American Mineralogist, Volume 93, pages 7–21, 2008

Element mobility and scale of mass transport in the formation of quartz veins during regional metamorphism of the Waits River Formation, east-central Vermont

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Abstract

Veins and adjacent alteration selvages in the Waits River Formation were investigated to determine whether associated mass transfer was due primarily to large-scale advection or small-scale diffusion. Samples of the vein, selvage, and adjacent wall rock were collected from the earliest and most numerous generation of veins in pelite and carbonate hosts from outcrops in the chlorite and the kyanite zones. Bulk compositions of selvages and unaltered wall rocks were compared using a reference frame defined by a combination of Zr, Ti, REEs, and U. Selvages from both outcrops typically exhibit losses of Si, K, Ba, and Rb relative to unaltered wall rock. Kyanite zone selvages show losses in Mg and Cs in addition. Differences in K, Ba, Rb, Cs, and Mg between the vein-selvage system as a whole and adjacent unaltered wall rock are possibly accounted for by development of micas in veins. The addition of Si and Ca to veins is not balanced by removal of Si and Ca from the selvages. Vein-selvage systems contain more Si than wall rock, with an overall addition of ≈40 mg Si/cm^3 to the chlorite zone and ≈55 mg Si/cm^3 to the kyanite zone. Mass balance of Si at the outcrop scale requires that >90% of the Si in quartz veins was derived externally. Quartz veins studied formed primarily by fluid flow and large-scale advective mass transfer with a relatively minor component of local mass transport by diffusion. The estimated time-integrated fluid flux necessary to produce the observed amount of quartz in veins in an entire outcrop is ≈2–6·10^6 cm^3 fluid/cm^2 rock. Mineral inclusions in garnet and fracturing of garnets adjacent to veins indicate that formation of selvages and veins initiated prior to formation of garnet and continued after the end of garnet growth.

Keywords: Mass transfer, regional metamorphism, veins, fluid flow