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OCELLAR QUARTZ LEUCOGABBRO (CENTRAL BOHEMIAN PLUTON) AND GENETIC PROBLEMS OF OCELLAR ROCKS

(Fig. 1—18)

Abstract: Unusual ocellar quartz gabbroic rocks are described from the contact zone between basic rocks (hornblende gabbro and hornblendite) and granitic rocks of the Central Bohemian Pluton. The possible modes of origin of these ocellar rocks are considered, with special regard to the discussion promoted by the paper of V. Hanuš, M. Palivcová (1969) and N. S. Agus's (1971) commentary on this problem. None of the existing working hypotheses can explain the origin of similar rocks without reservation.

Резюме: Необыкновенные оцеллярные породы описываются на контакте основных пород (амфиболовое габбро и горнблендит) с гранитоидными породами Среднечешского плутона. В работе обсуждаются возможные образы возникновения этих оцеллярных пород принимая во внимание дискуссию, вызванную работой В. Гануша, М. Паливцовой (1969) и замечаниями Н. С. Ангуса (1971) к этой проблеме. Ни одна из существующих в настоящее время гипотез не объясняет безоговорочно происхождение подобных горных пород.

Introduction

The term "ocellar" is here used in the sense recently employed by N. S. Angus (1962) and V. Hanuš and M. Palivcová (1969) that is, denoting textures of rocks containing minute essentially quartz bodies rimmed with mafic minerals, which occur in dioritic and gabbroic rocks and their xenoliths in granitoids. Ocellar quartz is commonly of similar habit and size as the quartz of the surrounding granitoids. Thus the explantation of ocellar quartz poses similar problems as those discussed about large feldspars in exocontact and in xenoliths of granitic intrusions. The mafic rims of quartz ocelli resembling reaction rims make the problem still more complicated.

Ocellar diorites and gabbros referred to in the literature are distinguished by ocellar bodies in the groundmass of dioritic, gabbroic and noritic composition, which contain mafic minerals. The ocellar rocks under discussion differ from all so far known ocellar diorites and gabbros in texture: mafic minerals are almost entirely concentrated in the rims of ocelli and the groundmass of these ocelli is composed almost completely of felsic minerals.

Geology

The leucogabbros occar at three localities in the Příbram and Milín areas, within the Central Bohemian Pluton of Variscan age (Fig. 1). In all three cases the rocks are confined to the contacts of basic bodies with granitis rocks, but the contact is not continously exposed.

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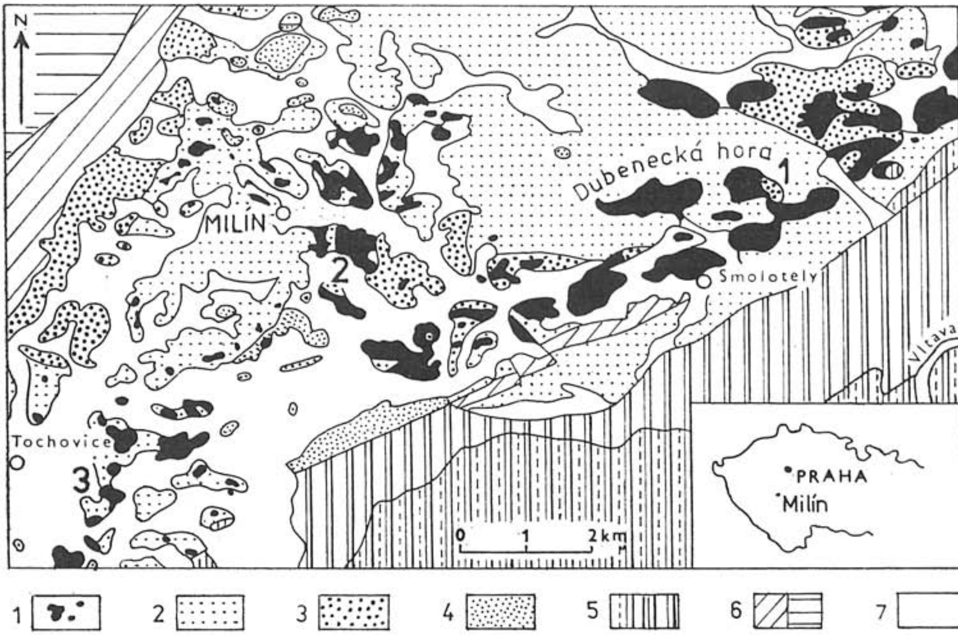

Fig. 1. Geological map of the Central Bohemian Pluton in the Milín area showing the occurrences of ocellar basites. After the Příbram map sheet, on a scale of 1 : 75,000 (D. Andrusov et al., 1939)
1 — basic rocks of the Central Bohemian Pluton (predominantly hornblende gabbro); 2 — biotite granodiorite (± amphibole) — Blatná type; 3 — porphyritic biotite granite (± amphibole) — marginal type; 4 — granite aplite; 5 — metavolcanics of the Jílové Zone (a — basic, b — acid); 6 — sediments of the Pluton contact (a — Upper Proterozoic, b — Lower Palaeozoic)" 7 — loams, alluvium, denoted only in the Pluton area.

At the first, most typical locality — Dubenecká hora Hill, 2 km north of Smolotely — the rock forms blocks, at the eastern margin of the basic body surrounded by coarse-grained granite of "marginal type". At Kojetín, 1 km SE of Milín, the rock occurs in the southern marginal parts of the Kojetín basic body. The adjacent granite of "marginal type" grades here into fine-grained Příbram granite. The third locality is the abandoned Podtochovice Quarry, 1 km E of Tochovice, situated in the marginal part of a basic body. surrounded by the Blatná granodiorite. All these occurences present local development not exceeding $^1/_2$-1 m in diameter.

The ocellar leucogabbro is invariably associated with the accumulation of leucocratic pegmatoid material at the gabbro — granite contact.

The basites of the Pluton are considered by most authors to be its oldest component. They were and are interpreted differently, even contradictorily, either as primary plutonic rocks or as reworked earlier metabasites or subvolcanics. Z. Vejnar has recently proposed a compromising interpretation, regarding some gabbro types as primary (1972) and others, coming from the same association, as metagabbros (1975).

Granitic rocks are generally thought to be younger than the basic bodies. The relationship between the two main (marginal and Blatná) granitic types is not clear, but the Blatná Granodiorite is thought to be older. The radiometric ages of the rocks involved determined by K/Ar method are the following: Příbram Granite from borehole JD-370 m. y. (VSEGEI U. S. S. R. in V. Šmejkal 1964, biotite concentrate); marginal granite, Radětice — 362 ± 12 m. y. (biotite); Blatná Granodiorite, Blatná-354 ± 12 m. y. (biotite); Pecerady Gabro-334 ± 20 m. y. (hornblende). The last three analyses were performed at IGEM AN U. S. S. R. in 1973 (analyst M. M. Arakelyants).

Brief survey of the petrography of basic and granitic rocks

The basic body of the Dubenecká hora Hill, about 4 sq. km in area, is composed of hornblende gabbro resembling the Pocerady Gabbro (M. Palivcová et al., 1975); it consists of porphyritic, poikilitic mottled brownish-green or green Mg-hornblende (even actinolitic in the marginal crystal zones) and fine-grained groundmass. The essential minerals of the groundmass are zoned plagioclasse (An_{90-25}, normat. An_{62} common green hornblende, occasionally some salite and a small amount of potash feldspar and quartz; sphene, apatite, epidote, magnetite and chlorite are accessories. The rock contains about 50 vol. per cent of mafites.

The Kojetín (Milín) basic body, some 2 sq. kilometres in area, is built up of hornblendite, hornblende gabbro of Pecerady type and fine-grained varieties of melagabbro, gabbro and diorite. Hornblendite is massive, coarse-grained and consists of mottled isometric common hornblende (1—2 cm large) ranging from brown to brownish-green, green to colourless actinolitic hornblende and of subordinate, rarely fresh plagioclase (bytownite to anorthite). Clinopyroxene and olivine, accessory hypersthene, biotite, magnetite and pyrite occur in small and varying amounts. The mafite content is about 90 per cent. For details see V. Rosický, 1921.

The Podtochovice basic body (ca. $^1/_2$ sq. kilometre in area) is composed of medium-grained hornblende-melagabbro to olivine gabbro-hornblendite. It has a similar composition as the Kojetín hornblendite but with a higher content of plagioclases, clinopyroxene and olivine. The composition changes according to the character of mafites: the facies containing inhomogeneous mottled amphibole usually have decomposed unzoned calcic plagioclase and more mafic accessories, whereas facies with more homogeneous common green hornblende contain notably zoned and fresh plagioclase with basic cores, and often also accessory quartz and potash feldspar. The content of mafites varies between 50 and 70 per cent.

