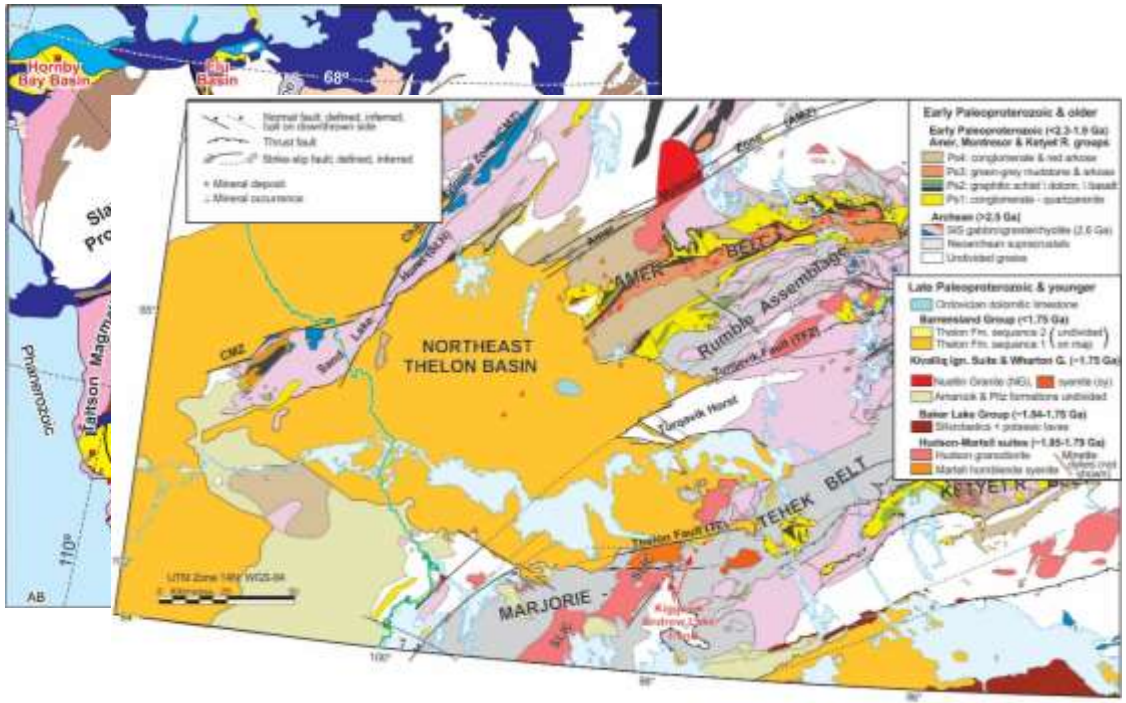
Physical rock property constraints and regional geophysical interpretations of the northeast Thelon Basin, Nunavut

Vicki Tschirhart*, Bill Morris,

Charlie Jefferson

Workshop 8: "Improving Exploration with Petrophysics: The Application of Magnetic Remanence and Other Rock Physical Properties to Geophysical Targeting"

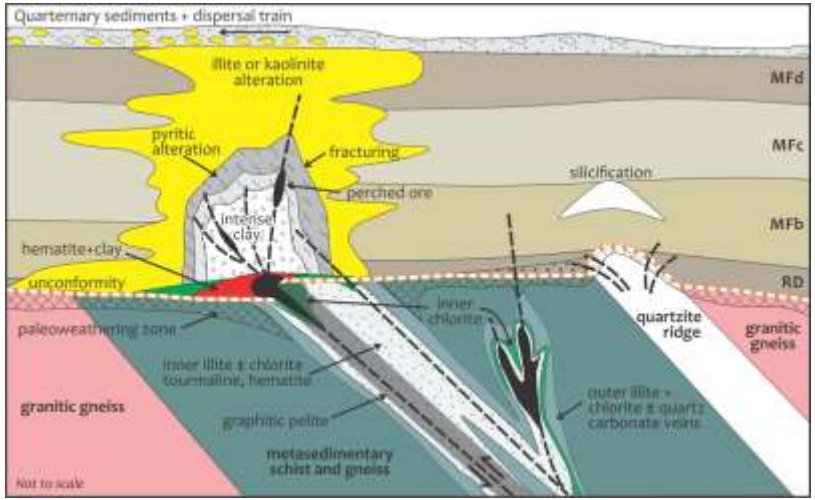
Northeast Thelon Basin, Nunavut



- >1000 m of sedimentary rocks unconformably overlie:
  - early Paleoproterozoic felsic intrusions
  - Paleoproterozoic supracrustal rocks
  - Archean crystalline basement
- Host to Kiggavik, End and Andrew U deposits and additional prospects
- Unconformity-style U along the Kiggavik-Andrew Lake trend is controlled by east-west faults associated with alteration halos in the Archean supracrustal rocks
- Stratabound U occurrences in the Amer Group

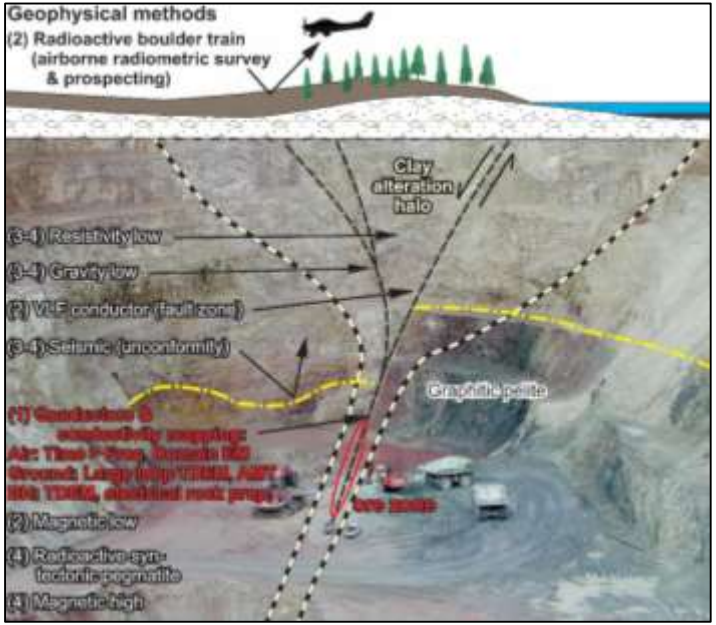
- Intersecting high angle reactivated faults cross-cutting fertile basement units near the basement-sandstone interface

Eastern Athabasca unconformity-related U model



Potter and Wright (2015)

Targeting parameters for unconformity-related U in the eastern Athabasca Basin



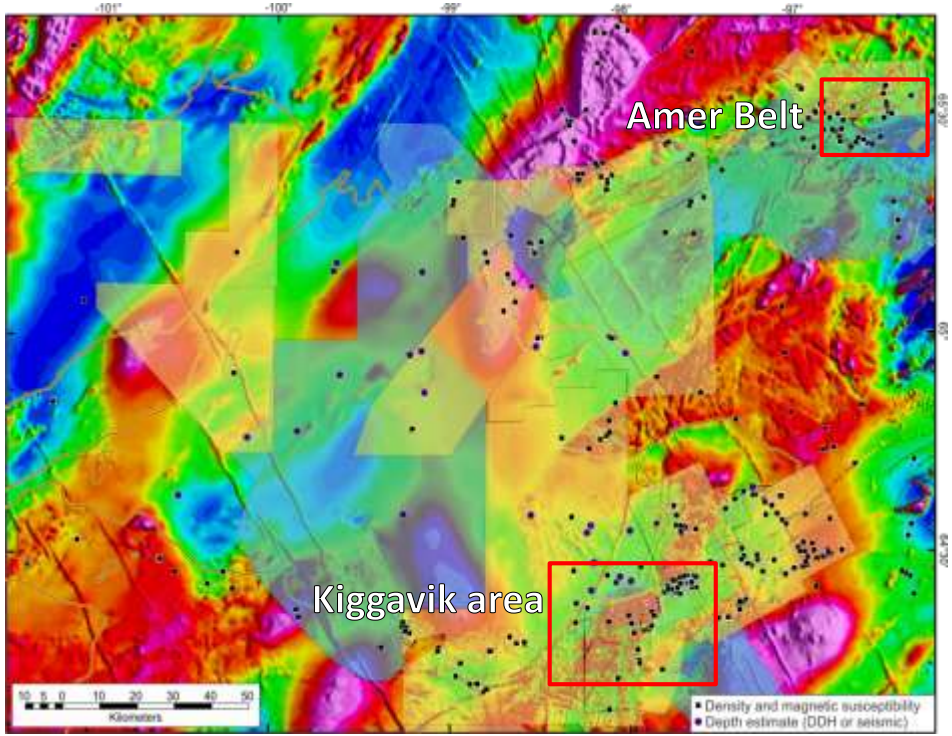
Potter and Wright (2015)

