Stratigraphy, metallogeny and crustal architecture of the Rainy River greenstone belt

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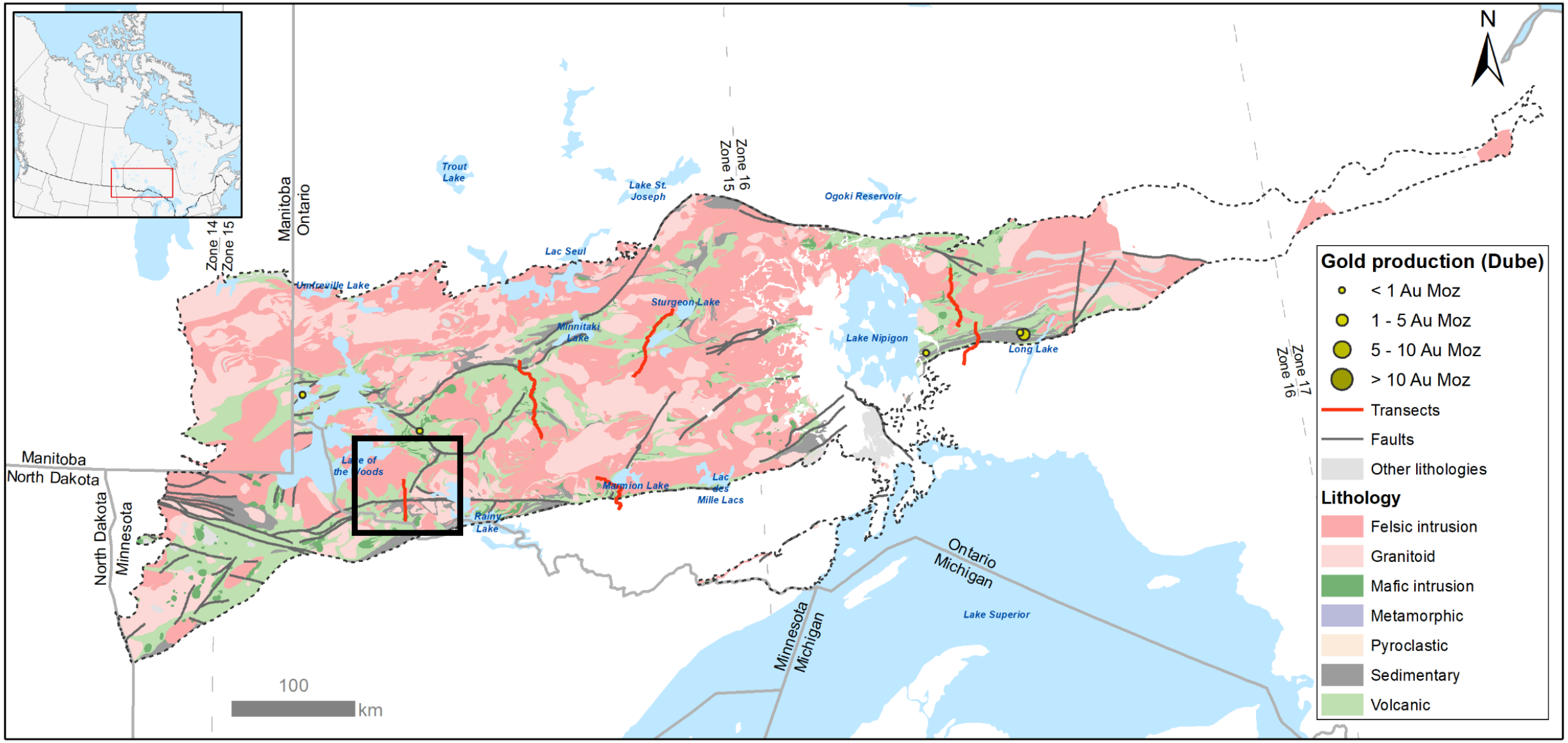
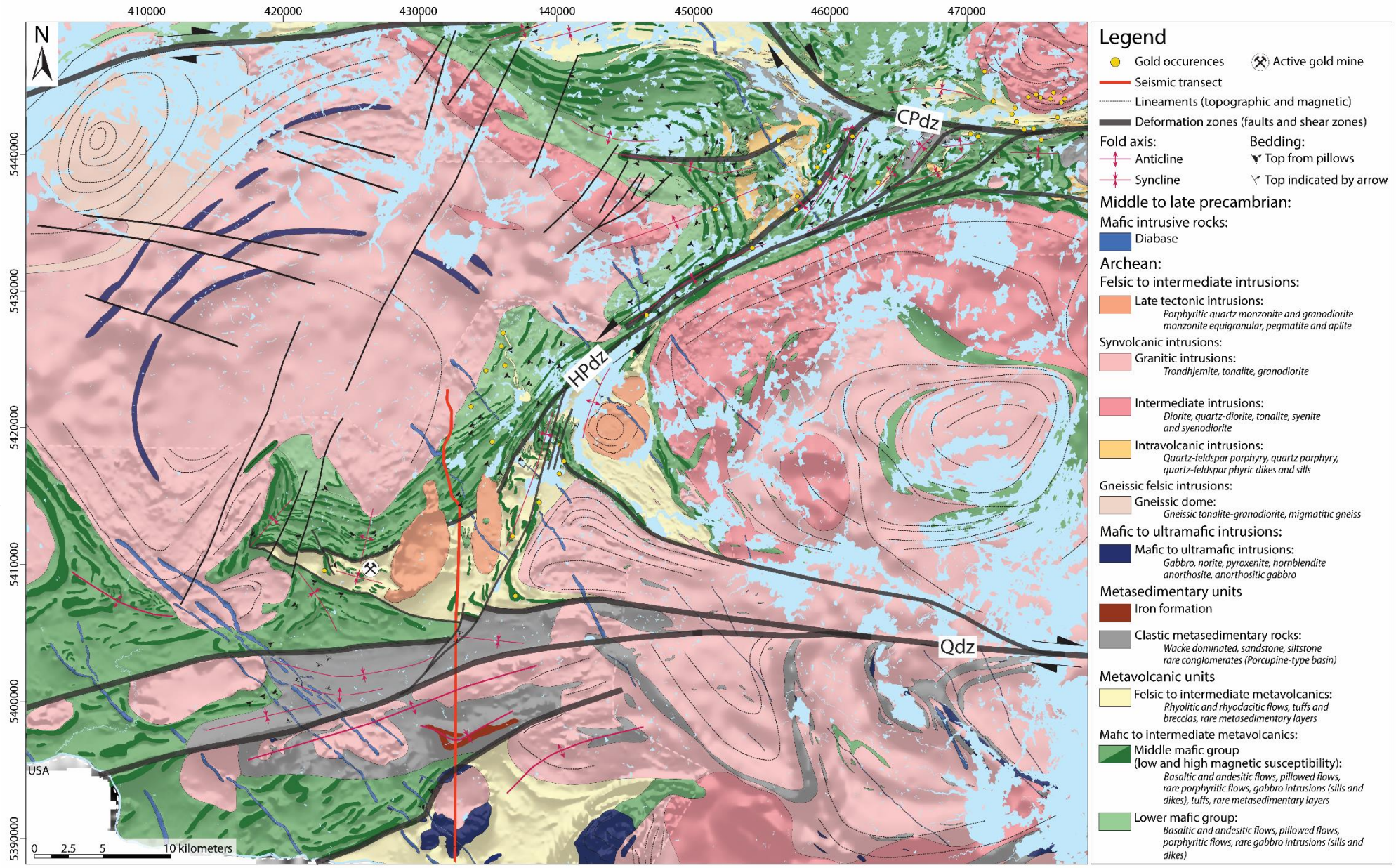
MERC
Mineral Exploration Research Centre
at the HARQUAIL School of Earth Sciences

