Sborník geologických věd	Ložisková geologie, mineralogie, 31	Pages 27–50	9 figs.	3 tabs.	4 pls.	ČGÚ Praha 1997	ISBN 80-7075-204-1 ISSN 0581-9180

The Central Bohemian Plutonic Complex: Geology, chemical composition and genetic interpretation

Středočeský plutonický komplex: geologie, chemické složení a genetická interpretace

FRANTIŠEK V. HOLUB[1] - JIŘÍ MACHART[2] - MAGDALENA MANOVÁ[3]

Received June 10, 1996

Key words: Bohemian Massif, Plutonic rocks, Petrology, Geochemistry, Radioactivity, Genesis, Hercynian orogeny

HOLUB, F. V. - MACHART, J. - MANOVÁ, M. (1997): The Central Bohemian Plutonic Complex: Geology, chemical composition and genetic interpretation. – Sbor. geol. Věd, ložisk. Geol. Mineral., 31, 27–50. Praha.

Abstract: The Central Bohemian Plutonic Complex of Lower Carboniferous age is a composite batholith comprising a great number of various plutonic and dyke rocks. Among them, at least six compositional groups can be distinguished: CA – the calc-alkaline group varying from hornblende gabbro to biotite-hornblende granodiorite; HK – the high-K calc-alkaline to shoshonitic group of scarce monzonitic rocks and voluminous amphibole-biotite granodiorite to monzogranite varieties; UK – the ultrapotassic group comprising amphibole-biotite and pyroxene-biotite melasyenitic to melagranitic rocks, KMgG – more acidic high-K, high-Mg granites closely related to UK; AlG – peraluminous granodiorites; CaG – Ca-rich and K-pooor acid granitoids of biotite granodiorite to trondhjemite composition. In addition to them, numerous dykes of leucogranites (LG) occur.

The prevailing granitoids are of I- or rather H- (hybrid) type and various mantle-derived mafic magmas (calc-alkaline, shoshonitic and ultrapotassic) were involved in their origin. Nevertheless, some typical S-granitoids are present in subordinate amount (the AlG and perhaps also LG).

The CA group is the oldest among unmetamorphosed plutonic rocks in the area. Tonalites and granodiorites of this suite (= the Sázava type) correspond geochemically to volcanic-arc granitoids. On the other hand, their pre-collisional setting is improbable because of they did not suffer the intensive shearing accompanying a strike-slip displacement of the Barrandian and Moldanubian blocks in the zone of the Central Bohemian suture.

Relatively younger high-K intrusions are more magnesian and appreciably richer in hygromagmatophile elements in respect to the CA group. These intrusions appear as related to crustal extension, uplift and decompression of the Moldanubian block.

Ultrapotassic rocks are extremely rich in K, Rb, Cs, Th, U but bear chemical indications of rather primitive mantle-derived magmas. Origin of both the UK and KMgG rocks can be explained in terms of partial melting of highly anomalous mantle sources followed by extensive hybridization of ultrapotassic magmas with acid crustal melts.

The UK, KMgG and at least some S-type granitoids intruded relatively late in respect to other voluminous rocks of CBPC, and their distribution is apparently independent on the Central Bohemian Suture.

[1]*Department of Petrology, Charles University Prague, Albertov 6, 128 43 Praha 2*

[2]*Czech Hydrometeorological Institute Prague, Division Milevsko, Geological Institute of the Czech Academy of Sciences, Rozvojová 135, 165 00 Praha 6 - Suchdol*

[3]*Czech Geological Survey, Klárov 2, 118 21 Praha 1, Czech Republic*

Introduction

The Central Bohemian Plutonic Complex (CBPC) is a large composite batholith cropping out on a total area of about 3200 km^2 in central and southern Bohemia south of Prague (Praha). In older Czech literature it was referred to as the "Central Bohemian Granite Massif" and more recently, starting with papers by Orlov (1935a, b), as the "Central Bohemian Pluton".

This batholith displays the most varied composition among plutonic bodies in the Bohemian Massif. The plutonic rocks correspond to gabbro and even hornblendite, biotite-hornblende tonalite and prevailing amphibole-biotite granodiorite to granite, amphibole-biotite melasyenite (durbachite) to melagranite and biotite-pyroxene melasyenitic rocks, leucogranite, and some other varieties. In addition, a great number of highly variable rock dykes are present (minettes, spessartites, microgabbros, diorite and melasyenite to granite porphyries, etc.).

The Central Bohemian Plutonic Complex has been studied by many authors from various points of view. Besides the great number of papers dealing with some limited part of the batholith or some special problem, there are synoptic papers by Kodym Jr. (1966) and Palivcová (1965, 1984). Most data are, however, scattered over the Czech-written literature.

Modal composition has been extensively studied by Steinocher (1950 to 1963), and numerous more recent data can be found in explanatory notes to geological maps and some other papers.

There are some specialized papers on rock-forming minerals, e.g., by Poubová (1971, 1974) on composition of amphiboles, by Fiala and Vejnar (1976) on biotites, by Johanová (1969) and Kodymová and Vejnar (1974) on assemblages of accessory minerals in the principal rock types.

Chemical composition of plutonic rocks in respect to major oxides was studied by many authors but papers by Orlov (1935b), Steinocher (1969) and, above all, Vejnar (1973), are the most important among them. There are more than 300 whole-rock analyses yet published. A great majority of them was summarized by Vejnar (1973), together with some principal statistical parameters. Some more recent analyses were presented in explanatory notes to new geological maps 1 : 25,000 (e.g., Žežulková et al. 1980; Tonika et al. 1980a, b).

Trace element contents were discussed by Vejnar (1974b), Jakeš (1977; both papers present only averages for individual rock types), Tauson et al. (1977), and Bouška et al. (1984). Radioactive elements (K, Th, U) in granitoids were studied by Manová (1975).

The major shortcomings of many geochemical papers from CBPC are a separate treatment of major and trace elements, uneven quality of data and also the fact that correspondence of many samples to the local petrographic types has been determined erroneously.

Moreover, the frequently used arithmetic means of individual rock types (Steinocher 1969; Vejnar 1973, 1974a,b) can obscure the existing variability and evolutional trends. Consequently, some attempts at discrimination of natural (both geochemical and petrogenetic) rock groups, which were based on average compositions only (Steinocher 1969, Vejnar 1974b), led to contradictory results; an exception is represented by the dark and potassium-rich granitoids to syenitoids, which were correctly recognized as a distinct petrochemical group (Steinocher 1969; Sattran and Klomínský 1970).

Petrogenetic interpretations yet published are rather speculative and frequently controversial. Many papers are focussed on the "granite controversy" (e.g., Palivcová 1965; Palivcová et al. 1989a, b). Attempts at more up-to-date interpretations are still scarce (Bendl and Vokurka 1989; Janoušek and Rogers 1994; Janoušek et al. 1995).

Hence, the aim of our paper is to summarize the most important geological, petrographical and geochemical information on the individual rock types, to define natural groups of genetically related rocks, and to discuss their petrogenesis and relationship to geodynamic setting. This study should serve as a starting point for further, more detailed papers.

Regional setting

The geological situation of the Central Bohemian Plutonic Complex is illustrated in Figure 1. The Complex is situated along an important, generally NE-SW trending tectonic zone called the Central Bohemian Suture, which separates the Barrandian block (or Bohemicum or the Teplá-Barrandian region) in the north-west from the Moldanubian block (Moldanubicum) in the south-east.

According to geophysical data, the suture is formed principally by the NE-SW trending Klatovy and Benešov deep faults shifted by the transverse (NW-SE) Jáchymov and Sázava faults (Blížkovský et al. 1988).

During Hercynian orogeny, the boundary between the Barrandian and Moldanubian blocks experienced polyphase ductile deformation with both sinistral and dextral sense of transport (Rajlich 1993).

The Upper Proterozoic and Lower Paleozoic rocks surrounding the northern part of the Complex and forming the roof of intrusions were extensively deformed prior to formation of CBPC by progressive simple shear in the ductile shear zone, named by Rajlich et al. (1988) as the Central Bohemian Shear Zone and interpreted as resulting from a strike-slip movement with horizontal displacement exceeding 100 km. More recently, Rajlich (1993) assumes a shorter distance of transport.

The adjacent part of the Barrandian block comprises the Upper Proterozoic series (slates, mudstones, greywackes, conglomerates, basaltic and rhyolitic volcanic rocks accompanied by volcanoclastic beds) and the Lower Paleozoic, mainly Cambrian greywackes, sandstones and conglomerates (in the Příbram area), but locally also Ordovician to Lower Devonian sedimentary rocks (Havlíček 1977).

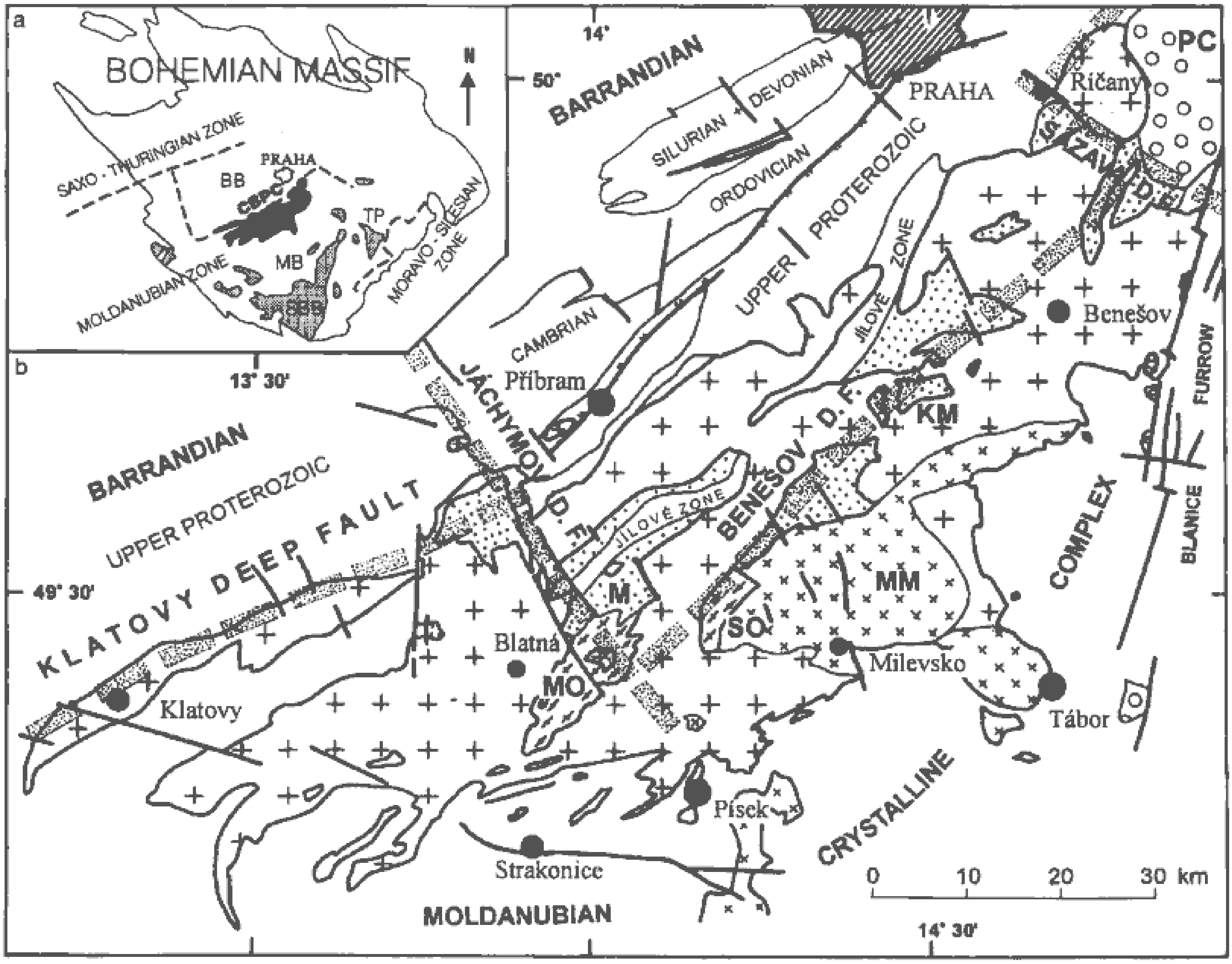
The Klatovy apophysis of CBPC follows the Klatovy deep fault accompanied by the Klatovy shear zone. The north-western boundary of the complex continues to NE generally in the same direction being relatively straight in geological map regardless the course of the gravimetrically indicated suture.

Nature of the contact is intrusive with many apophyses and only locally has been modified by younger faults. The generalized contact plane is steeply dipping (50–80°) to SE (i.e., downward beneath CBPC), as could be directly observed up to a depth of 1800 m in mines around Příbram (e.g., Vlašímský 1976).

A thermal aureole is developed in a total width ranging from about 100 m to more than 1 km. Maximum temperatures of contact metamorphism correspond to the amphibole-hornfels facies.

Granitoids neighbouring with sedimentary country rocks may contain numerous xenoliths of hornfelses (Plate I-1) or, at localities adjacent to Cambrian conglomerates, of quartz pebbles.

Relics of Upper Proterozoic to Devonian sedimentary sequences and volcanic rocks occur as large contact-metamorphosed roof pendants ("metamorphic islets" on the plutonic rocks (= the "Islet Zone", e.g. Kettner 1930; Chlupáč 1992). In spite of the generally reduced thickness and (still uncertain) absence of Cambrian, lithology of the Lower Paleozoic sediments in the Islet Zone is similar to Barrandian with some exceptions like the presence of quartzites and quartz conglomerates of Lower or Middle Devonian age (?) which are the uppermost member of the sedimentary pile (typically in the Sedlčany-Krásná Hora islet) and have no counterparts in the Prague basin of Barrandian.



1. (a) Location of the Central Bohemian Plutonic Complex (CBPC) and other plutonic bodies in the Moldanubian Zone of the Bohemian Massif. BB – Barrandian block, MB – Moldanubian Block, SBB – South Bohemian (= Moldanubian) Batholith, TP – Třebíč Pluton.
(b) Geological outline of the Central Bohemian Plutonic Complex.: Crosses – granitoids and subordinate mafic rocks of CBPC; small overturned crosses – ultrapotassic plutonic rocks; dots – Upper Proterozoic to Devonian sedimentary and volcanic rocks of the Islet Zone (thermally metamorphosed roof pendants); elongated crosses – orthogneisses; open circles – Permo-Carboniferous sediments. KM – Křečovice migmatites, M – Mirovice metamorphosed islet, MO – Mirotice orthogneiss, SO – Staré Sedlo orthogneiss, MM – Milevsko massif, PC – Permo-Carboniferous.

Maximum metamorphic conditions within the islets reached those of the hornblende-hornfels or even pyroxene-hornfels facies (Suk 1973a). In some places, suitable rocks of semipelitic composition were partially melted (e.g., the Křečovice migmatites).

Several good exposures in the northern part of CBPC display a finger-like intrusive contact of granitoids penetrating the surrounding metamorphic rocks of the "Islet zone" along their schistosity (see, e.g., Kettnerová 1920).

The Jílové zone is a conspicuous lithological unit of the roof. It represents a narrow belt about 65 km in length, formed by Upper Proterozoic basaltic and acidic volcanic rocks accompanied by minor intrusions of gabbro, tonalite and trondhjemite (albite granite). Northernmost part of the zone has character of an anticlinal zone and lithologically grades into overlying sediments (the Štěchovice group of the Upper Proterozoic) whereas central part appears as a septum between granitoids. Southern parts of the belt pertain to the Neveklov and Mirovice metamorphic islets.

The rocks were affected by a strong ductile to brittle deformation with development of the outstanding subvertical "Jílové cleavage" and low-grade metamorphism prior to intrusions of CBPC. A later thermal metamorphic overprint is related to Hercynian granitoids.

The Mirotice and Staré Sedlo orthogneisses, which form important parts of the Mirovice and Sedlčany-Krásná Hora islets, were believed by many authors to be also of the Upper Proterozoic age, although their intrusive contacts against the Lower Paleozoic (Ordovician?) sediments have been mentioned, e.g., by Mrázek (1964). Recently the rocks have been identified as intensively deformed and metamorphosed calc-alkaline granitoids of Middle-Upper Devonian age (Košler et al. 1993).

In the south and east, CBPC extends far into the Moldanubian crystalline complex which is represented by the Monotonous and Varied Groups. The former unit consists mostly of paragneisses and migmatites with minor occurrences of quartzite and calc-silicate rocks, the latter one is rich in marbles, calc-silicate rocks, quartzites, graphitic schists, amphibolites, etc. All these high-grade metamorphic rocks correspond to the upper amphibolite facies. There are also some high-pressure, high-temperature rocks, namely in the Gföhl unit comprising partly anatectic gneisses, amphibolites, granulites and eclogites. According to recent interpretations, the Gföhl unit represents an upper sheet in the crystalline nappe pile of the Moldanubicum and surrounds CBPC along its eastern margin (e.g., Matte et al. 1990).

The Moldanubian Crystalline Complex may include some old elements (Early Proterozoic, Wendt et al. 1993) assembled to younger ones (Upper Proterozoic to Lower Paleozoic in age) during the Hercynian orogenesis. Some parts of the Varied Unit with abundant marbles at S contact of CBPC seem to be lithologically comparble to the Lower Paleozoic rocks of the Islet Zone (Chlupáč 1992).

The Hercynian (Lower Carboniferous) age of the last metamorphism is now generally accepted and evidenced by U/Pb dating of gneisses and granulites (e.g., van Breemen et al. 1982; Aftalion et al. 1989; Wendt et al. 1994).

Foliation planes in the Moldanubian complex along south and south-east margin of CBPC are generally NW-dipping (i.e., they dip under the plutonic complex). The southern boundary of CBPC is complicated by many apophyses, which are mostly concordant with foliation planes in the surrounding metamorphic rocks, and may be accompanied by pearl gneisses.

Various xenoliths occur in all plutonic rocks and their abundance usually increases towards the roof pendants. These remnants of the roof suggest an important role of stoping during the predominantly passive emplacement of voluminous plutonic bodies.

Those xenoliths which are enclosed in relatively late, small intrusions, were apparently transported from depth. Xenoliths of various gneisses, quartzitic rocks, amphibolites, calc-silicate rocks, etc., within bodies of the Zbonín granite (Plate I-2) or ultrapotassic rocks, may argue for presence of the Moldanubian crystalline complex below the SE part of CBPC (Holub 1980).

A multi-stage character of the igneous activity is evidenced by internal sharp boundaries within CBPC and by presence of the older plutonic rocks as xenoliths enclosed in the younger intrusions (Plates II-1,2 and III-1).

A conspicuous regional dyke swarm of Hercynian age is developed in the area of CBPC (except in its youngest parts) and in adjacent part of the Šumava Moldanubicum S of CBPC. Most dykes strike W-E to NW-SE and are represented by lamprophyres (namely minettes, Plate III-2) and various melasyenite to granite porphyries.

Eastern part of the northernmost lobe of CBPC (the subcircular Říčany massif) is covered by Permo-Carboniferous continental sediments of late Stephanian C to Autunian age.

These clastic rocks occur also as small relics within a narrow, N-S to NNE-SSW trending, graben-like fault system of the Blanice Furrow, which continues southward to the Moldanubian crystalline complex. Faults of this system truncated the easternmost part of CBPC represented by deformed granitoids (namely the so-called "Benešov type").

Unmetamorphosed and almost undeformed to weakly deformed plutonic rocks of CBPC are believed to be of Hercynian age (Kettner 1930, Kodym Jr. 1966). Speculations about considerably higher ages of many granitoids in this area (e.g., Chaloupský 1978) lack any geological or geochronological evidence. These rocks are appreciably younger than (Lower) Devonian sediments and also than orthogneisses whose protoliths were dated as Middle-Upper Devonian (Košler et al. 1993). Intrusions of granitoids should span the time interval between the main (low-pressure) metamorphism of the Moldanubian Complex and deposition of Permo-Carboniferous clastic beds onto the NE part of CBPC.

Geophysical outline

The Central Bohemian Suture is indicated by markedly steep gravimetric gradient between the positive area of the Barrandian block and the generally negative Moldanubian area (Blížkovský et al. 1985, 1992). The existence of deep vertical faults affecting even the Moho discontinuity has been proved by international deep-seismic profiles DSS VI and VII.

The thickness of the crust reaches about 37 km, i.e. the maximum value in the Bohemian Massif, at the SE margin of CBPC and adjacent part of the Moldanubian crystalline complex (Beránek and Zounková 1977; Blížkovský et al. 1992). Vertical inhomogeneity of the crust is demonstrated by varying seismic velocities (Beránek et al. 1975).

Deep seismic reflection profile 9HR has shown SE-dipping reflection planes in the Barrandian block but NW-dipping planes in the Moldanubian area; it also indicated thickness of about 4.5 km for seismically transparent granitoids in the SW part of CBPC SW of Blatná (Tomek and Vrána 1992). For other parts of the Complex, such data are not available.

Positive gravity anomalies in the central part of CBPC, NW of the Benešov fault, can be accounted for by both the metabasites of the Jílové belt and the gabbroic rocks of CBPC, which may be more abundant at some depth (the so-called "Sázava batholith" according to Tomek 1975). According to Šalanský (1983), both rock groups are responsible also for magnetic anomalies within the so-called Central Bohemian regional magnetic zone).

The gravity low region comprises several pronounced negative anomalies. One of them belongs to the Říčany granite body. Other negative anomalies are situated in the middle part of the Blatná granodiorite (SW of the Jáchymov fault) and even at the SE border of the Complex, which is built of relatively more dense granitoids of the Červená type (Blížkovský et al. 1985).

A large negative anomaly situated S of Písek, i.e. just outside the Complex, has been interpreted by Tomek (1975) as a hidden body of very light granites (the "Putim batholith"). A great number of leucogranite dykes is typical for that area, but the exact nature of the rocks responsible for this anomaly, as well as their relation to the CBPC, are questionable.

