Mineral-specific pore-scale characterisation using x-ray microscopy

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Reactive surface area is thought to be an important control on the rates of interfacial processes occurring between minerals and aqueous solutions. Key interfacial processes occurring in natural porous materials, e.g. sandstones, include mineral dissolution and growth and nucleation of solids. In geochemical modeling, the continuum hypothesis is based on the assumption that such system can be represented by a sufficiently large number of representative elemental volumes. There has been recent interest in studying the significance of this assumption to systems in which mineral reactions and groundwater transport are coupled. In this paper, the relationship of pore-scale heterogeneity to the distribution of reactive surface area is assessed. 3-D images obtained using x-ray micro-tomography were used to characterize the distribution of reactive surface area. Nitrogen BET surface areas were one to two orders of magnitude higher than measurements from x-ray micro- tomography. Co-registered images of Berea sandstone from x-ray and energy dispersive spectroscopy imagery suggest that quartz, K-feldspar and most clays could be identified. In Berea sandstone, mineral surface area fraction was poorly correlated to the mineral volumetric fraction. Clay and feldspar minerals exhibited higher surface area fractions than estimated from bulk mineralogy. In contrast, in the Edwards carbonate samples, modal mineral composition correlated with mineral-specific surface area. Berea sandstone revealed a characteristic pore size at which a surface area distribution may be used to quantify heterogeneity. Conversely, the carbonate samples suggested a continuous range of pore sizes across length scales. A comparison between these observations and simulations of pore networks from the literature indicates that statistical descriptions of surface area and pore volume heterogeneity in network modeling studies were largely consistent with our observations. However, the common assumption that surface area and pore volume are uncorrelated has lead to unrealistic estimates of the distribution in the surface area to pore volume ratio. We suggest pore-network models adopt a moderate correlation between these properties based on observations such as those reported here to reduce the implied heterogeneity in the surface area to pore volume ratio.