БЪЛГАРСКА АКАДЕМИЯ НА НАУКИТЕ • BULGARIAN ACADEMY OF SCIENCES

ГЕОХИМИЯ, МИНЕРАЛОГИЯ И ПЕТРОЛОГИЯ • 37 • СОФИЯ • 2000
GEOCHEMISTRY, MINERALOGY AND PETROLOGY • 37 • SOFIA • 2000

New radiometric data from Late Cretaceous plutons in Eastern Srednogorie area, Bulgaria

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Abstract. New radiometric datings for the located in the Eastern Srednogorie area plutons Granitovo, Omana-Fakya, Prohorovo, Polskigradetz, Zidarovo and Malkoturnovo are reported. The Late Cretaceous age of these plutons has been confirmed or more precise redefined. K-Ar data on whole-rock and minerals gave ages ranging from Turonian (Prohorovo) through Santonian-Late Campanian (Granitovo and Zidarovo), Campanian (Malkoturnovo) to Early Maastrichtian (Omana-Fakya and Polskigradetz).

Rb-Sr data indicate subduction-related mantle magmatism with minor crustal contamination. The initial $^{87}Sr/^{86}Sr$ ratios of the whole-rock samples are within the range of 0.7038-0.7053.

On the basis of several new isotopic analyses of lead in galena and K-feldspars the Late Cretaceous magmatic event has been supported. A depleted of U/Pb and Th/Pb ratios mantle source enriched with crustal materials has been supposed for the lead. Leaching of lead from the country rocks and its remobilization during the Late Cretaceous magma evolution has been guessed.

Keywords: geochronology, K-Ar, Rb-Sr, Pb-Pb data, plutons, Eastern Srednogorie.

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Каменов, Б. К., Е. Тарасова, Р. Недялков, Б. Амов, П. Момчев, Б. Маврудчиев. 2000 Нови радиометрични данни за къснокредни плутони от Източното Средногорие, България. *Геохим., минерал. и петрол.,* **37**, 13-24.

Резюме. Представени са нови радиометрични датировки за разположените в Източното Средногорие плутони Гранитовски, Омано-Факийски, Прохоровски, Полскоградецки, Зидаровски и Малкотърновски. Къснокредната възраст на тези плутони е потвърдена или по-точно определена. Възрастите по K-Ar данни върху общи проби или върху минерали варират от турон (Прохорово) през сантон-късен кампан (Гранитовски и Зидаровски), кампан (Малкотърновски) до ранен мастрихт (Оманофакийски и Полскоградецки).

Субдукционен мантиен магматизъм със слабо корово замърсяване се извежда от Rb-Sr данни. Началните $^{87}Sr/^{86}Sr$ отношения на общите скални проби са в обхвата 0,7038-0,7053.

Въз основа на няколко нови изотопни анализи на олово в галенити и калиеви фелдшпати е обосновано едно къснокредно магматично събитие. За произхода на оловото е предположен един изтощен на отношенията U/Pb и Th/Pb мантиен източник, обогатен с корови материали. Предполага се и излужване на олово от вместващите скали и неговата премобилизация по време на къснокредната магмена еволюция.

Ключови думи: геохронология, K-Ar, Rb-Sr, Pb-Pb данни, плутони, Източно Средногорие.
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Introduction

The intrusive magmatism in the Eastern Srednogorie area of the Late Cretaceous island-arc system in Bulgaria includes numerous larger or smaller hypabyssal and subvolcanic bodies outcropped in the Strandja Intrusive and in the Yambol-Burgass Volcano-Plutonic zones (Dabovski, 1988). The problem of the geological emplacement age of these bodies is repeatedly discussed in the Bulgarian professional literature, but recently the opinions on their timing are unified around the most likely range Turonian-Campanian. For a variety of regional and tectonic considerations Dimitrov (1951) refered the intrusive rocks of these bodies in Strandja Mountains originally to "Laramidian" magmatism of Paleocene age. This age was adopted and grounded by Yanishevski (1946) and by Borissov (1954). The idea was much shaken by finds of intrusive rocks amongst the Cenonian in age agglomerate pieces (Kulaksazov et al., 1964) and in the Olistostrome Unit from the lower levels of the Cenonian section (Antonov et al., 1977). The geological data point to the eventually compatibility of the volcanic and intrusive activities in the span between Cenomanian-Turonian (Kunchev, 1966) to Upper Santonian (Petrova et al., 1980) with a maximum in the Campanian (Popov, 1981).

