SEG 100 Conference
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Post-conference workshop WS07: Greenstone Belt Architecture and Metal Endowment of the Superior Craton

# Tectonic evolution of the western Wabigoon terrane in the Sturgeon Lake region:

## Implications for understanding structural controls on the greenstone belt and its VMS deposits

Presented by Chong Ma

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Contributors
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# Outline

PART I

Crustal architecture of the western Wabigoon terrane in the Sturgeon Lake region

PART II

New stratigraphic, geochronologic, and isotopic data from the Sturgeon Lake greenstone belt

PART III

Tectonic evolution of the western Wabigoon terrane in the Sturgeon Lake region and structural control on VMS deposits

# PART I

# Crustal architecture of the western Wabigoon terrane in the Sturgeon Lake region

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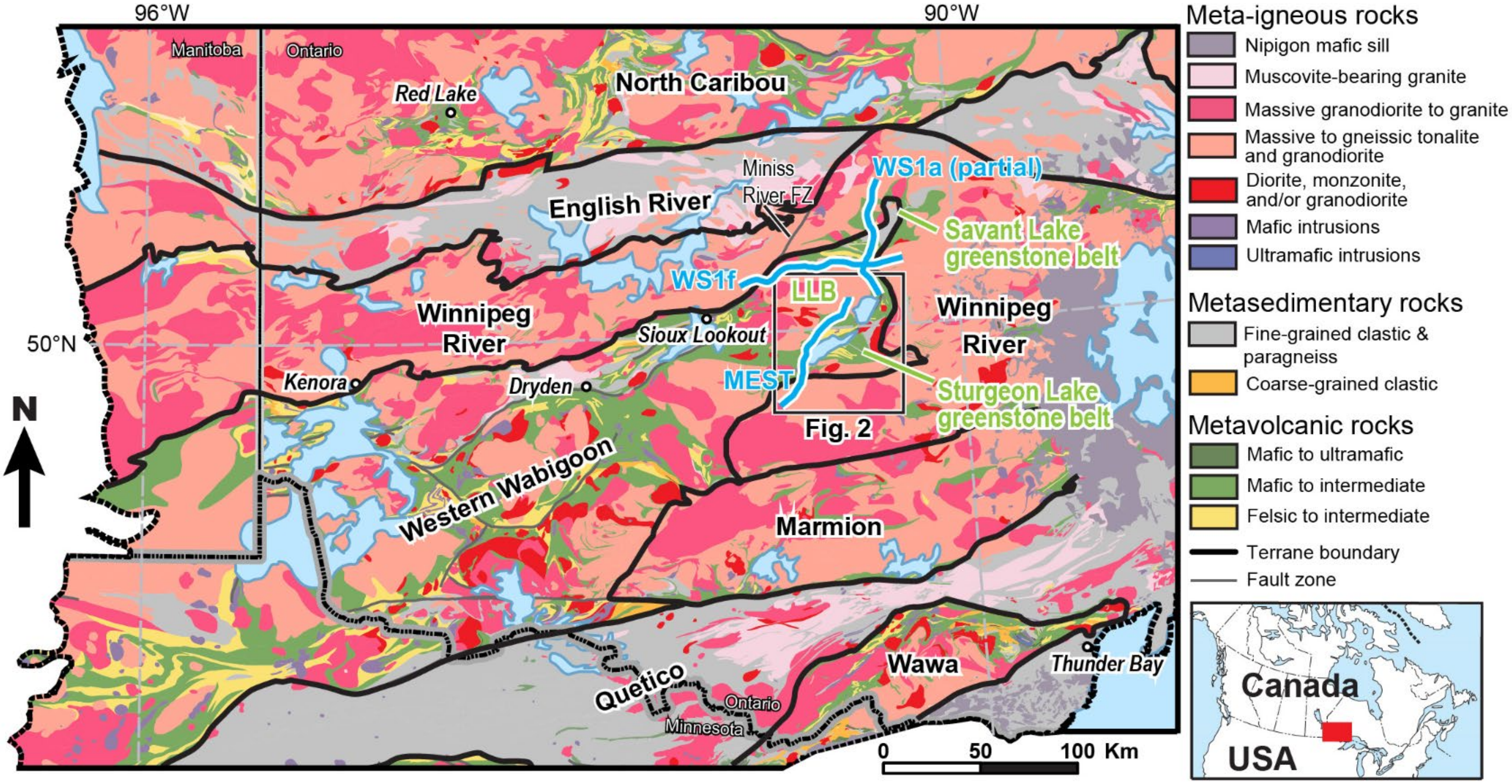
# Geologic background

MEST = Metal Earth Sturgeon transect
WS1a & WS1f = Lithoprobe transects




Modified from Montsion et al., 2018

# Geologic background

## Western Wabigoon terrane (WWT)

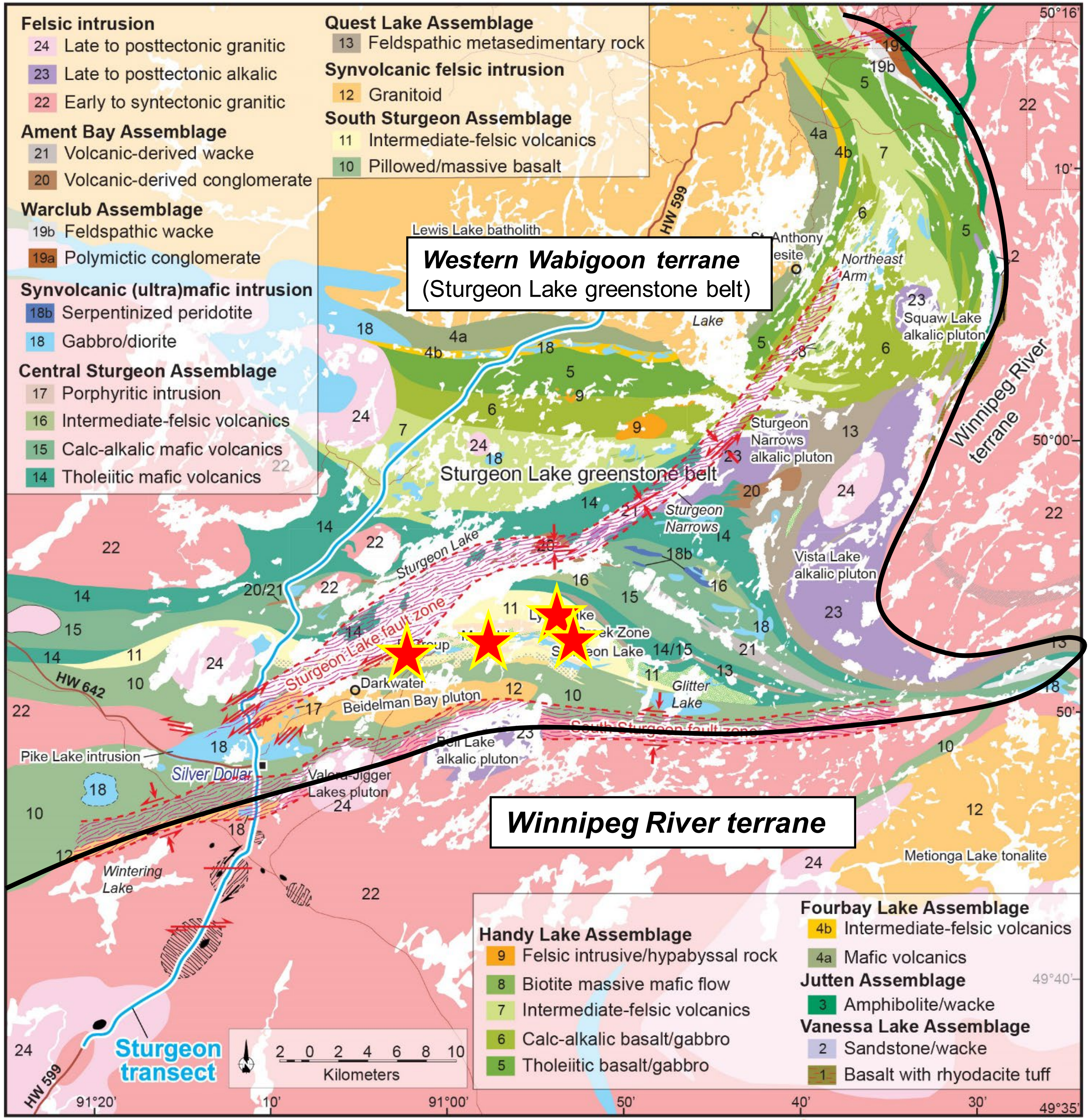
- 4 volcanic assemblages (~2775-2720 Ma)
- Syn-volcanic & post-tectonic intrusions
- VMS deposits (**Zn-Cu**-Pb-Au-Ag)
- Folded at the map scale (syncline)
- Two major fault zones

## Winnipeg River terrane (WRT)

- Basement rocks intruded by syn- to post-tectonic granitoids with a variety of textures and compositions.

## Major deformation between WWT and WRT:

~2700–2695 Ma (Sanborn-Barrie and Skulski, 2006)




Map modified after Sanborn-Barrie and Skulski (2005) and Stone et al. (2002)

