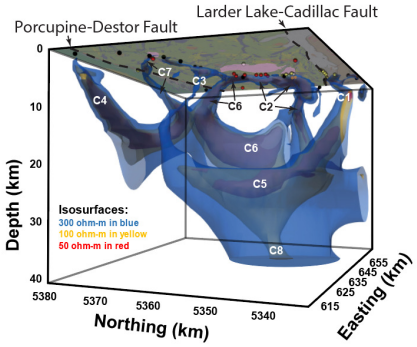
THE WORLD'S PREMIER MINERAL EXPLORATION & MINING CONVENTION

Session: New geophysical and geological insights into how crustal architecture influences the gold and base metal endowment of Precambrian terranes
Saturday, March 4th, 2023, 9:00 AM to 4:30 AM (ET)

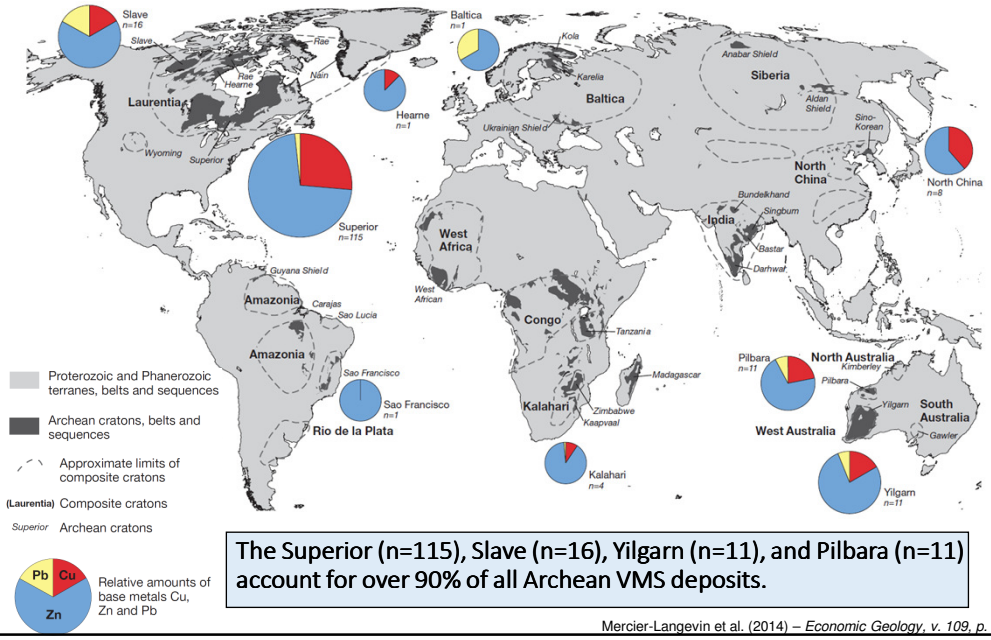
Crustal Architecture and VMS Endowment: Insights from the Rouyn-Noranda Camp, Abitibi Greenstone Belt

TAUS R. C. JØRGENSEN



CRUSTAL ARCHITECTURE AND VMS ENDOWMENT: INSIGHTS FROM THE ROUYN-NORANDA CAMP, ABITIBI GREENSTONE BELT

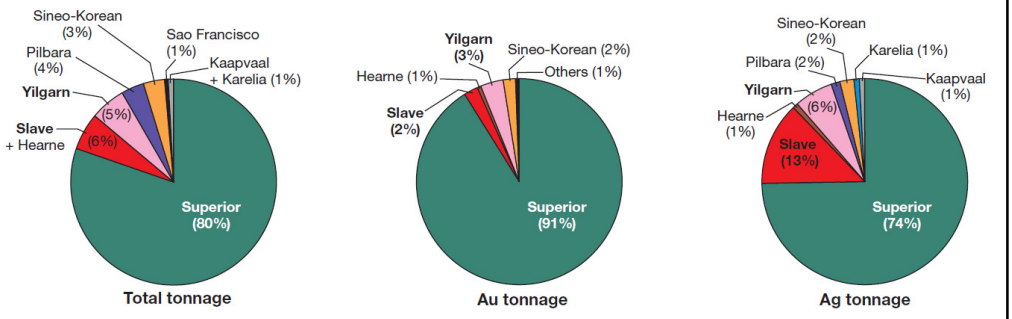
• Global geographic distribution of Archean cratons and VMS



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*

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



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

CRUSTAL ARCHITECTURE AND VMS ENDOWMENT: INSIGHTS FROM THE ROUYN-NORANDA CAMP, ABITIBI GREENSTONE BELT

- 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) Cu	Zn	Pb	Endowment (t/km²) 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*

CRUSTAL ARCHITECTURE AND VMS ENDOWMENT: INSIGHTS FROM THE ROUYN-NORANDA CAMP, ABITIBI GREENSTONE BELT

METAL EARTH

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CANADA FIRST RESEARCH EXCELLENCE FUND

Canada

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

CRUSTAL ARCHITECTURE AND VMS ENDOWMENT: INSIGHTS FROM THE ROUYN-NORANDA CAMP, ABITIBI GREENSTONE BELT

Introduction
- *Distribution of Archean cratons and VMS*
- ***Endowment and first-order control***
- ***Pattern of differential endowment***
- ***Prolific VMS formation during the Blake River episode***
- ***Au-rich VMS***
- ***The Rouyn-Noranda district: an end-member***

Crustal architecture

Implications/Conclusions

METAL EARTH

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CANADA FIRST RESEARCH EXCELLENCE FUND

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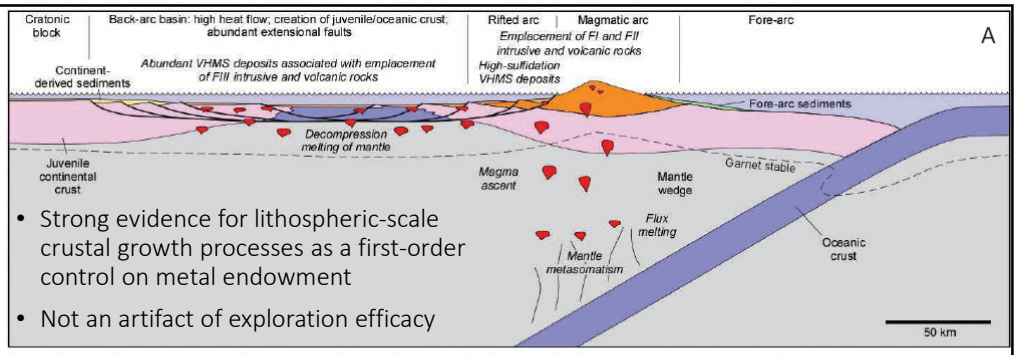
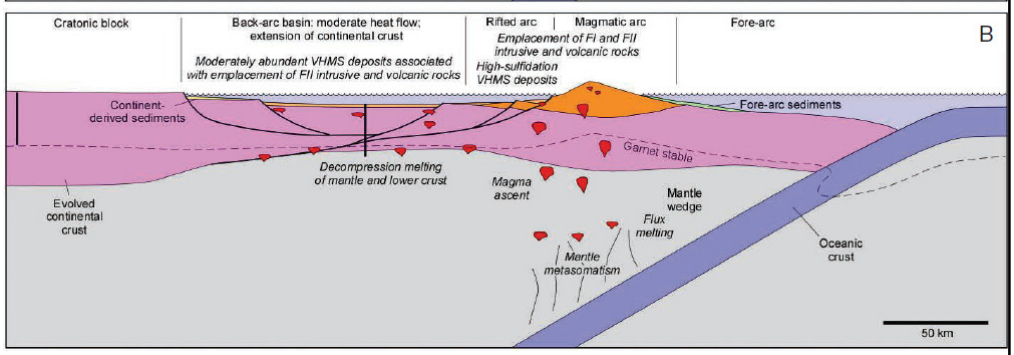


