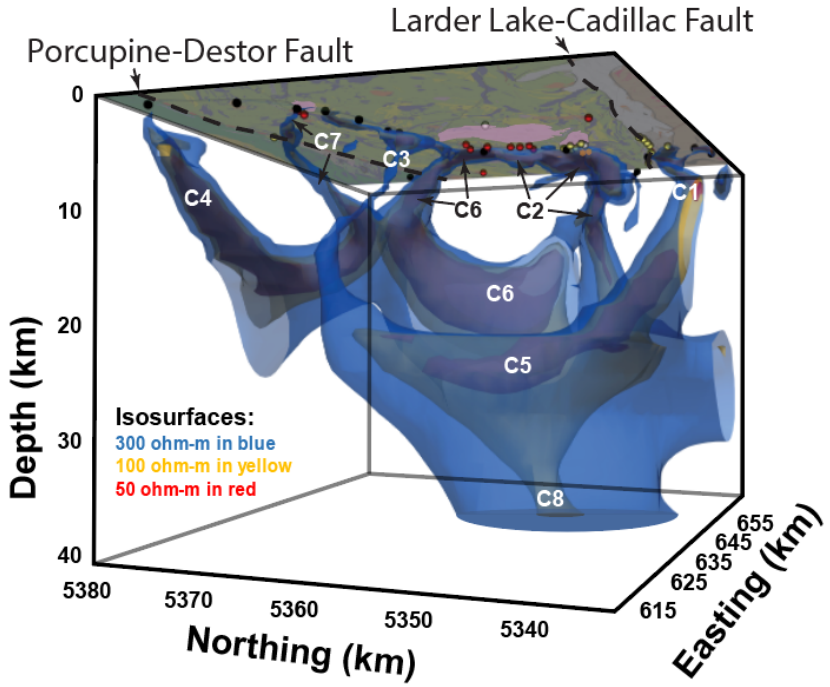
CONGRÈS AEMQ QMEA CONVENTION XPLOR

*Short Course: New insights into crustal-scale influences on gold and base metal endowment in the Archean Superior Province*
*Tuesday, October 29th, 2024, 9:00 AM to 4:00 PM (ET)*

# Assessing differential VMS Endowment in the Abitibi Greenstone Belt -

## *Insights from the Noranda Camp and Abitibi-wide assemblage and lithological compilations*

TAUS R. C. JØRGENSEN

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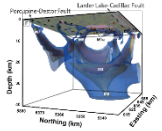

CRUSTAL ARCHITECTURE AND VMS ENDOWMENT: INSIGHTS FROM THE ROUYN-NORANDA CAMP, ABITIBI GREENSTONE BELT

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- ***Au-rich VMS***
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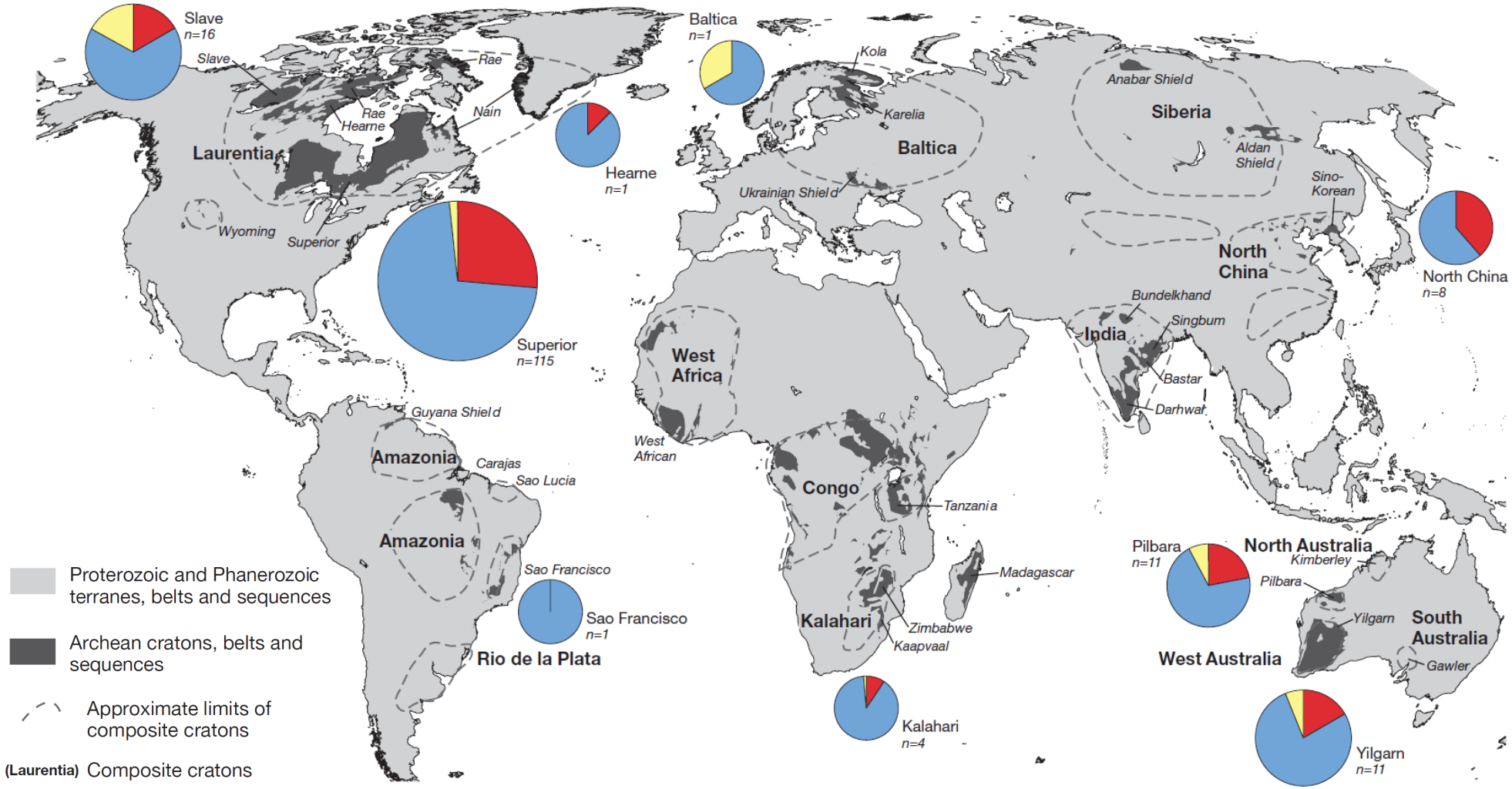
***Crustal architecture***

***Implications***

***What's next: Assemblage and lithological compilations of the AGB***


# • 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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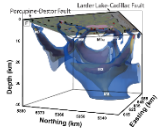

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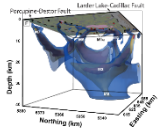
- VMS metal endowment of Archean cratonic blocks in Canada and Australia
- Measured as the quantity of metal contained in geologic resources per unit surface area

| 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

| Craton/terrane/domain | Area ($km^2$) | Contained metal (Mt) | | | Endowment ($t/km^2$) | | | |
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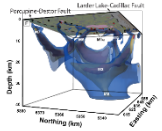

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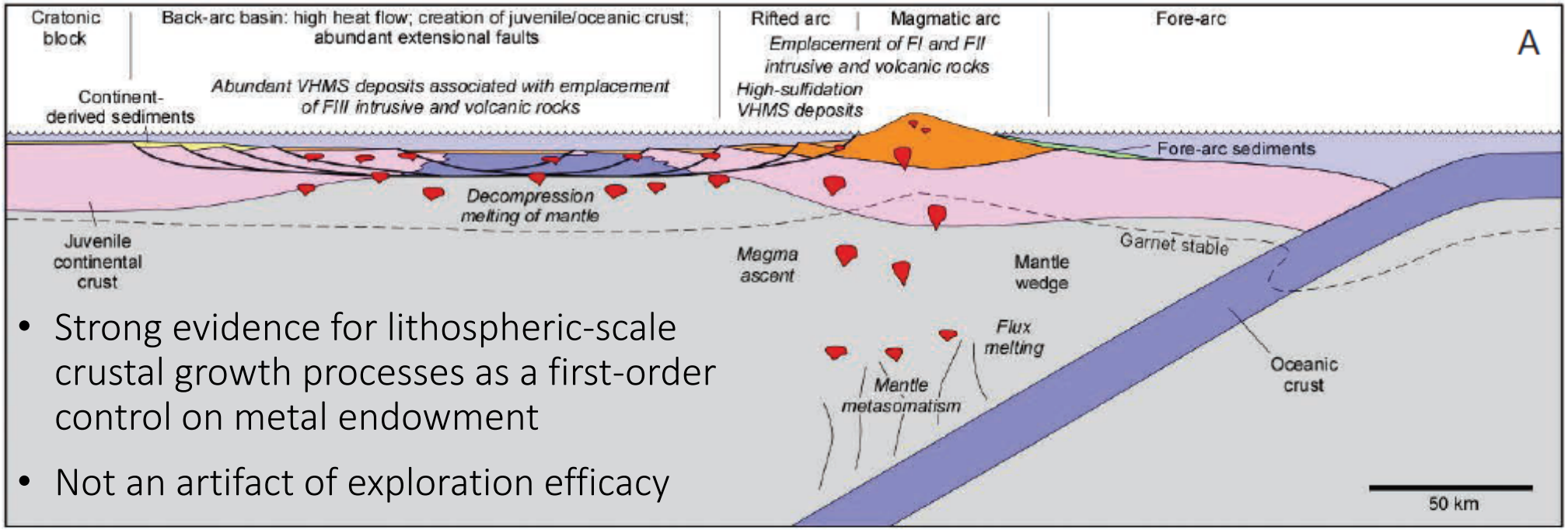
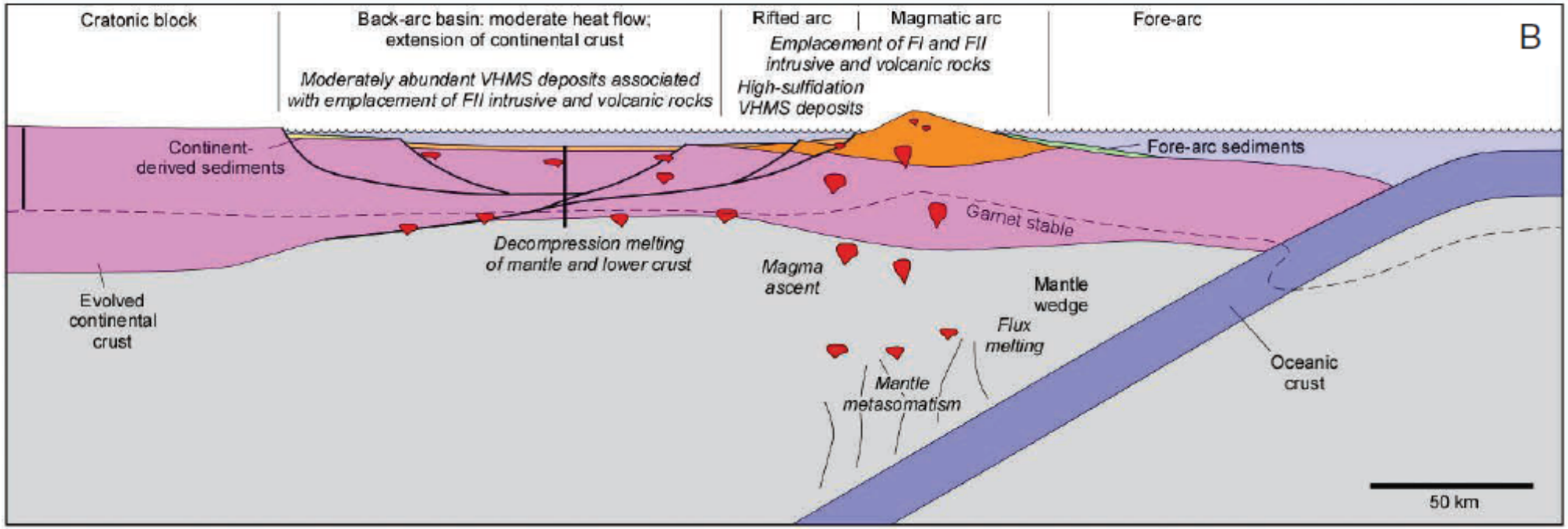



- Strong evidence for lithospheric-scale crustal growth processes as a first-order control on metal endowment
- Not an artifact of exploration efficacy




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

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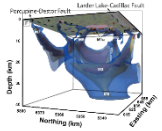

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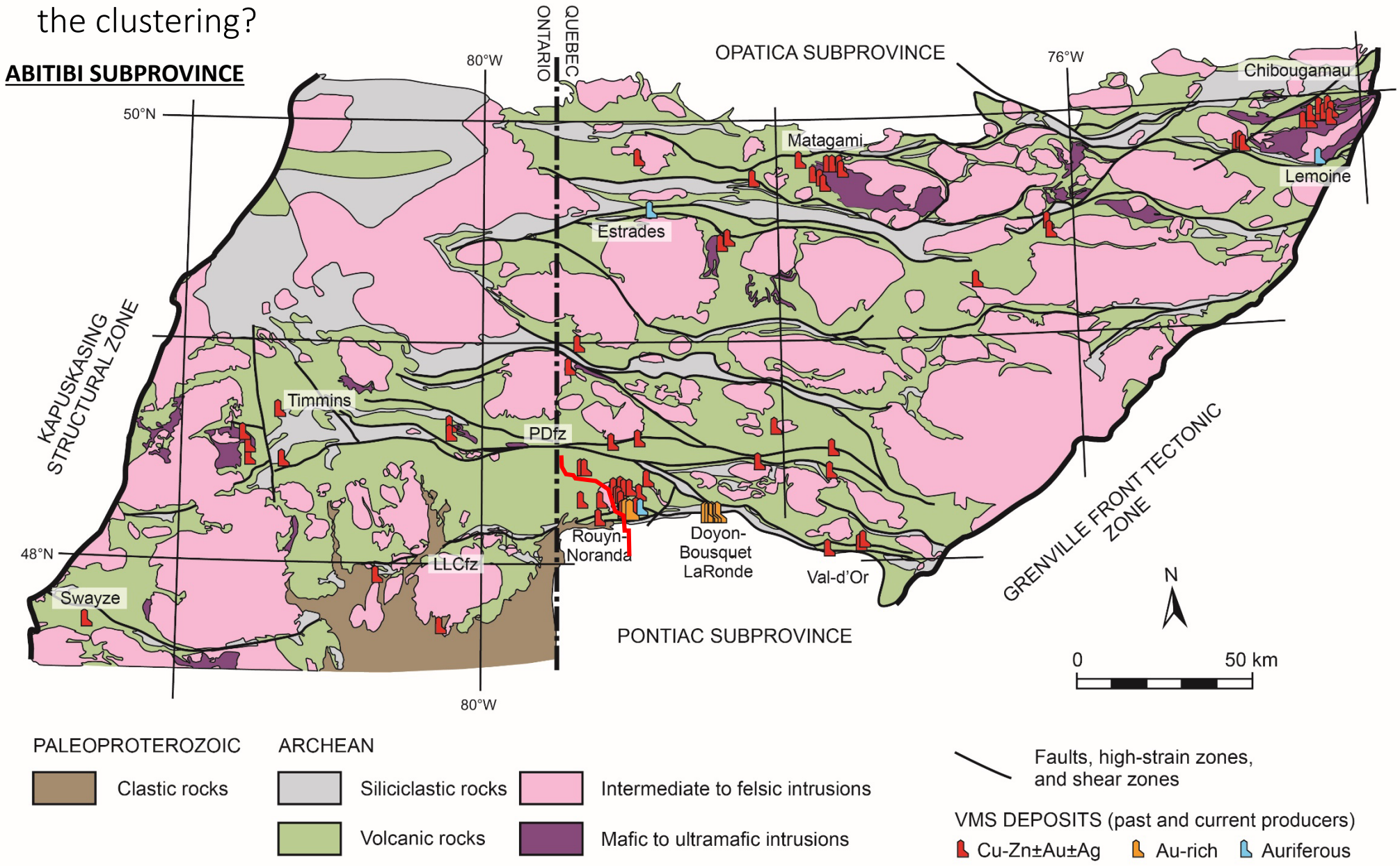
- Within individual cratons a few provinces are more endowed than the rest. This pattern continues to the level of districts within terranes/belts. What geological features causes the clustering?