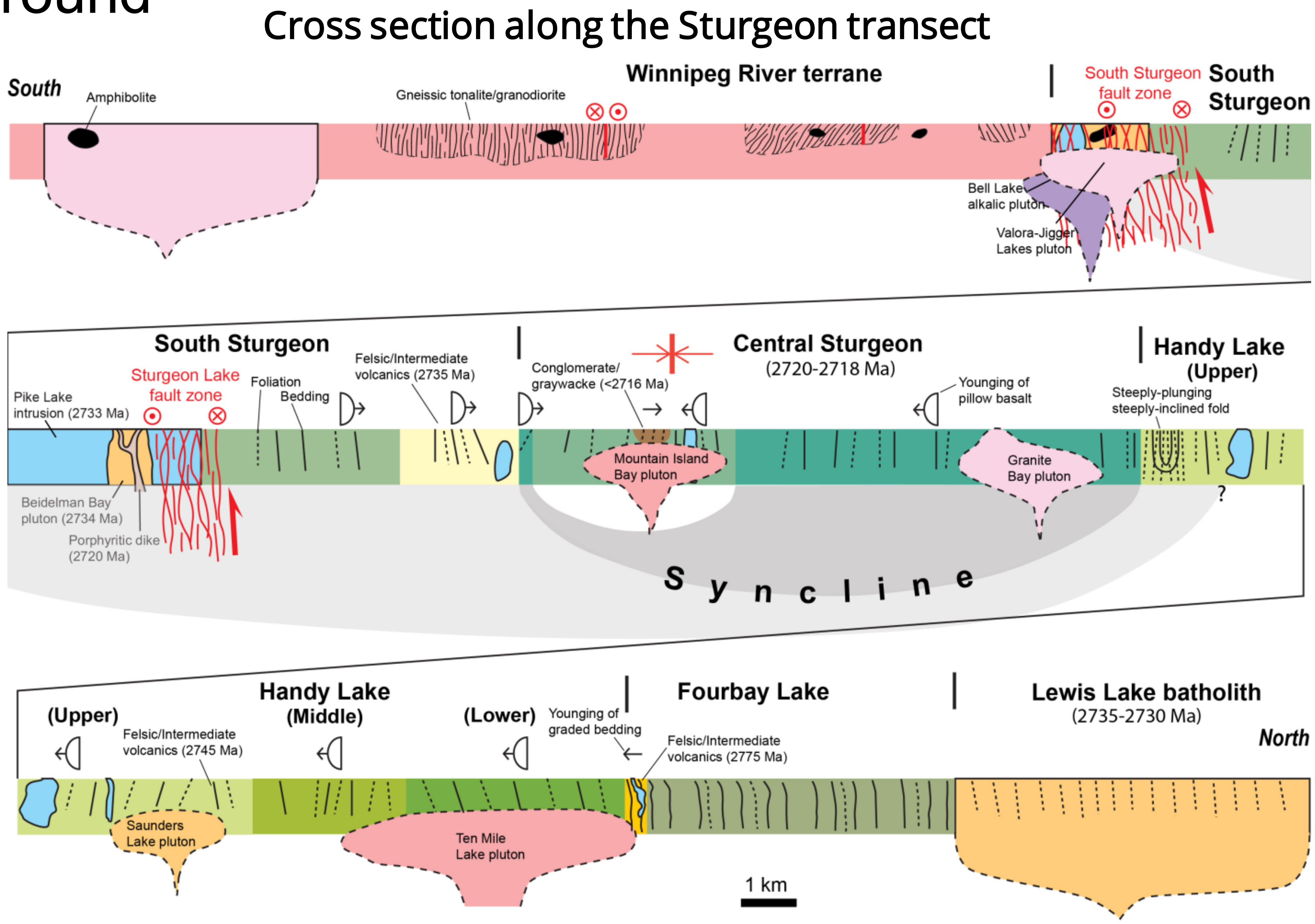
# Geologic background

## Winnipeg River terrane

Rafts of basement rocks in syn-tectonic granitoid

## Western Wabigoon terrane

Map-scale syncline with core in Central Sturgeon & E-W axial plane



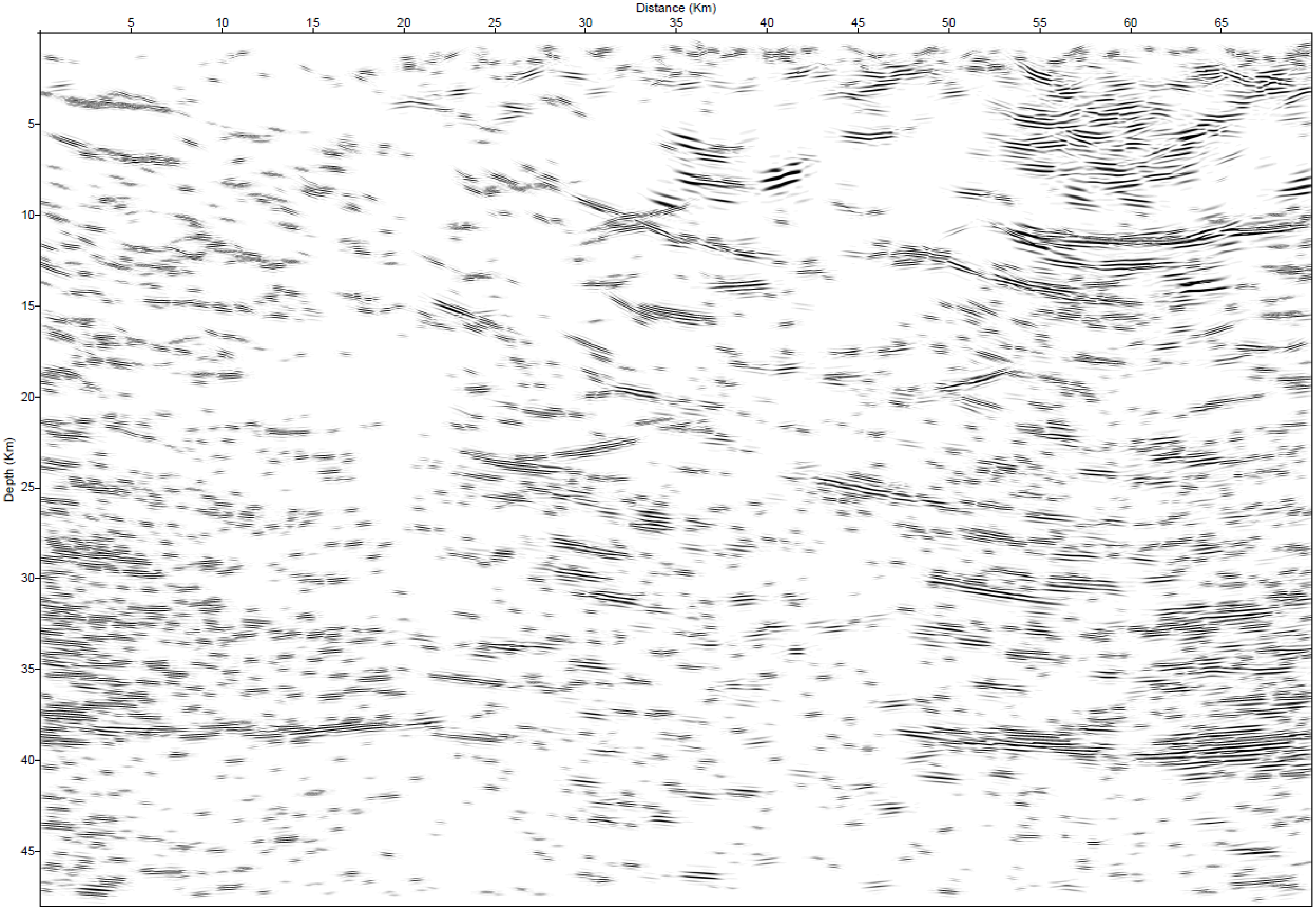
# Reflection seismic survey

**Pre-stack migrated seismic reflection of Sturgeon transect**

70 km long & 48 km deep

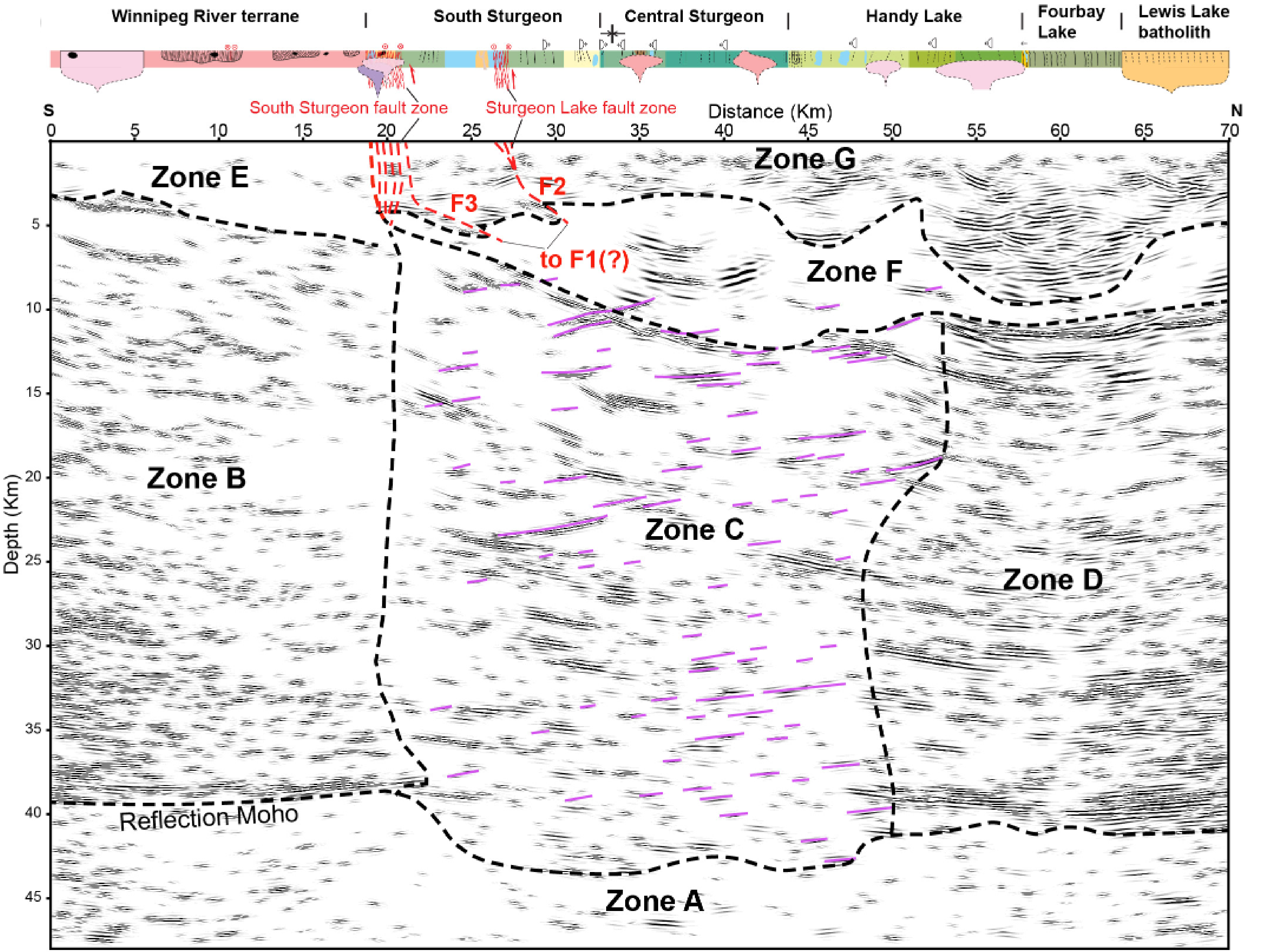
Source spacing: 50 m

Receiver spacing: 25 m



# Reflection seismic survey

- 7 zones of distinctive reflectivity
- 2 fault zones



# Reflection seismic survey

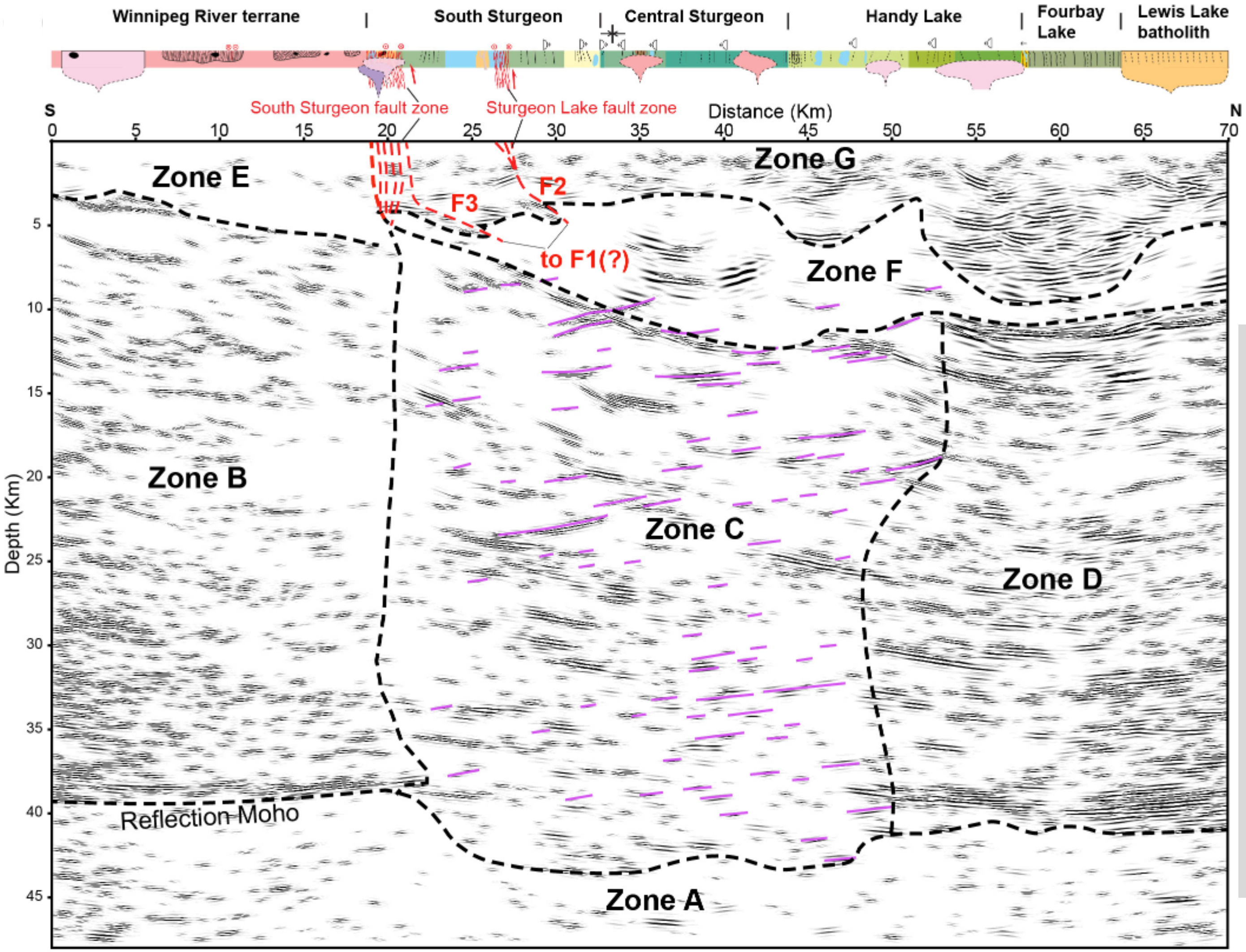
**Zones B, C, D, E, F:**

**Prominent reflections -** gneissic fabrics and/or mafic layers

**Poorly reflective zones -** granitoid layers and bodies

**= Winnipeg River terrane** (gneisses and granitoids intruded by younger granitoids)

**The south-dipping reflectors in Zone C:** mafic-ultramafic dikes imaged by out-of-plane seismic ray (exclusively above the apparent crustal root)



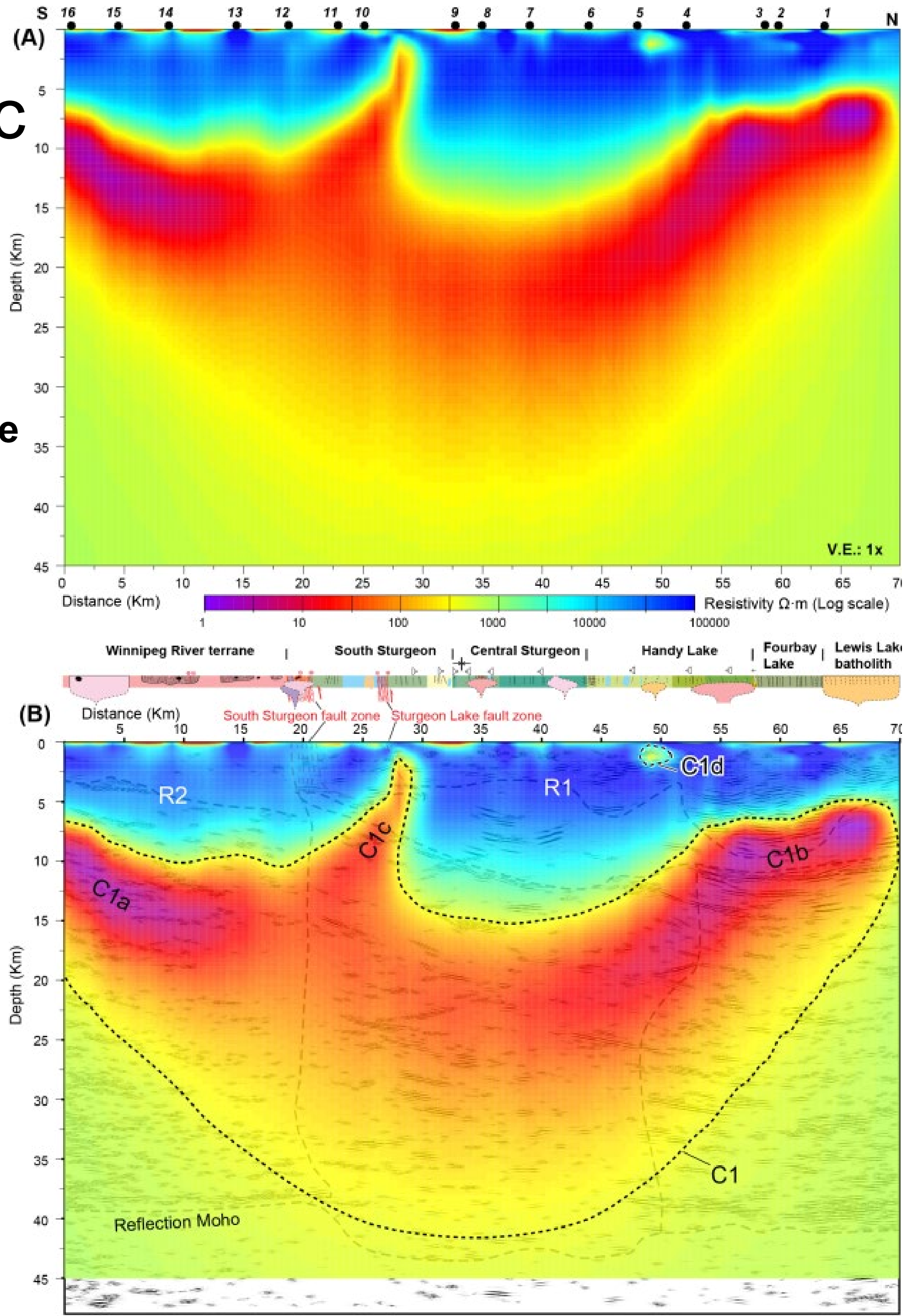

**An apparent crustal root -** the middle part of Moho with deeper depths; possibly caused by partial melting of mantle rocks that would result in interlayered felsic and mafic rocks, similar in reflectivity to that of the lower crust

**Zone G:**
Minimum thickness of Sturgeon Lake greenstone belt

**Greenstone basal boundary:**
- Beneath Zone G & above the Zone F reflectors
- **A thrust fault zone**

# Magnetotelluric survey

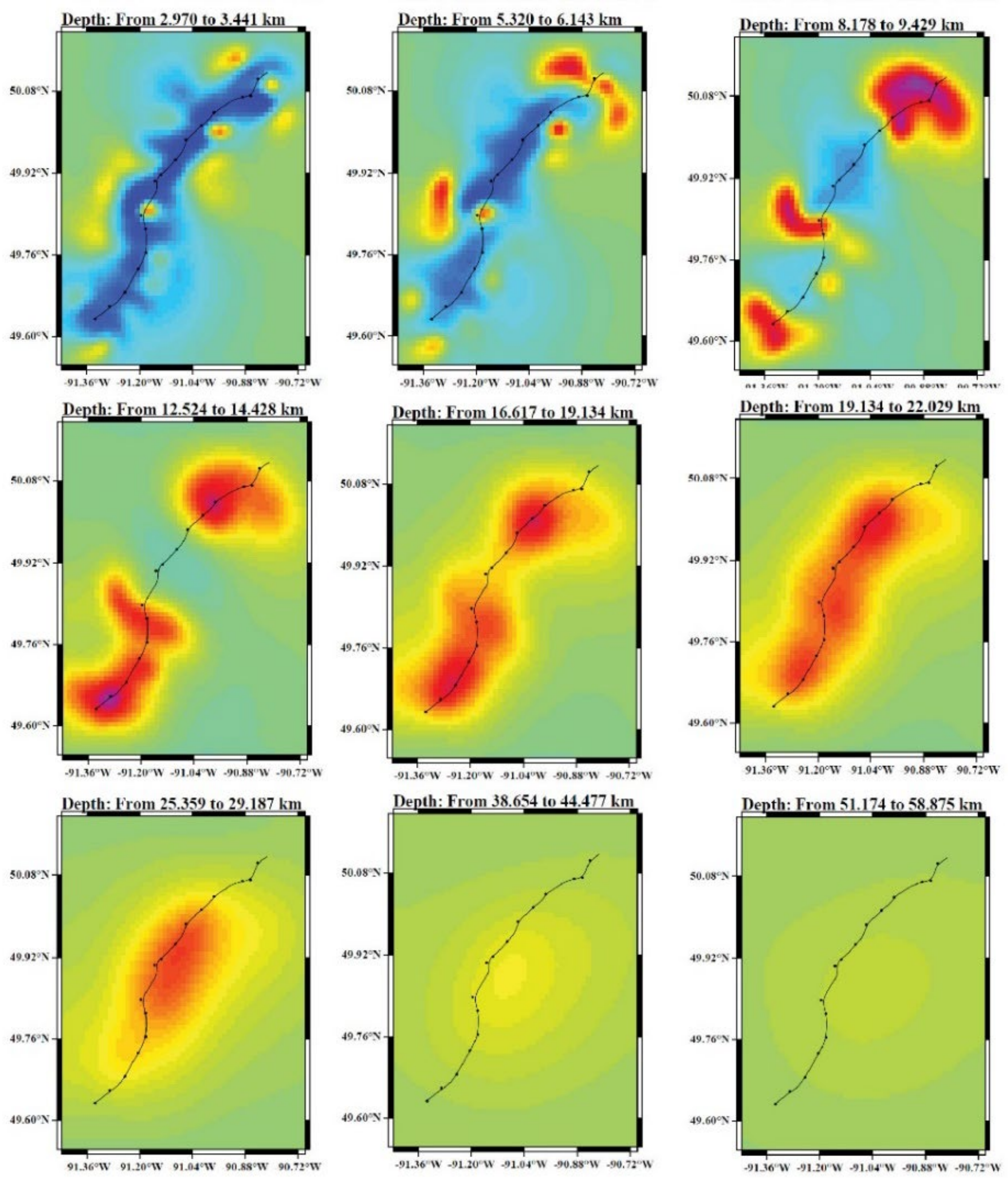
**Cross-section of 3D inversion model along the seismic line**




