Petrochan and Klissura plutons in Western Balkan: relationships, *in situ* and single grain U-Pb zircon/monazite dating and isotope tracing

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Introduction

The Petrochan and Klissura pluton are exposed in the core of the Berkovitsa anticline, SE—NE of the Berkovitsa town in the Western Balkan. Usually they are considered as part of the "Stara Planina Calc-Alkaline Formation" (Dimitrov, 1959; Vutov, 1967, 1968; Mircheva, Veznev, 1969; Dimitrova, Arnaudova, 1977). Based on some peculiarities of the Klissura granite and the relationships to the surrounding high-grade metamorphic rocks N and NW of the village of Burzya (former called Klissura) Haydoutov et al. (1979, 1992) came to the conclusion that both units are part of the diatectites of the Burzya migmatitic complex with a probable Cambrian age (Carrigan et al., 2003). Here we present new field, geochemical and isotope-geochronological data for both plutons with the aim to understand their geotectonic position, generation and relationships.

Geological setting and sampling

The position of Klissura granite is defined by a system of faults striking NE 50—55° and NW 320—340°, which were reactivated several times (Malinov et al., 2004). The granite is fine-, medium- and coarse-grained, often pegmatite-like. Usually in the marginal parts to the phyllites and diabases of the Berkovitsa group (Haydoutov et al., 1979) they get porphyritic and in the field it is very difficult to distinguish these porphyritic parts from the porphyry varieties of the Petrochan pluton. White aplitic veins cross cut the body in some places.

The main rock-forming minerals are plagioclase (albite-oligoclase), K-feldspar, quartz, hornblende, biotite and muscovite, and the accessories — zircon, monazite and magnetite. The structure of the granite is hipidiomorphic to granoblastic. Despite on the surface the granites look leucocratic and amphibole-free (Dimitrov, 1932; Vutov, 1967—1968; Mircheva, Veznev, 1969; Dimitrova, Arnaudova, 1977) in fresh samples from boreholes. Malinov et al. (2004) describe more than 5% of green hornblende, the latter usually recrystallised in structurally controlled fissures/fractures. According to the classification diagram of Peccerillo and Taylor (1976) the fresh rocks of the Klissura pluton belong to the high-K granites, whereas weathered samples lie in the fields of normal granites and high-K granodiorites.

The Petrochan pluton is a complex body, built up by gabbroic to granitic rocks with a prevailing distribution of the acid and intermediate varieties. According to Haydoutov (1979) and Haydoutov et al. (1992) it is formed in a vertical magma feeder structures, in the cross area of the E—W situated Variscan Stara planina tectonic belt and a perpendicular N—S fault. The magmatic succession resulted from prolonged magma replenishment. The pluton is metaluminous with calc-alkaline and high-K calc-alkaline affinity. Mafic magmatic enclaves (MME) are characteristic feature of the Petrochan pluton in the outcrops north of Spantchevtsi village. The MME reveal transitional composition between the gabbroic and granitoid magma. They have similar composition like the granitoids of the Petrochan pluton, but different proportion of the main rock-forming minerals. Field, petrographic and geochemical data for the enclaves and the main rock varieties give evidence for processes of magma mingling and mixing, additional to the normal AFC processes (Tacheva et al., this volume).

Based on field observations the time relationships between the Klissura and Petrochan plutons are not clear, as the contacts are tectonic (NE from Burzya),

covered by weathered sediments and soil, or the plutons are separated by the host rocks. The host Early Paleozoic (Carrigan et al., 2003; Peytcheva, von Quadt, 2004) phyllites and diabases of the Berkovitsa group are contact metamorphosed. The Petrochan pluton is overlain by Mesozoic sediments. Isotope dating of Carrigan et al. (2003) suggests an age of about 500 Ma for the Klissura granite (in situ SIMS analyses). Conventional U-Pb ID-TIMS and in situ LA-ICP-MS studies of zircons and monazites by Malinov et al. (2004) on the other side argue for a Carboniferous age (329.7 ± 5.4 Ma) of granite formation. For the granodiorites of the Petrochan pluton Carrigan et al. (2005) recently determined an age of 304 ± 4 Ma.

In present study we used for dating samples from the porphyry Klissura granite (AvQ136), hybrid gabbro and a granodiorite of Petrochan pluton from a quarry N of Spantchevtsi village (AvQ-171 and AvQ-172, respectively) and a gabbro cropping out N of Berkovitsa, which according to the present geological map 1:100 000 represents the first phase of the Petrochan pluton (sample AvQ-195). The isotope analyses are carried out at the Institute of Isotope Geology and Mineral Resources, ETH-Zurich using a precise conventional U-Pb-zircon and monazite method and ID-TIMS (Isotope Dilution — Thermal Ionisation Mass Spectrometry) techniques, combined with *in-situ* LA-ICP-MS analyses of both accessories.

