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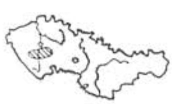
MARIE PALIVCOVÁ*

MICROTEXTURES OF GABBROIC AND DIORITIC ROCKS ASSOCIATED WITH INTRUSIVE GRANITOID COMPLEXES

Figs. 19



Abstract: The method of microtextural study was applied to correlate the rocks of satellitic basic bodies associated with intrusive granitoid massifs. An extreme diversity of microtextural rock types on the one hand and a remarkable constancy of the textural diversity on the other hand are exemplified on hornblende gabbros and diorites, especially at the contact with granitoids, in massifs of various regions and different geological ages. The petrogenetic significance of these analogies is discussed.

Резюме: Петрографический микроструктурный анализ был использован в ходе корреляции малых основных тел, которые ассоцируют с сложными интрузивными гранитоидными комплексами. Речь идет о породах, которые соединяются в так называемую габбро-диорит-гранодиоритовую формацию в русской литературе. На примере роговообманковых габбро и диоритов этих тел показана чрезвычайная разнородность микроструктурных типов с одной стороны, однако постоянство их повторяющейся микроструктурной ассоциации с другой стороны, в массивах различных областей и различного геологического возраста. Дискутируется значение этих микроструктурных подобностей для петрогенезиса.

Introduction

Significance of satellitic basic bodies for the development of granitoid complexes

The basic rocks studied belong to the group of small basic bodies called minor intrusions, minor bodies, bossies or satellites. They are associated with complex large intrusive granitoid massifs of the calc-alkaline series. Above all, the rocks have been studied using the example of the Central Bohemian Pluton and then correllated with material from similar occurrences of different regions of the Earth's crust. The whole rock series from basic to acid members, the so called gabbro-diorite-granodiorite formation in the sense of Soviet geologists (J. A. Kuznecov, 1964) is typically developed in these intrusive complexes. The presence of tonalites and closely associated dioritic rocks and xenoliths („tonalitic association" — M. Palivcová, 1972) is a marked feature of the same. The granitoid massifs of this type are located on the deep faults of orogenic belts („inter-block massifs"), commonly at the contact of units markedly different in geological structure and composition. Some authors regard them as typical for intramontane blocks of the Earth's crust. Recently a close relationship to the subduction zones has been emphasized as many of the coast „batholiths" of Northern and Southern America (e. g. Southern Californian massif — E. S. Larsen, Jr., 1948, Peruvian massif — E. J. Cobbing — W. S. Pitcher, 1972) are examples of this type of massifs.

* RNDr. M. Palivcová, CSc., Institute of Geology and Geotechnics of the Czechoslovak Academy of Sciences V Holešovičkách 41, 182 09 Praha 8 — Libeň.

A high number of basic petrological references is connected with the examination and study of these massifs. Their origin has not been solved univocally in spite of many analogies and similarities. Fundamental petrogenetic hypotheses have been deduced from their study, from that of magmatic fractionation, hybridization, assimilation, to the theory of granitization joined with basification. Especially the origin of basic and intermediate members and their relation to granitoids are highly controversial and lead to contradictory interpretations. Basic rocks formerly generally held for syngenetic with granitoids, are considered by some authors to be autonomous, independent bodies (G. D. Dobrecov — T. G. Dobrecova, 1972) in spite of close spatial association. The opinion about the temporal interval between the origin of basic rocks and that of granitoids is very different. The basic rocks of satellite bodies are mostly considered to predate the granitic rocks. However, there exist some contradictional relationships (for instance intricate geological relations, crystallization development of both rock groups, etc.) that evoke reevaluation. Hypotheses about contemporaneous intrusion of basic and acid magma (T. Vogel — B. M. Walker, 1975) or about remobilization of granitic parent material by intrusion of basic magma arise. Other authors are protagonists of the origin by recrystallization or remobilization of the older basic wall-rocks. Hence the basic rocks are thought to stimulate the origin of granitic magma in the Earth's crust on the one hand and to be products of basification complementary to granitization on the other hand. The interpretation of intermediate dioritic and quartz dioritic members is extremely controversial. The diorite problem is so complicated that even the most classic and detailed works about the petrology of igneous rocks do not mention the term diorite in the index at all (compare F. J. Turner — J. Verhoogen, 1960).

In spite of these discrepancies, curious and striking analogies in the development of small basic bodies associated with granitic complexes have been reported. These analogies have been summarized for the first time and most completely by G. A. Joplin 1959. The said author emphasized the analogy with petrographically and texturally varied series called „appinitic suite" (according to Appin Mts., Argyll, Scotland) by British geologists. This series is characterized by the occurrence of typical hornblende gabbros and diorites ranging to ultrabasic as well as tonalitic and granodioritic members; subordinate amount of mica-pyroxene dioritic series is usually also present. This series has been described from a number of localities of Caledonian Irish and Scottish massifs, many of them becoming classical in the petrological literature (see e. g. W. J. French, 1966, W. A. Deer, 1950; W. S. Pitcher — H. H. Read, 1952; S. R. Nockolds, 1941, newly W. S. Pitcher — A. R. Berger, 1972). Some recent papers record the presence of appinitic suite in various other parts of the Earth's crust (E. J. Cobbing — W. S. Pitcher, 1972; A. Boriani et al., 1975; M. Palivcová et al. 1975; J. Ulrych et al., 1976). On the contrary D. R. Bowes and A. C. McArthur, 1976 disagree with the wide application of the term „appinitic suite"; they emphasize the petrogenetic and geological differences of appinites from basic rocks in the granitoid complexes and recommend to preserve the term for the rocks of the original locality.

Under these circumstances the correlation of the rocks of small basic bodies in different granitoid complexes becomes significant. However, in consequence of a high variability of the rocks, it is very difficult to find and realize a suitable method of correlation. Intimate transitions and rapid changes of rock features (compare G. A. Joplin c. l.) make the mapping of different types only hardly possible. For the same reasons the geochemical criteria should be used very cautiously as they are unreliable without detailed knowledge of geology and petrography. It is evident that the crystallization of gabbroic and dioritic rocks has been influenced by a number of factors among which dominantly that of recrystallization during postmagmatic processes — by autometasomatic solutions or introduced from granitoids — was the most effective. However, by recrystallization the primary stages of rock development have commonly been obliterated.

The present account represents an attempt to make use of the detailed microtextural study of the rocks for their correlations in different massifs. Such an access was particularly stimulated by the considerations about the significance of microtextures of metamorphic rocks in the introduction of the A. Spry's work (1962); the same comments are meant to be valid for igneous rocks, too. The microtextural research of basic and intermediate rocks has been long omitted if compared for instance with ultrabasic, granitic and other groups of crystalline rocks (L. R. Wager and G. N. Brown, 1967; F. K. Drescher—Kaden, 1948, 1969; S. S. Augusthitis, 1973, 1978). (The latest worky by Augusthitis (1979) was not available to the author).

Geological position of basic rocks in the massifs studied and their main petrographical characteristics

The study of basic rocks of Central Bohemian pluton in the Czech massif performed during many years was the basis for microtextural correlation. The material for correlation was mostly collected by the author herself, partly it was gained by way of exchange or as presents. The material from the following different massifs was available: Adamello Massif, Northern Italy (Mte Mattoni, Mte Cadino, Mte Frerone), massif Jelšica — Bošulja from Bulgarian Srednegorie (Vetren region), Appin region, Scotland (massif Ballachulish, Strontian), Sierra di Escambray, Cuba (Manicaragua region), French Vosges (loc. Denipaire, Hurbache). Microtextural analogies could be partly further verified on the material from Chile (Valparaiso), Pyrenean French massifs (Mt. Louis, Guérigut) and also on the original slides of Wells and Wooldridge from New Jersey (Channel Island, Ronez loc.).

In most of the granitoid massifs studied the basic rocks occur in the endocontact or close exocontact, in the Appin area also in broader exocontact. In the Central Bohemian Pluton the basic rocks are exposed as an almost continuous belt of small bodies along the contact of granitoids and Upper Proterozoic to Lower Palaeozoic volcano-sedimentary wall-rocks, or they are located at the boundaries between some intrusive types of granitoids (see e. g. M. Palivcová, 1978, fig. 1). Quite continuous zone parallel with a zone of Devonian metabasites was mapped by J. P. Eller, 1964 in Variscan Northern Vosges. In the Variscan Pyrenean massifs mentioned, basic rocks are situated mostly in the endocontact. In the Periadriatic Neoid Adamello massif the basic bodies studied are exposed at the contact of granitoids with Mesozoic calcareous rocks (see the map of Padovian school in E. Raguin, 1970, p. 60). In the complex of Bulgarian Srednegorie they are located on deep zones at the contact of granitoids with epi- to mesometamorphites (S. Boyadzhiyev et al., 1979); they are of Laramide age. The Cuban and Chilian occurrences are also of Mesozoic age. In the Appin region the „appinitic suite" is associated with Caledonian granitoids; similarly as in the Irish Ardara pluton, the bodies are in the periphery of the intrusive granitoid massif and some of them have the character of explosion breccia pipes (for instance Back Settlement locality — see D. R. Bowes and A. C. McArthur c. l.).

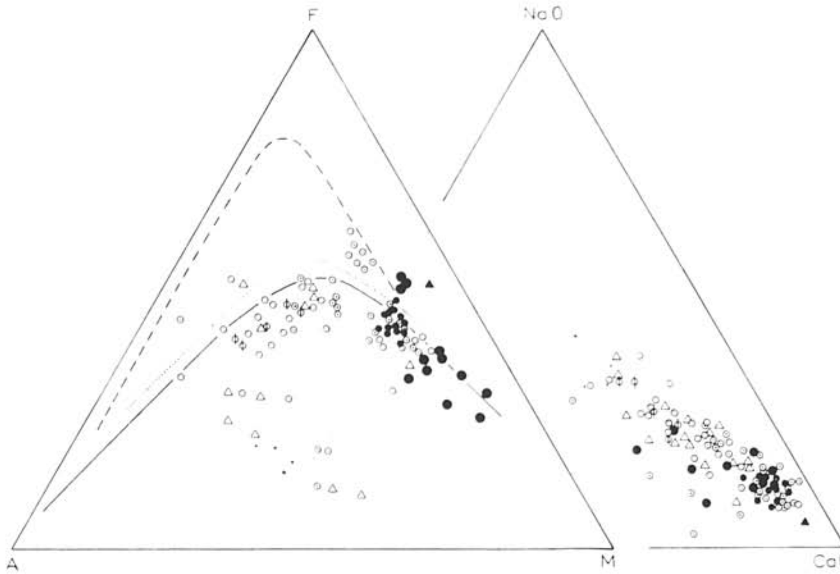


Fig. 1. AFM and K_2O — Na_2O — CaO chemistry of hornblende gabbros and diorites of Central Bohemian pluton; dashed — Skaergard trend, full line — the main trend in the Central Bohemian pluton after Z. Vejnar, 1973, dotted — Hawaiian alkaline trend. Explanations see fig. 2.

All features summarized by G. A. Joplin (c. l.) can be observed in the massifs under study. Varied and complicated massifs are involved which comprise „older" and „newer" granitoids, the former mostly of hornblende bearing granodiorite composition, the latter of more acid, often coarse-grained and porphyritic biotite granite composition. The size of minor basic bodies usually does not exceed 1—2 km in diameter, it can be of several hundred or ten meters only. The bodies are not uniform in shapes; sometimes they are elongated similar to sills, sometimes rounded stocks, in other cases they are of irregular forms. The minute bodies of granitoid endocontact cannot be easily distinguished from the blocks enclosed in granitoids. The bodies of larger size are sometimes more intensively differentiated than the small ones, the coarse-grained gabbroic types forming the central part and the finer-grained, mostly dioritic types the marginal parts of the body. The internal architecture of the bodies can be very irregular. The smaller bodies are often finer-grained and dioritic in composition. The fine-grained dark marginal zone of the same type as described by A. K. Wells and S. W. Wooldridge, 1931, p. 191 is another characteristic feature developed at the periphery of most bodies, blocks and basic xenoliths. A curious feature is the analogy of some lamprophyric dykes with the fine-grained marginal zones. Aplopegmatoid hornblende bearing accumulations and „pockets" in the centre or at the margins of the bodies occur. Rarely aplites and felsites appear in the bodies. Basic and particularly dioritic rocks were subjected to the influence of granitoid intrusions. Zones of basic intrusion breccia are typically developed, mostly at the endocontact of granitoids. Hornblende gabbros and diorites are the most common gabbroic types. They pass to gabbro-hornblendites and hornblendites, sometimes to olivine ultramafic rocks, or to pyroxenites. On the other hand there are transitions through dioritic and quartz dioritic rocks to allied granodiorites.

