

Scanning Electron Microscopy of Bitumen Saturated Sandstone

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Introduction.

The McMurray Fm of the Athabasca region has been estimated by the ERCB, Alberta Government, to have 1.7 trillion barrels of oil in place and yet imaging of the oil *in situ* within the pore systems of rock samples using a scanning electron microscope (SEM) has been problematic until very recently. This is due to the tendency of bitumen to degas under vacuum, precluding the high vacuum required for proper operation of a conventional SEM, and to mobility of the bitumen when irradiated by an electron beam. Recently the University of Calgary has obtained an FEI Quanta FEG 250 Variable Pressure Environmental Scanning Electron Microscope (VP-ESEM) manufactured in the Czech Republic and installed it in the Instrumentation Facility for Analytical Electron Microscopy (IFFAEM) of the Department of Geoscience. This SEM is further equipped with a high-performance Bruker Quantax 5030 SDD-type energy dispersive X-ray spectrometer (EDX), and a Gatan Alto2500 cryogenic stage and cryo-transfer system. This combination of equipment yields an ideal system for the examination of oil sands with *in situ* hydrocarbons.

Method and Observations.

During the 2012 drilling program at Suncor Firebag some McMurray Fm core samples were collected from the G07 well (07-08-95-5W4) and prepared for examination. A piece of bitumen saturated sandstone about 2cm³ was glued to a stub and placed into the observation chamber. With the VP-ESEM it is not necessary to coat the sample with gold or other electrically conductive material, unlike conventional SEM techniques. It was found that high-resolution images of the sample could be obtained. Kaolinite booklets were observed within the bitumen along with silt and very fine-grained silica crystals. This suggests that the clay minerals are not necessarily in contact with the sand grains and may be removed during Dean Stark preparation. Furthermore, if the bitumen sample was bombarded for a long time then it was found that the bitumen could be moved about, Figure 1. Surprisingly, however, the machine did not get coated with oil and cleaning was not an issue.

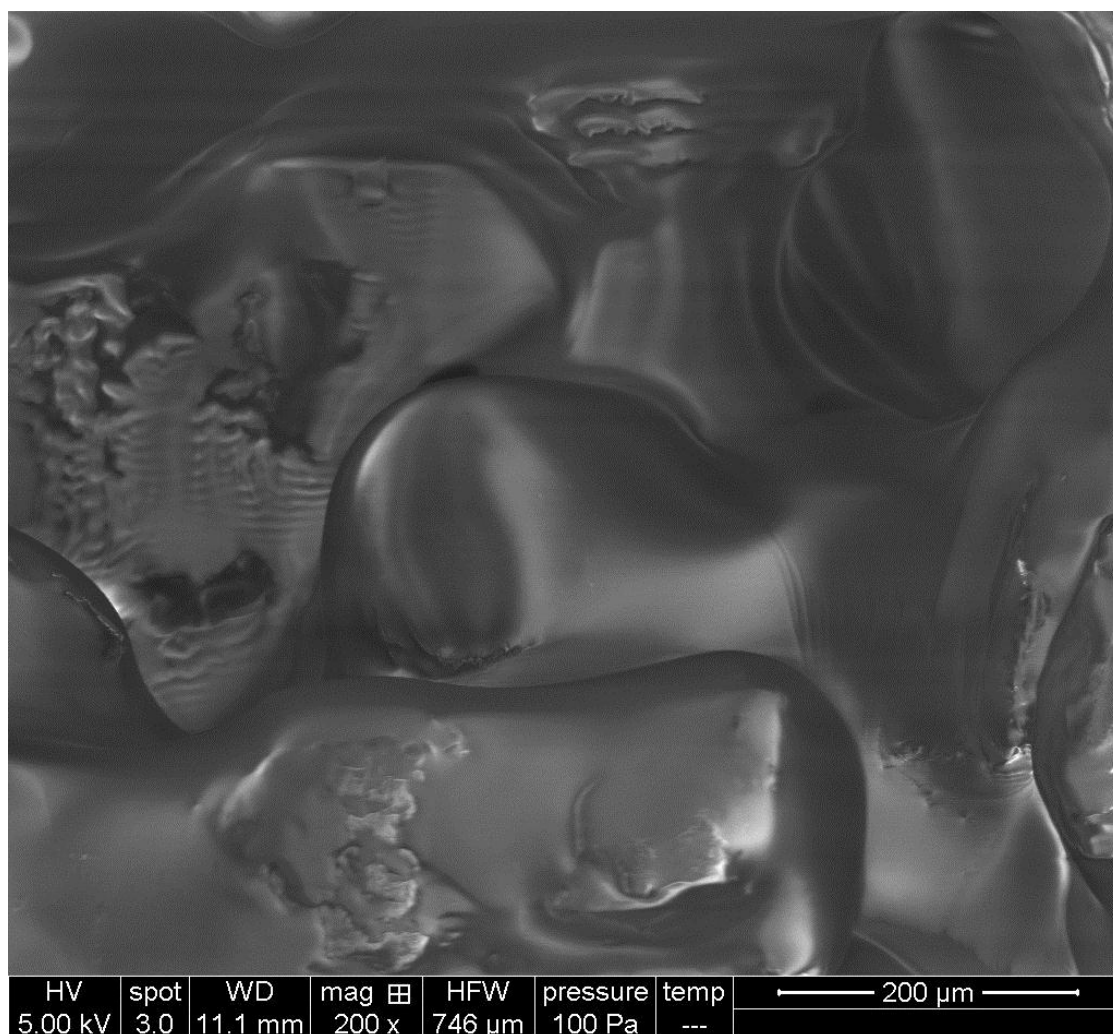


Figure 1: Image of glassy bitumen covering coarse angular sand grain. The rippling is the result of the electron beam exciting the bitumen

