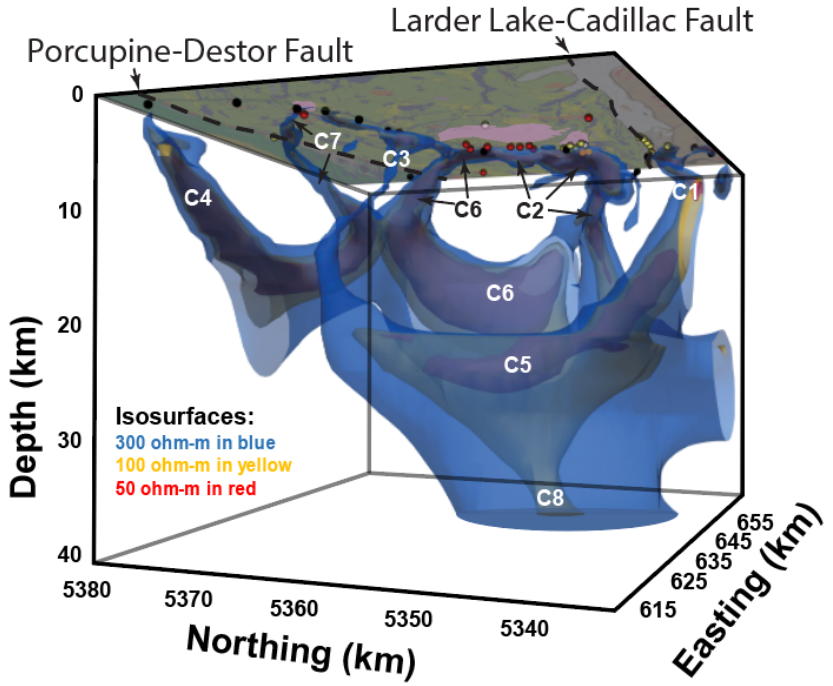
2023 SASKATCHEWAN GEOLOGICAL OPEN HOUSE
November 27 to 29 | Delta Bessborough Hotel, Saskatoon

Short Course: New insights into crustal-scale influences on gold and base metal endowment in the Archean Superior Province
Saturday, November 27th, 2023, 9:00 AM to 4:30 AM (ET)

Crustal Architecture and VMS Endowment: Insights from the Rouyn-Noranda Camp, Abitibi Greenstone Belt

TAUS R. C. JØRGENSEN



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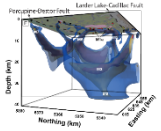

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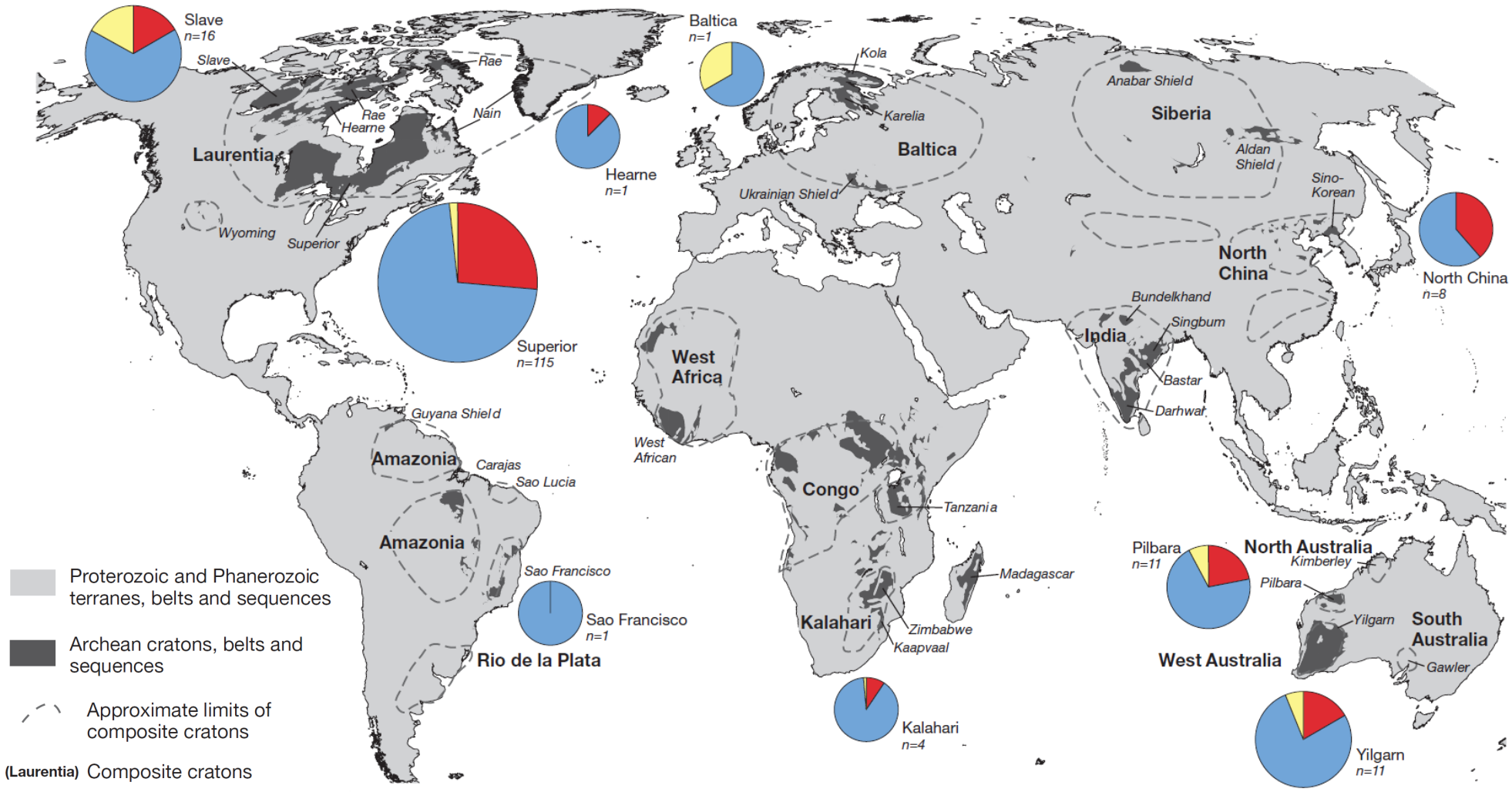
- Global geographic distribution of Archean cratons and VMS



The Superior (n=115), Slave (n=16), Yilgarn (n=11), and Pilbara (n=11) account for over 90% of all Archean VMS deposits.

Mercier-Langevin et al. (2014) – *Economic Geology, v. 109, p. 1-9*

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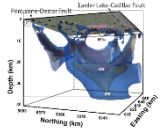
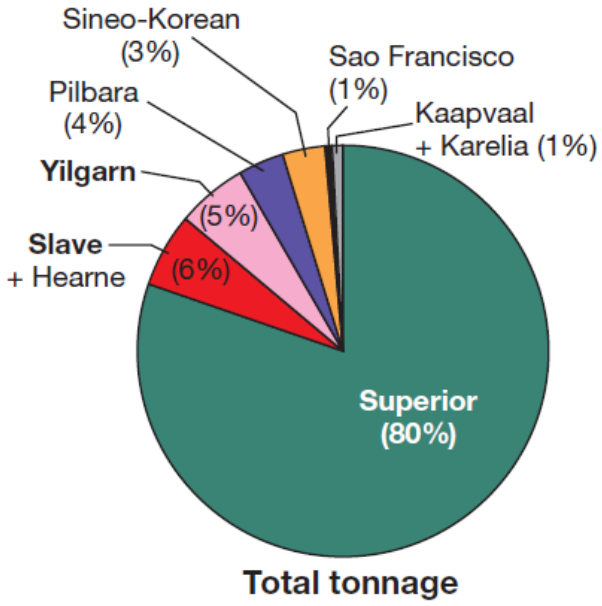
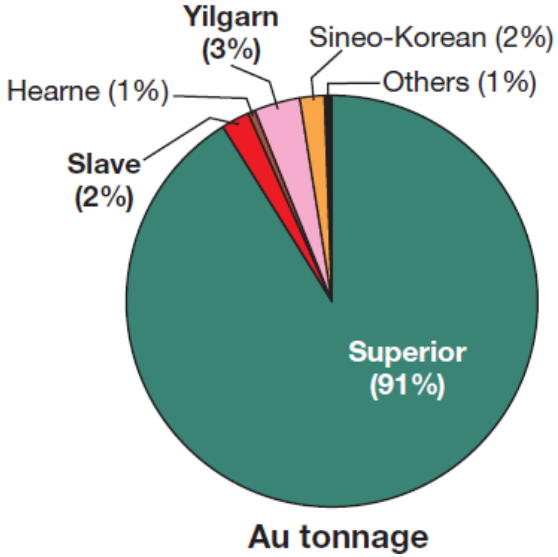
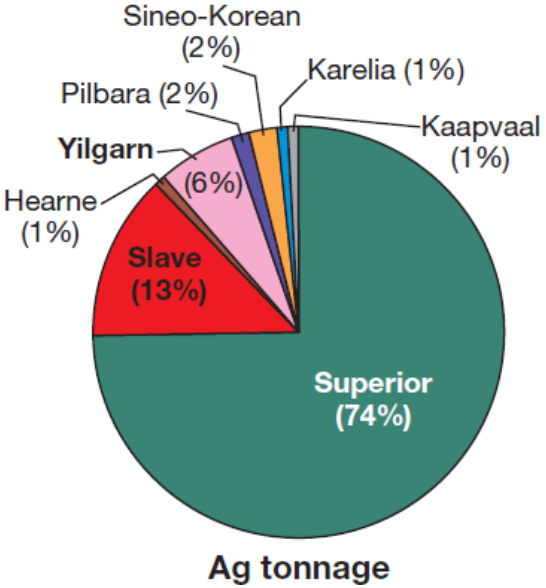


• Global VMS resources distribution per Archean craton (tonnage, Au, and Ag)







Mercier-Langevin et al. (2014) – *Economic Geology, v. 109, p. 1-9*

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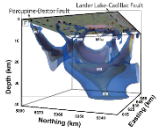

Crustal Architecture and VMS Endowment: Insights from the Rouyn-Noranda Camp, Abitibi Greenstone Belt

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- VMS metal endowment of Archean cratonic blocks in Canada and Australia
- Measured as the quantity of metal contained in geologic resources per unit surface area

Craton/terrane/domain	Area (km²)	Contained metal (Mt)			Endowment (t/km²)			
		Cu	Zn	Pb	Cu	Zn	Pb	Cu+Zn+Pb
North Pilbara granite-greenstone terrane	82,000	0.396	1.126	0.095	4.8	13.7	1.2	19.7
East Pilbara granite-greenstone terrane	65,000	0.241	0.890	0.035	3.7	13.7	0.5	17.9
Mallina basin	11,000	0.105	0.165	0.060	9.5	15.0	5.5	30.0
West Pilbara granite-greenstone terrane	5,700	0.025	0.035	0.000	4.4	6.2	0.0	10.6
Whundo greenstone belt	*520*	*0.025*	*0.035*	*0.000*	*48.4*	*68.2*	*0.0*	*116.5*
Yilgarn craton	185,000	0.838	4.234	0.363	4.5	22.9	2.0	29.4
Eastern Goldfields superterrane	68,000	0.158	0.635	0.042	2.3	9.3	0.6	12.3
Teutonic zone	*15,000*	*0.158*	*0.635*	*0.042*	*10.5*	*42.3*	*2.8*	*55.7*
Youanmi terrane	*72,000*	*0.681*	*3.599*	*0.321*	*9.5*	*50.0*	*4.5*	*63.9*
Cue zone	*11,000*	*0.539*	*2.349*	*0.237*	*49.0*	*213.6*	*21.6*	*284.2*
Superior province	890,000	11.577	28.183	0.841	13.0	31.7	0.9	45.6
Abitibi-Wawa subprovince	*224,000*	*11.282*	*26.355*	*0.676*	*50.5*	*117.9*	*3.0*	*171.4*
Uchi subprovince	35,000	0.075	0.236	0.000	2.1	6.7	0.0	8.8
Wabigoon subprovince	97,000	0.220	1.592	0.165	2.3	16.5	1.7	20.4
Slave province	211,000	0.975	5.566	0.698	4.6	26.4	3.3	34.3
Eastern Slave province	130,000	0.586	3.473	0.417	4.5	26.7	3.2	34.4
Western Slave province	81,000	0.389	2.092	0.281	4.8	25.8	3.5	34.1

Notes: Total contained metal data are based on Franklin et al. (2005) updated to include new data from company press releases; italics indicate metallogenic provinces with high (>50 t/km² Cu + Pb + Zn) volcanic-hosted massive sulfide endowment

Huston et al. 2014 - *Economic Geology, v. 109, p. 11–26*

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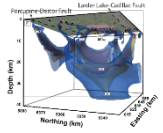

- When grouped according to crustal character, as indicated by Pb and Nd isotopes, juvenile terranes show higher endowment than terranes with more evolved crust

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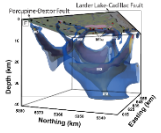

