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PETROGENESIS OF ANATECTITE-GRANITES AND MIGMATITES

(Figs. 2)

Abstract: Structural-petrologic study of granitoids and migmatites of the Belomorian polymetamorphic complex allowed us to separate three groups of stages and to determine that the early stage of ultrametamorphism (3.0 b.y.) originated under conditions of granulite facies, the second stage (2.8 — 2.7 b. y.) in the amphibolite facies of high pressure and the third stage (2.0 — 1.9 b.y.) in low temperature subfacies of the amphibolite facies af increased pressure. The analysis of chemical composition — a pair leucosome- melanosome of migmatites and granitoids of all three stage groups allow us to enclear on the basis of 4^{x}-structural diagram albite- anorthite — orthoclase — quartz — (water) that among migmatites and granitoids rocks of non anatectic origin prevail and correspondingly the anatectic migmatite — granite formations take origin especially during the third stage and they are confined to the zones of faults as well as to the crests of open folds of the deformation cycle and at the same time, in rocks of anchigranite structure.

Резюме: Структурно-петрологическое изучение гранитоидов и мигматитов беломорского полиметаморфического комплекса позволило расчленить их на три возрастные группы и установить, что ранний этап ультраметаморфизма (3,0 млрд. лет) происходил в условиях гранулитовой фации, второй этап (2,7 — 2,8 млрд. лет) — в амфиболитовой фации высокого давления и третий этап (2,0 — 1,9 млрд. лет) — в низкотемпературной субфации амфиболитовой фации повышенного давления. Анализ химического состава пар лейкосома — меланосома мигматитов и гранитоидов всех трех возрастных групп на основе 4^{x}-компонентной диаграммы Альбит-анортит-ортоклаз-кварц (вода) позволяет выяснить, что среди мигматитов и гранитоидов преобладают породы неанатектического происхождения, а собственно анатектические мигматит-гранитные образования возникают главным образом на третьем этапе, локализуются в замках складок и в зонах вязких разрывов, причем в породах анхигранитного состава.

The problem of the generation of granitoid magmatic rocks remains actual yet in magmatic and metamorphic petrology. The authors have performed a petrological study of granitoids and migmatites of the deeply-eroded Archean massif in the eastern part of the Baltic Shield and obtained some new data which seem to contribute to the pattern of ultrametagenic processes of granite formation.

The Belomorian polymetamorphic gneiss and migmatite complex, as the structural-petrological investigations by O. I. Volodichev, M. M. Stenar, V. L. Duck indicated, had been originally affected 3.0 b.y. ago by the regional metamorphism during granulite facies of intermediate by pressure (6.0—6.5 kbar, 700 °C). Subsequently, in the time range 2.8—2.7 b.y. the whole thick (7—8 km) gneissic series had suffered repeated folding and regional migmatization and granitization in the thermo-dynamic environment of almandine amphibolite facies of high pressure (9—10 kb, 650—700 °C). Later, at the third deformational-metamorphic stage (dated to 2.0—1.9 b.y.) the Belomorian

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complex of migmatized gneisses has been subjected to the rheomorphism to form granite-migmatite tracts, fissure intrusions of granite-aplites and pegmatites (including commercial mica-bearing ones) connected with zones of tectonic displacements. The conditions of the metamorphism corresponded to garnet — cyanite — biotite — muscovite subfacies of a higher pressure (7.5—8.0 kbar, 580—650 °C).

Both the earlier and the repeated migmatizations show irregular character. A fair assessment of the migmatization scale can be made in exposures by estimates of proportions of substratum rocks, generally modified to some extent during the migmatization (paleosome or melanosome), and the new-formed quartz-feldspathic material (neosome or leucosome). In the field such an arduous procedure is usually neglected, and the scale of the migmatization is a visual estimate of morphologic migmatite types (Fig. 1). This morphologic classification developed by K. A. Shurkin (1957) takes into account not only a distribution pattern of the leucosome within the substratum, the scale of its reworking and tectonic environment during migmatization, but to a certain degree reflects genetic features of the migmatites.

According to modern conceptions the latter can originate in several ways: 1. By the penetration of a granitoid melt into tectonic fissures or along the schistosity of the substratum (injection migmatites); 2. by the metasomatic feldspathization of the substratum along the mechanically weak zones or by its dispersed-intergranular granitization (metasomatic migmatites); 3. during the crystallization-metamorphic differentiation of the substratum matter to form separated leucocrate components (segregated migmatites or venites) and 4. as a result of intimate interrelations between the processes of metasomatosis, crystallization differentiation and anatexis of the substratum giving rise to its reworking under conditions of ultrametamorphism which is commonly simultaneous to folded (in bedded rocks) and disjunctive (in brittle rocks) dislocation (ultrametagenic or heterogeneous migmatites).

