Hydrogen Sulphide within the Triassic Montney Formation, Northeastern British Columbia and Northwestern Alberta (NTS 083K–N, 084C–F, 093I, J, O, P, 094A, B, G, H)

G.R.L. Chalmers, The University of British Columbia, Vancouver, British Columbia, garethchalmers@gmail.com

R.M. Bustin, The University of British Columbia, Vancouver, British Columbia

A.A. Bustin, The University of British Columbia, Vancouver, British Columbia

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Introduction

The Triassic Montney Formation is a large unconventional gas play in western Canada and contributed a significant proportion (34%) of natural gas to the total Canadian gas production in 2017 (National Energy Board, 2018). The Montney Formation is a tight liquids-rich gas reservoir in northeastern British Columbia (BC) with a gas-in-place estimate of 55 642 billion cubic metres (1965 tcf; BC Oil and Gas Commission, 2015). As development expands, a greater proportion of the Montney Formation is found to contain nonhydrocarbon gases such as hydrogen sulphide (H_2S) and carbon dioxide (CO_2). The authors currently estimate 27% of the Montney Formation producing wells have tested or produced greater than 100 ppm of H_2S gas. Hydrogen sulphide gas impacts the economics of the development of this hydrocarbon play as well as poses a risk to the environment and the health and safety of the populace. Hydrogen sulphide in produced gas, even in trace amounts (i.e., ppm), impacts the economics of drilling, production, treatment, and marketing of gas and associated liquids. The occurrence of H_2S in produced fluids is also one of the most serious environmental hazards and risks to gas resource development.

The stratigraphic and lateral variation in H_2S changes across the Montney gas play areas in BC. The distribution, in some areas, can be inexplicable and there are multiple reasons for the presence of H_2S in some Montney Formation producing wells. Hydrogen sulphide in petroleum systems comes from mixed sources, which include: 1) bacterial sulphate reduction; 2) thermal sulphate reduction; 3) kerogen cracking; and 4) sulphide oxidation and/or decomposition of surfactants used for well completions. Understanding H_2S distribution is further complicated by the fact that H_2S can be produced in situ within the Montney reservoir or may have migrated either from above or below through more permeable beds or fracture networks.

To reduce the uncertainty associated with H_2S production from the Montney reservoir, the source and processes that generate H_2S need to be understood, which will require: a) mapping lateral and stratigraphic distributions of H_2S and b) determining the sulphur isotopic composition of H_2S gas, as well as the potential sulphur sources (kerogen, pyrite, anhydrite).

Results

The Montney Formation is over 200 m thick within the study area (Figure 1) and the authors have informally subdivided the formation into the upper, middle and lower Montney members (Figure 2). These subdivisions are based on the sequence-stratigraphic–based boundaries of Davies et al. (2018). The thickness of the informal upper, middle and lower Montney members have been mapped across the study area (Figures 3–5). Using geoLOGIC systems ltd.'s geoSCOUT version 8.8 (geoLOGIC systems ltd., 2019) GIS software, well search criteria were set to identify Montney producers that have tested or produced sour gas (presence of H_2S). The H_2S distribution within the Montney play area of BC and Alberta has been mapped using the thickness data from the geological models (Figures 6–8) in combination with the fluid analysis data from geoSCOUT.

Thickness Maps of the Upper, Middle and Lower Members of the Montney Formation

A total of 200 well tops were used to map the thickness (isochore) variation for the informal upper Montney (Figure 3), middle Montney (Figure 4) and lower Montney (Figure 5) members of the Montney Formation. The thickness of the upper Montney member increases toward the

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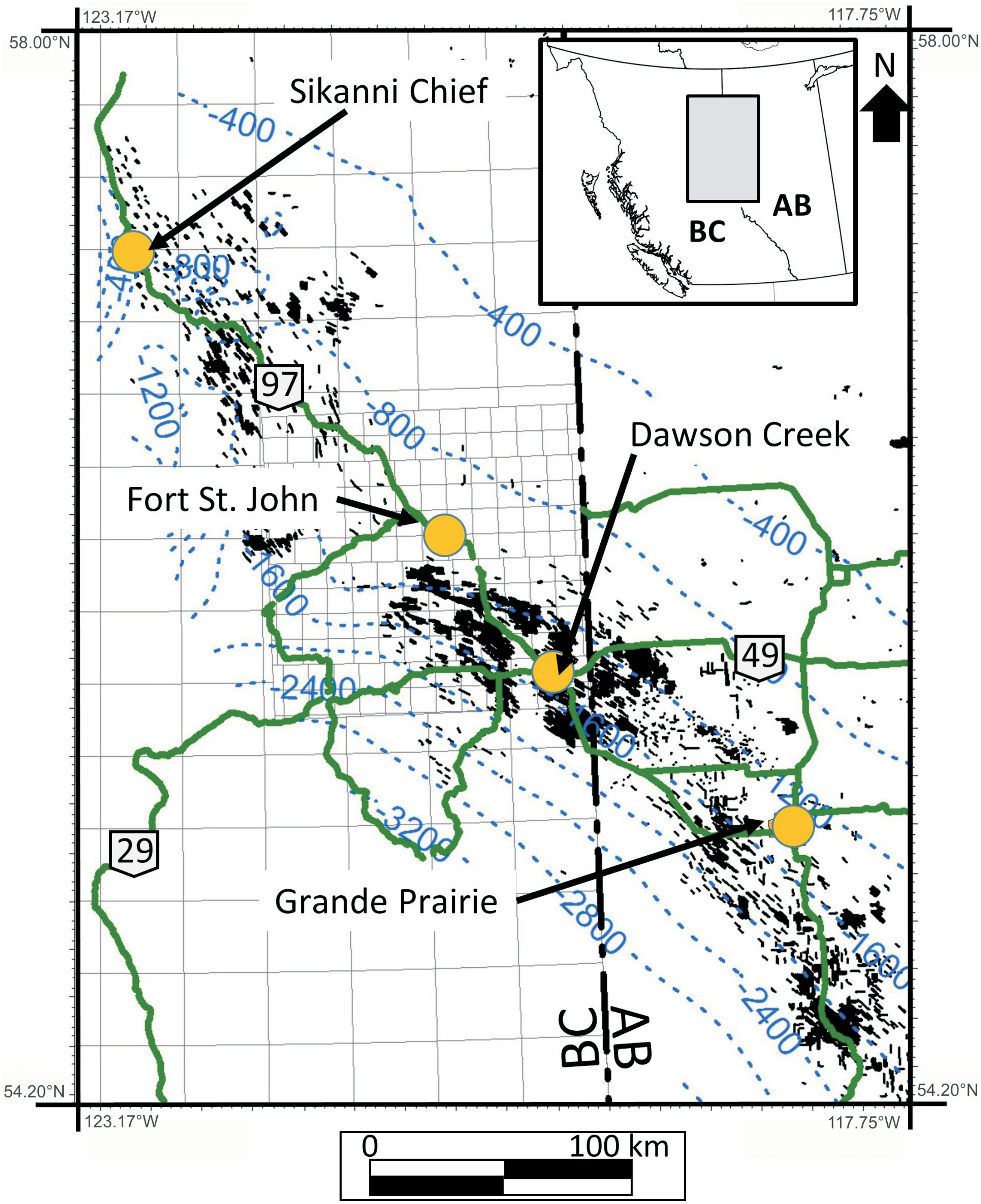