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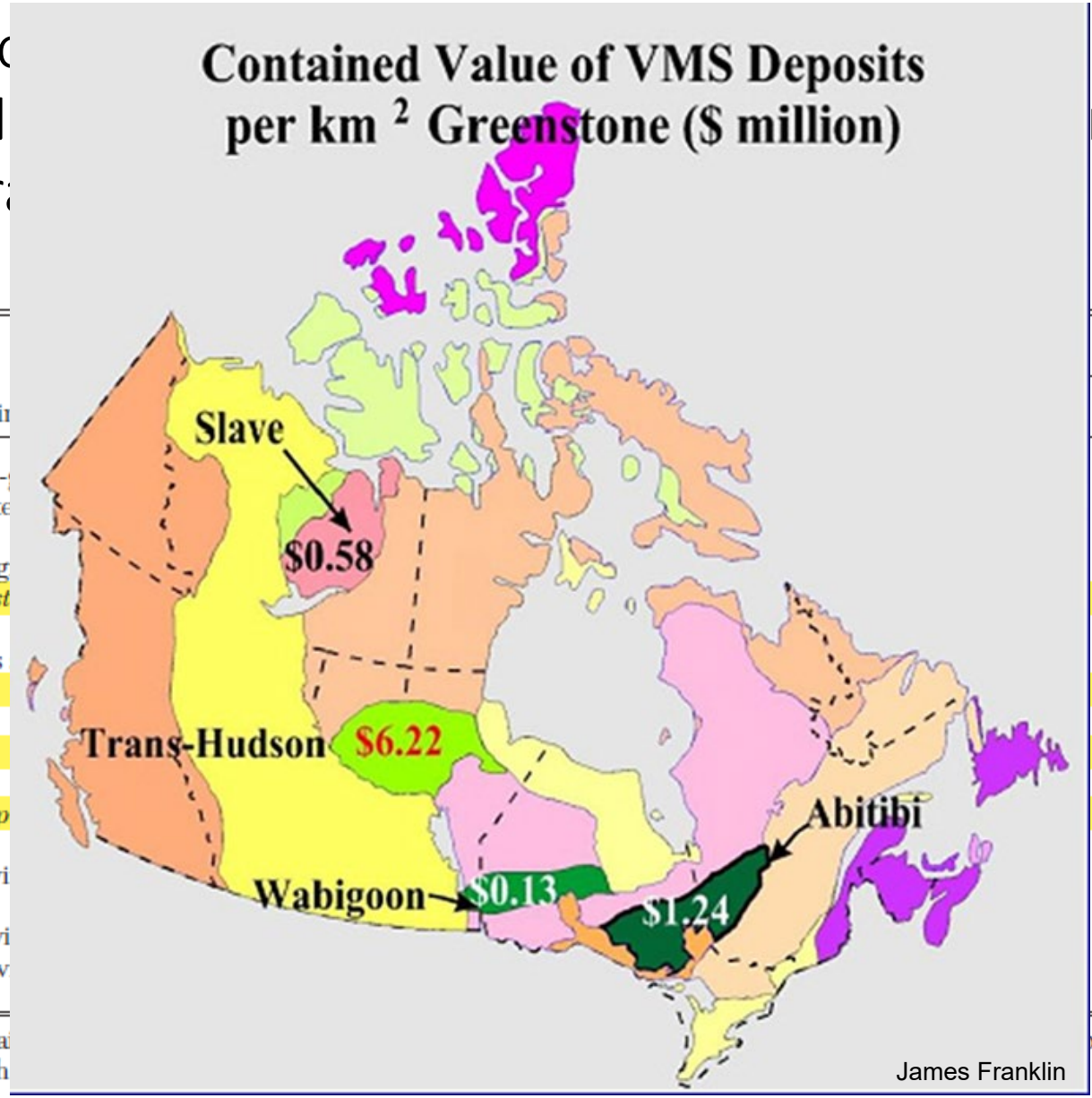
- When gro… Pb and N… than terr… …ndicated by …r endowment



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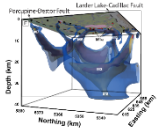

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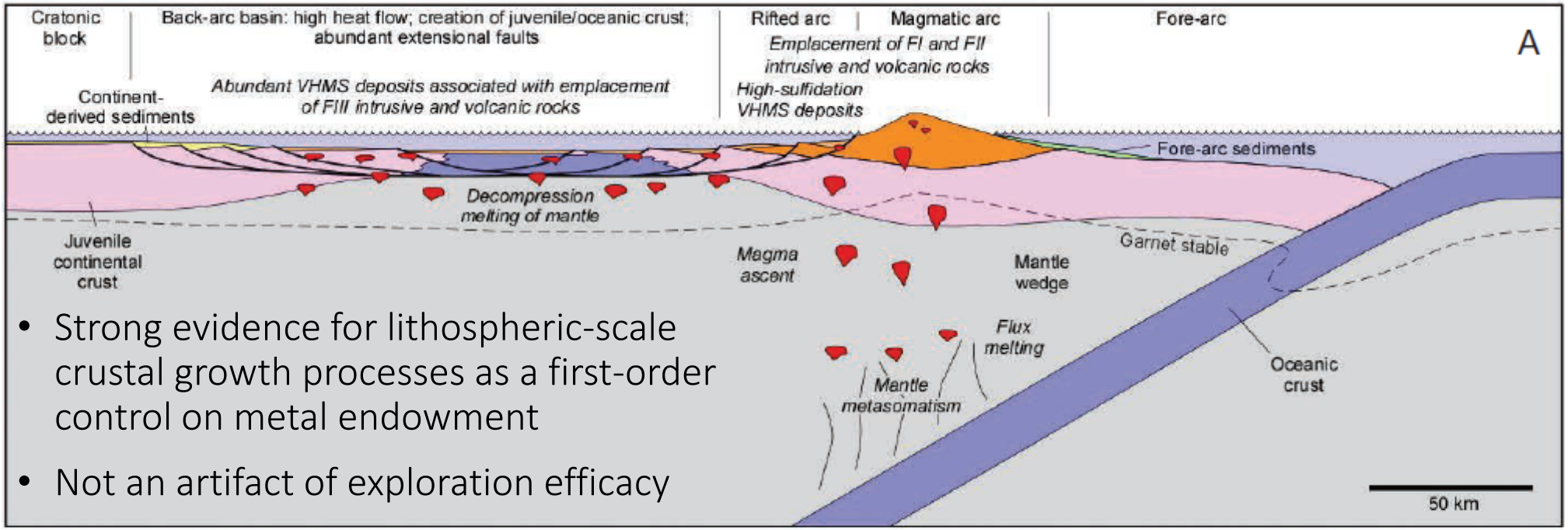
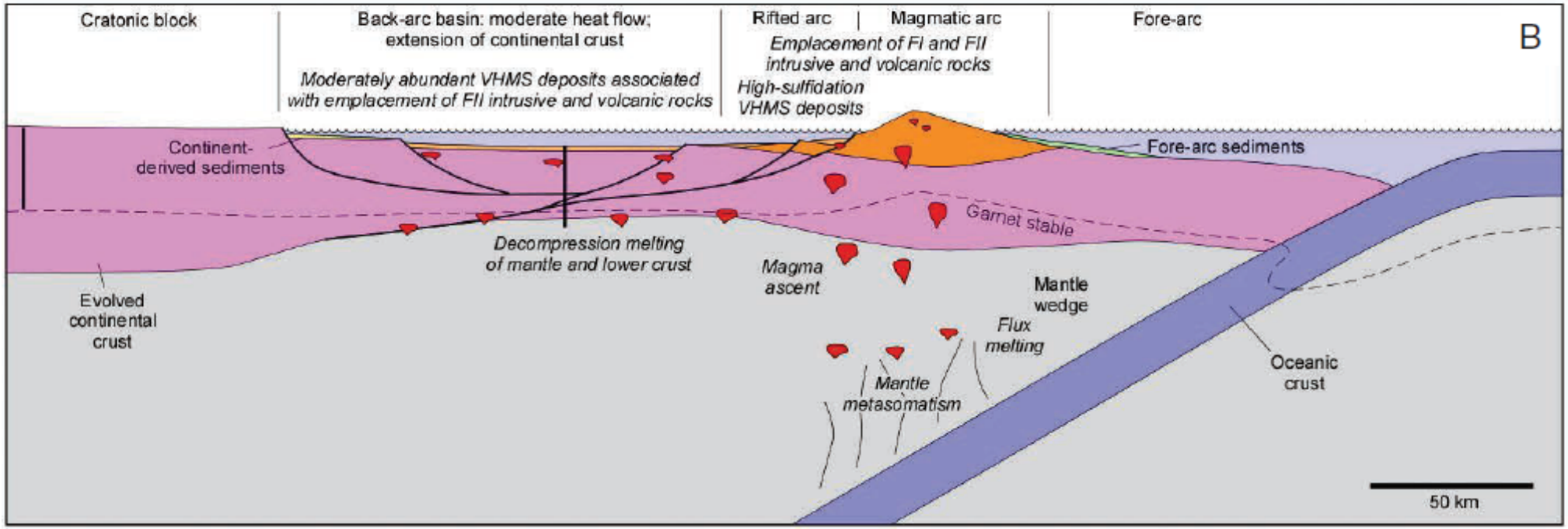


- Strong evidence for lithospheric-scale crustal growth processes as a first-order control on metal endowment
- Not an artifact of exploration efficacy



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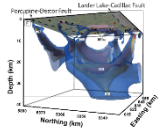

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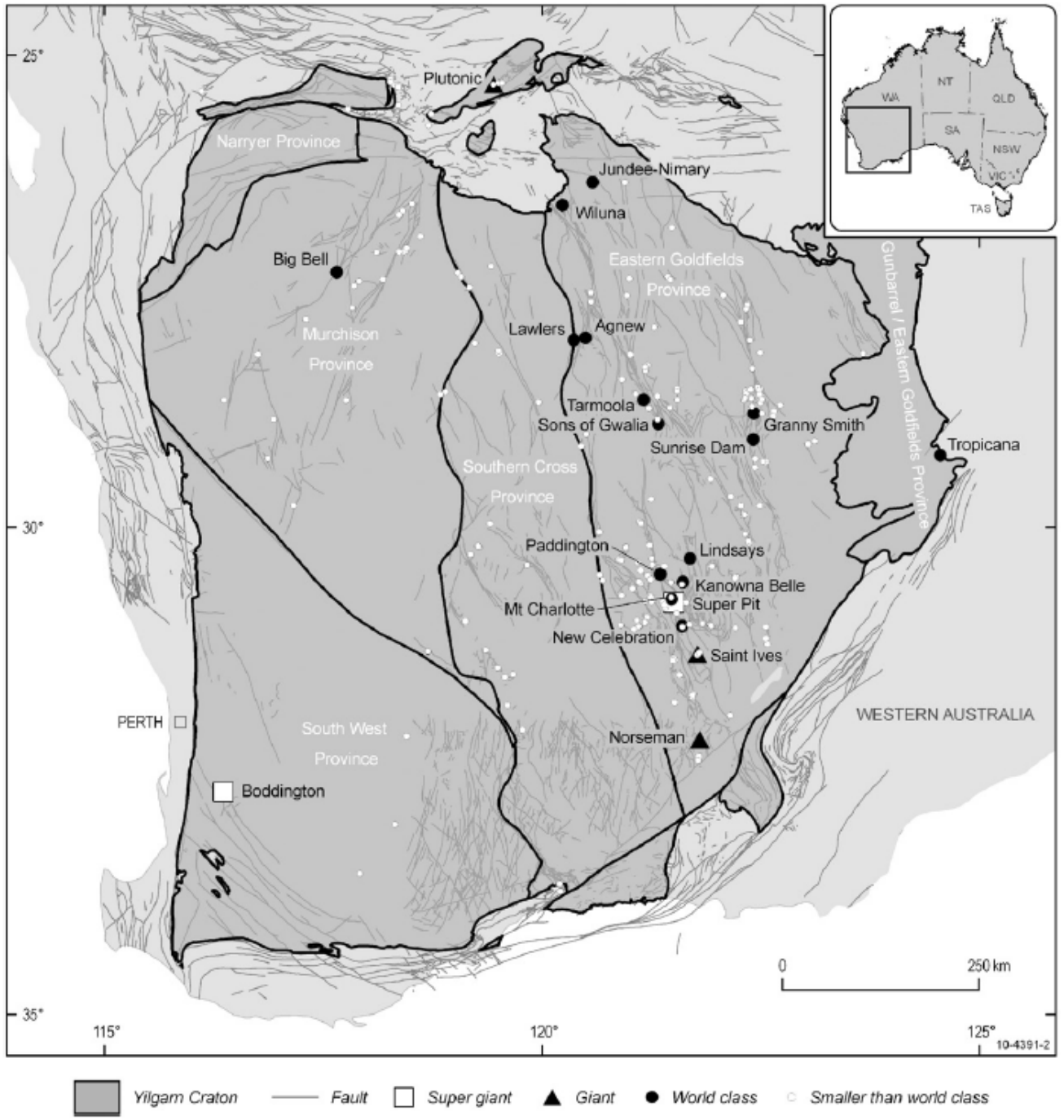
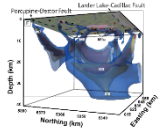
YILGARN CRATON

- Within individual cratons a few provinces are more endowed than the rest. This pattern continues to the level of districts within terranes/belts. What geological features causes the clustering?



Jaireth and Huston (2010) – *Ore Geology Reviews, 38, p. 288-303*



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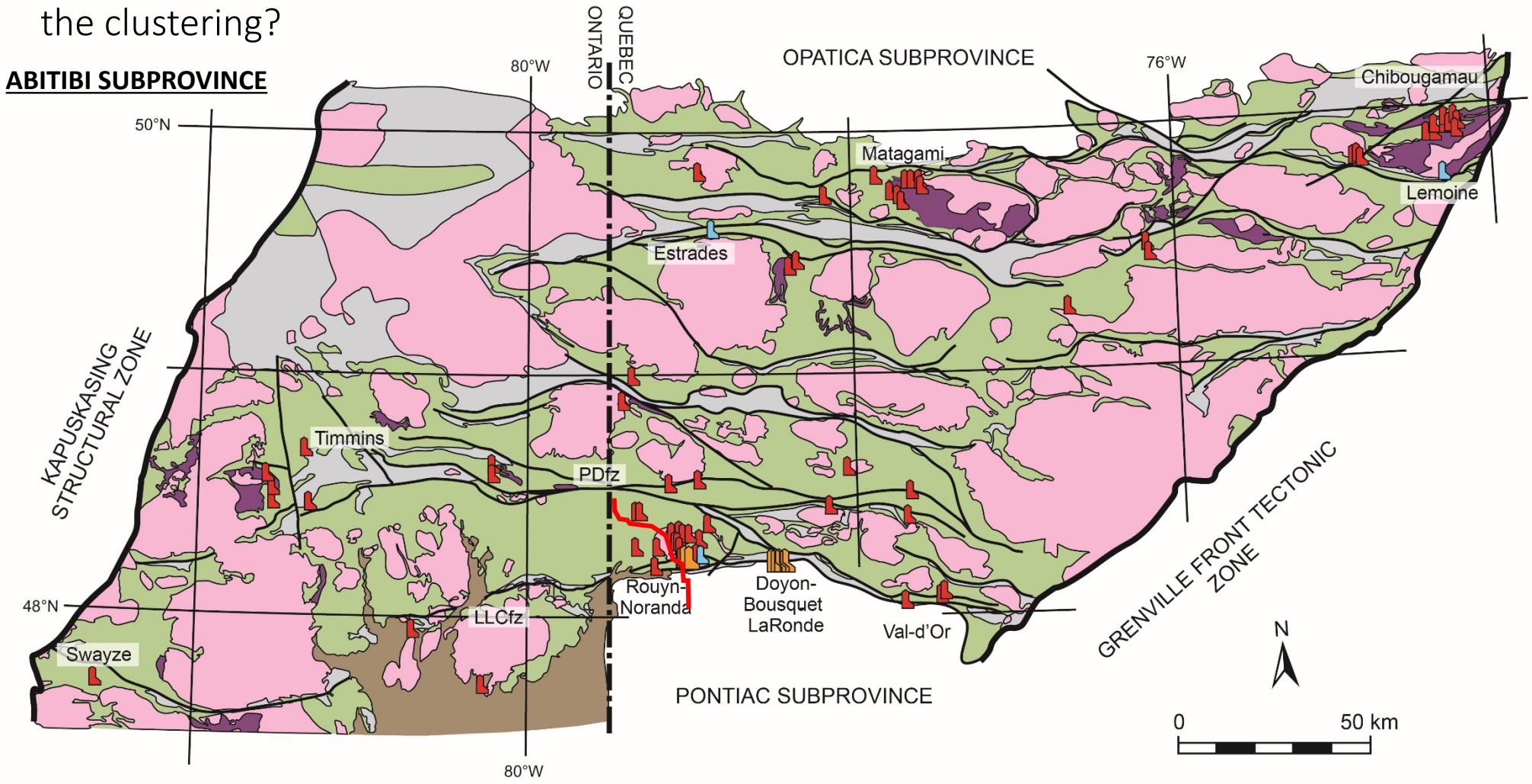