U-Pb isotope geochronology and isotope tracing

Zircons of sample AvQ-136 are mainly brownish, transparent, prismatic, and the monazites are transparent, yellow-green or yellow-orange. In CL (cathode luminescent) and BSE (back scattered electron) images zircons show magmatic oscillatory zoning, U-rich outer parts, and in the shorter crystals inherited cores and recrystallized parts are present. This complex composition reflects in the discordant position of the measured zircons on the Concordia diagram (fig.1) and the bigger scatter of the points. Two zircons and two monazites define an Upper intercept age of 317 ± 12 Ma, which coincides roughly with the age of the equigranular coarse-grain Klissura granite (329.7 ± 7.6 Ma; Malinov et al., 2004). The common origin of both varieties become more clear, when calculating separately the zircon and respectively the monazite ages of samples AvQ-135 and AvQ-136; in this case the age for the zircons is 332 ± 7 Ma (using not abraded grains) or 340.2 ± 4.5 Ma (using also two abraded crystals) and 318.0 ± 8.2 for the monazites. Although the time difference is not significant, younger monazite age could be explained by generally later crystallization or/and low-T hydrothermal lead loss.

In situ LA-ICP-MS analyses of zircons from the porphyritic Klissura granite are consistent with conventional age data. Although older (Lower Paleozoic) cores are present in some measured zircons, the majority of the $^{206}Pb/^{238}U$ ages are Carboniferous with weighted average of 324 ± 28 Ma.

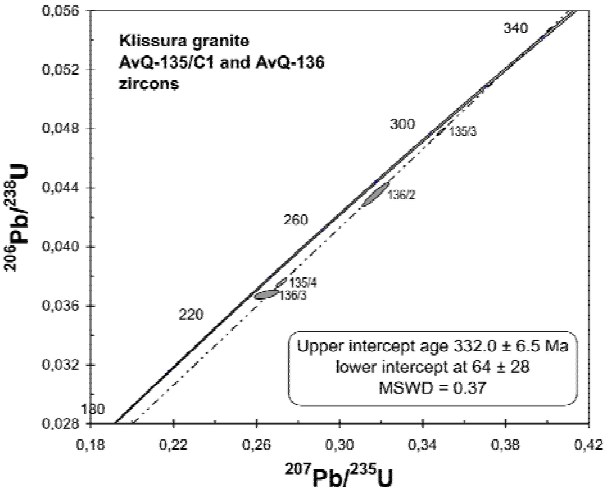

Fig. 1. U-Pb concordia diagram for zircons of samples AvQ135-C1 and AvQ-136, Klissura granite

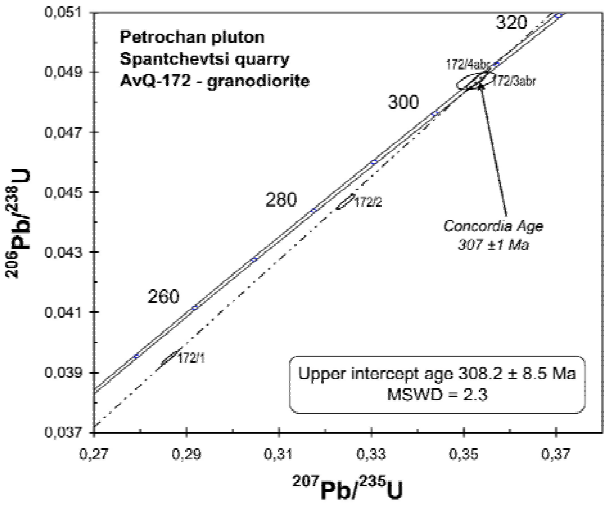

Fig. 2. U-Pb concordia diagram for zircons from granodiorite sample AvQ-172 of the Petrochan pluton

Both samples from the Spantchevtsi quarry of Petrochan pluton are Variscan in age, but younger than the Klissura granite. Transparent brownish zircons of the granodiorite (AvQ-172) define a discordia line with upper intercept age 308.2 ± 8.5 Ma, but two air-abraded zircons are concordant at 307 ± 1 Ma (fig. 2).

Zircons of sample AvQ-171 reveal some characteristic features of hybrid gabbros, as they are observed in the Velichkovo gabbro (southern parts of Central Srednogorie (Peytcheva et al., 2005) — they are brownish, U-rich and in sufficient quantity. Two of the measured zircons are discordant, with lead

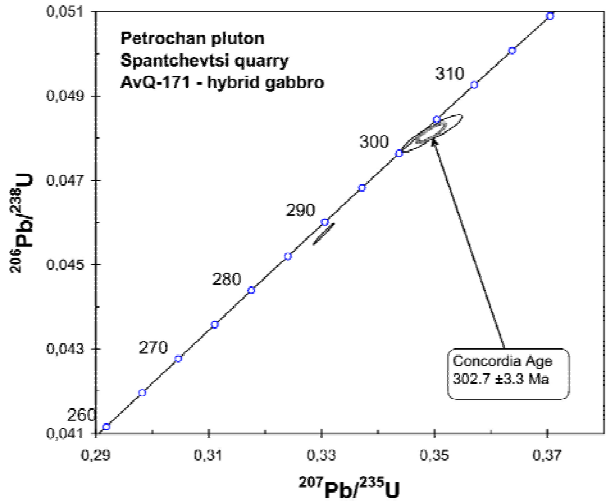

Fig. 3. U-Pb concordia diagram for zircons of sample AvQ-171, hybrid gabbro from the Spantchevtsi quarry of Petrochan pluton

loss, whereas two others are concordant at 302.7 ± 3.3 Ma (fig. 3).

