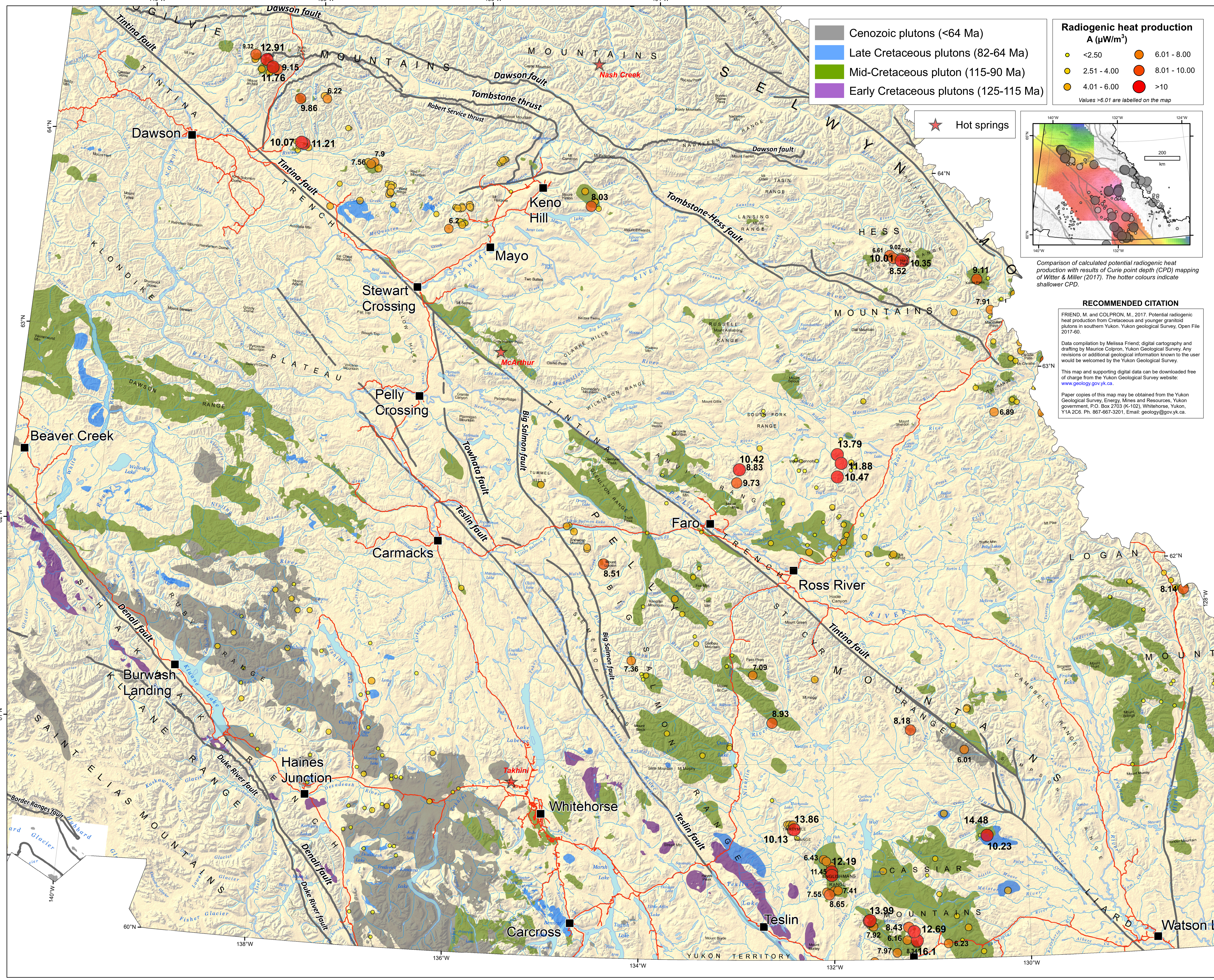
YUKON GEOLOGICAL SURVEY

Yukon Energy, Mines and Resources



Comparison of calculated potential radiogenic heat production with results of Curie point depth (CPD) mapping of Witter & Miller (2017). The hotter colours indicate shallower CPD.

RECOMMENDED CITATION

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Data compilation by Melissa Friend; digital cartography and drafting by Maurice Colpron, Yukon Geological Survey. Any revisions or additional geological information known to the user would be welcomed by the Yukon Geological Survey.

This map and supporting digital data can be downloaded free of charge from the Yukon Geological Survey website: www.geology.gov.yk.ca.

Paper copies of this map may be obtained from the Yukon Geological Survey, Energy, Mines and Resources, Yukon government, P.O. Box 2703 (K-102), Whitehorse, Yukon, Y1A 2C6. Ph. 867-667-3201, Email: geology@gov.yk.ca.

NOTES

This map presents results for calculations of the potential for Cretaceous and younger granitoid plutons to produce radiogenic heat. The calculations were performed using U, Th, and K concentrations from whole rock geochemical data compiled from literature and from the Yukon Geological Survey's (YGS) archives. The objective of this exercise was to identify plutons with anomalously high potential for radiogenic heat production to use as a targeting tool for geothermal resource exploration.