Modified from Monecke et al. (2017) – *Reviews in Economic Geology, v. 19, p. 7-49*

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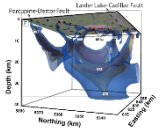

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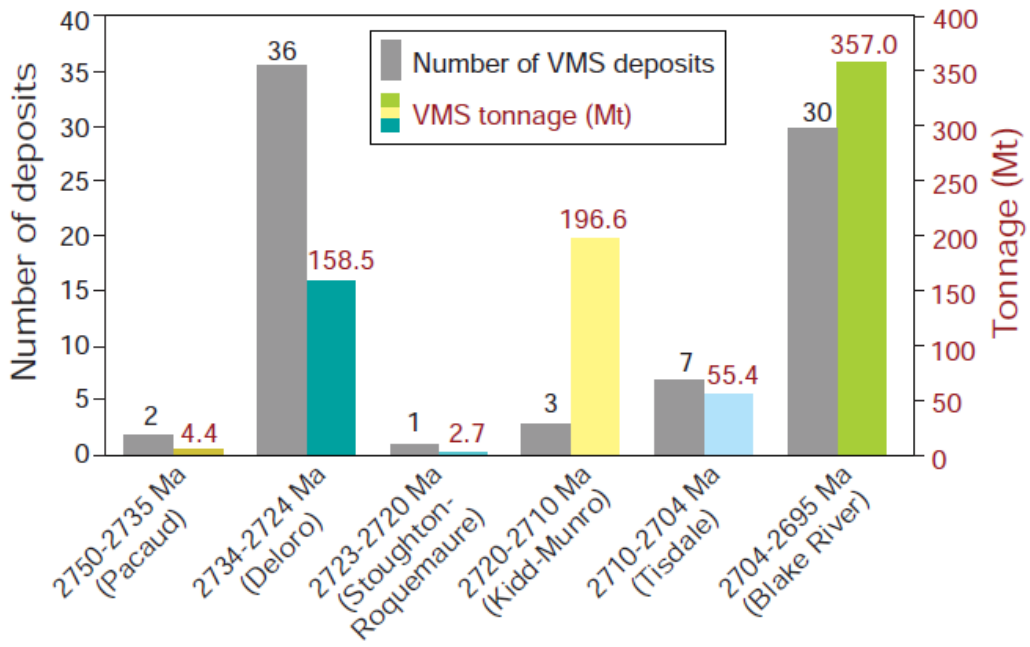
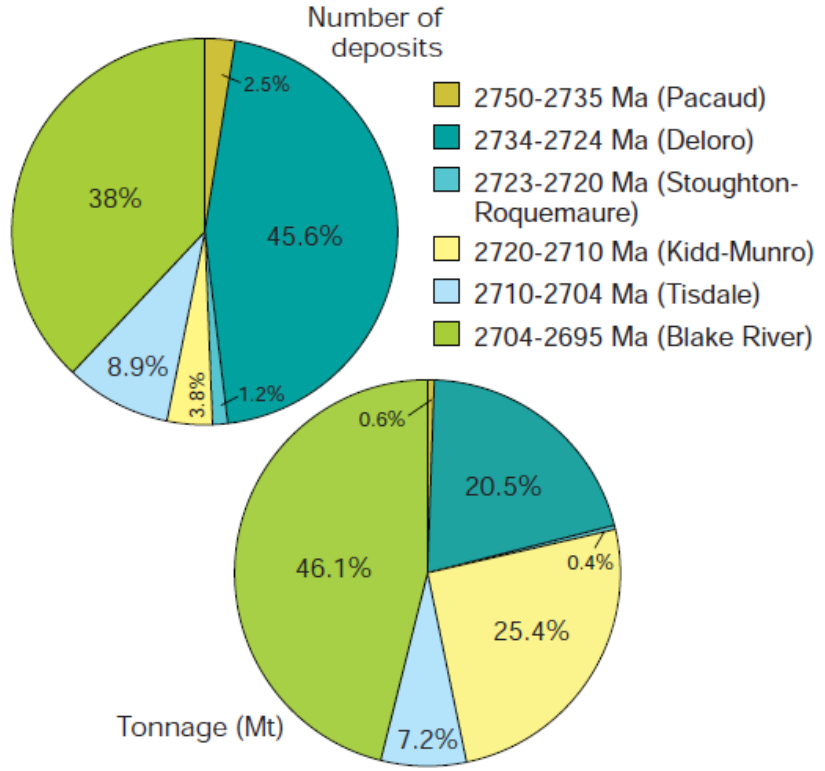
- The Blake River episode was a prolific period of VMS formation





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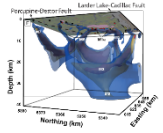

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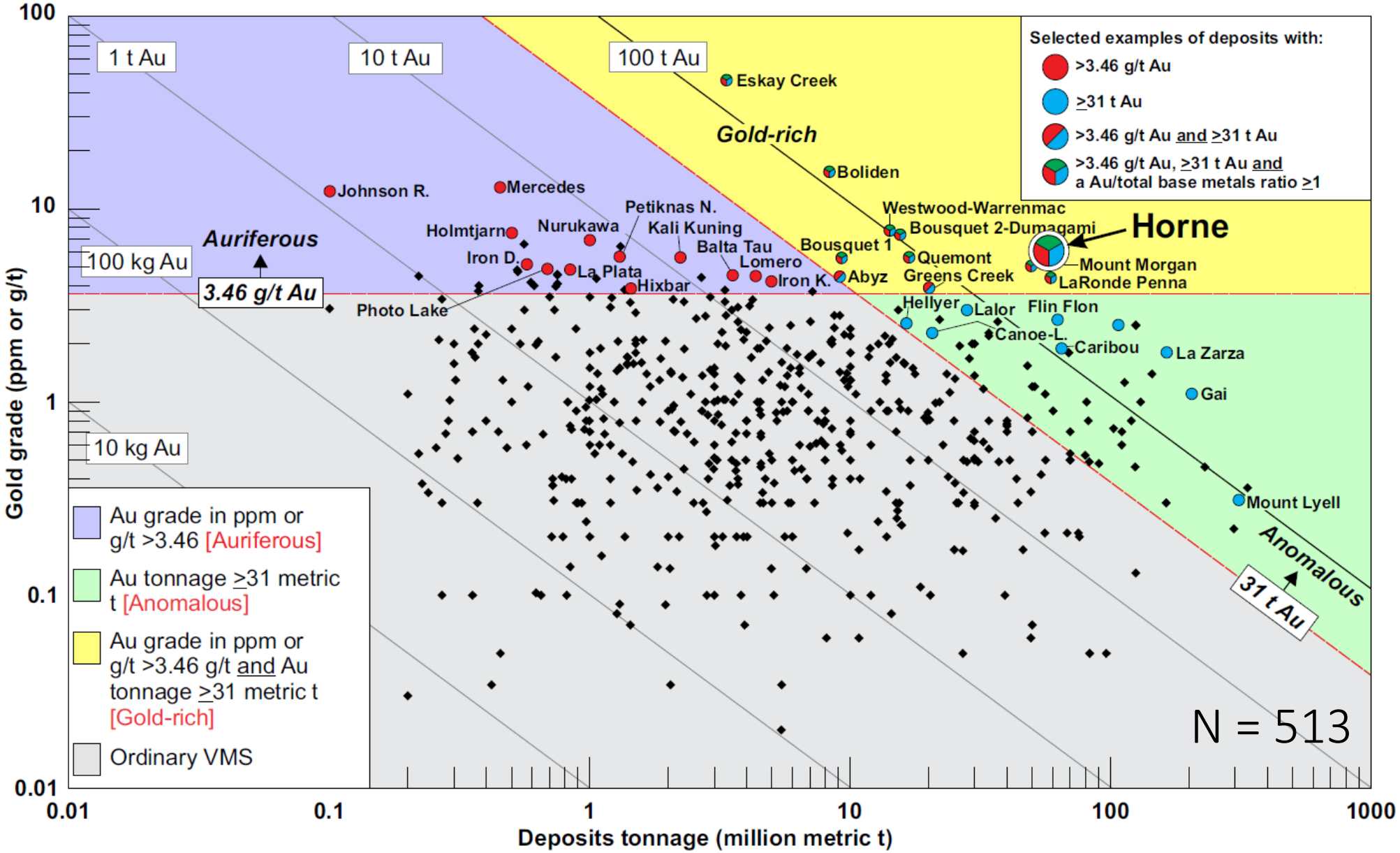
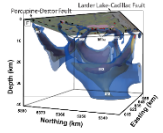
- Gold grade vs. tonnage of VMS deposits



Mercier-Langevin et al. (2011) – *Mineralium Deposita, v. 46, p. 509-539*



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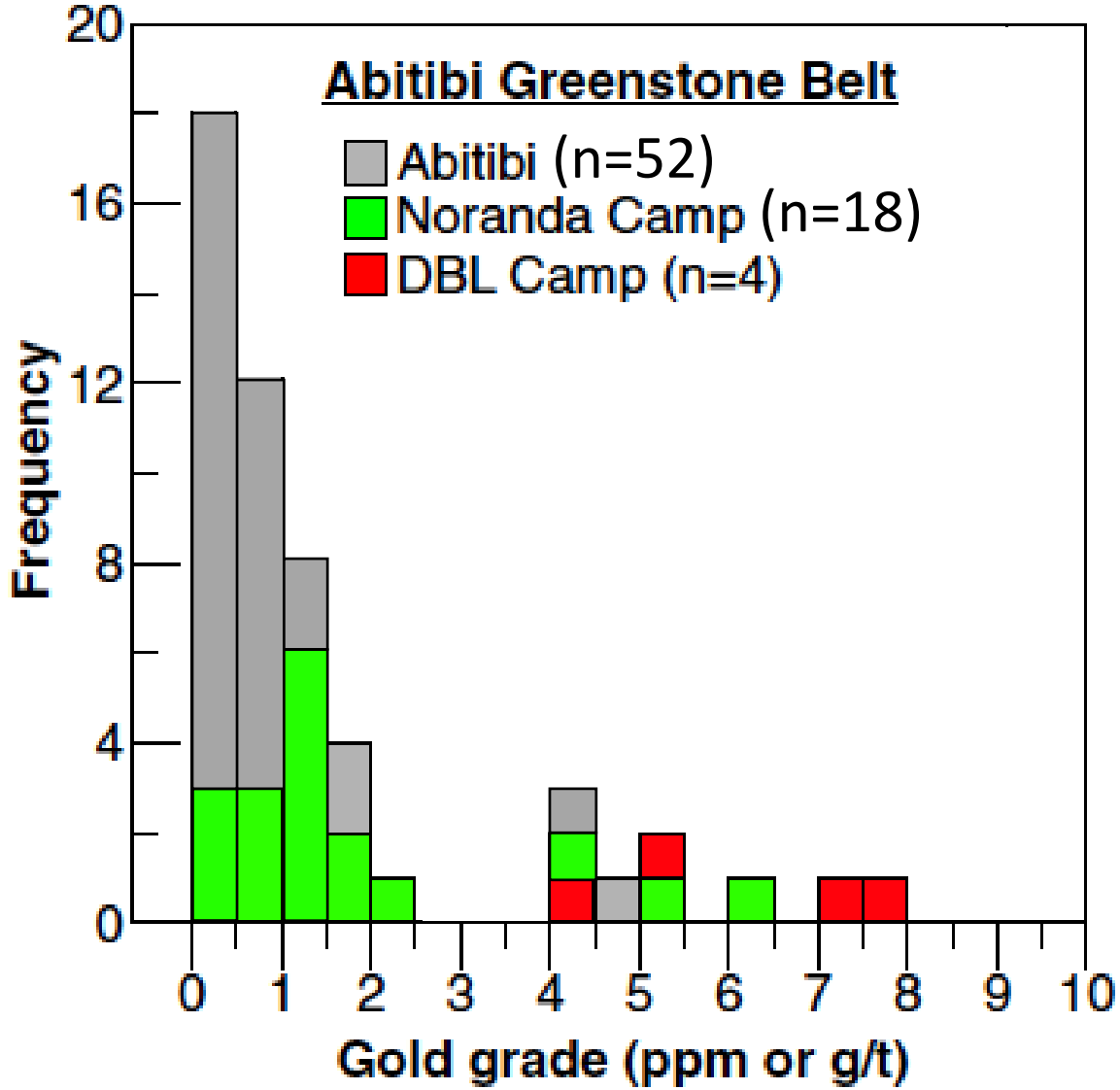
- The Blake River episode accounts for 92% of Abitibi VMS gold



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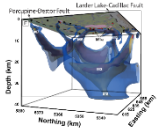