Wabigoon subprovince



Regional context of the Rainy River transect



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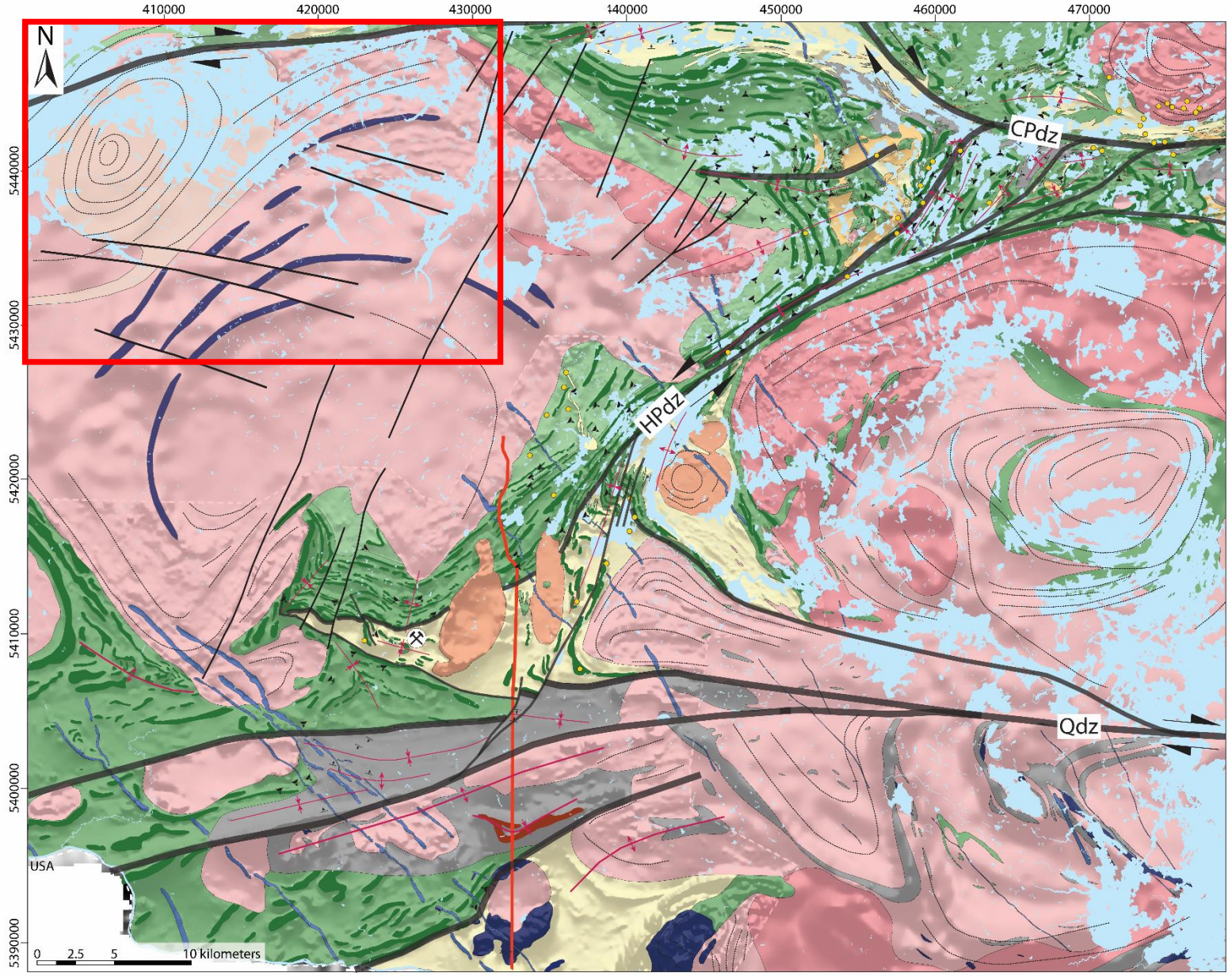

- **Morson gneissic dome:**
  - ➢ Exhumation of the mid-lower crust?
  - ➢ Structural control of the dome exhumation?
  - ➢ Crustal scale architecture and stratigraphy
- **Synvolcanic Au-Ag-rich sulphide deposits (Rainy River 3.7 Moz of Au/9.4Moz of Ag):**
  - ➢ Stratigraphy of RRGB
  - ➢ Timing of the felsic volcanism related to Au mineralization
  - ➢ Geodynamic and volcanic context favorable for the formation of these deposits?
- **Synorogenic sedimentary basins and major deformation (Qdz) zones**

BUT poorly endowed:

- ➢ Geometry of deformation zone at depth
- ➢ Crustal stratigraphy and architecture
- ➢ Comparison with endowed transects from the Abitibi subprovince
- ➢ What parameters control the endowment of deformation zones?

