LAYERING IN THE BASIC AND ULTRAMAFIC SMALL BODIES FROM THE MUREŞ OPHIOLITIC SUTURE, ROMANIA

HARALAMBIE SAVU

Geological Institute of Romania, 1 Caransebeş St. 012271, Bucharest 32, E-mail geol. @ igr. ro

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In the basic and ultramafic small bodies from the Mureş ophiolitic suture the layering process manifested itself like in the big intrusions of the sort, but at a small scale. It occurred like a rhythmic process, in which the crystallization of leucocratic minerals (plagioclase) alternates with the crystallization of the melanocratic minerals (pyroxenes, olivine, magnetite). Usually, the iron minerals (V-Ti-magnetite, ilmenite) concentrate at the base and on the margins of the small intrusions, forming there a special layer. The alternating leucocratic and melanocratic layers usually are variable in thickness, suggesting that not only the rhythmic crystallization determines the layering phenomenon. It must be influenced at the same time by the vapour tension in the tholeiitic intrusions, a process more evident in the gabbro bodies, in which the vapour tension was higher than in the ultramafic ones. Thus, the layering process was controlled by two main factors: the rhythmic crystallization and the vapour tension.

Key words: layering process; rhythmic crystallization; vapour tension, layered structure.

INTRODUCTION

The layering process was known since the beginning of the 19th century, as a process of pseudostratification, in which the layers were regarded as strata (see Phillips[1]; Hitchcock[2]). Later on Wager and Brown[3] studied the layering phenomenon in the classical big bodies of gabbros from different continents, establishing the terms of this process. But the layering process occurs also, at a small scale, in the small bodies of basic (gabbros) (Giuşcă, Cioflica[4]; Cioflica, Savu[5]; Savu *et al.*[6]) and of ultramafic rocks bodies (Savu[7]; Savu *et al.*[8)] from the Mureş ophiolitic suture.

In the present paper I tried to realize a synthesis on the layering process occurring in the basic and ultramafic small bodies from the Mureş ophiolitic suture, which differ from one another both by size and structure. On this purpose there was presented further down a characteristic layered body for each category of basic and ultramafic bodies from this ophiolitic suture.

OCCURRENCE OF THE BASIC AND ULTRAMAFIC BODIES IN THE MREŞ OPHIOLITIC SUTURE

The Mureş ophiolitic suture occurred as a result of the closing of the Mureş Ocean. The evolution of this ocean started by the beginning of the Liassic (ca. 180 Ma, Herz *et al.*[9]), after a period of continental rifting, which was manifesting itself since the end of the Triassic. The Mureş Ocean was situated on an area corresponding to the actual Transylvanian domain, and extended toward northeast through Maramureş, where olistoliths of ophiolitic rocks are present in the flysch formations (Bombiță, Savu[10]), and through Carpathia to meet the Carpathian Ocean, and toward southwest through Banat to unite with the Vardar Zone in Serbia (Savu[11]). Although there are evidences of its northeastern junction with the Carpathian Ocean, yet in some new maps this connection is not represented, because it was disturbed by some faults and covered by recent deposits, so that it is not evident.

The Mureş Ocean occurred due to a spreading process, that lasted up to the Upper Jurassic (Oxfordian), when there started its closing by a bilateral subduction process, determined by the concomitant subduction of the Apuseni Mountains and the Transylvanian convergent plates under the median zone of the ocean (Savu[12]). By the collision of these two plates there resulted the actual Tisa Plate. The bilateral subduction engendered in the Mureş Ocean a northern Mariana-type island arc and a southern Andean-type island arc.

By the bilateral subduction a huge slab of ocean crust, an olistoplate, was obducted from the median zone of the Mureş Ocean (Fig. 1), so that the Mureş ophiolitic suture resulted there.

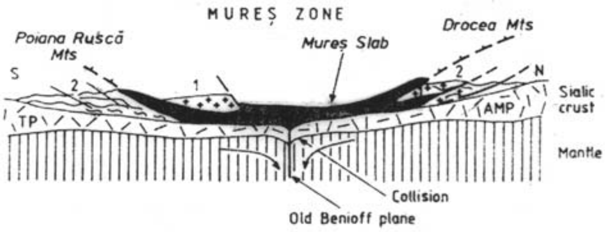

Fig. 1. Model to show the position of the obducted ophiolitic megaslab in the Mureş ophiolitic suture and its tectonic changes after obduction (not to scale). 1, ophiolitic megaslab in black; 2, volcanics from the southern Andean-type volcanic arc; 3, Tithonian-Neocomian flysch deposits with Late Kimmerian volcanics from the northern Mariana-type island arc; 4, Barremian-Aptian deposits; AMP, Apuseni Mountains Plate; TP, Transylvanian Plate.

