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K/Ar RADIOMETRIC DATING ON ROCKS FROM THE NORTHERN PART OF THE DITRÓ SYENITE MASSIF AND ITS PETROGENETIC IMPLICATIONS

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ABSTRACT

Several opinions have been published on the date of the formation of the Ditró syenite massif. Direct contact of this massif and sedimentary rocks can not be found. It is probable that the syenite massif lithostratigraphically formed during the time between the Saalic and the Laramian orogenic cycles. Valuable radiometric data (less than 30) gained by different methods (Pb/Pb, K/Ar, Rb/Sr) have mainly been related to the syenites and nepheline syenites (STRECKEISEN and HUNZIKER, 1974; MÎNZATU, 1980 in JAKAB et al., 1987; JAKAB and POPESCU, 1979; JAKAB and POPESCU, 1984; JAKAB and POPESCU, 1985 in JAKAB et al., 1987). Although valuable data for hornblendites (BAGDASARIAN, 1972) differ from those of syenites, most researches dated the formation of the massif as a whole to the Jurassic on the basis of the radiometric data for the syenites and the nepheline syenites.

In this work 25 K/Ar radiometric data of the rocks (hornblendites, diorites, granites, nepheline syenites, syenites, alkaline feldspar syenites) are evaluated and based on it, devising of a petrogenetic model is attempted.

K/Ar radiometric age of the hornblendites is Middle and Upper Triassic (Ladinian and Carnian), and that of the granites is Upper Triassic (Rhaetian) – Lower Jurassic (Hettangian), the diorites indicate mixed age – Upper Triassic (Rhaetian) and Middle Jurassic (Bajocian), age of the nepheline syenites is Middle Triassic (Ladinian), and that of the syenites and the alkaline syenites is Middle Jurassic (Aalenian) – Lower Cretaceous (Albian). These data indicate two great geological events (intrusions). One happened in the age of the Upper Triassic – Lower Jurassic, and the other was formed in the Middle Jurassic – Lower Cretaceous. These events partly coincide with each other. It is proved by the mixed age of the diorites, which were probably formed by a hybridization of the hornblendites and the syenites during the second event.

INTRODUCTION

The syenite massif of Ditró (46°48' N, 25°30' E) is situated on the S-SW part of Gyergyó Alps (Romania). Diameters of its surface are 19 km and 14 km in NW and SE directions, respectively; its area is 225 km^2 including the bordering zones as well (*Fig. 1.*).

According to our present knowledge the syenite massif of Ditró is a complex magmatic body of E and NE (and perhaps SE and S) inclination, which has divided into some parts.

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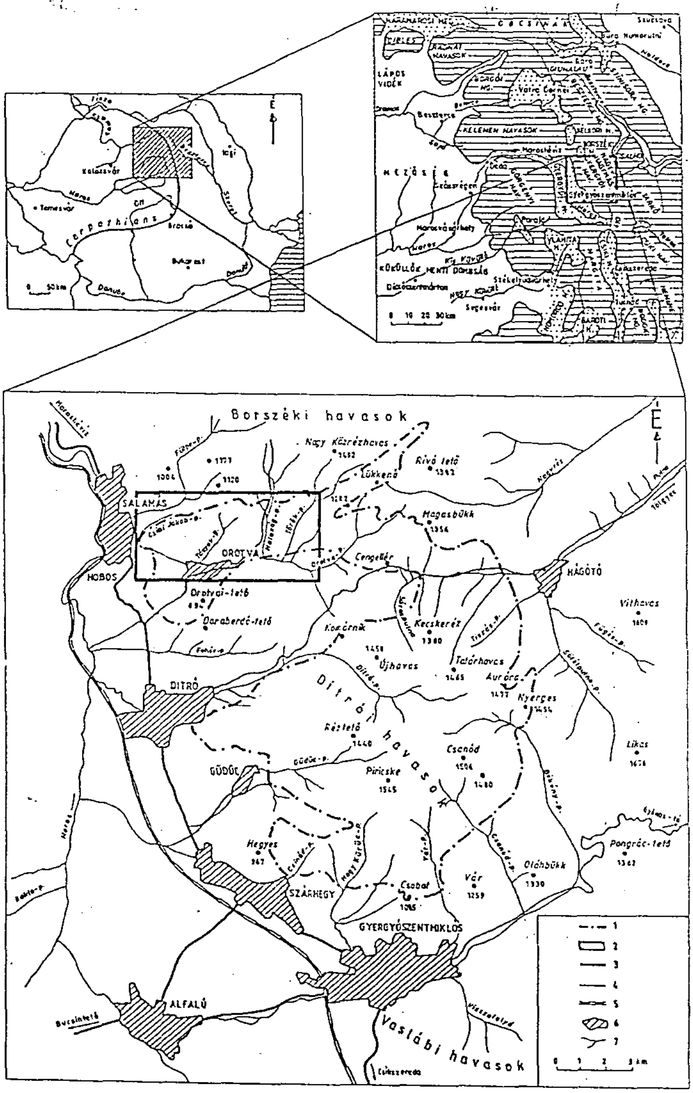

Fig. 1. Narrower and wider geographic environment of the Gyergyó Alps (Transylvania, Romania)
1. Boundary line of the Ditró syenite massif; 2. Study area; 3. Modernized road; 4. Non-modernized road; 5. Railway; 6. Settlement (town); 7. River (creek)

Geophysical (telluric and magnetotelluric) investigations of the Pacani–Tîrgu Neamt–Ditró–Régen geotraverse (VISARION et al., 1987) showed that it is a 2–2.5 km deep allochtonous body and it forms a part of the Bucovina Nappe.

According to the two dimensional model of JAKAB et al. (1987) this 6500 m thick massif is an intrusive, pseudostratified body. Its contact with the surrounding crystalline rocks can well be traced; inclination of the plane of the contact is low (10–40°) between its surface bordering line and the level line of the –1000m, and it is inclined outward, while it turns toward the massif below the level of the –1000 m (50–80°). The syenite massif is allochtonous, and its reverse fault planes are 3500 and 5000 m deep in the west and in the east, respectively.

