U-Pb zircon and monazite geochronology of Variscan magmatism related to syn-convergence extension in central northern Portugal

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The Variscan magmatism in Central Northern Portugal is characterized by the systematic association of two main groups of granitoids: (a) peraluminous two-mica granites produced by dehydration melting of mid-crustal levels and (b) metaluminous to slightly peraluminous biotite-dominant monzogranites associated with minor intrusions of basic and intermediate rocks. The geochemical and Sr-Nd isotopic signature of the biotite-dominant monzogranites and basic rocks is consistent with variable degrees of interaction between crustal and mantle derived melts.

Granite emplacement is associated with two major crustal-scale transcurrent faults: the N-S striking Porto-Tomar dextral shear zone and the Douro-Beira-Penalva do Castelo sinistral shear zone.

Field relationships and petrographical studies show that the two groups of granitoids were essentially generated during and/or slightly after the metamorphic climax. The metapelitic country rocks record a typical clockwise P-T path. Rocks of suitable composition experienced partial melting during the high T decompression stage. Although the timing of the metamorphic climax of the area has not been precisely determined, previous works in adjacent sectors point to ages ranging between 320–310 Ma for the metamorphic peak (Chamine et al., 1998; Barbero and Rogers, 1999)

New studies involving U-Pb zircon and monazite geochronology and geochemistry have been carried out on representative granitoid bodies of Central Northern Portugal and allowed the discrimination of, at least, three distinct magmatic pulses.

The early 311 Ma pulse is represented by the Maceira biotite-dominant monzogranite and the Casal Vasco peraluminous two-mica granite. The granitic rocks of the two suites yield identical U-Pb ages and show structural evidence of having been emplaced syntectonically along the Douro-Beira-Penalva do Castelo sinistral shear zone.

In the western sector, the syntectonic intrusion of the Junqueira peraluminous two-mica granite within the Porto-Tomar dextral shear zone marks a second pulse of magmatic activity at 308 Ma.

The K-feldspar porphyritic biotite monzogranite of Cota is one of the youngest intrusions of the area (306 Ma). The Cota monzogranite intrudes, at shallow depth, along the high strain NW-SE trending segment of the Douro-Beira-Penalva do Castelo fault which has also controlled the location of a narrow Upper Carboniferous sedimentary basin.

In the context of the tectono-magmatic evolution of the Iberian Variscan Belt, the obtained U-Pb ages can be interpreted according to the following scenario: (1) major crustal thickening due to Variscan continental collision, (2) re-equilibration of the thickened lithosphere through uplift/erosion, extension and mantle delamination, (3) hot mid-crustal rock units experience decompression melting during active exhumation (4) basaltic melts generated within upwelling asthenosphere supply additional heat to the already hot lower crustal levels and trigger large-scale dehydration melting, (5) crustal anatectic melts are produced at various levels and may mix in varying degrees with mantle material to generate magmas of contrasting compositions, (6) large volumes of granite magmas are extracted and collected along active crustal-scale faults and ascent to higher crustal levels (311–308 Ma), (7) continued tectonic exhumation leads to the concomitant formation of the Late Carboniferous detritical basin, (8) basin inversion and emplacement of the younger granites (306 Ma) in an overall transcurrent tectonic regime. Basin subsidence, deformation and voluminous granite magmatism are short-lived and coeval processes.

The narrow time-span between peak T metamorphic conditions (320–310 Ma) and the intrusion of granitic melts (311–308 Ma) implies very fast uplift rates accommodated through active tectonic exhumation. Magma compositions evolve through time, reflecting the increasing underplating effect of an upwelling asthenospheric mantle at the base of a thinning and stretching continental crust.

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The geothermobarometry of Variscan medium-grade metamorphic rocks from the Kutjevačka Rijeka (Slavonian Mts., Croatia)

(1 fig.)

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A disrupted Variscan belt that extends southeastwards of the Bohemian Massif through the Carpathians to the Caucasus also occurs south of the western Carpathians and builds the crystalline basement beneath the southern parts of the Tertiary Pannonian Basin (Tisia Unit). Tisia is commonly regarded as a lithosphere fragment that was broken off from the margin of Eurasia and after a complex drifting and rotation, occupies its present tectonic position. In the South Tisia, the largest and best outcrops of Variscan crystalline rocks occur in Slavonian Mts: Psunj, Papuk and Krndija located between the Sava and Drava rivers (Croatia).