The hornblende gabbroic and dioritic types were selected for detailed microtextural study. In spite of this restriction it is not possible to demonstrate completely their high microtextural variability in one paper. Therefore, specific, most typical textural types have been subjected to examination, above all those the interpretation of which is highly controversial in literature. The aim of this account is to illustrate the remarkable analogies not only of different textural types, but also the surprising repeated similarity of the whole microtextural association.

The petrochemical characteristics

The petrochemistry of the rocks is shown in one region only, on the example of basic rocks of Central Bohemian pluton; here the chemical analyses could be related to the individual microtextural rock types. In fig. 1 the main petrochemical diagrams are given, in fig. 2 petrochemical relations are plotted which are considered as indicative of „appinitic series" (A. Hall, 1967). The field of MgO/Al_2O_3 contents of the gabbroic and dioritic rocks of the Central Bohemian pluton distinctly coincides with the field of original appinites. The difference in the CaO/Al_2O_3 trend is probably due to the more intensive postmagmatic alteration (manifested by the presence of calcite, epidote, albite) in the Scottish appinites.

Microtextural types of hornblende gabbros and diorites

From the textural types studied the type sub 1 and also some types sub 3 occur as individual types of larger bodies. For instance the basic body Mte Mattoni in Adamello massif or the Pecerady gabbroic body of the Central Bohemian pluton consist by far the greater portion of hornblendephyric gabbroic rocks, the Mte Cadino body similarly as Velké Popovice in the Central Bohemian pluton consist of the types sub 3. In basic bodies of the Central Bohemian pluton two main schematized textural groups of basic rocks have been described in the literature, i. e. „porphyritic" (= hornblendephyric in this paper) and „equigranular" (J. Kratochvíl and A. Orlov, 1930;

K. Beneš et al., 1980). The other types described in this paper are irregularly distributed in small bodies, or in xenoliths, often as fine-grained marginal facies of larger bodies. They also appear in problematic dyke-like elongated bodies close to hornblende lamprophyres in composition, the distinction of which between dykes and xenoliths is very uneasy. Almost among all textural types described below gradational boundaries can be found; the rocks pass one into the other. They all can be present in the same body as exemplified in the Pecerady gabbroic body of the Czech massif (M. Palivcová et al., 1975). The petrographic composition varies from hornblende-pyroxene and hornblende gabbros to hornblende diorites. Hornblende-bearing gabbroic and specially dioritic members contain unevenly and irregularly distributed amount of felsic minerals, quartz, potash feldspar, sometimes micropegmatite and/or albite, which causes their petrographic variability. The content of these felsic minerals varies in the different as well as in the same textural types. Thus the quartz gabbroic, quartz dioritic as well as monzogabbroic, monzodioritic rocks of different textures appear in places. The major constituents are common brown-green to green hornblende and basic to intermediate plagioclase; the hornblende is patchy and the plagioclase has a complex twinning and zoning. In the more basic types usually fine-grained pyroxene (salite, diopside) is present, rarely orthopyroxene or olivine in ultramafic rocks. Accessories include apatite, sphene, rarely magnetite, pyrite, arsenopyrite; from other minerals almost always „primary" epidote and often „primary" calcite and some chlorite are present.

The similarity of textural types from different regions described below is shown in figs. 3—13 with the morphology and distribution of hornblende; three examples always are compared. It should be mentioned again that only restricted number of examples could be presented for illustration and that each textural type can always be completed from other regions, too. The natural texture of rock is manifested in some microphotographs (fig. 14—19). All figures and photos are taken from the slides of the rock collection now deposited in the Institute of geology and geotechnics of the Czechoslovak Academy of Sciences in Prague. The number of thin sections examined are indicated in parentheses under each picture.

1. *Hornblendephyric textural* type (fig. 3, 14) is distinguished by the presence of conspicuous porphyritic equant and mostly euhedral stubby hornblende (0.5 mm — 1 cm in size) in fine-grained greyish green or whitish matrix. The general appearence of the rocks is coarse-grained. The green hornblende in the gabbroic rocks of the Central Bohemian pluton is magnesio-hornblende passing to ferrohornblende after Leake's classification — e. g. J. Ulrych, 1975; Z. Vejnar, 1975). The hornblende contains brownish tchermakitic cores and patches and lighter rims and patches of actinolitic green hornblende to tremolite. Minute pyroxene and basic plagioclase grains of the groundmass are embedded in the hornblende. Skeletal opaque formations of Ti and Fe oxides (schillerizing after A. K. Wells and A. C. Bishop, 1955) are an outstanding feature of mottled amphiboles in most of the occurrences of this textural type. (Fig. 14a). Rhytmic zoning of hornblende can develop against some felsic minerals (quartz, K-feldspar) and best against interstitial calcite; in the latter case rhytmic overgrowth by actinolite to tremolite analogous to that described by D. R. Bowes et al., 1964 in appi-

nites or J. Ulrych c. l. in kaersutite — melagabbro is remarkable. The groundmass of this textural type is of two kinds: with or without pyroxene (salite) grains in addition to small plagioclase and hornblende crystals. Some subporphyritic to porphyritic plagioclases — strikingly patchy in places —

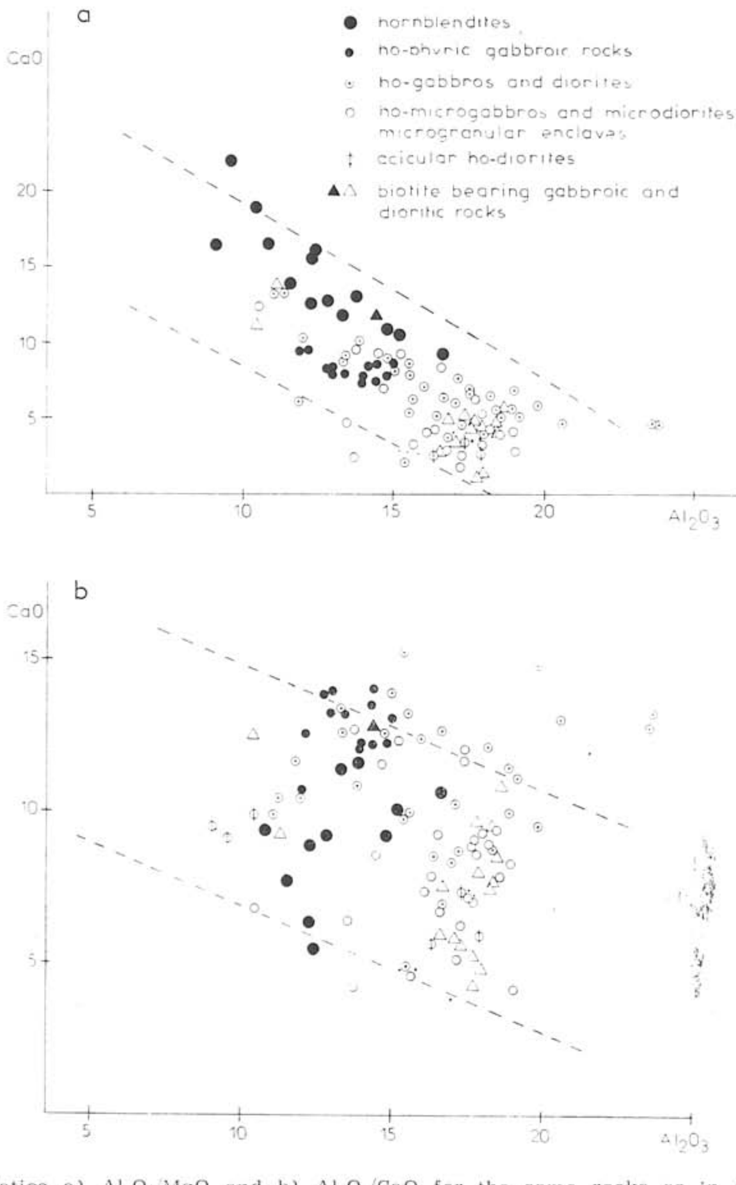


Fig. 2. Ratios a) Al_2O_3/MgO and b) Al_2O_3/CaO for the same rocks as in fig. 1. The field of chemistry of the original appinites according to W. S. Pitcher and A. R. Berger, 1972 is plotted witr a dashed line. On fig. 2a up should by MgO instead CaO.

can appear [see Boyadzhiyev S. et al., 1979, fig. 5; M. Lang, 1975, fig. Pl.1].

By accumulation of these large plagioclases the rock changes into coarse--grained plagioclase-hornblende gabbro or hornblende diorite. Usually some amount of quartz, potash feldspar or albite is present. The hornblende can gain strong idiomorphism in such a case and loses its inhomogenities. By larger accumulation of late felsic minerals pegmatoid pockets develop. On the contrary, accumulation of hornblende crystals and reduced amount of the

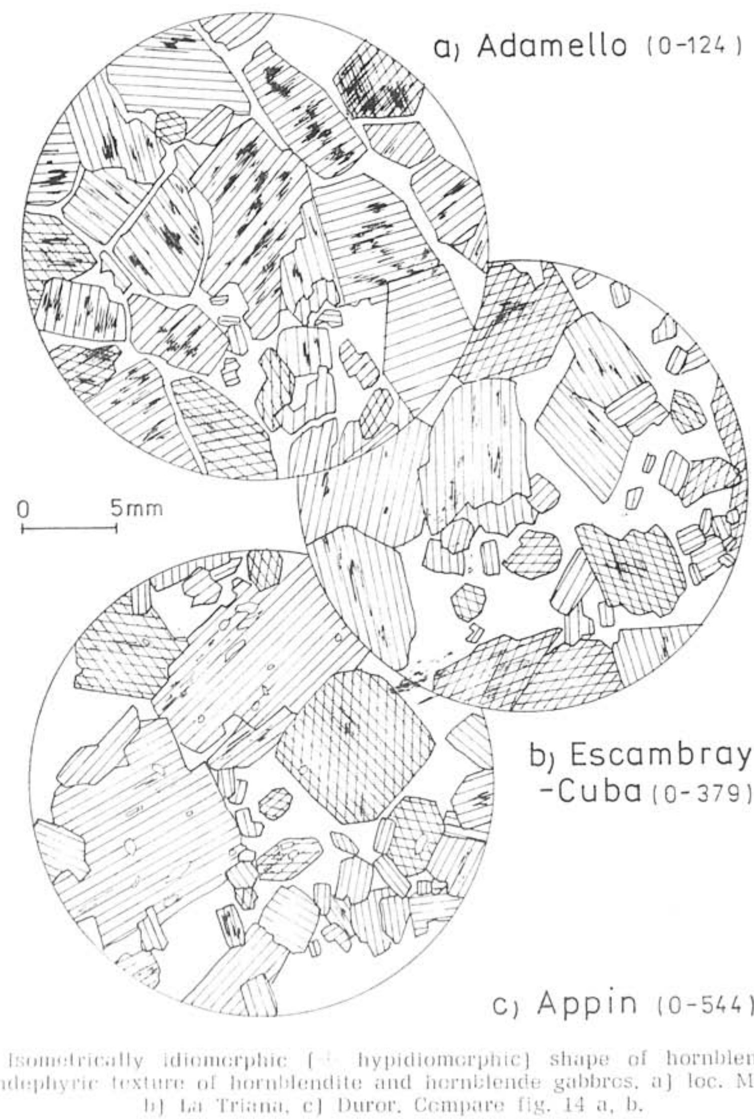


Fig. 3. Isometrically idiomorphic [± hypidiomorphic] shape of hornblende in the hornblendephyric texture of hornblendite and hornblende gabbros. a] loc. Mte Mattoni, b] La Triana, c] Duror. Compare fig. 14 a, b.

matrix lead to gabbrohornblendites and hornblendites. Gradual transitions to prismatically porphyritic and prismatic (quartz-) gabbros and diorites (Fig. 15 c, d) and further to subvariolitic ones and to many other facies of microdioritic and microgabbroic rocks as well as to poikilitic (Fig. 4) types can be seen.