The basic rocks described belong to the series passing into dioritic and ultrabasic rocks. Many members of this series compare with the rocks of the "appinitic series" (J. E. Richey, 1953) as, with the rocks of "appinitic series" and "appinitic rocks" in the sense of S. R. Nockolds (1941) and many others (M. Palivcová ed. 1975). The association is distinguished by compositional and textural variety and numerous transitions within and between the bodies.

The granitic rocks. The granite of "marginal type" (called according to its position along the north-west contact of the pluton) is light-coloured, coarse-grained porphyritic biotite granite, composed of orthoclase, zoned plagioclase An_{36-40}, large rounded quartz grains (felsic minerals in "eutectic ratio), biotite (3–8 %) and rarely green hornblende (1–2 %) – Both mafic minerals are rich in Mg. Sphene, apatite, orthite, zircon, magnetite and epidote are accessories. The Příbram granite is light-coloured, pinkish and finer-grained; the marginal type passes into it through decreasing content of porphyritic feldspar. Its composition is transitional between biotite granite and granodiorite, which is near to trondhjemite. The Blatná Granodiorite, the most widespread granitic rock of the area, is a light-grey biotite granodiorite (up to granite, after Streckeisen), evenly medium-grained. Plagioclase An_{30-33} slightly predominates over potash feldspar and quartz; biotite content is about 10 %, and hornblende (2 % at the most), sphene, apatite, zircon, orthite, epidote and magnetite are accessories.

Petrography of ocellar quartz leucogabbro

The ocellar quartz leucogabbro resembles normal black-white mottled, medium--to coarse-grained feldspar-rich gabbro. Only close inspection reveals that "mafic minerals" are actually ocellar bodies mainly of quartz rimmed with hornblende (Fig. 2).

The ocelli with thin hornblende rims are best developed. They are identical with those which, according to N. S. Angus (1962), are typical of ocellar hybrids, and with the forms described by V. Hanuš and M. Palivcová (1969) from the Milín area. They have isometric, elongated, irregular or distinct crystal shapes (rectangular, square, hexagonal cross-sections – Fig. 2, 3, 6, 10, which are contoured by mafic rims.).

The rims of ocelli (Fig. 4, 6, 10) are simple, mostly continous and formed of tiny green hornblende crystals, occasionally with brownish or lighter cores. Hornblende crystals often grow perpendicular to ocelli and towards their centres become perfectly euhedral. The continuity of rims may be broken by plagioclase, potash feldspar or quartz.

The cores of ocellar formations consists mainly of quartz (Photo 5), often accompanied by potash feldspar (Fig. 4, 5, 12) and andesine at the inner margins of the rims. Quartz may be a single crystal but mostly consists of several, differently oriented grains (Fig. 7). It often shows undulatory extinction and usually constitutes the central part of the ocelli; their border is formed of potash feldspar (Fig. 8). The two minerals may overgrow into the groundmass without disturbing the original form of the rim. In places, micropegmatitic cores are developed Quartz is bound with crystal faces against potash feldspar (Fig. 4, 5, 12, 8, 9), but is also penetrated by the former along the fissures. Epidote and sphene appear rarely in the ocellar quartz.

The ocellar structures of the other type are subordinate. They are also fringed by amphibole rims but consist of fine-grained microdioritic mass (the grain--size is of tenths of a millimetre order) composed of zoned plagioclase (chiefly andesine), green hornblende and a small amount of potash feldspar and quartz (Fig. 10, 11, 8). Surprisingly enough, the crystal form of the ocelli is apparent in this case too.

The hypidiomorphic granular groundmass (matrix of the rock) is formed of plagioclase, quartz and little potash feldspar. The mean grain-size is 2–3 mm.

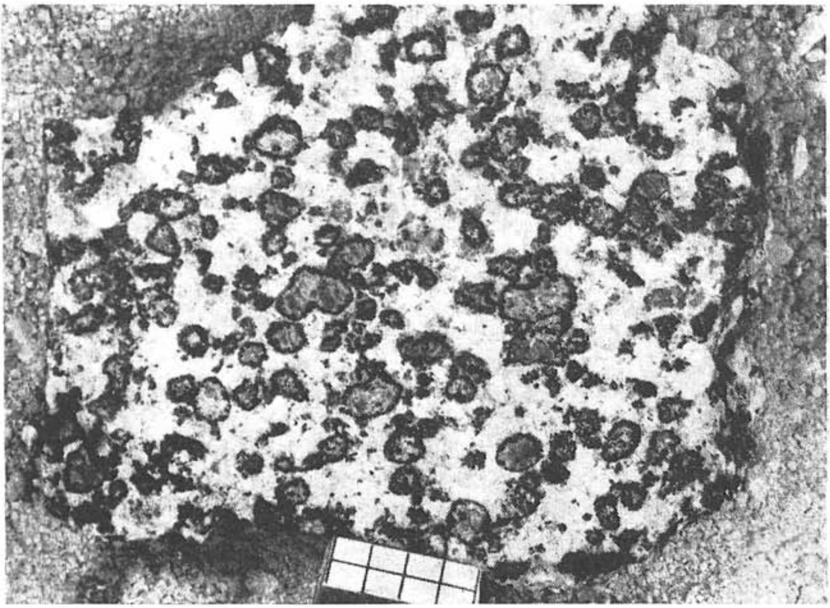

Fig. 2. Ocellar quartz leucogabbro, Dubenecká hora. Plagioclase $\pm$ potash feldspar (white), amphibole (black), quartz (grey). Euhedral forms of some ocellir are evident Natural size.

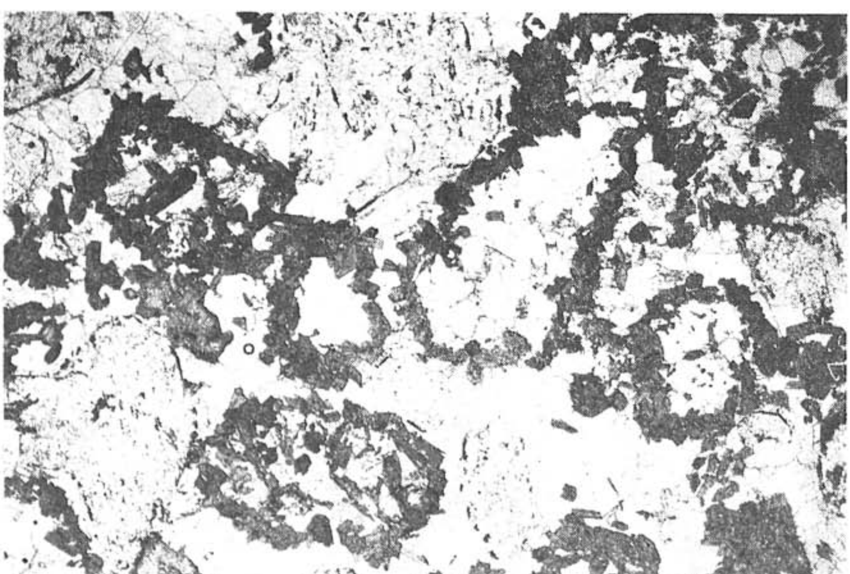

Fig. 3. Ocellar texture in leucogabbro shown on Fig. 2, with quartz (small ocellus in the centre), quartz-potash feldspar (larger ocellus in the centre) and microdioritic filling (on the lower and upper left), x 5.5, // nicols. For details see Fig. 12 and scheme on Fig. 9.

