International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:12, No:5, 2018

Jalovchat Gabbroic Intrusive of the Caucasus: Petrological Study, Geochemical Peculiarities and Formation Conditions

Giorgi Chichinadze, David Shengelia, Tamara Tsutsunava, Nikoloz Maisuradze, Giorgi Beridze

Abstract**—**The Jalovchat intrusive is built up of hornblende gabbros, gabbro-norites and norites. Within the intrusive hornblende-bearing gabbro-pegmatites are widespread. That is a coarse-grained rock with gigantic hornblende crystals. By its unusual composition, the Jalovchat intrusive has no analogue in the Caucasus. However, petrologically and geochemically, the intrusive rocks were studied insufficiently. For comprehensive investigations, the authors applied appropriate methodologies: Microscopic study of thin sections, petro- and geochemical analyses of the samples and also different petrogenic, rare and rare earth elements diagrams and spidergrams. Analytical study established that the Jalovchat intrusive by its composition corresponds mainly to the mid-ocean ridge basalts and according to geodynamic type belongs to the subduction type. In general, it is an anomalous phenomenon, as in the rocks of such composition crystallization of hornblende and especially of its gigantic crystals is atypical. The authors believe that the water-rich magma reservoir, which was necessary for the crystallization of gigantic hornblende crystals, appeared as a result of melting of water-rich mid-ocean ridge basaltic rocks during the subduction process in Bajocian time.

Keywords**—**Gabbroic intrusive, petrology, geochemistry, genesis, the Caucasus.

I. Introduction

THE Caucasus situated between the Eurasian and Afro-Arabian plates is a central link of the Mediterranean (Alpine-Himalayan) mobile belt. One of the most important components of the Caucasus is the Main Range structural zone of the Greater Caucasus. The zone thrust over the fold system of the southern slope of the Greater Caucasus by the Main Thrust. With the above thrust a number of Jurassic intrusives of basic and acid composition are associated. Their majority is elongated in general Caucasian direction and is spread both in the pre-Alpine crystalline basement of the Main Range zone and the Mesozoic fold system of the southern slope. One of the intrusives of basic composition is the Jalovchat gabbroic intrusive. The intrusive intruded into the rocks metamorphosed under conditions of a high-grade amphibolite facies and is exposed on both slopes of the axial part of the of the Main Range zone of the Greater Caucasus particularly in the Aksaut river head and in left tributaries of the Atsgara upper reaches (Fig. 1). It covers the area of about 25 km^2 with 10 km of length and with a maximum width of 3.5 km. Moreover, its thin (0.5-2.0 m) concordant or crossing bodies occur in host metamorphic rocks represented by quartz-plagioclase-mica bearing, garnet-, andalusite-, staurolite-, sillimanite- and cordierite-quartz-plagioclase-mica bearing schists, migmatites and epidote-, diopside-, garnet-quartz-plagioclase-hornblende bearing amphibolites. The K-Ar age dating of the intrusive shows 176±20 Ma [1].

II. Petrological Description

It should be noted that by its composition the Jalovchat gabbroic intrusive has no analogue not only in the Main Range zone of the Greater Caucasus, but also in the Caucasus on the whole. The Jalovchat intrusive is composed mainly of hornblende gabbro; gabbro-norites and norites connected with each other by gradual transitions are less spread and do not form independent bodies.

Gabbroids are massive, medium- and coarse-grained rocks of black and dark grey color. Their structure is gabbroic, rarely gabbro-ophitic or poikilogabbro-ophitic. The main rock-forming minerals are: grayish brown hornblende (≈40%) of Mg-hastingstite and Mg-hornblende composition, hyperstene, diopside (≈20%) and plagioclase (Pl^{82-89}; ≈40%). Diopside, hyperstene and a grayish brown hornblende formed as a result of basite magma crystallization. Accessory minerals are represented by apatite, rutile and ore minerals. Due to postmagmatic transformations cummingtonite, blue-green hornblende, biotite, tremolite, actinolite, chlorite, prehnite and scapolite occur. As a results of petrographic study cummingtonization of primary minerals (hyperstene, diopside and of a grayish brown hornblende) and simultaneously deanorthitization of plagioclase took place. In particular, diopside partially was transformed into a grayish brown hornblende, but plagioclase is replaced by saussurite, prehnite and scapolite.