- For exploration within the basin, prioritizing areas for advanced exploration and development requires knowledge of:
  - Basement geology
  - Fault location and timing
  - Depth to basement (thickness of sandstone cover)

- Geophysical methods provide a valuable tool to map geology based on lateral contrasts in physical properties presumed to represent lithologic contacts

- Use available geophysics to understand subsurface geology:
  - Correlation of geophysical data with outcrop information and physical properties for construction of a remote predictive geological map
  - Lineament mapping using geophysical maps, elevation models and remote sensing imagery
  - Geophysical depth estimation techniques to model thickness of sedimentary cover

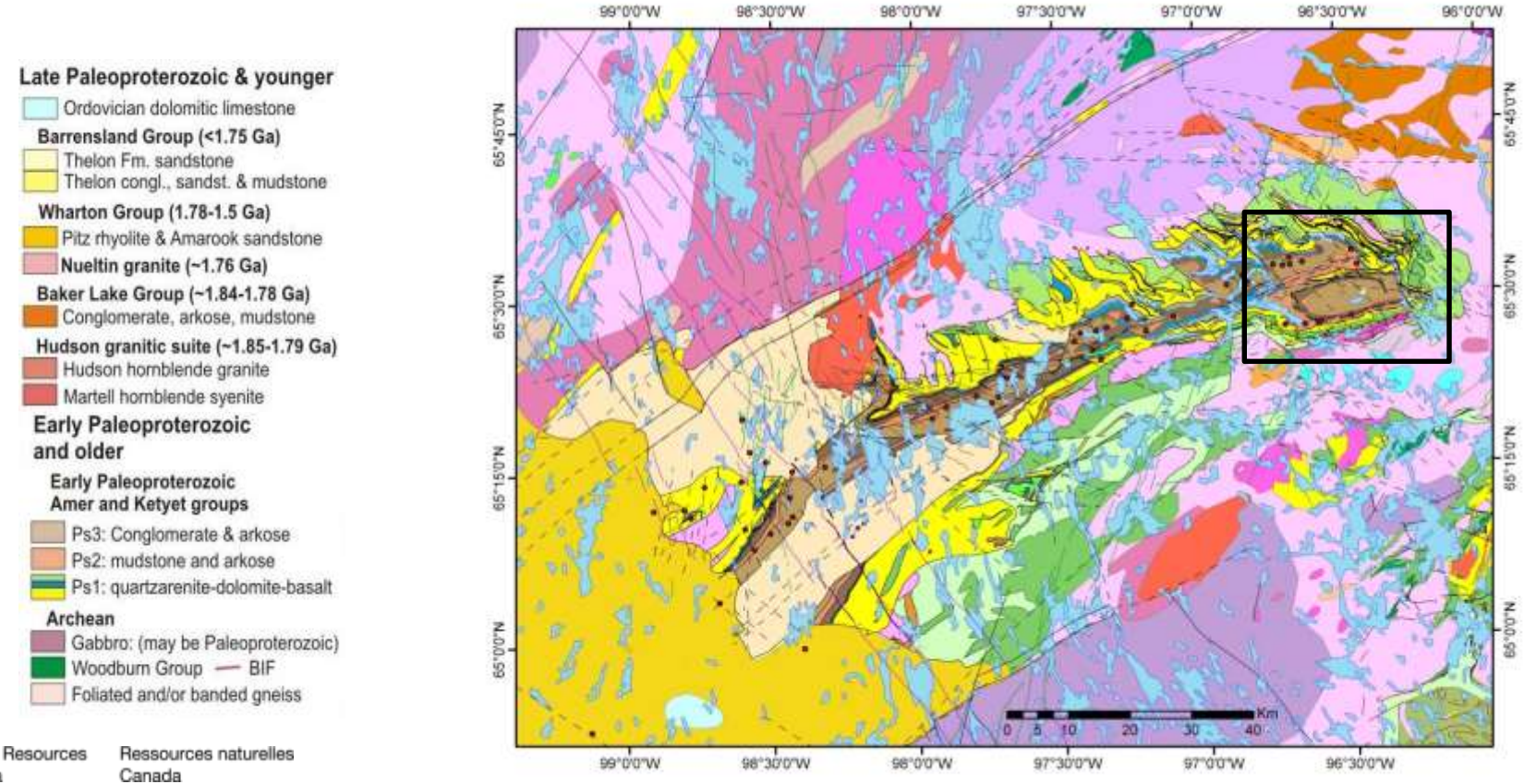
Available datasets



- Eight industry aeromagnetic surveys (200–300 m spaced lines)
- Three 400 m spaced lines aeromagnetic and radiometric surveys
- 21 DDH or seismic refraction depth estimates
- Densities and magnetic susceptibilities
- Two bedrock mapping field seasons (2010–2011) and targeted field visits/sampling (2007–2009, 2012)

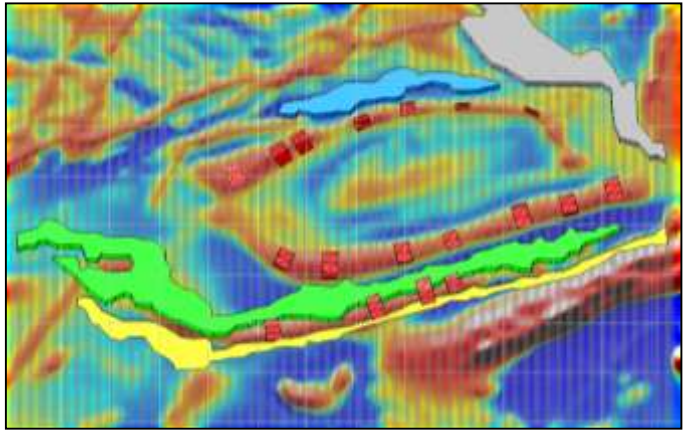
Two training areas provide structural insight and rock property characteristics to help with the interpretation below the Thelon cover

