PETROGRAPHY AND CHEMISTRY DATA OF THE BASEMENT OF MOESIAN PLATFORM (STREHAIA REGION) FROM DRILLING CORE SAMPLES

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Several drillings were performed during 1965–2005 on Strehaia structure in the Western part of the Moesian Platform in order to explore and exploit hydrocharbons accumulations. Only one of these drillings intercepted the platform basement at 3434 m and two core samples were extracted from it. By now these core samples represent the only source of information available about the nature of the basement in this Western part of the Moesian Platform. Both were extracted from the same igneous body. This paper presents the petrographical and geochemical features of this basement rock and the important characteristics of mineral phases are discussed in detail. After its modal composition is estimated the conlusion is that the rock is a quartz diorite. Taking into account the microscopic mutual spatial relationships among the mineral phases a scheme with crystallization order of the silicate minerals is suggested. Taking into account the perfect preservation of igneous textures and using a geochemical discriminat diagram based on major elements the most probable conclusion is that this pluton was consolidated in the geotectonic setting of a continental plate, during a pre-collision stage. Concerning the size of this dioritic body it's more likely that it represents, just a relatively small component of a large petrographically heterogeneous pluton.

Key words: Quartz diorite; Basement of the Moesian Platform; Strehaia structure.

INTRODUCTION

The petrographic constitution of the Moesian Platform's basement in its Central-Western region is almost at all known. Several drills intercepted the basement in the Balş – Optaşi region, where, due to the basement raising, the sedimentary cover has the lowest thickness (1600–2000 m). Studying basement core samples from these drillings, Barbu and Dăneţ [1], pointed out the existence of both igneous and metamorphic rocks and described the following petrographic types:

– gabbros, diorites, quartz-diorites and granodiorites (Balş-Dioşti sector, in the South Western part of the Balş – Optaşi region);
– muscovite bearing granites, biotite bearing granites and granitic aplites (Slatina-Mogoşeşti sector, in the North-Eastern part of the Balş – Optaşi region);
– chlorite-quartz-muscovite schists, porphiro-blastic albite-zoisite-chlorite schists and hornblende-quartz-epidote-chlorite schists (Optaşi sector, close to Slatina locality).

All the mentioned igneous rocks were assigned to Balş igneous massif, considered Paleozoic.

The Strehaia structure belongs to the Vidin-Strehaia major structural raising, which crosses the Western part of the Moesian Platform and extends Southward across the Danube, on the Oprişoru-Branişte-Dârvari-Cetate alignement. It was identified by interpretation of seismic data produced during 1980–1995. The sedimentary cover of the platform in the Strehaia region is well known due to several drillings performed in the period 1965–2005. From all these drillings, only one (Strehaia drilling 2), located 6 km westward Strehaia locality (Figure 1) intercepted the basement. The drilling advanced 14 m deep in the basement rocks and 2 core samples were extracted.

The drillings from the Strehaia region intersected Cenozoic, Mesozoic and Paleozoic sedimentary formations. The Paleozoic was intercepted by one drilling only and it consists of Silurian, Devonian and Carboniferous deposits (*** *Proiect geologic privind săparea sondei explorare-deschidere pentru țitei 2 Strehaia Județul Mehedinți*).

– Silurian mainly consists of lutitic rocks (argillites), with thin intercalations of sandstones;
– Devonian has carbonatic rocks in the upper part (Călăraşi formation) and detritic rocks in the lower part;
– Carboniferous is mainly detritic but having carbonatic rocks in the lower part.

The Mesosoic transgressively and discordantly covers the Paleozoic rocks and it consists of Triassic, Jurasic and Cretaceous deposits.

– Triassic, represented by the Lower Triassic only, is discontinuous and consists of clayey sandstones (the so called "lower red member");
– Jurassic, observed everywhere in the Strehaia structure, is stratigraphically incomplete and consists of mainly micrite-limestones with intercalations of shales and marns;
– Lower Cretaceous is petrographically similar with the Upper Jurassic and the Upper Cretaceous is made of micro- and mesocrystalline sparite-limestones, having thin intercalations of chalkous marls.

The Cenozoic transgressively and discordantly overlays the Mesozoic, covering the paleorelief. It comprises in a complete serie the Miocene (Badenian, Sarmatian, Meotian and Pontian) and Pliocene.