In the intrusive vein formations (thickness 0.3-0.6 m) of microgabbro and gabbro-diabase porphyrite, anorthosite and hornblende gabbro-pegmatite are widely spread. The veins of microgabbro and gabbro-diabase porphyrite do not differ in composition from the rocks of the intrusive; they rarely contain quartz. Anorthosites form thin bodies of uneven shape and veins; sometimes there occur up to 1 m thick veins forming eruptive breccias. The rock is mainly anchimonomineralic, though hornblende inclusions occur rarely (Fig. 2).

Tamara Tsutsunava is with the Alexander Janelidze - Ivane Javakhishvili Tbilisi State University, Georgia (e-mail: tsutsunava@yahoo.com).

International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:12, No:5, 2018

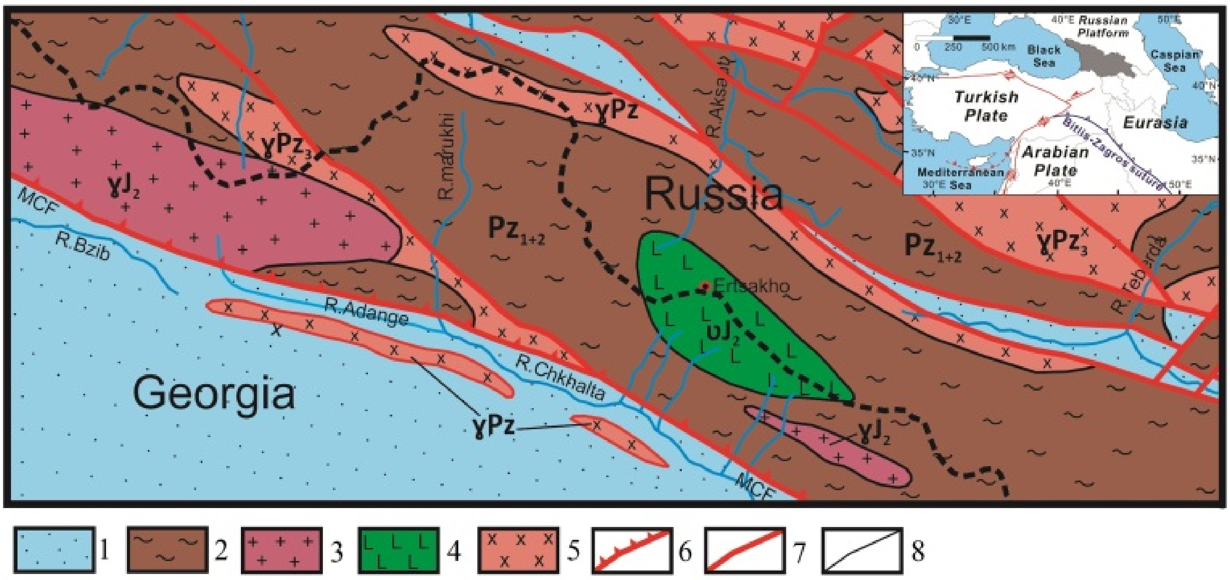

Fig. 1 Schematic geological map of the Greater Caucasus Main Range zone in the area of exposure of the Jalovchat intrusive. 1 - Jurassic sedimentary rocks; 2 - Pre-Alpine metamorphic complex; 3 - Middle Jurassic granitoids; 4 - Middle Jurassic gabbroids; 5 - Paleozoic granitoids; 6 - MCF- Main Thrust of the Greater Caucasus; 7 – Ruptures; 8 - Geological boundaries

Fig. 2 Gabbro-pegmatites. Gigantic crystals of hornblende in anorthosite mass

Among the vein formations of the Jalovchat intrusive, hornblende gabbro-pegmatites are most widespread. Spatially, they are closely associated with anorthosites. The shape, size and position of gabbro-pegmatitic bodies vary within a very wide range. They occur in the form of veins, lenses and bodies of uneven shape. Their dimensions are measured in tens of centimeters, rarely reaching 1-1.5 m. Veins mainly of 15-40 cm thickness with indefinite orientation are observed. Contacts of bodies with enclosing rocks are usually clear, but in places, indistinct gradual transitions are observed as well. Hornblende gabbro-pegmatites are coarse inequigranular. Sizes of hornblende prisms amount several centimeters, sometimes reaching gigantic sizes of 30-50 cm. The crystals are arranged randomly, oriented along the strike or perpendicular to the vein salbands. Gabbro-pegmatites are very homogeneous: the main minerals are hornblende and plagioclase; secondary minerals - biotite, chlorite, tremolite, actinolite, prehnite, scapolite and epidote group minerals; accessories are apatite, ore minerals and rarely rutile.