Pecerady gabbro from the Central Bohemian pluton, gabbro Mte Mattoni from Adamello massif, gabbro Gradišče (Vetren) from Bulgaria, gabbros from Escambray can be reported as typical examples of this textural facies. Simi-

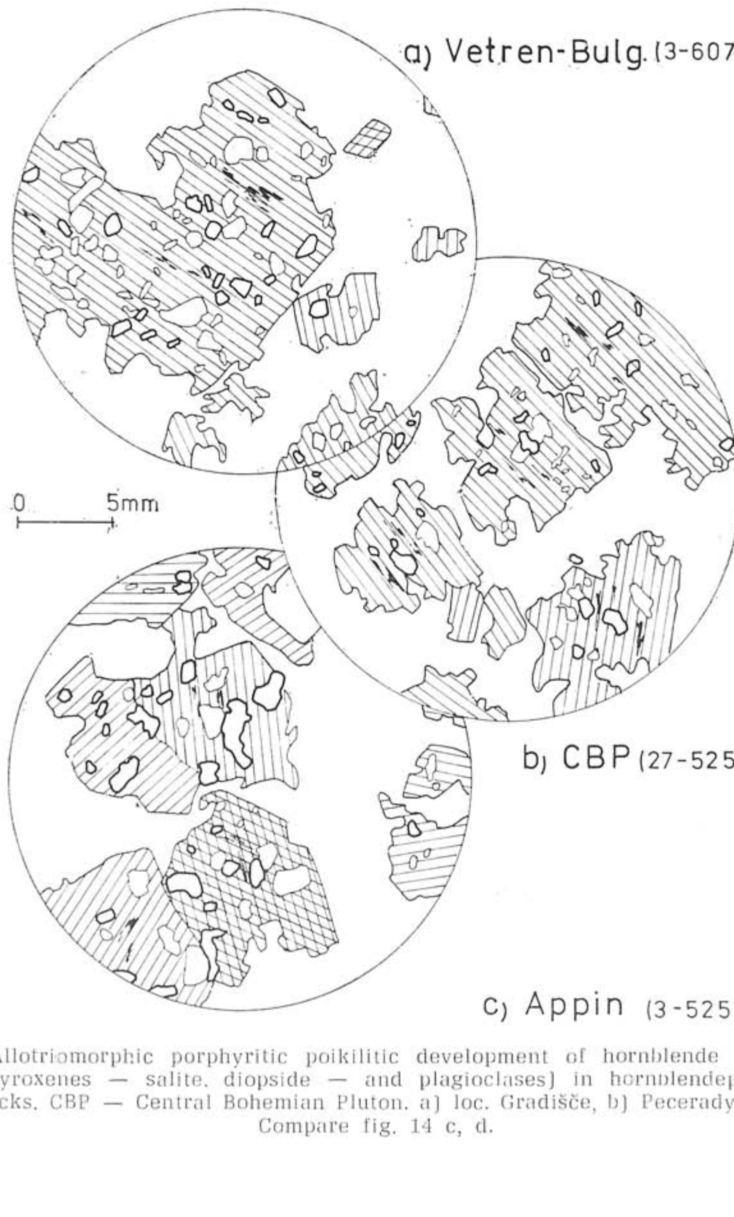


Fig. 4. Allotriomorphic porphyritic poikilitic development of hornblende (inclusions of clinopyroxenes — salite, diopside — and plagioclases) in hornblendephyric gabbronic rocks. CBP — Central Bohemian Pluton. a) loc. Gradišče, b) Pecerady, c) Duror. Compare fig. 14 c, d.

lar hornblendephyric types occur at Ronez in Jersey as could be verified on original slides from the material of A. K. Wells and S. W. Wooldridge in the British Museum. Hornblendites belonging to this textural type can be reported from the Central Bohemian pluton (Milín area), Mte Mattoni, Manicaragua etc. Hornblende pyroxenite described by A. Hietanen, 1963 (p. 12D) from Idaho batholith is evidently allied with this gabbroic rock series. Hornblendephyric gabbros were found at Appin (loc. Duror, Back Settlement), here especially with all transitions to prismatic textural types. Surprisingly enough the hornblende of these original appinites may be almost fresh and homogeneous in spite of a strong alteration of the matrix (with epidote, al-

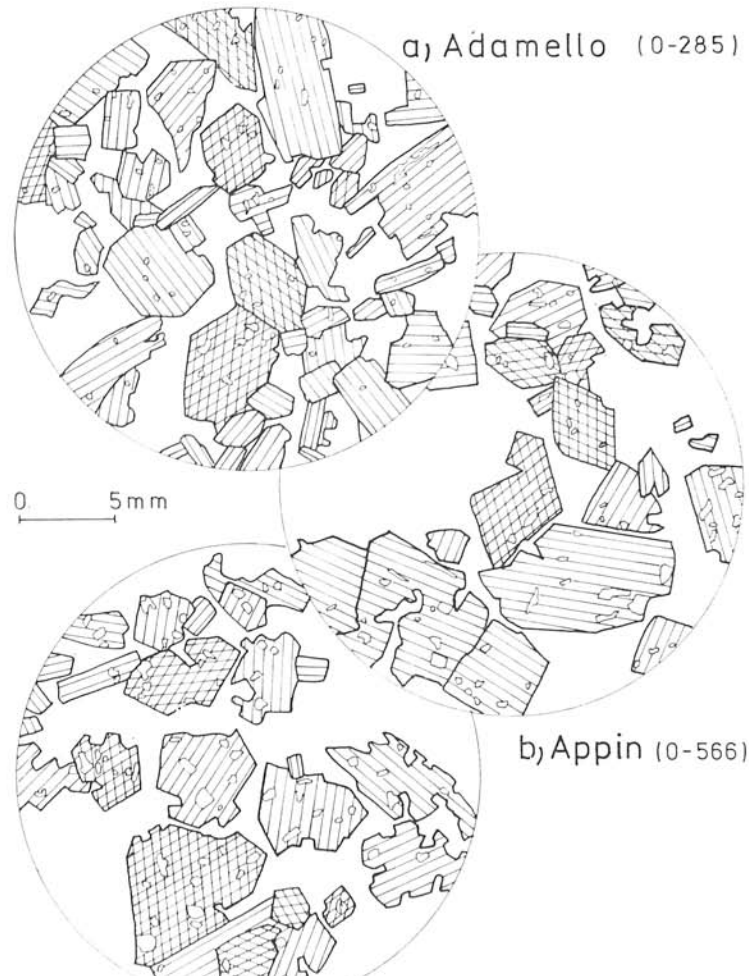


Fig. 5. Isometrically idiomorphic hornblende in plagioclase-hornblende gabbros and diorites. a) Lago di Bissina, b) Back Settlement, c) Pecerady. Compare fig. 15 a, b.

bite, calcite, chlorite, etc.). Appinite intrusion breccia described by W. S. Pitcher and H. H. Read, 1952, as well as the „appinite" in W. A. Deer, 1950 belong to similar textural facies.

The porphyritic hornblendes of this rock type (as well as the rocks themselves) have been interpreted highly controversially in the literature: as primary hornblendes subsequent to and replacing older mafites (pyroxenes or older brown amphiboles), or as porphyroblasts (megablasts) growing metasomatically in solid rocks.

2. *Poikilitic hornblendephyric textural type* (figs. 4, 7; 14c, d, 16a, b) clearly represents a textural facies of the preceeding type, rich in poikilitic horn-

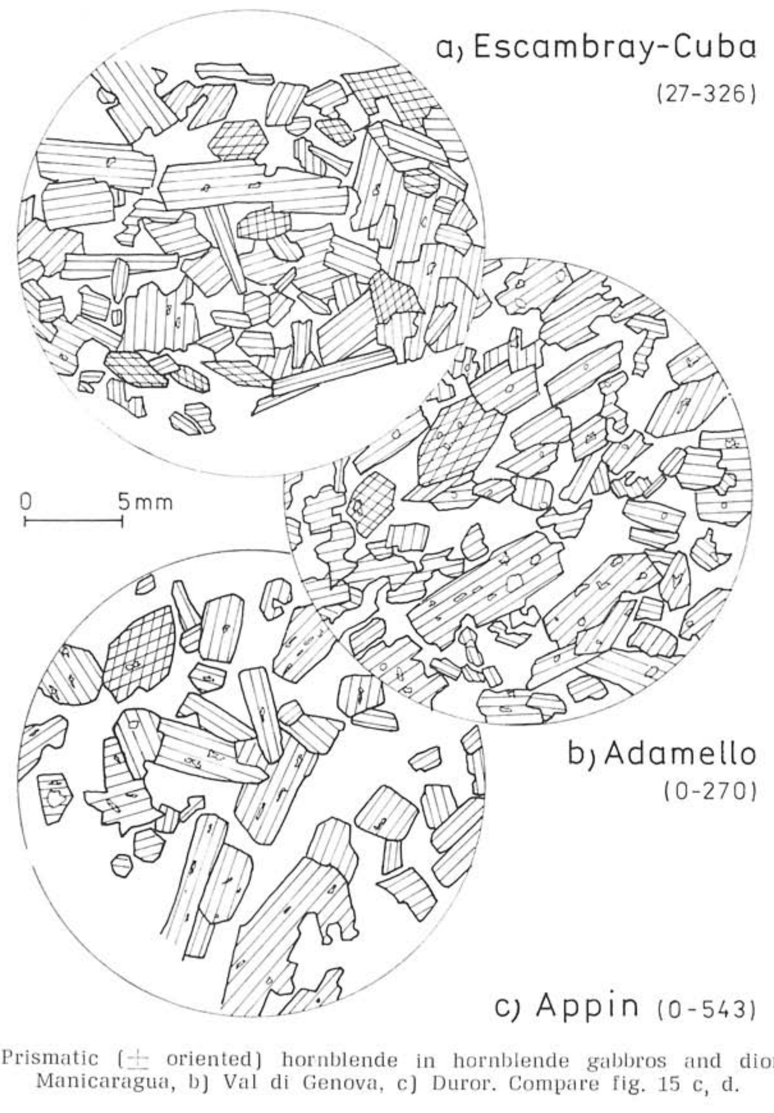


Fig. 6. Prismatic (⊥ oriented) hornblende in hornblende gabbros and diorites. a) Manicaragua, b) Val di Genova, c) Duror. Compare fig. 15 c, d.

blende. The guest minerals are minute basic plagioclase and salite grains. Hornblendes are of typical irregular, embayed shapes. Poikilitic hornblende overcrowded with tiny plagioclases are of sieve-like appearance. Such hornblendes lose their continuity in some places and thus transitions to microgabbroic or microdioritic rocks exist [fig. 7]. The rocks are called „ophimottled" gabbros, spotted gabbros, diorites lustrées, tachetées, Fleckendiorite, etc. The direction of the textural development is quite controversial. The desintegration of primary hornblende or porphyroblastic growth of hornblende megacrysts have been assumed for this case.