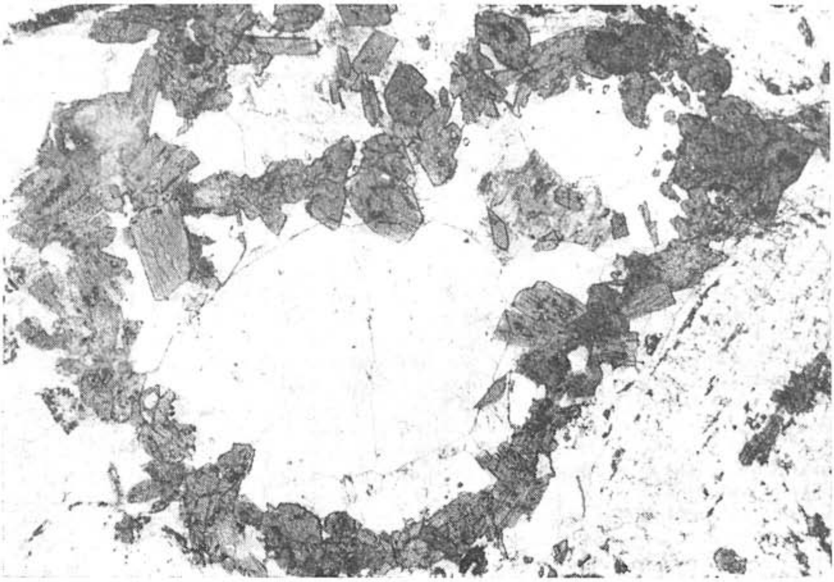

Fig. 4. A complicated ocellar form filled with quartz and potash feldspar in leucogabbro. Potash feldspar concentrated to the rim margin separates two undulatory quartz crystals bound by crystal faces against it. Minute anhedral quartz crystals are seen in the potash-feldspar rim (cf. Fig. 5). Dubenecká hora; // nicols, x 11 (cf. scheme on Fig. 8).

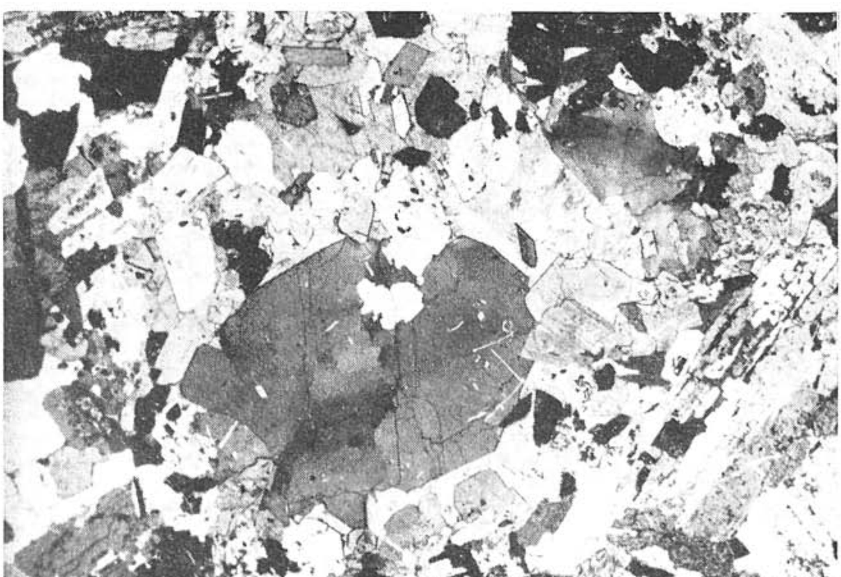

Fig. 5. The same as on Fig. 4, under crossed nicols. Large undulatory quartz — blackish — grey in the centre, potash feldspar — light-coloured rim.

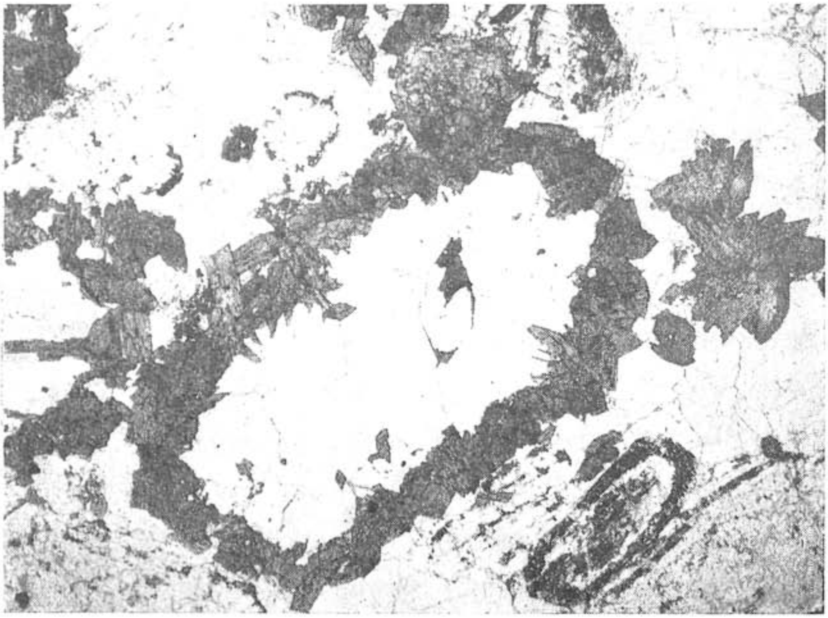

Fig. 6. Anhedral ocellus filled with oligocrystalline quartz (cf. the next Fig.) and sheathed by a continuous amphibole rim. (A fallen-out anhedral amphibole crystal in the centre). Dubenecká hora; // nicols, x 11.

Fig. 7. The same as on Fig. 6 under crossed nicols.

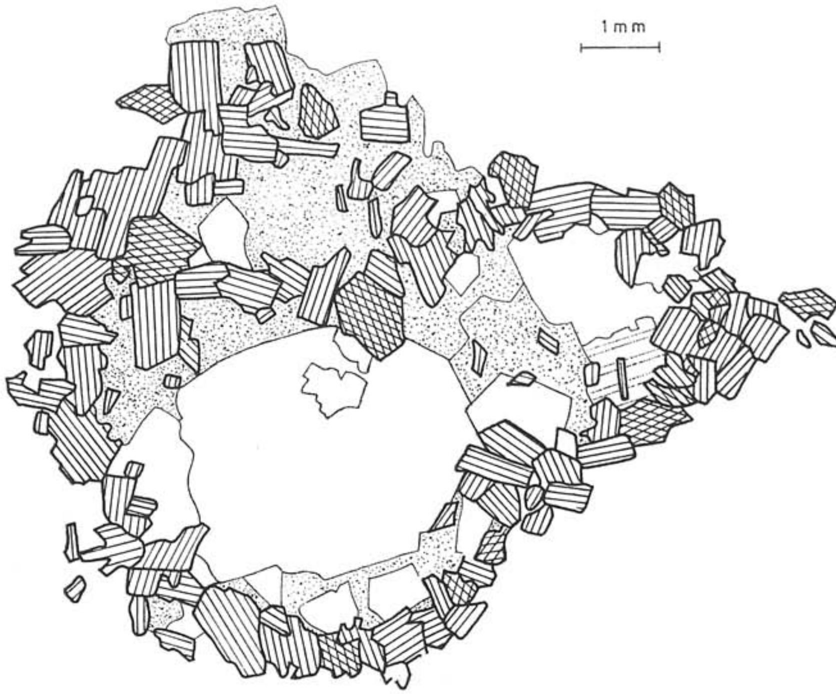

Fig. 8. Sketch to Fig. 4, showing the relationship between potash feldspar and quartz in ocelli. For explanation see Fig. 9.

Accessories are apatite, epidote and ore grains and are rather sparse. The groundmass corresponds in composition to quartz anorthosite and is essentially hololeucocratic. At the contact of the Podtochovice basic body this hololeucocratic mass "intrudes" the melagabbro by thin veinlets in places.

Microscopicaly, the groundmass shows some peculiar features of crystallization. The most conspicuous is crystallization of euhedral plagioclase, which developed obviously in two distinctly separate crystallization phases: calcic plagioclase-labradorite to anorthite (up to An_{96}) forms relicts, which are often set discordantly in the younger twinned and zoned andesine (An_{53-33}) (Fig. 13). Relicts are frequently preserved in a ring form, which indicates the original limitation of calcic plagioclase. The crystal form of the ring is not respected by andesine, which grows independently of the original form of the calcic plagioclase. Aggregates of minute individuals forming combination twins with continuous common lamellae and zones (denoted as syneusis texture) are frequent. Quartz and a small amount of potash feldspar in the groundmass are interstitial between plagioclase, often forming "pools" uniformly oriented over a large area; the groundmass quartz is not sheathed with rims.

The mode of the rock is varying, depending on the concentration of ocelli and, consequently, of amphibole. Several measurements and theoretical mode calculated from the norm (N) are listed in the following table:

Fig. 9. Sketch to Fig. 3 showing the association of ocelli with silicified parts of the rock and the relic character of ocelli rims. Hatched — amphibole, dotted — potash feldspar, double dotted line — plagioclases (schematically, without zoning), white — quartz.