The Jalovchat gabbroic intrusive contain xenoliths of amphibolites and metaterrigenous rocks. The first of them is more or less unchanged, and the xenoliths of meta-terrigenous rocks have been greatly altered as a result of the contact effect. There have been established mineral parageneses of regional and contact metamorphisms. The mineral parageneses of regional metamorphism are:

biotite+garnet+staurolite+gedrite+plagioclase+quartz;
biotite+ garnet+ sillimanite + plagioclase+quartz;
biotite+garnet+gedrite+plagioclase+quartz;
garnet+gedrite+plagioclase+quartz.

Due to influence of the intrusion cordierite, spinel (rarely replaced by corundum) and basic plagioclase ($An_{78\text{-}82}$) are formed in xenoliths and regionally metamorphosed rocks. Newly formed mineral parageneses correspond to hornblende-bearing hornfels facies of contact metamorphism.

III. Petro-Geochemical Study

The Jalovchat intrusive was insufficiently studied from the petrologic and geochemical viewpoint. There was an opinion about the formation of the Jalovchat intrusive in deep horizons of the Earth's crust as a result of crystallization of water-saturated Bajocian basalt magma [1]. Though, the above inference was not suitably corroborated by petro-geochemical data. This shortcoming is filled with new data adduced in the article.

Petrogenic elements and RE and REE contents in the rocks of the Jalovchat intrusive are presented in Tables I and II.

TABLE I
CONTENT OF PETROGENIC ELEMENTS (MASS %) IN THE ROCKS OF JALOVCHAT INTRUSIVE

№	6015	6025	6032	6093	6906	6029	6040	6909	6053	6095	6908
SiO_2	44.02	45.32	48.03	47.63	46.83	47.15	44.67	46.01	44.55	43.60	48.81
TiO_2	1.10	1.10	0.82	1.00	0.62	0.77	0.75	0.88	0.66	1.50	0.92
Al_2O_3	18.13	17.79	17.35	20.50	19.85	13.30	15.34	17.08	19.43	13.77	14.71
Fe_2O_3	4.95	4.76	5.11	3.50	3.69	5.10	4.53	4.04	4.10	7.65	3.00
FeO	8.64	6.12	7.56	5.08	7.92	7.08	7.92	7.36	6.09	9.36	7.82
MnO	0.14	0.14	0.21	-	0.14	0.17	0.21	0.33	-	0.21	0.25
MgO	7.68	7.96	8.29	5.83	5.60	11.15	10.24	9.86	8.56	10.26	10.09
CaO	11.69	12.21	2.89	12.13	10.02	10.93	13.30	11.00	12.94	10.48	10.03
Na_2O	2.00	2.40	2.0	2.60	2.40	1.91	2.00	1.92	2.30	2.10	2.56
K_2O	0.20	0.42	-	0.50	0.50	0.20	-	-	0.05	-	0.36
P_2O_5	0.12	0.08	0.09	-	-	0.07	0.08	0.09	-	0.11	-
H_2O^-	0.68	0.62	0.22	-	01.0	-	0.29	0.09	-	0.75	0.37
LOI	0.44	0.78	0.84	1.36	1.66	1.86	0.37	1.61	1.12	0.45	1.51
∑	99.8	99.7	99.9	100.2	99.95	101.1	99.7	100.2	100.2	99.86	100.3

Gabbro - 6015, 6025, 6032, 6093, 6906; microgabbro - 6029, 6040, 6909; gabbro-pegmatite - 6053, 6095 and 6908. Analytical investigations are conducted in the Laboratory of the Department of Geology of Georgia.

