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Depositional and Diagenetic Controls on Reservoir Development, Big Valley Formation ("Alberta Bakken"), Tight Oil Play, Southern Alberta

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Introduction

The Upper Devonian (late Famennian) Big Valley Formation has been presented as a potential unconventional light oil play in southern Alberta. This occurred as the result of several investment houses applying the informal term “Alberta Bakken” to the Bakken age equivalent Exshaw Shale (Zaitlin et al. 2011; Bryden, 2011). The use of the “Alberta Bakken” term suggests prolific production of liquid hydrocarbons from an unconventional reservoir analogous to the Bakken Shale of the Williston Basin. However, production is interpreted to be mainly from the underlying Big Valley Formation. The Big Valley Formation is considered in part equivalent to the prolific oil producing interval in the Three Forks Formation of the Williston Basin (Figure 1).

The study area is from Township 4 to Township 11, Range 22 to Range 26 west of the fourth meridian inclusive in southern Alberta (Figure 2). Data for this study is based on 21 cores and 84 geophysical logs that penetrate through the Big Valley Formation. Cores along with wireline data logs are used to constrain depositional and stratigraphic trends of the Big Valley Formation within the study area.

Published literature on regional stratigraphy and nomenclature of the Upper Devonian Wabamun Group in and proximal to the study area is inconsistent, particularly with respect to the Big Valley and Stettler formations. Present nomenclature places depositionally related Big Valley units within the Stettler Formation. A proposed revision of the stratigraphy is presented in this paper as a necessary step in determining the origin and aerial distribution of potential reservoir zones (Figure 3).

Depositional Setting

The Big Valley Formation is a shallow open-marine to peritidal carbonate succession deposited on an open platform to epeiric shelf setting. Regionally, the Big Valley Formation in southern Alberta consists of two distinct but depositionally related carbonate facies associations: (1) shallow open marine, and (2) peritidal. The shallow open marine unit is composed of crinoid-brachiopod nodular lime mudstones to wackestones and never forms part of the oil-bearing interval. The peritidal facies association is the hydrocarbon bearing zone which is divided into four main lithofacies: (1) mid- to high intertidal microbial dolomite laminites, (2) mid-to high intertidal laminated dolo to calcareous mudstones, (3) shallow subtidal-shoals consisting of calcareous and dolomitized peloidal grainstone-packstone deposits, and (4) intraclastic dolomite breccia-laminites related to shallow ephemeral tidal drainage channels.

Local, autocyclical events dictate the stratal patterns and facies depositional sequences of the ~1 m thick peritidal units. Individual Big Valley Formation facies distributions are laterally discontinuous due to the dynamic depositional settings of the peritidal environments. The top of the Stettler Formation is a key stratal surface, and is regionally traceable on geophysical well log signatures. The Stettler Formation is an evaporitic succession deposited in a sabkha or salina setting. Regionally, the Stettler Formation is composed of nodular to bedded anhydrite and minor dolomite. The Big Valley Formation is grouped as a single regionally traceable package, bounded by the stratal surfaces of the underlying Stettler Formation and overlying lower Exshaw Shale (Figure 4).

State of Play

The Big Valley Formation is an emerging light oil play in southern Alberta which currently produces at depths greater than 2000 m. At present, the highest cumulative producing Big Valley well (100/10-30-008-23W4/00) has yielded 250,000 barrels of oil. This high producing well exhibits anomalously thick Exshaw (17 m) and Big Valley formations (25 m), which contrasts with regional thickness trends of 7 to 10 m respectively (Figure 5). The Big Valley Formation in southern Alberta is in the early stages of exploration with further development of the play dependent on accurately predicting these depositionally thick trends. As an upside, the stratigraphically equivalent Three Forks Formation in the Williston Basin has an estimated 2 billion barrels of recoverable oil (Sonnenberg et al., 2011).

Rock Fabric and Petrophysical Relationship

Conventional core analyses of Big Valley lithofacies indicate relatively low permeability and low porosity values. Porosities greater than 5% generally define the hydrocarbon-saturated pay zones in the Big Valley Formation. In current producing wells the highest porosity lithofacies and primary productive reservoir zone is the calcareous and dolomitized peloidal grainstone-packstone deposits (Figure 6). Rock fabric of the reservoir facies consists of low density porous grains that have been adhered together by biofilm, a microbial laminate structure. The highest production to date is associated with early primary intergranular porosity, coupled with diagenetically enhanced intercrystalline and intragranular porosity resulting from the replacement of calcite with euhedral to subhedral dolomite crystals. This diagenetically enhanced facies generates a distinctive low gamma-ray and high neutron-porosity response on well logs.