The Variscan crystalline complex of Slavonia, though tectonically disturbed, builds up domal structure with S-type granites in the core that are winded by migmatitic zones and regionally metamorphosed sequences at the flanks. Mesozoic (mainly Triassic) sediments and Tertiary sediments of the South Pannonian Basin disconformably overlie the Variscan domal structure. All these Variscan crystalline rocks also make up the basement of the South Pannonian Basin.

The aim of this preliminary communication is to present the geothermobarometry of Variscan medium-grade metamorphic rocks from poorly known sector of the Variscan orogen.

The Kutjevačka Rijeka north-south striking profile is one of the best outcrop of the progressively metamorphosed Barrow-type metamorphic sequences, which contain in its medium-grade parts mica schists and paragneisses with orthoamphibolite intercalations.

In the *mica schists*, two different garnets are present: large (up to 1 mm) pre- to syn-tectonic, hipidiomorphic, discontinuously zoned garnets (Fig. 1A) generally have Mn-rich cores (X_{Alm}=0.690, X_{Sps}=0.102, X_{Prp}=0.117, X_{Grs}=0.091) and Ca-rich rims (X_{Alm}=0.717, X_{Sps}=0.008, X_{Prp}=0.094, X_{Grs}=0.181) whereas smaller syn-tectonic

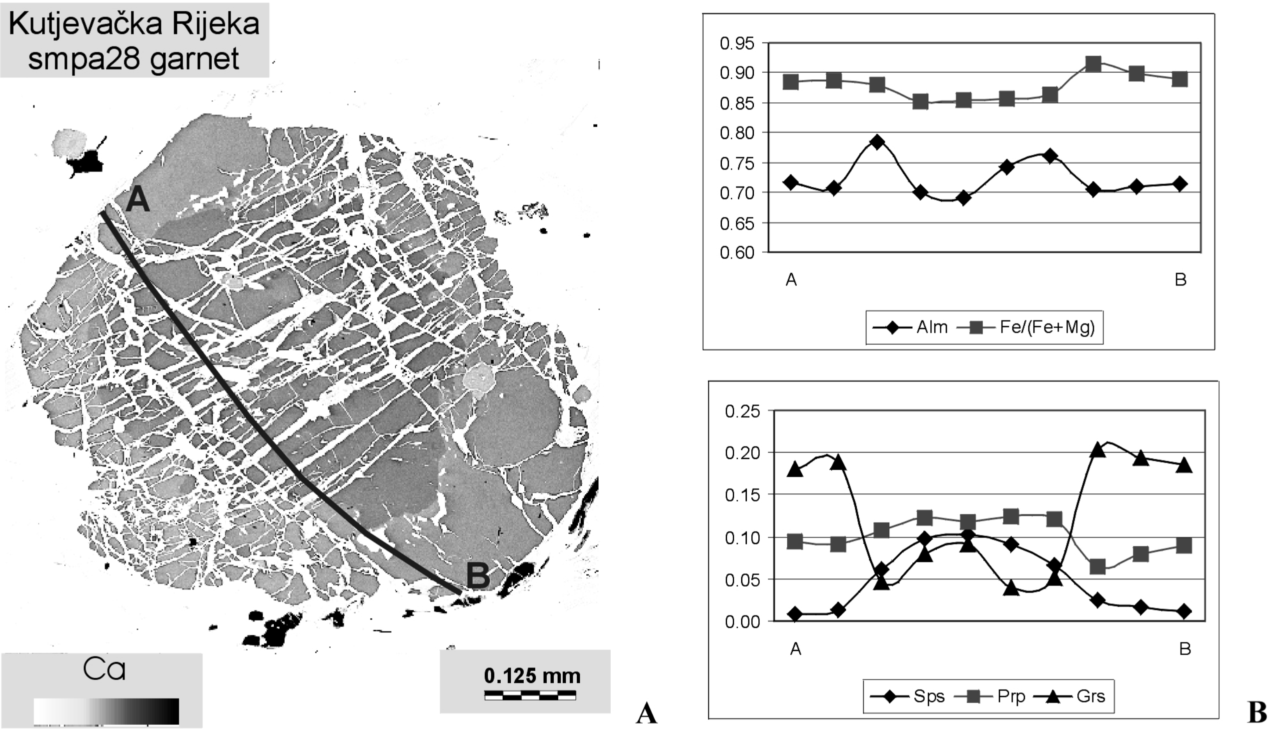

Fig. 1 A – BSE image of zonal garnet from Kutjevačka Rijeka mica schist (processed with Scion Image software); B – typical chemical profiles for X_{Alm}, X_{Sps}, X_{Prp}, X_{Grs} and Fe/(Fe+Mg) ratio in the zonal garnet.