Published radioisotopic age data (Vassilev, Lilov, 1971; Palshin et al., 1989) on some of the plutons (Manastir Heights, Malkoturnovo, Rossen, Varlibryag, Omana-Fakya and Granitovo) define a rather wide time span - between 50 and 95 Ma. This dispersion of the ages some of the authors interpret with a radiogenic "rejuvenation" or "aging" by various reasons (Boyadjiev, 1981; Lilov, 1985; Lilov, Stanisheva, 1998). The introduction of corrections for systematic errors is not always enough well substantiated from methodological point of view. The attempts to apply Rb-Sr and Pb-Pb methods are scarce and not successful in many cases. U-Pb zircon- and Ar-Ar methods are not exercised on samples from these plutons at all.

The isotopic datings of the volcanic complexes often are stratigraphically controlled, but the intrusive representatives of this magmatism emplaced sometimes only in the older metamorphic sequences definitely need well-founded radioisotopic data for the timing of their emplacement. Without such data every usage of the indicatory role of this intrusive magmatism in geodynamic reconstructions will be insufficiently implicit and elaborated.

The presented in this paper new isotopic data and ages on representative samples from the plutons studied are collected during 1990-1997 period. The investigated plutons are even distributed within the Eastern Srednogorie area and they are typical for its magmatism. The plutons Prohorovo, Polskigradetz and Granitovo occur in the westernmost sector of the area, the Omana-Fakya occupies its central sector and the Malkoturnovo - the southernmost part of the axial part of the area. Zidarovo pluton is selected as a representative of the Yambol-Burgass volcano-intrusive zone (Dabovski, 1988). Our results shed additional light and details on the Late Cretaceous affiliation of the plutons Malkoturnovo, Omana-Fakya and Granitovo and they are the only ones of their kind published radiogeochronological data up to now for the plutons Prohorovo, Polskigradetz and Zidarovo.

Brief petrographical outline

The petrological peculiarities of the studied plutons are comparatively well investigated. The common feature of all of them is that they are multi-phase bodies with relatively wide extent of their magmatic differentiation and with variegated seriality.

Prohorovo pluton

The pluton is located in the northwest part of Saint Ilya Heights (Nedyalkov, 1964) and intrudes the Paleozoic and Mesozoic sequences - schists, conglomerates, phyllites, marbles and quartz-porphyries and their tuffs (Ignatovski, 1980; Bogdanov, Bogdanova, 1984). Late Cretaceous volcanism precedes the emplacement of a complex offsetting body, presented by great number of apophyses probably joining in the depth. The Mesozoic sequences around the body are transformed into hornfelses and skarns. The intrusive process is two-phased at least - quartzdiorites and quartzmonzodiorites. Dykes presented by diorite-porphyrite, quartz-diorite-porphyrite, granite porphyry, lamprophyre and aplite cut the plutonic body. The dated samples (Table 1) are from the first phase of the pluton (biotite-hornblende quartzdiorite).

Polskigradetz pluton

The Polskigradetz pluton (Nedyalkov, 1983; Kamenov, Tarassova, 1995) is dominantly intermediate in petrographic composition, showing a wide range of differentiation. The pluton is emplaced both in the Lower Triassic sequence, assigned by Chatalov (1985) to the Paleocastro Suite (metasandstones, metaconglomerates, garnet-bearing muscovite schists) and in the Ustrem Suite (metasandstones, mica-bearing calc-schists and fine-grained marbles). The country rocks are contact metamorphosed (hornfelses and skarns occur). The pluton is covered by the sedimentary sequence of Miocene age. Several intrusive phases are observed: I (quartzdiorite passing gradually into quartzmonzodiorite), II (granodiorite and granite), III - leucogranite. The dated samples (Tables 1, 2 and 3) are taken from the wide spread biotite-hornblende quartzdiorites and quartzmonzodiorites of the I-st phase.

Granitovo pluton

The Granitovo pluton (Verguilov, Stoycheva, 1968; Kolcheva, 1970; Kamenov et al., 1996; Kamenov, 2000) is emplaced simultaneously in a complex of a problematical Precambrian age, showing high metamorphic grade and in the low grade metamorphic rocks of Triassic age. The eastern end of the pluton cuts Upper Cretaceous volcanics and pyroclastics. The pluton comprises four intrusive phases: gabbro, quartzdiorite, granodiorite and granite. Skarns are observed southward of the periphery of the pluton within the limestones of Triassic age. Stoyanov (1975) adduces lead-isotopic data for the granite of the pluton, relevant to the model age 255 Ma, but this age is not in accord with the geological position of the pluton. The published K-Ar ages (50 to 70 Ma) by Palshin et al. (1989) are likely to be affected by postmagmatic leaving of ^{40}Ar from the minerals with high potassium content. These data do not agree with the geological considerations for the time span of the volcanic activity in the Eastern Srednogorie area (Lilov, Stanisheva, 1998). Here-dated samples represent the most volumetric phases of the pluton, granodiorite and granite ones.