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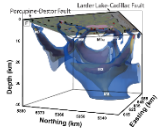

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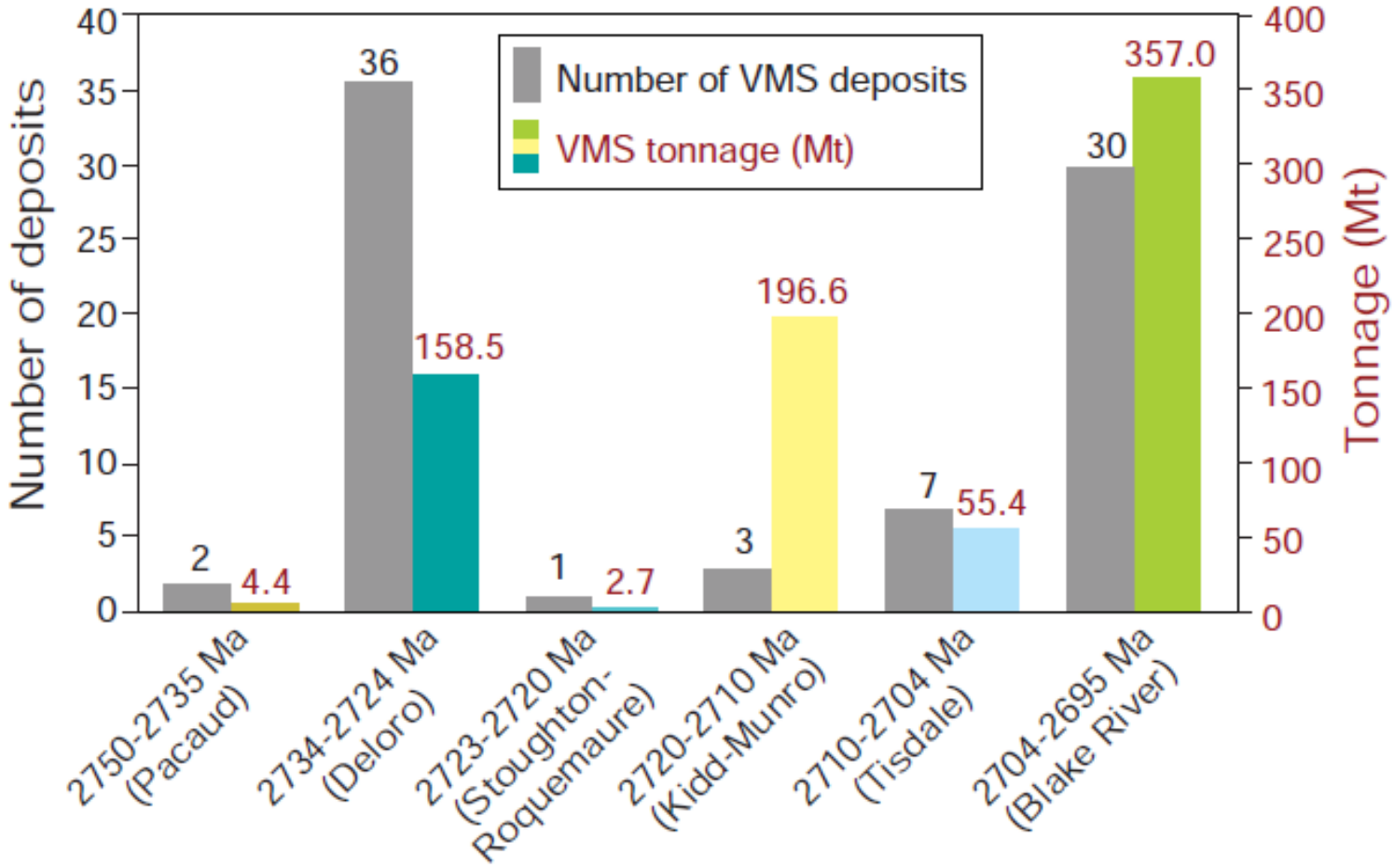


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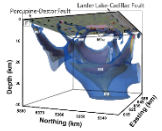

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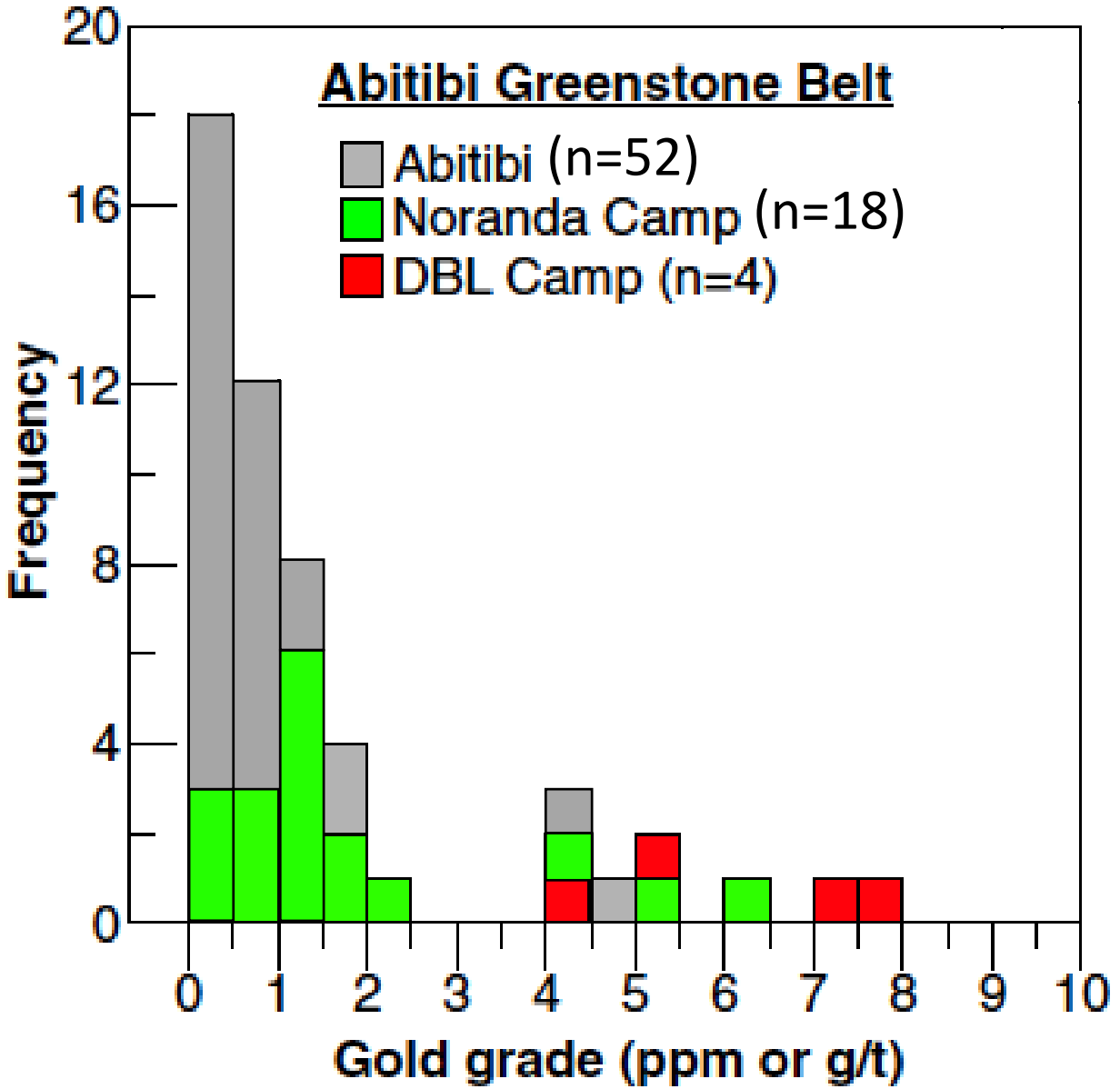
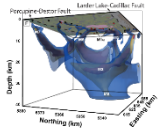
- The Blake River episode accounts for 92% of Abitibi VMS gold




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



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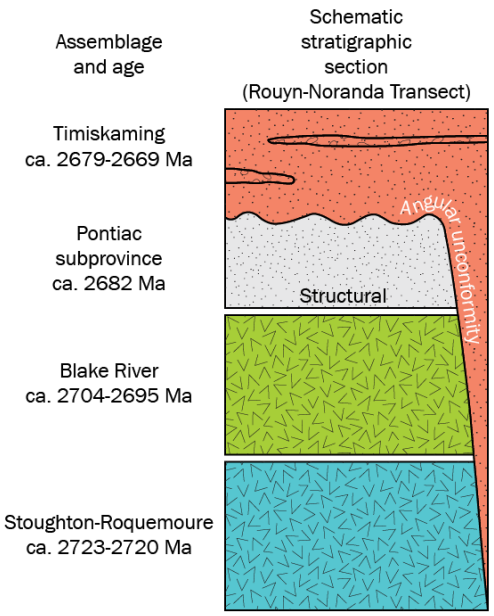
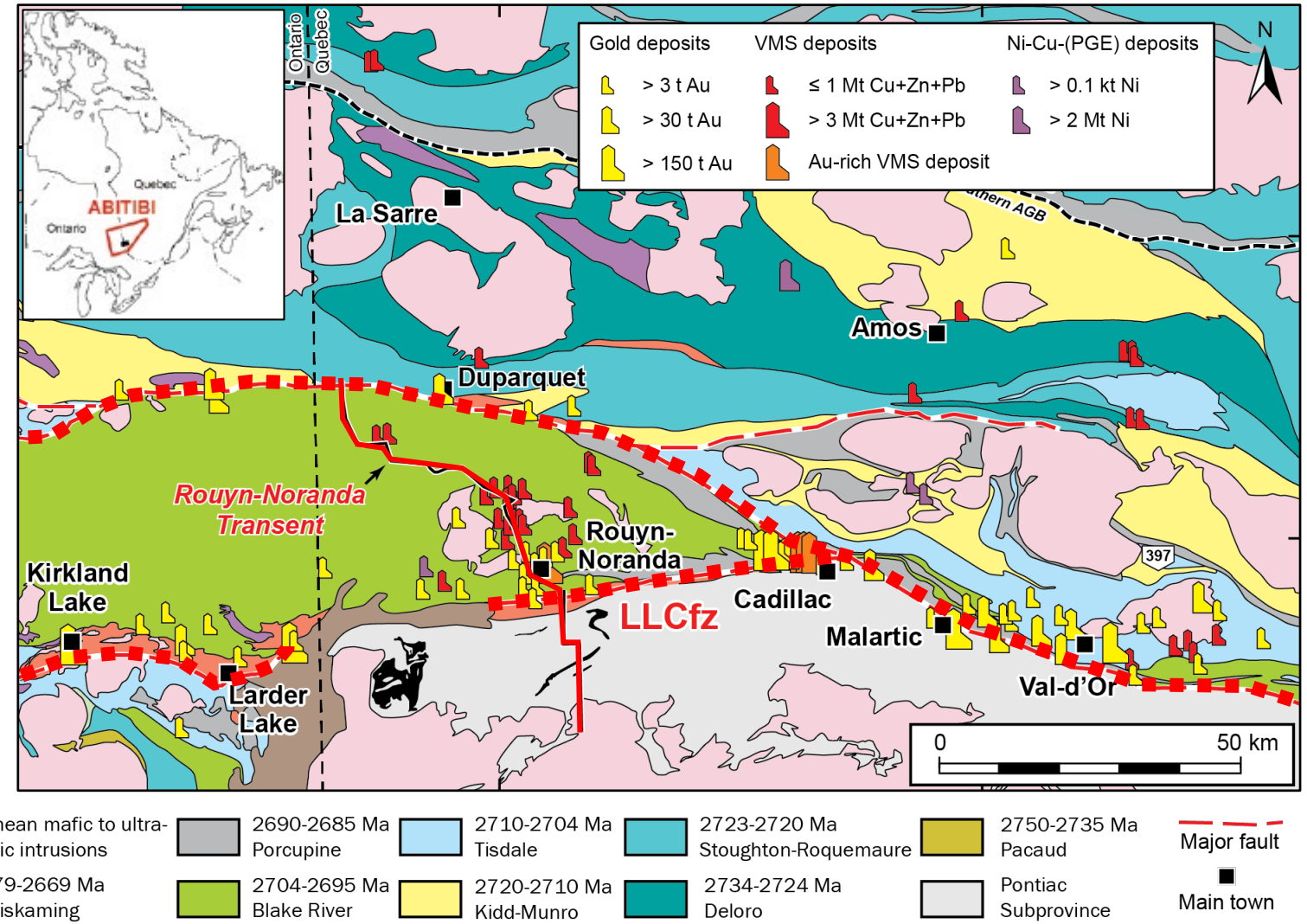
- Transects world-class VMS camp and two transcrustal structures associated with orogenic Au




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*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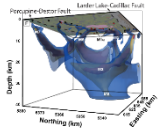

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- ***3-D gravity inversion***
- ***3-D resistivity model***
- ***Surface area analysis***
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**PROTEROZOIC**

- Huronian sedimentary rocks
- Dikes

**ARCHEAN**

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

**Abitibi Assemblages**

- Timiskaming 2679-2669 Ma
- Porcupine 2690-2685 Ma
- Undifferentiated sedimentary rocks
- Blake River 2704-2695 Ma

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

- Tisdale 2710-2704 Ma
- Kidd-Munro 2720-2710 Ma
- Stoughton-Roquemaure 2723-2720 Ma
- Deloro 2734-2724 Ma

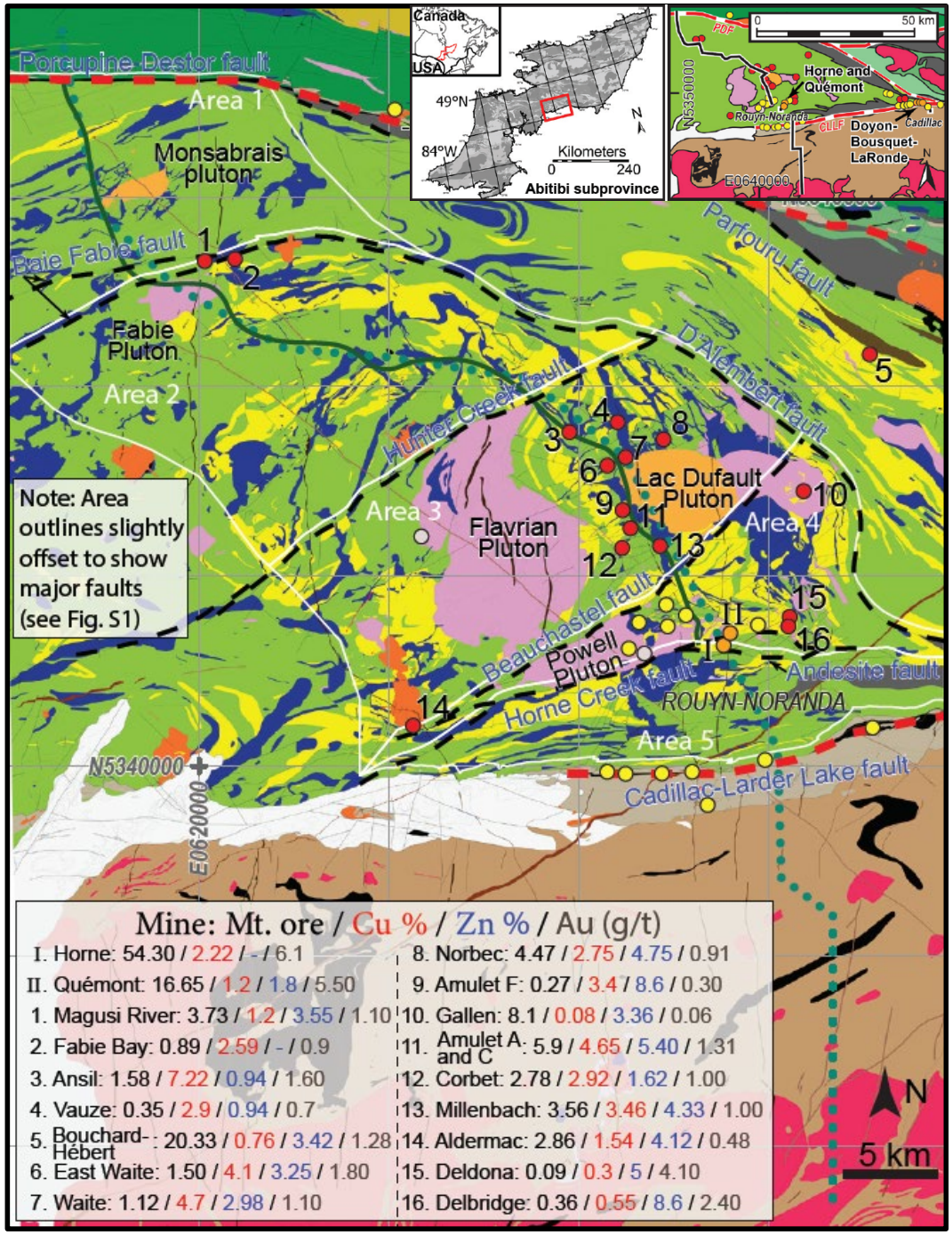
**Mines/Mineralization**

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

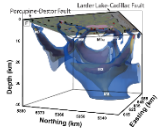
**Contacts**

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

- 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)