– Badenian is discontinous and it is mainly made of marns, having at the upper part a relatively thin evaporitic sequence with thin intercalations of marns;
– Sarmatian dicordantly covers the Badenian or, in some areas, directly covers the pre-Neozoic rocks. It consists of arenitic and lutitic rocks (marls with transitions to sandy marls). Within the Sarmatian detritic rocks there are accumulated gaseous deposits, known in several locations within the platform (Ursoaia, Isalnița, Predeşti, Răcari, etc.);
– Meotian was divided on petrographic criteria in two complexes: a) the lower comples, mainly made of marls with thin intercalations of sands and b) upper complex, which is arenitic with intercalations of sandy marls. Within both complexes were found gaseous deposits in varios structures from the Moesian Platform (Isalnița, Pitulați, Bibeşti, etc.);

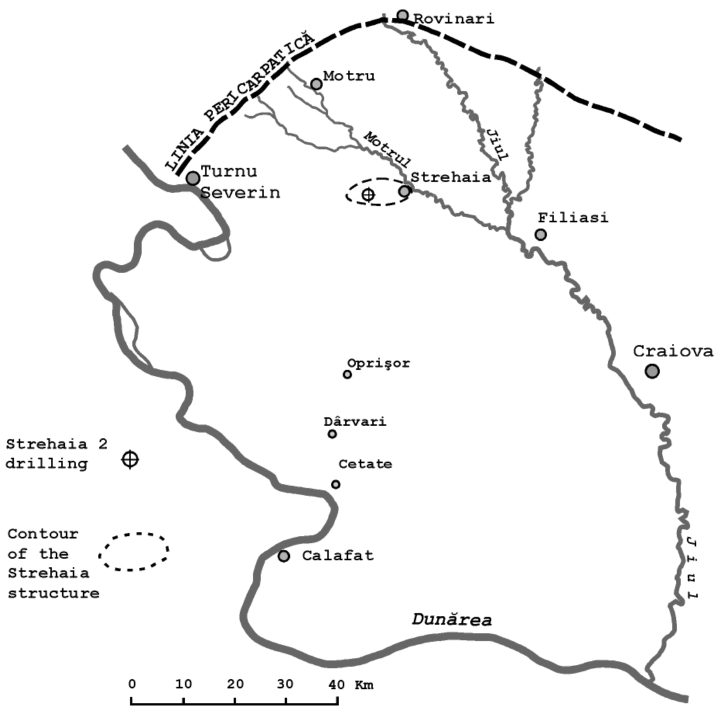

Fig. 1. Sketch with localization of the Strehaia structure and Strehaia 2 drilling.

– Pontian continued in sedimentation over Meotian and it is mainly lutitic with over 500 m thickness. In the lower part there is an arenitic complex of 80–100 m thickness;
– Pliocene mainly consists of detritic rocks (fine to coarse sands and gravels) which alternate with marns and shales having thin coal intercalations.

The main stratigraphic depth limits intercepted by the Strehaia 2 drilling are:

Pontian/Meotian=676 m (–451m);
Meotian/Sarmatian=1195 mm (–970m);
Sarmatian/Badenian=2158 m (–1943m);
Badenian/Cretacic=2227 m (–2012m);
Cretacic/Malm=2698 m (–2483m);
Malm/Triasic=2720 m (–2505m);
Triasic/basement=3434 m (–3219m).

The synthetic section of the Strehaia 2 drilling is presented in Figure 2.

The core samples extracted from the basement belong to the same igneous body and are similar at both macro- and microscopic scales. The objective of this paper is to point out the petrography and chemistry data for these samples, offering the only compositional and structural information existing so far, regarding the basement in this region.

For the optical study, thin sections were made from both core samples. The bulk chemistry, as well as the minor and trace elements were determined on a 190 g weight sample, in the ALS Chemex laboratory, Vancouver, Canada.

