Jean Marie Facies: Elleh Area

Rick Wierzbicki*
EnCana Corp, Calgary, AB
richard.wierzbicki@encana.com

Christine Zahynacz
EnCana Corp, Calgary, AB, Canada

and

Adam Hedinger
Independent Consultant, Calgary, AB Canada

Summary

The Jean Marie is a Frasnian aged carbonate ramp that developed on the edge of the North American craton in what is now northeastern British Columbia. The carbonate ramp is a gas charged, under-pressured, low permeability, limestone reservoir. The Jean Marie has been developed by EnCana in the Elleh area, using underbalanced horizontal wells. Downhole logging beyond a basic gamma log is not done on the horizontal wells. The main geological information on the reservoir comes from ditch cutting descriptions, net gas production while drilling, and from vertical pilot wells that are logged and cored. There is a great value in having a good facies model as the ditch cutting based interpretation of facies is a major component in geosteering decisions.

Through 2005 to 2007 Adam described 90 cores from pilot wells and older vertical wells in the Elleh area. Based on these descriptions, a facies model has been constructed to aid in the prediction of facies distribution in new horizontal wells. Our presentation will be of a transect of wells from the ramp edge to the ramp interior. The core will be used to display fauna, facies distribution, and diagenesis of the Jean Marie.

Introduction

The Jean Marie carbonate ramp prograded across a Fort Simpson shale clinoform in late Nisku time. The ramp is thickest at its western edge where the underlying Fort Simpson drops away. The ramp changes laterally in to argillaceous limestone and shale. The Jean Marie is overlain by the Redknife shale, and so forms a thin carbonate zone (15 to 70 meters thick) between two thick shale packages. On seismic data the ramp rim is shown to be built of a series of linear isochron thicks which are interpreted as linear reef trends. The ramp interior also has linear isochron thicks and local large oval features which are interpreted as linear reefs and large patch reefs. Cores taken within these isochron thicks show they are formed predominantly by *Renalcis* encrusted wafer Stromatoporoid boundstones, often with a significant geopetal mud component. Intermound sediments show an open marine character, even well within the platform. Our interpretation of the depositional setting is that the reefs grew on a deeper water slope and only reached fair weather wave base occasionally.

The reef and reef flank sediments and a large portion of the inter-reef sediment show evidence of burial diagenesis with slight dolomitization, and extensive leaching of *Renalcis* and peloids. In addition carbonate mud has often been neomorphically altered to a fine micro-spar with common microsucrosic texture. This has resulted in a widespread but discontinuous, low to moderate porosity development, mostly of micro-intercrystalline and micro-moldic pores. The small pores have resulted in a relatively low permeability which explains the low deliverability of vertical wells and the successful development of the reservoir using horizontal underbalanced wells. These wells minimize formation damage, connect to large areas of reservoir, and intersect the occasional fracture which enhances permeability.

Method

This presentation is the result of a three year core description project undertaken by Adam Hedinger for EnCana. His work was complimented by discussions with fellow EnCana geologists working on the Jean Marie development program; and an associated diagenetic study undertaken by Jeff Dravis. Based on the data. a facies and diagenetic model was developed for the reservoir for the ramp interior. This model was extended to the ramp margin when examination of cores in that area revealed the same general facies. Conversations with Bill Martindale, on the nature of Nisku sedimentology at Meekwap, and with Jack Wendte, on Jean Marie sedimentology at July Lake, contributed to our regional understanding of the Jean Marie and Nisku in the area.

Facies Model

The reservoir was broken into three major facies packages: those associated with the buildups observed on seismic data, those associated with the intermound areas, and those associated with the underlying deep water carbonate ramp that occurs at the transition from Fort Simpson to Jean Marie.

Build-up Facies Association

B 1: Reef flank to backreef lagoon environment.

Dark to medium brown limestone, symmetrical to ragged oncolite, *Megalodon*, branching stromatoporoid, rare wafer stromatoporoid, gastropod, robust *Amphipora, Syringopora*, horn corals, floatstone to rudstone; mudstone to pelloidal packstone to rare grainstone matrix; hint of nodular texture, slightly argillaceous. Varies to medium to dark brown limestone, wafer or laminar and dendroid stromatoporoid, branching coral, crinoids, brachiopod, wackestone, floatstone, rarely rudstone; generally muddy matrix but occasional grainstone matrix; interbedded with intermound sediments.

B 2: Shoal to reef capping shoal, above fair weather wave base.

Tan to medium brown limestone, oncolite, *Megalodon*, dendroid stromatoporoid, *Thamnopora*, rugose corals, and brachiopod fragments, floatstone to rudstone; skeletal grainstone/packstone to pelletal grainstone matrix. Varies to tan limestone, dendroid stromatoporoid, *Amphipora* rudstone with an interclast and skeletal grainstone matrix

B 3: High energy reef, at fair weather wave base.