Pressure-solution compaction has contributed to a reduction in pore space producing interlocking sutured grain contacts between dolomite crystal rhombs. Porosity occlusion is due to calcite and anhydrite cementation of the pore space. Fenestral porosity is common in the microbial laminated dolostone and mudstones, and is generally filled by late stage evaporites.

Conclusions

In southern Alberta the Big Valley Formation represents a regionally hydrocarbon saturated and over pressured reservoir interval. The reservoir intervals have significant variability in reservoir quality and thickness. Revision of the Upper Wabamun Group will appropriately characterize the aerial distribution of the hydrocarbon reservoir into the lower Big Valley Formation. Further development and exploration of the play is dependent on thorough characterization and prediction of depositional and diagenetic facies.

References

Bryden, P., 2011. Exploration of the Alberta Bakken: A Resource Play Mosaic in the Making?. Scotia Capital Equity Research Industry Report, March, 2011. p.68.

Mossop,G. and I. Shetsen (Compilers), 1994. Atlas of Western Canada Sedimentary Basin, Calgary, Canadian Society of Petroleum Geologists and Alberta Research Council, p.501.

Sonnenberg, S.A., A. Gantyno and R.Sarg, 2011. Petroleum Potential of the Upper Three Forks Formation, Williston Basin, USA. Search and Discovery Article #110153.

Zaitlin, B., Smith Low, W., Kennedy, J., and Kehoe, S., 2011. The Alberta Bakken petroleum system-update: BMO Capital Markets Oil and Gas Report, p.34.

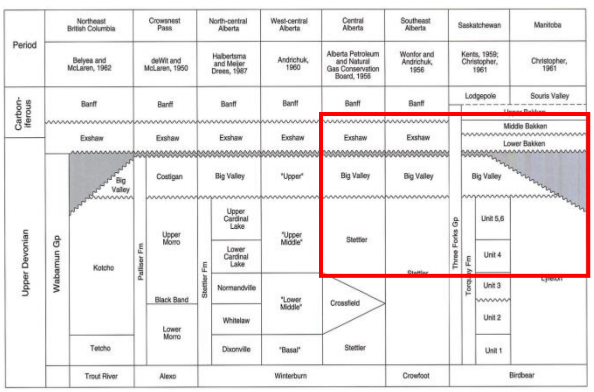

Figure. 1 Stratigraphic correlation for the Upper Wabamun and Exshaw Formations across Western Canada (Adapted from the Geological Atlas of the WCSB, Mossop and Shetsen, 1994).

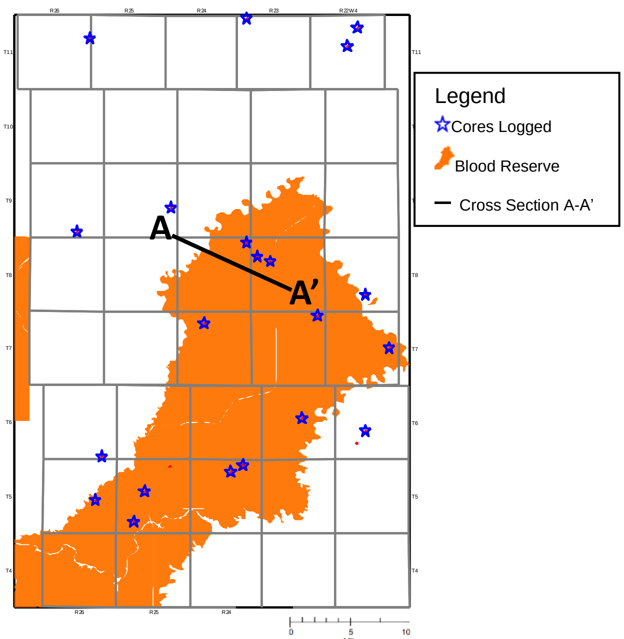

Figure 2. Southern Alberta study Area of the Big Valley Formation.