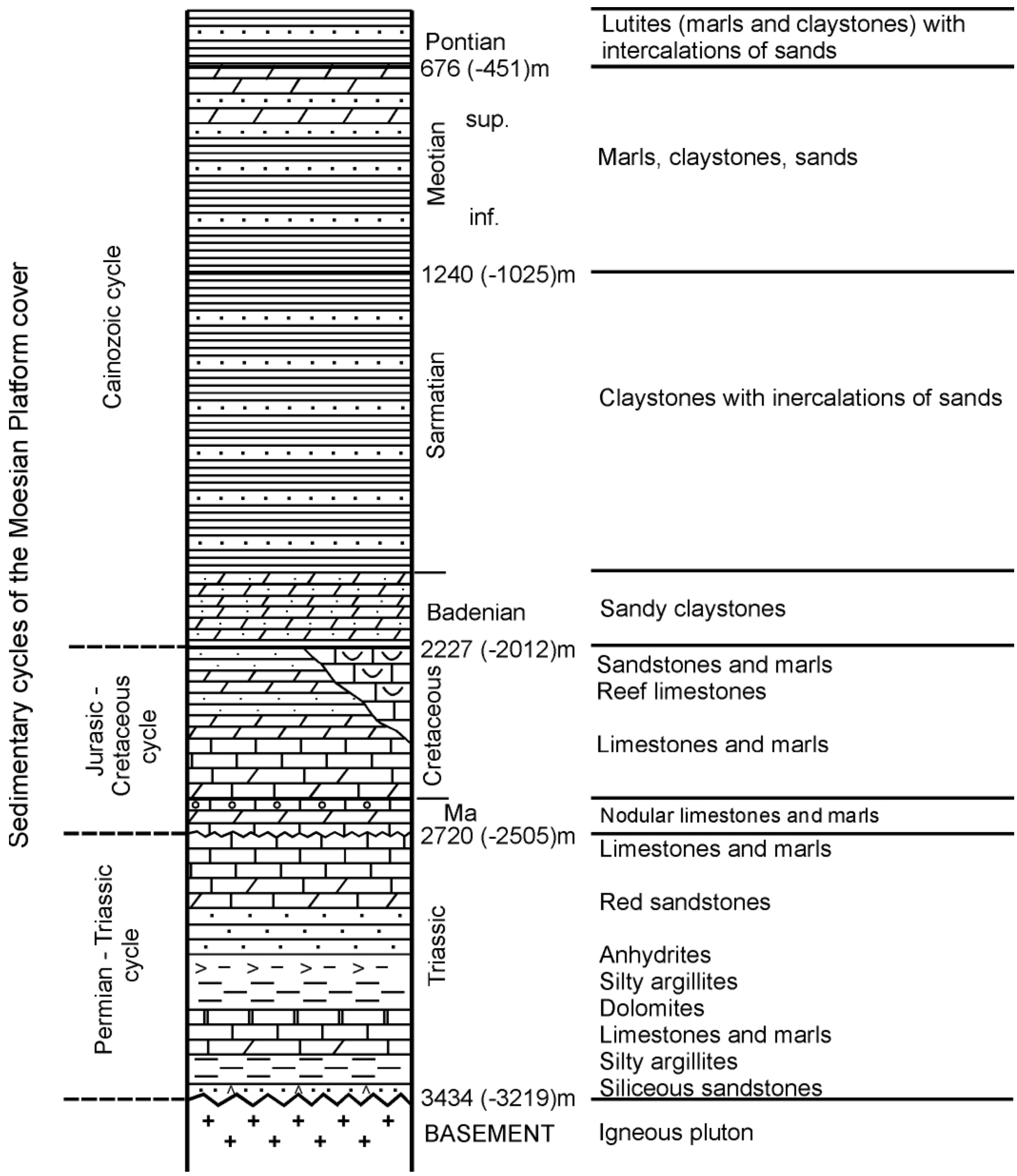

Fig. 2. Synthetic section of the Strehaia 2 drilling (realized according to the drill logs and core samples).

RESULTS AND DISCUSSIONS

Petrographic type of the basement rock

According to the IUGS-SCIR standards, the petrographic type of a plutonic, phaneritic rock is given by the modal composition. Macroscopically, the basement rock is homogenous, phaneritic, equigranular, having a typical plutonic aspect (Figure 3).

Fig. 3. Fragment of core sample extracted from the basement (Strehaia 2 drilling).

The modal composition (Table 1) was optically estimated with a petrographic microscope, using polarized light. A micrometric ocular was used in estimations of the modal average compositions from three thin sections.