	1	2	3	N	
amphibole	26.4	25.5	33.5	23.2	
plagioclase	42.5	43.6	28.7	44.6	
K-feldspar	4.3	3.8	2.8	8.9	average number of
quartz	26.9	27.2	35.0	22.6	points = 2000
	99.9	99.9	100.0	99.9	

The rock is unusual in composition. It is consistent with tonalite according to the high quartz content (IUGS 1973) and with quartz-rich quartz gabbro (A. Johannsen 1932) according to the An-content of the plagioclase (virtual at average as well as normative more than An_{50}.). The groundmass has the composition of a quartz anorthosite. The content of ocellar quartz inclusive its hornblende rims broadly corresponds to the average of hornblende in the gabbro of Dubenecká hora Hill. In order to emphasize close relation of the rock to the gabbroic bodies (and dissimilarities of surrounding granitoids) the rock is called quartz leucogabbr and not tonalite.

Table 1 and Fig. 14 show the composition of hornblende fringing the ocelli compared with that of hornblende from the gabbros of the Central Bohemian Pluton. Although the hornblende is a component of relatively acid rock (63.5 % SiO_2) no distinct Fe-enrichment can be seen if compared with the composition of the hornblende of other gabbroic rocks of the pluton; in some cases in retains the chemistry of highly magnesious hornblende of basic rocks of the area.

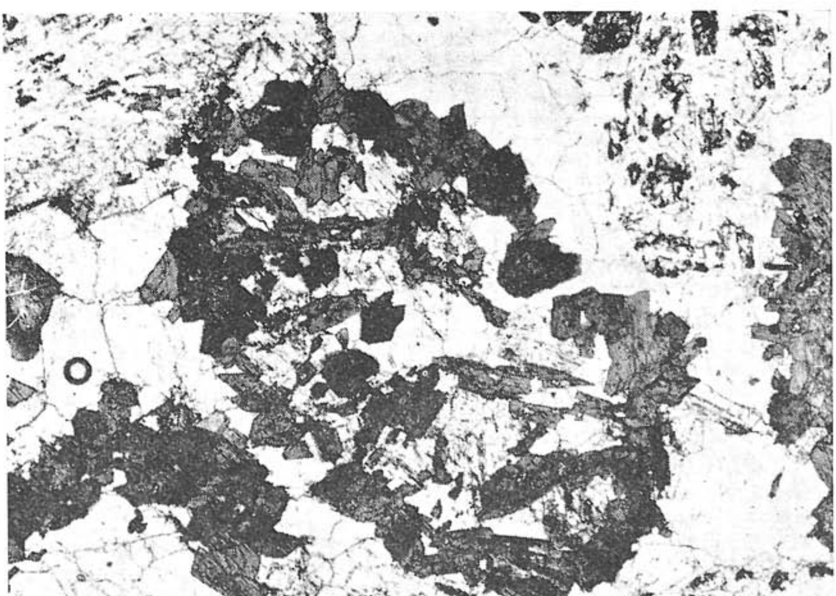

Fig. 10. An ocellar form of „microdioritic" composition and texture, composed of tiny plagioclase, hornblende and quartz grains. Dubenecká hora; // nicols, x 11.

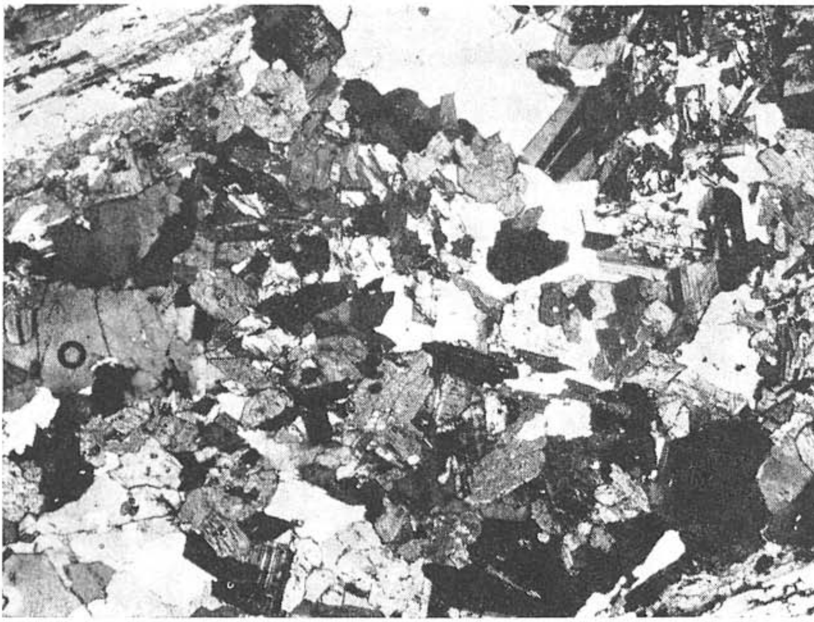

Fig. 11. The same as in Fig. 10 under crossed nicols.

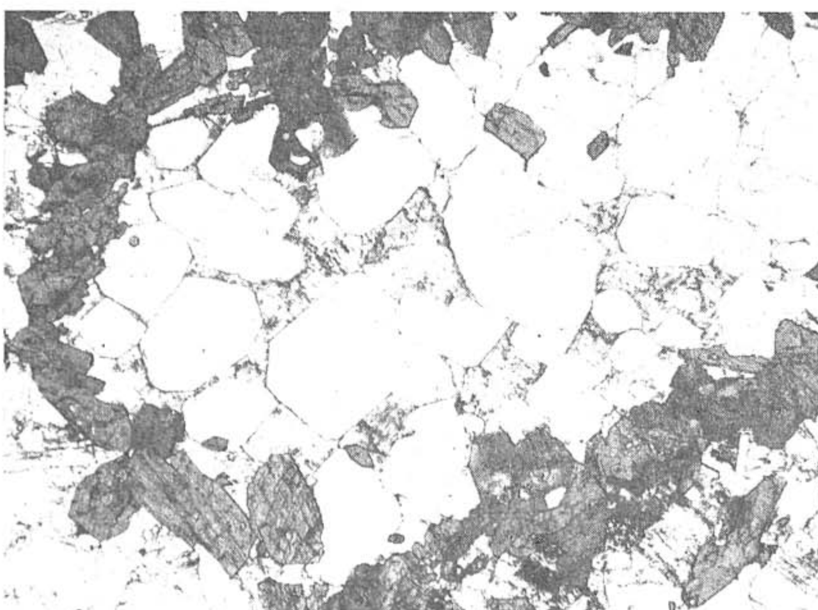

Fig. 12. Detail of the central part of Fig. 8. Micropegmatitic filling of an ocellus, composed of anhedral quartz and interstitial potash feldspar. x 18.5, // nicols.

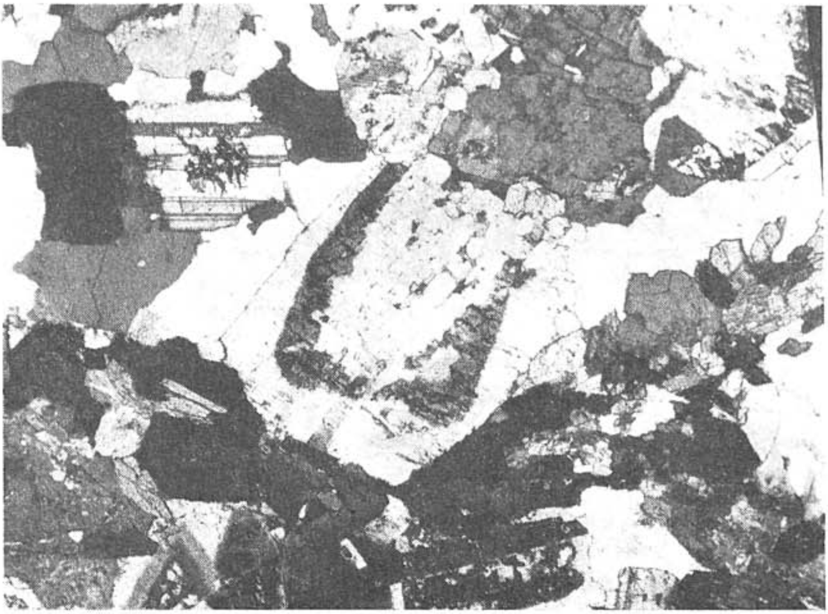

Fig. 13. Plagioclase (andesine) with discordant relic zone of anorthite (black) in ocellar leucogabbro. Quartz is abundant (white, blackish-grey) in the rock. Dubenecká hora; crossed nicols, x 24.