- Strong evidence for lithospheric-scale crustal growth processes as a first-order control on metal endowment
- Not an artifact of exploration efficacy



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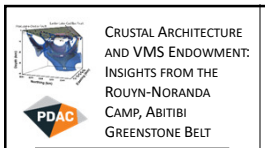


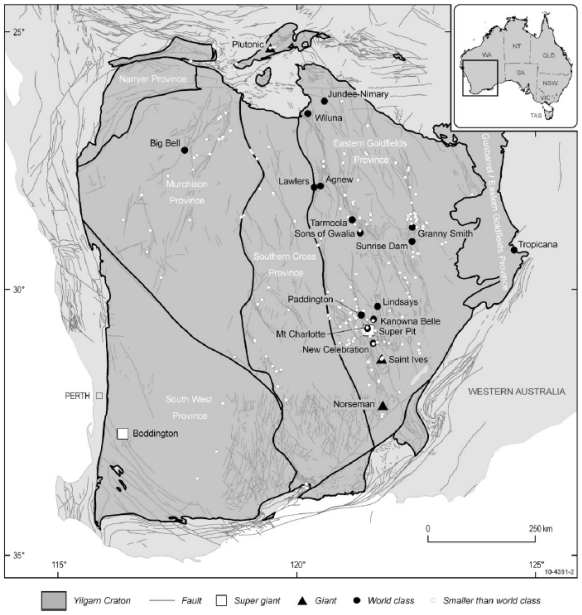
CRUSTAL ARCHITECTURE AND VMS ENDOWMENT: INSIGHTS FROM THE ROUYN-NORANDA CAMP, ABITIBI GREENSTONE BELT

- 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?

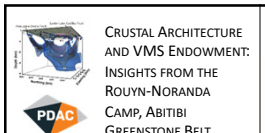
World-class, giant, and super-giant deposits

Singer (1995) definition of world-class deposits: **Upper 10% of deposits in term of contained metal amounting to at least 100 tonnes gold, 2 million tonnes copper, and 1.7 and 1 million tonnes of zinc and lead, respectively.**

Jaireth and Huston (2010) definition of giant and super-giant deposits: **Roughly 3 and 10 times larger than deposits defined as world-class by Singer (1995).**



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



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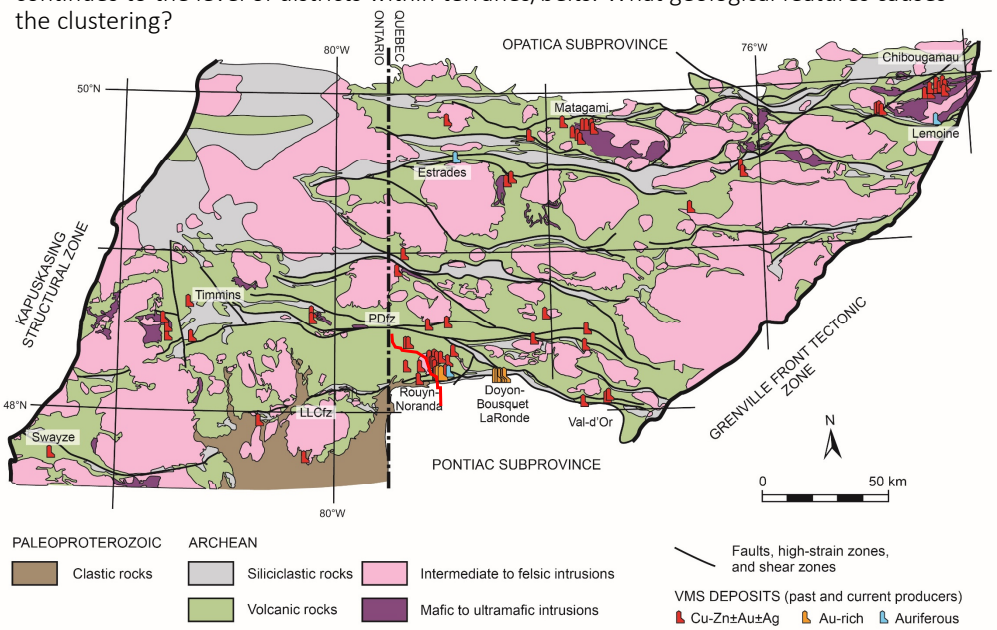

Modified from Monecke et al. (2017) – *Reviews in Economic Geology, v. 19, p. 7-49*

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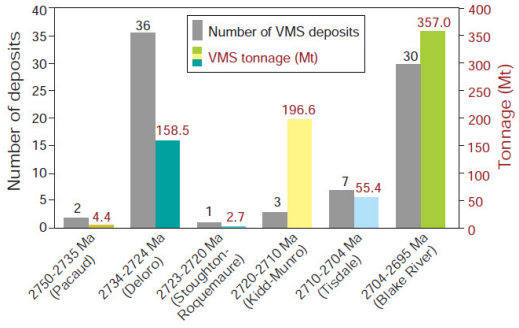
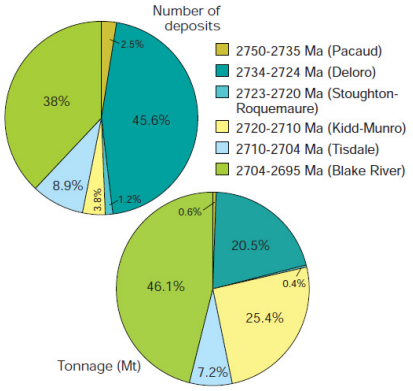
• The Blake River episode was a prolific period of VMS formation





