

## Liard Basin Hydrocarbon Project: Shale Gas Potential of Devonian-Carboniferous Strata in the Northwest Territories, Yukon and Northeastern British Columbia

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### Summary

The Liard Basin Hydrocarbon Project was initiated in 2012 to examine the shale gas potential of Middle Devonian to Carboniferous strata based on integrated subsurface and outcrop-based field studies. The project is a collaboration of the Northwest Territories Geoscience Office (NTGO) with the Yukon Geological Survey, the British Columbia Ministry of Energy, Mines and Natural Gas and the Geological Survey of Canada. The primary objective of the project is to evaluate source rocks and refine stratigraphic correlation within the basinal succession of the Middle to Upper Devonian Besa River Formation and its Horn River "Formation" equivalents (Evie, Otter Park, and Muskwa members), as well as the Upper Devonian to Mississippian Exshaw Formation and Mississippian Golata Formation. The Liard Basin lies within three jurisdictions: the Northwest Territories (NT), Yukon (YK) and British Columbia (BC). In northeast BC it hosts several gas fields but remains largely underexplored in the NT and YK. During the initial field season, more than 500 m of strata were measured and described from three sections: 1) Golata Formation in the NT; 2) Besa River Formation in the YK; and 3) Besa River Formation in northeast BC. A detailed lithologic description was completed for each section and spectral gamma-radiation counts measured with a handheld spectrometer at one-metre intervals. Shale chip samples were collected at two-metre intervals for: Rock-Eval/total organic carbon (RE/TOC), vitrinite reflectance (VR), lithochem, X-ray diffraction mineralogy (XRD), and microfossil biostratigraphy.

## Introduction

The Liard Basin lies within the eastern Canadian Cordillera and consists of broadly folded Paleozoic and Mesozoic strata. It preserves a thick succession of basin strata west of the Bovie Fault, where prospective Devonian shale gas horizons have been dropped relative to their position in the Horn River Basin to the east (Fig. 1; Ferri et al., 2012b). The western border of the Liard Basin is the deformed Proterozoic and Paleozoic strata of the Selwyn Fold Belt. Its boundary to the north is defined by the limits of the Mattson Formation of the Mackenzie and Franklin Mountains in the NT and to the south by the time-equivalent strata of the Stoddard Group of the Rocky Mountains in BC.

Gas has been found structurally trapped in Devonian and/or Mississippian strata in the Liard Basin in conventional reservoirs at Beaver River (northeast BC), Kotaneelee (YK), Pointed Mountain (NT) and Liard (NT). From 2009 to 2012, Apache Corporation drilled and validated a new unconventional Devonian age Besa River shale gas play in the Liard Basin of northeastern BC with net estimated sales gas of 48 TCF over an area of 430,000 acres (Apache, 2013). Apache's D-34-K/94-O-5 well had a thirty day initial production rate of 21 mmcfpd and has been called "the most prolific shale gas resource test in the world" (Vanderklippe, 2012; Apache, 2012; 2013). Exploration targets for Devonian shale gas have been identified by EFL Overseas Inc. (EFL Overseas Inc., 2013) at Kotaneelee (YK) and by Lone Pine Resources Inc. at Pointed Mountain (NT) (Globe and Mail, 2011; Lone Pine Resources Inc., 2013 and EFL Overseas Inc., 2013). The Lone Pine Resources Inc. website has a current post that states:

As of December 31, 2011, we had approximately 52,995 net acres in the Liard Basin, located in the Northwest Territories, that are prospective for the Muskwa Shale. This is a newly developing natural gas shale play adjacent to the producing Horn River Basin. We believe that our acreage in the Liard Basin is analogous to the Muskwa Shale in the Horn River Basin....In the third and fourth quarters of 2011, we re-entered and recompleted a well in the Liard Basin and intend to submit an application to the National Energy Board to potentially continue the lease for up to 21 more years (Lone Pine Resources, 2013).

More than 400 wells have been drilled in northeastern British Columbia, but the basin remains underexplored in the NT (81 wells) and YK (13 wells; Fig.1). If the Kotaneelee and Pointed Mountain unconventional Devonian shale gas targets are successful, Apache's productive Besa River shale gas trend might extend well into southeastern YK and southwestern NT.