Warm colors: conductive zone

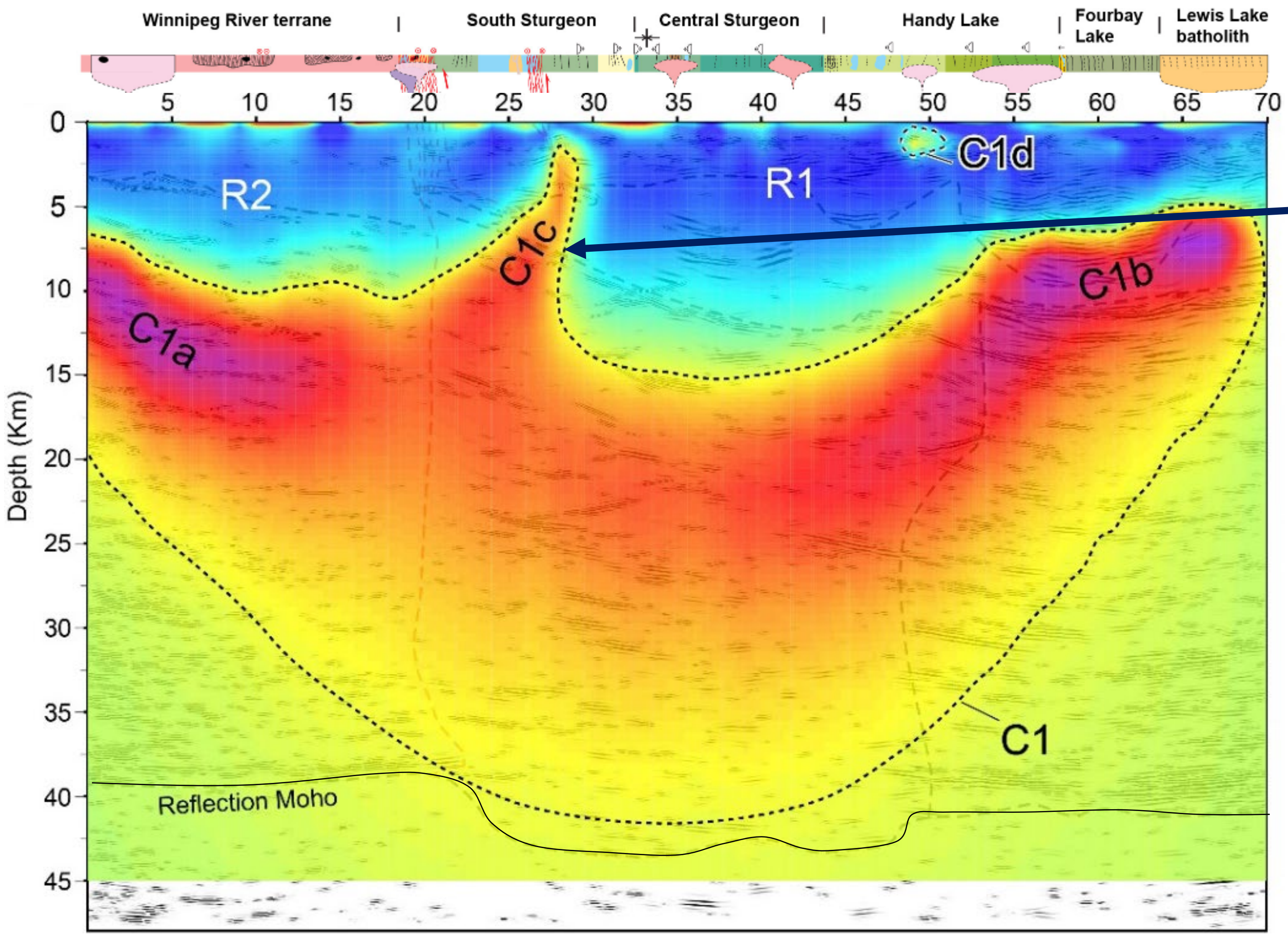
Cold colors: resistive zone

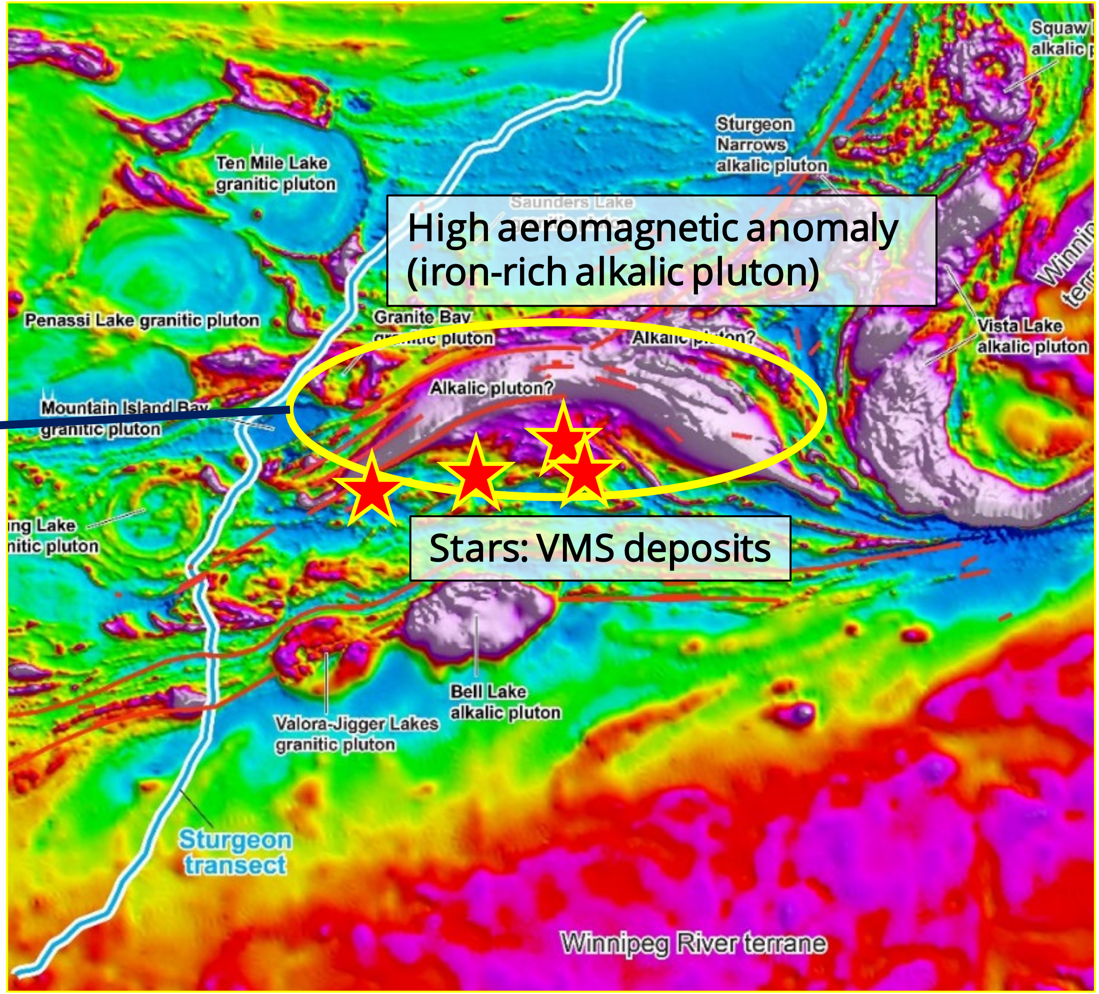
**Horizontal slices of resistivity structures from surface to mantle**



# Magnetotelluric survey

**Trans-crustal conductor**
(from Moho through the entire crust)



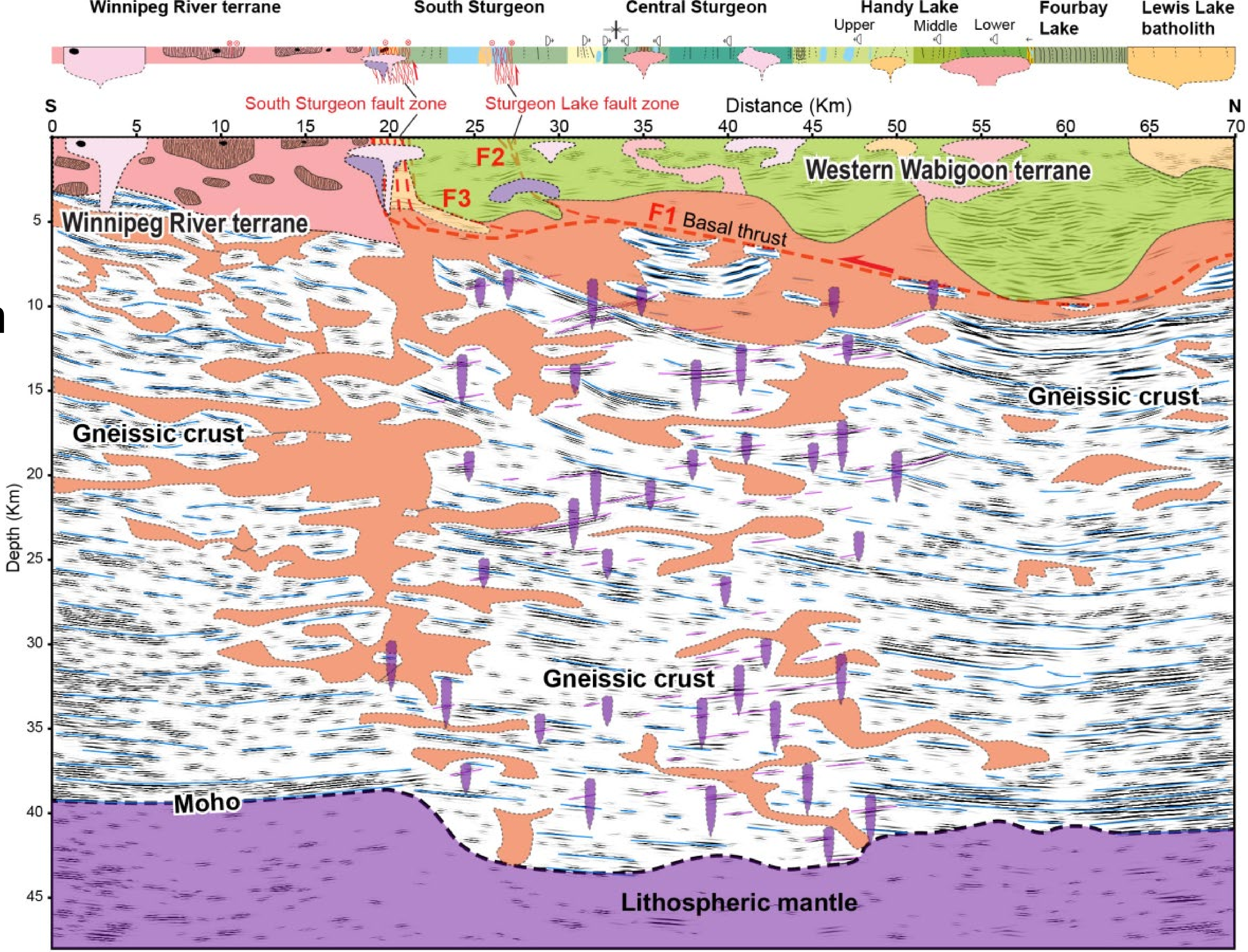

(Data source: Ontario Geological Survey Geophysical Data Set 1037)

**Upper-crustal conductive fingers:**
Interconnected sulfides and/or high iron content in Fe/Mg-bearing silicates

**Mid- to lower-crustal conductor:**
- Interconnected grain-boundary graphite films
- Diffusion of hydrogen in nominally anhydrous silicates due to extensive crustal partial melting involved mantle components

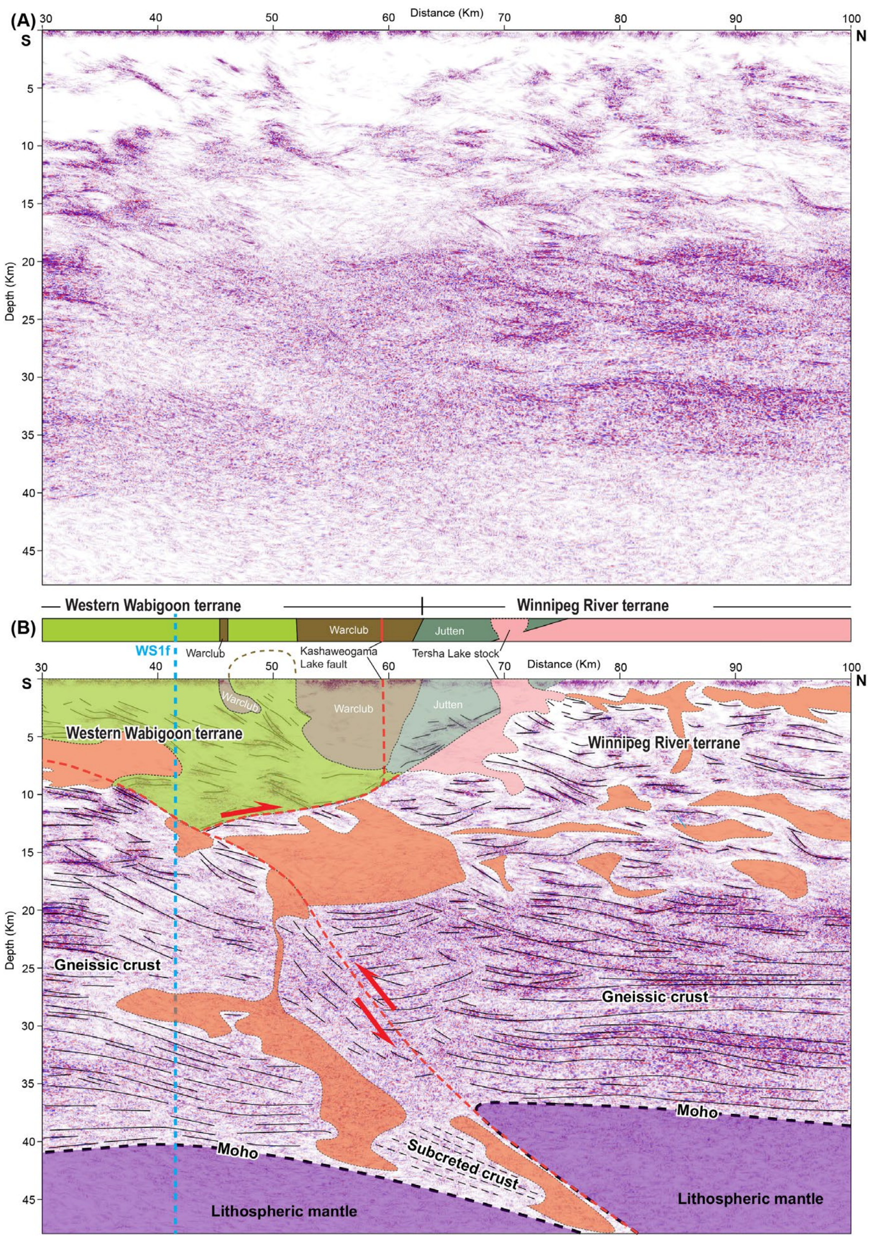
# Interpretation:

## Crustal structure beneath Sturgeon transect

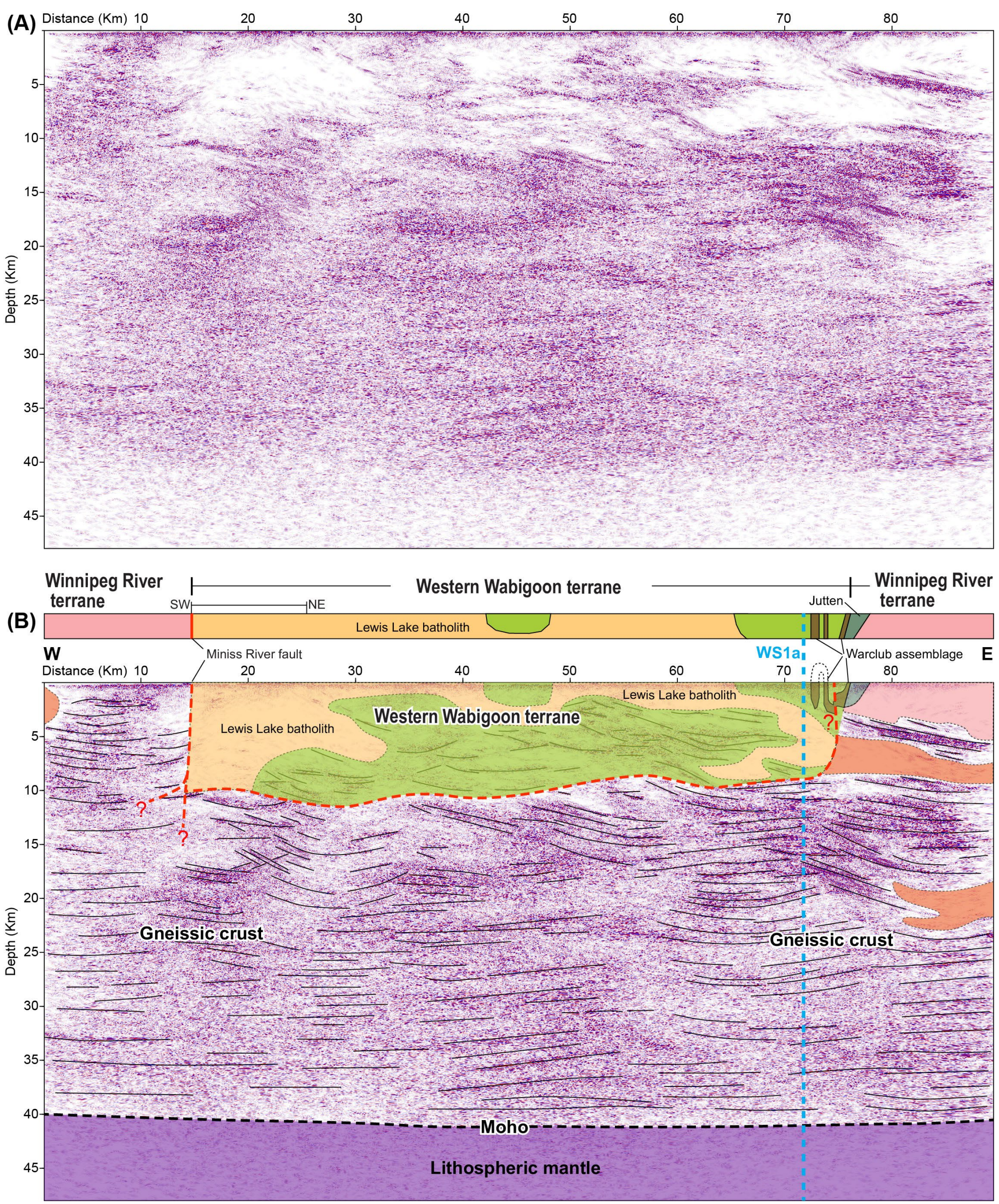


# Lithoprobe seismic transects


Lithoprobe WS1a line (N-S, partial)