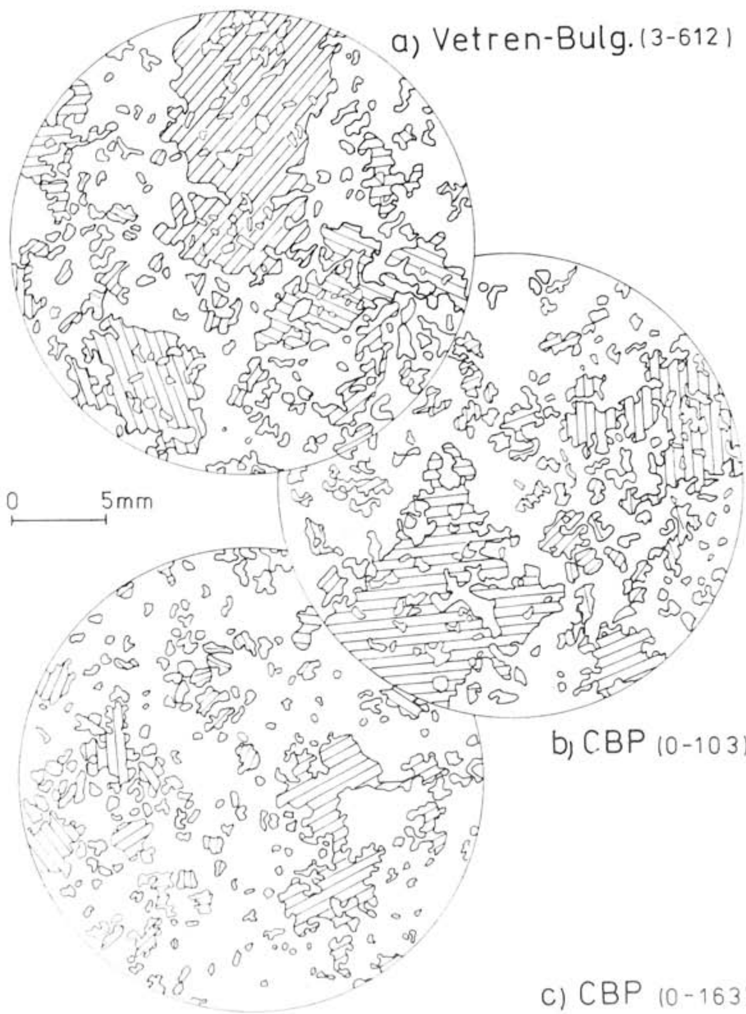


Fig. 7. Highly poikilitic (sieved) hornblende in spotted hornblende gabbros and diorites. Fig. c): transition to fine-grained dioritic rocks. a) Gradišče, b), c) Draha near Milín. Compare fig. 16 a, b.

Typical examples of poikilitic (poikiloblastic?) hornblendephyric gabbroic and dioritic rocks are for instance from the Milín area as well as the Benešov area in the Central Bohemian pluton; they seem to concentrate here rather at the endocontact of the bodies. In Bulgarian Vetren gabbro characteristic examples (S. Boyadzhiyev et al., c. 1., fig. 1,2) occur in the centre of the body.

3. *Microgranular hornblende gabbroic and dioritic rocks* (figs. 13, 19a-c). The term is used in the sense of J. Didier, 1973 who applied it to the most frequent textural type of basic xenoliths in granitoids. The equigranular,

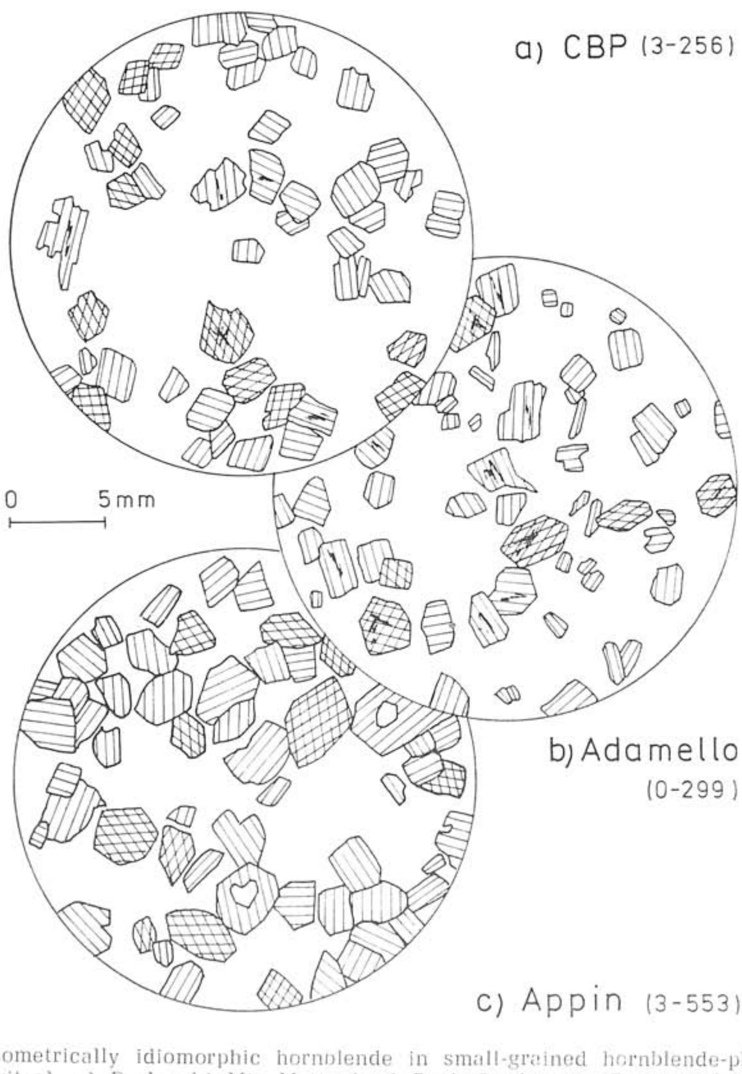


Fig. 8. Isometrically idiomorphic hornblende in small-grained hornblende-phyric gabbros (diorites). a) Draha, b) Mte Mattoni. c) Back Settlement. Compare figs. 16 c, d.

usually hypidiomorphic granular textural facies are involved consisting of small grains (about 1 mm) of strongly zonal plagioclase and common hornblende. Sometimes salite is present. The idiomorphism of plagioclase and that of hornblende alternates, the rapid change in the morphology of hornblendes is striking. Types with highly idiomorphic to highly allotriomorphic hornblende grains, with individual crystals as well as their accumulations occur. Thus many textural facies originate. In addition, the colour index varies rapidly due to an uneven amount of late felsic minerals. Some microgranular types contain a certain amount of biotite and pass into biotite hornblende

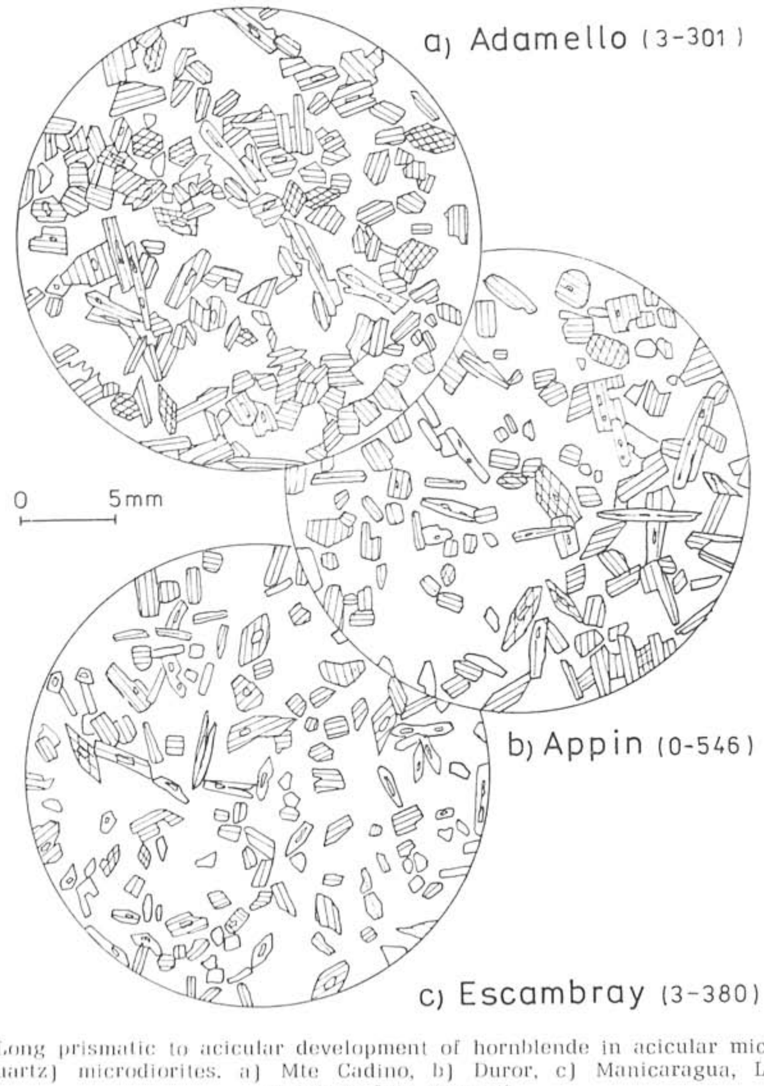


Fig. 9. Long prismatic to acicular development of hornblende in acicular microgabbros and (quartz) microdiorites. a) Mte Cadino, b) Duror, c) Manicaragua, La Triana. Compare figs. 18 a—d.

quartz diorites which in turn can be associated with pyroxene mica diorites. There are common transitions into fine-prismatic types, subvariolitic and acicular types and patchy poikilitic types.

The microgranular textural types of gabbroic and dioritic rocks are characteristic facies of marginal zones of all larger bodies under study, of basic xenoliths, and of small occurrences, but they can also be the prevailing types in some larger bodies, as said above.

4. *Acicular (needle-like) textural types* (figs. 9, 10, 12, 18, 17c, d, 19d) represent an extreme case of prismatically grained and microgranular textural

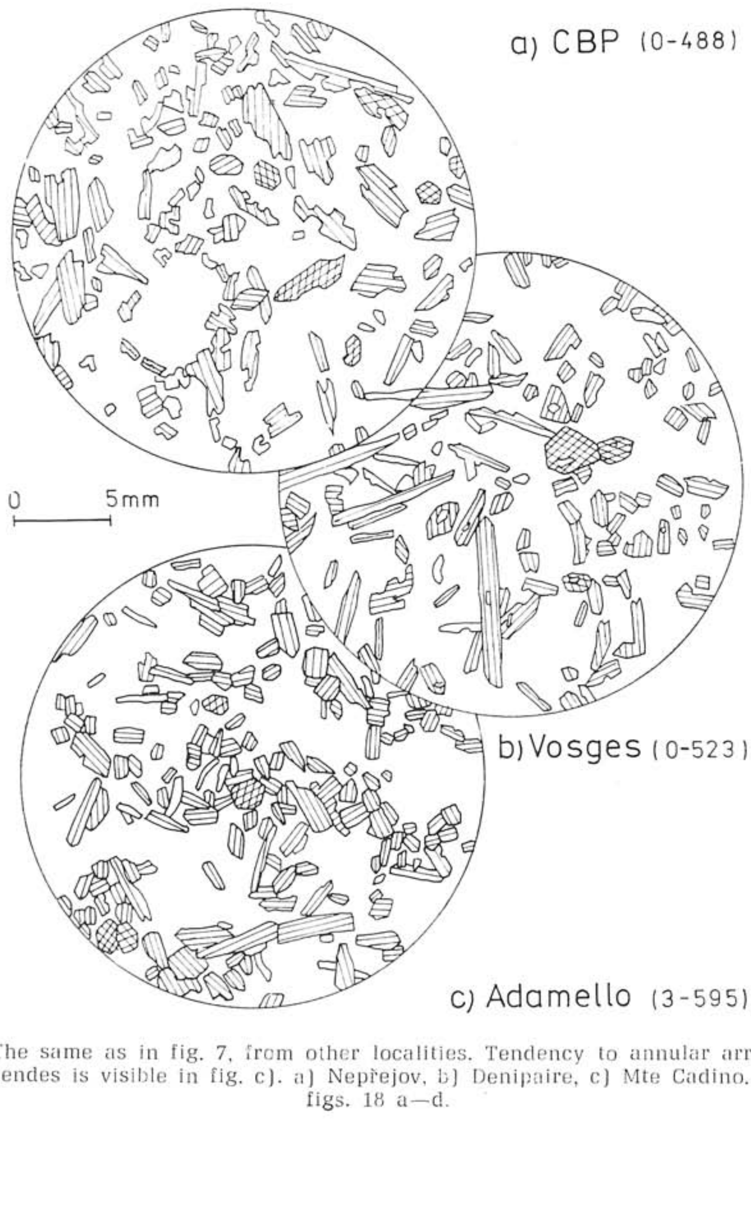


Fig. 10. The same as in fig. 7, from other localities. Tendency to annular arrangement of hornblendes is visible in fig. c). a) Nepřejov, b) Denipaire, c) Mte Cadino. Compare figs. 18 a—d.