The data of our researches are plotted on different petrochemical diagrams. On AMF diagram (Fig. 3) most of the spots are disposed in the field of tholeiitic basalts.

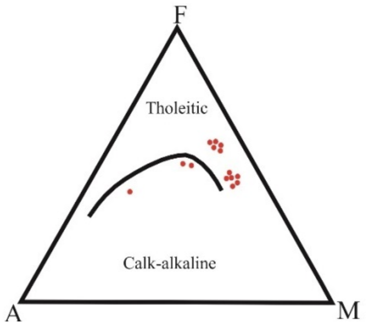

Fig. 3 Arrangement of spots of the Jalovchat intrusive rocks on AFM diagram. Series: I – tholeiitic, II – calk-alkaline [2]

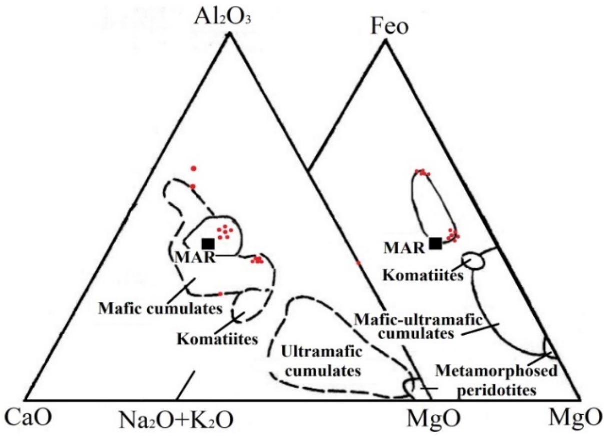

Fig. 4 Distribution of Spots of the Jalovchat Intrusive Rocks on ACM and AFM Diagrams [3]

According to ACM-AFM double diagram (Fig. 4) the samples have been distributed in the fields of mid-oceanic ridges and mafici cumulates.

On TiO_2-FeO/MgO, Zr-Y-Zr and Ti/Cr-Ni diagrams and on Ti-Zr-Y triangular diagram the figures arranged in the fields of island-arc and mid-oceanic basalts or along the trends corresponding to mid-oceanic ridges or island arcs (Figs. 5-8).

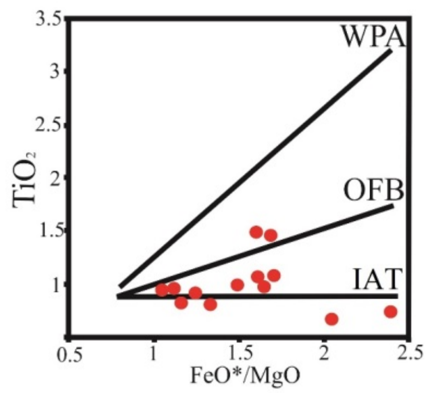

Fig. 5 Discriminative lines of island-arc tholeiites (IAT), mid-oceanic (OFB) basalts and within-plate (WPA) alkali basalts [4]

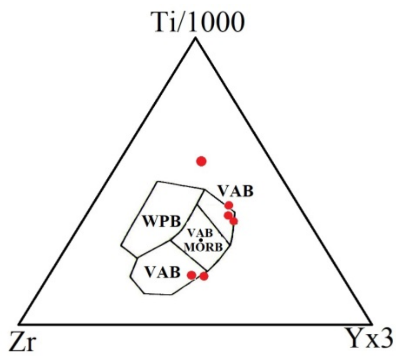

Fig. 6 WPB – within-plate basalts, VAB+MORB – island-arc basalts and basalts of mid-oceanic ridges, VAB – island-arc basalts [5]

In K_2O/TiO_2 diagram (Fig. 9) the spots occupy fields of normal and enriched type mid-oceanic ridges.