On the basis of rock densities and interpretation of residual gravity anomalies, Marek and Palivcová (1968) proposed rather small thickness of some rock types, especially the relatively dark granitoids in the SE part of CBPC, which could be underlain by some less dense granitic rocks. Dobeš and Pokorný (1988) studied the local gravity field and interpreted the Milevsko massif of ultrapotassic plutonic rocks (= the Čertovo břemeno complex) as a subhorizontally oriented tabular body only 2–3 km thick with some less dense rocks below.

A great majority of granitoids (except the Sázava and Požáry types) are significantly more radioactive than the surrounding Upper Proterozoic and Lower Paleozoic rocks, especially the metavolcanics of the Jílové belt and similar rocks. Consequently, the boundary of CBPC is partly well marked in the aeroradiometric map (Fig. 2). On the other hand, there is much less distinct contrast against some migmatites of the Moldanubian metamorphic complex bordering the CBPC at south. An exception is represented by the extremely radioactive, ultrapotassic melasyenitoids and melagranitoids of the Čertovo břemeno and Tábor types (Matolín 1970; Manová 1975).

Petrographic features

Since the petrographical variability of CBPC is too large, it is conventional to use special names for distinct varieties of granitoids and more mafic rocks; there are 30 odd names of local rock types in the literature. Some of them are, however, ill-defined, questionable or redundant.

Table 1 provides a brief summary of local petrographic types and their most important features resulting from critical evaluation of a large set of published and unpublished data. The individual types are arranged into several groups defined on both petrographical and geochemical grounds. A generalized surface distribution of rock types is illustrated in Fig. 3.

The following more detailed petrographical and mineralogical characteristics of the rock types are largely based on papers which were already cited in the Introduction.

Gabbroic to dioritic rocks (CA group)

Gabbroic to dioritic rocks of the calc-alkaline group are present in the northern and central part of CBPC, usually in a close association with granitoids of the Sázava type.

The most characteristic ferromagnesian mineral of gabbro is amphibole ranging in composition from tschermakite (in crystal cores) to much more abundant magnesio-hornblende, rarely with actinolitic overgrowths. The amphiboles are magnesium-rich with *mg* as atomic 100Mg/(Mg+Fe) ranging from 54 to 70 (Vejnar 1975; Ulrych 1975, 1985). Clinopyroxene is diopside (mostly salite, Fiala 1975, Fiala et al. 1974). Andesine, some interstitial K-feldspar and quartz are often present besides calcic plagioclase (e.g., in the famous Pecerady gabbro, Knotek 1975).

The gabbroic rocks are variable in textures but similar to many gabbroids intimately associated with calc-alkaline granitoids elsewhere (Palivcová 1981). They are often porphyritic with large (up to 10 mm) stubby hornblende crystals which are frequently arranged into a centric (spheroidal) texture, described and interpreted by Hanuš and Palivcová (1970) in terms of recrystallized variolitic texture of volcanic rocks.

Some quartz gabbroes may contain light "ocelli" up to several mm in size, composed of quartz or quartz plus feldspars (e.g., Palivcová 1978). Such rocks of presumably hybrid origin are known as small masses in the central part of CBPC E of Příbram.

Olivine gabbro is rare and occurs in a mafic body at Tužinka near Benešov (e.g., Vejnar 1972). Pyroxene-bearing olivine hornblendite associated to gabbroic rocks is known from a few localities in the vicinity of Příbram.

Sázava type (CA group)

Granitoids of the Sázava type range from biotite-hornblende tonalite or quartz diorite to granodiorite. Only in the most acidic varieties of granodiorite, biotite prevails over amphibole which may be even absent in rocks close to contacts with metamorphosed semipelitic schists. Plagioclase may contain calcic cores surrounded by andesine to oligoclase. The K-feldspar is subordinate and never forms phenocrysts in contrast with granitoids of the HK and KMgG groups.

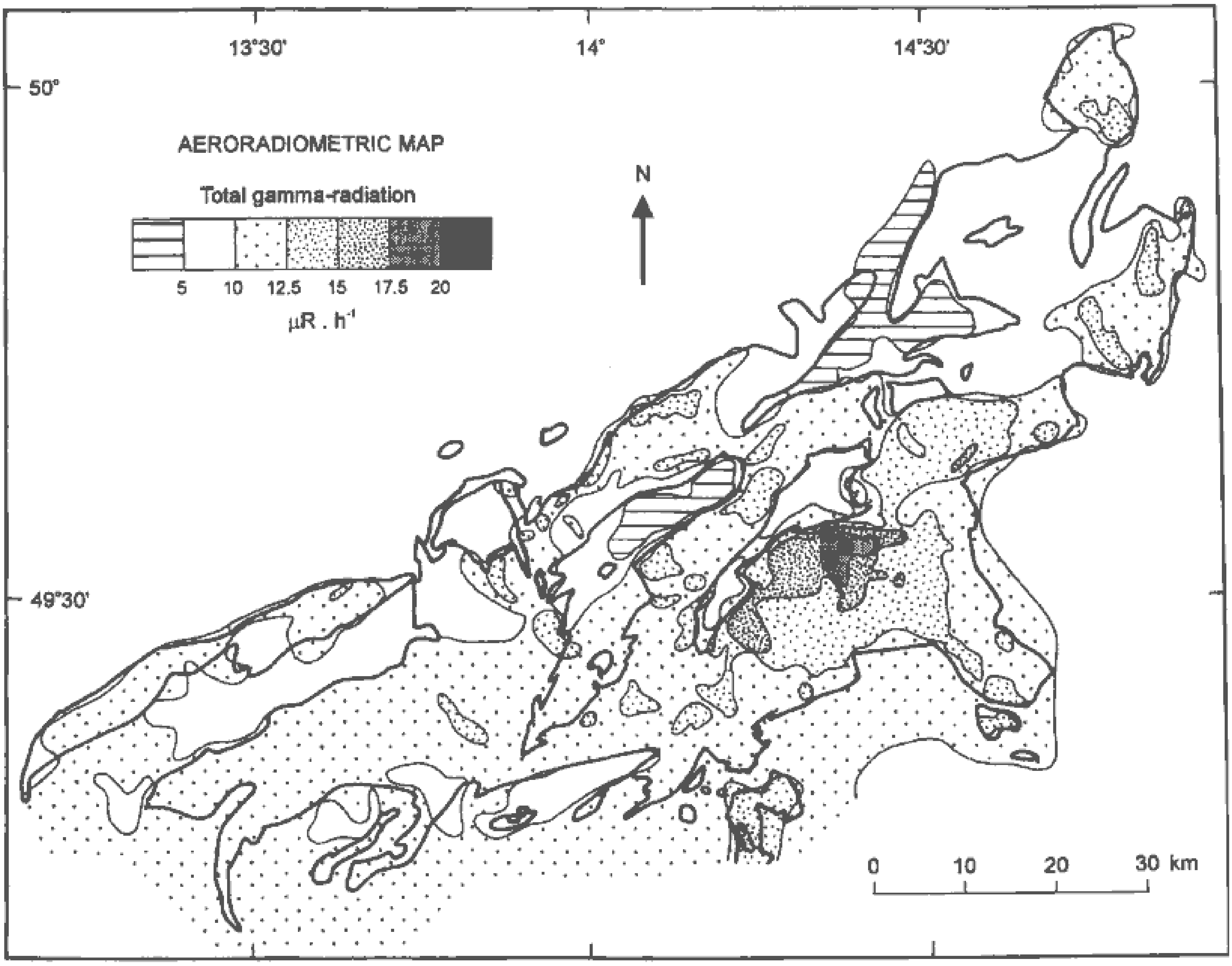
Characteristic ferromagnesian minerals are ferrohornblende (*mg* 46–48) and Fe-biotite (*mg* 42–46). The most common accessory minerals are magnetite, pyrite, some ilmenite, sporadic titanite, some zircon and apatite, and abundant (secondary) epidote.

These granitoids contain ubiquitous microgranular enclaves of quartz gabbro or diorite to melatonalite composition. Shape of the enclaves frequently indicates their plasticity during emplacement (Dudek and Fediuk 1957; also Plate IV).

Many authors (e.g., Kodym Jr. et al. 1963; Vejnar 1973) used the term "Sázava type" in much broader sense and included into it also the hornblende-biotite granitoids of the Kozárovice (or Vltava) type. Since the latter rocks differ considerably in mineral chemistry, accessory mineral assemblage, modal and whole-rock chemical composition, they should be regarded as members of the high-K group, however.

Požáry and Nečín types (CaG group)

The Požáry and Nečín types occur in two isolated bodies which intruded the Sázava type. These rocks are equigranular biotite (leuco)granodiorites to trondhjemites. Sodic plagioclase often contains irregular more calcic cores. Iron-rich biotite (high in siderophyllite component, with *mg* <32) is usually the only mafic mineral. Amphibole occurs rarely and only in accessory amount. Accessory magnetite is common.



2. Simplified airborne radiometric map of the Central Bohemian Plutonic Complex. Exposition power of gamma radiation in $\mu R.h^{-1}$.

Monzonitic rocks and Zalužany type (HK group)

Monzonitic rocks form subordinate bodies associated with granitoids of the central and southern part of CBPC. Compared to common gabbroes and diorites, these mafic rocks are richer in potassium minerals (namely K-feldspar) and correspond to clinopyroxene-bearing biotite-amphibole monzogabbro, melamonzonite and quartz melamonzonite (e.g., the monzonitic rocks from Lučkovice near Mirotice, Ledvinková 1985). A less mafic variety is represented by the fine-grained biotite-amphibole quartz-monzonite to melagranodiorite of the Zalužany type (Hejtman 1948).

Amphibole of these rocks is usually magnesio-hornblende to actinolic hornblende. Biotite is also Mg-rich with *mg* 55–71 (Ledvinková 1980).

Kozárovice and Těchnice types (HK group)

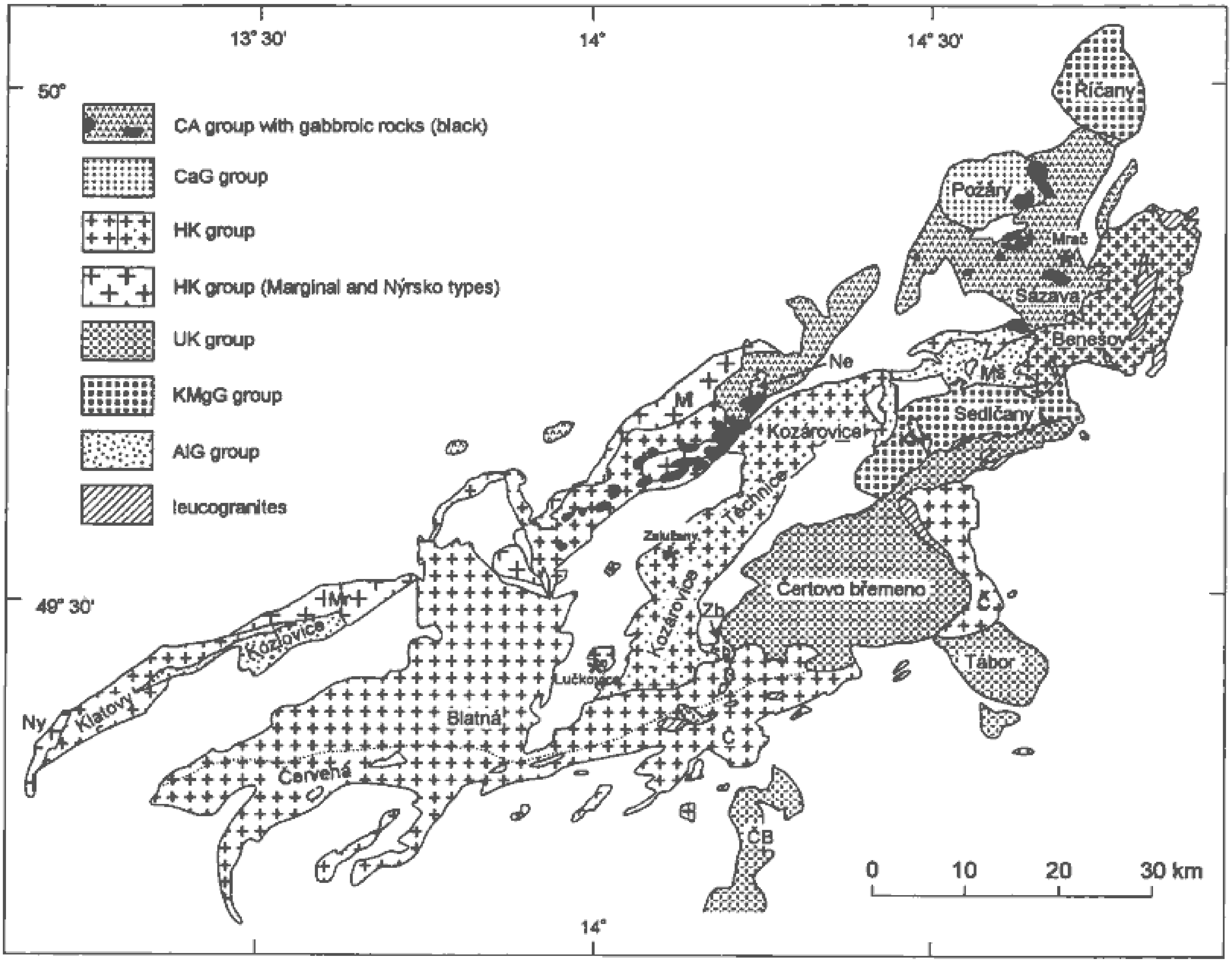
These amphibole-biotite granodiorites occur in the central part of CBPC. The Kozárovice type is common amphibole-biotite granodiorite with only a weak tendency to porphyritic texture. The Těchnice type of similar composition is a porphyritic variety containing rather sparse megacrysts of K-feldspar, 3–5 cm in length.

Amphibole corresponds to magnesiohornblende with *mg* about 50–60 and considerably lower Al compared to the Sázava type. Small relics of diopside may be present. The Mg-Fe-biotite has *mg* about 50–54. The most characteristic accessory minerals are apatite and zircon accompanied by scarce sulphides (mostly pyrite); magnetite is rare or lacking.

The Kozárovice granodiorite contains dark microgranular enclaves which are frequently of monzonitict to quartz-monzonitic composition and may approach the petrographic character of the Zalužany type (Hejtman 1948; Holub 1990).

Červená type (HK group)

The Červená type corresponds to porphyritic amphibole-biotite granodiorite, in places even melagranodiorite, and occurrs along the southern and south-eastern border of CBPC where it is foliated parallel to the contact with Moldanubian gneisses and migmatites. This type passes



3. Generalized distribution of principal rocks (with local names for granitoid types) and their groups in the Central Bohemian Plutonic Complex. Dyke rocks and a great majority of small leucogranite bodies are omitted.
Abbreviations for some local rock types: Ne – Nečín, Č – Červená, Mr – Marginal, Ny – Nýrsko, ČB – Čertovo břemeno, Zb – Zbonín, Mš – Maršovice, KH – Kosova Hora

continually into the very homogeneous and lighter Blatná granodiorite.

Despite of the different appearance, the Červená type is very similar to the Kozárovice type in modal composition and mineral chemistry.

Composition of locally frequent dark microgranular enclaves corresponds to (clinopyroxene)-biotite-hornblende diorite, monzonite and, more rarely, to melasyenite (Souček 1971; Holub 1990).

Blatná type (HK group)

Amphibole-bearing biotite granodiorite to granite of the Blatná type is the most widespread and homogeneous granitoid rock of the southern half of CBPC. Some parts of the body have been named also the Zvíkov (Urban 1931; Žežulková et al. 1980) and Hudčice types, the relatively darker variety which is transitional to the Červená granodiorite as the Zavlekov type (Vejnar 1955). Amphibole is magnesiohornblende to actinolitic hornblende. It may be lacking in the most acidic variety of the Blatná type.

Marginal type (HK group)

The "marginal" type comprises medium- to coarse-grained varieties of light, frequently pink-coloured, biotite granites to granodiorites which occur mostly close to the western boundary of the batholith, i.e. in the Příbram area and the Klatovy apophysis. Biotite is higher in Fe (mg 43–47) compared to the Blatná type, amphibole is scarce.

Nýrsko type (HK group)

The Nýrsko type is poorly known biotite granite to granodiorite which may represent a finer-grained equivalent to the marginal type. It occurs in the westernmost part of the Klatovy apophysis.

Mrač type (HK group)

The Mrač type is a fine-grained biotite granodiorite known as a single NE-SW elongated body intruding the Sázava tonalite N of Benešov (Fig. 3). Mineral composition is similar to the Blatná granodiorite.

Čertovo břemeno type and related rocks (UK group)

The Čertovo břemeno type, frequently referred to as durbachite or the durbachite series, is a conspicuously dark porphyritic (K-feldspar-phyric) amphibole-biotite melasyenite to melagranite. It can be subdivided into dark and light-coloured facies. The most mafic variety of the dark facies is well comparable with durbachite from the Black Forest (see Sauer 1893) and the Vosges (Gagny 1968; Fluck 1980), the less mafic varieties correspond with the Granite des Cretes from the Vosges.

Amphibole is rich in Mg ($mg \geq 71$) and Si but poor in Al; it usually corresponds to actinolitic hornblende with crystal rims of actinolite composition. Abundant biotite is also highly magnesian (mg 62–72) and relatively poor in Al, with very low Al^{VI}.

The durbachitic rocks are markedly rich in apatite (up to 3 %). Other accessory minerals are zircon, some sphene and occasionally allanite. Johanová (1969) reported also presence of topaz and less frequent fluorite, rutile, scheelite and baryte. Opaque minerals are scarce, being represented especially by pyrrhotite which highly prevails over pyrite.

Much less porphyritic and finer-grained variety (the marginal facies of the Čertovo břemeno type) from borders of the body has been often called the Dehetník type and confused with the adjacent Červená granodiorite.

Extremely dark melasyenites form several small bodies, either associated with the Čertovo břemeno type or occurring in the area of the so-called Benešov type.

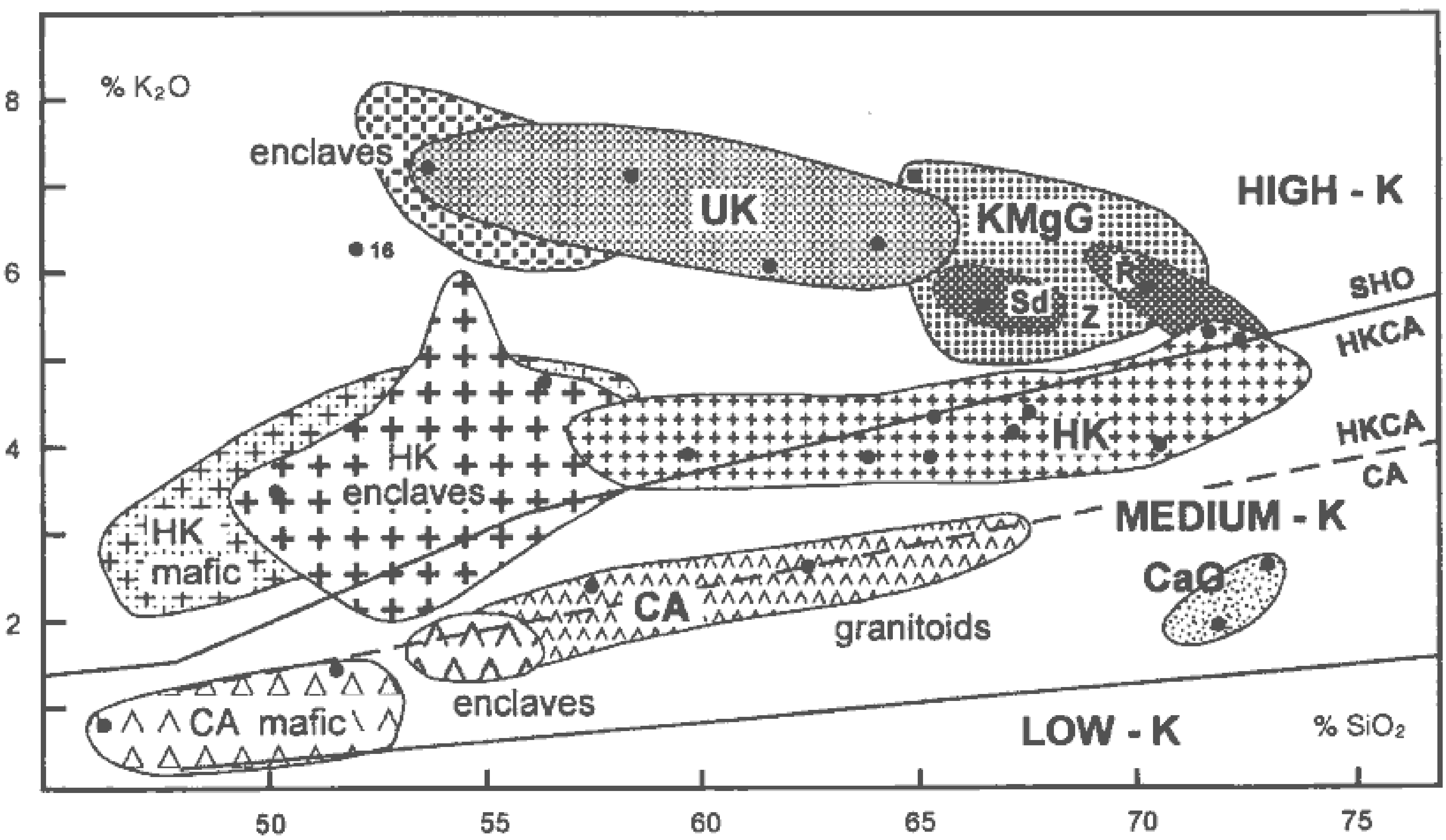
Ultrapotassic granitoids to syenitoids enclose various xenoliths of metamorphic rocks and ubiquitous microgranular enclaves of melasyenite to potassium-feldspar melasyenite or quartz melasyenite composition (Holub 1977, 1990).