Figure 1. Location of the study area (grey box) within northeastern British Columbia and northwestern Alberta. The depth to the top of the Montney Formation is shown as blue dashed lines and is measured as subsea total vertical depth (metres). The black well traces are for all Montney Formation producing, tested or produced wells. Orange circles represent major population centres in the region and the dark grey lines are the primary roads. Data sourced from geoLOGIC systems ltd. (2019).

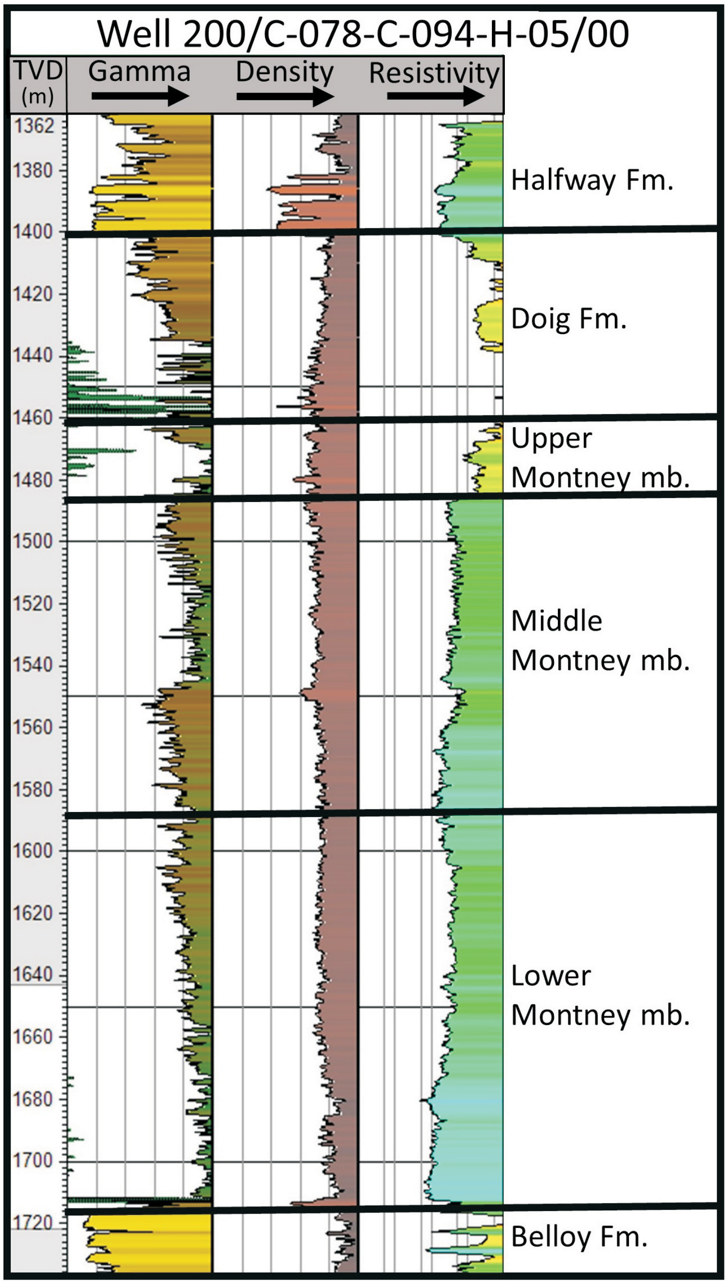

Figure 2. Stratigraphy and log response of the Halfway, Doig, Montney and Belloy formations in well 200/C-078-C-094-H-05/00 (geoLOGIC systems ltd., 2019). The Montney Formation is informally subdivided into the upper, middle and lower Montney members based on a sequence stratigraphic model of Davies et al. (2018). Abbreviation: TVD, total vertical depth.

southwest, from approximately 2 m thick in the eastern part of the study area to over 330 m adjacent to the deformation front along the western margin of the study area (Figure 3). The middle Montney member shows similar distribution as the upper Montney member but remains consistently thicker (i.e., >100 m) across the majority of BC and west-central Alberta (Figure 4). The lower Montney member is the thinnest member of the Montney Formation and is less than 90 m thick across the majority of the study area with the greatest thicknesses of over 120 m along the western margin of the study area (Figure 5).

Hydrogen Sulphide Distribution within the Montney Formation

A total of 2813 wells have been identified that either tested for, produced or currently produce sour gas within the study area (Figures 6–8; geoLOGIC systems ltd., 2019). The H_2S concentrations vary widely across the study area and range from 212 500 ppm (21.25%) to <100 ppm. There are more sour Montney Formation wells in Alberta and they also span a greater geographic area than in BC. The presence of H_2S also varies stratigraphically, with the majority of sour horizontal wells being drilled in the informal upper and middle Montney members of the Montney Formation in BC (Figures 6, 7). The majority of sour wells in Alberta are within the middle and lower Montney members of the Montney Formation (Figures 7, 8). The upper Montney member thins to 1–2 m within Alberta, which is the reason for the low number of upper Montney member sour wells in Alberta. Comparing the Montney members, most sour wells are located within the middle Montney member, which also covers the largest geographic area in both Alberta and BC. There are also more sour wells drilled within the lower Montney member compared to the upper Montney member (Figures 6, 8).