types. By grain diminution they can pass into extremely fine-grained acicular facies of marginal zones on the one hand, by prismatic growth into pegmatoid long prismatic „pockets" on the other hand. The mineral composition is the same as in the preceeding group. Individual facies differ in the shapes and the development of acicular hornblende and in the highly variable proportion of felsic minerals. „Cored" and „open prisms" of acicular hornblendes as shown by A. K. Wells and A. C. Bishop, 1955 are a characteristic feature of most of them. The cores are of felsic or secondary (biotite, chlorite) minerals. The latter seem to be alteration products of brown hornblende centers. „Tubular", „hollow", case-like („futraloobraznye") are other terms for

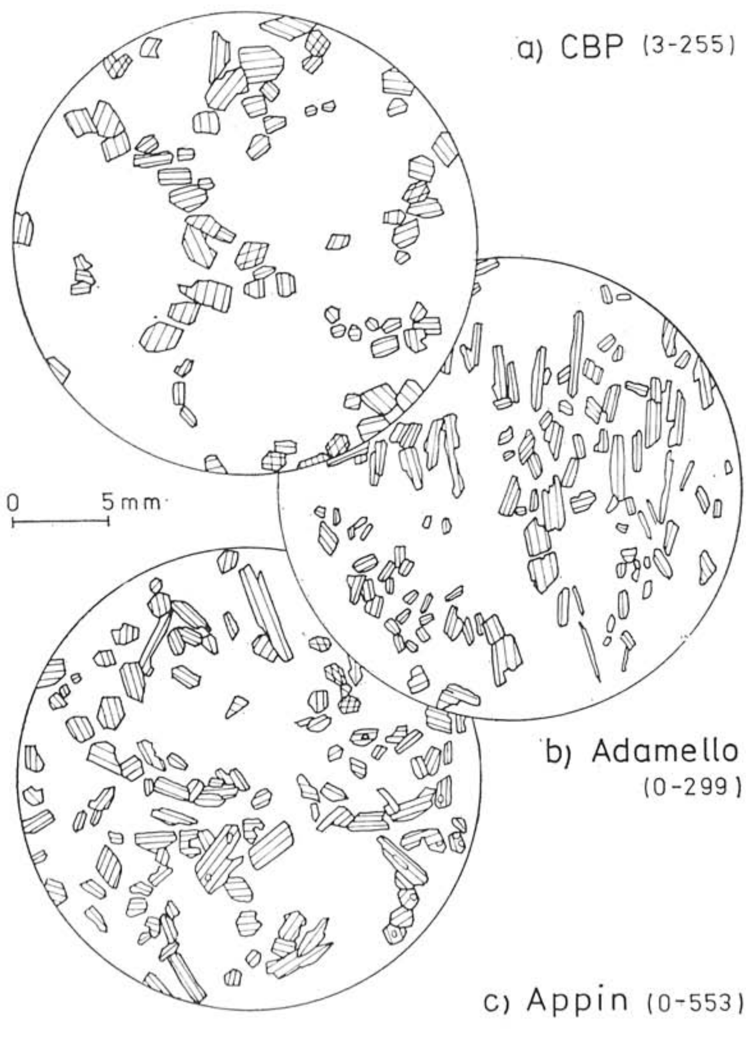


Fig. 11. The textural arrangement of hornblende in subvariolitic microgabbros and microdiorites. a) Draha, b) Mte Mattoni, c) Back Settlement. Compare fig. 17 a.

the same hornblende development. (Figs. 18a, d, 19d). The open prisms as well as the splitting of crystals can be regarded as evidence of rapid crystallization of the hornblende. The acicular textural types are highly variable in composition due to different amount of felsic minerals. A certain amount of quartz, potash feldspar, ± albite is almost always present, dioritic and quartz dioritic composition prevails. The late felsic minerals, especially quartz, often tend to subocellar and ocellar formations. The combination with ocellar and/or subporphyritic plagioclase textures (see following textural types) as well as with subvariolitic texture is common (fig. 17d).

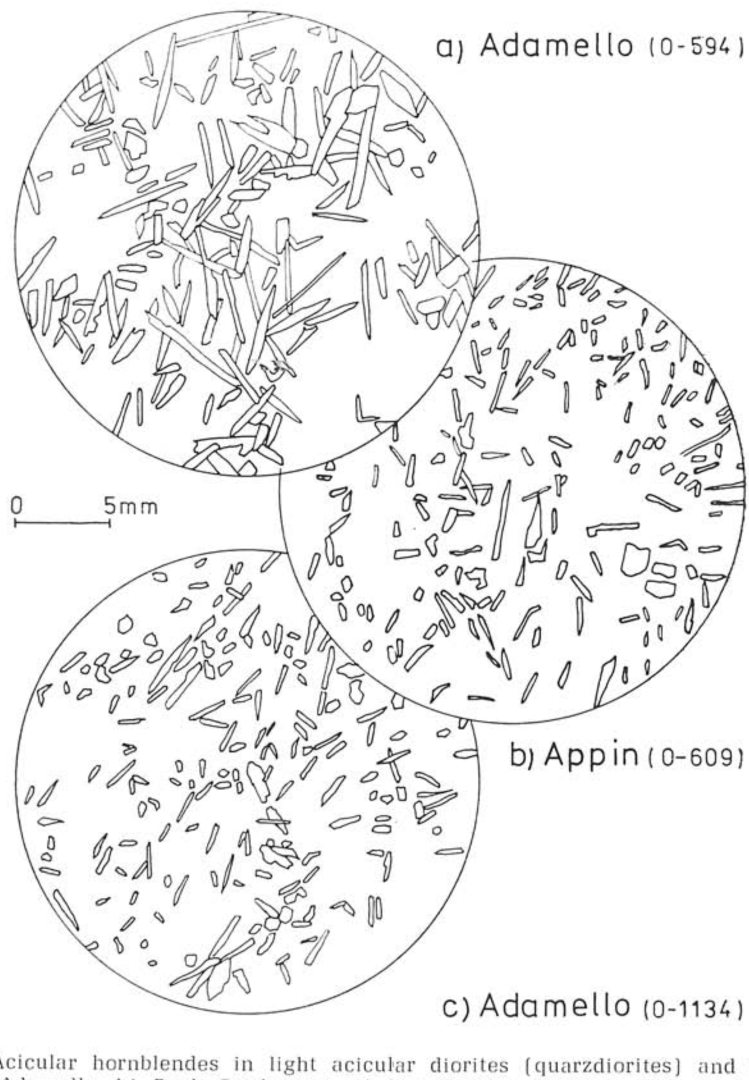


Fig. 12. Acicular hornblendes in light acicular diorites (quarzdiorites) and microdiorites. a) Adamello, b) Back Settlement, c) Mte Cadino. Compare figs. 18 c, d, 19 d.

The needle diorites („Nadeldiorite" of Austrian and French geologists — comp. J. P. E l l e r, 1965) have been described in detail by the latter author from Vosges (J. P. E l l e r, 1964). Exclusive basic types of needle quartz diorites were found in Adamello massif. The prismatic and acicular types are present in all regions under study (fig. 9—12). The continuous series of acicular types of varied — from gabbroic to dioritic — composition can be documented in each region. The prismatic and acicular hornblende is a typical textural feature of appinites according to some authors (W. J. F r e n c h, 1966; A. K. W e l l s and A. C. B i s h o p, 1955) and it was used as a criterion

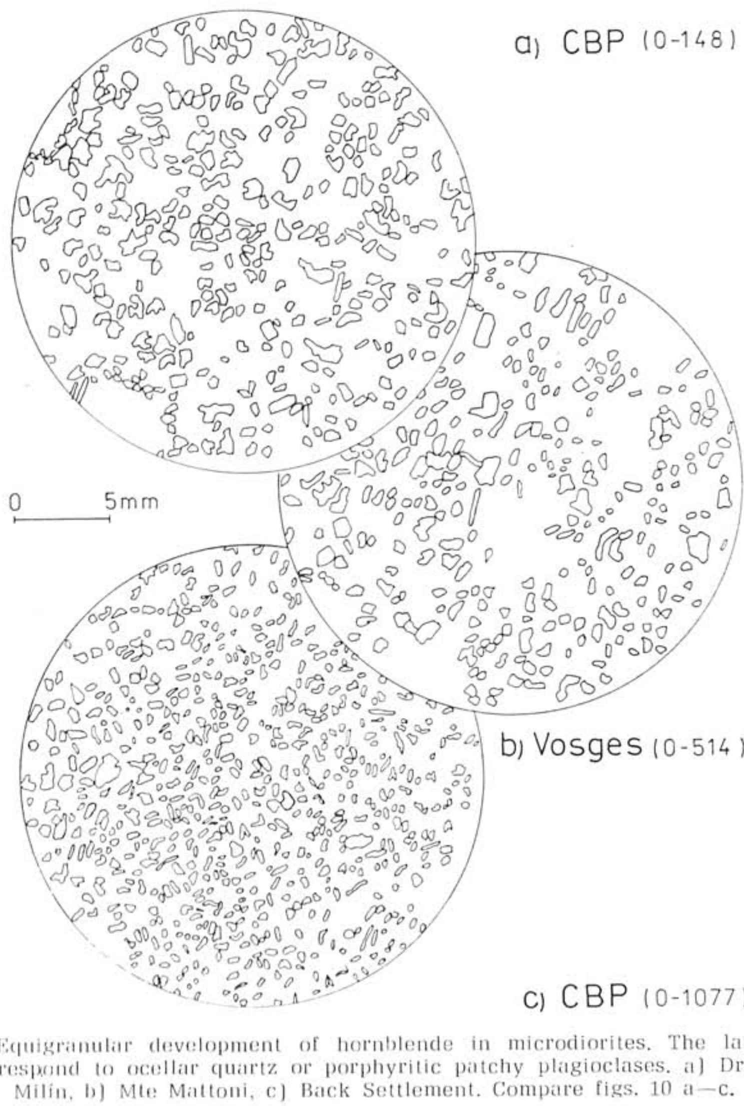


Fig. 13. Equigranular development of hornblende in microdiorites. The large white areas correspond to ocellar quartz or porphyritic patchy plagioclases. a) Drsník near Milín, b) Mte Mattoni, c) Back Settlement. Compare figs. 10 a—c.