The gabbro of Berkovitsa is still not precise dated, as there two types of zircons are observed — the first defining a Lower Paleozoic age, and the second almost concordat at ~305 Ma. Not like the hybrid gabbro from the Spantchevtsi quarry, zircons are sparse and U-poor.

Source characteristics of the magma are inferred from the ε-Hf-zircon values, corrected for the age of crystallization. Noteworthy they are positive in all zircons and give evidence for mantle influence in the studied rocks. The highest ε-Hf (T) zircon values are measured in the gabbro samples (respectively +5.0 and +4.2) and the Petrochan granodiorite AvQ-172 (+5.2).

Discussion and conclusions

Klissura and Petrochan plutons are Variscan in age. They have Ca-alkaline affinity and reveal equigranular and porphyritic textures.

Klissura pluton is built up only by acid rocks — granites and granodiorites with an age 332 ± 7 Ma. Although the latter coincides with the time of high-grade metamorphism in Central Srednogorie basement (Carrigan et al., 2005) and let us suppose the same age of metamorphism of the Burzya migmatite complex, the positive ε-Hf zircon values of the zircons suggest more complicated generation of the granitoid magma with a participation of mantle source.

U-Pb dating of the Petrochan pluton follows the idea of Haydoutov et al. (1992) for prolonged magma replenishment. Granodiorites are dated at 307 ± 1 Ma, and the hybrid gabbro of the Spantchevtsi quarry at 302.7 ± 3.3 Ma. In the same range is the age 304 ± 4 Ma, calculated by *in situ* SIMS dating of Carrigan et al. (2005). Mafic magmatic enclaves (MME), field relationships of the basic and acid varieties and characteristic petrographic and geochemical features give evidence for processes of magma mingling and mixing, additional to the normal AFC processes (see also Tacheva et al., this volume), whereas the basaltic magma intruded in not fully solidified granitoid mush in a middle/upper crust magma chamber. The positive ε-Hf (T) of dated zircons (mainly between +2 and +5) give evidence for mixed crust-mantle origin of the magma and confirm the idea for post-collisional tectonic setting of their generation.

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Петроходски и Клисурски плутони в Западния Балкан: взаимоотношения, *in situ* и конвенционално U-Pb датиране на цирконi/монацити и изотопни характеристики

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Резюме. Петроханският и Клисурският плутон се разкриват в ядката на Берковската антиклинала в Западния Балкан. Обикновено се разглеждат като част от „Старопланинската калциево-алкална формация“, но съществуват и мнения, че Клисурският гранит е диатектит от долнопалеозойския Бързийски мигматитов комплекс. В настоящото изследване се представят нови полеви, геохимични и изотопно-геохроноложки данни за двата плутона, с цел да се разберат тяхната геоложка позиция, генериране и взаимоотношения. За датиране са използвани образци от порфирната разновидност на Клисурския гранит (AvQ136), гранодиорит и хибридно габро от Петроханския плутон в кариерата при с. Спанчевци (AvQ-172 и AvQ-171), както и габро, разкриващо се непосредствено Ю от гр. Берковица, разглеждано досега като първа фаза на Петроханския плутон.

Двата изследвани плутона са с Варистка възраст. Те принадлежат към калциево-алкалната магмена серия и имат както равномернозърнести, така и порфирни разновидности.

Клисурският плутон е изграден само от кисели скали — гранити и гранодиорити с възраст 332 ± 7 Ma. Въпреки че последната съответства на времето на високостепенен метаморфизъм във фундамента на Централното Средногорие (Carrigan et al., 2005), и следователно подобна възраст може да се предположи и за метаморфизма на Бързийския мигматитов комплекс, позитивните стойности на ε-Hf (T) на датираните цирконi предполага по-сложен механизъм на генериране на гранитоидната магма с участие и на мантиен източник.

U-Pb датиране на Петроханския плутон подкрепя идеята на Хайдутов и др. (1992) за продължително постъпване на магми. Гранодиоритите са с възраст 307 ± 1 Ma, а хибридното габро от кариерата при Спанчевци е датирано като като 302.7 ± 3.3 Ma. В същия интервал е и възрастта на гранодиоритите 304 ± 4 Ma, получена с *in situ* SIMS метод от Carrigan et al. (2005). Мафичните магмени включения (ММВ), полевите и времеви взаимоотношения на базичните и кисели разновидности, и характерните петрографски и геохимични особености на ММВ (виж също Тачева и др., този сборник), дават основание да се предположи, че образуването им е резултат не само на диференциация и фракциониране на първоначална базична магма, но и на процеси на смесване на магми, като високотемпературната базична магма е интрудирана в една по-студена кисела топилка в магмена камера в горната кора. Позитивните стойности на ε-Hf (T) в цирконите (основно в интервала +2 до +5) потвърждават корово-мантийния им произход във вероятна пост-колизионна тектонска обстановка.