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The Garbutt shale of the B.C. Liard Basin: A potential liquids-rich play?

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Summary

Rock-Eval analysis of samples from the organic-rich Radioactive Zone of the lower Garbutt Formation indicate that this horizon is: dominated by Type II kerogen; is currently within the oil generation or wet gas zones; and has average total organic carbon contents over 3 per cent. Subsurface mapping shows that the top of the Radioactive Zone occurs at a depth of between 1500 and 2000 m west of the Bovie structure and that the southern part of this area reaches thermal maturities within the wet gas zone (Tmax 450 to 460^{o} C).

Introduction

The Liard Basin straddles the British Columbia – Yukon – Northwest Territories border. This basin is bounded to the east by the Bovie structure, a feature which was likely first active in the mid-Paleozoic as a west-side-down extension structure and was then re-activated in the Mesozoic as an extension and contraction structure (MacLean and Morrow, 2004). The Liard Basin is defined by its thick successions of Carboniferous and Mesozoic clastic strata. In Liard Basin, late Early Cretaceous (Albian) marine shale of the Garbutt Formation represents a transgressive sequence which rests in sharp contact on fluvial to marine sediments of the Chinkeh Formation or unconformably on Triassic and older sediments (Ferri et al., 2011; Leckie and Potocki, 1998; Stott, 1982). This dominantly shale succession grades upwards into shallow marine shelf to shoreface siltstone and sandstone of the Scatter Formation (Leckie and Potocki, 1998). The Garbutt Formation is markedly thicker within the Liard Basin suggesting the Bovie structure was active during its deposition. The Garbutt Formation correlates, in part, with the Wilrich and Moosebar formations to the south (Stott, 1982).

In this poster, the Garbutt Formation has been subdivided into three units: 1) an upper shale sequence with minor siltstone and sandstone horizons (these transition into the overlying Scatter Formation); 2) an organic-rich, high gamma ray horizon (Radioactive Zone) and 3) a lower shale sequence.

Shale of the upper Garbutt Formation is micaceous, grey to grey-brown with uneven partings and has relatively uniform on log signatures. It is locally glauconitic and can contain siderite nodules. An organic-rich zone, informally termed the Radioactive Zone, occurs near the base of the Garbutt Formation (Leckie and Potocki, 1998; Chalmers and Bustin, 2008a, b; Ferri et al, 2011; Haeri Ardakani et al., 2015) and outwardly looks very similar to overlying upper Garbutt shales. It is distinguished not only by its higher gamma ray counts and organic contents, but also locally by the presence of multiple tuffaceous horizons which can be over 0.5 m in thickness. Mapping shows this zone to thicken dramatically across the Bovie structure. East of this structure, the Radioactive Zone is generally 10 to 20 m thick. At several localities it is absent and the overlying upper Garbutt is relatively thin. West of the Bovie structure, the Radioactive Zone can be up to 80 m thick. The thickening of this unit is accompanied by a decrease in the high gamma ray signature and a general decrease in organic content, probably due to sediment dilution.

On the west side of the Bovie structure, and along the southern part of the map area, the Radioactive Zone is underlain by a shale sequence displaying lower gamma ray levels but with a variability distinct from the monotonous signature of the upper Garbutt Formation. This unit is lithologically very similar to the upper Garbutt Formation, but has slightly higher organic carbon contents.

Subsurface mapping of the Garbutt and Scatter formations demonstrates that sediments supply was from the southwest during Garbutt times and that sediment input shifted to a more westerly source during deposition of the Scatter Formation. Isopach mapping clearly defines abrupt thickness increases west of the Bovie Lake Fault showing that this structure was active during deposition of these units. In addition, the lack of variation in isopach values along the southern extent of the Bovie structure suggests a decrease in motion along this structure during deposition of Garbutt. The top of the Garbutt Formation reaches depths greater than 2000 m in the core of the Liard Syncline west of the Bovie structure and the southern end of the Maxhamish area. Depths decrease quickly eastward across the Bovie structure where the top of the Garbutt Fm averages 200 to 300 m depths.

Rock-Eval Data

Rock-Eval data on core and cuttings samples across the Garbutt Formation indicate that it is dominated by Type II kerogen and that terrestrial Type III kerogen becomes more dominant in the west, closer to the sediment supply (Chalmers and Bustin, 2008a, b; Ferri et al, 2011; see Haeri Ardakani et al., 2015; for the detailed geochemical and petrological characterization of Garbutt cores). Although this sampling is not systematic, average ranges for the various units of the Garbutt Formation are:

Total Organic Contents (weight per cent) Garbutt Formation:

Unit	Range*	Average
Upper Garbutt Formation	0.7 to 3.2 % (n=274)	1.5 %
Radioactive Zone	0.6 to 15.1 % (n=269)	3.1 %
Lower Garbutt Formation	0.6 to 2.9 % (n=80)	1.8 %

