THE SOUTHERN EXTENSION OF THE SREDNOGORIE TYPE UPPER CRETACEOUS MAGMATISM IN RILA-WESTERN RHODOPES: CONSTRAINTS FROM ISOTOPE-GEOCHRONOLOGICAL AND GEOCHEMICAL DATA

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Key words: Rila-West Rhodopes granitoids; metadiorite and metagranite; U-Pb zircon and monazite dating; Nd-Sr isotope tracing

Introduction

The Apuseni–Banat–Timok–Srednogorie (ABTS) belt, Europe's most extensive belt of calc-alkaline magmatism and Cu-Au mineralisation, is related to the subduction of the Tethys ocean beneath the European continental margin during the Late Creta-ceous phase of the Alpine – Himalayan orogeny. Extensive U-Pb dating of zircons from subvolcanic intrusions and major plutons in Central Srednogorie reveals a general youngling of the magmatism from ~92 Ma in the north (Elatsite) to ~78 Ma in the south (Capitan Dimitrievo). This age progression is explained as a consequence of slab retreat during oblique subduction. Noteworthy Cu-Au deposits are restricted to the northern and central part of the profile (ranging in age from ~92 to ~86 Ma, (von Quadt et al., 2005), while the southernmost part exposes more deeply eroded mid-crustal plutons devoid of economic mineralisation. Accretion of a continental fragments south of the ABTS belt - in the Rhodopes – is suggested to explain this phenomenon, which led to greater uplift of the youngest Late Cretaceous intrusions and removed any ore deposits that might have been formed in this area.

Looking more to the south, in the Rhodopes, the Alpine magmatism is dated mainly as post-Palaeocene in age, but an Upper Cretaceous one is also supposed by many authors. In the Rila-West Rhodopes batholith Пейчева и др., (1998) and Kamenov et al. (1999) distinguished an Upper Cretaceous pre-metamorphic unit of plastically deformed hornblend-biotite granitoids (≈ 80 Ma), and other two units which revealed Late Alpine age (about 40 and 36±1 Ma). The batholith is situated directly south of the western parts of Central Srednogorie (Fig. 1) and provides good opportunity to extend the N-S profile to the Rhodopes – to the accreted continental fragments. Present study focuses on the isotope-geochronological and geochemical features of the presumably Upper Cretaceous rocks in Eastern Rila and Western Rhodopes (Fig 1). Conventional U-Pb isotope single grain zircon method and ID-TIMS technique are used to specify aging. Sr and Nd isotope studies contribute to constrain the magma sources. Few additional isotope investigations are made on some rocks of the hosting metamorphic complexes and the main Rila granitoids with the aim to better understand the relations of the rocks and the possible geodynamic environment.

Geological setting and sampling

The granitoids of the Rila-West Rhodopes batholith crop out over more then 2000 km^2 in the Rila and the Rhodopes Mountains (fig. 1). They consist of three main rock types: hornblend-biotite and biotite granodiorites (unit 1), biotite and two mica granites (unit 2) and fine-grained leucogranites and aplitoid granites (unit 3) (Вылков и др., 1989; Kamenov et al., 1999). The first unit differs not only in age (as mentioned above), but also in petrographic and geochemical characteristics from the second and third units (Kamenov et al., 1999).

The first unit granitoids, which are the main topic of present study, are coarse grained, melanocratic, inequigranular to porphyritic. In all outcrops they are variably overprinted and plastically deformed. The metamorphic foliation is low grade (10-25°) dipping to the NNW-NNE (Kamenov et al., 1999). It is entirely conform to the foliation of the country metamorphic rocks. The syn-kinematic shear criteria show top-to-SSE-SSW direction of the synmetamorphic transport (Dimov, 1994; Kamenov et al., 1999). The same direction of syn-kinematic transport is typical also for the granites of the second unit, whereas the criteria are clearly observed in some areas (SW of Velingrad, Kanina river valley), but mainly in the contact zones to the metamorphic complexes.