Malkoturnovo pluton

The Malkoturnovo pluton (Vassilev et al., 1964; Ivanova-Panayotova, Stoykov, 1969; Popov, Chanev, 1980; Dabovski, 1988) is exposed in the Southern Strandja volcano-intrusive subzone straddling the Bulgarian-Turkey borderline. It intrudes low-grade metamorphic carbonate and terrigenous rocks of a probable Triassic age (Chatalov, 1990). The country rocks are contact-metamorphosed into variegated skarns and hornfelses. The pluton is built up by 4 phases: I (gabbro and pyroxenite); II (monzonitoids); III (quartz-syenite) and IV (mostly porphyry type acid in composition dykes).

Vassilev, Lilov (1971) obtained K-Ar age of the biotite gabbro (93-95 Ma, biotite) and of the skarns (93 Ma). The radiometric K-Ar age

Table 1. *K-Ar data of samples from Late Cretaceous plutons in Eastern Srednogorie area*
Таблица 1. *K-Ar данни на проби от къснокредни плутони от Източното Средногорие*

№	Field №	Rock	Phase	Fraction	$^{40}K.10^{-6}(g/g)$	$^{40}Ar_{rad.\ 10}{}^{-6}(g/g)$	Isotopic age(Ma)
A. Granitovo pluton - Гранитовски плутон							
1	4/Gr-1	Gd	III	W.R.	2.99	0.0150	84±4
2	4/Gr-2	Gd	III	Hb+	5.74	0.0270	79±3
3	II/Gr-1	G	IV	W.R.	3.21	0.0156	81.5±5
4	II/Gr-2	G	IV	Bt	3.21	0.0156	83±4
B. Omana-Fakya pluton – Омано-Факийски плутон							
5	IV/OM-1	QMd	II	W.R.	4.06	0.0167	69.5±5
6	IV/OM-2	QMd	II	Hb+	2.61	0.0105	68±3
7	OF/1-1	Mz	III	W.R.	2.29	0.00866	64±3
8	OF/1-2	Mz	III	Bt	3.26	0.0120	64±3
9	OF/1-3	Mz	III	Hb+	2.99	0.0150	70±4
C. Prohorovo pluton - Прохоровски плутон							
10	70-1	Qd	I	W.R.	1.83	0.00994	90±3
11	70-2	Qd	I	Bt	4.87	0.0261	90±3
D. Polskigradetz pluton - Полскоградецки плутон							
12	P/1-1	Qd	I	W.R.	2.29	0.00839	62±4
13	P/1-2	Qd	I	Hb+	3.29	0.0141	72±3
14	P/34-1	QMd	II	Bt	3.96	0.0162	69±4
15	P/34-2	QMd	II	Hb+	2.51	0.0101	68±5
E. Zidarovo pluton - Зидаровски плутон							
16	ZIS-I/1	Gbp	-	W.R.	2.29	0.0125	92.5±3
17	ZIS-ST10	Gb	I	W.R.	1.86	0.00921	83±3
F. Malkoturnovo pluton - Малкотърновски плутон							
18	1/92	Gb	I	W.R.	2.96	0.0115	76±3
19	MT-I/92	QMz	II	W.R.	6.27	0.0248	77±3
20	MT-I/92	QMz	II	Bt	5.22	0.0196	74±3
21	MT-130	Gd	IV	W.R.	3.21	0.0107	66±4

The monomineral separation is performed in the Laboratory of mineral separation at the Geological and Geographical Faculty by S. Miteva. Abreviations: Gb - gabbro; Gbp - gabbro-porphyrite; Qd - quartzdiorite; QMd - quartzmonzodiorite; Mz - monzonite; QMz - quartzmonzonite; Gd - granodiorite; G – granite. Fractions used: W. R. - whole-rock, 0.50-0.10 mm; Bt - biotite, 0.25-0.10 mm; Hb+ - heavy electromagnetic, containing over 90% hornblende with contaminations mainly of biotite, 0.25-0.10 mm; 4. K-Ar isotopic age is calculated with the folowing decay constants $\lambda_K=0.581.10^{-10}a^{-1}$ and $\lambda_ß=4.962.10^{-10}\ a^{-1}$