The Liard Basin Hydrocarbon Project is focused on the Middle Devonian to Carboniferous age Besa River and Golata shale formations. The Besa River Formation overlies the middle Devonian Dunedin-Nahanni Formation carbonate and contains the basinal equivalents to the platform carbonate succession of the Upper Keg River to Debolt formations (Figs. 2, 3; Ferri et al., 2011). The Besa River Formation also contains facies equivalents to the Horn River, Muskwa, Exshaw, and Golata formations. The upper part of both the Besa River and Golata formations are gradational with the Middle to Late Mississippian Mattson Formation (Fig. 4; Richards, 1989).

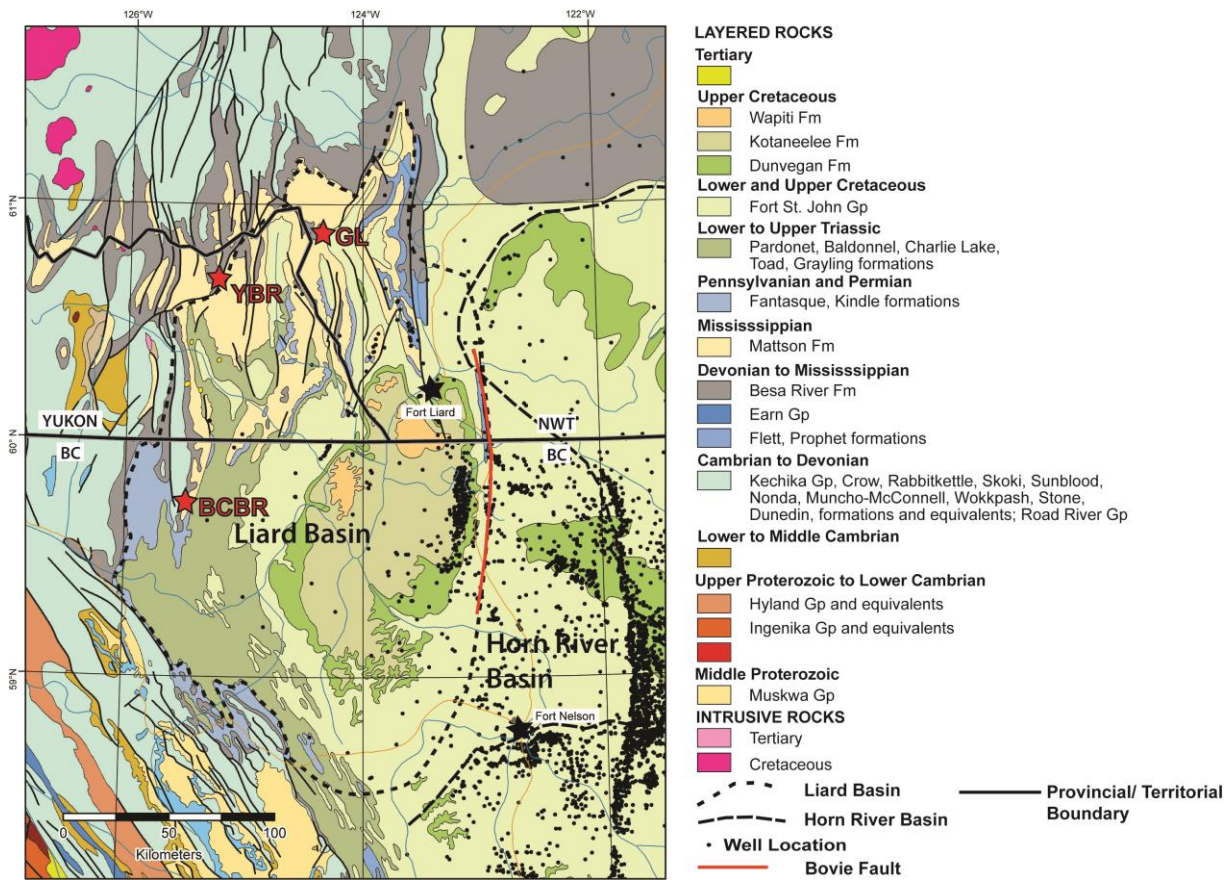


Figure 1: Geology map of the Liard Basin region. This map also shows the Horn River Basin, oil and gas wells, territorial and provincial boundaries, Bovie Fault and stratigraphic sections measured in 2012. GL - Golata Section, NT; YBR - Besa River Section, YK; BCBR - Besa River Section, BC (after Ferri et al., 2012b).

