Zeitschrift: Eclogae Geologicae Helvetiae

Herausgeber: Schweizerische Geologische Gesellschaft

Band: 63 (1970)

Heft: 1: Geochronology of phanerozoic orogenic belts : papers presented at the "Colloquium on the Geochronology of Phanerozoic Orogenic Belts"

Artikel: K-Ar dating by neutron activation of some igneous and metamorphic rocks from the southern branch of the Romanian Carpathians

Autor: Soroiu, M. / Popescu, G. / Gherasi, N.

DOI: https://doi.org/10.5169/seals-163845

Eclogae geol. Helv.	Vol. 63/1	Pages 323–334	With 3 figures in the text and 2 tables	Basle, April 1970

K-Ar Dating by Neutron Activation of some Igneous and Metamorphic Rocks from the Southern Branch of the Romanian Carpathians

by M. SOROIU[1]), G. POPESCU[1]), N. GHERASI[2]), V. ARSENESCU[2]) and P. ZIMMERMANN[2])

ABSTRACT

The paper presents 81 K-Ar ages obtained on metamorphic and igneous rocks from the Southern Branch of the Romanian Carpathians, namely from the region delimited by the river Olt and the Danube. The experimental procedures used were fast neutron activation for potassium and thermal neutron activation for radiogenic argon determinations.

In the investigated area the metamorphic rocks are of epizonal and mesozonal degree of metamorphism. The epimetamorphic rocks are intruded by igneous rocks and it is considered that the mesometamorphic rocks represent a nappe covering the other formations.

The samples for the K-Ar study were collected from both types of metamorphic rocks as well as from the igneous rocks intruding the epimetamorphic ones.

The K-Ar ages show the existence of some old formations of at least Cambrian age and obviously point out the importance of the cretaceous movements in the building up of the present configuration of this fragment of the Carpathian Chain.

Introduction

The geochronological investigation discussed in the present paper was carried out in an area of the Southern Branch of the Romanian Carpathians bounded by the river Olt and the Danube.

This area is made up of metamorphic, igneous and sedimentary rocks, the latter being Paleozoic to Tertiary in age. The mesometamorphic rocks consist particularly of gneisses, mica schists and amphibolites while the epimetamorphic rocks are formed mainly of chloritosericitic schists. In the epimetamorphic rocks numerous granitoid intrusions are located. It is considered that the mesometamorphic rocks have formed a large overthrust sheet, the Getic Nappe, covering the Danubian Autochthonous, which defines the area formed of metamorphic schists and granitoid intrusions. According to this theory the front of the sheet should be situated on a line connecting the Mehedinti Plateau with the locality Valari, the Godeanu Mountains representing a patch of the overthrust sheet. The 81 samples analysed in the present study were obtained from both types of metamorphic rocks as well as from the granitoid intrusions.

In this paper the analytical procedures and the geology of the investigated areas are briefly described. K-Ar ages are presented and interpreted.

[1]) Institute for Atomic Physics, Bucharest.

[2]) State Committee of Geology, Bucharest.

Analytical Procedures

For the determination of radiogenic argon a modified version of the thermal neutron activation method set up at the Bucharest Institute for Atomic Physics (M. Soroiu et al., 1965; M. Soroiu & M. Cerei, 1967; M. Soroiu & G. Popescu, in preparation) was used.

The precision of this method, checked by repeated runs on the same sample, and its accuracy, controlled by determinations carried out on interlaboratory standard samples is 3%. Errors exceeding 3% were obtained for samples with a high contamination in atmospheric argon.

Potassium was determined by the fast neutron activation method using the reaction ^{39}K (n, p) ^{39}A (M. Soroiu & G. Popescu, in preparation), the errors being in the order of 2–3%.

Most of the determinations were carried out on biotite concentrates. For preparing the mineral concentrates, the samples were ground to a grain size of 0.20–0.40 mm and separated using an electromagnetic separator and bromoform. For some samples the separation of biotite from amphiboles failed, and in these cases concentrates containing both minerals were used. Samples of muscovite, amphiboles, whole rock and potassium feldspar were also analysed.

General Geology of the Rîul Mare-Muntele Mic, and Lotru-Parîng Areas

a) Rîul Mare-Muntele Mic Area (Fig. 2)

Mesozonal crystalline schists outcrop on the northern and western margins of the region. In the south, mesometamorphic rocks appear in the patch of the overthrust sheet represented by the Godeanu Mountains.

The epizonal crystalline schists of the Danubian Autochthonous belong to several series, which in order of their succession in the stratigraphic column are:

- The Rof series. Initial metamorphism of the series occurred under mesozonal conditions. Subsequently this series have suffered a diaphtoresis.
- The Rîuşorul series made up of quartz biotite schists, and of grey biotite phyllites.
- The Măgura series with a pronounced sedimentogenous character.
- The Zeicani series in which basic metatuffites predominate.
- The Rîul Mare series, consisting of graphitic phyllites.
- The Tulişa series and Vidra formation formed by a very mild reworking of some Paleozoic sediments including Carboniferous ones.