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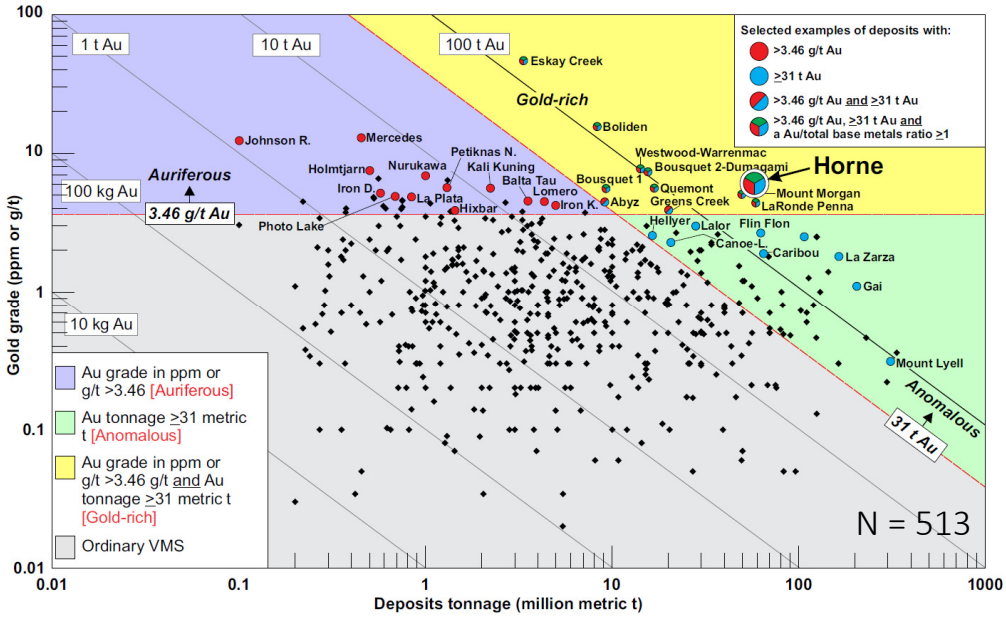
• Gold grade vs. tonnage of VMS deposits



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

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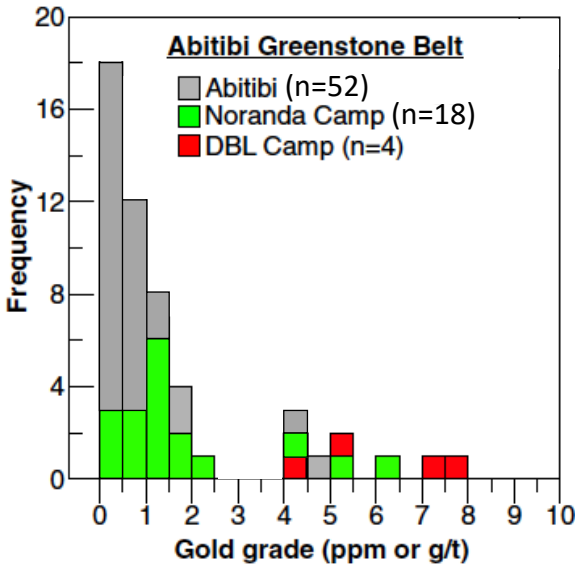
- The Blake River episode accounts for 92% of Abitibi VMS gold



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

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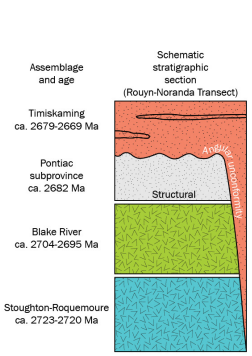
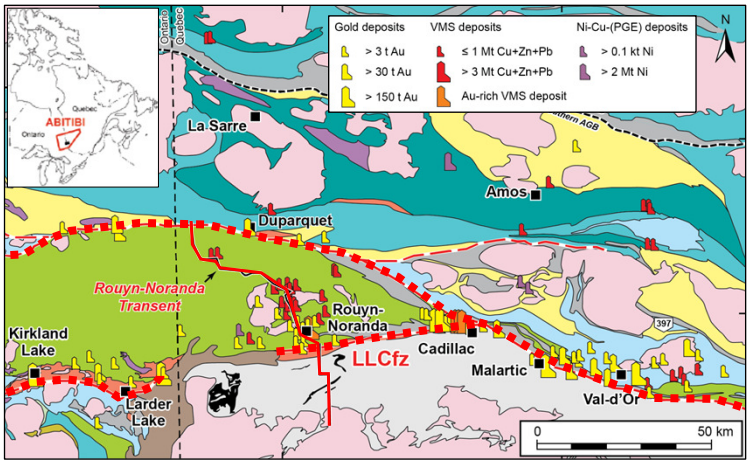
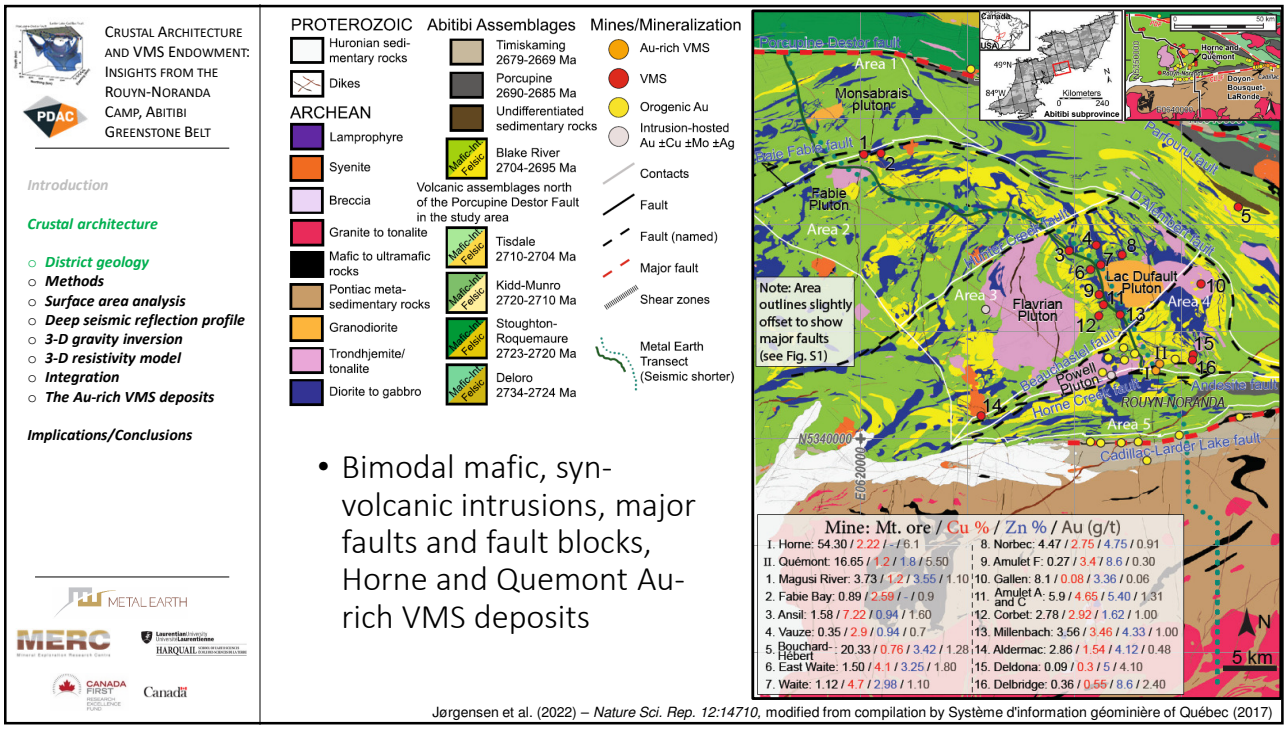
- Transects world-class VMS camp and two transcrustal structures associated with orogenic Au



