

Overpressure detection in the Beaufort-Mackenzie Basin, northern Canada, using an integrated approach

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Summary

The Beaufort-Mackenzie Basin is a late Cretaceous-Cenozoic post-rift basin that is composed of a series of normally pressured and overpressured, folded and faulted deltaic complexes. It extends northward from the onshore Mackenzie Delta to the outer shelf and slope beneath the Beaufort Sea in Arctic Canada. Overpressure is associated with rapid sediment accumulation, undercompacted shale, shale diapirism, and major fault systems (Hitchon et al., 1990; Issler, 1992; Issler et al., 2002; Chen et al., 2010). More than 280 wells have been drilled in the basin and studies by the GSC demonstrate the strong association between overpressure and shale porosity trends within Cenozoic strata that are detectable using multiple well logs (Issler, 1992; Katsube and Issler, 1993; Issler and Katsube, 1994; Katsube et al., 1995, 1996, 2011; Issler et al., 2002). Previously, Issler et al. (2011) mapped the distribution of overpressure at well locations using fluid pressure and shale log data.

This study focuses on overpressure detection in the Beaufort-Mackenzie Basin by employing an integrated approach that combines geophysical, drilling, and well testing data from petroleum exploration wells. It not only presents detailed documentation of the large comprehensive datasets and refined interpretations for the top of the overpressure zone in exploration wells (Hu et al., 2021), but it also presents stratigraphic frameworks to illustrate the distributions of the detected overpressure along schematic stratigraphic cross sections throughout the basin.

One hundred and fifty-two depths to the top of overpressure were determined for 112 wells based on the integrated analysis of the proposed multi-parameter data (well logs, well seismic interval velocity, mud weight, and pressure test), most of which were confirmed by formation pressure tests, and the overpressure interpretations were ranked according to a quality assessment scheme. Overall, well logs and log-derived formation properties in shale sections are good indicators of overpressure. However, the most reliable and consistent geophysical parameters for detecting overpressure are shale sonic transit-time (and its porosity) and continuous sonic velocity because of the abundance of these data and the sensitivity of rock acoustic properties to porosity and stress. In general, mud pressure trends calculated from drilling mud weight data are mostly consistent with overpressure interpretations from geophysical data and fluid pressure measurements.

The interpreted depth to the top of overpressure varies from <1000 to over 4500 m (GL/SL) and is largely confined to undercompacted sediments in the central-northern delta and offshore areas. The top of overpressure is predominantly restricted to the Paleocene-Eocene Aklak, Taglu and

Richards sequences on Richards Island, and occurs in progressively younger strata northward in the offshore toward the outer shelf. In the central shelf region, the top of overpressure is mainly within the Richards and Kugmallit sequences, while it rises above the base of the thick Pliocene-Pleistocene Iperk Sequence in the outer shelf.

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References

- Chen, Z., Osadetz, K.G., Issler, D.R. and Grasby, S.E. 2010. Fluid pressure patterns in Tertiary successions and hydrodynamic implications, Beaufort-Mackenzie Basin, Canada. *Bulletin of Canadian Petroleum Geology*, v. 58, no. 1, p. 3-16.
- Hitchon, B., Underschultz, J.R., Bachu, S. and Sauveplane, C.M. 1990. Hydrogeology, Geopressures and Hydrocarbon Occurrences, Beaufort-Mackenzie Basin. *Bulletin of Canadian Petroleum Geology*, v. 38, no. 2, p. 215-235.
- Hu, K., Issler, D.R., Chen, Z., Dietrich, J. 2021. Overpressure detection from geophysical, drilling and well-testing data for petroleum exploration wells in the Beaufort-Mackenzie Basin, Yukon and Northwest Territories; Geological Survey of Canada, Open File 6692, 1 .zip file. <https://doi.org/10.4095/327948>
- Issler, D.R., Hu, K., Lane, L.S. and Dietrich, J.R. 2011. GIS Compilations of Overpressure, Permafrost Distribution, Geothermal Gradient, and Geology, Beaufort-Mackenzie Region, Northern Canada. Geological Survey of Canada, Open File 5689 (1 CD-ROM), <https://doi.org/10.4095/289113>
- Issler, D.R., Katsube, T.J., Bloch, J.D. and McNeil, D.H. 2002. Shale compaction and overpressure in the Beaufort-Mackenzie Basin of northern Canada. Geological Survey of Canada, Open File 4192, 10 p. (1 diskette) <https://doi.org/10.4095/213052>
- Issler, D.R. 1992. A new approach to shale compaction and stratigraphic restoration, Beaufort-Mackenzie Basin and Mackenzie Corridor, northern Canada. *AAPG Bulletin*, v. 76, p. 1170-1189. 36
- Issler, D.R. and Katsube, T.J. 1994. Effective porosity of shale samples from the Beaufort-Mackenzie Basin. In: *Current Research, 1994-B*, Geological Survey of Canada, p. 19-26. <https://doi.org/10.4095/193649>
- Katsube, T.J., Issler, D.R. and Connell-Madore, S. 2011. Porosity characteristics of shale samples for varied compaction zones in the Beaufort-Mackenzie Basin, Northwest Territories. Geological Survey of Canada, *Current Research (Online)* no. 2011-12, 14 p. <https://doi.org/10.4095/289040>
- Katsube, T.J., Issler, D.R. and Coyner, K. 1996. Petrophysical characteristics of shale from the Beaufort-Mackenzie Basin, northern Canada: permeability, formation factor and porosity vs. pressure. In: *Current Research 1996-B*; Geological Survey of Canada, p. 45-50. <https://doi.org/10.4095/207430>
- Katsube, T.J., Bloch, J.D. and Issler, D.R. 1995. Shale pore-structure evolution under variable sedimentation rates in the Beaufort-Mackenzie Basin. In: Bell, J.S., Bird, T.D., Hillier, T.L. and Greener, P.L. (eds.), *Proceedings of the Oil and Gas Forum '95 - Energy from Sediments*, Geological Survey of Canada Open File 3058, p. 211-215. <https://doi.org/10.4095/203623>
- Katsube, T.J. and Issler, D.R. 1993. Pore-size distributions of shales from the Beaufort-Mackenzie Basin, northern Canada. In: *Current Research, Part E*, Geological Survey of Canada, Paper 93-1E, p. 123-132. <https://doi.org/10.4095/184104>