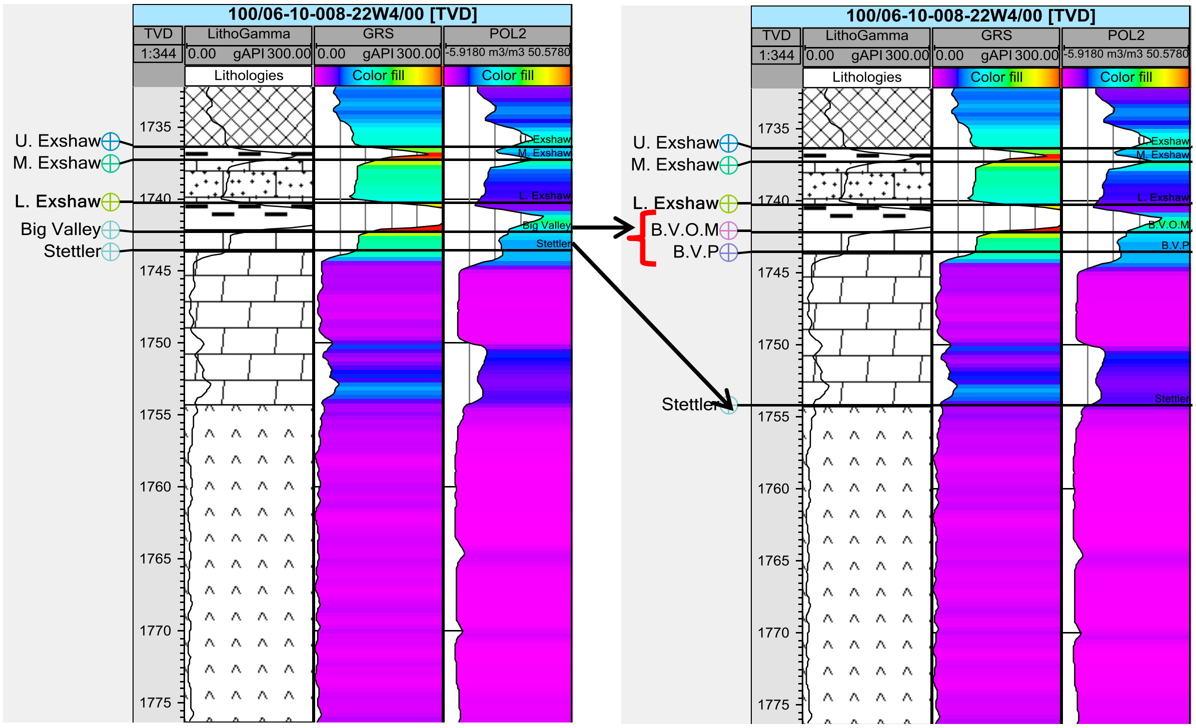

Figure 3. Formation top well log picks using current nomenclature (left) versus proposed nomenclature (right).

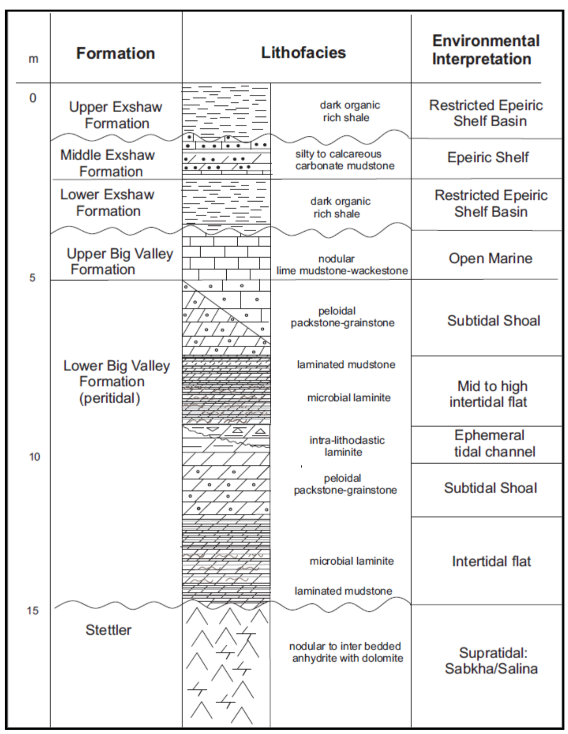

Figure 4. A proposed regional representation of the Big Valley Formation lithofacies sequence and the stratigraphic relationship between the Stettler and Exshaw formations.