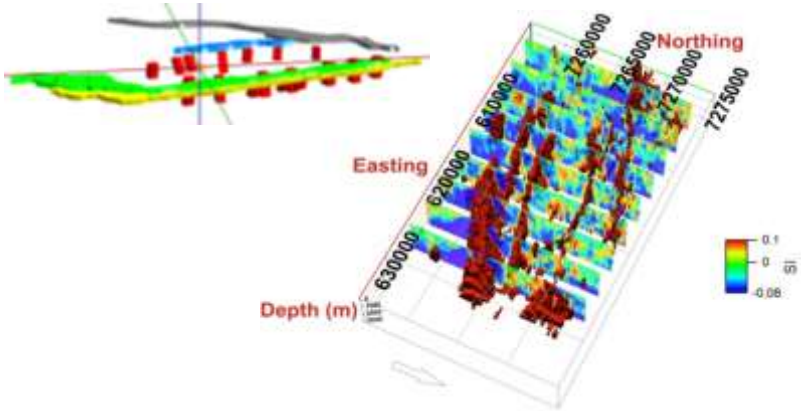
Geological map of the Amer Belt

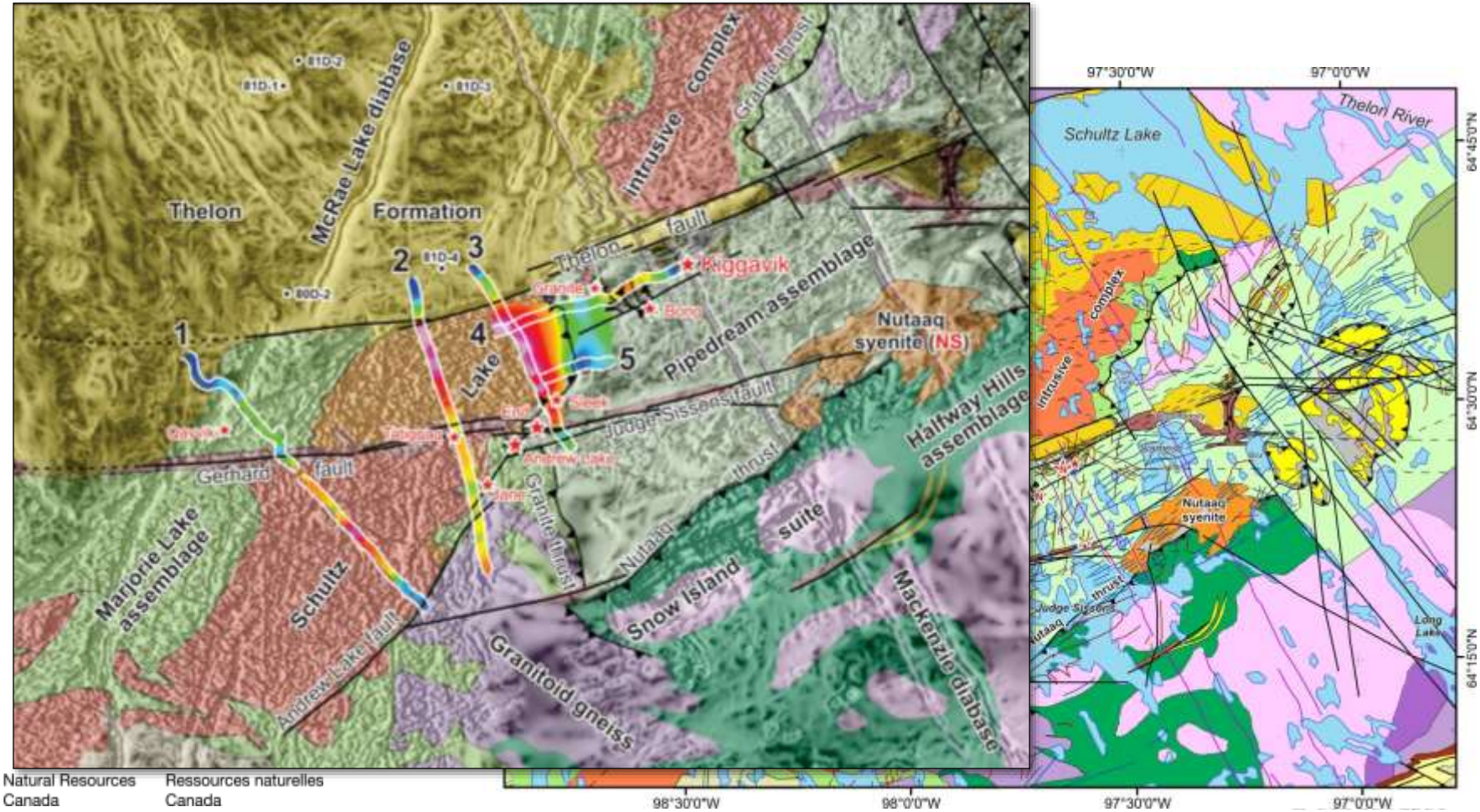


Northeast Amer belt

- ‘Bullseye’ magnetic anomaly
- Discrete magnetic-stratigraphic horizons (Ps2 basalt, Ps3 mudstone and siltstone) approx. simple dipping bodies (parametric inversion) and constrain 3D magnetic inversion
- Open, doubly plunging syncline cored by Ps4 overlying folded and imbricated Ps1–3

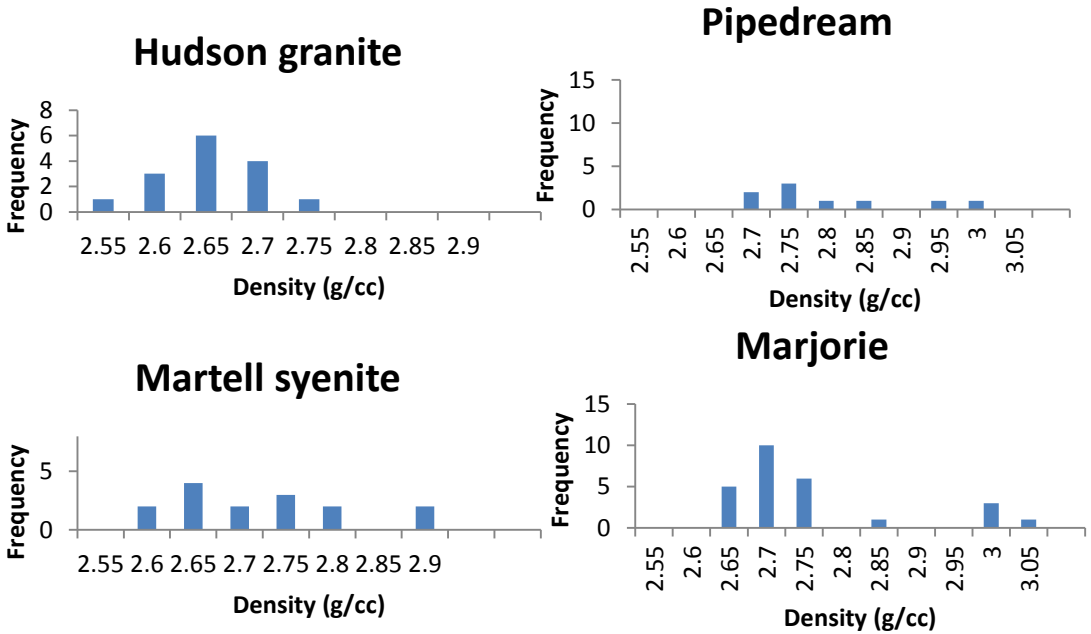





Thelon
McRae Lake diabase
Formation
Intrusive complex
Granite thrust
Thelon fault
Kiggavik
Pipedream assemblage
Nutaaq syenite (NS)
Lake
Judge Sissons fault
Halfway Hills assemblage
Gerhard fault
Granite thrust
Nutaaq suite
Marjorie Lake assemblage
Schultz
Snow Island
Mackenzie diabase
Andrew Lake fault
Granitoid gneiss
1
2
3
4
5
Schultz Lake
Thelon River
97°30'0"W
97°0'0"W
64°45'0"N
64°30'0"N
64°15'0"N
98°30'0"W
98°0'0"W