TABLE II
RE AND REE CONTENT (PPM) IN THE ROCKS OF THE JALOVCHAT INTRUSIVE

	6025	6906	6912	6092	6056	6913
P	399	465	1050	374	281	589
Sc	32.0	27.6	39.0	56.7	60.0	11.5
Ti	8910	6871	11000	10380	15240	2874
V	343	261	365	473	625	53.5
Cr	145	20.2	27.5	93.5	45.6	13.9
Mn	1130	1335	1460	1446	1181	1102
Co	36.9	32.0	35.2	51.8	59.9	15.1
Ni	31.3	13.7	15.9	58.9	84.4	8.39
Cu	21.1	43.1	46.4	33.4	72.4	11.5
Zn	67.6	85.7	84.0	84.5	80.4	57.2
Ga	16.9	20.8	19.4	16.1	16.2	15.8
Ge	1.24	1.49	1.75	1.63	1.60	0.919
As	0.476	0.439	1.89	0.518	0.544	0.402
Se	0.0334	0.0524	0.0109	0.0589	0.0449	0.0262
Rb	14.7	24.3	4.18	22.4	3.13	11.5
Sr	154	202	276	76.8	159	175
Y	31.6	30.2	7.47	37.0	37.2	20.3
Zr	34.8	47.2	50.9	77.5	35.6	90.3
Nb	1.86	3.10	11.0	3.48	3.11	2.90
Mo	—	—	1.48	—	—	—
Ag	0.0221	0.0248	0.0310	0.0338	0.0198	0.0421
Cd	0.0256	0.0308	0.0273	0.0415	0.0270	0.0281
Sn	1.01	0.793	—	1.76	1.11	0.640
Sb	0.266	0.168	0.184	0.0605	0.0857	0.0954
Te	0.0016	0.0047	0.0099	0.0034	0.0035	0.0023
Cs	0.443	0.819	0.423	1.17	0.144	0.540
Ba	35.2	102	28.7	74.0	25.5	75.3
La	2.60	6.31	11.7	5.78	2.29	8.41
Ce	7.44	16.5	25.4	15.8	8.12	18.1
Pr	1.34	2.58	3.38	2.42	1.60	2.36
Nd	7.74	12.6	14.4	11.6	9.60	10.1
Sm	3.08	3.92	2.98	3.92	3.95	2.58
Eu	1.05	1.20	1.17	1.20	1.25	0.834
Eu	1.10	1.25	1.23	1.28	1.29	0.860
Gd	4.05	4.44	2.62	4.95	5.06	2.96
Tb	0.746	0.754	0.294	0.874	0.929	0.461
Gd	4.53	4.75	2.41	5.38	5.67	2.96
Dy	5.43	5.21	1.48	6.26	6.68	3.13
Ho	1.21	1.14	0.301	1.38	1.46	0.703
Er	3.21	3.07	0.790	3.78	3.81	2.00
Tm	0.465	0.463	0.113	0.554	0.539	0.319
Yb	2.88	2.87	0.770	3.46	3.25	2.17
Lu	0.428	0.428	0.125	0.513	0.466	0.357
Hf	1.31	1.74	1.32	2.39	1.47	2.63
Ta	0.0039	0.0062	0.0211	0.0086	0.0063	0.0096
W	0.127	0.141	0.307	0.231	0.118	0.0537
Tl	0.226	0.374	0.123	0.355	0.0802	0.149
Pb	2.40	2.67	2.56	1.85	1.33	3.76
Th	0.360	1.15	1.08	1.05	0.118	2.38
U	0.124	0.310	0.309	0.425	0.0518	0.716

Gabbro - 6025, 6906, 6912, 6092; gabbro-pegmatite - 6056 and 6913. Analytical researches were conducted in the Laboratory of Geological Researches of National Chung-Cheng University, Taiwan.

According to Th/Nb/Y ratio the Jalovchat intrusive corresponds to the field of depleted mantle, but by Sm/Y-Ce/Sm – to the MORB area (Fig. 10).

Th/Y and Nb/Y ratios correspond to the MORB composition, Th/Yb-Ta/Yb and La/Nb-Ti ratios – to N MORB, and Rb/Y and N/Y correspond to the lower crust formations. Though, on Ce/Pb-Ce and Nb/Th-Nb diagrams the figures occupy the field of primitive mantle.

