Laboratory Analytical Results for Sampling of Eleven Wells in the Northwest Territories

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Taís Fontes Pinto[1], Eva Enkelmann[1], Viktor Terlaky[2]
1: University of Calgary, Department of Geoscience, Calgary, Alberta
2: Northwest Territories Geological Survey, Yellowknife, NT

Introduction

The southwest Northwest Territories (NWT) is comprised of Archean-Proterozoic basement overlain by Phanerozoic sediments of the Western Canada Sedimentary Basin (WCSB). The region is known for its anomalously high geothermal gradient (>40° C/km) and heat flows (70-120 mW/m^2) and is therefore a target for geothermal energy exploration. However, little is known about the development of the thermal anomaly in terms of its timing and source.

The purpose of the well sampling program was to collect samples from wells in the Liard Basin, an area of interest for geothermal energy exploration. Understanding the thermal history of the basin is a key step toward understanding the timing and origin of the heat present in the basin and the current-day geothermal energy potential. In this study we employed low-temperature thermochronology and performed zircon (U-Th)/He analysis to evaluate the burial and erosional history of the region.

The NTGS Energy Team lead by Dr. Viktor Terlaky is currently working in collaboration with Dr. Eva Enkelmann from the University of Calgary and graduate student Taís Fontes Pinto on a project called “Thermal Evolution of Phanerozoic Sediments of the Southern Northwest Territories”, which complements other geothermal related studies in this region. Due to low outcrop occurrence between the Great Slave Lake and the Cordilleran deformation front, sampling of well cores was necessary to obtain samples (Figure 1). Samples from the eastern portion of the study area were previously obtained from 5 mineral wells and the data was reported in an NTGS Open File (Enkelmann et al., 2023). Previously no data were available from the western part of the basin. This study aims to fill this data gap.

