THE TRIASSIC CONTINENTAL BASALTIC ROCKS FROM NORTH DOBROGEA, ROMANIA – AN EXAMPLE OF WPB TO MORB TRANSITIONAL MAGMATIC ROCKS*

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North Dobrogea represents a tectonized aulacogen, the evolution of which started since the Trias and lasted up to the beginning of Lias, when it was abandoned as a failed branch of the Carpathian Triple Junction. In its structure there are an infrastructure and a superstructure. The first is formed of the East European and Moesian sialic plates and of the peneplanized Variscan Orogen. These units consist of crystalline schists and granitoids, intruded by the Triassic Măcin bimodal dyke swarm and other basic dykes. The superstructure is formed of Triassic volcanics related to the dyke swarm and Mesozoic sedimentary deposits. The Triassic volcanics erupted during three phases: the Măcin-Somova bimodal volcanism phase, the Niculiţel flood basalt phase and the Izvoarele basic dyke phase. The tholeiitic parental magmas of the basic rocks formed in the mantle at a depth of about 50 km, by the melting of ca. 9 to 10 % of the mantle source. But the parental magma of the Măcin basic rocks from the Măcin dyke swarm had a chemical composition close to that of a pyrolite, formed by the melting of 1 % of the mantle source. By their tectonic setting all of the Triassic igneous rocks – dykes and volcanics – are within-plate rocks. But by the chemical composition they represent WPB to MORB transitional rocks, a feature more obvious at the Măcin basic dykes. The last rocks are bearing an ambiguous WPB-MORB character, derived from the almost pyrolitic character of their parental magma. The origin of this magma must lie in the weak melting of the mantle source, occurred under pre-ocean continental incipient rifting conditions.

Key words: aulacogen; basic rocks; geochemistry; WPB - MORB characteristics; origin.

INTRODUCTION

Different opinions have been set forth so far about the tectonic setting and origin of the Triassic bimodal volcanics from the North Dobrogea aulacogen. Thus, as long ago as the 80s years of the last century, there was shown that these rocks, as well as their coevals from the East Carpathians and Făgăraş Mountains are within-plate volcanics (Savu[1]), or within-plate bimodal volcanics (Savu *et al.*[2]). On the same occasion, there was observed that the volcanics from North Dobrogea plotted on the discriminant diagrams in the witin-plate basalt field, too, but nearer to the ocean floor basalts (OFB and MORB) fields, some of them plotting even inside these fields.(see Savu[1], Figs. 2 and 3). Later on, Nicolae and Seghedi[3] supposed that these volcanics are ocean floor rocks.

Recently, Saccani *et al.*[4], using a few analyses, showed that these rocks occurred under an extensional tectonic setting and derived from a MORB-type asthenospheric mantle

The ambiguity of the situation incited me to check again the geological occurrences and the geochemical characteristics of the Triassic basic rocks from this area, and to elaborate a general study, with the purpose to solve this controversy and to establish the geochemistry, tectonic setting and origin of these rocks, comparing them with the South Carpathian Liassic ophiolites, which are without any doubt MORB-type rocks. The results of these investigations are presented further down.

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GEOLOGICAL EVOLUTION OF THE NORTH DOBROGEA AULACOGEN

For a better understanding of the genesis of the Triassic volcanics from the North Dobrogea aulacogen, first of all there must be presented the geological evolution of this region in relation with the neighbouring areas. And, to start with, there must be shown that the North Dobrogea aulacogen takes part in the Carpathian Foreland, which is made by the Moldavian Platform, the Moesian Platform and the North Dobrogea aulacogen. The structure of this area involves two structural levels: an infrastructure and a superstructure (see also Savu *et al.*[5]).

The infrastructure consists of two sialic plates – the East European Plate and the Moesian Plate – formed of Pre-Variscan crystalline schists, between which a peneplanized Variscan Orogen is located. The latter is formed of Paleozoic anchimetamorphic formations (Seghedi, Oaie[6]), associated with Paleozoic ophiolites like those from the Gâlmele Înşirate slice, and granitoid intrusions (Savu *et al.*[7]). Triassic dykes are intruding these structural units.

The superstructure, which occurred after the Permian long period of intense erosion, consists of the Triassic Niculițel flood basalts (Savu *et al.*[5, 8]) and Somova bimodal volcanics (Savu *et al.*[2]), as well as of Mesozoic sedimentary formations (Mirăuță[9]; Grădinaru[10,11]; Baltreş[12]) and younger deposits.

The North Dobrogea Mesozoic mobile belt, from which the North Dobrogea aulacogen resulted, inherited an older mobile belt occurred as far back as in the Precambrian, when along this area a system of NW-SE trending trans-crustal fractures created a break in the primordial Archean continent, separating the two sialic plates above mentioned (see Giuşcă *et al.*[13]; Savu [14]). Like in the Carpathian Chain, three tectono-magmatic cycles evolved along this mobile belt: the Pre-Variscan, Variscan and Alpine cycles.

This mobile belt represented, in fact, the southeastern branch of the long-lived Carpathian Triple Junction (Savu[14, 15]), which had a complete evolution within this area only during the Variscan cycle, it being failed during the Mesozoic cycle. It extended eastwards by Crimea up to Caucasus.