A number of igneous rocks are intruded in the metamorphic rocks. We list them in the assumed order of their emplacement:

- The Măru amphibolites, which originate from basic igneous rocks intruded in and metamorphosed simultaneously with the Zeicani series.
- The Sucu diorite.
- The Petreanu gneiss considered to be derived from migmatisation of the Rîuşorul series.
- The Furcătura gneiss.
- The Muntele Mic granitoids with gneissic texture.
- The vîrful Pietrei granite with massive texture.

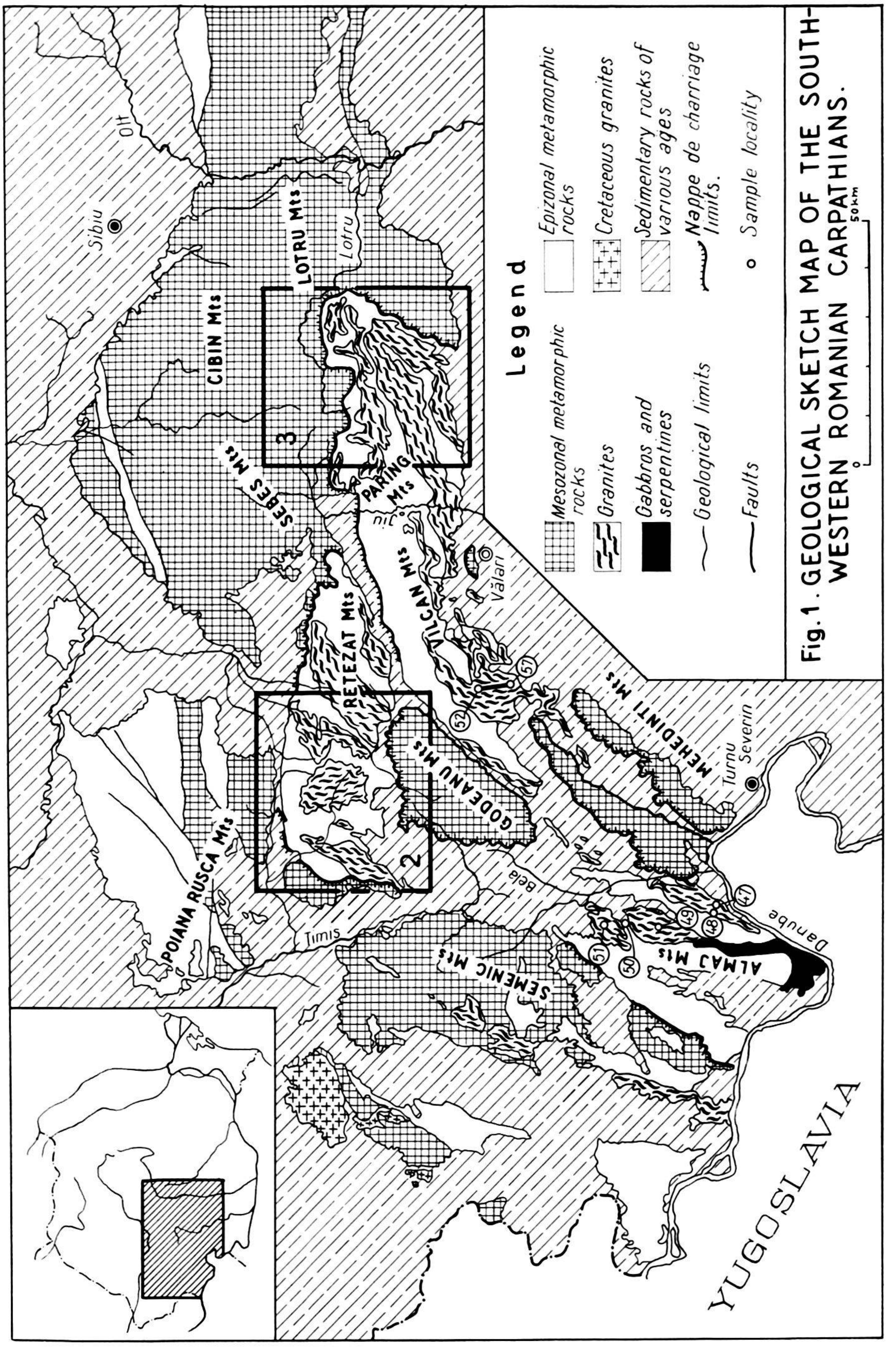

Fig. 1. Western Romanian Carpathians.