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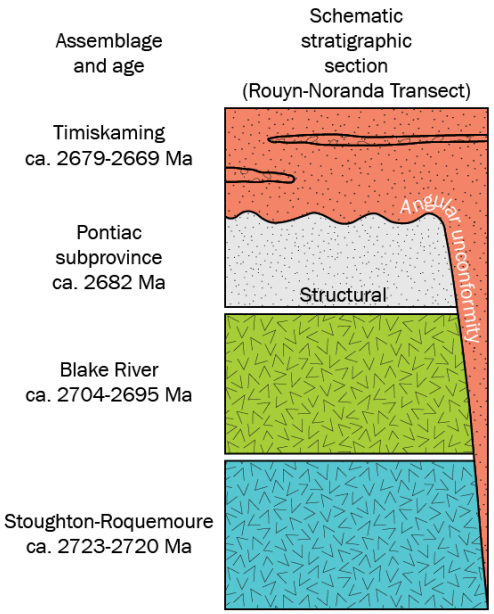
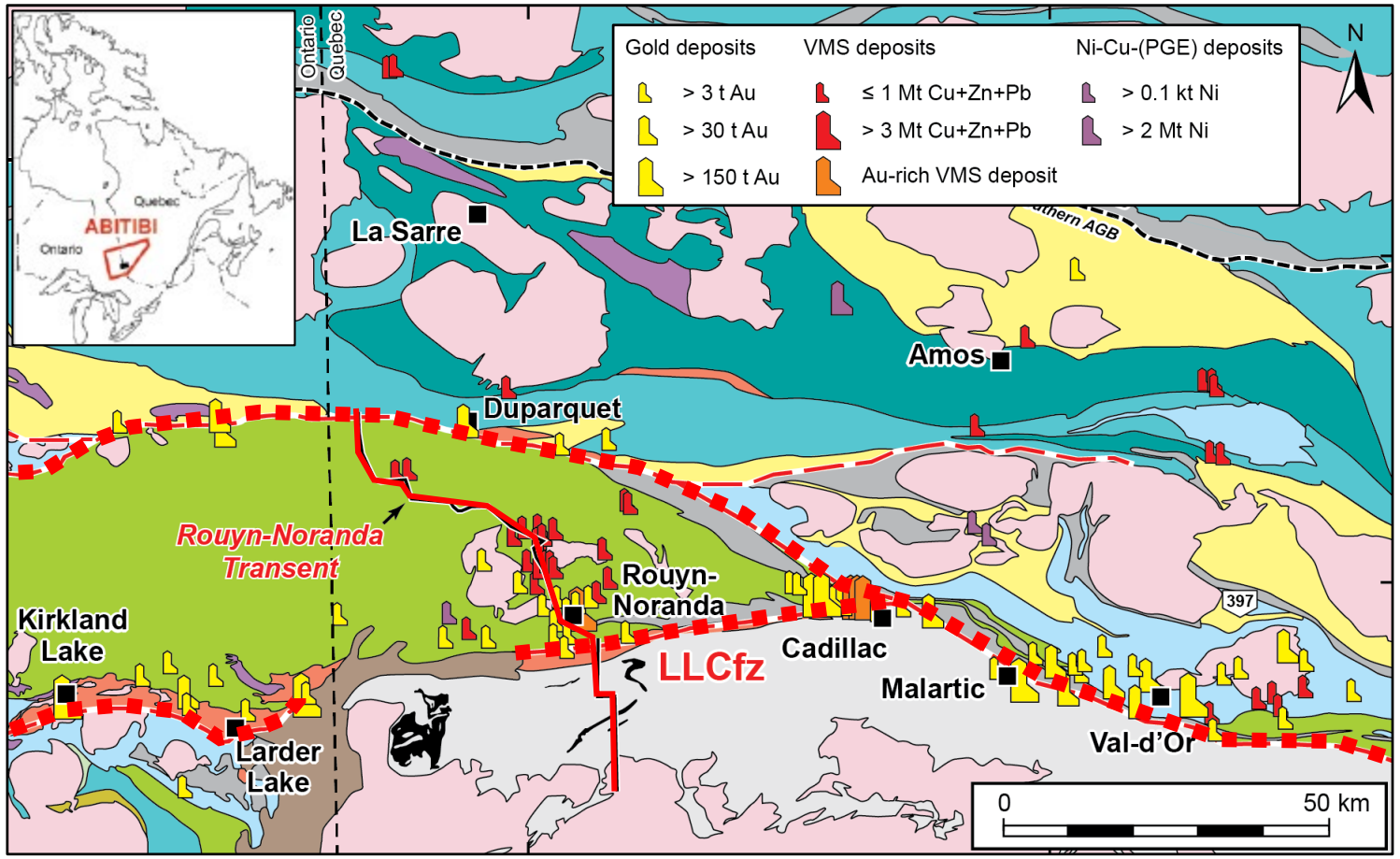
- Transects world-class VMS camp and two transcrustal structures associated with orogenic Au



Modified after Frieman (2018) – *PhD thesis*



Monecke et al. (2017) – *Reviews in Economic Geology, v. 19, p. 169-223,* modified after Thurston et al. (2008) – *Economic Geology, v. 103, p. 1097-1134*

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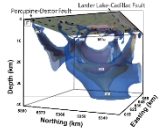

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PROTEROZOIC

- Huronian sedimentary rocks
- Dikes

ARCHEAN

- Lamprophyre
- Syenite
- Breccia
- Granite to tonalite
- Mafic to ultramafic rocks
- Pontiac metasedimentary rocks
- Granodiorite
- Trondhjemite/ tonalite
- Diorite to gabbro

Abitibi Assemblages

- Timiskaming 2679-2669 Ma
- Porcupine 2690-2685 Ma
- Undifferentiated sedimentary rocks
- Mafic-Int. Felsic — Blake River 2704-2695 Ma

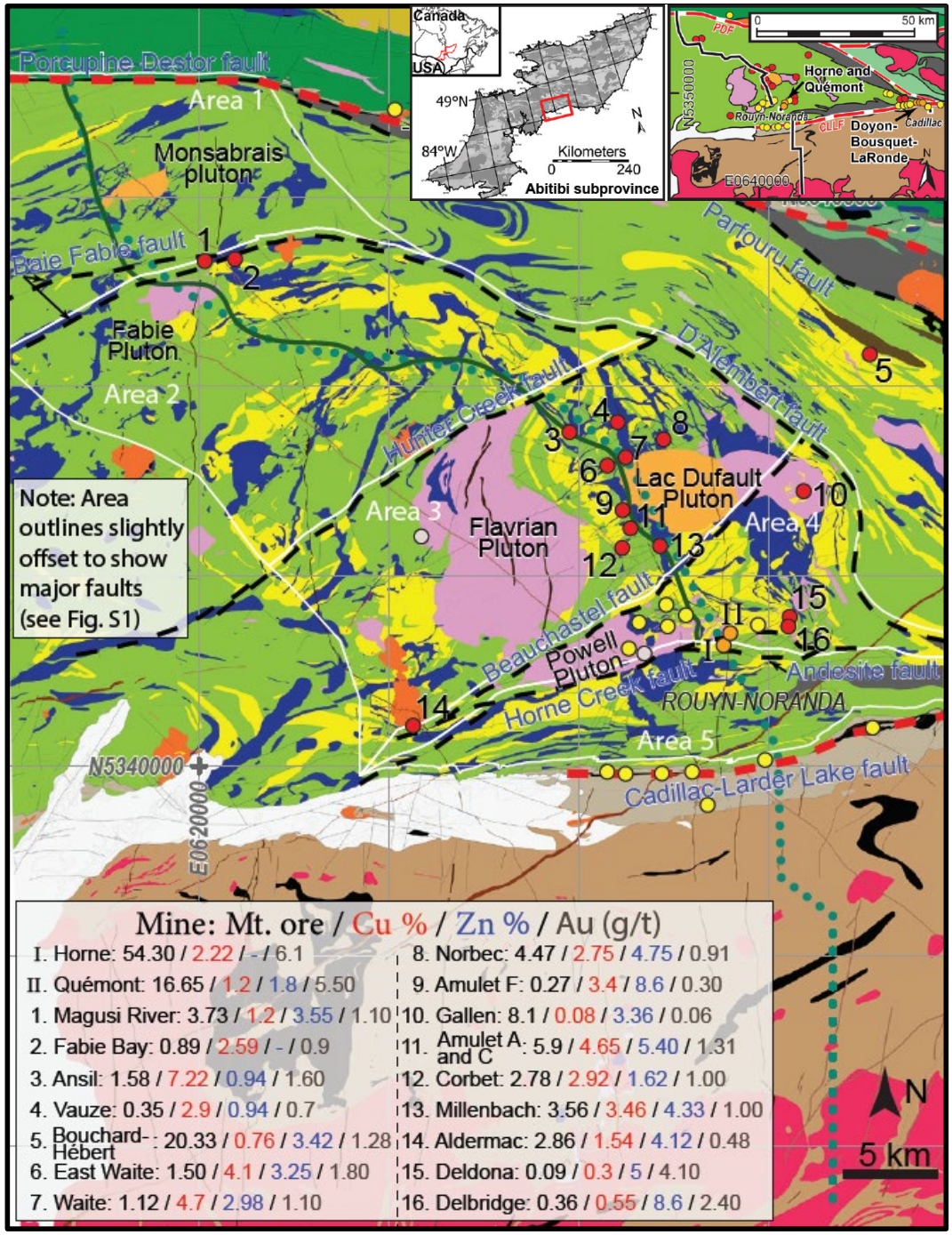
Volcanic assemblages north of the Porcupine Destor Fault in the study area

- Mafic-Int. Felsic — Tisdale 2710-2704 Ma
- Mafic-Int. Felsic — Kidd-Munro 2720-2710 Ma
- Mafic-Int. Felsic — Stoughton-Roquemaure 2723-2720 Ma
- Mafic-Int. Felsic — Deloro 2734-2724 Ma

Mines/Mineralization

- Au-rich VMS
- VMS
- Orogenic Au
- Intrusion-hosted Au ±Cu ±Mo ±Ag

- Contacts
- Fault
- Fault (named)
- Major fault
- Shear zones
- Metal Earth Transect (Seismic shorter)

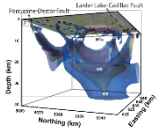


Mine: Mt. ore / Cu % / Zn % / Au (g/t)

I. Horne: 54.30 / 2.22 / - / 6.1
II. Quémont: 16.65 / 1.2 / 1.8 / 5.50
1. Magusi River: 3.73 / 1.2 / 3.55 / 1.10
2. Fabie Bay: 0.89 / 2.59 / - / 0.9
3. Ansil: 1.58 / 7.22 / 0.94 / 1.60
4. Vauze: 0.35 / 2.9 / 0.94 / 0.7
5. Bouchard-Hébert: 20.33 / 0.76 / 3.42 / 1.28
6. East Waite: 1.50 / 4.1 / 3.25 / 1.80
7. Waite: 1.12 / 4.7 / 2.98 / 1.10
8. Norbec: 4.47 / 2.75 / 4.75 / 0.91
9. Amulet F: 0.27 / 3.4 / 8.6 / 0.30
10. Gallen: 8.1 / 0.08 / 3.36 / 0.06
11. Amulet A and C: 5.9 / 4.65 / 5.40 / 1.31
12. Corbet: 2.78 / 2.92 / 1.62 / 1.00
13. Millenbach: 3.56 / 3.46 / 4.33 / 1.00
14. Aldermac: 2.86 / 1.54 / 4.12 / 0.48
15. Deldona: 0.09 / 0.3 / 5 / 4.10
16. Delbridge: 0.36 / 0.55 / 8.6 / 2.40

- Bimodal mafic, syn-volcanic intrusions, major faults and fault blocks, Horne and Quemont Au-rich VMS deposits

Jørgensen et al. (2022) – *Nature Sci. Rep. 12:14710,* modified from compilation by Système d'information géominière of Québec (2017)



Crustal Architecture and VMS Endowment: Insights from the Rouyn-Noranda Camp, Abitibi Greenstone Belt

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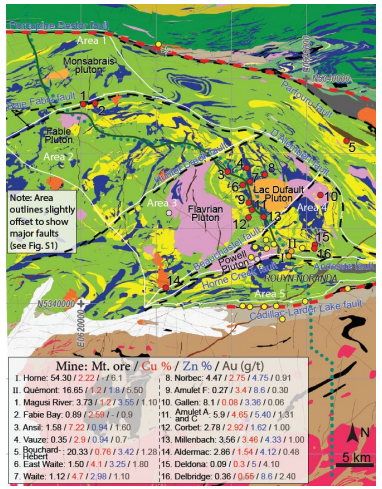
- Multi-disciplinary examination of a world-class mineral district that offers insights into the crustal-scale architecture and controls on differential endowment

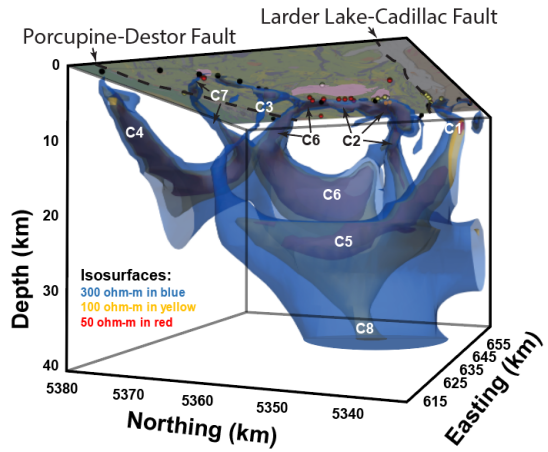
Geology (field and compilation work)



Deep seismic reflection survey

Gravity survey

Magnetotelluric survey



Jørgensen et al. (2022) – *Nature Sci. Rep. 12:14710*

Metal Earth

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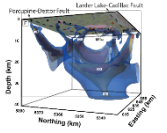