By the end of the Variscan cycle, in Permian, the entire Europe area as well as the old Carpathian Orogen and the North Dobrogea Variscan Orogen underwent an intense peneplanization process. By the end of the Trias, along the Variscan ophiolitic suture, including the North Dobrogea one, a distension process started. It determined the occurrence of a system of trans-crustal fractures –- a pre-ocean incipient rifting – parallel to the three branches of the old Carpathian Triple Junction, that just started to be reactivated. Consequently, the Triassic transgression took place, which resulted in the occurrence of an epicontinental deep sea (Savu[16]) in North Dobrogea and the neighbouring mobile belts, which was regarded as a rift by some authors. According to Grădinaru[11], it was an ensialic deep-water basin.

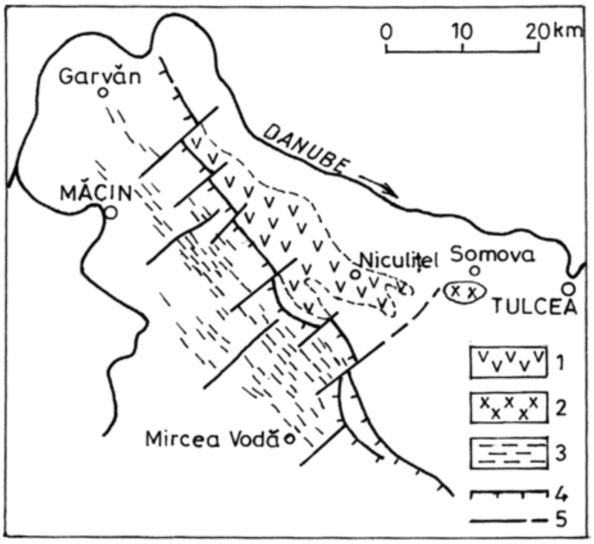

Fig.1. Sketch-map of the northwest area of the North Dobrogea aulacogen showing the three types of Triassic intra-plate volcanics. 1, Niculițel flood basalts; 2, Somova bimodal volcanics; 3, Măcin bimodal dyke swarm; 4, Luncavița – Consul reverse fault; 5, normal fault.

Along the trans-crustal fractures basic and acid magmas erupted, resulting in a dyke swarm system (Fig.1), now visible in the sialic basement of the Măcin Unit, where the superstructure of Triassic volcanics and sedimentary deposits has been eroded. These dykes functioned as feeder channels for the bimodal volcanics, which accumulated along with sedimentary deposits in the epicontinental sea.

When the opening of the Carpathian Ocean took place, at the beginning of the Juras, along the two Carpathian branches of the triple junction, the mobile belt of North Dobrogea was abandoned (Fig. 2) as a failed branch (Savu [15]), or as an aulacogen, respectively (Vlad[17]). It will have an atypical geological evolution during the Alpine cycle, differing from that of the Carpathian Ocean, within which ocean floor (MORB) basalts associated with ultramafic rocks occurred, that finally resulted in the Carpathian ophiolitic suture (Savu[18]). During the Early Kimmerian movements the North Dobrogea aulacogen underwent a compression process. Therefore, it was crushed between the East European Plate that had the tendency to plunge southwards and the Moesian Plate that had the tendency to rise – a process that manifested itself on the NE-SW direction of the old Variscan compression. Consequently, the infrastructure of the North Dobrogea aulacogen, along with the superstructure, underwent a strain process, which resulted in a system of reverse faults facing the East European Plate, as Savu *et al.*[5] have shown in a structural section. This fracture system was also oriented parallel to the old Variscan structures and to the NW-SE trending Triassic pre-ocean rifting system. It probably happened when the Balkan block moved northwestwards, the North Dobrogea aulacogen serving as a hinge between it and the East European Plate (Savu[14]). It determined an overlapped structure, consisting of several tectonic units (Săndulescu[19]), which looks like a scale system, the tectonic units of which being separated one another by NW-SE trending reverse faults. Each scale includes both the infrastructure and the superstructure (see the geological section in Savu[16], Fig.1). This tectonized aulacogen was previously considered as the North Dobrogea Orogen.

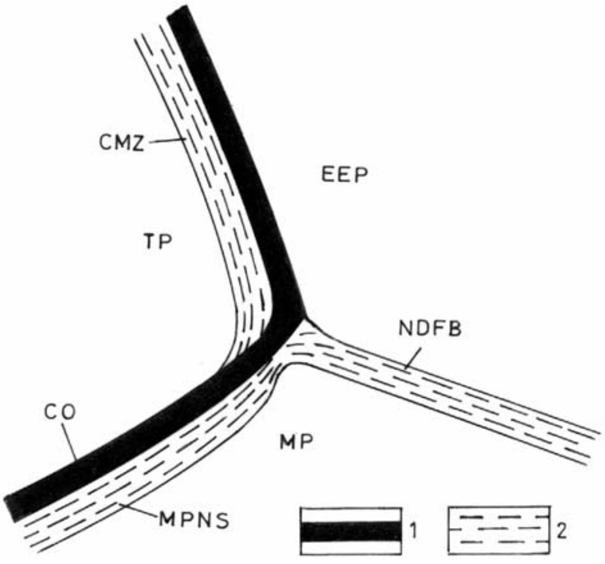

Fig. 2. Sketch showing the evolution of the Carpathian Triple Junction. 1, ocean zone; 2, remnants of the three initial branches of the triple junction marked by parallel dyke swarms; CMZ, Crystallino-Mesozoic Zone of the East Carpathians; MPNS, Moesian Plate northern area; NDFB, North Dobrogea failed branch; EEP, East European Plate; MP, Moesian plate; CO, Carpathian Ocean.