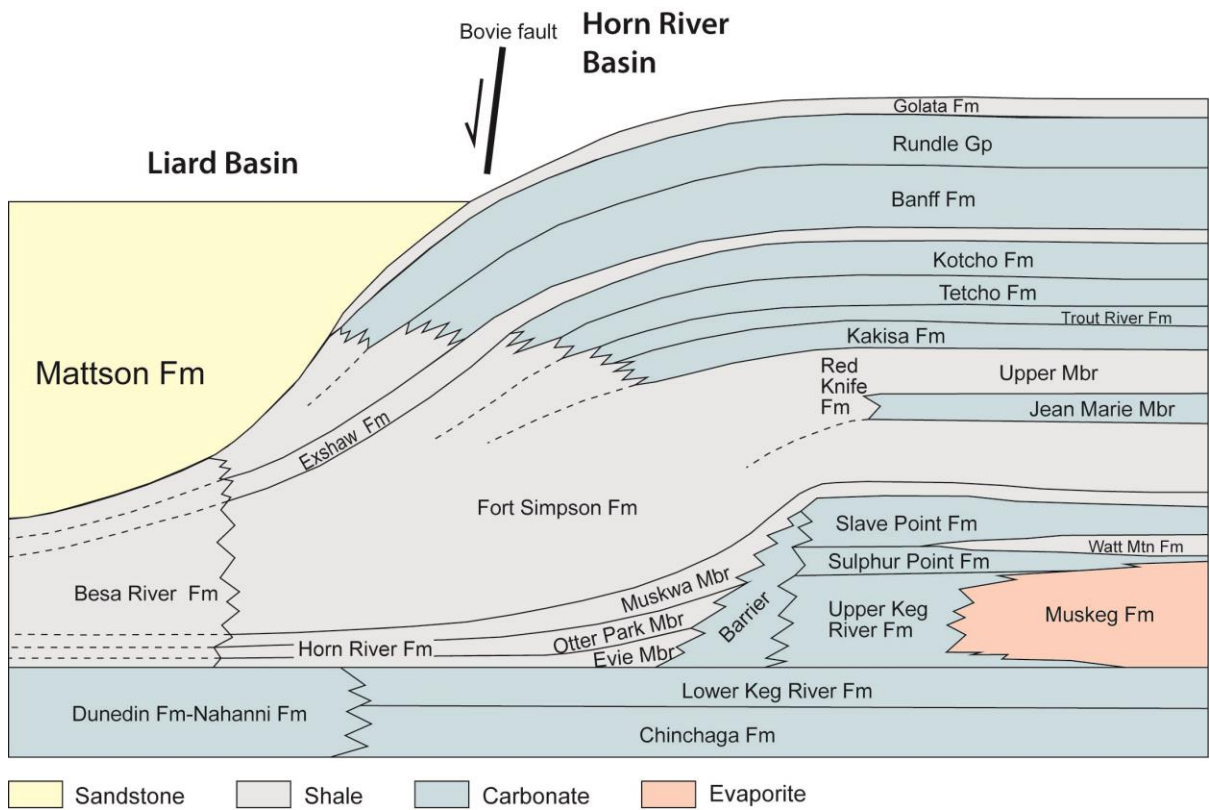
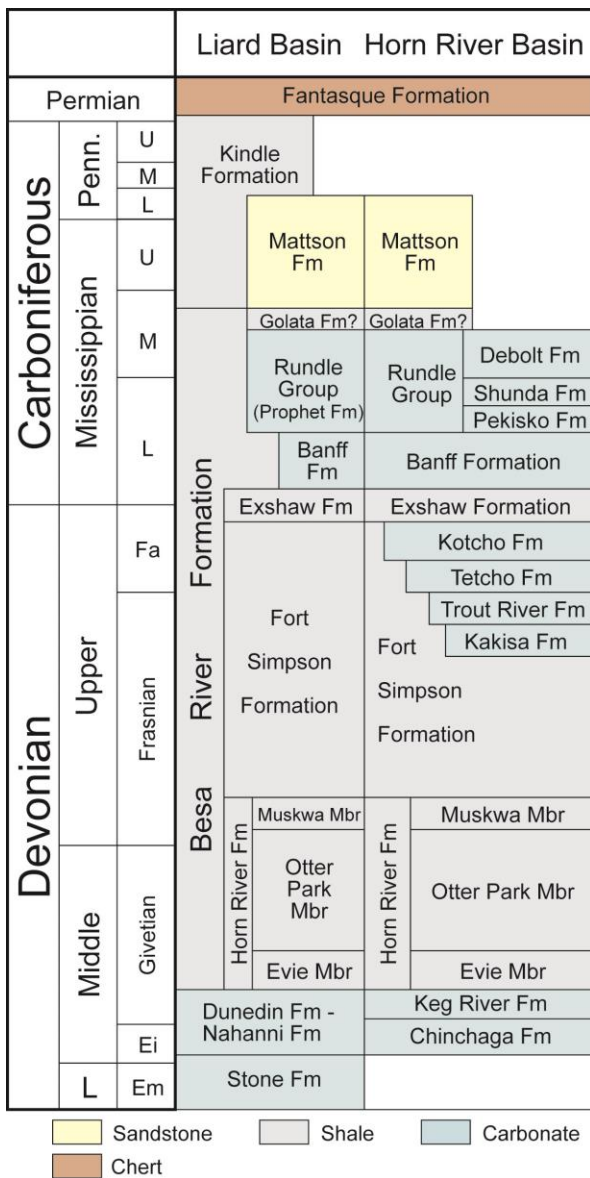


