The Story of One Pluton - The Veľká Fatra Mts. (Western Carpathians)

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Alike the Pyrenees, Alps or Himalayas, the Carpathian mountain chain is a typical Alpine collisional fold belt. Their pre-Mesozoic rocks complexes however belong to the Hercynian basement within the Alpine-Carpathian orogenic belt. During the Alpine tectonism, the Carpathian part of the Hercynian belt has been disrupted and sliced into blocks, which were incorporated to the Alpine (nappe and/or terrane) complexes and subsequently uplifted to different degree. This polyorogenic history makes the reconstruction of Hercynian structures rather difficult but provides an excellent exposure of various levels of the Hercynian crust. The Western Carpathians represent a direct eastern continuation of the Eastern Alps. The Pre-Alpine crystalline basement crops out mainly in the Central Western Carpathians (CWC), the heart of the Western Carpathians, consisting of three principal crustal-scale superunits: the Tatricum, Veporicum and Gemericum and several cover-nappe systems of the Fatricum, Hronicum and Silicicum (generally from N to S). In the Tatricum, granite rocks form backbones of the so-called Core Mountains.

The Veľká Fatra Mts. exemplify the core mountain ranges in the Western Carpathians. The crystalline basement, represented by the Ľubochňa granitoid massif, shows stratigraphic and/or local tectonic boundary with the Mesozoic autochthonous or paraautochthonous Šipruň envelope sequence. The Upper Mesozoic nappe structure is represented by the Krížna and Choč nappes. The crystalline complex includes four Hercynian granitoid rock types that comprise a normally zoned pluton. The upper part of the pluton consists of Smrekovica tonalites (ST) with xenoliths and wall rocks of paragneisses and orthogneisses. Other components of the body in a vertical sequence include the Kornietov granodiorites (KGD), the Lipová granites (LG) and youngest Ľubochňa leucogranites (LLG). The LLG were emplaced along tectonic zones into an already partly solidified block of the „pre-existing body" of ST+KGD+LG.

Granitoids of the Veľká Fatra Mts. have peraluminous to metaluminous compositions (ASI = 0,9 ~ 1,4) and represent a low- to medium-potassium calc-alkaline series of magmatic rocks. The Peacock index for the whole Veľká Fatra granitoid series has the value of ALI = 59.5. Chondrite-normalized patterns of REE exhibit either no or slightly negative Eu anomalies and uniform fractionated distribution trends. The Rb/Sr range of 0.16-0.30 for the granodiorites-tonalites, 0.4-0.6 for two-mica granites, and 0.55-0.70 for leucogranites (LLG), can be interpreted as fractional crystallization within the magma chamber. However, all granitoid types have isotopically variable Sr, Nd and O. Initial strontium isotope ratios (I_{Sr} = 0.7057 ~ 0.7065) indicate an inhomogeneous, Rb-depleted lower crustal source. The apparent crustal residence ages, indicated by Nd model ages t_{DM} = 1.2 ~ 1.9 Ga and t_{DM2st} = 1.2 ~ 1.4 Ga respectively, together with $eNd_{(0)}$ = -4.8 ~ -6.4, support the concept of Liew and Hofmann (1988) that the Hercynian Europe comprises mainly recycled Proterozoic components with significant new Paleozoic addition. Moreover, the evident isotopic heterogeneity may partly rsult from contamination of primary magmas by crustal material by an AFC mechanism. There is a fairly large range in $d^{18}O$ values in the Veľka Fatra granite massif, from 8.8 to 11.7‰. The relatively high values indicate predominance of crustal oxygen. Oxygen isotope ratios have a positive correlation with $^{87}Sr/^{86}Sr$, with the lower values of both isotopic systems trending toward values for the amphibolite country rock.

During the main Meso-Hercynian event (360-340 Ma) the crust tectonically thickened in the Western Carpathians. As a consequence of the collision of the upper overheated unit with the lower, cooler one, the thermal relaxation resulted in melting of a vertically-zoned lower crust. The source was formed due to mixing of older products of a volcanic arc (mantle-derived magmas) with crustal metasediments. The source of non-magnetic leucocratic LLG was crustal metasedimentary and/or metaigneous rock only. The Veľká Fatra granitoids may be considered a product of mixing of isotopically distinct sources. Mixing of the sources and mixing within the magma chamber was, however, imperfect. Complete isotope and chemical homogenization within the Veľká Fatra pluton, however, did not take place. The isotopic characteristics (Sr - Nd) of the Veľká Fatra granitoid pluton preclude a crustal origin only.

Thermochronometry from the granitoid pluton shows the following results: U-Pb single-zircon upper discordia age of 356 ± 25Ma (ca. 1000°C); Rb/Sr WR isochrone-age of 342 ± 4.5 Ma (650 ± 25°C); Rb/Sr muscovite - 340 ± 3.5Ma (425 ± 25°C or 550 ± 50°); Ar/Ar + K/Ar muscovite and biotite - 338 ± 1.8Ma (300 ± 25°C). Thermobarometry estimates from metamorphic xenoliths - cordierite-free migmatites - indicate the PT conditions of 700 °C and 7 kbar, while the cordierite-bearing ones reached 600 °C and 4 kbar, documenting nearly isothermal decompression. P-T-t data from the Veľká Fatra Mts. suggest rapid uplift and exhumation during waning stages of the Hercynian collisional orogeny. Within 4 Ma, from 342 Ma (pluton crystallization) to 338 Ma (closure temperature of biotite), granitoid pluton was emplaced from the depth of about 10 - 12 km to 3 - 4 km, indicating the uplift rate of about 2 mm/year, with an average cooling rate of 87 ± 2°C/Ma. Such relatively rapid uplift was most probably facilitated by tectonic shearing and extension during an orogenic collapse of overthickened crust.