Distribution of Hydrogen Sulphide Above and Below the Montney Formation

Hydrogen sulphide in the Montney Formation can be generated in two ways: 1) via sourcing elemental sulphur from within the reservoir as either sulphate, sulphide or organic sulphur, or 2) from migration of hydrogen sulphide from either above or below the reservoir through conduits like natural fractures, faults or permeable beds. Elemental sulphur within the Montney Formation can either be formed in situ from Triassic seawater or postdepositionally from migration of sulphate in solution. The major sources of sulphate occur above the Montney Formation in the Triassic Charlie Lake Formation and below in the Permian, Mississippian and Devonian rocks (i.e., Belloy, Debolt, Slave Point, Muskeg formations). Using geoSCOUT version 8.8, fluid analysis module, the sour wells that have either tested for, produced or are producing H_2S gas from both above (Figure 9) and below (Figure 10) the Montney Formation have been mapped to understand the potential risk of producing sour gas within the Montney Formation. A stronger overlap occurs

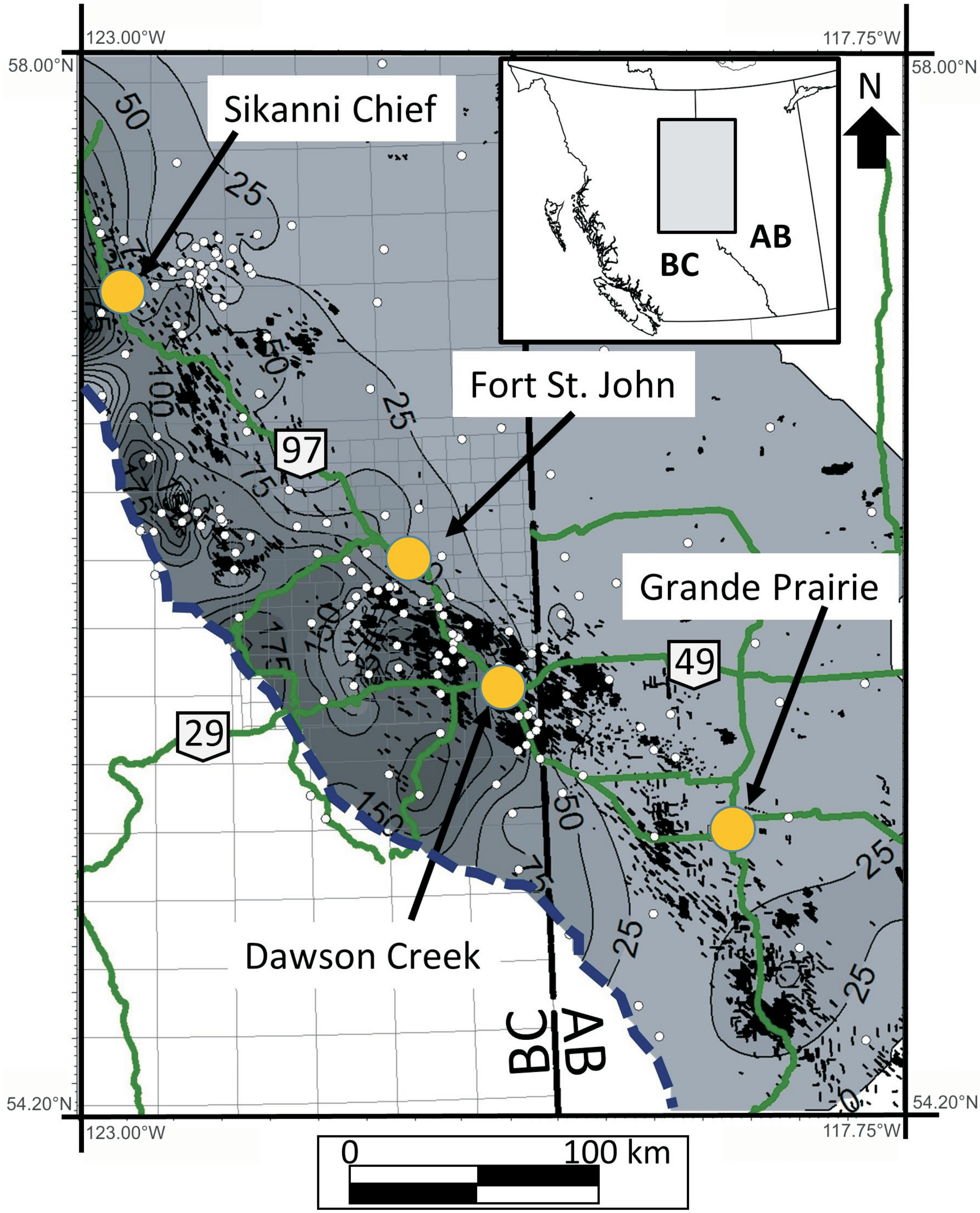

Figure 3. Thickness variation of the informal upper Montney member of the Montney Formation across the regional gas play in northeastern British Columbia and northwestern Alberta. The thickness varies from 338 m in the northwestern part of the study area to less than 2 m in the eastern part of the study area. White filled circles are the well control for thickness contours. Contour interval is 25 m. The black well traces are for all Montney Formation producing, tested or produced wells. Orange circles represent major population centres in the region and the green lines are the primary roads. Blue dashed line is the deformation front (approximate location). Data sourced from geoLOGIC systems ltd. (2019).

