geoconvention
Calgary • Canada • May 15-19 2017

Provenance of the Peace River and Athabasca Oil Sands: Implications from Mineral Assemblages and Detrital Zircon Ages

Lynsey L McKinnon, Ronald J Spencer, Sytle M Antao
University of Calgary

Summary

The Bluesky Formation in the Peace River Oil Sands and McMurray Formation in the Athabasca Oil Sands have been consistent producers of heavy oil and bitumen since the development of SAGD techniques in the last few decades. Although the production of oil is an important aspect of these formations, both geological history of sediment deposition and mineralogical characteristics should be considered in order to understand the sediment drainage pathways that existed during the Early Cretaceous in North America.

Several studies have been conducted on detrital zircon (DZ) ages across North America. DZ ages observed in the McMurray Formation of the Athabasca region have yielded several interpretations of sediment drainage systems to explain deposition and provenance of sediments in Northern and Central Alberta (Gehrels and Pecha, 2013; Benyon et al., 2014; Blum and Pecha, 2014). Sources of DZ and proposed sediment drainage pathways will be discussed to interpret DZ age populations in the Bluesky Formation in comparison to the McMurray Formation.

Scanning electron microscope (SEM), X-Ray Diffraction (XRD) and X-Ray Fluorescence (XRF) technologies were also used to identify mineral assemblages of clays, framework grains, and heavy minerals in the Bluesky Formation for comparison to McMurray Formation mineralogy. This study aims to determine the broad mineralogical characteristics of both formations by combining these techniques with geothermochronology of detrital zircons.

Introduction

The Athabasca and Peace River Oil Sands are part of the largest deposit of heavy oil in Canada with total estimated reserves of approximately 167 billion barrels of producible crude oil (Alberta Energy Regulator, 2017). The major producing formations in the Athabasca region are the McMurray Formation and the Clearwater Formation. The McMurray Formation is an Early Cretaceous sandstone composed of stacked sequences of point bars, estuarine incised valleys and tidal channel sandstone packages (Hein et al., 2001). It unconformably overlies Devonian carbonates, is bounded above by an uncomformity, and overlain by the marine shales of the Clearwater Formation (Hein et al., 2001). In the Peace River area, the Early Cretaceous Bluesky and Gething formations are targeted for oil production. They are stratigraphic equivalents to the Wabiskaw Member (Clearwater Formation) and McMurray Formation respectively. The Bluesky Formation is composed of a complex system of marginal marine-estuarine sandstone deposits

(Hubbard et al., 1999). The Bluesky Formation is overlain by the marine shales of the Wilrich Member of the Spirit River Formation which is also age equivalent to the Clearwater Formation (Hubbard et al., 1999)).

Theory and/or Method

The provenance of sediment can be determined in part by DZ ages using laser ablation inductively coupled mass spectrometry (LA ICP-MS). Ratios of $^{206}Pb/^{238}U$, $^{207}Pb/^{235}U$ and $^{207}Pb/^{206}Pb$ in DZ of the Bluesky Formation are then compared to DZ samples of established standard ages. A relative age is determined for the Bluesky DZ which identifies sediment provenance, and appropriate sediment drainage pathways can be interpreted.

Scanning electron microscopy and XRD was used for qualitative analysis to determine mineralogical compositions in the Bluesky formation. XRF was also used to quantify mineralogy and confirm mineral identifications from SEM and XRD.

Conclusions

Overall, Bluesky Formation has considerable mineralogical differences compared to the McMurray Formation. Based on DZ ages, both local and regional sediment drainage sources were responsible for deposition that may be related to fluctuations in regional sea level. Dawsonite varies throughout the Bluesky Formation, with complex emplacement and timing of formation depending on location. Clay mineralogy in the Bluesky Formation is also important to consider for oil production.

Acknowledgements

University of Calgary, Shell Canada and Suncor Energy Inc.

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