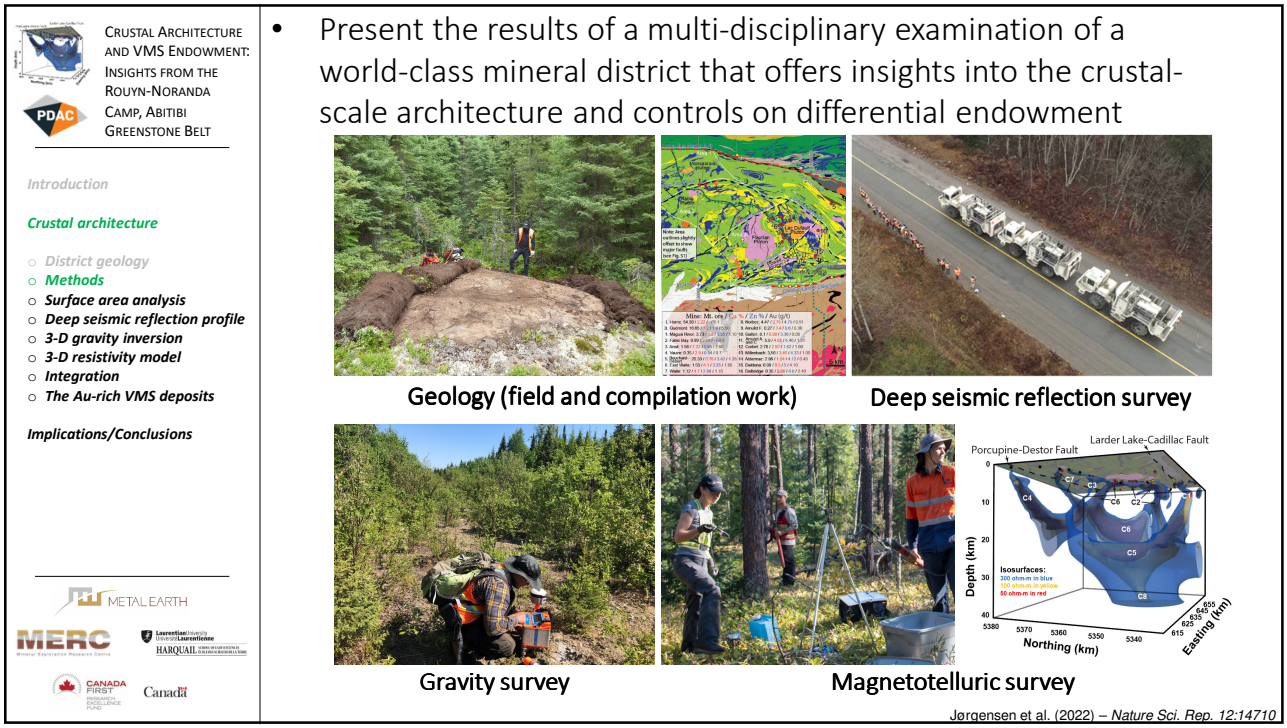
Modified after Frieman (2018) – *PhD thesis*



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*



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



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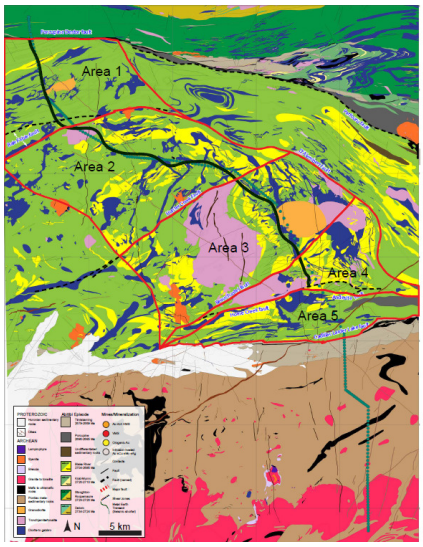
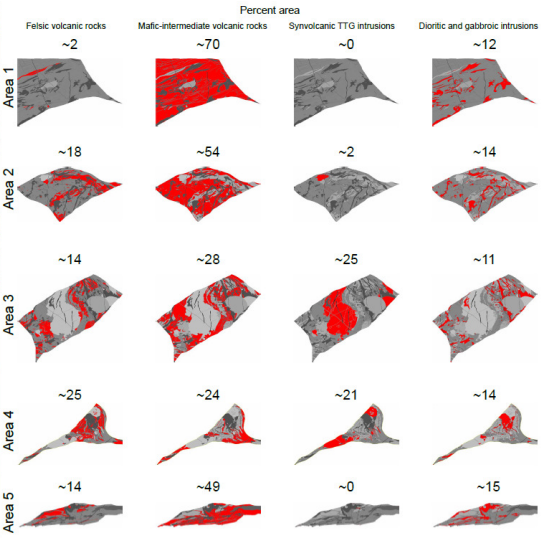
Crustal architecture

- *District geology*
- *Methods*
- ***Surface area analysis***
- ***Deep seismic reflection profile***
- ***3-D gravity inversion***
- ***3-D resistivity model***
- ***Integration***
- ***The Au-rich VMS deposits***

Implications/Conclusions





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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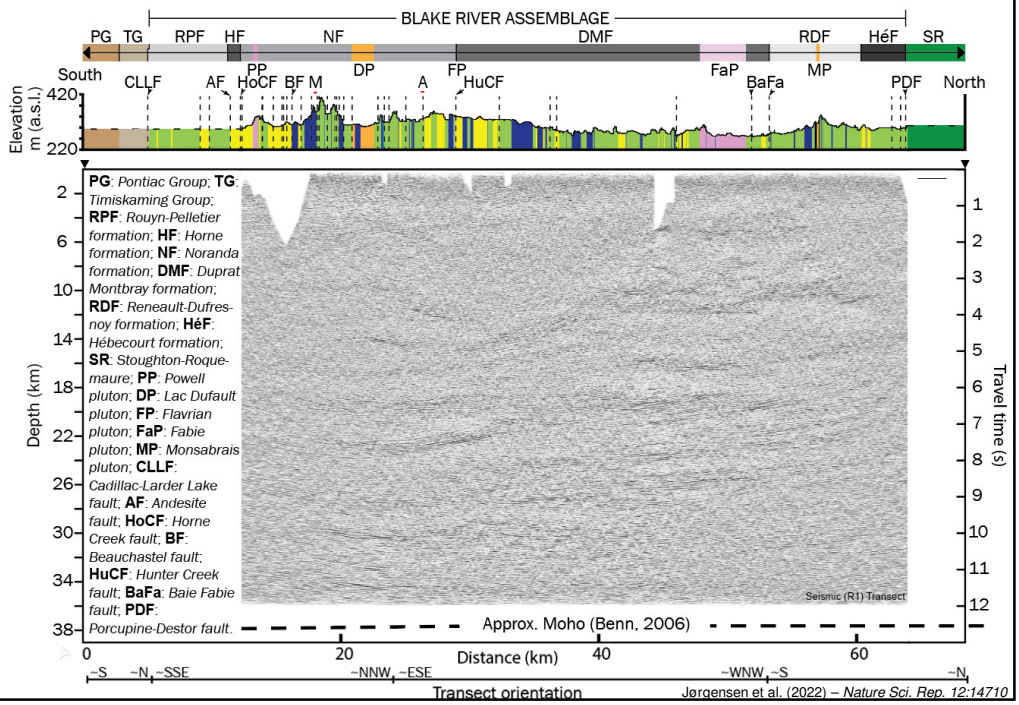