A follow up experiment was completed using the cryogenic imaging facility to determine the state of water in the bitumen saturated sandstone. A small sample (3-4 mm) was frozen to -196°C in a liquid nitrogen 'slushy'. The frozen sample was then fractured under vacuum and transferred to the cryo-stage for examination. The secondary electron image was colourized using elemental data derived from the X-ray spectrometer, providing clear and intuitive visual discrimination of various mineral and fluid phases, including sand grains (i.e., quartz), oil, and water (ice). This found that water was present and for the first time observed to be coating grains with oil sitting in the pore spaces Figure 2. This is direct confirmation that the McMurray Fm in the Firebag area is water-wet which previously had only been inferred from core flooding experiments (Czarnicki et al. 2005). Furthermore, cryofixation of the sample stabilizes the bitumen under electron beam bombardment and allows for clear and stable imaging of the relationships among the mineral and fluid components of the reservoir.

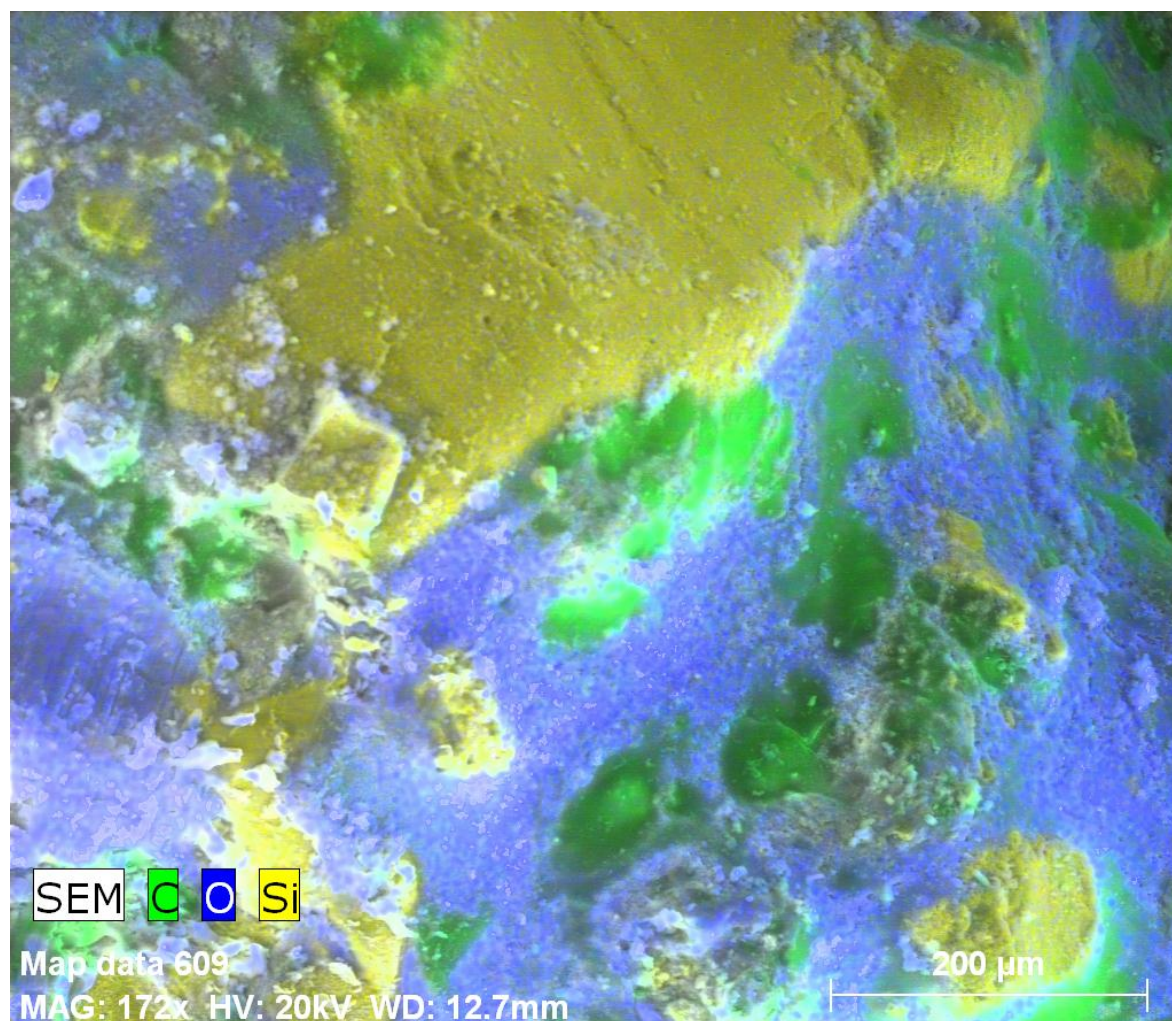


Figure 2: Image of sand grains (yellow) with water (blue) and bitumen (green)

Conclusion

This project has shown that the VP-ESEM has the ability to image bitumen saturated sandstones and discriminate between different clay particles found in the bitumen. Furthermore the rock is shown to have bitumen in the center of pores surrounded by water and sand grains.

Acknowledgements

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References

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