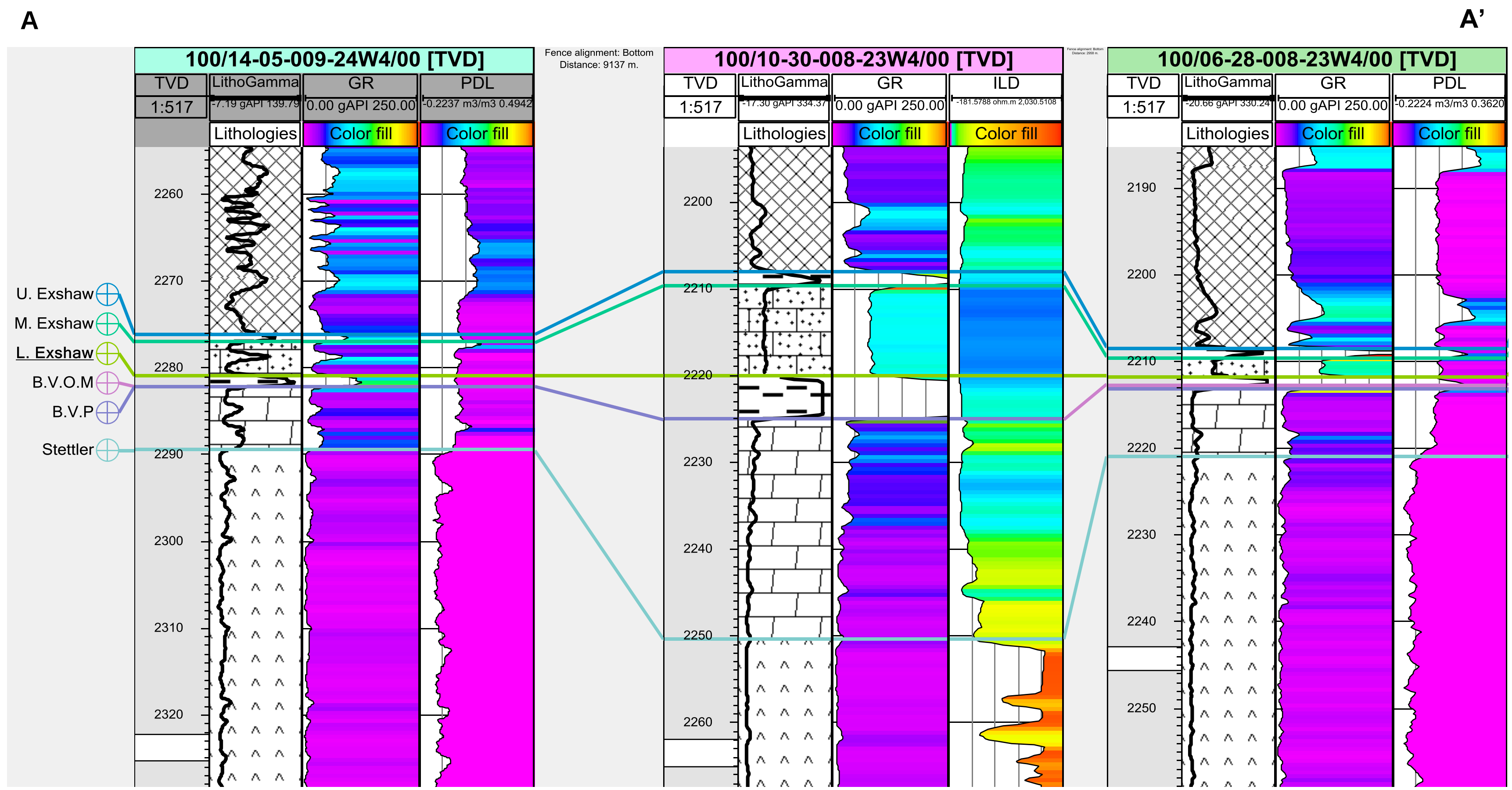

Figure 5. Cross-section of Big Valley Formation using lower Exshaw Formation as datum. Note anomalous thickening in the prolific oil producing 100/10-30-008-23W4/00 well.

