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Basin evolution and its impact on the geothermal gradients of the easternmost Great Slave Plain, Northwest Territories

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Summary

Anomalously high geothermal gradients of up to 70°C/km are found in the southwestern Northwest Territories (e.g., Grasby et al., 2011; Rajaobelison et al., 2024) (Figure 1). The high geothermal gradients are confined to the Great Slave Plain and the Liard Basin, both part of the Western Canada Sedimentary Basin. Many studies have focused on understanding the origin of these gradients, as they enable the exploitation of geothermal energy in northern communities (Grasby et al., 2011; Majorowicz, 2018). However, the question of why the southwestern Northwest Territories is so “hot” remains unresolved. We approach this question by assessing whether the burial, uplift and erosional history of the easternmost Great Slave Plain plays a role in the geothermal patterns found. For that, we use low-temperature thermochronology to constrain the thermal history of the area (Figure 1). Our thermal history models evidence two burial and exhumation patterns: (1) protracted phase of Devonian–Early Cretaceous burial followed by Late Cretaceous cooling within the Great Slave Plain, and (2) Devonian–Carboniferous burial immediately followed by slow cooling in the exposed Canadian Shield.

Theory / Method / Workflow

High geothermal gradients are often found in areas of young magmatic activity (e.g., Mount Meager volcanics) (e.g., Grasby et al., 2011). Less commonly, high gradients are the product of rocks moving rapidly towards the surface, preventing isotherms from equilibrating (Glotzbach et al., 2009). This process of rock exhumation can be constrained using low-temperature thermochronology. These radioactive dating methods are temperature-sensitive and therefore provide information on burial temperatures and timing when rocks last experienced temperatures between 55–200°C (Reiners et al., 2004; Zeitler et al., 1987). To understand the burial and exhumation history of the Great Slave Plain, we analyze Cambrian and Devonian clastic strata and Precambrian basement rocks, from outcrops and boreholes (Figure 1).

A Great Slave Plain

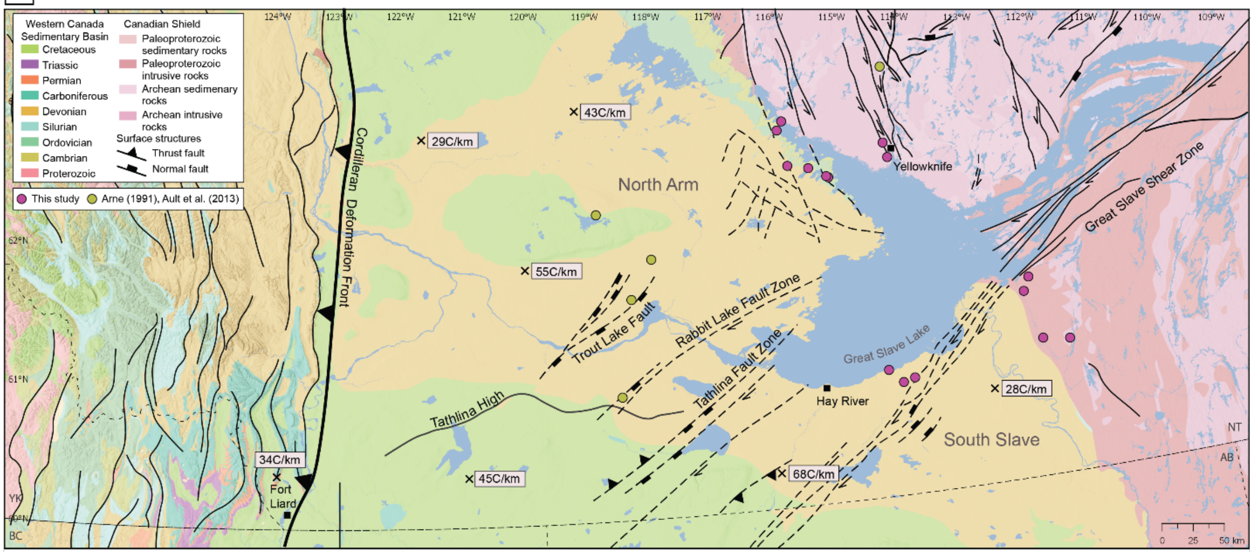

Figure 1. Geological map of the study area, major structures and sample locations. A few geothermal gradients are included (“x” marks) to represent the overall high values within the basin.

Results, Observations, Conclusions

Our dataset comprises Cambrian-Devonian strata (8 samples) and basement rocks (9 samples). Those samples come from both outcrops (exposed Canadian Shield) and boreholes (within the basin) of up to 400 m depth. In terms of methods, we acquired mostly apatite and zircon (U-Th)/He data (Ahe and Zhe, respectively). Our AHe and ZHe single grain dates varied widely across the area. The sedimentary samples yield 14-300 Ma (AHe) and 206-1720 Ma (ZHe), and basement samples yield 18-692 Ma (AHe) and 55-1216 Ma (ZHe). The large date dispersion prevents direct interpretation of the data, so we model the data to constrain the thermal histories of each of the samples across the area. Our preliminary models show that most sedimentary samples from the Great Slave Plain experienced burial temperatures >120°C, followed by a Late Cretaceous cooling phase. Such cooling evidences the influence of the Cordilleran orogeny on the exhumation history of the basin. Conversely, most of the basement samples experienced post-Cambrian temperatures of 140-200°C. Unlike the sedimentary samples, the basement samples underwent very slow cooling since Carboniferous.

Novel/Additive Information

Our study will provide a better understanding of the evolution of the Great Slave Plain and how it was affected by major processes that took place close to basin’s western margin (e.g., Cordilleran orogeny). Ultimately, we will correlate the thermal histories and other geological information (e.g., basement structures, stratigraphy) with the geothermal gradients to assess whether there is a causal relationship between them.

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