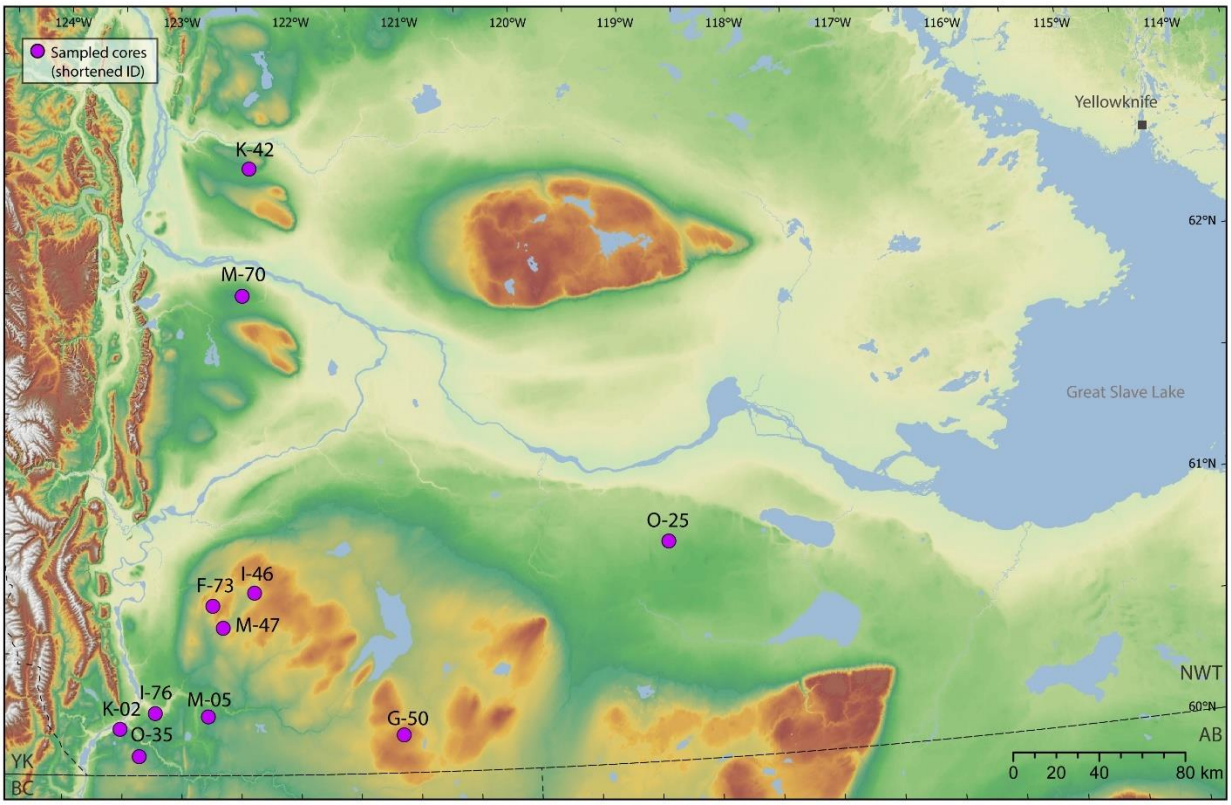

Figure 1. Location of sampled well cores with shortened identification name. Full name of well cores can be found in Table 1.

Testing/Analysis Procedures

The sampled material for this study comprised cut sections of wells that are stored at the Core and Sample Repository, Geological Survey of Canada (GSC) in Calgary, Alberta. Due to Covid-19-related restrictions, the chosen well intervals were shipped from the Core and Sample Repository to the Geosciences Department at University of Calgary. Sampled intervals were chosen based on sample lithology. Sandstones, conglomerates and igneous rocks were targeted due to their likelihood to yield apatite and zircon minerals. Samples of up to 2 kg were collected from portions of the cores, avoiding those that were previously sampled. A total of 20 samples from 11 boreholes were collected (Table 1).

A total of 15 samples went through mineral separation (detailed procedure description reported in Enkelmann et al., 2023), which includes the hydraulic press, rock crusher, disk mill, sieving, water table, Franz magnetic separator, and heavy liquids. Prior to mineral separation, a small portion of the samples was kept for thin section preparation and petrographic analysis. After mineral separation, each sample was observed under a stereomicroscope to evaluate presence/absence of apatite and zircon. Full description of mineral separation results can be found in (Pinto et al., in review).

A total of 6 samples yielded zircons suitable for (U-Th)/He dating (mineral separation result in next section). No suitable apatite grains were found in any of the sampled materials.

The 5 samples that did not undergo mineral separation, as well as remaining light fractions of separated sampled have been returned in February 2023 to the Core and Sample Repository, Geological Survey of Canada (GSC) in Calgary, Alberta.

Data and Interpreted Results

Zircon (U-Th)/He dating was performed at the Geochronology and Thermochronology Laboratory at the University of Calgary. Data are reported in Table 2. Interpretation and other analytical results will be disseminated in an NTGS Open Report?

Mineral separation results from each core sampled

- PARAMOUNT ET AL FORT LIARD O-35: Zircon grains are very small and mostly rounded. Most grains are colourless, but reddish tones are also present. No apatite observed.
- I0E AMOCO BOVIE M-05: Zircon grains are very small and mostly rounded. Grains vary from oval shaped to prismatic. Most of prismatic grains present broken facets, internal fractures or inclusions. Apatite grains are colorless, rounded and fragmented.
- CNRL WEST BOVIE I-76: Zircon grains present variable degrees of roundness and sphericity. Mostly round and oval-shaped, or prismatic and rounded. Quite often as fragments. Small quantity available. No apatite observed.
- CNRL LIARD K-02 (Mount Coty K-02): Zircon grains present variable degrees of roundness and sphericity. Grains that are prismatic and slightly rounded often present internal fractures and inclusions. Abundance of colourless and high spherical grains. Grains are either colorless or of orange tint. No apatite observed.
- IMPERIAL SUN ARROWHEAD AURORA M-47: Zircon grains are colorless and rounded. Small yield. No apatite observed.
- IMPERIAL SUN NETLA RAVEN F-73: Zircon grains present variable degrees of roundness and sphericity. They can be prismatic and colorless; oval-shaped and reddish; prismatic, rounded and fragmented. Apatite grains are colorless and fragmented.
- BRIGGS RABBIT LAKE NO. 2(O-25): No zircons or apatites.
- MOBIL FORT SIMPSON M-70: No zircons or apatites.
- IMP ISLAND RIVER NO. 1 (G-50): No zircons or apatites.
- AQUIT HIGHLAND L K-42: No zircons or apatites.
- IMPERIAL SUN ARROWHEAD I-46: No zircons or apatites.