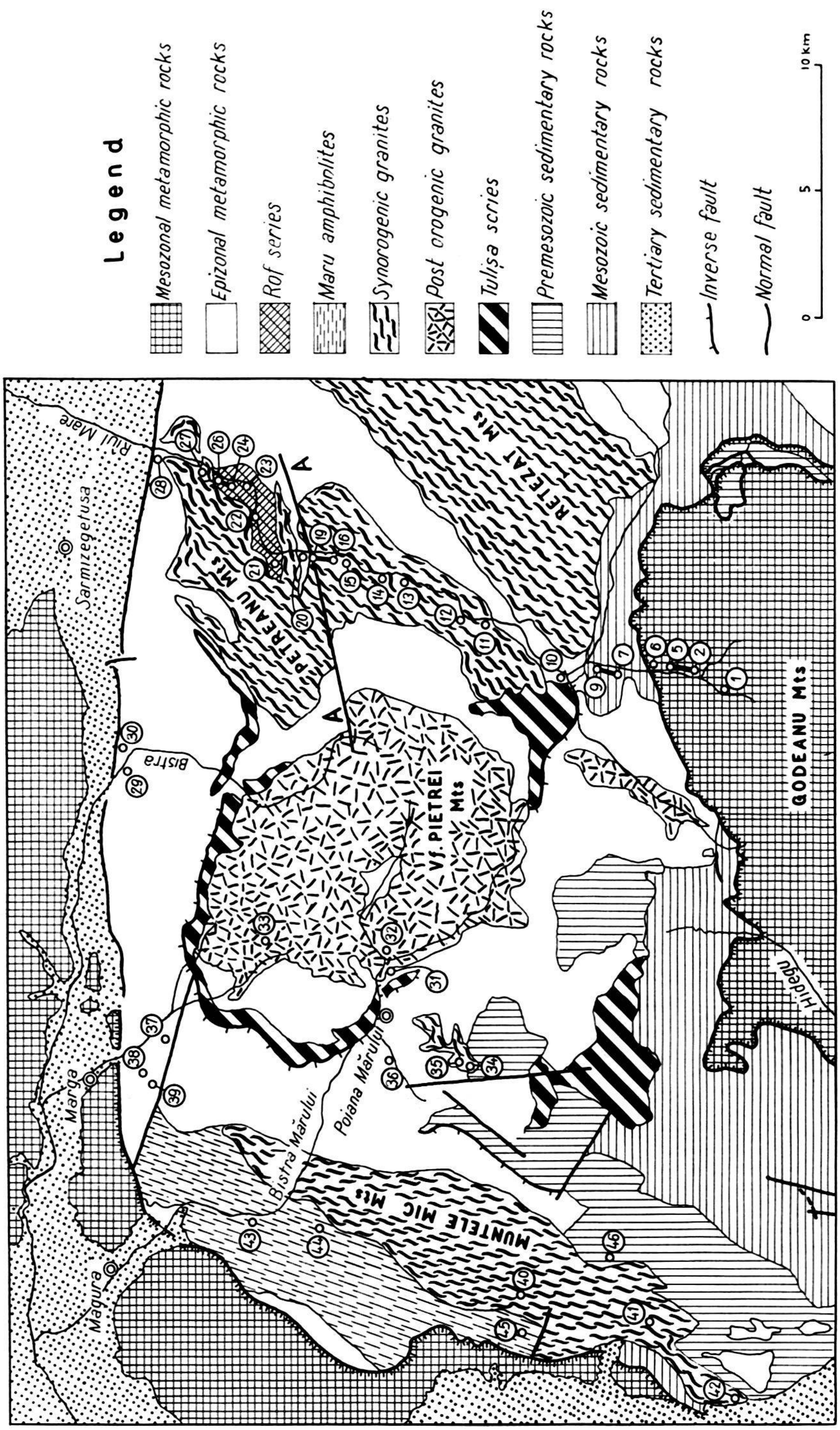

Fig. 2. Geological map of Riul Mare-Muntele Mic area. 1 : 300.000.