Table 1

Modal composition of the core samples from the basement (Strehaia 2 drilling)

Mineral	%vol
Plagioclase	70.2
Quartz	7.8
Biotite+chlorite (on biotite)	7.8
Hornblende	7.4
Uralite (actinote)	5.7
Opaque minerals	≈1
Apatite	<0.5
Muscovite	<0.5
Clinopyroxene	<0.5
Titanite	<0.5

The total content of mafic minerals (including secondary mafics resulted by pseudomorph substitution of primary mafics) represents ~24% vol. Therefore, the QAP ternary diagram for plutonic rocks was used in discrimination of the petrographic type (Figure 4).

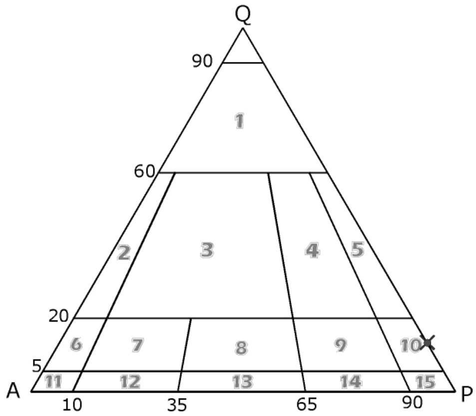

Fig. 4. The modal composition of the basement rock within the QAP diagram:
1–quartz-rich granitoids; 2–alkali feldspar granite; 3–granite; 4–granodiorite; 5–tonalite; 6–quartz alkali feldspar syenite; 7–quartz syenite; 8–quartz monzonite; 9–quartz monzodiorite and quartz monzogabbro; 10–quartz diorite, quartz gabbro and quartz anorthosite; 11–alkali feldspar syenite; 12–syenite; 13–monzonite; monzodiorite and monzogabbro; 14– diorite, gabbro and anorthozite.

The estimated modal composition plots in the quartz diorite, quartz gabbro and quartz anorthosite field (Figure 4). Taking into account the mafic content and plagioclase feldspar composition (less than 50% anorthite) the rock is a quartz diorite[5]. Because the color index (M) of the rock is ~23 it should be considered as "normal" from this point of view (no leucocrate, nor melanocrate).

Characteristics of mineral phases

Primary minerals

The plagioclase is polysynthetically twinned and presents a normal compositional zonality. The twinned crystals consist of relatively euhedral cores (acid andesine or oligoclase) with fine albite rims (Figure 6). The limit between core and rim is marked by an abrupt discrepancy in the anorthite content. The majority of the plagioclase crystals are subhedral having the average grain size range between 2–2.5 mm, conferring a "medium granular" feature of the studied rock (Figure 3).

The quartz occurs as anhedral crystals, forming skeletal textures developed between plagioclase and hornblende boundaries. These skeletal crystals are greater than 2 mm in size. Most of the quartz grains are undeformed but some of them show weak ondulatory extinction (Figure 5).

The pyroxene is monoclinic and occurs with a very low frequency as untransformed relicts that escaped the amphibole substitution (Figure 9). The optical features fit with the diopside composition.

The amphibole is represented by hornblende, a complex and unhomogenous solid solution. Several grains show heterogeous type compositional zoning, with greenish-brown core and greenish rims. Knowing that these colours are controlled by the O/OH ratio from the hydroxyl group, we can suggest that the core of the grains is more oxidized than the rim. Within the brown cores only, scarce exsolutions could be noticed (Figure 8). The amphibole occurs as euhedral grains included in plagioclase (Figure 7) or by contrary, including the plagioclase (ophitic textures). In few situations, the amphibole and plagioclase grains show a graphic intergrowth trend.

The biotite is redish-brown, presents skeletal textures and together with quartz, fills as “cement” the intergranular space between the plagioclase grains. Locally, the biotite is chloritized along cleavages, whereas the secondary muscovite developed on biotite is rare (Figure 10).

The opaque mineral is a magnetite developed as anhedral, isometric grains.

The apatite occurs as an accessory phase; it is euhedral and mainly included in the mafic minerals, and less in plagioclase.

Secondary minerals

The secondary minerals (< 5% vol.) are represented by chlorite, muscovite, sericite, uralite and titanite. *The uralite* is a fibrous actinolite which replaces older mafic grains, probably pyroxene (Figure 6). *The titanite* seems to be formed together with chlorite during the replacement of a probably Ti-rich biotite.

