Silica Diagenesis in the Devonian Woodford Shale (Central Basin Platform, West Texas) and Cretaceous Mowry Shale (Powder River Basin, Wyoming): Controls on Reservoir Quality

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Summary

Silica type in certain siliceous mudrock reservoirs of disparate ages is revealed by new imaging techniques to be dominated by silica nanospheres. The timing and morphology of such siliceous frameworks are discussed along with their implications for porosity preservation, mechanical properties, and possible controls on producible hydrocarbon fluid phase.

Introduction

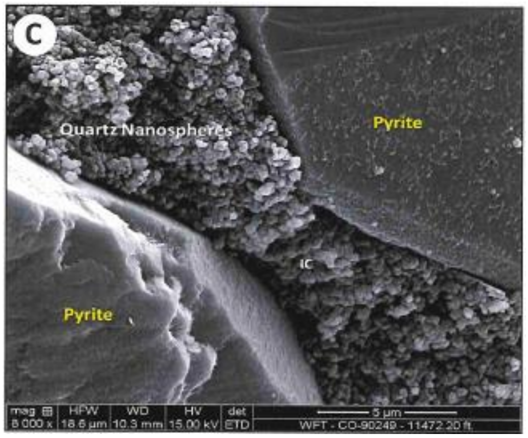
The Devonian Woodford Shale and Cretaceous Mowry Shale consist of relatively deep (below storm wave base) intracratonic basin deposits commonly referred to as "shales" because of their dark gray to nearly black color, very fine grained nature, pelagic fossils such as radiolarians, and common amorphous marine kerogen. These shales typically contain less than 30% detrital clay by weight and more than 50% quartz (locally up to 80%). The quartz is a mix of biogenic grains (mainly radiolarians) and authigenic silica along with some detrital quartz silt of extrabasinal origin. Recent advances in integrated imaging techniques (SEM, Cathodoluminesence, x-ray mapping of mineralogy) allow investigation of the morphology and nature of the quartz at the very small scale necessary to resolve such information.

Theory and/or Methods

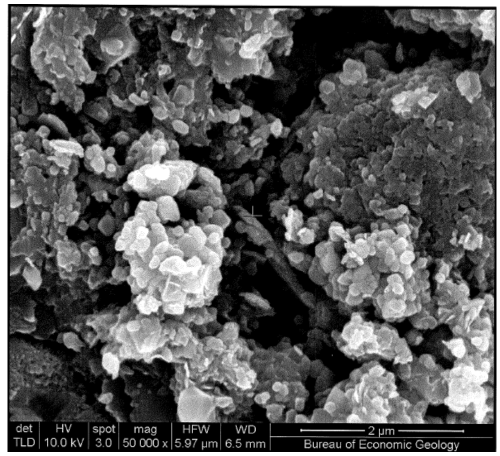
Core samples of these two basin-centered siliceous shale reservoirs were characterized with a variety of techniques including thin-section petrography, crushed rock (GRI) analyses (cf. Luffel and Guidry, 1992), X-ray diffraction, Rock-Eval analyses and/or vitrinite reflectance. Additional, image-based data were collected using field-emission scanning electron microscopy (FE-SEM) using both secondary and backscatter imagery, cathodoluminescence, and X-ray elemental mapping. SEM imaging was performed on freshly broken surfaces, mechanically polished thin sections (C-coated), and argon-ion-milled surfaces (Ir-coated). Woodford samples came from one cored well in the late oil window (0.92% Vitrinite Reflectance Equivalent) on the Central Basin Platform in the Permian Basin of West Texas (Drake et al., 2017). Mowry samples came from 5 cored wells representing a range of thermal maturity (0.72 to 1.15% R_o) (Longman et al., in press). Mercury injection cap pressure data from most Mowry samples show a dominant pore throat size between 7 and 11 nm.

Examples

SEM images of broken surfaces in both Woodford (Fig. 1A) and Mowry (Fig. 1B) samples show abundant quartz nanospheres in the matrix



A



B

Fig. 1. SEM images of broken surfaces from Woodford (A) and Mowry (B) showing silica nanospheres of less than 0.5 micron diameter. From Longman et al., in press.

Cathodoluminescence combined with SEM images on polished surfaces demonstrates the nature of the authigenic silica—similar to biogenic particles but distinct from detrital quartz (Milliken and Olson, 2017).

A search for ancient analogs of siliceous reservoir rocks with silica nanospheres similar to those seen in the Woodford and Mowry led to papers published on the late Precambrian to early Cambrian Athel Silicilyte (e.g. Al Rajaibi, 2011; Al Rajaibi et al., 2015). The age of this possible analog suggests that the source and mechanism for silica dissolution and reprecipitation may not be biogenic particles such as radiolarians but rather microbial activity at or near the sediment/water interface (radiolarians did not exist in the early Cambrian). The source of the common authigenic silica found in the Mowry and Woodford remains open to debate.

Where the silicification process ceased prior to complete silica cementation, the early silica nanospheres are associated with up to 15% interparticle microporosity. This gives the Woodford and Mowry good potential reservoir quality. The authigenic silica nanospheres provide a rigid framework that also enhances the mechanical properties of these siliceous mudrocks to a degree much greater than would the presence of the detrital quartz particles alone. The small particle size of both the silica nanospheres and the clay component of the matrix, at least in the Mowry, may also control the pore throat size distribution, which in turn may control the both the matrix permeability and the size of producible hydrocarbon molecules.

Conclusions

Quartz in the Woodford Shale and Mowry Shale includes a mix of biogenic grains (mainly radiolarians) and authigenic silica along with some detrital quartz silt. Authigenic quartz in these units commonly takes the form of weakly luminescent silica nanospheres, a morphological form of microquartz that is less than a half micron in diameter. Silica nanospheres are associated with up to 15% intercrystalline microporosity. This gives the Woodford and Mowry good potential reservoir quality. The abundance and framework nature of the silica nanospheres also enhance mechanical properties much more than would detrital quartz alone.

Acknowledgements

The Mowry samples examined by Milliken and Olson (2017) were kindly contributed along with supplementary data (e.g., Rock-Eval, Ro, XRD, and GRI core analyses) by three anonymous companies.

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