The Čertovo břemeno type constitutes also numerous small bodies and massifs which are scattered along a zone trending NNE-SSW through the Moldanubian crystalline complex further to the south; those masses are conventionally counted to the Moldanubian Batholith, although their peculiar composition and the entirely independent distribution are apparent.

Tábor type (UK group)

The Tábor type also ranges in composition from melasyenite to melagranite but it does not contain the large K-feldspar phenocrysts and, moreover, its mineral assemblage is almost dry.

The principal ferromagnesian minerals are represented by orthopyroxene, clinopyroxene, and less abundant Mg-biotite. The "dry" assemblage is, nevertheless, often partly or even completely degraded to the "wet" one with abun-



4. Variation diagram of K_2O versus SiO_2 (wt. %) for plutonic rocks of the Central Bohemian Plutnic Complex. The boundary line between the high-K calc-alkaline (HKCA) and shoshonitic (SHO) fields is from Peccerillo and Taylor (1976), other boundaries are as recommended for volcanic rocks by IUGS (Le Maitre 1989).
Fields of major granitoid groups or types are outlined with full lines, associated mafic rocks with dashed lines, mafic enclaves with dot-and-dashed lines, the AIG granitoids with dotted line. Analyses from Table 2 are represented by filled circles.

Table 1. Synopsis of the rock types of the CBPC

Rock type	Area km²	Petrography	Mafic minerals	M.I.	Enclaves
CA group (calc-alkaline)					
Basic rocks Sázava	? 250	Hb, Gb, QGb, D, QD, To, GD	(ol), cpx, amp amp > bi	var. 15-25	– D, Gb
CaG group (high-Ca acid granitoids)					
Požáry Něčín	60 3	lGD-Tr lGD	bi bi	5 5	– –
HK group (high-K calc-alkaline to shoshonitic)					
Monzonitic rocks	< 3	MGb, MD, mM	(cpx), amp, bi	40–80	–
Zalužany	< 1	mQM–mGD	cpx, amp, bi	40	–
Kozárovice	230	GD, mGD	bi > amp	15–25	M, D, QM,
Těchnice	70	pGD–pMG	bi > amp	15–20	M, D
Blatná	630	GD, (MG)	bi > (amp)	10–15	D, M, mGD
Blatná-dark	–	GD	bi > amp	15–25	D, M
Červená	185	pGD, (QMD)	bi > amp	20–25	D, M, mS
Klatovy	60	(p)GD	bi > amp	15–25	D, M
Mrač	1	GD	bi	10	X
Marginal	55	coarse–gr. G	bi	< 10	Do, D
Polánka	12	catacl. G	bi	< 10	?
Nýrsko	10	G	bi	< 10	?
UK group (ultrapotassic)					
Čertovo břemeno Tábor	225 60	pmS, pmQS, pmG, mS, mQS, mG	bi >amp bi, opx, cpx, amp	25–55 25–45	mS, mQS mQS, Bi
KMgG group (K-Mg-granites)					
Sedlčany	100	pMG	bi > amp	17–20	mG, mS
Zbonín	?	pMG	bi, (co, mu)	variable	X, mG
Říčany	130	(p)MG	bi, (mu)	5–10	mG, mQS
AlG group (peraluminous granitoids)					
Kozlovice	25	GD	bi, (mu, co)	15–20	X
Maršovice	45	GD	bi, (mu, co)	variable	X
Kosova Hora	5	pGD-MG	bi, (mu, co)	10–15	X

Rocks: l – leuco-; m – mela-; p – porphyritic; Bi – biotitite; D – diorite; Do – dolerite; G – granite; Gb – gabbro; GD – granodiorite; Hb – hornblendite; M – monzonite or prefix monzo-; Q – quartz-; S – syenite; To – tonalite; Tr – trondhjemite; X – abundant xenoliths. Minerals: amp – amphibole; bi – biotite; co – cordierite; cpx – clinopyroxene; mu – muscovite; ol – olivine; opx – orthopyroxene

dant biotite and actinolitic amphibole (similar to the Čertovo břemeno type), particularly at borders of the body (Jakeš 1968). Characteristic accessory minerals are apatite, rutile, and zircon.

Sedlčany granite (KMgG to UK group)

The Sedlčany type is porphyritic amphibole-biotite granite resembling the most acidic variety of the Čertovo břemeno type; compared to the latter, the Sedlčany type is somewhat lighter ($M \leq 20$), poor in amphibole, and the shape of its K-feldspar is less pronouncedly tabular.

Microgranular enclaves are abundant and their composition ranges from amphibole-biotite melagranite to quartz melasyenite (Holub 1990).

Zbonín granite (KMgG group)

Compared to the previous type, the Zbonín granite is less-conspicuously porphyritic and finer-grained, usually amphibole-free and rarely cordierite-bearing. It forms small bodies and irregular dykes associated with the Čertovo břemeno type.

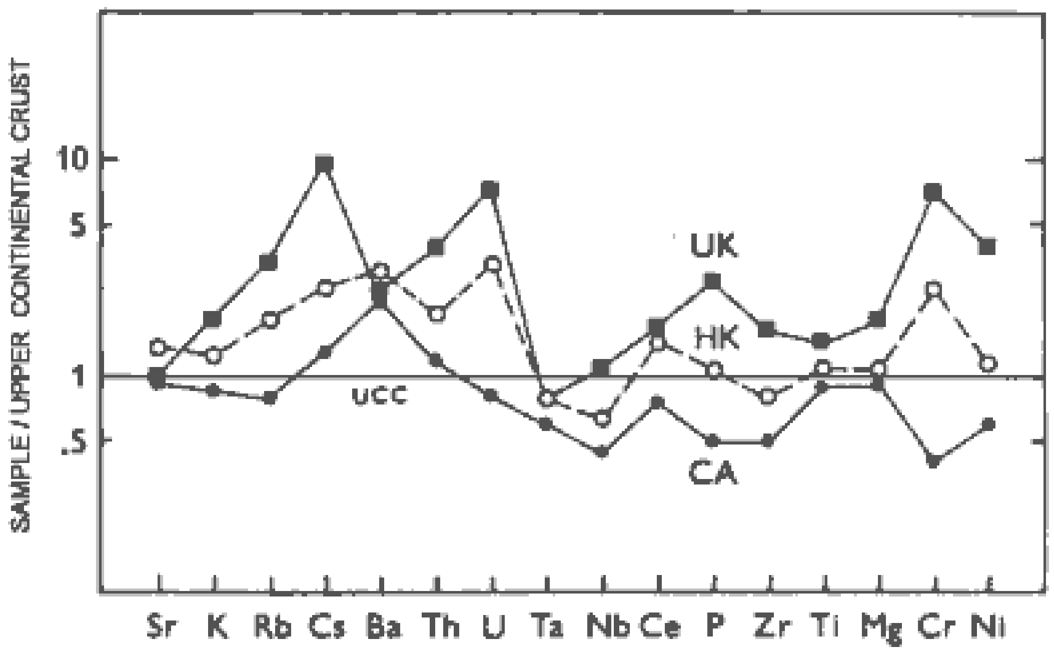
The Zbonín granite carries a great number of various xenoliths of metamorphic rocks. Among them, the restitic gneisses extremely rich in garnet, cordierite, sillimanite and

Table 2. Representative analyses of mafic and granitoid rock types from the Central Bohemian Plutonic Complex

Group	CA				CaG		HK									UK						KMgG				AIG
Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
SiO_2	46.38	51.92	57.40	62.25	71.89	72.92	50.12	56.39	59.65	63.82	65.35	67.15	67.55	70.59	71.63	52.01	55.42	61.61	53.77	58.43	64.16	66.52	64.93	70.23	72.27	65.28
TiO_2	1.11	1.15	0.73	0.54	0.33	0.21	1.10	0.94	0.83	0.68	0.55	0.54	0.59	0.21	0.22	0.91	1.05	0.71	1.20	1.06	0.73	0.52	0.67	0.31	0.19	0.76
Al_2O_3	12.42	17.75	16.80	15.32	14.61	13.66	12.55	14.93	16.05	15.76	15.09	14.95	15.45	14.58	13.84	10.93	13.30	13.95	12.69	13.76	13.38	15.11	15.31	14.25	13.89	15.9
Fe_2O_3	1.35	2.43	3.13	5.55*	1.18	0.68	2.53	0.97	0.78	0.78	0.79	0.78	0.67	0.86	0.18	1.32	0.49	5.30*	1.13	6.58*	0.68	0.72	0.67	0.30	0.20	1.17
FeO	11.91	6.58	4.17	–	1.27	1.32	6.62	5.83	4.66	3.56	3.32	2.12	2.34	1.35	1.58	4.30	6.84	–	5.61	–	3.26	2.31	3.18	1.03	0.58	4.60
MnO	0.19	0.23	0.15	0.12	0.04	0.06	0.18	0.14	0.09	0.06	0.08	0.05	0.05	0.06	0.03	0.10	0.12	0.08	0.10	0.09	0.07	0.05	0.06	0.02	0.01	0.06
MgO	10.25	5.02	3.10	2.21	0.49	0.38	8.67	4.66	3.63	2.58	2.39	1.58	1.45	0.78	0.56	10.71	8.26	5.21	8.81	6.29	4.04	2.48	2.84	1.07	0.58	2.29
CaO	11.78	9.08	7.28	5.30	3.51	2.23	9.78	6.36	4.67	3.99	3.41	2.82	2.72	2.52	1.60	7.53	4.76	3.89	4.58	3.71	2.92	2.23	1.24	1.13	1.04	0.85
Na_2O	0.69	2.48	2.86	3.17	3.67	3.83	1.57	2.22	3.31	3.12	3.01	3.22	3.29	3.10	3.11	1.64	1.58	2.30	1.54	1.60	2.51	2.90	2.06	3.78	3.92	2.74
K_2O	0.80	1.46	2.37	2.32	1.82	2.54	3.48	4.70	3.83	3.80	4.27	4.06	4.28	3.91	5.24	6.24	6.11	5.99	7.17	7.33	6.25	5.76	7.02	5.68	5.16	3.80
P_2O_5	0.17	0.18	0.20	0.14	0.09	0.07	1.02	0.73	0.36	0.30	0.21	0.20	0.20	0.06	0.06	1.45	1.10	0.65	1.17	1.01	0.57	0.32	0.37	0.14	0.09	0.16
mg	58.2	50.5	44.2	44.1	27.3	26.0	63.5	55.3	54.7	51.9	51.4	50.0	46.8	39.6	36.4	77.7	66.9	66.1	70.3	65.4	65.0	59.9	57.2	59.0	57.8	41.9
Cs	–	–	3.9	4.9	2.5	4.0	6.5	17.5	–	4.0	9.6	13.8	10.3	–	–	–	5.5	–	21.7	22	31	28.4	–	29.3	32.6	8
Rb	28	39	73	84	60	73	180	215	200	165	205	185	165	148	154	259	261	319	381	400	385	330	366	360	336	145
Sr	420	455	540	328	380	211	360	548	419	405	468	340	194	464	251	1060	605	458	461	469	342	358	395	333	305	145
Ba	650	550	970	1255	1350	1155	1850	2280	1310	1300	1690	930	760	2900	1390	5300	2890	1840	2410	1980	1210	1240	1670	1100	850	800
Pb	–	13	47	23	34	47	–	38	–	24	–	66	44	–	–	62	40	–	36	–	–	73	–	70	70	–
Th	2.5	5.0	14.7	13.5	11.2	13.1	9	22.7	20	19.8	20.9	19.6	19.5	–	–	–	5	32.0	38.5	52.6	41.5	30.8	30.8	34	29.8	11
U	3.3	4.6	4.7	4.2	2.6	2.3	5	11.6	–	6.3	9.7	12.4	5.6	–	–	–	2	13.3	14.7	18.5	20.9	17.4	9.1	7	10.5	7
Zr	2	90	–	93	163	110	–	180	202	275	147	175	175	121	163	–	170	492	475	389	311	260	394	240	150	190
Y	16	25	–	11	4	5	–	33	26	28	16	26	19	–	–	–	30	33	32	26	22	21	17	4	5	–
La	–	9	29	–	35	–	35	35	–	55	43	44	55	–	–	–	44	52	55	–	–	46	–	28	26	37
Ce	–	19	55	49	50	–	67	82	69	126	82	77	82	–	–	–	109	128	129	119	97	90	120	76	63	85
V	375	94	201	183			210	113	86	61	62	59	51	–	–	123	–	79	–	50	–	–	27	29	42	
Cr	120	70	42	14	13	17	373	188	106	54	90	59	52	–	–	701	560	320	540	380	290	125	135	72	38	50
Co	66	21	19	–	3	6	41	24	11	12	12	8	12	–	–	38	31	18	33	22	14	10	–	3	–	–
Ni	–	15	5	12	10	6	–	25	–	24	18	18	18	–	–	249	85	67	184	–	–	29	–	25	20	–
Zn	113	85	75	63	29	39	–	79	88	58	60	63	73	–	–	73	202	117	100	–	70	62	89	37	38	–

* – total Fe as Fe_2O_3

1 – olivine gabbro, Tužinka near Benešov, 2 – hornblende quartz-gabbro to diorite, Teletín, 3 – biotite-hornblende tonalite, Mrač, 4 – biotite-hornblende granodiorite, Všešimy, 5 – biotite granodiorite to trondhjemite, Požáry type, Prosečnice, 6 – biotite granodiorite, Nečín type, Něčín, 7 – monzonite, Lučkovice (from Ledvinková 1985, anal. no. 3), 8 – quartz monzonite to melagranodiorite, Zalužany, 9 – amphibole-biotite granodiorite, Červená type (dark variety), Hory Matky Boží, 10 – amphibole-biotite granodiorite, Červená type, quarry Smrčí near Kolinec, 11 – amphibole-biotite granodiorite, Kozárovice type, Kozárovice, 12 – amphibole-bearing biotite granodiorite, Blatná type, quarry Řečice near Blatná, 13 – biotite granodiorite, Mrač, 14 – biotite granite, "marginal" type, Radětice, 15 – biotite granite, "marginal" type, Novotníky, 16 – amphibole-biotite melasyenite, Okrouhlice, 17 – biotite-cpx-opx melasyenite, Tábor type (dark variety), Dražice near Tábor, 18 – pyroxene- biotite quartz melasyenite, Tábor type, Tábor – Klokoty, 19 – durbachite (= very dark variety of the Čertovo břemeno type), Květuš, 20 – am-bi quartz melasyenite, Čertovo břemeno type (medium-dark variety), Velká near Milevsko, 21 – amphibole-biotite melagranite, Čertovo břemeno type (light variety), Vepice, 22 – amphibole-biotite granite, Sedlčany type, Vápenice near Vysoký Chlumec, 23 – biotite granite, Zbonín type, Zbonín, 24 – biotite granite, Říčany type, Žernovka, 25 – muscovite-bearing biotite granite, Říčany type (light variety), Srbín, 26 – (cordierite)-biotite granodiorite, Maršovice type, Zderadice



5. Spidergrams showing the geochemical difference between typical granitoids (about 63–65 % silica) of the CA, HK and UK/KMgG groups of CBPC. Abundances of elements were normalized to average composition of the upper continental crust. Normalizing values are from Taylor and McLellan (1985).

biotite are particularly frequent. Rounded microgranitoid enclaves rich in magnesian biotite and apatite occur sporadically.

Říčany granite (KMgG group)

The Říčany type forms a separate body at the northernmost apex of CBPC. It is relatively light biotite granite frequently containing some muscovite. The rock is coarsely porphyritic in marginal parts of the zoned body (Kašpar 1936). Biotite is highly magnesian (*mg* 53–59) compared to common granites and, in respect to other granitoids of the CBPC, much richer in fluorine (Fiala and Vejnar 1976). The Říčany granite is poor in zircon but contains an increased amount of anatase or rutile (Kodymová and Vejnar 1974). Dark microgranitoid enclaves rich in biotite and sometimes containing sparse megacrysts of K-feldspar are present (Orlov 1933; Palivcová et al. 1992).

Kozlovice, Maršovice, and Kosova Hora types (AlG group)

Granodiorites of the Kozlovice and Maršovice types contain Al-rich biotite, muscovite and usually also cordierite. The Kosova Hora type is similar to them but its composition may approach that of sparsely porphyritic granite. These rocks are usually inhomogeneous and include many xenoliths of biotite-rich metamorphic rocks, rounded quartz etc., whereas microgranular enclaves are absent. In the case of the Kozlovice granodiorite, transitions to nebulitic migmatite and abundant quartz xenoliths have been observed (Palivcová et al. 1988).

Accessory minerals of the Kosova Hora type are apatite, zircon, tourmaline, monazite, garnet, sulphides and rare ilmenite (Kodymová and Vejnar 1974).

Leucogranites (LG group)

Leucogranites, frequently described as aplitic or dyke granites, are abundant as many dykes and small dyke-like bodies in the eastern part of the Complex and also in the adjacent parts of Moldanubicum south of CBPC. There are biotite, two-mica and tourmaline-bearing varieties with many transitions even within a single body. Leucogranite bodies occurring in the Říčany granite are known as the Jevany type.

Other plutonic rocks

A special comment should be addressed to the so-called Benešov type (the "older biotite granite" according to Kettner 1930) occurring at the NE margin of the Complex (about 175 km^2). This "type" comprises variable rocks which have been grouped together because of their conspicuous but varying degree of deformation, hardly a good criterion for classification and age estimation (cf. Orlov 1933). Vejnar (1973) distinguished the light and dark Benešov types but there are even more units (leucogranites, biotite to amphibole-biotite granodiorites, K-rich biotite granites, melasyenites).

Our list does not include some poorly known and volumetrically insignificant rocks, for instance the Kšely granite (porphyritic biotite granite which is mostly covered by Permo-Carboniferous sediments of the Blanice Furrow), and diopside granitoids forming small bodies in the area of the Sázava and Blatná types, e.g., the pyroxene tonalite to leucotonalite ("quartz diorite") from Chleby (Štěpánek 1929).

GEOCHEMISTRY

Selected major- and trace-element analyses representing all the petrochemical groups and their most important members are given in Table 2. Moreover, the radioactive element abundances determined by gamma spectrometry in a large set of samples are presented as average values for the local petrographic types (Table 3). The original data from Manová (1975) have been re-evaluated in order to fit in our scheme of rock types.

For distinguishing individual geochemical groups of plutonic rocks we have found the following criteria as the most indicative:

(a) content of K_2O at a given level of SiO_2 or MgO (Fig. 4),

(b) contents of P_2O_5 and selected hygromagmatophile trace elements (Rb, Cs, Th, etc.) at a given level of SiO_2 or MgO (cf. Fig. 5),

(c) the K_2O/Na_2O ratio,

(d) the A/CNK value (i.e., the alumina saturation index) as molar ratio of $Al_2O_3/(Na_2O+K_2O+CaO)$,

(e) variation of *mg*-value as atomic ratio 100Mg/ $(Mg+Fe_{tot})$ with respect to SiO_2 or MgO.

Combination of these parameters enabled us to define six natural groups of plutonic rocks (Holub 1991) which are geochemically characterized in the following paragraphs. Leucogranitic rocks are added as the seventh group with poorly known relations to other suites.

1. Calc-alkaline (CA) group

This group comprises the gabbroic rocks and granitoids of the Sázava type and has been called the "andinotype association" by Palivcová 1984).

In the K_2O-SiO_2 diagram (Fig. 4), this rock association corresponds to the calc-alkaline series. Mafic members plot typically into the medium-K field, whereas many granitoid samples straddle the boundary line between the medium-K and high-K field after Le Maitre (1989), i.e. the calc-alkaline versus high-K calc-alkaline boundary after Peccerillo and Taylor (1976).

The granitoids are metaluminous and, compared to rocks of the HK and UK groups (see below), they display appreciably lower *mg*-values (*cf.* also the mineral compositions) and Cr contents as well as lower K_2O, P_2O_5, and many incompatible trace elements (Rb, Cs, Th, U) at any given level of SiO_2.

The total gamma activity (Table 3) is only about half of that of the Kozárovice granodiorite (HK) and, consequently, the CA and HK groups are distinct also in the aeroradiometric map (cf. Fig. 2 and 3). Isotopic composition of Sr is rather primitive and the lowest among rocks of CBPC (Janoušek et al. 1995).

Most gabbroic rocks are silica-saturated or even slightly oversaturated. Their contents of Cr, Ni, and also *mg*-values are frequently much lower than those in mafic members of other groups and even in some HK, UK and KMgG granitoids.

2. Ca-rich acid granitoids (CaG)

Granitoids of the CaG-group are distinct by their high content of CaO and low K_2O combined with a high acidity. In the K_2O versus SiO_2 diagram (Fig. 4) they plot into the medium-K field of common calc-alkaline series. The K_2O contents are even lower than would correspond to a prolonged trend of the CA-group. Granitoids are only weakly peraluminous with A/CNK < 1.05.

Table 3. Total gamma-ray activity (ppm equivalent U), average contents of radioactive elements K (wt. %) U and Th (ppm), and average mineralogical rock-densities of granitoid types from CBPC

Rock type	n	ekv U ppm	K %	U ppm	Th ppm	Th/U	n	σ g/cm³
Čertovo břemeno	74	37.3	5.2	15.9	39.4	2.5	29	2.73
border facies	10	30.0	5.0	10.3	34.7	3.5	9	2.74
Sedlčany	20	32.1	4.5	13.3	34.6	2.6	20	2.69
Tábor	13	27.1	5.2	9.8	30.2	3.1	15	2.78
Říčany	30	19.5	4.3	5.2	24.2	4.7	24	2.64
Těchnice	33	19.4	3.6	6.0	23.6	3.9	30	2.70
"Benešov type"	33	18.8	4.0	6.3	21.0	3.3	22	2.64
Marginal type	31	17.8	3.1	4.7	24.4	5.2	27	2.64
Červená	40	17.4	3.6	5.6	20.3	3.6	35	2.69
Blatná	97	16.8	3.3	6.1	18.2	3.8	3.3	2.69
Kozárovice	42	16.6	3.3	6.1	17.8	3.1	37	2.76
Maršovice	14	14.2	3.4	4.8	14.6	3.0	14	2.68
Kozlovice	11	11.3	2.5	3.4	13.4	3.9	9	2.70
Požáry	11	10.2	2.4	2.6	11.5	4.4	10	2.66
Sázava	64	8.4	2.0	2.7	9.6	3.6	56	2.77

Average values are based on gamma-spectrometric analyses from Manová (1975).