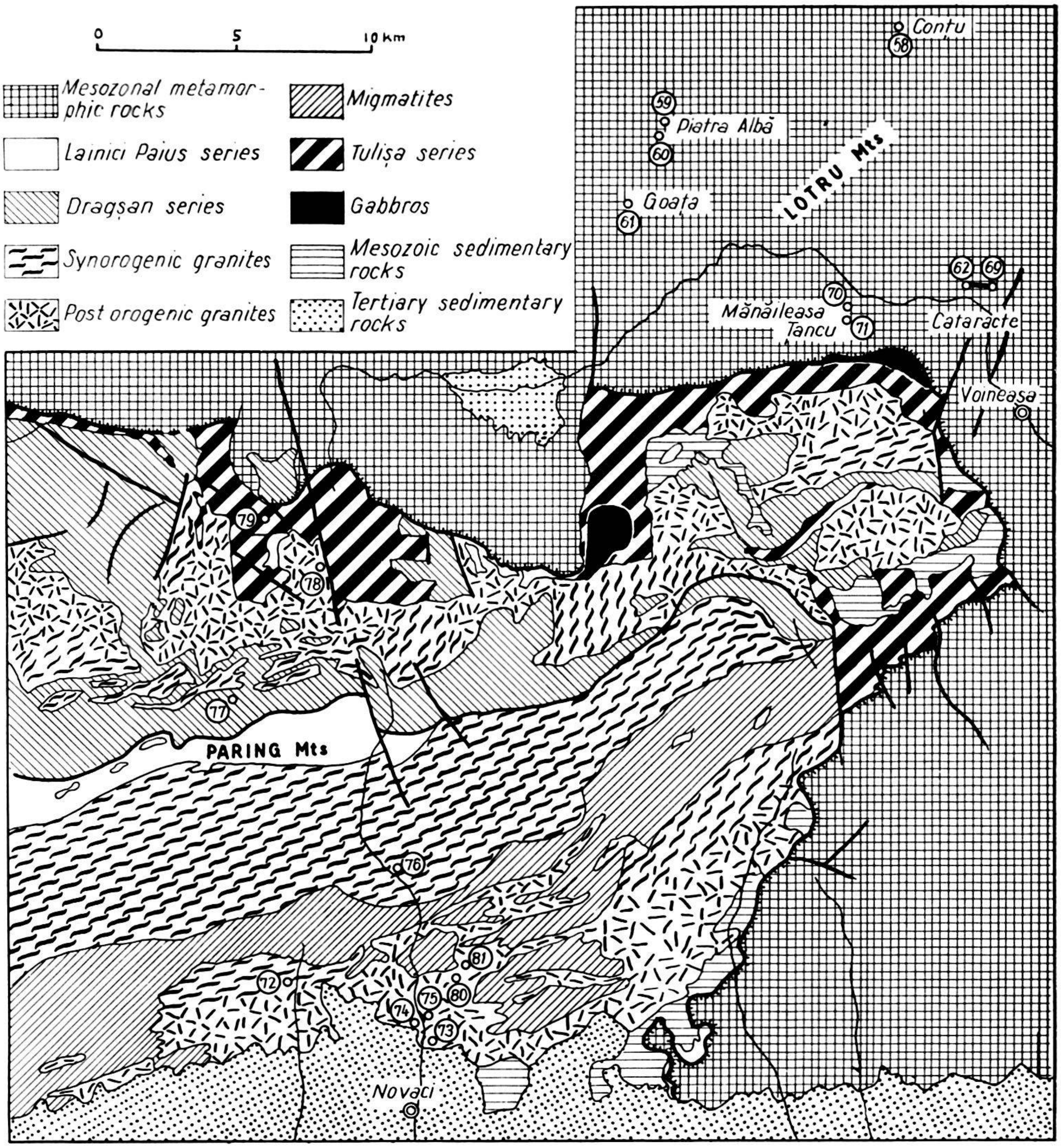

Fig. 3. Geological map of Lotru-Paring Mountains area. 1:300.000.

b) Lotru-Parîng Mountains Area

This zone is also situated at the contact between the mesometamorphic rocks of the Getic Nappe, and the epimetamorphic rocks of the Danubian Autochthonous.

The crystalline series of the Danubian Autochthonous include:

- The Lainici-Păiuş series represented by a varied range of chlorito-sericitic schists.
- The Dragaşan series consisting of a lower amphibolitic and an upper chlorito-sericitic complex.
- The Tulişa series, which we have encountered also in the Rîul Mare-Muntele Mic area.

In the Lotru-Parîng Mountains area granitoid intrusions appear both in the gneissic and in the massive facies.

Granitoids formed in massive facies are equidimensionally grained, e.g. Suşiţa granitoids, or contain large potassium feldspar phenocrysts in the case of the Tismana granitoids. The latter penetrate the Suşiţa granitoids, and hence are younger than these. There is a possible connection between the Tismana granitoids and the migmatites observed in the Lainici-Păiuş series.

Suşiţa and Tismana type granitoids have been sampled also in the Vîlcan Mountains area – Figure 1; samples 52–57; Table 2.

In this paper also five K-Ar ages are reported which were obtained on samples from the granitic massifs of Ogradena, Cherbelezu and Sfîrdinu from the Almajul Mountains between the mesometamorphic rocks zones of the Semenic Mountains and the Mehedinţi Plateau – Figure 1; Samples 47–51; Table 1.

Potassium-argon Ages

The K-Ar ages are shown in Table 1 for the Rîul Mare-Muntele Mic area and in Table 2 for the Lotru-Parîng area. In calculating the K-Ar ages the constants λ_β = 4.72 10^{-10} year^{-1}, λ_e = 0.585 10^{-10} year^{-1}, and 1.22 10^{-4} g^{40}K/g. K. were used.

We shall first discuss the K-Ar ages from the mesozonal metamorphic rocks sampled in the Lotru and Godeanu Mountains. It is considered that these rocks were metamorphosed in the Proterozoic.

In the Lotru Mountains a number of 13 mica samples from pegmatites, consisting of large mica sheets, and three mica samples from the country rock were analysed. Only three of the 16 mica samples show values between 200 and 225 m.y. and 13 have ages between 115 and 170 m.y. In comparison with samples from the country rock, the corresponding mica samples from pegmatites show K-Ar ages that are about 10 m.y. higher, a difference that could be explained by a single cooling episode. Five samples of mica collected from the Godeanu mesometamorphic rocks give K-Ar ages between 120 and 160 m.y. An amphibole sample coming from the same rocks has a considerable higher K-Ar age of 330 $\pm$ 20 m.y.