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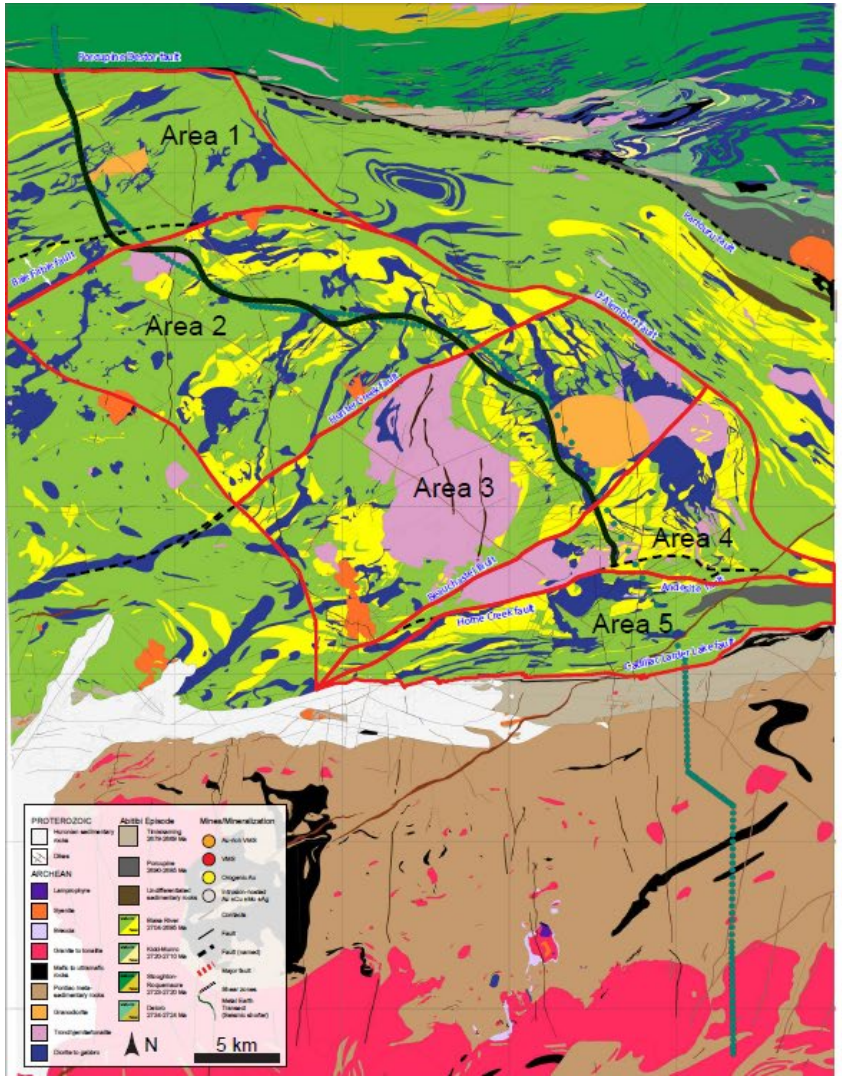

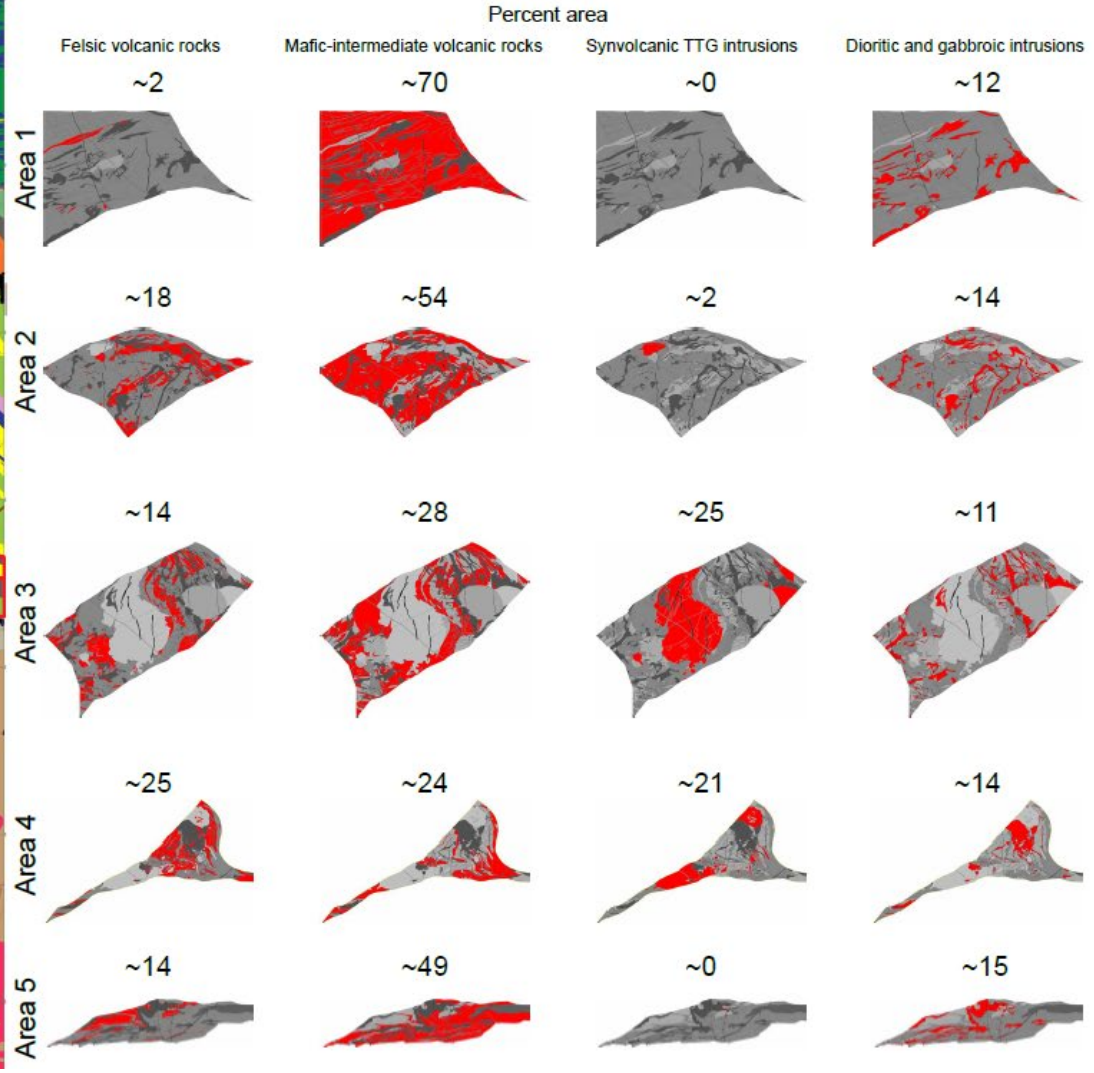

Area	Ore (Mt)	Au (g/t)	Faults intersected by transect	Fault density (faults/km transect)	Felsic volcanic rocks	Mafic-intermediate volcanic rocks	TTG intrusions	Diorite and gabbro intrusions
1 - Northern Hunter block	4	<2	3	0.25	2	70	0	12
2 - Southern Hunter block	1	<2	4	0.19	18	54	2	14
3 - Flavrian block	24.5	<2	15	1.24	14	28	25	11
4 - Powell & Horne block	79.5	>5	7	1.65	25	24	21	14
5 - Rouyn-Palletier block	0	N/A	0	0.00	14	49	0	15

Jørgensen et al. (2022) – *Nature Sci. Rep. 12:14710*

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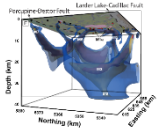

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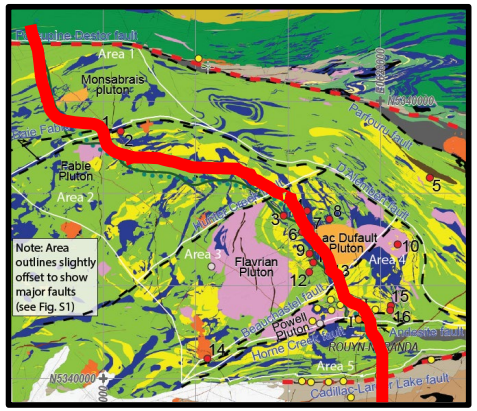
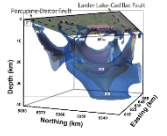


Jørgensen et al. (2022) – *Nature Sci. Rep. 12:14710*



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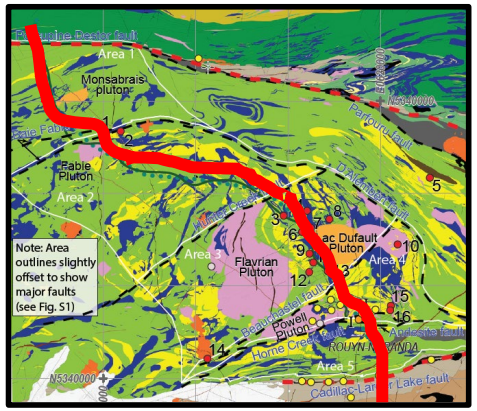
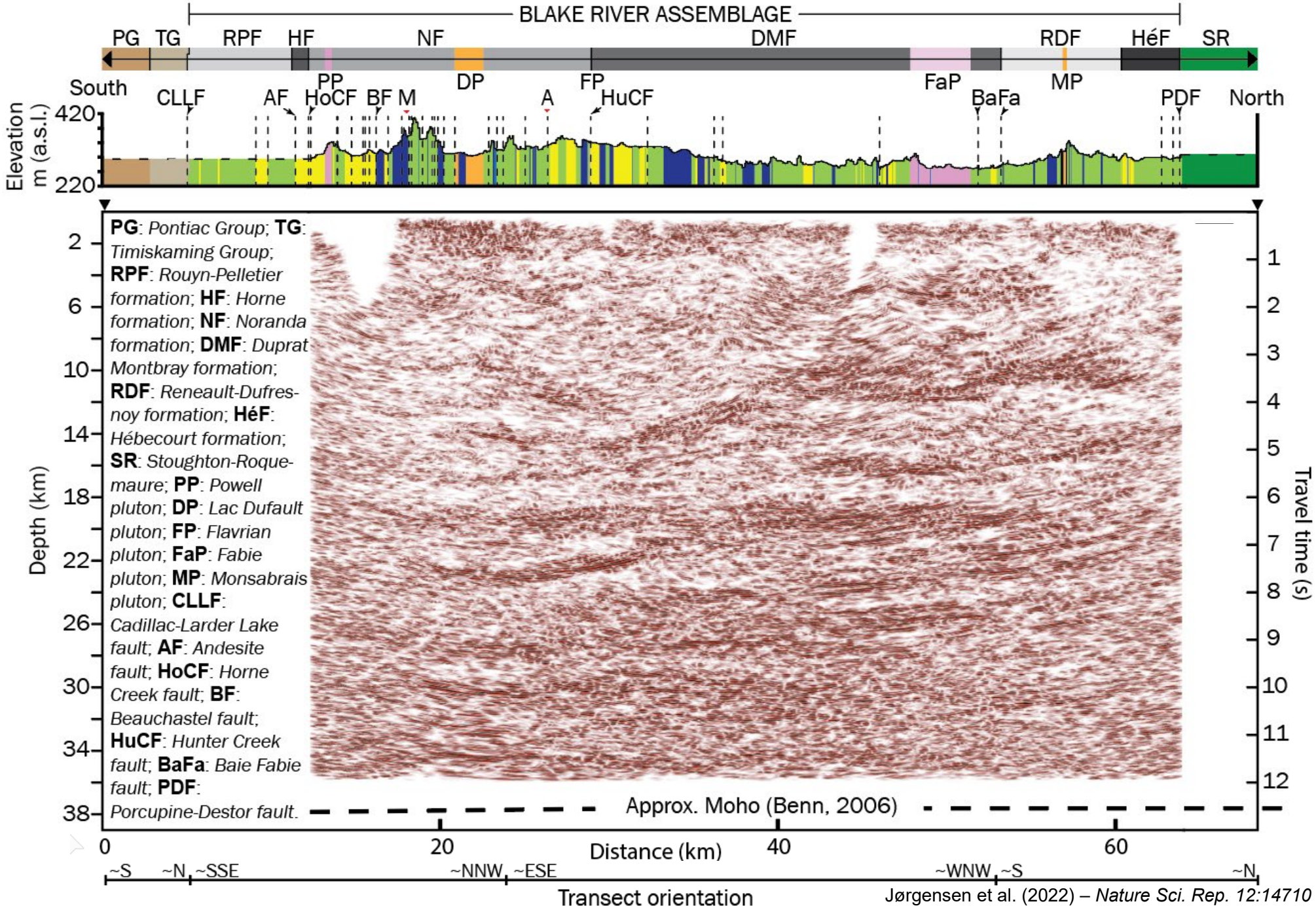
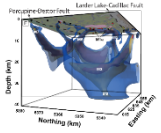




Jørgensen et al. (2022) – *Nature Sci. Rep. 12:14710*



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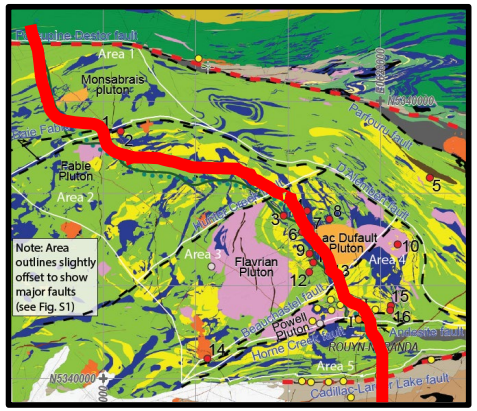

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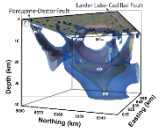

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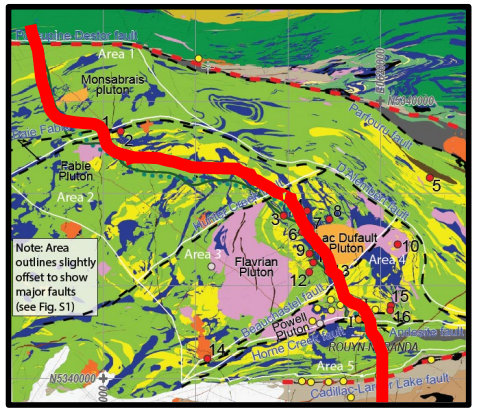


BLAKE RIVER ASSEMBLAGE

PG TG RPF HF NF DMF RDF HéF SR

South CLLF AF PP HoCF BF M DP A FP HuCF FaP BaFa MP PDF North

Elevation m (a.s.l.) 420 220

PG: *Pontiac Group*; **TG**: *Timiskaming Group*; **RPF**: *Rouyn-Pelletier formation*; **HF**: *Horne formation*; **NF**: *Noranda formation*; **DMF**: *Duprat Montbray formation*; **RDF**: *Reneault-Dufresnoy formation*; **HéF**: *Hébecourt formation*; **SR**: *Stoughton-Roquemaure*; **PP**: *Powell pluton*; **DP**: *Lac Dufault pluton*; **FP**: *Flavrian pluton*; **FaP**: *Fabie pluton*; **MP**: *Monsabrais pluton*; **CLLF**: *Cadillac-Larder Lake fault*; **AF**: *Andesite fault*; **HoCF**: *Horne Creek fault*; **BF**: *Beauchastel fault*; **HuCF**: *Hunter Creek fault*; **BaFa**: *Baie Fabie fault*; **PDF**: *Porcupine-Destor fault*.