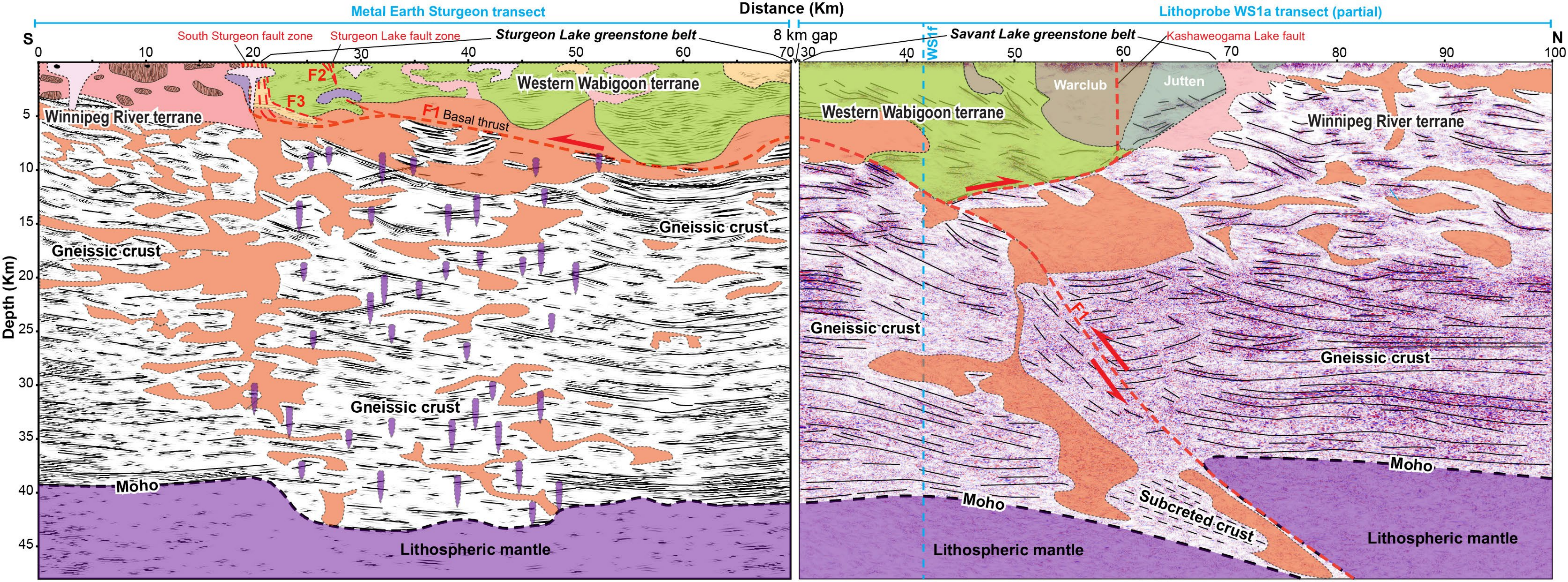



Lithoprobe WS1f line (E-W)




Ma et al. (2021)

# Composite crustal section (South-North) (Sturgeon transect + partial WS1a)

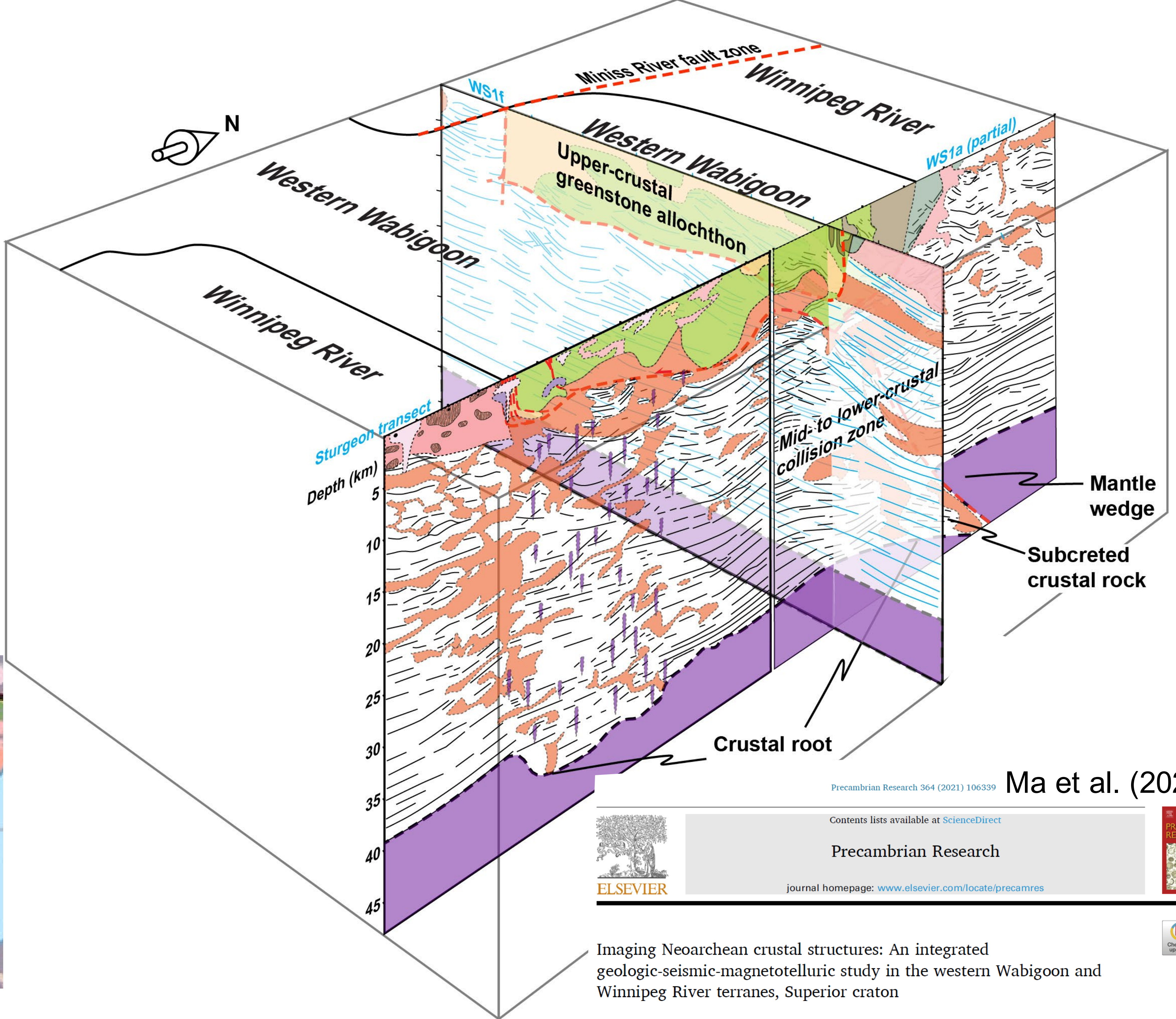



Ma et al. (2021)

- Continuous distribution of greenstone belt as a 5–10 km thick thrust sheet in the upper crust
- A collision zone in the mid- to lower-crust
- A trans-crustal fault zone, F1, accommodated the collision of basement and the emplacement of greenstone belt
- Subcreted crust in the mantle
- Thickened crust beneath the greenstone belt

# 3D crustal structure

Sturgeon transect + Lithoprobe WS1a & WS1f





Ma et al. (2021)

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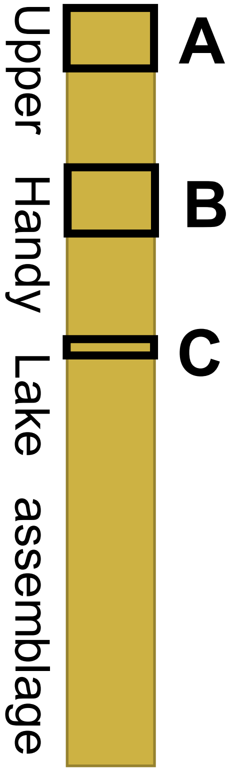
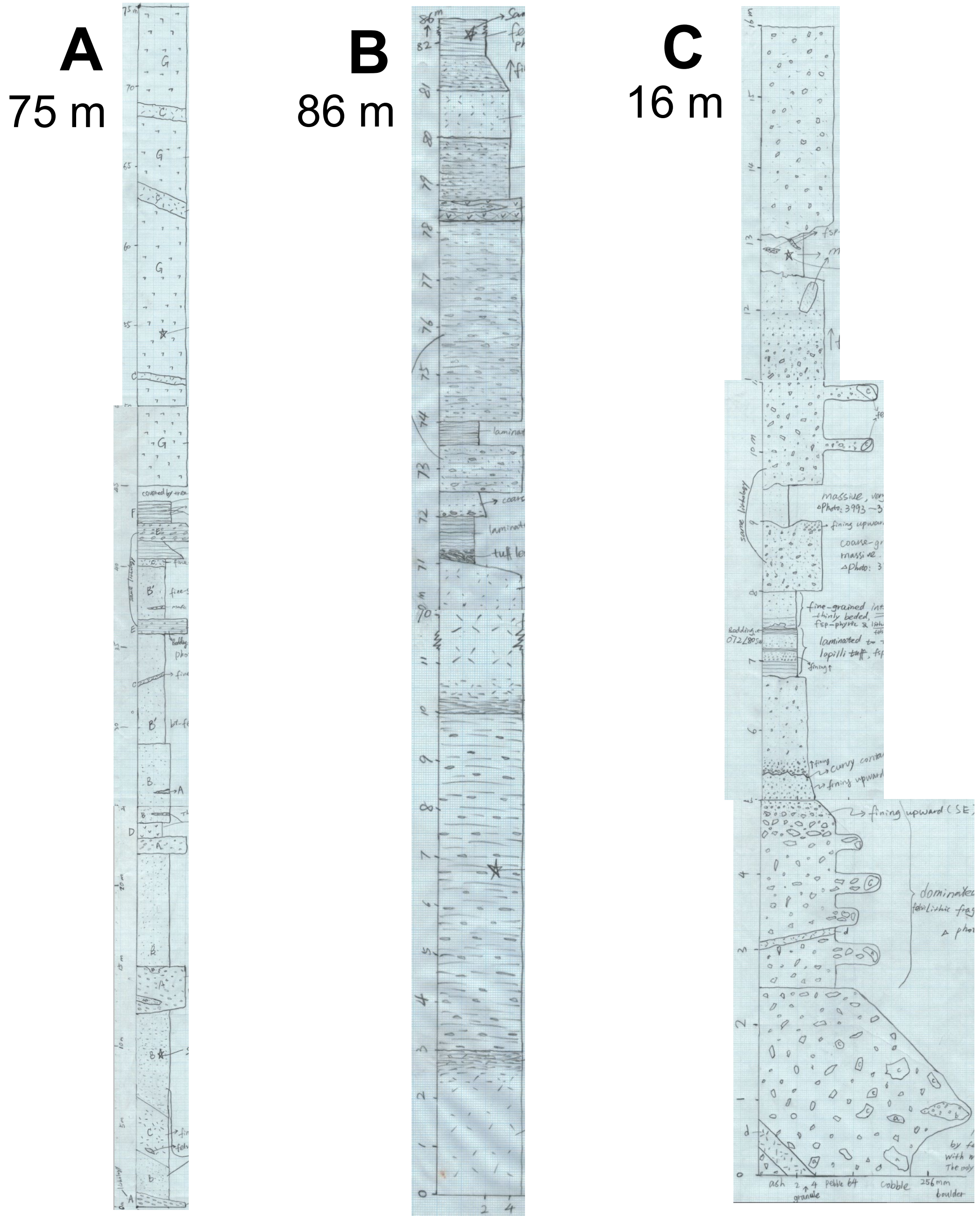
Imaging Neoarchean crustal structures: An integrated geologic-seismic-magnetotelluric study in the western Wabigoon and Winnipeg River terranes, Superior craton

# PART II

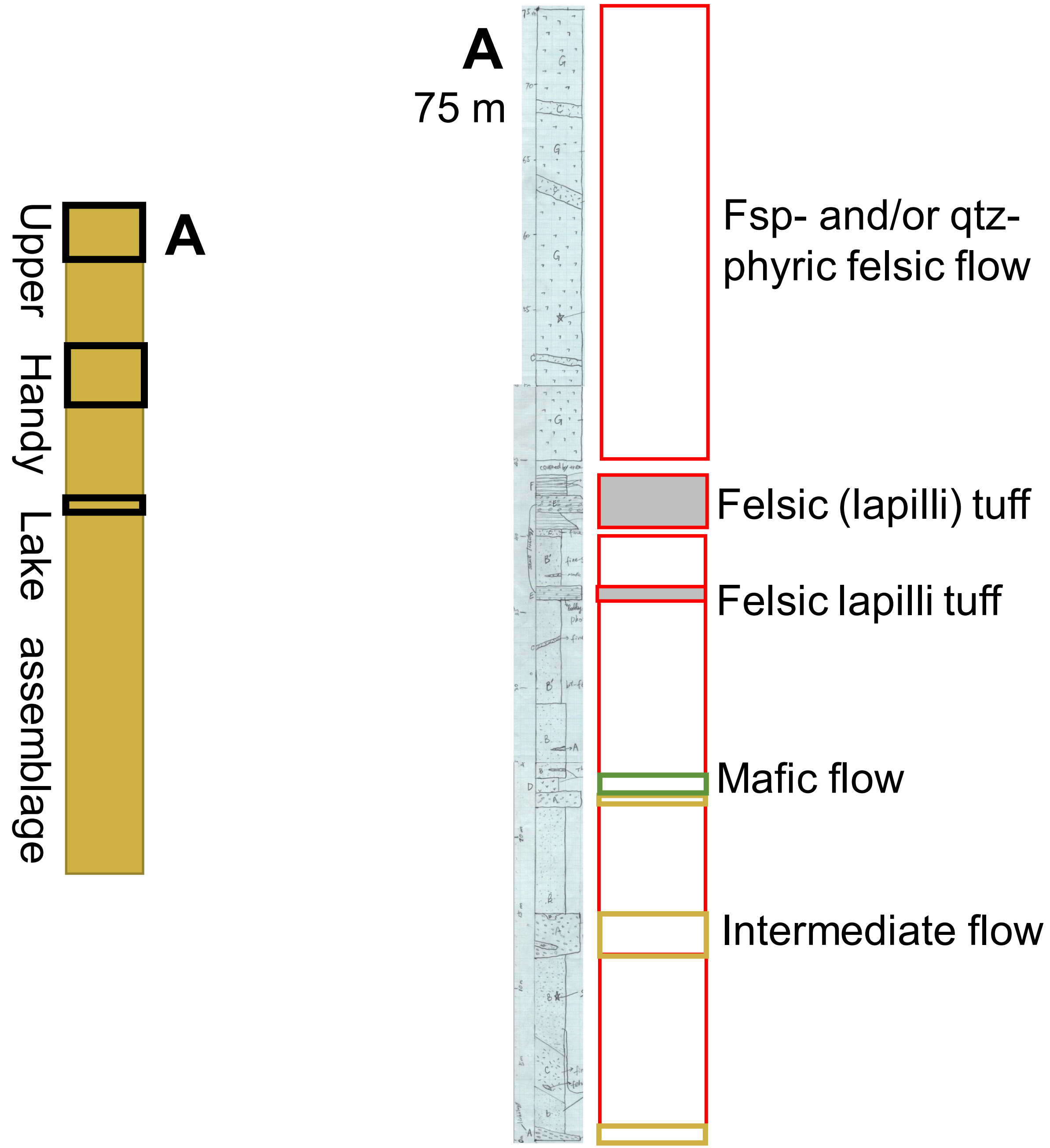
## New stratigraphic, geochronologic, and isotopic data from the Sturgeon Lake greenstone belt