Мономинералното разделяне е извършено в Лабораторията по минерално сепариране на ГГФ от С. Митева. Съкращения: Gb - габро; Gbp - габропорфирит; Qd - кварцдиорит; QMd - кварцмонцодиорит; Mz - монцонит; QMz - кварцмонцонит; Gd - гранодиорит; G – гранитл Фракции: W. R. - обща проба, 0,50-0,10 mm; Bt -биотит, 0,25-0,10 mm; Hb+ - тежка електромагнитна, съдържаща повече от 90% амфибол със замърсяванията главно от биотит, 0,25-0,10 mm. Изотопната възраст е изчислена със следните константи на разпад: $\lambda_K=0,581.10^{-10}a^{-1}$ и $\lambda_ß=4,962.10^{-10}\ a^{-1}$

of the outcropped in the immediate vicinity in Turkey Derekoy pluton (Ercan et al., 1984; Moore et al., 1980) is in the time span 70.3-81.7 Ma (samples represent granodiorite, monzodiorite and tonalite-porphyrite). The obtained here new K-Ar ages (Table 1) are whole-rock samples from the I phase (gabbro), II phase (quartzmonzonite) and IV phase (granodiorote-porphyry), as well as a biotite separate from the II phase. 7 determinations of Rb-Sr ratio on representative samples form the individual intrusive phases are also carried out.

Omana-Fakya pluton

The Omana-Fakya pluton (Borissov, 1954; Dabovski, Savov, 1985; Kamenov, 1997) is emplaced in a Precambrian metamorphic sequence, Paleozoic (?) granites, Paleozoic, Triassic and Jurassic low-grade metamorphic rocks. The pluton intrudes also a Senonian in age sedimentary sequence. 15 K-Ar age determinations are available (Palshin et al., 1989) covering the range of ages between 66 and 72 Ma. The pluton consists of four phases. The phase I includes pyroxenite, gabbro, quartz-gabbro and their transitions. Phase II comprises monzodiorite, monzonite, quartzdiorite, quartz-monzodiorite, quartzmonzonite and quartz-syenite. The Marginal facies of the rocks of phase II is contaminated and richer in rock varieties, while the inner facies contains mainly quartzmonzonite, which is the prevailing in the pluton petrographical kind. Phase III is built up by porphyry rocks of intermediate to acid composition - quartzmonzonite-porphyry, monzonite-porphyry, granodiorite-porphyry. Phase IV includes only aplite

Here-dated samples are from the widest-distributed rocks of the II-d phase – quartz-monzodiorite (peripheral facies) and quartz-monzonite (inner facies).

Zidarovo pluton

The Zidarovo pluton is an important element of the Zidarovo ring-like volcano-intrusive complex (Dabovski, 1988), relatively well-studied in petrographical and structural sense

Table 2. *Rb-Sr data of some Late Cretaceous plutons in the Eastern Srednogorie area*
Таблица 2. *Rb-Sr данни от някои къснокредни плутони в Източното Средногорие*

No	Sample	Rock	Phase	^{87}Rb (g/t)	^{86}Sr (g/t)	^{87}Rb/^{86}Sr	^{87}Sr/^{86}Sr
			A. Malkoturnovo pluton - Малкотърновски плутон				
1	MT-119u	Gb	I	28.80	106.07	0.272	0.70472
2	MT-U/92	QMz	II	79.68	45.27	1.760	0.70970
3	MT-101	Sy	II	63.58	57.60	1.104	0.70730
4	MT-119-3	Mz	II	56.73	56.91	0.997	0.70640
5	MT-K/92	QMz	II	72.13	54.05	1.334	0.70622
6	MT-2/92	QSy	III	114.2	22.48	5.080	0.71089
7	MT-111	QMzp	IV	41.48	53.94	0.769	0.70945
			B. Zidarovo volcano-intrusive centre - Зидаровски вулкано-интрузивен център				
8	ZIS-1	B	-	18.83	73.96	0.17348	0.70882
9	ST-10/250	Gbp	-	18.82	87.56	0.2148	0.7087
10	PRI-1525	Gb	I	16.54	87.37	0.18927	0.70858
11	3-1001	MGbp	-	-	-	0.2970	0.7039
12	3-1003	Qd	II	-	-	0.2372	0.7058
			C. Polskigradetz pluton - Полскоградецки плутон				
13	P/ST1	Qd	I	25.09	65.01	0.3859	0.7052
14	34	QMd	II	25.66	62.34	0.4116	0.7057

The abreviations of the rock types are the same as in the Table 1. Additional symbols: Sy - syenite; QSy - quartzsyenite; B - basalt; QMzp - quartzmonzodioritic porphyrite (subvolcanic dyke); MGbp - monzogabbro-porphyrite. Calculated initial ratios ^{87}Sr/^{86}Sr 0.7048 and 0.7053 for the samples P/st 1 and 34 respectively. We thank V. Gergelchev and S. Dobrev for the placed at our disposal two unpublished results (11 and 12) concerning the Zidarovo magmatic center