From the North Dobrogea tectonic units two are more important, which include the other ones: the Tulcea Unit and the Măcin Unit. These two tectonic units are separated one another by the Variscan long-lived Luncavița-Consul reverse fault (Fig.1), which occurred at the end of the Paleozoic (Savu, Stoian[20]). Along this fault the Măcin Unit was raised and the Tulcea Unit submerged. Therefore, in their peneplanized infrastructure now different formations crop out. The infrastructure of the first unit is made mostly of the Pre-Variscan crystalline schists of the Moesian Plate, intruded by the Triassic dyke swarm. The infrastructure of the second tectonic unit consists of the Variscan anchimetamorphic formations and related island arc granitoids, also intruded by Triassic dykes. It is of note that the area between North Dobrogea and the Carpathians is now covered by younger formations, which disguise the Triassic magmatic and structural relationships between the two main regions.

OCCURRENCE OF THE TRIASSIC VOLCANICS AND PETROGRAPHIC ASPECTS

The Triassic igneous rocks erupted in the North Dobrogea aulacogen during the activity of the pre-ocean within-plate volcanism, which manifested itself within the southeastern branch of the Carpathian Triple Junction. Its activity developed during three eruption phases: 1, the bimodal volcanism phase, 2, the flood basalt phase and 3, the basic dyke phase (Table 1). The rocks produced by these volcanic eruption phases are distributed now along two NW-SE trending zones (Fig. 1).

1.1. Acording to the data of Mirăuță[9] and Baltreş[12], the bimodal volcanic phase manifested itself during the Spathian (Scythian) period. The volcanic products occur on both margins of the North Dobrogea aulacogen (Fig.1; see also Savu[16]). A northeastern zone on which the bimodal volcanism occurred was the Isaccea-Somova-Malcoci one, located in the Tulcea Unit. As shown by Savu *et al.*[2] and *Savu*[16]*,* the volcanic activity was weak and started with the Isaccea acid rocks (rhyolites and quartzkeratophyres) and alternatively continued with acid and basic volcanics, which are intercalated in the Somova bedded carbonatic formation. They lie on the detrital Werfenian Sarica deposits, which unconformably cover the Variscan anchimetamorphic formations from the infrastructure. South of Somova, there also occur rhyolites, ignimbrites and pyroclastics associated with pillowed basalts flows. Dykes of dolerites, among which a multiple dyke of basic rocks, and rhyolites, which cut the Somova volcano-sedimentary formation also occur. The acid rocks are associated with barite deposits and hydrothermal and metasomatic mineralizations. At Malcoci the drillings crossed skarns intruded by quartzdolerite dykes. According to Savu *et al.*[2] and Savu[16], these volcanics are within-plate rocks.

Table 1

Evolution of the Triassic volcanism in the North Dobrogea aulacogen

Phase	**Age**	**Aulacogen western western margin**	**Aulacogen median zone**	**Aulacogen North-Eastern margin**
III	Ladinian	Basic dykes	Basic dykes	Basic dykes
II	Anisian –Spathian Spathian	?	Niculițel flood basalts, dolerites, gabbro-dolerites, spilites.	?
I	Spathian (Scythian)	Măcin bimodal dyke swarm, Meidanchioi-N. Balcescu volcanics	?	Isaccea-Somova bimodal volcanics Somova-Malcoci basic and acid dykes barite and base metal mineralizations

1.2. A second zone with bimodal volcanics extends along the southwestern margin of the aulacogen, between Garvăn and Mircea Vodă, in the Măcin Unit (Fig. 1). There the igneous rocks are present under two aspects: as a bimodal dyke swarm and as volcanic rocks. The first one is emplaced in the Pre-Variscan crystalline schists of the Măcin Unit, where NW-SE trending bimodal dykes do occur. As shown by Nicolae and Seghedi[3], the dykes consist of basic and acid rocks and show a thickness of a few cm up to 60 cm. The acid sequence consists mostly of rhyolites, but the basic one shows a more varied petrographic composition, the dykes consisting of basalts, dolerites and gabbro-dolerites, the texturure of which changes from the intersertal and intergranular up to medium grained one. They are formed of basic plagioclase, partly altered clinopyroxene and rarely serpentinized olivine. According to the above quoted authors and to Saccani *et al.* (2004), the basic rocks of this dyke swarm show a MORB signature.

