# The use of mining boreholes as a key tool for heat flow estimation in geothermal energy research: data from the Labrador Trough, Northern Québec

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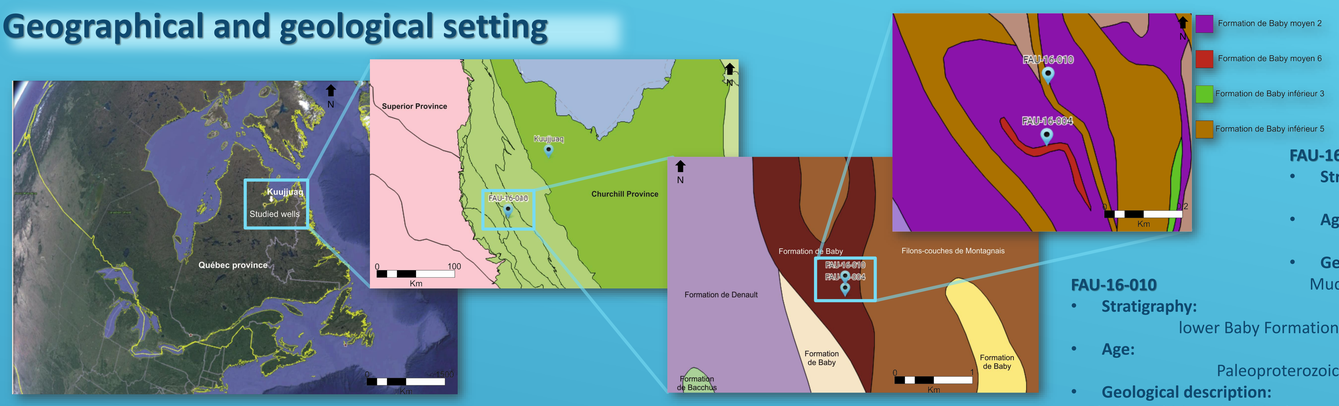
## Geographical and geological setting




Images adapted from Google Earth and SIGÉOM – Système d'information géominière du Québec (http://sigeom.mines.gouv.qc.ca)

**FAU-16-004**
- **Stratigraphy:** middle Baby Formation;
- **Age:** Paleoproterozoic;
- **Geological description:** Mudstone and black slate, locally graphitic and pyritic

**FAU-16-010**
- **Stratigraphy:** lower Baby Formation;
- **Age:** Paleoproterozoic;
- **Geological description:** Black graphitic and pyritic slate and pyritic silstone

## Mathematical solution – paleoclimate corrections and heat flow calculation

- **Daily and seasonal cycles**
(Beardsmore and Cull, 2011)

$$z = 2\pi/\varepsilon = (4\pi P\kappa)^{1/2}$$

P = period of a perturbation (s);
κ = thermal diffusivity (≈ 0.75 x10$^{-6}$ m$^2$ s$^{-1}$)

maximum depth reached by a temperature perturbation caused by a cyclic surface temperature

- **Paleoclimate**
(Jessop, 1990)

$$\frac{dT}{dz} = g + T_1\left[\frac{1}{\sqrt{\pi\kappa t_1}}exp\left(-z^2/4\kappa t_1\right) - \frac{1}{\sqrt{\pi\kappa t_2}}exp\left(-z^2/4\kappa t_2\right)\right]$$

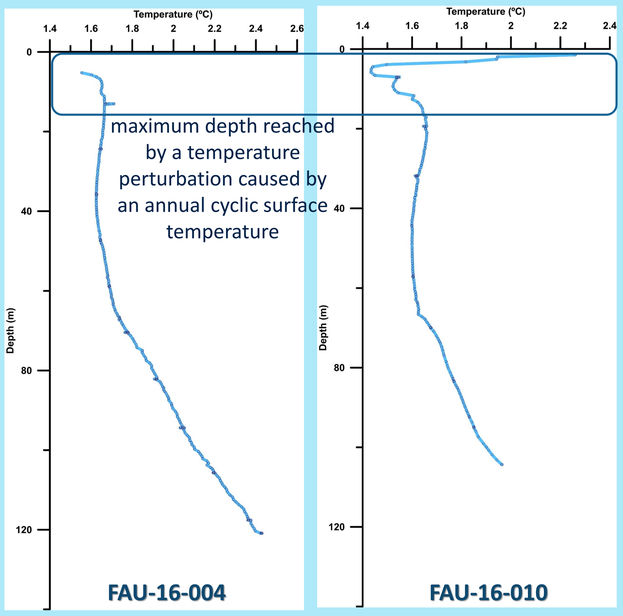
$\frac{dT}{dz}$ = geothermal gradient (K m$^{-1}$);
$T_1$ = temperature step (K);
z = depth (m);
$t_1$ and $t_2$ = times of the end and beginning of an ice-age (s);
κ = thermal diffusivity (≈ 0.75 x10$^{-6}$ m$^2$ s$^{-1}$)

- **Fourier's Law**

$$q = -\lambda\frac{dT}{dz}$$

$\frac{dT}{dz}$ = geothermal gradient (K m$^{-1}$);
λ = thermal conductivity (≈2 W m$^{-1}$ K$^{-1}$);
q = surface heat flow (mW m$^{-2}$)

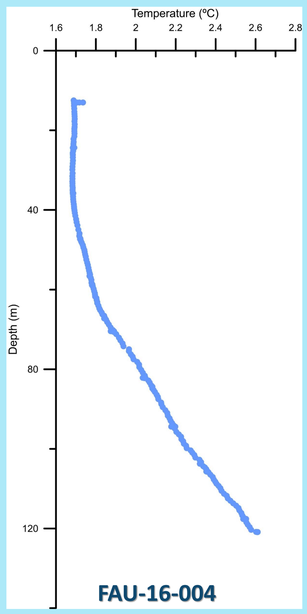
## Temperature and geothermal gradient profiles

