Mudstones and siltstones: geologically under-utilised sediments in bitumen pay descriptions, with examples from the McMurray and Clearwater Formations

Russell, P.W. Stancliffe, Grant Sanden, Yannai Segal, and Martin Trobec
Enersoft

Summary

Muds and silts are commonly present in bitumen pay zones of the Clearwater and McMurray Formations. New technological advances in hyperspectral imaging, optical cameras and XRF acquisition make it possible to study these sediments in significantly greater detail than previously. Results have applications in developing geological and engineering models, understanding the depositional environment, and the strength of cap rock, along with the aerial extent of mud deposition.

Introduction

Fine-grained sediment studies have always played second fiddle to sandstone studies due to a number of reasons. Firstly, they do not contain the primary porosity from which bitumen can be cheaply produced. Also, because of the small grain size, it has traditionally been difficult and expensive to image the particles, determine the porosity and resolve which minerals are present in the samples. This has resulted in small expensive datasets being collected and their properties being upscaled in geological and engineering models with potential inaccurate results.

Methodology

Recent technical advances and integration of Red Green Blue imaging, hyperspectral data collection and XRF technology has opened the possibility of analysing fine-grained sediments quickly and significantly cheaper than traditional XRD, thin sections and SEM studies. Automated high-resolution cameras can now resolve grains down to 15 microns in size, locate bitumen in siltstones and collect roundness datasets. Hyperspectral imaging can picture the distribution of clay types, organic particles and metal minerals on the core surface. For detailed clay types and their distribution, XRF technology is used, though this has now been automated and includes helium head immersion so that sodium clays can be resolved. The datasets recorded are huge, on the order of 15 Gigabytes for a 25m core, but ‘big data’ technology can now manipulate and interrogate the information quickly and easily.

Data obtained

The key new dataset of use in mud and silt studies is the high resolution images (Figures 1-3) which, on a standard scan, can resolve grains down to 25 microns (below the 64 micron size limit of sand grains). With a more powerful lens and significant processing the resolution increases to circa 2 microns which is at the 2-4 micron boundary of mud/silt differentiation. The particle size distribution can be calculated for silt as well as sand along with how it changes within the bed.

With standard imaging it is now possible to image bedding features and how the upper and lower bed contacts are developed. The clay distribution over the core can be resolved and further processing can automatically provide the thickness and area of mud in the core. Small trace fossils can now be resolved without using thin section techniques and faults/fractures examined. The presence of bitumen can be electronically 'removed' to show sedimentary structures and detailed structures within trace fossils.

Mud and silt volumes in the caprock sediments can also now be measured and the variability of the sediments both vertically and laterally determined. Furthermore, with the integration of geophysical log data, the Poisson's ratio and Young's moduli can be determined. Also, the exact sediments tested in a minifrac can now be imaged to determine if they really are representative of the cap rock entirety.

Future developments

The complete electronic dataset can now be further processed to create automatic reservoir quality matrices. Some companies consider 1.5m thick muds a barrier to steam and these can now be quickly located. Should this thickness need to be changed at a later date, it is simple and quick to repeat the exercise using a different cut off.

Mud breccia are often a common component of the McMurray and Clearwater Fm pay. Sometimes companies include it in the pay thickness, though this seems not to be based on a standard scientific concept. With image processing the types of breccia can be discriminated (rounded, angular, laminated, blocky) and the stacking patterns (touching, en echelon, floating) shown along with the size ranges of the clasts. Furthermore, the percentage of mud breccia clast in relation to sand can be calculated and cut offs for pay vs non pay determined more accurately. The grain size of the surrounding sand grains can also be resolved along with the potential presence of increased clays. This could be used to determine if the breccia is acting as a baffle and potentially how much of one. The results can be then added to the geostatistical models commonly used to provide inputs into the production models.

The drilling of post steam and solvent core is fast becoming part of the drilling program in mature fields. With multispectral imaging and XRF scanning it is possible to determine the alterations of clays and zones which have not been accessed by the production technology used.

A further area of potential is the recognition of muds and silts which have been flocculated prior to deposition. This could assist in the determination of the environment of deposition (fluvial vs brackish) and the aerial extent of the mud laminae. Integration with bitumen geochemistry datasets could further resolve which beds of muds and silts are barriers and which are not.

Conclusions

Overall the fusion of high resolution imaging, hyperspectral scanning and XFR data taken over a core can now provide information unavailable previously for mud and silt bed interpretation. Further work will assist with mud breccia interpretation and the capacity of the cap rock to contain the production process used.

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Figure 1: A high resolution RGB image of a dipping mud laminae which contains trace fossils filled with bitumen stained sands, a small fault, a sharp base and a more defuse top with a gradual change in mud content. The scale on the left is in centimeters.

