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Producing Oil Sands Thin Sections for Reservoir Characterization

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Summary

Reservoir quality of oil sands can be observed directly in thin sections. Direct observation of important geological factors that control reservoir quality include: texture, grain size and sorting; grain orientation and packing; and any cementation if present. Additional observations include silts and clays, clay infilling of pore spaces, and size and shape of voids. Thin sections provide a means of detecting secondary physical/chemical processes that have altered the primary depositional texture which affects the final geometry of the pore structure. Geologic factors are known to directly impact reservoir porosity and permeability.

As part of a large 2D to 3D case study, thin section analysis was carried out on the pore to grain scale of Upper McMurray Member oil sands. Samples used were obtained from a non-industry outcrop and non-industry cores with no industry funding in order to ensure fair practice. Oil sands, as observed under the microscope, exhibit a 2D fabric which is the result of the components including: primary grains; fines such as silt and clay; bitumen; and voids along with their spatial relationship. Going from 2D to 3D, the fit of oil sands fabric determines flow through the reservoir during recovery.

The routine method of producing thin sections in unconsolidated material was employed for the oil sands samples with few modifications applied in order to identify an approach that would least alter the bitumen contained in the samples. Due to the unconsolidated nature of oil sands reservoirs, application of conventional thin section methods must be modified and tailored for the unique nature of the oil sands. This short methods paper discusses producing thin sections from non-frozen samples and common artefacts which can occur during production.

Introduction

The Canadian oil sands are loose sand or unconsolidated to partially consolidated sandstone, which is loose and very friable. During in situ production, oil sands will exhibit the characteristics of sand with the recovery of bitumen and changes in compaction. Oil sands, as observed under the microscope, exhibit a fabric. Kubiena (1938) first introduced the concept of fabric to soil, an unconsolidated material, as "the arrangement of constituents of the soil in relation to each other" which was further developed by Brewer and Sleeman (1960) as the relative distribution of 'skeleton grains' and 'plasma' although these terms are associated with soil genesis. According to Stoops (2003), who took a more geological perspective, important elements of fabric are spatial distribution, orientation, size, sorting and shape. Oil sands fabric incorporates and expands this concept by viewing the constituents as reservoir material without inferring genesis. When viewed through a microscope, setting a typical size limit of 10 µm, resulting constituents include: coarse components or primary grains; fines such as silt and clay; bitumen; and voids along with the spatial relationship to each other (Bell, 2014). Determination of oil sands fabric is an important tool in determining reservoir characteristics and quality.

Material and Method

Undisturbed oil sands samples from the Upper McMurray Member were collected from the Hangingstone Section near Fort McMurray, Canada which is a well-documented estuarine tidal depositional environment (Hein et al., 2001). The stratigraphy of the study area is the Wabiskaw Member, overlying the Upper McMurray Member, which in turn overlies the Middle McMurray Member. Two groupings of select samples were taken from the Upper McMurray Member, one from the argillaceous sands and the other from the bioturbated areas. Individual samples were collected in Teflon tubes ϕ=81 and h=150 mm to ensure sample integrity and to maintain an undisturbed nature.

Mammoth-sized petrographic thin sections (7 x 12 cm) were prepared from the oil sands samples refer to figure 1. The routine method for producing thin sections from unconsolidated or loosely consolidated material was employed (Fitzpatrick, 1983; Jongerius and Heintzberger, 1975). Dehydration was carried out in an oven at 30°C overnight. Alternatively and time permitting, samples could be air dried to limit time spent in an oven, although similar studies indicate that either drying techniques should yield the same results. Three different modifications from standard procedures were applied to the epoxy stage, in order to identify causes that least alter the bitumen contained in the oil sand samples. As is commonly accepted when working with unconsolidated or loosely consolidated non-rock samples, epoxy diluents should always be added to epoxy resin in order to lower viscosity for better penetration into the pores. In procedures 1 and 2, an epoxy diluent was therefore used. As a first or tentative attempt in procedure 1, polyester resin and a catalyst were used as glue to bond the samples to the slides. This was the first choice as a more exothermic reaction of the epoxy resin polymerization could induce dissolution of the oil between the grains on the contact surface when mounting sample blocks to the slides. Epoxy resin and hardener without epoxy diluent have been used as glue in procedures 2 and 3. In procedure 3, epoxy diluent was not used even in the impregnation stage. The use of polyester resin was excluded for the impregnation stage because it requires resin to be mixed with acetone which would alter the bitumen. Samples could be put in shrink bags which would better control the epoxy while impregnating. Dye was not used in the 3 procedures, as it can mask the fabric of the fine material. During the sawing, leveling, lapping and polishing stages, water was used as coolant instead of the usually employed IsoparTM to avoid melting of bitumen.