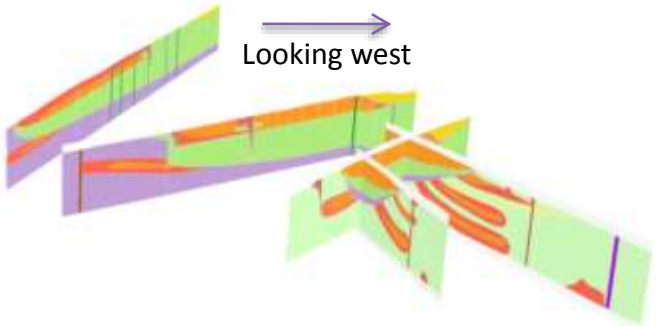
Kiggavik-Andrew lake trend

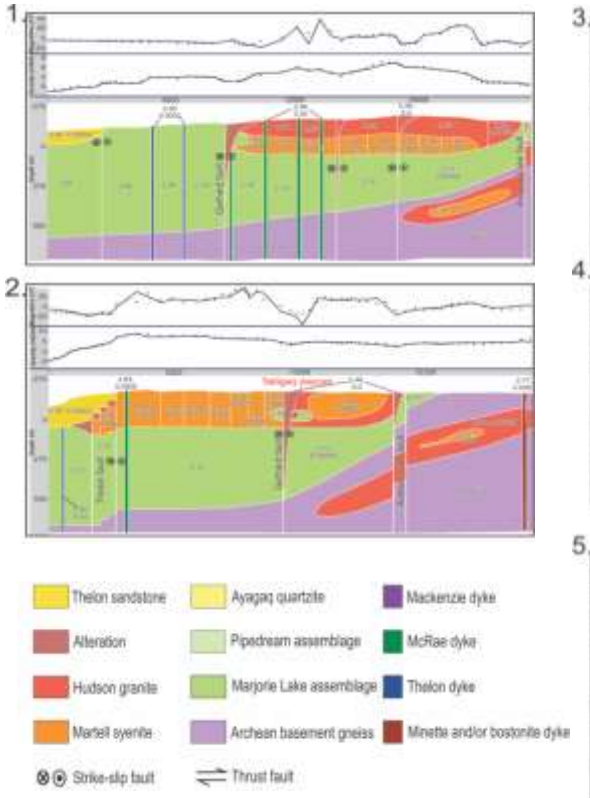
- Joint gravity and magnetic forward modelling
- Characterized density and magnetic susceptibility of Archean supracrustal basement and intrusive suites (Nueltin vs Hudson vs Martell)

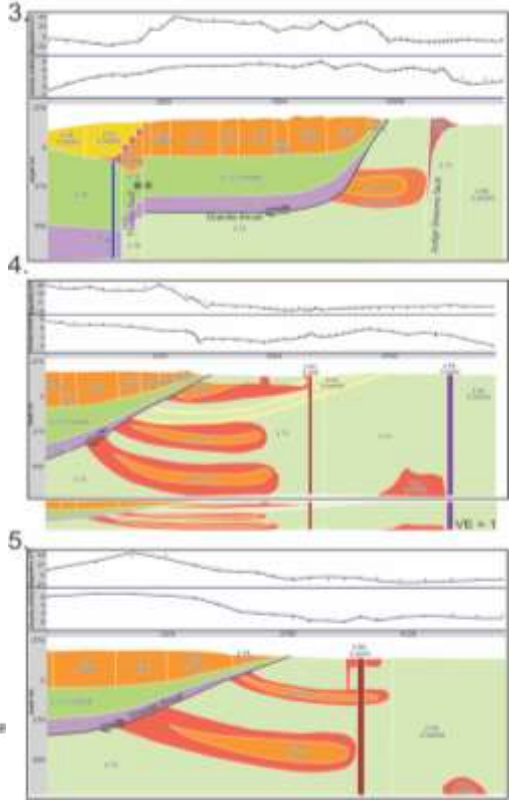


Forward modelling

Shultz Lake intrusive complex modelled as thick sills (200–300 m) within the Marjorie supracrustals thrust over the Pipedream supracrustals



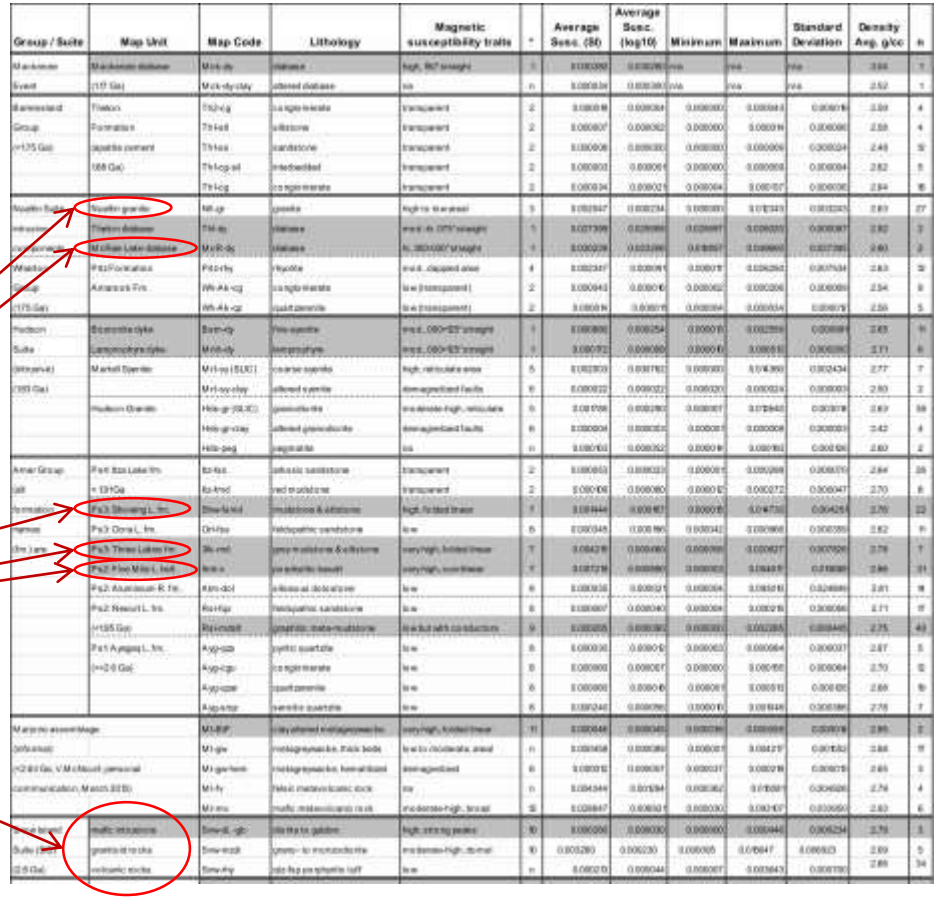




Rock property database

Rock property information provides the fundamental link between the geophysical signature and geology

