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Advances in geothermal research in the southern NWT: toward reservoir characterization and geothermal potential assessment.

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Summary

The Northwest Territories Geological Survey (NTGS) is collaborating with the Institut national de la recherche scientifique (INRS) on two geothermal projects: (1) the Liard Basin Geothermal Project, which focuses on reservoir quality characterization of the Nahanni Formation and its dolomite-altered Manetoe Facies; and (2) the South Slave Project (Hay River – Ft. Providence areas) that aims to assess the geothermal potential of this region. The preliminary results show/suggest that (1) the matrix of the Nahanni and Manetoe rocks is tight and that reservoirs might only be present in heavily fractured areas and fault controlled; and (2) that

Method

The Fort Liard Geothermal Project commenced in 2019 and is scheduled to wrap up in 2023 with recommendations for further work. For this project, the NTGS sampled eight legacy cores from oil and gas wells and nine outcrops from the regions surrounding Ft. Liard. The eight wells were selected based on their location and availability of cored Nahanni Formation and Manetoe facies strata. Cores were photographed and described by NTGS. Samples were collected from the core by AGAT Laboratories (Calgary, AB) under supervision of the Core and Sample Repository, Geological Survey of Canada (GSC), Calgary in 2019. Field sampling by the NTGS in the summer of 2021 targeted the same facies that were sampled from core. A total of 72 samples were collected from locations west of Fort Simpson from Cli Lake toward the south and west of Nahanni Butte in southwestern NWT. Core and outcrop samples were analysed for porosity and permeability, mineralogy, and pore space characterization.

The South Slave project was initiated in the summer of 2022, and also commenced with sampling of legacy core. A total of 84 samples were collected from 35 wells that cover eight formations, including: Slave Point, Watt Mountain, Muskeg, Horn Plateau, Sulphur Point, Keg River, Nahanni, and Chinchaga. Core samples were selected based on their location and availability of cored formation at GSC's Core Repository in Calgary by INRS. Geochemical analysis and measurement of thermal and hydraulic properties are carried out at the Open Geothermal Laboratory of INRS (Québec City) whereas mineralogical analysis is conducted by an external laboratory. The project is will conclude in 2024.

Results

The results of the Liard Geothermal Project indicate that reservoir quality is limited through most of the Nahanni Formation and Manetoe Facies, which comprise fine-grained and well-cemented

limestone and crystalline dolomite. Permeability associated with the rock matrix of samples across the region is in the order of 0.01-0.1 mD and porosity is commonly <<1 %. Reservoir quality is, however, locally moderate through the stratigraphy, where dolomitization increased vuggy pore space (1 to ~40 mD and 1-7 % porosity). Field observations support the presence of a patchy facies fabric. The discontinuous nature of the Manetoe facies was also noted in the field. In the southern part of the study area this facies is thick, well developed and laterally continuous, however toward the north it becomes increasingly discontinuous and only affects the limestone of the Nahanni Formation in discrete, several m to Dm wide lenses. Fracture pattern and density varies greatly both in core and in outcrop, which results in discontinuous secondary fracture porosity that was not evaluated through laboratory analysis.

The preliminary results of the South Slave project comprise the porosity, permeability, and thermal properties measurement of all 84 samples. Mean matrix porosity of the rocks is between 1.8% and 6.9%; the anhydrite facies of the Sulphur Point Formation shows the lowest values, and the highest values are in the limestone and dolostone facies of the Sulphur Point Formation and Nahanni Formation dolostone. Mean matrix permeability of all rocks is low with values measured in the 10^{ths} to 100^{ths} of mD; only the limestone of the Sulphur Point Formation shows an average permeability of 2.7 mD. The average thermal conductivity of the rock samples is between 2.9 $Wm^{-1}K^{-1}$ and 5.6 $Wm^{-1}K^{-1}$. The thermal diffusivity varies between 1.1 10^{-6} m^2s^{-1} and 2.2 10^{-6} m^2s^{-1}, and the volumetric heat capacity is between 2.3 MJ m^{-3} K^{-1} and 3.6 MJ m^{-3} K^{-1}. Using a cut-off value of 3.5 W m^{-1} K^{-1}, the results indicate that the rocks of Slave Point, the Watt Mountain and Horn Plateau Formations would be intermediate between conductive and insulating rocks, whereas the remainder of the formations would act as heat conductors. In terms of volumetric heat capacity, the Keg River Formation dolostone and the Chinchaga Formation anhydrite would have the best heat storage potential, although there is some variability among the lithologies. Conductive to force convective heat transfer is expected in such rocks that is suitable for enhanced geothermal systems and deep borehole heat exchangers (Figure 1).