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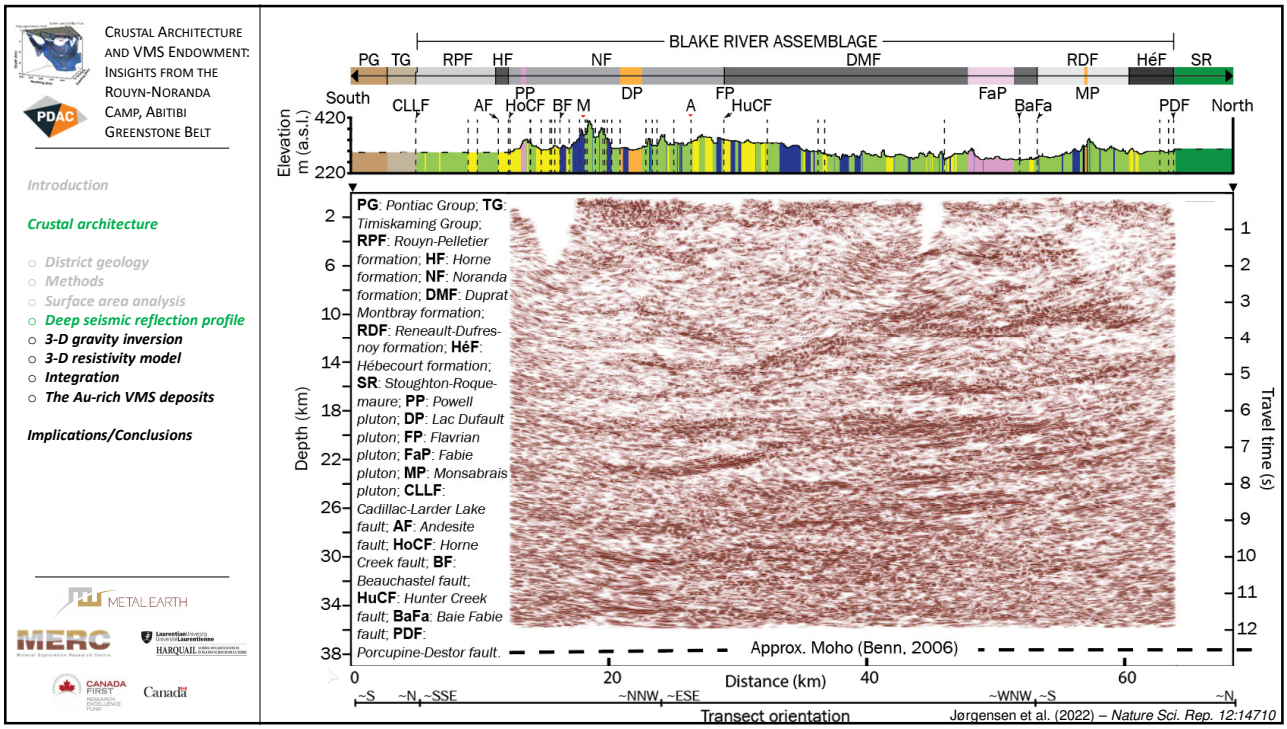
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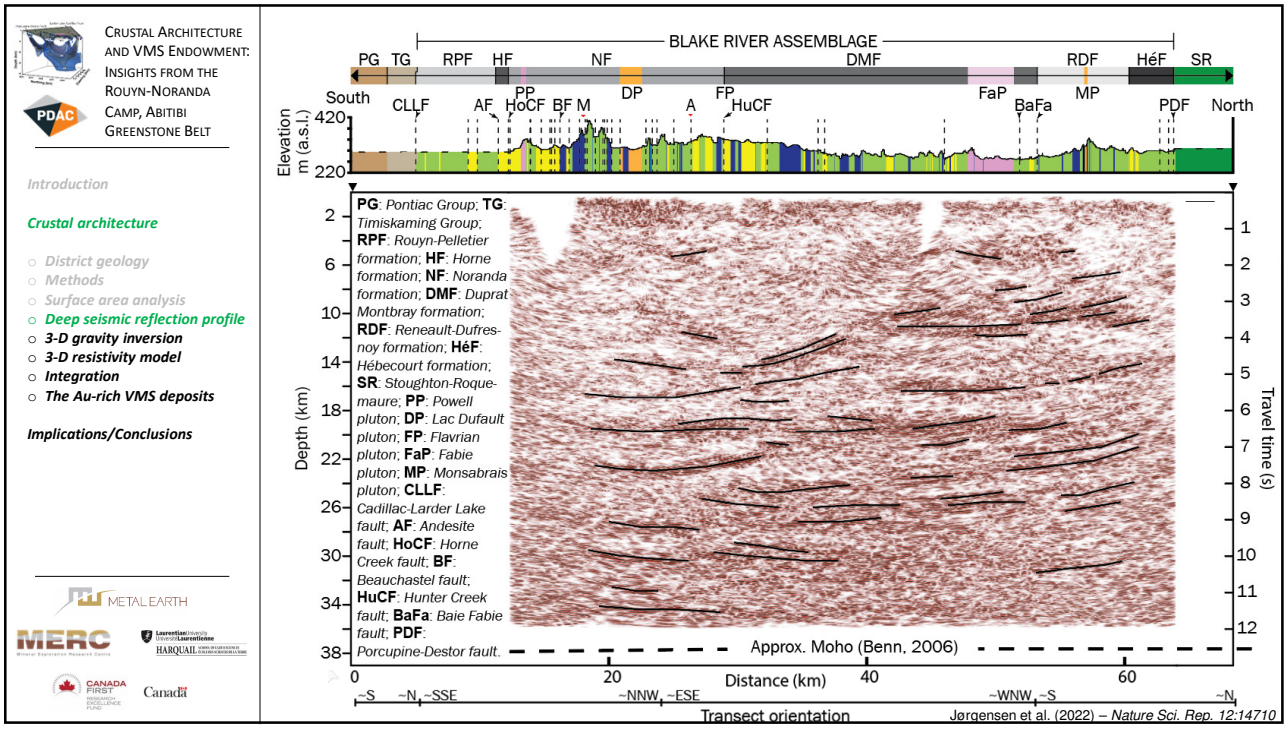
BLAKE RIVER ASSEMBLAGE
PG TG RPF HF NF DMF RDF HéF SR
South CLLF AF PP HoCF BF M DP A FP HuCF FaP BaFa MP PDF North
Elevation m (a.s.l.)
420
220
PG: Pontiac Group; TG: Timiskaming Group; RPF: Rouyn-Pelletier formation; HF: Horne formation; NF: Noranda formation; DMF: Duprat Montbray formation; RDF: Reneault-Dufresnoy 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.
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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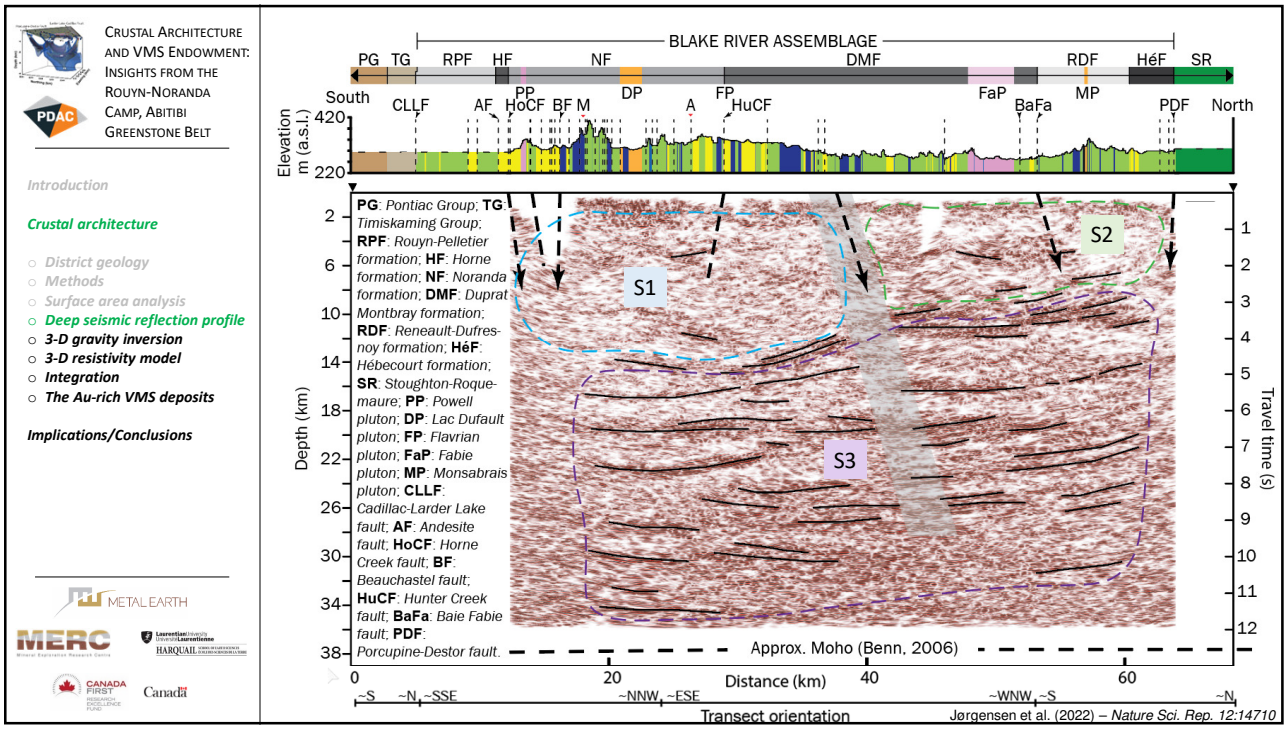
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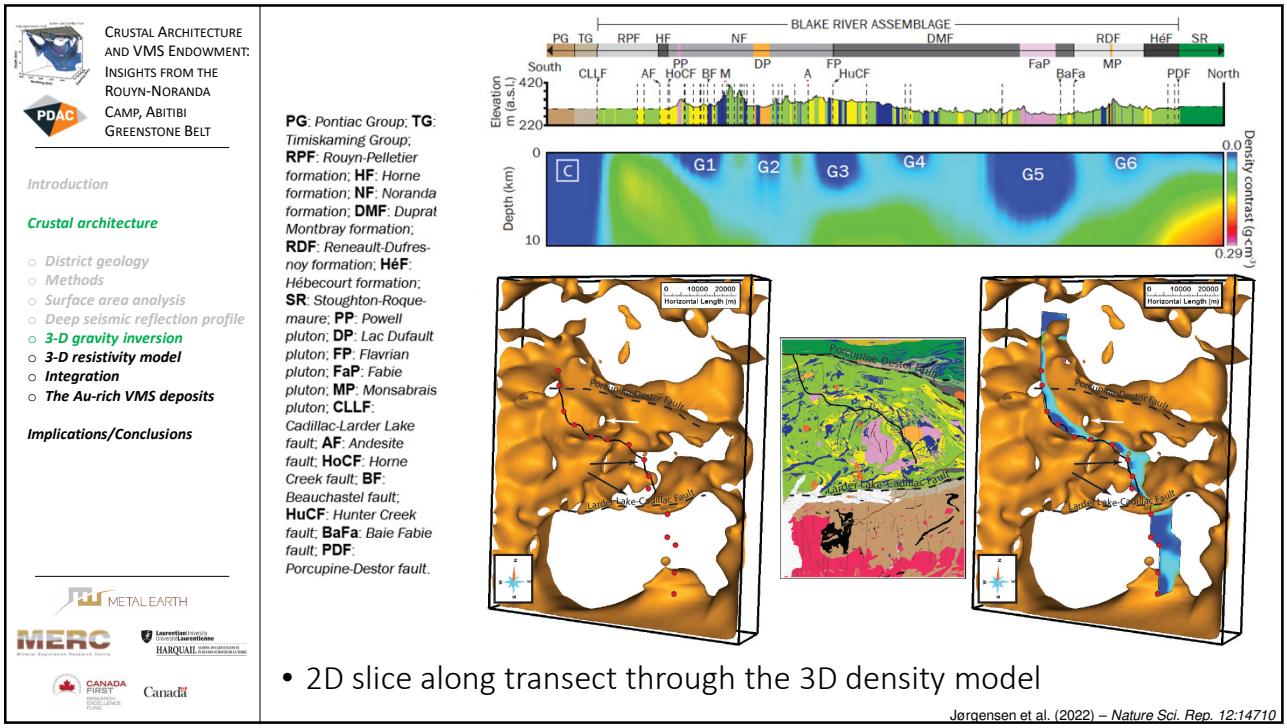
Depth (km) 2 6 10 14 18 22 26 30 34 38
Travel time (s) 1 2 3 4 5 6 7 8 9 10 11 12