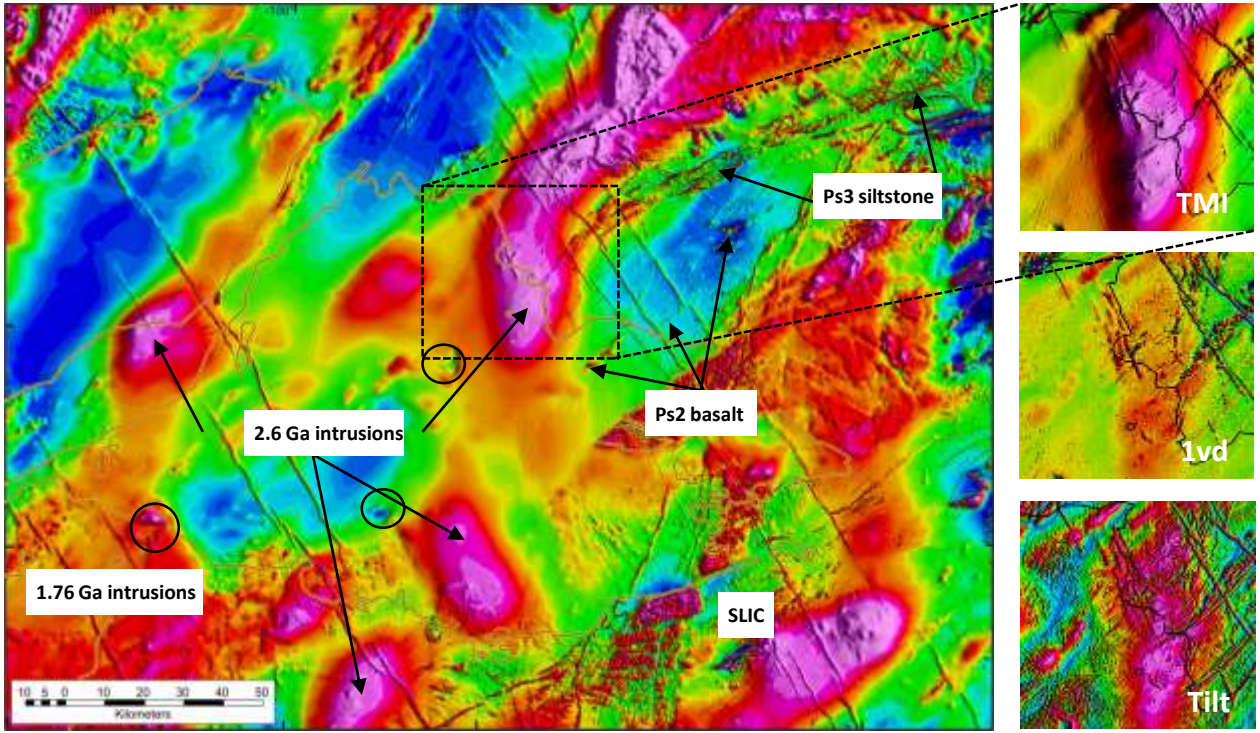
Identification of key magnetic-lithologic units and their textural characteristics

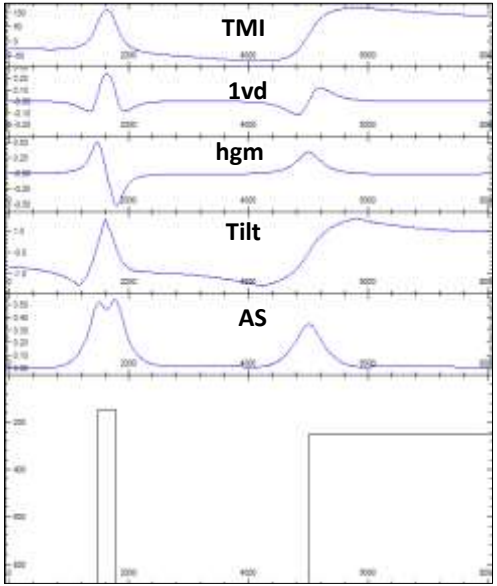


Group / Suite	Map Unit	Map Code	Lithology	Magnetic susceptibility traits	*	Average Susc. (SI)	Average Susc. (log10)	Minimum	Maximum	Standard Deviation	Density Avg. g/cc	n
Marshmoor	Marshmoor diabase	Mrsh-dy	diabase	high, 90° straight	1	0.030000	0.030000	n/a	n/a	n/a	2.86	1
Event	(1.17 Ga)	Mrsh-dy-clay	altered diabase	no	n	0.000034	0.000000	n/a	n/a	n/a	2.52	1
Baresteland	Tirelon	Tl-cg	conglomerate	transparent	2	0.000018	0.000004	0.000000	0.000043	0.000018	2.69	4
Group	Formation	Tl-ss	siltstone	transparent	2	0.000007	0.000002	0.000000	0.000016	0.000006	2.68	4
(>1.75 Ga)	(apatite cement	Tl-ss	sandstone	transparent	2	0.000008	0.000003	0.000000	0.000026	0.000024	2.48	5
	1.68 Ga)	Tl-cg-ss	interbedded	transparent	2	0.000003	0.000001	0.000000	0.000008	0.000004	2.62	5
		Tl-cg	conglomerate	transparent	2	0.000034	0.000021	0.000004	0.000157	0.000038	2.64	15
Nueltin Suite	Nueltin granite	Nl-gr	granite	high to moderate	5	0.002947	0.002234	0.000000	0.018349	0.003245	2.63	27
Intrusive	Tirelon diabase	Tl-di	diabase	med.-hi, 070° straight	1	0.027309	0.029986	0.029987	0.029993	0.000007	2.82	2
Intrusive	McKillan Lake diabase	Mcll-di	diabase	hi, 350-000° straight	1	0.030029	0.030029	0.030027	0.030031	0.000002	2.80	2
Wheeler	Pitz Formation	Pitz-hy	rhyolite	med., clapped area	4	0.002347	0.000951	0.000019	0.006262	0.001764	2.63	19
Group	Amarook Fm	Wh-Ak-cg	conglomerate	low (transparent)	2	0.000943	0.000016	0.000002	0.000206	0.000089	2.64	9
(1.75 Ga)		Wh-Ak-qz	quartz arenite	low (transparent)	2	0.000018	0.000015	0.000004	0.000034	0.000015	2.66	5
Hudson	Bienvenue dyke	Bien-dy	fine syenite	med., 080+/-25° straight	1	0.000800	0.000254	0.000015	0.002359	0.000681	2.65	11
Suite	Lamprophyre dyke	Mrlll-dy	lamprophyre	med., 080+/-25° straight	1	0.000172	0.000080	0.000010	0.000515	0.000150	2.71	6
(Intrusive)	Markell Syenite	Mrl-sy (SUC)	coarse syenite	high, reticulate area	5	0.002303	0.001781	0.000003	0.014390	0.002434	2.77	7
(1.65 Ga)		Mrl-sy-clay	altered syenite	demagnetized faults	6	0.000022	0.000022	0.000020	0.000024	0.000003	2.80	2
	Hudson Granite	Hds-gr (SUC)	granodiorite	moderate-high, reticulate	5	0.001708	0.001280	0.000007	0.012642	0.003078	2.63	59
		Hds-gr-clay	altered granodiorite	demagnetized faults	6	0.000004	0.000003	0.000001	0.000009	0.000003	2.62	4
		Hds-peg	pegmatite	no	n	0.000163	0.000052	0.000019	0.000781	0.000196	2.60	2
Amer Group	Fort Enz Lake fm.	Ez-ss	arkosic sandstone	transparent	2	0.000053	0.000023	0.000015	0.000269	0.000070	2.64	28
(all	+ 1.91 Ga	Ez-md	red mudstone	transparent	2	0.000108	0.000080	0.000015	0.000272	0.000047	2.70	8
formations	Pa3: Shoaring L. fm.	Shw-fg-md	mudstone & siltstone	high, folded linear	7	0.038444	0.030167	0.000015	0.247731	0.064251	2.70	22
names	Pa3: Dora L. fm.	Dr-f-ss	feldspathic sandstone	low	6	0.000345	0.000195	0.000042	0.000966	0.000335	2.62	11
(fm.) are	Pa3: Three Lakes fm.	3lk-md	gray mudstone & siltstone	very high, folded linear	7	0.084219	0.000460	0.000030	0.000827	0.000509	2.78	7
	Pa2: Five Mile L. fsst.	fmi-s	quartzofeldspathic basalt	very high, scan linear	7	0.037239	0.000580	0.000003	0.244819	0.218088	2.86	31
	Pa2: Asuriaqun R. fm.	Asn-dol	siliceous dolostone	low	6	0.000018	0.000021	0.000004	0.000218	0.000486	2.81	18
	Pa2: Nesurt L. fm.	Ns-f-ss	feldspathic sandstone	low	6	0.000087	0.000040	0.000004	0.000218	0.000056	2.71	11
	(>1.95 Ga)	Ns-md-slt	gray mic. meta-mudstone	low but with conductors	9	0.000205	0.000080	0.000001	0.002285	0.000445	2.75	43
	Pa1 Ayagaq L. fm.	Ayg-qza	cyclic quartzite	low	6	0.000030	0.000010	0.000003	0.000084	0.000027	2.67	5
	(>2.0 Ga)	Ayg-cgs	conglomerate	low	6	0.000000	0.000001	0.000000	0.000018	0.000004	2.70	12
		Ayg-qza	quartzarenite	low	6	0.000000	0.000000	0.000000	0.000000	0.000000	2.65	19
		Ayg-sv-qz	sericitic quartzite	low	6	0.000240	0.000078	0.000001	0.001848	0.000388	2.78	7
Marginal to ancient Magn.		MrMP	strongly altered metagreywacke	very high, folded linear	11	0.000048	0.000040	0.000018	0.000084	0.000018	2.85	2
(structural)		Mrl-gw	metagreywacke, thick beds	low to moderate, areal	n	0.000458	0.000280	0.000001	0.004219	0.000832	2.66	11
(>2.60 Ga, V.M.Kilcourt, personal		Mrl-gw-fsmt	metagreywacke, hematitized	demagnetized	6	0.000012	0.000001	0.000001	0.000218	0.000078	2.65	3
communication, March 2015)		Mrl-fy	felsic metavolcanic rock	no	n	0.004344	0.001594	0.000062	0.018001	0.004928	2.74	4
		Mrl-mv	mafic metavolcanic rock	moderate-high, broad	10	0.028847	0.008501	0.000030	0.082157	0.030050	2.83	6
Nueltin Suite	mafic intrusions	Smw-E-gb	diabase to gabbro	high, strong peaks	10	0.000200	0.000080	0.000000	0.000446	0.000234	2.79	3
Suite (Lower	granodiorite to	Smw-mzd	gneiss to monzodiorite	moderate-high, domal	10	0.003280	0.000230	0.000005	0.018647	0.006923	2.69	5
(2.6 Ga)	volcanic rocks	Smw-fy	felsic fsp porphyritic tuff	low	n	0.000215	0.000044	0.000001	0.003843	0.000730	2.69	34