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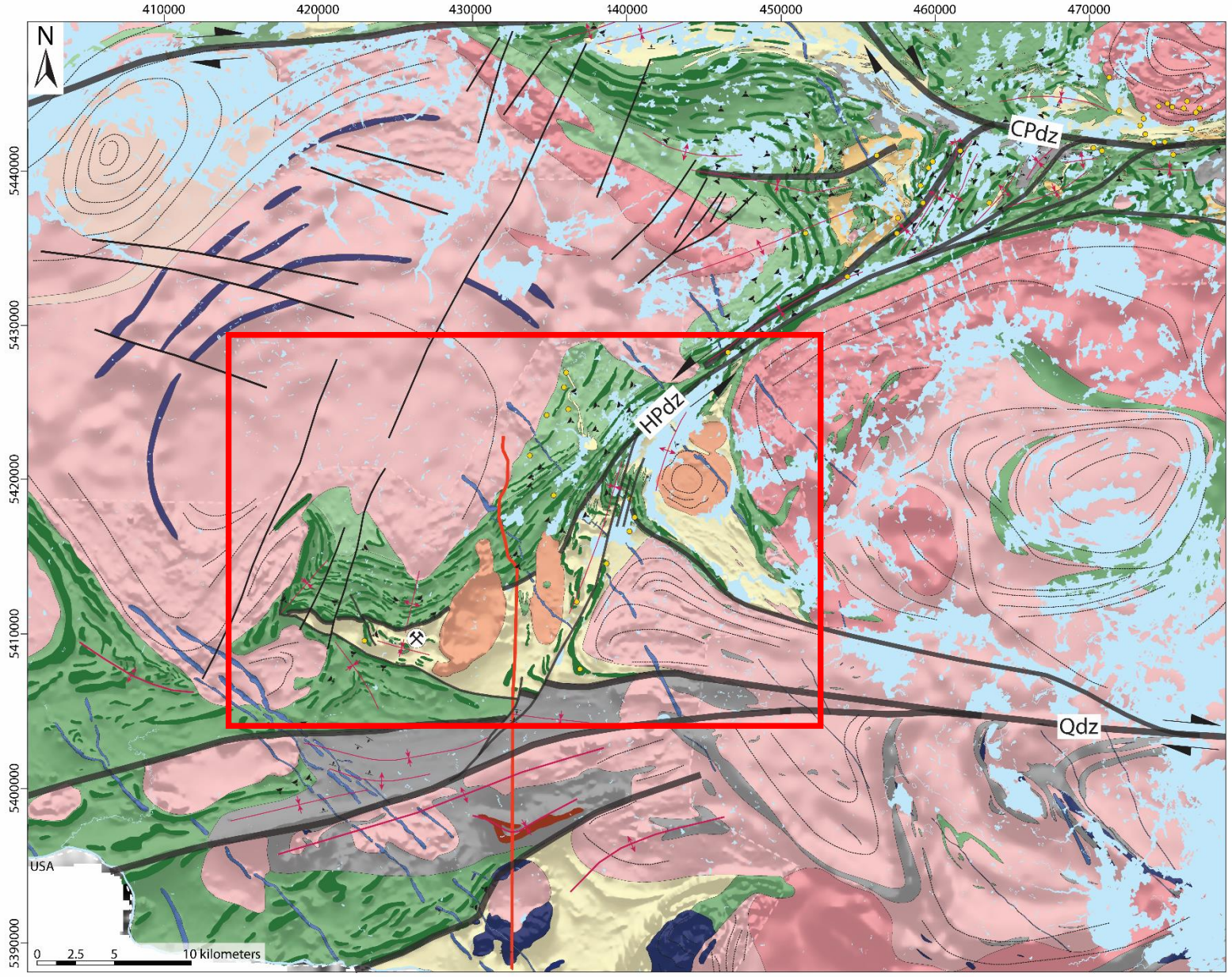

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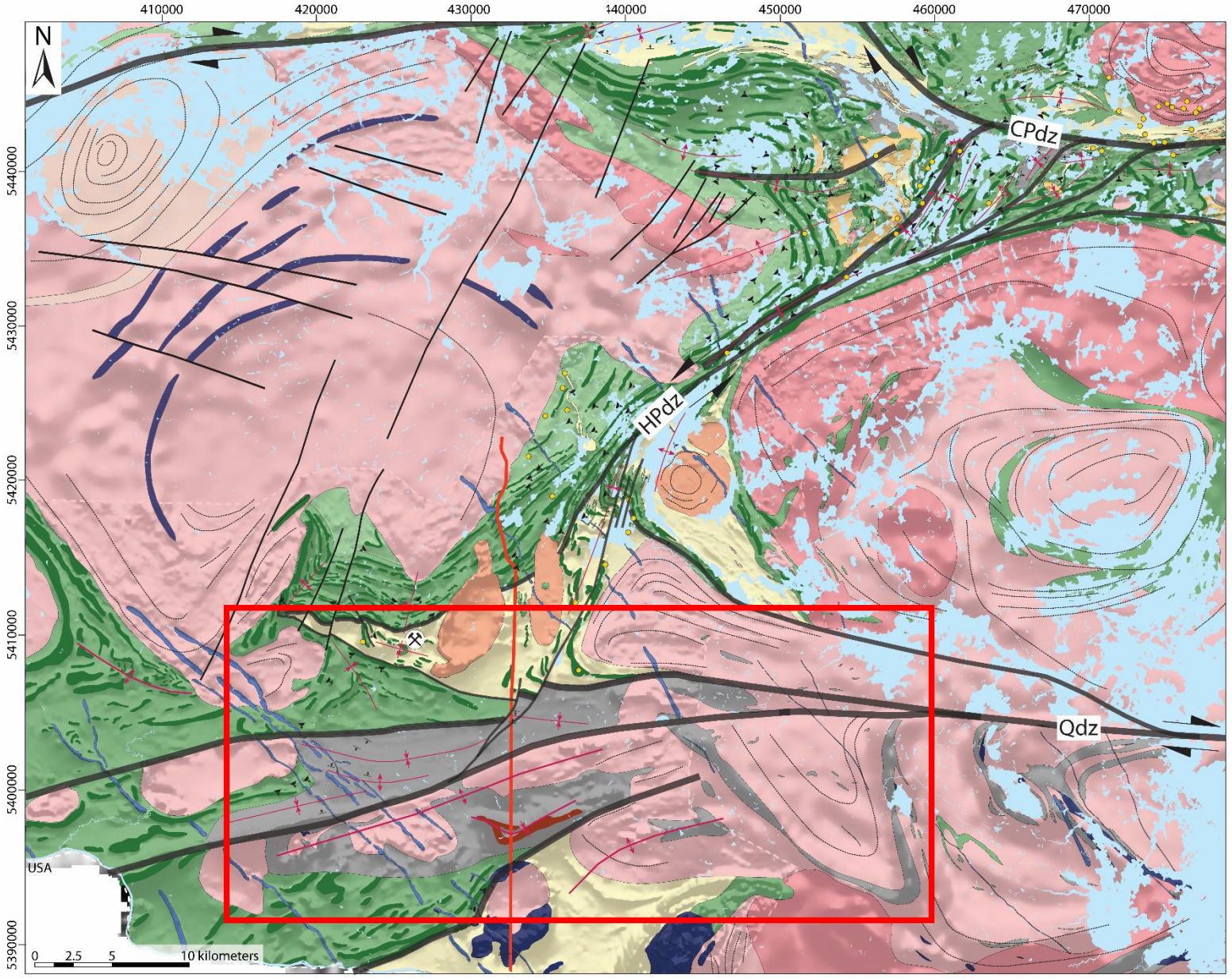