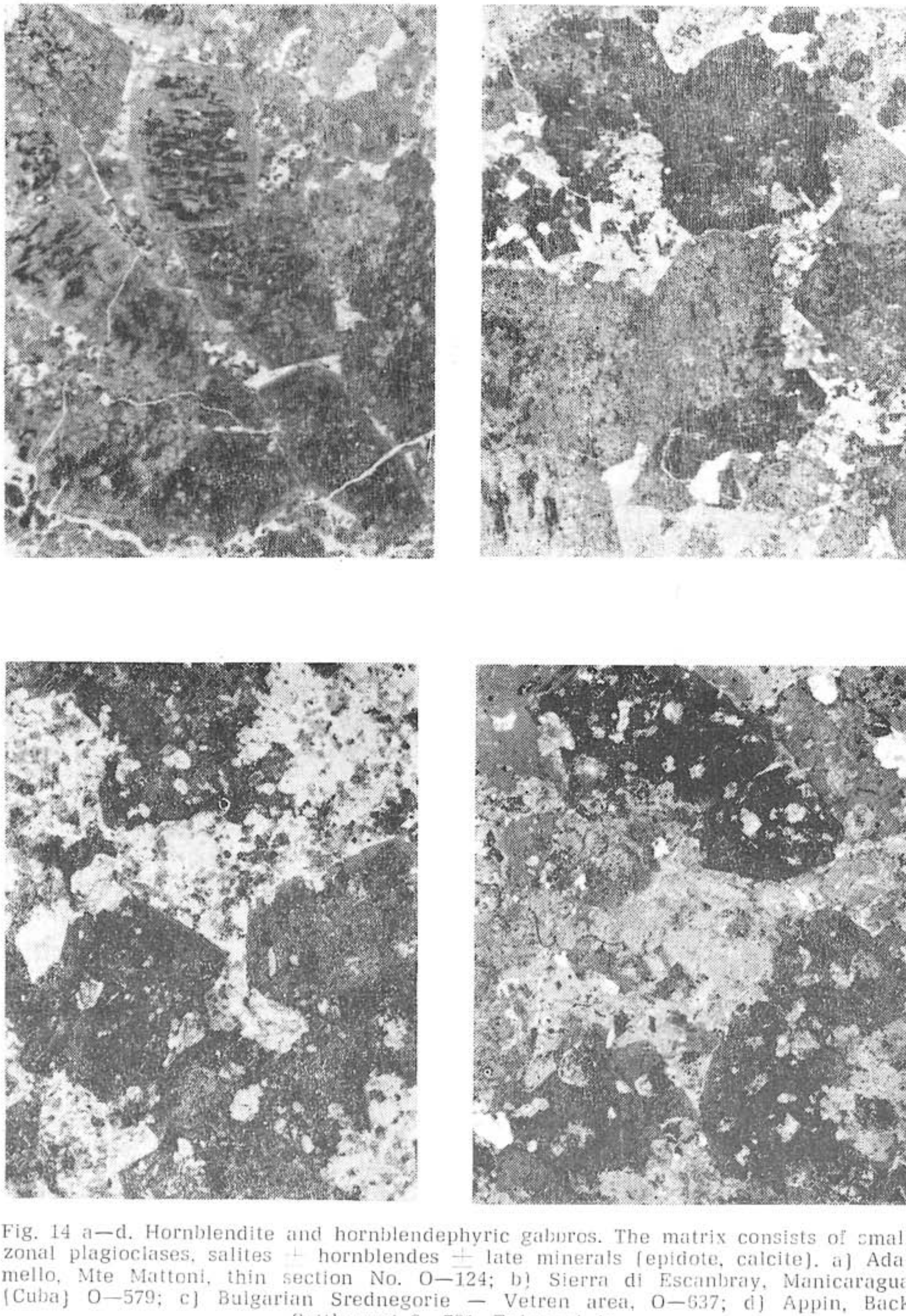


Fig. 14 a—d. Hornblendite and hornblendephyric gabbros. The matrix consists of small zonal plagioclases, salites ± hornblendes ± late minerals (epidote, calcite). a) Adamello, Mte Mattoni, thin section No. O—124; b) Sierra di Escanbray, Manicaragua (Cuba) O—579; c) Bulgarian Srednegorie — Vetren area, O—637; d) Appin, Back Settlement O—701. Enlarged 4x.

for distinguishing the „appinitic" and „dioritic" series (W. J. French, 1966). From other references cited (W. S. Pitcher and H. H. Read, W. A. Deer, A. K. Wells and S. W. Wooldridge c. l.) it follows that also other than acicular textural facies have been decribed as typical appinites. In Adamello and in Vosges as well the acicular texture is a prominent texture of basic xenoliths. Rapid diminution of grain size to the dark acicular marginal zone is conspicuously developed in them („antichilled" zones according to personal proposition of E. Callegari). Dark acicular and subvariolitic textural types from the Adamello massif and Appin region are near to lamprophyres in appearence.

5. *Subvariolitic (subsphaeroidal) textural types* (figs. 17 a—c) represent together with acicular types particularly characteristic endocontact facies of gabbroic and dioritic rocks. Similarly to those they are characterized by remarkable diminution of grain size towards the boundary with granite. This texture often develops from coarse-grained hornblendephyric types. It may pass into or be associated with other microgranular textures. The subvariolitic texture arises from the tendency of gabbroic plagioclase to form rounded formations. The plagioclase „varioles" have a rather complicated arrangement. They are formed by some zoned plagioclase crystals or their accumulations with quite particular complex and crosscutting twinning. The twinn lalamellae as well as the irregular marginal (andesinic to oligoclasic) zones are continuous for several or all plagioclase crystals. The basic centers of the latter may be overcrowded with minute pyroxene (salite) grains. To the more acid plagioclase margins the pyroxenes may be substituted by tiny hornblendes the relation of both mafic minerals being quite complicated. Most of hornblendes in the interstitial mass among the plagioclase „varioles" are arranged in the manner of more or less continuous to discontinuous rings. Other minerals of the interstitial mass are small plagioclases and minor variable amount of potash feldspar and quartz. The mafic rings differ in the arrangement and shape of hornblende grains. These may be idiomorphic equant stubby crystals or accumulations of allotriomorphic grains. Acicular development of hornblende in the rings of subvariolitic types may also occur (typically at Mte Cadino in Adamello, figs. 17 c, 18 b).

Instructive examples of subvariolitic types were found in Central Bohemian pluton (see for instance V. Hanuš and M. Palivcová, 1970), good examples come from Adamello massif and the tendency to this development could be observed in all other occurrences described (see figs. 17 a—d and schematically figs. 8, 11).

The term „subvariolitic" has been applied according to L. R. Wager and E. B. Bailey, 1953 who found fine grained edges of similar texture in dolerites at the contact with a granophyre. Analogous position is well evidenced in Pecerady gabbro or in Milín area in Central Bohemian pluton, alternatively at the contact with coarse-grained (porphyritic) granite. Although the gabbroic rocks are suggested to be older than granites, fine-grained edges develop at the endocontact of the former and gradations to extremely fine-grained subvariolitic texture are visible in the margins of basic xenoliths in the granite. Thus the problem is the same as that strongly discussed in the fifties, the problem that entered into the history of petrology as the problem of „chilled and baked contacts" or „dark margins" (A. C. Bishop, 1963).

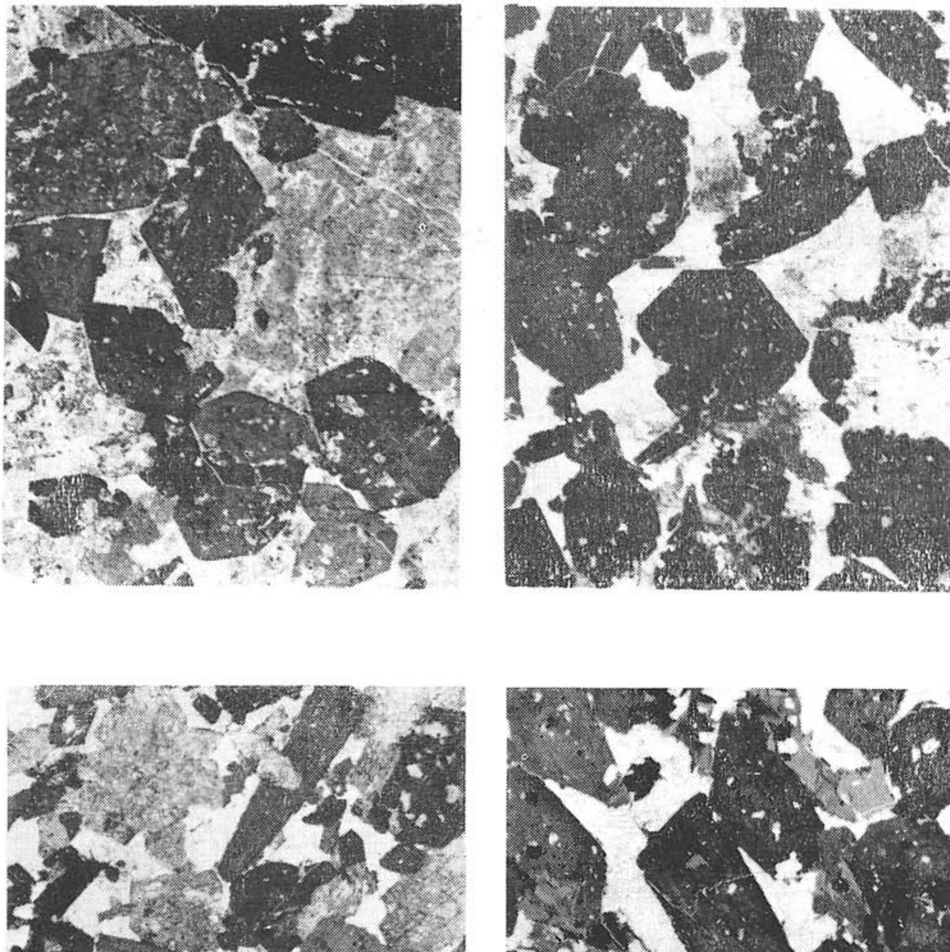


Fig. 15 a—d. Hornblende-plagioclase gabbros and diorites (± quartz), showing idiomorphic isometric (a, b — enlarged 4x) and prismatic (c, d — enlarged 7x) hornblende. a) Appin, Back Settlement, thin section No. O—566; b) Adamello, Lago di Bissine, O—285; c) Sierra di Escambray, Manicaragua, 27—356; d) Adamello, Val di Genova 27—261. Without polarizer.

One of the best first examples of this phenomenon in granitoid complexes was described by A. K. Wells and S. W. Wooldridge, 1931 from Jersey. There is no place nor intention to discuss the problem in this account. In spite of the fact that much attention has been paid to this phenomenon from different views (e.g. A. C. Bishop c. l., B. C. King, 1964, etc.) it seems to the present author that in granitic complexes the problem has not yet been solved satisfactorily.

6. *Plagioclase-phyric textural facies with patchy („sieved") plagioclases* may appear in all above types; preferentially they occur in fine-grained micro-granular types as well as in porphyritic hornblende-poikilitic types. Ocellar formations (see below) are frequently associated with. Plagioclase-phyric textural types of dioritic or gabbroic rocks are characterized by the presence of idiomorphic porphyritic or subporphyritic plagioclases of curious appearance. Rarely the plagioclases are developed as individual phenocrysts. More frequently they form agglomerations of several crystals in various degree of coalescense by continuous common zones and lamellae. The plagioclases would probably be assigned to the typical examples of synneusis in J. A. Vance's interpretation (1969). Nevertheless, they are striking by spectacular patchy development which is due to almost regular sieved replacement of anorthite by andesine to oligoclase. In addition, potash feldspar, quartz and — surprisingly enough — often also hornblendes can alternatively be present instead of andesine. Thus skeletal hornblends or hornblendes sieved by anorthite grains may originate in the core or central parts of plagioclase accumulations overgrowing several plagioclase grains. This hornblende is doubtlessly a porphyroblastic one. In Cuban and Chilian diorites clinopyroxene instead of hornblende was found in the same position in plagioclases and epidote in some examples of Central Bohemian pluton, too.

By accumulation of porphyritic plagioclases of the above type the so called plagioclase gabbros originate displaying different degree of replacement of basic plagioclase by intermediate one. Gabbroic and dioritic rocks with intricately twinned and zoned normal plagioclases develop progressively. Neverthless, if carefully observed, traces of the above patchy development still remain preserved. A high complexity of the development history has to be supposed. Such traces were found in many gabbroic rocks of Adamello, Cuba, Valren area, Strontian massif, Chile, (Fig. 19 b), etc. The best developed patchy plagioclases derive from the gabbroic rocks of the Central Bohemian pluton (fig. 19 a).