1.3. The correspondent volcanics of the bimodal dyke swarm occur in the Somova Formation from the Consul Unit (Baltreş[12]), in the southeastern extremity of the Garvăn –Mircea Vodă zone, between Meidanchioi and N.Bălcescu (Fig. 1). There the volcanic rocks are intercalated in the Spathian carbonatic formation – the Consul facies – that is lying on the Paleozoic infrastructure. These volcanics consist of rhyolite tuffs, ignimbrites and perlites, associated with granophyres and porphyritic microgranites. In the Malciu Hill a quartzdolerite dyke cuts these volcanics (Savul[21]). At Iulia the magmatic rocks are associated with skarns bearing magnetite and haematite. According to Seghedi *et al.*[22]), these volcanics are calc-alkaline rocks, that occurred in intra-plate tectonic setting and originated in crustal derived magmas, probably formed in some secondary magmatic chambers (see also Savu *et al.*[5]).

2. The flood basalt phase manifested itself during the Late Spathian and Anisian (Table 1) by large basalt flows, which formed the Niculițel basalt complex of about 200 meters thick. The basic rocks are lying on the Variscan anchimetamorphic formations and granitoids from the Tulcea Unit infrastructure, as it can be observed in the Pârâul Viilor creek at Sarica, and west of Mânăstirea Cocoş, where remnants of Triassic basalt flows occur over the same Variscan anchimetamorphic formations from the aulacogen infrastructure. The volcanic activity developed in the same epicontinental sea, as indicated by the beds of Triassic limestone and red argillites often occurring as intercalations between the basalt flows. Rocks like those from the Niculițel complex occur as flows in the Triassic deposits from the southern margin of the Moldavian Platform, as olistoliths in the Izvoarele Formation and as flows on the Black Sea continental shelf (see Savu[23]).

The volcanic rocks consist of basalt, hyalobasalt, amigdaloidal basalt, and anamesite flows, often in pillow lava facies. The melanocratic mineral in basalts usually is a redish-violet prismatic titanaugite. Rarely there occur sills of gabbro-dolerites. Spilitic rocks are present, too, like in the Decan trapp complex (see Sukheswala[24]). Initially, the basalt complex had a more large extension, as the above data let suppose, but now it covers an area of only 30 km length and 10 km breadth, situated in the median area of the aulacogen, between Luncavița and Sarica. Savu *et al*[2,5] and Savu[1,16] considered the volcanics of the Niculițel complex as intra-plate rocks.

3. The last basic rock phase manifested itself by N40^{0}W trending dykes, like the Izvoarele dyke that intruded the Ladinian deposits. Other dykes are crossing the Niculițel basalt complex in the Asan Hill and the Mesozoic formations on the Ormanu Valley at Somova.

As it results from the above data, the rock associations of the Triassic volcanics in the North Dobrogea aulacogen are typical continental within-plate rocks.

GEOCHEMISTRY AND TECTONIC SETTING

The average chemical composition of the basic rocks from the Măcin dyke swarm and the related basic volcanics is presented in Table 2. From this table it results that the Măcin dyke swarm rocks are more basic than the related volcanics, as their average SiO_2 is of 47.41 % in the first rocks and of 48.35 % to 49.42 %, respectively, in the second. Consequently, the Măcin basic rocks are richer in MgO (9.22 %) and CaO (8.26 %) than the Niculițel and Somova ones. But the richest rocks in iron components are the Niculițel flood basalts, in which FeOtot is higher than 10 %. Besides, the same volcanics contain the highest amount of P_2O_5.

In the basic rocks from the Măcin dyke swarm the average of Na_2O is only of 2.57 %, while in the Somova and Niculițel basic volcanics, in which the spilitization process intervened, it is of 3.75 % and 4.15 %, respectively. The K_2O content is a variable one, its highest value occurring in the Somova basaltic rocks.

Save the V content, which is higher in the Niculițel flood basalts, the other trace elements from its group, like Ni, Co, Cr and Sc show the highest contents in the Măcin basic rocks. In contrast to these elements, Y and Yb present the highest contents in the flood basalts, in which Y is of almost 55 ppm and Yb of 5.73 ppm. Zr is richer in the basalts from the Somova bimodal volcanics. The same rocks present the highest content of Ba and Sr, too.

Table 2

Average chemical composition of the basic rocks from the North Dobrogea aulacogen*

Oxides, Elements	**1**	**2**	**3**	**4**	
SiO_2 %	47.40	49.42	48.35	REE	Average
Al_2O_3	15.52	16.65	14.63	A - Măcin basic rocks	
Fe_2O_3	3.17	2.60	4.70	La	5.4
FeO	6.89	5.15	6.33	Ce	15.55
MnO	0.20	0.10	0.20	Pr	2.7
MgO	9.22	6.58	5.50	Nd	13.45
CaO	8.26	6.41	7.78	Sm	3.85
Na_2O	2.57	3.75	4.15	Eu	1.35
K_2O	0.99	1.44	0.96	Gd	4.05
TiO_2	1.72	2.32	2.75	Tb	0.77
P_2O_5	0.28	0.25	0.64	Dy	4.77
H_2O^+	3.10	4.0	2.73	Ho	1.02
CO_2	0.67	1.15	0.90	Er	2.63
S	0.25	0.04	0.08	Tm	0.4
Total	100.24	99.86	99.0	Yb	2.47
Ni	243	95.75	65.81	Lu	0.35

Table 2 (continued)