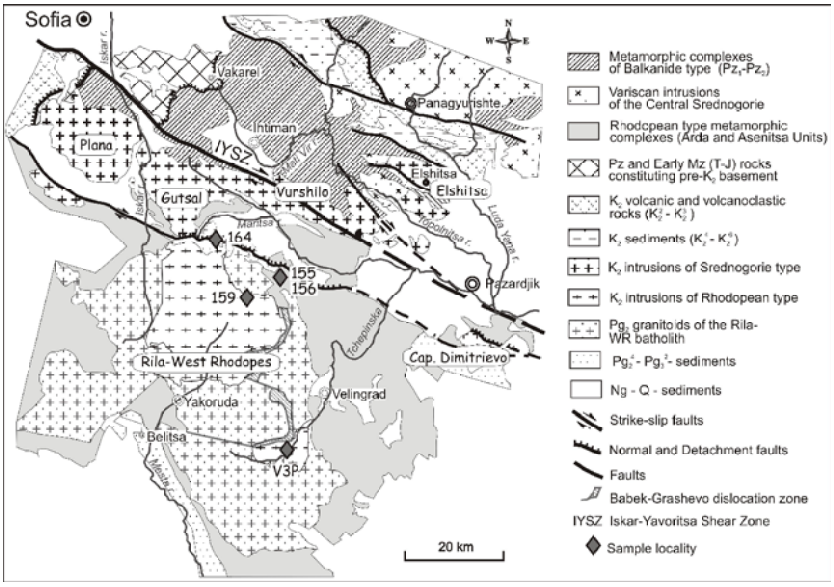

Fig. 1. Simplified geological map of the western parts of Central Srednogorie (after Ivanov *et al.*, 2002) and Rila-West Rhodopes batholith (after Вылков и др., 1989) with sample localities.

The tectonic contact between the Srednogorie and Rhodopes is marked by the SW-SE to E-W orientated Maritsa fault zone (Bonchev, 1946). In the studied area it is followed on the northern slopes of Rila and West Rhodope Mountains (Fig. 1) and described as a dextral strike-slip zone, active from Crataceous to Late Alpine time (Ivanov, in press). According to Ivanov (in press) the Late Alpine evolution of the zone is connected initially with a SE directed extension and the development of the Rila-West Rhodopean Dome. A series of detachment faults were formed at that time, which lead to separation of the Assentsa and Arda lithotectonic units (Ivanov et al., 2000) in the region of Belovo and formation of the Paleogen depressions, north of the Rhodopes and Rila (Fig. 1). Later on, in Post-Oligocene time strike-slip faults were prevailing, causing the formation of the elongated Ng-Q pull-apart depressions.

The samples for present study are from the Belmeken and Gruntcharitsa bodies of the first unit granodiorites (AvQ159 and V3P) and from a strongly milonitized granite from the fault zone, south of Dolna Banja village (second unit, AvQ164; Fig. 1). Additionally we sampled an amphibolite and cross-cutting gneiss vein of the Arda Unit, east of the batholith and about 500 m from the contact to the Assenitsa Unit (AvQ155 and AvQ156, Fig. 1).

U-Pb isotope geochronology and Nd-Sr isotope geochemistry

U-Pb zircon and monazite dating. High-precision U-Pb single grain method and ID-TIMS (Isotope Dilution – Thermal Ionisation Mass Spectrometry) technique are used for the dating of zircons from all samples and monazites of samples 164 and 156. For the calculation of the age the program ISOPLOT (Ludwig, 2000) is applied, whereas uncertainties are reported at the 2s level. The most long prismatic zircon grains were chosen for the analyses. The zircon color varied from beige and pale beige (majority of the zircons) to colorless (some grains from samples AvQ155 and AvQ159).

Most zircons from both granodiorite samples of unit 1 (AvQ159 and V3P) are concordant or almost concordant (Fig 2). The grains with the best fit of the $^{206}Pb/^{238}U$ and $^{207}Pb/^{235}U$ ages are used to calculate concordia ages of 69.26±0.26 Ma and 66.79±0.29 Ma respectively. Consequently the Upper Cretaceous magmatism proceeded between 66.5 and 69.5 Ma (error uncertainties included).

Three out of the four granite zircons from the shear zone (AvQ164) reveal lead inheritance and are slightly discordant. Only one of the analyzed grains is concordant at 37.47 Ma. Two monazites from the same sample are overconcordant with a $^{207}Pb/^{235}U$ age of 27 and 23 Ma. It is well known, that despite the temperature stability of the monazites (blocking temperature of 700-800°C), post-metamorphic recrystallisation and/or Pb-loss during fluid circulations are considered the main processes that reset monazite ages under low-temperature (<450°C) conditions (Townsend et al., 2000). Therefore we interpret the zircon data as the lower bracket of the granite magmatism, whereas the monazite ages reflect lead-loss due to the long-living shear/fault zone.