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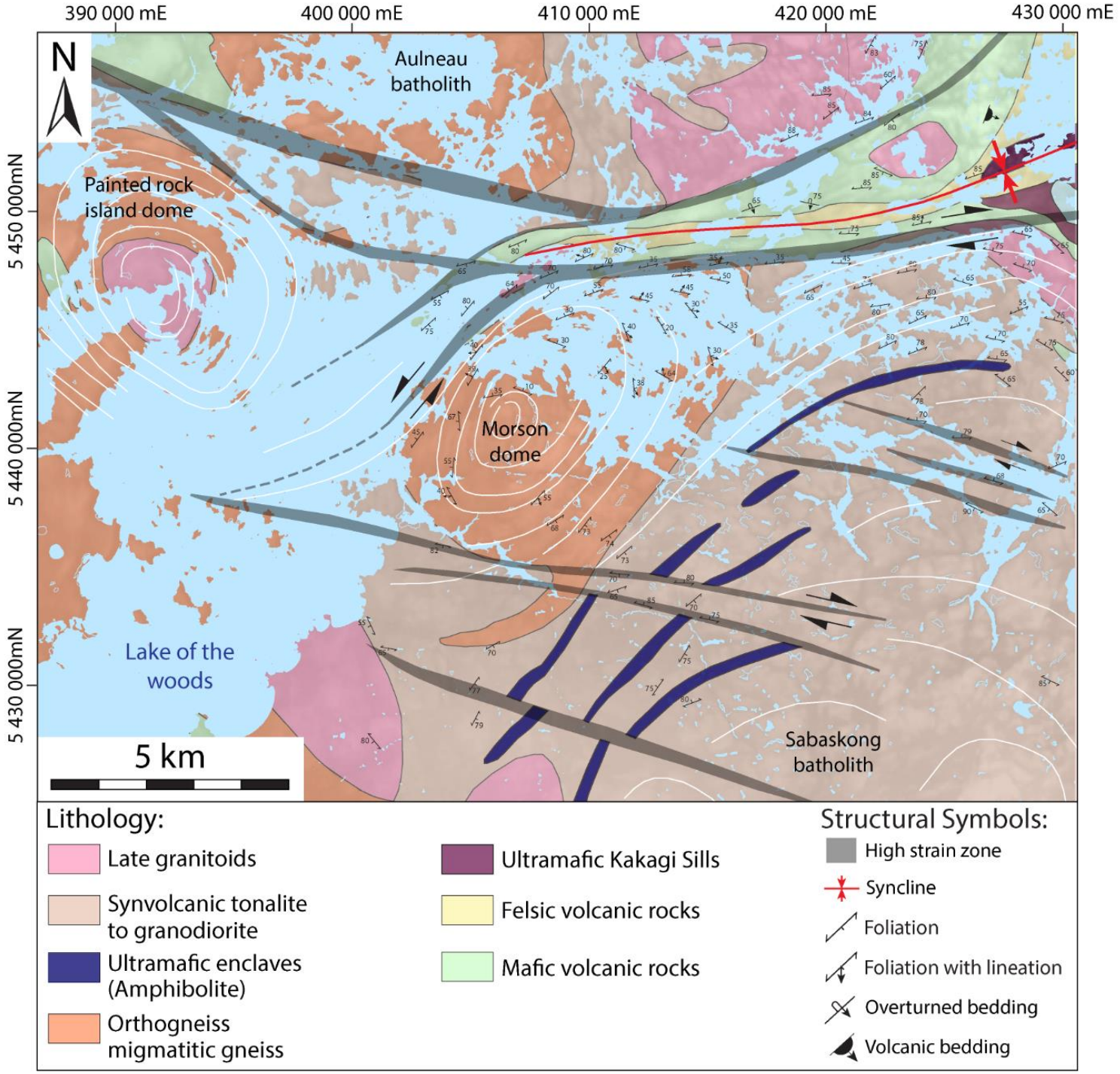
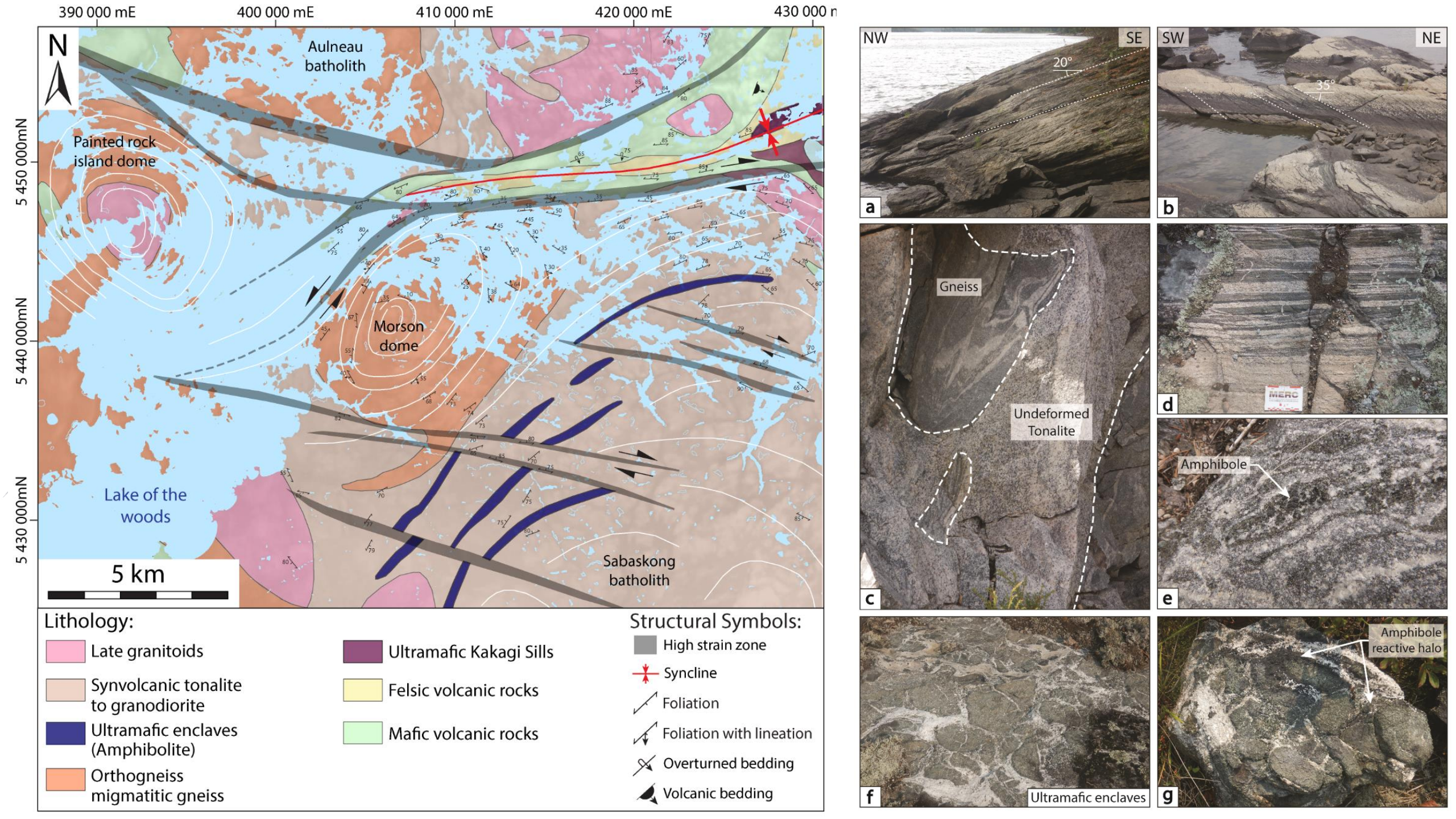
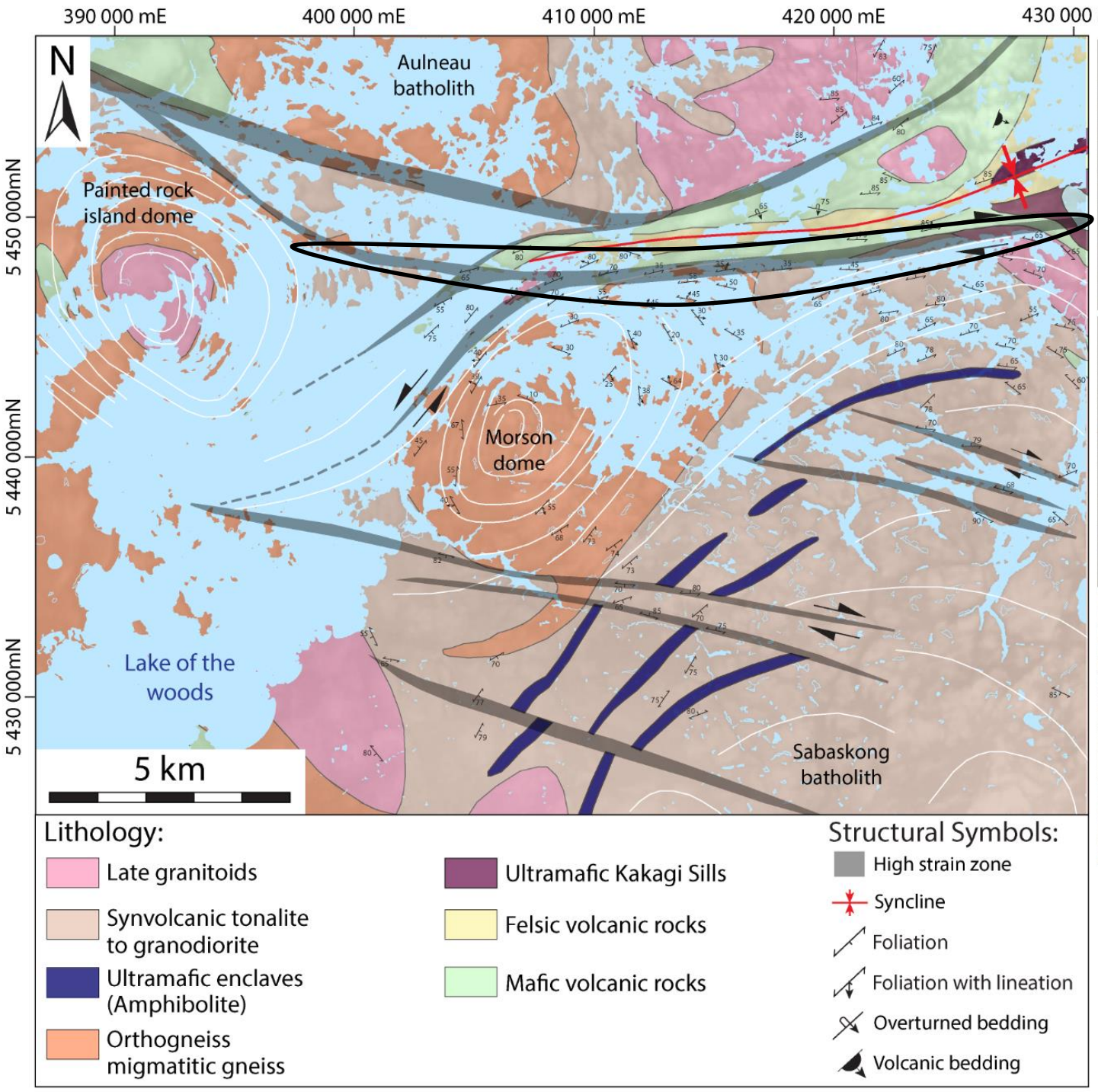
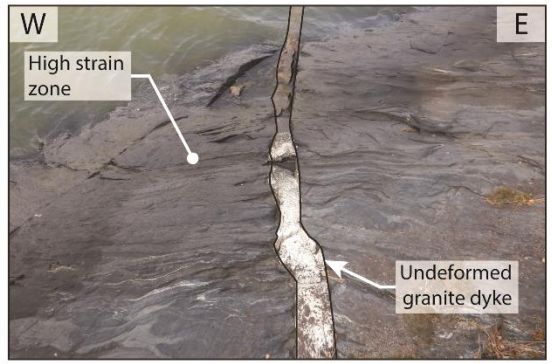
Morson gneissic dome