We consider that the K-Ar ages obtained on samples from the mesozonal metamorphic rocks in the Lotru and Godeanu Mountains can be interpreted as cooling ages. After being formed, these rocks were buried for a long period of time at depths where accumulation of radiogenic argon occurred, according to DAMON's theory of "real" K-Ar clocks (P. E. DAMON, 1967) under the conditions of a transient equilibrium, or at temperatures somewhat smaller than those corresponding to the transient equilibrium. Differences between K-Ar ages obtained for mesometamorphic rocks can be explained by "built in age components" of different sizes.

In the Danubian Autochthonous the argillite samples from Mesozoic sedimentary rocks at the bottom of the Godeanu Mountains, and from the Paleozoic sedimentary rocks on the SE of Muntele Mic as well as the chlorite-sericitic schists from the Rîul Mare and Zeicani series, the Vidra formation, and the Tulişa series show all but one K-Ar ages between 89 and 105 m.y. The exception is sample 7 with a K-Ar age of 128 $\pm$ 10 m.y.

The quartz biotite schist inclusions in the Petreanu gneiss, or in the Vîrful Pietrei granite characterized by a very fine grained biotite have K-Ar ages between 94 and 128 m.y. Sample 19 also representing a biotitic schist inclusion in the Petreanu gneiss, but having a larger grain size, has a K-Ar value of 656 m.y. the highest age that we have found.

Mica samples from the rocks of the Danubian Autochthonous collected at a distance less than two kilometers from the contact with mesometamorphic rocks show very low K-Ar ages. These are two muscovite samples from the Zeicani series with K-Ar ages of 125 m.y., a sample of biotite adjacent to a serpentinite lens from the same series yielding 107 m.y. and a sample of biotite, 94 m.y. old, from a quartz diorite intruded also in the Zeicani series.

Biotite samples from the Suşiţa granite, Furcătura gneiss, Muntele Mic granitoid, and Ogradena granite collected at a distance of about two kilometers from the contact with mesometamorphic rocks have ages between 220 and 270 m.y. Samples of biotite collected at a distance of more than two kilometers from the contact with mesozonal metamorphic rocks show higher K-Ar ages namely 311 m.y. in the Cherbelezu granite, 339 m.y. in the Sfîrdinu granite, 298 and 352 m.y. in the Rof series, and 303, 527, and 324 m.y. in the Petreanu gneiss.

Only one of the three samples collected from the Măru amphibolites with a K-Ar age of 448 m.y. is of interest because it is the only one consisting of amphiboles exclusively. The other two samples contain biotite also, which could not be separated from the amphiboles. The presence of this mineral with a much smaller retentivity explains the appreciably lower K-Ar ages of 320 and 283 m.y. of these samples.

In the Vîlcan Mountains two biotite samples from the equal grained Suşiţa granitoids, and two more biotite samples from the porphyroidic Tismana granitoids were analysed. All samples show remarkably high K-Ar ages of 500 to 550 m.y. In the Parîng Mountains, samples of Tismana granitoids representing biotite and amphibole concentrates continue to show high K-Ar values, 426, 494, and 498 m.y., except one of 266 m.y. A same low value of 266 m.y. was obtained on a biotite sample from the Suşiţa granitoids in the Parîng Mountains, although these granitoids also show a higher value of 402 m.y.

In examining K-Ar ages of samples from the Suşiţa and Tismana type granitoids, as well as the potassium concentrations of these samples it is concluded that samples which, considering their mineralogic composition, have abnormally low potassium contents show at the same time low K-Ar values.

Probably the same intensive metasomatic processes that led to the formation of Tismana granitoids were responsible for the partial removal of potassium from the lattice of some biotites the retentivity of which thus being diminished.

Discussion of Results

The K-Ar age pattern of the Danubian Autochthonous show that this area was intensively affected by metamorphic processes which took place in the Cretaceous period.

K-Ar ages of mesometamorphic rocks from the Lotru and Godeanu Mountains prove that these rocks have suffered an uplift and cooling in the same period.

Reaching the surface, the mesozonal metamorphic rocks had a temperature sufficiently low to permit accumulation of radiogenic argon in the large crystallized micas they contain, but sufficiently high temperature to produce argon losses in micas with smaller grain size in the rocks they contacted. The influence of mesometamorphic rocks was more intensive along the first two kilometers from the contact plane between these rocks and the epimetamorphic ones.

Sample 11 from the Petreanu gneiss with a K-Ar age of 115 $\pm$ 4 m.y. seems to show that the thermal influence of the Godeanu mesometamorphic rocks has produced almost complete radiogenic argon loss even at a distance of seven kilometers. The low K-Ar values of 183 and 155 m.y. obtained for two samples from the Sucu diorite may also be due to the thermal action produced by the Godeanu Mountains rocks.