The most important mean tectonic element of the massif and its surrounding is fracture zone (G8) running along the line of Salomás–Hodos–Remete–Alfalu (N-W). This zone was detected by gravitational and magnetotellurical measurement, as weel; according to the magnetotellurical measurements, it is inclined toward the west. Probably, it is the "consummation" paleoplane of the Outer Dacides (VISARION et al., 1987), i. e., collision plane of tectonic plates.

The syenite massif of Ditró intruded into the central crystalline rocks of the Eastern Carpathians, and it took part in the Alpine tectonic events together with them (PÁL MOLNÁR, 1994a, c). Within the Bucovina Nappe, the greatest part of the massif is in contact with the Tölgyes Series of the prealpine Putna Nappe. In smaller areas it also touches the Rebra and the Bretila Series. In the immediate vicinity of the massif the situation of the series is as follows (upwards from below): Rebra Series, Tölgyes Series, Bretila Series (PÁL MOLNÁR, 1994a, c). Each of these series is broken through by the syenite massif of Ditró. According to KRÄUTNER et al. (1976), on the basis of K/Ar radiometric dating, ages of formation of the series are as follows: Bretila Series and Rebra Series – 850±56 Ma; Tölgyes Series – 505±5 Ma.

Any contact of the syenite massif with sedimentary rocks can not be found. According to BALINTONI (1981) Mesozoic sedimentary rocks are absent, among others, under the prealpine Putna Nappe because this nappe was formed before the Trias. He suggests that prealpine nappes broken through y the syenite massif formed during the paroxysm of the Saalic tectogenesis.

The alpine nappes were formed under the influence of the Cretaceous orogenic phases (Austrian, Laramian). Therefore, the syenite massif was lithostratigraphically formed between the Saalic and the Laramian orogenic phases.

OUR MOST IMPORTANT KNOWLEDGES ON THE FORMATION AGE OF THE MASSIF AND ON THE SUCCESSION OF THE PROCESSES WITHIN THE MASSIF

REINHARD (1911) was the first researcher who dealt with the formation age of the syenite massif of Ditró. According to him its rocks are hypabyssal ones of the magma whose effusion formed the rocks of the Görgény Alps, i. e., this hypabyssal magmatic intrusion is younger (post Neocomian) than the last tectonic movements of the Eastern Carpathians.

In 1923 MAURITZ and VENDL stated that there are not any trace of cataclasis with the exception of the joints filled with fine sodalite-cancrinite-muscovite material, therefore, it was the only dynamic influence on the rocks. Consequently, these are traces of young folding and, in this way, it is not possible that the massif was formed before the Mesozoic.

STRECKEISEN (1931) agrees with REINHARD (1911) that the massif was formed after the Middle Cretaceous tectonic movements. He is of opinion that correlation of the rocks of the massif and those of the young Kelemen-Hargita volcanic range is not unambiguous.

IANOVICI (1929–1938), however, denies Reinhard's theory and points out the fact that syenites (Atlantic suite) do not correspond to the eruptive rocks (Pacific suite) of the Kelemen-Hargita range. It was a long time between the syenite intrusion and the Neogene volcanism of the Eastern Carpathians, and during this period rocks covering the massif were eroded, and, in this way, Neogene andesites, agglomerates and volcanic breccias deposited directly on the syenites. He suggests that the syenite intrusion is Pre-Cretaceous.

According to FÖLDVÁRI (1946) volcanic ranges consisted of Tertiary andesites, dacites and rhyolites have their granitic-dioritic magma chambers in the depth. These granitic-dioritic intrusions, assimilating the Mesozoic limestones of the Nagyhagymás Mountain, formed the nepheline syenitic rocks of the massif. If this theory is true, the syenite intrusion is at least Upper Cretaceous because there are Cretaceous limestones as well in the Nagyhagymás nappe.

From of his field studies and tectonic characters, STRECKEISEN (1952–1954) concludes that alkaline granites and alkaline syenites are of the same age, nepheline syenites are younger, while the "Ditró" essexites and the ultrabasic rocks are the oldest ones. In his opinion these rocks are of common origin.

IONESCU et al. (1966) made the first radiometric age determinations for the rocks of the massif (Table 1). The measurements were performed on zircons and monazites using Pb-α method.

TABLE 1

Summarizing table of the radiometric ages of the rocks from the Ditró syenite massif and the related contact zones

Author, year	No.	Number of the sample	Method	The studied rock type, locality	The studied fraction	Age (Ma)
IONESCU et al., 1966	1.	–	Pb-α	**Monacite**	–	326
	2.	–	Pb-α	**Zircon**	–	297
BAGDASARIAN, 1972	3.	5138	K/Ar	**Hornblendite** from lens in gneissic diorites, west of the conjunction of the Tászok and the Orotva creeks.	whole rock	196±6
	4.	5136a	K/Ar	**Hornblendite** from the zone of the gneissic syenites, west of the conjunction of the Orotva and the Simó creeks.	whole rock	161±2
	5.	5134a	K/Ar	**Hornblendite** from xenolite, west of the conjunction of the Orotva and the Halaság creeks.	whole rock	161±10
	6.	5139	K/Ar	**Hornblendite** with plagioclase inclusions, Ditró valley and the spring are of the Putna Creek.	whole rock	177±1
	7.	5137	K/Ar	**Pegmatite syenite**, from veins in hornblendites, east of the conjunction of the Orotva and the Tászok creeks.	whole rock	142±7
	8.	5135	K/Ar	**Syenite**, east from the conjunction of the Orotva and the Simó creeks.	whole rock	128±
	9.	5134	K/Ar	**Syenite**, central part of the Orotva valley.	whole rock	121±2
	10.	5140	K/Ar	**Syenite** from gneissic vein, road between the Ditró valley and the Putna Creek.	whole rock	121.5±0.5
	11.	5133	K/Ar	**Leucogranite**, conjunction of the Orotva and the Hompot creeks.	whole rock	125±10
	12.	5142	K/Ar	**Nepheline** syenite, road between the Ditró valley and the Putna Creek	whole rock	152±1
	13.	5141	K/Ar	**Mica-schist**, basin of the Putna Creek, Ditró-Tölgyes road, km 20.	whole rock	284±14

TABLE 1 contd.