The megaslab of ocean crust obducted from the Mureş Ocean, was formed of ocean floor basaltic rocks, including basic and ultramafic small bodies, island arc volcanics and oceanic sedimentary deposits (Fig. 2).

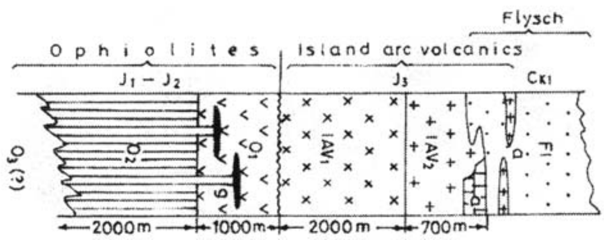

Fig. 2. Litho-stratigraphic column showing the complexes of ocean floor and island arc rocks from the obducted megaslab. Fl. Flysch deposits and island arc volcanics; IAV_2, island arc leucocratic volcanic complex; a, Upper Jurassic-Lower Cretaceous reef limestone; IAV_1, island arc basaltic complex; unconformity; O_1, ocean floor pillowed basalt complex; O_2, sheeted dyke complex; O_3, the missing (unobducted) gabbro-peridotite complex.

The consanguineous intrusive small bodies from the ophiolitic suture consist of gabbro and ultramafic rocks. Both types of intrusive bodies show processes of layering more or less evident. According to their form, the small gabbro bodies from the Mureş ophiolitic suture have been separated into three categories, as follows: 1, sills (intrusive sheets); 2, layered big dykes; 3, laccolite-like bodies.

LAYERING IN THE CĂZĂNEŞTI-CIUNGANI SILL

The Căzăneşti-Ciungani sill, or the intrusive sheet according to Giuşcă and Cioflica[4], represents the only structure of the sort in the Mureş ophiolitic suture. It was discovered by means of drillings. Later on the sill was thoroughly described by Cioflica[14]. This sill extends from Sorbu Valley eastward up to the Furu Valley on a length of about 4 km and a width of 1.5 km, showing a thickness of more than 300 m in its central part and of 180 m on the margins. In its structure the quoted authors separated three horizons (layers) of gabbros. These are the diopside gabbro, the magnetite gabbro and the preponderant dolerite horizons, to which Cioflica[14] added the beerbachite horizon, which represents, in fact, a basic hornfels zone, as compared with that from the Almăşel gabbro body (see Savu[15]).

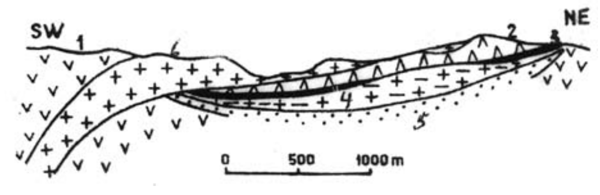

Fig. 3. Structure of the Căzăneşti-Ciungani sill (data from Giuşcă and Cioflica[4], revised). 1, pillowed basalts complex; 2, diopside gabbro horizon; 3, discontinuous V-Ti-magnetite gabbro hoizon (in black); 4, dolerite horizon; 5, the basic hornfelses zone; 6, Pietroasa granodiorite intrusion (Late Kimmerian).

1. The upper diopside gabbro horizon shows a thickness of about 100 m in the central part of the sill and of only 25 m on the margins. It represents the most part of the sill mass and consists of plagioclase (bytownite) and diopside, without any magnetite. The component rocks show a medium granulation. Often, there occur transitions from the diopside gabbros to leucogabbros and even to anorthosites, which are occurring as schlieren.