Results and Discussion

Photomicrographs of thin sections with the three modifications are presented in Figure 2. Details are pointed out regarding specific artefacts from all three procedures. In procedure 1 (Figure 2A), the bitumen is melted and expanded around the borders of the primary grains. This is clearly a consequence of the polyester resin used in the mounting stage which produced a chemical dissolution of bitumen while adhering the sample to the slide. In procedure 2 (Figure 2B), the yellow background between the grains indicate a slight dissolution of bitumen. This can be attributed to oil dissolution during the impregnation stage. Since this effect was not observed in procedure 3 (impregnation without epoxy diluents), the epoxy diluents are likely the reason for the effect observed in procedure 2. In procedure 3 (Figure 2C), an appreciable melting of bitumen creates an apparent higher presence of bitumen due to expansion. The undesired effect occurred as a higher viscosity of epoxy resin, not containing epoxy diluent, created difficulties during the complete impregnation of the samples, as resin did not reach the center of the sample. This artifact can be overcome by choosing sections further from the center of the soil block. Another difference occurred between procedures 2 and 3 while attempting to obtain the desired thickness value of 30 µm for thin sections. In procedure 2, a thickness of 30 µm was obtained; while in procedure 3, there was a tendency to lose the sample section entirely when attempting to go under a thickness of 80 µm.

As mammoth-sized thin sections are larger, they obviously provide a wider range of view than ordinary petrographic slides and therefore provide a better overall understanding of the oil sands fabric. The oil sands fabric as observed in photomicrograph, Figure 2D, has primary grains which are predominately sub-angular to sub-rounded quartz grains surrounded by fines, likely of both silts and clay sized, which are brownish in color. The primary quartz grains range in size, which was a common feature observed in bioturbated samples. A few grains are fractured and infilled with fines. Bitumen, estimated at approximately 15%, was observed was observed as dark brown in color and both mixed within the fines and as individual components. Voids, which are vughs, are observed between grains.

Conclusions

Thin sections are a powerful tool in determining oil sands fabric as they facilitate the direct observation of reservoir characteristics and subsequently, reservoir quality. It is possible to make good quality thin sections of oil sands samples from non-frozen samples and cores. Artefacts can occur during the preparation of thin sections and these should be noted. This study showed that the alteration of bitumen within the oil sand samples during thin section preparation was more a result of chemical dissolution due to the components rather than from the heat of polymerization.