garnets (up to 0.5 mm) with composition corresponding to rim of the larger garnets. Apatite, ilmenite and quartz are inclusions in cracked core of large garnets. Apart from these, peak mineral assemblage comprises biotite, muscovite, plagioclase (~18% An) and quartz. Distribution of chemical elements in profile show same trend but with rapid „Ca jump“ in core-rim transition area (Fig. 1B). The large garnet rims and small garnets show continuously decreasing X_{Grs}, X_{Sps}, and Fe/(Fe+Mg) ratio and increasing X_{Prp} and X_{Alm} toward garnet rim. Such pattern suggests prograde metamorphic conditions during the garnet rim crystallization. The same, but less prominent, prograde pattern is also present in the core region up to „Ca jump“. The rapid change of Ca composition and discontinuous character of garnet zoning probably involve breakdown and consummation of earlier-formed Ca-bearing phase (apatite?). It may imply a complex evolution of these rocks with two different metamorphic stages or a change in the reaction assemblage during prograde evolution. The distribution of Mn shows undisturbed „bell-shaped“ pattern throughout whole grain that supports the latter assumption.

Paragneiss assemblage comprises syn-tectonic garnets with slightly different core (X_{Alm}=0.659, X_{Sps}=0.077, X_{Prp}=0.128, X_{Grs}=0.136) and rim composition (X_{Alm}=0.699, X_{Sps}=0.044, X_{Prp}=0.133, X_{Grs}=0.124), suggesting prograde character. Peak assemblage includes biotite, amphibole (Si 6.20, Mg 1.95, Fe^{2+} 1.23 p.f.u.), plagioclase (~28 %An) and quartz. Apatite, ilmenite, zircon, amphibole (Si 6.97, Mg 3.24, Fe^{2+} 0.60 p.f.u.) and quartz are inclusions in garnets.

Amphibolites also contain syn-tectonic garnets with core compositon of X_{Alm}=0.595, X_{Sps}=0.121, X_{Prp}=0.081, X_{Grs}=0.203 and rim with X_{Alm}=0.677, X_{Sps}=0.065, X_{Prp}=0.122, X_{Grs}=0.145. Cation distribution suggests prograde character. Peak assemblage also includes amphibole (Si 6.06–6.82, Mg 1.58–2.50, Fe^{2+} 1.27–1.79 p.f.u.), plagioclase (20–30 %An) and quartz, with minor ilmenite, apatite, titanite, epidote-clinozoisite.

Thermobarometric calculations are performed using Holland & Powell’s THERMOCALC and Gerya & Perchuk’s GeoPath software, and individual calibrations of Graham – Powel (1984) for Grt+Hbl geothermometry, Kohn – Spear (1990) for Grt+Hbl+Pl geobarometry, Holland – Blundy (1994) for Hbl+Pl geothermometry.

In the *mica schists,* Grt+Bt thermometry yielded 572±14 °C and Grt+Ms+Bt+Qtz barometry yielded P values of 7.0±0.5 kbar using GeoPath software, while with THERMOCALC we obtained 600–630 °C and 9–11 kbar.

In the case of *gneisses* we obtained 600–630 °C and 6.5–7.5 kbar with THERMOCALC, while results for Grt+Hbl+Pl assemblage are 500–580 °C and 8–10 kbar. Additionally, using GeoPath, temperature values of 591±11° C (Grt+Bt), 595±29 °C (Grt+Hbl) and 640±12 °C (Hbl+Pl) were obtained.

In the *amphibolites* calculated T values are 619±37 °C for edenite-tremolite and 588±45 °C for edenite-richterite reaction using Holland – Blundy (1994) calibrations. In addition, Grt+Hbl thermometry yielded 490–570 °C, while using Grt+Hbl+Pl barometry we obtained 7–10 kbar.

The presented peak metamorphic data together with additional microtextural, paragenetic and mineral chemical data can be correlated with similar results obtained in nearby parts of the South Tisia in Hungary, which support an idea of a complex evolution path in sense of a model (Variscan-Variscan or pre-Variscan-Variscan) with two different stages of metamorphism.

References

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