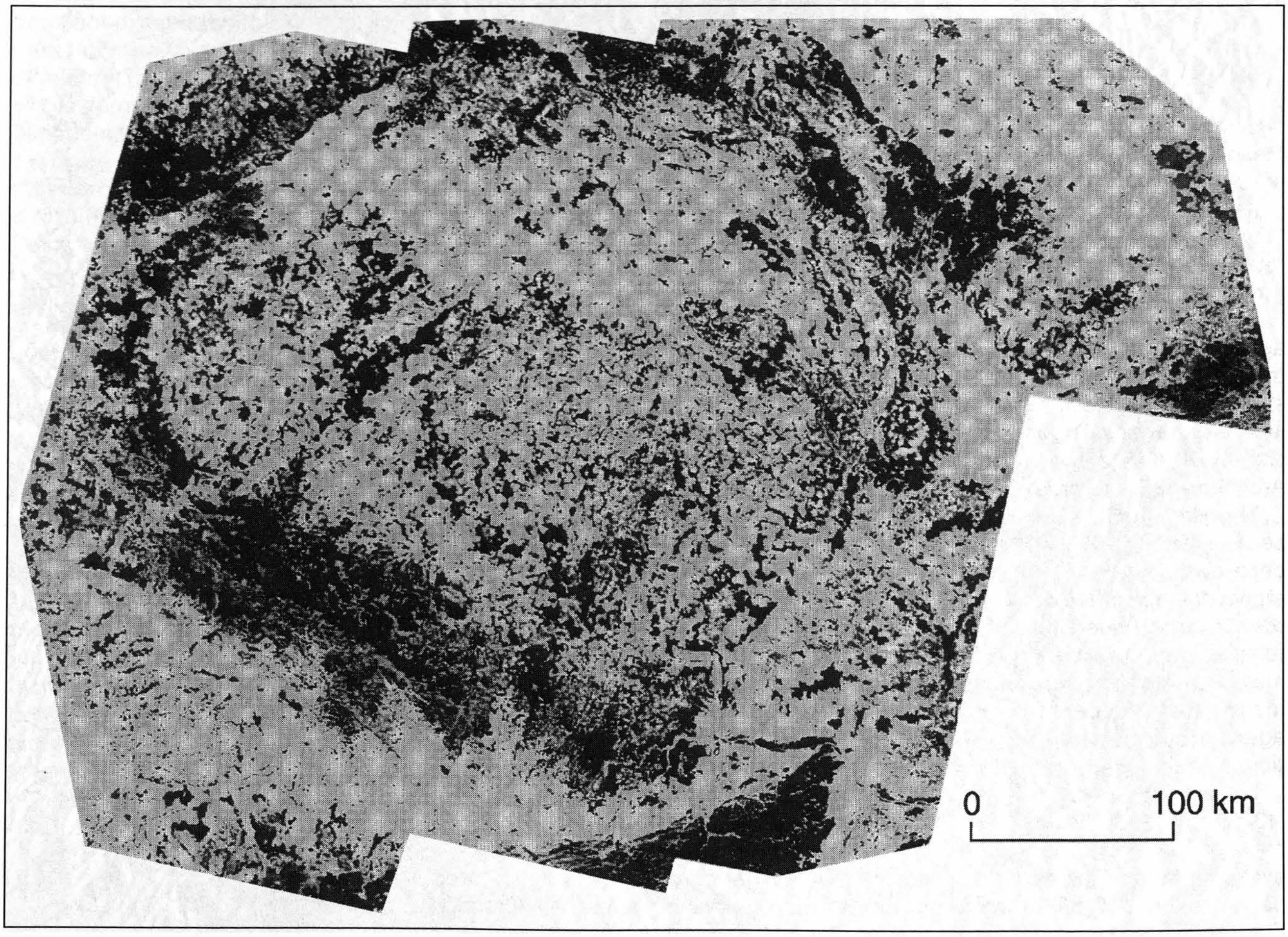
The newly propagating ideas of plate tectonics considered the structure as a result of the plates collision and several converging directions and suture zones were proposed by different authors. In the same time the dating by the modern geochronological methods proved that the highest metamorphism paragenesis in the Moldanubian in fine grained metamorphosed granites – granulites is Variscan in age and Panafrican age was confirmed for the granite batholites on the periphery of the Massif (VAN BREEMEN et al., 1982).

The plate tectonic concepts found their continuation in the hypothesis of the tectonostratigraphic terrains, (FRANKE, 1989; MATTE et al., 1990; CHALOUPSKY, 1989) which either docked laterally along the strike slip zones (BADHAM, 1982) or aggregated perpendicularly to their boundaries CHALOUPSKY (1989). The plate tectonics concepts however failed in the clear definition of a single suture zone in this area, as suggested by the work of BARD et al. (1980), BEHR (1978, 1980, 1983), MATTE (1983) and others. From it could be concluded that a significant amount of pre-Variscan crust and relatively minor amounts of oceanic crust were involved in the Hercynian structures, as suggested by BADHAM (1982) and CHALOUPSKY (1986). The plate tectonics ideas somewhat stabilised on the two stage model e.a. the earlier convergence and the later overall dextral strike slip (ARTHAUD and MATTE, 1977; MATTE, 1983, 1986). Once more, different convergence vectors and sutures are proposed (Central Bohemian zone as suture and N–S convergence [MATTE et al., 1990], Rhenohercynian zone in Germany and N–S convergence [BEHR et al., 1984] and Moravian zone NW–SE convergence [SCHULMANN et al., 1990]). The plate tectonics because sometimes applied to the former belt division of Europe and junction of inner units of the Bohemian Massif into it did not explain the shape of the Massif.

The new impetus to understanding of the structure brought the application and identification of the stretching lineation in the metamorphic terrains as the final strain trajectory and its systematical plotting. It led to the recognition of the principal shear zones in the area and their arrangement (identification, as far as it concerns the massif boundary forming shear zones) as ductile strike-slips. The principal structural and kinematical division into units of the Bohemian Massif have also been characterized (RAJLICH, 1987; RAJLICH & SYNEK, 1987; FRANKE, 1989; MATTE et al., 1990 etc.).

From the study it became clear that the Massif developed as a result of multiple deformations – repeated wrenching (transpression/transtension): sinistral in the Panafrican and Devonian and dextral in the Upper Carboniferous. The inner segments separated by the strike-slip zones underwent both transpression and moderate crustal thickening through thrust stacking, and transtension and normal faulting, pull apart basins formation or granite intrusions. Differing deformation and thus mobility can also be observed in these segments as first noted by STILLE (1951). The prominent shear zones overlap frequently with the formerly defined deep seated faults. The Bohemian Massif is bounded from all sides by strike-slip faults which form the polygonal structure tangential to the inscribed circle.

The circular inner form of the Bohemian Massif seams to have been observed first by PETRASCHECK et al. (1944), Text-Fig. 4. It attracted once more the attention only in the last years (see also RAJLICH et al., 1984) not least also be-



Text-Fig. 1.
Landsat mosaic of the Bohemian Massif.

cause the satellite photographs were declassified and put into the public use in Czechoslovakia.