Based on the mutual spatial relationships among the mineral phases, we suggest a scheme of crystallization order (Figure 11). Plagioclase and hornblende obviously germinated before quartz and biotite, the later completely crystallizing in solidus conditions. However, the curved boundaries between some plagioclase and quartz grains and between hornblende and quartz grains, respectively (Figs. 5 and 7) suggest that plagioclase and hornblende continued their growth to the last moment of igneous crystallization.

Consequently, during the last stage of igneous crystallization, corresponding to solidus of diorite system, the hornblende and biotite crystallized as stable phases, beside plagioclase and quartz. In the presence of melt, such possibility occurs at P_{H2O}>1kbar, pressure which implies that crystallization took place at depths of 3–4 km at least. In the present day, the diorite body is transgresively and discordantly covered by Permo-Triassic sedimentary cover, suggesting that, from the final magmatic stage up to the Permian times, the Moesian Platform in the Strehaia zone suffered at least 3 km of denudation.

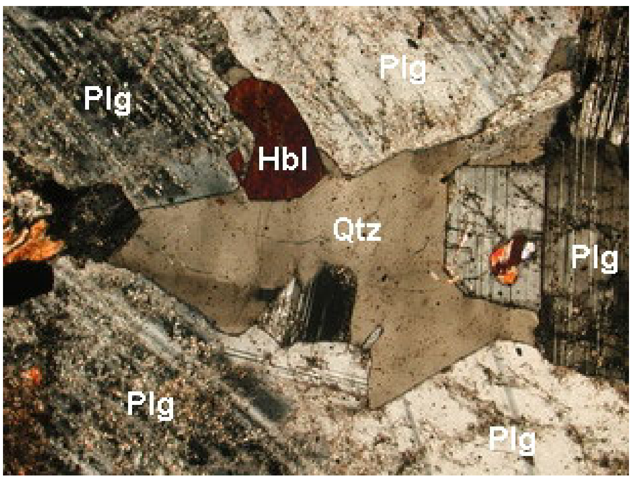

Fig. 5. Hypidiomorph texture of quartz-diorite. Notice the curved boundaries between quartz and plagioclase, evidence of their simultaneous growth (N+ 40×).

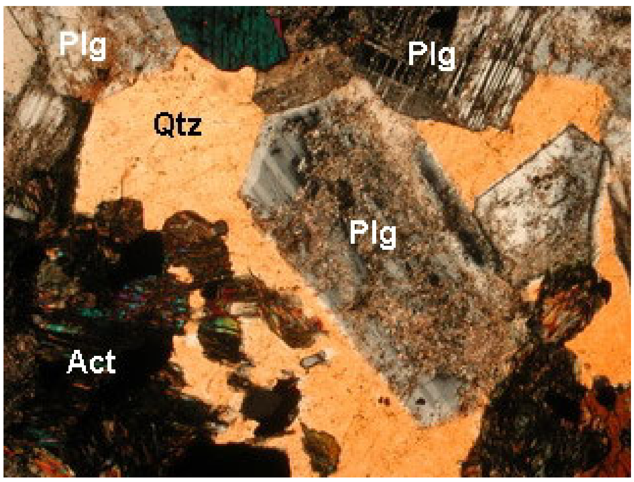

Fig 6. Twinned euhedral plagioclase with albite rim, partially sericitized, included in anhedral quartz and pseudomorph of fibrous actinolite (uralite) after older pyroxene (N+ 40×).

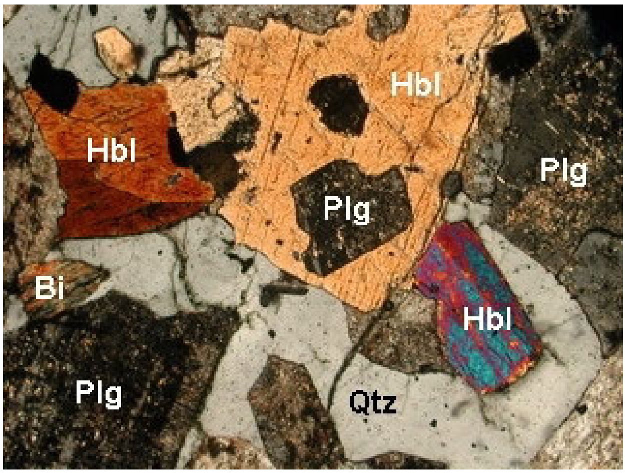

Fig. 7. Plagioclase included in hornblende and curved boundaries between hornblende and quartz, evidence of their simultaneous growth (N+ 100×).