The study of the Belomorian gneiss-migmatite complex was intended to reveal a pattern of dominant migmatite-forming processes at each of the three stages of the ultrametamorphism mentioned above and also to determine a genetic nature of the granitoids occurring in nebulites as small homogenous bodies with diffusive margins.

Field observations indicate that migmatites of different morphologic types within the domains of low and moderate degree of migmatization are of mainly metasomatic origin, and in migmatites of high gradient metamorphism some varieties showing features of the injection and sometimes of the lateral segregation genesis are locally recorded. But within the higher metamorphosed domains the ultrametagenic migmatites are distinctly prevailing, for which the dominant petrogenic role of any process of the leucosome formation is not established. In thin section all the morphologic migmatite types are characterized by blastic textures complicated by the corrosion development of minerals in the succession: plagioclase — microcline — quartz (± muscovite), it is to emphasize that leucosome does not show features of magmatic crystallization even in distinct injection minerals. Earlier this evidence allowed N. G. Sudovikov (1937) to conclude that the Belomorien complex of migmatites and granitoids had been formed in the course of regional granitization, related to endogenous siliceous-alkaline solutions. Such a concept

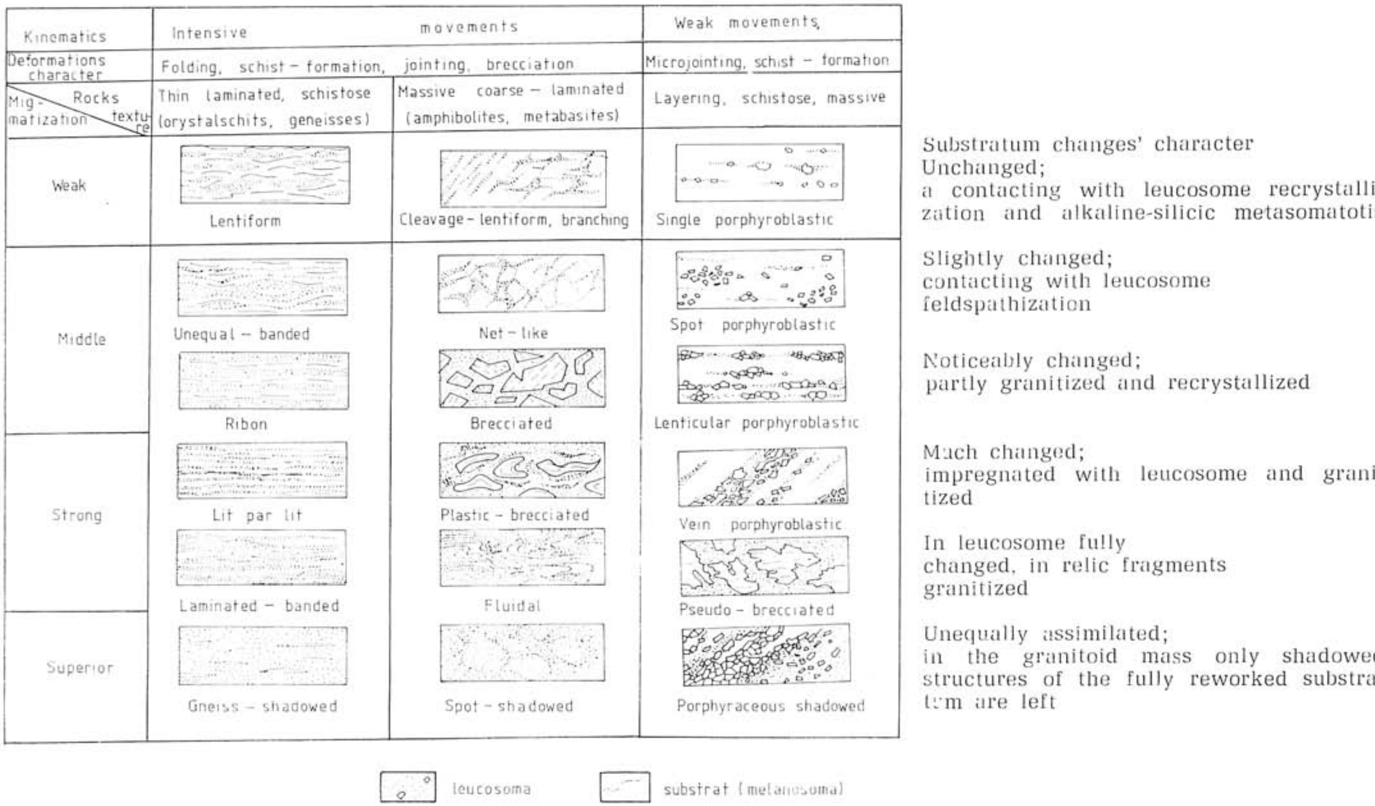

Fig. 1. Morphological types of migmatites.

principally agrees with the famous ideas of D. S. K o r z h i n s k i y (1952) about „through-magmatic solutions" releasing from the Earth interiors and resulting in the infiltration granitization of the crustal rocks.

