VARISCAN AND ALPINE TECTONIC PROCESSES IN THE EASTERN CARPATHIAN OROGEN: EVIDENCE FROM $^{40}AR/^{39}AR$ MINERAL AGES AND STRUCTURAL ANALYSIS

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Three hornblende and eleven muscovite concentrates from sample collected within basement rocks of various Alpine and pre-Alpine nappes along a E-W section in the Eastern Carpathian orogen have been studied with $^{40}Ar/^{39}Ar$ techniques in order to constrain pre-Alpine and Alpine tectonic processes. The study area comprises in structural upward order the Infra-Bucovinian, Sub-Bucovinian, and Bucovinian nappe complexes. The new $^{40}Ar/^{39}Ar$ mineral ages combined with microfabrics and textural observations suggest that rocks within the Infra-Bucovinian nappe complex exposed within western sectors of the Rodna window were penetratively rejuvenated during Alpine orogeny. A muscovite concentrate (from the Bretila gneiss) yielded a plateau age of 116.1 ± 0.1 Ma that is overprinted by a low grade thermal event at c. 100 Ma. Western sectors of the structurally overlying Sub-Bucovinian nappe complex are non-retrogressed record muscovite plateau ages between 98.1 ± 0.1 Ma and 94.1 ± 0.1 Ma, and hornblende plateau ages of 117.0 ± 0.3 Ma and 266.7 ± 0.6 Ma (the latter close to the basal nappe contact). We interpret these ages to date cooling following the culmination of Alpine metamorphism that partly exceeded c. 500°C. This interpretation is in line with metamorphic mineral assemblages that include new grown garnet with normal prograde chemical zonation within meta-pelites.

The penetratively retrogressed Bretila gneiss of the Infra-Bucovinian nappe complex exposed within the Rusaia structural window (central study area) yielded a hornblende plateau age of 374.5 ± 0.3 Ma, and muscovite plateau ages 270.4 ± 0.2 Ma and 268.1 ± 0.2 Ma where low grade experimental increments display a staircase patterns with ages down to < 200 Ma. The muscovite ages are interpreted to reflect penetrative retrogression associated with ductile shearing, perhaps during phases of low angle, Permian extension.

Sectors of the Sub-Bucovinian and Bucovinian nappe complexes exposed east of the Rusaia/Iacobeni structural culmination display only minor effects of the Alpine metamorphism and pre-Alpine fabrics are well-preserved. Kinematic details of Variscan nappe assembly may therefore be resolved. Muscovite from the low grade metamorphic Tulghes Group sediments and metavolcanics yielded both in the Sub-Bucovinian (307.1 ± 0.2 Ma) and Bucovinian nappe complexes (303.5 ± 0.2 Ma) similar ages that are interpreted to represent muscovite formation ages during Variscan ductile shearing within low-grade metamorphic conditions. Muscovite from a low grade metavolcanic phyllite from the Variscan Pietrosul nappe (beneath the Tulghes Group within the Sub-Bucovinian nappe complex) yielded a 283.2 ± 0.1 Ma age that may record shearing during Early Permian extension as within the Infra-Bucovinian nappe complex of the Rusaia window. Furthermore, a muscovite concentrate from an amphibolite-grade sample of Bretila gneiss within tectonically highest basement levels of the Bucovinian nappe complex yielded a 330.9 ± 0.2 Ma age.

In summary, the new $^{40}Ar/^{39}Ar$ mineral ages suggest the following tectonothermal evolution of eastern segments of the Carpathian orogen: (1) the Bretila Group was metamorphosed during early phases of Variscan orogenesis (hornblende: 374 Ma) and slowly cooled through muscovite argon retention temperatures at c. 330 Ma. (2) Variscan nappe assembly occurred at c. 305 Ma within low grade metamorphic conditions was likely related to continuing extension within the Bucovinian microplate. (3) Localized Early Permian retrogression and shearing within low-grade metamorphic conditions is explained to relate to ongoing extension of the Bucovinian continental microplate, formation of horst and graben structures, and deposition of intramontane molasse sediments. (4) There is a strong gradient of peak P-T conditions of the Alpine metamorphic overprint from W (close to amphibolite facies conditions) and E (c. 300°C) both within Alpine Infra-Bucovinian and Bucovinian nappe complexes. These relationships argue for a ramp origin of these nappes, and cooling after peak metamorphic conditions during nappe emplacement. (5) Final cooling and exhumation of Alpine metamorphic units in the western Rodna mountains was apparently synchronous with formation of a Cenomanian-Late Cretaceous sedimentary basins. In comparison to Alps and Western Carpathians, Alpine tectonic processes (burial, nappe stacking, and subsequent exhumation of previously metamorphosed and buried units) occurred earlier as in Alps and Western Carpathians, and show, therefore, diachroniety during Cretaceous tectonic processes in the Alpine-Carpathian realm.