S1 S2 S3

Depth (km) 2 6 10 14 18 22 26 30 34 38

Travel time (s) 1 2 3 4 5 6 7 8 9 10 11 12

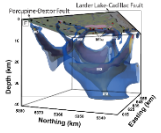
Approx. Moho (Benn, 2006)

0 20 40 60 Distance (km)

~S ~N ~SSE ~NNW ~ESE ~WNW ~S ~N

Transect orientation

Jørgensen et al. (2022) – *Nature Sci. Rep. 12:14710*



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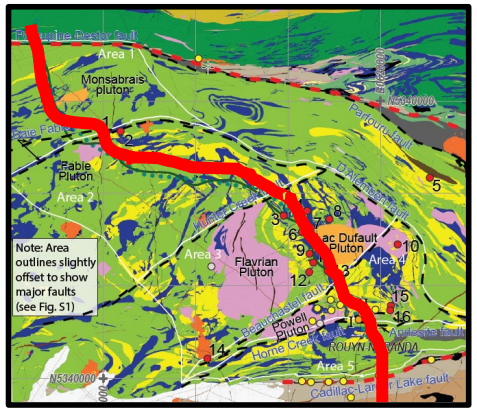
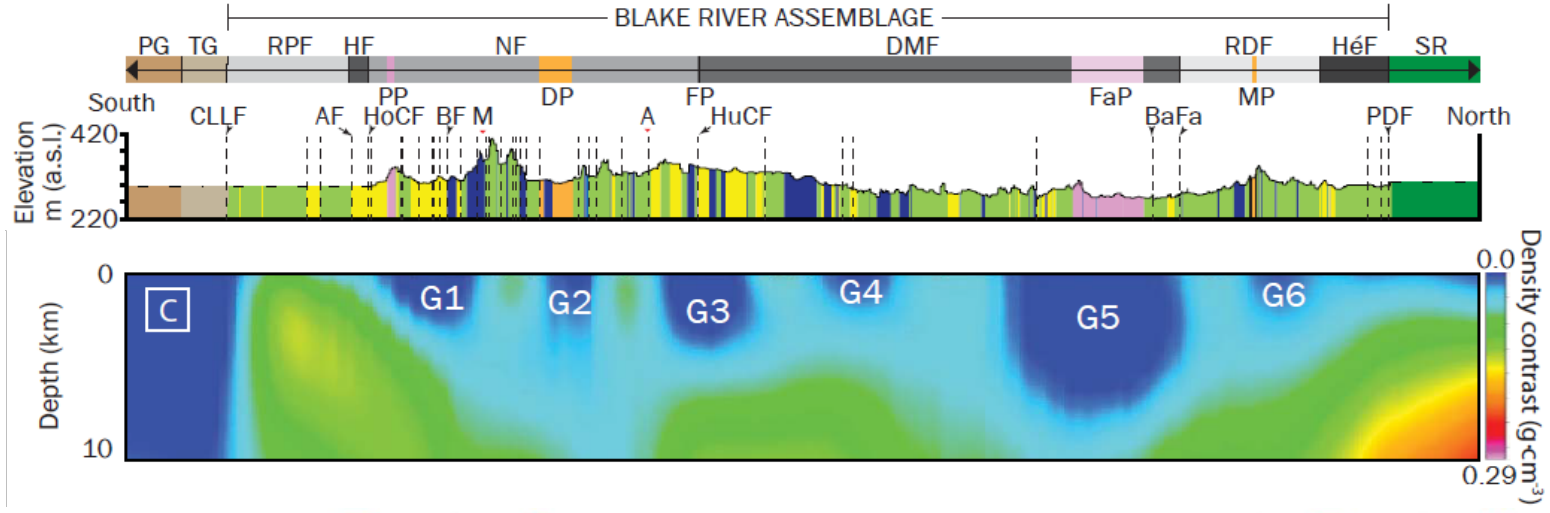
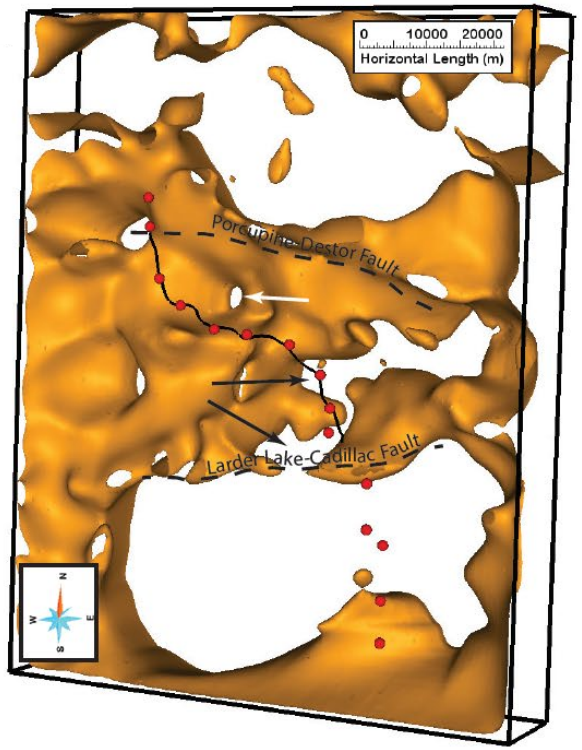
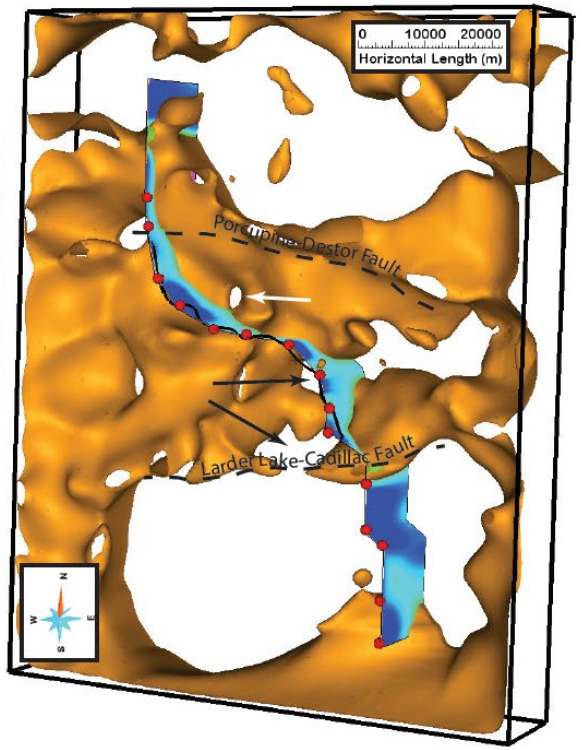


PG: *Pontiac Group*; **TG**: *Timiskaming Group*; **RPF**: *Rouyn-Pelletier formation*; **HF**: *Horne formation*; **NF**: *Noranda formation*; **DMF**: *Duprat Montbray formation*; **RDF**: *Reneault-Dufresnoy formation*; **HéF**: *Hébecourt formation*; **SR**: *Stoughton-Roquemaure*; **PP**: *Powell pluton*; **DP**: *Lac Dufault pluton*; **FP**: *Flavrian pluton*; **FaP**: *Fabie pluton*; **MP**: *Monsabrais pluton*; **CLLF**: *Cadillac-Larder Lake fault*; **AF**: *Andesite fault*; **HoCF**: *Horne Creek fault*; **BF**: *Beauchastel fault*; **HuCF**: *Hunter Creek fault*; **BaFa**: *Baie Fabie fault*; **PDF**: *Porcupine-Destor fault*.

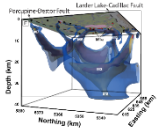






- 2D slice along transect through the 3D density model

Jørgensen et al. (2022) – *Nature Sci. Rep. 12:14710*



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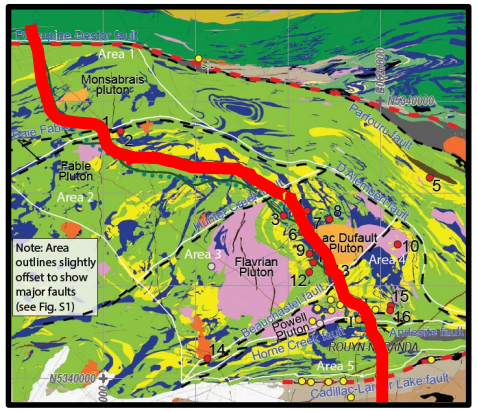
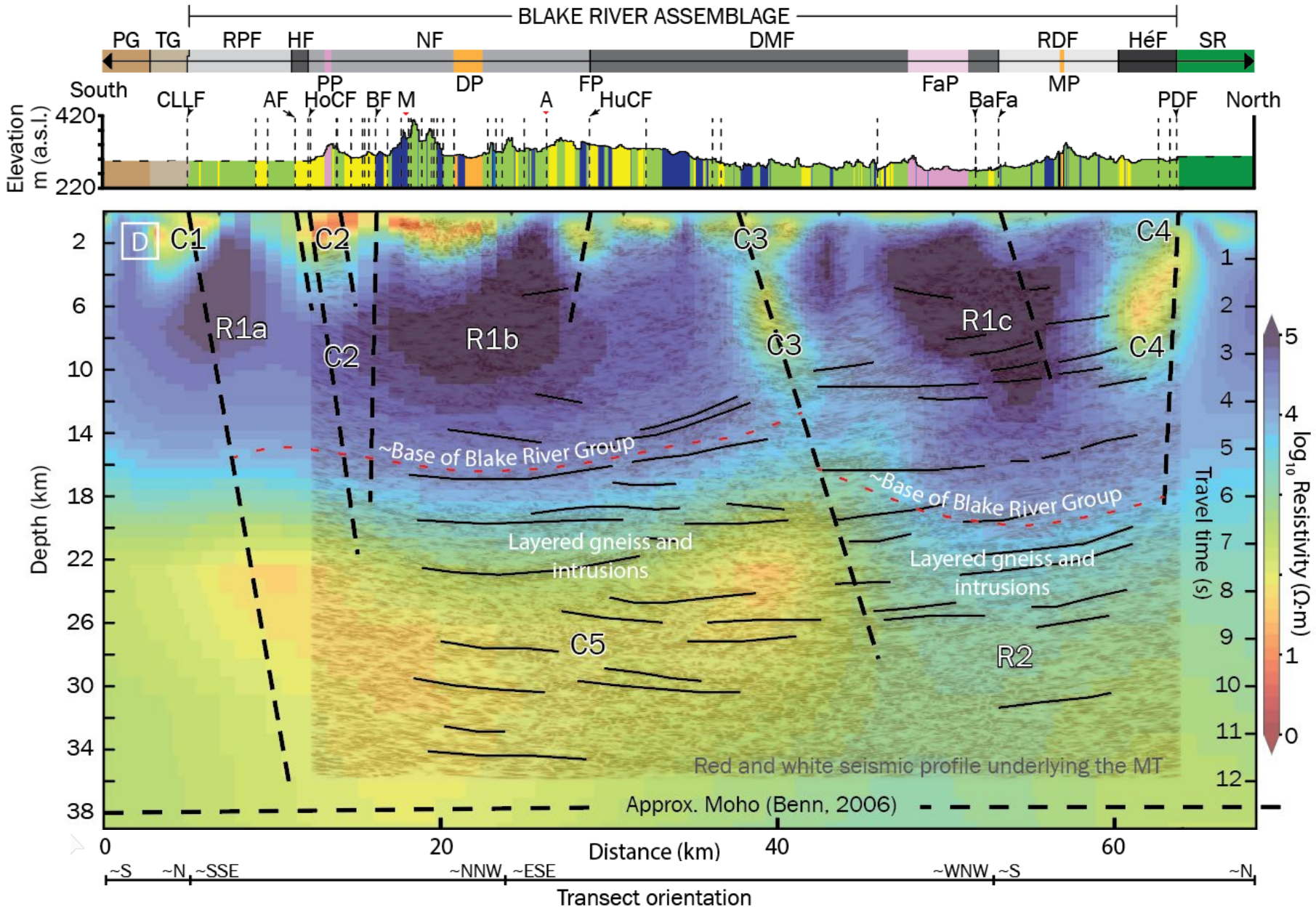
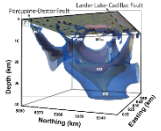