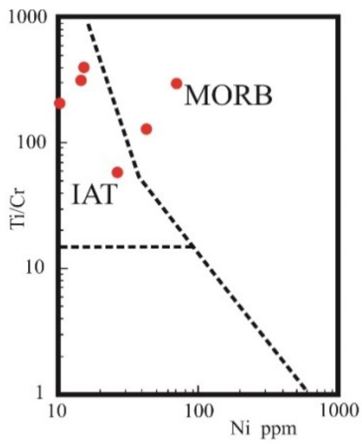

Fig. 7 IAT and MORB [6]

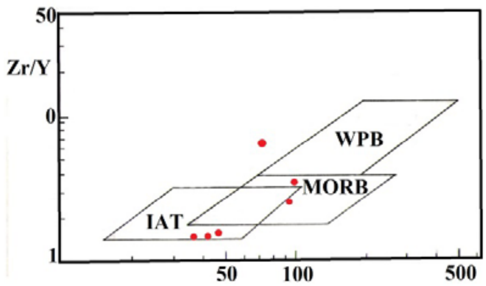

Fig. 8 IAT (island-arc tholeiites), MORB and WPB (within-plate basalts) [5]

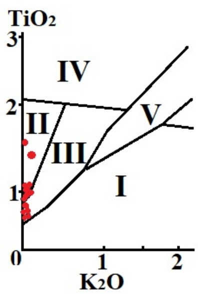

Fig. 9 Arrangement of spots of the Jalovchat intrusive rocks on K_2O/TiO_2 diagram. I – island-arc basalts; II – normal tholeiitic basalts of mid-oceanic ridges; III – enriched basalts of mid-oceanic ridges; IV – within-plate basalts; V – basalts of platform activation zones [6]

Spidergramms are characterized by almost horizontal trend, weakly expressed Eu minimums and by a slight depletion of light REE (Fig. 11).

A comparison of the spidergrams shows, that tholeiitic basalts of the Jalovachat intrusive are more depleted in light REE elements than the archaic tholeiitic basalts [7].

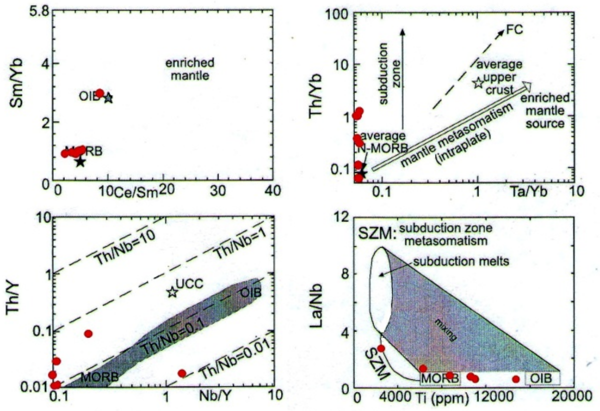

Fig. 10 Arrangement of spots of the Jalovchat intrusive rocks on Sm/Yb-Ce/Sm, Th/Y-Nb/Y, Th/Yb-Ta/Yb and La/Nb-Ti diagrams

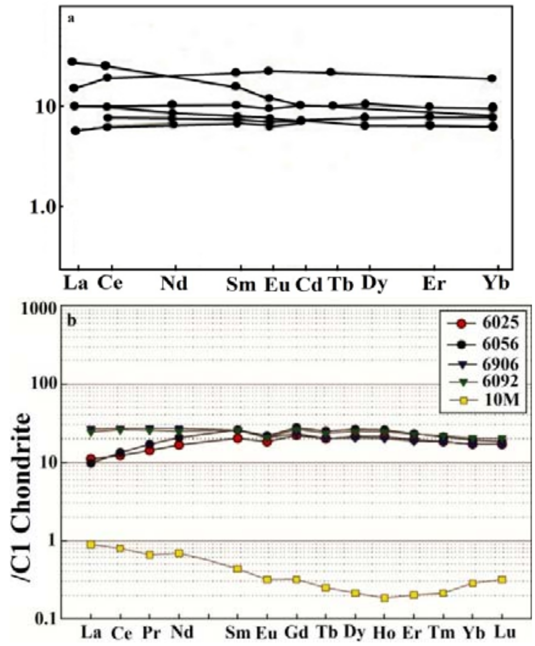

Fig. 11 (a) spidergram of REE distribution for the tholeiitic basalts [7]; (b) spidergram of REE distribution in the Jalovchat intrusive

According to above diagrams perto-geochemical characteristics of the Jalovchat gabbroic intrusive predominantly correspond to MORB. Generally, it is an anomalous phenomenon, as giant prysmatic gabbro-pegmatites are not indicated in the well-known "ophiolitic" section. For the crystallization of hornblende and especially of its gigantic crystals water-rich magma reservoir was needed; The authors believe that in the Jalovchat intrusive the existence of such magma reservoir was conditioned by melting of water-rich MORB rocks during the subduction process in Bajocian time. This event is presented by the authors on the scheme of the palinspastic reconstruction of the Caucasian segment of the Mediterranean (Fig.12).