Zircon (U-Th)/He dating

Zircon (U-Th)/He dating was performed on six samples from five boreholes. Out of the total dated samples, one did not yield results likely due to the misidentification of zircon. The results are listed

below, reporting the range of uncorrected single-grain dates and number of grains. The sample lithology and depositional age is also reported. Single-grain information is reported in Table 2.

- PARAMOUNT ET AL FORT LIARD O-35 (Lab ID 112-30): Total of 3 grains dated out of the 5 analyzed. Single-grain dates range from 281.2 ± 11.6 to 922.3 ± 37.0 Ma. Sample's lithology is sandstone from the Carboniferous Mattson Formation .
- IMPERIAL SUN NETLA RAVEN F-73 (Lab ID 112-35): Total of 5 grains dated out of the 5 analyzed. Single-grain dates range from 70.1 ± 2.5 to 444.2 ± 18.7 Ma. Sample's lithology is likely basal clastics (sandstone?) from the Devonian Tsetso Formation.
- CNRL LIARD K-02 (Mount Coty K-02) (Lab ID 112-38 and 112-40): Total of 5 grains dated for both samples. Single-grain dates for 112-38 range from 273.8 ± 13.2 to 553.4 ± 22.2 Ma and for 112-40 range from 232.5 ± 9.3 to 399.3 ± 23.5 Ma. Sample's lithology is sandstone from the Carboniferous Mattson Formation.
- I0E AMOCO BOVIE M-05 (Lab ID 112-48): Total of 5 grains dated out of the 5 analyzed. Single-grain dates range from 332.1 ± 12.5 to 437.7 ± 21.5 Ma. Sample's lithology is sandstone, likely from the Cretaceous Scatter or Chinkeh Formation.
- CNRL WEST BOVIE I-76 (Lab ID 112-32): the 2 grains analyzed did not result in any dates due to misidentification of zircon.

References

Enkelmann, E., Pinto, T.F., Matthews, W., and Terlaky, V., 2023. Preliminary data for thermal evolution of Phanerozoic sediments of southwestern Northwest Territories; Northwest Territories Geological Survey, NWT Open Report 2022-001, 35 pages and digital data. https://doi.org/10.46887/2022-001

Pinto, T.F. Enkelmann, E., Matthews, W., and Terlaky, V., in review. Thermal evolution of Phanerozoic sediments of southwestern Northwest Territories; Northwest Territories Geological Survey, NWT Open Report 2023-003.

Appendices

Table 1. List of sampled well cores with their respective interval, lithology, age and mineral yield after mineral separation. Each sampled interval received a laboratory identification number (Lab ID) and its (U-Th)/He results are reported on Table 2.

Table 2. (U-Th)/He dating results for each of the analyzed aliquots.

Table 1. List of sampled well cores with their respective interval, lithology, age and mineral yield after mineral separation. Each sampled interval received a laboratory identification number (Lab ID) and its (U-Th)/He results are reported on Table 2.