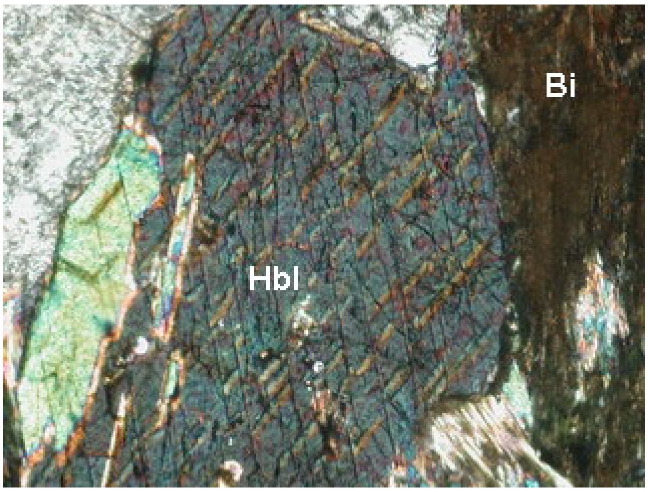

Fig. 8. Brown hornblende with exsolution lamellae (N+ 100×).

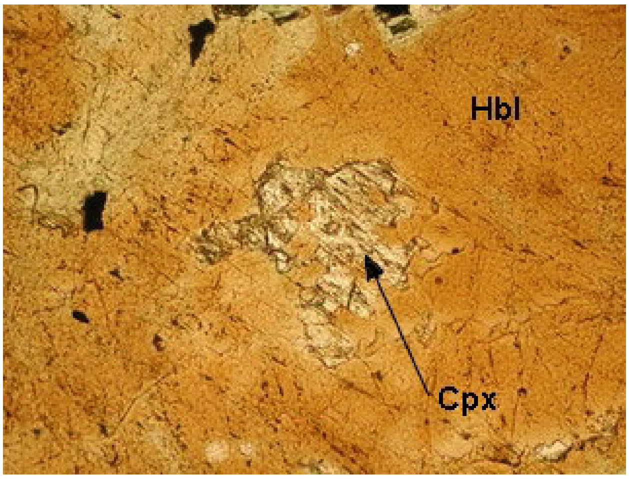

Fig. 9. Clinopyroxene relics (diopside) included in hornblende (N+ 100×).

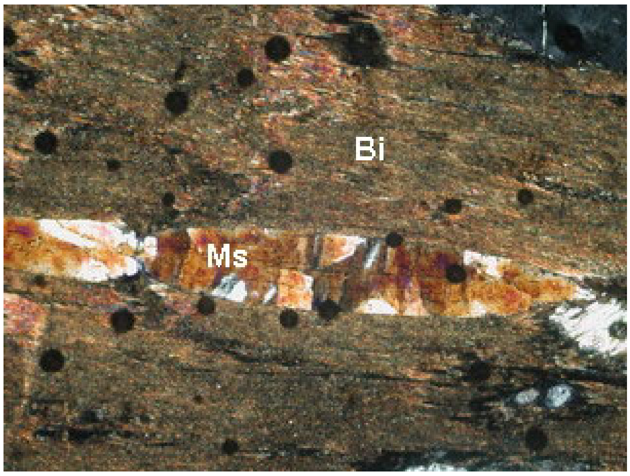

Fig. 10. Biotite replaced by muscovite along the cleaveges (N+ 100×).

