# GEOCHEMISTRY AND GENESIS OF THE HERCYNIAN GRANITES FROM THE WESTERN CARPATHIANS

M. KOHÚT[1], P. NABELEK[2], U. POLLER[3], C. RECIO[4] and W. TODT[3]

[1] *Dionýz Štúr Institute of Geology, Mlynská dolina 1, 817 04 Bratislava, Slovakia, milan@gssr.sk*
[2] *Department of Geological Sciences, University of Missouri-Columbia, Columbia, MO 65211, USA,*
[3] *Max-Planck Institut für Chemie, Abteilung Geochemie, Postfach 3060, D-55020 Mainz, Germany,*
[4] *Facultad de Ciencias, Universidad de Salamanca, E 37008 Salamanca, Spain*

**Abstract:** Genesis of the two most extended granitic rocks within Hercynian basement of the Western Carpathians is discussed with respect of their geochemistry. The Meso-Hercynian (Visean) peraluminous granites were produced in the consequence of crustal thickening from metagreywackes with contribution of amphibolitic lower crust. The Neo-Hercynian (Westphalian – Stephanian) calc-alkaline, metaluminous granites were derived after delamination by advection of mantle heat, from mafic and felsic lower crust with dioritic addition.

**Key words:** granitic rocks, genesis, geochemistry, radiogenic and stable isotopes, Hercynian orogeny, Western Carpathians.

### *Introduction*

The origin of igneous rocks is nowadays understood in substantial detail based on the interpretation of mineral, chemical and isotopic data. Radiogenic and stable isotope systems (Sr, Nd, Pb, O, S) play a critical role in many aspects of granite petrology in as much as these systems directly record characteristics of the source and/or of the various components contributing to their origin.

There is general consensus that the Hercynian orogeny has a continent-continent collisional character within the present European realm. The voluminous felsic Hercynian magmatism resulted in four main granite types within the Western Carpathians basement (WCB) as a consequence of: i) subduction and amalgamation of oceanic lithosphere, ii) crustal thickening by continental collision, iii) lithospheric delamination or slab breakoff, iv) post-collisional – extensional tectonics. Changing tectonic processes produced Devonian – Older S-type granites (later transformed in orthogneisses); Lower Carboniferous – Younger S-type peraluminous granites; Upper

Carboniferous calk-alkaline I-type granites, and Permian post-orogenic subalkaline A/S-type granites in the WCB (Petrík & Kohút, 1997). However, detailed geochemical and isotopic characterisations are available only for the Visean peraluminous (Younger S-type) and Westphalian – Stephanian calc-alkaline (I-type) granite magmatism up to now.

### *Results*

The Visean granites are peraluminous (ASI = 1.1 – 1.5), dominated by two-mica granites and granodiorites while biotite granodiorites to tonalites are less common. The accessory mineral association monazite + ilmenite, and the presence of host (metamorphic) rock xenoliths is typical for these rocks. From a geochemical point of view, Ba, Sr and Rb range widely (up to 1600, 600 and 200 ppm respectively) with Rb/Sr = 0.2 – 0.8; rarely up to 1.8. $SiO_2$ varies from 66 to 77 wt.% and $K_2O/Na_2O$ = 0.7 – 1.4. The contents of CaO, $TiO_2$ and $P_2O_5$ are generally low (<2.5; <0.7 and <0.3 wt.%.). The REE content is moderate, with a fractionated pattern and a small, negative, Eu anomaly. Initial Sr ratios are between 0.706 – 0.708; □$Nd_{(350)}$ = -0.62 to -4.24; the $^{206}Pb/^{204}Pb$ ratios of the whole rock samples range from 18.39 to 19.28 and the $^{207}Pb/^{204}Pb$ ratios from 15.59 to 15.74, and the stable isotope (O and S) values range between □$^{18}O_{(SMOW)}$ = 8.8 to 11.3‰ and □$^{34}S_{(CDT)}$ from -0.9 to +5.7‰. Magmatic intrusion ages of these granites are between 350 – 330 Ma, with most values around 340 Ma. These granitic rocks resemble, in the classical alphabetic nomenclature, common S-type and/or Ilmenite series granites.

