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Factors affecting heat transfer in natural SiO_2 solids

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ABSTRACT

To determine which factors affect thermal diffusivity (D) of mineral aggregates, we compared accurate measurements of D for five quartzites, two microcrystalline samples (chert and agate), chalcedony, and two partially crystalline opal specimens (of type opal-CT) with single-crystal quartz. Samples were characterized using infrared (IR) spectroscopy, electron microprobe analysis, optical microscopy, and X-ray powder diffractometry (XRD). Using laser flash analysis, we measured D of the quartzites and microcrystalline samples between room temperature and 1000 °C, and D of the opal specimens and chalcedony up to the temperatures where these samples failed (300 and 650 °C, respectively). Data between 20 and 500 °C can be fit by $1/D = AT + B$. Values of A and B for quartzites, microcrystalline samples, opal specimens, and chalcedony are distinct from each other and from those of directionally averaged quartz single-crystals. Lower D at room temperature correlates with inflated B values of polycrystalline samples and results from porosity (all samples), hydration (all samples), grain boundaries (microcrystalline samples and chalcedony), and disorder (opal specimens and chalcedony). Dehydration and pore space reduction alter the temperature derivatives of D; dehydration causes the low A in chalcedony and opal. Above 600 °C, D changes negligibly with temperature and is lower than directionally averaged quartz, suggesting an increase in contact resistance as cracks open during heating. Thermal cracking is greatest in samples with large grain sizes and abundant, fluid-filled pores. The prevalence of cracking in polycrystalline samples suggests that high-temperature laboratory measurements generally underestimate heat transport properties in geologic environments, wherein confining pressures limit thermal expansion.

Keywords: Quartzite, silica, thermal diffusivity, laser flash analysis, porosity, grain size, temperature