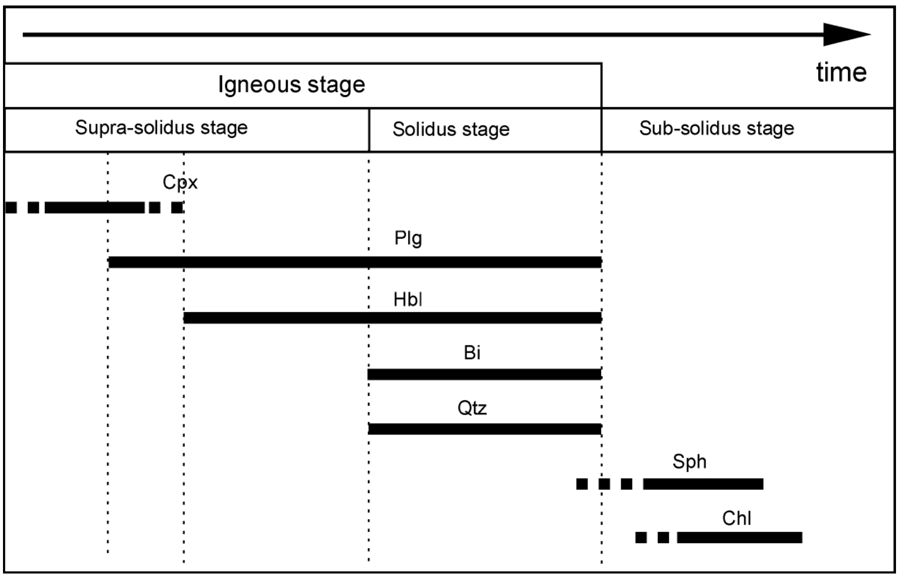

Fig. 11. Scheme with crystallization order of the silicate minerals during the supra-solidus, solidus and sub-solidus stages.

Chemical composition of the basement core samples from Strehaia 2 drilling

The bulk chemistry, as well the minor and trace elements were analyzed using an ICP-AES, MS and the results are presented in the tables below. Table 2 gives the bulk composition of the quartz-diorite from Strehaia 2 drilling (column 1), together with bulk chemistry of other "classic" petrographic types, for comparison (columns 2–7). The minor and trace elements of the studied rock are presented in the Table 3.

The bulk composition of the studied quartz-diorite is almost similar with the bulk composition of other dioritic rocks occuring worlwide (Table 1) but it significantly differs from granodiorites. The small differences between the bulk composition of diorites reflect small differences in their modal composition. For example, the quartz-diorite from Strehaia zone has lower SiO_2 and a higher MgO comparing to the quartz-diorite from Sierra Nevada (7), which suggests lower quartz and higher ferro-magnesian phases, respectively. The slightly higher silica content of the studied rock compared to diorites, *sensu stricto*, is obviously due to the slightly higher quartz percentage that is specific to quartz diorites. Compared to the anorthosites (6), the studied rock has almost the same silica content, but it is very different concerning Al_2O_3, MgO and $FeO+Fe_2O_3$ content because of the fact the latter have higher proportions of plagioclase and very small proportions of ferro-magnesian minerlas.

Based on major elements and using the Batchelor and Bowden [2] discriminant (Fig. 5), we suggest that the geotectonic setting during the genesis of quartz-diorite from the Strehaia basement was a continental plate, during a pre-collision stage.

Table 2

Bulk chemistry of quartz diorite (Strehaia 2 drilling), and other "classic" petrographic types

	1	2	3	4	5	6	7
SiO_2	54.9	73.4	62.2	52.10	53.02	54.54	59.0
TiO_2	1.32	0.2	0.7	0.48	0.80	0.67	0.82
Al_2O_3	18.80	14.1	16.6	18.89	15.82	25.61	17.2
Fe_2O_3	5.34	0.7	1.4	1.68	1.50	1.00	2.0
FeO		1.7	4.5	4.41	6.00	1.26	4.6
MnO	0.09	0.02	0.06	0.16	0.16	–	0.14
MgO	4.43	0.4	2.7	5.95	6.15	1.03	2.8
CaO	6.37	2.1	5.7	9.61	8.37	9.92	6.2
Na_2O	4.07	3.4	3.4	2.70	3.35	4.58	3.3
K_2O	0.98	3.5	1.6	1.36	1.63	1.01	2.1
H_2O	1.89	0.3	0.6	2.97	1.78	0.55	1
P_2O_5	0.30	–	0.09	–	0.02	–	0.34

1. Quartz diorite intercepted in the basement of Moesian Platform (Strehaia 2 drilling);
2. Granodiorite (average composition) – Woodson Mountain, Southern California Batholith (Larsen, 1948);
3. Tonalite (average composition) – Southern California batholith (Larsen, 1948);
4. Leucodiorite – SE Jersey, Channel Islands (Bishop & Key, 1983);
5. Diorite – Guernsey, Channel Islands (D'Lemos, 1992);
6. Anortozite (average composition) – Adirondak massif (Buddington, 1939);
7. Quartz diorite – Sierra Nevada Batholith, USA (P.C. Bateman *et al.*, 1963).