Contents of transition metals and many incompatible elements except for Sr, Ba and Th are considerably low.

Uranium content (< 3 ppm) is much lower than in other granitoids and, consequently, the CaG group belongs to the least radioactive rocks in CBPC (cf. Fig. 2 and 3).

3. High-K (HK) group

Granitoids of the Kozárovice, Červená, Těchnice, Blatná, and Klatovy types and perhaps also the marginal type together with the monzonitic rocks form this most voluminous group.

The increased level of K_2O makes these rocks comparable to the high-K calc-alkaline to shoshonitic series. Namely the subordinate mafic members and the relatively dark varieties of granitoids display the shoshonitic character and some less common samples may be classified as even ultrapotassic.

All the rocks are more magnesian and richer in incompatible elements compared to members of the CA group at the same level of SiO_2 (Fig. 5). On the other hand, CaO and, to a lesser degree, also Na_2O, are appreciably lower in the HK group.

The rocks are metaluminous except for the most acidic varieties of the Blatná type and the marginal type which may be weakly peraluminous. Some samples of the marginal type differ from the typical HK granitoids in lower MgO/CaO and *mg* values (see Table 2).

Average values of total gamma-activity of the individual granitoid types vary within a narrow range (Table 3); they are higher than in the CA but lower than in the UK group.

Isotopic composition of Sr from granitoids of the HK group was reported by van Breemen et al. (1982) and Bendl and Vokurka (1989), both Sr and Nd by Janoušek and Rogers (1994); initial Sr^{87}/Sr^{86} ranges from 0.7073 to 0.7083 and ε Nd from –3.4 to –5.3.

4. Ultrapotassic (UK) group

Melasyenitic to melagranitic rocks of the Čertovo břemeno and Tábor types plus some melasyenitic and melagranitic samples from the "dark Benešov type" are characterized by very high K_2O (4.5–8 %), K_2O/Na_2O and MgO (3–13 %) and, therefore, correspond to typical ultrapotassic rocks as defined, e.g., by Foley et al. (1987). Compared to the HK group including its most potassic (shoshonitic) members, the UK rocks are much more magnesian and lower in CaO, the MgO/CaO being always >>1.

In accord with the major elements, also the trace element pattern is peculiar and distinct: The rocks are rich in Cr (Ni), Rb, Cs, Th, U, but poor in Sr (Fig. 4). Very high radioactivity (Matolín 1970; Manová 1975; Fiala et al. 1983; Table 3) is typical for both the mafic and intermediate to acidic members of the UK group.

5. K-Mg-rich granites (KMgG)

This suite consists of Ca-poor and K-rich granites with conspicuously high *mg* and Cr contrasting with relatively high silica. Due to the lower MgO (less than 3 %), these rocks cannot be classified as ultrapotassic, though a pronounced affinity to the ultrapotassic rocks is notable especially for the Sedlčany granite which contains abundant ultrapotassic microgranular enclaves (Holub 1991).

Compared to the most acidic variety of the Čertovo břemeno type, the Sedlčany granite is slightly richer in Al_2O_3 but less magnesian and has lower MgO/CaO. There are also some subtle differences in trace-element ratios (e.g., the Rb/Sr is somewhat lower).

The Zbonín granite is more variable in chemical composition. Many samples are much poorer in CaO and richer in K_2O compared to the Sedlčany type.

The Říčany granite is distinct by its higher SiO_2, lower K_2O/Na_2O, and increased fluorine content; also the microgranular enclaves are frequently much less potassic than in other KMgG granites (see Palivcová et al. 1992).

All the three rock types are rich in hygromagmatophile elements (Fig. 5) and highly radioactive; the Sedlčany granite belongs to the most radioactive granitoids in CBPC being rich in K, Th and namely U with low Th/U (Table 3).

Janoušek and Rogers (1994) and Janoušek et al.(1995) stated an evolved isotopic composition for the Říčany and Sedlčany granites; the latter type with initial Sr^{87}/Sr^{86} 0.7126 to 0.7128 and Nd −7.2 to −7.8 is isotopically similar to minette from the same area.

6. Peraluminous granitoids (AlG)

These rocks display only a narrow range of SiO_2 (66–68 %). In contrast to common CA and HK granitoids of similar acidity, these rocks are peraluminous and conspicuously poor in CaO, with A/CNK ranging from 1.1 to 1.25). In AlG granitoids, the K_2O only slightly prevails over Na_2O. The bulk composition is similar to some sedimentary rocks of Upper Proterozoic or Lower Cambrian age from the Barrandian area and also to many migmatites of the Moldanubian crystalline complex (Palivcová et al. 1988). However, the contents of alkalis, namely potassium, are increased in granitoids.

7. Leucogranites (LG)

Some leucogranitic rocks may represent most acid varieties of other granitoid types (HK and KMgG groups) but, nevertheless, there seems to exist also a distinct leucogranite group.

Typical leucogranites are highly acidic (SiO_2 from 71 to 75.5 %), Mg-poor (MgO < 0.5 %, usually < 0.25 %) and slightly peraluminous rocks approaching the composition of the "granite minimum". The K_2O/Na_2O varies from about 1 to 1.6 with values around 1.2 being most frequent. Content of Rb is usually high but the trace element abundances are variable and hitherto poorly known.

Temporal relations

The CBPC intrusions are likely to span the time interval between the intensive shearing of the Middle to Upper Devonian granitoids (orthogneisses) forming part of the roof (Košler et al. 1993) and the unroofing of granitoids followed by sedimentation of the uppermost Carboniferous to Permian beds onto the Říčany granite.

Problems of age relations of various rock types and suites could not be solved by the K-Ar method which provided controversial results (Šmejkal 1960; Steinocher 1969; Dubanský 1984). The published data for individual rock types range too widely and there are even quite different "ages" for biotite and K-feldspar separated from the same rock samples (Pivec 1970).

More reliable age determinations based on the Rb-Sr or Ar-Ar methods are rare in the area and their results are not fully consistent with field observations.

What is commonly but incorrectly cited as the age of the Central Bohemian Plutonic Complex is the whole-rock Rb-Sr determination on the Blatná granodiorite by van Breemen et al. (1982). Their isochrone corresponding to the age of 331 ± 4 Ma has been confirmed with the same method by Bendl and Vokurka (1989) as 331 ± 9 Ma. However, we find it hard to believe that these data represent authentic age of the Blatná granodiorite because of the isochrones were based not only on the granodiorite itself but also on aplitic or leucogranitic veins. In fact, these results are inconsistent with new determinations of zircon crystallization ages (349±10 Ma, Holub et al. 1996 – in print) and also with the published Ar-Ar cooling age of 336 Ma for the Čertovo břemeno type (Matte et al. 1989), if we consider the younger relative age of the ultrapotassic rocks (Holub and Žežulková 1978).

Relative ages of individual rock types are among the most discussed problems of CBPC. Some published opinions are controversial (e.g., Kodym Jr. 1966 versus Suk 1973b; Suk et al. 1975) and also the recent graphical summary of temporal relations given by Klomínský and Dudek (1994) is partly inconsistent. Moreover, some authors have stressed the so-called "antinomies" in the geological relations of individual granitoid types and explained them in terms of transformism (Palivcová 1965 and more recent papers).

In fact, there is no contradiction in field relations of rocks and the only problem arises from absence of contacts between some rock types whose relative ages can be judged only indirectly.

A new scheme of field relations and relative ages of plutonic and also selected dyke rocks in the area of CBPC is presented in Fig. 6. This scheme does not include the problematic rocks such as the so-called "Benešov type" which does not represent a single intrusion.

The oldest rock suite among unmetamorphosed plutonic rocks is the calc-alkaline group of gabbroes and tonalites to granodiorites of the Sázava type (CA). The higher age of the CA group compared to the HK granitoids has been confirmed by direct observations, namely in the mining district of Příbram (e.g., Vlašímský 1973, 1976). Moreover, only rocks of the CA group are intruded by abundant dykes of microdiorites and hornblende lamprophyres.

Various opinions on the temporal relations between gabbroic and granitic rocks of this suite have been published. However, typical shape and sometimes also chilled margins of the mafic enclaves may demonstrate at least partial contemporaneity of mafic and granitoid magmas.

Rocks of the most voluminous HK group appear as younger. The Mrač granodiorite is definitely younger than the Sázava tonalite (Jelínek 1935). Other pieces of evidence are mentioned above.

Plutonic rocks of both the CA and HK petrochemical groups are intruded by numerous dykes of lamprophyres and granitoid porphyries (Plate III-2).

The Ca-rich acid granitoids (CaG) are younger than the Sázava type (Plate II-1) but their temporal relations to other rocks are far from being proved. According to Kodym et al. (1963), the Nečín granodiorite intruded even the Blatná type; however, his observation probably depends on misinterpretation of the surrounding granitoids which perhaps belong to a relatively acid facies of the Sázava type.

Other rock groups (UK, KMgG, AlG) are younger than both CA and HK granitoids but temporal relations between them are in part still problematic.

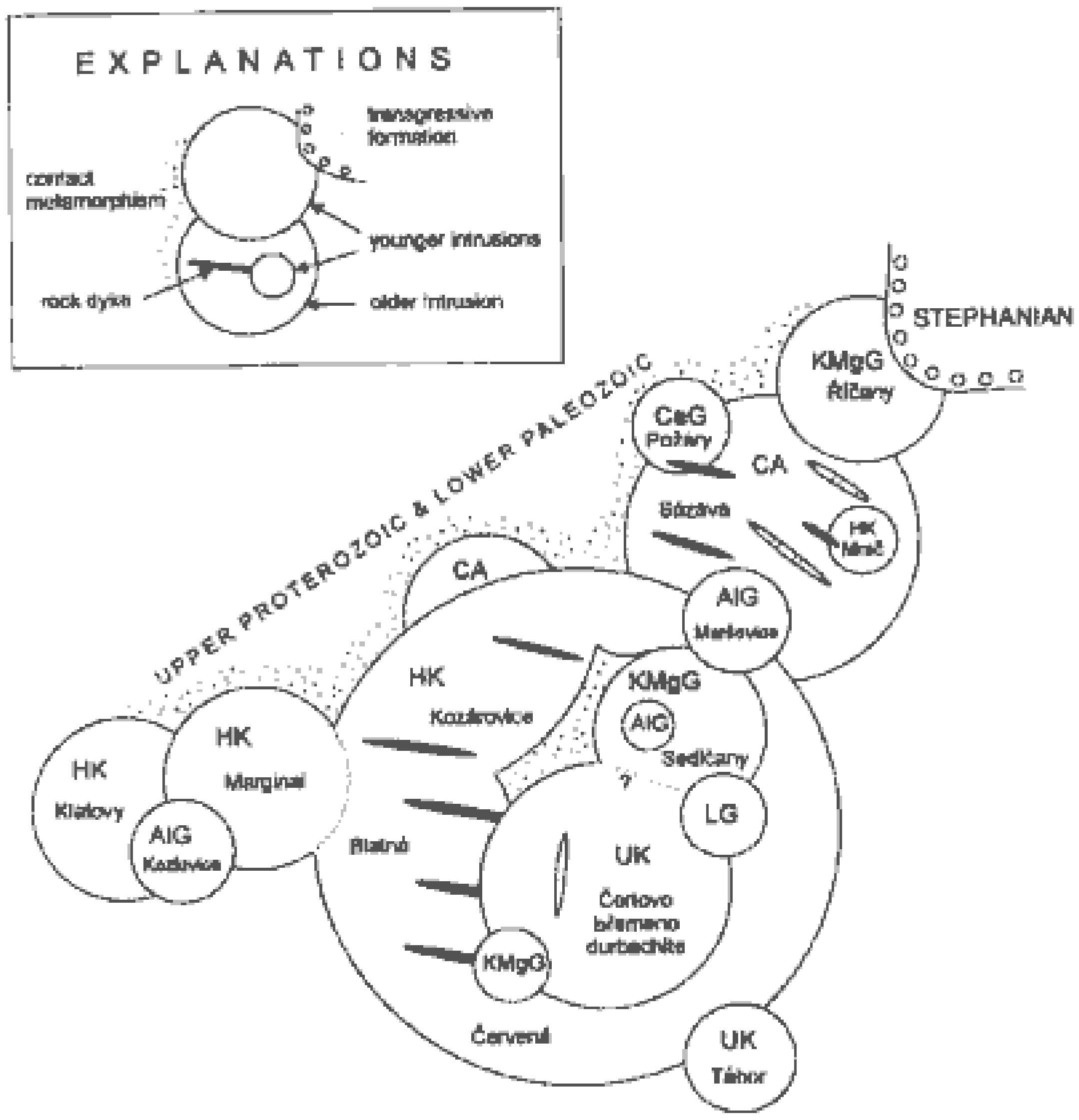
The ultrapotassic rocks of the Čertovo břemeno type are definitely younger than HK granitoids (Urban 1931; Kodym Jr. et al. 1963; Plate II-2) and even than many E-W trending rock dykes (Holub and Žežulková 1978; see also Holub – this volume), though the relation is considered as the contrary by some authors (e.g., Matte et al. 1990; Rajlich 1993).

The Čertovo břemeno type itself has been intruded by numerous leucogranite dykes and sheets and also by the rare N-S trending dykes of felsitic granite porphyry of rhyolitic appearance. The latter rock closely resembles some dykes known as the youngest intrusions in the area of the Moldanubian Batholith (e.g. Klečka 1984; Klečka and Vaňková 1988). Those dykes were recently dated by the whole-rock Rb-Sr method which provided the age of 295±5 Ma, corresponding to the Upper Carboniferous close to the Westphalian/Stephanian boundary (Klečka et al. 1994). Therefore, these dykes may be considered as just preceding sedimentation within the Blanice Furrow.

The occasionally published opinion that the Tábor type is significantly older than the Čertovo břemeno type has been based on misinterpretation of syenitic microgranular enclaves in some other granitoids. In fact, the exact relationship between the two ultrapotassic rock types is still unknown.

The Říčany granite is commonly regarded as one of the youngest plutonic rocks in the area. Such interpretation is based, e.g., on absence of any rock dykes except for some leucogranitic bodies. There is no evidence for younger age in respect to other KMgG rocks, however.

The Zbonín granite appears to be slightly younger than or almost contemporaneous with the Čertovo břemeno type. The time relation between the Sedlčany granite and the Čertovo břemeno is still uncertain but the difference in age should be small and rather insignificant.



6. Diagrammatic scheme of relative temporal relations between rock types of the Central Bohemian Plutonic Complex. Intrusions of individual rock types or closely related groups are represented by circles whose position approximately corresponds to the map (compare Fig. 3).

Also the peraluminous granodiorites of the AlG group are younger than HK granitoids (the Kozlovice granodiorite intruded the "marginal" type – e.g., Menčík 1951; Kodym Jr. et al. 1961). The Kosova Hora granite appears as somewhat younger than the Sedlčany type and their relationship is probably the same as that of the Zbonín and Čertovo břemeno types.

In spite of some existing problems, the field relations discussed above lead to the conclusion that there were three principal periods of plutonism postdating the main deformation in the Central Bohemian shear zone. The oldest one comprises the CA group (gabbro to granodiorite), the middle is high-K calc-alkaline to shoshonitic (HK), and the third is much more compositionally diversified comprising the ultrapotassic, KMgG and probably also AlG groups plus at least some leucogranites. However, some leucogranite intrusions could be even younger and temporally related to granites of the Moldanubian Batholith.

Discussion

Igneous origin versus granitization

Over the past thirty years many papers appeared which emphasized the role of transformation or granitization *sensu lato* in origin of some particular rock types or the Central Bohemian Plutonic Complex as a whole.

Röhlichová (1964) argued that the Červená granodiorite originated through metasomatic granitization of Moldanubian gneisses, and similar origin was attributed by Žežulková (1971) to granitoids of the Benešov type. The Kozlovice granodiorite has been interpreted as isochemically transformed conglomerates of the Cambrian age (Palivcová et al. 1988).

Many papers deal with gabbroic rocks whose origin was explained in terms of transformation of older basalts (Hanuš and Palivcová 1968, 1969, 1970, 1971a, b; Palivcová 1978; Knotek 1975; Palivcová and Knotek 1975; Beneš et al. 1980).

The Čertovo břemeno type has been regarded as metasomatized or isochemically transformed metasedimentary hornfelses (Röhlichová 1962; Hamtilová 1969), or as recrystallized pre-Hercynian alkali basalts (Tauson et al. 1977), the Tábor type as product of K-metasomatism of a mafic volcanic rock (Vejnar 1973).

More recently, Palivcová et al. (1989a, b) and Vlašímský et al. (1992) elaborated their hypothesis of isochemical granitization which is believed to be responsible for origin of the whole CBPC from various older protoliths corresponding to (1) the Moldanubian rocks, above all mildly alkalic volcanic rocks of a continental rift (now the Čertovo břemeno and Tábor types, the Říčany granite), and derived metasediments (now the Sedlčany, Mrač and Kosova Hora types), (2) tholeiitic and calc-alkaline volcanic rocks of the Jílové Zone (the Sázava, Něčín and Libčice granodiorites, gabbroic rocks), (3) mixed (volcanoclastic?) rocks containing various proportions of material originated in the Jílové Zone and Moldanubicum (the Blatná, Červená, Těchnice, Kozárovice, Sedlec and in part also Benešov types), and (4) mixed rocks from the Barrandian and Moldanubian sources (the marginal, Nýrsko, Klatovy, Požáry and Kozlovice types).

These papers ignore some important geological observations like the intrusive contacts and xenoliths, the homogeneity of great volumes of many rock types, the magmatic flow phenomena, many generations of unmetamorphosed dyke rocks, the contact aureole, etc. Instead, the authors overemphasize some selected textural phenomena which are, however, interpreted in subjective ways: For instance, K-feldspar phenocrysts have been described as porphyroblasts or, more recently, inherited phenocrysts in granitized volcanic and volcanoclastic rocks, felsic ocelli and various centric textures in mafic rocks as textural relics from the volcanic precursor (disregarding their absence in the spatially associated metavolcanic rocks), existence of chilled margins of many mafic microgranular enclaves and some gabbroic bodies as an odd "antichilling", etc. Also the classification of various types of plutonic rocks and characteristics of the "precursors" listed above are highly speculative and are not based on evaluation of appropriate geochemical data.

In fact, there are no phenomena which could not be well or at least satisfactorily explained in terms of magmatic origin. According to our observation and in accord with many other geologists who have worked in CBPC or similar batholiths, all types of granitoid and mafic rocks excepting some products of local postmagmatic and later hydrothermal alteration (e.g., the albitites and desilicated "diorites" which originated from granitoids – Palivcová 1967, Palivcová and Hejl 1976) display features typical for true igneous rocks crystallized under plutonic conditions. Consequently, we exclude the granitization hypothesis from further consideration.

Granitoid typology

Genetic typology of many granitic rocks of CBPC is not recognized satisfactorily. Klomínský et al. (1981) attempted at the I versus S classification in terms of the classical work of Chappell and White (1974). Unfortunately, their results are largely based on erroneous values of A/CNK. Also the scheme of I- and S-type granitoids published by Palivcová et al. (1989b) is rather inconsistent.

On the other hand, we agree with those general objections against the I, S, M and A classification which were stressed recently by Clarke (1993) and others.

Only the AIG group represents indisputable S-type granitoids (or C-, i.e. crustal group in the sense of Barbarin 1990), as can be proved by the high A/CNK, low CaO, typical mineralogy, and abundant metasedimentary restitic material. In comparison to common S-granites, the silica content is rather low and the rocks correspond with unfractionated primitive S-granitoids whose composition is similar to their source (Chappell and White 1992).

Perhaps also many leucogranites belong to the "pure" S-type but without any detailed geochemical and isotopic data this statement cannot be proved.

Among acidic rocks especially the Požáry and Něčín granodiorites (the CaG group) correspond to typical I-granitoids (see the predominance of Na over K, high Ca, A/CNK below 1.05 at high SiO_2).

Also the most widespread CA and HK granitoids whose metaluminous varieties contain amphibole and which include dark gabbroic to dioritic or monzonitic enclaves, fulfil criteria for the I-type, despite of the increased K_2O, Rb, and initial Sr isotopic ratio in the HK group (see van Breemen et al. 1982; Janoušek and Rogers 1994).

Liew et al. (1989) classified those granitoids of the Moldanubian Batholith, which are rich in K_2O and whose Sr- and Nd- isotopic composition covers "transitional" values, as a mixed I/S type. Such granitoids (excepting the dark K-rich rocks of the Rastenberg pluton) are, however, characterized by absence or scarcity of typical microgranular enclaves which are so frequent in rocks of the Central Bohemian Plutonic Complex.

Petrographic character of the mafic enclaves usually correspond to broadly coeval magmatic rocks and not to mafic restites, supposed for typical I-granites by Chappell and White (1974) or Chappell et al. (1987). Therefore, we consider the CA and HK granitoids as rocks of hybrid origin, i.e. the H-type in the sense of Barbarin (1990) or Castro et al. (1991). A hybrid nature is likely also for the highly potassic rock types.

In the hybrid granitoid groups, the granitic component may be either of crustal origin and the I-, I/S or S-type, or may represent fractionated mantle-derived magma. The Zbonín granite appears to be a typical H_S-granite, i.e. a hybrid of mafic and S-type granitic magma as defined by Castro et al. (1991).

