Origin of Quartz Cementation and Implications for the Upper Paleozoic Tight Sandstone Reservoirs, Northern Ordos Basin, China: Evidences from Petrology, Geochemistry and Numerical Modeling

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Abstract

Quartz cement is the most important pore-occluding mineral in the upper Paleozoic tight sandstone reservoirs from moderately to deeply burial (2000~3500 m). Based on detrital petrology, most sandstone lithofacies are medium- to coarse-grained feldspathic litharenites and sublitharenites. Quartz cement mainly occurs as syntaxial overgrowths (2-100 mm thick) around detrital quartz grains and, less commonly, as euhedral, prismatic crystals (5-200 mm in length) within intergranular pores. Two distinct generations of quartz overgrowths were identified based on thin section observations and microthermometric data from fluid inclusions. First-generation inclusions have homogenization temperatures (Th) ranging from 70°C to 110°C with a peak at approximately 95°C that was prior to oil filling the sandstones whereas the second-generation inclusions have Th values between 90°C and 135°C with a peak at 115°C that was synchronous with or slightly postdated oil charging the sandstones. Mass balance calculations indicate burial diagenesis of the upper Paleozoic tight sandstones acts as a geochemically closed system with respect to quartz cementation. The amount of silica derived from pressure solution of quartz grains and feldspar dissolution is sufficient to be the source of quartz cements within tight sandstones. Transport mechanism is predominantly controlled by slow diffusion in the process of quartz precipitation and the silica derived from pressure solution of quartz grains and feldspar dissolution is referred to be re-precipitated in-situ or in adjacent pores. Grain-coating chlorites show a negative correlation with pressure solution abundance and it indicates that quartz cementation is most likely to be inhibited by the presence of grain coating clays. Numerical modeling results reveal that quartz cementation is acted as a kinetically controlled process and is greatly influenced by temperature, pressure and fluid compositions. In addition, kinetic modeling related to the internal-sourced quartz cementation illustrates that the slowest rate-limiting step in the overall quartz cementation process is referred to be quartz precipitation rate. Implications of quartz cements for tight sandstone reservoirs are: (1) the overall porosity would not decrease significantly as pore types were changed from primary macropores to secondary pores and micropores by the precipitation of authigenic quartz due to pressure solution and feldspar dissolution within the sandstones; (2) the occurrence of quartz cements would significantly reduce the permeability and enhance reservoir heterogeneity especially when they are associated with kaolinite and hair-like illite minerals.

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