However, the ideas of some authors about the crustal derivation of migmatite-granite associations by the interior mobilization of the granitoid material during the ultrametamorphic processes of the Belomorian volcano-sedimentary series itself seems to be more preferable.

Yet in the course of elaboration of the morphologic migmatite classification (S h u r k i n, 1957) geologic-petrologic data were obtained that indicated to the existence of two genetic types — magmatic allochthonous and metasomatic autochthonous, among the migmatite-granites of the Belomorian complex.

Physico-chemical analysis of both types based on the experimental Ab — Or — Qu — H_2O system after O. T u t t l e and N. B o w e n have shown that the first type migmatites inspite of the absence of the structures of magmatic crystallization due to the autometasomatic reworking, are characterized by the anchieutectic normative mineral composition whereas the composition of the second type migmatites exhibits wide variations in terms of triple system due to the above-eutectic content of quartz, plagioclase or microcline in most samples (P o l k a n o v et al., 1963). Taking into consideration the possibilities of using normative quantitative mineralogic parameters as indeces of phase relationships and thermodynamic conditions of the leucosome formation, several pair samples of leucosomes and melanosomes of allochthonous and autochthonous granitoids of different age were collected by T. F. Zinger. The calculated CJPW norms were recalculated to coordinate of 4-componental system of Ab — An — Or — Qu — H_2O with $P_{tot} = P_{H_2O}$ 0.5 — 3 kbar (Fig.2).This system is developed by E. I. K r a v t z o v a (1974) on the basis of the synthesis of the experimental data on melting-crystallization of 2—3 components systems and rather well reflects the compositions of real granitoids. The direction of the replacement (trend) of a point of the leucosome composition relevant to its pair melanosome can give evidence on the genetic features of migmatites. A displacement of leucosome into the field of the ancheutectic compositions, i.e., according to the theoretically predicted or experimentally determined trend of melting from the given substratum of granitoid melt, provides strong evidence for physico-chemical control of the phase relationship in the system melanosome-leucosome. A deviation of the leucosome composition from the anchieutectic composition in such a pair suggests that this leucosome was not formed by the process of anatexis.

Relict leucosomes in kyanite — garnet — biotite gneisses of the first metamorphic stage in teared off crests of minor isoclinal fold are represented by the fine-grained quartz-feldspathic and often by the garnet — and pyroxene-bearing material. In all cases the trend analysis of pair samples of such migmatites has not shown any anatectic pattern in the change of their compositions. It suggests that these high aluminous rocks had not been subjected to the selective anatexis at the granulite facies metamorphism, and their leucosome has been formed as the result of the metamorphic differentiation with the confinement to crests of folds where relatively low pressure occurred in the course of deformations.

At the second stage the ultrametamorphic processes under conditions of amphibolite facies of higher pressure were most intensive troughout the Belomorian gneisses. As is indicated by the structural analysis, the generation of ultrametagenic granitoids is recorded only since the formation of tight isoclinal folds. In addition, it was established that aluminous gneisses of cyanite — garnet — biotite composition had suffered recrystallization with integration of grain during migmatization. The leucosome comprises 20 — 30 per cent of rock volume and is predominantly represented by quartz-plagioclase material. In the intercalated amphibole -biotite gneisses the leucosome amount icreases up to 60 — 80 per cent and it commonly contains microcline. Trend analysis of pair samples of migmatized aluminous gneisses has shown a dispersed pattern of points of the leucosome composition and their