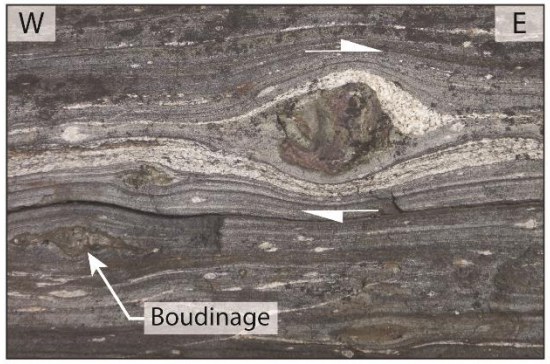


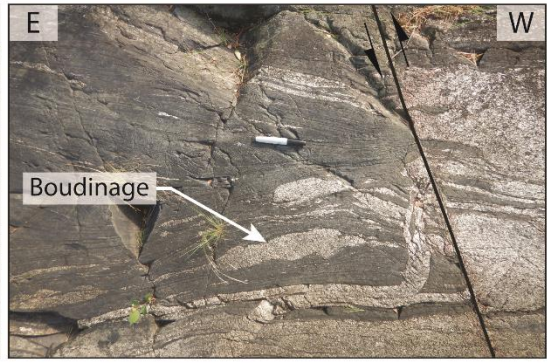
- Domes of orthogneiss and migmatitic gneiss enclosed within synvolcanic tonalite-granodiorite
- Bt-Hbl-Kfsp orthogneiss
- Domes bounded to the North by a dextral deformation zone


390 000 mE
400 000 mE
410 000 mE
420 000 mE
430 000 mE
5 450 000mN
5 440 000mN
5 430 000mN
N
Aulneau batholith
Painted rock island dome
Morson dome
Lake of the woods
Sabaskong batholith
5 km
Lithology:
Late granitoids
Synvolcanic tonalite to granodiorite
Ultramafic enclaves (Amphibolite)
Orthogneiss migmatitic gneiss
Ultramafic Kakagi Sills
Felsic volcanic rocks
Mafic volcanic rocks
Structural Symbols:
High strain zone
Syncline
Foliation
Foliation with lineation
Overturned bedding
Volcanic bedding
NW
SE
20°
a
SW
NE
35°
b
Gneiss
Undeformed Tonalite
c
d
Amphibole
e
f
Ultramafic enclaves
g
Amphibole reactive halo