# Stratigraphy of Upper Handy Lake assemblage

# Stratigraphy of Upper Handy Lake assemblage



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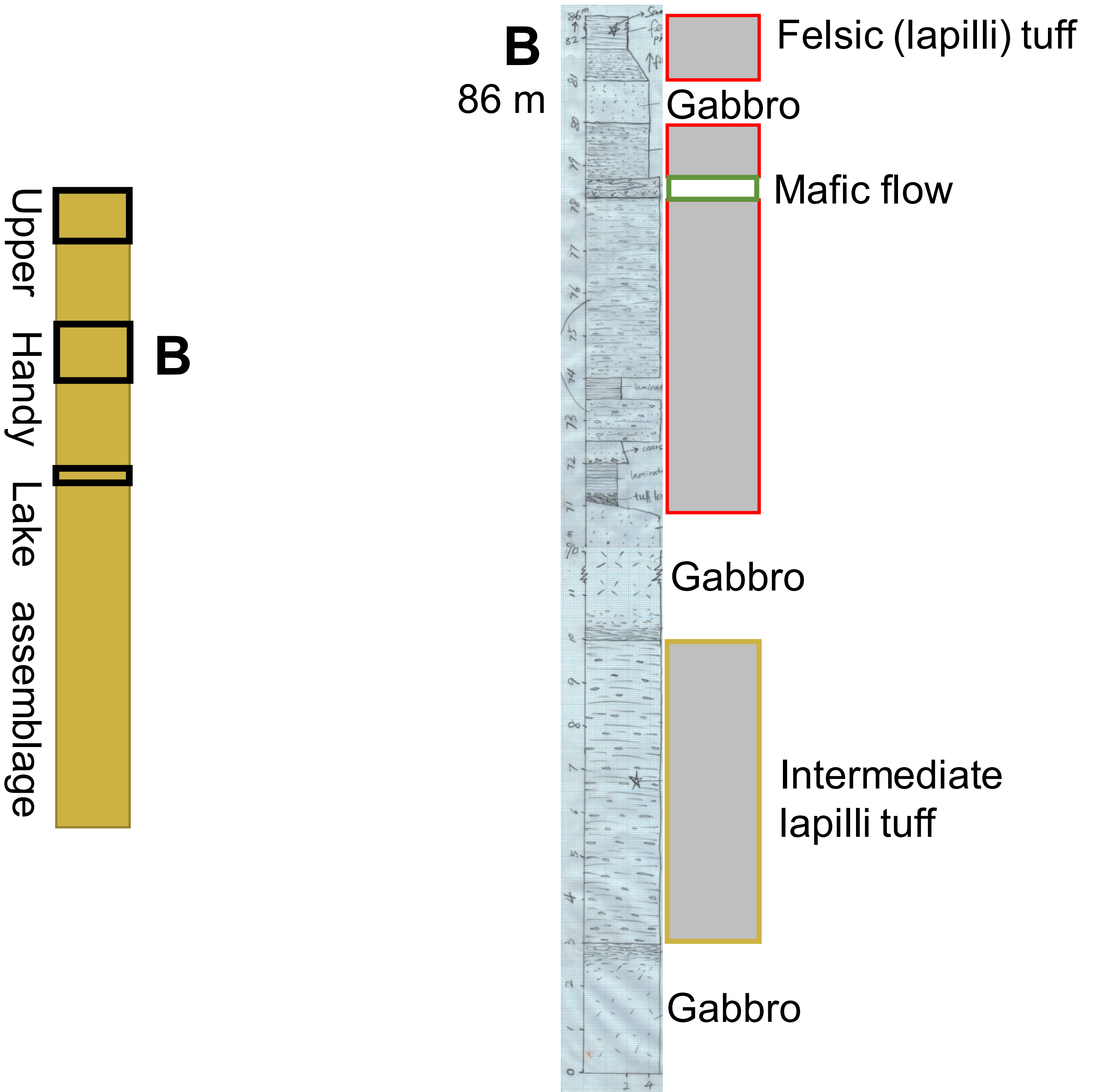
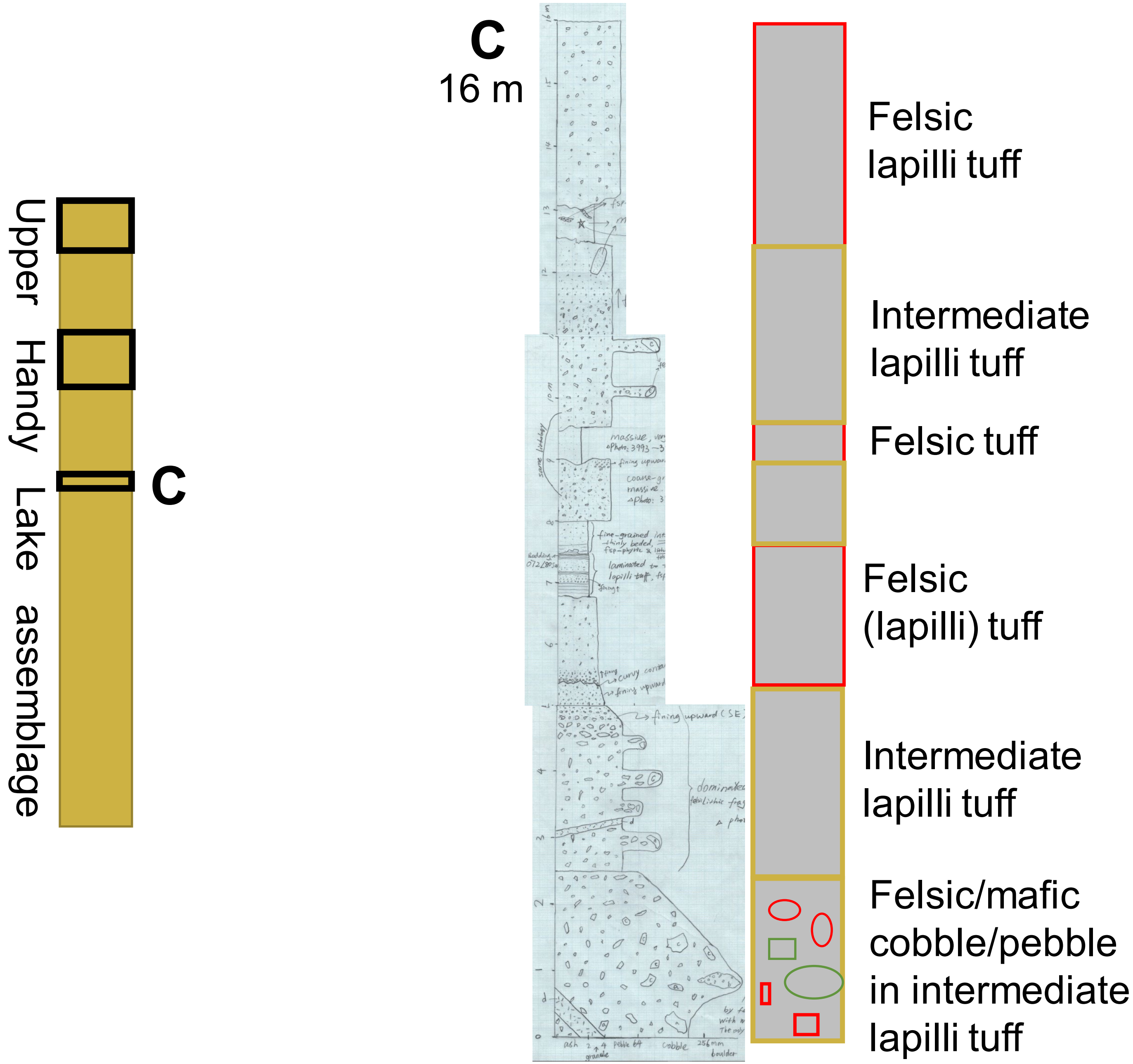
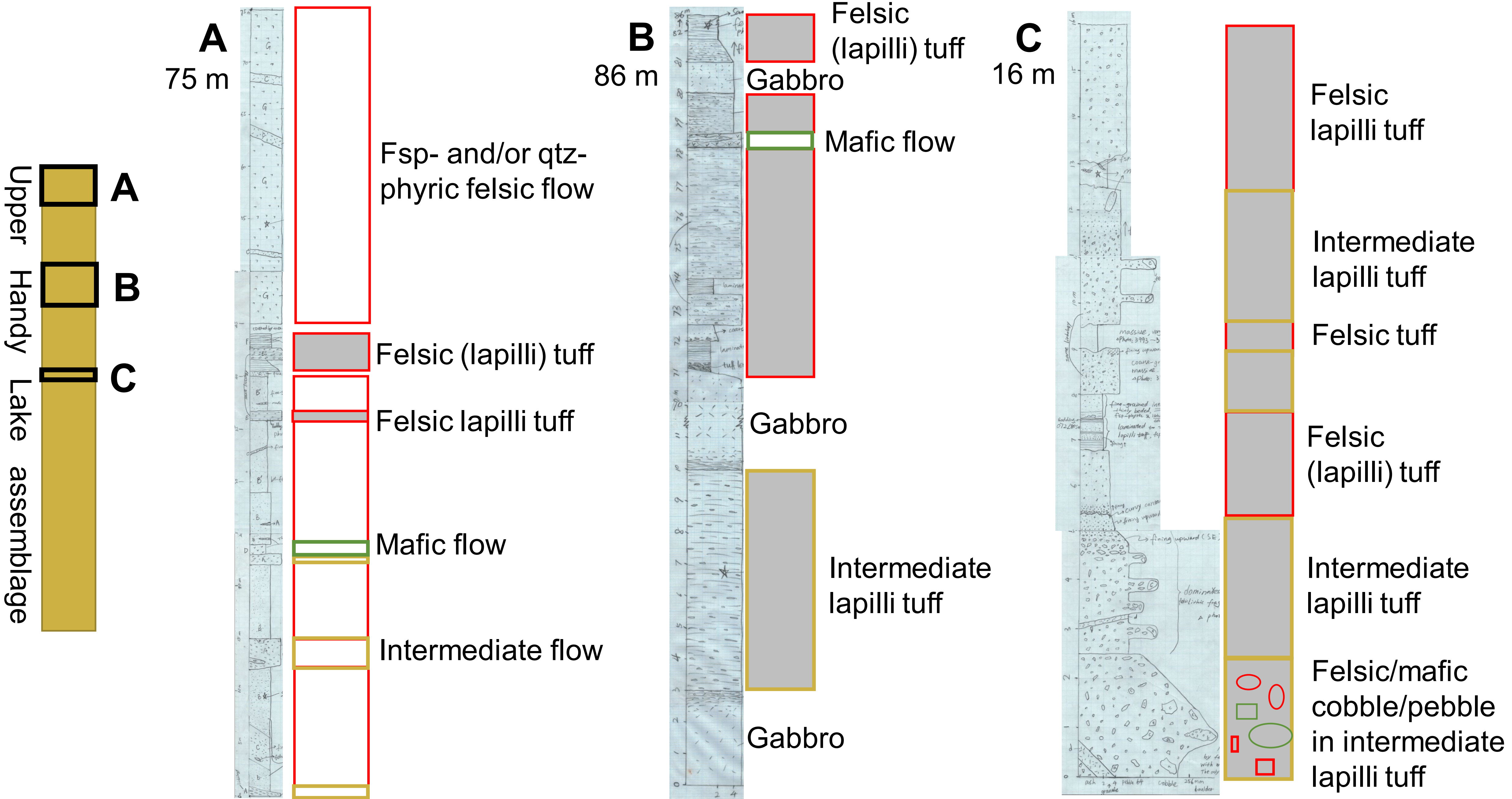


# Stratigraphy of Upper Handy Lake assemblage

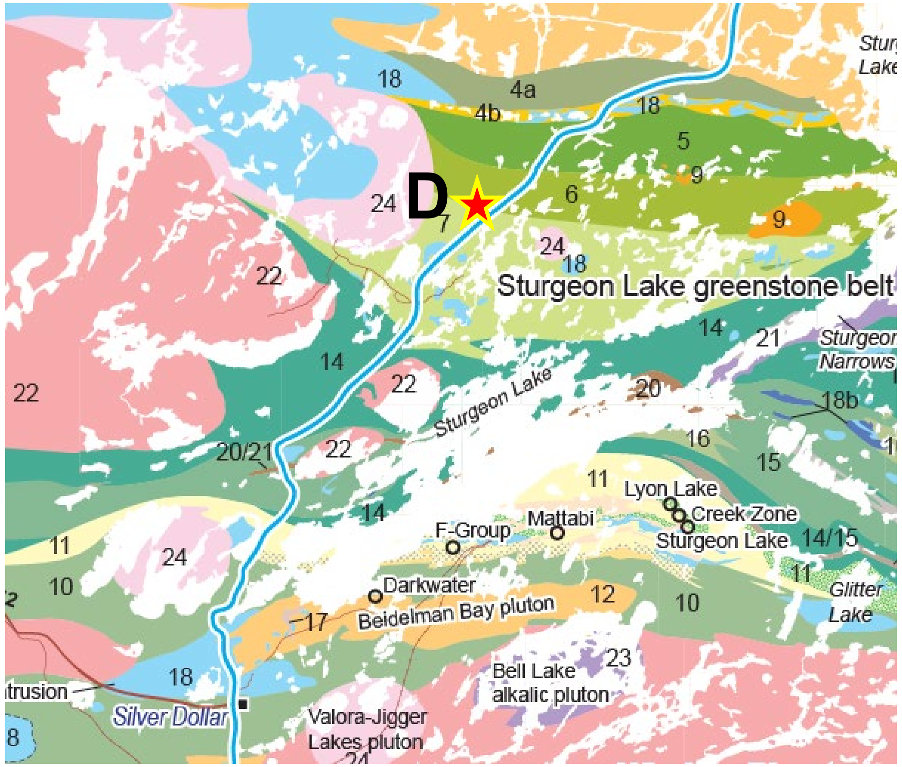


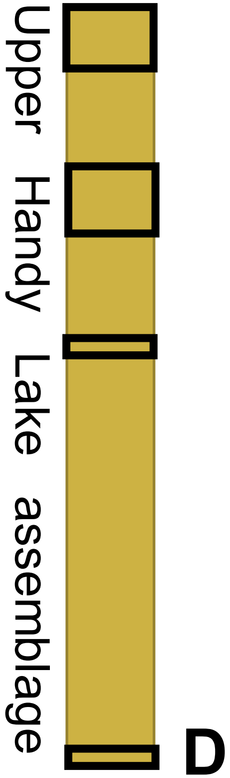
# Stratigraphy of Upper Handy Lake assemblage