Magnetic-lithologic units

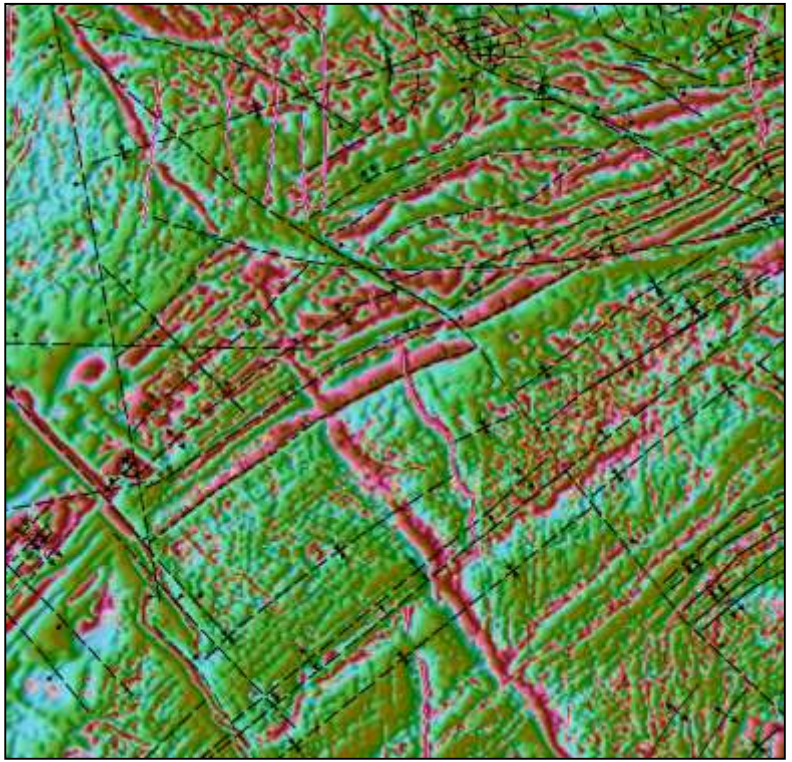
RTF over the northeast Thelon Basin





Structural interpretation

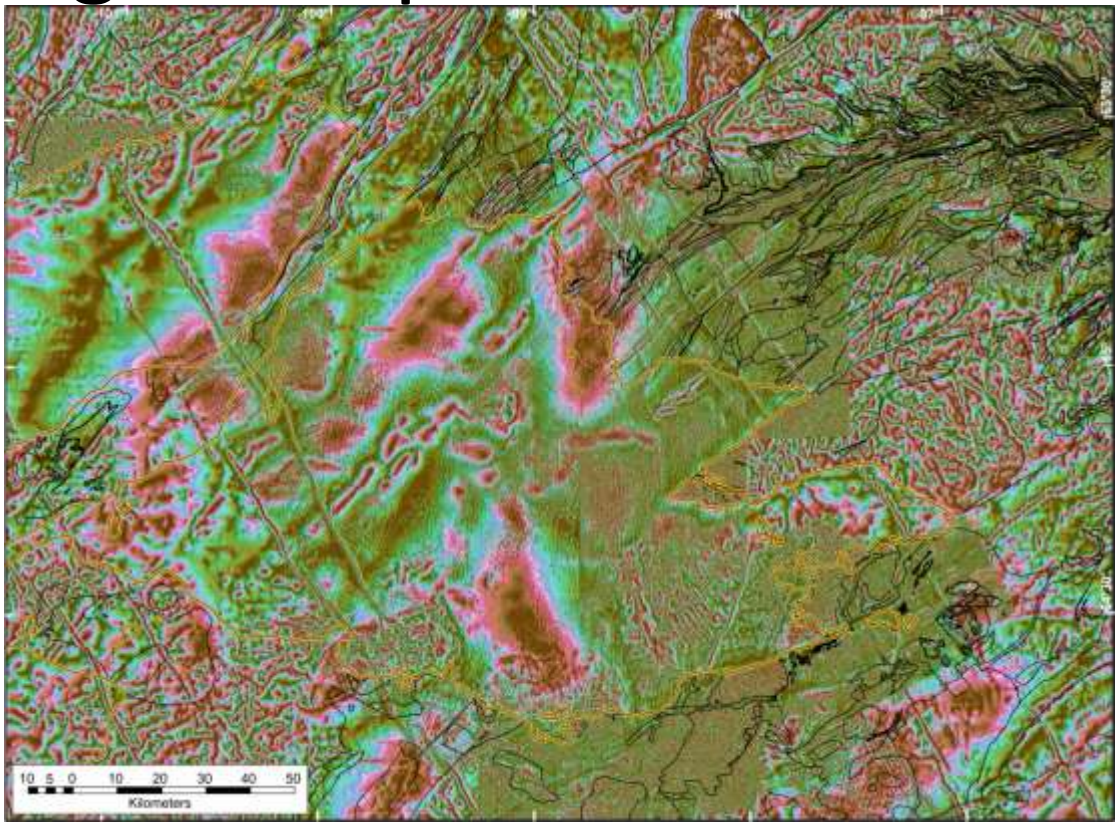
- Distribution of faults and folds
  - Orientation
  - Spacing
- Fault displacement
  - Relative displacement
- Fault timing
  - Fault-fault offsets
  - Displacement of marker units
  - Relative ages
- Fault characteristics
  - Width of alteration zone (+ or – anomaly; linear or curved)
  - Demagnetization