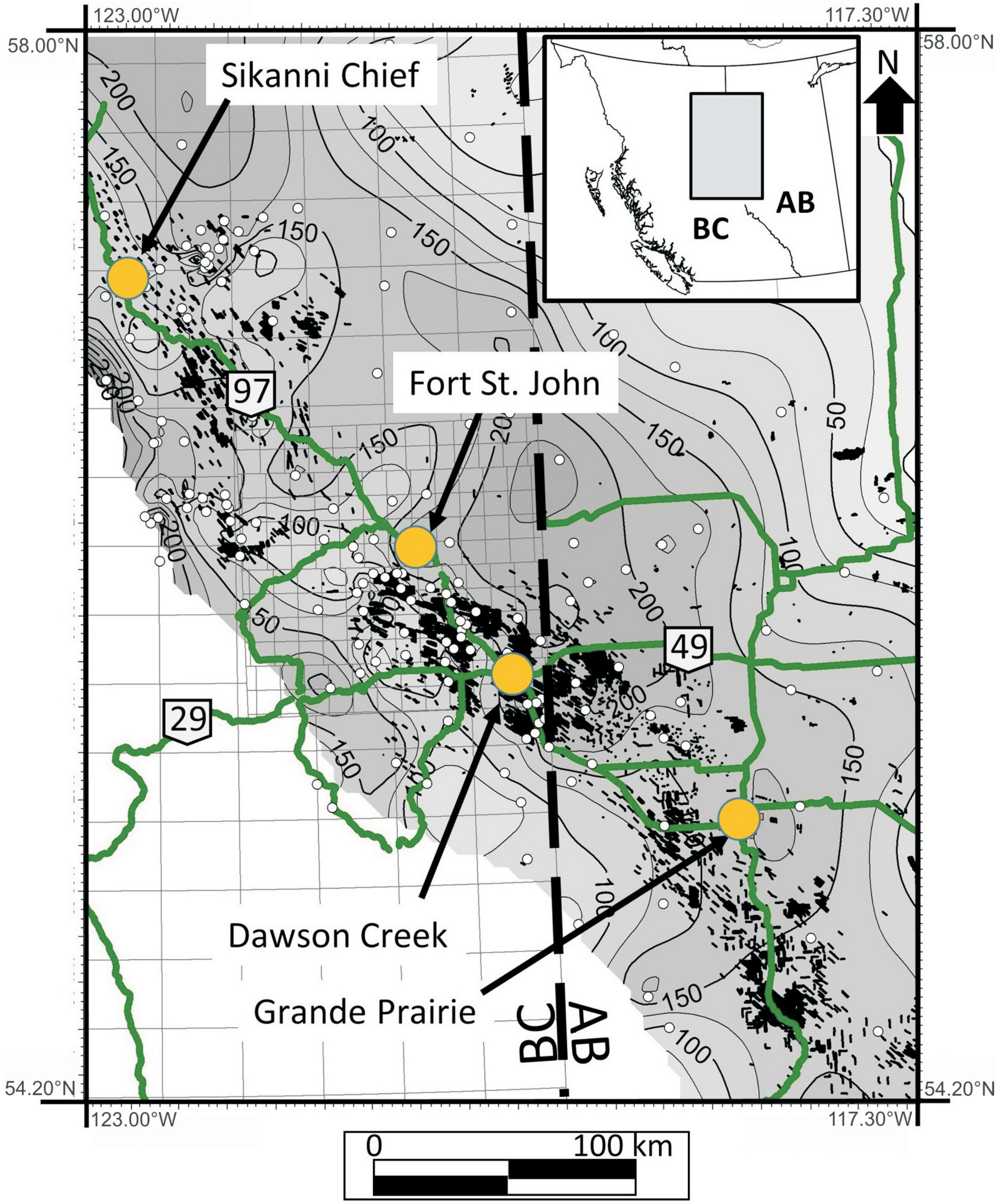

Figure 4. Thickness variation of the informal middle Montney member of the Montney Formation across the regional gas play in northeastern British Columbia and northwestern Alberta. The thickness varies from 300 m in the northwestern part of the study area to less than 11 m in the eastern part of the study area. White filled circles are the well control for thickness contours. Contour interval is 25 m. The black well traces are for all Montney Formation producing, tested or produced wells. Orange circles represent major population centres in the region and the green lines are the primary roads. Data sourced from geoLOGIC systems ltd. (2019).

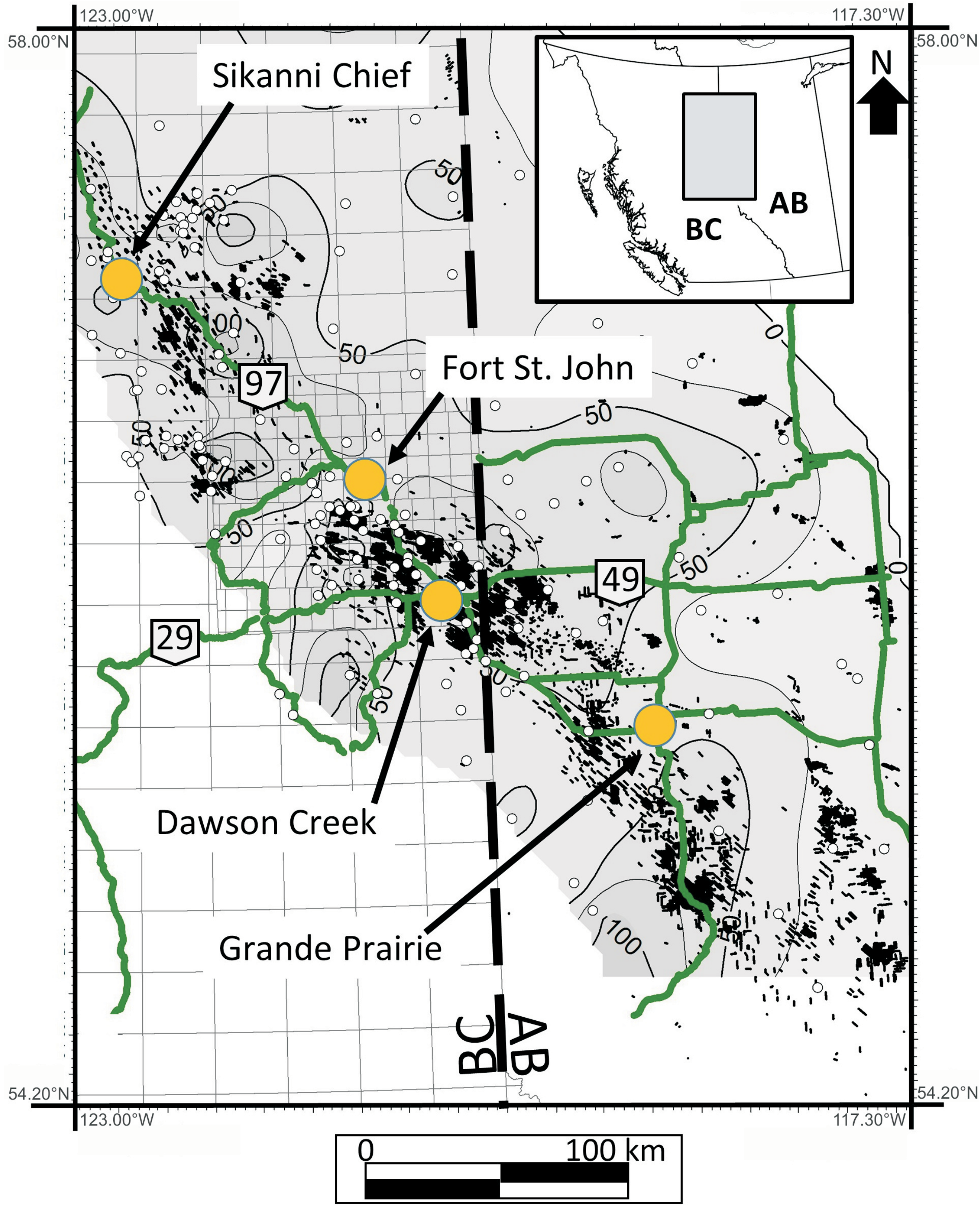

Figure 5. Thickness variation of the informal lower Montney member of the Montney Formation across the regional gas play in northeastern British Columbia and northwestern Alberta. The thickness varies from 229 m in the northwestern part of the study area to less than 10 m in the eastern part of the study area. White filled circles are the well control for thickness contours. Contour interval is 25 m. The black well traces are for all Montney Formation producing, tested or produced wells. Orange circles represent major population centres in the region and the green lines are the primary roads. Data sourced from geoLOGIC systems ltd. (2019).