Съкращенията на скалните типове са същите, както на табл. 1. Допълнителни символи: Sy - сиенит; QSy - кварцсиенит; B- базалт; QMzp - кварцмонцодиоритов порфирит (субвулканска дайка); MGbp - монцогабропорфиритова дайка. Изчислени начални отношения ^{87}Sr/^{86}Sr 0,7048 и 0,7053 , съответно за пробите с номера P/ST1 и 34. Авторите благодарят на В. Гергелчев и на С. Добрев за предоставените два непубликувани анализа (11 и 12) от Зидаровския магматичен център

Таблица 3. *Оловно изотопни състави на проби от някои къснокредни плутони от Източното Средногорие*
Table 3. *Lead isotope compositions of some minerals from Late Cretaceous plutons in Eastern Srednogorie area*

No	Sample №	Isotopic ratios			Model age		Model parameter T Ga
		$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$	Pb-urano-genic Ma	Pb-thoro-genic Ma	
I. Potassium feldspars from Granitovo pluton (1) and Omana-Fakya pluton (2)							
1	Kf/II-G	18.651	15.651	38.661	90	110±10	3.160
2	Kf/IV-Om	18.638	15.664	38.715	95	105	3.190
II. Galenas from the occurrence Dobroseletz (3) and from Polskigradetz pluton (4)							
3	6/9010	18.660	15.659	38.664	85	115	3.175
4	97/42	18.626	15.657	38.698	105	105	3.175
III. Galenas from Ustrem-Lessovo ore field (Amov et al., 1985)							
5	Average of 23 samples	18.363 ±0.032	15.659 ±0.019	38.459 ±0.072	269 ±20	254 ±20	3.213 ±0.014

The comparative data for the galenas from Ustrem-Lessovo ore field are after Amov et al. (1985) - average of 10 samples. 13 new unpublished results of Amov are added to these as well
Сравнителните данни за галенити от Устрем-Лесовското рудно поле са по Amov et al. (1985) - 10 проби, като към тях са прибавени и 13 нови непубликувани резултати на Амов

(Stanisheva-Vassileva, 1972; Rashkov et al., 1978; Marinov, 1980; Marinov, Bairaktarov, 1981; Popov, 1981; Bairaktarov et al., 1983; Nedyalkov, 1994). The accumulative structure of the paleovolcano is built up by predominantly effusive rocks (mainly basalts and trahybasalts) and to inconsiderable degree by epiclastics and pyroclastics rocks. The volcanics were cut later on by the Zidarovo ring-like subvolcanic complex of the pluton. Postintrusive dykes occur too. The subvolcanic complex consists of dykes and small intrusions of gabbro-porphyrite, monzogabbro-porphyrite, diorite-porphyrite and syenite-porphyry. The pluton is a sheet-like body comprising gabbro, gabbro-diorite, monzonite and aplite, the transitional alkaline rocks predominated quantitatively. The post-intrusive dykes are very rare and they are presented by diorite-porphyrite and syenite-porphyry (Marinov, 1980).

Analytical methods

K-Ar dating

The analyses were performed at the Radiogeochronology Laboratory of "Geology and Geophysics" Corporation, Sofia. The freshest material available was selected for dating. All dating was performed on jaw-crushed and sieved whole-rock fractions and on hornblende-rich and biotite separates. Potassium was determined in duplicate or triplicate by flame photometry using a FLAPHO-4 instrument (reproducibility about 1-3 % standard deviation). Radiogenic ^{40}Ar was extracted using a conventional vacuum-fusion technique and isotopic dilution with ^{38}Ar-enriched spike as a tracer. The calibrated with standard probes "Asia" 1/65 and "Bern"-4M mass-spectrometer MI-1305 was used. Operating conditions of the emission were 1 mA with a ionizing voltage 50V. The precision in the determination of the radiogenic argon was estimated by reproducibility of interlaboratory standards (1-3%). Rather high and variable atmospheric argon contents were found (57-81%). Neveretheless, all duplicate analyses agree to within the quated 2σ errors. There is no systematic difference in age between the fine and coarse size fractions.

Rb-Sr data

Rb and Sr contents were performed on pressed powder pellets with a FRA-20 X-ray fluorescent spectrometer. Uncertainty on determinations was 5-10%. The isotopic $^{87}Sr/^{86}Sr$ ratio was analyzed on automated MI-1320 mass-spectrometer with experimental dispersion of ± 0.03%. The calculated isotopic ratios are normalized to the $^{87}Sr/^{86}Sr$ ratio of 0.1194. The decay constant $\lambda_{Rb} = 1.42x10^{-11}a^{-1}$ is used (Steiger, Jagger, 1977).