Well Name	Well ID[a]	OROGO WID[b]	Latitude (NAD83)	Longitude (NAD83)	Formation[c]	Formation Age[d]	Interval (m)[e]	Lab ID[f]	Mineral yield[g]
PARAMOUNT ET AL FORT LIARD O-35	300/O-35-6010-12315/0	1868	60.07993N	123.35802W	Mattson	Carboniferous	1645 - 1654	112-30	Bad quality apatite, good quality zircon
CNRL WEST BOVIE I-76	300/I-76-6020-12300/0	1986	60.25977N	123.22431W	Scatter	Cretaceous	543 - 561	112-31/32	Bad quality apatite, good quality zircon (112-32)
IMPERIAL SUN NETLA RAVEN F-73	300/F-73-6050-12230/0	205	60.70704N	122.73762W	Scatter	Cretaceous	528.2 - 543.5	112-33/34	No apatite, bad quality zircon (112-33)
					Basal sandstone (Tetso?)	Devonian	2421 - 2425.6	112-35	No apatite, good quality zircon
MOBIL FORT SIMPSON M-70	300/M-70-6200-12215/0	591	61.99801N	122.46639W	Basement rock	Proterozoic	989.1 - 1006.5	112-36	No apatite, no zircon
CNRL LIARD K-02 (Mount Coty K-02)	300/K-02-6020-12330/0	1826	60.19349N	123.51973 W	Mattson	Carboniferous	1101.5 - 1160.6	112-37/38/39	No apatite, good quality zircon (112-38)
					Mattson	Carboniferous	1217.3 - 1255.7	112-40-41	No apatite, good quality zircon (112-40)
IMPERIAL SUN ARROWHEAD AURORA M-47	300/M-47-6040-12230/0	204	60.61509N	122.65011W	Basal sandstone (Tetso?)	Devonian	2584.7 - 2587.8	112-42	No apatite, no zircon
					Scatter	Cretaceous	489.2 - 518.2	112-43	No apatite, bad quality zircon
AQUIT HIGHLAND L K-42	300/K-42-6240-12215/0	792	62.52784N	122.39493W	Tetso	Devonian	978.4 - 983	112-44	No apatite, no zircon
IMPERIAL SUN ARROWHEAD I-46	300/I-46-6050-12215/0	199	60.76043N	122.38123W	Scatter	Cretaceous	388.9 - 398.1	112-45	No apatite, no zircon
BRIGGS RABBIT LAKE NO. 2(O-25)	300/O-25-6100-11845/0	122	60.91469N	118.82565W	Basement rock	Pre Cambrian	864.7 - 887	112-46/47	No apatite, no zircon
I0E AMOCO BOVIE M-05	300/M-05-6020-12245/0	483	60.24609N	122.77905W	undif. sandstone	Cretaceous	481.6 - 498.4	112-48	No apatite, good quality zircon
IMP ISLAND RIVER NO. 1 (G-50)	300/G-50-6010-12100/0	116	60.15808N	121.13943W	undif. sandstone	Cretaceous	650.1 - 656.2	112-49	No apatite, no zircon

a - Well identfication number

b - OROGO well identification number

c - Geological Formation provided by OROGO

d - Deposition age of geological Formation and estimated crystallization age of basement rocks

e - Well core depth in meters. Samples were collected from small sections

f - Geo-Thermochronology laboratory identification number at University of Calgary. Slash separates samples that were collected on the same well.

g - Results of mineral separation. Number in brackets identify to which sample the results refer to, when a well had more than one sample collected.

Table 2. (U-Th)/He dating results for each of the analyzed aliquots.