Author, year	No.	Number of the sample	Method	The studied rock type, locality	The studied fraction	Age (Ma)
STRECKEISEN & HUNZIKER, 1974	14.	429	K/Ar	**Nepheline syenite**, Komarnik plateu	biotite	151±9
	15.	1764	K/Ar	**Nepheline syenite**, Ditró Creek, gallery 1.	biotite	153±3
	16.	1195	K/Ar	**Hornfels**, Tászok Creek, 750 m SE	biotite	150±6
	17.	835	K/Ar	**Tinguaite**, Csanód feje, 500 m E	whole rock	161±7
	18.	204	K/Ar	**Tinguaite**, Pricske, 500 m, NE	whole rock	156±6
MÎNZATU et al., 1980	19.	–	K/Ar	**Biotite syenite**, Ditró valley	whole rock	112
	20.	–	K/Ar	–	biotite	117
	21.	–	K/Ar	**Biotite syenite**, Ditró valley, gallery VII.	whole rock	131
	22.	–	K/Ar	**Biotite syenite**, Ditró-Tölgyes, km 11	whole rock	136
	23.	–	K/Ar	**Biotite hornfels**, Auróra, borehole F 144.	whole rock	138
	24.	–	K/Ar	**Biotite hornfels**, Auróra, gallery* VII.	whole rock	172
JAKAB & POPESCU, 1979	25.	–	Pb/Pb	**Galenite**. Békény.	–	Jurassic
JAKAB & POPESCU, 1984	26.	–	Rb/Sr	7 rock types (hornblendite, diorite, nepheline syenite, bostonite, liebnerite syenite, microsyenite, biotite lamphrophyre)	whole rock	not intrepretable
JAKAB & POPESCU, 1985	27.	Rb/Sr	Rb/Sr	8 samples of nepheline syenite + liebernite, 8 samples of white nepheline syenite, 5 samples of microsyenite, 5 samples of granite, 5 samples of hornblendite-diorite (Orotva), 5 samples of essexite (Güdüc-Ditró)	whole rock	about 143 not interpretable

In 1966, BAGDASARIAN made a short field trip in the massif and determined the radiometric age of the collected samples using the K/Ar method. His results were published in 1972 (Table 1). In his opinion the age of the diorite-hornblendite complex is Pre-Jurassic. He suggests that age of the syenites and the nepheline syenites are synchronous, and the higher age of the nepheline syenites can be regarded as a result of the cancrinite of this rock because it has influence on the radiometric age because of its higher Ar content.

In 1974 STRECKEISEN and HUNZIKER described the succession of the formation for the different rocks in the massif that they believed to be a magmatic one: (1) lit-par-lit intrusion of dioritoid and gabbroid magmas into the existing crystalline schists; (2) intrusion of the syenitic magma that broke through the rocks of the dioritic complex; in the marginal parts of the massif granitic rocks were formed as a result of the assimilation of the adjacent rocks; (3) intrusion of the nepheline syenitic magma yielding the common hybridization and metasomatic processes; (4) pegmatites, nepheline syenitic aplites, lamprophyres. K/Ar radiometric ages published by them are listed in Table 1. In their opinion the intrusion is not older than Jurassic.

According to MÎNZATU (1980, see in JAKAB et al., 1987) (Table 1) K/Ar radiometric age of the syenites is Lower- Cretaceous, and the contact hornfels were formed in the Dogger.

JAKAB and POPESCU (1979) and JAKAB (1982) tried to determine the age of the ores (mostly galenite) associated to the massif using the Pb/Pb method. On the basis of the Pb^{206}/Pb^{207} ratio, comparing the data to those of reference galenites, they regard the formation age of the galenites to be Jurassic (Table 1). They state, however, that Pb/Pb method is not really suitable for dating Post-Hercynian formations.

Rb/Sr radiometric dating (JAKAB and POPESCU, 1984, 1985 in JAKAB et al., 1987) had not concrete results. More than 40 Rb/Sr measurements were performed on the different rocks of the massif but only the age of the red syenites could be determined; it is about 143 Ma. Data for the other rocks could not be interpreted because of the high standard deviation values.

ANASTASIU and CONSTANTINESCU (1978–1980) interpret the formation of the massif as process of several phases. On the basis of the great petrographic variety they suppose two independent hypabyssal magmatic intrusions:

– a basic one of mantle origin (parental),

– a crustal one assimilating Si-poor rock-association.

Formations of these intrusions are spatially similar, but temporally different.

According to JAKAB et al. (1987) the formation history of the massif is the following: (1) The first great process was a magmatic intrusion causing Fe-Mg metasomatism of varying intensity for the crystalline rocks. The metasomatism formed very heterogeneous rocks that are often interjointed. (2) The second great geological event was the intrusion of the nepheline syenites. This process happened at the marginal parts of the massif (excluding the western part). The metasomatic process associated with the intrusion formed, depending on the original compositons, granitoid, melanosyenitic or monzonitic rocks. These rocks have sialic character (as Sr and La isotopes show), all the other rocks of the massif are simatic. (3) During the third, and the last, process of the general alkali metasomatism formed the present state. Its material penetrated the existing basic rocks and created a metasomatic syenite "crown" around them. The alkali metasomatism of the basic rocks led to form diorites, essexites, monzonites, etc. The crystalline schists, depending on their compositions, transformed into essexites, monzonites or syenites.

From the petrographic studies of the hornblendites of the Orotva-Putna zone PÁL MOLNÁR (1992) concludes that problem of the massif can only be solved by the correct interpretation of the ultrabasic rocks.

K/AR RADIOMETRIC DATING THE ROCKS OF THE NORTHERN PART OF THE DITRÓ SYENITE MASSIF

As almost each rock type of the massif can be found on the surface in the N-NW part of the Ditró syenite massif, the K/Ar radiometric measurements were performed on the fresh samples colledted from there. Sampling points of the area is shown by *Fig. 2*, and the results are listed in Table 2.