Pb-isotopic data

Representative mineral separates were analyzed for lead isotopes using a modified MI-1305 mass-spectrometer. Isotopic composition of Pb was determined at the Institute of Nuclear Research and Nuclear Energetic, Sofia. Precision and reproducibility of the analyses is better than 0.1%. The obtained results are normalized to the absolute lead-isotopic standard SRM 981 (Catanzaro et al., 1968). The correction coefficient of the isotopic fractionation is 0.1 per mass unit difference of the isotopes. The potassium feldspars are chemically processed to obtain an enriched in lead product. The model ages of the uranogenic and thorogenic lead are computed by the use of the model of the continuous dynamic isotopic evolution of the lead (Amov, 1983). All the measurements and interpretations of the lead-isotopic data and model age calculations are performed by B. Amov.

Results and discussions

K-Ar ages

The obtained ages (Table 1) identify the Prohorovo pluton as Turonian (90 ± 3 Ma). The K-Ar ages for the different fractions of the samples from Granitovo and Zidarovo plutons scatter between 79 and 84 Ma. Within the framework of the laboratory inaccuracies (± 4 Ma) these ages fall in the range of the Early Campanian (82-83 Ma). Significant age divergence amongst the different intrusive phases is not established.

The data for the Malkoturnovo pluton vary around 76 Ma (Later Campanian) and only the rocks from the IV-th phase of the pluton (granodiorite-porphyry dyke-like body) yield considerable younger age of about 66 Ma (Maastrichtian). Comparing these new data to the Cenomanian K-Ar datings between 93 and 108 Ma obtained by Vassilev and Lilov (1971) we are bound to state that the difference is significant. The discrepancy is in order of some 20 Ma. Boyadjiev (1981) through the idea of the so-called "under-screen" accumulation of radiogenic argon accepts a kind of process of radiogenic "aging" of the samples. Lilov and Stanisheva (1998) established excess ^{40}Ar in pyroxenes from basic high-magnesium and high-potassium magmatic rocks of the Tamarino paleovolcano.

Our ages are closer to the data by Moore et al. (1980) for the outcropped in Turkey Sukrupasa pluton (81.7 ± 1.7 Ma), as well as to the published K-Ar data of the Derekoy pluton (76.7 and 78.0 Ma) by Ohta et al. (1988). These two plutons apparently are genetically related to Malkoturnovo pluton. Should the Cenomanian age be further substantiated, the possibility is raised that the specimen dated in this study has not lost argon and that its apparent age is too young. This possibility of rejuvenation of the dyke-like bodies from the IV-th phase relevant to partial argon leaving is not to be rejected, but the dated sample shows no petrographical evidence for additional introduction of potassium or any hydrothermal alteration. Since similar considerably younger K-Ar age is obatined also for the latest dyke-like rocks of the Omana-Fakya pluton, we are willing to accept, for the time being, that the K-Ar age of these rocks actually reflects a later stage of the evolution of the both plutonic complexes. The monzonite-porphyry dykes of the Derekoy pluton in Turkey, for example have published dating of 70.9 ± 3 Ma (Ohta et al., 1988).

The Omana-Fakya and Polskigradetz plutons (Table 1) manifest varying 69-70 Ma K-Ar ages, fixing Maastrichtian time. The field relations to the country rocks do not impose geological limits for these ages, but the results are comparatively wide-dispersed in a rather prolonged range of some 6-10 Ma, which is doubtful to reflect the real duration of the magma crystallization. The time span of the obtained by us datings is between 62 and 72 Ma, almost coinciding with the K-Ar ages range by Palshin et al. (1989). Narower geochronological differentiation of the studied plutons is not possible to be achieved at the present time and that is why essential distinctions between the age of the individual intrusive phases are not established.

However provisional, the interpretations of the so-dispersed K-Ar data range are, it may be emphasized that the predominantly monzonitoid plutons, like Malkoturnovo, Omana-Fakya and Polskigradetz are relatively younger and show longer evolution span than the calc-alkaline plutons, like Granitovo, Zidarovo and Prohorovo do. The obtained ages are compatible with the acceptable geologically and tectonically age range of the magmatic belt extended from Apusseni Mountains and Banat area through Timok and Srednogorie zones up to the Pontides. This equivalence concerns still better the metallogeny of the area studied. The new age determinations require some modifications to the geological history, suggested by precedent authors.