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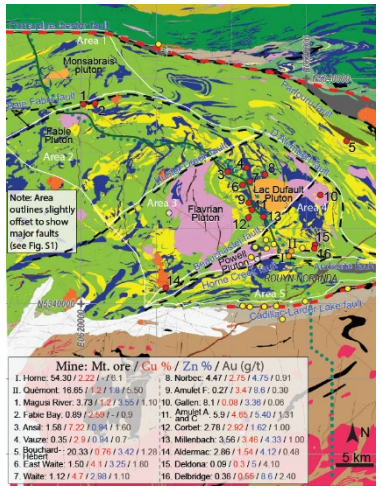
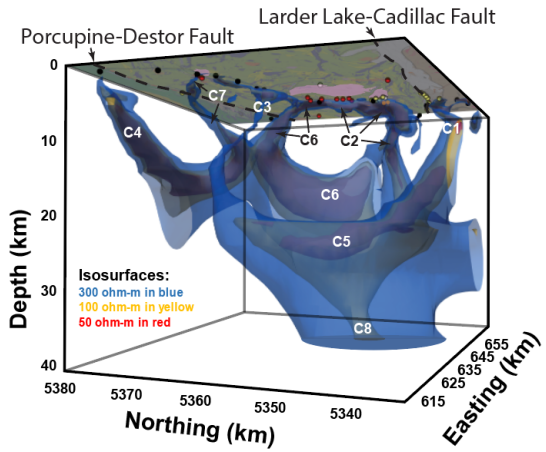
- Multi-disciplinary examination of a world-class mineral district that offers insights into the crustal-scale architecture and controls on differential endowment

Geology (field and compilation work)




Deep seismic reflection survey

Gravity survey




Magnetotelluric survey

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

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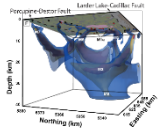

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XPLOR


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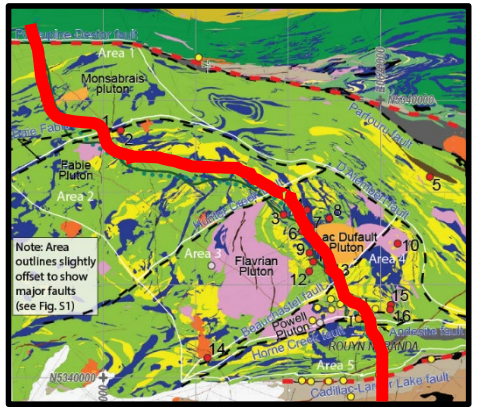
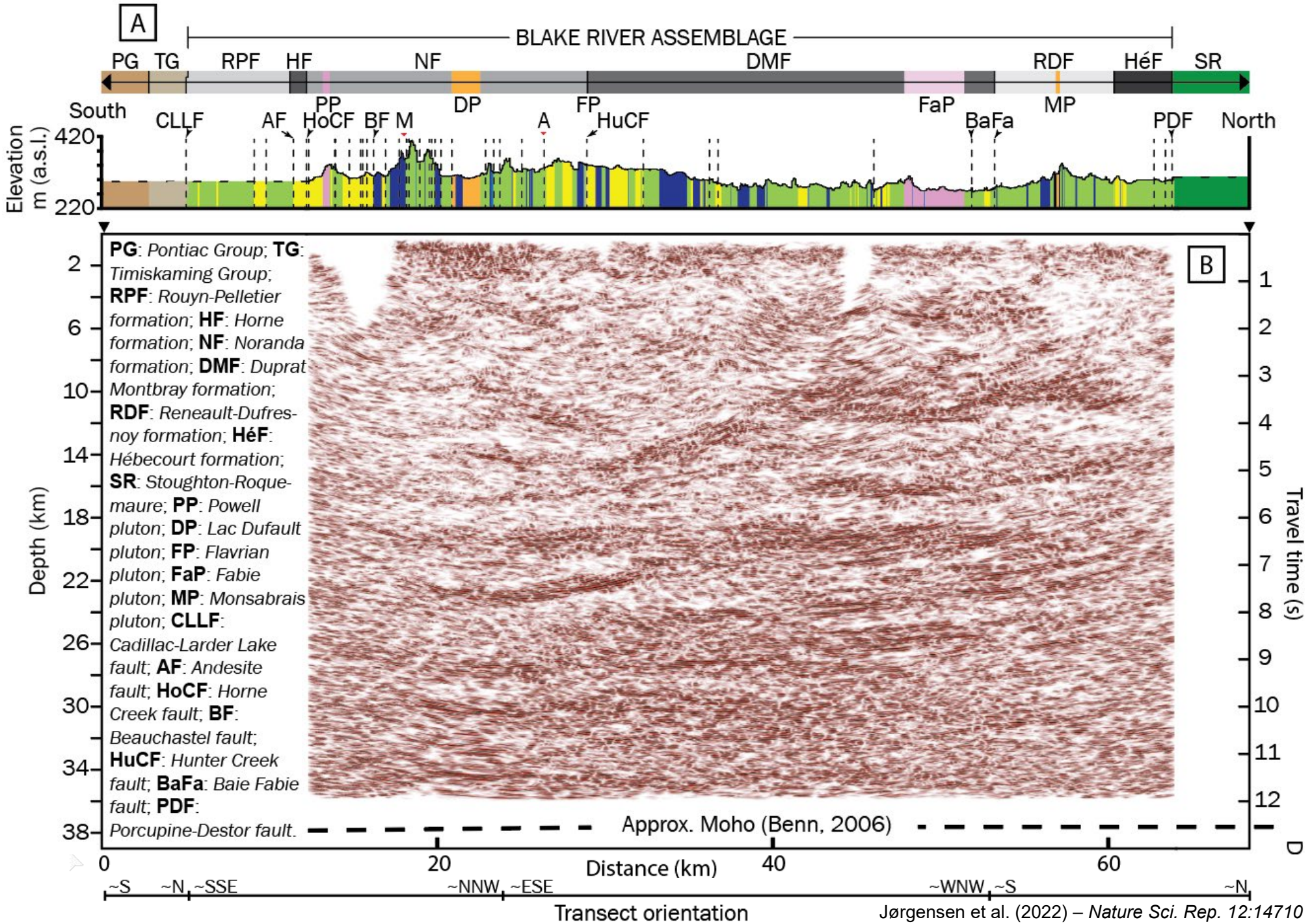
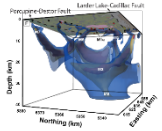



Jørgensen et al. (2022) – *Nature Sci. Rep. 12:14710*



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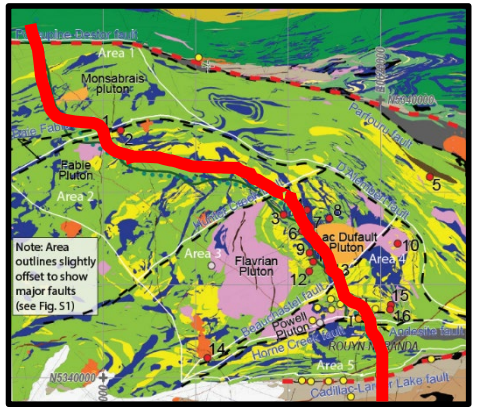


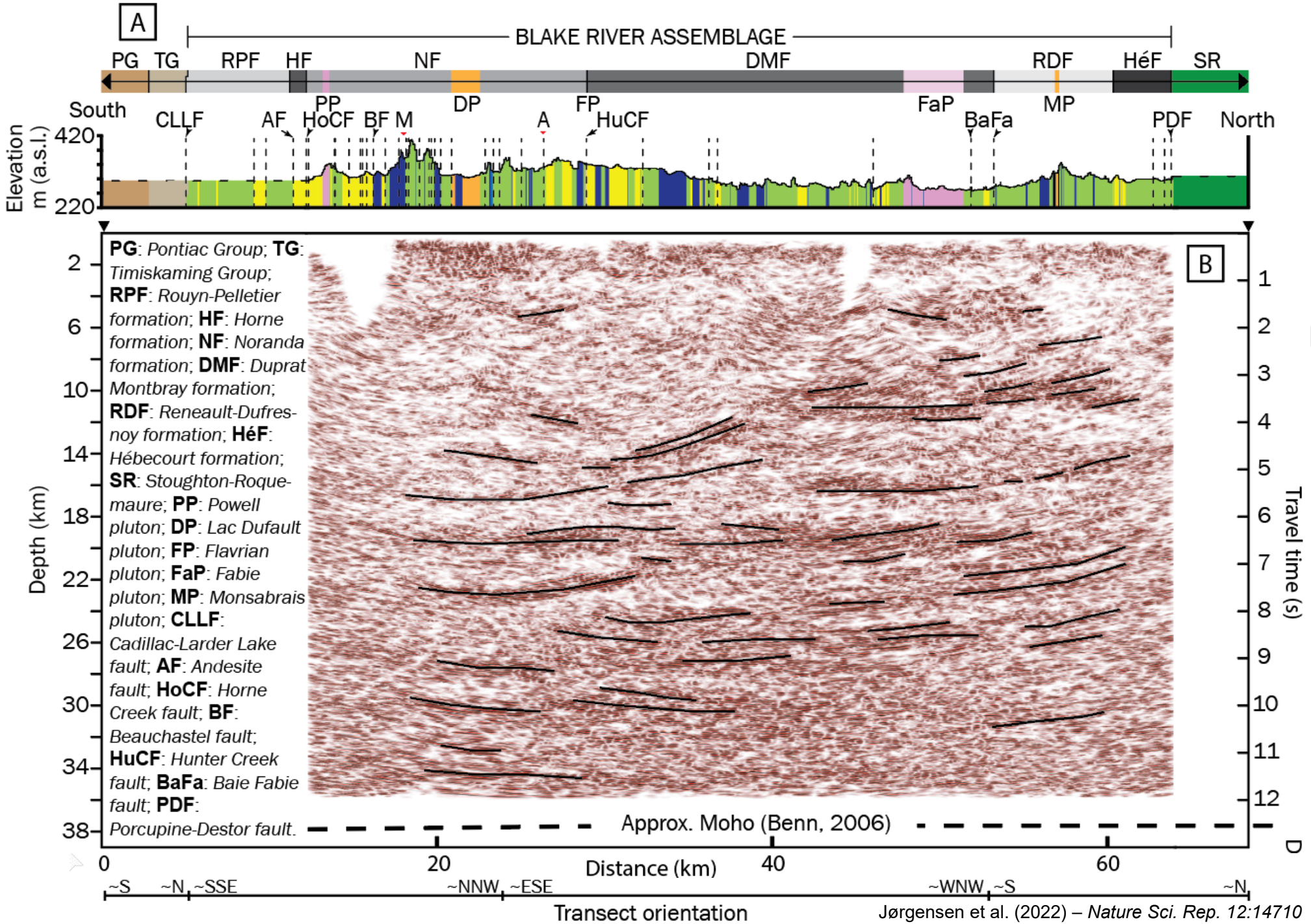


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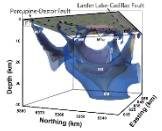

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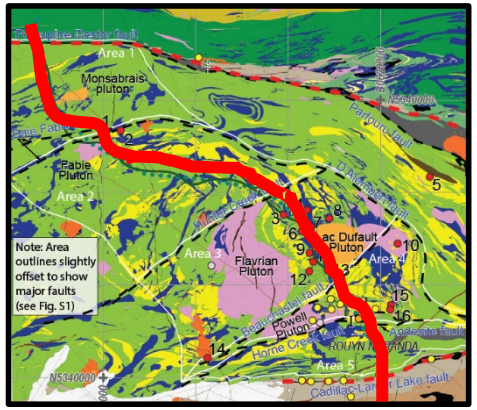


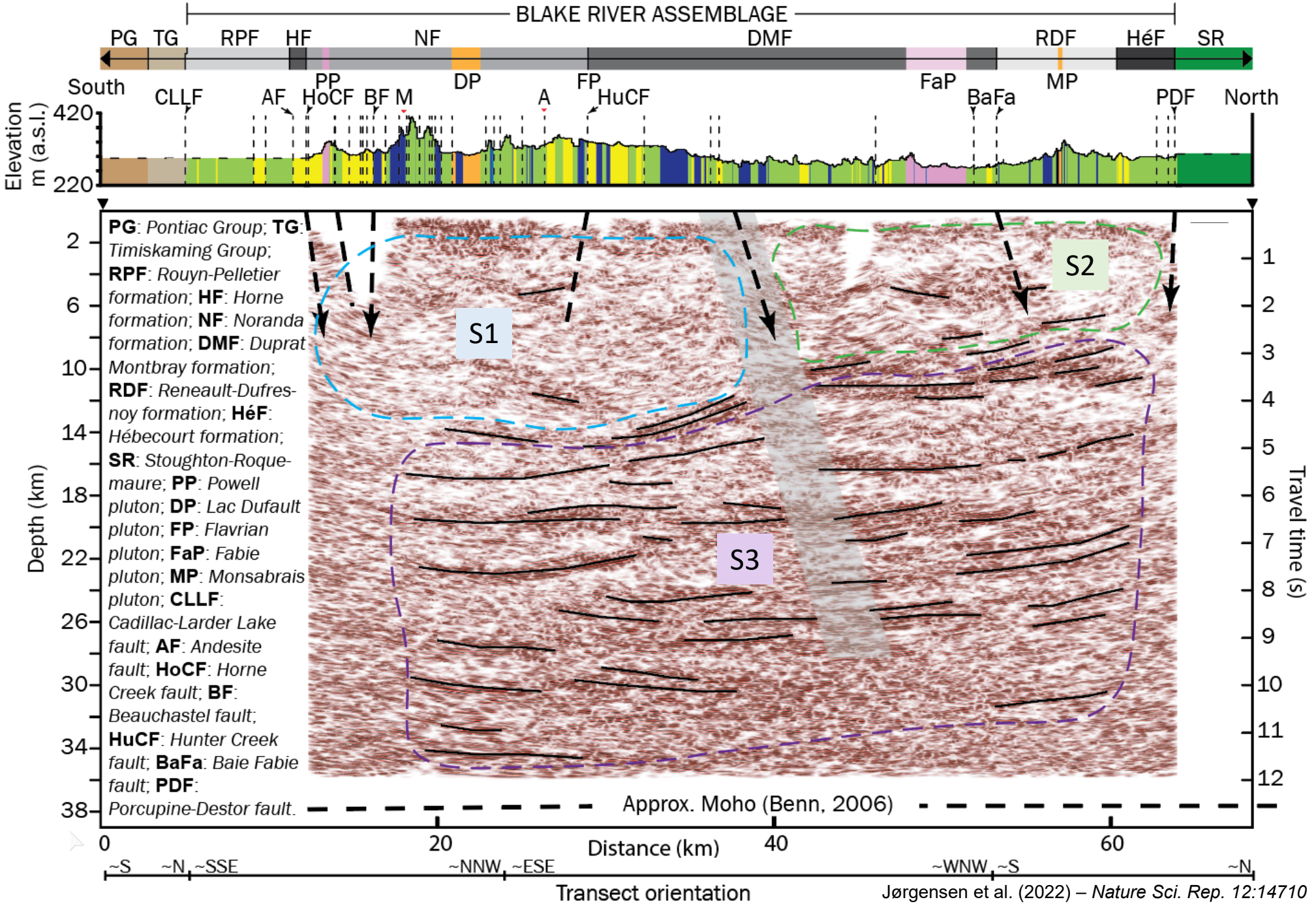


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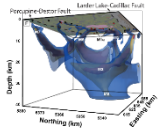