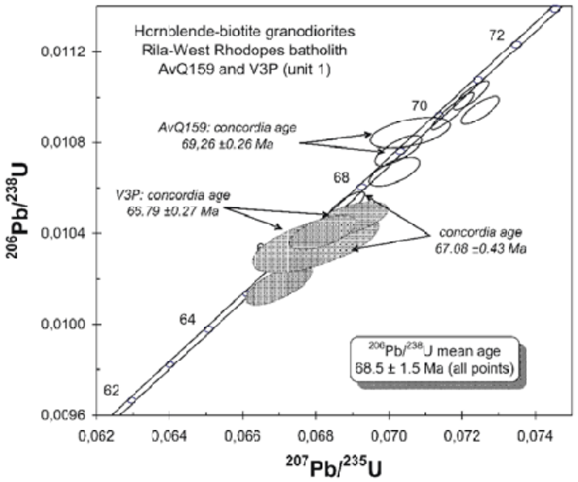

Fig. 2. Concordia diagram for zircons of samples AvQ159 and V3P (filled symbols).

The two samples from the Arda Unit, ENE of the batholith, reveal different protolithic ages. The zircons from the amphibolite show clear magmatic oscillatory zoning pattern which is evident for magmatic origin of the protolith (diorite). The analyzed zircon grains define a discordia with an upper intercept age of 253±13 Ma. The zircons of the cross-cutting gneiss (with magmatic oscillatory zoning as well) usually show inherited lead component, but one of them is concordant at 43.5 Ma, and two are almost concordant at about 45 and 40 Ma respectively. All analyzed monazites are inversely discordant, two of them showing a mean $^{207}Pb/^{235}U$ age of 41.02±0.74 Ma, and one reveals a lead loss ($^{207}Pb/^{235}U$ age of 33 Ma). The BSE images of the monazites show usually oscillatory zoning, that suggests crystallization from a liquid/magma. Both, the metadiorite and the metagranitic vein are plastically deformed, therefore we interpret the obtained geochrono-logical data as the age of synmetamorphic intrusion of granitic magma at about 40-43 Ma ago.

Zircon saturation thermometry. Zircon saturation thermometry is calculated for the granitoids of the Rila-West Rhodopes batholith using the equation of Watson and Harrison (1983), which rearranged for T yields a geothermometer for melt:

$$T_{zr} = 12900/[2.95 + 0.85M + \ln(496000/Zr_{melt})]$$

In this equation T_{zr} is the zircon saturation temperature in kelvins (in the following text all temperatures have been converted to °C), M is the ratio (Na + K +2*Ca)/(Al*Si), all in cation fraction, Zr_{melt} is the concentration of Zr in the saturated melt (measured in the rock sample) in ppm, and 496000 is the concentration of Zr (ppm) in the zircon.

The calculated zircon saturation temperatures of the Rila-West Rhodopes granitoids lie in the field of the "cold" (T< 800°C) granites of Miller et al. (2003), generated in the crust. However the zircon saturation temperature of the first unit granitoids range from 755 to 783°C (average of 770) and is about 30°C higher then these of the main phase granites (average of 740°C).

Nd and Sr isotope geochemistry. The Nd and Sr isotope characteristics give evidence for mixed and not homogenised sources of the granitoid magma (see also Peytcheva *et al.*, 1998), but emphasize the differences between the unit 1 and 2. The granodiorites of unit 1 reveal crust-mantle features with e-Nd (70) in the range of -3.3 to +0.6 and initial ($^{87}Sr/^{86}Sr$) of 0.7064-0.7066. The granites of unit 2 are crust dominated, showing e-Nd (40) from -2.6 to -9.1 and ($^{87}Sr/^{86}Sr$) of 0.7065-0.7085. Noteworthy is the similarity of the latter with the source characteristics of AvQ156 (metagranitic vein from Arda Unit) revealing e-Nd (40) of -7 and ($^{87}Sr/^{86}Sr$) of 0.7072. In the metadiorites from the Arda lithotectonic unit the e-Nd (250) of -2.7 and initial ($^{87}Sr/^{86}Sr$) of 0.7061 argue for a mixed (mantle-crustal) source of the Upper Permian/Lower Triassic magma.

Discussion and conclusions

The new precise single crystal U-Pb zircon and monazite data confirm the age differences of the Rila-West Rhodopes granitoids of unit 1 from one side, and unit 2 and 3 from the other. The plastically deformed granodiorites of unit 1 reveal crust-mantle isotope characteristics and geochemical similarities (Kamenov et al., 1999) to the Srednogorie type magmatism. Furthermore the magmatism gets younger to the south, but also more crustal influenced, which give evidence for a real change in the geodynamic environment in the Mastrichtian after the accretion of continental fragments south of the ABTS belt. If we look for correlates in the Serbian part of the belt possible candidates are the subvolcanic dacites of the west situated Ridanj-Krepoljin Zone (Karamata et al., 1997), dated recently at 69±2 Ma. As the latter are not overprinted shallow level intrusions it becomes clear, that after the Late Cretaceous time both regions are subjects of quite different tectonic regimes.