Figure 2: Schematic cross-section west to east across the Bovie Fault (Fig.1) showing relative thickness variations between Middle to Upper Paleozoic shelf and offshore succession (after Ferri et al., 2011). Age of units is indicated in Fig. 3.



Sandstone
  Shale
  Carbonate
  Chert

Figure 3: Time stratigraphic chart of middle to upper Paleozoic strata showing main stratigraphic units in Liard and Horn River basins (after Ferri et al., 2011).

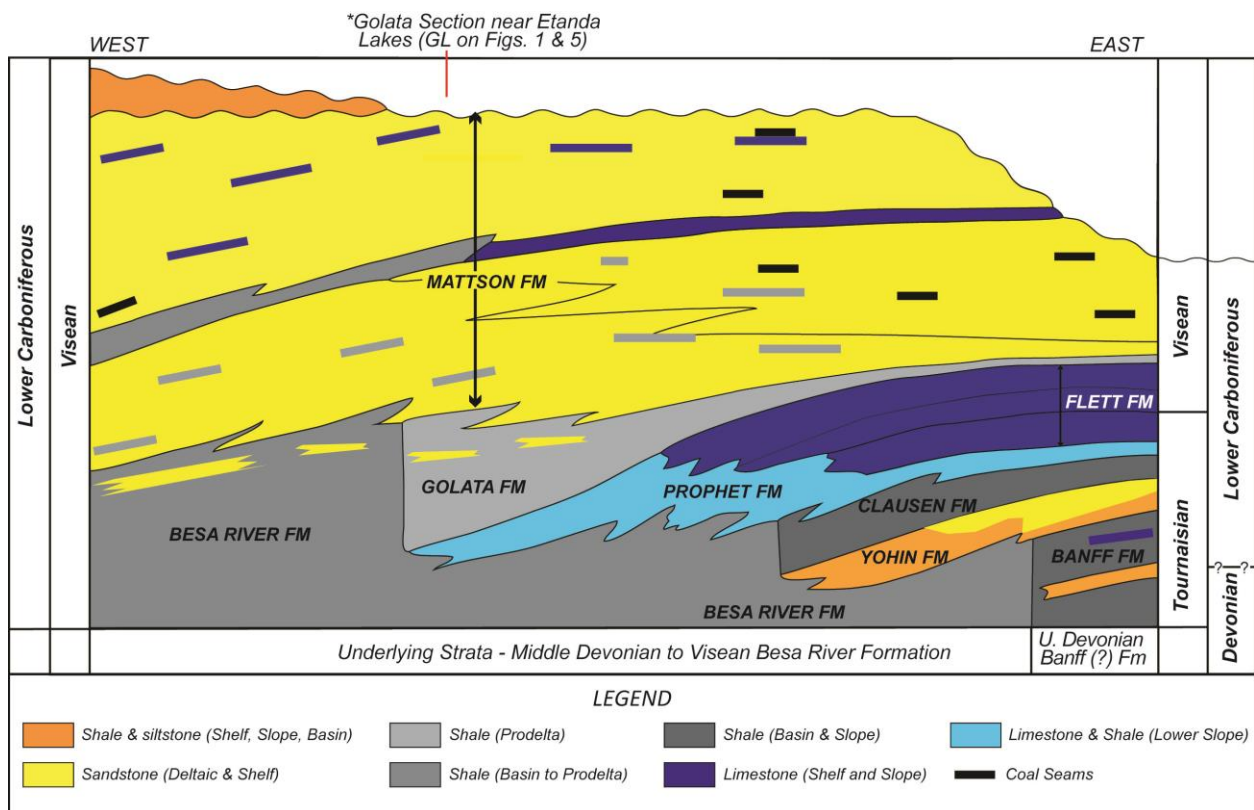


Figure 4: Schematic West (YK) to East (NT) cross-section across the study area showing the approximate location of the Golata Section (Fig. 5) near Etanda Lakes, NT (after Richards, 1989).

## Methods

An initial phase of field scoping and sample collection took place in July 2012. The project team focused its efforts in the Liard Plateau exploration region in southwestern NT, southeastern YK and northeastern BC. Over 500 m of strata from three sections were examined (Fig. 5): 1) lower Golata Formation between the Prophet and Mattson formations in the NT (N60.846, W124.375); 2) middle Besa River Formation in the YK between Devonian carbonate and Mattson Formation (N60.730, W125.232); and 3) lower to middle Besa River Formation in BC between the Dunedin and Mattson formations (N59.712, W125.515). The field program involved collection of data to determine source rock characteristics and to aid in regional correlation between other surface sections and subsurface wells.

Detailed lithologic descriptions were completed at each section. Spectral gamma radiation counts were measured with a handheld spectrometer at one-metre intervals. Shale chip samples were collected at two-metre intervals for the following assessments: 1) evaluation of organic-rich shale for source rock potential (Rock-Eval, total organic carbon, and vitrinite reflectance); 2) X-ray diffraction mineralogy; 3) whole rock geochemistry; and 4) microfossil biostratigraphy using radiolarians and conodonts. Preliminary results are forthcoming in Spring 2013.