- 2D slice along transect through the 3D resistivity model

Jørgensen et al. (2022) – *Nature Sci. Rep. 12:14710*



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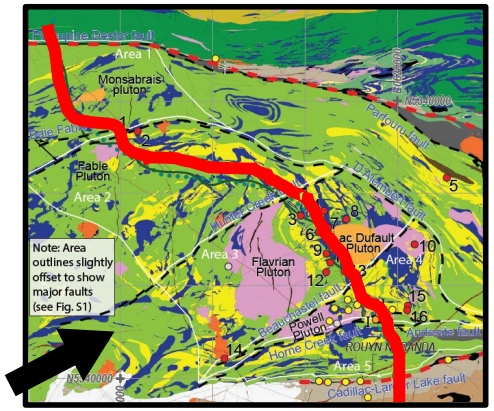
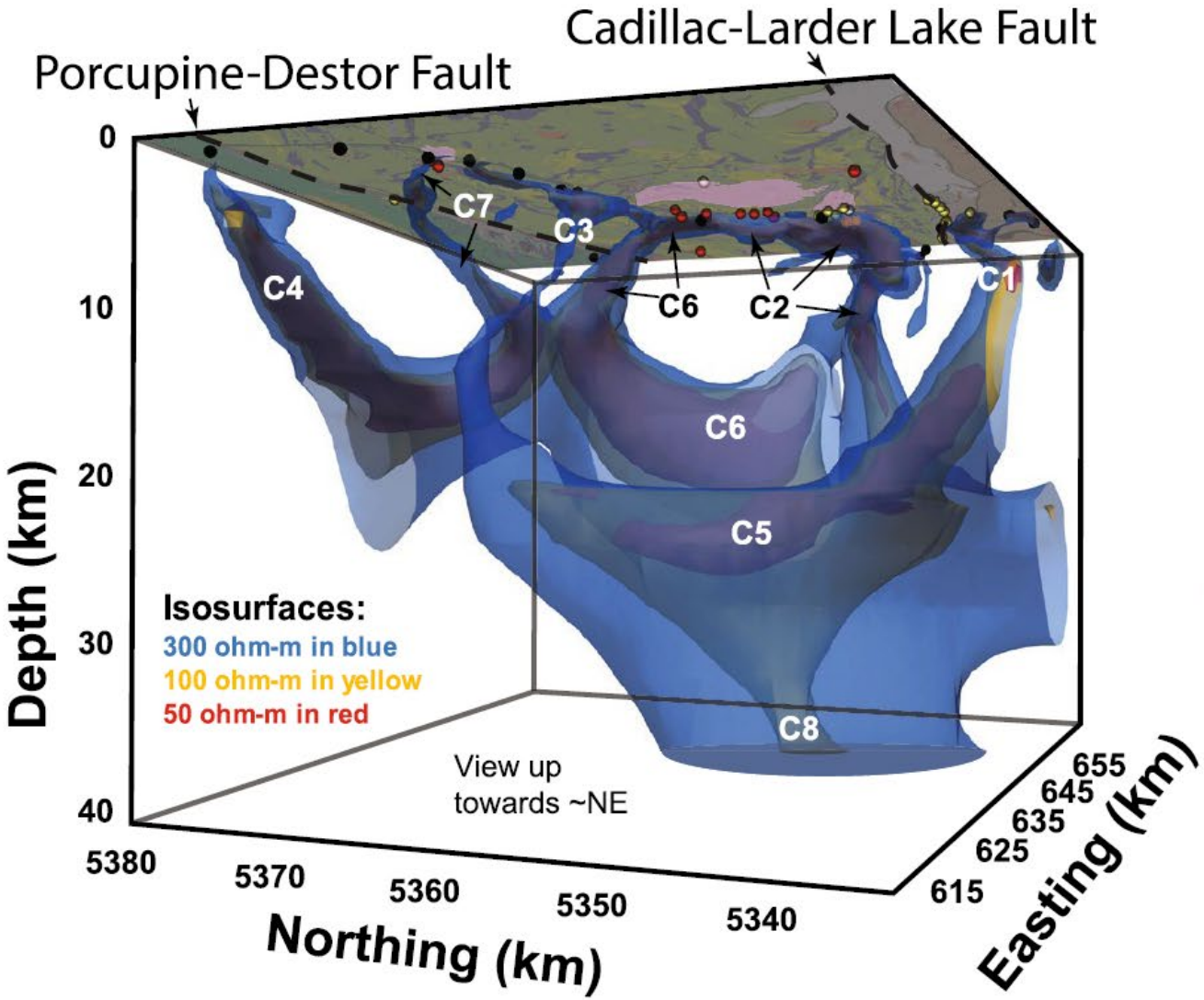
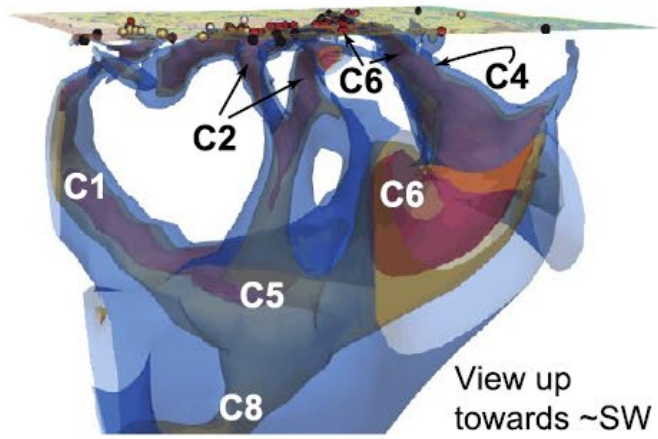
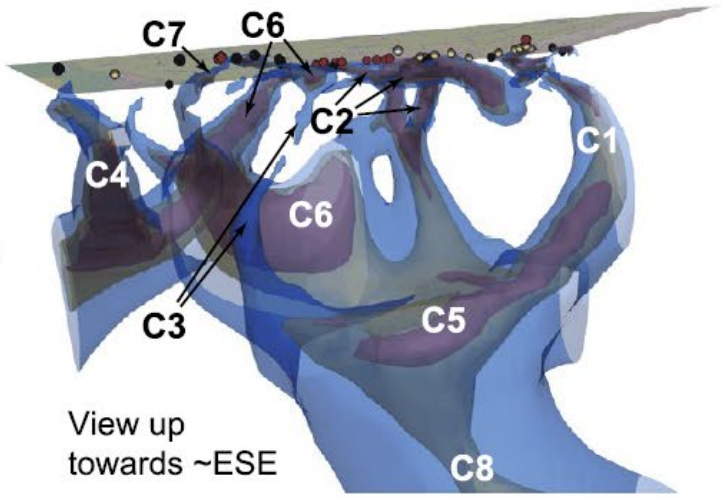


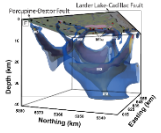






- 3-D MT model reveal pipe-like vertical features and the connectivity to a lower crustal low-resistivity volume
- Potentially connected to the lithospheric mantle??

Jørgensen et al. (2022) – *Nature Sci. Rep. 12:14710*



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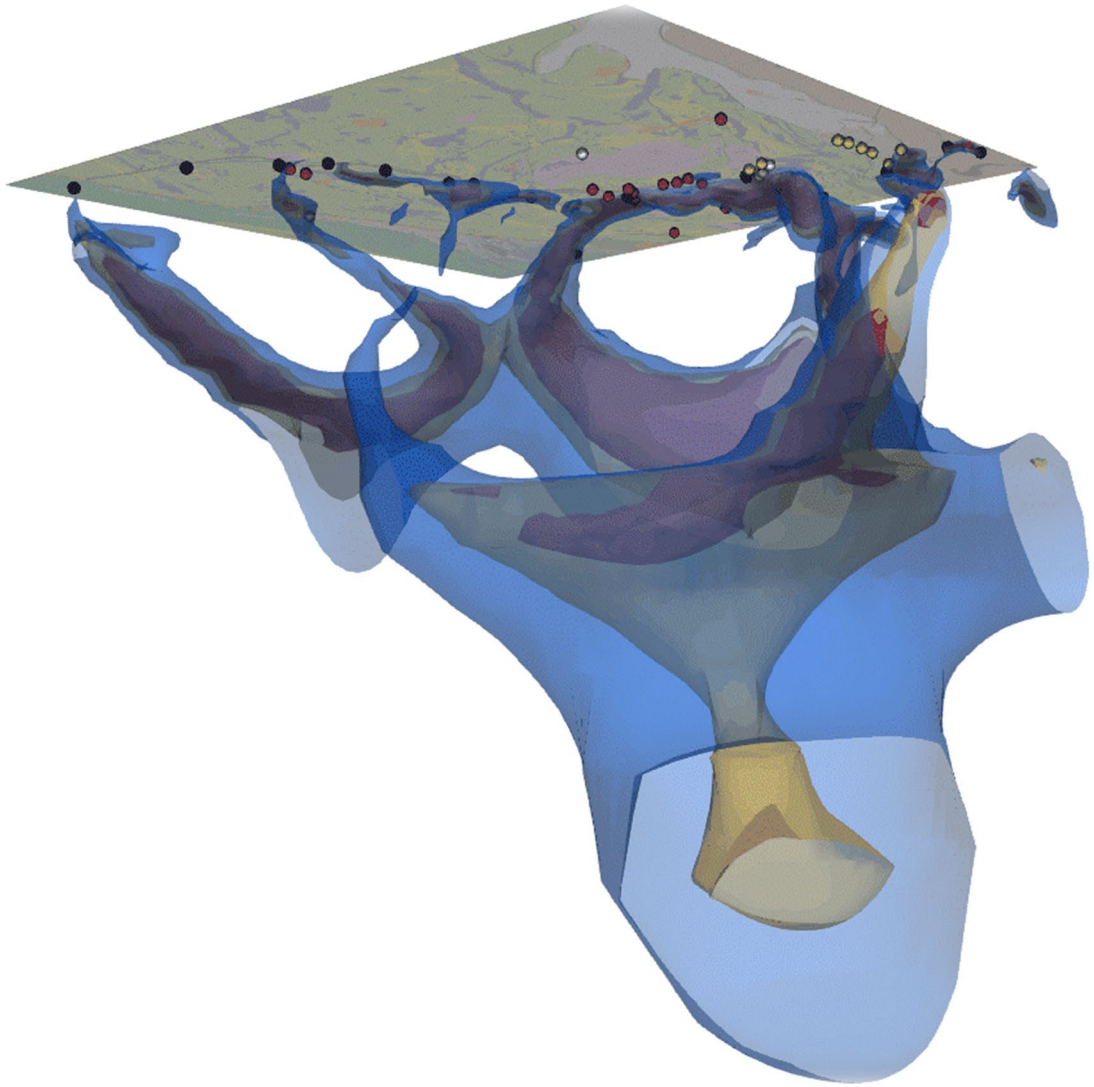

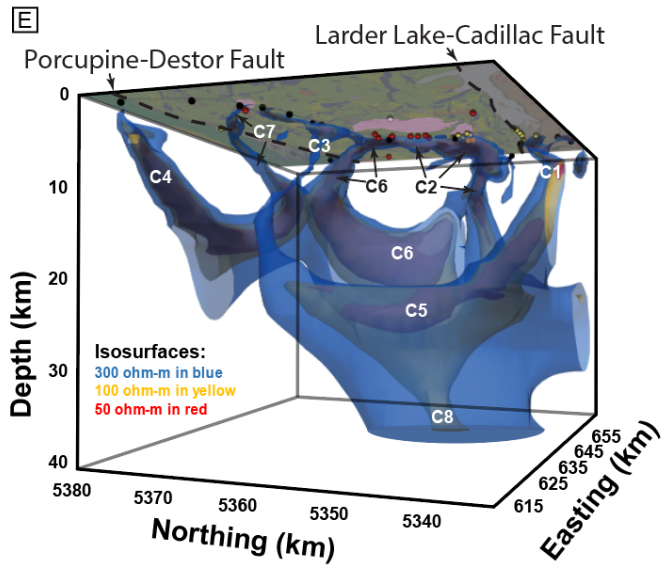

- 3-D MT model reveal pipe-like vertical features and the connectivity to a lower crustal low-resistivity volume
- Potentially connected to the subcontinental lithospheric mantle??

Jørgensen et al. (2022) – *Nature Sci. Rep. 12:14710*

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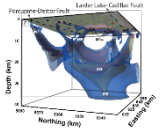

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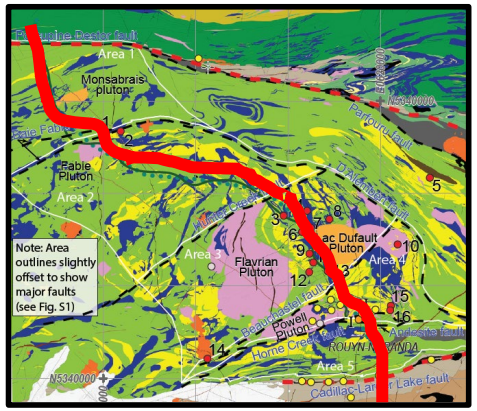
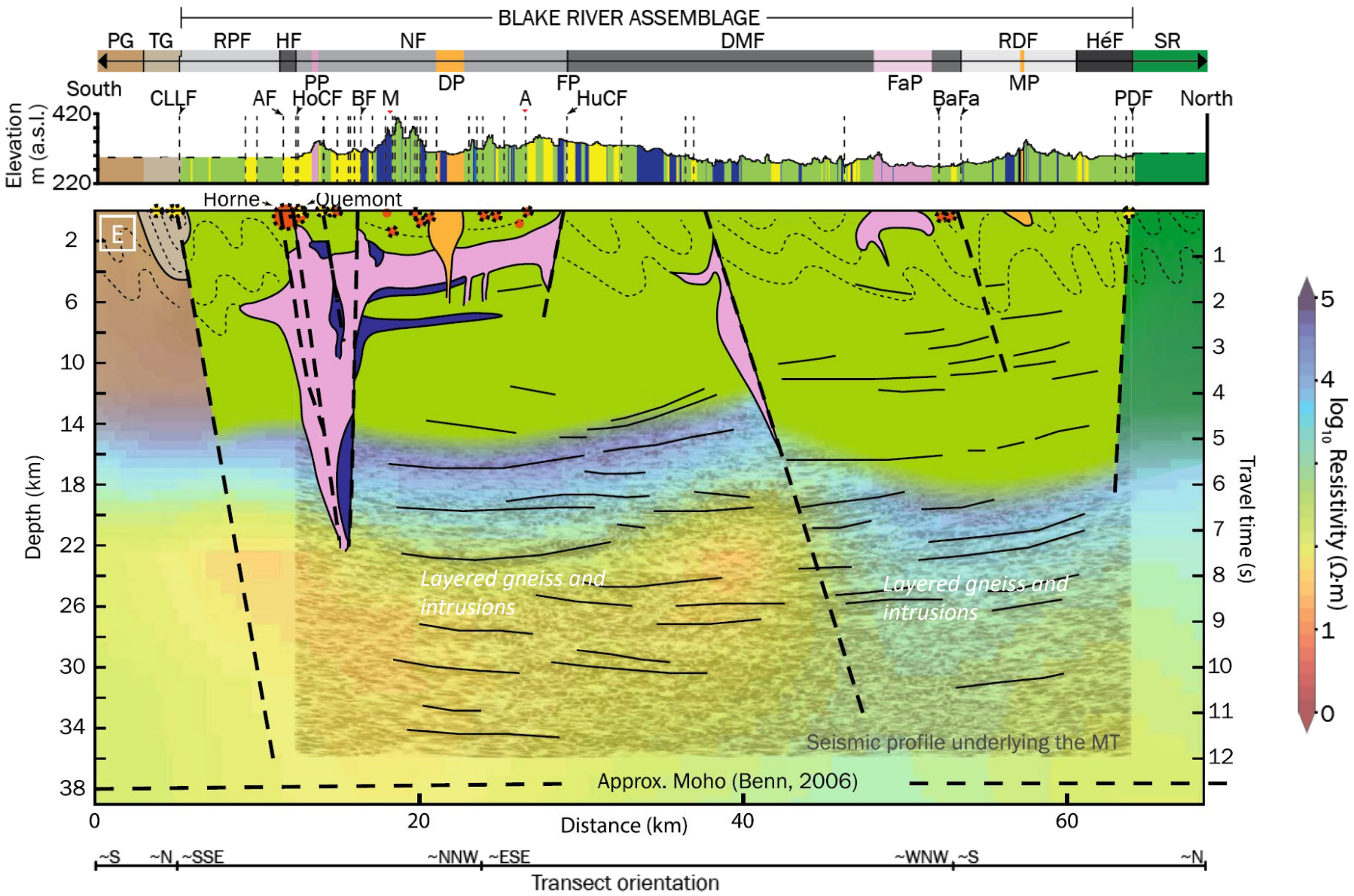
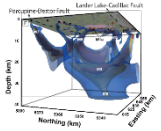