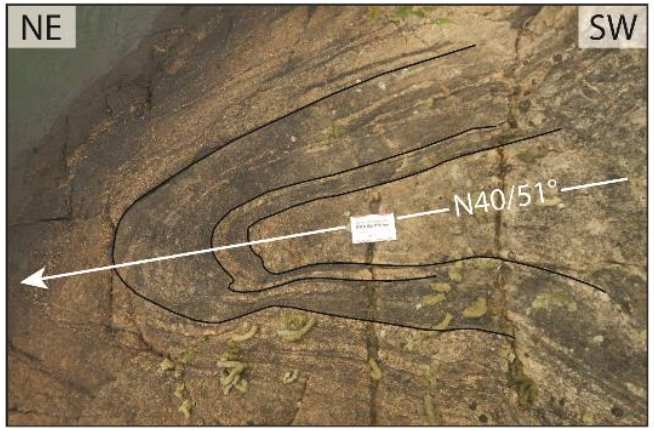


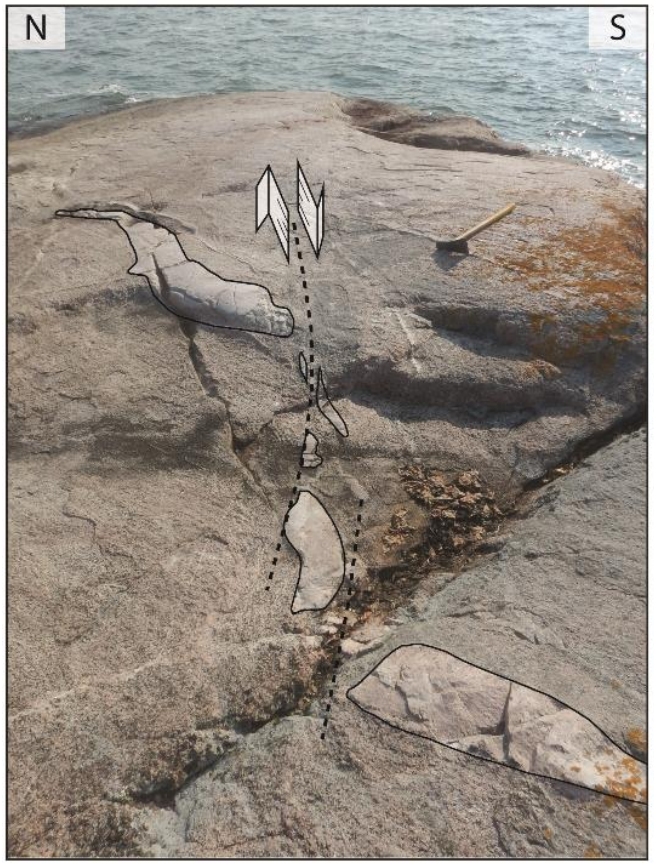


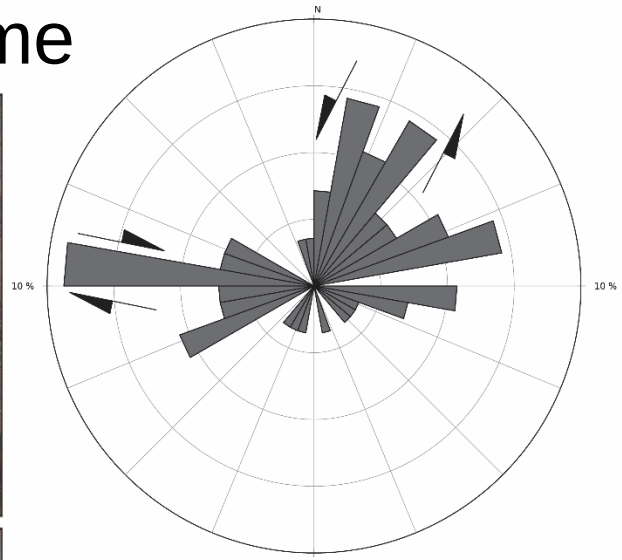


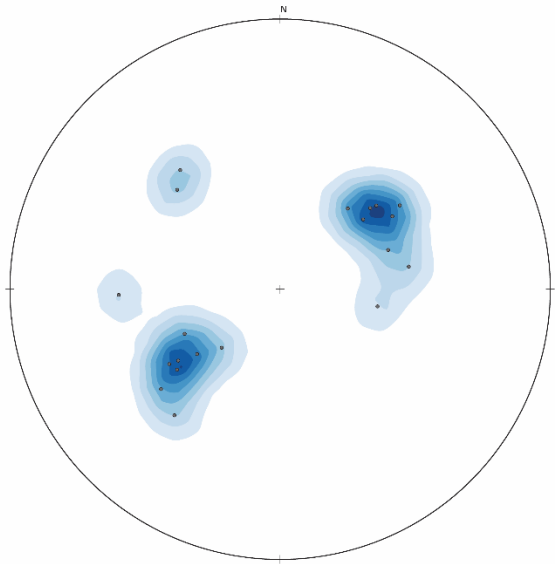
- Morson gneissic dome bounded to the North by E-W mylonitic deformation zone
- Dextral sense of shearing
- Deformation associated with felsic magmatism