The classification and the general petrographic characterization of the rocks studied is given in our previous works (PÁL MOLNÁR, 1988, 1992, 1994b, c).

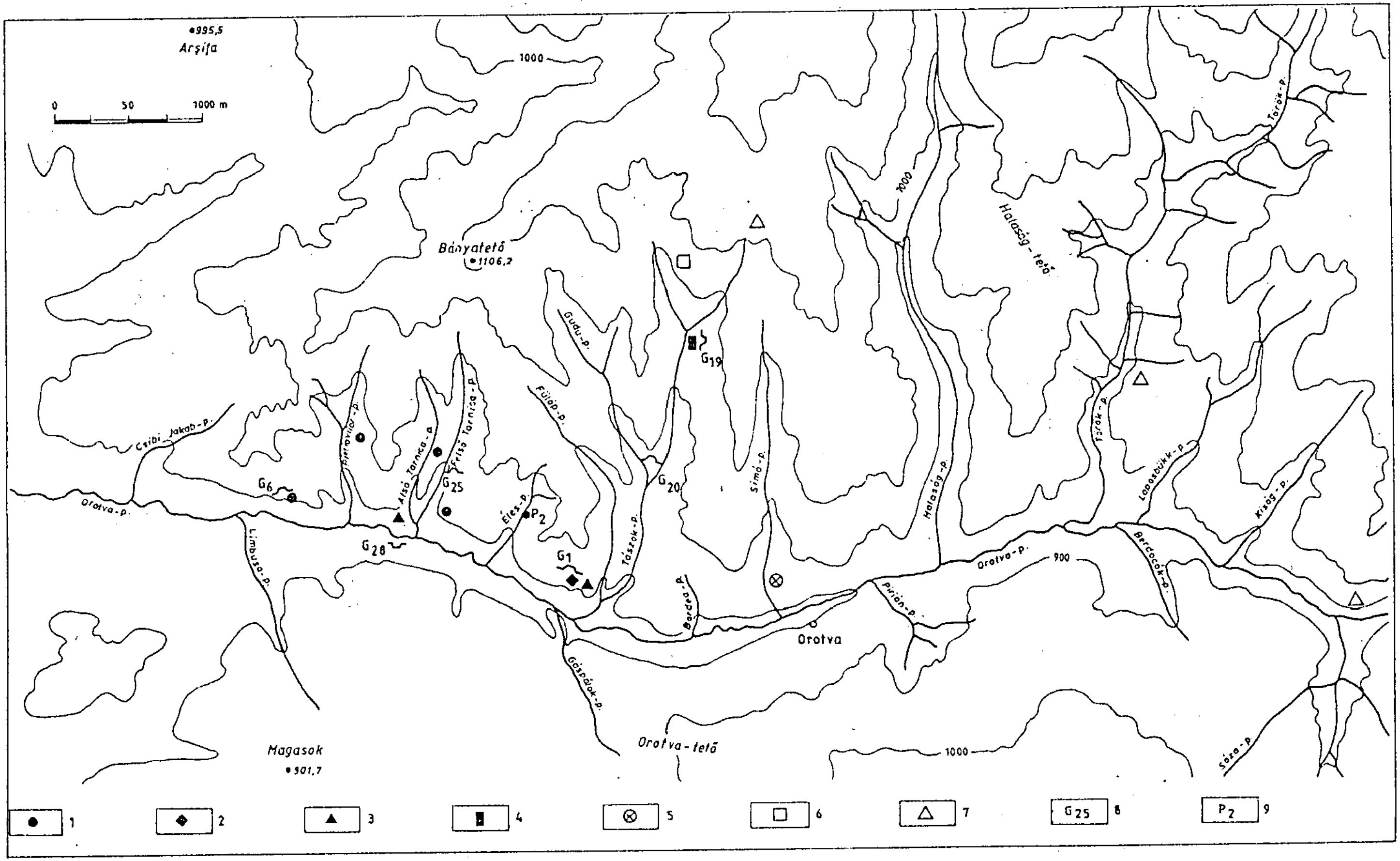

Figure 2. Localities of the sample studied in the basin of the Orotva Creek (northern part of the Ditró syenite massif)
1. hornblendite; 2. meladiorite; 3. diorite; 4. syenite; 5. alkaline feldspar syenite; 6. sodalite nepheline syenite; 7. granite; 8. gallery; 9. pit

TABLE 2

New K/Ar ages of the magmatic rocks from the northern part of the Ditró syenite massif