Co	46.91	38.15	40.8	B - Niculițel basic rocks	
Cr	379	243.5	135.3	La	10.47
V	242.5	217.8	260.6	Ce	24.55
Sc	34.66	29.25	28.46	Pr	19.94
Y	38.33	36.87	54.90	Nd	18.76
Yb	2.81	3.70	5.73	Sm	5.0
Zr	179.75	223.3	197.76	Eu	1.6
Ba	133.16	1097	158.19	Gd	5.09
Sr	212.08	283.5	149.13	Tb	0.95
Pb	7.50	5.06	3.44	Dy	5.0
Cu	49.50	33.47	34.67	Ho	1.23
Ga	15.56	15.75	18.23	Er	3.22
Sn	2.53	2.0	3.46	Tm	0.41
Nb	-	-	33.31	Yb	3.01
Li	-	-	16.39	Lu	0.45
MgO/FeOtot	0.92	0.87	0.52	C – Somova basic rocks	
Ti/V	42.5	63.85	61.83	La	13
Cr/Ni	1.55	2.54	2.05	Ce	27
Co/Ni	0.19	0.39	0.61	Sm	5.1
(La/Sm)N	0.89	1.60	1.30	Eu	1.79
Sm/Yb	1.55	1.66	1.21	Yb	4.2

* The average analises in the table represent: 1, Average of 14 basic rocks from the Măcin bimodal dyke swarm (data from Nicolae and Seghedi[3]; Saccani *et al.*[4]); 2, Average of 14 basic rocks from the Somova bimodal volcanics (data from Savu *et al.*[2]); 3, Average of 30 rocks from the Niculițel basalts (data from Savu *et al.*[5]); 4, Averages of REE from the North Dobrogea aulacogen basic rocks:A, Average of 2 rocks from the Măcin dyke swarm (data fron Saccani *et al.*[4]); B, Average of 3 rocks from the Niculițel flood basalts (data from Saccani *et al.*[4]) ; C, Average of 10 rocks from the Somova bimodal volcanics (data from Savu *et al.*[2])

Depending on the relationships between FeOtot, alkalies and MgO (Fig. 3) the averages of the basic rocks from Table 2 plot in the tholeiitic magma domain, except for the average of the Somova basic volcanics, which plot in the CA field due to the spilitization process that was intensive enough in these rocks. It is of note that the tholeiitic magmas are characteristic for both the ocean floor and the intra-plate basalts. What discriminates these rock groups is TiO_2. It has an unexpected low content (1.73 %) in the Măcin basic rocks, in comparison with the related rocks from the Niculițel flood basalts and Somova bimodal volcanics. This fact has a great importance in establishing the tectonic setting of the Triassic volcanics. Thus, on the Zr/Y vs. Ti/Y diagram (Fig. 4), because of the Ti low content, most of the Măcin basic dykes plot in the MPB field. Only some of these rocks occur in the field of the Niculițel within-plate flood basalts and of Somova basic rocks. It is of note that some initial basaltic rocks from the Liassic ophiolites of the South Carpathians, which, by their nature, are margin plate basalts, pass into the WPB field, too.

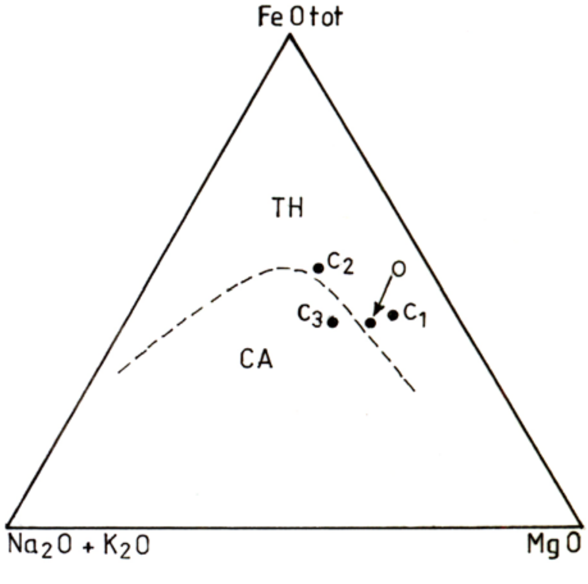

Fig. 3. Plot of the basic rocks on the FeOtot-Na_2O+K_2O-MgO diagram. Fields according Irvine and Baragar[25]: TH, tholeiitic; CA, calc-alkaline; C_1, average of the Macin basic rocks; C_2, average of the Niculitel flood basalts; C_3, average of the Somova basic rocks; O, average of the South Carpathian ophiolites (data from Savu *et al.*[26]).