Why do the granitoids with different age crop now together in "one batholith"? So far we can just suppose a Late Alpine exhumation of both granitoids, connected with the postcollisional collapse of the stacked crust in the Rhodope region (Burg et al., 1996; Ricou et al., 1999; Ivanov et al., 2000). The mechanism of the metamorphic core complex could be a passable explanation, but this idea remains just a hypothesis without detailed structural data.

The zircons of the studied granitoids spread along the concordia. Consequently the calculated concordia ages lie in an interval of 1-3 Ma. This phenomenon could be due to a long crystallization in a deep magma chamber. The deep crustal generation (> 25 km) of the Late Alpine granitic magma was suggested earlier through the presence of magmatic epidote in the Kalininski granite in Rila (Чернева, Арнаудова, 1998).

The present data provide some preliminary information about the protoliths of the Arda Unit east of the batholith – there mantle-crustal Upper Permian/ Lower Triassic metadiorites are cross cut by Late Alpine granitic veins. Both rock types are metamorphosed and plastically deformed, presumably contemporary with the intrusion of the granitic melts. The genetic relation of the latter with the biotite granites of the batholith seems likely because of the close crystallization ages and geochemical features, but again the lacking detailed studies hamper to make this conclusion convincing. Furthermore present and published isotope data give evidence for a crystallization of the Rila biotite granites to about 37-38 Ma and cooling to about 300 °C at 36± 1Ma (Peytcheva et al., 1998). The monazite ages of the granites in the shear zone (North Rhodopean detachment/Maritsa fault) argue for a long living tectonic zone, active to at least 23 Ma ago.

Further complex studies will contribute to better constrain the geodynamic reconstructions of the region.

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ЮЖНОТО ПРОДЪЛЖЕНИЕ НА СРЕДНОГОРСКИЯ ТИП ГОРНОКРЕДЕН МАГМАТИЗЪМ В РИЛА-ЗАПАДНИ РОДОПИ: ИЗОТОПНО-ГЕОХРОНОЛОЖКИ И ГЕОХИМИЧНИ ДАННИ

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Настоящото изследване представя изотопно-гехроноложки и геохимични изследвания на гранодиорити с предполагаема Горнокредна възраст в Източна Рила и Западни Родопи (фиг. 1, проби AvQ159 и V3P), някои предварителни изотопни данни за протолитите на Ардинската литотектонска единица, източно от Рило-Западнородопския батолит (амфиболит AvQ155 и секуща гнайсова жила AvQ156), както и за проба (AvQ164) от основния Рилски гранит от зоната на Севернородопския разлом на отделяне/Маришкия разлом.

Болшинството анализирани циркони от гранодиоритите са конкордантни или почти конкордантни (фиг. 2). Зърната с най-добро съвпадение на $^{206}Pb/^{238}U$ и $^{207}Pb/^{235}U$ възрасти са използвани за изчисляване на конкордантни възрасти 69,26 ± 0,26 Ma и 66,79 ± 0,29 Ma. Nd и Sr характеристики потвърждават принадлежността им към Средногорския тип магматизъм, но с по-голямо участие на коров материал в Родопската част. Три от четирите анализирани циркона на проба AvQ164 от разломната зона показват наличие на унаследено олово и са слабо дискордантни. Само един от цирконите е конкордантен с възраст 37,47 Ma. Двата анализирани монацита от същата проба са разположени над конкордията и определят $^{207}Pb/^{235}U$ възрасти съответно 27 и 23 Ma. Двата образеца от метаморфозираната Ардинска единица показват различни протолитни възрасти. Осцилаторна зоналност на цирконите от амфиболита свидетелстват за магматичен произход (метадиорити). Анализираните единични зърна определят дискордия с възраст по горно пресичане с конкордията 253 ± 13 Ma. Цирконите от секущата гнайсова жила също са с осцилаторна магматична зоналност. Унаследеното олово в тях е причина за обикновено дискордантното им положение, но един от тях е конкордантен при 43,5 Ma, а два други са почти конкордантни при 45 и 40 Ma. Анализираните монацити от същата проба са с излишък на ^{206}Pb, като два от тях са със средна $^{207}Pb/^{235}U$ възраст 41,02 ± 0,74 Ma. Направени са някои разсъждения за взаимоотношенията на изследваните скали и възможната геодинамична обстановка.