The Říčany granite has been proposed as representing the A-type (Palivcová et al. 1989b) or at least compositionally approaching it (Janoušek 1991). Among geochemical criteria summarized by Eby (1990), especially the high content of alkalis, low CaO and increased fluorine content seem to fit such a classification. However, the trace element pattern is not typical and the considerably high *mg*-value is in sharp contradiction to the low-Mg nature of true A-granites (Whalen et al. 1987; Eby 1990).

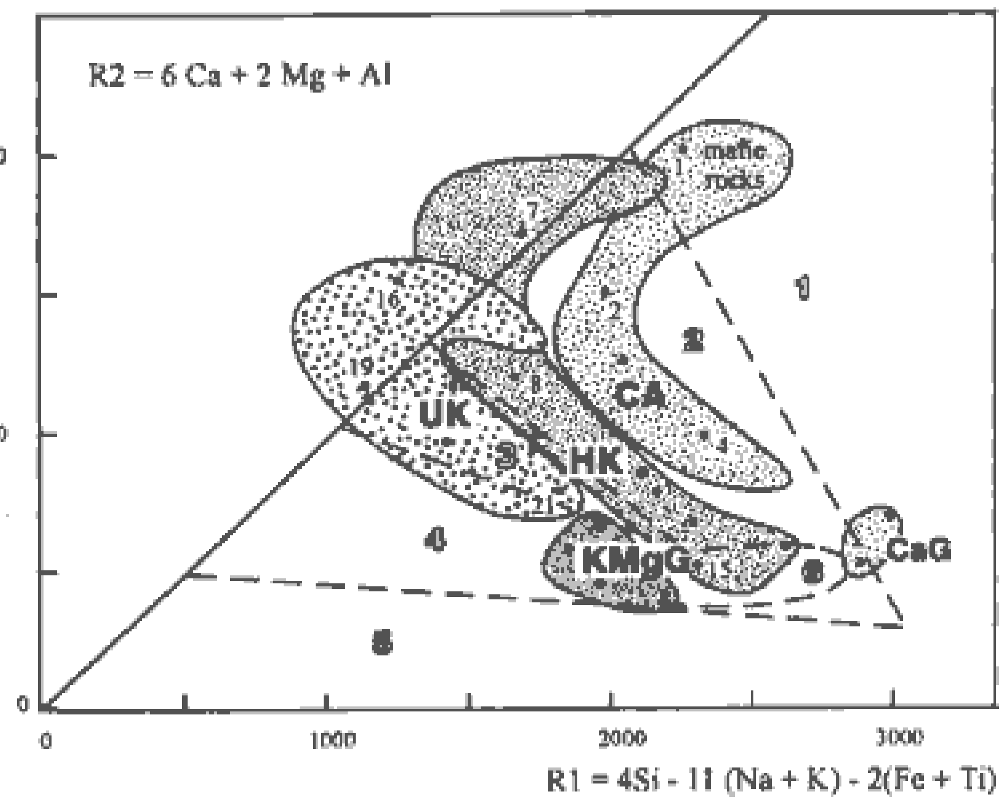
Tectonomagmatic affinity

For estimation of tectonomagmatic position of granitic rocks, various geochemical diagrams are widely used which are based on either major oxides (e.g., Batchelor and Bowden 1985; Maniar and Piccoli 1989), or trace elements (e.g., Pearce et al. 1984).

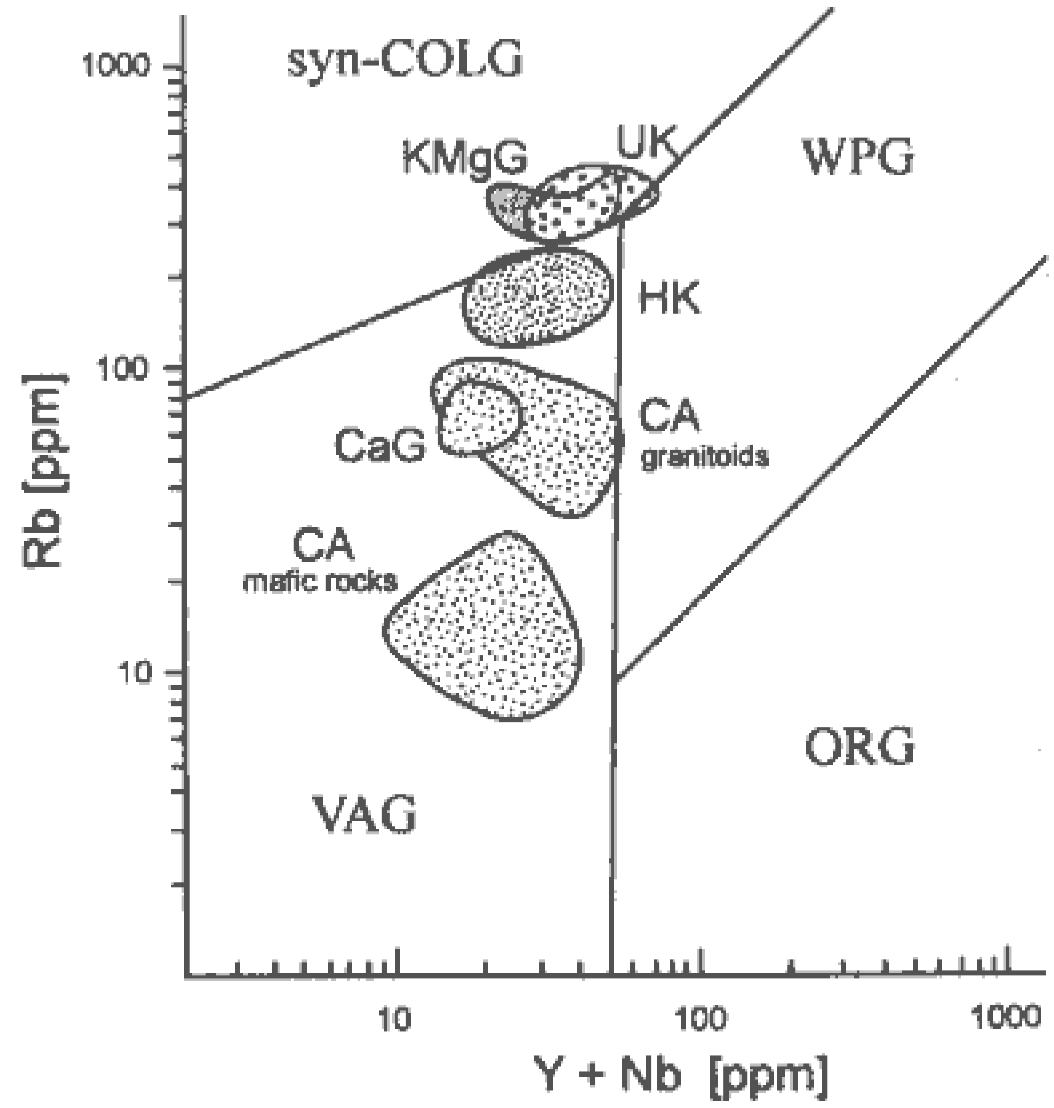
In the multicationic discrimination diagram after Batchelor and Bowden (Fig. 7), granitoids of CA group (= the Sázava type) plot within the "pre-plate collision" field and correspond to rocks associated with destructive plate margins. The CaG rocks plot at the boundary or even into the field of "mantle fractionates".

The HK-rocks more or less straddle the boundary of pre-plate collision field with that denoted as "post-collision uplift" and their most acid members approach the area of "syn-collision granites". Ultrapotassic plutonites plot into the field of rocks associated with post-orogenic uplift or at the boundary with the adjacent field of late-orogenic granites. The Zbonín and Říčany granites can be discriminated as late-orogenic.

However, many acid members of various groups plot into a "transitional" area where the above-mentioned fields join and meet with that of the syn-collision granites despite of their geochemical differences. Leucogranites plot into the syn-collision field.



7. Multicationic discrimination diagram after Batchelor and Bowden (1985) for principal rock groups of the Central Bohemian Plutonic Complex. Analyses from Table 2 are represented by filled circles. Tectonomagmatic divisions: 1 – Mantle fractionates; 2 – Pre-plate collision (destructive active plate margin); 3 – Post-collision uplift; 4 – Late-orogenic (sub-alkaline plutons); 5 - Anorogenic (post-orogenic); 6 - Syn-collision (anatectic) granites.



8. The Rb versus Nb+Y discrimination diagram after Pearce et al. (1984) for principal rock groups of the Central Bohemian Plutonic Complex. VAG – volcanic-arc granites; syn-COLG – syn-collision granites; WPG – within-plate granites; ORG – ocean-ridge granites

Of discrimination diagrams after Pearce et al. (1984), only the Rb versus Y+Nb diagram is shown in Fig. 8.

Granitoids of the CA group plot in the field of volcanic arc "granites". The same is true also for the CaG group. The HK granitoids plot also into that field but because of the increased content of Rb they are near to the syn-collision granites.

Granitoids of the ultrapotassic, KMgG and LG groups plot in the syn-collision field, indicating Rb-rich sources, and some UK rocks may approach the boundary of the within-plate granite field. However, both the UK and some KMgG rocks are different in chemistry from common syn-collision granites which are usually defined as peraluminous and rich in silica (e.g., Maniar and Piccoli 1989).

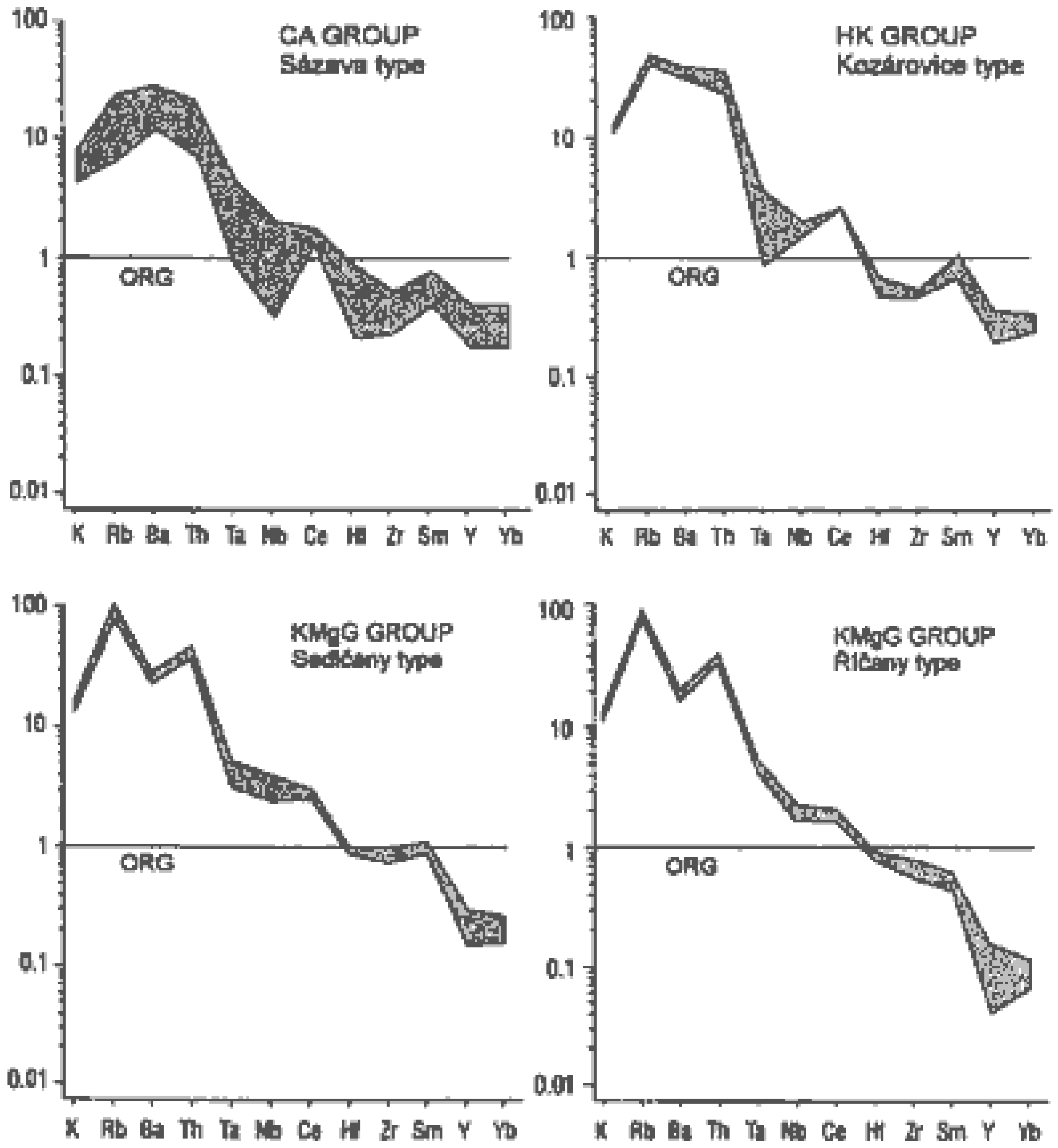
For comparison with granitoids of known tectonomagmatic position, also plots of trace element abundances normalized to the ocean-ridge granite (Pearce et al. 1984) are shown for selected granitoid groups of CBPC (Fig. 9).

Spidergram for the CA granitoids of the Sázava type is typical for volcanic-arc granites in concert with the discrimination diagrams. The HK granitoids represented by the Kozárovice type (Fig. 9b) resemble rocks of perhaps continental-arc affinity or some post-collision granitoids.

Spidergrams of KMgG granites display prominent Rb and Th spikes, characteristic for many continent-related magmas. Nevertheless, their interpretation in terms of tectonomagmatic affinity is problematic, because of their rather transitional appearance resembling some granitoids from continental volcanic arcs, syn-collision, post-collision and even some within-plate setting.

Spidergrams for AlG rocks and typical leucogranites (not shown) resemble those of syn-collision granites.

In summary, all the diagrams indicate a volcanic-arc (or



9. Spidergrams of selected elements normalized to average ocean-ridge granite (ORG) after Pearce et al. (1984) for 4 granitoid types representing three principal rock groups of CBPC.

pre-collision) setting for the calc-alkaline granitoids. The tectonomagmatic position of younger groups is, however, rather equivocal or transitional though the post-collision uplift or late-orogenic affinity seems to be appropriate for most of them. Paradoxially, the typical leucogranites displaying the most pronounced "syn-collision" affinity, are younger than those "post-collision" granitoids.

Despite of these results we attach to the geochemically indicated geodynamic regime only a limited value for the following reasons: (1) The geochemical definition of the "syn-collision" granites (e.g., Pearce et al. 1984) is based on assumption that the Rb-rich Hercynian granites do, indeed, represent true syn-collision magmas; (2) the discrimination plots based on trace elements do not enable us to distinguish pre-collision and post-collision granitoids; (3) a wide spectrum of geotectonic settings is indicated by geochemistry of rocks which originated within a limited area during rather short time interval; (4) we stress the importance of mineralogical and geochemical characteristics of the magma sources which may reflect previous processes and may not be controlled by the actual geodynamic regime during partial melting and magma emplacement (cf. Arculus 1987); (4) composition of the most voluminous granitoid types could be affected substantially by interaction with mafic magmas of subcrustal origin.

Role of mafic magmas

Because the most voluminous granitoid rocks of CBPC are intimately associated with mafic microgranular enclaves and mafic masses which do not bear any features of cumulates from crustal magmas, the important role of mantle-derived mafic magmas in their origin is evident.

These enclaves bear all typical features of the microgranular enclaves which are best explainable as blobs of mingled and partly mixed more mafic magmas (e.g., Vernon 1983, 1984; Didier 1987; Zorpi et al. 1989; Castro et al. 1991; Poli and Tommasini 1991) which were aligned and elongated during magma flow (cf. Vernon et al. 1988; see also Plate IV-1,2).

The larger irregular bodies of dioritic and gabbroic rocks associated with the calc-alkaline granitoids represent more voluminous portions of mafic magma which may or may not be hybridized and which are more or less coeval with the surrounding granitoids. Some masses are apparently the sources of mafic enclaves which are markedly abundant in granitoids adjacent to more mafic rock bodies (e.g., in the quarry near Teletín).

Many mafic masses, namely the quartz-bearing "ocellar" varieties described by Palivcová (1978), may be interpreted as rocks of hybrid origin. Some other gabbroids including the rare olivine-bearing rocks (e.g., from Tužinka near Benešov, see Vejnar 1972) are almost unaffected by reaction with granitic magmas and their composition is modified principally by fractionation processes.

Some portions of mafic magma intruded during or after consolidation of granitoids; those mafic rocks are represented by numerous dykes of microgabbro to microdiorite whose composition is similar to both the coarser-grained gabbroes to diorites and some microgranular enclaves (Palivcová 1965).

In most cases the mafic magma portions associated with the CA granitoids underwent a pronounced fractionation which is evidenced by relatively low *mg*-values and often very low Cr and Ni contents. Nevertheles, some bodies (e.g., the olivine gabbro from Tužinka) display relatively primitive nature.

Shoshonitic mafic rocks associated with the HK-granitoids appear as considerably less fractionated because of the relatively high *mg*-values, Cr and Ni contents. Their low CaO and Na_2O contents imply a depleted source whereas the increased concentrations of hygromagmatophile elements suggest a strong enrichment in K, Rb, Cs, Th, U, etc.

Ultrapotassic mafic rocks represent primitive, highly magnesian, mantle-derived magmas which could originate only in some anomalous mantle sources. The sources have been recognized as strongly depleted and, subsequently, extremely enriched in hygromagmatophile elements (Holub 1988, 1990, and this volume).

Ultrapotassic magma of similar but not identical composition participated also in origin of the Sedlčany granite whose hybrid nature is apparent (Holub 1990). Distinct varieties of potassic to ultrapotassic mafic magmas took a role perhaps also in genesis of other KMgG granites containing microgranular enclaves.

Besides the direct chemical interaction like partial or bulk mixing, it is necessary to consider very important thermal effects of invading mafic magmas. Since transport of heat by a rising magma is much more efficient than by conduction in the solid crust, the mafic magmas could disturb the temperature gradient considerably and may be responsible for anomalous heating of the crust, thus supporting anatexis and triggering intrusions of granitic and hybrid melts into relatively shallow crustal levels.

Role of subduction?

Some geochemical criteria may support the presumed genetic relations of the most voluminous granitoids, which are associated with mafic rocks (i.e., the CA, HK, UK plus KMgG), to some subduction-related processes (Holub 1991).

The CA group of CBPC resembles many calc-alkaline series spatially related to subduction zones elsewhere, namely those situated at active continental margins. Taking into account only the Hercynian belt of Central and Western Europe, the intermediate members of the CA group display a close geochemical similarity to Late Devonian - Early Carboniferous quartz diorites and tonalites occurring on western margin of the Massif Central, France (the Limousin tonalite belt); the latter are recently interpreted by Shaw et al. (1993) as being related to a short-lived subduction at an active continental margin and representing the earliest plutonism post-dating the main phase of Hercynian metamorphism in that area.

Also the succession and compositional changes between major groups of granitoids and associated mafic rocks of CBPC are in accord with an idealized igneous succession above subduction zones at active continental margins or epicontinental island arcs, where the calc-alkaline magmas are usually linked with a mature stage of subduction, and shoshonitic rocks with steepening and reorientation of the zone or failure of the subduction activity (Morrison 1980). The ultrapotassic rocks usually originate even later, often under extensional conditions, and may be related to fossil subduction zones and long-lived mantle anomalies.

On the other hand, the actual situation in the central Bohemian area may not be so simple. Principal conditions affecting the origin and composition of a magma are the existence of geochemically appropriate source regions and also the heat and/or volatiles available for partial melting. The time relations between igneous processes and tectonics may be complex and influenced also by some other factors, e.g. by ability and rate of magma ascent.

Within an inter-continent collision belt, probably represented by younger stages of the Hercynian chain, the resulting spatial and temporal pattern of igneous activity may be rather complicated. What seems to be proved is the late- to post-tectonic position of the CBPC in respect to the Central Bohemian shear zone and, consequently, the fact that the granitoids can hardly be considered really pre-collisional; however, their geochemistry is far from representing "typical" syn-collision rocks.

The complexity of the problem can be illustrated by Finger and Steyrer's paper (1990a) with subsequent comments and replies (Neubauer 1990; Finger and Steyrer 1990b), dealing with perhaps younger (late-Hercynian) granitoids in the southern Moldanubicum and the Alps.

Pattern of magmatic suites and their relationship to the Central Bohemian suture

Some authors emphasized existence of a zoned structure of the Central Bohemian Plutonic Complex and discriminated three geochemically distinct zones trending NE-SW, i.e. parallel to elongation of the complex and to the Central Bohemian Suture (Palivcová 1965; Poubová 1974; Palivcová et al. 1989b).

The belt close to the Barrandian is supposed as K_2O-poor and tonalitic, the central zone as transitional and the south-eastern zone along contact with Moldanubicum as composed of dark and K_2O-rich rocks and broadly "durbachitic" in character. The zoned structure has been stressed by Rajlich and Vlašímský (1983) who assumed it as resulting from differentiation by thermal diffusion in great magma body between the rather cold contact with Bohemicum and much warmer contact with the Moldanubian crystalline complex.

Evaluation of distribution and temporal relations of individual geochemical groups of plutonic rocks leads to a different conclusion, however.

The calc-alkaline association occur in the northern part of CBPC and in the Příbram area; thus it is almost exclusively restricted to the area which, on the ground of geophysical data, belongs to the Barrandian block (i.e., NW of the Benešov deep fault). Of all the groups, this one displays the closest spatial relationship to the Barrandian block and the presumed strike-slip zone of the Central Bohemian Suture.

A little younger rocks of the high-K group (HK) prevail in, but are not restricted to, the "Moldanubian part" of CBPC (i.e., the gravity-low area). Their geochemical nature is not directly controlled by distance to the "Barrandian" nor "Moldanubian" contact (see Machart 1991).

This relatively simple pattern of CA and HK intrusions is disturbed by bodies of ultrapotassic and KMgG groups belonging to the third intrusive period; these younger intrusions mostly follow a NNE-SSW trending zone which continues further to S and is apparently independent on both the Central Bohemian suture and older granitoids.