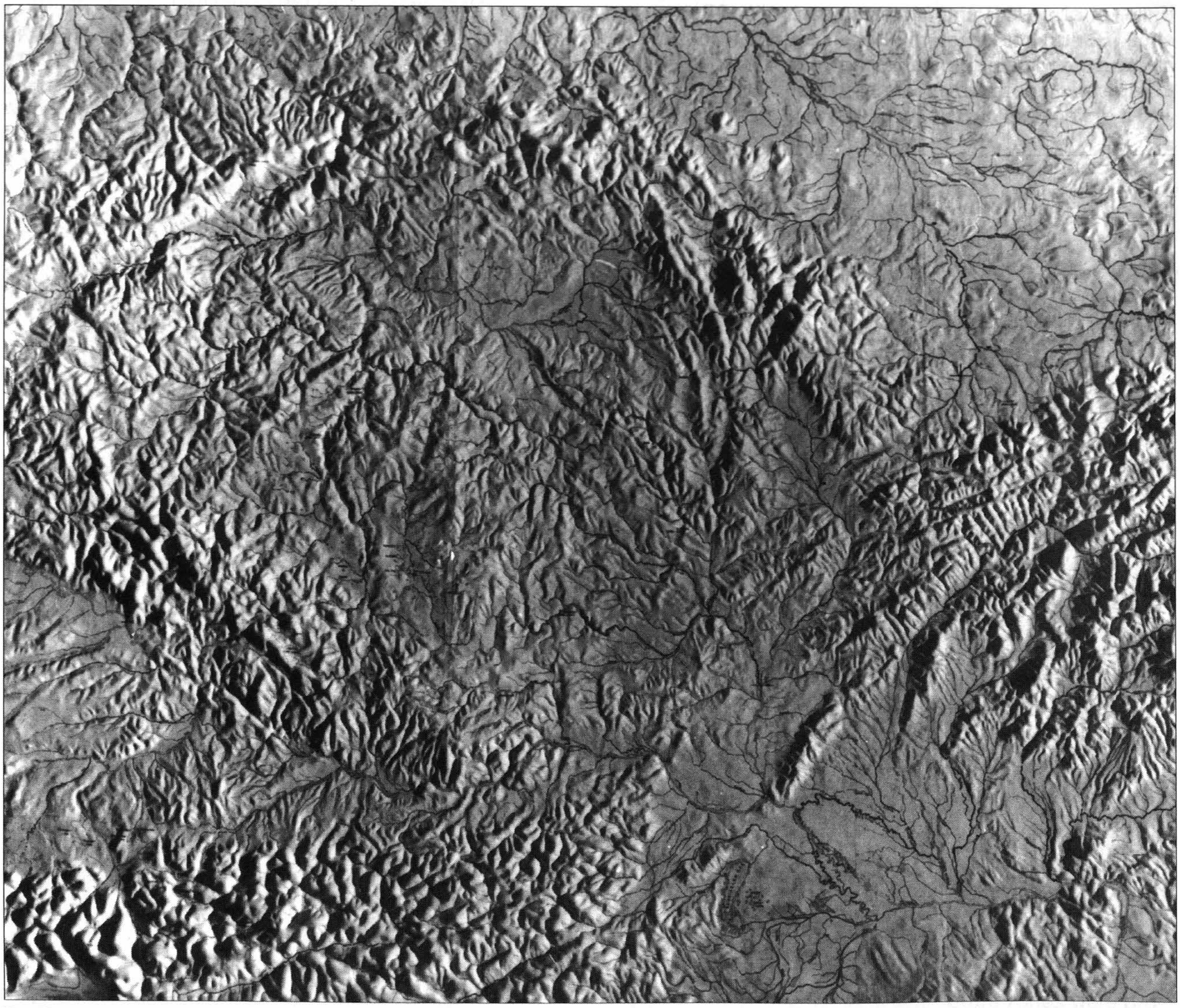
3. Geometrical Characteristics of the Bohemian Massif

The Bohemian Massif appears as the lozenge-like Tertiary horst rising from the surrounding Mesozoic cover sediments. The E–W lozenge axis is 540–480 km long, the shorter N–S 360–390 km long. The axes deviate not more than 10° from the exact meridian and from the longitudinal position. The outer shape of the structure is defined by the prominent single faults or by closely spaced parallel faults. The innermost boundary faults of the lozenge are tangential to the inner circular-elliptical structure defined by topography (depression), by the hydrological network and by geology (Figs. 1–6).

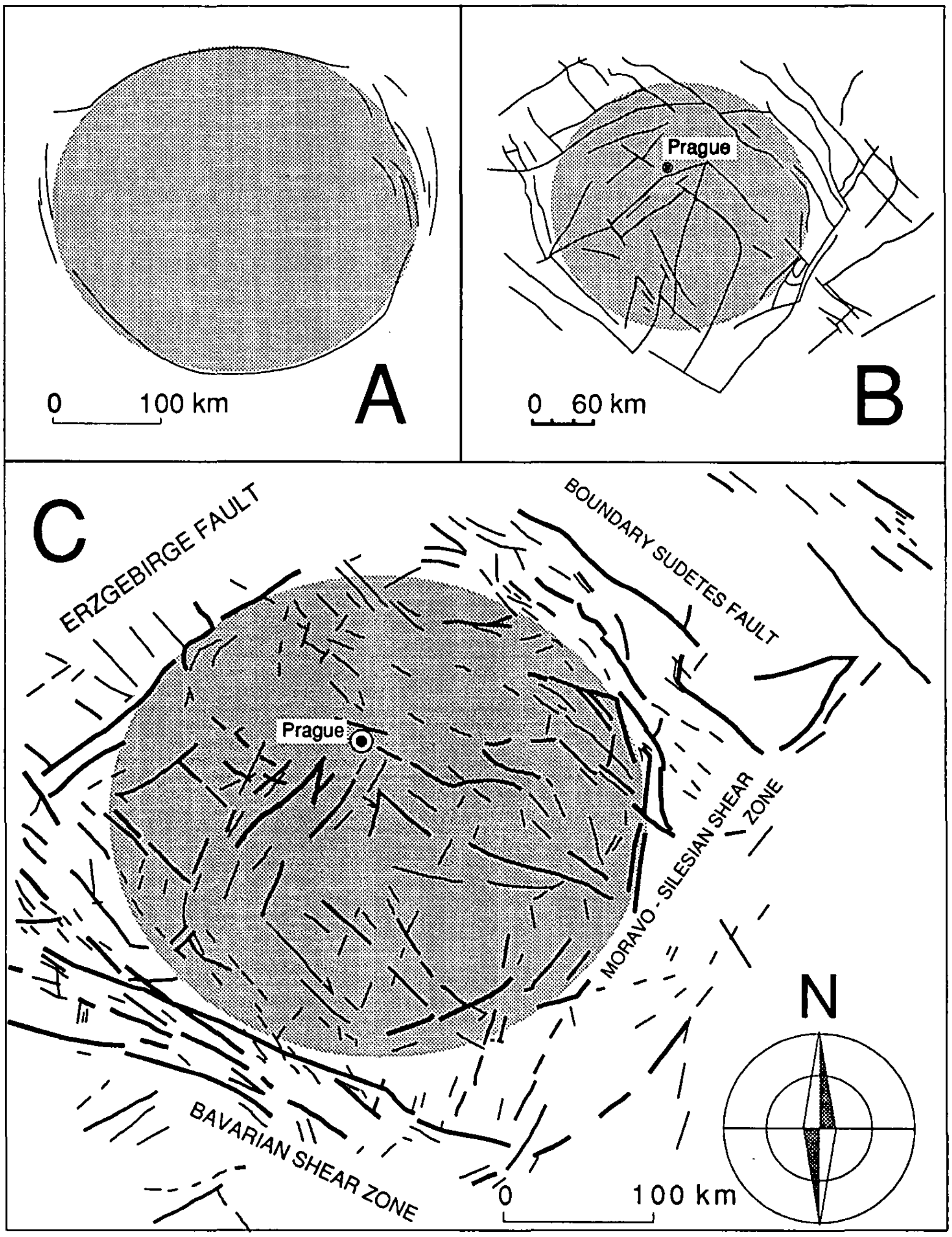
3.1. Inner Circular Structure – Geometrical Definition of Filling Units

The inner circular/elliptical structure of the Bohemian Massif, positioned in Central Europe, northerly from the Alps is well visible on space photographs (Text-Fig. 1) (PAPAGIANIS & EL BAAS, 1988) and well documented geologically. It is 260 km large in the E–W diameter and 235 km large in the N–S diameter. Three quarters of its envelope (SW–W–NW–N–NE) can be seen in the recent topography and water courses (Text-Fig. 6) and it can be completed by the important geological boundaries i.e. the Precambrian southeastern oriented thrust which was intruded by the special finger-like syntectonically emplaced granites, and by different geological and topographical details (Text-Fig. 8). Its most conspicuous features are the Permian basins on its eastern (Text-Fig. 7) and NE border (Text-Fig. 4) and the circular limit of the Proterozoic basin. While the above mentioned lozenge-like boundary of the massif represents rather the mountainous areas, the inner circular structure is mostly topographically low or upland, lower than the surrounding mountains. This is also documented by the largest part of the circular depression drained by one single (Elbe) river and by the Cretaceous half circular basin.