Aliquot	Length 1 (μm)[a]	Width 1 (μm)[b]	Length 2 (μm)[a]	Width 2 (μm)[b]	Geometry[c]	Np[d]	^{4}He (fmol)[e]	± fmol (2σ, ABS)[f]	U (ng)[g]	± ng (2σ, ABS)[f]	Th (ng)[h]	± ng (2σ, ABS)[f]	Th/U	Rs (μm)[j]	Mass (μg)[k]	Uncorr Date (Ma)[l]	± (2σ, ABS)[m]
112-30-1	169.4	114.1	-	-	prism	0	2858.8	5.9	1.725	0.076	0.472	0.020	0.3	64.1	10.28	281.2	11.6
112-30-2	190.1	126.1	185.9	130.2	prism	2	2059.2	3.1	0.605	0.027	1.054	0.048	1.7	65.5	7.84	431.5	14.8
112-30-3	182.2	118.6	-	-	prism	0	7717.8	8.3	1.008	0.050	1.755	0.083	1.7	67.1	11.92	922.3	37.0
112-35-1	207.9	172.8	-	-	prism	0	5254.9	3.6	2.791	0.124	1.678	0.121	0.6	91.5	28.87	297.7	11.8
112-35-2	206.9	144.5	-	-	prism + broken face	1	2422.0	3.5	2.855	0.121	1.876	0.119	0.7	77.5	15.41	134.7	4.9
112-35-3	151.4	151.2	-	-	prism + broken face	0	2944.3	4.0	0.993	0.048	0.794	0.042	0.8	75.6	16.09	444.2	18.7
112-35-4	204.7	126.7	-	-	prism + broken face	1	1348.0	1.6	1.695	0.073	1.357	0.085	0.8	70.9	12.13	122.8	4.5
112-35-5	221.7	176.1	-	-	prism + broken face	0	1203.3	2.3	2.653	0.109	2.175	0.138	0.8	94.5	31.97	70.1	2.5
112-38-1	178.8	115.9	-	-	prism	2	2887.8	4.0	1.340	0.058	1.002	0.045	0.7	65.7	11.17	329.8	12.3
112-38-2	202.7	127.5	-	-	prism + broken face	1	10236.3	11.4	3.001	0.127	1.023	0.056	0.3	71.0	12.11	553.4	22.2
112-38-3	157.3	60.7	-	-	prism	2	781.9	1.1	0.426	0.018	-0.018	-0.001	0.0	38.1	2.00	332.9	14.2
112-38-4	159.7	83.7	-	-	prism	1	1035.8	1.2	0.510	0.026	0.273	0.012	0.5	49.1	4.29	324.9	14.7
112-38-5	215.3	109.3	-	-	pill	-	440.6	0.9	0.274	0.014	0.071	0.003	0.3	63.9	6.28	273.8	13.2
112-40-1	128.9	46.1	-	-	prism	2	318.2	0.6	0.171	0.008	0.030	0.002	0.2	29.4	0.97	321.0	13.6
112-40-2	93.5	58.9	-	-	prism	2	201.0	0.5	0.107	0.005	-0.076	-0.004	-0.7	31.4	0.87	399.3	23.5
112-40-3	104.6	63.1	-	62.5	prism	2	435.9	0.7	0.330	0.014	0.042	0.002	0.1	34.4	1.16	232.5	9.3
112-40-4	109.8	54.5	-	50.1	prism	2	205.8	0.5	0.133	0.005	-0.037	-0.003	-0.3	32.0	1.01	298.5	12.1
112-40-5	98.1	40.6	-	42.3	prism	2	164.6	0.7	0.085	0.003	-0.011	-0.001	-0.1	25.1	0.54	355.8	12.9
112-48-1	169.5	70.4	-	-	prism	2	366.3	0.5	0.159	0.007	0.058	0.003	0.4	43.5	2.83	379.8	15.8
112-48-2	147.8	62.4	-	-	prism + broken face	1	539.3	0.7	0.252	0.011	0.099	0.005	0.4	38.5	2.30	351.7	14.0
112-48-3	118.3	58.0	-	-	prism	2	381.3	0.6	0.205	0.009	0.020	0.001	0.1	34.2	1.25	326.2	13.9
112-48-4	152.4	59.8	-	-	prism	2	589.8	1.1	0.312	0.012	0.029	0.001	0.1	37.4	1.87	332.1	12.5
112-48-5	120.9	75.9	-	-	prism	2	373.7	0.9	0.160	0.007	-0.038	-0.002	-0.2	40.6	1.88	437.7	21.5

a - Length is measured parallel to the c-axis and includes pyramidal terminations. It is measured twice on two perpendicular sides.

b - Width 1 is measured perpendicular to the c-axis. Width 2 is measured perpendicular to both the c-axis and width 1.

c - Geometry is defined as described in Figure 1 of Pupin (1980) and Figure 3 of Ketcham et al. (2011) in brackets. 1 is ellipsoid, 2 is cylinder, 3 is tetrahedral prism, and 4 is hexagonal prism

d - Np denotes the number of pyramidal terminations of the grain.

e - Blank-corrected ^{4}He

f - Uncertainties on ^{4}He, U, and Th are reported at 2σ standard deviations and include the propagated uncertainties on the measurements of the sample, blank, isotopic spike, and calibration standard.

g - Total blank-corrected ng of ^{238}U and ^{235}U. Total ^{238}U is measured and ^{235}U is calculated assuming ^{235}U = ^{238}U/137.818 after Hiess et al. (2012).

h - Total blank-corrected ng of ^{232}Th

j - Rs is the radius of a sphere with an equivalent alpha-ejection correction as the grain, calculated using Ketcham et al. (2011).

k - Mass is the mass of the crystal. Determined from the measured grain dimensions, the volume assuming the reported grain geometry, and the volume equations and mineral densities in Ketcham et al. (2011).

l - Uncorrected (U-Th)/He date is calculated iteratively using the first two terms of a Taylor explansion of the age equation (linear approximation)

m - Uncertainty on the uncorrected (U-Th)/He date is reported at 2σ and includes the propagated total analytical uncertainties (TAU) on the U, Th, and He measurements.