Number of the sample	Rocks type, locality	Studied fraction	K-content (%)	$^{40}Ar_{rad/g}$ (ncm^3/g)	$^{40}Ar_{rad}$ (%)	K/Ar age (Ma)
6546	Hornblendite with textural ordering Orotva, Felső Tarnica Creek	amphibole	1.158	$1.1417\cdot10^{-5}$	77.9	237.4±9.1
6547	Hornblendite with textural ordering Orotva, Pietrarilor Creek	amphibole	1.150	$1.0245\cdot10^{-5}$	56.5	216.0±8.8
6548	Hornblendite without textural ordering Orotva, gallery 6	amphibole	1.210	$1.1302\cdot10^{-5}$	49.2	226.0±9.6
6705	Pegmatoidic hornblendite Orotva, Felső Tarnica Creek (gallery 25)	amphibole	1.210	$1.1780\cdot10^{-5}$	40.5	234.7±10.8
		plagioclase	0.240	$1.5729\cdot10^{-6}$	25.4	161.3±9.8
		biotite (Ø> 0.315 mm)	7.440	$4.9074\cdot10^{-5}$	97.6	162.4±6.1
		biotite (Ø< 0.315 mm)	4.780	$3.2758\cdot10^{-5}$	48.5	168.3±7.2
6549	Meladiorite with textural ordering Orotva, Tászok Creek	amphibole	1.894	$1.6238\cdot10^{-5}$	64.7	208.3±8.3
		feldspar	0.551	$3.0753\cdot10^{-5}$	52.3	138.2±5.8
6550	Diorite with textural ordering Orotva, Tászok Creek	amphibole	2.960	$2.1309\cdot10^{-5}$	88.2	176.6±6.7
		feldspar	1.240	$6.8774\cdot10^{-6}$	61.3	137.4±5.5
5667	Diorite with feldspar aggregates Orotva, Alsó Tarnica Creek	amphibole	1.880	$1.6974\cdot10^{-5}$	85.8	218.7±8.3
		feldspar	0.520	$5.5430\cdot10^{-6}$	38.3	255.4±5.8
6680	Syenite Orotva, Tászok Creek (gallery 19)	biotite	5.616	$2.4163\cdot10^{-5}$	83.7	107.6±4.1
		K-feldspar	3.733	$2.7889\cdot10^{-5}$	88.5	182.7±6.9
6679	Alkaline feldspar syenite Orotva, Simó Creek	biotite	6.405	$2.6269\cdot10^{-5}$	72.3	102.6±4.0
		K-feldspar	5.162	$2.3492\cdot10^{-5}$	95.3	113.5±4.3
6678	Sodalite nepheline syenite Orotva, Tászok Creek	biotite	4.154	$3.0968\cdot10^{-5}$	94.3	182.4±6.9
		nepheline + sodalite	5.270	$5.0820\cdot10^{-5}$	90.2	232.7±8.8
6677	Granite Orotva, Török Creek	biotite	4.443	$3.9891\cdot10^{-5}$	84.6	217.6±8.3
		feldspar	3.728	$2.2004\cdot10^{-5}$	80.5	146.0±5.6
6703	Granite Orotva, Tászok Creek	biotite	3.044	$2.6757\cdot10^{-5}$	79.9	213.5±8.2
		K-feldspar	3.844	$2.1606\cdot10^{-5}$	73.9	139.1±5.4
6704	Granite Orotva, Nagyág Creek	biotite	4.482	$3.8038\cdot10^{-5}$	95.2	206.3±7.8
		K-feldspar	3.844	$2.2165\cdot10^{-5}$	62.9	142.7±5.7

Analytical methods

The least weathered ones were selected from more than 100 rock samples for the K/Ar radiometric dating.

Measurements of K/Ar ages were performed in the Institute of Nuclear Research of the Hungarian Academy of Science (ATOMKI), Debrecen, Hungary.

As the first step of the preparation process the samples for analysis were broken and carefully washed out.

Samples were broken to grains of 0.1–0.315 mm. After a dry sieving, dust was washed out from the samples. The sample part for potassium determination was pulverized before the chemical digestion that necessary for the flame photometric measurement.

Separated mineral fractions were used for the radiometric dating. The separation was performed by magnetic separator, flotation in heavy fluids (bromoform, methylene-iodide), and a "shaking technique", which uses the shape varieties of the different minerals. These techniques were comined with each other. In this way, mostly biotite, amphibole, feldspars and feldspathoids were separated from the samples. If the state of the sample made it possible, several mineral fractions were obtained from one rock.

Ar content of the samples was released by ignition at about 1500 °C in closed vacuum system. Degassing of the samples was performed by high frequency induction heating in molybdenum crucibles, spike enriched in ^{38}Ar to 98% was introduced into the line prior to degassing with a gas pipette. Zeolite, CuO, titanium sponge and traps cooled with liquid nitrogen as well as SAES St 707 getter were used for cleaning the argon. The cleaned argon was directly introduced into a 90° deflection magnetic mass spectrometer of 150 mm radius suitable for static analysis. This instrument was developed at the Institute of Nuclear Research of the Hungarian Academy of Science (ATOMKI), Debrecen. After the determination of the argon isotopic ratio, quantity of the radiogene argon was determined by isotopic dilution analysis using the added ^{38}Ar as a base.

Potassium content was measured by a digital flame photometer. The pulverized minerals were digested in HF, adding some H_2SO_4 and HNO_3 to it. The digested samples were dissolved in 0.25 N Hcl. By the applied dilution, 1% K was equivalent of 1 ppm concentration; 100 ppm Na as buffer and 1000 ppm Li as inner standard was used.

Accuracy was checked by repeated measurements of interlaboratory standards: Asia 1/65 (Soviet), GL-O (French), LP-6 (American) and HD-B1 (German). Details of the instruments, the applied methods and results calibration have been described elsewhere (BALOGH, 1985; ODIN et al., 1982). Ages were calculated with the constants suggested by STEIGER and JÄGER (1977).

Limits of errors given beside the age data show only the analytical errors (standard deviation) because the geological "errors" (argon loss, extra argon, etc.) may not be revealed by study of one sample. Decrease of the geological errors is mainly possible by study on rocks and minerals that are suitable for K/Ar radiometric dating. Amphibole and, in our case, nepheline does not easily release argon (nepheline retains argon very well, experience gained from study on Precambrian rocks shows that its argon retention ability is higher than that of amphiboles), but biotite also has a high argon retention ability. Argon easily escapes from potassium feldspars, in particular, because it is susceptible to exsolution. Consequently, determination of formation age of rocks is primarily available by study of amphibole and biotite. Feldspars generally show the ages of the postmagmatic processes or the secondary geological events (magmatic intrusion, assimilation, hybridization, etc.). Ages measured on hypabyssal magmatic rocks are generally younger than the real ages because of the argon loss of their feldspars. Therefore, these data can only be interpreted as minimal ages. K/Ar ages older than the real ones can rarely occur, mainly in case of minerals of low potassium or that of K-poor rich rocks that crystallized selaing off from the air in great deep and in geological environs which have radiogenic argon. Although in different scale, subsequent tectonic or metasomatic processes rejuvenate all types of the minerals.

K/Ar age

It is well-known that K/Ar ages measured on metamorphic rocks can be interpreted as blocking age in most cases. K/Ar age indicates the date when a rock got under the blocking temperature of the Ar. This temperature is 4–500 °C for the amphibole, about 300

°C for the biotite, and ranges from 120 to 130 °C for the feldspars. If a rock body rapidly emerged (and cooled) after its formation, and it was not affected by other processes, the K/Ar ages of its particular minerals well approach the real geologic age. Henceforth, if the formation age of the rock is mentioned only the Ar blocking age of the particular minerals is considered.