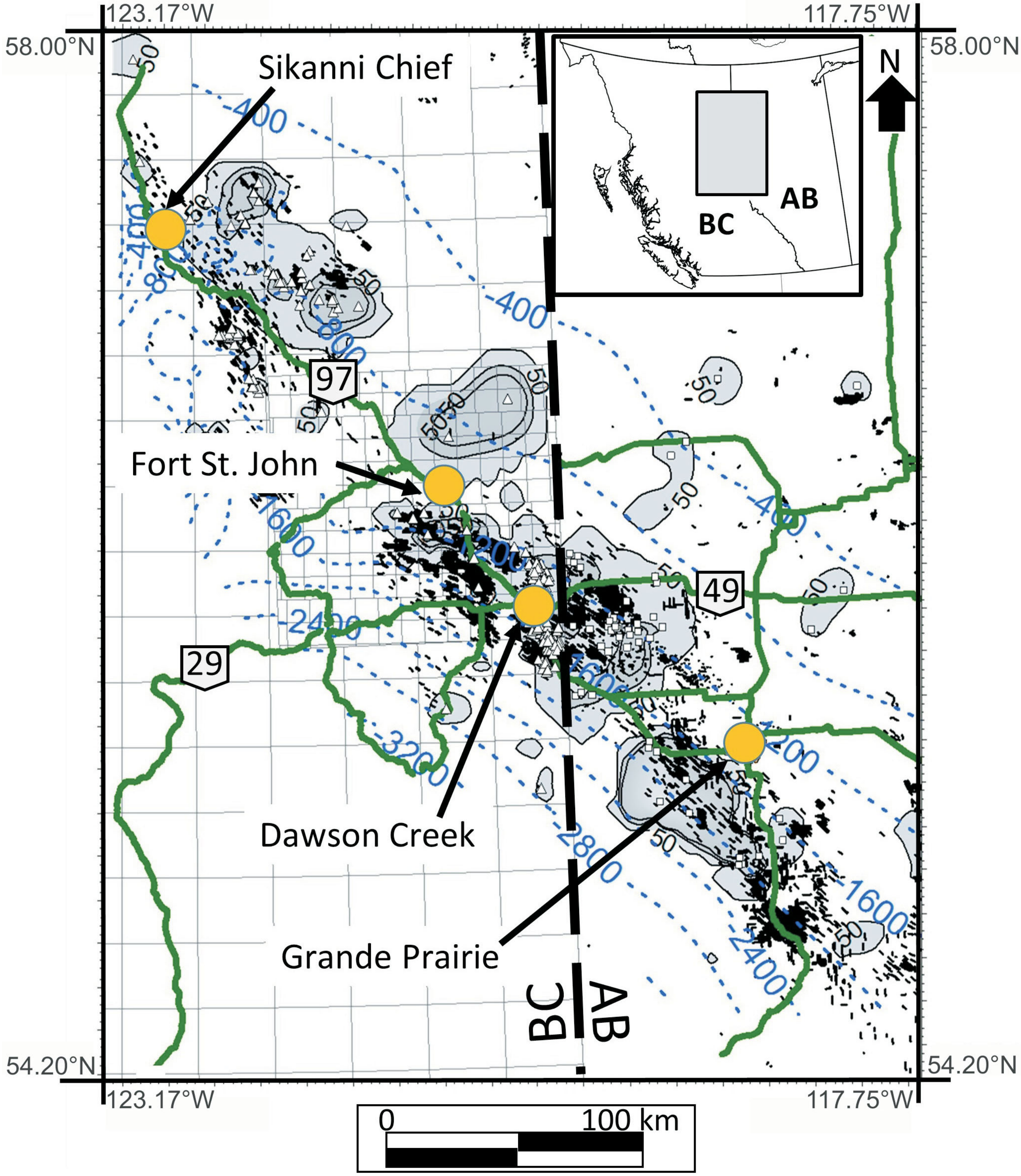

Figure 6. Sour gas distribution within the informal upper Montney member of the Montney Formation across the regional gas play in northeastern British Columbia and northwestern Alberta. The H_2S concentration is in parts per million (ppm) and the contour interval (solid black lines) is 5000 ppm. The H_2S concentrations vary between 100 and 116 000 ppm (0.01–11.6%). The depth contours (blue dashed lines) are to the top of the upper Montney member and are measured in subsea total vertical depth (SSTVD; metres). White triangles represent sour wells in British Columbia and white squares represent sour wells in Alberta. Orange circles represent major population centres in the region and the green lines are the primary roads. Data sourced from geoLOGIC systems ltd. (2019).

