



Stratigraphy or facies: which is the more important building block in fine grained reservoirs

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Summary

As the amount of data available on unconventional fine grained reservoirs in North America continues to increase, it clear that one key to successfully developing an asset is drilling multi-lateral wells that remain in a pre-defined sweet spot along their entire length. Typically, sweet spots are assigned to an informal stratigraphic unit within the parent formation, thereby implying that provided the well-bore remains between the upper and lower limits of this stratigraphic unit, it will be in the sweet spot.

While getting the landing zone in the right stratigraphic interval is without doubt important, the reservoir quality and how a lateral well performs will largely be dependent on mineralogy and TOC, not stratigraphy. Although a fine grained reservoir may look lithologically homogenous within a stratigraphic sweet spot, particularly if cuttings are the only medium available, mineral facies vary both vertically and laterally within a stratigraphically defined sweet spot. Using the mineral facies to land a well is negated by their non-unique and repetitive character in a vertical sense.

In order to land and complete a lateral well effectively, both stratigraphic and facies information are required, i.e. both stratigraphy and facies are important when dealing with fine grained reservoirs.

Introduction

Successfully completing and producing from fine grained unconventional reservoirs typically involves multi-lateral drilling campaigns and fracking, which require large capital investments. The biggest challenge to successfully (=profitably) developing these assets is efficiency and effectiveness at all stages in development. Numerous studies have demonstrated that one key efficiency factor is the need to land lateral wells in an optimum zone and ensure lateral well-bores remain in this zone (or as they have become termed, sweet spots) for as much of its length as possible (Baihy et al., 2010, Schmidt et al., 2010, Sena et al., 2011, Yang et al., 2013).

What actually constitutes a sweet spot in terms of mineralogy, lithology, TOC etc., is not the focus of this paper, rather it is consideration of whether a sweet spot is best thought of as a stratigraphic (litho- or chrono-) interval or if it is a distinctive facies. In the literature, the implication is that sweet spots are stratigraphic intervals, for example: SQ1 and SQ2 in Marcellus (Yang et al., 2013), Chemo Lower Eagleford (Schmidt et al., 2010), “rabbit ears” interval at the base of the Upper Haynesville (Lui et al., 2014),

Niobrara “B” Bench etc. However, when sweet spots and landing zones are described, they are described in terms of lithology, mineralogy and TOC contents (Sahoo et al., 2013, Pierce and Parker, 2015, Zou et al., 2015), which relate to rock mechanical properties as well as porosity and permeability. In facies-driven concept of a sweet spot, the reservoir quality will vary in a predictable manner that is related to facies changes along a well-bore.

The use of stratigraphic sweet-spots for landing wells and subsequently geosteering, despite the apparent importance of facies, probably stems from the fact that historically, the ability to recognize a stratigraphic sweet-spot is achievable based on data acquired while drilling (Schmidt et al., 2010, Ratcliffe et al., 2012, Pierce and Parker, 2015). Here, we advocate a combined stratigraphic and mineral facies approach to increase efficiency in drilling multi-lateral wells.

Methodology

Recognizing stratigraphic sweet spots in fine grained unconventional reservoirs while drilling is generally achieved using a combination of biostratigraphy, lithostratigraphy (often wireline log based) and chemostratigraphy, or a combination of techniques (Schmidt et al., 2010). These data can all be acquired while drilling, from downhole tools or cuttings samples, thereby enabling wells to be landed and subsequently geosteered to maximize time spent in the sweet spot. Quantitatively defining facies from cuttings samples while drilling is more problematic. The facies defined here are mineralogical, based on data obtained from cuttings samples while drilling. Mineralogy data (quartz, feldspar, illite-smectite, kaolinite, chlorite, carbonate and pyrite), together with TOC data, are acquired using a portable Fourier transform infrared attenuated total reflectance (FTIR-ATR) instrument. This instrument provides the mineralogy and TOC data by direct cuttings analysis, with a preparation and analytical time of approximately 5 minutes. The quick turnaround time and the portable nature of the FTIR instruments enables data collection at well-site while drilling.

The mineral facies are determined by their position on a Quartz+Feldspar vs. Total Clay vs. Total Carbonate ternary diagram. Each sample is assigned to a unique mineral facies (Figure 1) allowing the mineral facies to be translated to the well-bore (in TVD or MD) (Figure 1).

