The development of oil sands as one of the world’s leading oil resources has not come without some challenges. In surface mined oil sands there are significant environmental issues around tailings ponds and management of various waste streams, and overall there are challenges with the carbon dioxide footprint associated with converting the heavy bitumen into transportation fuels. In an industry where two tonnes of ore are needed to produce one barrel of bitumen, on any given day a typical operation will process 500,000 tonnes of oil sands ore using 500,000 tonnes of water. Microscopy is not necessarily the first tool that comes to mind when discussing operational problems on this scale. In fact there are many examples of the applications of microscopy in solving important industry challenges related to tailings handling, separation of water and mineral from the final bitumen products, and generally improving the environmental sustainability of one of Canada’s largest industries.

The micrograph in Figure 1 shows just one of the many examples of the application of microscopy to the production end of the oil sands to crude oil process. The surface mined oil sands bitumen extraction process is quite efficient, with typically more than 95% of the bitumen recovered from the sand and clay minerals. One of the first steps in the bitumen recovery process is the flotation and concentration of the bitumen in a froth. In this froth flotation process, the process temperature is such that bitumen will engulf an air bubble. Figure 1 shows a cryo-SEM image of the interior of such an air bubble where hydrocarbon droplets have collected. With time, the number of hydrocarbon droplets crossing the air-bitumen boundary will increase, suggesting that this behavior might be the first step in the development of a nano-refinery that might help in the upgrading of bitumen to transportation fuels.

Figure 2 shows a micrograph of the mineral particles in a typical oil sands process tailings. Understanding and manipulating the small clay minerals that make up the tailings suspensions is the first step in reclaiming the large tailings ponds associated with surface mined oil sands development. It is an understanding of the processes on the microscopic scale that help define the environmental and production solutions and that have directly led to multi-million dollar changes in important oil sands processes. Some interesting examples will be given where multimillion dollar process changes were made based only on evidence provided by microscopy.

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Fig. 1: Cryo-SEM image of the interior of a bitumen froth air bubble at initial attachment (left) and after some minutes (right). The inset x-ray spectra show a high sulphur content associated with the bitumen in the droplets (left), but not in the bulk (right).

Fig. 2: SEM micrograph of the mineral particles making up oil sands tailings. The distinctive plate like nature of the kaolinite clays is evident, as is the presence of many mineral components only a few hundred times larger than the water molecules in which they are suspended.