Rb-Sr data

No acceptable whole-rock isochrons were constructed either using the analyzed samples together or using samples as separate groups. Neveretheless, our attempt on 3 samples from the Malkoturnovo pluton (№ 1, 5 and 6, Table 2) gave an isochron with MSWD 0.986. The calculated age when these points are included is 90 ± 4.5Ma and the initial $^{87}Sr/^{86}Sr$ ratio is 0.70444. All other variants were unacceptable and subsequently they had been rejected. The sample M-111 (quartzmonzonite-porphyry of the IV phase) belongs to clear differing isotopic system and its joining in the modelling leads to unrealistic results. The $^{87}Sr/^{86}Sr$ ratio for this sample is rather high (0.70945). This single analysis from the dyke-like rocks serves neither as basis of reliable estimation on the origin of their magma, nor for their age evaluation, but it is significant. It is noteworthy to mention once more that K-Ar dating of the rocks from the IV phase of the pluton is fairly younger than the other phases and this supposes quite different source for them.

The juxtaposition of the Rb-Sr model ages with K-Ar datings (Table 1) manifests considerably rejuvenation of the last ones in order of around 15 Ma. The problem for more precise age assessment of the Malkoturnovo pluton will be left open until we have at our disposal a high quality isochron made up by more samples, or until the age is confirmed by some other methods. For all that, if K-Ar datings of the situated in neighbourhood Derekoy pluton (Ohta et al., 1988) were plausible methodically and geologically (78.3-84.0 ± 2.0 Ma) we would rather rely on the K-Ar new results.

Assuming the age from the K-Ar data, we have made an attempt to calculate the model initial $^{87}Sr/^{86}Sr$ ratio for the samples from the Polskigradetz pluton. These ratios are 0.7048 and 0.7053 respectively.

If the both isotopic Rb-Sr data (№ 12 and № 14, Table 2) were grasped of the jointly development of common homogenization of the magma system, then the approximate value of the calculated presumable initial Sr-ratio would be still lower - 0.7038. These calculated initial Sr-ratios will be acceptable only if the following assumptions are valid: (1) the specimens representing the plutonic rocks to have remained a closed for Sr and Rb system; (2) the accepted out of the K-Ar data ages to be assigned to the entire plutonic complex undergone isotopic magma evolution; (3) the analytical data to have been representative for the plutonic complex, keeping in conformity with the international standards for such investigations.

The slight increase of Sr isotope ratio with SiO_2 and 1/Sr indicates an open- rather than a closed-system differentiation process. The negative correlation between Ca and Sr/Ca expressed in the samples from Polskigradetz and Malkoturnovo plutons is noticed also in Vitosha pluton (Zagorchev, Moorbath, 1987; Lilov, 1989; Amelin at al., 1989), where the initial Sr-ratio is 0.70462. The isotopic data presented are plausible for mantle-derived magmas with very little contamination with crust materials.

Pb-Pb isotopic data

Table 3 shows the results, compared to the published (Amov et al., 1985) and new unpublished data for galenas from Ustrem-Lessovo ore field. The isotopic composition of lead in the K-feldspars from Omana-Fakya and Polskigradetz plutons has not been studied up to now. Only one determination of Pb-isotopic ratios in K-feldspars from Granitovo pluton is available (Stoyanov, 1979) to present, but the obtained uranogenic model age is too far from the real Late Cretaceous geological age. It is most likely that this age discordance is due to the use of old isotopic data with higher experimental errors and to a normalization not to the wide-accepted today absolute lead-isotopic standard (Catanzaro et al., 1968). The supposed genetical inter-connection of the Ustrem-Lessovo ore field and the Granitovo pluton, deduced from the misjudged resemblance in the abundance of uranogenic lead in galenas from Ustrem-Lessovo and in the K-feldspars from the Granitovo pluton, does not correspond to the notions of the metallogenic specialization of the ore field. The comparative data with galenas from Ustrem-Lessovo ore field indicate that the ore mineralizations there are not likely to be related to Granitovo pluton or to the other Late Cretaceous magmatic activity in the area. The lead in their galenas was isolated from the uranium during an earlier magma-tectonic activization.

Lead-isotopic ratios in the galenas from the ore Dobroseletz occurrence within the Granitovo pluton and the ones from K-feldspars of its magmatic rocks are almost identical. We consider this as a proof of close genetical relation between plutonic activity and the ore-formation process. The uranogenic age of these galenas is 85 Ma, and the one of the pluton is 90 Ma. The divergence with the K-Ar dating of rocks and minerals from the Granitovo pluton (Table 1) is 6-8 Ma, but nevertheless the model ages are in the range of the Late Cretaceous.