There is not any sedimentary formation known which is confined uniquely to its interior. The distribution of all sedimentary formations although controlled by the circular structure and mostly interrupted on the elevated lozenge-



Text-Fig. 2.
Relief map photograph of the Bohemian Massif illuminated from the East.



Text-Fig. 3.
Faults and lineaments of the Bohemian Massif.
A = topographical lineaments of the circular structure; B = main faults from the geological maps following Misar et al. (1983), modified; C = major photolineaments from the Landsat mosaic (Text-Fig. 1).

borders can be traced in the surrounding regions. From the most prominent formations there is in the northern half of the circular structure a crescent shaped Upper? Proterozoic basin with the recently indicated depth of 5 km by reflection seismics (Tomek and Vrana, oral communication). The sediments are mostly lithic greywackes, sandstones and shales with sharp edged grains. In the lower portion of the stratigraphical sequence there occur pillow lavas and gabbros. Their thickness is unknown but does not exceed the thickness of the clastic sediments. The age of the whole formation is poorly constrained. The upper limit is provided by the other most probably Upper Proterozoic formation and Cambrian on the top of it.

The southern quarter of the pie shaped block fragmentation is represented by the sediments of the so called Moldanubian supergroup (after the rivers Moldau and Danube), composed mainly of gneisses and migmatites, marbles and amphibolites of unknown age but older than the Proterozoic sediments.

The circular structure especially in its eastern part is than respected by Permian and Cretaceous troughs which follow the reactivating faults of circular shape (Text-Fig. 4). Volcanic and magmatic rocks cut sometimes in detail through the structure as their distribution is controlled by the brittle upper crust (see Text-Fig. 5A) but on the whole their distribution (especially of Cadomian gabbros) is controlled by it. The dating of the structure may be approximated by the geometrical control of the structure over the inner sedimentary basins. The Upper? Proterozoic basin is the first sedimentary formation controlled by it.

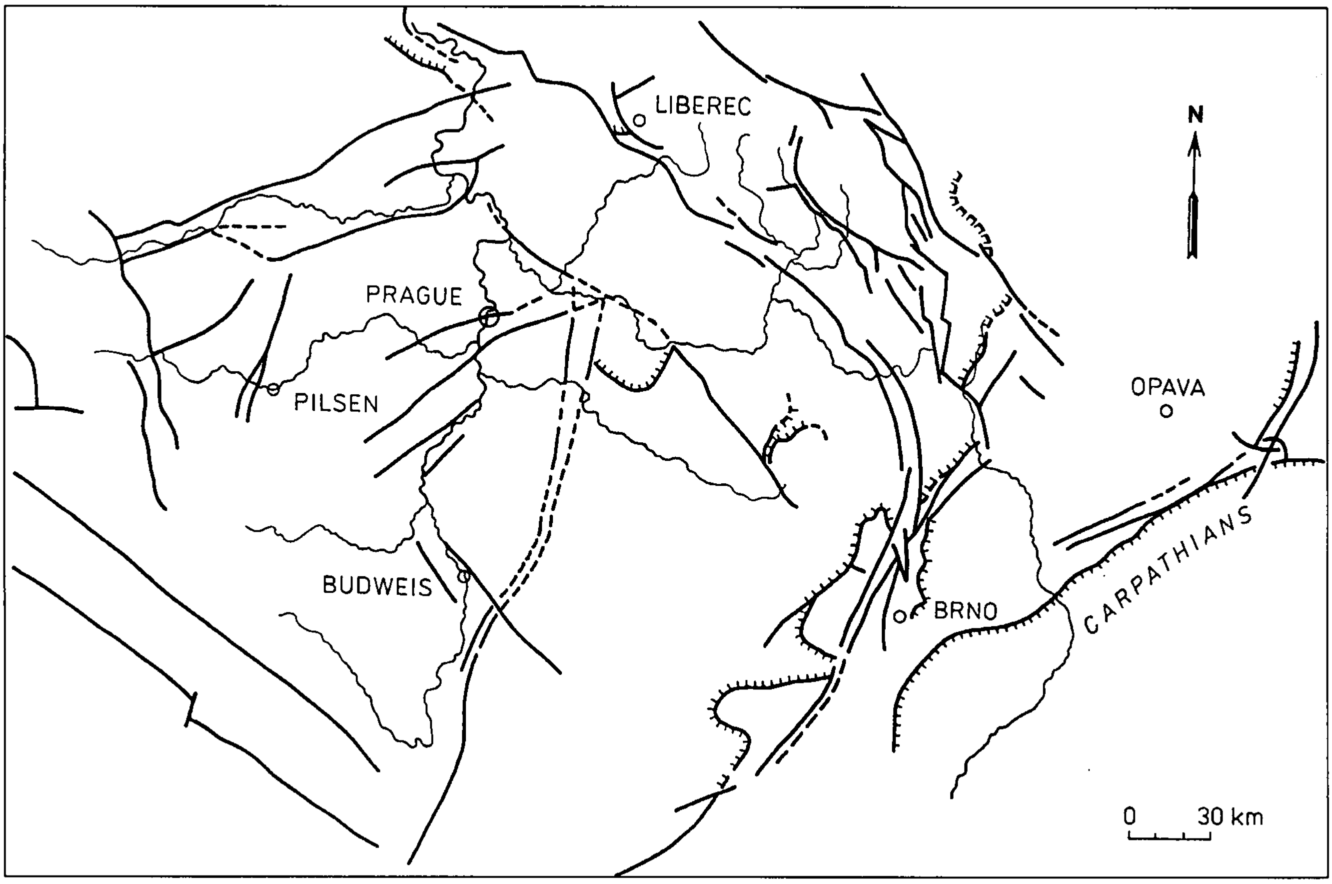
3.2. Structural Relationships of the Fault and Shear Zones to the Circular Structure

If we study the relationship of the main fault and shear zones to the circular structure we see that the main shear zones surround it in a polygonal way. The curved circular geometrical pattern seen on the satellite photographs is featured by the Permian Cretaceous basins on the northeastern and eastern part (Text-Fig. 1). The smaller shear zones split off the straight elements such as the Bavarian, Odra; shear zones as the circular structure preserve its shape during the progressive deformation. This can be observed for example in the region of the (a) Marianske Lazne fault which conforms itself and defines the circular shape of the structure on the western side of the massif, (Text-Fig. 5B, 8).

The other important faults as for instance the (α1) Moravo-Silesian shear zone (Text-Fig. 5B) are tangential to the circular structure.

3.2.1. System of Fault Indexation

Because of the remobilisation of structures repeated over a long time and because of the tradition of their description, many historical names of faults and/or fault zones do not exactly comply with their real nature. They very often describe only one aspect of it. So for instance



Text-Fig. 4.
Faults of the Bohemian Massif according to PETRASCHECK (1944).

the Bavarian lode is the 200 km long Upper Permian brittle fault which partially reactivates the larger and longer Bavarian shear zone. Also the trends in the geological reasoning mirrored in the way many faults were interpreted, especially in the time when only vertical movements were presumed and geophysical block boundaries were classified as the deep seated faults.

In order to avoid new names I describe the structures simultaneously using the geometry symbols. I have put the local names collectively with selected citations of authors in the parentheses.

The outer lozenge envelope can be described by four points A, B, C and D so that the NE border is the line AB, the southeastern border the line BC, the SW border line CD, and the northwestern border DA.

The circle envelope is denoted by the letter a.. and hierarchically the lower order faults transecting the structure – mostly parallel to the borders – are denoted by numbers 1...XX and by upper case letters (A, B, C, D) which signify the parallelity of these faults with the main border. The system is visualised on Text-Fig. 5B. The blocks defined by the boundary faults are referred to by upper case letters (E, F.).The faults of NNE–SSW and E–W direction which do not fit in the present directional and geometrical scheme are denoted by α.

