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Alpine fluid-assisted recrystallization of Variscan granitoids from the Inner Western Carpathians, Slovakia: Microstructural and mineralogical constraints

CHRISFANEL EURODE KIANGUEBENE - KOUSSINGOUNINA[1], MARTIN ONDREJKA[2], MARIÁN PUTIŠ[1], ONDREJ NEMEC[1] AND PETER RUŽIČKA[1]

[1]Department of Mineralogy, Petrology, and Economic Geology, Faculty of Natural Sciences, Comenius University
[2]Comenius University Bratislava

The Inner Western Carpathians host extensive Variscan granitoid bodies forming part of the pre-Alpine crystalline basement. These granitoids yielded Late Devonian–Early Carboniferous U–Pb zircon and apatite ages (~364–343 Ma), consistent with Variscan magmatism. They are peraluminous, calc-alkaline to high-K calc-alkaline, associated with the magmatic arc and post-collisional settings. Sr–Nd isotope compositions confirm a mixed mantle–crustal source and preserve the original Variscan isotopic signature despite Alpine metamorphic overprint.

During the Late Cretaceous Alpine orogeny, they were overprinted under greenschist-facies conditions (330–500°C, 350–700 MPa), constrained by thermodynamic modelling and supported by Ar–Ar phengite ages of 100–80 Ma.

The studied rocks include leucogranites, granites, granodiorites, and tonalites, together with their mylonitic–ultramylonitic equivalents. Primary magmatic assemblages (quartz, K-feldspar, plagioclase, Ti-rich biotite, muscovite) are locally preserved but display significant microstructural modification due to Alpine deformation. Quartz exhibits undulose extinction and dynamic recrystallization, forming ribbons and polygonal aggregates indicative of strain localization. Feldspars are partially replaced by fine-grained white mica; plagioclase is variably albitized and sericitized, and biotite is commonly altered to chlorite and celadonite-rich muscovite (phengite).

Alpine recrystallization produced secondary assemblages comprising quartz, albite, chlorite, phengite, Ti-poor biotite, sagenitic titanite, Ca-rich garnet, epidote–clinozoisite, tourmaline, calcite, stilpnomelane, and rare chloritoid. Accessory monazite-(Ce) exhibits fluid-mediated retrograde breakdown and replacement by massive coronae of fluorapatite and allanite-(Ce)–clinozoisite. Primary allanite-(Ce) is partly replaced by epidote–clinozoisite.

Microstructures record progressive mylonitization from protomylonite to ultramylonite. These results highlight the role of fluid-assisted recrystallization in controlling microstructural evolution, accessory mineral stability, and element mobility during Alpine reworking of Variscan continental crust.

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