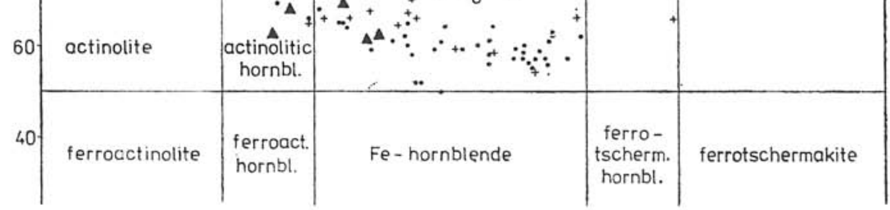

Fig. 14. Amphiboles from Table 1 (triangles) in Leake's classification compared with hornblendes of gabbros (Central Bohemian Pluton). Points — hornblende of the Pacerady gabbro (J. U l r y c h 1975); crosses — amphiboles of melagabbros of Central Bohemian Pluton (Z. V e j n a r 1975); open cirles—hornblendes from the Milín and Podtochovice basites (J. U l r y c h 1975)

Table 1. Chemistry of hornblende from the rims of ocelli in quartz leucogabbro. Dubenecká hora — triangles in Fig. 14 (Microprobe JXA — 50A, GLÚ ČSAV).

	1	2	3	4	5	7	9
SiO_2	49,29	46,13	49,68	51,56	48,49	48,62	51,90
TiO_2	0,87	0,34	0,68	0,62	1,31	1,20	0,99
Al_2O_3	8,22	10,82	6,13	5,71	6,70	6,67	5,73
FeO tot.	7,13	8,42	12,37	13,27	14,58	14,73	14,89
MnO	0,09	0,21	0,39	0,41	0,38	0,39	0,45
MgO	18,01	17,25	15,94	15,39	13,59	13,44	13,55
CaO	12,47	11,47	12,01	11,66	11,67	11,76	12,12
Na_2O	1,18	1,94	0,70	0,62	1,17	1,15	0,53
K_2O	0,18	0,43	0,39	0,29	0,50	0,50	0,34
	97,44	97,01	98,29	99,53	98,39	98,46	100,50
	Structural formullae calculated to 24 oxygens (2 % H_2O estimated)						
Si	7,012	6,663	7,174	7,341	7,085	7,102	7,375
Al	0,988	1,332	0,826	0,659	0,915	0,898	0,625
	8,000	8,000	8,000	8,000	8,000	8,000	8,000
Al	0,388	0,508	0,215	0,298	0,237	0,248	0,333
Ti	0,093	0,036	0,147	0,066	0,287	0,131	0.106
Fe	0,845	1,014	1,488	1,575	1,775	1,793	1,763
Mn	0,011	0,026	0,048	0,050	0,047	0,048	0,054
Mg	3,844	3,740	3,453	3,287	2,978	2,945	2,888
	5,181	5,324	5,351	5,276	5,324	5,165	5,144
Ca	1,901	1,776	1,858	1,779	1,827	1,845	1,845
Na	0,324	0,543	0,196	0,171	0,331	0,324	0,145
K	0,032	0,080	0,071	0,053	0,093	0,093	0,061
	2,257	2,399	2,125	2,003	2,251	2,262	2,051
$\frac{Mg}{Mg + Fe + Mn}$	0,818	0,782	0,692	0,669	0,620	0,615	0,614

Chemistry of ocellar quartz leucogabbro and associated rocks

The chemistry of ocellar quartz leucogabbro is shown in Table 2 and Fig. 15 (anal. no. 8), which also present the composition of basic (an. nos. 1, 2, 5) and granitic rocks (an. nos. 10—13) from the Central Bohemian Pluton and from the Tyrone area Ireland, described by N. S. Angus (c. l.) — an. nos. 3, 4, 6, 9) labelled A_1-A_4. The rocks are arranged according to decreasing SiO_2. Group I comprises basites inclusive weakly ocellar rocks (an. nos. 3, 5); group II includes typical ocellar rocks and group III granitic rocks. The relationship between these three groups is also shown in diagrams 6—8.

In these diagrams, the ocellar rocks of the Central Bohemian Pluton and the Irish area are so strikingly identical in chemistry that, as already mentioned by N. S. Angus, their genesis can hardly be explained in different terms. As can be inferred from the QLM diagrams (Fig. 16), the granitic rocks of the two areas also seem to be analogous; their chemistry is uniform in the Central Bohemian Pluton. The basite group, however, displays higher variability, even within one area. Some members of the Central Bohemian Pluton are unusually rich in Mg, whilst those of the Tyrone area contain more Fe; some of them are virtually ferrogabbros (Fig. 17).

In both areas the ocellar rocks are of two types: rocks of the first type contain about 57 % SiO_2, corresponding thus to dioritic rocks and in the An-content of plagioclases to gabbroic rocks (IIa — an. nos. 6, 7); rocks of the second type are richer in SiO_2 (about 64 %) and correlate with quartz gabbroic and leucodioritic rocks (IIb — an. nos. 8, 9). These pairs appear as chemically related in all diagrams. Particullarly the rocks of group IIb, i. e. "leucogabbro" of M. Palivcová and N. S. Angus's "ocellar hybrid" are almost identical, apart from small differences in Ca and Na, which are levelled out. Although these ocellar rocks are highly inhomogeneous megascopically, their chemistry is surprisingly analogous also in the content of MgO, Fe_2O_3 and SiO_2 (Fig. 5). The rocks in the more acidic group IIa, that is "ocellar quartz gabbro" of V. Hanuš and M. Palivcová and "felsic diorite" of Angus, are also very near. Although the number of chemically analysed ocellar rocks is very small (no other analyses than those tabulated have been found in the literature) the agreement between the two pairs of such specific rocks is clear. In all petrochemical diagrams employed these pairs lie in similar position between basic and granitic rocks. Such a position is usually petrogenetically interpreted either as evidence of magmatic differentiation, according to the Bowen's scheme, or of hybridization in the sense of S. R. Nocklods (e. g. N. S. Angus 1971). A comparison of the FMA diagram (Fig. 17) with those by H. Roche Fig. 18a, b, shows that the position of ocellar leucogabbro between granitic and basic rocks is not regular. The ocellar quartz leucogabbro of the Central Bohemian Pluton together with the Tyrone ocellar hybrids clearly approaches the group of basic rocks in Fig. 8a, whereas it is strikingly shifted to the field of granitic rocks in Fig. 8b. If the SiO_2 content corresponding to free quartz is substructed from the Bohemian rock (an. no. 14), the composition is very near to that of the basic body (an. no. 5)), in the contact of which the analysed rock occurs. The irregular in diagram position between granitic and basic rocks — the same for rocks of different regions-speaks for Angus's metasomatic-hybrid interpretation of ocellar rocks under supply of SiO_2 better than for differentation scheme.

Table 2. Chemistry of original basites (I), ocellar gabbros (II) and adjacent granitoids (III)

	Group I (gabbro)					Group IIa IIb (ocellar gabbro)				Group III (granitic rocks)				
Serial no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Doc. no.	P_{122}	P_{168}	A_2	A_1	P_{13}	A_4	303/65	1/72	A_3	P_{162}	P_{136}	P_{154}	P_{160}	X
SiO_2	45,85	47,08	47,68	49,44	50,32	56,35	57,40	63,51	64,68	68,83	69,71	70,48	71,46	50,01
TiO_2	0,61	0,66	1,14	1,17	0,46	0,68	0,47	0,38	0,60	0,30	0,23	0,28	0,47	0,52
Al_2O_3	13,76	10,78	16,21	15,87	18,18	15,40	16,34	14,39	14,27	15,23	15,17	14,60	13,97	18,75
Fe_2O_3	3,03	2,66	7,36	3,23	2,58	3,34	1,54	1,76	1,34	1,97	1,83	1,67	1,29	2,41
FeO	6,53	7,13	7,77	6,22	4,41	4,80	4,03	3,18	3,45	1,79	1,31	1,56	2,08	4,36
MnO	0,21	0,17	0,20	0,17	0,13	0,20	0,14	0,12	0,13	0,10	0,07	0,07	0,12	0,16
MgO	13,09	16,61	5,29	8,35	6,55	5,51	5,16	4,04	3,91	1,06	0,56	1,12	0,94	5,6
CaO	11,70	9,36	9,75	11,08	12,11	8,11	10,29	7,36	5,35	4,25	3,19	3,03	2,08	10,1
Na_2O	1,75	1,48	2,00	2,11	2,50	2,22	2,30	2,40	3,22	3,66	3,36	2,90	3,20	3,29
K_2O	0,95	1,06	0,99	0,42	0,87	1,32	1,02	1,50	1,36	1,58	3,64	3,38	3,46	2,06
P_2O_5	0,16	0,11	0,06	0,10	0,12	0,08	0,08	0,10	0,07	0,20	0,22	0,14	0,16	0,18
H_2O+	2,13	2,65	1,89	1,90	1,42	1,84	1,29	0,96	1,59	0,66	0,53	0,42	0,53	1,37
H_2O-	0,16	0,28	—	—	0,34	—	—	0,25	—	0,19	0,23	0,14	0,20	0,34
	99,93	100,03	100,34	100,06	99,99	99,85	100,06	99,95	99,07	99,82	100,06	99,79	99,96	100,15