Approx. Moho (Benn, 2006)
0 20 40 60
Distance (km)
~S ~N ~SSE ~NNW ~ESE ~WNW ~S ~N
Transect orientation
Jørgensen et al. (2022) – Nature Sci. Rep. 12:14710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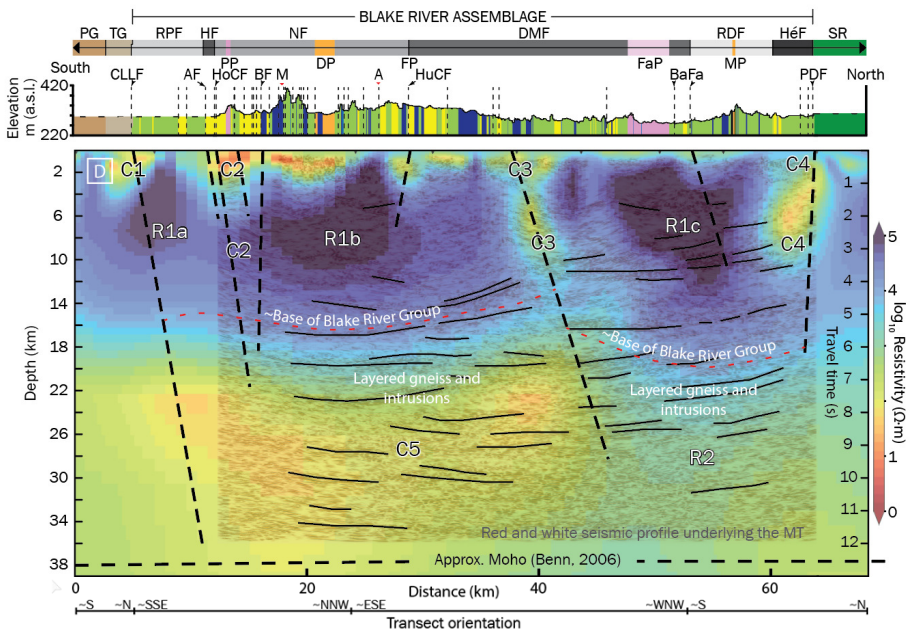
BLAKE RIVER ASSEMBLAGE
PG TG RPF HF NF DMF RDF HéF SR
South CLLF AF PP HoCF BF M DP A FP HuCF FaP BaFa MP PDF North
Elevation m (a.s.l.) 420 220
PG: Pontiac Group; TG: Timiskaming Group; RPF: Rouyn-Pelletier formation; HF: Horne formation; NF: Noranda formation; DMF: Duprat Montbray formation; RDF: Reneault-Dufresnoy 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.
C
G1 G2 G3 G4 G5 G6
Depth (km) 0 10
Density contrast (g·cm⁻³) 0.0 0.29
Horizontal Length (m)
Porcupine-Destor Fault
Powell-Monsabrais Fault
Larder Lake-Cadillac Fault
• 2D slice along transect through the 3D density model
Jørgensen et al. (2022) – Nature Sci. Rep. 12:14710