Cream to tan to medium brown limestone, wafer to tabular with rare bulbous stromatoporoid and *Renalcis* consortium, rudstone to dominantly boundstone, dendroid stromatoporoids, rare solitary and rugose corals, *Amphipora*, brachiopods; little mud in matrix, open framework with large cavities partially to completely in filled with spar cement or grainy debris, grainstone to pelletal packstone matrix. Varies to *Renalcis* dominated thrombolites and *Renalcis* sands and muds with very little stromatoporoid material. *Renalcis* dominated zones may be shoals or large infilled cavities "caves" or sheltered areas where thrombolitic growth dominated. In the Stromatoporoid-Renalcis consortium, pendant or encrusting *Renalcis* is the dominant depositional form.

B 4: Moderate to low energy reef, below fair weather wave base or interior of mound.

Light cream to medium to dark brown limestone, tabular to wafer stromatoporoid *Renalcis* consortium, floatstone to rudstone to boundstone, trace brachipods, gastropods, dendroid stromatoporoids, *Thamnopora*, rare coral heads, shelter cavities partially to completely filled in with *Renalcis* encrustations and mudstone or pelletal muds, wackestone to mudstone matrix. Varies to cream to tan, dense wafer strom boundstone with little mudstone and *Renalcis* dominating in shelter cavities

B 5: Stromatoporoid biostroms to incipient Stromatoporoid Renalcis consortium reef.

Medium to dark brown limestone, wafer Stromatoporoid with very rare *Renalcis*, scattered dendroid stromatoporoids, *Thamnopora*, brachiopods, trace *Amphipora,* wackestone to floatstone, rare rudstone, mudstone to rare skeletal wackestone matrix.

Inter-Mound Facies Association

I 1: Open platform normal marine, generally below fair weather wave base.

Dark to medium brown to grey, dendroid and rare wafer stromatoporoid, horn corals, crinoids, brachiopod, rare colonial corals, *Syringopora*, rare heavy pelecy pod fragments, wackestone to floatstone, hints of nodular texture, lime mud matrix,

I 2: Low energy open platform.

Dark to medium brown limestone, mudstone to rare wackestone, rare beds of skeletal debris, corals, wafer stromatoporoid fragments, dendroid stromatoporoid fragments, *Amphipora*, *Thamnopora*, brachiopod, crinoids, not nodular. Varies to dull dark green to dark brown to medium brown limestone, mudstone with a strong nodular texture, little fauna, slightly argillaceous. Varies to medium brown peloidal grainstone.

I 3: Low energy restricted platform.

Medium to dark brown limestone, mostly barren mudstone, very rare small *Amphipora*, *Megalodon* fragments, brachiopods, occasional wispy beds of black argillaceous mudstone, nodular texture occurs, sometimes with dark green shale partings.

I 4: Channel fill between mounds.

Light tan to pale brown limestone, barren fine grained calcarenite to bioclastic wackestone to packstone with rare fragments of corals, stromatoporoids, and interclasts, varies to dark brown slightly argillaceous calcarenite packstone, trace skeletal debris as above. Skeletal grains were swept off mound tops into channels, below fair weather wave base but perhaps strong currents in channels.

Lower Carbonate Ramp Facies Association (Basal Transition)

R 1: Deeper water open ramp, basal Jean Marie.

Dark brown limestone, coral, crinoids, scattered cup corals and brachiopods, rare wafer stromatoporoids, wackestone to floatstone, argillaceous, varies to dark brown nodular mudstone with interbeds of dark green argillaceous mudstone.

R 2: Deeper water biostromes

Dark brown to dark green limestone, coral stromatoporoid rudstone, argillaceous muddy matrix. Small biostromes, slight increase in thickness of platform, slight relief off seafloor.

Diagenesis (Summarized from Internal Report by Jeff Dravis)

Porosity is best developed in platy stromatoporoid buildups but very good porosity can also be found in the flanks of buildups in more micritic units. Preserved porosity is dominantly secondary and appears to have form coincident with pressure solution of shortly thereafter. Porosity is developed by secondary dissolution of micritic fabrics such as: *Renalcis*, some stromatoporoids, peloids, micritic coatings, and cryptocrystalline grains. Stable calcite grains such as crinoids , calcispheres, and corals are also dissolved. Associated mineral deposited include authogenic quartz, sphalerite, and kaolinite. Microfractures are common and provide enhanced permeability.

This implies that more acidic and perhaps hot fluids were involved in the dissolution process. The geochemical work released by Jack Wendte in 2007 in GSC openfile --- show hot deeper sourced fluids were involved in dolomitization and dissolution in the July Lake area.

Conclusions

The reefs on the Jean Marie carbonate ramp are made up of platey stromotoporoid boundstone to rudstone with abundant Renalcis encrustations and have dominantly a muddy wackestone to packstone matrix. The interreef sediments show a low energy open marine to restricted marine facies. On that basis we suggest that the Jean Marie ramp was a lower energy deep water ramp with reefs occasionally growing up above the fair weather wave base. The reefs themselves show a shallowing up profile.

Porosity development is associated with secondary dissolution and results in a dominantly microporous pore system. Permeability is low due to the small pore throats but is enhanced by microfractures and the occasional macrofracture. Underbalanced horizontal wells are an ideal way to develop this reservoir.

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