3.2.2. Faults and Shear Zones Related to the Circular Structure

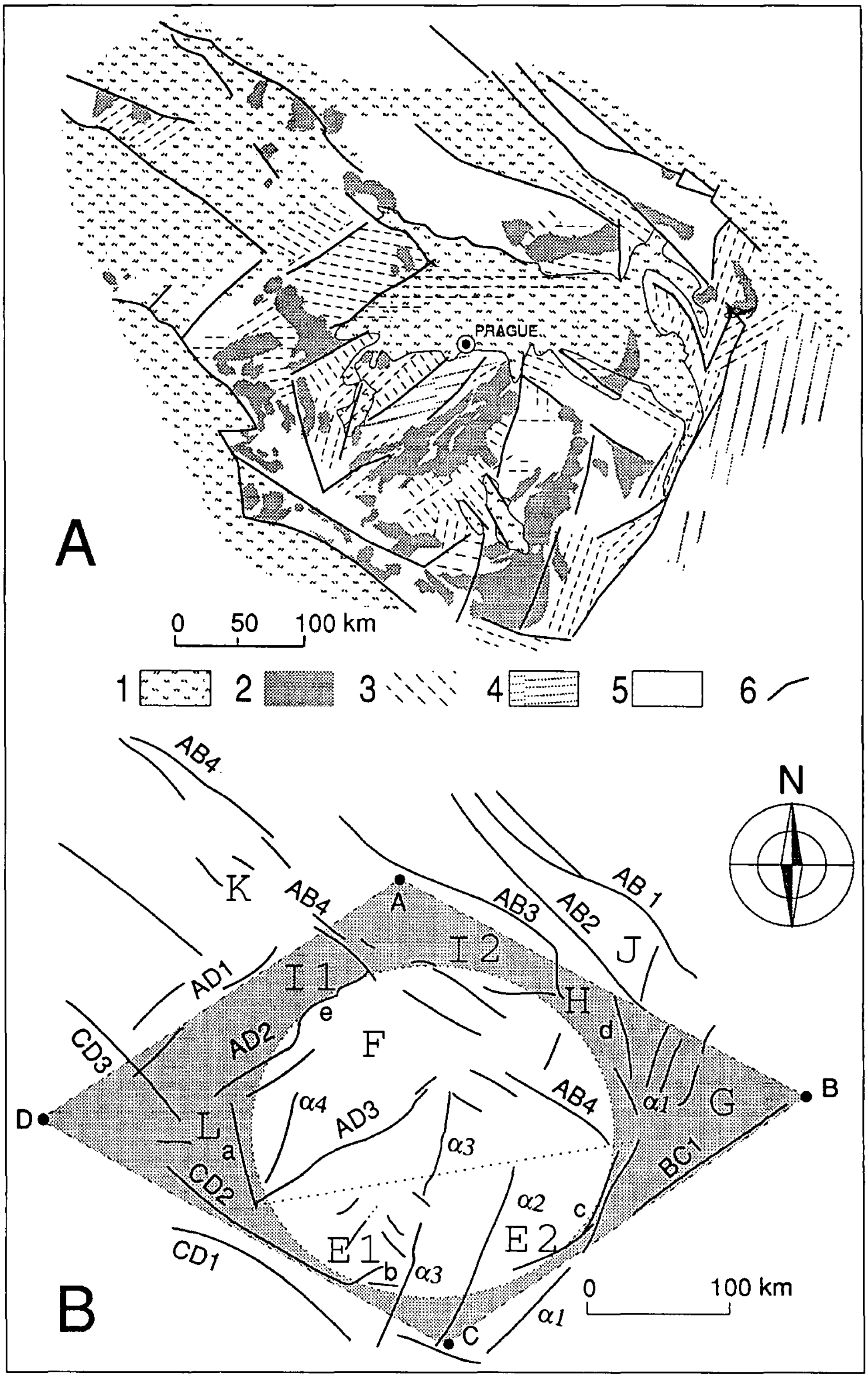
The circular structure is outlined by the following faults:

a) the Marianske Lazne fault (Text-Fig. 8),
b) granite intrusions on E–W faults close to the α3-Rodel line,
c) the Kravsko fault and the Boskovice furrow (Text-Fig. 7),
d) the Orlice Permian trough,
e) the NE part of the Erzgebirge fault (AD2).

These fault zones are the real geological expression (besides the topography) of unequally developed single segments of the circular structure. They are found along the whole length of the circle. Together with the recent topography further following geological formations participate at the definition of the circular structure:

a) Permian basins,
b) Tertiary basins and volcanic rocks,
c) Variscan granites,
d) tectonical contacts between Moldanubian and overlying Middle to Upper Proterozoic sediments,
e) tectonical contact between underlying Varied and overlying Monotonous Groups.

Starting on the east where they are best visible on the topography the longest such segment is exemplified by the Permian reactivated α1 fault (Boskovice furrow) and by the Adler Permian trough as noted by PETRASCHECK et al. (1944) (Text-Fig. 4). These faults appear mostly as shorter slightly curved lines with the opening controlled by the oblique intersecting fractures. They follow the circular structure in the polygonal tangential way. Just as one straight part terminates the other onsets. This is visible in the eastern part on the northern and southern termination of the Boskovice furrow (c). The largest opening is found on the transecting and circular faults crossings. The faults represent the brittle response of the stress field to the circular rheological inhomogenity in the basement. The geo-



Text-Fig. 5.
A) Simplified structural map of the Bohemian Massif.
1 = Younger Upper Cretaceous to Tertiary sediments; 2 = Variscan granites; 3 = ductile (stretching) lineations; 4 = folds in the inverted sedimentary basins; 5 = metamorphic units; 6 = faults.
B) Principal geometry of the Bohemian Massif with the indexation of single faults and blocks.

logical history of these faults allows for tracing of the history of the circular structure.

3.2.2.1. Marianske Lazne Fault (a)

The rejuvenation of the older circular structure border can be seen on the splitting of a (the Marianske Lazne) shear zone from the Bavarian shear zone (CD2). This fault is partially intruded by the Bory granite massif (Text-Fig. 8) and by the Panafrican gabbros. The Proterozoic rocks are down faulted and right laterally sheared. On its crossing with the AD2 – the faults of the Eger Erbendorf-Erzgebirge fault system – occurs the large body of amphibolites, gabbros and eclogites (horst – metamorphic core complex of Marianske Lazne) and the greatest Tertiary volcanic apparatus (Doupovske Hory) of the Middle Bohemian Mts. The circular structure as reported from the space photographs and from the topography follows the SE contact of the body and goes through the centre of the volcanic apparatus. The Late Permian–Triassic activity along the fault is expressed by the Bohemian Quartz Lode similar to the Bavarian one. Quaternary to Tertiary reactivation is evidenced by the topographical expression of the fault.