*Ferri et al., 2013; Walsh and McPhail, 2007; McMechan et al., 2013; Obemajer et al., 2012

Thermal maturation trends for the Garbutt Formation, based on Tmax values, are markedly different on either side of Bovie structure, likely reflecting the level of burial attained by the unit. Although data is very sparse east of the Bovie structure, the Radioactive Zone is undermature in the north and enters the oil window towards the south. West of the Bovie structure, thermal maturities are lowest just west of the northern trace of the structure where organic matter within the Radioactive Zone has just entered the oil window. Thermal maturity increases to the southwest and Tmax values reach approximately 460^{o} C, which is within the wet gas zone for Type II kerogen. This wet gas zone also corresponds to areas where the Radioactive Zone is currently at its deepest levels, roughly 2000 m. Although the Radioactive Zone is relatively deep just west of the northern part of the Bovie structure, thermal maturities are much lower suggesting either greater burial and uplift in the southwest and/or a lower geothermal gradient to the north.

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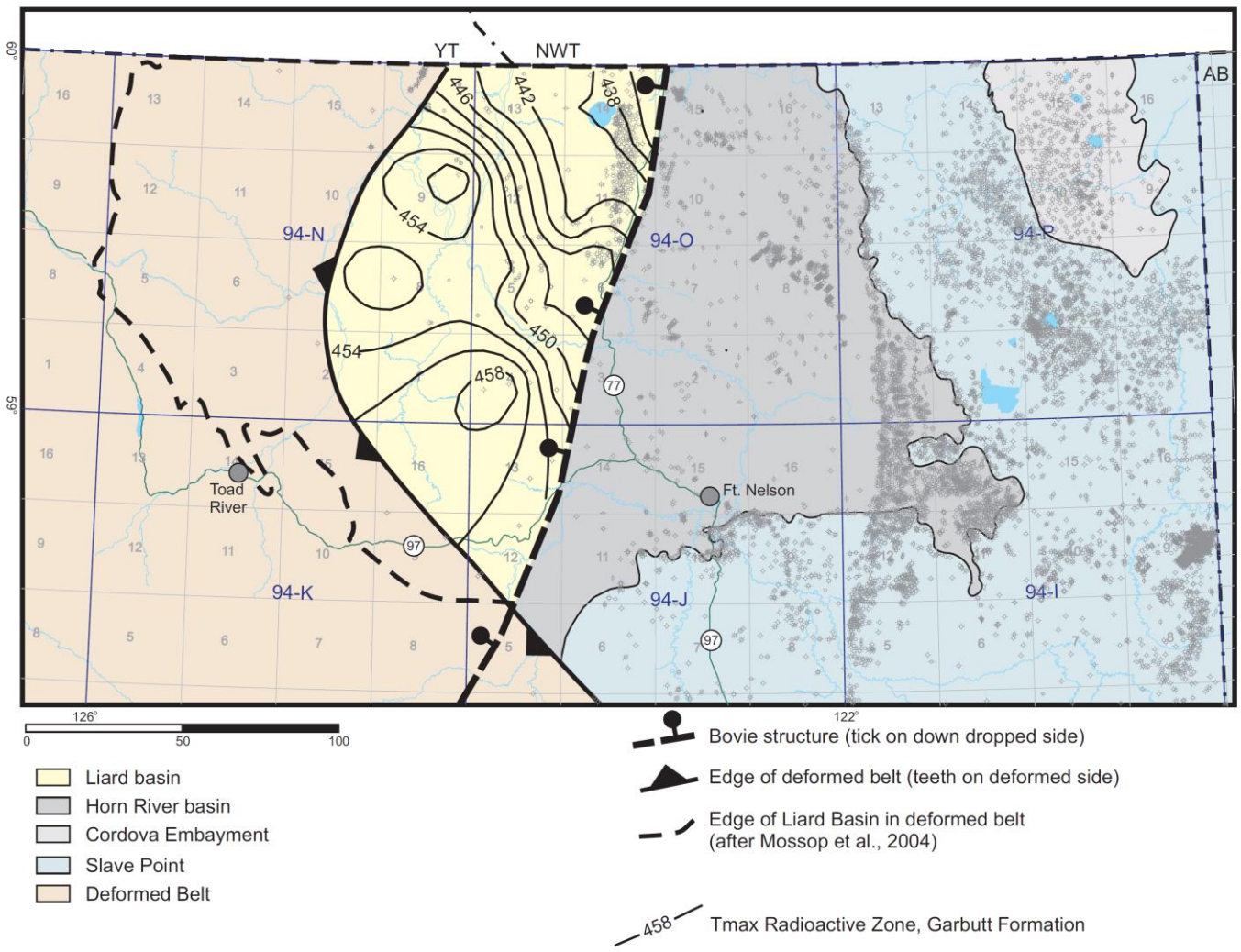

Location of the Liard Basin in northeast BC with average Tmax values within the Garbutt Formation. Note that the highest values occur in the southern half of the Liard Basin.