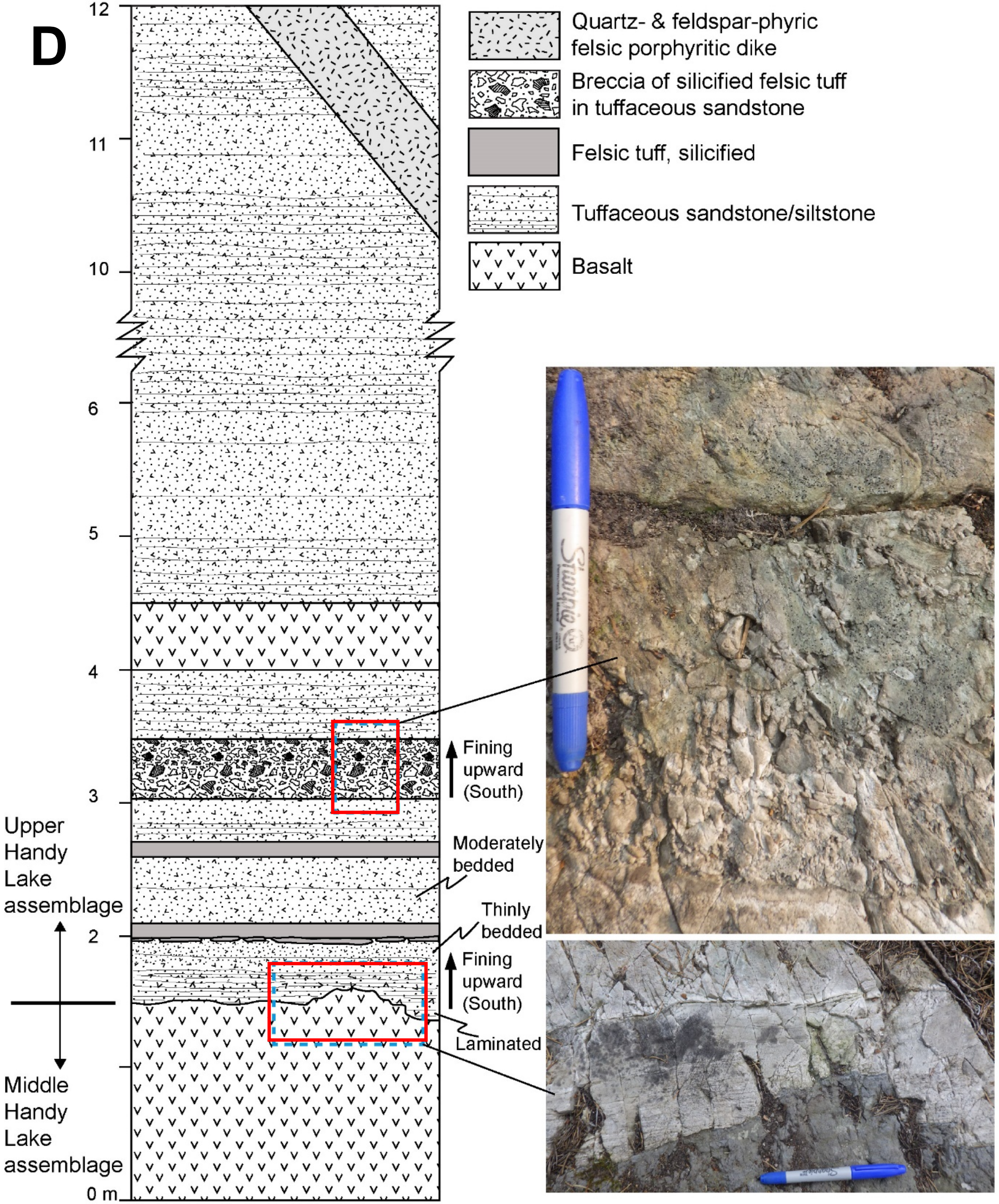


# Stratigraphy of Upper Handy Lake assemblage

Contact between Upper HLA and Middle HLA



# Stratigraphy of Upper Handy Lake assemblage

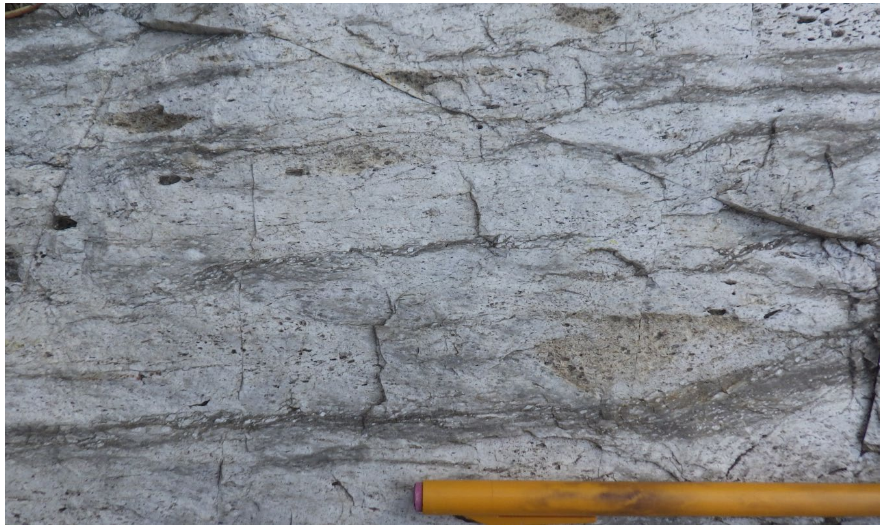
**Flow**

Fsp- & qtz-phyric felsic flow

Fsp-phyric mafic flow

**(Lapilli) tuff**

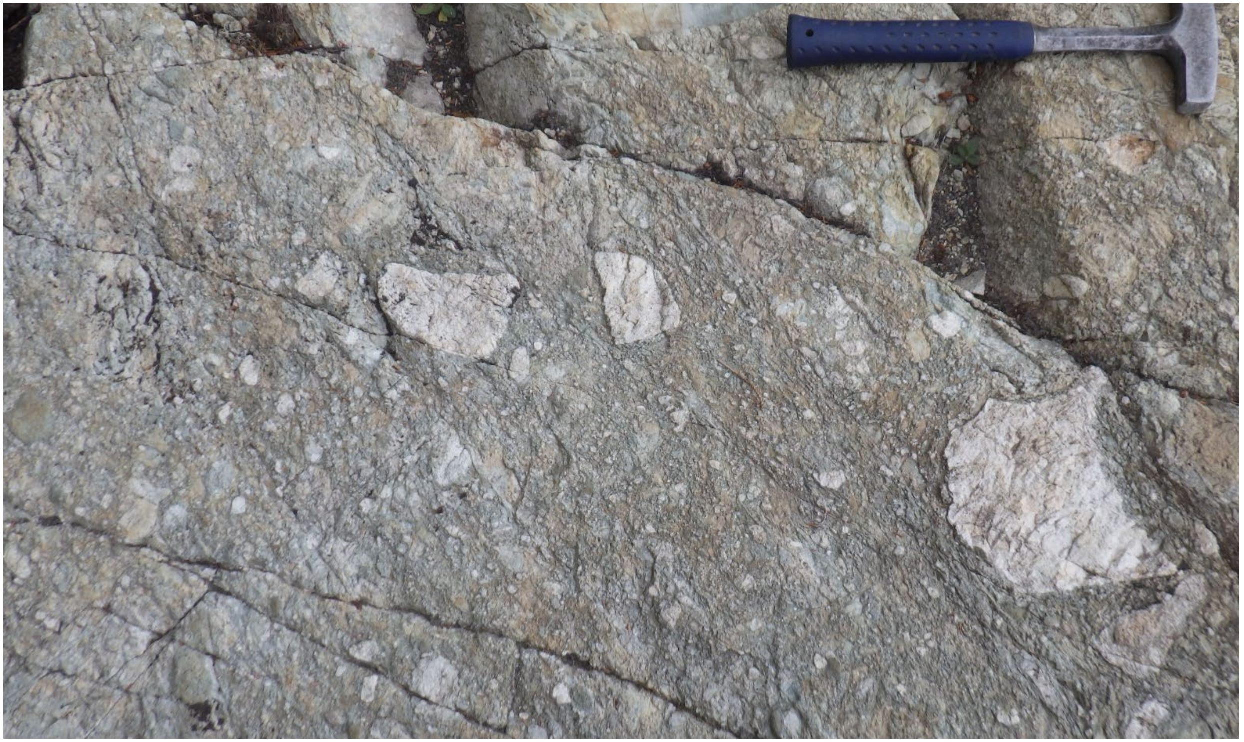
Qtz- & fsp-phyric felsic crystal tuff



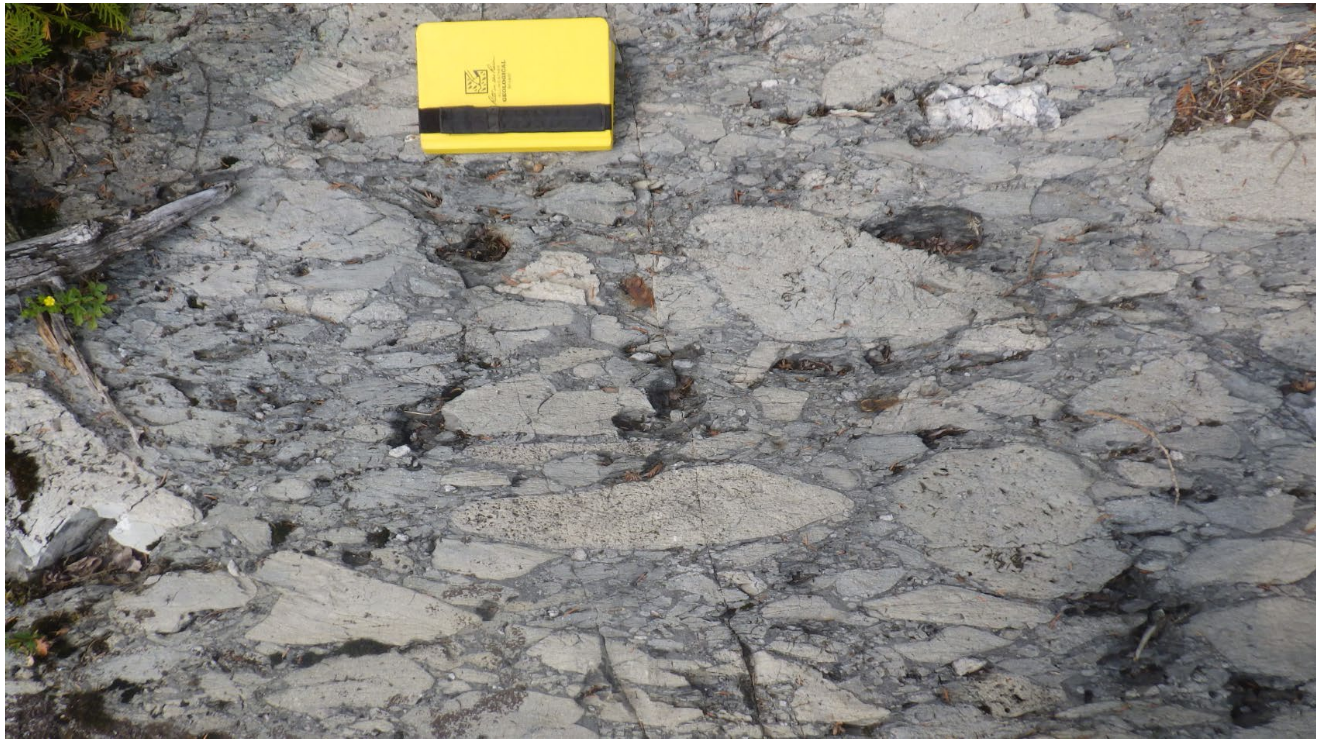
Interbedded felsic tuff & felsic lapilli tuff

# Stratigraphy of Upper Handy Lake assemblage

## **Pyroclastic breccia**



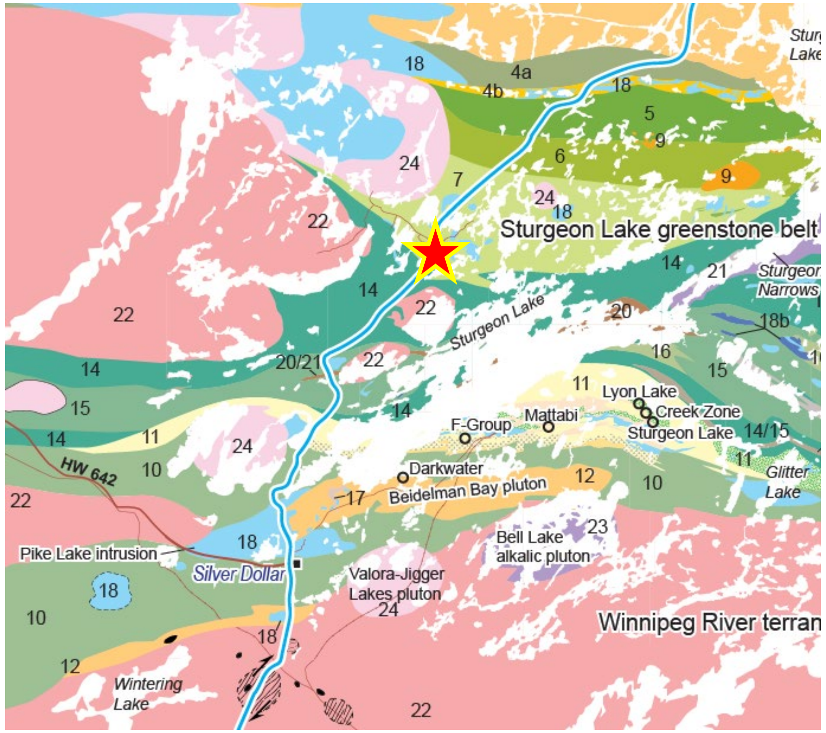
Felsic & mafic blocks supported by intermediate lapilli tuff

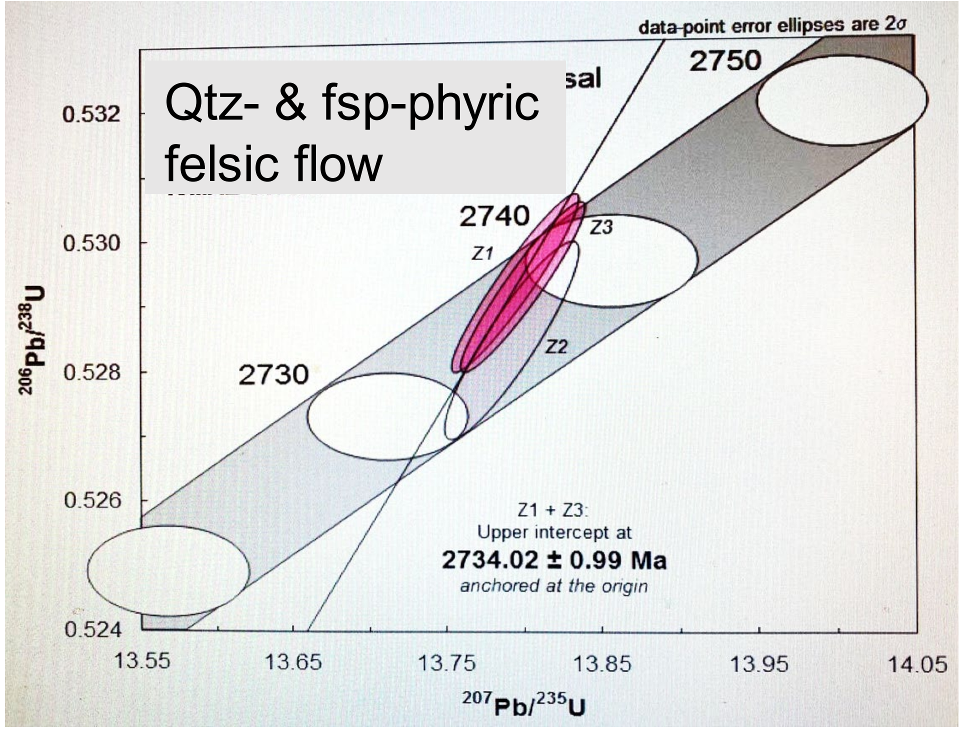


Felsic blocks supported by qtz-phyric felsic crystal tuff

# New geochronological and isotopic results (TIMS)

## Felsic flow of Upper Handy Lake assemblage




**2734 ± 1 Ma**

Published zircon ages from the VMS-bearing South Sturgeon assemblage:

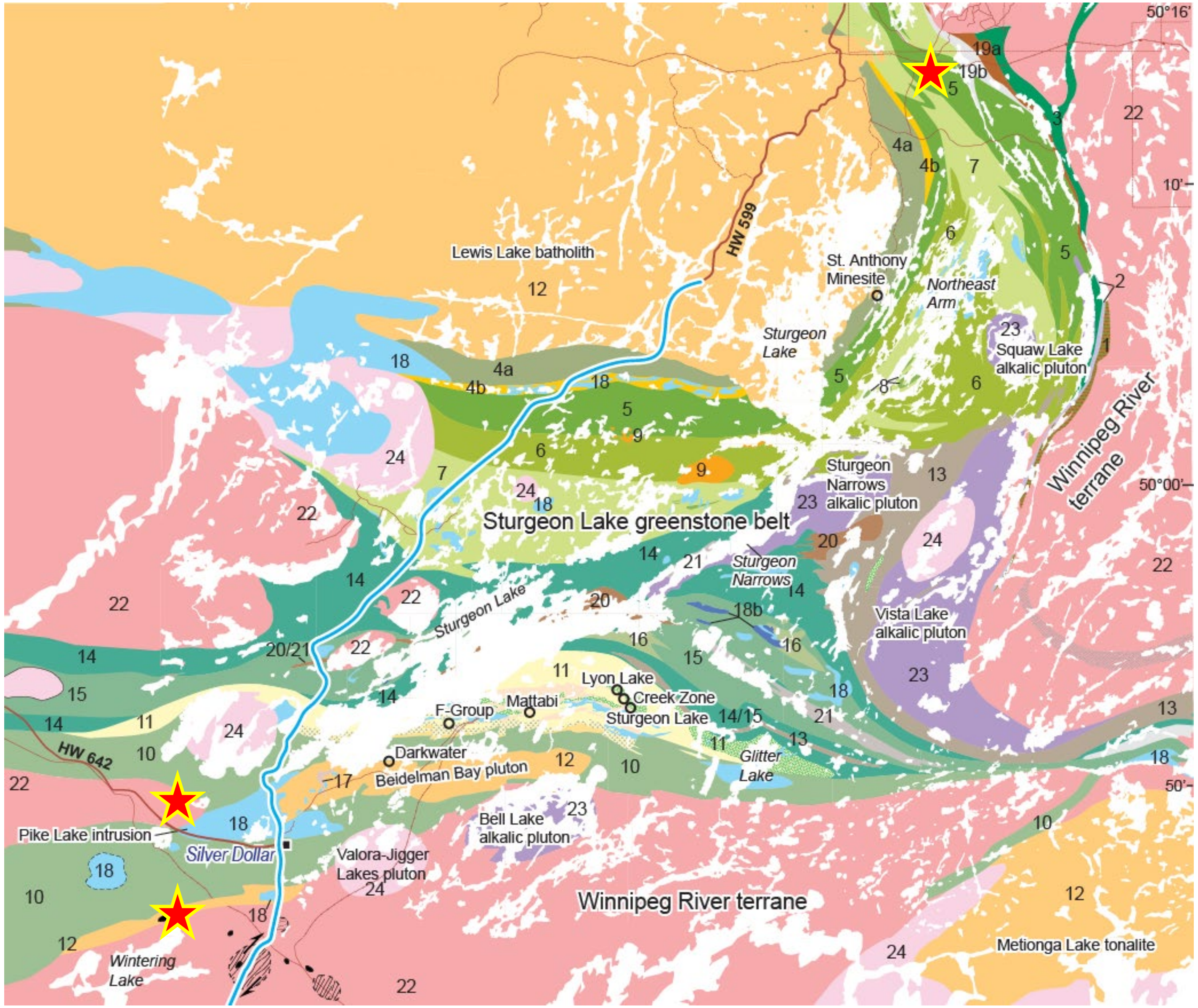
| | |
|---|---|
| Mattabi rhyolite | > 2734.7 ± 1.6 |
| NBU rhyolite | 2735 ± 1.7 |
| NBU rhyolite | 2735.5 +3/-1.9 |
| NBU rhyolite | 2736.3 +9.3/-3.9 |
| Lyon Lake rhyolite | 2735.2 +6.9/-3.2 |
| Lyon Lake rhyolite | 2734.8 +2.8/-2.5 |
| Lyon Lake rhyolite | 2736 ± 1.8 |

