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Topology of syntectonic melt-flow networks in the deep crust: Inferences from three-dimensional images of leucosome geometry in migmatites

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ABSTRACT

We have determined the three-dimensional form of leucosome in two migmatites produced by syntectonic anatexis of different protoliths: (1) stromatic migmatite derived from pelite, which comprises sheets of leucosome (quartzofeldspathic layers with Grt) with walls of melanosome (Bt-rich selvages) in mesosome (schistose layers of Bt + Pl + Qtz ± Grt ± Crd) and (2) a migmatitic garnet-amphibolite derived from basalt, which is composed of spindle-shaped leucosomes (Qtz + Pl), spatially associated with peritectic Grt, in melanosome (Hbl + Qtz ± Cpx). Three-dimensional images were generated from two-dimensional representations of spatial data obtained by two methods: (1) serial grinding and (2) high-resolution X-ray computed tomography (HR X-ray CT). Projections of three-dimensional images of stromatic migmatite derived using data from either method show the planar nature of leucosome throughout the sample; melt transport through this rock when it was partially molten could be modeled as flow in parallel conduits. In the image derived from HR X-ray CT data, garnet in leucosome is only rarely in contact with melanosome, which suggests these garnet grains were suspended in melt during flow. Projections of three-dimensional images of the migmatitic garnet-amphibolite do not reveal the full extent of leucosome connectivity, due to the irregular geometry of leucosome. Connectivity in this sample can be shown, however, by virtual slicing of the three-dimensional images perpendicular to the plane of the two-dimensional representations (approximately parallel to the lineation defined by the leucosome), and by using three-dimensional projections of a single leucosome connectivity "tree" constructed by projecting leucosome patches from slice to slice and noting the overlap. Based on leucosome geometry and volume, we estimate effective porosity for flow in this rock to have been 20 vol% at stagnation. Leucosome in the migmatitic garnet-amphibolite occurs in strain shadows around garnet, which are inferred to have been obstacles to flow along linear paths. Blocking of inferred flow channels by garnet contributes to the high degree of path-length tortuosity in this sample (τ = 2–6), which is expressed visually by the complex form of the leucosome in three dimensions. Cross-sectional areas for individual inferred melt flow paths are highly variable (over 2–3 orders of magnitude) and minimum channel radius is changeable (by ~1 order of magnitude), meaning there was large variability along the channels and implying strong local flow divergences. Based on these data, unusually straight and uniform channels would have dominated the mesoscopic melt flux through this rock when it was partially molten.