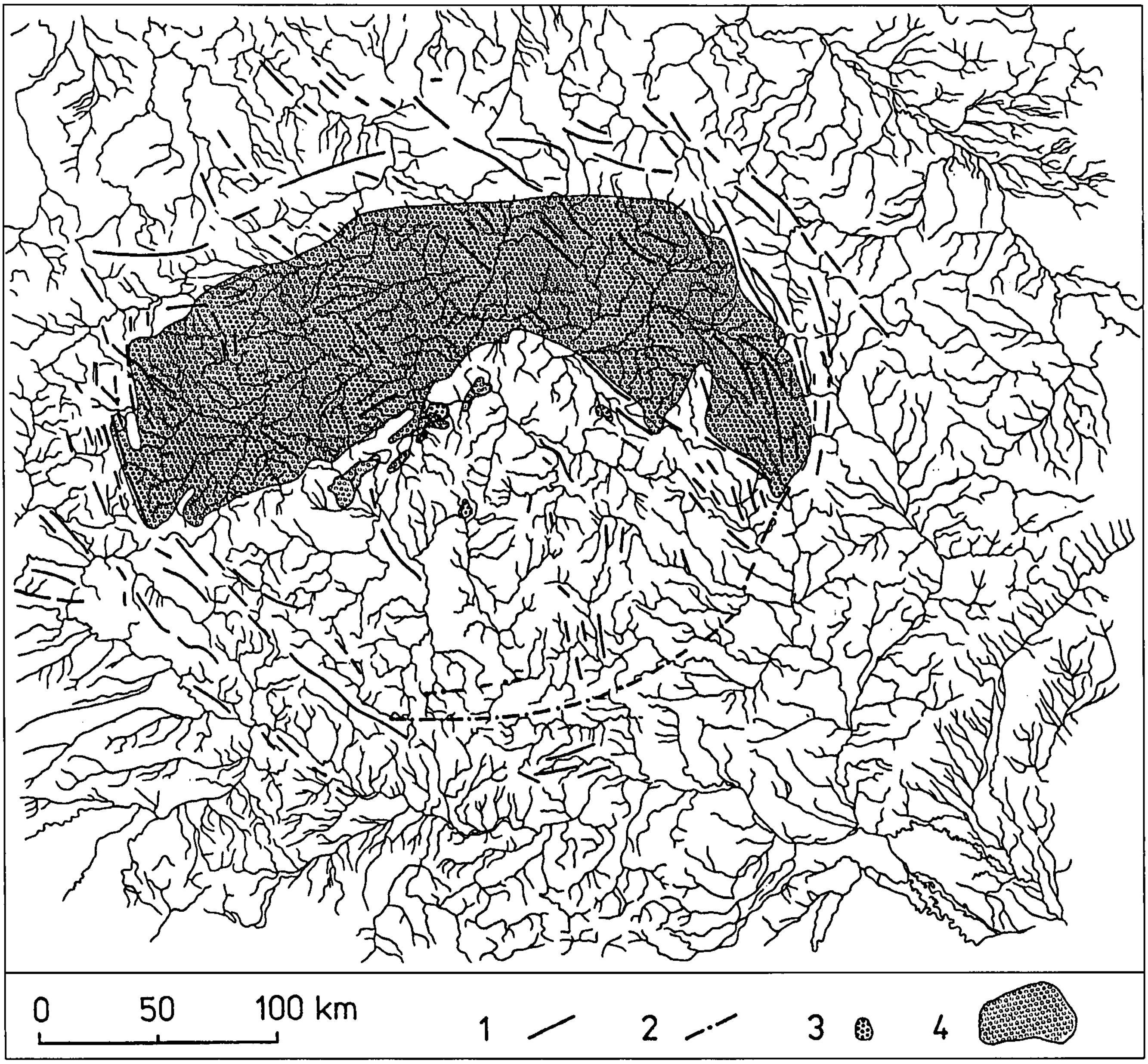
From the series Panafrican gabbro bodies the 535 m.y. old Kdyne gabbro (U-Pb [Quadt & Gebauer, 1988]) is the most important with other spilite bodies with intrusive contacts.

3.2.2.2. Kravsko Fault (c)

It is in its youngest development, normal, top to the N fault (Schulmann, 1990). It is the major structural boundary (F.E. Suess, 1912) in the Moravian-Silesian (Rajlich, 1989) shear zone.

It is parallel and close to the boundary which separates the area of the regular distribution of NNE–SSW trends of Variegated rock strips in the southern Moldanubian from the area devoid of it in the north (Text-Fig. 5A).

It tectonically erodes the Bites gneiss in its latest development. This fault is one of the evidences of the thrusted Moldanubian rocks over the Moravian in the SE part of the Bohemian Massif (F.E. Suess, 1912). The normal faulting



Text-Fig. 6.
Watercourse network of the Bohemian Massif with the position of the Upper and Middle ? Proterozoic basin.
1 = topographical lineaments; 2 = completion of the circular structure by geological details; 3 = outcrops of the pseudotachylite breccias; 4 = Upper/Middle? Proterozoic sedimentary basin.

occurred under brittle conditions and it is kinematically related to the late Variscan dextral shearing on the Moravo-Silesian shear zone. The fault lies directly on the circular structure and it branches from the α1 Moravo-Silesian shear zone in the place where the straight zone separates from the direct contact with the circular structure. The fault is also topographically expressed.

3.2.2.3. Boskovice Furrow (c)

This 5 km narrow 2 km deep and 40 km long compressed trough (Text-Fig. 7) is developed on the α1 (Moravo-Silesian shear zone) in the place where it obliquely comes into contact with the inner circular structure.

The basin is larger on its northern part where it is crossed by the NW–SE faults as it results from the overall dextral shear in the surroundings of the Bohemian Massif.

Its length is limited to the immediate vicinity of the circular structure. It is well defined topographically and represents part of the topographical features (linear topographical low) which rim the circular structure of the Bohemian Massif on E and NE (Text-Fig. 1, 2).

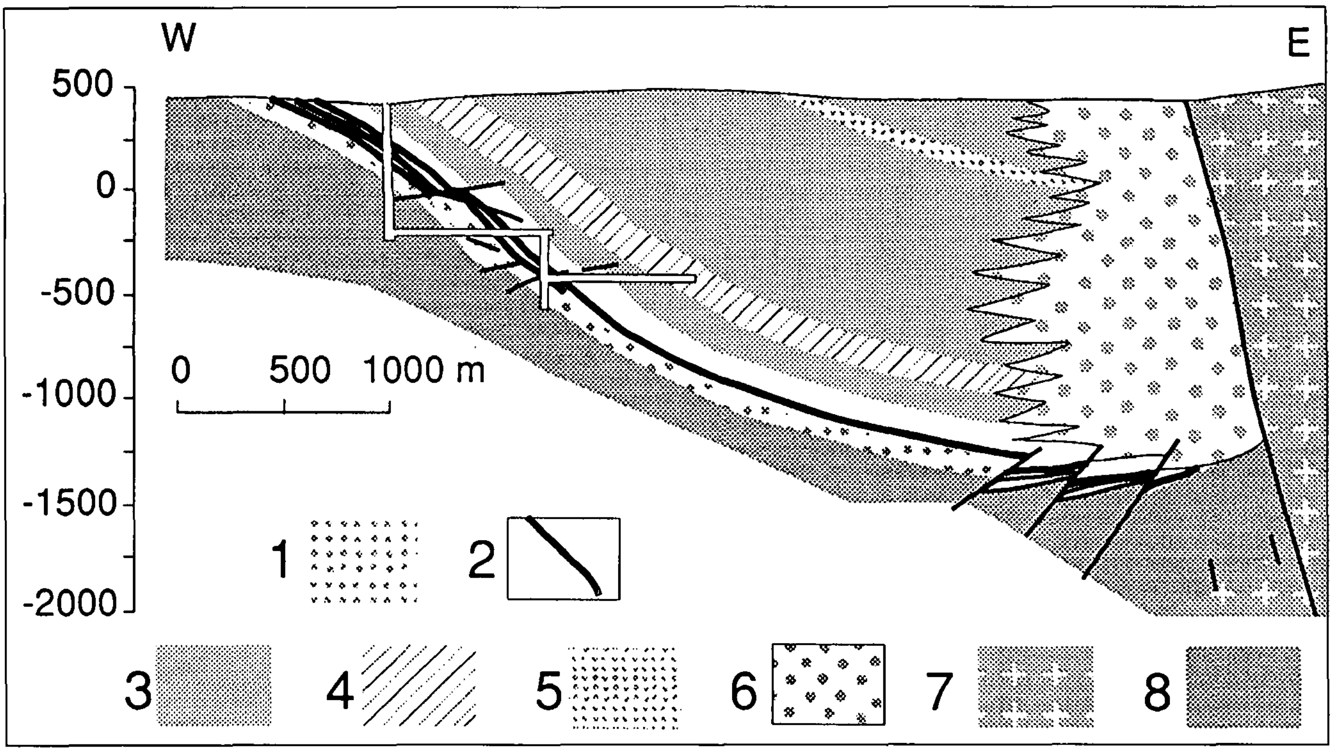
3.2.2.4. Orlice Permian Trough, Králíky Trough and Lower-Silesia Trough (d)

These structures are the direct northern continuation of the Boskovice furrow to the NW. The Permian basins subsided along these structures and were later compressed along the same faults (Text-Fig. 1, 2, 3, 4).

In this place the circular faults rim the inner structure of the Bohemian Massif. The Permian is here also up to 2 km deep in narrow troughs and the sediments are accompanied by basalt intrusions.

3.2.2.5. Nysa Klodzka Cretaceous Basin (d)

The curved axis of the shallow basin, not deeper than 300 m copies the circular structure on its NE part. It shows the best development of the scissor blades form of opening, narrowing to the south (Text-Fig. 4).



Text-Fig. 7.
Carboniferous-Permian basin of the Boskovice furrow (c) after MALY and KVET (1988), modified.
6 Permian and Carboniferous: 1 = conglomerates and breccias; 2 = coal seams; 3 = brown and red nonarcosic sediments; 4 = gray nonarcosic sandstones; 5 = arcoses; 6 = conglomerates.