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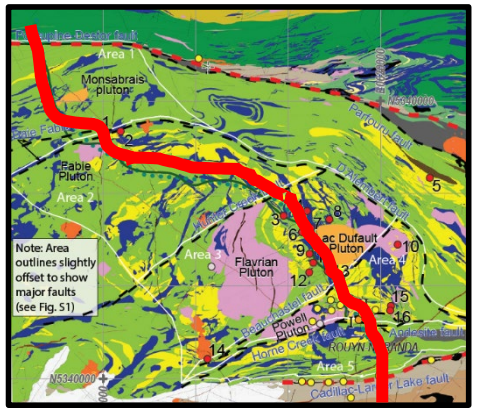
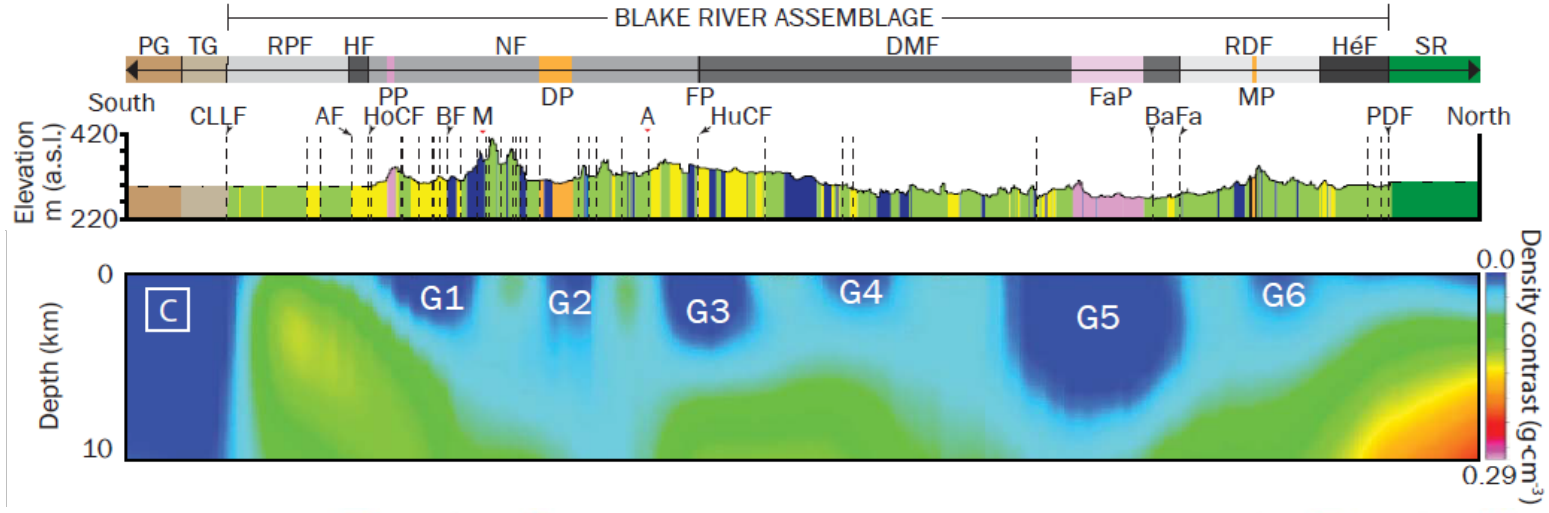
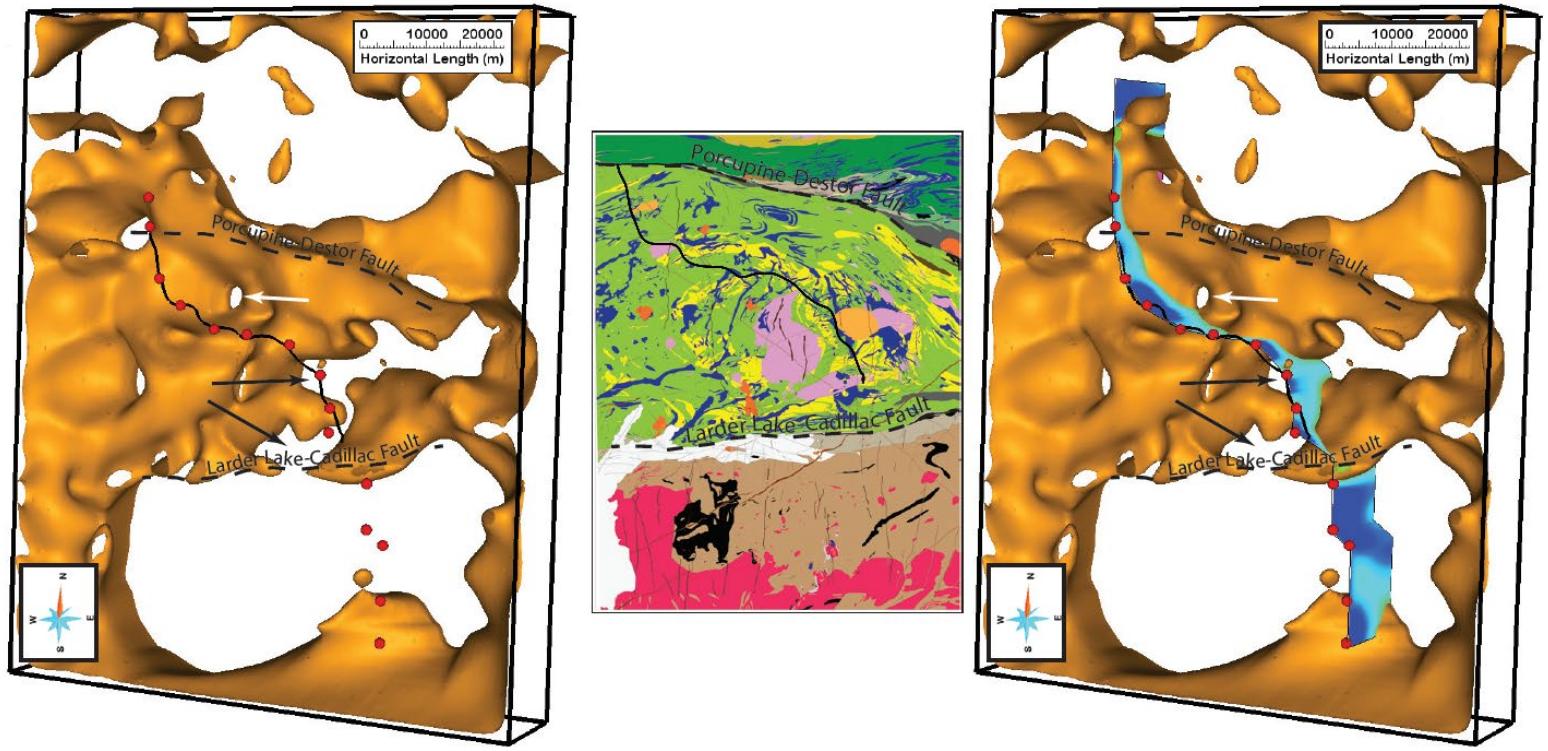


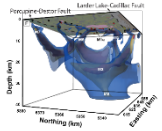

**PG**: *Pontiac Group*; **TG**: *Timiskaming Group*; **RPF**: *Rouyn-Pelletier formation*; **HF**: *Horne formation*; **NF**: *Noranda formation*; **DMF**: *Dupra Montbray formation*; **RDF**: *Reneault-Dufresnoy formation*; **HéF**: *Hébecourt formation*; **SR**: *Stoughton-Roquemaure*; **PP**: *Powell 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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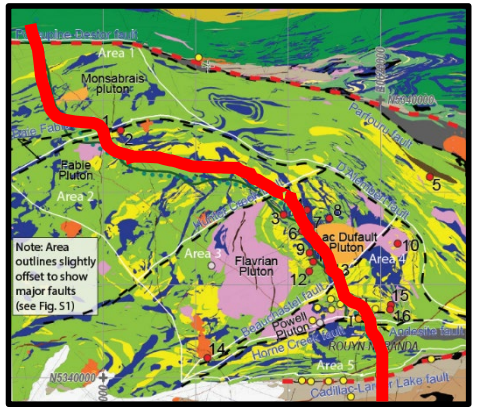


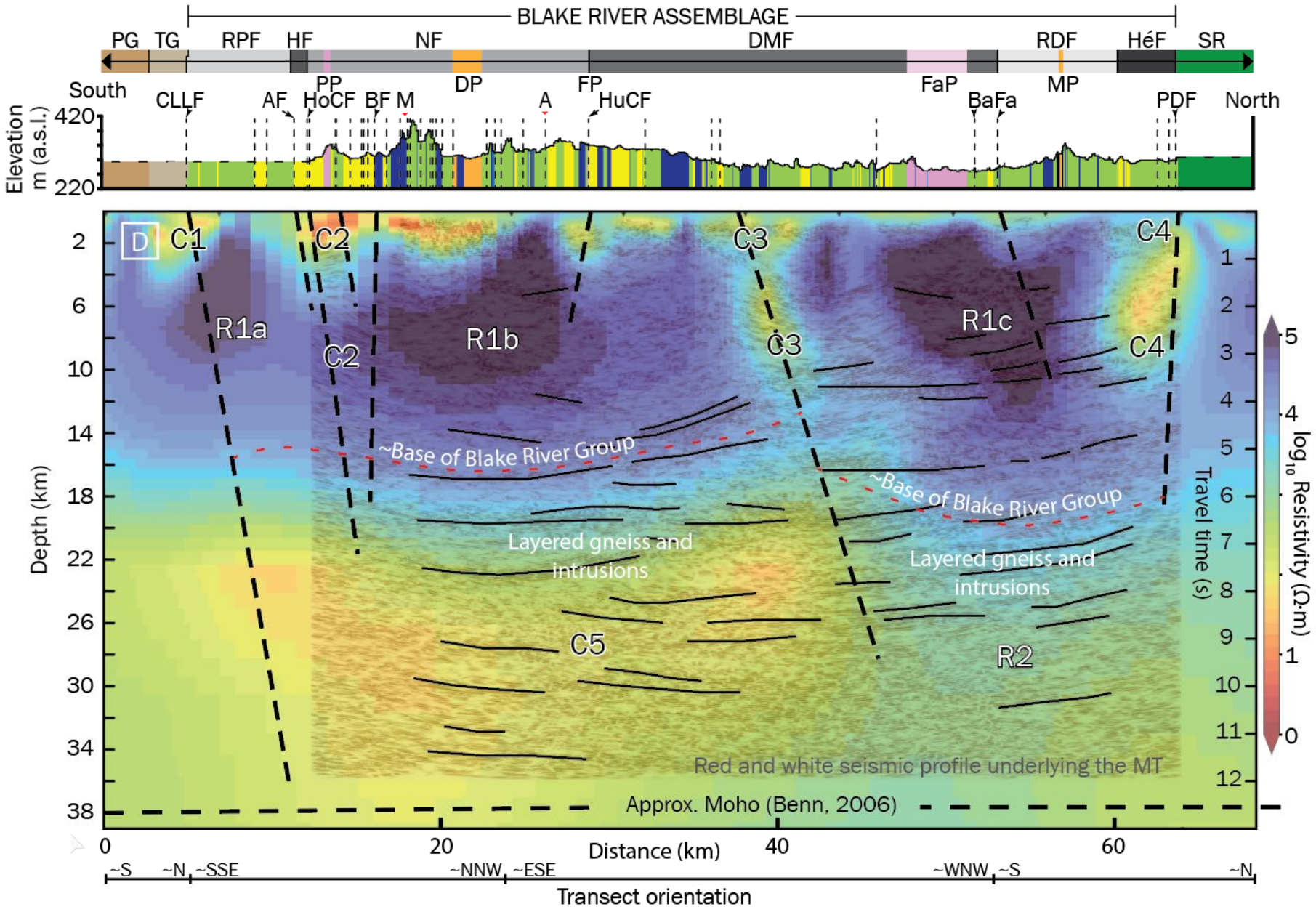


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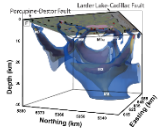