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

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

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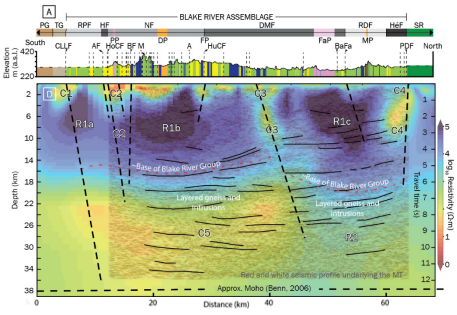

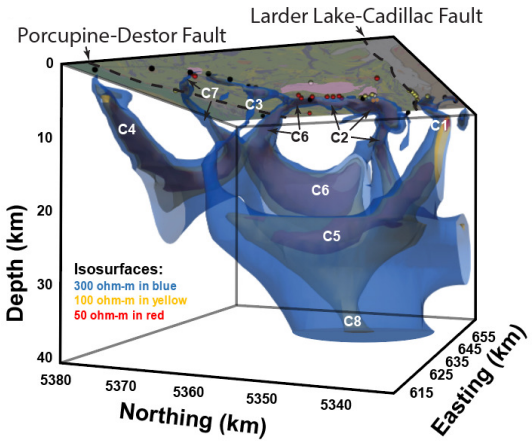

- 3-D MT model reveal pipe-like vertical features and the connectivity to a lower crustal low-resistivity volume
- Potentially connected to the lithospheric mantle??

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

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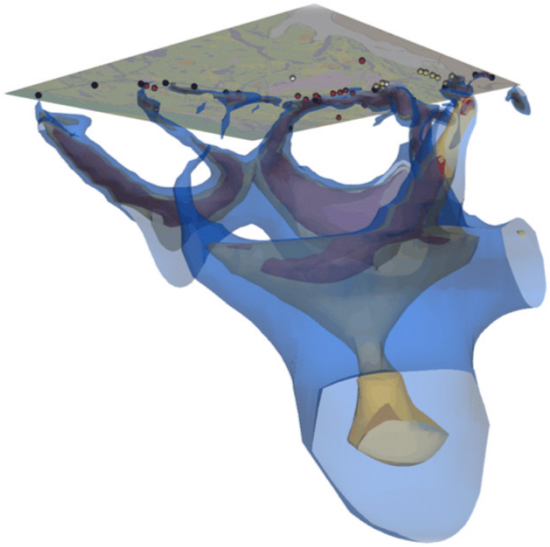

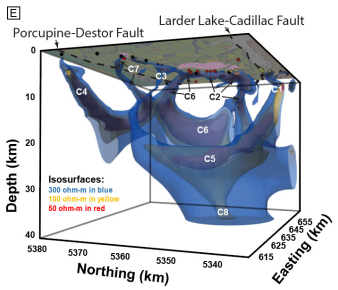

- 3-D MT model reveal pipe-like vertical features and the connectivity to a lower crustal low-resistivity volume
- Potentially connected to the subcontinental lithospheric mantle??

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

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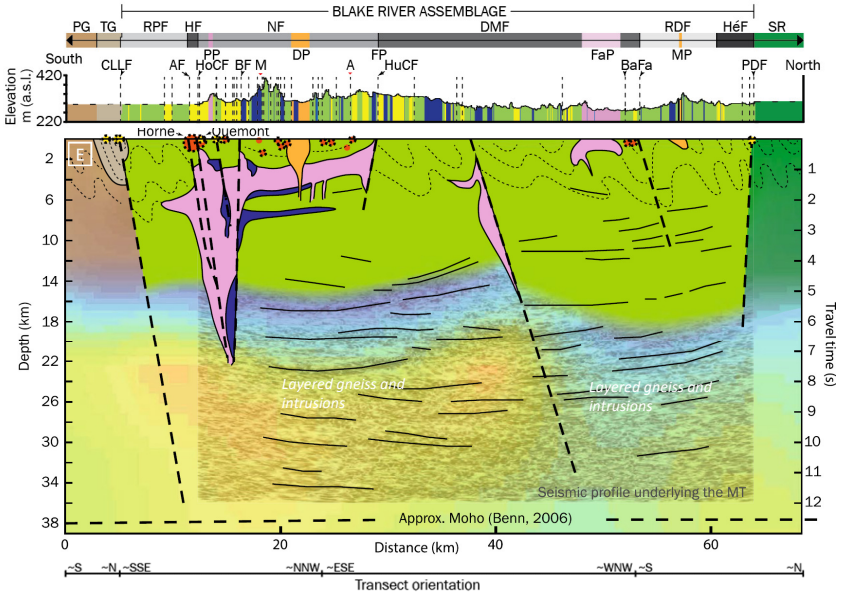
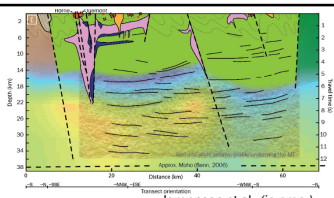


