Petrographic Characterization of Chemical Reactions in Clastic Diagenesis

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Two classes of diagenetic reactions can be identified, based on a constellation of petrographic characteristics. Reaction rate-limited processes (including precipitation of authigenic phases and dissolution of detrital phases) are volumetrically significant and at the microscale show significant evidence of nucleation difficulty and restriction of reaction to highly specialized sites. At larger scales the products of these reactions have spatial distributions that are prominently governed by temperature. Within very broad limits, individual reactions of this type can be described using empirical kinetic rate laws, without reference to other simultaneously occurring reactions. In contrast, transport-limited minerals are typically cements that are volumetrically less significant than the products of reaction-limited reactions and do not exhibit any strong thermal controls on their spatial distribution. Instead, transport-limited minerals reflect local variations in solutes, and thus require the use of kinetic reaction rate laws combined with a description of transport phenomena in order to describe or predict their behavior.

The validity of this petrography-based but phenomenology-descriptive model is tested using a quantitative model Balance that implements kinetic and thermodynamic reactions, advective and diffusive mass-transfer processes, and a dynamic texture model. The model is applied to sediments of the Gulf of Mexico sedimentary basin, for which an extensive database of petrographic and chemical analyses is available. The results show coherent and consistent trends between petrographic observations and simulation predictions, and suggest extensive mass exchanges between shales and adjacent sandstones.