3.2.3. Faults of Lozenge Form in the Bohemian Massif

The lozenge-like form of the horst controls and/or is controlled by the distribution of the main faults as far as for the interior, so far as for its boundaries. These faults are mainly of NW–SE and SW–NE direction (Text-Fig. 5B). From their length, width, displacement indicators, the exterior faults are the most important. The combination of lozenge boundaries of horst and of the circular faults creates the triangle shaped blocks in the surroundings of the circular structure. The inner segmentation of the circular structure produces the pie-shaped unequal blocks (Text-Fig. 5B). The largest faults have a complex history resulting from their polyphased development and all ranges of kinematics and shear reversals as well as of ductility can often be found on them. Also the blocks found between the prominent faults represent often the ductile structure of the deeper level of faulting. Kinematical information provide also the sedimentary basins confined to the main faults and volcanic and magmatic rocks with the distribution mostly controlled by faults. They indicate the kinematics for the single stages of the tectonic evolution of the massif.

The amplitude of the movement of the following shear/fault zones is considered as the most important (Text-Fig. 5B):

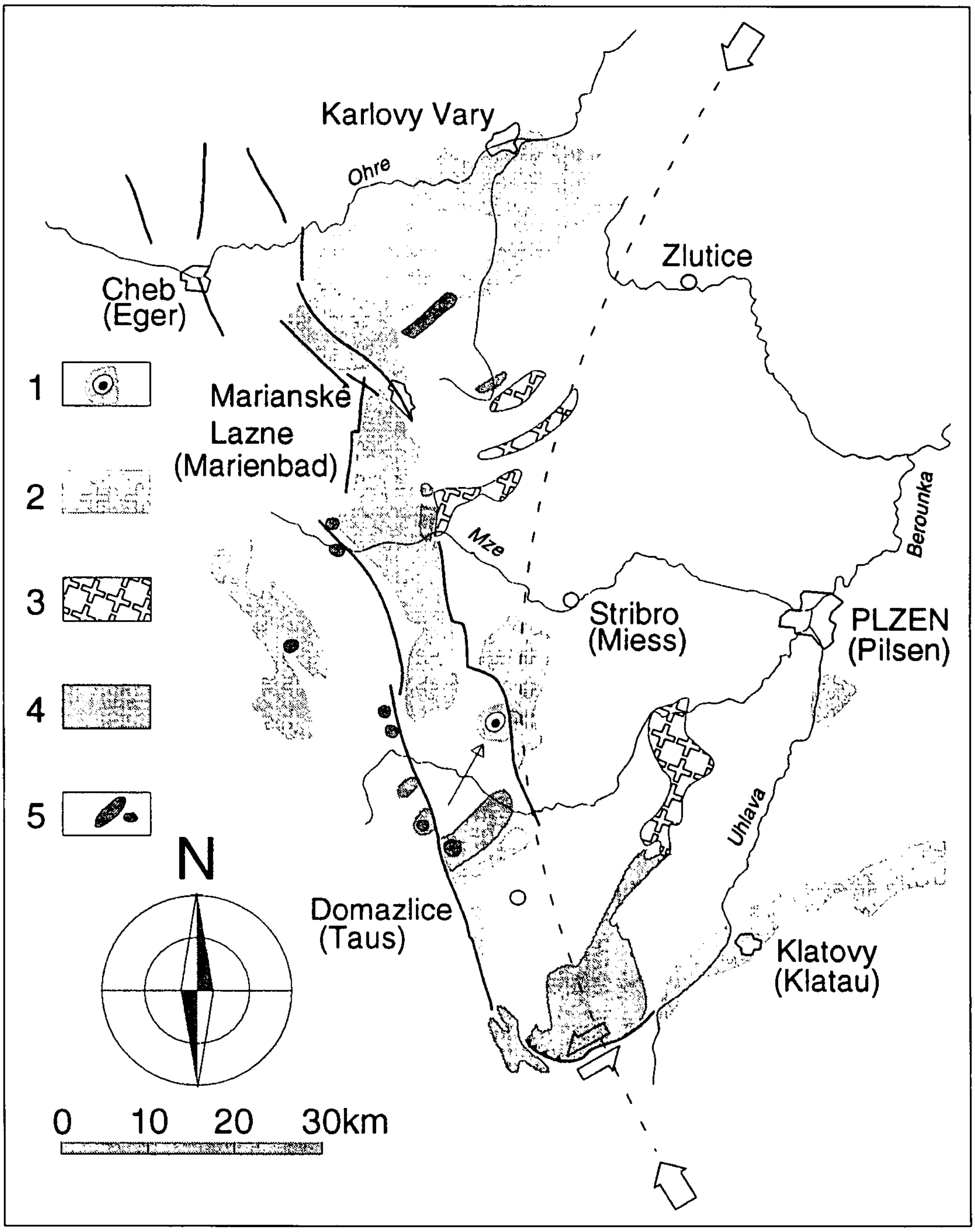
- CD1–CD2, Bavarian shear zone (RAJLICH, 1987), Bavarian quartz lode, zone of the NW–SE direction ductile strike-slip with several brittle rejuvenations,
- AB4–AB5–AB6 the NW–SE, segmented Elbe shear-zones,
- AB1–AB2–AB3, the Oder shear zone, Odra lineament [DVORAK & PAPPROTH, 1969], boundary Sudetic fault, Inner Sudetian shear zone,
- BC1–α1, the Moravian-Silesian zone NNE–SSW,
- AD1, the Central Saxony lineament (PIETSCH, 1956),
- AD3, the Central Bohemian shear zone NE–SW,
- α2, the Pribyslav shear zone NNE–SSW,
- α3, the Blanice furrow.

As it was mentioned, the movement in these zones occurred in several phases and it is witnessed by the ductile structures with the strong linear fabrics or with the strong mylonitization. The surrounding rocks of brittle faults are mostly older tectonites transected by the network of smaller shear zones. The kinematical characteristics such as the strike-slip or normal fault giving to the fault correspond thus to the last ductile movement.

3.2.3.1. Bavarian Shear Zone (CD1 & CD2)

This is one of the most prominent topographical (elevated) features of the system of NW–SE trends of the latest Neoidic remobilisations in the Bohemian Massif (Text-Fig. 1–4). It delimitates from the SW the Bohemian Massif and it is one of the principal sides of the lozenge like horst. Its total length, so as it is outlined on the Text-Fig. 5A is close to 500 km, the width can be estimated following to the belt of the reoriented cleavages (STETTNER, 1972, 1974) on 50 km. Its kinematics is complex because of several rejuvenations. The latest movement created the CD1 structure, the so called Danube fault with the down faulted Mesozoic sediments, which acts as normal fault in the latest stage of the Bohemian Massif horst development. The other neoidic etap of reactivation is indicated by the system of quartz lodes and mylonites associated with them. This dextral strike-slip phase dates from the Late Permian (S & C mylonites in the close vicinity of the Bavarian quartz lode). The dextral movement with the relatively low temperature deformation (amphibolite facies) in the granites in the vicinity of the quartz lode is indicative for the late Hercynian activity. The older Variscan granite

Text-Fig. 8.
Example of the detailed correlation of geological data in Western Bohemia with the circular structure from the fit to the topographical lineaments.
1 = Sedmihori intrusive ring structure; 2 = Variscan granites; 3 = Panafrican granites; 4 = Panafrican gabbros; 5 = ultramaphic rocks.



intrusions are subordinated to the structural trend of the zone. They are either elongated along its strike or perpendicular but delimited by the zone boundaries.

The asymmetric vorticity indicator on the map scale is provided by the bent of the foliations in the zone of the Rozmberk-Kaplice micaschists (SVOBODA et al., 1964) and shows the dextral shift.

The total displacement of several tens of km is constrained by the continuity of the area with the specific geochemistry similar to the Brunovistulian block from southern Moravia to the Alps (DUDEK, oral communication) and by the continuity of the positive gravity anomaly from southern Moravia up to Vienna (Text-Fig. 9). The strain in the whole thickness of the zone is not homogeneous. The planar pearl gneisses and migmatites with the recognisable E–W lineation are transected by the network of the relatively narrow zones.

