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Redistribution of heat-producing elements during melting of mafic crust

CARSON KINNEY[1], CHRIS YAKYMCHUK[1], JILLIAN KENDRICK[2] AND MANUEL DUGUET[3]

[1]University of Waterloo
[2]McGill University
[3]Ontario Geological Survey

Presenting Author: ckinney@uwaterloo.ca

The production and transfer of heat in the crust is a fundamental process that plays an integral role in the evolution of Earth's lithosphere. Radiogenic decay is a major source of new heat within the Earth, with >99% of radiogenic heat produced through the decay of K, U, and Th (i.e. heat-producing elements). Heat-producing elements preferentially partition into a few phases during anatexis and therefore are assumed to be enriched in the melt phase. Consequently, most interpretive cross-sections of continental crust include a higher concentration of the heat-producing elements in the upper and middle crust and a complementary depletion in the lower crust. However, this assumption relies mainly from xenoliths which are inherently exotic with little tectonic information. Further, the minerals (along with their metamorphic stability) that sequester heat-producing elements remains unknown and the effects of heat-producing element redistribution during anatexis on metamorphic timescales is abstract.

We integrate field observations, whole-rock compositions, thermodynamic equilibrium and accessory mineral modelling with heat production and heating time modelling to provide insights into the partitioning of heat-producing elements during anatexis of metabasites as well as the effects this has on metamorphic timescales. We use the Kapuskasing Uplift (Canada) as a natural laboratory as it is a tilted Archean crustal section comprised of upper-crustal greenstones, middle-crustal TTGs, and lower-crustal high-grade metabasites. We model six natural metabasite compositions ranging from fertile greenstones to residual amphibolites/mafic granulites. Modelling of heat-producing element redistribution reveals that most of the heat-producing element budget is hosted in apatite, hornblende, K-feldspar, epidote, and melt. The partitioning of heat-producing elements into low-density melt decreases the heat production of the system, however this can be buffered by the persistence of dense minerals that contain high amounts of heat-producing elements. Our modelling suggests that 1) the mantle is an equal to or greater source of heat than heat-producing elements during the anatexis of metabasites; and 2) the lower crust is not depleted in heat-producing elements during anatexis. These results indicate that the "depleted" lower crust is not always so and encourages a change in our current approach to estimating crustal heat-production in the deep crust.