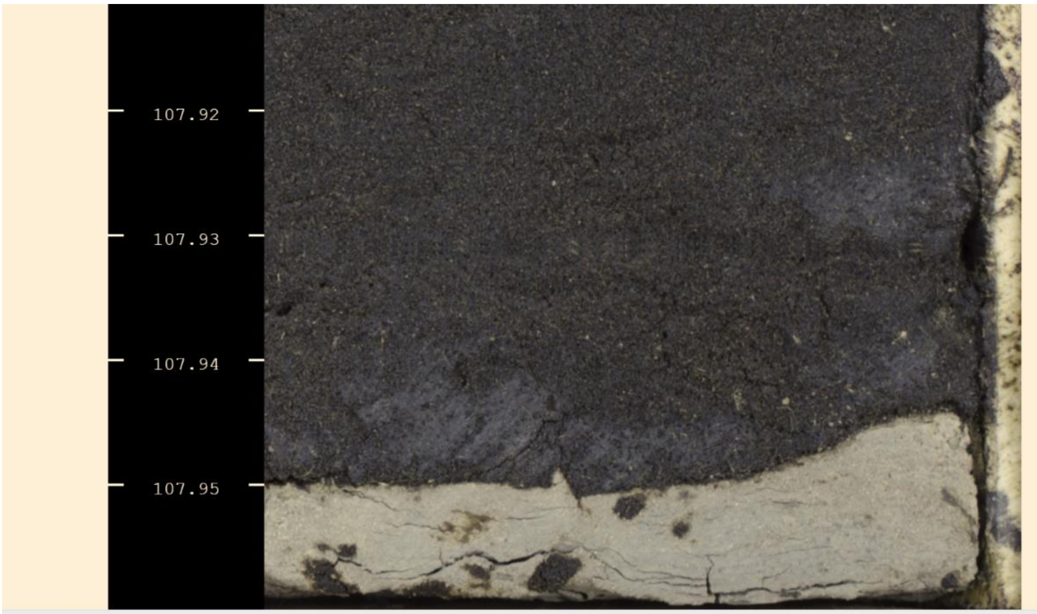

Figure 2: The mud laminae at the base of the bitumen saturated sands has scattered trace fossils, sharp top and bottom contacts, and internal silt and sand grains which are laminated.

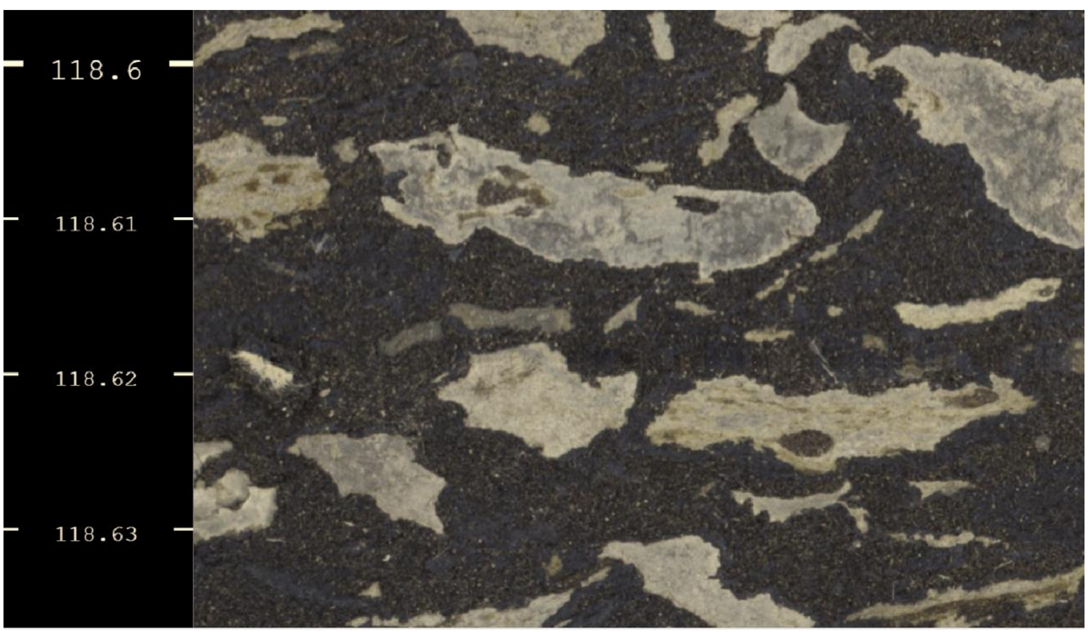

Figure 3: An image of mud breccia in a fine-grained bitumen-saturated sand. Note that the clasts are not touching, angular, partly bioturbated, and appear coarsely bedded.