K/Ar radiometric ages were fallen under the geological timetable supposed by HARLAND et al. (1982).

K/Ar ages of the amphiboles separated from hornblendites (samples 6546, 6547 and 6548) range from 216±8.8 to 237±9.1 Ma. As measures were performed on minerals having high Ar retention ability, and taking the fact mentioned above into consideration that ages of the rocks may only be older, the gained Middle Triassic (Ladinian) – Upper Triassic (Carnian) age possibly well approaches the real age of these rocks.

K/Ar age of the amphibole separated from pegmatoidic hornblendite 6705 (Table 2) is 234.7±10.8 Ma, i. e.., Middle Triassic (Ladinian). Feldspars (plagioclase) from the same rocks are 161.3±9.8 Ma, while the ages of the biotites of diameters less and greater than 0.315 mm are 162.4±6.1 Ma and 168.3±7.2 Ma, respectively. Age of the amphiboles, which have very high argon retention ability, corresponds to that of amphiboles from the hornblendite within the limit of error, while the feldspars and the biotites show the age of the secondary effects (Middle Jurassic [Callovian] – Upper Jurassic [Oxfordian]).

Up to the present only Bagdasarian (1972) performed radiometric (K/Ar) measures on the hornblendites (Table 1). Although, because of the argon loss of the feldspars of the rocks his data of whole rock measurements are lower than our ones, however, also suggest a Pre-Jurassic formation for the hornblendites.

In the case of the diorites (samples 6549, 6550, 6567), the two studied fractions (amphibole and biotite) are characterized by quite different data. For meladiorites with textural ordering, age of the amphiboles is 208.3±8.3, while that of the feldspars is 138.2±5.8 Ma. Ages of the amphiboles and feldspars from the diorites with textural ordering were proved to be 176.6±6.7 and 137.4±5.5 Ma, respectively. Amphiboles and feldspars of the diorites with feldspar aggregates gave 218.7±8.3 and 255.4±12 Ma, respectively. Feldspars may lose their argon content without any secondary effects (hence, in general, they are not suitable for K/Ar radiometric dating), but they are sensitive to these processes. It is possible that concurrent Upper Cretaceous (Berriasian, Valanginian) K/Ar ages of the feldspars of meladiorites and diorites (excepting the very high deviating [?] age of the feldspars of the diorites with feldspar aggregates) indicate such a secondary effect. Presumably, this fact can explain the slightly lower (Upper Triassic [Rhaetian] – Middle Jurassic [Bajocian]) K/Ar ages of the amphiboles separated from the same rock in relation to that of the amphiboles of the hornblendites. By the rule of the mathematical statistics, difference between two ages with errors of 67% can be determined if the difference of the data greater than double the sum of the errors. In the present case, highest K/Ar age of the amphiboles of the hornblendites and the lowest one of the amphiboles of the diorites (Table 2) give the following ratio:

$$\frac{237.4 - 176.6}{9.1 + 6.7} = 3.84,$$

therefore, the difference can well be determined. If the average ages of the amphiboles of the diorites and hornblendites are considered, however, this ratio will be below 2 (1.56).

Taking the above mentioned facts into consideration it is possible that argon content of the diorites was partly removed, and the determined K/Ar age is a mixed age. It is also possible that age of the secondary effect corresponds to the K/Ar age of the feldspars.

BAGDASARIAN could not perform measures on the diorites "in absence of potassium", and, therefore, he considered the diorites as old as the hornblendites. JAKAB et al. (1984, 1985 in JAKAB et al., 1987) tried to determined the radiometric ages of the hornblendites and diorites using Rb/Sr method. This method, however, is really suitable for only siliceous rocks even in ultraclean circumstances and using up-to-date mass spectrometer. Other radiometric dating has not been performed yet.

The two analyzed fractions (biotite and potassium feldspars) of the syenite (sample 6680) proved to be 107.6±6.7 and 182.7±6.9 Ma, respectively. The investigated rocks are not derived from the classic syenitic localities (e.g., the central part of the massif), but from the rock-debris of a gallery driven at the Tászok Creek. K/Ar radiometric ages of the syenites (mainly measured on feldspars) are quite similar to each other (Table 1). Comparing our data with K/Ar radiometric ages that were previously measured on the syenites (Table 1: 8, 9, 10, 19, 21, 22), it can be seen that only the value of 182.7±6.9 Ma is differ from the calculated mean age of 133.2±2.8 Ma. This mean age is averaged value of at least three measuring series (Table 2; BAGDASARIAN, 1972; MÎNZATU, 1980 in JAKAB et al., 1987), and measuring method of one of them is not known (MÎNZATU, 1980 in JAKAB et al., 1987). According to the above mentioned facts, the syenites could be formed in the period from the Middle Jurassic (Aalenian) to the Lower Cretaceous (Albian).

The two fractions (biotite and nepheline+sodalite) of the studied sodalite nepheline syenite (ditróite) yield 182.4±6.9 and 232.7±8.8 Ma, respectively. K/Ar age of the biotite fraction is similar to the average value of 152.6±4.3 Ma of the previously determined K/Ar and Rb/Sr ages of nepheline syenites (Table 1: 12, 14, 15, 17, 18, 27) measured on the whole rock.

K/Ar radiometric ages of the two fractions (biotite and potassium feldspars) of the alkaline feldspar syenite (sample 6679) almost correspond to each other: 102.6±4 and 113.5±4.3 Ma, respectively. This refers to the period of the Lower Cretaceous (Aptian, Albian). It very possible that it indicates the real formation age of the alkaline feldspar syenites.

In the case of the granites (samples 6677, 6703, 6704) the biotite and the feldspars were the separated fractions (Table 2). K/Ar radiometric ages of the biotite and the potassium feldspars range from 206.3±7.8 to 217.6±8.3 and from 139.1±5.4 to 146.0±5.6 Ma, respectively. K/Ar age of the biotite of high argon retention ability possibly indicates the minimal Upper Triassic (Rhaetian) – Lower Jurassic (Hettangian) age of the granites, while the Upper Jurassic (Tithonian) – Lower Cretaceous (Berriasian) age of the feldspars refers to a secondary effect.