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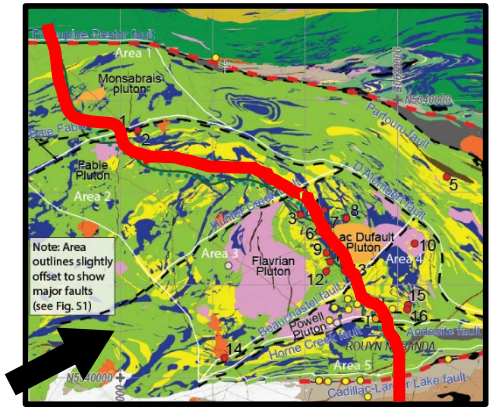
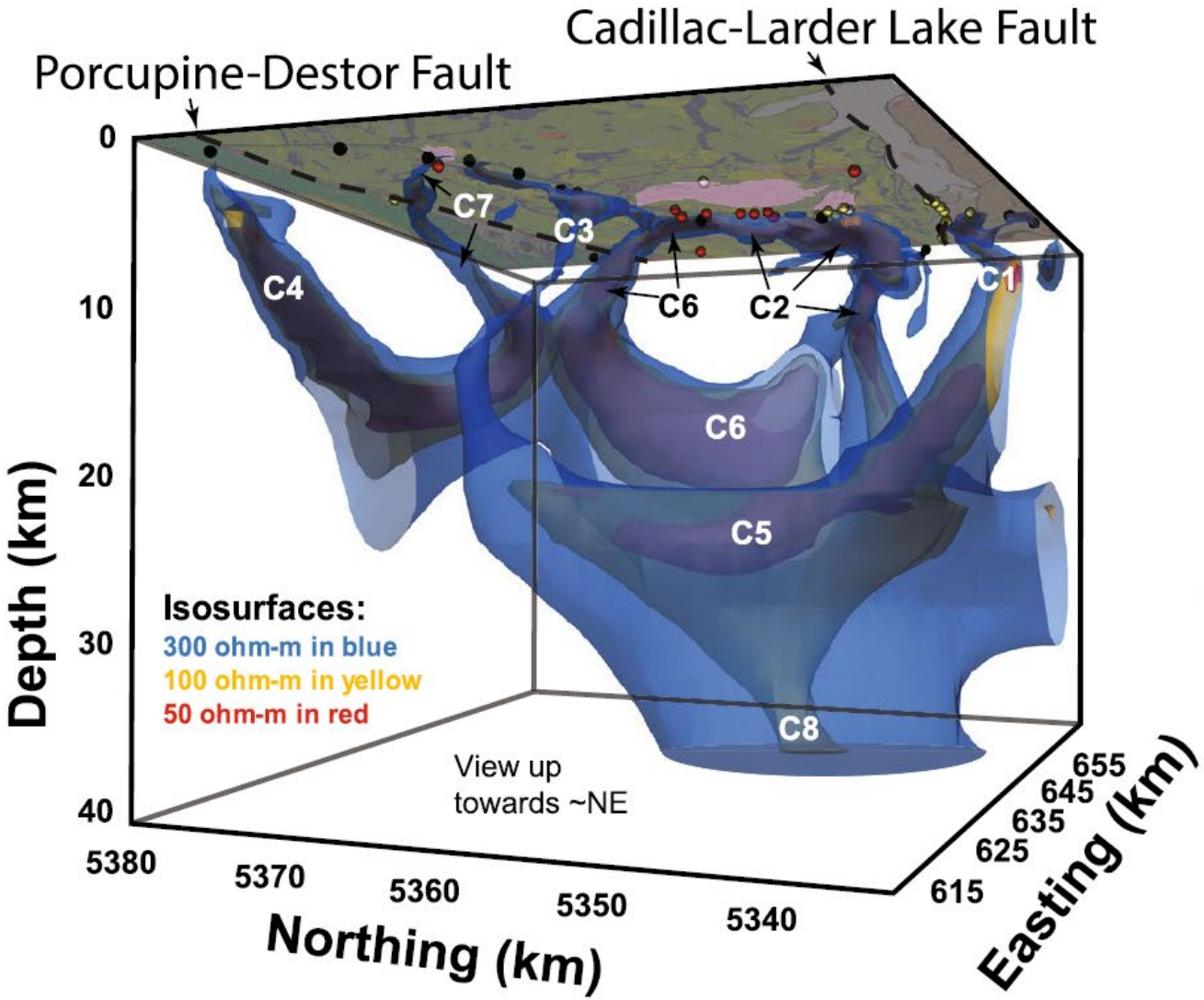
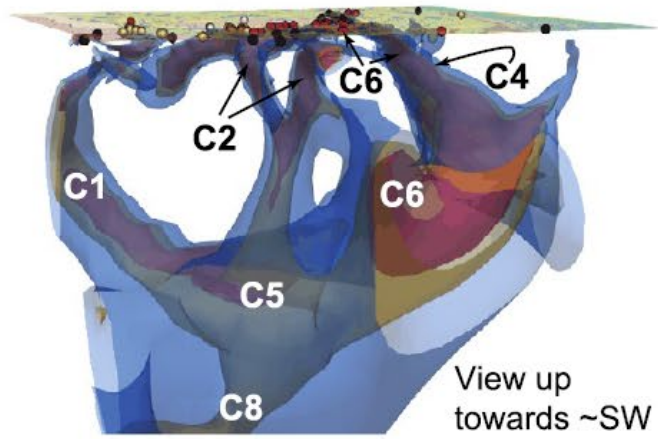
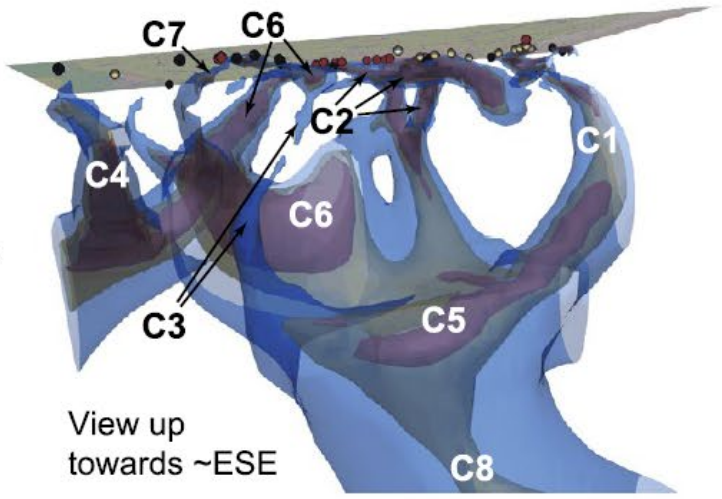


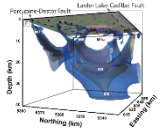




- 3-D MT model reveal pipe-like vertical features and the connectivity to a lower crustal low-resistivity volume
- Potentially connected to the lithospheric mantle??

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



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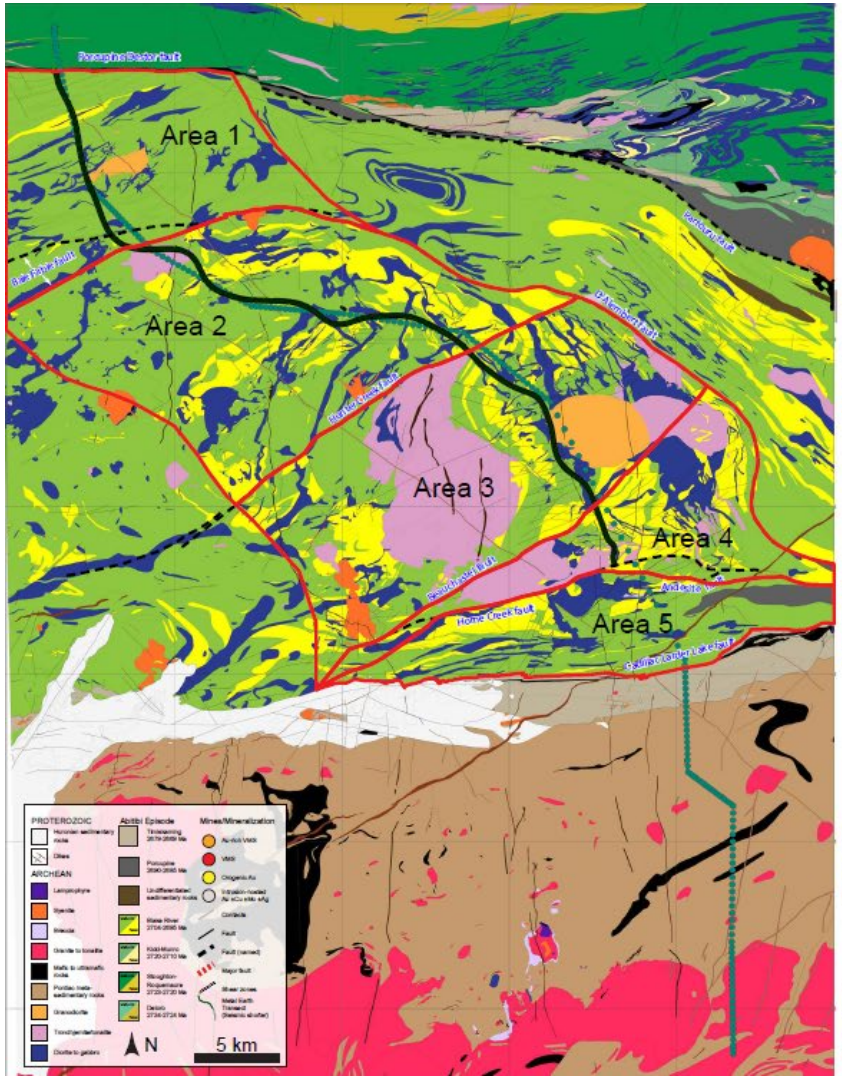


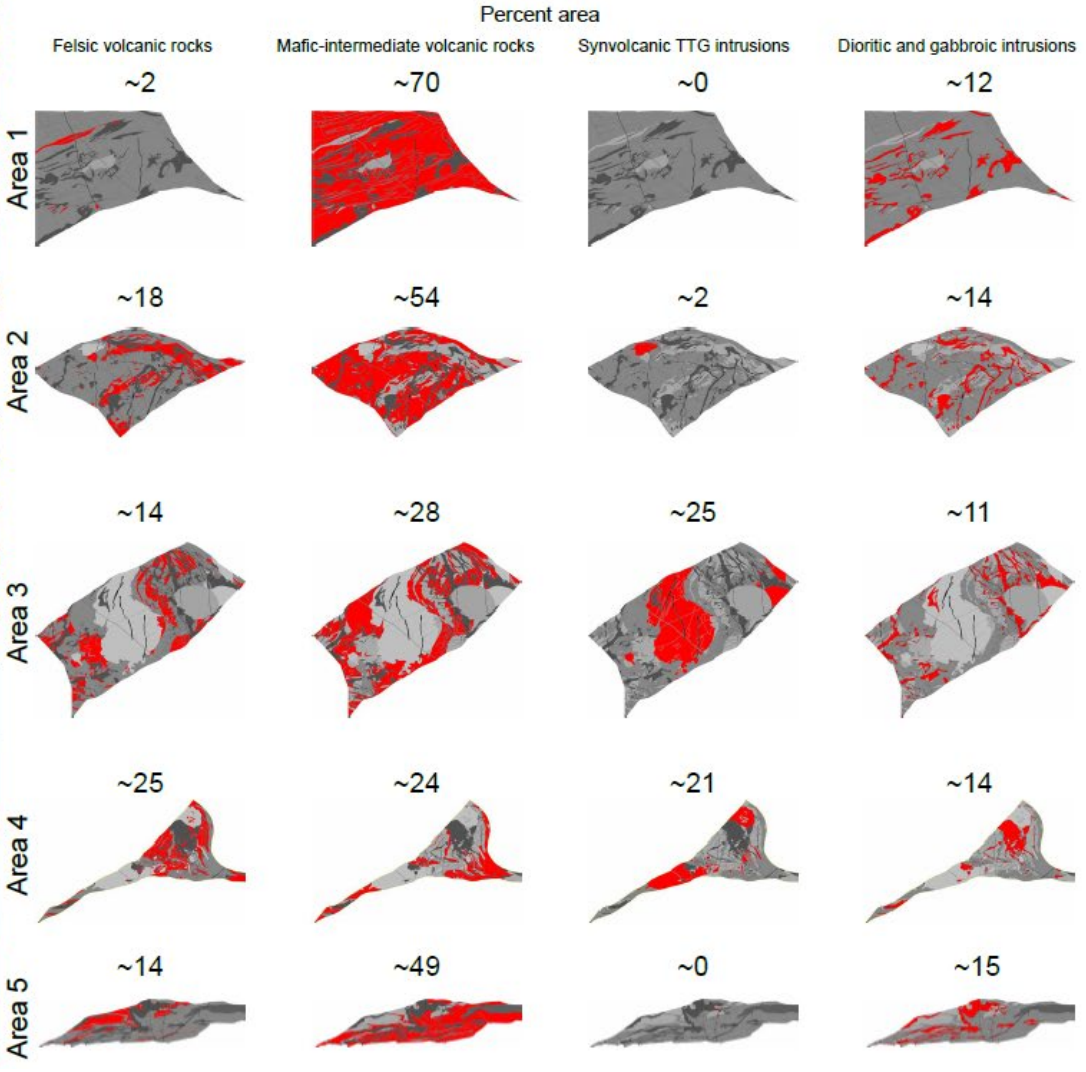


| Area | Ore (Mt) | Au (g/t) | Faults intersected by transect | Fault density (faults/km transect) | Felsic volcanic rocks | Mafic-intermediate volcanic rocks | TTG intrusions | Diorite and gabbro intrusions |
|---|---|---|---|---|---|---|---|---|
| 1 - Northern Hunter block | 4 | <2 | 3 | 0.25 | 2 | 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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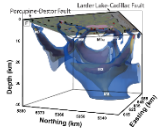

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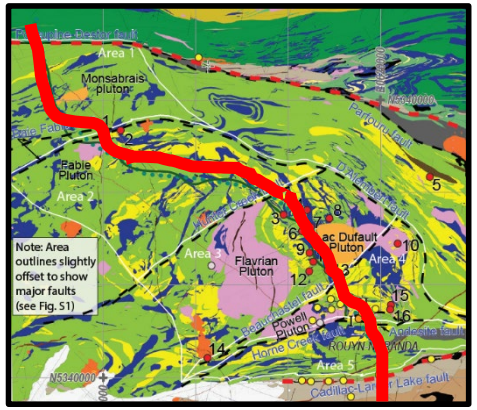
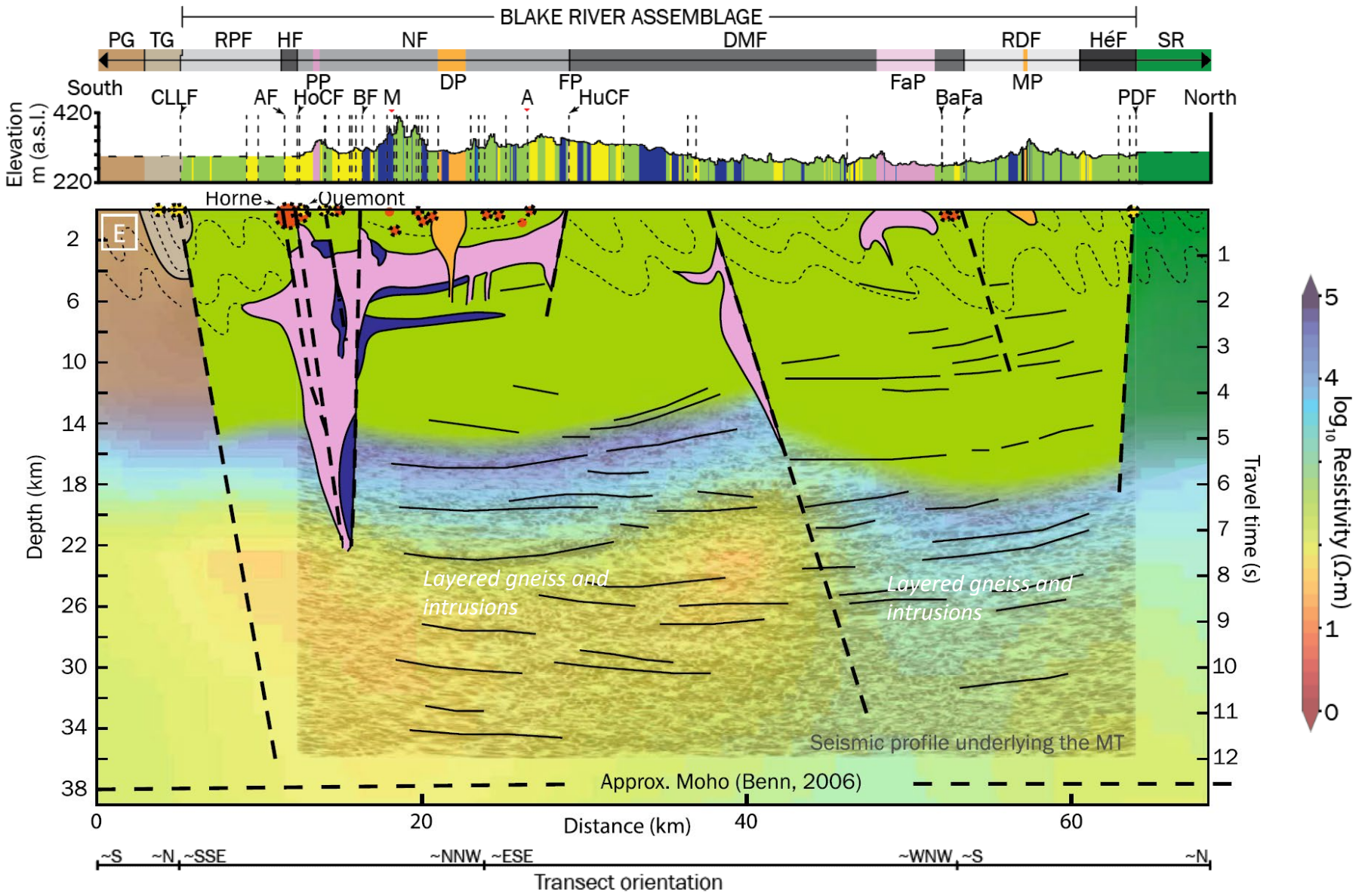
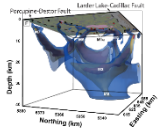



- Asymmetry in geology, crustal architecture, number of VMS deposits and the tenor of these deposits