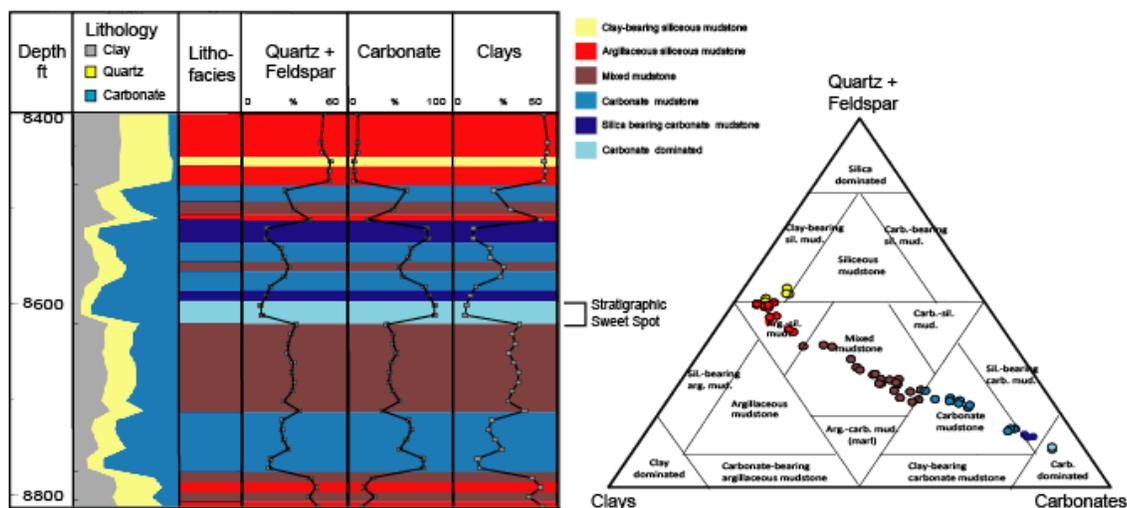


Figure 1. Mineral data acquired from cuttings in the Niobrara formation are used to quantitatively define mineral facies for each sample. The stratigraphic sweet spot appears in the vertical well to be composed of homogenous Carbonate Dominated facies. Mineral facies from a lateral well are displayed in Figure 2.

Examples

The stratigraphic landing zone in Figure 1 is defined using chemostratigraphy; elemental data gathered by X-ray Fluorescence are used to define a chemostratigraphic framework for the Niobrara Formation and a sweet spot identified pre-drill. The elemental data are then used to land the build section and determine which parts of the lateral well-bores remain in the sweet spot. Figure 2 displays a lateral well that remains in the stratigraphically defined sweet spot along its entire length. However, when the mineral facies are plotted along the well-bore, it is apparent that there are two dominant facies present; an almost pure limestone (Carbonate Dominated facies), but with significant lengths of the well-bore penetrating a more clay- and quartz-rich carbonate (Carbonate Mudstone Facies). The two facies do not appear to be stratigraphically constrained, with the Carbonate Mudstone Facies being present at the base of the stratigraphic sweet spot between 9800-10600ftMD, the top of the sweet spot between 11600-11900ftMD and in the middle of the sweet spot at the toe of the well. This implies that either there is a significant dip change, or even minor faulting, or the amount of clay and quartz varies laterally within the sweet spot. With both scenarios plausible, this in turn will affect the reservoir quality even within an apparently homogenous stratigraphic interval.

Additional examples will be presented to demonstrate how laterally and vertically variable the mineral facies are within several key shale plays of North America.

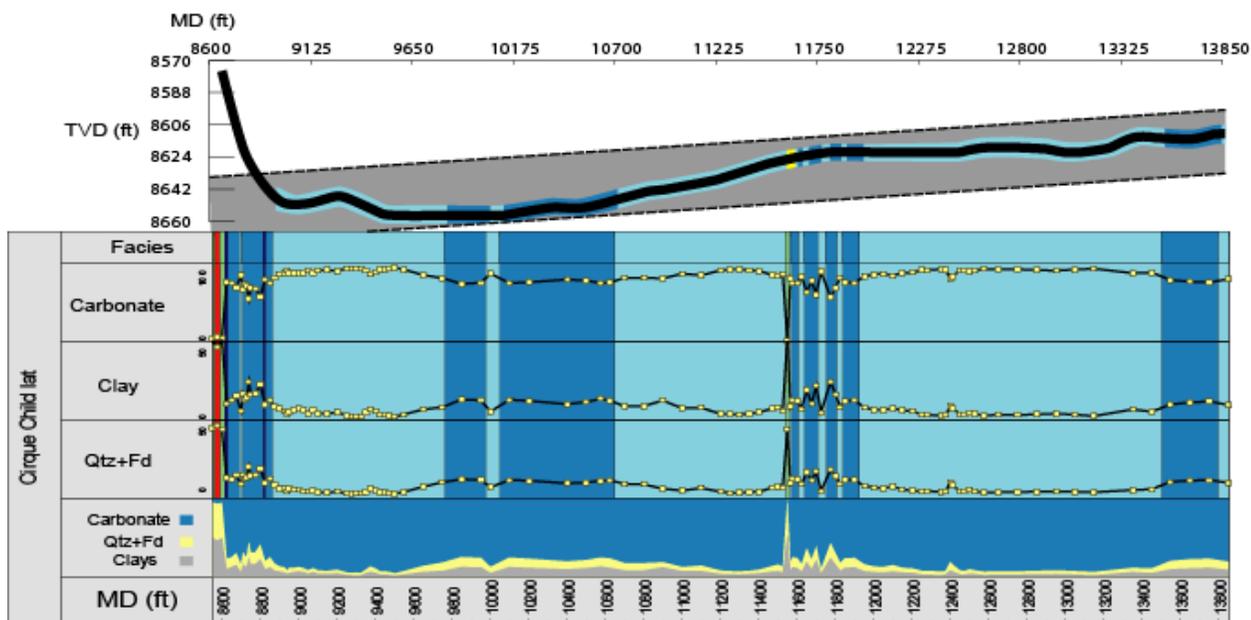


Figure 2. Mineral facies defined using FTIR-ATR data along a lateral well in Niobrara formation. The facies defined from the cuttings in the lower panel are placed along the length of the well-bore in the upper panel. The grey box represents the stratigraphically defined sweet spot, with the dashed lines being the upper and lower boundary of that zone. See Figure 1 for mineral facies key

Conclusions

Mineralogy and TOC are two key controls on how a fine grained reservoir will perform. In consequence, the ability to define mineral facies from cuttings samples while drilling is one key to improving efficiency in drilling and completing multi-lateral wells. However, mineral facies are not stratigraphically diagnostic, with facies being repeated throughout formations and varying laterally within a play. Therefore, both stratigraphy

and facies data are required and are of equal importance to ensure effective and efficient multi-lateral drilling campaigns in fine grained reservoirs.

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