Source edge interpretation

Many SEDs were tested but for display purposes TDX and Theta used

TDX highlights edges of magnetic units; Theta enhances compositional variations



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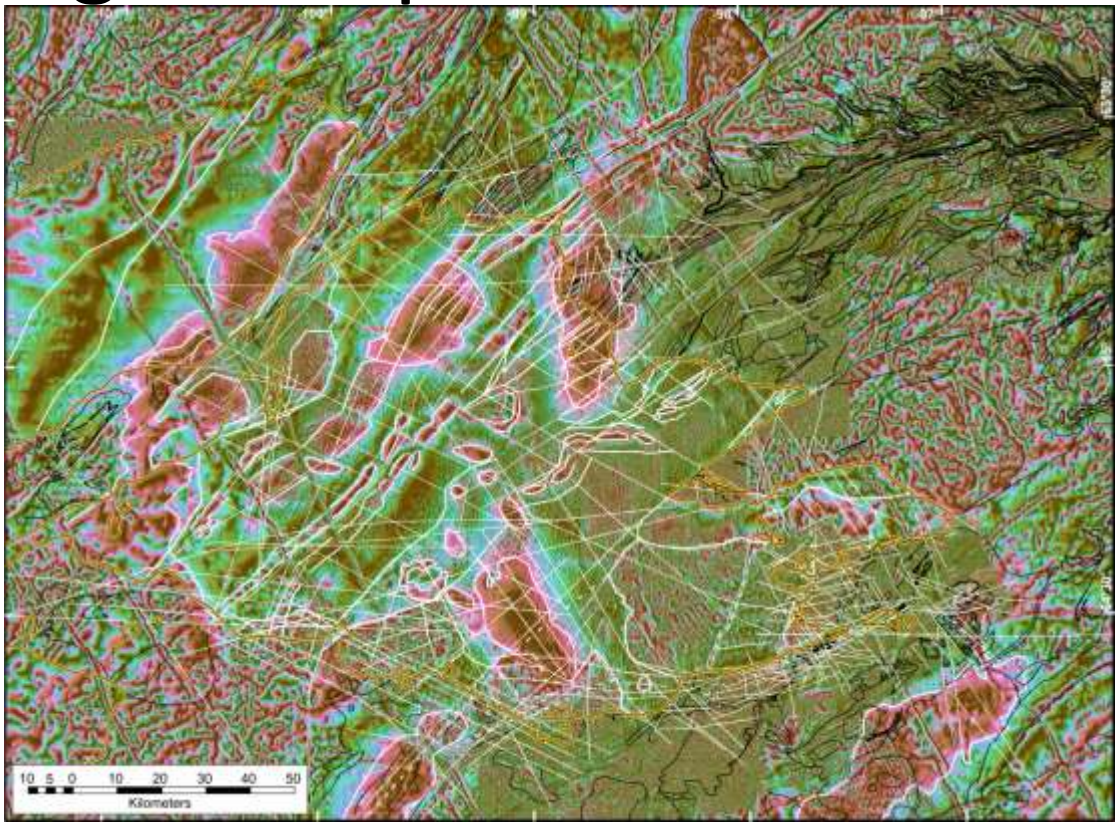
Source edge interpretation

Identify areas of similar magnetic-lithologic character and extrapolate below sedimentary cover

Lineaments and discontinuities (‘structure’)

Reactivated faults critical for U



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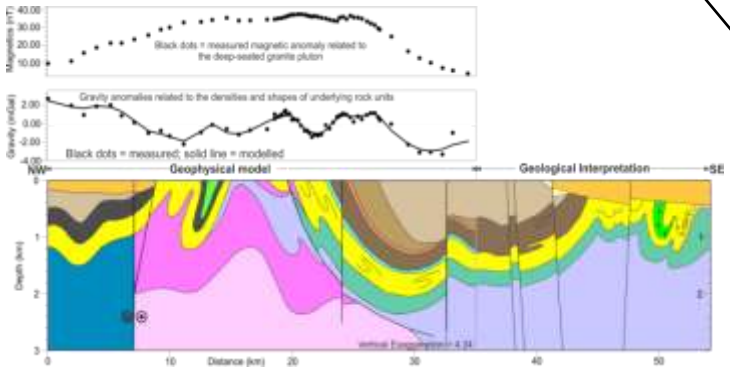
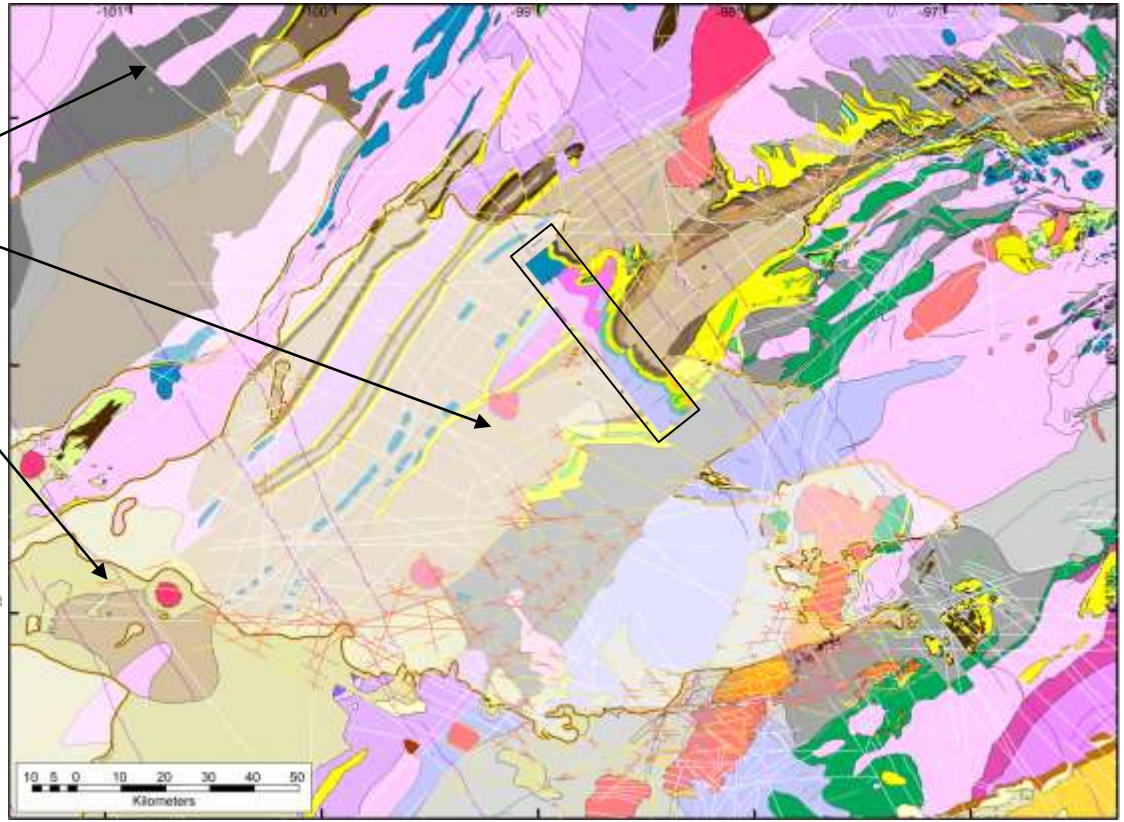
Predictive geological map

White lines – interpreted and mapped faults
Yellow lines – faults in fertile basement units
Red lines – intersecting faults in fertile basement units

