СПИСАНИЕ НА БЪЛГАРСКОТО ГЕОЛОГИЧЕСКО ДРУЖЕСТВО, год. 80, кн. 3, 2019, с. 61–63
REVIEW OF THE BULGARIAN GEOLOGICAL SOCIETY, vol. 80, part 3, 2019, p. 61–63

Национална конференция с международно участие „ГЕОНАУКИ 2019"
National Conference with international participation "GEOSCIENCES 2019"

Petrology of the Plovdiv pluton

Петрология на Пловдивския плутон

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Keywords: Late Cretacous igneous activity, petrology, geochemistry.

Introduction

The Plovdiv pluton is intruded along the Maritsa strike slip fault zone in the southern part of Central Srednogorie Zone. The erosion is exposing several hills in the town of Plovdiv that provides excellent outcrops for studyng the pluton. The main igneous phase is presented by monzonitic rocks that constitute most of the pluton. The presence of mafic enclaves and intermediate dyke-like and irregular small bodies with similar by composition enclaves around them shows typical mingling structures with the hosting magmas. The latest phase is presented by aplitic and pegmatiod veins that crosscut all of the previous phases. The pluton is intruded in Upper Cretaceous lava rocks and metamorphic basement. The recent LA-ICP-MS U-Pb zircon age from Sahat Tepe hill is 80.02±0.33 Ma (Georgiev et al., 2018) which precise the previous K-Ar ages of feldspars and amphiboles that are giving comparatively wide interval of the formation in the range of 81–78 Ma (Boyadziev, Lilov, 1981).

Although it is easily accessible and well outcropped, the last comprehensive petrology and geochemistry studies of the rocks from Plovdiv pluton are accomplished, a long time ago by Boyadzhiev (1973) and after that it is included mostly in regional interpretations. Here we provide new geochemical, isotope and petrology data with the aim to constrain better the petrology, geochemistry, generation and magma sources and give some thermobarometric implications.

Analytical methods and sampling

Major elements of bulk samples are determined using dilution ICP-AES (at Aquaterratest Lab) and the trace elements are obtained on fused pellets using LA-ICP-MS (at GI-BAS, Sofia). The major element mineral chemistry is achieved by energy-dispersive X-Max Large Area Analytical Silicon Drifted spectrometer (Oxford) coupled with a scanning electron microscope JSM-259 6610 LV at the University of Belgrade. The whole-rock $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios are obtained after a chromatographic cleaning procedure by ID-TIMS (TritonPlus) and the $^{176}Hf/^{177}Hf$ ratios of the heterogeneous zircons are achieved by spatial controlled in-situ LA-MC-ICP-MS at ETH-Zurich.

Petrology and mineral chemistry

The main intrusive phase of the Plovdiv pluton is presented by medium to coarse-grained massive rocks with typical monzonitic texture presented by poikilitically enclosed amphibole and Pl in the Kfds. Myrmecitic texture at the border of plagioclase and Kfds is often visible (Fig. 1a). The rock-forming minerals are plagioclase, Kfds, quartz, amphibole, clinopyroxene and rarely biotite (Fig. 1b, c). The accessory minerals are well presented by titanite, apatite, zircon, magnetite and allanite. The ***mafic enclave***s are presented by fine-grained gabbroic rocks with primary minerals of plagioclase and amphibole, but also rarely biotite and clinopyroxene (Fig. 1d). The accessory minerals are presented mostly by titanite, allanite and apatite. ***The small irregular and dyke-like bodies*** are porphyritic with phenocrysts of plagioclase, quartz, amphibole and rarely biotite and clinopyroxene set in fine-grained groundmass and accessories of apatite, titanite, zircon and magnetite (Fig. 1e). The ***aplitic veins*** are built predominantly of microcline