CIPW norm (after Wolff-Poldervaart 1950)

	1	2	3	4	5	6	7	8	9	10	11	12	13
Q	−9,90	−9,66	3,84	1,38	−0,18	13,09	12,19	22,58	23,06	30,66	28,86	32,76	33,42
or	5,56	6,67	6,12	2,22	5,56	7,79	6,12	8,90	7,79	9,45	21,68	20,01	20,57
ab	15,20	13,10	16,78	17,82	21,48	18,87	19,40	20,44	27,26	31,44	28,82	24,63	27,25
An	27,52	20,02	32,26	32,82	36,42	28,09	31,15	24,19	20,58	20,57	14,18	14,46	9,73
di	24,77	21,70	13,07	16,92	19,06	9,16	15,93	10,04	4,06	—	—	—	—
hy	30,83	42,92	13,55	19,64	13,16	14,63	10,73	9,54	22,26	4,02	1,93	3,85	4,64
mt	4,41	3,94	10,65	6,63	3,71	4,86	2,31	2,55	1,85	2,78	2,78	2,55	1,86
ilm	1,22	1,37	2,12	2,28	0,91	1,37	0,91	0,76	1,21	0,61	0,46	0,61	0,91
An % norm.	64	61	65	65	63	60	62	53	43	40	33	37	26

Table 2

1 — P_{122} Olivine-hornblende melagabbro; Podtochovice near Milín, Central Bohemian Pluton, anal. no. 28; 2 — P_{168} Gabbro-hornblendite" Milín (Bělč), Central Bohemian Pluton, anal. no. 117/74; 3 — A_2 initially hybridized dolerite (T_{291}); Craigballyharky, Tyrone, Ireland (N. S. Angus, 1971); 4 — A_1 uralite dolerite (T_{277}); Craigbardahessiagh, Tyrone, Ireland (N. S. Angus, 1971)" 5 — P_{13} weakly ocellar hornblende gabbro; Dubenecká hora near Milín, Central Bohemian Pluton, anal. no. 29/72: 6 — A_4 felsic diorite (T_{295}) of o xenolith; Craigballyharky, Tyrone. Ireland (N. S. Angus, 1971); 7 — 303/66 hornblende quartz gabbro; Draha near Smoletely, Central Bohemian Pluton (V. Hanuš—M. Palivcová, 1969), anal. nos. 42812, 44815, average; 8 — 1/72 quartz-rich hornblende leucogabbro" Dubenecká hora near Smolotely, Central Bohemian Pluton, anal. no. 111/74; 9 — A_3 ocellar hybrid (T_{279}), Craigbardahessiagh, Tyrone, Ireland (N. S. Angus, 1971); 10 — P_{162} biotite granodiorite; Alexandr shalft, 8th level, Vrančice near Milín, Central Bohemian Pluton, anal. no. 164/73; 11 — P_{136} biotite granite" Redětice shaft near Milín, Central Bohemian Pluton, anal. no. 211/72; 12 — P_{154} biotite granite; Radětice shaft near Milín, Central Bohemian Pluton, anal. no. 134/73; 13 — P_{160} biotite granite; Bytíz near Milín (road cutting), Central Bohemian Pluton, anal. no. 162/73; 14 — X hypothetical composition of hornblende gabbro, derived from leucogabbro, spec. no. 8 — 1/72 Dubenecká hora" after subtraction of 35 % vol. (i. e. 13.5 weight %) of SiO_2.

Discussion on the origin of ocellar texture of the quartz leucogabbro

In the literature, very different modes of origin have been ascribed to the ocellar quartz with rims: metasomatic-hybrid, relic-metamorphic, primary magmatic, xenocrystic (for details see the two papers cited below). The first two interpretation have recently been discussed on the example of ocellar basites

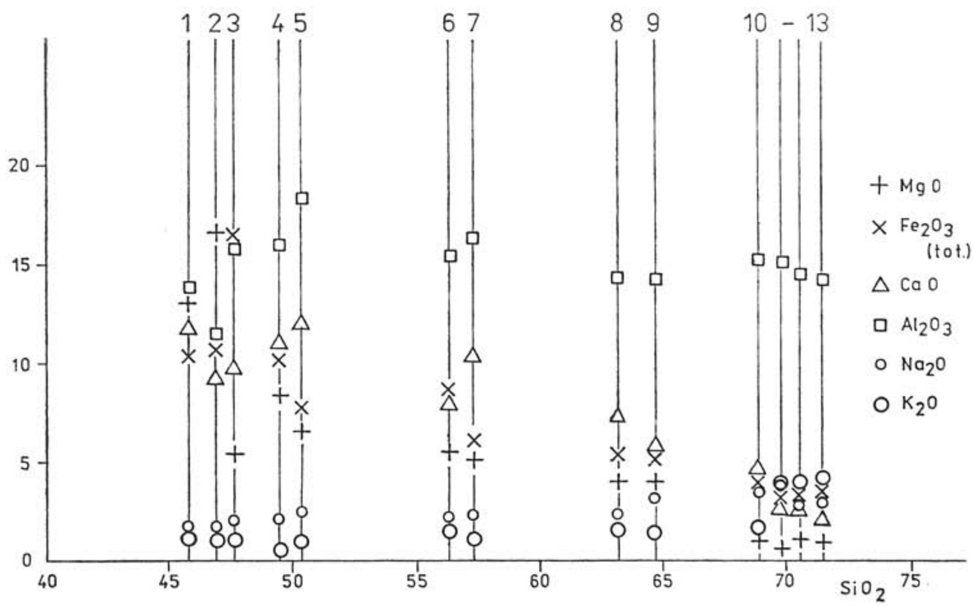

Fig. 15. Diagram of principal oxides relation to SiO_2; analogy between the ocellar gabbro pairs from the Tyrone area (6, 9) and the Central Bohemian Pluton (7, 8) is well seen. See Table 1. 1 — 5 basic rocks, 10 — 13 granitic rocks.

and diorites in the Tyrone area, Ireland (N. S. Angus 1969, 1971 – metasomatic hybrid explantion) and in the Central Bohemian Pluton (V. Hanuš and M. Palivcová 1979, 1974 – relic metamorphic interpretation).

The inerpretations mentioned above will be discussed on the example of ocellar quartz leucogabbro.

Metasomatic-hybrid interpretation (N. S. Angus 1969, 1971). Following reasons speak in favour of this interpretation: a) geological occurence of the quartz leucogabbro at the contact between basic and granitic rocks as it is the case in the Irish area and elsewhere b) at least two stage development of the rock: basic material on the one hand (relics of calcic plagioclases in dicordant orientation – Fig. 13, cores of hornblendes) and acid-alcalin leucocratic solutions took place in the formation of the quartz leucogabbro, c) the continusous transitions to the hornblende gabbros and progressive development of ocellar quartz inside of hornblende crystals, d) the analogy of mineralogical, petrographical and petrochemical character with Tyrone hybrids.

The source of solutions in Tyrone area is seen in acid fluids emanating from the granitic intrusive; the hybridization is the consequence of the interaction of basic volcanics with granitic magma (N. S. Angus 1971, p. 386).