Conclusions

The results of the Fort Liard study indicate that the rock matrix of the Nahanni Formation and Manetoe Facies is tight with patchy and disconnected pockets of moderate reservoir quality. This study focused on rock porosity and permeability only, but fracture porosity is noted to be significant locally. Better quality reservoirs can be fracture and fault controlled, however the paucity of available structural studies makes reservoir mapping difficult.

The South Slave project encompasses a larger portion of the stratigraphy, but sampling has been limited to the legacy core so far. A field sampling program is planned for the summer of 2023. Results indicate geothermal potential in shallow, low temperature formations that could host sufficient heat for small-scale applications in local communities including Hay River, Enterprise, and Ft. Providence.

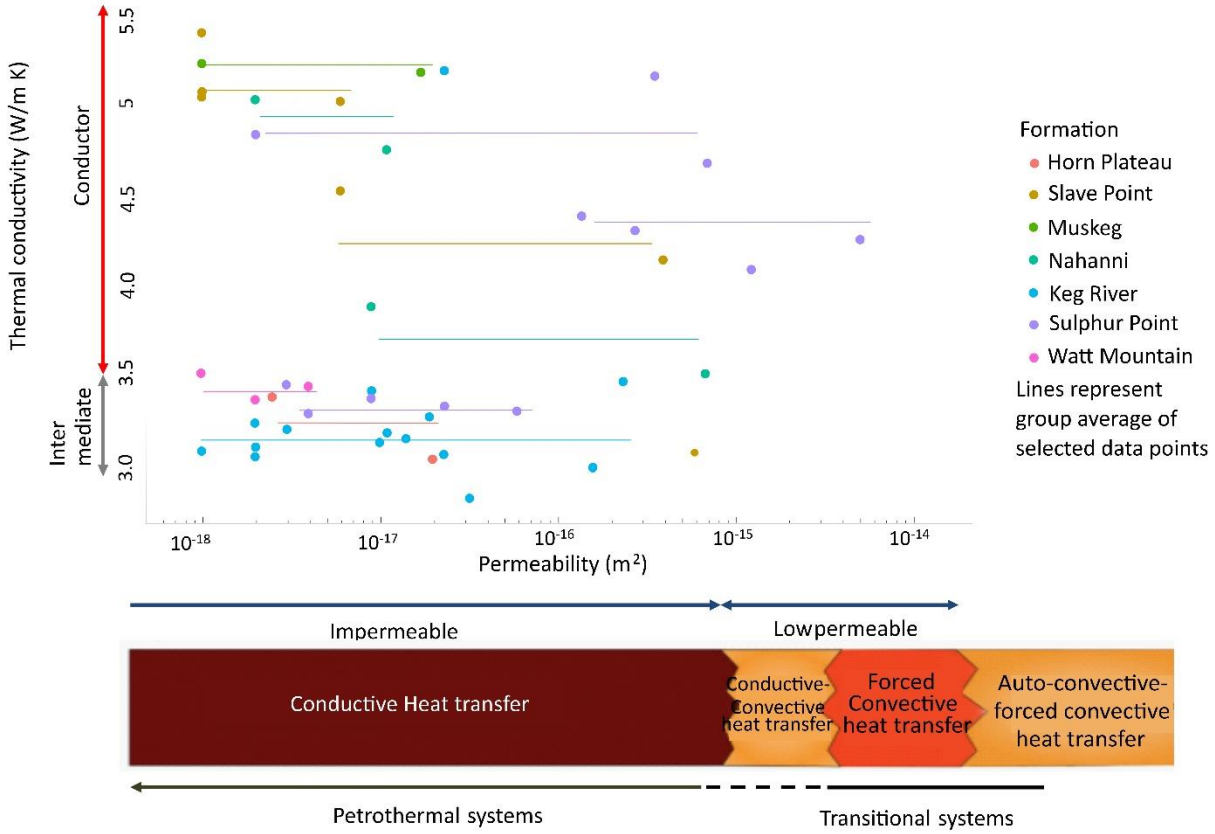

Figure 1: Expected heat transfer mechanism for rock matrix in the South Slave region according to the thermofacies concept.

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