K/Ar age of the biotite separated from the granites corresponds to that of the amphiboles of the hornblendites within the limit of the errors. Consequently, the hornblendites and the granites emerged (cooled) in he same time, and this process was rapid because minerals of different blocking temperature indicate the same age within the limit of the errors.

Up to the present only one valuable radiometric age (125±10 Ma) has been measured (BAGDASARIAN, 1972) for the granites. This measure was performed on the whole rock, and it is lower than our data.

GENETIC IMPLICATIONS OF THE K/Ar RADIOMETRIC AGES

On the basis of the K/Ar radiometric dating performed on rocks from the northern part of the Ditró syenite massif (principally taking that of the biotite and the amphibole into

consideration, which are of high argon retention ability) the following sussession can be stated:
hornblendite→nepheline syenite→granite→diorite→syenite→alkaline feldspar syenite.

This chronological succession, however, does not mean the succession of the geological processes. Considering data of the feldspars indicating the secondary processes beside the age of the minerals of high argon retention, two greater formations chronological intervals can be determined:

I. Middle Triassic – Lower Jurassic,

II. Middle Jurassic – Lower Cretaceous (*Fig. 3.*).

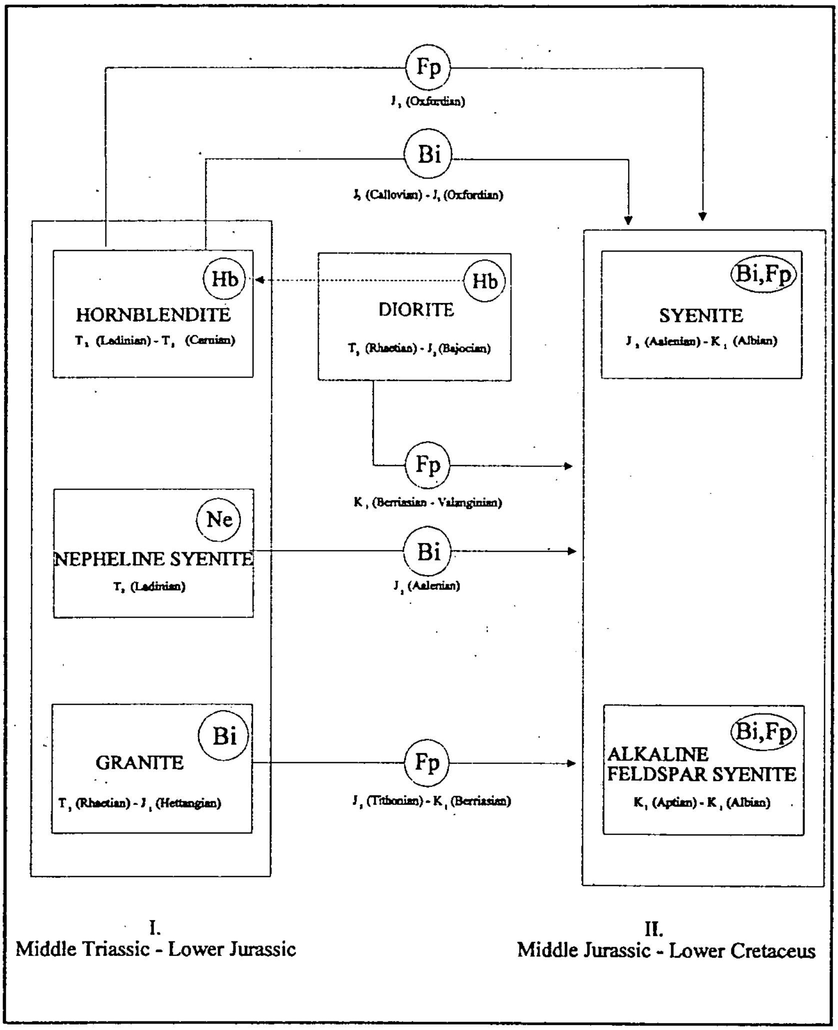

Fig. 3. K/Ar radiometric ages of the rocks of the Ditró syenite massif, and the two formation intervals determined on the basis of this data
Studied fractions: Hb – amphibole (hornblende), Ne – nepheline+sodalite, Bi – biotite, Fp – feldspar

Differences can not be pointed out by statistics between the ages of the minerals with high argon retention ability of the hornblendites, nepheline syenites and granites belonging to the first interval. A petrographical connection of the nepheline syenites and the granites is possible (PÁL MOLNÁR, 1988). However, connection of the hornblendites and granites as well as the nepheline syenites has not been proved yet. Ages of the minerals with lower argon retention ability of the three rock groups also correspond to each other within the limits of the errors. Therefore, their ages were changed by the same geological process.

As it was mentioned, mean K/Ar age of the amphiboles from the diorites corresponds to that of the amphiboles from the hornblendites within the limit of the errors, however, minimal K/Ar age of it corresponds to the maximum K/Ar age of the feldspars from the syenites within the limit of the errors. Difference between the minimal K/Ar age of the amphiboles from the hornblendites and the maximum K/Ar age of the syenites can well be determined. Consequently, it is possible that the K/Ar age of the diorites is a mixed age.

Rocks that can be ordered into second group are the syenites and the alkaline syenites.