On the other hand, the quartz leucogabbro of the Central Bohemian Pluton shows drawbacks and difficulties of the metasomatic-hybrid interpretation from the point of crystallization development of the ocellar rocks in general. The most relevant features are: a) two types of ocellar formations as shown on the Fig. 9 b) concentration of mafites preferentially in the rims of ocelli and the

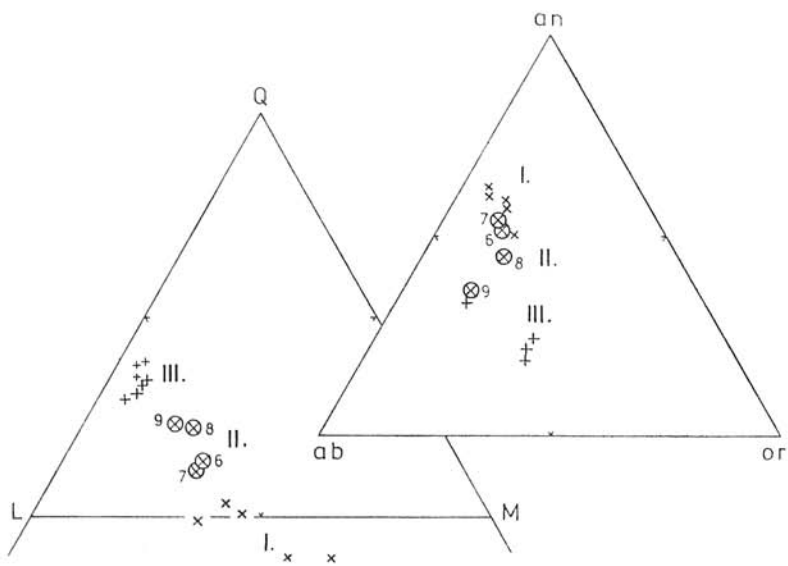

Fig. 16. Classification diagram QLM (after A. Poldervaart 1950) of ocellar quartz leucogabbro (no. 8) and associated rocks, and a normative fiagram or-ab-an of the same rocks. I – basic rocks (x), II – ocellar hybrid rocks nos. 6–9 in Table 2 (circles), III – surrounding granitic rocks (larger crosses – Central Bohemian Pluton, small crosses in diagram QLM – Tyrone).

coarse-grained character of the groundmass, c) heteromineral "cores" (filling?) of ocelli under preservation of inherited foreign crystallographic shape of ocelli, d) relic character of ocellar rims in felsic minerals e) crystallization relationships between the minerals in ocelli and those of the groundmass of the rock.

As the metasomatic-hybrid origin is the most accepted and elaborated one, these features will be discussed more thoroughly.

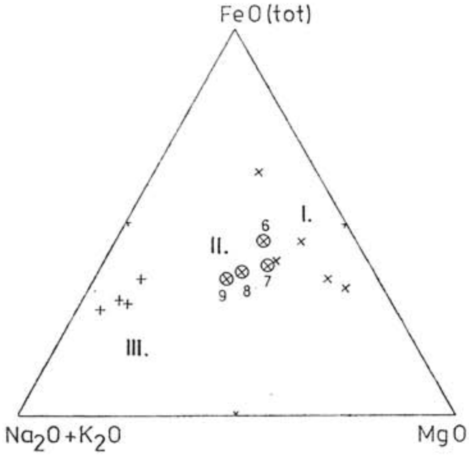

Fig. 17. Diagram FMA (FeO tot., MgO, alk.) of the rocks shown in Fig. 16.

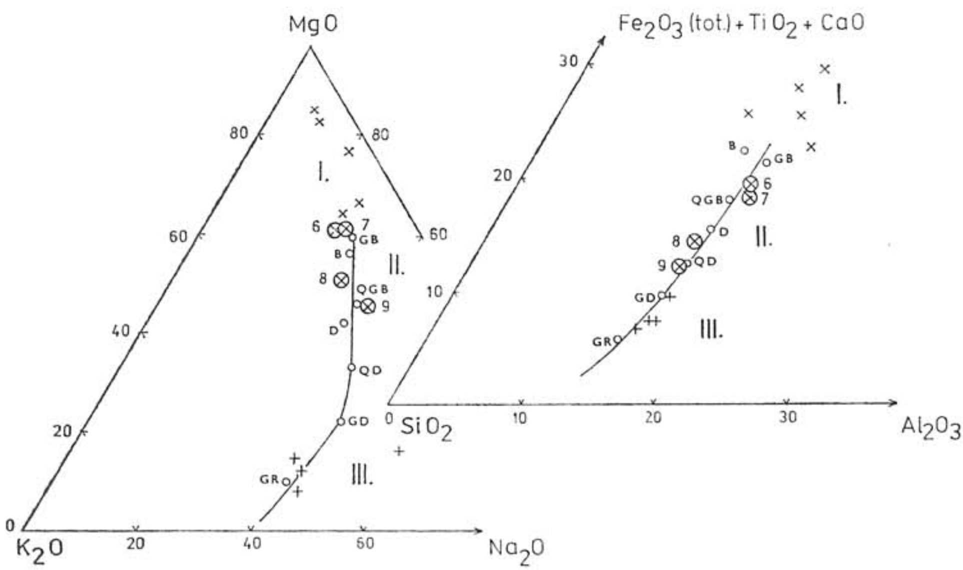

Fig. 18. Diagrams of $K_2O - Na_2O - MgO$ and of $SiO_2 - Al_2O_3 - Fe_2O_3$ tot. + TiO_2 + CaO (after H. de la Roche 1965). Positions of average igneous rocks (av. from several tens of analyses) are plotted (GR — granite, GD — granodiorite, D — diorite, QD — quartz diorite, QGB — quartz gabbro, GB — gabbro). For explanation see Fig. 16.

ad a) Leucogabbro contains ocelli constituted of quartz (Fig. 4, 6) and those constituted of microdioritic mass (Fig. 10, 11). Both of them are mantled with similar hornblende. Microdioritic ocellar formations are hard to explain. However they cannot be explained as initial stages of growths in the sense of N. S. Angus (1962) because they differ from the surrounding groundmass in the grain size, content of mafites and texture. The assumption that the ocelli are relics from the original basaltic rocks would lead to the conclusion that the whole mass of the coarse-grained quartz leucogabbro, including calcic plagioclase, is the product of recrystalization. This is the only way to explain its coarse-grained texture in this interpretation.

ad b) The concentration of hornblende to the rims of ocellar bodies (Fig. 2) suggests that these originated most likely in the place of mafites or material strongly enriched in mafic minerals; it seems improbable that the mafic material was present originally in the present-day plagioclasic portions of the rock, as the primary mafites must have been removed by plagioclases.

ad c—e) The explanation of the heteromineral cores of ocelli and the relic character of their rims (in quartz and potash feldspar) necessarily demands a very complicated mechanism of the metasomatic-hybrid process. One must presume several generations of the same metasomatic mineral and the development of the same crystallization relations to other minerals, as these (quartz--plagioclases, quartz-K-feldspar, felsic-mafic minerals) are analogous in the rock matrix and ocelli.

The difficulties connected with the interpretation of these relations are apparent even from N. S. Angus's excellent unbiased description of the rocks, which apart from negligible diversities, can also be applied to the ocellar rocks of the Central Bohemian Pluton.

Let us cite several examples (N. S. Angus 1962): „In the intial stage of hybridization (of the groundmass) quartz is in small interstitial crystals“ (p. 15), in the stage 2 „in relatively large poikilitic crystals“ (p. 16), in stage 3 „it is more uniform in its distribution, but retains a subpoikilitic relationship to plagioclase“ (p. 18); in altered ocellar hybrid with disrupted ocelli there is „the porphyroblastic quartz which shows a tendency towards coalescence with the interstitial quartz“ (p. 18). In the groundmass of the same altered rock „quartz is abundant interstitially and often forms poikilitic pools. .... Adjacent to potash feldspar, the quartz exhibits somewhat conflicting relationships. In many cases it is idiomorphic, but in others it is rounded or embayed and appears to have been corroded by the potash feldspar. Indeed as with the quartz ocelli thin veinlets of potash feldspar may be seen penetrating the interstitial quartz . . .“ (p. 19). „In the typical ocelli, plagioclase is completely displaced and it must be assumed that the Ca, Na and Al ions have migrated and transfused through the hornblende mantles into the surrounding rock“. (p. 23). „Surprisingly the ocelli do not appear to have been disrupted in any way during mobilization of the hybrid. .... the preservation in such a mobile medium is not readily explained, though it may possibly be attributed, in part, to the protective armour of the hornblende mantles“ (p. 24).“

It is evident that many of these Angus's observations allow contradictory conclusions: f. i. the rims of ocelli enable difusion of quartz and potash feldspar on the hand and serve as protective armour on the other hand; plagioclase phenocrysts occur together with plagioclase porphyroblasts of a near (andesinic) composition in the same rock. Particularly intricate are the relations of quartz to other minerals, mainly to potash feldspar in both ocelli and the groundmass. At least two generatins of idioblastic quartz and one xenomorphic (xenoblastic?) must be presumed: the earlier one represented by large ocellar monocrystal metacrysts, the later one as small crystals replacing together with potash feldpar the earlier one (Fig. 8, 9, 12; cf. Fig. 6a, b, p. 157 in V. Hanuš, M. Palivcová 1969), and the third one, interstitial in the groundmass (Fig. 9). Small idioblastic quartzes are developed in the groundmass potash feldspar, too (cf. N. S. Angus 1962, fig. 3 on p. 19). Large metacrysts (porphyroblasts) of ocellar quartz are replaced by potash feldspar penetrating them along fissures (cf. Fig. 3b, p. 151 in V. Hanuš, M. Palivcová c. l., and N. S. Angus the same fig.). As ocellar bodies were found disrupted by potash feldspar and quartz, coalescence of ocellar quartz and interstitial quartz of the rock matrix has been assumed by Anguss. Such a coalescence of ocellar quartz and matrix quartz is difficult to accept if ocelli — as often is the case — are built by subgrains of quartz which overlap the mafic ocellar rims.