These observations demonstrate a progressively decreasing significance of the Central Bohemian suture with time, and suggest some changes in tectonic conditions in course of igneous activity.

Though some HK intrusions exploited the zone of the Klatovy deep fault and its continuation to NE, the group as a whole appears as related to structure of the adjacent parts of the Moldanubian crystalline complex, namely the NE-SW trending and NW dipping foliation planes and normal faults originated during an extensional regime (Rajlich 1993). Despite of comparable strike of arising structures, such regime is different from the older transcurrent deformation within the Central Bohemian shear zone.

Assymetric regional extension associated with rapid uplift and decompression of Moldanubian rocks may be responsible for the contrasting thermal conditions at NW contacts and along the Moldanubian side of the HK intrusions. Decreasing depth of intrusions may be indicated also by the lower alumina contents in hornblendes from HK granitoids compared to the CA group.

Ultrapotassic rocks and related KMg granites intruded during somewhat later stage of extension within the Moldanubian block.

We consider the recognition of geochemical magma types and their succession as well as some preliminary petrogenetic interpretations as only the first step to understanding the problems.

New and precise geochemical and geochronological data accompanied by new structural analysis of the area are needed for reconstruction of tectonomagmatic history of the Central Bohemian Plutonic Complex and for its correlation to other parts of the Hercynian orogenic belt.

Conclusions

(1) Among plutonic rocks of CBPC, six compositional and genetic groups can be distinguished as follows: The calc-alkaline group (CA); the Ca-rich acid granitoids (CaG); the high-K group of shoshonitic and high-K calc-alkaline rocks (HK); the ultrapotassic group (UK); the high-K, high-Mg granites (KMgG) related to the previous group but more acidic; peraluminous granodiorites (AlG). The seventh group of leucogranites (LG) is poorly defined and perhaps polygenetic.

(2) There are three major pulses of the plutonic igneous activity: I – CA group; II – HK group; III – UK, KMgG and probably also AlG groups. Position of the CaG group is still problematic. Between these periods innumerable dyke rocks intruded the partly cooled granitoids.

(3) Geological, petrographical and structural observations fail to support the granitization hypotheses.

(4) In terms of the I versus S typology, a great majority of CBPC granitoids is of the "I"-type, whereas the "S"-granitoids are represented only by the peraluminous granitoids of the AlG group and perhaps some leucogranites. Most of the "I"-granitoids are of apparently hybrid origin and the "H-type" is often more appropriate for them.

(5) If only geochemical criteria are taking into account, the oldest granitoids (CA) correspond with volcanic arc "granites"; individual younger intrusions could be classified as being mostly post-collision or, less frequently, syn-collision.

(6) In origin of a great majority of CBPC granitoids, various mantle-derived magmas have been involved; these mafic magmas could fractionate and/or mix together with crustal melts, provided extra heat for crustal melting and triggered intrusions of granitoids into relatively shallow levels.

(7) Geochemical character of mafic magmas was changing with time from calc-alkaline to shoshonitic to ultrapotassic. This succession is well comparable to igneous activity in volcanic arcs situated above mature subduction zones, or, in the case of the ultrapotassic activity, above fossil subduction zones.

(8) Trace element patterns in the K-rich mafic rocks suggest the origin of their parental magmas by partial melting of anomalous mantle sources which suffered an earlier depletion and subsequent enrichment in incompatible elements; the enrichment seems to be of the same character as above subducted lithospheric plates.

(9) The true genetic and time relation of plutonism to the subduction activity and the continental collision remains to be determined. We emphasize the role of mafic magmas whose composition may reflect the relatively long-persisting inhomogeneities within the lithospheric mantle instead of the actual geodynamic regime in the area.

(10) All the rocks of CBPC appear to be younger than principal tectonic transport and shearing along the strike-slip zone of the Central Bohemian suture and, therefore, they could hardly be actually pre-collisional.

(11) Rock suites younger than the CA group, i.e. the HK, UK, KMgG, AlG, and LG, seem to be linked with extensional regime and uplift of the Moldanubian block relative to the Barrandian. The youngest intrusions with mafic members (UK, KMgG) follow a NNE-SSW trending zone which continues to the Moldanubian crystalline complex and their distribution is quite independent on the Central Bohemian Suture.

(12) Both the more detailed correlation of CBPC with igneous activity in other parts of the Hercynian orogenic belt and determination of its tectonic setting require further geochemical, structural, and reliable geochronological data.

Acknowledgements
We are grateful to Emil Jelínek, Martin Novák and Karel Žák for their constructive reviews of the manuscript. Thanks are also due to Vladimír Tolar for technical assistance. This work was supported in part by Grant 205/94/0689 from the Grant Agency of Czech Republic.

Recommended for print by E. Jelínek
Translated by the author

References

AFTALION, M. - BOWES, D. R. - VRÁNA, S. (1989): Early Carboniferous U-Pb zircon age for garnetiferous, perpotassic granulites, Blanský les massif, Czechoslovakia. – Neu Jb. Mineral. Mh., 1989, 145–152.

ARCULUS, R. J. (1987): The significance of source versus process in the tectonic controls of magma genesis. – J. Volcanol. geotherm. Res., 32, 1–12.

BARBARIN, B. (1990): Granitoids: main petrogenetic classifications in relation to origin and tectonic setting. – Geol. J., 25, 227–238.

BATCHELOR, R. A. - BOWDEN, P. (1985): Petrogenetic interpretation of granitoid rock series using multicationic parameters. – Chem. Geol., 48, 43–55.

BENDL, J. - VOKURKA, K. (1989): Strontium isotope model of formation of Blatná granodiorite. – Geol. Zbor. Geol. carpath., 40, 655–664.

BENEŠ, K. - HANUŠ, V. - KNOTEK, M. (1980): Relict fabric of the NW part of the Central Bohemian pluton. – Krystalinikum, 15, 125–140.

BERÁNEK, B. - DUDEK, A. - ZOUNKOVÁ, M. (1975): Rychlostní modely stavby zemské kůry v Českém masivu a Západních Karpatech. – Sbor. geol. Věd, užitá Geofyz., 13, 7–20.

BERÁNEK, B. - ZOUNKOVÁ, M. (1977): Investigation of the Earth's crust in Czechoslovakia using industrial blasting. – Stud. geophys. geod., 21, 273–280.

BLÍŽKOVSKÝ, M. - MAŠÍN, J. - MÁTLOVÁ, E. - MITRENGA, P. - NOVOTNÝ, A. - POKORNÝ, L. - REJL, L. - ŠALANSKÝ, K. (1988): Linear structures in the Czechoslovak part of the Bohemian Massif derived from geophysical data (English abstract). – Věst. Ústř. Úst. geol., 63, 275–290.

BLÍŽKOVSKÝ, M. - NOVOTNÝ, A. - SUK, M. (1985): Přehled tíhových struktur Českého masivu. – Věst. Ústř. Úst. geol., 60, 143–154.

BLÍŽKOVSKÝ, M. - BUCHA, V. - IBRMAJER, J. - SUK, M. (1992): Geophysical pattern of the Bohemian Massif. – In: Kukal, Z. (Ed.), Proceedings of the 1st International Conference on the Bohemian Massif, 21–28. Czech Geol. Survey, Prague.

BONIN, B. (1990): From orogenic to anorogenic settings: evolution of granitoid suites after a major orogenesis. – Geol. J., 25, 261–270.

BOUŠKA, V. - JELÍNEK, E. - PAČESOVÁ, M. - ŘANDA, Z. - ULRYCH, J. (1984): Rare earth elements and other trace elements in the rocks of the Central Bohemian Pluton. – Geol. Zbor. Geol. carpath., 35, 355–376.

CAMBEL, B. - KAMENICKÝ, L. - KLOMÍNSKÝ, J. - PALIVCOVÁ, M. (1980): Petrochemical correlation of granitoids of the Bohemian Massif and the West Carpathians. – Geol. Zbor. Geol. carpath., 31, 3–36.

CASTRO, A. - MORENO-VENTAS, I. - DE LA ROSA, J. D. (1991): H-type (hybrid) granitoids: a proposed revision of the granite type classification and nomenclature. – Earth Sci. Rev., 31, 237–253.

CHALOUPSKÝ, J. (1978): The Precambrian tectogenesis in the Bohemian Massif. – Geol. Rdsch., 67, 72–90.

CHAPPELL, B. W. - WHITE, A. J. R. (1974): Two contrasting granite types. – Pacific Geol., 8, 173–174.

CHAPPELL, B. W. - WHITE, A. J. R. (1992): I- and S-type granites in the Lachlan Fold Belt. – Trans. Roy. Soc. Edinburgh, Earth Sci., 83, 1–26.

CHAPPELL, B. W. - WHITE, A. J. R. - WYBORN, D. (1987): The importance of residual source material (restite) in granite petrogenesis. – J. Petrology, 28, 1111–1138.

CHLUPÁČ, I. (1992): The metamorphic Palaeozoic of the "Islet Zone" as a possible connecting link between the Barrandian and the Moldanubicum. – In: Kukal, Z. (Ed.), Proceedings of the 1st International Conference on the Bohemian Massif, 49–52. Czech Geol. Survey, Prague.

CLARKE, D. B. (1992): Granitoid Rocks. – Chapman & Hall, London - Glasgow – New York. 283 pp.

DOBEŠ, M. - POKORNÝ, L. (1988): Gravimetry applied to the interpretation of the morphology of the Čertovo břemeno durbachite body in the Central Bohemian Pluton (English abstract). – Věst. Ústř. Úst. geol., 63, 129–135.

DUBANSKÝ, A. (1984): Stanovení radiogenního stáří kalium-argonovou metodou (geochronologická data z Českého masivu v oblasti ČSR). – Sbor. věd. Prací Vys. Šk. báňské v Ostravě, Ř. horn.–geol., 30., 137–170.

DUDEK, A. - FEDIUK, F. (1957): Basic inclusions and fluidal phenomena in the granodiorite at the border of the Central-Bohemian Pluton near Teletín (English summary). – Sbor. k osmdesátinám akad. F. Slavíka, 97–112. Ústř. úst. geol. Praha.

EBY, G. N. (1990): The A-type granitoids: A review of their occurrence and chemical characteristics and speculations on their petrogenesis. – Lithos, 26, 115–134.

FIALA, J. (1975): The clinopyroxene of the Pecerady gabbro. – In: Palivcová M. (Ed.) et al., Peceradské gabro – příklad tělesa appinitické série ve středočeském plutonu, 69–83. Stud. ČSAV, 12.

FIALA, J. - HANUŠ, V. - JUREK, K. - PALIVCOVÁ, M. (1974): Pyroxene in spheroidal gabbro of the Central Bohemian Pluton – magmatic or metamorphic? – Krystalinikum, 10, 101–112.

FIALA, J. - VEJNAR, Z. - KUČEROVÁ, D. (1976): Composition of the biotites and the coexisting biotite-hornblende pairs in granitic rocks of the Central Bohemian Pluton. – Krystalinikum, 12, 79–111.

FIALA, J. - VAŇKOVÁ, V. - WENZLOVÁ, M. (1983): Radioactivity of selected durbachites and syenites of the Bohemian Massif. – Čas. Mineral. Geol., 28, 1–16.

FINGER, F. - STEYRER, H. P. (1990a): I-type granitoids as indicators of a late Paleozoic convergent ocean-continent margin along the southern flank of the central European Variscan orogen. – Geology, 18: 1207–1210.

FINGER, F. - STEYRER, H. P. (1990b): Reply (to A.H.G. Mitchell); Reply (to F. Neubauer). – Geology, 18, 1245–1248.

FOLEY, S. F. - VENTURELLI, G. - GREEN, D. H. - TOSCANI, L. (1987): The ultrapotassic rocks: characteristics, classification, and constraints for petrogenetic models. – Earth Sci. Rev., 24, 81–134.

HANUŠ, V. - PALIVCOVÁ, M. (1968): Formation of gabbros from basalts stimulated by postvolcanic alteration. – 23rd Int. Geol. Congress, Czechoslovakia. Proc., Section 1 – Upper Mantle (Geological Processes), 221–232. Academia. Prague.

HANUŠ, V. - PALIVCOVÁ, M. (1969): Quartz-gabbros recrystallized from olivine-bearing volcanics. – Lithos, 2, 147–166.

HANUŠ, V. - PALIVCOVÁ, M. (1970): Relic variolitic texture in basic plutonites. - Neu Jb. Mineral., Mh., 1970, 433–455.

HANUŠ, V. - PALIVCOVÁ, M. (1971): Presence and significance of amygdules in hornblende gabbros. – Krystalinikum, 8, 27–43.

HAVLÍČEK, V. (1977): The Paleozoic (Cambrian - Devonian) in the Rožmitál area. – Věst. Ústř. Úst. geol., 52, 81–94.

HOLUB, F. V. (1977): Petrology of inclusions as a key to petrogenesis of the durbachitic rocks from Czechoslovakia. – Tschermaks mineral. petrogr. Mitt., 24, 133–150.

HOLUB, F. V. (1990): Petrogenetická interpretace chemismu kaliových lamproidů evropských hercynid na příkladu centrální a jižní části Českého masivu. – Thesis, Charles University, Prague. 265 pp.

HOLUB, F. V. (1991): Contribution to petrochemistry of the Central Bohemian Plutonic Complex (English summary). – In: Souček J. (Ed.): Horniny ve vědách o Zemi, 117–140. Charles University, Prague.

HOLUB, F. V. - COCHERIE, A. - ROSSI, PH. (1996): Radiometric dating of calc-alkaline to ultrapotassic plutonic rocks from the Central Bohemian Plutonic Complex (Czech Rep.) – C. R. hebd. Séanc. Acad. Sci., sér. II. Paris.

HOLUB, F. V. - ŽEŽULKOVÁ, V. (1978): Relative ages of intrusives of the Central Bohemian Pluton near Zvíkov (English summary). – Věst. Ústř. Úst. geol., 53, 289–297.

JAKEŠ, P. (1968): Variation of the chemical and modal composition of the Tábor Massif (English summary). – Čas. Mineral. Geol. 13, 63–73.

JAKEŠ, P. (1977): Geochemická charakteristika horninových typů středočeského plutonu. – Unpublished report, Czech Geol. Survey, Prague.

JANOUŠEK, V. (1991): Izotopy stroncia v říčanské žule. – Thesis, Charles University, Prague. 87 pp.

JANOUŠEK, V. - ROGERS, G. (1994): The Sr-Nd isotope geochemistry of the Central Bohemian Pluton, Czech Republic. – J. Czech Geol. Soc., 39, 51–52.

JANOUŠEK, V. - ROGERS, G., - BOWES, D. R. (1995): Sr-Nd isotopic constraints on the petrogenesis of the Central Bohemian Pluton, Czech Republic. – Geol. Rdsch., 84, 520–534.

JELÍNEK, J. (1935): Příspěvek k otázce diferenciace ve středočeském žulovém masivu (Mračské lomy u Benešova). – Rozpr. Čes. Akad. Věd Umění, Tř. II, 44, 1–12.

JOHANOVÁ, V. (1969): Výzkum akcesorických minerálů z hornin středočeského plutonu. – Zpr. geol. Výzk. v Roce 1968, 41–43.

KAŠPAR, J. (1936): Stručný nástin mineralogie a geochemie říčanské žuly. – Věda přír., 17, 168–171.

KETTNER, R. (1930): Geologie středočeského žulového masivu. – Příroda, 23 (11), 1–6. (Brno).

KETTNEROVÁ, M. (1920): Kontakt středočeské žuly u Žampachu na Sázavě. – Čas. Mus. Král. čes., 1920, 19–28.

KLEČKA, M. (1984): Felsitic and vitreous dyke rocks from the vicinity of Lásenice near Jindřichův Hradec (English summary). – Čas. Mineral. Geol., 29, 293–298.

KLEČKA, M. - VAŇKOVÁ, V. (1988): Geochemistry of felsitic dykes from the vicinity of Lásenice near Jindřichův Hradec (South Bohemia) and their relation to Sn-W mineralization. – Čas. Mineral. Geol., 29, 293–298.

KLEČKA, M. - BENDL, J. - MATĚJKA, D. (1994): Rb-Sr-dating of acid subvolcanic dyke rocks – final magmatic products of the Moldanubian Batholith. – Mitt. Österr. mineral. Gessell., 139, 66–68.

KLOMÍNSKÝ, J. - DUDEK, A. (1978): The plutonic geology of the Bohemian Massif and its problems. – Sbor. geol. Věd, Geol., 31, 47–66.

KLOMÍNSKÝ, J. - DUDEK, A. (1994): Plutonites. – In: Klomínský, J. (Editor), Geological Atlas of the Czech Republic – Stratigraphy, p. 15. Czech Geol. Survey, Prague

KLOMÍNSKÝ, J. PALIVCOVÁ, M. - CAMBEL, B. - GURBANOV, A. G. (1981): Petrochemical correlation and I/S classification of Variscan granitoids from the Czech Massif, West Carpathians (Czechoslovakia), and the Caucasus Mts. (USSR). – Geol. Zbor. Geol. carpath., 32, 307–315.

KNOTEK, M. (1975): Geology and petrography of the Pecerady gabbro (English summary). – In: Palivcová, M. (Ed.) et al., Peceradské gabro – příklad tělesa appinitické série ve středočeském plutonu, 9–33. Stud. ČSAV, 12.

KODYM, O. Jr. (1966): Moldanubicum. – In: Svoboda J. (Ed.): Regional Geology of Czechoslovakia, Part I. The Bohemian Massif, 40–99. Geological Survey, Prague,

KODYM, O. Jr. et al. (1961): Vysvětlivky k přehledné geologické mapě ČSSR 1 : 200 000, M-33-XXVI Strakonice. – Ústř. úst. geol., Praha, 149 pp.

KODYM, O. Jr. et al. (1963): Vysvětlivky k přehledné geologické mapě ČSSR 1 : 200 000, M-33-XXI Tábor. – Geofond, Praha, 232 pp.

KODYMOVÁ, A. - VEJNAR, Z. (1974): Accessory heavy minerals of the Central Bohemian Pluton (English summary). – Sbor. geol. Věd., ložisk. Geol. Mineral., 16, 89–128.

LE MAITRE, R. W. (Editor) (1989): A Classification of Igneous Rocks and Glossary of Terms: Recommendations of the International Union of Geological Sciences Subcommission on the Systematics of Igneous Rocks. – Blackwell, Oxford – London. 193 pp.

LIEW, T. C. - FINGER, F. - HÖCK, V. (1989): The Moldanubian granitoid plutons of Austria: Chemical and isotopic studies bearing on their environmental setting. – Chem. Geol., 76, 41–55.

MACHART, J. (1991): Chemical types of granitoids in the southern part of the Central Bohemian Pluton (English summary). – In: Souček J. (Ed.): Horniny ve Vědách o Zemi, 107–116. Charles University, Prague.

MANOVÁ, M. (1975): Zpracování radiometrických dat z oblasti středočeského plutonu a srovnání výsledků s geofyzikálními a geologickými poznatky. – Unpublished thesis, Charles University, Prague.

MAREK, F. - PALIVCOVÁ, M. (1968): Deeper structure of the Central Bohemian Pluton on the basis of density measurements and gravity anomalies (English summary). – Čas. Mineral. Geol., 13, 333–346.

MATOLÍN, M. (1970): Radioaktivita hornin Českého masivu. – Knih. Ústř. Úst. geol., 41, 99 pp.

MATTE, PH. - MALUSKI, H. - RAJLICH, P. - FRANKE, W. (1990): Terrane boundaries in the Bohemian Massif: Result of large-scale Variscan shearing. – Tectonophysics, 177, 151–170.

MENČÍK, E. (1951): Geology and petrology of the area between Plánice and Nepomuk (English summary). – Sbor. Ústř. Úst. geol., Odd. geol., 18, 49–88.

MORRISON, G. W. (1980): Characteristics and tectonic setting of the shoshonite rock association. – Lithos, 13, 97–107.

MRÁZEK, P. (1964): Nové poznatky o geologii sedlčansko-krásnohorského metamorfovaného ostrova. – Zpr. geol. Výzk. v Roce 1963, 25–27.

NEUBAUER, F. (1990): Comment (to Finger and Steyrer 1990a). – Geology, 18: 1246.

ORLOV, A. (1933): Contribution l'étude pétrographique du massif "granitique" de la Boheme Centrale (région de Říčany – Benešov – Milevsko – Písek) (French summary). – Věst. Stát. geol. Úst. Čs. Republ., 9, 135–145.

ORLOV, A. (1935a): Problémy středočeského plutonu. – Věda přír., 16, 43–48.

ORLOV, A. (1935b): Zur Kenntnis der Petrochemie des mittelböhmischen Plutons. – Mineral. petrogr. Mitt., N.F. 46, 416–446.

PALIVCOVÁ, M. (1965): The Central Bohemian Pluton – a petrographic review and an attempt at a new genetic interpretation. – Krystalinikum, 3, 99–131. (Prague).

PALIVCOVÁ, M. (1967): Igneous-looking metasomatic hudrothermal albitites ("syenite of Smolotely", Central Bohemian Pluton). – Sbor. Nár. Muz., Ř. B, 23, 125–148.

PALIVCOVÁ, M. (1978): Ocellar quartz leucogabbro (Central Bohemian Pluton) and genetic problems of ocellar rocks. – Geol. Zbor. Geol. carpath., 29, 19–41.

PALIVCOVÁ, M. (1981): Microtextures of gabbroic and dioritic rocks associated with intrusive granitoid complexes. – Geol. Zbor. Geol. Carpath., 32, 559–589.

PALIVCOVÁ, M. (1984): Basic series of an "Andinotype batholithic association" in the Variscan Central Bohemian Pluton. – Geol. Zbor. Geol. carpath., 35, 39–60.

PALIVCOVÁ, M. - HEJL, V. (1976): Dioritic rocks with actinolite, sphene and epidote, originated by alteration of biotite granitoids (Central Bohemian Pluton). – Čas. Mineral. Geol., 21, 147–166.

