Late Early and Middle Jurassic Sequence Stratigraphy and Depositional History, Sverdrup Basin, Arctic Canada*

Ashton Embry1

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Abstract

Late Early and Middle Jurassic (Pliensbachian-Callovian) strata of Sverdrup Basin comprise two 2nd order sequences which share a major 1st order boundary of latest Aalenian age. The Pliensbachian-Aalenian 2nd order sequence contains three 3rd order sequences and the strata consist of shallow to deep shelf siliciclastics. The shield areas to the east and south were the main source areas and sediment supply was moderate to low. The most extensive sandstone unit occurs in the upper portion of the Aalenian, 3rd order sequence and it prograded northwards. Crockerland, a source area which lay to the north, also contributed sediment and a Crockerland-derived, Aalenian sandstone occurs along the northwest margin of the basin.

Significant uplift occurred along the basin flanks in latest Aalenian and was associated with the final progradation of the Aalenian sandstone unit. In the far southwest portion of the basin, extensional faults which parallel the current Amerasia Ocean Basin developed for the first time. The oldest strata overlying the unconformity are earliest Bajocian.

The Bajocian-Callovian, 2nd order sequence consists of three 3rd order sequences which approximate the Bajocian, Bathonian and Callovian stages. Sediment supply to the basin was greatly reduced following the latest Aalenian, 1st order boundary. One input centre during the Bajocian-Callovian interval occurred in the southwestern corner of the basin and thick marine sandstone units derived from the south were deposited, with thicknesses partly controlled by north-south extensional faults. A small input centre occurred on northern Ellef Ringnes Island and Bajocian and Bathonian sandstones prograded southwards from the rift shoulder of the newly formed Amerasia rift system. Over most of the basin, Bajocian and Bathonian strata are thin, often condensed sediments. There is no evidence of sediments of this age having been derived from the south or east over most of the basin.
A unit of Callovian shale, derived mainly from the south, occurs over much of the basin and equivalent shallow marine sandstone units are rarely preserved. The Callovian strata are separated from the overlying Upper Jurassic, Oxfordian strata by a 2nd order sequence boundary. Following this brief tectonic episode, sediment supply greatly increased from the south and east and no northerly-derived Oxfordian sediments have been identified.

The latest Aalenian sequence boundary is interpreted to coincide with the onset of rifting in the adjacent Amerasia Basin. The Aalenian strata appear to be the final sedimentary wedge derived from Crockerland which was subsequently broken up and buried as the Amerasia Basin evolved from Bajocian through Albian. The Middle Jurassic is a time of greatly reduced sediment supply for the western Arctic from the Barents Shelf to the Alaskan North Slope.
Sverdrup Basin
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<th>3rd Order</th>
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**Talk**

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- 2.32 my
- 47 my
This talk will look at two 2nd order sequences which are separated by a major 1st order boundary.
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<tr>
<th>JURASSIC</th>
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<td>Oxfordian</td>
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**Delta Front / Shallow Shelf**

**Prodelta, Offshore Shelf**

**Subaerial Unconformity, Unconformable Shoreline Ravinement**

**Maximum Regressive Surface**
Isopach Pliensbachian-Aalenian
2nd Order Sequence
Eastern Margin to Basin Centre Cross Section
Pliensbachian-Aalenian 2nd Order Sequence
NE Sawtooth Range, Ellesmere Island
Yelverton Pass, NE Ellesmere Island

Pliensbachian Sequence

Sinemurian Sequence

Yelverton Pass, NE Ellesmere Island
Taleman J-34

Oxfordian Sequence

Aalenian Sequence

Toarcian Sequence

Pliensbachian Sequence
Depot Point Creek, Eastern Axel Heiberg Island
Ermine Ridge, west central Axel Heiberg Island
Detrital Zircon Ages, Aalenian Sandstone
Northwest Axel Heiberg Island

Omma et al, 2011
Cape Allison C-47

Bajocian Sequence

Aalenian Sequence

Toarcian Sequence

Pliensbachian Sequence
Reindeer Peninsula, NW Ellef Ringnes Island
Southwest Basin Cross Section
Pliensbachian-Aalenian 2nd Order Sequence
Depot Island C-44
Emerald K-33
Cape Mamen F-24