Check magnetic-lithologic interpretation with gravity data





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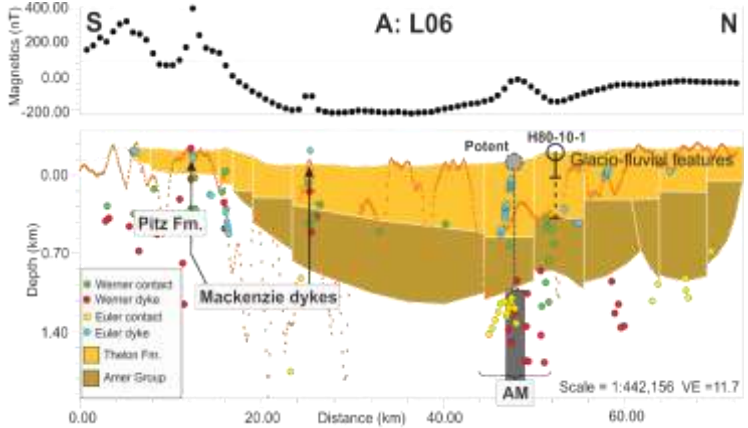
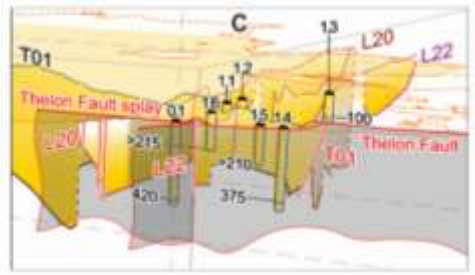
Depth to basement

- Depth to basement calculated using semi-automated depth estimation techniques and inverse modelling, and hard constraints (where available)
- Prioritize depth indicators with respect to reliability of constraint: DDH, seismic, known geology and fault displacement, discrete parametric models, UBC-GIF inversion, source depth routines/empirical basement indicators (Euler, Werner, and SPI)
- Faults assigned a down-drop direction based on the apparent throw of cross-cutting magnetic units

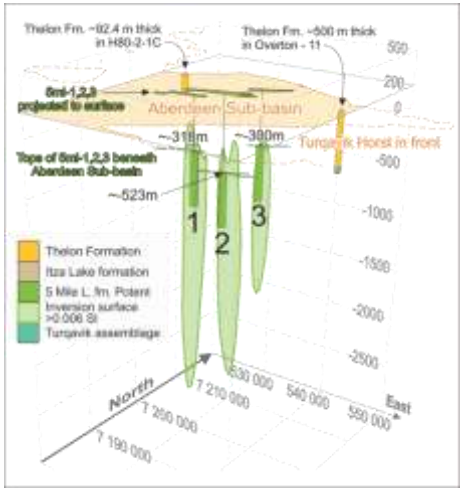
- Three layers:
  - Thelon Formation
  - Amer Group
  - Undifferentiated basement



Semi-automated routines + DDH + 2D inversions



DDH constraints

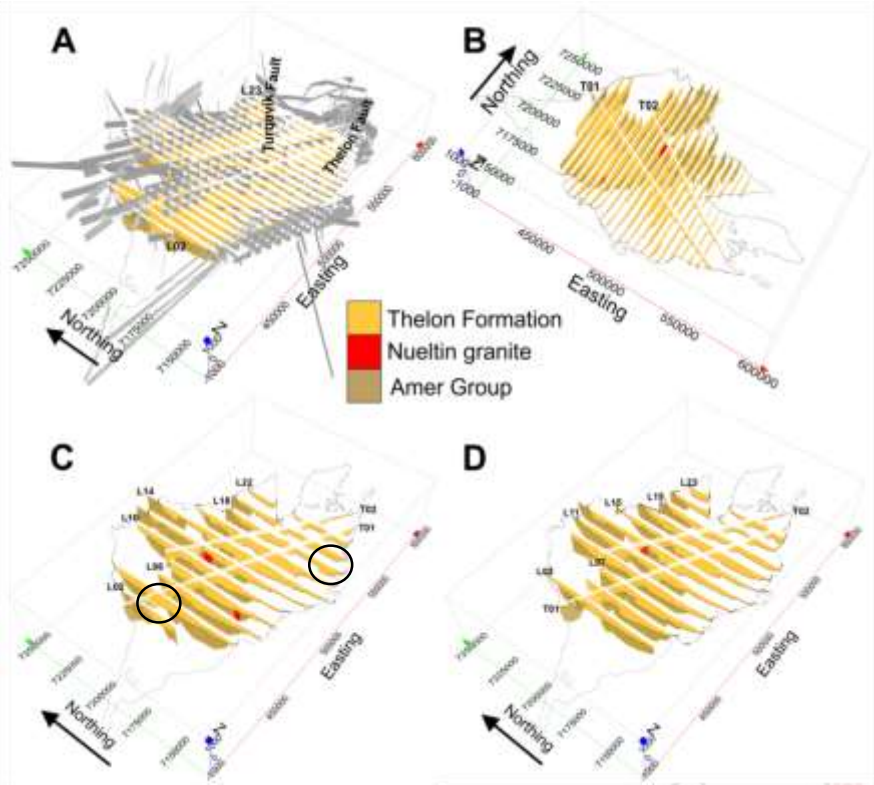


Inversion constraints

Pseudo 3D model

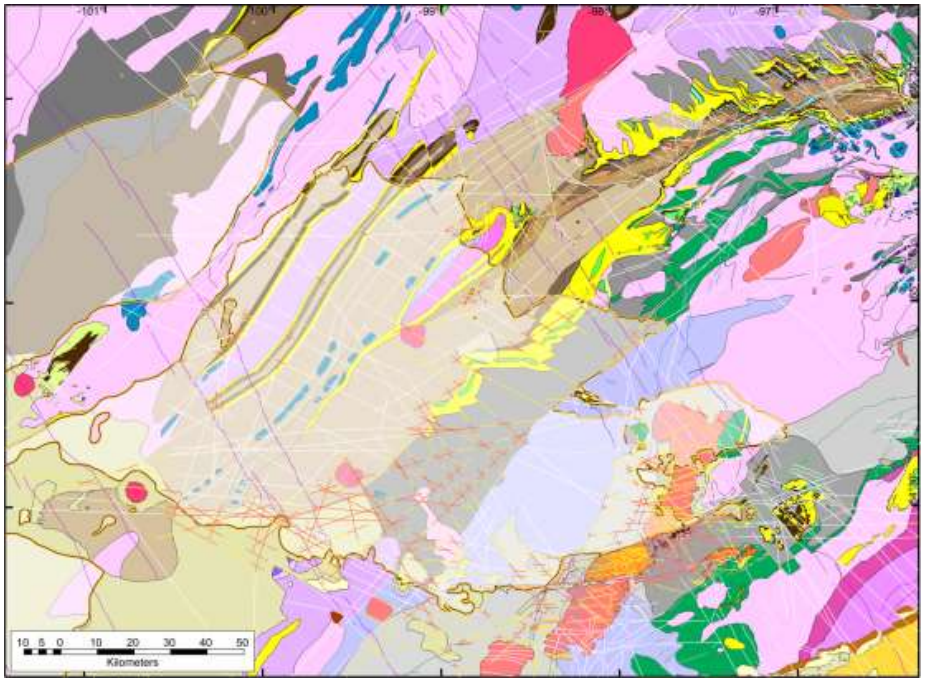
- By ensuring coherency across profiles and abiding to the mapped fault down-drop direction can construct a pseudo-3D model of the subsurface

- Deepest regions located at ?Tur-5 and Itza-2 (black circles)
- Northwest-southeast fault system dominant structural array controlling geometry



Conclusions

- Without rock property and geological information the geophysical signature is non-unique and cannot be accurately tied to the surface geology
- Rock property datasets provided vital information to inform regional geological-geophysical interpretations
- Regionally prospective areas include:
  - Intersecting faults in fertile units such as Ps3 Showing lake formation, Marjorie, Rumble and Nueltin granite under few 100 m of sedimentary cover
- Next steps: model that combines *depth to basement* information with the predictive *geological map* and favourable *fault intersections*




Thanks!
Questions / comments?