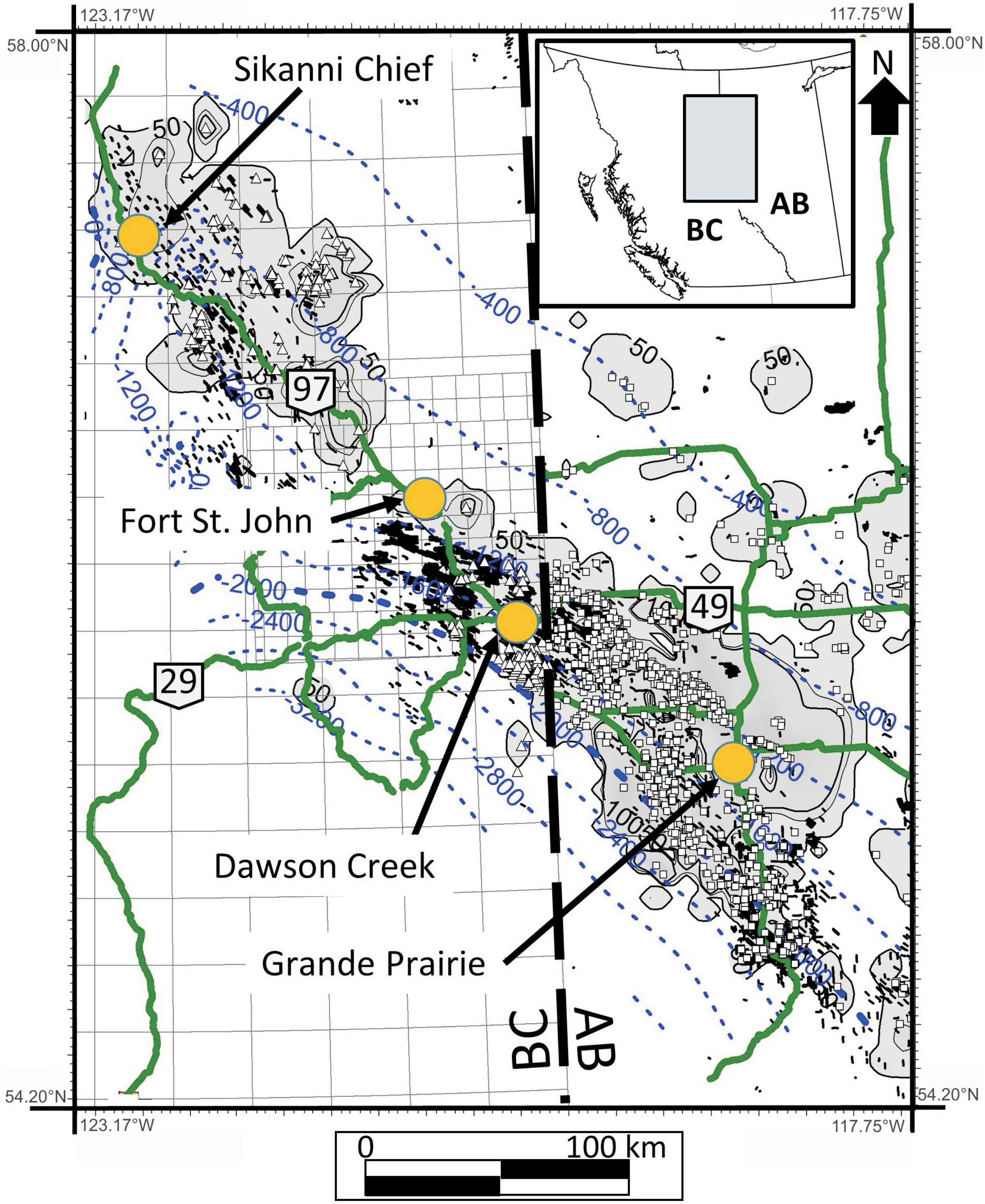

Figure 7. Sour gas distribution within the informal middle Montney member of the Montney Formation across the regional gas play in northeastern British Columbia and northwestern Alberta. The H_2S concentration is in parts per million (ppm) and the contour interval (solid black lines) is5000 ppm. The H_2S concentrations vary between 100 and 212 500 ppm (0.01–21.25%). The depth contours (blue dashed lines) are to the top of the middle Montney member and are measured in subsea total vertical depth (SSTVD; metres). White triangles represent sour wells in British Columbia and white squares represent sour wells in Alberta. Orange circles represent major population centres in the region and the green lines are the primary roads. Data sourced from geoLOGIC systems ltd. (2019).

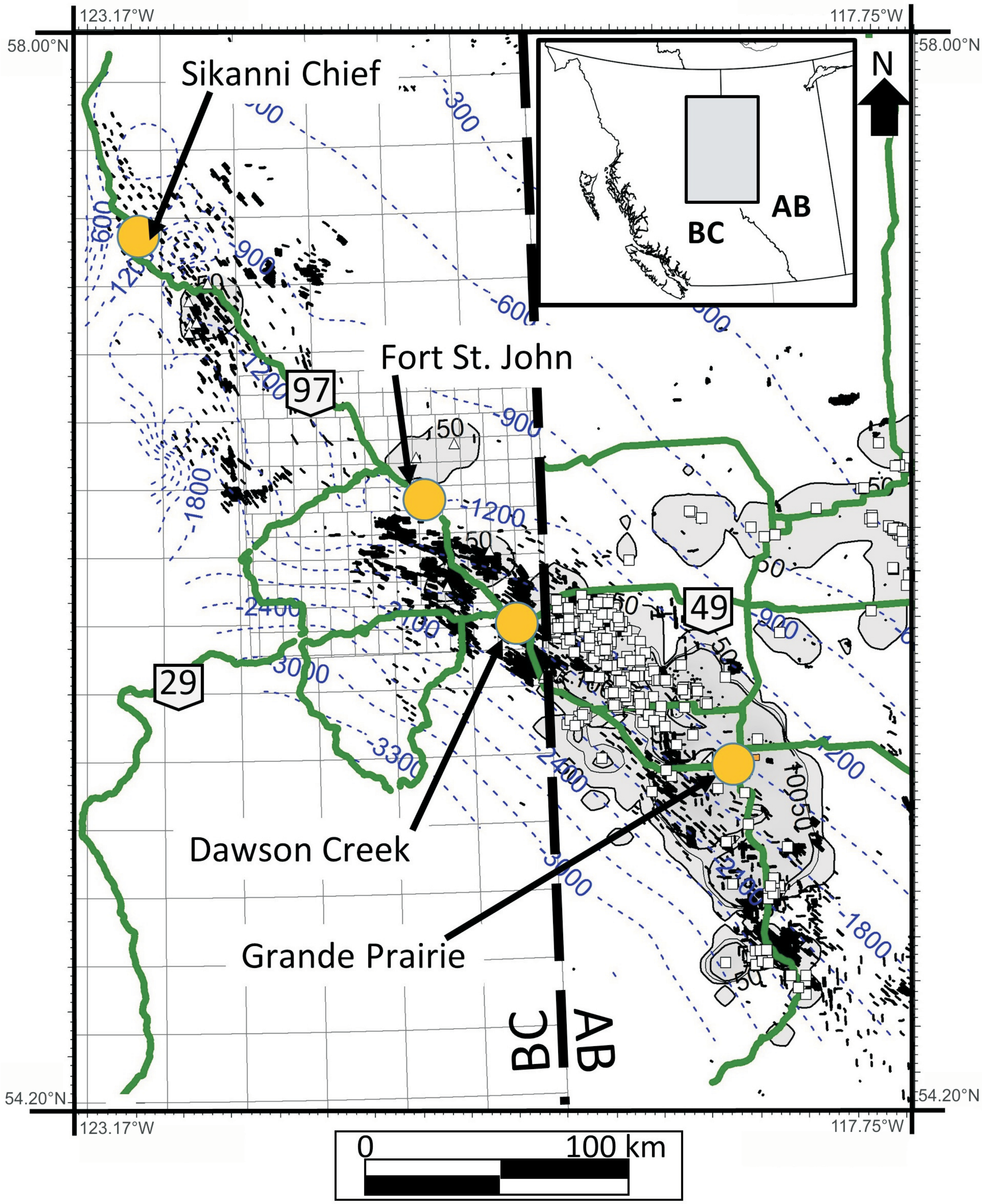

Figure 8. Sour gas distribution within the informal lower Montney member of the Montney Formation across the regional gas play in north-eastern British Columbia and northwestern Alberta. The H_2S concentration is in parts per million (ppm) and the contour interval (solid black lines) is 5000 ppm. The H_2S concentrations vary between 100 and 137 000 ppm (0.01-13.7%). The depth contours (blue dashed lines) are to the top of the lower Montney member and are measured in subsea total vertical depth (SSTVD; metres). White triangles represent sour wells in British Columbia and white squares represent sour wells in Alberta. Orange circles represent major population centres in the region and the green lines are the primary roads. Data sourced from geoLOGIC systems ltd. (2019).