IV. Conclusions

The above diagrams of petrogenic elements, RE and REE show that perto-geochemical characteristics of the Jalovchat gabbroic intrusive predominantly correspond to MORB. The authors consider that the existence of these rocks within the area of the Caucasian marginal sea (contemporary area of the Caucasian Main Range Zone) was conditioned by drawing down of water-rich MORB type rocks to the deeper horizons, by its melting, formation of magma chamber and finally by its intrusion into the Earth's crust during Bajocian time. Correspondlingly the Jalovchat intrusive belongs to the subduction geodynamic type.

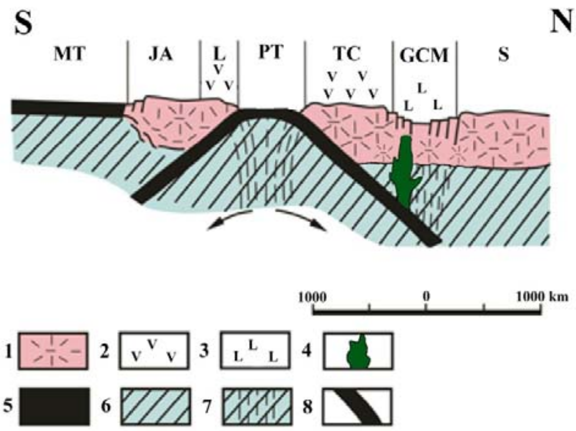

Fig. 12 Palinspastic reconstruction of the Caucasus segment of the Mediterranean belt along N-S profile for Jurassic time [8] with the authors additions:1 – consolidated continental crust; 2-3 – manifestation of volcanism: 2 – calc-alkaline, 3 – basaltic, 4 – gabbro of the Jalovchat intrusive; 5 – newly formed oceanic crust and ophiolites; 6 – upper mantle; 7 – heated upper mantle; 8 – subduction zones; Oceanic areas and small sedimentary basins: PT – Paleotethys, MT – Mesotethys (Neotethys), GCM – Greater Caucasus marginal sea. Continental plates and microplates: TC – Transcaucasian island arc, L – Lock-Karabach Zone, S – Scythian Plate, JA – Iran-Afghanian Plate

References

[1] G. Chichinadze. On the genesis of Jalovchat gabbroid intrusive. Bul. of the Acad. of Sciences of the Georgian SSR 85, N. 1, 1977, pp. 113-116.
[2] T. Irvine, W. Barager. A guide to the chemical classification of the common volcanic rocks. Canadian J. Earth Sci. V.8, N.5, 1971, pp.523-548.
[3] R. Coleman. Ophiolites. Springer-Verlag Berlin-Heidelberg-New York, 1977, 261 p.
[4] A. Myiashiro, F. Shido. Tholeiitic and calc-alkaline in relation to the behavior of titanium, vanadium, chromium and nickel. Amer. J. Sci. V. 275, 1975, pp. 265-277.
[5] K. Hatzipanagiotou, G. Pe-Pier. Ophiolitic and sub-ophiolitic metamorphic rocks of the Vatera area, Southern Lesbos (Greace): geochemistry and geochronology, 1994, pp. 17-29.
[6] L. Beccaluva et al. Magma affinities and fractionation trends in ophiolites. Ofioliti. V.8, N.3, 1983, pp. 307-324.
[7] S. Taylor, S. McLennan. The Continental crust: its composition and evolution. London, Blackwell, 1985, 384 p.
[8] I. Gamkrelidze. Geological structure of Georgia and geodynamic evolution of the Caucasus. Proceedings of IGCP Forth Plenary Conference, 2016, pp. 69-76.