2. The intermediate magnetite gabbro horizon occurs only on the margins of the sill, being located between the diopside gabbro and the dolerite horizons. The maximum thickness of this

horizon is of 40 m. It consists mostly of Sorbu magnetite gabbros, magnetite hyperithes, rarely magnetite olivine gabbros, olivine gabbros and hyperites. On the northern margin of the sill there occurs a structure very characteristic for the layered gabbro bodies, in comparison with the southern margin, where the gabbro body is more homogeneous. There, at the base of the horizon, a magnetite hyperite layer of 25 m thick occurs, which at the upper part passes to the Sorbu gabbros and hyperithes without any magnetite. Toward east the magnetite hyperithe passes upward to both Sorbu gabbro and hyperites without any magnetite. In the central part of the sill the Sorbu magnetite gabbro and the magnetite hyperites disappear, their place being took by the augite gabbro, which still preserves the structural characteristics of the magnetite gabbro horizon (Fig.3).

The southern margin of the sill mostly consists of Sorbu gabbro, which presents numerous schlieren and some lenses of pegmatoid gabbro and albite granophyres, probably of trondhjemitic nature, like those from the Juliţa gabbro body (Savu *et al.*[16]).

The rocks from the magnetite gabbro horizon consist of labradorite, augite and magnetite, sometimes hyperites being associated with. Often, within this horizon more feldspathic and more melanocratic thin layers occur.

3. The lower preponderant doleritic horizon shows a variable thickness, it being of about 120 m in the central part of the sill and only of 10-20 m on the margins, where this horizon get more and more thin. In the central part of the sill this horizon supports the diopside gabbro horizon, whereas on the margins it is intercalated between the magnetite gabbro horizon and the basic hornfelse zone from the base of the sill. This horizon presents a large variation both in the structure and the mineralogy. Thus, on the northern margin there occur olivine gabbro and augite gabbros, which toward the lower part show transitions to rocks with a troctolitic composition. Often, with these rocks norites, hyperstene dolerites and hyperstene magnetite dolerites are associated.

4. The "beerbachite horizon" which was considered by Cioflica[14] as a marginal microgabbro facies of the sill, represents, in reality, a basic hornfels zone, determined by the high temperature of the intruded sill, which at the contact with the surrounding cold pillowed basalts should have been of 700° to 800° C (see Savu and Udrescu[17]). It mostly consists of a very fine isometric granular basic hornfels, sometimes passing to rocks with a higher granulation, with aspect of a micrgabbro, formed of fine crystals of plagioclse, pyroxenes and magnetite.

LAYERING IN THE GABBRO DYKE OF ALMAŞ SELIŞTE

Within the Mureş ophiolitic suture there are two gabbro bodies showing a form of big layered dykes, like the Almaş Selişte, which is presented further down, and the Almăşel gabbro body (Savu[15]), from which the most characteristic is the first one. The big gabbro dyke of Almaş Selişte is situated approximately in the central part of the Mureş ophiolitic suture. Savu discovered this gabbro body in 1953 (unpubl. rep.), then, its structure and petrographic facies were investigated by drillings (Cioflica and Savu[5]). Savu *et al.*[6] studied the gabbro dyke from the structural and geochemical points of view.

The gabbro dyke was intruded into the ocean floor pillowed basalt complex of the Mureş ophiolitic suture (see Savu[12]). The dyke is oriented on the NE-SW direction, being of 2.6 km long and of maximum 1 km width. By its structure it looks like a swollen dyke (Fig. 4).

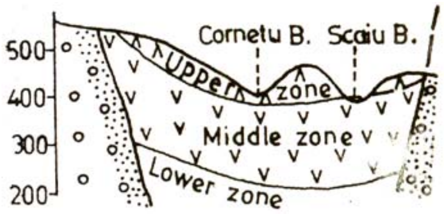

Fig. 4. Geological section showing the inner structure of the Almaş Seliste gabbro dyke and its basic hornfelses at the contact with the pillowed basalt complex.

In the structure of the dyke there have been separated three main zones the thickness of which is different (Fig. 4).

1. The upper zone is formed mostly of leucogabbros and anorthosites with gabbro intercalations (Savu *et al.*[6]). The anorthosites consist of about 90 % plagioclase (An_{55}) and a little clinopyroxene, titanite, rutile, magnetite and ilmenite. The late magmatic solutions from the deuteritic stage determined the formation of an andesine (An_{34}) zone around of the plagioclase crystals and the substitution of clinopyroxene by secondary minerals, especially a deuteric hornblende. The rare thin layers occurring in this zone consist of plagioclase (An_{55-48}), diopside replaced by the deuteric brown-greenish hornblende, on which a bluish hornblende and actinolite were formed.