A schematic model shown by *Fig. 4* can be created on the basis of the K/Ar radiometric ages of the rocks studied. According to this model two great geological events

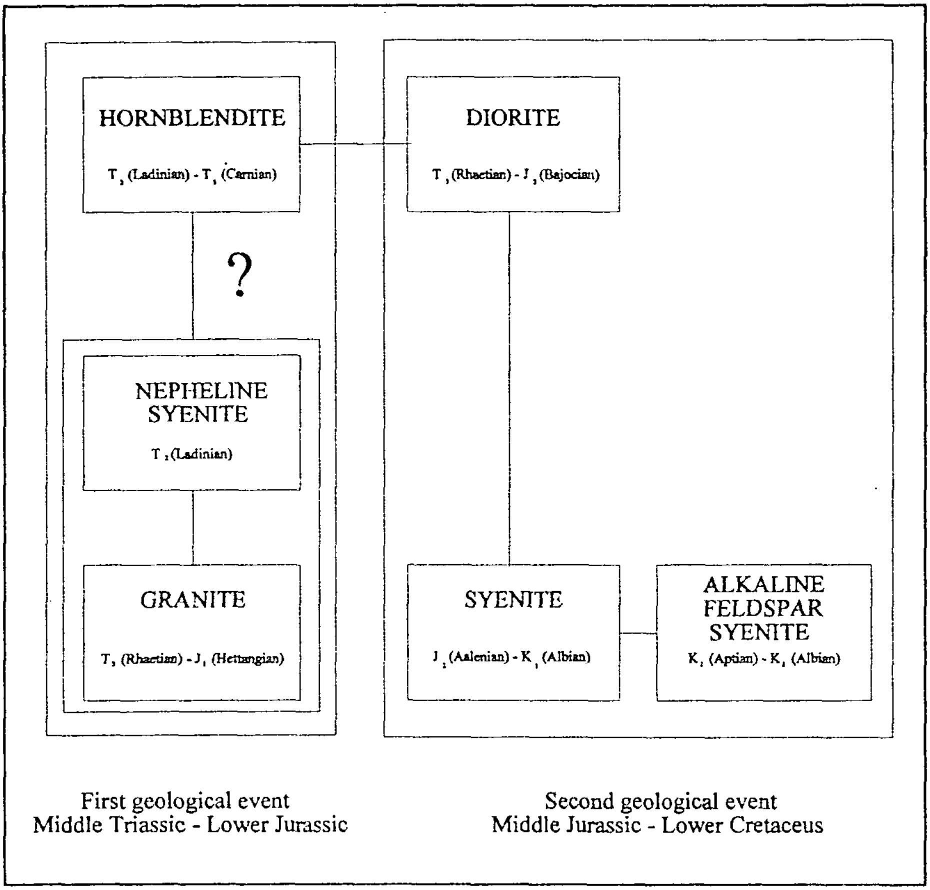

Fig. 4. Genetic model of the Ditró syenite massif on the basis of the K/Ar data

(magmatic intrusion) can be identified. During the first one, appearance of the hornblendites was followed by the formation of the nepheline syenites and the granites. In the second event the syenites and the alkaline feldspar syenites intruded as well as the diorites were formed. In spite of the fact that mineralogical composition of the diorites is similar to that of the hornblendites (PÁL MOLNÁR, 1994c), the diorites formed during the second event. Their structure suggests an injection bordering zone (PÁL MOLNÁR, 1994c). It is possibly the case of mixing hornblendites and syenites.

The alkaline feldspar syenites occur both in the syenites and the hornblendites as veins (PÁL MOLNÁR, 1988), therefore, they represent the magmatic vein phase finishing the second geological event.

CONCLUSIONS

Evaluation of 25 K/Ar radiometric dating of the studied 6 rock types has thrown a new light upon the formation of the Ditró syenite massif.

The previous radiometric datings (Pb/Pb, K/Ar, Rb/Sr) were mainly performed on the syenites and the nepheline syenites (STRECKEISEN and HUNZIKER, 1974; MÎNZATU, 1980 in JAKAB et al., 1987; POPESCU, 1979; JAKAB and POPESCU, 1984, 1985 in JAKAB et al., 1987). Radiometric ages of the hornblendites outcropping in other parts of the massif were studied by BAGDASARIAN (1972), and he suggested the formation of the rocks before the Jurassic period. Although radiometric age of the diorites (essexites) was studied (JAKAB et al., 1984, 1985 in JAKAB et al., 1987), however, valuable results were not yielded. On the basis of these results it was the dominant idea that the Ditró syenite massif was formed in the Jurassic period.

According to our studies, there were two greater geological events in the Ditró syenite massif: one in the Middle Triassic – Lower Jurassic, and another in the Middle Jurassic – Lower Cretaceous period.

K/Ar age of the amphiboles of the hornblendites is Middle Triassic (Ladinian) – Upper Triassic (Carnian) (first geological event), and that of the feldspars and the biotite is Middle Jurassic (Callovian) – Upper Jurassic (Oxfordian) (second geological event, the age of the formation of the syenites). K/Ar age of the amphiboles of the diorites id Upper Triassic (Rhaetian) – Middle Jurassic (Bajocian) (first geological event, the age of the formation of the hornblendites), and that of the feldspars from this rock is Lower Cretaceous (Berriasian, Valanginian) (second geological event, age of the formation of the syenites). K/Ar age of the nepheline+sodalite fraction of the nepheline syenites is Middle Triassic (Ladinian) (first geological event), that of their biotites is Middle Jurassic (Aalenian) – Lower Cretaceous (Albian) (second geological event). Both fractions (biotite and potassium feldspars) of the alkaline feldspar syenites are Lower Cretaceous (Aptian, Albian) (second geological event). K/Ar age of the biotites from the granites is Upper Triassic (Rhaetian) – Lower Jurassic (Hettangian) (first geological event), that of the potassium feldspars is Upper Jurassic (Tithonian) – Lower Cretaceous (Berriasian) (second geological event, age of the formation of the syenites).

Our results confirm the hypothesis that the syenite massif was formed by a multi-stage process; i. e., it was formed either by two entirely independent magmatic intrusions (?) or, perhaps, by an obduction (ultrabasic rocks) and an intrusion (nepheline, syenite, granites) and, subsequently, another intrusion which partly influenced the rocks formed by the first geological event (syenites, alkaline feldspar syenites, monzonites). Mixed ages of the diorites prove that these rocks are into connection with both the hornblendites and the syenites, therefore, they are hybrid rocks. The hybridization undoubtedly connects with the second geological event.

Evidence of this genetic model and that of the difference or the connection between the hornblendites and the granites, the hornblendites and the nepheline syenites, the hornblendites and the syenites, the nepheline syenites and the granites, as well as, the syenites and the alkaline feldspar syenites can only be proved by major and trace element geochemistry, radiogene isotopic ratio, and petrogenetic model calculations.

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