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Reservoir Characterization of Bioturbated Tight Gas Reservoirs

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Summary

A thorough analysis of dolomitized burrows, and their influence on reservoir quality, was completed on the Upper Devonian Wabamun Group in the Pine Creek gas field of central Alberta, Canada. Using spot-permeametry measurements, the dolomitized burrows are found to have permeabilities ranging between 1 and 350 millidarcies (mD). Conversely, the lime mudstone-wackestone matrix that surrounds the burrows commonly has permeabilities of less than 1mD. Numerical modeling revealed that bulk reservoir permeability is best estimated using the harmonic and geometric mean in scenarios where burrow-associated dolomite is minimal. On the other hand, the arithmetic mean best estimates bulk reservoir permeability in scenarios where burrow-associated dolomite is moderate to high. Collectively, the Wabamun Group represents a reservoir where much of the natural gas that is stored within the matrix is produced through the higher permeable burrows. This burrow-matrix association is herein referred to as Ichnofossil Hosted Tight Gas (IHG).

Introduction

The Pine Creek gas field (Townships 56-58 and Ranges 19-20 west of the fourth meridian) is located in central Alberta, Canada, roughly 110 km east of the Canadian Rocky Mountains. Occurring throughout most of western Canada, the Upper Devonian (Famennian) Wabamun Group is stratigraphically equivalent to the outcropping Palliser Formation in British Columbia and Alberta. Within the study area, bioturbated mudstones-wackestones and peloidal grainstones-packstones have been identified by Fong et al. (2001) and Green and Mountjoy (2005) as the primary reservoir facies. Further to this point, the bioturbated mudstones-wackestone form the primary reservoir intervals (Baniak et al., 2013) and therefore represents the primary focus for this study.

Methods

Slabbed core samples recovered from the Pine Creek gas field were used to identify the sedimentological, ichnological, and petrophysical properties (i.e., permeability) of the bioturbated fabrics. Following core analysis, two- and three-dimensional imagining techniques (micro-CT and helical-CT) were used to visualize the dimensions and orientations of the burrow fabrics. Permeability measurements were obtained using spot-permeametry measurements. Following this, numerical flow simulations were completed to better understand single-phase fluid in bioturbated media.

Results

The dolomitized burrows, although difficult to discriminate within core, are most comparable to examples of *Thalassinoides* and *Palaeophycus* based on morphology and orientation. Both micro-CT and helical-CT imaging revealed that the dolomitized burrows are highly complex spatially at the centimeter scale. In this context, horizontal burrow connectivity is typically more common than vertical burrow connectivity, except in the most pervasively bioturbated sections. Numerical models showed that the volume of bioturbation and magnitude of permeability difference between the burrows and matrix influence the bulk reservoir permeability. Within dual-porosity numerical models (i.e., contrast in permeability between the matrix and burrows is less than two orders of magnitude), bulk permeability was best projected using the geometric mean at low to moderate volumes of burrow dolomite (25-65%) and arithmetic mean at high volumes of burrow dolomite (65-80%). Within dual-permeability numerical models (i.e., contrast in permeability between the matrix and burrows is greater than three orders of magnitude), bulk reservoir permeability is best estimated using the geometric mean at low to moderate volumes of burrow dolomite (10-50%) and arithmetic mean at moderate to high volumes of burrow dolomite (50-80%).

Conclusions

This case study presents another example of a hydrocarbon reservoir that is profoundly impacted by bioturbation (see Gingras et al., 2012 for the most recent detailed review of biogenic permeability). Specifically to the Wabamun Group in the Pine Creek gas field, dolomitized burrows positively influence reservoir quality by enhancing bulk reservoir permeability. Perhaps more importantly, the dolomitized burrows will also act as a preferential flow pathway for movement of natural gas from the surrounding matrix. As a result, Ichnofossil Hosted Tight Gas (IHG) (Baniak et al., 2013) is a new term proposed to demarcate tight gas reservoirs, such as the Wabamun Group, where natural gas is produced predominately from the low-permeability matrix via burrows.

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