2. The middle zone of the dyke is very characteristic for the rhythmic layering phenomenon. In its structure four horizons have been separated: (a) an upper horizon formed of gabbros with thin layers of leucogabbros, including diopside and quartz gabbros and hypersthene gabbros; (b) then, there followed in the depth three horizons, which form a structure with rhythmic layering, the concavity of which being upwards (Fig. 4). The horizons of the middle zone present thin layers of rocks varying both in structure and composition, they being formed of dolerites, hyperstene gabbros, hyperites, V-Ti- magnetite gabbros (5–15% magnetite) etc. The gabbros from these horizons consist of 50 % plagioclase (An_{52}), but in some schlierens they tend to enrich in pyroxenes and brown-greenish deuteric hornblende, the last mineral occurring also on the rocks fissures. Other schlierens from these horizons are formed of pegmatoid gabbros.

The rocks from the three rhythmic layered horizons differ from other gabbros by the more elongated aspect of the plagioclase crystals and the divergent structure. The xenomorphic diopside crystals present pigeonitic exsolutions on the cleavage. The V-Ti-magnetite is also xenomorphic and presents ilmenite exsolutions.

3. The lower zone of the dyke is more homogeneous, as it consists of diopside gabbros, in which rare layers of hyperithes and magnetite gabbros can be observed.

It is noteworthy to show that the ocean floor pillowed basalts hosting the gabbro dyke have been thermally metamorphosed at the contact. They have been transformed into basic hornfelses (beerbachites) with the following general mineral assemblage: plagioclase(An_{55})-clinopyroxene (hypersthene)- deuteritic amhibole-magnetite. This mineral assemblge was formed under the conditions of the hornblende facies (see Winkler[18]) at about 700°C, a temperature established by Savu and Udrescu[17], by means of the Buddington *et al.*[19] Fe_3O_4 -FeO-Ti O_2 system, for the gabbroic body genesis. It is also of note that the mineral assemblages from the hornfelses are consistent with those from the gabbro body, since both of them include the deuteritic brown-greenish hornblende.

The basic hornfelses formed around the gabbro bodies in the rocks of which a deuteritic hornblende is not present, it is missing from their basic hornfelses, too, as it results from the following assemblages of the Almăşel gabbro body (Savu[15]):

1. Plagioclase-diopside (hypershene, olivine)-magnetite, in the gabbroic rocks.
2. Plagioclase-diopside hypersthene-magnetite, in the basic hornfelses

LAYERING IN THE LACCOLITE-LIKE GABBRO BODY OF JULIȚA

The gabbro body of Julița (Savu *et al.*[16]) is situated in the western part of the Mureş ophiolitic suture, namely, in the zone of the sheeted dyke complex, being intruded on the roof of this complex. It was cut by the DN7 Highway, so that the rhythmic layering (Fig. 5) from its base was uncovered during the road construction. The body has a shape of E-W elongated laccolite. Close shapes and structures to that of Julița body show also the gabbro bodies of Cuiaş-Toc, Banieş Valley and the Buneşti body from the eastern part of the Mureş ophiolitic suture.

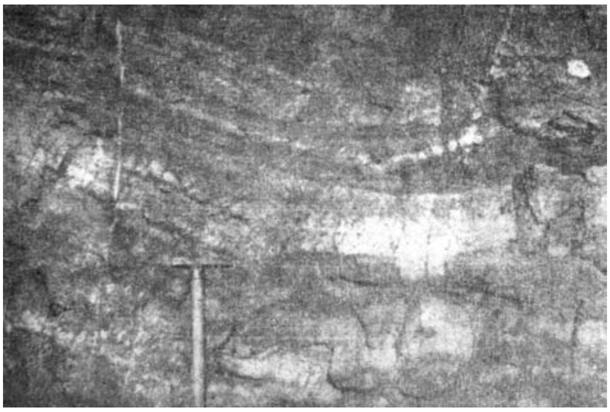

Fig. 5. Photograph showing the rhytmic layering in the base of the Julița gabbro body, occurring along the DN7 Highway. Remark the varied thickness of the layers.

