

The Role of Bioturbation in Low Permeability Gas Charged Reservoirs

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In the past, trace fossil research in hydrocarbon reservoir rocks was almost always confined to exploration geology, however, recent research shows that ichnology has significant applications in production geology. Permeability enhancement in bioturbated media has been recognized in five interrelated scenarios: 1) Surface-constrained textural heterogeneities; 2) Non-constrained textural heterogeneities; 3) Weakly defined textural heterogeneities; 4) Diagenetic textural heterogeneities; and 5) Cryptic bioturbation. Each of these flow-media types is further examined for its impact on flow tortuosity and overall reservoir heterogeneity. This is done by numerically modeling capillary transport in conjunction with detailed models of pore-throat distribution.

Our data demonstrate that substrate-controlled ichnofossil assemblages can enhance the permeability and vertical transmissivity of a low-permeability matrix. Permeability enhancement develops when burrows into a firm ground are filled with coarser sediment. If the burrow-fill lithology contrasts with the encapsulating firm-ground substrate, anisotropic porosity and permeability are developed: this can influence reserve calculations. If the burrows have enhanced permeability, reserve calculations may be too low. These effects are more dramatic in gas-prone reservoirs where slight grain size variations significantly influence the transmissivity of gas. Likewise, if the burrows have lowered permeability, the reserve calculations may be too high. Understanding the flow dynamics of the anisotropic permeability provides a potentially powerful reservoir development tool. The implications of such understanding are far reaching, particularly pertaining to calculations of reserves and deliverability.

Of the aforementioned categories, discretely packaged and weakly defined heterogeneities, and cryptic bioturbation represent primary fabrics generated by burrowing infauna. In contrast, diagenetic fabrics are produced by chemical alteration associated with primary burrow fabrics, or are enhanced by compositional variations that enhance diagenetic processes.

Considering that burrow-associated enhanced permeability is evident in the rock record, it is surprising that little consideration is afforded it in the geological literature. Perhaps one reason is

the matter of scale. The permeability of geological media is a bulk character. Thus, the three-dimensional arrangement of sediment heterogeneity must be understood if flow behavior is to be predicted. Unfortunately, the bulk characteristics of sediment dominated by small-scale heterogeneities are difficult to both assess and numerically model. Overlooking the potential impact of these structures can lead to inaccurate assessments of the flow characteristics of a sedimentary rock, and misidentification or non-recognition of permeability streaks in a hydrocarbon reservoir. Again, this is especially important in gas-prone reservoirs where slight variations in permeability can have dramatic effects on storativity, reserve calculations and deliverability. For example, in the Trinidad TP 50 Sequence (Cassia 30 Sand) over 1 TCF has been produced (the average is about 200 bcf per well) from what was considered to be a poor-quality bioturbated facies.

A developing play in both Alberta and Saskatchewan revolves around Upper Cretaceous low permeability gas-prone non-associated reservoirs. These fields produce from relatively shallow zones (less than 1000 metres) in thin bedded or muddy units. Such zones can be laterally extensive and continuous and in most cases are interbedded with (or *are*) the source rock. In this example the gas is biogenic in origin and is thought to have been generated recently. Therefore the gas does not have to migrate into the reservoir but will accumulate in any internal zones that show permeability and porosity enhancement such as burrow systems. Such low permeability gas-prone reservoirs have also been examined in the United States including the Mississippian Barnett Shale in the Fort Worth Basin in Texas and the Woodford Shale in the Arkoma Basin in Oklahoma

Just as important is the recognition that hydrocarbon production from bioturbated rock is generally more complex than producing from laminated media. This is because flow paths through burrow-related flow conduits are comparatively tortuous. Further complicating geological and reservoir models this tortuous, heterogeneous media presents a notable complication for reservoir development. Burrows may provide flow conduits that interact extensively with the surrounding matrix; their tortuous nature implies that dead ends and cut-offs may be common. An understanding of how burrow-associated heterogeneities control fluid flow within sedimentary units is necessary if production from bioturbated reservoirs is to be optimized.