Zoned and twinned plagioclases of similar types evoked discussion in the fifties about amygdaloidal and porphyritic plagioclases (E. B. Bailey, 1952; D. L. Reynolds, 1952, M. J. Le Bas, 1955). Independently — before the interpretation was known to them V. Hanuš and M. Palivcová, 1968 have come to the similar (amygdaloidal) interpretation. In the light of new observations the development seems to be more intricate than supposed by the authors as well as by Le Bas and further studies are necessary. The above plagioclases together with the following ocellar formations bear important but still puzzled wittness about the complicated crystallization history of the rocks.

7. *Ocellar textures of gabbroic and dioritic rocks* (Figs. 19 a—c) are distinguished by the presence of small (about 0.5 cm) ocellar formations (the

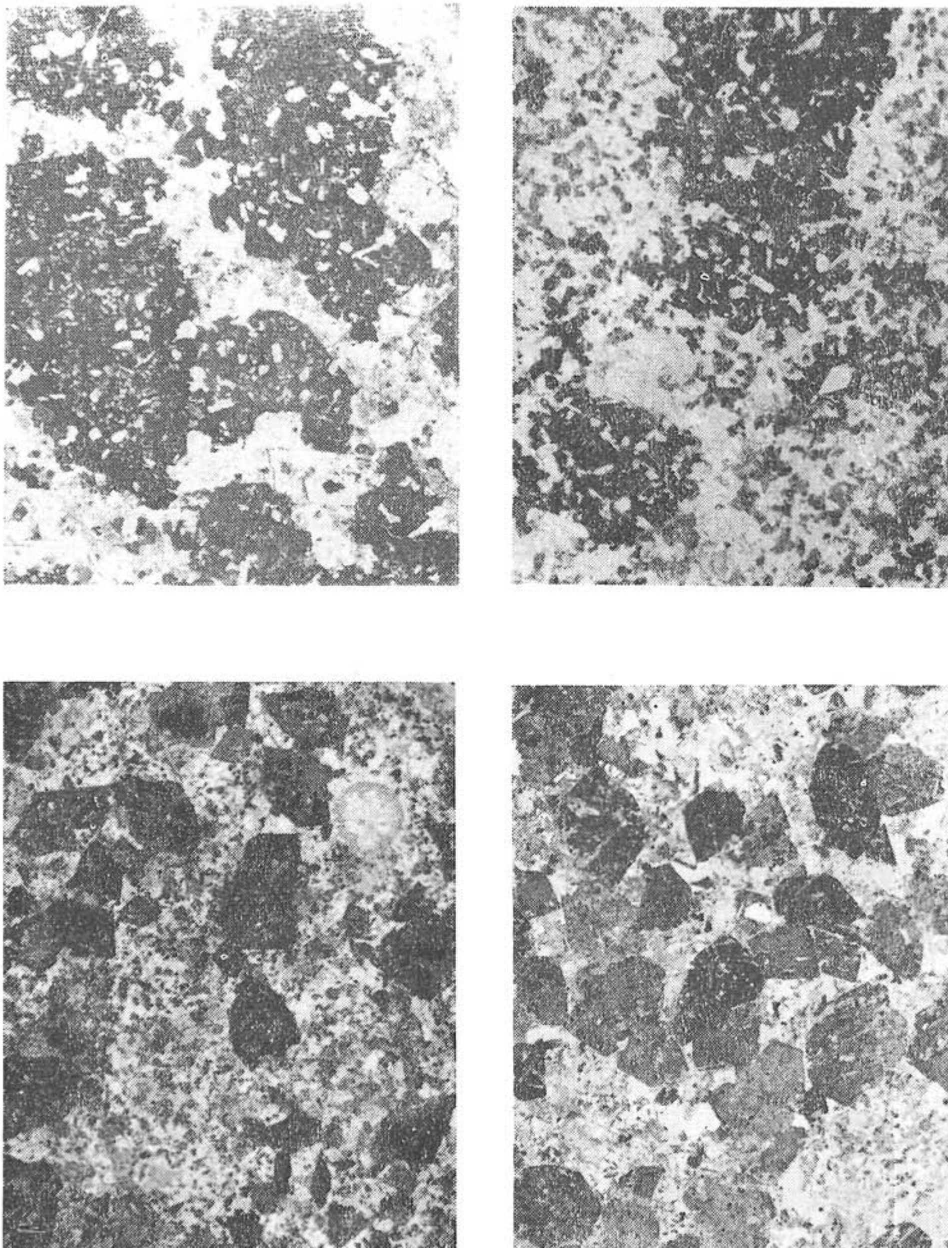


Fig. 16 a—d. Poikilitic hornblendephyric gabbroic and dioritic rocks (a, b — enlarged 7x) and small hornblendephyric gabbro with pyroxene in the martix (c, d — enlarged 4x). a) Central Bohemian pluton — Pecerady, thin section No. 27—432; b) Bulgarian Srednerogie, Vetren 3—612; c) Adamello, Mte Mattoni 0—593; d) Appin Back Settlement 0—533. Without polarizer.

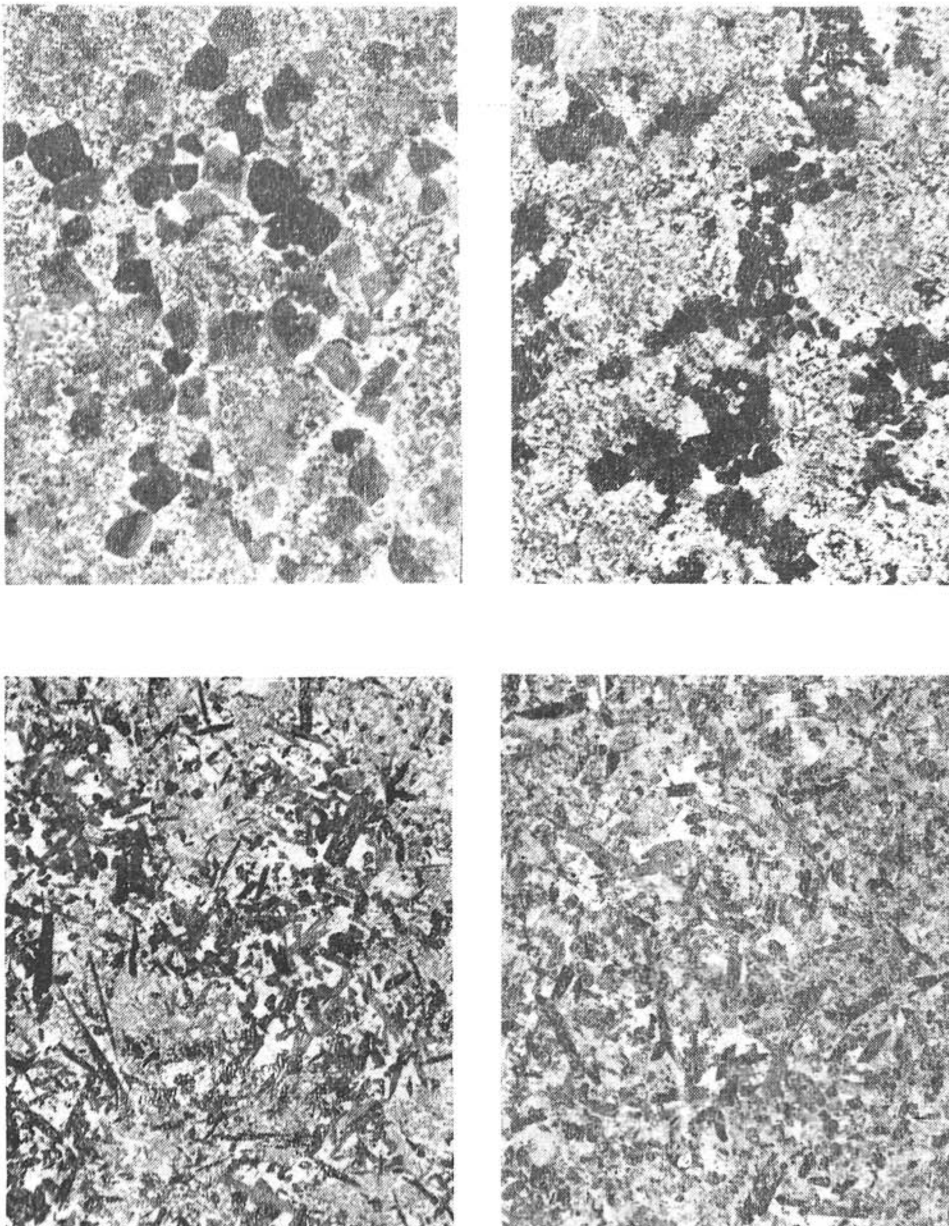


Fig. 17 a—d. Subvariolitic hornblende-pyroxene gabbros showing isometrical (a, b) and acicular (c, d) hornblendes. a) Central Bohemian pluton — Draha, thin section No. C—266; b) Central Bohemian pluton, Pecerady — Svárov 0—388; c) Adamello, Mt. Cadino 0—366; d) Appin, Back Settlement 0—559. Enlarged 4x. Without polarizer.

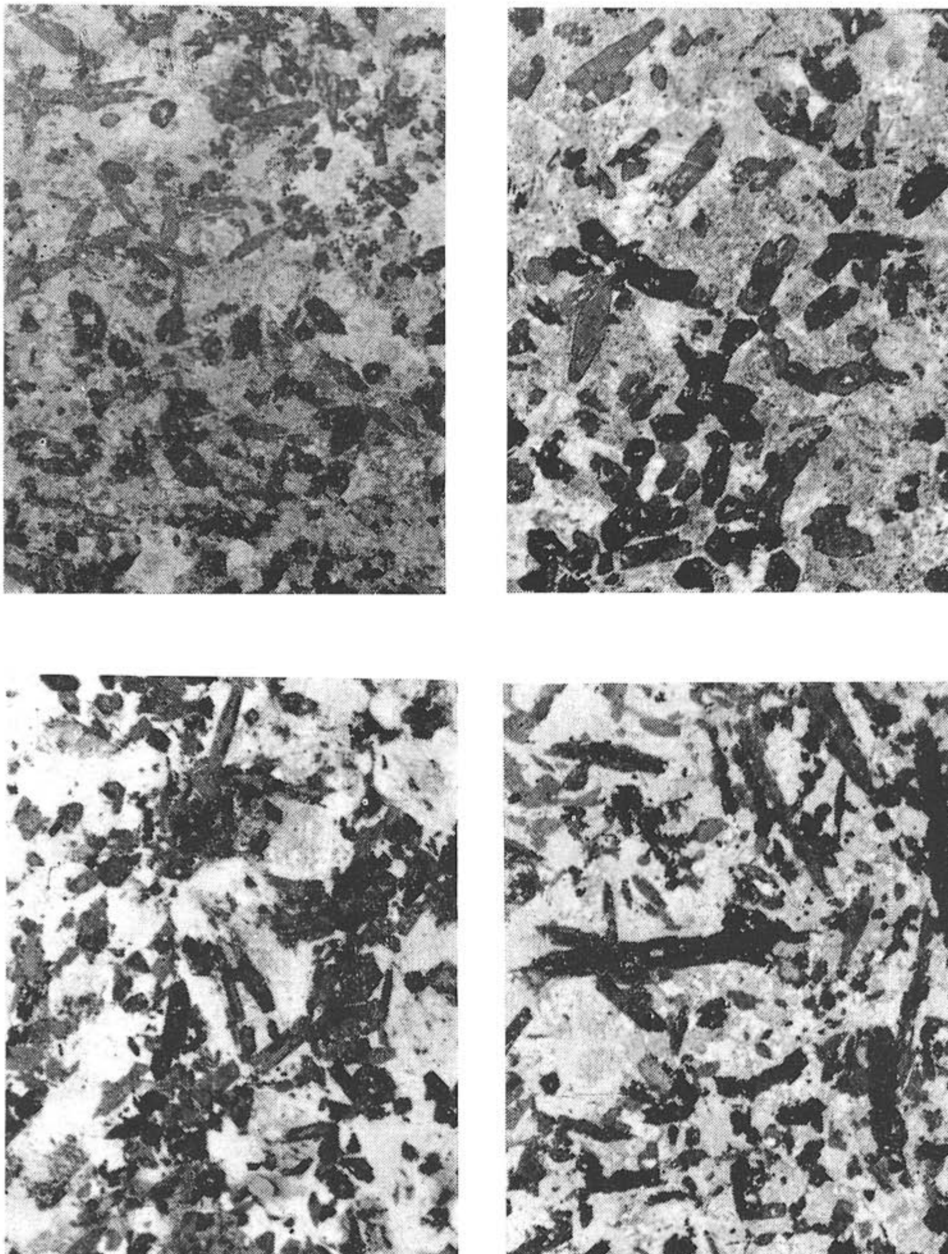


Fig. 18 a—d. Hornblende diorites containing long prismatic (hollow) to acicular hornblende. In Fig. c) d) subporphyritic patchy plagioclases are seen. a) 0—380 Sierra di Escambray, La Triana (Cuba), thin section No. 0—380; b) Appin, Back Settlement 0—568; c) Adamello, Mte Cadino 0—598; d) Northern Vosges, Denipaire. Enlarged 4x. Without polarizer.