We have shown at the beginning that the relations between mesozonal and epizonal metamorphic rocks are explained by a large overthrust sheet with a minimum shift of 60 kilometers, covering the Danubian Autochthonous as far as the Mehedinţi-Vălari line. It is considered that the initial thickness of the body of the sheet was 6 000 meters.

Considering this point of view, samples collected from the Danubian Autochthonous would have been covered by a 6 000 meter thick sheet of rocks, still keeping some of the heat of the deeper zones from where they had been brought by a fast uplift. These samples would have been found at a depth greater than 6 000 meters because the thrust plane of the nappe was above the present topographic surface. The thermal gradient was very probably higher than the normal one because in the neighbourhood of the investigated area, west of the Poiana Ruscă Mountains, granodioritic intrusions of upper Cretaceous age are found.

The question is if not under such conditions all biotite samples from various granitoid massifs should have K-Ar clocks completely reset by the cretaceous metamorphism. It seems unlikely that, being covered by the Getic nappe, biotite samples from the Suşiţa and Tismana granitoids or from the Petreanu gneiss would have been able to preserve K-Ar ages, as high as 500 to 650 m.y.

Another explanation of the relations between mesozonal and epizonal metamorphic rocks may be suggested by the K-Ar age pattern of the Danubian Autochthonous. Accordingly mesozonal metamorphic rocks from the Godeanu Mountains or Mehedinţi Plateau would not have come from somewhere else but are blocks having emerged from the Autochthonous basement as a result of very strong lateral pressures exerted on it probably during the Austrian phase of the Alpine orogeny. In areas that have never been covered by a 6 000 meter thick nappe of rocks, K-Ar ages higher than about 120 m.y. could be expected. If the Godeanu massif is considered to be a body having emerged from the Danubian Autochthonous, K-Ar age pattern of the Rîul Mare valley profile can also be explained.

The very strong lateral pressures leading to the emergence of the Godeanu massif had previously fractured the Autochthonous in the present Rîul Mare area into two compartments along the A fault. The southern compartment has overridden the northern one which consequently sank. Proof of this sinking is shown by the very low K-Ar ages of the samples located directly north of the fault, namely 205 m.y. for the muscovite sample 22 and 103 m.y. for the amphibole sample 21. On the other hand, in the overriding block south of the A fault high K-Ar ages of 527 and 656 m.y. are found. After the uplift of the Godeanu massif the southern end of the upper block penetrated below the Godeanu Mountains rocks retreating at the same time from the block north of the A fault. With such a model the K-Ar age of 115 m.y. of sample 11 may be explained. It is possible that this sample has been located directly under the Godeanu massif, whose area was subsequently reduced by erosion. In this case it would represent a sample that was actually buried under a cover of mesozonal rocks.

A conclusive solution of the problem raised by the relations between mesozonal and epizonal metamorphic rocks undoubtedly requires further thorough investigations, this paper being only a very modest beginning.

From the present data it can be seen once more that the potassium-argon method is an excellent tool for clearing up the most recent episodes in the thermal and tectonic history of a region.

With respect to the geologic evolution of the Danubian Autochthonous prior to the cretaceous diastrophism, K-Ar ages show that some granitoids were formed as early as during the assyntic orogeny. Rejuvenation of the old, at least assyntic ages, could exclusively be produced by the Alpine orogeny. In this case the Danubian Autochthonous was not effected by the hercynic orogeny, the metamorphism of the Tulişa series being also the result of the Alpine orogeny.

Table 1. K-Ar ages from the Rîul Mare-Muntele Mic area.

	Sample No.	Rock Type	Mineral[a])	K (%)	$^{40}Ar_{rad}$ (10^{-9} moles/g)	Age (m.y.)
Godeanu	1	Amphibolite	A	0.303	0.194	330 ± 20
Mesometamorphic	2	Pegmatite	B	7.62	1.70	121 ± 4
Rocks	3	Pegmatite	B	7.96	1.85	126 ± 4
	4	Migmatite	B	7.28	2.10	154 ± 5
	5	Migmatite	M	7.63	2.25	159 ± 5
	6	Migmatite	M	7.80	2.30	158 ± 6
Mesozoic	7	Argillite	W.R.	1.29	0.303	128 ± 10
Sedimentary Rocks	8	Argillite	W.R.	3.72	0.600	89 ± 6
	9	Argillite	W.R.	1.34	0.258	105 ± 6
Rîul Mare Series	10	Sericitic schist	W.R.	2.40	0.445	102 ± 4
Petreanu Gneiss	11	Gneiss	B	6.19	1.32	115 ± 4
	14	Gneiss	B	4.28	2.50	303 ± 12
	15	Gneiss	B	5.17	2.40	243 ± 9
	16	Gneiss	B	3.42	1.23	190 ± 8
	17	Gneiss	B	2.44	2.65	527 ± 20
	18	Gneiss	B	6.76	4.25	324 ± 10
Rîuşorul series	12	Quartz-biotite-schist	B	6.02	1.43	128 ± 5
inclusions in	13	Quartz-biotite-schist	B	5.66	1.20	115 ± 5
Petreanu Gneiss	19	Biotite-schist	B	5.56	7.78	656 ± 19
	20	Quartz-biotite-schist	B	4.96	0.925	104 ± 6
Rof series	21	Amphibolite	A	0.530	0.100	103 ± 10
	22	Leptynite	M	8.20	3.18	205 ± 8
	23	Biotite-sericitic schist	W.R.	2.11	0.648	164 ± 6
	24	Biotite schist	B	7.02	3.75	278 ± 9