In the structure of this gabbro body two main horizons have been separated: a lower and an upper horizon (Fig. 6). The lower horizon is better cropping along the DN7 Highway and at the mouth of the Dâmbovița Creek. This horizon is characteristic for the rhythmic layering (Fig. 5) in the meaning of Wager and Brown[3]. The rocks of this horizon generally show an ophitic texture, consisting of a network of elongated plagioclase crystals (An_{54-60}) and melanocratic minerals, It consists of diopside gabbros, hyperites, pegmatoid gabbros, gabbrodolerites and dolerites which alternate in the rhythmic structure. The rocks from the rhythmic layering differ from one another by the following features: 1, some of them are more leucocratic, being richer in plagioclase crystals;

2, other rocks are more melanocratic , being richer in pyroxenes, magnetite and sometimes olivine often substituted by bowlingite and iron oxides.

Fig. 6. Structure of the Juliţa gabbro body (not to scale). 1, sheeted dyke complex; 2, contact zone; 3, lower horizon with rhythmic layering; 4, upper horizon of diopside gabbros; 5, roof remnants.

Over the lower horizon there develops an upper one, which is rather homogeneous as regards its structure. It is about 200 m thick. This horizon consists of numerous types of gabbros, such as olivine gabbros, hyperites and V-Ti-magnetite gabbro, as well as thin separations of pegmatoid gabbros.

In the central part of the gabbro body the upper horizon is covered by dolerites and anamesitic rocks, associated with basic hornfelses, intruded by several gabbro sills as remnants from the body roof. The basic hornfelses represent the products of the contact metamorphism acting on the roof rocks of the gabbroic body.

The lower contact zone crops on the northeast margin of the gabbro body (Fig. 6). Veins of pyroxenites or magnetite pyroxenites intruded this contact zone. Like in case of the previously presented gabbro bodies, the characteristic rocks of the lower contact zone shows the same mineral assemblage presented for the Almăşel gabbro body.

LAYERING IN THE SMALL ULTRAMAFIC BODIES

In the mass of the pillowed basalt complex from the axial zone of the Mureş ophiolitic suture a few small ultramafic bodies are located (Savu[7]; Savu *et al.*[8]). They have the characteristics of small hypabysal intrusions. Two of the ultramafic bodies are located west of the Roşia Nouă Village (Savu[20]). One of them occurs on the Drumul Radei Creek, which has a surface of about 0.02 sq. km. The second presents a surface of 0.06 sq. km. and is located at the mouth of the Marcu Brook. As both of them are intruded into the pillowed basalt complex, shows that they erupted during the first eruptions of the tholeiitic ocean floor magmas. The thickness of the ultramafic bodies varies from 200 m as in case of the Drumul Radei body to 50 m in as case of the Marcu Brook body. The most characteristic ultramafic body is the small body located in the pillowed basalt complex on the Strâmbu Brook, west of Almaş Selişte (Savu[7]; Savu *et al.*[8])

As regards the layering in the small ultramafic bodies a good example is offered by the Drumul Radei ultramafic body. Its structure shows that the body is mostly formed of olivine gabbros. In its central part two horizons (layers) differentiated, namely, an upper horizon of melagabbros and a lower horizon of peridotites (Fig. 7). These horizons resulted, like in the above bodies, by the differentiation *in situ* of the intruded magma, which in the present case had the composition of an olivine gabbro.

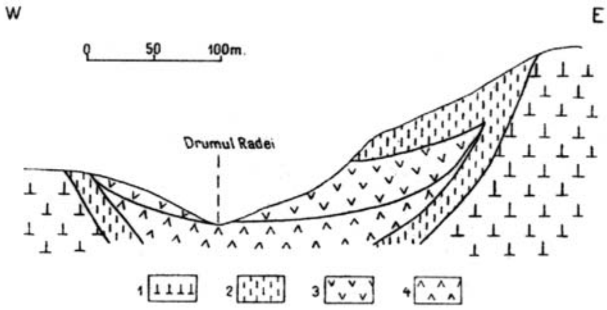

Fig. 7. Structure of the ultramafic body from the Drumul Radei Creek. 1, pillowed basalts; 2. olivine gabbro; 3, melagabbro; 4, peridotite.

But a more characteristic rhitmic layering occurs in the Marcu Brook ultramafic body

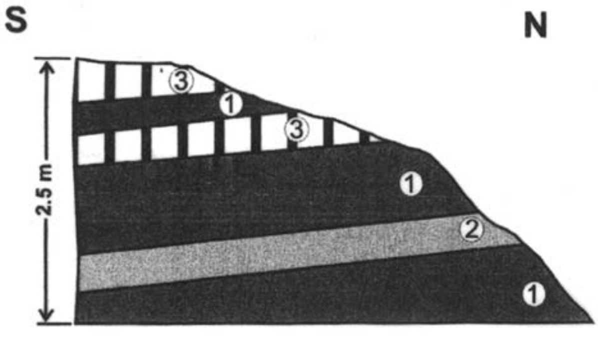

Fig. 8. Rhytmic layering in the ultramafic body from the Marcu Brook. 1, peridotite; 2, melagabbro; 3, olivine gabbro.