Exhumation of the Morson gneissic dome

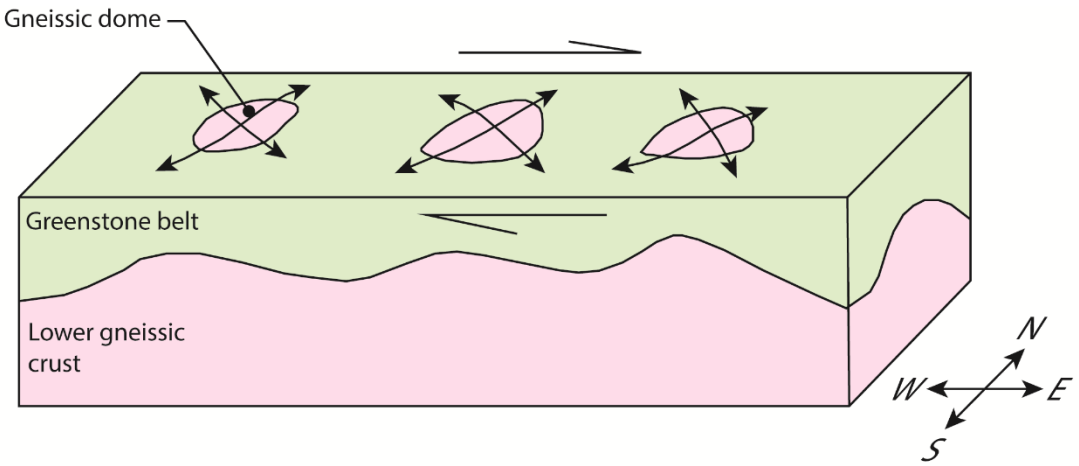




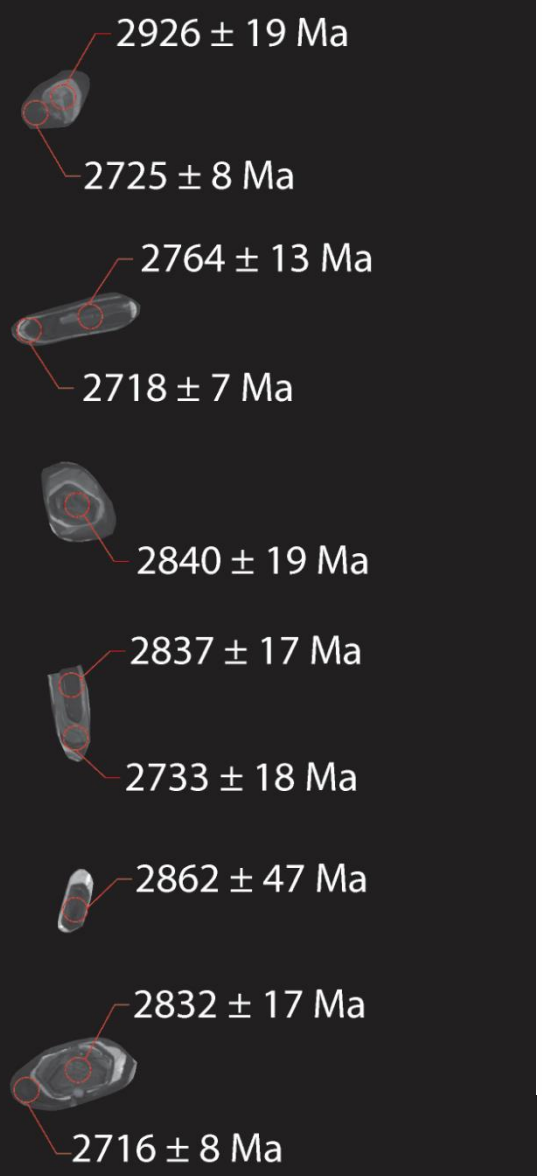


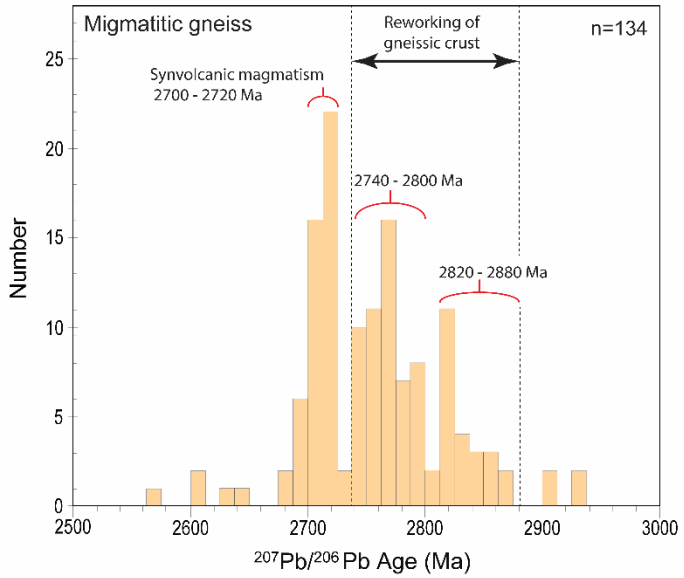


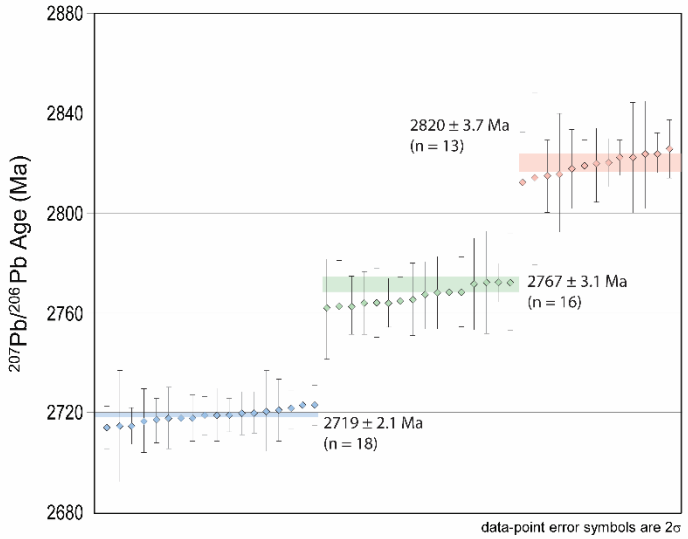
- Conjugated dextral and sinistral shear zones
- NE-SW folding of gneiss = NW-SE shortening
- **Exhumation of gneissic dome during NW-SE transpressive deformation with a dextral sense of shearing**