Background:

More than 80% of the heat produced in the Earth's crust comes from granitoid rocks. When granitoid rocks form they naturally concentrate radioactive elements such as U, Th, and K, and the radiogenic decay of these elements is an exothermic reaction. The radioactive decay of these elements within a granitoid body may generate local heat anomalies and elevated geothermal gradient at relatively shallow crustal levels (Kolker, 2008). In combination with other local rock properties (e.g., porosity, permeability, thermal conductivity), radiogenic heat has the potential to generate a geothermal resource.

The decay of radioactive elements converts mass into radiation energy, which in turn gets converted to heat. While all naturally radioactive isotopes generate some heat, significant heat generation only occurs from the decay of ^{238}U, ^{235}U, ^{232}Th and ^{40}K. Therefore, potential heat production is governed by the concentrations of U, Th and K in the rock (Rybach, 1981). In igneous rocks, radiogenic heat production is dependent on the bulk chemistry of the rock and decreases from acidic (e.g., granite) through basic to ultrabasic rock types (Rybach, 1981). Therefore, granites with anomalously high concentrations of U, Th and K are targets for calculating potential radiogenic heat production.

One method for calculating potential radiogenic heat production (**A**) from plutonic rocks is given by Rybach (1981):

$$\mathbf{A}\ (\mu W/m^3) = 10^{-5}\ \rho\ (9.52c_U + 2.56c_K + 3.48c_{Th})$$

where **c** is the concentration of radioactive elements U and Th in ppm, and K in %; and ρ is the rock density. Heat production constants of the natural radio-elements U, Th, K are $9.525 \cdot 10^{-5}$, $2.561 \cdot 10^{-5}$ and $3.477 \cdot 10^{-9}$ W/kg, respectively (Rybach, 1981).

Data and Methods:

Geochemical data from ~560 samples of Cretaceous and younger plutonic rocks from southern Yukon were compiled from published and archival sources at YGS to calculate potential heat production using Rybach's (1981) equation. Rock densities were extracted from a compilation of physical rock properties in southwestern Yukon (Tempelman-Kluit and Currie, 1978). For ease of calculating such a large dataset, and because the resulting **A** value is not significantly affected by slight variations in density, the density values used in calculations were averaged by rock type for felsic, felsic-intermediate, intermediate, mafic and ultramafic compositions (see accompanying digital data table).

The calculated values for radiogenic heat production (**A**) are plotted over the mapped distribution of Cretaceous and younger plutonic rocks extracted from the compilations by Colpron et al. (2016a,b). Major crustal faults are also shown for reference.

Results:

The average granite has a characteristic radiogenic heat production value of 2.45 µW/m³ (Rybach, 1981). The calculation of heat production from radio-element concentrations in southern Yukon yielded several high heat production (**A**) values: with a large number of samples ranging from 3-10 µW/m³ and approximately 25 samples with anomalous **A** values greater than 10 µW/m³.

Most significant anomalies are associated with Cretaceous plutons. Notable anomalies are found in mid-Cretaceous granitoid plutons of the Thirtymile and Englishmans ranges, east of Teslin, where 8 samples yielded **A** values greater than 10 µW/m³. The Late Cretaceous Allan pluton, in the eastern Cassiar Mountains northwest of Watson Lake, yielded the most anomalous results with 5 samples yielding **A** values greater than 20 µW/m³; those samples were collected at a Uranium showing (Minfile 105B 126).

In the Anvil and South Fork ranges, north of Ross River, mid-Cretaceous plutons also yielded anomalous **A** values greater than 10 µW/m³. Farther north in Selwyn basin, alkalic plutons of the mid-Cretaceous (94-90 Ma) Tombstone suite (Colpron et al., 2016b) also indicate elevated potential for radiogenic heat production near Macmillan Pass and northeast of Dawson. Uranium mineralization is also locally associated with plutons of the Tombstone suite (e.g., Minfile 116B 058, 116B 107, 116B 108).

Younger, Cenozoic plutons are most abundant in southwestern Yukon. They generally yield average **A** values and appear less favourable for radiogenic heat production than the Cretaceous plutons. However, high-level intrusions along the northeastern flank of the Ruby Range batholith near Aishihik Lake, yielded **A** values greater of 3.5-4.2 µW/m³; and the Eocene Ting Syenite in southeastern Yukon, near the Pool Creek hot spring, has anomalous **A** value of 5.36 µW/m³.

Plutons that yield the highest **A** values generally coincide with regions of shallower Curie point (~580°C) depth in Yukon, as determined from regional aeromagnetic data (Witter and Miller, 2017).

It should be noted that the Yukon lithogeochemical database was still under development at the time of preparation of this report. In particular, the dataset used here shows significant gaps, most notably in the Dawson Range and the Whitehorse region. It is anticipated that these gaps in data will be corrected with further development of the Yukon lithogeochemical database.

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Potential radiogenic heat production from Cretaceous and younger granitoid plutons in southern Yukon

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