Table 1. (continuation)

	Sample No.	Rock Type	Mineral[a])	K (%)	$^{40}Ar_{rad}$ (10^{-9} moles/g)	Age (m.y.)
	25	Biotite schist	B	6.68	3.85	298 ± 12
	26	Biotite schist	B	3.78	2.60	352 ± 13
Furcătura Gneiss	27	Gneiss	B	6.07	3.13	269 ± 8
Zeicani series	28	Sericitic schist	W.R.	2.62	0.445	92 ± 4
	29	Chlorite-albite-	M	8.55	1.93	123 ± 4
	30	quartz-schist	M	7.41	1.73	126 ± 4
	39	Secondary biotite near a serpentinite lens	B	6.96	1.37	107 ± 4
Scorila formation	36	Sericitic schist	W.R.	6.25	1.05	91 ± 4
Măru Amphibolites	43	Amphibolite	A + B	1.10	0.685	320 ± 13
	44	Amphibolite	A + B	1.50	0.815	283 ± 11
	45	Amphibolite	A	0.533	0.480	448 ± 18
Sucu Diorite	34	Meladiorite	B + A	2.66	0.765	155 ± 6
	35	Maladiorite	B	4.35	1.50	183 ± 7
Măgura series	37	Amphibolite	A	0.845	0.310	190 ± 10
Muntele Mic	40	Granodiorite	B	7.42	3.75	264 ± 10
Granitoids	41	Granodiorite	B	5.94	2.83	249 ± 10
	42	Adamellite	B	4.98	2.28	241 ± 10
Vîrful Pietrei Granite	31	Granite	M	7.00	3.78	280 ± 9
	32	Schist inclusion	B	5.35	0.935	96 ± 4
	33	in the granite	B	3.95	0.685	94 ± 4
	38	Quartz diorite	B	7.00	1.20	94 ± 4
Premesozoic Sedimentary Rocks	46	Argillite	W.R.	5.43	0.935	94 ± 4
Ogradena Granite	47	Granite	B	5.79	2.88	260 ± 9
	48	Pegmatite	M	7.60	4.83	326 ± 12
Cherbelezu Granite	49	Granite	B	6.62	4.00	311 ± 10
Sfîrdinu Granite	50	Amphiboles schist from the crystalline cover	A	0.636	0.490	388 ± 15
	51	Granite	B	6.83	4.53	339 ± 12

[a]) A = Amphibole, B = Biotite, M = Muscovite, W.R. = Whole rock.

Table 2. K-Ar ages from the Lotru-Parîng-Vîlcan Mountains area.

	Sample No.	Rock Type	Mineral[a])	K (%)	$^{40}Ar_{rad}$ (10^{-9} moles/g)	Age (m.y.)
Lotru Mesometamorphic Rocks	58	Pegmatite	M	7.64	2.40	168 ± 6
	59	Pegmatite	M	7.72	2.48	171 ± 5
	60	Pegmatite	M	8.04	3.13	207 ± 7
	61	Pegmatite	M	8.76	2.55	156 ± 5
	62	Country rocks mica schist	B	4.00	1.13	153 ± 6
	63		M	5.59	1.58	153 ± 5
	64		M	6.63	1.83	149 ± 6
	65	Pegmatite	B	8.16	1.73	115 ± 3
	66	Pegmatite	M	7.80	2.38	162 ± 5
	67	Pegmatite	B	7.34	1.85	141 ± 6
	68	Pegmatite	M	8.48	2.65	168 ± 6
	69	Pegmatite	M	8.88	2.40	145 ± 5