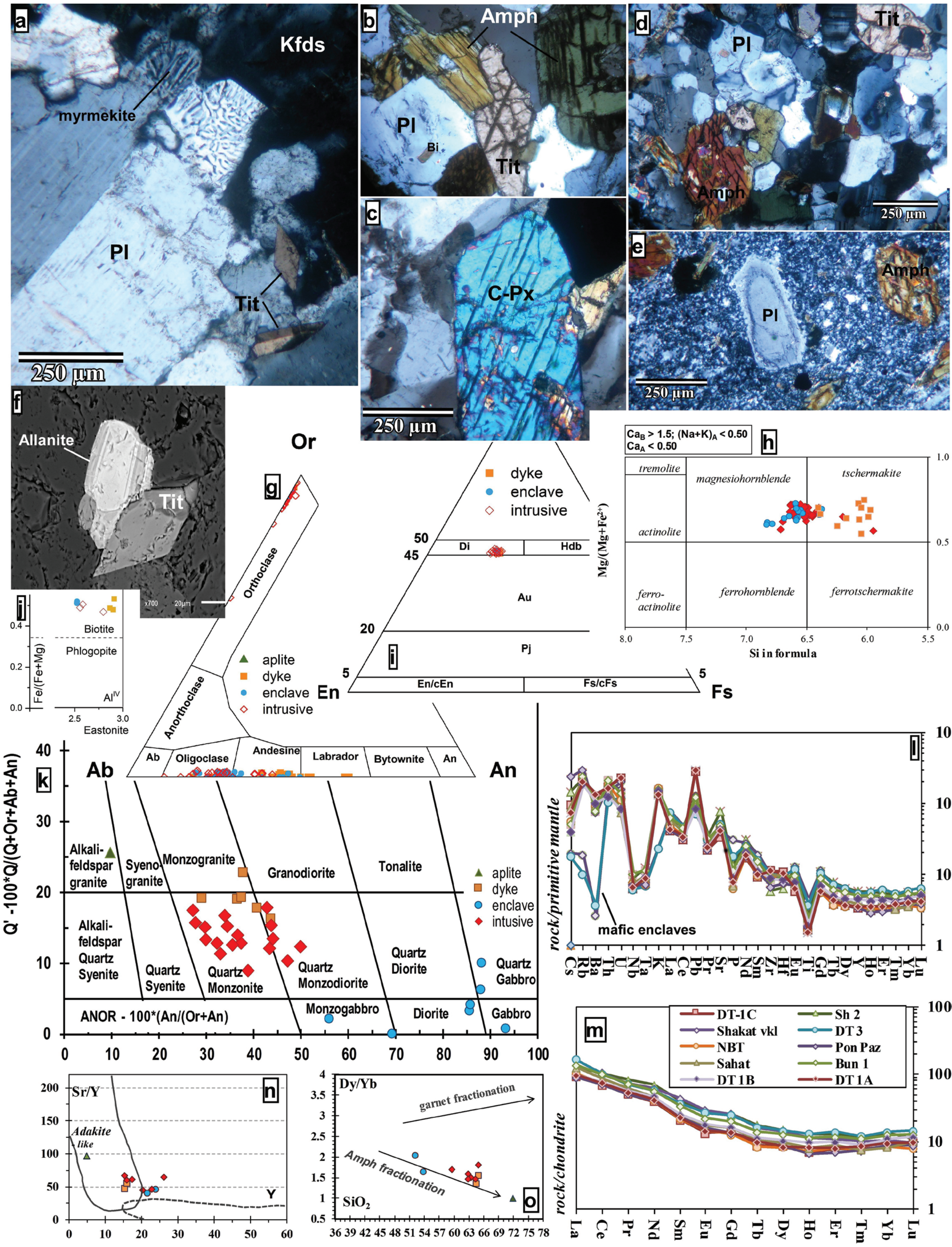

Fig. 1. Petrology features of Plovdiv pluton: ***Microphotographs*** (cross-polarised light): *a*) myrmekite at the border of Kfds and Pl; *b*) biotite embedded in plagioclase, amphibole and titanite; *c*) diopside in the quartz monzonite *d*) micrograined mafic enclave built of plagioclase, amphibole and titanite; *e*) quartz monzonite porphyry with amphibole and plagioclase (with sieved periphery) set in fine-grained groundmass; *f*) allanite and titanite in the aplitic veins (BSE image). ***Mineral diagrams:*** *g*) Ab-Or-An; *h*) amphibole; *i*) pyroxene; *j*) biotite; ***Geochemistry:*** *k*) Q-ANOR normative diagram of Streckeisen and Le Maitre (data from Boyadzhiev, 1973 included); *l*) primitive mantle normalized spidergram; *m*) chondrite normalized REE pattern; *n*) Y vs Sr/Y diagram for distinguishing adakite-like characteristics; *o*) SiO_2 vs Dy/Yb diagram.