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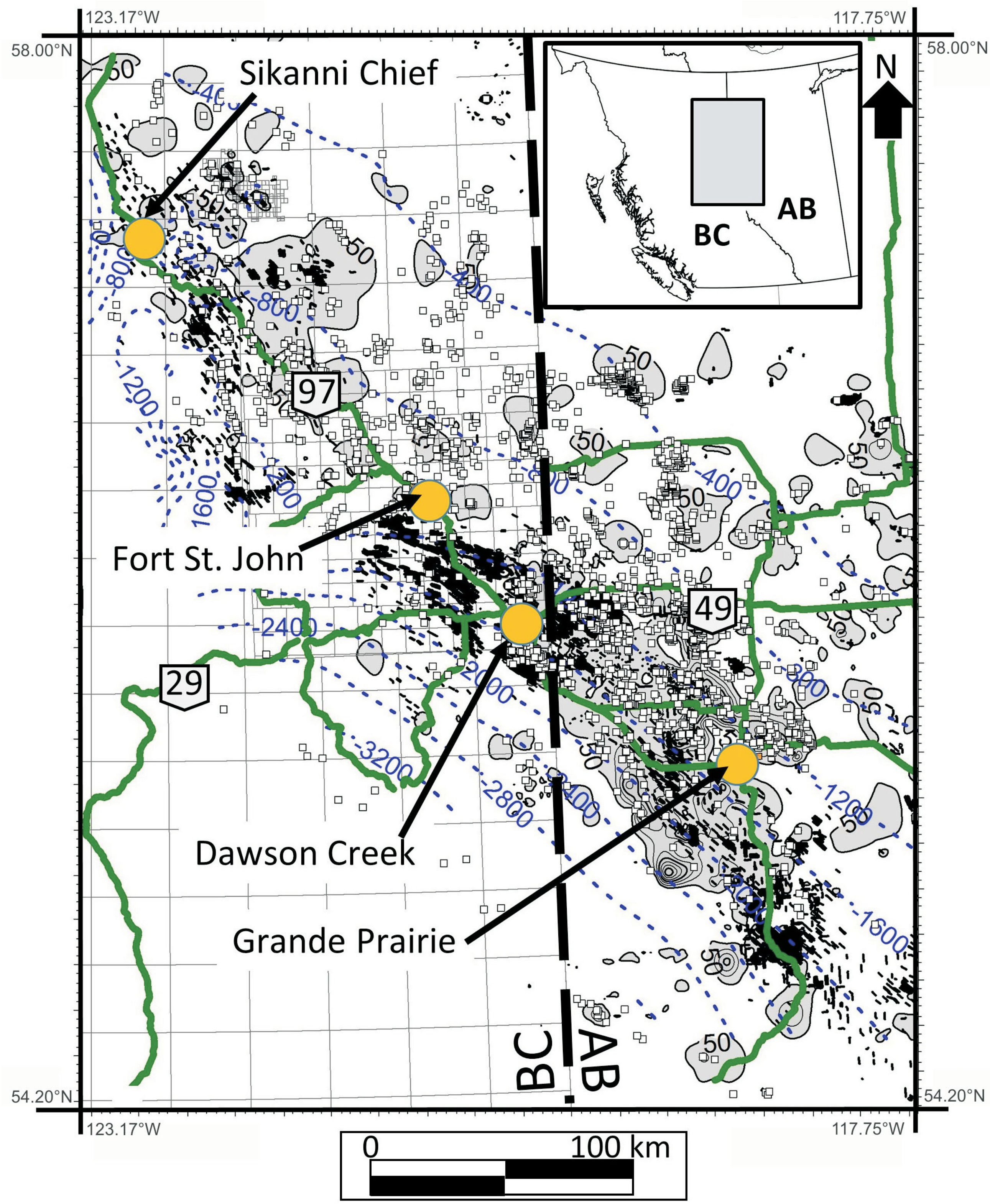

Figure 9. Hydrogen sulphide distribution in the Montney Formation along with sour wells in the overlying Doig and Charlie Lake formations (white squares). The depth contours (blue dashed lines) are to the top of the Montney Formation, measured in subsea total vertical depth (SSTVD; metres). Contour interval is 5000 ppm for the H_2S concentrations and 400 m for the depth contours. Orange circles represent major population centres in the region and the green lines are the primary roads. Data sourced from geoLOGIC systems ltd. (2019).