	Sample No.	Rock Type	Mineral[a]	K (%)	$^{40}Ar_{rad}$ (10^{-9} moles/g)	Age (m.y.)
	70	Pegmatite	M	7.66	3.28	226 ± 9
	71	Pegmatite	M	8.10	2.98	196 ± 6
Dragaşan series	77	Amphibolite	A	0.281	0.077	149 ± 11
Synorogenic Granites	76	Gneissic granite	B	3.44	1.97	296 ± 12
Post Orogenic	55	Suşiţa granite from the	B	5.03	5.10	496 ± 15
Granites	57	Vilcan Mts.	B	5.79	6.20	522 ± 16
	72	Suşiţa granite from	B + (A)	3.20	2.55	402 ± 14
	74	the Parîng	B	3.04	1.55	266 ± 10
	78	Mts.	B	3.20	1.30	219 ± 8
	53	Tismania granite from	B	5.15	5.93	554 ± 20
	54	the	B	5.04	5.60	537 ± 20
	52	Vilcan	F	8.83	4.80	283 ± 9
	56	Mts.	F	9.08	4.30	249 ± 7
	73	Tismana granite from	A + (B)	0.620	0.530	426 ± 17
	75	the	A + B	0.848	0.430	266 ± 10
	80	Parîng	A + B	2.28	2.30	494 ± 18
	81	Mts.	A + B	2.44	2.49	498 ± 18
Tulişa series	79	Chlorito-sericitic schist	W.R.	3.01	0.565	102 ± 4

[a]) A = Amphibole, B = Biotite, M = Muscovite, W.R. = Whole rock, F = Potassium feldspar.

REFERENCES

ARMSTRONG, R. L. (1966): *K-Ar Dating of Plutonic and Volcanic Rocks on Orogenic Belts.* In: O. A. Schaeffer and J. Zähringer (editors): *Potassium-Argon Dating.* (Springer, Berlin-Heidelberg-Göttingen), p. 117–133.

ARMSTRONG, R. L., JÄGER, E. and EBERHARDT, P. (1966): *A Comparison of K-Ar and Rb-Sr Ages on Alpine Biotites.* Earth Planetary Sci. Lett. *1*, 13–19.

DAMON, P. E. (1967): *Potassium-argon Dating of Igneous and Metamorphic Rocks with Applications to the Basin Ranges of Arizona and Sonora.* In: E. I. Hamilton and R. M. Farquhar (editors): *Radiometric Dating for Geologists* (Interscience Publishers, London).

GHERASI, N., ZIMMERMANN, V. and ZIMMERMANN, P. (1968): *Structura şi petrografia şisturilor cristaline din partea de N. a Munţilor Tarcu (Banatul de Est) Comitetul de Stat al Geologiei.* Dări de seamă ale şedinţelor *54*, 55–80.

GHERASI, N. and DIMITRESCU, R. (in preparation): *Contribuţii petrotectonice la structura Cristalinului Danubian în partea nordică a munţilor Retezat şi Petreanu.*

GHERASI, N. and SAVU, H. (in preparation): *Structura masivului granitoid de la Muntele Mic (Banatul de Est).*

HURLEY, P. M., HUGHES, H. and PINSON, W. R. jr., FAIRBAIRN, H. W. (1962): *Radiogenic Argon and Strontium Diffusion Parameters in Biotite at Low Temperatures Obtained from Alpine Fault Uplift in New Zealand.* Geochim. Cosmochim. Acta *26*, 67–80.

JÄGER, E. and NIGGLI, E. (1967): *Geological Meaning of Rb-Sr Age Results as Studied on Samples from the Central Alps.* Radioactive dating and methods of low level counting Symposium Monaco, 509–514.

LONG, L. E. (1961): *Isotope Ages from Northern New Jersey and Southeastern New York.* Geochronology of Rock Systems. Ann. N.Y. Acad. Sci. *91*, 400–407.

MOORBATH, S. (1967): *Recent Advances in the Application and Interpretation of Radiometric Age Data.* Earth Sci. Rev. *3*, 111–133.

ONCESCU, N. (1965): *Geologia României.* Editura tehnică, Bucureşti.

OXBURG, E. R., LAMBERT, R. ST J., BAADSGAARD, H. and SIMONS, J. G. (1966): *Potassium-argon Age Studies Across the Southeast Margin of the Tauern Window, the Eastern Alps.* Verhandl. Geol. Bundesanstalt *1–2*, 17–33.

PAVELESCU, L. and DIMITRESCU, R. (1966): *Contribuţii la studiul structurii şi genezei masivului granitic de Tismana.* Comitetul de Stat al Geologiei. Dări de seamă *52*, 95–104.
SOROIU, M., CEREI, M., ONCESCU, M., DANIŞ, A. and MĂNTESCU, C. (1965): *Radiogenic Argon Determination by Neutron Activation Analysis.* Geochim. Cosmochim. Acta *29*, 551–561.
SOROIU, M. and CEREI, M. (1967): *New Developments in Radiogenic Argon Determination by Neutron Activation Analysis.* Geochim. Cosmochim. Acta *31*, 1271–1279.
SOROIU, M. and POPESCU, G. (in preparation): *K-Ar Dating in the Apuseni Mountains (Romania).*

Carte géologique 1:200.000 de la Roumanie. Feuille 25 Deva. 1968.
Carte géologique 1:200.000 de la Roumanie. Feuille 26 Orăştie. 1968.
Carte géologique 1:200.000 de la Roumanie. Feuille 32 Baia de Aramă. 1968.
Carte géologique 1:200.000 de la Roumanie. Feuille 33. Tîrgu Jiu. 1968.