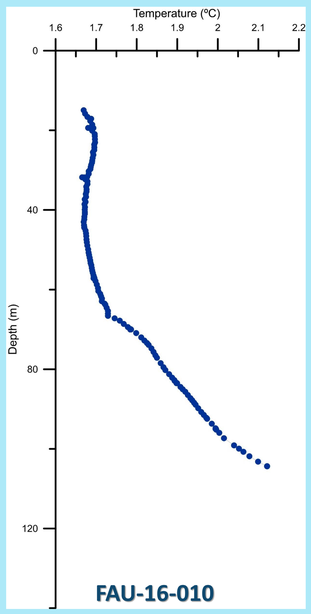




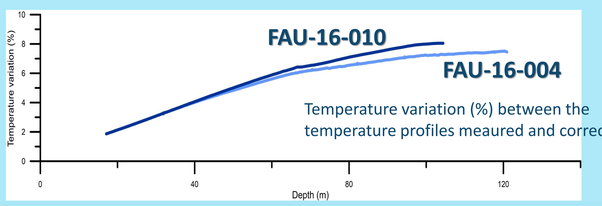


Temperature profiles measured



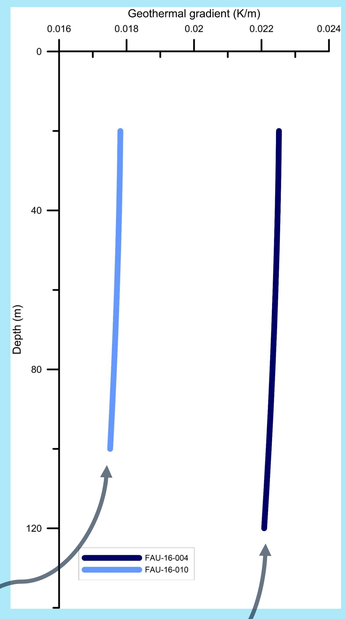




Temperature profiles corrected

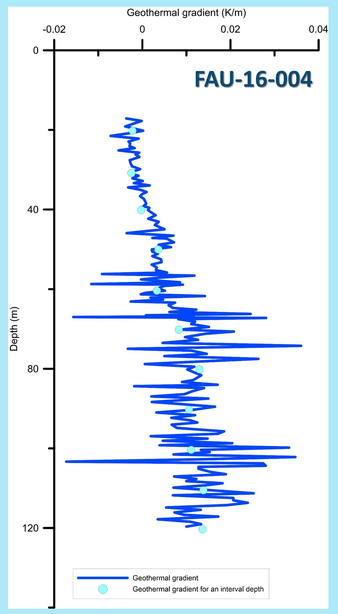



Temperature variation (%) between the temperature profiles meaured and corrected

**Corrected geothermal gradient:**
$$\frac{\Delta T}{\Delta z} = 18\ mK\ m^{-1}$$

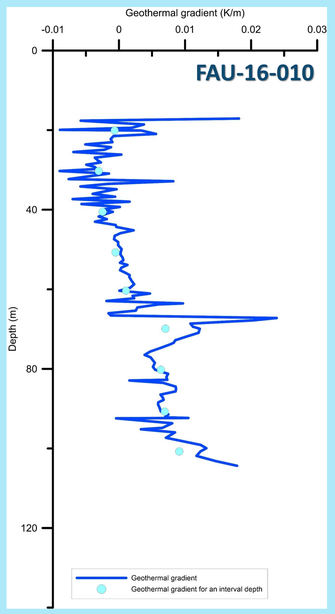



**Corrected geothermal gradient:**
$$\frac{\Delta T}{\Delta z} = 22\ mK\ m^{-1}$$




Geothermal gradient calculated based on regression line:
$$\frac{\Delta T}{\Delta z} = 7.7\ mK\ m^{-1}$$

Averaged geothermal gradient calculated based on interval method:
$$\frac{\Delta T}{\Delta z} = 6.6\ mK\ m^{-1}$$




Geothermal gradient calculated based on regression line:
$$\frac{\Delta T}{\Delta z} = 3.0\ mK\ m^{-1}$$

Averaged geothermal gradient calculated based on interval method:
$$\frac{\Delta T}{\Delta z} = 2.6\ mK\ m^{-1}$$

## Conclusions

- Applying a paleoclimate correction for the effects of the recent climate warming and the last four Quaternary glaciations, the averaged geothermal gradient increases from 7 mK m$^{-1}$ and 3 mK m$^{-1}$ to 20 mK m$^{-1}$.
- This increase in the geothermal gradient has influence in heat flow estimations:

**FAU-16-004**

**Uncorrected heat flow:**
$$q = 13 - 15\ mW\ m^{-2}$$

**Corrected heat flow:**
$$q = 42.5 - 44.5\ mW\ m^{-2}$$

**FAU-16-010**

**Uncorrected heat flow:**
$$q = 6\ - 8\ mW\ m^{-2}$$

**Corrected heat flow:**
$$q = 35 - 37\ mW\ m^{-2}$$

- This work shows the preliminary results of surface heat flow estimations in northern Labrador Trough, indicating limited geothermal potential that can only be exploited for direct use purposes. Further studies are needed to determine if geothermal heat can be viably produced for northern communities and mines.

**Acknowledgments**

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**References**

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- Beardsmore, G.R. and Cull, J.P., 2001 – Crustal Heat Flow – A Guide to Measurement and Modelling. Cambridge University Press