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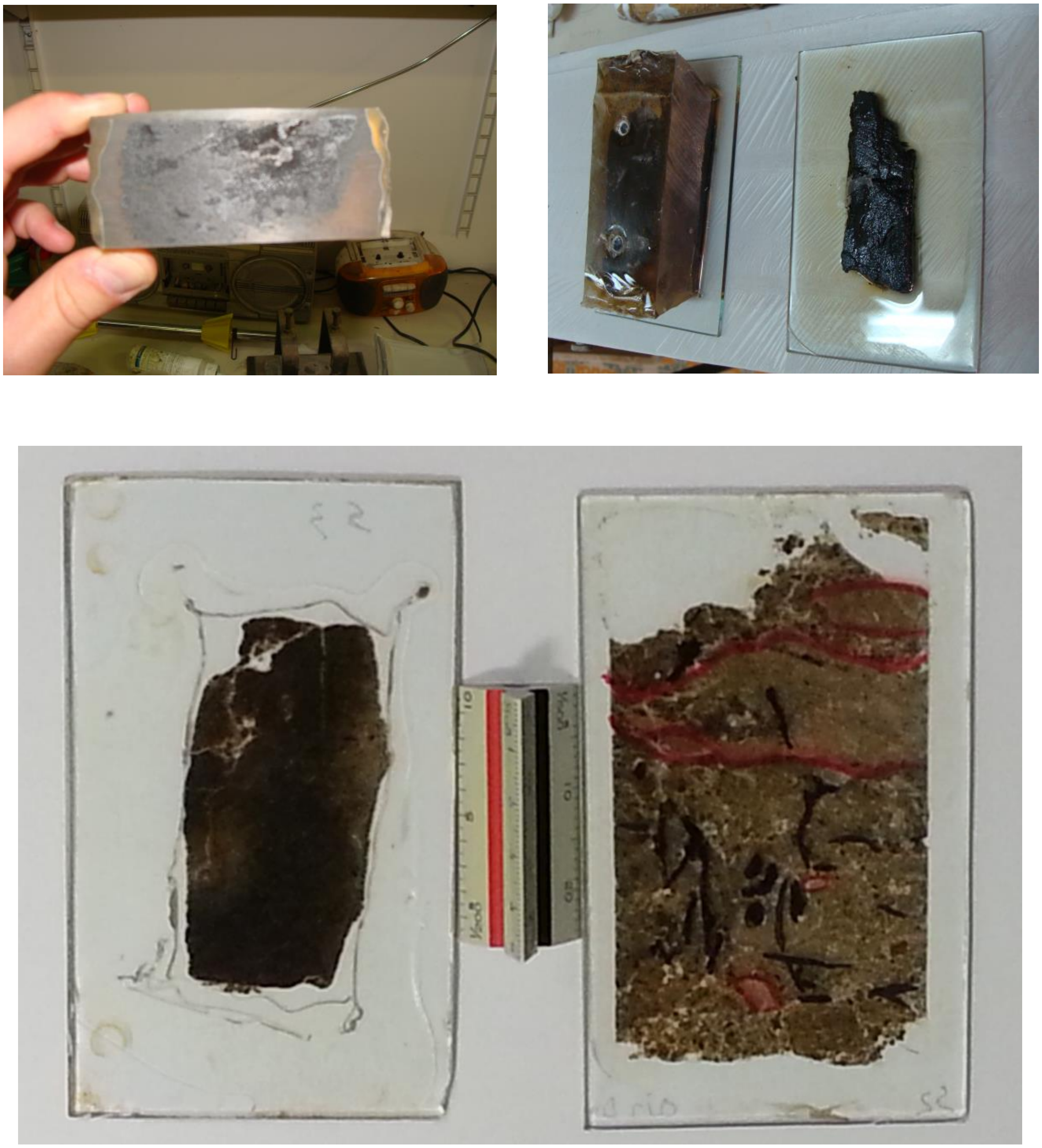
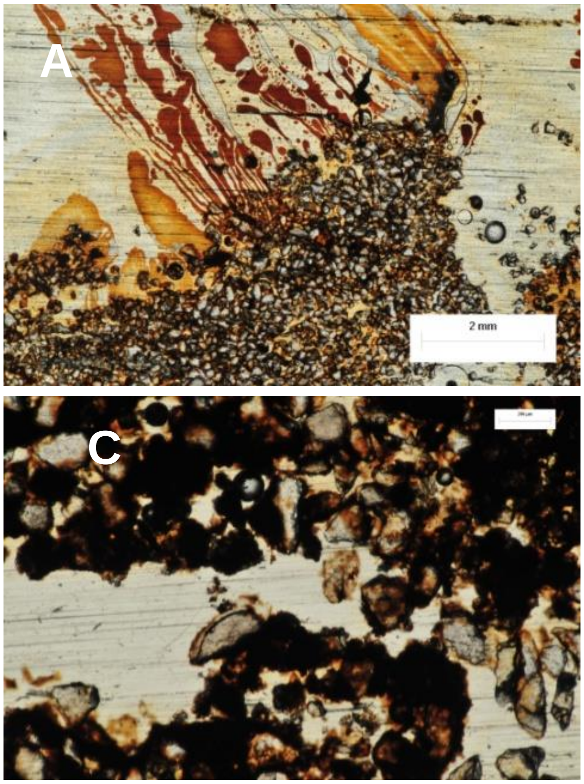
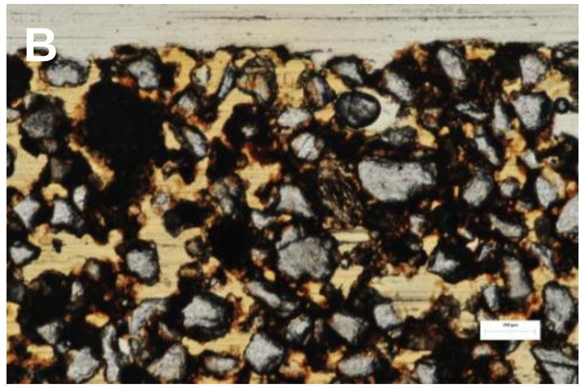