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



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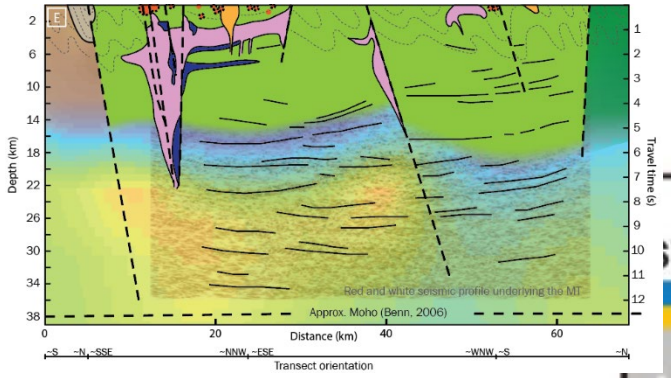
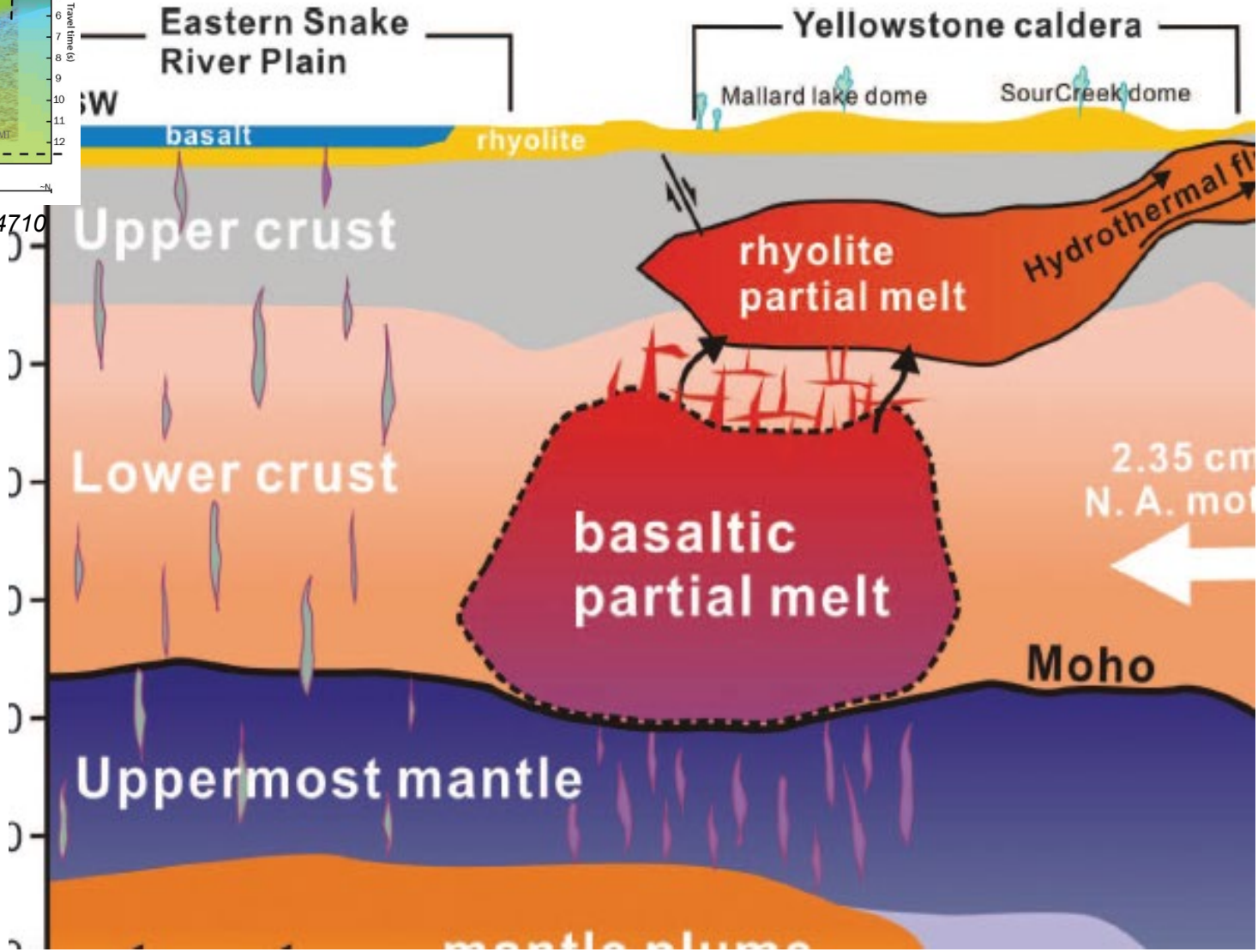



Jørgensen et al. (2022) – *Sci. Rep. 12:14710*

- 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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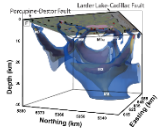

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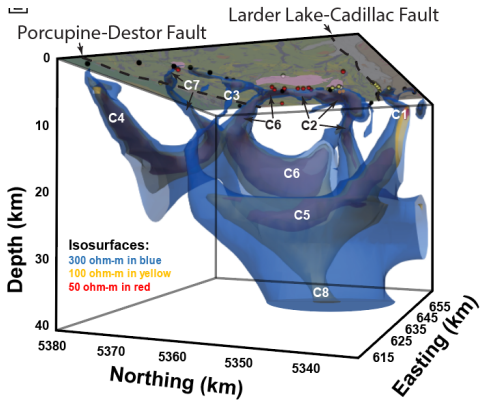
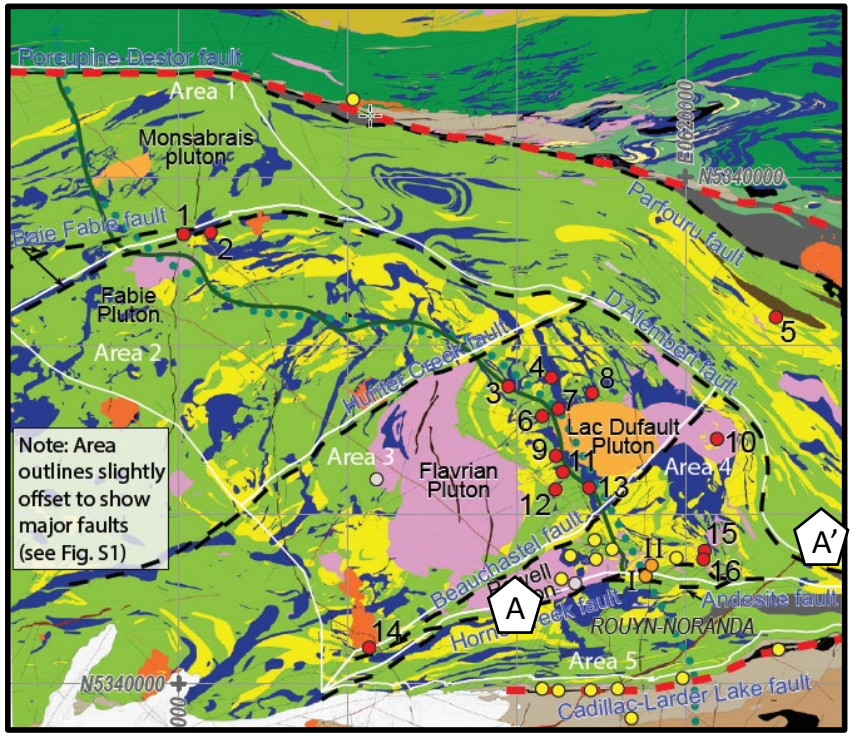
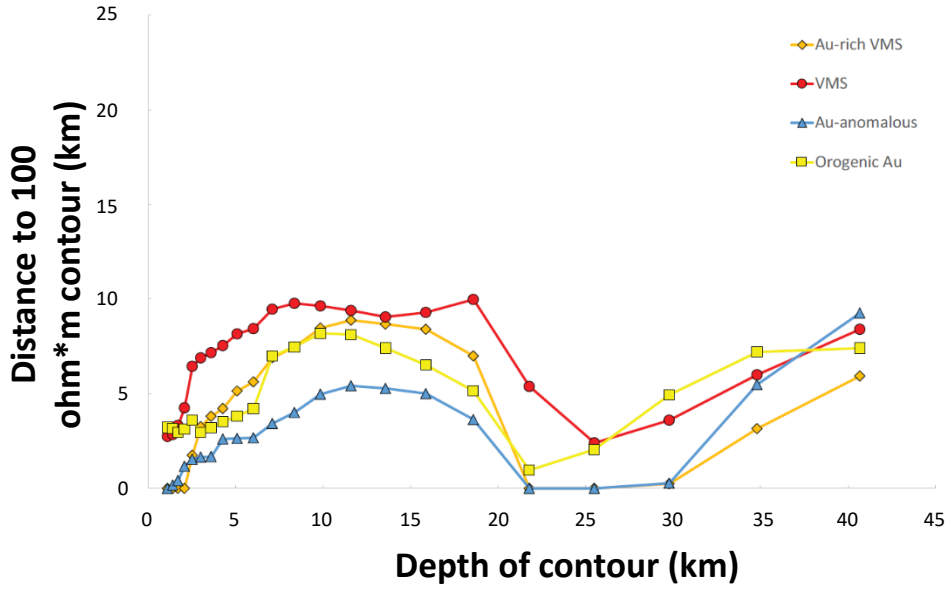
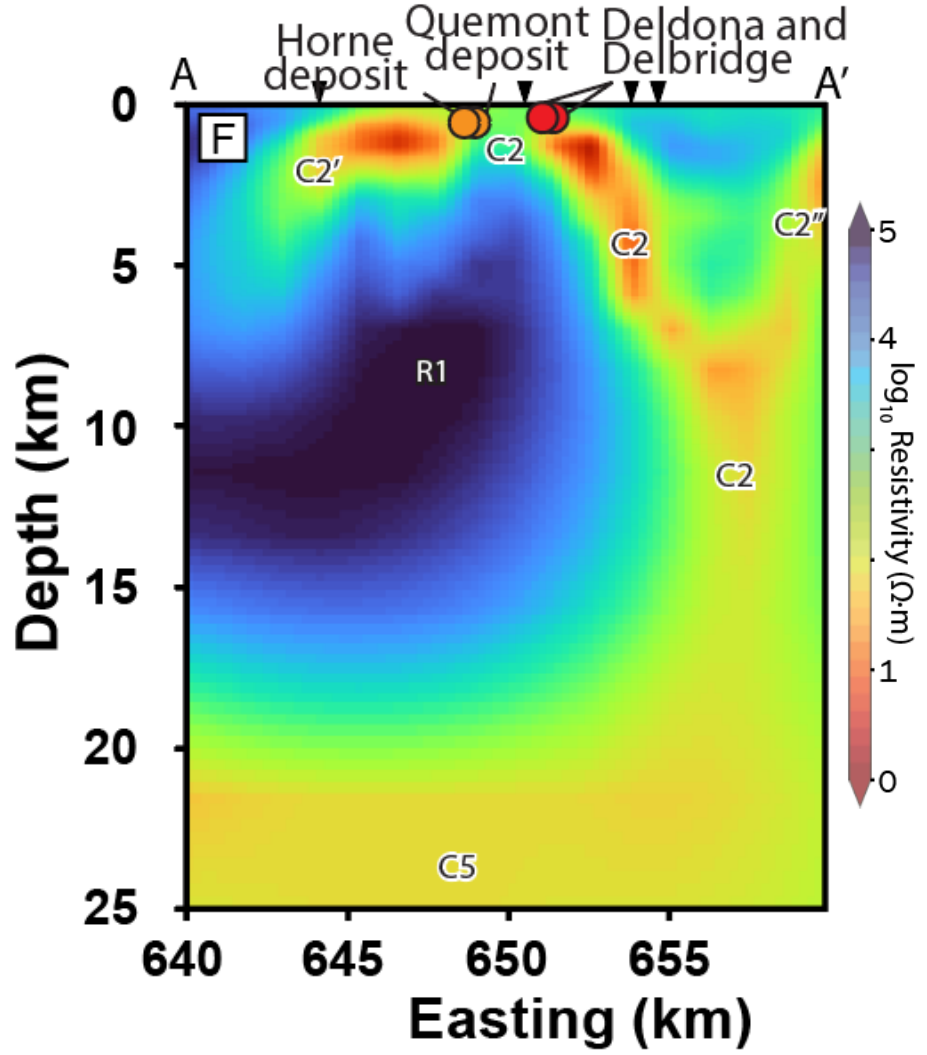


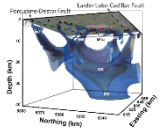




- Optimal location for a magmatic contribution of metals to the VMS system that may explain the localization of Au-rich deposits

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



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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
- 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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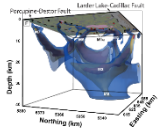

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- ***New AGB compilations***
- ***Surface area analysis***
- ***Assemblage growth***
- ***Significance of felsic rocks***
- ***Proportion of felsic volcanic rocks – assemblage scale***
- ***Proportion of felsic volcanic rocks – district scale***
- ***Differential VMS endowment – assemblage scale***
- ***Summary***


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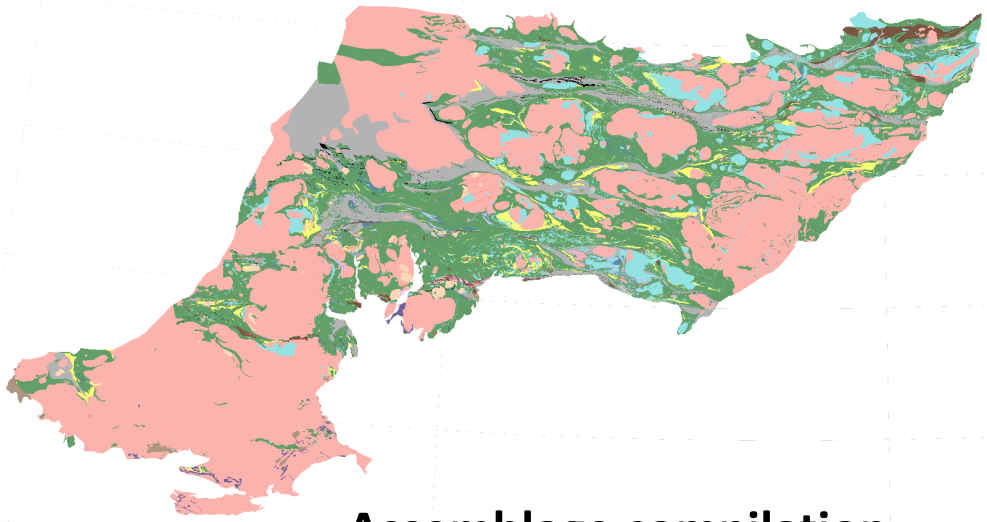
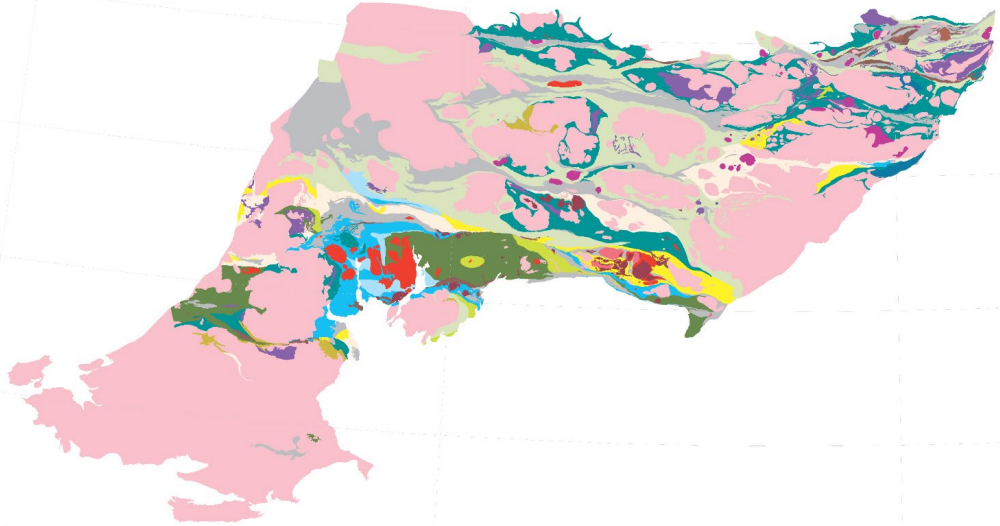
Metal Earth Abitibi Lithological Compil…