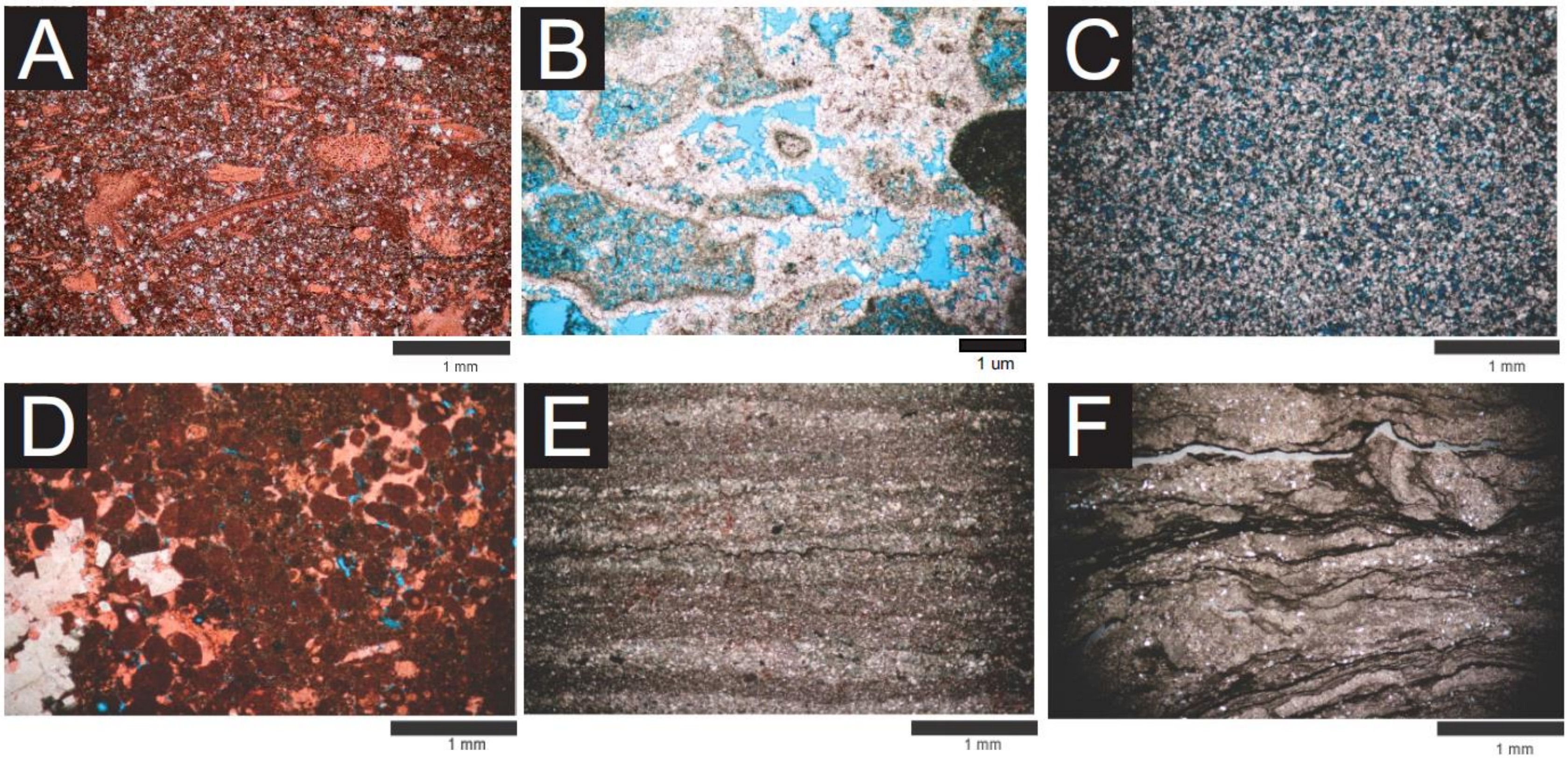

Figure 6. Thin section photomicrographs of the various Big Valley lithofacies.
A) Upper Big Valley: crinoid-brachiopod nodular lime wackestone. 16-27-11-22W4, (1793.35 m), PPL, x5.
B) Lower Big Valley: micritic porous grains with high intercrystalline and intraparticle porosity. Growth of coarse euhedral dolomite crystals into primary pore space. 16-31-11-22W4, (2055.16 m), PPL, x20
C) Lower Big Valley: euhedral crystalline dolostone with intercrystalline porosity. 06-13-009-26W4 (2245.18 m) PPL, x5
D) Lower Big Valley: calcareous peloidal grainstone with calcite and evaporite cement. 08-30-008-23W4 (2210.69 m), PPL, x5
E) Lower Big Valley: laminated microbial mudstone. 16-27-11-22W4 (1798.22 m), XPL, x2
F) Lower Big Valley: thrombolitic algal dolostone with interstitial gypsum crystals. 06-13-009-26W4 (2445.98 m), PPL, x2