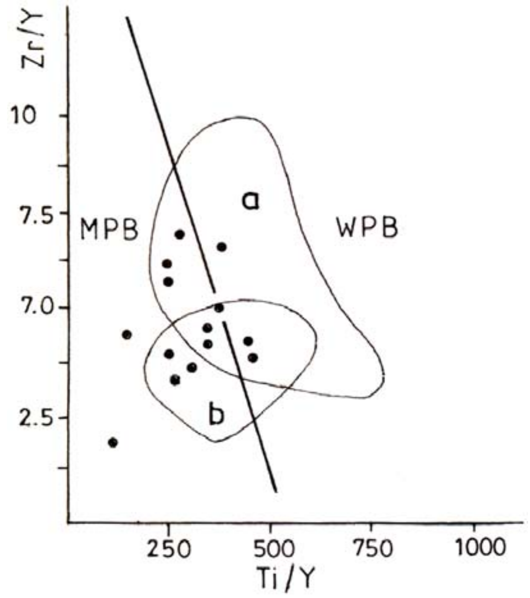

Fig. 4. Plot of the basic rocks on the Zr/Y vs. Ti/Y diagram. Fields according to Pearce and Gale[27]: MPB, margin plate basalt; WPB, within-plate basalt; a, field of the Niculițel and Somova basalts; b, field of the South Carpathian ophiolites (data from Savu *et al.*[26]); dot, Măcin basic rocks.

This inconsistence occurs on the V *vs*. Ti/1000 diagram (Fig. 5), too, on which the Măcin basic rocks plot within the MORB field, some of them passing into the WPB field, in which most of the Niculițel flood basalts and Somova basic rocks are situated. It is of note that most rocks of the Măcin basic rocks are plotting in the OFB (MORB) field of the Liassic South Carpathian ophiolites. The same situation results from the diagram in Figure 6, on which the Măcin rocks show rather N-Type MORB characteristics, like the Paleozoic Luncavița basic rocks (see Savu and Stoian[20]).

In contrast to these two diagrams, on the Zr/Y *vs*. Zr diagram (Fig. 7) most of the Măcin basic rocks plot in the WPB field and namely, within the field of the Niculițel flood basalts and Somova basic rocks. Only a few rocks occur in the MORB field.

The discriminant diagrams above presented, which are based on both major and trace elements, show that, by their chemical characteristics, the Triassic basic rocks from the North Dobrogea aulacogen are WPB to MORB transitional rocks. Depending on the chemical elements taken on the diagrams, these rocks plot either in the WPB field or in the MORB field, a characteristic more obvious at the Măcin basic rocks. The variable values of the ratios presented in Table 2 also show the differences between these basic rocks, and especially between the Măcin dyke rocks and the related volcanics. As for instance, the value of the (La/Sm)N ratio is lower than 1 in the Măcin basic rocks and higher in the related volcanics. It is useful to mention here that there are WPB to IAB transitional rocks, too, which are represented by the continental hotspot basaltandesites from the Mureş Rift (Savu[29]). The ambiguous characteristics of these rocks were determined by the parental magmas composition and evolution (see also Savu *et al.*[5]).

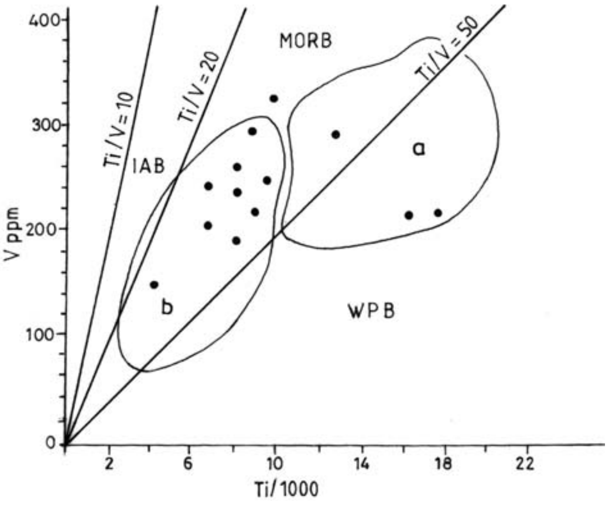

Fig. 5. Plot of the basic rocks on the V *vs*. Ti/1000 diagram. Fields according to Shervais[28]: IAB, island arc basalt; MORB, mid-ocean ridge basalt; WPB, within-plate basalt; a, field of the Niculiţel and Somova basic rocks; b, field of the South Carpathian ophiolites (sources like in Figure 3); dot, Măcin basic rocks.

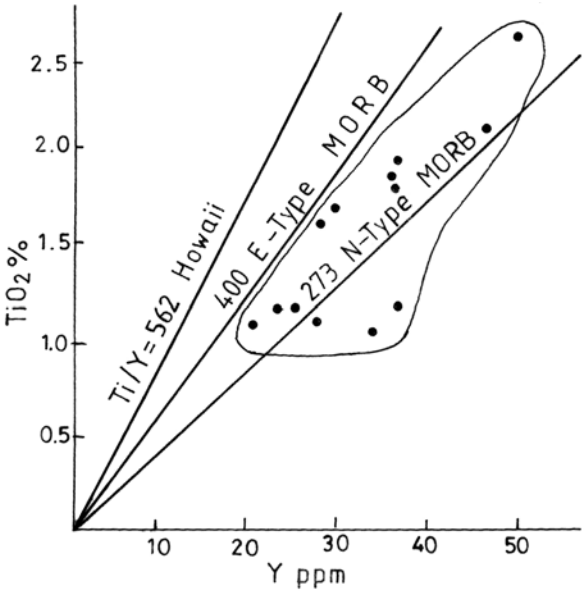

Fig. 6. Plot of the basic rocks on the TiO_2 *vs*. Y diagram. Ratios according to Perfit *et al.*[30]); dots and field represent the Măcin basic rocks.