Davis et al. (1985)

# New geochronological and isotopic results (LA-ICPMS)

## 4 synvolcanic granitoids

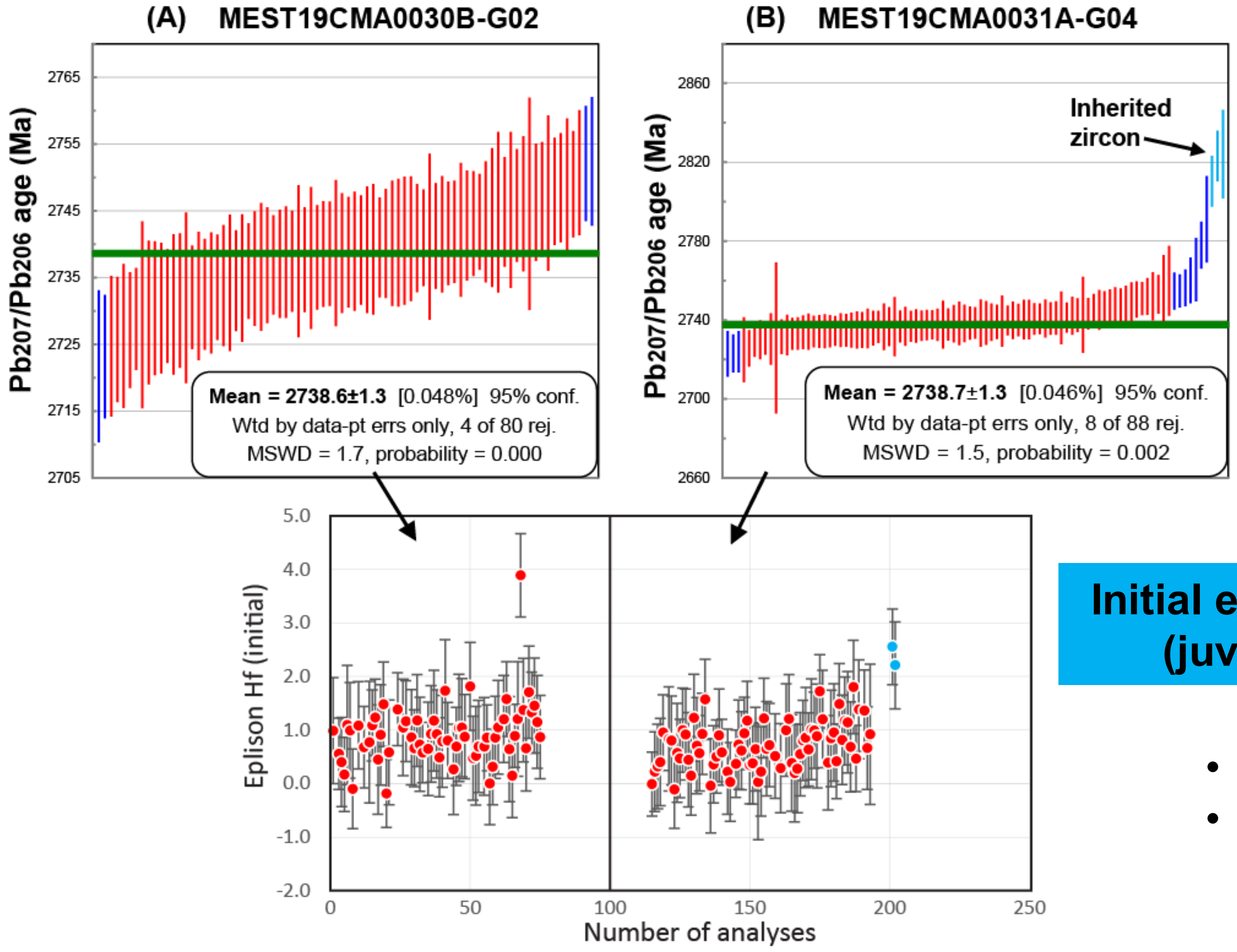
- South Sturgeon assemblage (n=2)
- Shanty Lake pluton (n=1)
- Lower Handy Lake granite (n=1)



# New geochronological and isotopic results (LA-ICPMS)

## Synvolcanic granitoid – in contact and coeval with the lowermost South Sturgeon assemblage

**2738.6 ± 1.3 Ma**




**2738.7 ± 1.3 Ma**

Inherited zircon: ~2820 Ma

**Initial epsilon Hf = +2 to 0 (juvenile magmas)**

- Juvenile
- Well mixed

# New geochronological and isotopic results (LA-ICPMS)

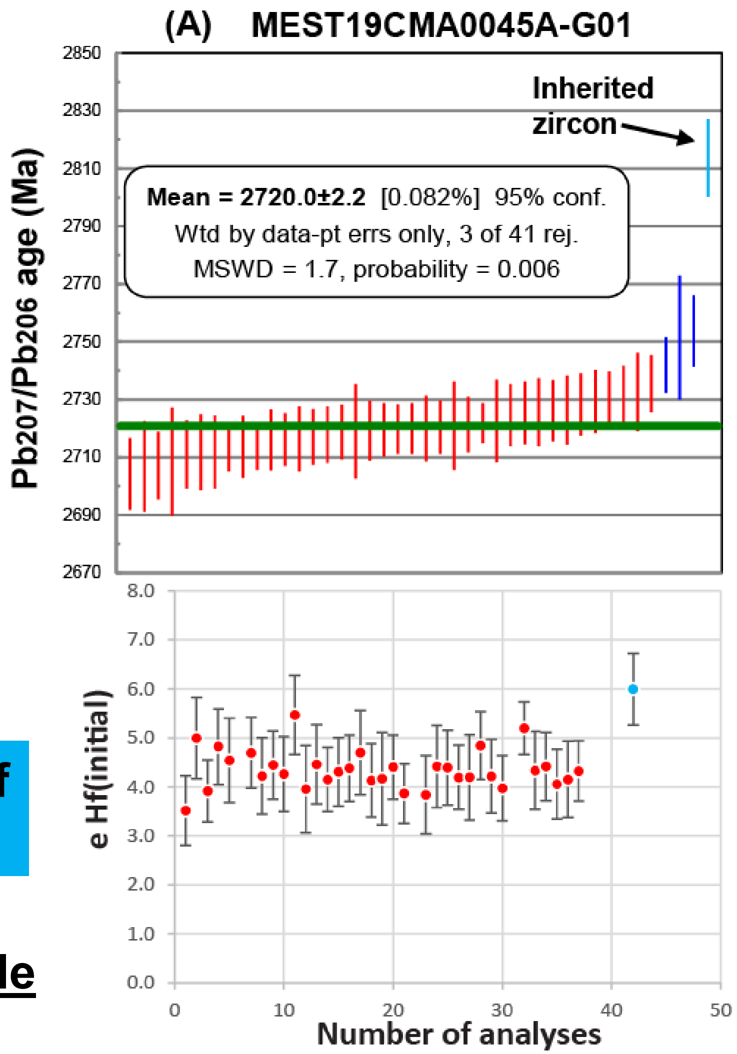
**Synvolcanic granitoid: Shanty Lake pluton & lower Handy Lake granite**

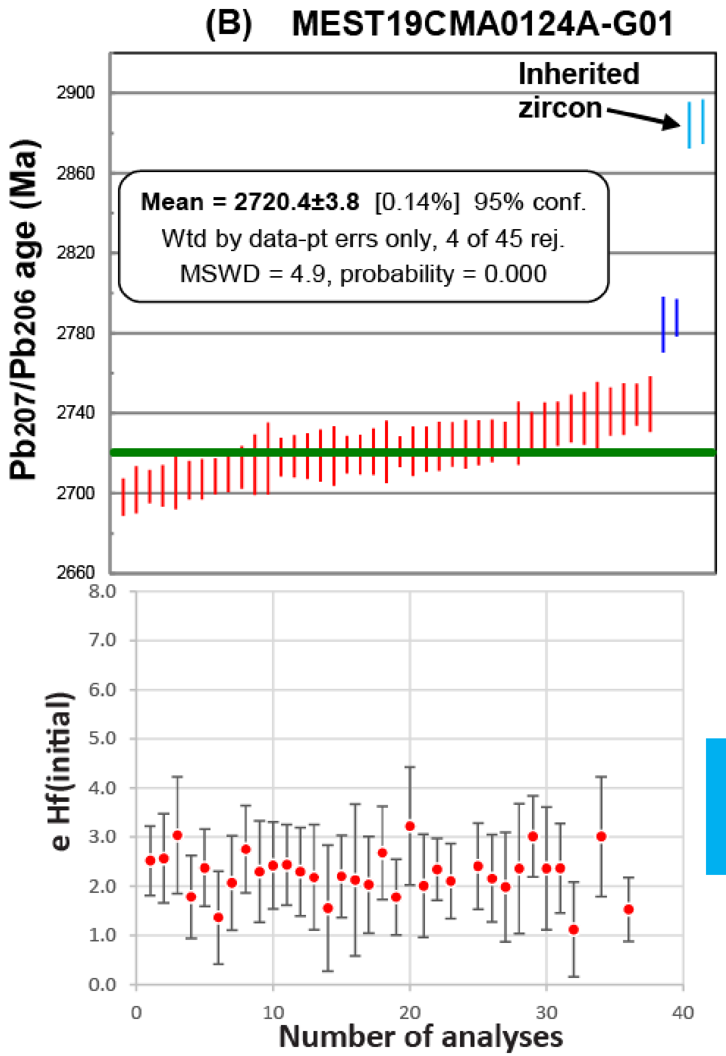
**2720 ± 2 Ma**

Inherited zircon: ~2810 Ma

**Initial epsilon Hf = about +4.5**

**More juvenile**




**2720 ± 4 Ma**

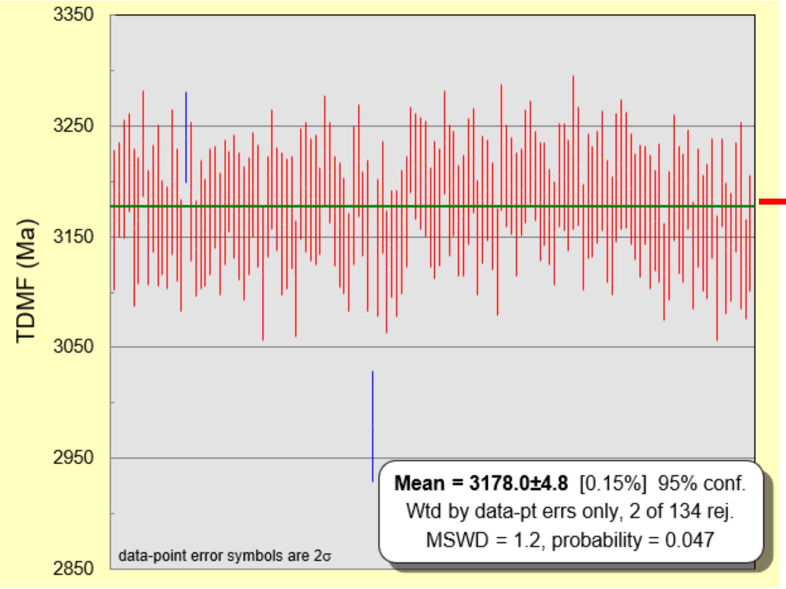
Inherited zircon: ~2880 Ma

**Initial epsilon Hf = about +2.5**

# New geochronological and isotopic results (LA-ICPMS)

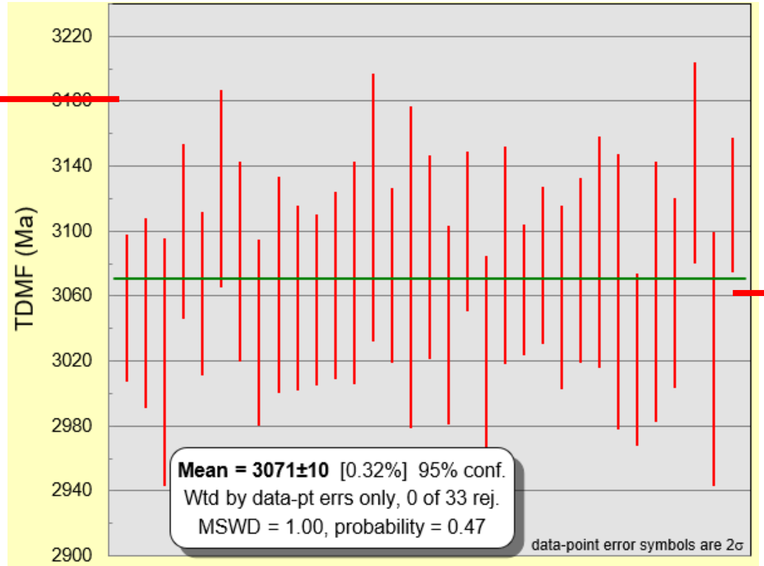
## Zircon depleted mantle Hf model ages of synvolcanic granitoids

**Zircon age: 2738.6 ± 1.3 Ma**



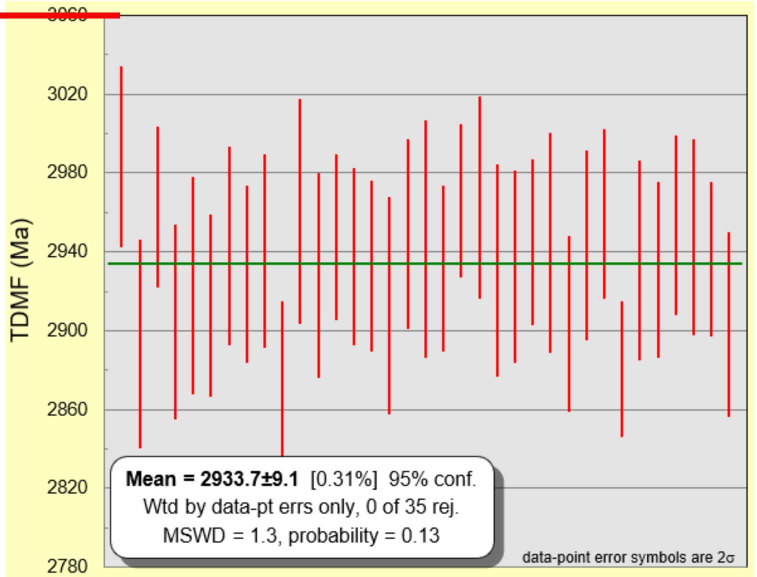

**3178 ± 5 Ma**

**Zircon age: 2720 ± 4 Ma**




**3070 ± 10 Ma**

**Zircon age: 2720 ± 2 Ma**




**2934 ± 9 Ma**

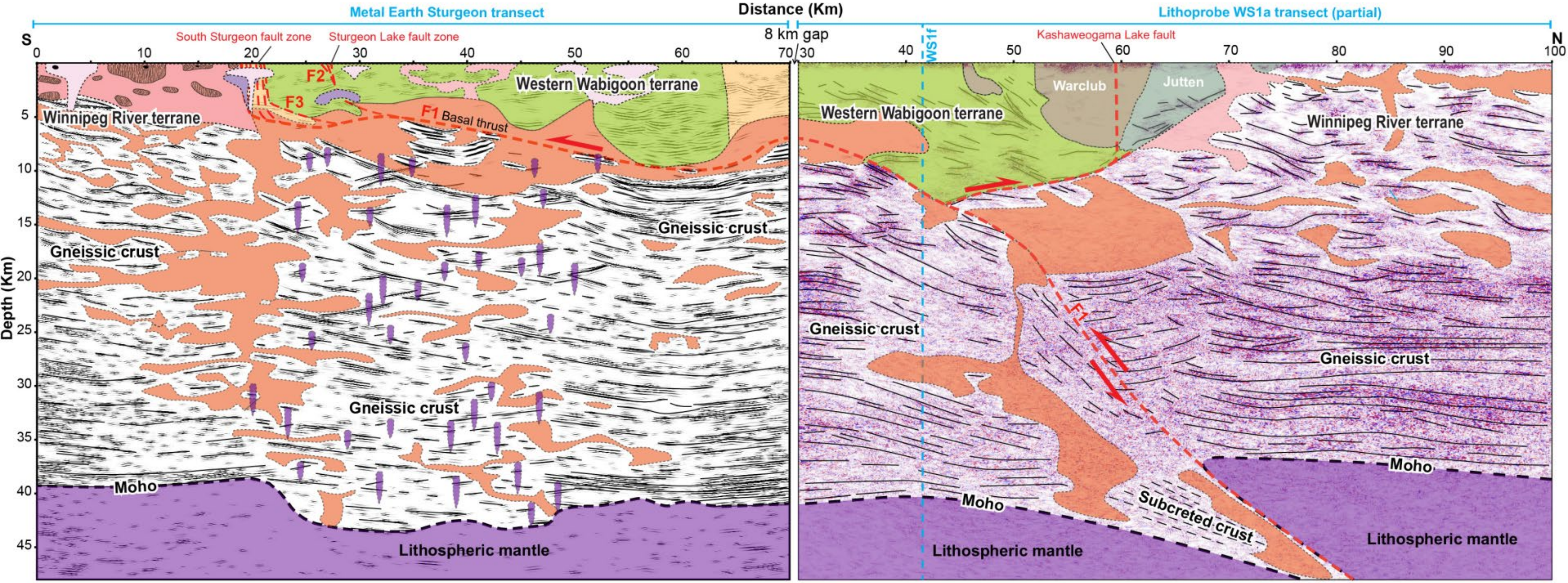
Minimum ages of crust extraction from mantle