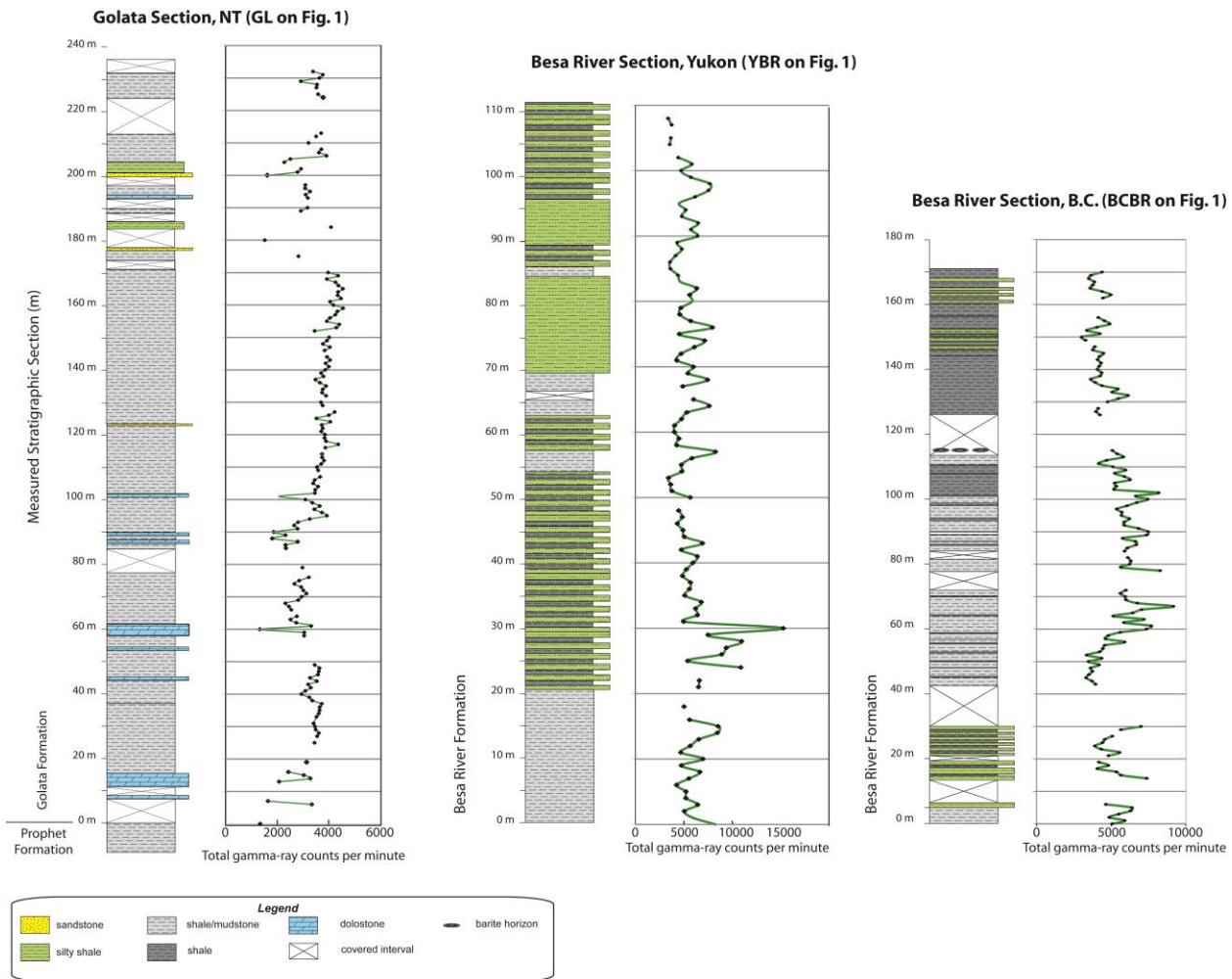


Figure 5: Measured stratigraphic sections from the 2012 field season, including the Golata Formation (NT) and Besa River Formation (YK and BC). Total gamma-ray count curves are plotted beside each section (Ferri et al, 2012b; Fraser et al., 2013).

## Previous Work

While the Liard Basin has been largely underexplored north of BC, Devonian strata of the Besa River Formation and its equivalents have been the focus of several studies in the past. One of the first characterizations of the Besa River Formation in the Liard Basin of northeast BC by Pelzer (1966) used mineralogical, geochemical and stratigraphic data to correlate the Besa River Formation and its equivalent strata from 58N to just south of the border between BC and YK. Morrow et al. (1993) published vitrinite reflectance, total organic carbon and Tmax data for several wells and outcrops in the Liard Basin of the NT and YK that included portions of the Besa River Formation. Isopach maps of the Besa River Formation and its submembers in the Liard Basin were produced from limited well log data by Ross and Bustin (2008). Ferri et al. (2011, 2012a) measured two sections of the Besa River Formation in the Liard Basin in northeast BC and correlated several subunits into the subsurface using nearby well log data.

## Conclusions

During the 2012 field season, more than 500 m of Middle Devonian to Carboniferous age strata from three sections were measured and described, one each from the NT, YK and BC. Preliminary results are forthcoming in Spring 2013. The goals of the NT/YK/BC research team are to evaluate source rocks and refine stratigraphic correlation within the basinal succession of the Middle to Upper Devonian Besa River Formation and its Horn River Formation equivalents; Evie, Otter Park and Muskwa Members as well as the Upper Devonian to Mississippian Exshaw Formation and Mississippian Golata Formation. In addition, analytical results will be reported on and published in each jurisdiction. The Northwest Territories Geoscience Office will publish forthcoming results on our website at <http://www.NTgeoscience.ca/>.

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## References

Apache Corporation, 2013. Liard Basin: 48 TCF, best unconventional gas reservoir in North America. URL << [http://www.apachecorp.com/Operations/Resource\\_rich\\_in\\_North\\_America/Liard\\_Basin/index.aspx](http://www.apachecorp.com/Operations/Resource_rich_in_North_America/Liard_Basin/index.aspx)>> accessed January 9, 2013.