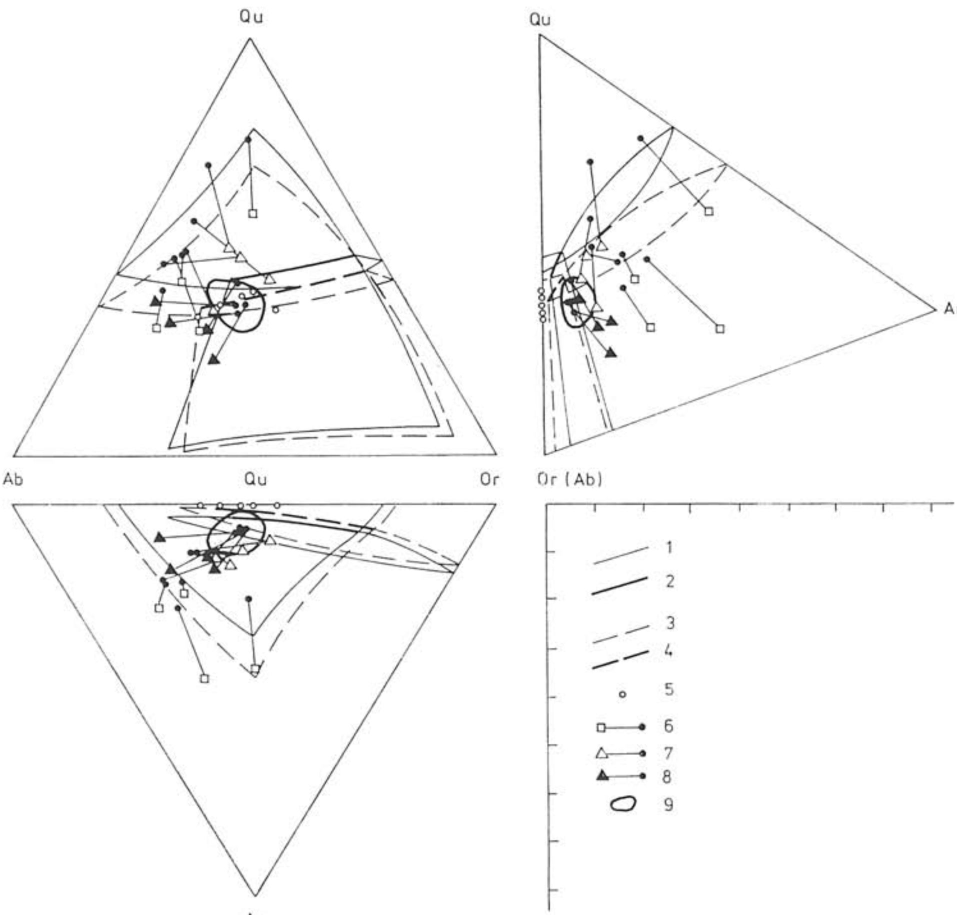

Fig. 2. The evolvent of the 4-component system Ab-An-Or-Q (H_2O) Crystallization surfaces (1) and cotectic line (2) under P_{H_2O} 0.5 kb; 3 and 4- accordingly under 3.0 kb; 5 — M points under P_{H_2O} from 0 to 3.0 kb; melanosome — leucosome (point): 6-migmatites of the non-anatectic (1 stage), 7 — also (2 stage), 8 — of the anatectic (3 stage); 9 — the field of the compositions 50 % out of 28 analysis.

inconsistency to the anatectic model of migmatite generation. At the same time, the normative leucosome compositions in garnet- and amphibole-bearing gneisses demonstrate a compact concentration within the coordinates of anatectic melts. Thus, a direct dependence of intensity of ultrametagenetic granite- and migmatite-forming processes and genetic nature of these rocks upon composition of an original substratum is recognized.

Finally, in the study of migmatite domains belonging to the third ultrametamorphic stage it was established that the maximum degree of migmatization and autochthonous granite generation are confined to the zones of faults as well as to the crests of open folds of this deformation cycle, i.e. the processes of the ultrametagenic granite formation are locally controlled. The pair trend anlysis has indicated that in this case in aluminous gneisses the leucosome of the preceding stage had suffered isochemical recrystallization and sometimes selective melting, and the leucosome of the biotite gneisses had been subjected to the rheomorphism having been separated as small masses of plagio-microcline granitoids of autochthonous and sometimes of allochthonous occurrence.

On the diagram (Fig. 2) the points of normative composition for these granitoids form a cluster within cotectic coordinates close to those of the original substratum, i.e. it is the case of the complete diatexis.

In conclusion it is necessary to emphasize that the trend physico-chemical analysis of the granite-migmatite associations has shown the following: 1. the dominance of the migmatite-forming processes of the non-anatectic nature, 2. the confinement of the anatektitegranites to the domains which exhibit the maximum development of the ultrametamorphic processes and 3. that the generation of the palingenic granitoid magmas within the Earth crust under conditions of the amphibolite facies regional metamorphism is connected first of all with the diatexis of the earlier metasomatically migmatized rocks and gneisses originaly closed in their composition to granitoids.

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