It follows from N. S. Angus's description that all the different generations of quartzes as well as the potash feldspar should be interpreted as metasomatic. However the matrix quartz (the potash feldspar as well) is an interstital quartz among euhedral plagioclases forming the texture commonly interpreted as typical successive magmatic one. The same texture is characteristic of tonalitic, granodioritic as well as quartz-gabbroic rocks of the Central Bohemian pluton. Thus metasomatic origin should be considered for their development, too.

The relation of quartz and potash feldspar to mafites (hornblende, epidote, sphene) is also a similar matter of discussion in ocellar rocks and surrounding granitoids. In conclusion unusually strong metasomatic changes in several successive phases should be presumed to account for the origin of ocellar rocks in metasomatic-hybrid interpretation. M. Lehijärvi, A. Lonka (1964) strongly reject the possibility of the formation of porphyroblastic felsic minerals in a more basic rocks pointing out the low bounding-potential of such minerals, referred to by Szádecký—Kardosz.

Relic metamorphic interpretation (newly V. Hanuš, M. Palivcová 1969, 1974). This interpretation was based in the Central Bohemian Pluton mainly on the facts that a) the ocellar formations exhibit crystallographic shapes b) these shapes indicated by mafic rims are relic in the light minerals (quartz, potash feldspar) of the cores of ocelli c) the "cores" (filling) of ocelli are oligocrystalline and heteromineral d) there are no differences between the relations-and in consequence between the crystallization of minerals forming the ocelli and those forming the groundmass. The shapes of ocelli were interpreted as relic, inherited forms from pre-recrystallization stage (or earlier mafic minerals crystal shapes or amgdules).

Difficulties of this interpretation were discussed in N. S. Angus's comments (1971). The study of ocellar leucogabbro indicates that Angus's objections are true in many respects: the ocelli are a phenomenon connected with the gabbro-granite contact as in the Tyrone area; the accumulation of ocelli in the quartz leucogabbro is abnormal, their relic crystallographic shapes are distinct. Therefore the explanation given by Hanuš and Palivcová c. l. (olivine shapes or amygdules) cannot be accepted.

On the other hand the relic metamorphic interpretation of ocelli and ocellar rocks cannot be completely rejected. The idea of recrystallization process which reflects earlier textural as well as compositional pre-recrystalization changes (f. i, earlier metasomatic, hydrothermal alterations) is the only way in view of the present author that can explain contrary relations between minerals of the same character and elucidate complex crystalization history of the ocellar rocks, as discussed above. Assuming that the original basites were intrusive subvolcanics or volcanics (cf N. S. Angus 1971, p. 387) their aerlier metasomatic and hydrothermal changes had to be taken into account. At present they may be difficult to recognize particularly if remobilisation of the material (K. R. Mehnert and W. Büsch, 1966; N. S. Angus, 1962) were presumed.

One of the main objections to metamorphic recrystalization is the insufficient homogenization of minerals. It is stressed by N. S. Angus (1971) on the basis of the relics of calcic plagioclase and by Z. Vejnar (1975) on the basis of systematics changes of coexisting amphiboles and pyroxenes. This objection cannot be a serious argument as, in the opinion of the author, the problem of "neocrysts" an "recrysts" (i. e. recrystallized relics) is the most questionable and less investigated in the process of metamorphism.

Primary magmatic interpretation has been recently proposed by J. Fiala et al (1975). These authors suggest a primary magmatic origin for the ocellar quartz in the Pecerady gabbro. They regard quartz ocelli as phenocrysts of idiomorphic quartz (similarly as J. P. Iddings 1883 in basic rocks) which crystallized before mafites in gabbroic melt at low P_{H_2O}. The relic character of the ocelli shapes (in quartz and K-feldspar) as well as heteromineral composition of the cores is the main objection against this conception. Strong postmagmatic metasomatic changes disturbing primary crystallization should be assumed so that original crystallization path (if magmatic or metasomatic) cannot be reconstructed. Figs. 3,9 clearly indicate that primary magmatic phenocrystic interpretation is hardly acceptable in the case studied.

Xenocrystic origin of ocelli has a very strong argument: numerous examples of reaction rims of mafic minerals around quartz xenocrysts in basaltic rocks have been described and analogically around quartzose xenoliths in granitic rocks (D. L. Muir, 1953 and his references). However the crystal shapes of ocelli, the relic character of the rims as well as the remarkable connection with leucocratic material are not consistent with this interpretation. Subsequent recrystalisation into crystallographic forms and metasomatic changes should be accepted as in the foregoing case.

Anatectic (or hybrid anatectic) origin. A. Kahma (1951) described ocellar quartz at the contact of rapakivi granite and "diabase". The diabase is younger, intrudes the rapakivi granite and produces its partial anatexis and rheomorphism of hybrid material. Quartz ocelli are developed (similarly as megafeldspars) in the marginal portion of the diabase as well as in the hybridized granite. They are interpreted as quartzes derived from rapakivi granite and fully crystallographically developed during anatexis.

Such an interpretation of ocelli is one of the most plausible ones, and in agreement with experimental data about behaviour of granitic and basaltic melts. The following Kahma's observation is of particular interest: according to the author, anatexis and rhemorphism of granitic material which penetrates into diabase can totally obscur the true age relations between basic and granitic rocks; they may appear to be quite opposite.

Gabbro-diorite-granite series of the Central Bohemian Pluton is an analogue of such classical massifs as Adamello in Italy, Quérigut in Pyrenees, South-Californian massif and many others (M. Palivcová, 1962; F. Karl, 1967; V. Steinocher, 1969). Basic rocks of these plutons are commonly considered as the oldest members of the series. Therefore the anatectic interpretation could be accepted under following presumptions only: a) granitic rocks are magmatic and are able to exert a partial anatexis on gabbroic rocks – a conception which is not commonly accepted on experimental grounds, b) or the geological relations of basic and acid rocks are apparent and should be revised from the point of view of Kahma's hypothesis. It is clear that such conception sub b) would be revolutionary for the Central Bohemian pluton. All three occurences of basic bodies discussed in the paper represent examples where gabbroic rocks have been held for older than granitic rocks on the basic of field investigations. This was the reason why the anatectic interpretation of ocellar-rocks was rejected in the first approximation. However, a recent paper of P. Vlašimský (1973) has shown that the age of basic bodies in the Central Bohemian pluton is still debatable.

Thus the only conclusion can be drawn from the discussion above that none of the existing hypotheses can explain the origin and development of the ocellar quartz leucogabbro (and of the ocellar rocks of the pluton in general) without reservation. The interpretation of ocellar rocks at the gabbro-granite contact is difficult as it concerns one of the most complicated aspect of petrology – the relation and mutual reactions of granitic and basic rocks in plutonic complexes. Ocellar rocks have been found by the present author to accompany "chilled" contacts of basic xenoliths and rocks. They represent only another side of the same problem which D. H. Blake et al (1965) and newly Th. Vogel and B. M. Walker (1975) try to solve using the hypothesis of contemporaneity of granitic and basic magma. Athough the origin of ocellar formations may be polygenic, it seems unlikely that it is quite different where they occur in an analogous association of basites and granitoids. N. S. Angus's comments (1971) suggest a similar opinion.

The occurences of ocellar gabbroic and dioritic rocks are probably more frequent than referred to in the literature as owing to their inconspicuous appearence and similarity with the normal basic and dioritic rocks they often escape attention. Futher investigations of their occurences are needed to get a deeper insight into the genesis of these enigmatic rocks.

Acknowledgement: The author wishes to express her thanks to Dr. A. Dudek, CSc. for stimulating comments, to Mrs. Zárubová for translating the paper, to Mrs. Kernerová for drawing the pictures and to Mrs. Matějková for photographs.

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Review by L. KAMENICKÝ Manuscript received June 30, 1976.