Bajocian
Aalenian
Toarcian

20 m

200 300 400

0 100
Late Pliensbachian Paleogeography

- Fluvial – Delta Plain
- Shoreface – Shallow Shelf
- Offshore Shelf

Crockerland

0 Kilometres 200
Late Aalenian Paleogeography

Shoreface – Shallow Shelf
Offshore Shelf

Kilometres

Crockerland
Isopach and Input Centres

Bajocian - Callovian 2nd Order Sequence

100 Bajocian-Callovian Isopach (in metres)

Surface Section

Well

ARCTIC OCEAN

GREENLAND

Isopach and Input Centres
Bajocian - Callovian 2nd Order Sequence
North-South Rifting Began at base Bajocian on Prince Patrick Island

Slide courtesy of Chris Harrison
Cross Sections for Bajocian - Callovian 2nd Order Sequence
Southwestern Margin Cross Section
Bajocian - Callovian 2nd Order Sequence
Sproule Peninsula, Northwest Melville Island

Bathonian Sequence

Callovian Sequence
Hoodoo of delta front sandstone, Callovian Sequence, Sproule Peninsula, NW Melville Island
Aalenian Sequence

Callovian Sequence

Oxfordian Sequence

East Kitson River, NW Melville Island
Ellef Ringnes Island Cross Section
Bajocian - Callovian 2\textsuperscript{nd} Order Sequence
Central Basin Cross Section

Bajocian - Callovian 2nd Order Sequence
Buchanan Lake, East Central Axel Heiberg Island
Bajocian-Callovian 2nd Order Sequence Eroded
North Wolf Fiord, South Central Axel Heiberg I.
Glauconite Bed at Base of Bajocian-Callovian Sequence, Geodetic Hills, Eastern Axel Heiberg I.
Ermine Ridge, west central Axel Heiberg Island
Rhaetian Sequence

Bajocian-Callovian Sequence

Oxfordian Sequence

Lake Hazen, Northeast Ellesmere Island
### EARLY PERMIAN – AALENIAN

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<tr>
<th>S</th>
<th>NORTH AMERICAN CRATON</th>
<th>SVERDRUP BASIN</th>
<th>CROCKERLAND</th>
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### BAJOCIAN – CRETACEOUS

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<tr>
<th>NORTH AMERICAN CRATON</th>
<th>SVERDRUP BASIN</th>
<th>SVERDRUP RIM</th>
<th>AMERASIA BASIN</th>
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</table>
Late Bajocian Paleogeography
Late Bathonian Paleogeography

- Fluvial – Delta Plain
- Shoreface – Shallow Shelf
- Offshore Shelf
- Starved Shelf

Amerasia Rift Basin
Sverdrup Rim

Kilometres

0 200
Late Callovian Paleogeography

- Fluvial – Delta Plain
- Shoreface – Shallow Shelf
- Offshore Shelf

Amerasia Rift Basin
Sverdrup Rim

Kilometres
0 200
Base Oxfordian Tectonic Unconformity
Petroleum Prospects

- Pliensbachian sandstones are major reservoirs in gas fields on Ellef Ringnes Island with the Toarcian shale being an effective seal.
Petroleum Prospects

• Toarcian to Callovian sandstone units are potential targets where they pinchout updip.
Conclusions

• The Pliensbachian to Callovian succession comprises two $2^{nd}$ order sequences which are separated by a $1^{st}$ order boundary of earliest Bajocian age.

• Each $2^{nd}$ order sequence contains three $3^{rd}$ order sequences which approximate Jurassic stages.
Conclusions

• The beginning of the Pliensbachian - Aalenian 2\textsuperscript{nd} order sequence is characterized by a greatly reduced sediment influx.

• The main sediment source area for the Pliensbachian to Aalenian sequence was the craton to the east and south. Crockerland also contributed sediment in the Aalenian.
Conclusions

• The 1\textsuperscript{st} order sequence boundary at near base Bajocian is characterized by the start of rifting of the Amerasia Basin and by a greatly reduced sediment influx.

• The main sediment source area for the Bajocian to Callovian 2\textsuperscript{nd} order sequence was the Sverdrup Rim.
Conclusions

• The current data strongly support the interpretation that the start of rifting for the Amerasia Ocean Basin began in latest Aalenian-earliest Bajocian.

• Structural/stratigraphic traps involving pinchouts of porous sandstone units on the flanks of highs offer the best potential petroleum accumulations.
Thanks to my employer, Geological Survey of Canada, for Continued Support
Thanks to Dave Sargent for Slide Preparation
Thank you for your kind attention

Time for a drink!