ORIGIN OF THE PARENTAL MAGMAS AND THEIR EVOLUTION

The origin and evolution of the parental magmas from which the volcanic rocks of the three Triassic volcanic zones in the North Dobrogea aulacogen derived, are somehow differing one another. As it results from the Haase and Devey (Dy/Yb)N *vs*. (Ce/Yb)N diagram, presented by Saccani *et al.*[4] (Fig. 10), the parental magmas of the Măcin basic rocks and of the other basic volcanics originated in a mixed source with 5 % garnet in its lherzolitic composition, in which the partial melting was of about 9 to 10 %. This fact would explain the ambiguous geochemical characteristics of the Triassic basic rocks from the North Dobrogea aulacogen, especially of those from the Măcin dyke swarm in which the MORB signature is more evident. It is remarkable that the chemical composition of the Triassic pre-ocean Coştei intra-plate basalts and that of the Liassic ocean floor basalts from the Mureş Zone, in Banat, are very close, too (see Savu[31]).

The Ce/Yb *vs*. Ce diagram (Fig. 8) shows that the parental magmas of the basic rocks from the three Triassic magmatic zones of the North Dobrogea aulacogen formed in the mantle at close depth. Thus, the parental magma of the Măcin basic rocks and of the Niculiţel flood basalts occurred at a depth of about 50–60 km, like the magma of the Decan within-plate trapp complex. From lower depth of about 30–40 km, came the parental magma of the basic rocks from the Somova bimodal volcanics. Such a possibility would be explained by the presence of a very thinned crust, strongly eroded during the long period of the Permian peneplanization. Now the Mohorovicić surface is located in the North Dobrogea aulacogen at a depth of about 34 km (Socolescu *et al.*[32]). On the contrary, the parental magma of the South Carpathian ophiolitic rocks formed at a depth of about 90 km, like the magma from the Réunion Island.

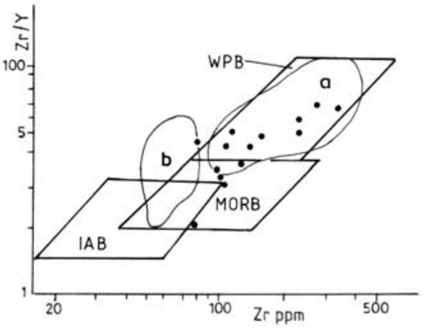

Fig. 7. Plot of the basic rocks on the Zr/Y vs. Zr diagram. Fields according to Pearce and Norry[33]: WPB, within-plate basalt; MORB, mid-ocean ridge basalt; IAB, island arc basalt; field *a* and dots represent the Măcin basic rocks.

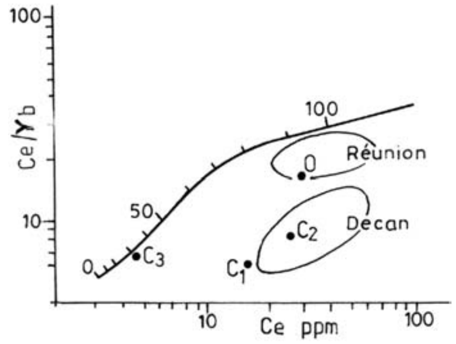

Fig.8. Plot of the basic rocks on the Ellam[34] Ce/Yb *vs*. Ce diagram. C_1, C_2, C_3 and O as in Figure 3.

As it results from the Th/Yb *vs*. Ta/Yb diagram (Fig. 9), the parental magma of the Măcin basic rocks derived from a depleted mantle of MORB-type, while the parental magma of the Niculiţel flood basalts and Somova basic rocks came rather from an enriched mantle of WPB-type.

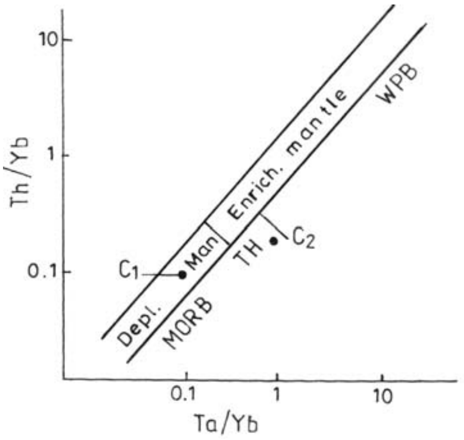

Fig. 9. Plot of the basic rocks on the Th/Yb vs. Ta/Yb diagram. Array and fields according to Pearce[35]: WPB, within-plate basalt; MORB mid-ocean ridge basalt; C_1 and C_2, as in Figure 3.