Apache Corporation, 2012. Liard Basin: 48 TCF, best unconventional gas reservoir in North America. URL << [http://api.ning.com/files/4Ox1VC64MH0G0Lm4-LhZzEGWfD\\*Sz-UV9YrY6\\*5mvmJGGFXxVJTMzjEKj6XlvEXaHkexyd4jVT6jnKsLf2U0mFLZeCoGLJV/ApacheLiardShale.pdf](http://api.ning.com/files/4Ox1VC64MH0G0Lm4-LhZzEGWfD*Sz-UV9YrY6*5mvmJGGFXxVJTMzjEKj6XlvEXaHkexyd4jVT6jnKsLf2U0mFLZeCoGLJV/ApacheLiardShale.pdf)>> Adobe file downloaded January 9, 2013.

EFL Overseas Inc., 2013. Investor Presentation. URL [http://www.efloenergy.com/\\_resources/2013-01-03\\_EFLO\\_FINAL\\_Investor\\_Presentation\\_Taylor\\_Dejongh\\_format.pdf](http://www.efloenergy.com/_resources/2013-01-03_EFLO_FINAL_Investor_Presentation_Taylor_Dejongh_format.pdf)>> Adobe file downloaded January 9, 2013.

Ferri, F., Hickin, A.S. and Reyes, J., 2012a, Horn River basin—equivalent strata in Besa River Formation shale, northeastern British Columbia (NTS 094K/15): in Geoscience Reports 2012, British Columbia Ministry of Energy and Mines, p. 1–15.

Ferri, F., Fraser, T.L., Fiess, K.M., and Pyle, L.J., 2012b, Liard Basin Petroleum Project: shale gas potential of Devonian-Carboniferous strata in Yukon, Northwest Territories and northeast British Columbia: in 40th Annual Yellowknife Geoscience Forum Abstracts of Talks and Posters.

Ferri, F., Hickin, A.S., and Huntley, D.H., 2011, Besa River Formation, western Liard Basin, British Columbia (NTS 094N): geochemistry and regional correlations: Geoscience Reports 2011, British Columbia Ministry of Energy and Mines, 1-18.

Fraser, T., Ferri, F., Fiess, K., and Pyle, L., 2013, Besa River Formation in Liard basin, southeast Yukon: report on 2012 reconnaissance fieldwork: in Yukon Exploration and Geology 2012, K.E. MacFarlane and M.G. Nordling (eds.), Yukon Geological Survey.

Globe and Mail, 2011. Lone Pine Resources Announces \$ 75 Million Borrowing Base Increase, Third Quarter Operational Update, Board of Directors Changes and Executive Appointment. URL<< <http://www.theglobeandmail.com/globe-investor/news-sources/?date=20110921&archive=ccnm&slug=20110921073065001>>> accessed January 9, 2013.



Lone Pine Resources Inc. 2013. Significant Properties, Shales. URL<<<http://www.lonpineresources.com/operations/significant-properties/>>> accessed January 9, 2013.

Morrow, D.W., Potter, J., Richards, B., and Goodarzi, F., 1993, Paleozoic burial and organic maturation in the Liard Basin region, northern Canada: *Bulletin of Canadian Petroleum Geology*, **41**(1), 17-31.

Pelzer, E.E., 1966, Mineralogy, geochemistry and stratigraphy of the Besa River Shale, British Columbia: *Bulletin of Canadian Petroleum Geology*, **14**(2), 273-321.

Richards, B.C., 1989, Uppermost Devonian and Lower Carboniferous Stratigraphy, Sedimentation, and Diagenesis, Southwestern District of Mackenzie and Southeastern Yukon Territory: *Geological Survey of Canada Bulletin* 390, 135 p.

Ross, D.J.K., Bustin, R.M., 2008, Characterizing the shale gas potential of Devonian-Mississippian strata in the Western Canada sedimentary basin: application of an integrated formation evaluation: *AAPG Bulletin*, **92**(1), 87-125.

Vanderklippe, N., 2012, Massive B.C. reservoir could double gas output: *Globe and Mail* article, June 14.