**Multiple phases of crustal formation in the WWT during the Mesoarchean**

# PART III (conclusions)

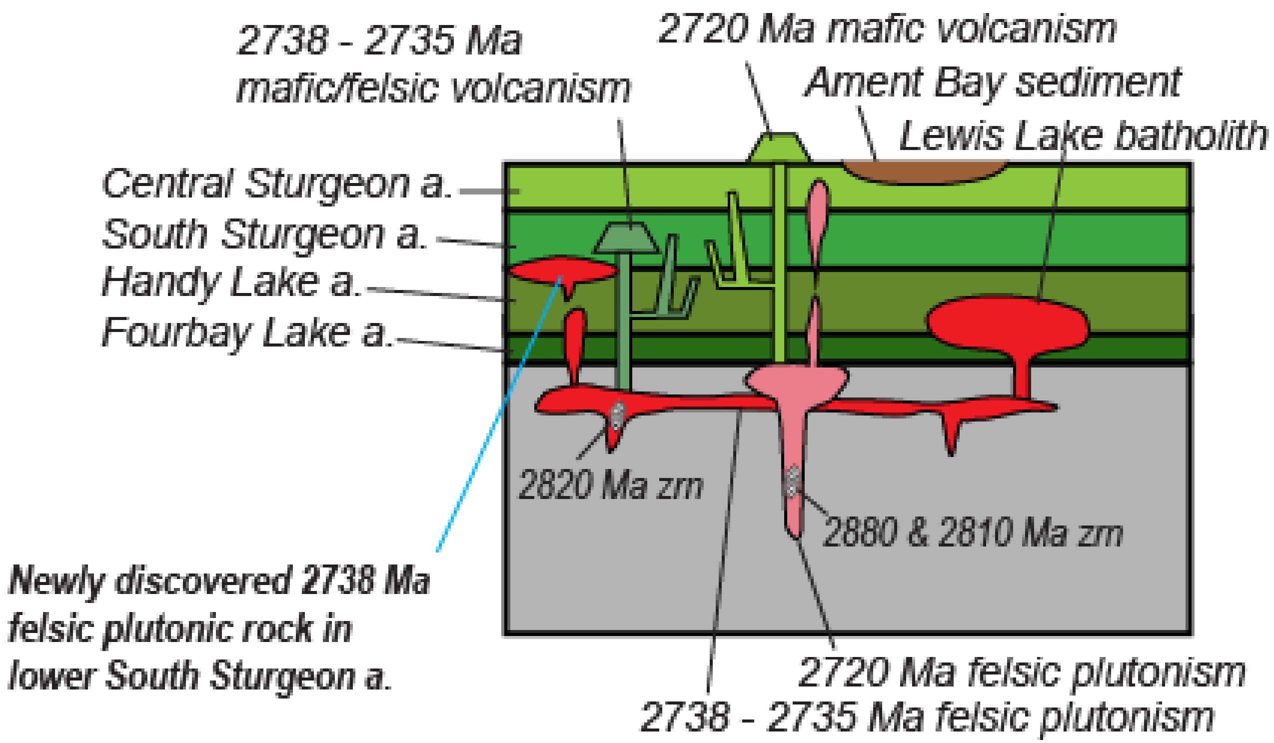
## Tectonic evolution of the western Wabigoon terrane in the Sturgeon Lake region:

Implications for understanding structural controls on the greenstone belt and its VMS deposits




- A *collision belt* between the main WRT to the north and a continental margin promontory of the WRT to the south.

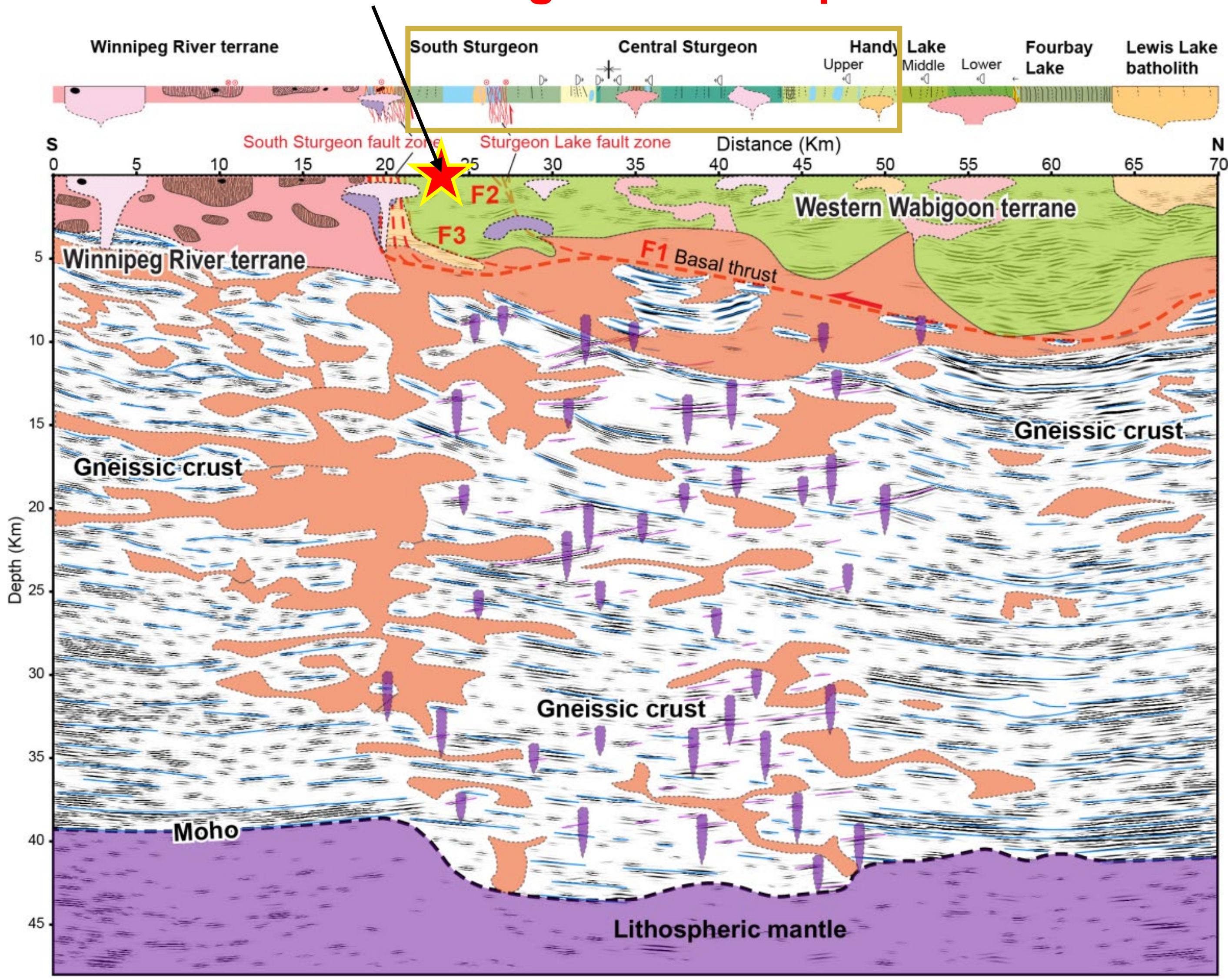
- Prior to the collision, the WWT was partially *accreted onto* and partially *subducted* under the WRT.

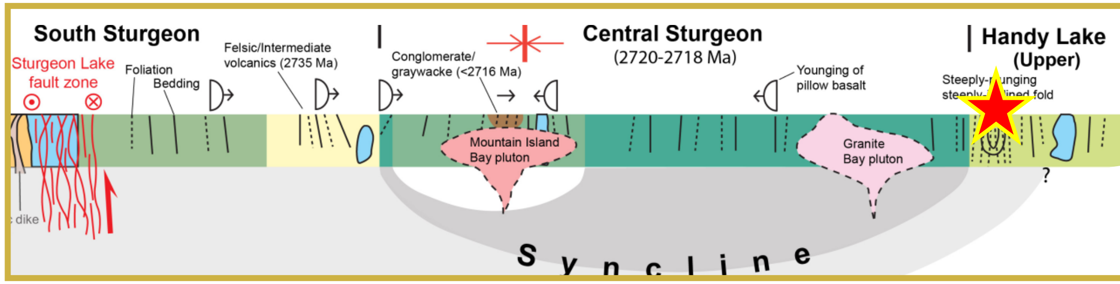



- Prior to the accretion, various *volcanic and plutonic* rocks of WWT were developed in an oceanic crust setting from *~2775 to ~2720 Ma*.

- The felsic intrusive rocks with *inherited zircons* of 2880, 2820, & 2810 Ma are *juvenile* and were melted from older juvenile sources that were *episodically* extracted from the mantle likely in the Mesoarchean.

# South Sturgeon VMS deposits

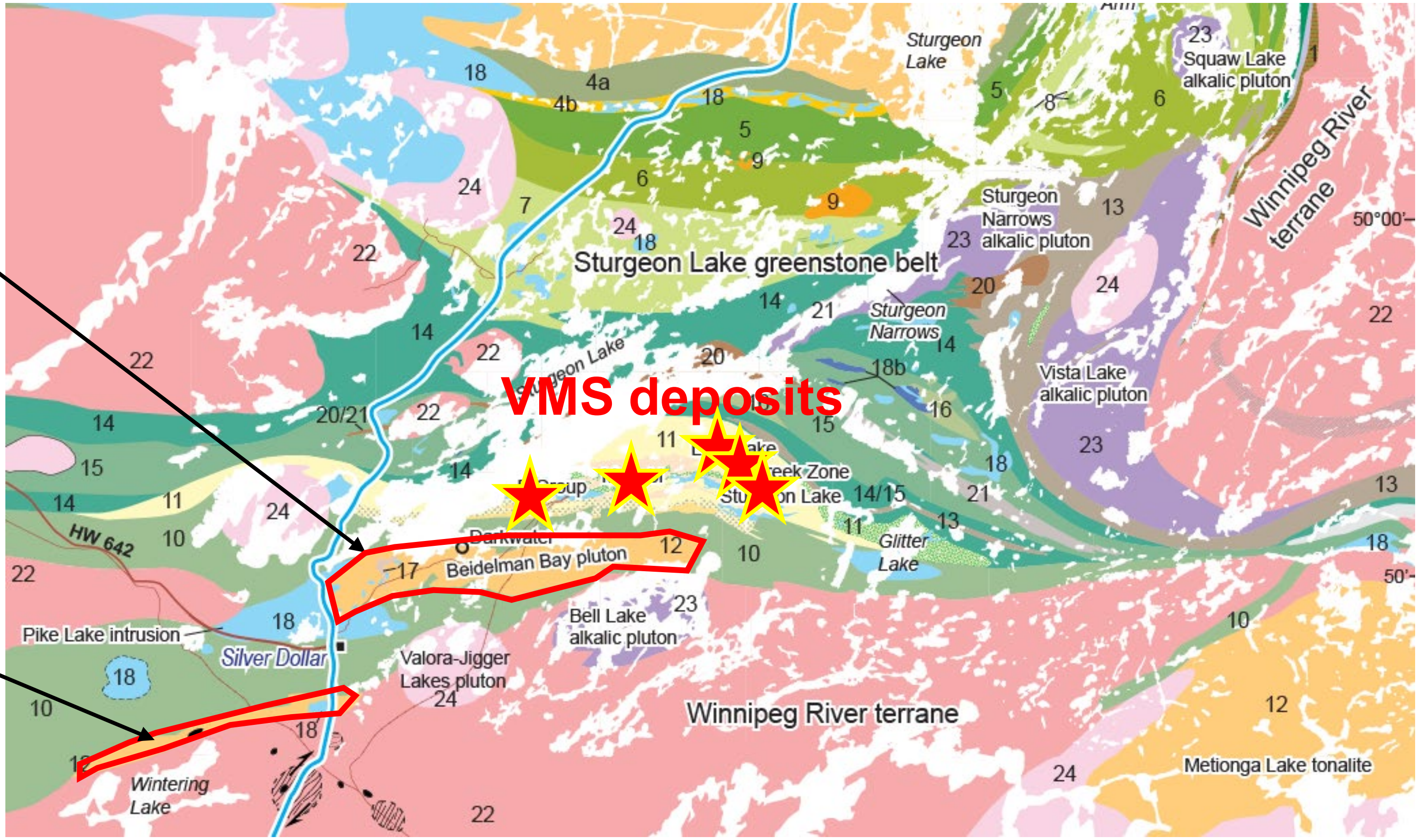


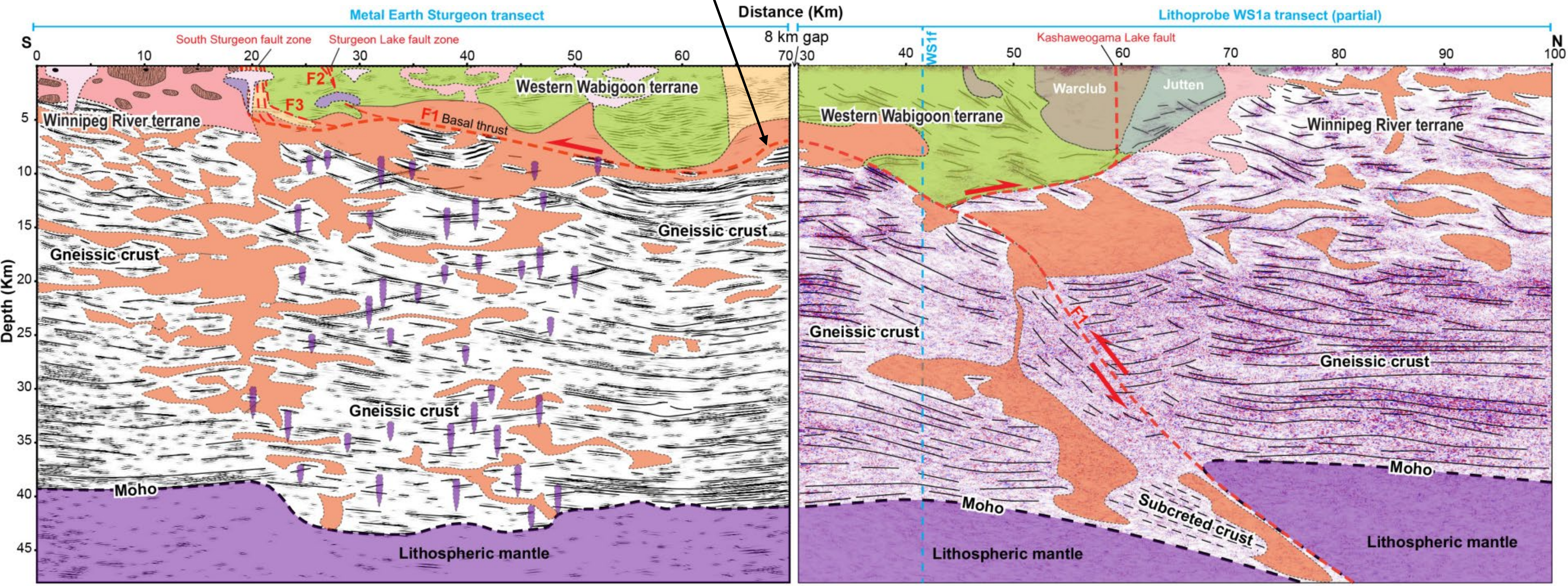

- In this model, the South Sturgeon VMS deposits were tectonically emplaced to the current position, implying that thrusting and folding of the greenstone belt did not liberate the VMS deposits.
- The newly identified 2734±1 Ma felsic flow in the Upper Handy Lake assemblage demonstrates occurrence of age-equivalent rocks to the VMS-bearing South Sturgeon assemblage in the north limb of the regional syncline.
- The stratigraphy of the upper part of the UHLA is consistent with that of the South Sturgeon felsic volcanic rocks.
- Prospective for VMS in this new ~2734 Ma unit (?)

The Beidelman Bay pluton is considered to have initiated and sustained the sub-seafloor convective system responsible for the formation of the South Sturgeon VMS deposits (Galley et al., 2000).

The *newly discovered 2738.6 ± 1.3 Ma felsic intrusion* at the base of the South Sturgeon assemblage may have jointly facilitated the formation of the VMS deposits.



# Neoarchean trans-crustal fault zone




- The Neoarchean trans-crustal fault zone F1 extends from surface into the mantle, which may have implications for gold prospecting, as crustal-scale fault zones are commonly related to orogenic gold (e.g., Frieman and Kuiper, 2019).

# Project Research & Funding Partners

| Academic | Industry | Government |
| --- | --- | --- |
| LaurentianUniversity UniversitéLaurentienne HARQUAIL School of Earth Sciences École des sciences de la Terre | GLENCORE | Ontario |
| Earth Sciences UNIVERSITY OF TORONTO | | |
| University of Wisconsin Eau Claire | | |

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# Thank you!

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