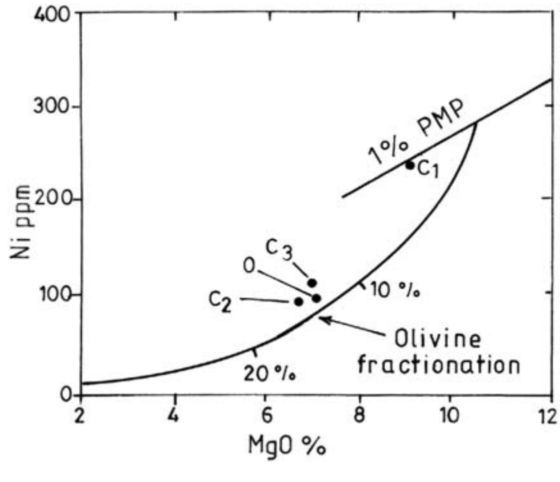

Fig 10. Plot of the basic rocks on the Ni vs. MgO diagram. The olivine fractionation curve and 1 % PMP (pyrolite melting line), are according to Volker *et al.*[36]; C_1, C_2, C_3 and O, as in Figure 3.

An essential characteristic of the magmas the present paper is dealing with, is pointed out by the Ni vs. MgO diagram (Fig.10). It shows that the parental magma of the Măcin basic rocks was a rudimentary magma, the composition of which was almost similar to that of a pyrolite formed by the melting of 1 % of the mantle source. The olivine crystals present in the Măcin basic rocks as well as their high MgO content support this feature. These aspects suggest that this parental magma erupted just after its formation. The parental magma of the Niculiţel flood basalts and of Somova basic rocks, as well as that of the South Carpathian ophiolites, underwent a longer evolution, during which the olivine fractionation process reached values of about 12 to 13 %. This fact would explain the differences in the geochemical characteristics of the related basic rocks and in their plotting on different discriminant diagrams.

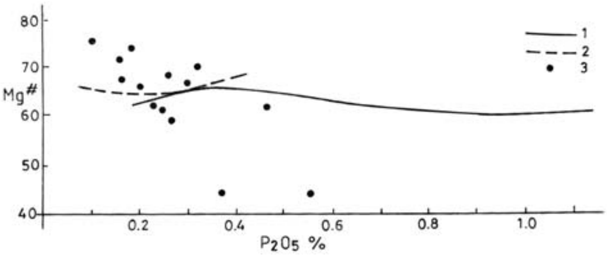

Fig. 11. Plot of basic rocks on the Mg$^{\#}$ *vs*. P_2O_5 diagram: 1, trend of the Niculiţel flood basalts; 2, trend of the South Carpathian ophiolites; dot, Măcin basic dyke rocks.

The different evolution of the parental magmas of the Triassic basic rocks and of the Liassic South Carpathian ophiolites also results from the Mg$^{\#}$ *vs*. P_2O_5 diagram (Fig.11). It shows that the parental magmas of the Niculiţel flood basalts and of Somova basic rocks had a longer evolution in comparison with that of the Măcin basic rock magma. Finally, it reaches the quartzdoleritic composition. The evolution of the parental magma of the South Carpathian ophiolites was a reduced one. This diagram also shows that the rocks with the highest values of Mg$^{\#}$ occur among the rocks from the Măcin dyke swarm, which is in conformity with the pyrolitic character of the parental magma and with the high content of MgO in the rocks (Table 2). The same diagram indicates a large variation in the composition of the Măcin basic rocks, as their plots on the diagram are very dispersed. Still, this dispersion maintains within the limits of the South Carpathian ophiolites.

CONCLUSIONS

The emplacement of the Măcin dyke swarm and of other basic dykes – which represented feeder channels for the Niculiţel and Somova volcanics – within the sialic infrastructure of the North Dobrogea aulacogen, represents a peremptory argument for the opinion that all these igneous rocks are WPB-type rocks. The flow of the volcanic rocks directly over the Pre-Variscan and Variscan infrastructure consisting of crystalline schists, represents an obvious argument in this respect, too. The volcanic rock associations in the North Dobrogea aulacogen, the bimodal dyke swarm and bimodal volcanic rocks as well as the related barite mineralizations are, also, strong arguments to support the within-plate tectonic setting of the Triassic igneous rocks.

The discriminant diagrams (Figs. 4, 5, 6) also support the within-plate tectonic setting of the Triassic volcanics. The Niculiţel flood basalts and Somova basic rocks show only a weak tendency toward OFB (MORB) field, while the Măcin basic rocks plot either in the WPB or in the MORB fields, depending on the used discriminant diagram.

The parental magma of the Măcin basic rocks was a rudimentary magma, the composition of which was very close to that of a pyrolite, resulted from the melting of 1 % of the mantle source. This magma was engendered in the deep mantle and rapidly erupted under the Triassic continental distension conditions, along the deep faults of the initial rifting zone. The occurrence of the parental magma under such conditions could explain the ambiguous characteristics of the derived rocks, too. It seems that in the pyrolitic stage, or near it, the primordial meltings of different tectonic settings do not differ much one another. These meltings differ one another by their MORB signature. For instance, the Măcin basic rock magma was rather of N-Type MORB, and that of the South Carpathian ophiolites was of E-type MORB magma (Savu[14]).

Briefly, the Triassic volcanics of the North Dobrogea aulacogen, which derived from more evolved magmas, are real within-plate rocks, with a weak tendency towards MORB. By the geological setting, as dyke swarms crossing the crystalline schists infrastructure, the Măcin rocks are without any doubt within-plate rocks, too, but according to their geochemical features they represent WPB to MORB transitional rocks.

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