The Westphalian – Stephanian calc-alkaline granites are rather metaluminous to subaluminous (ASI = 0.8 – 1.1), dominated by biotite tonalite to granodiorite with scarce hornblende. Muscovite-biotite granodiorite to granite are less frequent. The accessory mineral association magnetite + allanite, and the occurrence of mafic microgranular enclaves (MME), are characteristic of this group. Lower $SiO_2$ concentrations, from 60 to 68 wt.%, coincide with higher trace elements Zr, Ba, Sr (up to 380, 1350, and 800 ppm), higher LREE and Fe group element contents. REE patterns are typically steeper, with higher LREE and without Eu anomaly. The initial Sr = 0.704 – 0.707 with Rb/Sr = 0.05 – 0.7, are consistent with a Rb-poor crustal source and/or mixed lower crustal or mantle component. These rocks are clearly richer in CaO, $TiO_2$ and $P_2O_5$ than previous granites, whereas $K_2O/Na_2O$ = 0.5 – 0.9. Few Nd data fall within the S-type group with □$Nd_{(310)}$ = -1.7 to -3.5, although mafic dioritic enclaves with □$Nd_{(310)}$ = 1.8 to 0.5 clearly indicate interaction with a basic or intermediate, dioritic, lower crustal melt. The $^{206}Pb/^{204}Pb$ ratios of tonalitic whole rock samples range from 17.99 to 18.85, and the $^{207}Pb/^{204}Pb$ ratios from 15.53 to 15.70 suggest heterogeneous continental crustal source with recycled oceanic crust. The stable isotopic (O and S) ratios, with $\square^{18}O_{(SMOW)}$ = 7.8 – 9.9‰ and $\square^{34}S_{(CDT)}$ from -2.9 to +2.3‰ support melting of a more basic lower crustal protolith. Magmatic intrusion ages vary between 310 – 300 Ma, and these granitic rocks can be compared to I-type and/or Magnetite series.

Indeed, the isotopic signature of both groups of Hercynian granitic rocks of the Western Carpathians shows only small differences. Neither the Visean peraluminous, nor Westphalian – Stephanian metaluminous the granitic suites have typical geochemical characteristics of continent-continent collisional granites. In addition they are not compatible with derivation from metasedimentary source rocks, as it is the common case in the Himalayas! However, these isotopic characteristics are comparable to characteristics of granitic rocks produced during subduction of oceanic crust under the continental margin in a volcanic arc. The geochemical characteristics presented above rather invoke for a heterogeneous crustal source and interaction with lithospheric mantle.

***Conclusion***

Generally we suppose that the Main Meso-Hercynian period was characterized by collisional processes resulting in the formation of crustal-scale nappe structures and generation of collision-related felsic “S-type” – Visean granite magmatism. An appropriate source for these granite melts can be common greywackes at lower crustal conditions, with a significant contribution from amphibolitic/eclogitic rocks. However, often observed ocellar textures call for partial melting and mixing of two crustally derived magmas – one from supracrustal metasediments; another from lower crustal metaigneous rocks. In fact, the participation of common AFC processes cannot be excluded. A Neo-Hercynian stage is associated with the collapse of the collisionally thickened crust. The final collisional shortening was followed by gravitational instability of the thickened lithosphere, which resulted in the process of lithosphere thinning (lithospheric delamination, detachment of lithospheric root from the light continental lithosphere, or slab breakoff). This period was characterized by a shift from compressional towards extensional tectonics. As a result of the breakoff, upwelling of the asthenosphere, and thermal perturbation leads to melting of the lithospheric mantle and subsequent formation of Westphalian – Stephanian “I-type” granites at the base of the crust. A source represented by recycled amphibolitic crust or enriched mantle 2 (EM2) with a minor contribution from felsic metaigneous and dioritic rocks is inferred.

**References**

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**Fig. 1** Typical fabric of the Visean (S-type) granitic rock

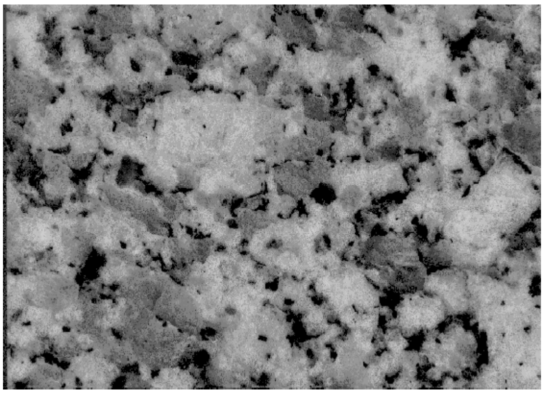

**Fig.2** Typical fabric of the Westphalian - Stephanian (I-type) granitic rocks