Figure 1: Mammoth-sized petrographic thin sections from oil sands samples obtained using procedure 2. Oil sand samples are from the Hangingstone Section, Upper McMurray Member, and Fort McMurray, Alberta. Thin section on the left is of the Argillaceous Sands and on the right is from bioturbated areas. Trace fossil is captured in the thin section, refer to the area highlighted in red.





The differences combinations of components used during thin section production are summarized as follows:

	Procedure 1	Procedure 2	Procedure 3
Impregnation	Epoxy resign Epoxy diluent Hardener	Epoxy resign Epoxy diluent Hardener	Epoxy resign Hardener
Pasting	Polyester resin Catalyst	Epoxy resign Hardener	Epoxy Hardener

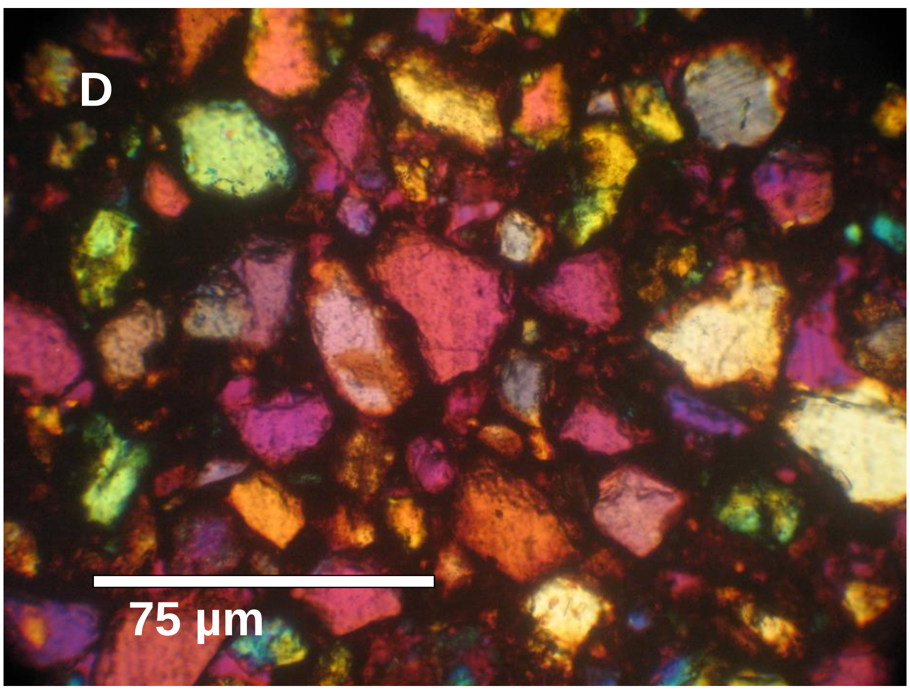


Figure 2. Photomicrographs of thin sections obtained, under transmitted light microscope, using procedure 1 (A), procedure 2 (B), procedure 3 (C) and of bioturbated sample under polarized light (D).