3.2.3.2. Oder Shear Zone, Odra Lineament; Boundary Sudetic Fault, Inner Sudetian Shear Zone (AB1, AB2, AB3)

The Odra fault zones (DVORAK & PAPPROTH, 1969) show the maximal Upper Paleozoic subsidence comparable to the Carpathian flysh foredeep. This is compatible with the degree of fracturing found in this area and with the late Paleozoic (290–250 m.y.) dextral kinematics in which the Odra lineament is found in the tensional sector of the deformational ellipse. The Moldanubian rocks are found in Gory Sowie (Eulengebirge), Upper Proterozoic up to Devonian rocks are found in the separate trough of Gory Kaczwskie.

3.2.3.3. Erzgebirge Fault (AD1)

Intense Tertiary (Oligocene, 35 m.y.) volcanism and a Tertiary brown coal basin (MALKOVSKY, 1988) formed along this left hand strike-slip zone. Its curved trend in the northeastern part (Text-Fig. 1, 5A) fits exactly the circle. The largest volcanic structure of Doupovske Hory is directly on it.

3.2.3.4. Blocks Limited by the Faults

The enumerated shear zones correspond to the main boundaries of the geological triangle shaped outer blocks to circular structure and crescent shaped inner units-blocks in the Bohemian Massif. Their form results from composite geometry of lozenge and circle (Text-Fig. 5B). The prominent structure is the Panafrican Brunovistulian block.

4. The Problem of Tectonic Preservation/Destruction of the Circular Structure

The most conspicuous feature of the structure is the interruption of continuity structural trends from outside or from inside by the circular structure. This phenomenon can be observed on the:

a) AB4 (The Elbe shear zone)
b) AD3 (Central Bohemian shear zone)

The AB4 Elbe shear zone of long living activity is the prominent structure. It extends further beyond the limits of the Bohemian Massif. It is parallel to the Bavarian shear zone. The total length of the Central German Crystalline Rise especially from the Flechtingen-Rosslauer block to the Moravian zone is close to 500 km. Its width varies between 15 to 80 km. In the AB4 segment in the Bohemian Massif it has a character of discontinuous outcrops (domes) of the flat strongly ductile ramps and as the bent and offset of maphic rocks.

At least two shearing events of the reversed sense can be observed. The prominent structural feature from inside of the Bohemian Massif is the right hand 25 kilometres long offset of the major magnetic anomalies belt which transect the whole Bohemian Massif, in the area of the Zelezne Hory, (Eisengebirge) under the cover of Cretaceous sediments (RAJLICH, 1987).

A left hand shear sense can be deduced. It corresponds to the position of the low angle normal fault from the Kourim orthogneiss in the diagram of WILCOX et al. (1973). It can be read from the bent of the N–S trending lineations southerly from the smaller parallel shear zone which separates the Kourim orthogneiss thrust from the Moldanubian (Text-Fig. 5A). The outcrop of the lateral ramp of the flat décollement in the neighbourhood of the prominent shear zone can be assumed from the restriction of the lineation trends to a clearly outlined zone which limits the Proterozoic basin from the south.

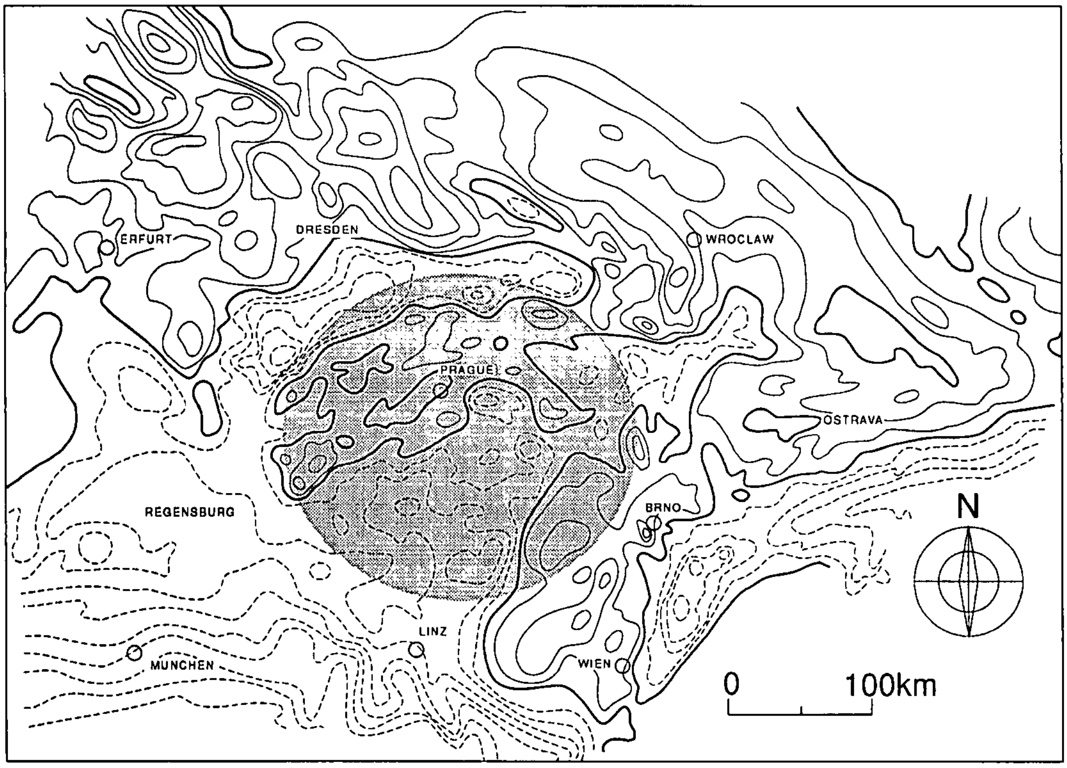
The perturbation of the continuity of this zone is visible on the northern border of the prominent negative E–W gravity gradient (Text-Fig. 9) conform to circular structure. It transects and obliterates the signature of the NW–SE trend. The Elbe lineament narrows in this area and it is represented by subordinate Oligocene Central Saxony thrust.

The Central Bohemian Shear zone with important mylonite zones is terminated abruptly against the Bavarian shear zone on the circular structure envelope (Text-Fig. 5A, 5B).

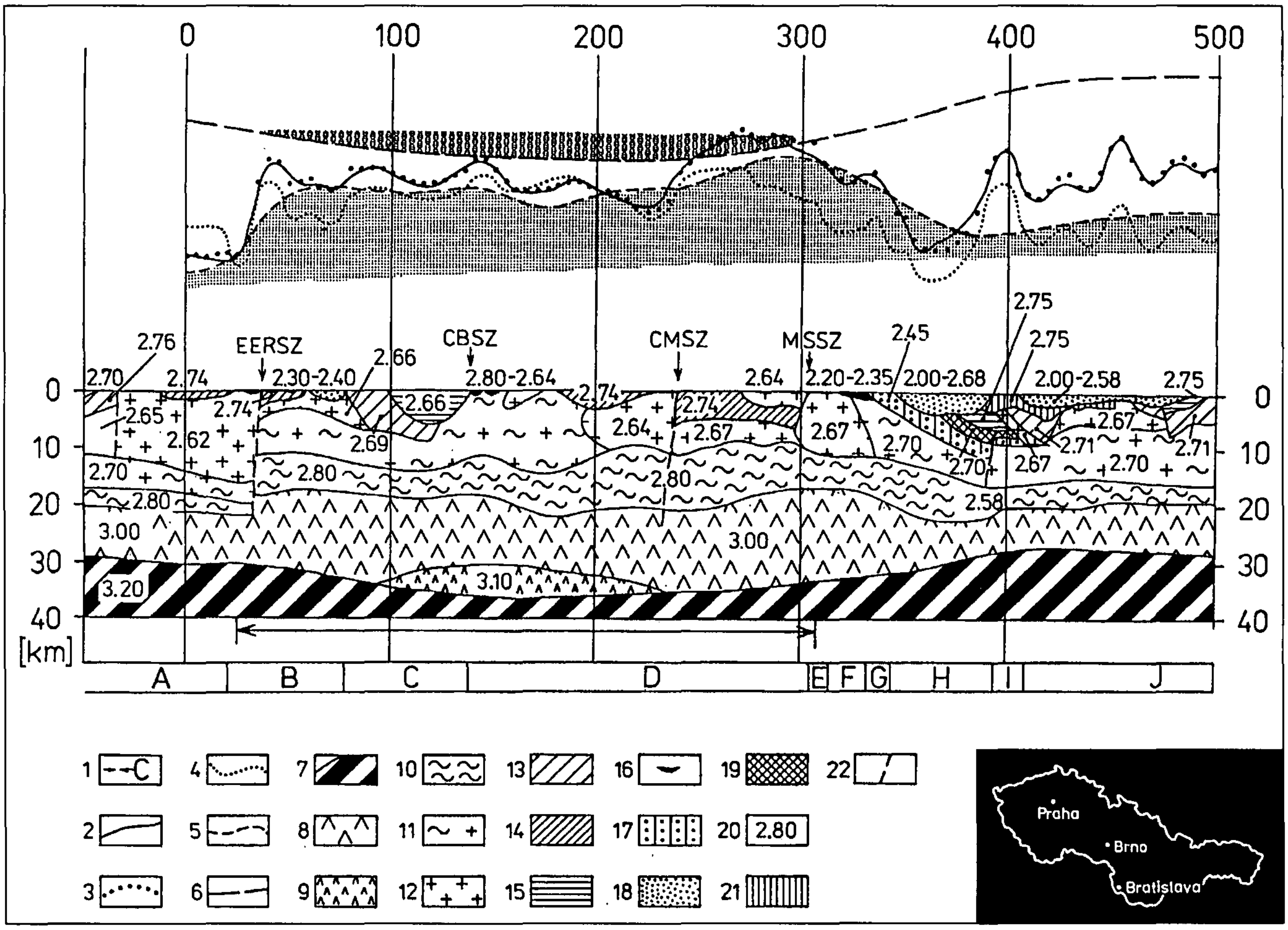
Necking in the Central Moldanubian pluton and contact between two intrusion types is the structural feature observed on the southern part of its crossing with the circular structure. All these phenomenons feature the stiffness of the structure which escaped to obliteration by perturbing and interrupting the course of important faults.