PALIVCOVÁ, M. - KNOTEK, M. (1975): The textural variability of the Pecerady gabbro and its causes (English summary). – In: Palivcová, M. (Ed.) et al., Peceradské gabro – příklad tělesa appinitické série ve středočeském plutonu, 35–67. Stud. ČSAV, 12.

PALIVCOVÁ, M. - LEDVINKOVÁ, V. - WALDHAUSROVÁ, J. - ŽEŽULKOVÁ, V. (1988): The Cambrian conglomerates as parent rocks of the Kozlovice granodiorite and adjacent Moldanubicum (English summary). – Čas. Mineral. Geol., 33, 171–183.

PALIVCOVÁ, M. - WALDHAUSROVÁ, J. - LEDVINKOVÁ, V. (1989a): Granitization problem - once again. – Geol. Zbor. Geol. carpath., 40, 423–452. (Bratislava).

PALIVCOVÁ, M. - WALDHAUSROVÁ, J. - LEDVINKOVÁ, V. (1989b): Precursors lithology and the origin of the Central Bohemian Pluton (Bohemian Massif). – Geol. Zbor. Geol. carpath., 40, 521–546. (Bratislava).

PALIVCOVÁ, M. - WALDHAUSROVÁ, J. - LEDVINKOVÁ, V. - FATKOVÁ, J. (1992): Říčany granite (Central Bohemian Pluton) and its ocelli- and ovoids-bearing mafic enclaves. – Krystalinikum, 21, 33–66.

PEARCE, J. A. (1982): Trace element characteristics of lavas from destructive plate boundaries. In: Thorpe R.S. (Ed.), Andesites, 525–548. Wiley, New York.

PEARCE, J. A. - HARRIS, N. B. W. - TINDLE, A. G. (1984): Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. – J. Petrol., 25, 956–983.

PECCERILLO, A. - TAYLOR, S. R. (1976): Geochemistry of the Eocene calc-alkaline volcanic rocks from the Kastamonu area, Northern Turkey. – Contr. Mineral. Petrology, 58, 63–81.

PIVEC, E. (1970): On the origin of phenocrysts of potassium feldspars in some granitic rocks of the Central Bohemian Pluton. – Acta Univ. Carol., Geol., 1970, 11–25.

POLI, G. E. - TOMMASINI, S. (1991): Model for the origin and significance of microgranular enclaves in calc-alkaline granitoids. – J. Petrol., 32, 657–666.

POUBOVÁ, M. (1974): Composition of amphiboles and rock type subdivisions in the Central Bohemian Pluton. – Krystalinikum, 10, 149–169.

RAJLICH, P. (1988): Tectonics of the NW border of the Central Bohemian Pluton and the Variscan transpression of the Bohemicum block structure (English summary). – Sbor. geol. Věd, Geol., 43, 9–81.

RAJLICH, P. (1993): Variská duktilní tektonika Českého masivu. – Knih. Čes. geol. úst., 65, 171 pp.

RAJLICH, P. - VLAŠÍMSKÝ, P. (1983): Regional geochemical trends in the Central Bohemian Pluton (English summary). – Acta Univ. Carol., Geol., 1983, 193–213.

RAJLICH, P. - SCHULMANN, K. - SYNEK, J. (1988): Strain analysis on conglomerates from the Central Bohemian shear zone. – Krystalinikum, 19, 119–134.

RÖHLICHOVÁ, M. (1964): To the genesis of granitic rocks on the southern margin of the Central Bohemian Pluton (English summary). – Čas. Mineral. Geol., 9, 1–8.

SATTRAN, V. - KLOMÍNSKÝ, J. (1970): Petrometallogenetic series of igneous rocks and endogenous ore deposits in the Czechoslovak part of the Bohemian Massif. – Sbor. geol. Věd, ložisk. Geol., 12, 65–154.

SHAW, A. - DOWNES, H. - THIRLWALL, M. F. (1993): The quartz-diorites of Limousin: Elemental and isotopic evidence for Devono-Carboniferous subduction in the Hercynian belt of the French Massif Central. – Chem. Geol., 107, 1–18.

SOUČEK, J. (1971): Basic inclusions in the Červená granodiorite in the area of Písek. – Acta Univ. Carol., Geol., 1971, 153–166.

STEINOCHER, V. (1950, 1953, 1955, 1958, 1959, 1961, 1963): The position of some plutonic and dike rocks of the Plutonic Mass of Central Bohemia in P. Niggli's quantitative mineralogical and chemical system, Part. I–VII (Stellung einiger plutonischer sowie gangförmiger Eruptivgesteine des mittelböhmischen Plutons im quantitativen mineralogischen und chemischen System von P. Niggli. Teil I–VII) (English or German summaries). – Sbor. Ústř. Úst. geol., Odd. geol., 17–1950, 241–288 (I); 20–1953, 101–128 (II); 21–1954, 721–764 (III); 24–1957, 309–351 (IV); 25–1958, 187–222 (V); 26–1959, 1–52 (VI); 28–1961, 191–230 (VII).

STEINOCHER, V. (1969): Die stoffliche Zusammensetzung, der provinziale Charakter und die petrologischen Verhältnisse des mittelböhmischen Plutons (German summary). – Rozpr. Čs. Akad. Věd, Ř. mat. přír. Věd, 79 (1), 1–99.

SUK, M. (1973a): Reconstruction of the mantle of the Central Bohemian Pluton. – Čas. Mineral. Geol., 18, 345–364.

SUK, M. (1973b): Rekonstrukce pláště středočeského plutonu. – Unpublished report, (Geofond, Praha P 23 573). 36 pp.

SUK, M. et al. (1975): Vysvětlivky k základní geologické mapě ČSSR 1:25 000, 22–243 Bernartice. – Ústř. Úst. geol., Praha, 54 pp.

ŠALANSKÝ, K. (1983): Regionální magnetické struktury Českého masivu na území ČSR. – Věst. Ústř. úst. geol., 58, 275–286.

ŠMEJKAL, V. (1960): Absolutní stáří některých granitoidů a metamorfitů Českého masivu stanovené kalium-argonovou metodou. – Věst. Ústř. Úst. geol., 35, 441–449.

ŠTĚPÁNEK, J. (1929): La diorite quartzifre pyroxene de Chleby dans la région de Benešov (French summary). – Věst. Stát. geol. Úst. Čs. Republ., 5, 116–125.

TAUSON, L. V. - KOZLOV, V. D. - PALIVCOVÁ, M. - CIMBAL'NIKOVÁ, A. (1977): Geokhimicheskie osobennosti granitoidov srednecheshskogo plutona i nekotorye voprosy ikh genezisa (In Russian). – In: Opyt korrelyacii magmaticheskikh i metamorficheskikh porod Czechoslovakii i nekotorych rayonov SSSR, 145–161. Nauka, Moskva.

TAYLOR, S. R. - MCLELLAN, S. M. (1985): The Continental Crust: Its Composition and Evolution. – Blackwell, Oxford.

TOMEK, Č. (1976): Deeper structure and petrogenesis of the Central Bohemian Pluton. – In: Výzkum hlubinné geologické stavby Československa (Sborník referátů, Loučná 1974–1975), 187–194. Geofyzika. Brno.

TOMEK, Č. - VRÁNA, S. (1992): Deep seismic reflection profiling in the South Bohemian Moldanubicum. – In: Seventh geol. workshop Styles of superposed Variscan nappe tectonics (Kutná Hora), Abstracts, p. 65.

ULRYCH, J. (1972): Leucocratic granitoids at the contact of the Central Bohemian Pluton and the Moldanubicum (English summary).– Čas. Mineral. Geol., 17, 71–84.

ULRYCH, J. (1985): Development of chemical zoning of amphiboles in mafic rocks of the Central Bohemian Pluton (English summary). – Acta Univ. Carol., Geol., 1985, 25–48.

ULRYCH, J. - PALIVCOVÁ, M. (1989): Tschermakite metamelagabbro from Ostrý Vrch (contact of the Slapy apophysis of the Central Bohemian Pluton with the Jílové Zone) (English summary). – Čas. Mineral. Geol., 34, 165–178.

URBAN, K. (1930): Géologie de la région aux environs de la jonction de la Vltava avec l'Otava (French summary). – Sbor. Stát. geol. Úst. Čs. Republ., 9, 109–187.

VAN BREEMEN, O. - AFTALION, M. - BOWES, D. R. - DUDEK, A. - MÍSAŘ, Z. - POVONDRA, P. - VRÁNA, S. (1982): Geochronological studies of the Bohemian massif, Czechoslovakia, and their significance in the evolution of Central Europe.– Trans. Royal Soc. Edinburgh, Earth Sci., 73, 89–108.

VEJNAR, Z. (1972): Petrology of the Tužinka gabbro, Central Bohemian Pluton. – Acta Univ. Carol., Geol., 1972, 253–262.

VEJNAR, Z. (1973): Petrochemistry of the Central Bohemian Pluton. – Geochemie, Geochemical Methods and Data (Prague), 2, 5–116.

VEJNAR, Z. (1974a): Application of cluster analysis in the multivariate petrochemical classification of the rocks of the Central Bohemian Pluton (English summary). – Věst. Ústř. Úst. geol., 49, 29–34.

VEJNAR, Z. (1974b): Trace elements in rocks of the Central Bohemian Pluton. – Věst. Ústř. Úst. geol., 49, 29–34.

VERNON, R. H. (1984): Microgranitoid enclaves in granites – globules of hybrid magma quenched in a plutonic environment. – Nature, 309, 438–439.

VERNON, R. H. - ETHERIDGE, M. A. - WALL, V. J. (1988): Shape and microstructure of microgranitoid enclaves: indicators of magma mingling and flow. – Lithos, 22, 1–11.

VLAŠÍMSKÝ, P. (1973): Stocks of basic and tonalitic rocks in the exocontact zone of the Central Bohemian Pluton in the Příbram area (English summary. – Acta Univ. Carol., Geol., 1973, 179–195.

VLAŠÍMSKÝ, P. (1975): The geochemistry of the plutonic rocks of the Central Bohemian Pluton in the Příbram area. – Acta Univ. Carol., Geol., 1975, 115–137.

VLAŠÍMSKÝ, P. (1976): Petrogeneze a geochemie hornin v příbramské rudní oblasti. – Unpublished report, Geofond, Praha.

VLAŠÍMSKÝ, P. (1982): The Příbram ore district: rock geochemistry and potential sources of hydrothermal mineralization (English summary). – Sbor. geol. Věd., ložisk. Geol. Mineral., 24, 49–99.

VLAŠÍMSKÝ, P. (1986): Stavba středočeského plutonu v důlních dílech v okolí Milína. – Zpr. geol. Výzk. v Roce 1984, 220–222.

VLAŠÍMSKÝ, P. - LEDVINKOVÁ, V. - PALIVCOVÁ, M. - WALDHAUSROVÁ, J. (1991): Hypotéza izochemické granitizace in situ a otázka geneze středočeského plutonu (na příkladu Příbramska). – Zpr. geol. Výzk. v Roce 1989, 178–180.

VLAŠÍMSKÝ, P. - LEDVINKOVÁ, V. - PALIVCOVÁ, M. - WALDHAUSROVÁ, J. (1992): Relict stratigraphy and the origin of the Central Bohemian Pluton (English summary). – Čas. Mineral. Geol., 37, 31–44.

WEAVER, S. D. - ADAMS, C. J. - PANKHURST, R. J. - GIBSON, I. L. (1992): Granites of Edward VII Peninsula, Marie Byrd Land: anorogenic magmatism related to Antarctic–New Zealand rifting. – Trans. Roy. Soc. Edinburgh, Earth Sci., 83, 281–290.

WENDT, J. I. - KRÖNER, A. - FIALA, J. - TODT, W. (1993): Evidence from zircon dating for existence of approximately 2.1 Ga old crystalline basement in southern Bohemia, Czech Republic. – Geol. Rdsch., 82, 42–50.

WENDT, J. I. - KRÖNER, A. - FIALA, J. - TODT, W. (1994): U-Pb zircon and Sm-Nd dating of Moldanubian HP/HT granulites from South Bohemia, Czech Republic. – J. Geol. Soc., 151, 83–90.

WHALEN, J. B. - CURRIE, K. L. - CHAPPELL, B. W. (1987): A-type granites: geochemical characteristics, discrimination and petrogenesis. – Contrib. Mineral. Petrol., 95, 407–419.

WHITE, A. J. - CHAPPELL, B. W. (1977): Ultrametamorphism and granitoid genesis. – Tectonophysics, 43, 7–22.

ZORPI, M. J. - COULON, C. - ORSINI, J. B. - COCIRTA, C. (1989): Magma mingling, zoning and emplacement in calc-alkaline granitoid plutons. – Tectonophysics, 157, 315–329.

ŽEŽULKOVÁ, V. (1982): Granitoids of the so-called Dehetník type in the Central Bohemian Pluton (English summary). – Věst. Ústř. Úst. geol., 57, 205–212.

ŽEŽULKOVÁ, V. et al. (1980): Vysvětlivky k základní geologické mapě ČSSR 1:25 000, 22–234 Oslov. – Ústř. úst. geol., Praha, 64 pp.

Středočeský plutonický komplex: geologie, chemické složení a genetická interpretace

(Resumé anglického textu)

František V. Holub - Jiří Machart - Magdalena Manová

Předloženo 10. června 1996

Středočeský plutonický komplex spodnokarbonského stáří je složité těleso batolitového charakteru. Tvoří jej značně rozmanité typy hlubinných a žilných hornin se širokými variacemi petrografického a geochemického složení, pohybujícího se od bazického po acidní a od vápenatoalkalického po ultradraselné.

Mezi horninami plutonického charakteru lze na základě látkového složení rozlišit šest až sedm skupin, které se navzájem liší i charakterem a chemickým složením horninotvorných minerálů (zejména amfibolů a slíd), povahou uzavřenin, celkovou radioaktivitou apod. Jsou to: CA – vápenatoalkalická skupina se složením od amfibolických gaber po biotit-amfibolické tonality a granodiority sázavského typu; HK – draslíkem bohatá vápenatoalkalická až šošonitová skupina objemově nejvýznamnějších amfibol-biotitických granitoidů, zahrnující typy blatenský, červenský, kozárovický, těchnický, pravděpodobně i klatovský a okrajový, a podřízených monzonitických hornin (zalužanský typ apod.); UK – ultradraselná skupina zahrnující amfibol-biotitické a biotit-pyroxenické melasyenitoidy až melagranitoidy typu Čertovo břemeno (durbachitické horniny) a táborského; KMgG – kyselejší granity bohaté K a Mg, zahrnující sedlčanský a zbonínský typ (oba jsou látkově příbuzné předešlé skupině, avšak neodpovídají již definici ultradraselných hornin) a říčanský typ; AlG – peraluminické granodiority typu kozlovického, maršovického a Kosovy Hory; CaG – vápníkem bohaté a draslíkem chudé acidní granitoidy typu požárského a nečínského o složení biotitického granodioritu až trondhjemitu. Navíc se vyskytují početné žíly a drobné masivky leukogranitů (LG). Většina těchto skupin (kromě CaG a AlG) má své zástupce také mezi velmi hojnými žilnými horninami.

Přehled petrografických charakteristik jednotlivých typů plutonických hornin podává tabulka 1, reprezentativní analýzy hlavních a vybraných stopových prvků v horninách jednotlivých skupin shrnuje tabulka 2, průměrné obsahy radioaktivních prvků a hodnoty celkové gama-aktivity jsou uvedeny v tabulce 3.

Pro granitoidy a bazika středočeského plutonického komplexu byly v posledních 30 letech mnohokrát předloženy hypotézy jejich vzniku metasomatickou nebo naopak izochemickou granitizací či transformací ze staršího vulkanického, sedimentárního, nebo smíšeného substrátu. Takové interpretace jsou však v rozporu s geologickými vztahy hornin v terénu, jejich petrografickou povahou i látkovým složením.

Převažující granitoidy mají charakter I-typu či spíše H-typu (hybridních granitoidů). Na jejich vzniku se podílela celá škála mafických magmat pláštového původu (vápenatoalkalická, šošonitická, ultradraselná), jak to dokládá přítomnost mafických členů jednotlivých skupin a typických mikrogranulárních enkláv (v horninách skupin CA, HK, UK, KMgG). Čistému I-typu odpovídají granitoidy skupiny CaG. Kromě toho jsou však v podružném množství přítomny i typické S-granitoidy (skupina AlG a nejspíše i LG).

Skupina CA je podle terénních kriterií mezi nemetamorfovanými plutonity dané oblasti nejstarší. Tonality a granodiority této skupiny, označované tradičně jako sázavský typ (v užším smyslu), geochemicky odpovídají granitoidům vulkanických oblouků. Na druhé straně je však nepravděpodobný jejich prekolizní vznik vzhledem k tomu, že nejsou postiženy intenzívními střižnými deformacemi podél hranice mezi barrandienským a moldanubickým blokem, tj. ve středočeské střižné zóně.

Relativně mladší draslíkem bohaté horniny (HK skupina) jsou proti předešlé skupině hořečnatější a značně bohatší hygromagmatofilními prvky včetně radioaktivních. Podle složení minerálů i celkové geochemie sem patří jednoznačně i kozárovický typ, v minulosti většinou mylně přiřazovaný k typu sázavskému. Intruze této skupiny jsou starší než plutonity skupin UK a KMgG, ale zdají se být již závislé na režimu korové extenze, vyzdvihování a dekomprese v moldanubickém bloku.

Ultradraselné horniny jsou extrémně bohaté K, Rb, Cs, Th, U apod., ale přitom mají charakter značně primitivních magmat pláštového původu a nikoliv pokročilých diferenciátů. Vznik primárních ultradraselných magmat daného charakteru vyžaduje parciální tavení silně anomálního pláštového zdroje, který byl nejspíše modifikován procesy spjatými s metamorfózou a dehydratací subdukované kůry zatím blíže neurčené litosférické desky. Světlejší členy skupiny UK a také jim blízké granity skupiny KMgG lze vysvětlit rozsáhlou hybridizací ultradraselných magmat acidními taveninami prav-děpodobně korového původu.

Magmata skupin UK, KMgG a přinejmenším některých S-granitoidů intrudovala později než jiné objemově významné typy, a jejich distribuce v oblasti je zjevně nezávislá na průběhu geofyzikálně indikované středočeské sutury.

Vysvětlivky k obrázkům

1. (a) Poloha středočeského plutonického komplexu (CBPC) a dalších plutonických těles v moldanubické zóně Českého masivu. BB – barrandienský blok, MB – moldanubický blok, SBB – moldanubický (= jihočeský) batolit, TP – třebíčský pluton.
(b) Geologická situace středočeského plutonického komplexu. Křížky – granitoidy a podřízeně i mafické plutonity CBPC; malé ležaté křížky – ultradraselné plutonity; tečkované plochy – svrchnoproterozoické až devonské horniny ostrovní zóny; protažené křížky – ortoruly; prázdné kroužky – permokarbonské sedimenty. KM – křečovické migmatity, M – mirovický metamorfovaný ostrov, MO – mirotické ortoruly, SO – starosedelské ortoruly, MM – milevský masiv, PC – permokarbon.

2. Zjednodušená aeroradiometrická mapa středočeského plutonického komplexu. Intenzita souhrnného gama-záření v $\mu R.h^{-1}$.

3. Rozšíření hlavních horninových typů a jejich skupin ve středočeském plutonickém komplexu (zjednodušeno). Jsou vynechány žilné horniny a většina těles leukogranitů. Zkratky pro některé místní horninové typy: Ne – nečínský, Č – červenský, Mr – okrajový, Ny – nýrský, ČB – Čertovo břemeno, Zb – zbonínský, Mš – maršovický, KH – typ Kosovy Hory.

4. Variační diagram K_2O versus SiO_2 (hmot. %) pro plutonity středočeského plutonického komplexu. Hranice mezi K-bohatými vápenatoalkalickými (HKCA) a šošonitickými (SHO) horninami jsou podle Peccerillo a Taylor (1976), ostatní hranice jsou podle doporučení IUGS (Le Maitre 1989). Rozptylová pole hlavních horninových skupin nebo typů jsou ohraničena plnou čarou, pole mafických mikrogranulárních enkláv čerchovaně, pole granitoidů skupiny AIG tečkovaně. Pozice analyzovaných hornin z tabulky 2 je vyznačena plnými kroužky.

5. Normalizační diagram ukazující geochemické rozdíly mezi typickými granitoidy skupin Ca, Hk a UK + KMgG při obsazích 63 až 65 % SiO_2. Skutečné obsahy prvků jsou normalizovány průměrným složením svrchní kontinentální kůry (Taylor a McLellan 1985).

6. Grafické vyjádření relativního stáří horninových typů středočeského plutonického komplexu. Dílčí intruze jednotlivých typů nebo blízce příbuzných skupin jsou reprezentovány kruhy, jejichž pozice přibližně odpovídá mapě (srov. obr. 3).

7. Multikationtový diskriminační diagram podle Batchelora a Bowdena (1985) pro hlavní horninové skupiny. Plné kroužky představují pozici analýz z tabulky 2. Původní označení polí podle charakteristické tektonomagmatické pozice: 1 – diferenciáty pláště; 2 – prekolizní (destruktivní aktivní okraje desky); 3 – postkolizní výzdvih; 4 – pozdně orogenní (subalkalické plutony); 5 – anorogenní (postorogenní); 6 – synkolizní (anatektické) granity.

8. Diskriminační diagram Rb versus Nb+Y podle Pearce et al. (1984). VAG – granitoidy vulkanických oblouků; syn-COLG – synkolizní granity; WPG – granity vnitřních částí desek; ORG – granitoidy oceánských hřbetů.

9. Normalizační diagramy vybraných prvků pro reprezentanty granitoidů tří hlavních geochemických skupin. Normalizováno průměrnými obsahy v granitoidech středooceánských hřbetů podle Pearce et al. (1984).