Table 3

Minor and trace elements in the Strehaia studied quartz-diorite

Cr_2O_3 (%)	0.03	V (ppm)	102
SrO (%)	0.07	Zn (ppm)	59
BaO (%)	0.03	Ce (ppm)	27.6
Ag (ppm)	<0.05	Dy (ppm)	2.2
As (ppm)	5	Er (ppm)	1.1
Be (ppm)	1.4	Eu (ppm)	1.3
Bi (ppm)	<2	Gd (ppm)	3.1
Cd (ppm)	<0.5	Ho (ppm)	0.4
Co (ppm)	19	La (ppm)	13.6
Cu (ppm)	15	Nd (ppm)	13.9
Mo (ppm)	1	Pr (ppm)	3.4
Ni (ppm)	82	Sm (ppm)	2.7
Pb (ppm)	6	Tb (ppm)	0.4
S (ppm)	<0.01	Th (ppm)	3
Sb (ppm)	<5	Y (ppm)	10.6

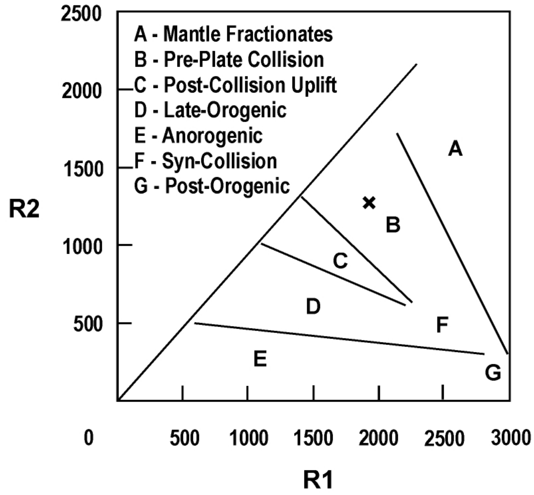

Fig. 12. Batchelor and Bowden [2] discriminant and the plot of the quartz-diorite from Strehaia 2 drilling [R1=4Si-11(Na+K)-2(Fe+Ti); R2=6Ca+2Mg+Al].

CONCLUSIONS

Based on the petrographic and chemical studies on the drill core samples from the Strehaia basement, we can conclude that:

a. The basement intercepted by the Strehaia 2 drilling consists of a quartz-diorite body.
b. The lack of crystal deformation and perfect preservation of igneous textures show that, from the moment of magma emplacement to the present day, the diorite body did not suffer major deformation, which suggests that the diorite was emplaced within a non-tectonic environment, specific for a platform. The geochemical features of the pluton also confirm such geotectonic setting. The interpretation of the drilling data suggests that the quartz-diorite was emplaced before the Permo-Triassic sedimentary cycle, since it is covered by sedimentary cover of this age. Before the deposition of the Permo-Triassic sediments, the covering rocks of this igneous body and maybe the body itself suffered strong erosion and denudation (at least 3 km thickness).
c. The real size of the plutonic body stays disputable, since it has not been yet intercepted by other drillings. The fact that both plagioclase and amphibole show growth-type compositional zoning, suggests that the cooling rate of the pluton was relatively high (but lower than the cooling rate of vulcanites). These microstructures could suggest: i) they formed at the margin of large plutons, where the cooling rates are higher compared to those from center of the pluton and ii) they represent a smaller pluton crystallized within hypoabisic conditions. If we consider a high rate of erosion, as inferred above, we can suggest that the size of the pluton was large and our samples represent a marginal facies of the pluton. On the other hand we know that worldwide, the dioritic bodies have relatively small sizes. One compromise could be to accept that Strehaia 2 drilling intercepted just a dioritic component of a complex, petrographically heterogenous, relatively large pluton.

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