5. The Position of the Circular Stiffened Body in the Crustal Profile of the Bohemian Massif

The vertical crustal section through the Bohemian Massif as modelled to fit the refraction seismology, gravimetry (Text-Fig. 9) and magnetic data (Text-Fig. 10) (BLIZKOVSKY et al., 1991) shows the Moho depression for the large wave gravity interpretations. The Moho depression is compensated by the increase of the thickness of lower crust and by the body of the intermediate density between the mantle and the lower crust. The thickened lower crust represents probably the stiffened circular body inside the horst reactivated through the various orogenies. I explain tentatively the nature of the thickened lower crust by the presence of maphic and ultramaphic intrusions (or protrusions). In fact the Moldanubian is rich in amphibolites, eclogites and ultramaphic rocks which occur densely inside the shear zones. Today, there are at least three such events of maphic intrusions. The youngest is the Givetian phase especially strong in the NE part on the α and (AB) zones. There is another event in the Silurian basalts from the Barrandian basin. An important phase is the intrusion of Panafrican gabbros.



Text-Fig. 9.
Generalized gravimetrical map of Central Europe (IBRMAJER et al., 1981), modified.
Positive anomalies = full lines, negative anomalies = broken lines.



Text-Fig. 10.
Crustal cross-section of the Bohemian Massif (BLIZKOVSKY et al., 1988).
1 = Extent of geological units: A = Erzgebirge – Thueringen area, B = Tepla crystalline and platform cover of the Ohre zone, C = Proterozoic in the Tepla Barrandian region, D = Moldanubicum, E = Boskovice furrow, Brunovistulicum, F = Carpathian foredeep, G = the flysh area of the West Carpathians, H = Vienna basin, I = core mountains of the Malé Karpaty, J = Danube Lowland, Arrow line = extent of the circular structure; 2 = Bouguer isanomals; 3 = total gravity effect of the density model; 4 = gravity effect of anomalous masses in the interval earth surface–depth of 10 km; 5 = gravity effect of anomalous masses in the depth range 10 to 25 km; 6 = gravity effect of anomalous masses in the depth range 25 to 40 km; 7 = mantle rocks, section through the Moho; 8 = 9 dense lower crust; 9 = body of the intermediate density on the mantle/lower crust interface; 10 = upper part of the lower (granulitic) crust; 11 = upper /granitic/ crust; 12 = granite batholites, including orthogneises; 13 = weakly metamorphosed upper Proterozoic and Palaeozoic rocks; 14 = strongly metamorphosed Precambrian rocks, 15 = Pelozoic rocks; 16 = volcanites; 17 = Tertiary flysh sediments and folded sedimentary formations in the West Carpathians; 18 = Late Tertiary sedimentary rocks (Neogene of the Erzgebirge-piedmont basin, the Carpathian foredeep, the Vienna Basin, the Danube basin and Central Bohemian Permocarboniferous; 19 = granites in the thrusted units of the Carpathians; 20 = density values used in the model; 21 = higher density metamorphic rocks in the Low Carpathians; 22 = major faults: EERSZ = Erbendorf – Erzgebirge – Riesengebirge shear zone (AD2), CBSZ = Central Bohemian shear zone (AD3), CMSZ = Central Moldanubian shear zone (Pribyslav fault) ($\alpha 2$), MSSZ = Moravian-Silesian shear zone ($\alpha 1$).

They occur especially along the α lines. Ultramaphic and maphic bodies are found in similar position on the intersection of the circular structure and of the oblique hatched line in Text-Fig. 5B. It joins the Letovice crystalline complex and Ceska Trebova gravity anomaly on the east and Kdyne gabbro on the west. The above mentioned examples are part of the crescent shaped basin of positive gravity signature (Text-Fig. 9), filled partly with the maphic volcanic.

6. The Problem of Origin of the Structure from the Tectonical Point of View

In most experiments or geometrical models the curved features are obtained in the deformation of the previously rectilinear elements. However this fits in well only with the extensional vein arrays (RAMSAY and HUBER, 1987). Many such circular features should arrange along some trend of the major fault system. The size of the Bohemian Massif would need the rotation of the shear arrays in the zone at least 300 km wide. Very probably such shear array would be filled by intrusion so what we would obtain is the curved maphic dyke or dykes. This bending would also produce an unrealistic amount of crustal thickening which is not observed here. On the contrary the Proterozoic sediments are indicative of the large depression in the subsiding area, it means the maphic undercompensated crust which existed here and still bears this signature.

The problem of the curving of the lineation trends from the Central Bohemian shear zone into the Elbe zone is less obvious for the explanation. This bend concerns also the small scale structures in the Proterozoic and consequently the basement faults. It correlates with the interruption of the AD4 fault course. During all later rejuvenations the small scale structures copied this trend. It is probable that the southern limits of the Proterozoic basin are formed of faults which were created or accentuated during the event which created also the rigid structure. They were coded into its behaviour as they became repeatedly reactivated in later orogenies.

The adaptation of the external shear zones to the circular structure reminds of the behaviour of the rigid particles in the ductile matrix. It can be observed on the circular crustal blocks of different size, see for instance the Tarim block of the Himalayan Mountain belt (COBBOLD et al., 1993). It is evident that the processes which occurred in the Bohemian Massif formed this structure. From the tectonic analysis of the surroundings and from the inner structures of the Massif we can judge about

1) the time of its foundation,
2) the processes which led to its formation.

7. Conclusions

The Tertiary horst of the Bohemian Massif displays the composite geometry of the inner circular depression of varying altitudes between 200–500 metres above sea level, and of the surrounding higher, sometimes mountainous area of the lozenge-form with E–W axis. This structure visible on the space photographs is materialised by

a) the composite lozenge outer fault – horst form,
b) the circular structure of the inner faults and of crossing elements,
c) detailed features of the intrusion emplacements,
d) forms or position of important geological boundaries.

The length of the longer axis of the lozenge is between 540–480 km. The shorter N–S axis is approximately 360–390 km long. The circular structure is 260 km large in the E–W diameter and 235 km large in the N–S section. The repetition of the geometrical configuration up from the Panafrican orogeny suggests Middle to Lower Proterozoic origin and the stiffened character of the crust in it. It may represent a very deeply eroded meteoritic scar.

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