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Enhanced anatexis as a consequence of mantle-derived magma intrusion in the middle crust: a case study from the Eastern French Massif Central

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The post-collisional stage of orogens corresponds to a dramatic change in mountain belts dynamics. During this period, large volumes of granitic melts are generated in the crust thus impacting its rheology and overall behavior. Evolving from compression/transpression to extension/transtension enhances exhumation of high-grade metamorphic rocks and subsequent decompression crustal melting. However, other processes can trigger anatexis such as heat or fluid fluxes from the mantle and the crust.

The Early Carboniferous nappe stack of the Eastern French Massif Central (EFMC) underwent two successive low-pressure melting events at the end of its evolution, during the Late Carboniferous. They are particularily evident in the southern edge of the Velay Complex, a 100 km-diameter migmatite-granite dome. The M_3 “pre–Velay” event corresponds to water-saturated melting in the amphibolite facies at T $<$ 750 ˚C, P $\geq$ 5 kbar. It is recorded by cordierite-free, stromatic migmatites and was quite long-lasting since available U–Th–Pb monazite ages span from 335 to 310 Ma. At that time, crustal melts mainly remained trapped in the source and few granite plutons were associated with this event. Contrarily, the M_4 “Velay” anatexis occurred under granulite-facies conditions at 760 $<$ T $<$ 850 ˚C and 2 $<$ P $<$ 5 kbar. The M_4 cordierite-bearing migmatites are nebulitic to diatexitic as a consequence of biotite breakdown which led to disruption of the solid framework of melanosomes and enhanced melt extraction. This widespread melting event is synchronous with emplacement of the cordierite-bearing restite-rich S-type Velay granite at ca. 305 Ma. Then, the EFMC records an evolution in melting conditions with a clear heat input at the M_3–M_4 transition.

The EFMC anatectic crust is intruded by widespread, Mg–K–rich biotite–rich diorites locally called “vaugnerites”. These mantle-derived melts emplaced in a partially molten setting, as evidenced by mingling features between vaugnerites and anatectic melts, as well as the presence of hybrid granitoids including a “vaugnerite” component. In situ (LA–ICP–MS) U–Pb zircon and monazite dating of vaugnerites or coeval granites in the Southern Velay area yielded ages mostly indistinguishable within analytical uncertainties, spanning from 307.4 $\pm$ 1.8 to 303.7 $\pm$ 3.1 Ma. Thus, mantle-derived magmas emplaced at ca. 305 Ma which is the very transition from M_3 to M_4.

This striking synchronism between enhanced crustal melting and mantle-derived magmatism suggests that vaugnerites could be the cause of the M_3–M_4 transition. Depending on the volume involved, the emplacement of hot (ca. 1000 ˚C) melts in mid crustal levels would have supplied significant amounts of heat. Vaugnerites could also be the manifestation of a (yet unconstrained) process enhancing the conductive mantle heat flux to the crust. For instance, delamination of a lithospheric mantle root or slab break-off would result in generation of mantle-derived melts as well as increase the heat conduction into the crust. Therefore, the relevant system that must be considered to study late-orogenic periods is not only the crust but the whole lithosphere, taking into account mass/heat transfer from the mantle to the overlying crust.