## Lithological compilation



## Assemblage compilation



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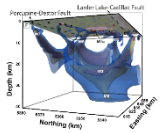

# Crustal Architecture and VMS Endowment: Insights from the Rouyn-Noranda Camp, Abitibi Greenstone Belt

CONGRÈS AEMQ QMEA CONVENTION XPLOR


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*Crustal architecture*

*Implications*

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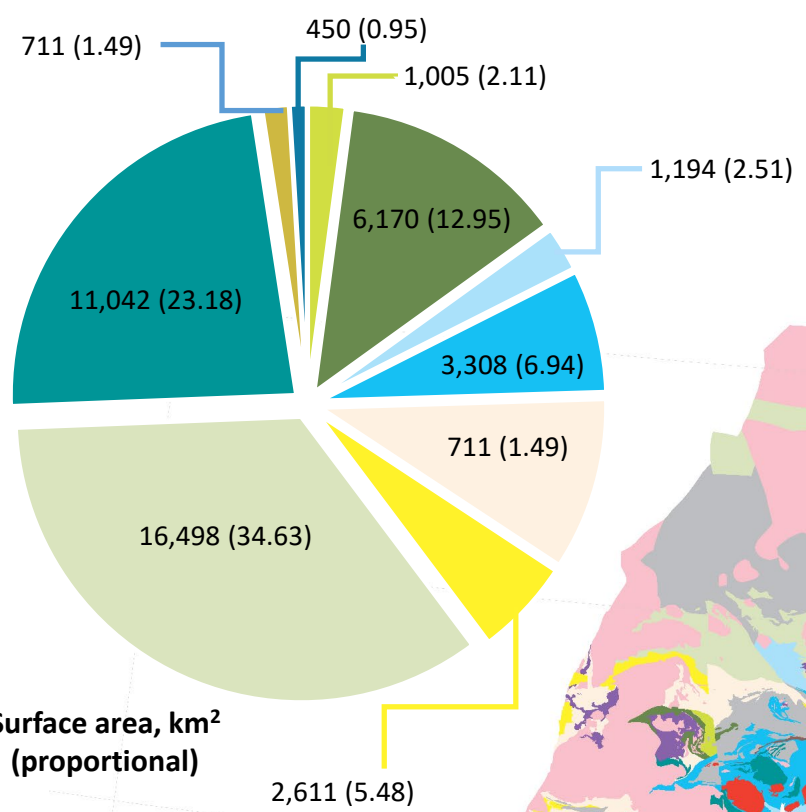





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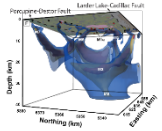

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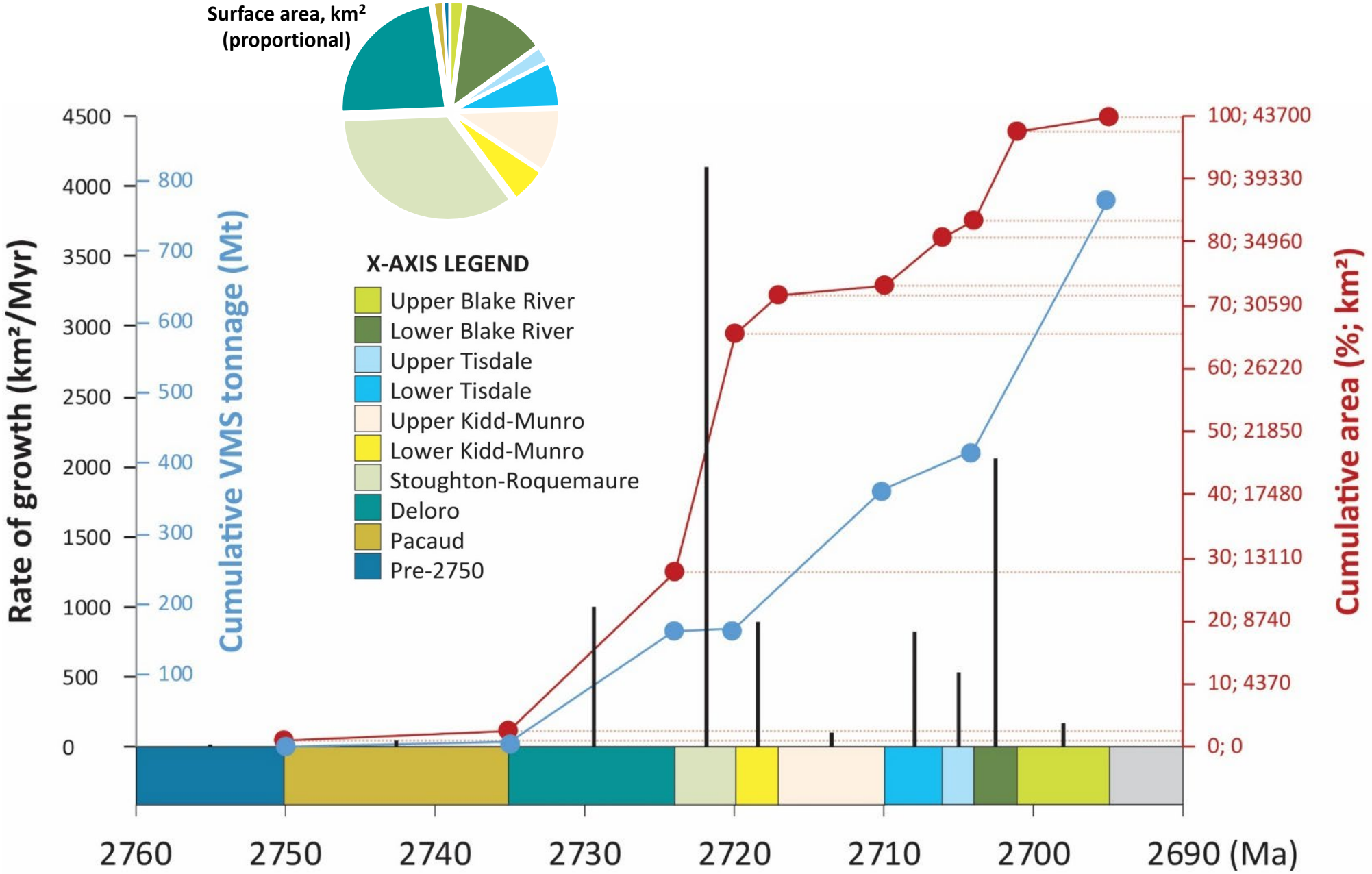
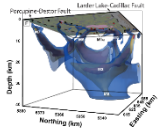



Jørgensen et al. (in prep.)



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- Franklin et al. (2005): *"High and mid crustal level subvolcanic **felsic intrusions and associated rhyolite** are interpreted to be a **product of crustal melting** within a **high heat flow**, extensional (**rift**) environment where the heat was obtained from mantle derived mafic magmas emplaced at high crustal levels (<12 km). As such they are **indicative of environments favorable for the development of long-lived convective hydrothermal systems and the formation of VMS deposits** (Barrie et al., 1999; Galley, 2003; Hart et al., 2004)."*

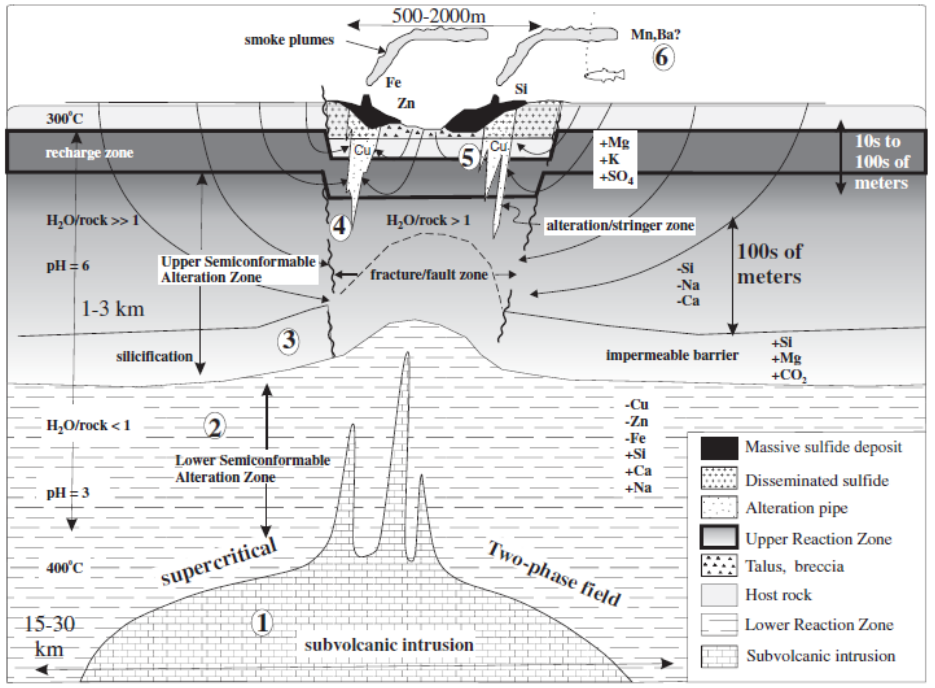
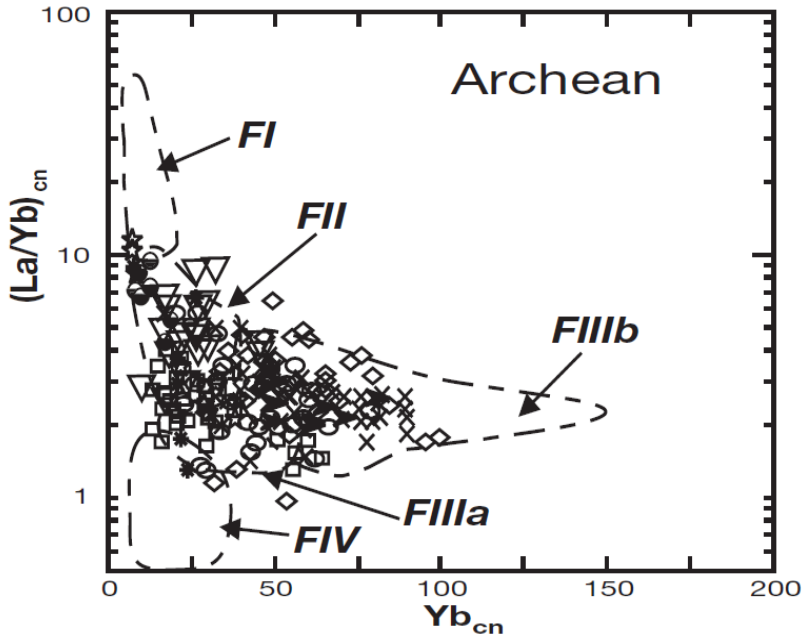


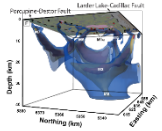

FIG. 11. General model for the formation of VMS deposits, illustrating the basic components of a high-temperature VMS hydrothermal system (after Galley, 1993; Franklin, 1995). Note variable horizontal and vertical scales. See text for numbers.

| F classification (Archean examples) | | |
|---|---|---|
| Different incompatible element behavior of LREEs and HREEs; strong partitioning of HREEs into garnet and amphibole | FI: alkaline to calc-alkaline affinity; low-degree partial melts; HREE poor due to garnet fractionation | Melting at deep crustal levels (mostly unmineralized, with important exceptions) |
| | FII: calc-alkaline affinity; high-degree partial melts; slightly HREE poor due to garnet fractionation | Melting at intermediate crustal levels (sometimes mineralized) |
| | FIIIa and FIIIb: tholeiitic affinity; low-pressure partial melts; HREE enrichment controlled by differences in crustal composition | Melting at shallow crustal levels (commonly mineralized) |
| | FIV: tholeiitic affinity; low-pressure, moderate-degree partial melts; HREE rich due to a lack of residual amphibole or garnet | Post-Archean intraoceanic island arc (sometimes mineralized) |