Vysvětlivky k tabulkám

1. Přehled petrografických charakteristik jednotlivých typů hornin středočeského plutonického komplexu.

2. Reprezentativní analýzy hlavních a vybraných stopových prvků v horninách středočeského plutonického komplexu.

3. Hodnoty celkové gama-aktivity a průměrné obsahy radioaktivních prvků v horninách plutonického komplexu.

Vysvětlivky k fotografickým přílohám

Příl. I
1. Xenolity biotitických rohovců (vzniklých z prachovců svrchního proterozoika) v biotitickém granodioritu okrajového typu. Vrt Novotníky, z. od Nepomuku.
2. Xenolity metamorfitů (rul, migmatitů atd.) v biotitickém granitu zbonínského typu. Výchozy na břehu orlické přehrady, 0,5 km sz. od hradu Zvíkova.

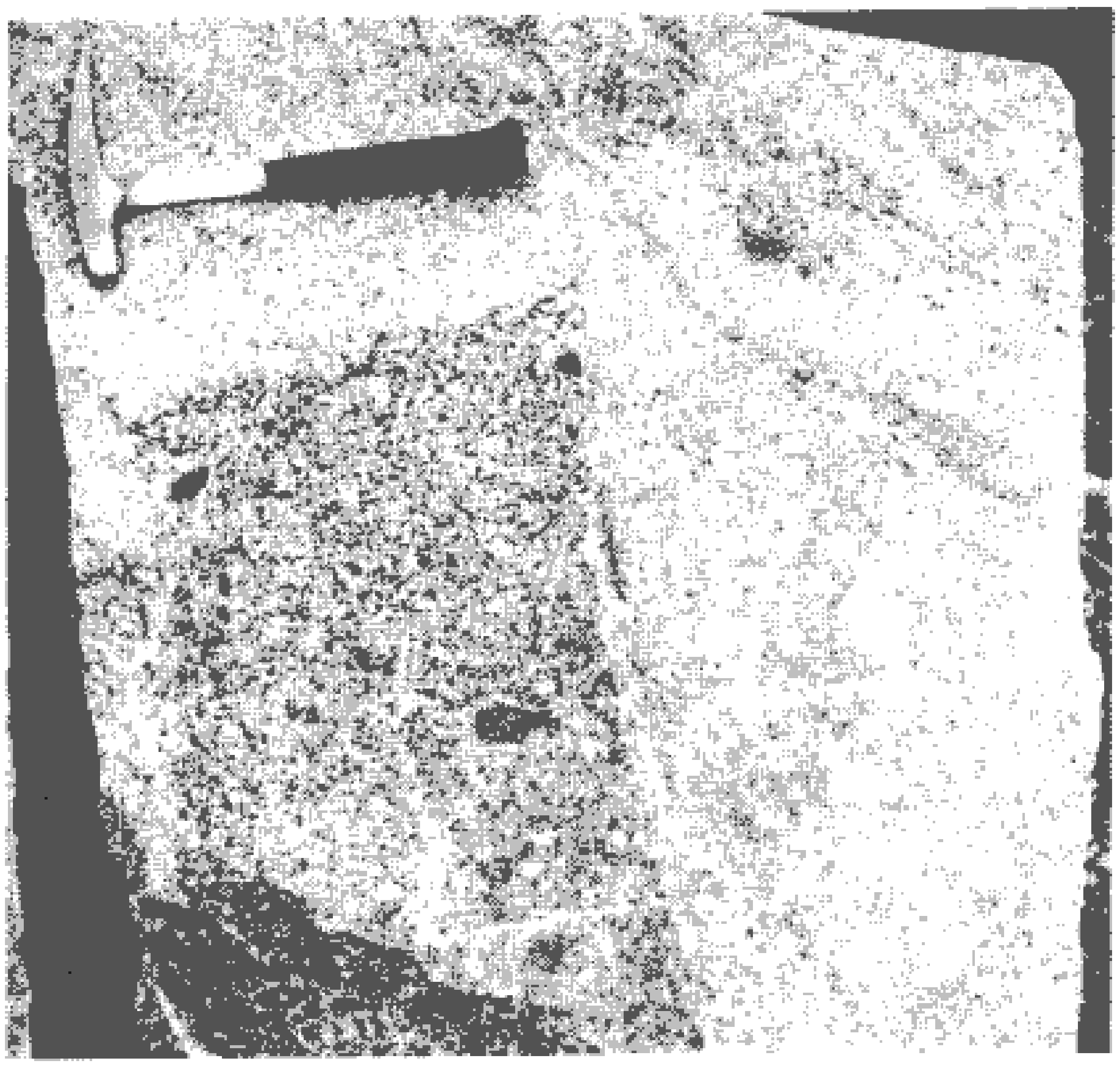
Příl. II
1. Xenolit sázavského granodioritu s drobnými mafickými enklávami, uzavřený v biotitickém granodioritu požárského typu. Požárské lomy nad zast. Prosečnice, 30 km jjv. od Prahy.
2. Xenolity blatenského granodioritu (světlejší bloky) v melagranitu typu Čertovo břemeno s velkými mafickými enklávami příbuzného složení. Skalní výchoz na břehu orlické přehrady, 1 km zjz. od Zvíkovského Podhradí.

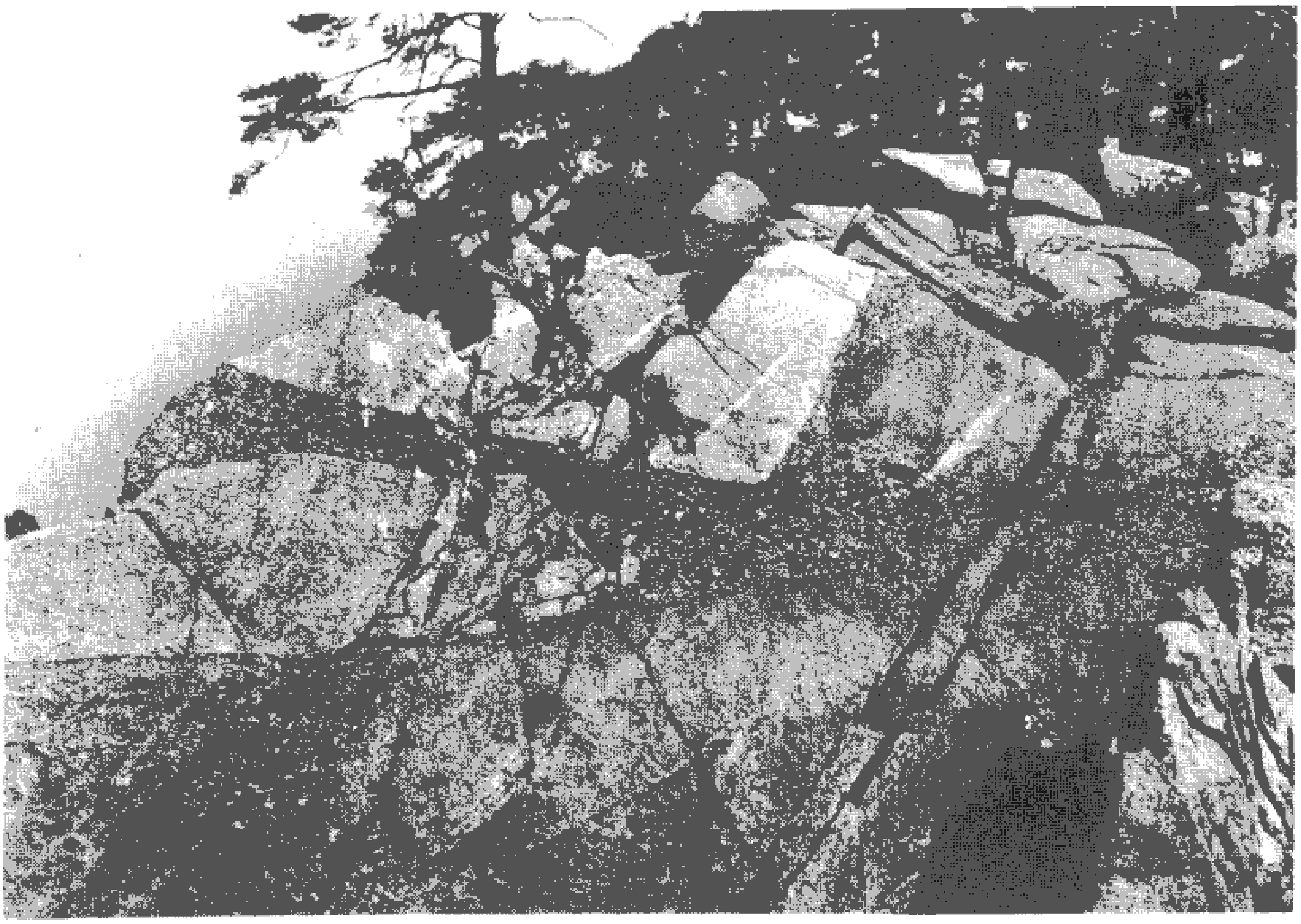
Příl. III
1. Vícenásobné intruze do blatenského granodioritu, Zvíkov, 15 km s. od Písku.
2. Žíly minet v blatenském granodioritu. Lom Kožlí u Čížové, 11 km sz. od Písku.

Příl. IV
1. Výrazné proudovité uspořádání zploštělých mafických enkláv v sázavském tonalitu. Lom Teletín, 35 km j. od Prahy.
2. Plastické tvary mafických enkláv, svědčící o deformaci během magmatického toku. Lom Teletín.

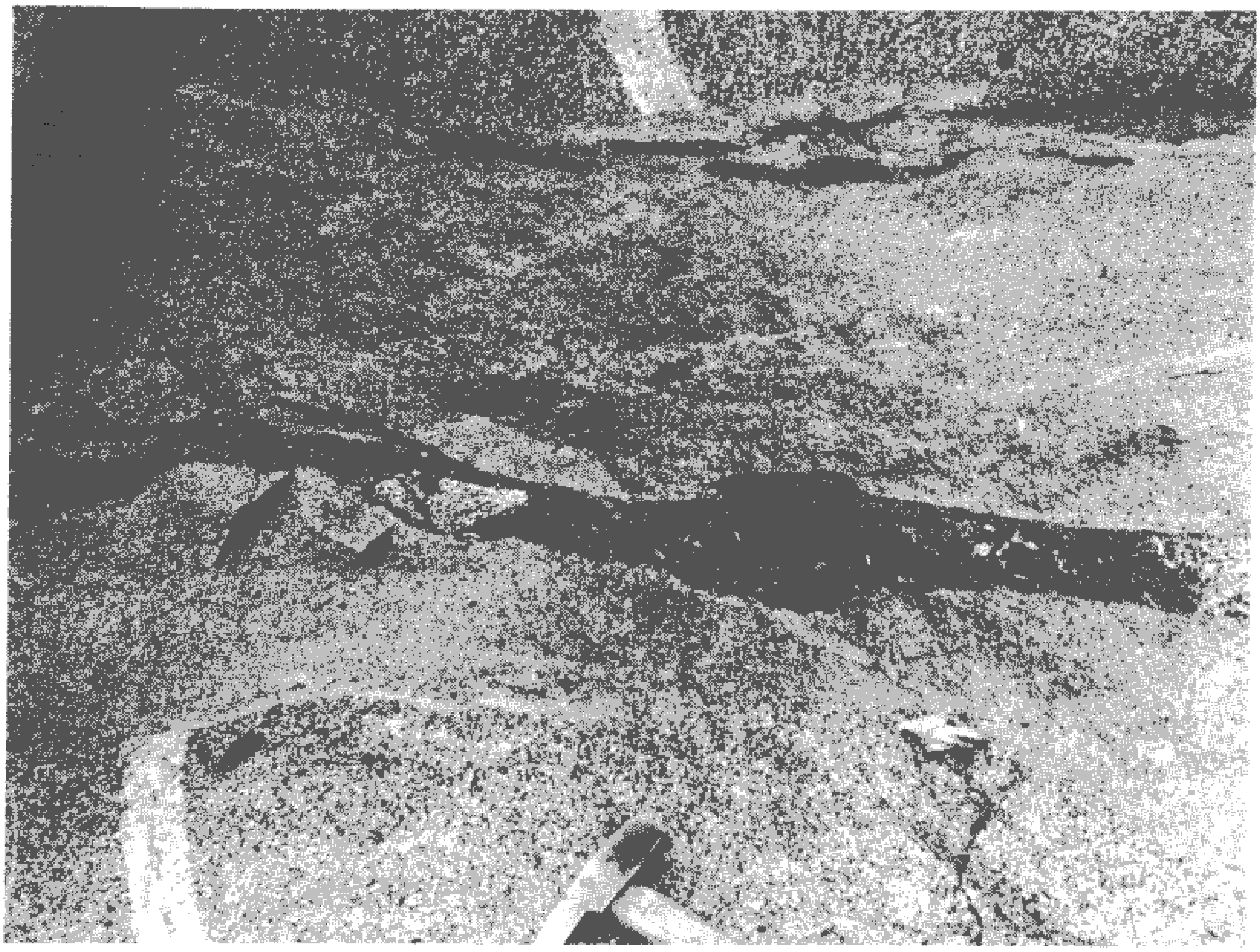
Foto F. V. Holub

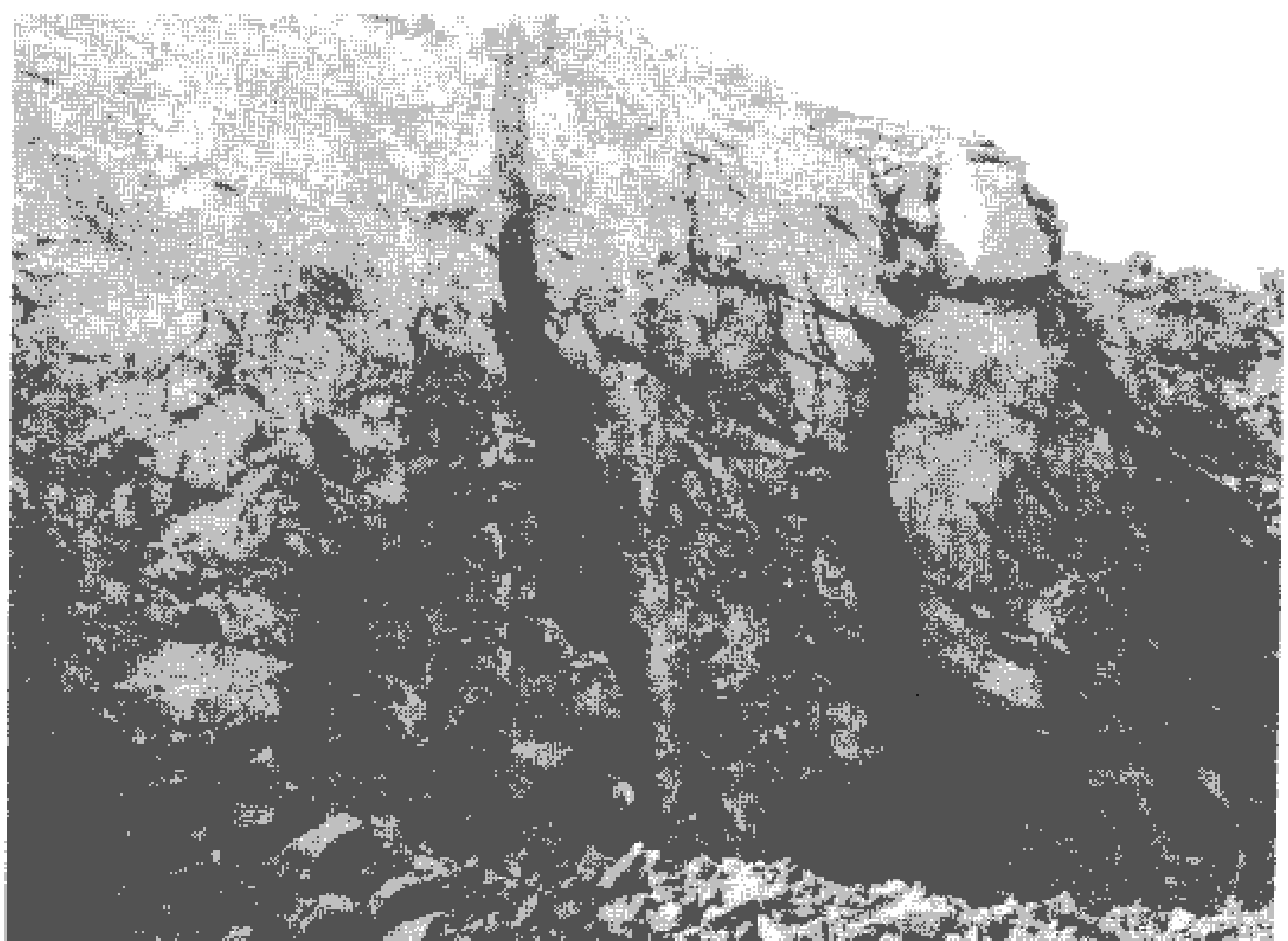
1. Xenolith of biotite hornfels (metamorphosed siltstone of the Upper Proterozoic complex) in the "marginal" granite. Borehole near Novotníky, W of Nepomuk.
2. Xenoliths of various metamorphic rocks (gneisses, migmatites, etc.) in biotite granite of the Zbonín type, 0.5 km NW of Zvíkov Castle, N of Písek.



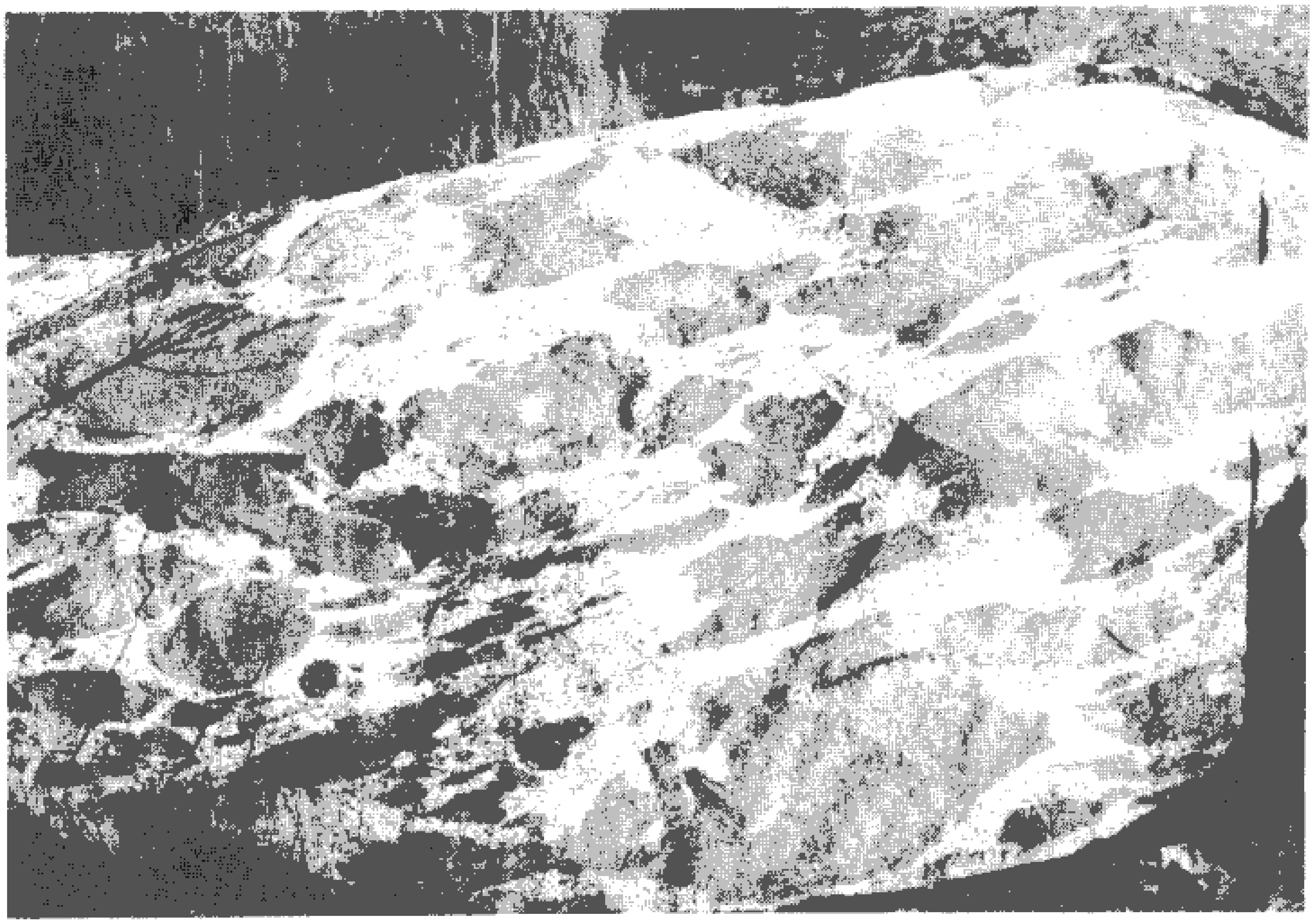


1. Xenolith of the Sázava granodiorite containing small mafic enclaves, enclosed within the biotite granodiorite of the Požáry type. Quarry Požáry near Prosečnice, 30 km SSE of Prague.
2. Xenoliths of the Blatná granodiorite (the lighter blocks) enclosed within melagranite of the Čertovo břemeno type which contains also large microgranular enclaves (dark). Outcrop 1 km SW of Zvíkovské Podhradí, 13 km N of Písek.





1. Multiple small intrusions into the Blatná granodiorite, Zvíkov.
2. Minette dykes intruding the Blatná granodiorite. Quarry Kožlí near Čížová, 11 km NW of Písek.



1. Strong alignment of elongated mafic enclaves in the Sázava tonalite, quarry Teletín, 35 km S of Prague.
2. Deformation of mafic enclaves in the Sázava tonalite during magmatic flow, quarry Teletín, 35 km S of Prague.