There has been formed by the differentiation of the magma with the composition of an olivine gabbro a rhythmic layering, in which layers of peridotite alternate with layers of melagabbro and olivine gabbro (Fig. 8).

CONCLUSIONS

From the present paper there are to be evidenced the following main conclusions.

1. The layering process does not occur in the acid intrusive bodies, because their parental magma is highly viscous, but in the basic and ultramafic bodies the parental magma of which has a high fluidity.

2. The layering process is characteristic for the tholeiitic intrusions, the parental magma of which is concentrating iron during its differentiation, as shown by Fenner[21].It seems that the iron components have the role of a catalyst in this process.

3. As shown by the figures above presented, the layering process manifested itself as a rhythmic process, in which alternate the crystallization of the leucocratic minerals (plagioclases) with the crystallization of the melanocratic minerals (pyroxenes, olivine).

4. But from the same figures it results that the alternating layers of leucocratic and melanocratic minerals are variable in thickness, showing that not only the rhythmic crystallization of the minerals determined the occurrence of the layering phenomenon. It must be influenced at the same time by the vapour tension in the basic tholeiitic intrusions (see also Cioflica and Savu[5]; Savu *et al.*[6]), a phenomenon that was variable, depending on the supply of gases and of their loss on the fissures of the host rocks.

Shortly, the layering process is controlled by both the rhythmic crystallization of leucocratic and melanocratic minerals and by the vapour tension in the body of basic and ultramafic magmas.

REFERENCES

1. Philips J., *Theories on geology, London, Longmans,* **1837**, 334 p.
2. Hitchcock E., *Butler*, **1841,** *1*, 1.
3. Wager, L.R., Brown, G.M., *Layered igneous rocks*, Oliver and Boyd, London, **1968**, 588 p.
4. Giuşcă D., Cioflica G., *An. Univ. Bucureşti,* **1957,** *13*, 163.
5. Cioflica G., Savu H., *Stud. cerc. geol*., **1962***, VII, 1*, 127.
6. Savu H., Udrescu C., Neacşu V., *Miner. Slov., Kosice,* **1984**, *16,1*, 43.
7. Savu H., *D.S.Com. Geol.*, **1962**, *XLV*, 59.
8. Savu H., Udrescu C., Neacşu V., *D.S. Inst. Geol. Geofiz*., **1986**, *70-71, 1*, 143.
9. Herz N., Jones M.L., Savu H., Walker R.L., *Geol. Soc. Am., Bull*., **1974**, *85*. 9, 1440.
10. Bombiţă G., Savu H., *Ann. Soc. Geol. Poloniae*, **1986**, *56*, 337.
11. Savu H., *An. Inst. Geol. Geofiz*., **1983**, *LXI*, 253.
12. Savu H., *Proc. Rom. Acad., Series B*, **2007**, *1*, 23.
13. Savu H., Udrescu, C., Neacşu, V., Nacu, D., *D.S. Inst. Geol. Geofiz*, **1987**, *72-73, 1*, 161.
14. Cioflica G., *An. Com. Geol*., **1962**, *XXXII*, 257.
15. Savu H., *An. Com. Geol*., **1962**, *XXXII*, 211.
16. Savu H., Vasiliu, C., Udrescu, C., *D.S. Inst. Geol. Geofiz*., **1982**, *LXVI*, 127.
17. Savu H., Udrescu, C., *D.S. Inst. Geol*., **1967**, *LIII, 2*, 185.
18. Winkler H.G.F., *Petrogenesis of metamorphic rocks*, **1967**, Springer-Verl., Berlin, 237 p.
19. Buddington A.F., Fahey J., Vlisidis A., *Am. J. Sci*., **1955**, *9*, *253*.
20. Savu H., Vasiliu C., Udrescu C., *D.S. Inst. Geol***., 1970**, *LVI*, 219.
21. Fenner H.P., *Am. J. Sci*., **1929,** *5*, 225.