Fassbender et. al (2023) – *Econ. Geo. v. 118, no. 2, pp. 319–345*




Hart et al. (2004) – *Economic Geology, v. 99, p. 1003-1013*



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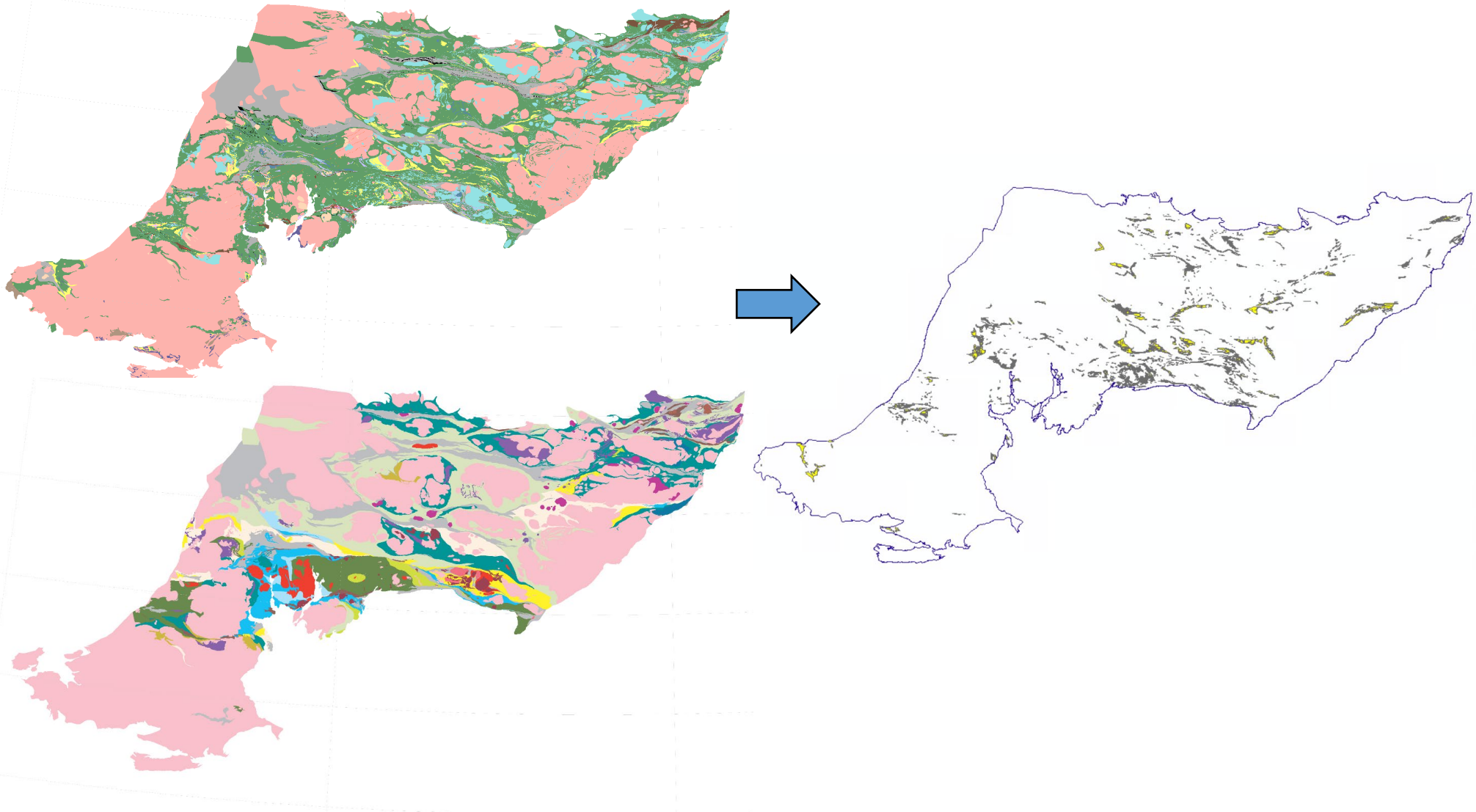
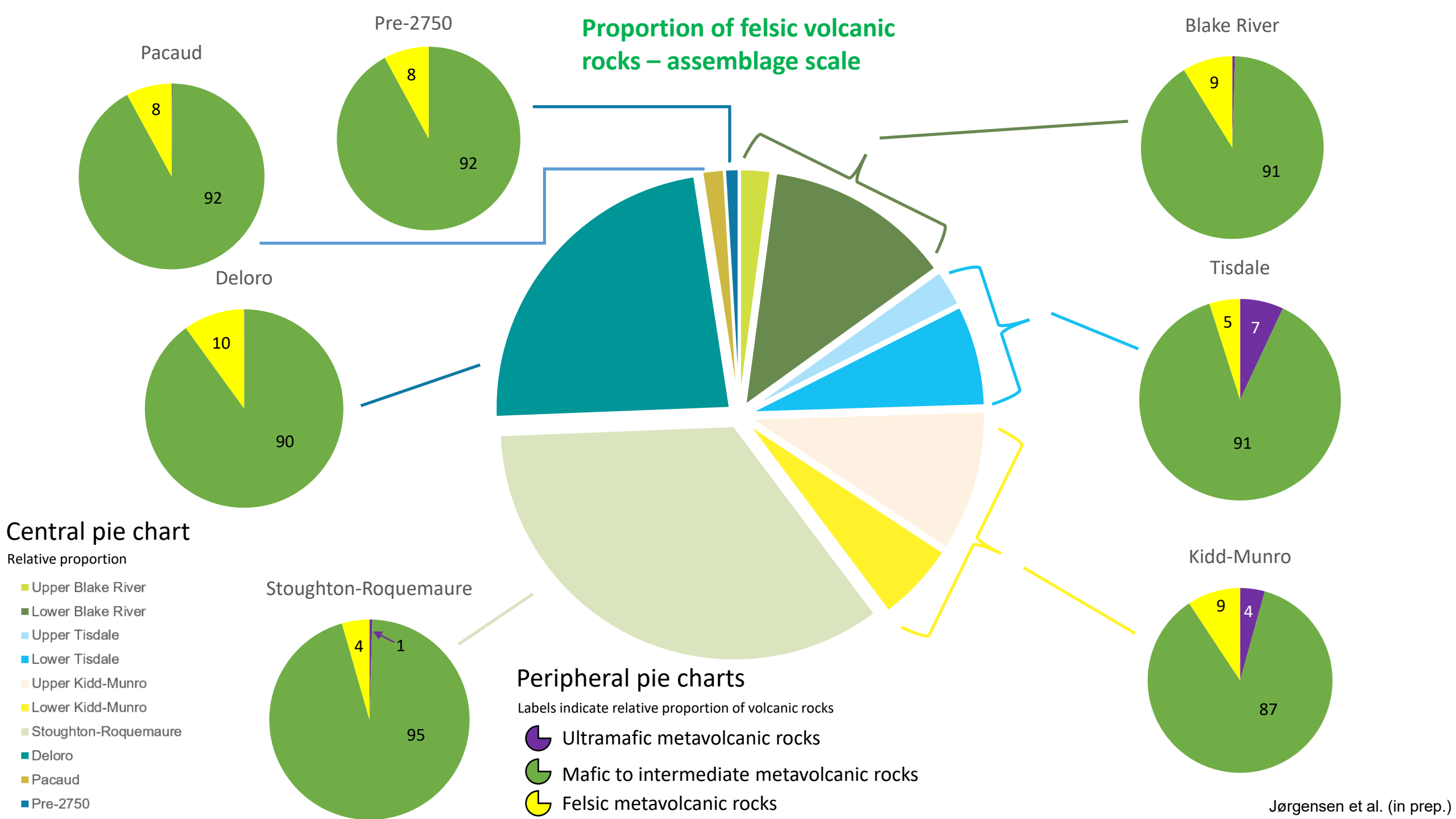


Jørgensen and Gibson (2024) – *MERC Geohub*

# Proportion of felsic volcanic rocks – assemblage scale

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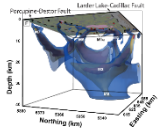

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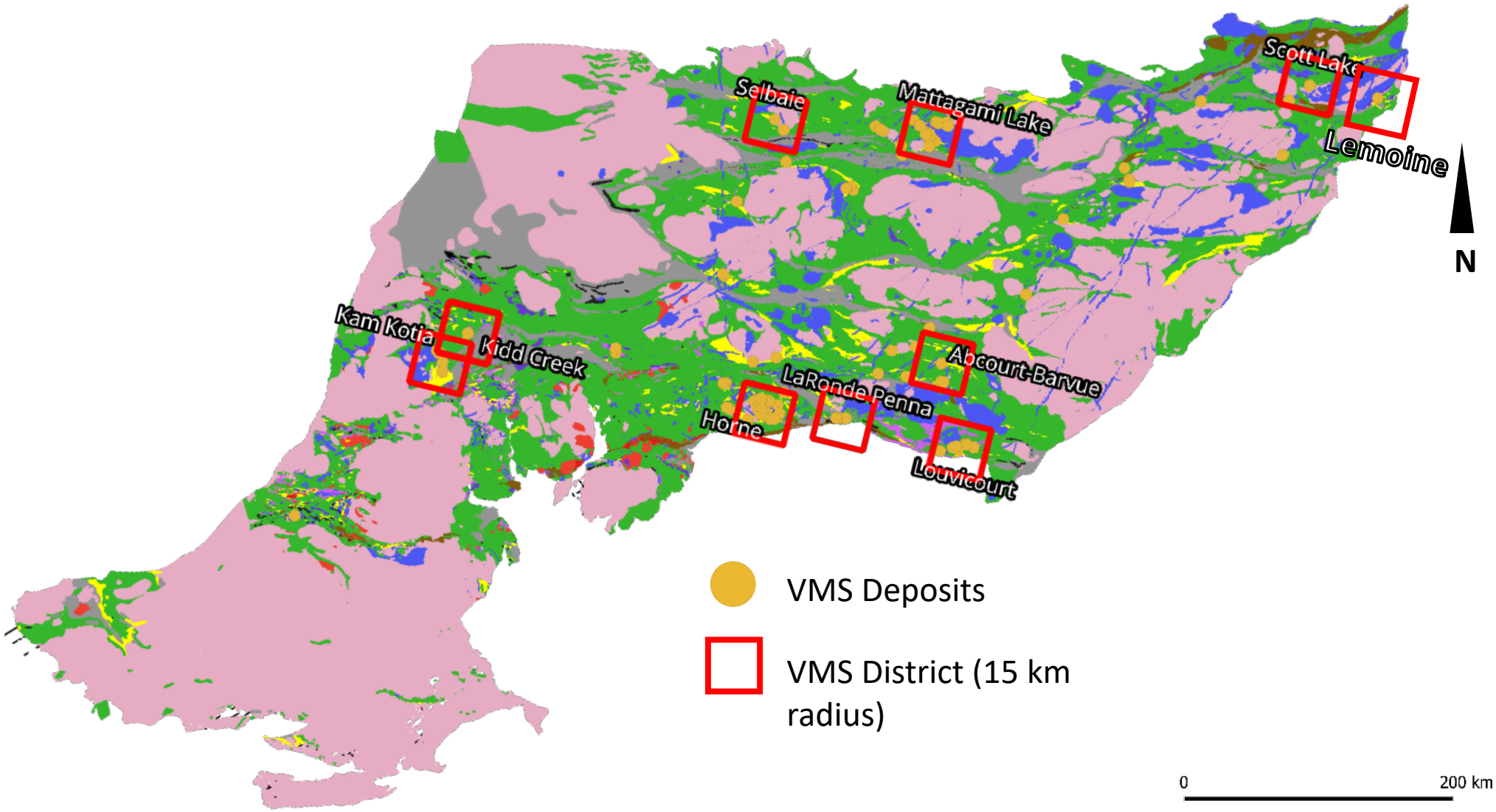
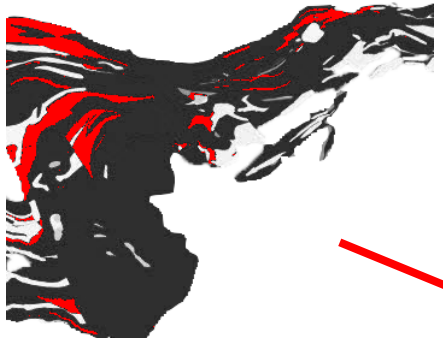


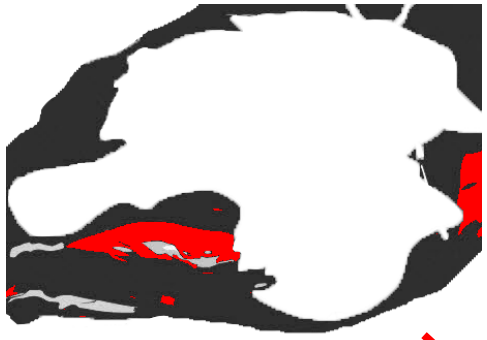

Jørgensen et al. (in prep.)

## Proportion of felsic volcanic rocks – district scale

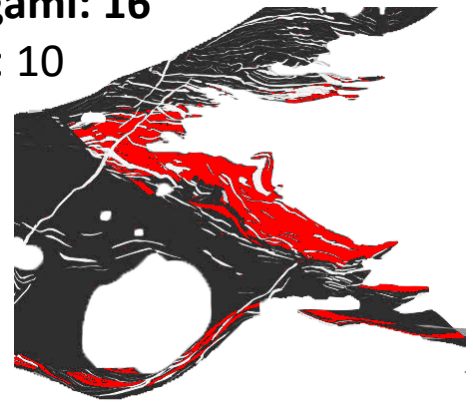
**Kidd Creek: 10**
U. Kidd Munro: 9



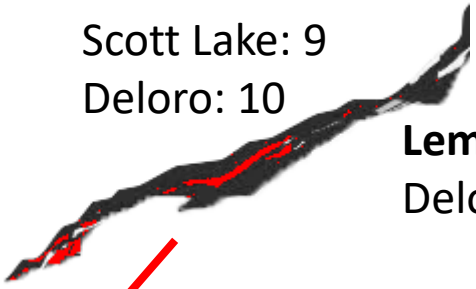
**Selbaie: 11**
Deloro: 10



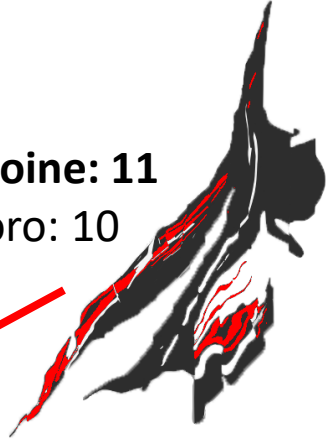
**Mattagami: 16**
Deloro: 10

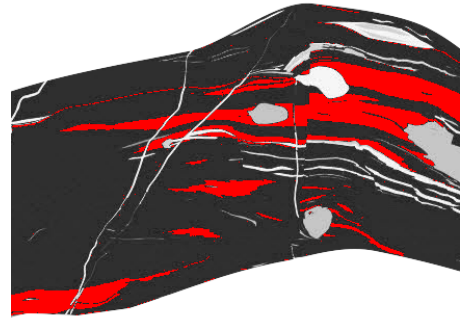


Scott Lake: 9
Deloro: 10



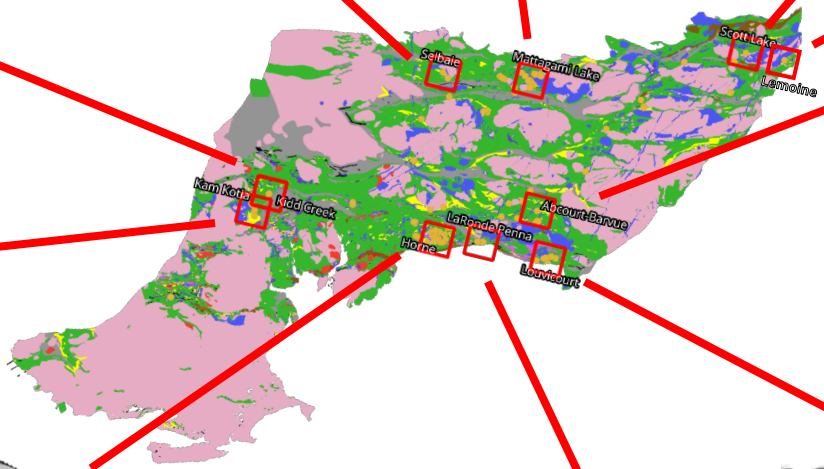
**Lemoine: 11**
Deloro: 10

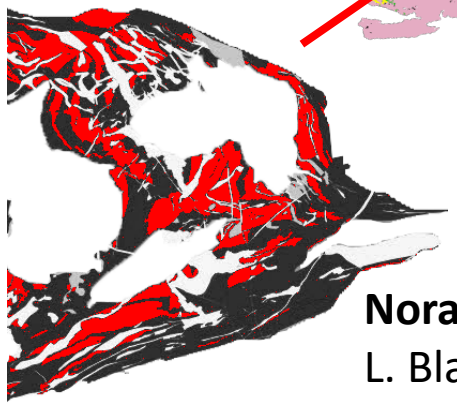




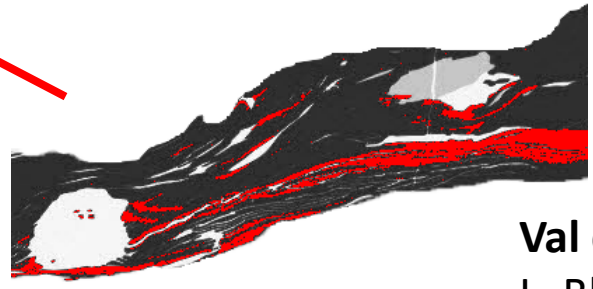
**Abcourt-Barvue: 14**
Deloro: 10

**Kam Kotia: 33**
L. Blake River: 9



**Noranda: 24**
L. Blake River: 9

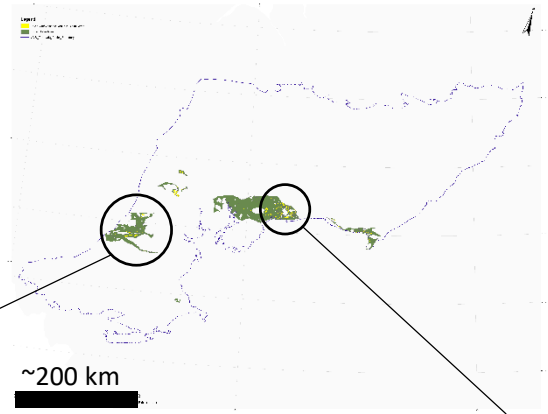


**Val d'Or: 14**
L. Blake River: 9

**DBL: 16**
U. Blake River: 9

Jørgensen et al. (in prep.)

## Blake River assemblage and Abitibi subprovince outline




## Differential VMS endowment – assemblage scale

**Swayze Area:**
**~1 VMS**

**Noranda Area:**
**~20 VMS**

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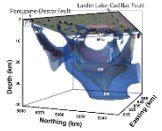



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- Abitibi lithological and assemblage compilations are available for download https://metalearth.geohub.laurentian.ca/
- Quantitative analysis highlights the importance of felsic magmatic centers in the Abitibi subprovince
- Age is perhaps less important than previously thought

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Taus R. C. Jørgensen, Harold L. Gibson, Eric A. Roots, Rajesh Vayavur, Graham J. Hill, David B. Snyder & Mostafa Naghizadeh

*Scientific Reports* **12**, Article number: 14710 (2022) | Cite this article

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