Omana-Fakya pluton fall in the same range, confirmed by the similarities in the lead-isotopic ratios of K-feldspars with the ones from Granitovo pluton, regardless of the fact that in this case the differences between K-Ar and the model uranogenic ages are quite essential.

The galenas from the gold-bearing quartz-sulphide mineralization related to the Polskigradetz pluton are also assigned to the Late Cretaceous metalogenic epoch, but they are notable for some deficit of radiogenic lead (lower $^{206}Pb/^{204}Pb$ ratios).

Regardless of some differences of the model ages of Pb with K-Ar datings of rocks and minerals from the studied plutons, they are in the range of the Late Cretaceous. In general, the model age of the lead does not always reflect correctly the real age, because it is a function of the variable nature of the source rock lead reservoirs, tapped during ore formation and pluton consolidation. The deviations depend on processes of chemical fractionation in the source, related to enrichment or depletion of U, Th or Pb. Usually the lead source reservoirs evolve towards more radiogenic compositions with time. Therefore, the isotopic composition of lead and the model ages should be used mainly as indicators for the type of the source and for investigation of genetical relationships between rocks and ores and between magmatic and ore-forming processes. The observed variations in lead isotope compositions between the mineral occurrences related to the plutonic activity predominantly reflect differences in source regions of the lead than age differences.

The isotopic composition of the lead and the relevant model ages of the studied plutons and ore mineralizations (Table 3) are close to those of some ore deposits in the Eastern Srednogorie area, namely Bakadjik, Varly Bryag and some other occurrences in Zidarovo (Amov et al., 1985; Amov, 1994; Amov, Arnaudov, 2000). This is significant of similar type sources and age of formation. A slight difference between the model ages and the intrinsic ones (if we accept K-Ar datings as closer to the real ones) in the Granitovo, Polskigradetz and Omana-Fakya plutons, is indicative of the fairly good homogenization of mantle and crust materials in their sources. Some older model ages extracted from the thorogenic lead (105-115 Ma) compared to the ones from the uranogenic lead (85-105 Ma) are in favour of the idea of an slightly depleted Upper Mantle with lower abundance of Th as a source of magma generation.

In some of the ore deposits from the Eastern Srednogorie and in most of them from the Western Srednogorie such a difference between model ages of uranogenic and thorogenic lead and the real geological age is greater, implying even stronger depletion of their mantle sources.

The lead-isotopic method allows estimation of the type of source by the value of the $^{207}Pb/^{204}Pb$ ratio. A model parameter T is introduced in the dynamic model of isotopic evolution of the lead (Amov, 1983) and it is pointed that it is well correlated with the values of the $^{207}Pb/^{204}Pb$ ratio. This parameter is used as an indicator for earlier or later enrichment of the source by U and Th and is possible to be used to determine the type of the source of the lead (Upper or Lower crust, oceanic crust, mantle etc.) Most frequently the source material had been repeatedly mixed during the geological history so the parameter T is a true reflector of mixtures in different proportions of matter from different sources. A juxtaposition with the model plumbotectonics by Doe and Zartman (1979) which gave curves of accumulation for three basic types sources, shows that the values of the model parameter T vary as follows: Upper crust - 3.35 Ga; orogen - 3.31 Ga; mantle - 2.7 Ga (Amov, 1983,b).

The specific values of parameter T for the plutons studied and mineralizations are demonstrated in Table 3. The variation is in short range (3.16-3.19 Ga) between the value for the "orogene" and for "Upper crust", but lying closer to those of the "orogene". The oceanic crust with variable mixtures of crustal and mantle sources is generally admitted to be analogous of such "orogene". Our results reveal a mixture between mantle- and crust-derived lead, with some preponderance of the last one in the sources of the magmas, thereby explaining the small divergence between the model and the real geological age of the plutons.

The published for Derekoy pluton results of two galena samples are similar (Wagner et al., 1985) to ours. The lead-isotopic ratios of these samples fall also close to the "orogene" model curve of incremental growth). The model parameter T in other deposits from the Srednogorie zone usually is with lower values, indicative for the prevalence of the depleted Upper Mantle-derived lead. That is why the both model ages of the uranogenic, and the thorogenic lead, are significantly older than their actual geological age.

The supported by the new Pb-isotopic studies idea that the most likely source of the generated during the Late Cretaceous magmas and fluids, was an depleted of U/Pb and Th/Pb ratios source could have something to do with the rise of metallogenic hypotheses for the ore-magmatic evolution in the area.

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Accepted December 19, 2000
Приета на 19. 12. 2000 г.