definition according to N. S. Angus, 1962) consisting of quartz, potash feldspar and other minerals of the late crystallization stage (sphene, epidote, calcite, pyrite etc.). Ocelli are rimmed by mafic minerals, clinopyroxene (salite) or hornblende, rarely by epidote grains. They show inherited relic crystal shapes which are indicated by mafic rims, even if the core of ocelli consists of several different minerals. The content of ocelli is variable and depends on the petrography of the rocks and on the individual regions. The recent research indicates that the contact of gabbroic rocks with coarse-grained (often porphyritic) biotite granite is favourable, if not a condition, for the occurrence of ocelli. In most cases, the latter exhibit a strikingly close relationship (size, forms) with the quartz grains of the granite. Therefore, they have been called „antagonistic quartzes" according to some Soviet authors. They have been developed in a characteristic manner and most frequently in microdioritic types associated with patchy plagioclases and poikilitic hornblendes. If the groundmass is very fine-grained the rock can get the appearance of hypabyssal quartz porphyry rocks. The geological relation of ocellar rocks to the granites is striking; they form xenoliths in one case but they seem to have a certain degree of intrusive mobility against the granite in the other case.

The occurrence of ocelli is not restricted to the hornblende gabbros and diorites, the same phenomenon occurs also in noritic gabbros (H. H. Thomas and W. Campbell—Smith, 1932).

In spite of the special character of the texture ocellar gabbros and diorites have been found in perfect or less perfect development in all massifs studied. Ocellar rocks were decribed in more details from Bulgarian gabbroic rocks (M. Palivcová et al., 1980). It should be mentioned, however, that they may be overlooked in the field very easily.

The mechanism of the origin and formation of ocellar texture is extremely complicated from the geological as well as from the petrological point of view. Most often hybrid metasomatic origin of ocelli has been suggested, but a series of other explanations has been presented, too (see the discussion in M. Palivcová, 1978 in this journal). The reconstruction of the crystallization history related to granites and gabbros is particularly difficult and obscure.

Conclusions

1. The gabbroic and dioritic rocks of satellitic basic bodies associated with intrusive complicated (more basic) granitoid complexes of the calc-alkaline rock series display the same microtextural development in many regions. The microtextures were studied on the rocks of basic bodies from Central Bohemian pluton (Czech massif), Adamello massif (Italy), Srednegorie Mts (Bulgary), Escambray (Cuba), Northern Vosges (France), and on singular samples available from Chile (loc. Valparaiso) and Pyrenean massifs (Mont Louis, Guérigut). Special attention was paid to the appinites from the original Appin area (Scotland).

2. There exists close microtextural analogy not only of individual petrographic types, but *an outstanding similarity of the whole microtextural rock*

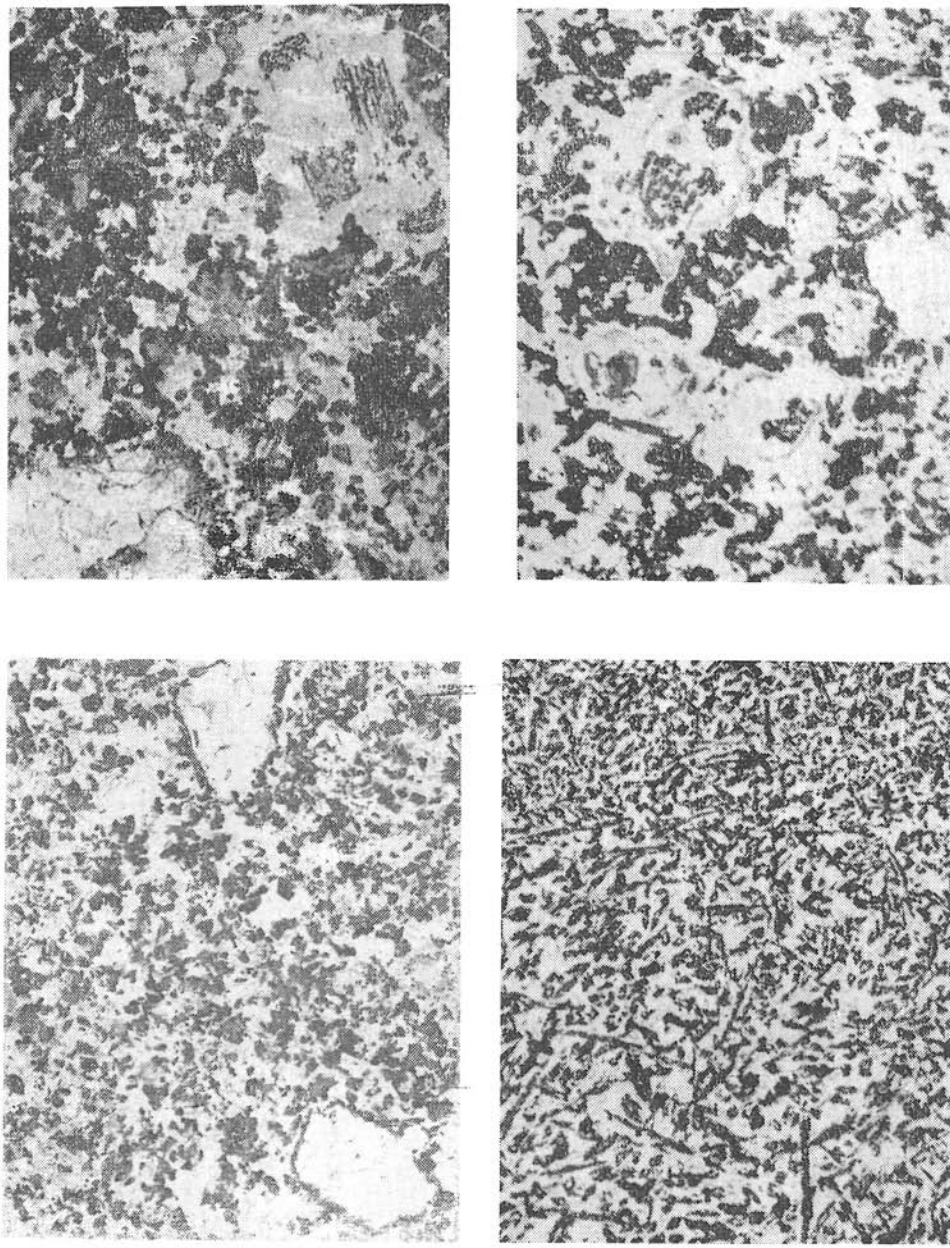


Fig. 19 a—d. Hornblende quartz microdiorites with porphyritic patchy and „filled" plagioclases (a, b) and with ocellar quartz (a, b, c). Microdiorite grades into acicular diorite in fig. d. a) Central Bohemian pluton, Kaliště near Milín, thin section No. 27—442; b) Valparaiso, Chile 27—289 (a, b — enlarged 7x); c) Central Bohemian pluton, Drsník near Milín 0—148; d) Adamello, Mte Cadino (c, d — enlarged 4x). Without polarizer.

association in the massifs studied in spite of the unusually *high microtextural variability*. It can be spoken *about constancy in textural variability*. The microtextural association recurs regularly. From the presence of some textural types the presence of other types can be predicted. Slight differences appear only in different completeness of the textural association. The microtextural variability of individual bodies often increases towards the contact with granitoids.

3. Dominant and some special microtextures in the group of hornblende gabbros and diorites are briefly described. They are as follows: hornblende-phyric, poikilitic hornblende-phyric, microgranular („microgabbroic", „microdioritic"), acicular, subvariolitic, plagioclase-phyric with patchy plagioclases and ocellar textures. The above mentioned types represent only a selection, they do not characterize the variability of textures as a whole.

4. Appinites from the classic locality of the Appin area do not differ substantially in microtextural development of the rock association from other basic bodies under study which are located at the contact with granitoids. Some differences in geological emplacement (e. g. the presence of explosion breccia) and in the degree of alteration (calcite, albite, epidote etc.) of appinites could be due to local different content of fluids and different effects of alkaline and acid solutions; the former (CO_2, H_2O etc.) are more effective in appinites, the latter in basic bodies of granitoid complexes. The parent magmatic source of basic rocks as well as their crystallization development have in deed been closely related in all massifs studied. Thus the Joplin's view that the „appinitic series" is typical for satelitic basic bodies associated with intrusive (discordant) granitic complexes is highly appreciated by the author. The broader definition of the term „appinitic suite" is preferred to the restricted one. The use of the term in question for varied and texturally complicated rock assemblages of basic bodies (characterized particularly by hornblende members) is recommended as highly useful and plausible.

5. *The constancy of microtextural variability is suggested to be a serious argument in favour of analogical petrogeny of basic rocks in satellitic bodies investigated.* These analogies do not depend on the local development of the Earth's crust nor on the geological age. The massifs studied are of Caledonian, Variscan, Neoid (Mesozoic, Laramide) age. The results suggest that the parental magma of the rock studied was derived from the same source in deeper zones of the Earth's crust and that the rock development was influenced by the same superimposed processes. All massifs studied are situated close to the important deep faults.

6. The microtextural rock types have a highly intricate but *similar trend of crystallization history in all bodies studied.* Several crystallization stages can be recognized. (M. P a l i v c o v á et al., 1975; J. U l r y c h et al., 1976). The replacement of minerals of an older crystallization stage (anorthitic plagioclase, high-temperature mafite) by a younger one (common green hornblende, clinopyroxene — salite, diopside, intermediate plagioclase) can always be observed even though in various intensity. The youngest stage is represented by alkali feldspar and quartz, also by actinolite-tremolite, sphene, epidote, calcite. The commonly present sphene — sometimes in considerable amounts — supports the view *that the parental magma was rich in titanium.* The crystallization stages involved are interpreted as successive

magmatic stages by some authors, while recrystallization in postmagmatic satge or in supperimposed processes is emphasized by the others.

7. The petrogenetic model of hornblende gabbros and diorites involved is dependent on the interpretation of temporal intervals among the above crystallization stages, as well as on the interpretation of the source and physical stage of the alkaline and acid solutions of the rocks. Despite the various (contradictional) petrogenetic interpretations the microtextural variability and analogy strongly support the view that the development history in all studied regions was highly analogous in general trend as well as in the details. A substantial role belongs to the crystallization of common green hornblende. Its crystallization is considerably affected by the amount of fluids as well as of alkaline and acid solutions. At least in some cases the metasomatic origin of hornblende by recrystallization in a previous texture of solid rock is doubtless.

8. The correlation of geochemical and petrochemical data of the above gabbroic and dioritic rocks can lead to distorted petrogenetic deductions unless more attention is paid to the microtextural features of the rocks.

Acknowledgments. The author wishes to express her thanks to all colleagues and professors from abroad who made it possible to visit the regions discussed, as well as to all colleagues (particularly to dr. V. Hanuš, CSc.) who helped to sample the rock material during the field excursions. She is indebted to V. Matějková for collaboration on the photomicrographs, to L. Kernerová for drawing the figures and to M. Kubínová for the revision of the English translation.

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