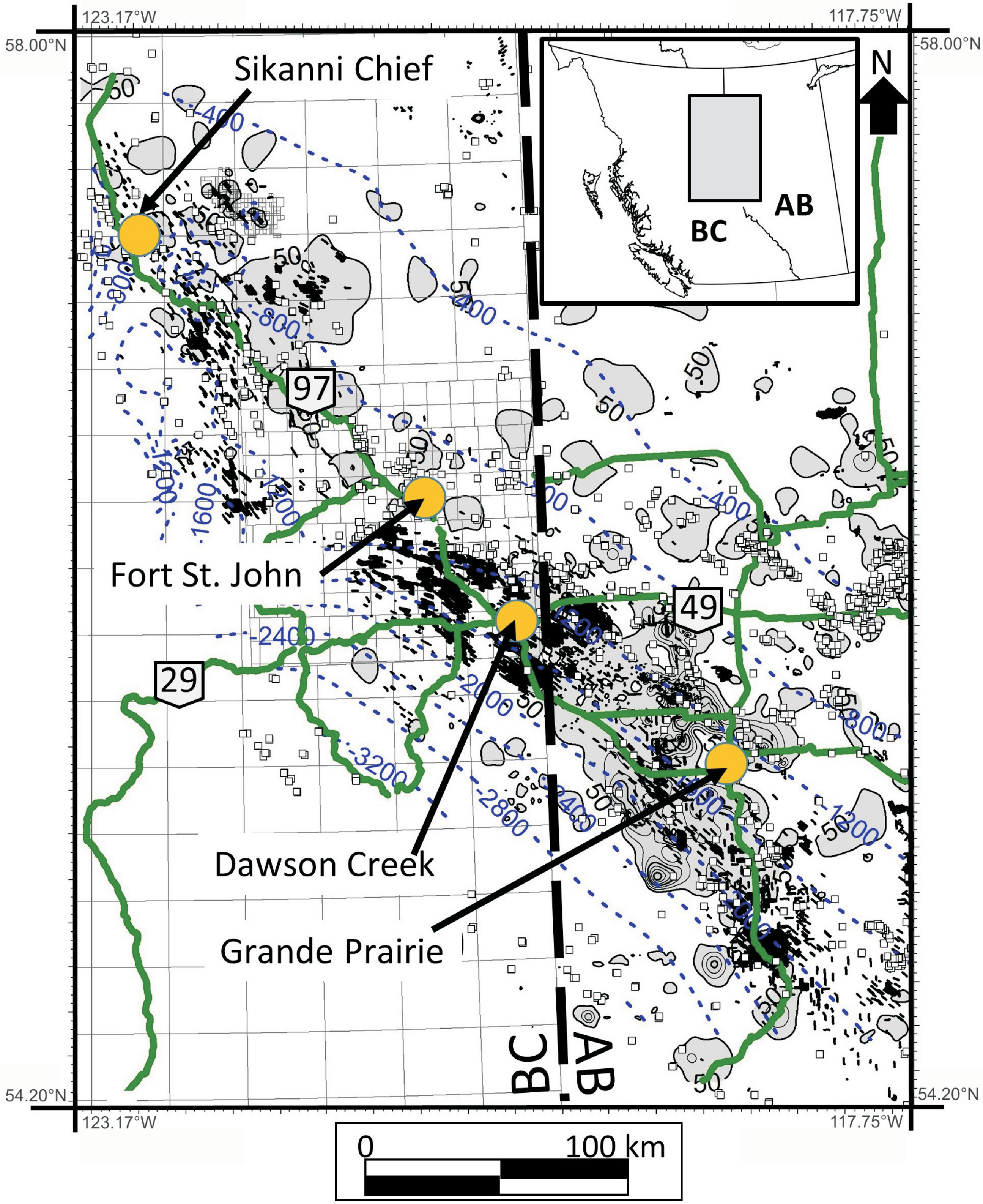

Figure 10. Hydrogen sulphide distribution in the Montney Formation along with sour wells in the underlying Permian, Mississippian and Devonian formations (white squares). The depth contours (blue dashed lines) are to the top of the Montney Formation, measured in subsea total vertical depth (SSTVD; metres). Contour interval is 5000 ppm for the H_2S concentrations and 400 m for the depth contours. Orange circles represent major population centres in the region and the green lines are the primary roads. Data sourced from geoLOGIC systems ltd. (2019).

between overlying sour wells (Doig and Charlie Lake formations) and the sour Montney Formation producers (Figure 9) compared to the underlying sour wells (i.e., Permian, Mississippian and Devonian rocks) and the sour Montney Formation producers (Figure 10). These trends illustrate that a connection may exist between overlying sour pools and areas with higher probability of Montney Formation producing souring within a play area. The connection that exists will be through local fracture systems or fractures associated with regional structures like the Fort St. John graben complex. Sharma (1969) observed anhydrite-filled fractures within the Halfway Formation where the anhydrite had migrated from the Charlie Lake Formation through groundwater circulation. This sulphate-rich water circulated through the Triassic system via fracture networks during early burial and no overpressuring existed as this was prior to any hydrocarbon migration. The anhydrite cementation then healed fractures and allowed a pressure differential to establish between the Charlie Lake and Halfway formations as the depth of burial increased. The same geological model may explain the souring of the Doig and Montney formations with fractures persisting through from the Charlie Lake to the Halfway, Doig and Montney formations. The fractures would allow anhydrite or H_2S gas (or a combination of both) to migrate into the Montney Formation. A predictive framework for sour Montney Formation production would include understanding the distribution of the overlying sour pools in the Doig, Halfway and Charlie Lake formations as well as understanding the fracture network system on regional and gas play scales.

Future Work

Sulphur isotopic data is currently being analyzed and compiled in order to test the geological model proposed above—that sour gas contributions are either from the migration of anhydrite or from H_2S gas from overlying sour pools in the Charlie Lake, Halfway and/or Doig formations. Sulphur isotopes are being analyzed from H_2S gas being produced in the Montney Formation, as well as from anhydrite, pyrite and organic matter concentrates from bulk rock samples of the Montney Formation. Anhydrite is also being analyzed from Triassic to Devonian rocks. This geological model will provide the information companies need to incorporate into their development plans, allowing them to reduce economic, health and environmental risks.

Conclusions

The study of the lateral and stratigraphic H_2S distribution within the Montney Formation in British Columbia (BC) indicates that the upper and middle portions of the Montney Formation in BC are at a higher risk of souring compared to wells that are placed in the lower portions (i.e., informal lower Montney member). However, there are fewer wells currently being drilled in the lower portions of the Montney Formation in BC, which may bias this interpretation. It appears all of the Montney Formation is at risk of souring in the gas play of Alberta. Mapping the sour wells above and below the Montney Formation indicates that souring of the Montney Formation may be linked with the overlying sour pools in the Doig and Charlie Lake formations, particularly in BC, and not linked to the underlying Permian, Mississippian or Devonian sour pools as initially thought. Isotopic analyses of sulphur from the H_2S gas and its sources (i.e., minerals or organic matter) will provide further clarity on the geological processes involved in souring of the Montney Formation.

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References

BC Oil and Gas Commission (2015): British Columbia's oil and gas reserves and production report, 2015; BC Oil and Gas Commission, 35 p., URL <https://www.bcogc.ca/node/13607/download> [October 2018].

Davies, G., Watson, N., Moslow, T. and MacEacher, J. (2018): Regional subdivisions, sequences, correlations and facies relationships of the Lower Triassic Montney Formation, west-central Alberta to northeastern British Columbia, Canada — with emphasis on role of paleostructure; Bulletin of Canadian Petroleum Geology, v. 66, p. 23–92, URL <https://pubs.geoscienceworld.org/cspg/bcpg/article/66/1/23/538508/regional-subdivisions-sequences-correlations-and> [October 2018].

geoLOGIC systems ltd. (2019): geoSCOUT version 8.8; geoLOGIC systems ltd., mapping, data management and analysis software, URL <https://www.geologic.com/products/geoscout/> [August 2019].

National Energy Board (2018): Canada's energy future 2018 supplement: natural gas production; National Energy Board, 12 p.

Sharma, G. (1969): Paragenetic evolution in Peejay field, British Columbia, Canada; Mineral Deposita, v. 4, issue 4, p. 346–354.