BSE, back scattered electron image; Pl, plagioclase; Kfds, potassium feldspar; Amph, amphibole; C-Px, clinopyroxene; Tit, titanite; Ab, albite; An, anorthite; Or, orthoclase, En, enstatite; Fs, ferrosilite; Wo, wollastonite; Di, diopside and less quartz and plagioclase with minor biotite and muscovite and accessories of titanite, apatite and allanite (Fig. 1f).

Plagioclase (Fig. 1g) represents the dominant mineral phase in the quartz monzonitic rocks (oligoclase-andesine, An_{15-41}). In the mafic enclaves it is presented by oligoclase-labrador (An_{20-50}) and in the porphyritic rocks it shows well expressed oscillatory zoning (An_{19-63}) sometimes with sieve zones overgrown by slightly more calcic rims that suggest mixing phenomena.

Amphibole (Fig. 1h) is the most abundant mafic mineral in the monzonitic rocks and enclaves. It is presented mostly by magnesihornblende and tschermakite. In the porphyritic rocks unless magnesihornblende and tschermakite, magnesiohastingsite is also present.

Clinopiroxene (*diopside*, Fig. 1f) is rare and forms euhedral crystals or it is found as small relicts embedded in the amphibole.

Biotite (Fig. 1j) is rare and it is found in the all rock varieties.

Titanite is abundant in all of the varieties and it forms euhedral crystals sometimes exceeding 6 mm.

Zircon in the monzonitic rocks is predominantly long, rarely short prismatic with well-expressed magmatic oscillatory zonation.

Apatite contains 6–7 wt% fluorine.

Geochemistry

The nomenclature of the rocks from the Plovdiv pluton is made using the Q-ANOR normative diagram of Streckeisen and Le Maitre (1979, Fig. 1k). The main intrusive phase falls mostly in the field of quartz monzonite and quartz monzodiorite while the porphyritic dykes-like and irregular bodies fall in the same field but contain more quartz. The mafic enclaves are mostly gabbro, monzogabbro and gabbrodiorite. The aplitic veins fall in the field of alkali feldspar granite. The most of the rocks are metaluminious, high-K calc-alkaline to shoshonitic while some of the mafic enclaves are medium-K calc-alkaline.

On a primitive-mantle normalized diagram (Fig. 1l), the rocks show peaks in LILE (U, Th, Pb) and troughs in Nb, Ta, Ti and P typical for orogenic magmas. They show high contents of LILE, decreasing MREE chondrite-normalized patterns and almost flat to listric-shaped HREE normalized profile (Fig. 1m). Some of the rocks exhibit geochemical adakite-like features with weak negative Eu (0.79 to 0.88) anomaly, high Sr (716 to 1667 ppm) and low Y (15 to 25 ppm) content (Fig. 1n). These feature along with decreasing Dy/Yb with increasing SiO_2 (Fig. 1o) most probably are due to amphibole (and probably titanite) fractionation.

The measured $^{87}Sr/^{86}Sr_{(80)}$ ratio in the quartz monzonites of Sahat tepe is 0.704254 and $\varepsilon Nd_{(80)}$ –0.38, while the isotopes of mafic enclave are slightly more primitive: 0.704143 and 1.90. The $\varepsilon Hf_{(80)}$ of the autocrystic zircons show variations in the range of +5 to +10.8 suggesting primitive magma source and magma mixing.

P-T conditions of crystallization

The P-T conditions of the amphiboles using the geothermobarometer of Ridolfi et al. (2010) shows continental depth of 6.6–4.8 km and 830–910 °C for the quartz monzonites. The amphiboles from the mafic enclaves show similar conditions (6.9–4.8 km and 810–897 °C) probably due to re-equilibration. The amphiboles from the porphyritic dyke-like and irregular small bodies show three peaks of the crystallization: 6.4–6.8 km and 880–890 °C; 10–14 km and 900–940 °C; 17–22 km and 950–1000 °C. The crystals have zoning (on Fe, Mg and Al) which some authors (Erdman et al., 2014) argue that influence the barometric accuracy. Nevertheless the results give good approximation for the crystallization depth of the amphibole in the porphyritic rocks.

Acknowledgements: The study is supported by grant 04/9 of the National Science Fund, Ministry of Education and Science, Bulgaria.

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