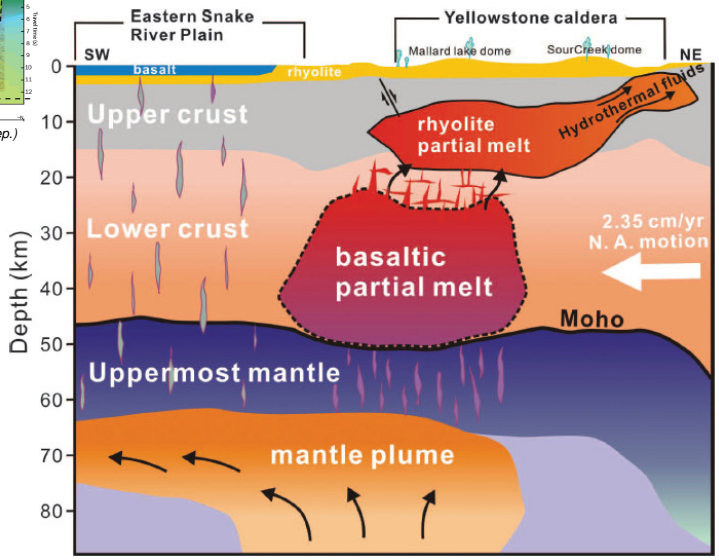
- Asymmetry in geology, crustal architecture, number of VMS deposits and the tenor of these deposits

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

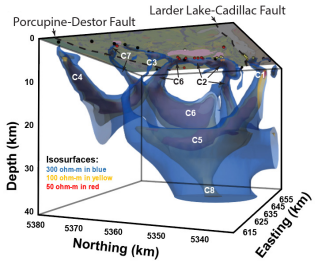


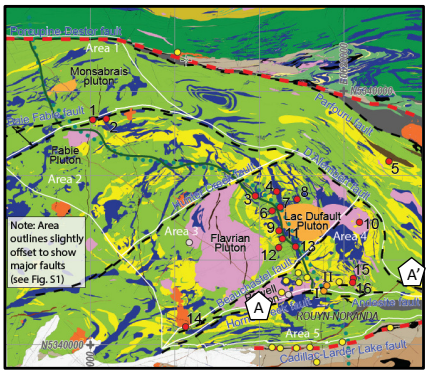
Jørgensen et al. *(in prep.)*

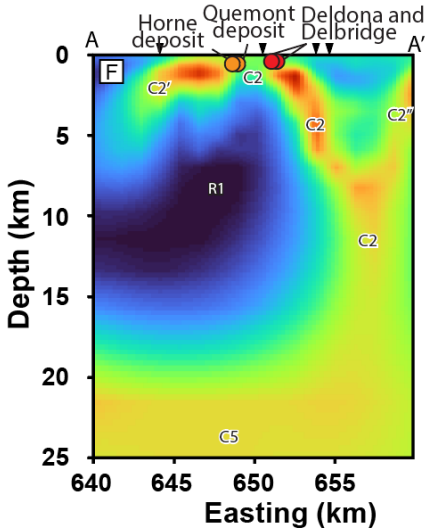
- May draw parallels to the architecture of some recent/modern volcanic centers (does not imply similar tectonic setting)
- Felsic magma reservoir at the Yellowstone Caldera overlies a middle and lower crust invaded by mantle derived basalt



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

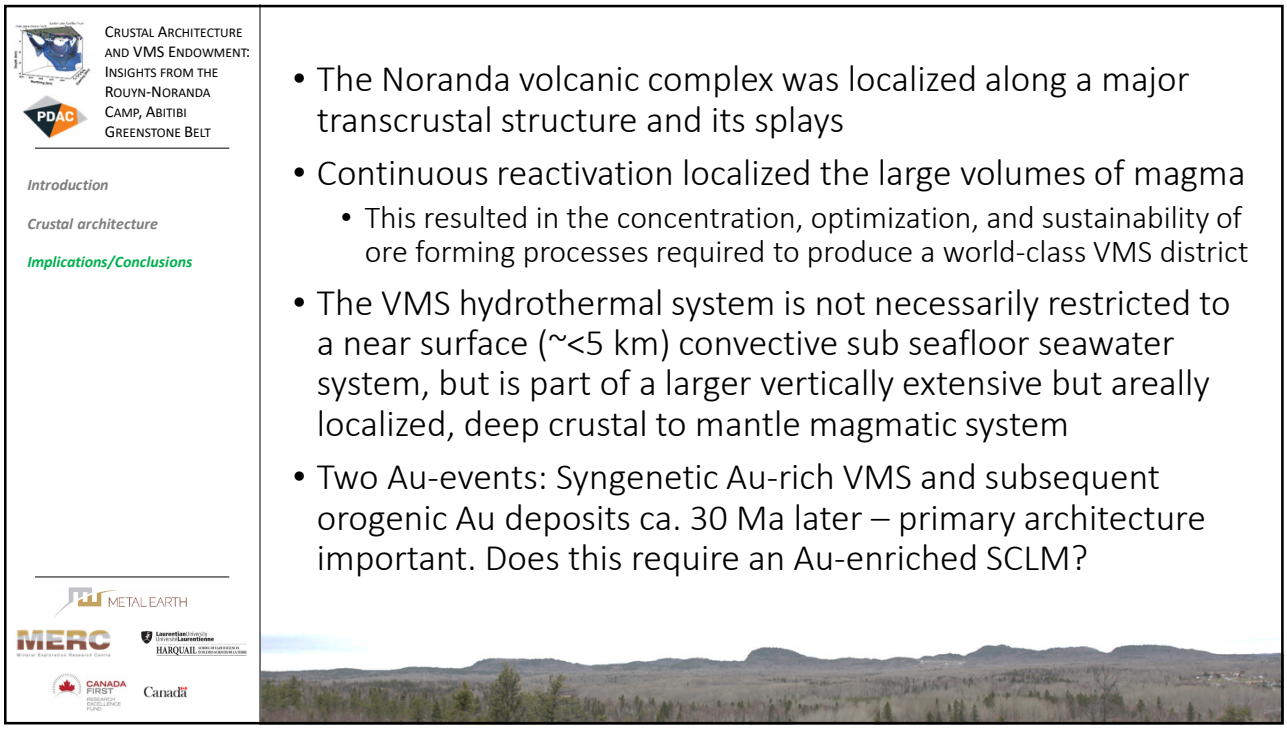






- Optimal location for a magmatic contribution of metals to the VMS system that may explain the localization of Au-rich deposits

Jørgensen et al. (2022) – *Nature Sci. Rep. 12:14710*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• 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
• Two Au-events: Syngenetic Au-rich VMS and subsequent orogenic Au deposits ca. 30 Ma later – primary architecture important. Does this require an Au-enriched SCLM?


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THANK YOU!
Session: New geophysical and geological insights into how crustal architecture influences the gold and base metal endowment of Precambrian terranes
Saturday, March 4th, 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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