- Asymmetry in geology, crustal architecture, number of VMS deposits and the tenor of these deposits

Jørgensen et al. (2022) – *Nature Sci. Rep. 12:14710*



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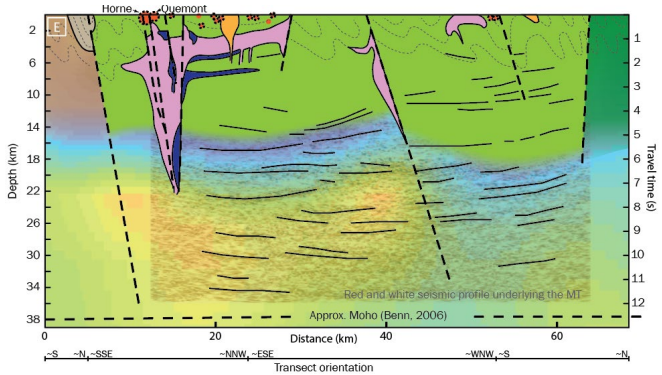
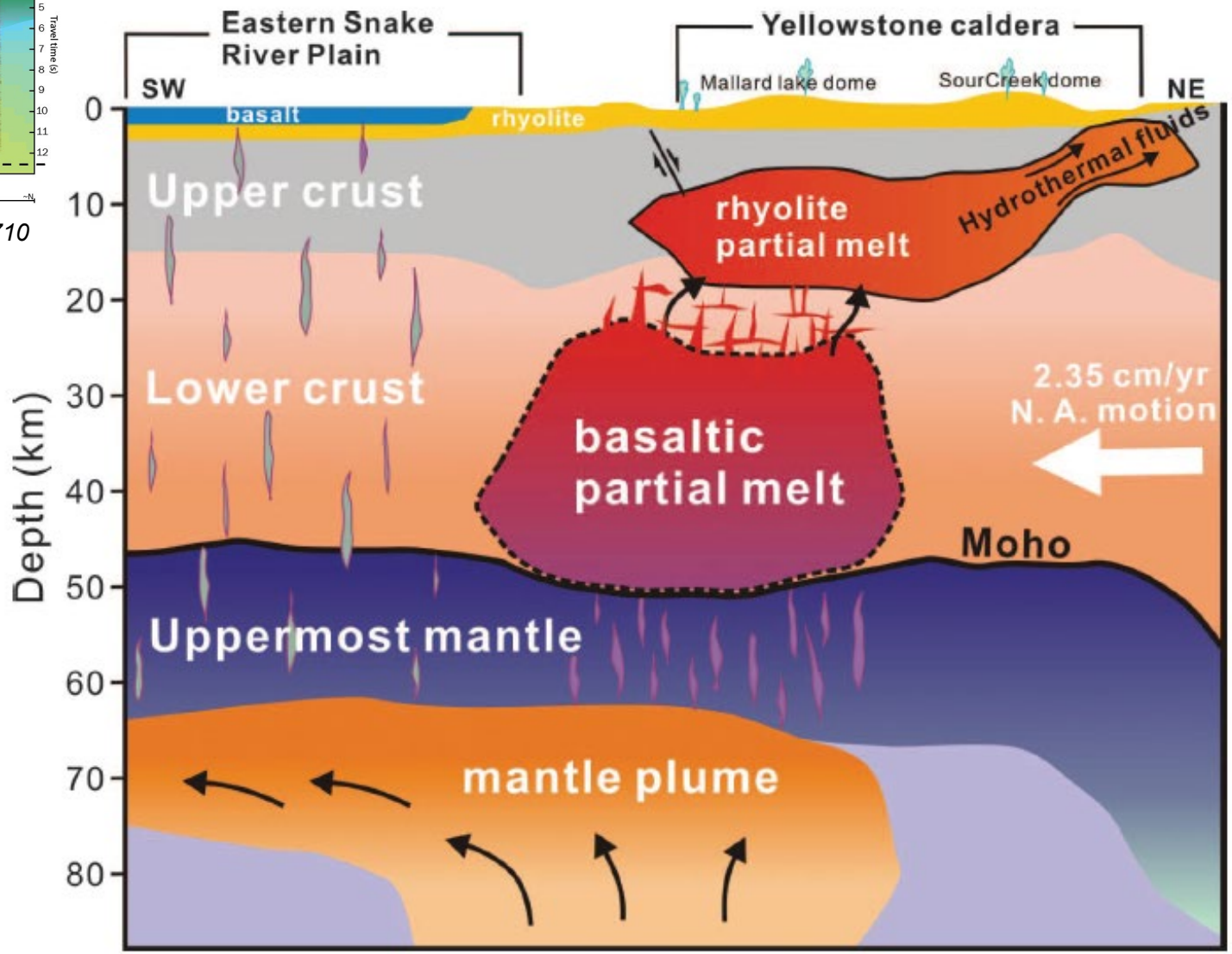


Jørgensen et al. (2022) – *Sci. Rep. 12:14710*

- May draw parallels to the architecture of some recent/modern volcanic centers (**does not imply similar tectonic setting**)
- Felsic magma reservoir at the Yellowstone Caldera overlies a middle and lower crust invaded by mantle derived basalt



Huang et al. (2004) – *Science, v. 348, p. 773-776*

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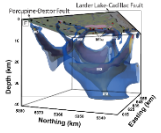

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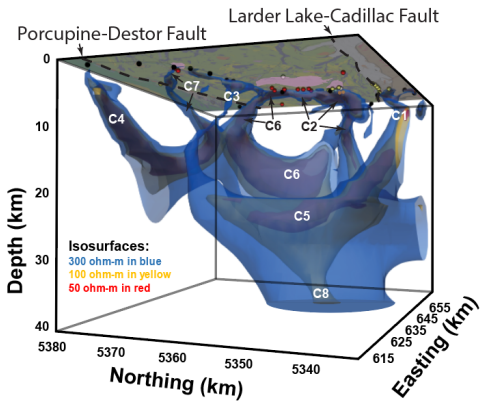
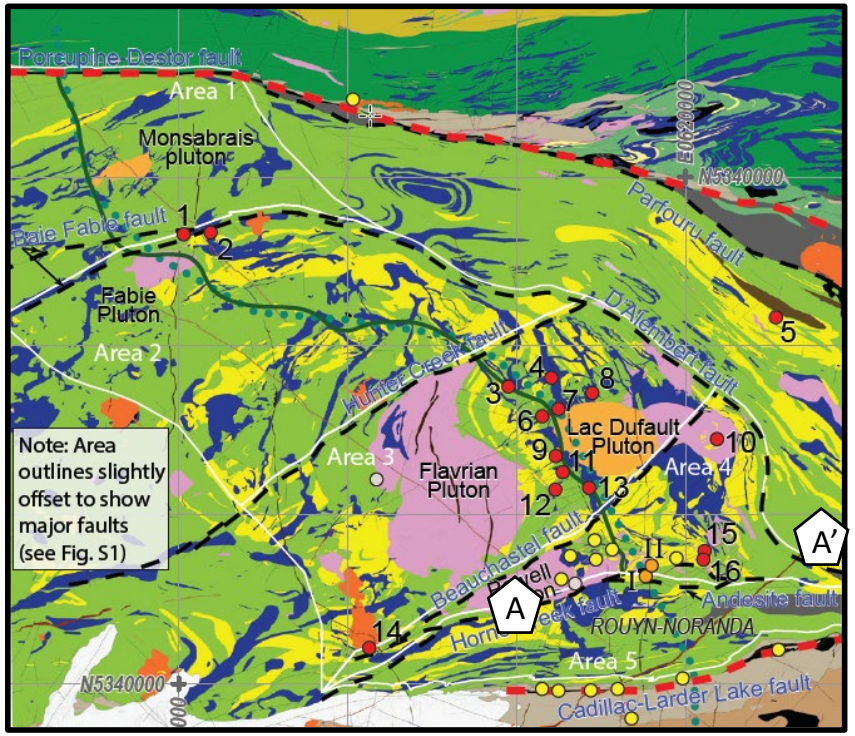
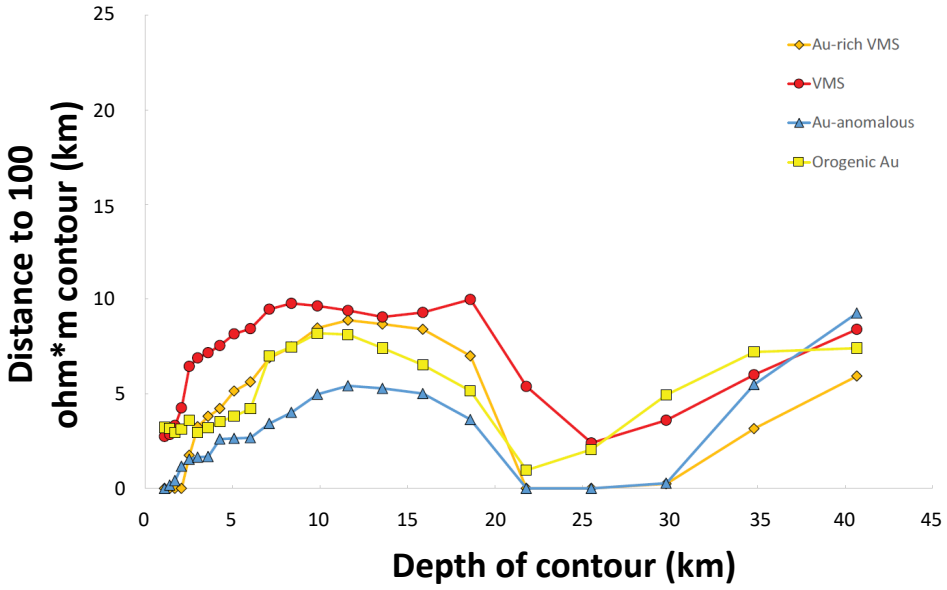
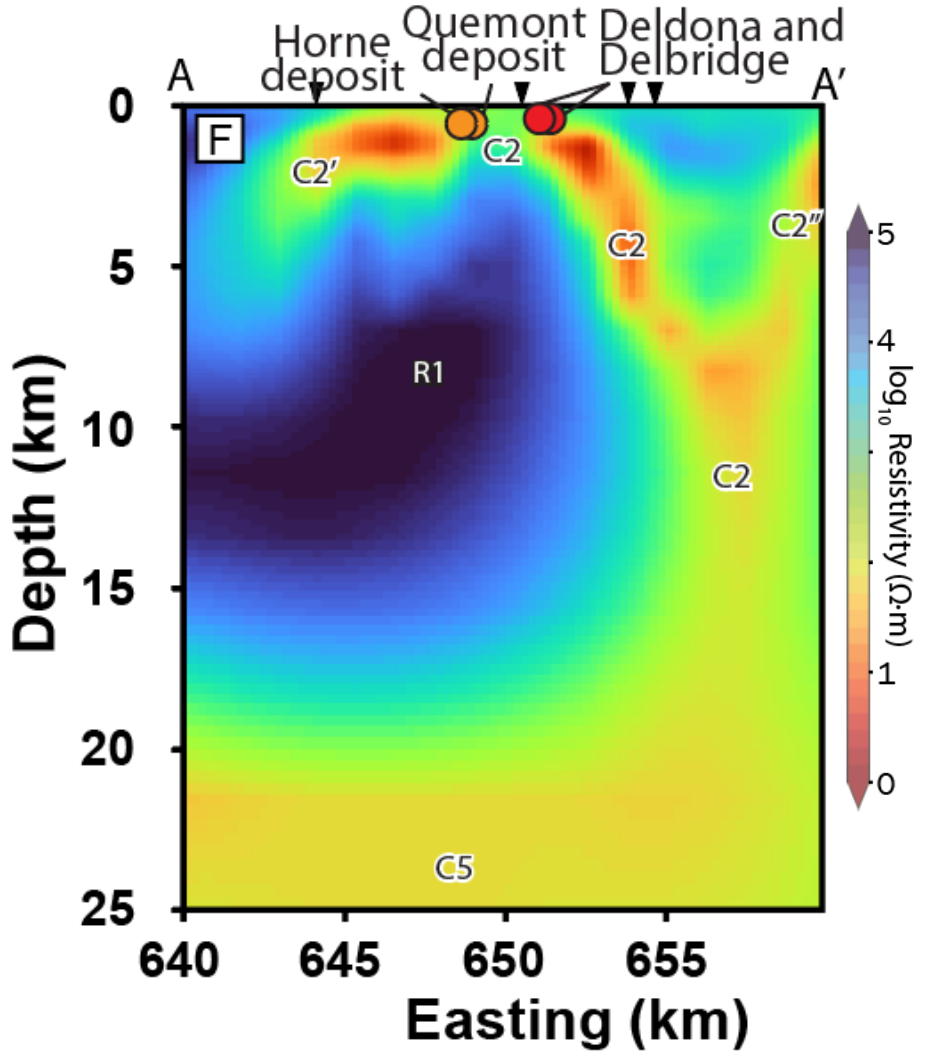


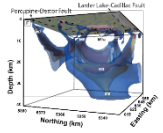






- Optimal location for a magmatic contribution of metals to the VMS system that may explain the localization of Au-rich deposits

Jørgensen et al. (2022) – *Nature Sci. Rep. 12:14710*



- The Noranda volcanic complex was localized along a major transcrustal structure and its splays
- Continuous reactivation localized the large volumes of magma - this resulted in the concentration, optimization, and sustainability of ore forming processes required to produce a world-class VMS district
- The VMS hydrothermal system is not necessarily restricted to a near surface (~<5 km) convective sub seafloor seawater system, but is part of a larger vertically extensive but areally localized, deep crustal to mantle magmatic system
- The spatial association with overprinting ca. 30 m.y. younger orogenic Au deposits suggest that the primary crustal architecture responsible for focusing VMS deposits may have played a role in localizing later Au mineralization

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THANK YOU!

Short Course: New insights into crustal-scale influences on gold and base metal endowment in the Archean Superior Province
Saturday, November 27th, 2023, 9:00 AM to 4:30 AM (ET)

Collaborators

Harold L. Gibson (Geology)

Eric Roots (Magnetotellurics)

Rajesh Vayavur (Gravity)

Graham J. Hill (Magnetotellurics)

David Snyder (Seismic)

Mostafa Naghizadeh (Seismic)

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