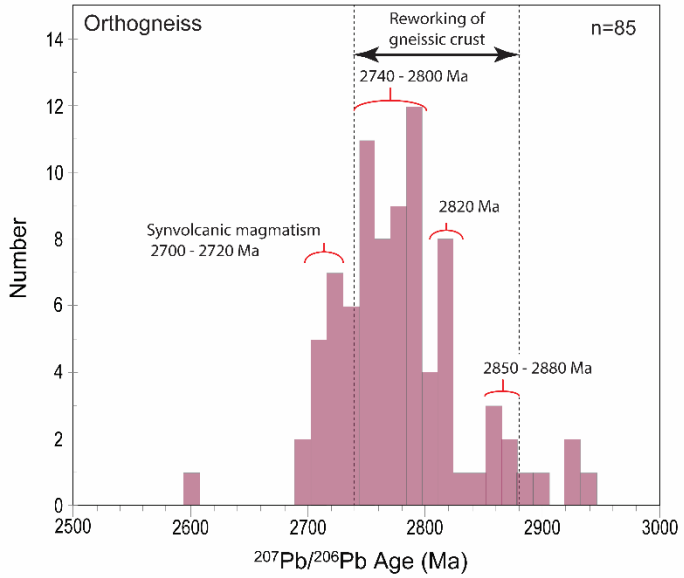


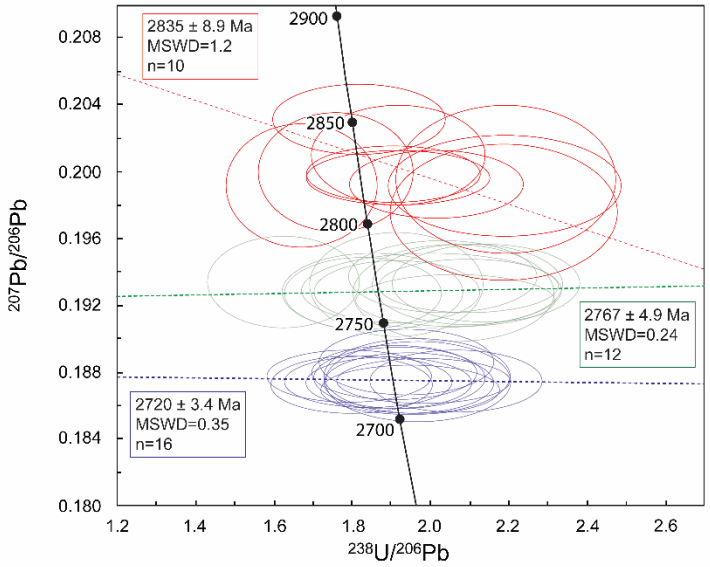
Migmatitic gneiss





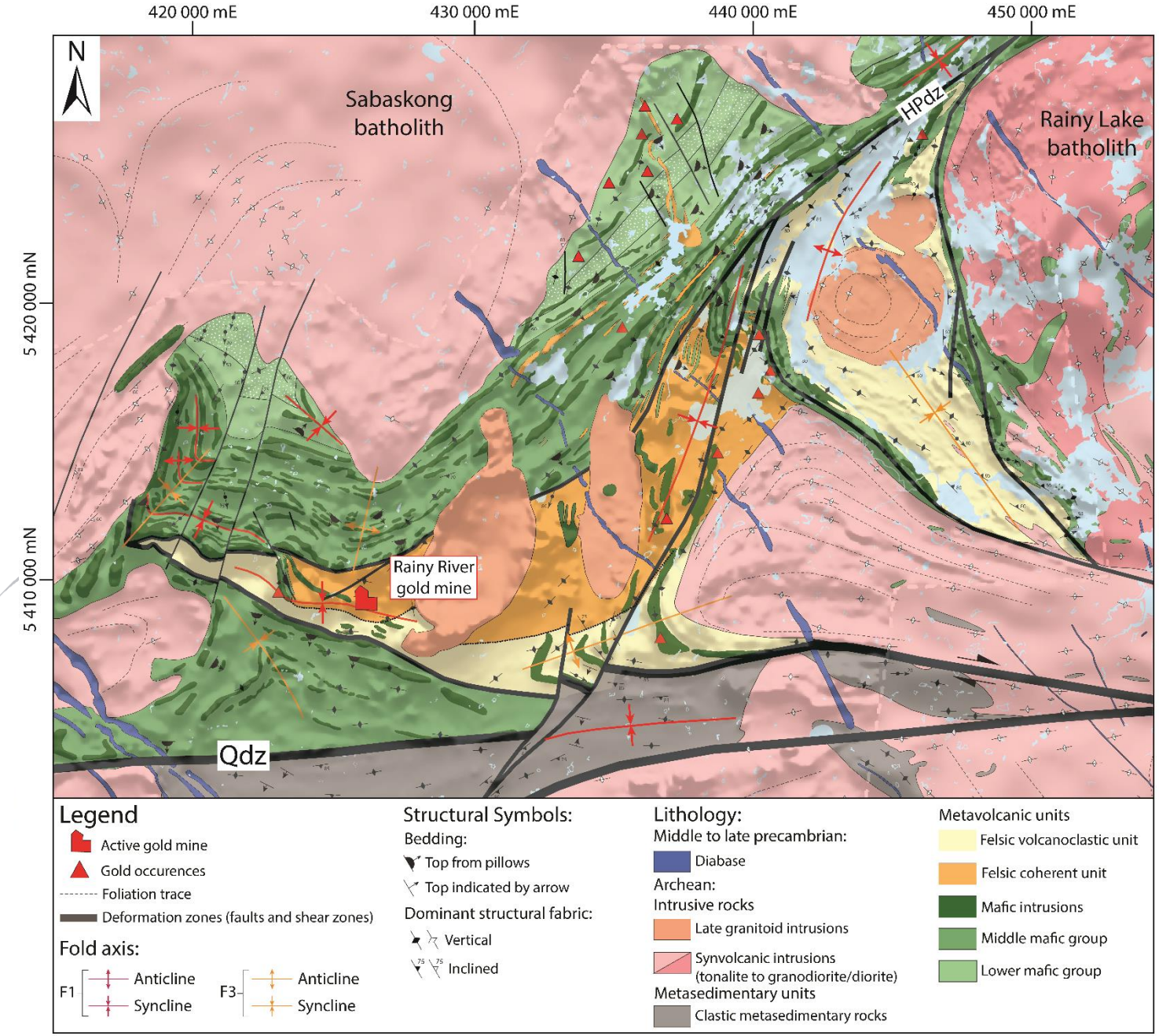


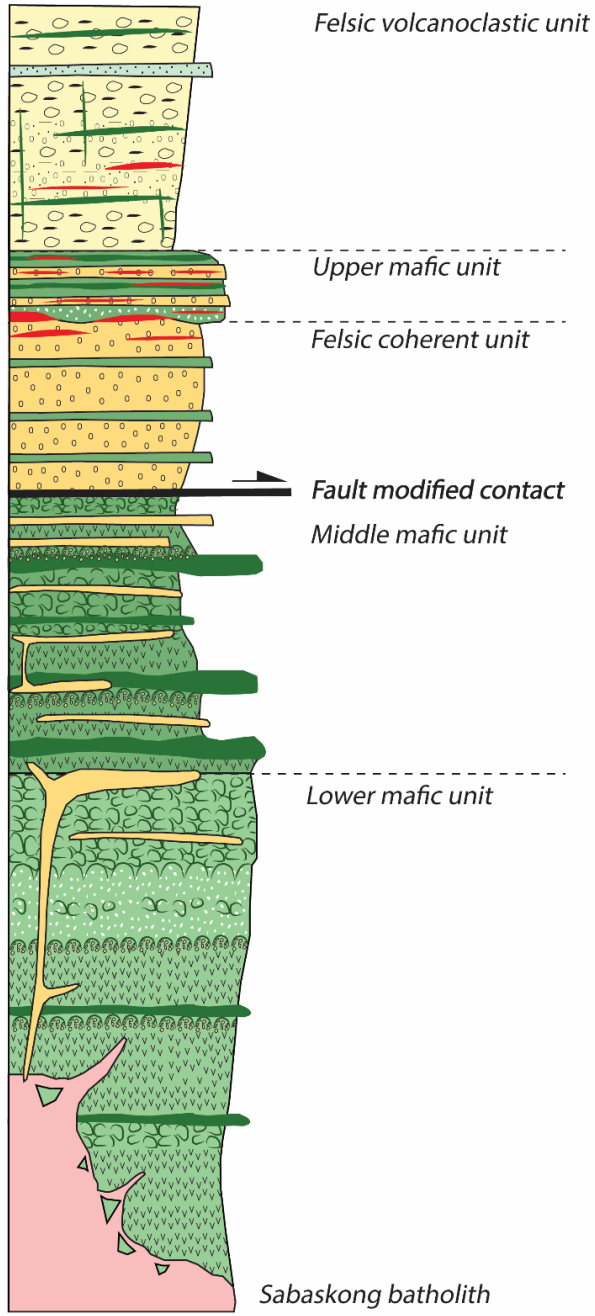


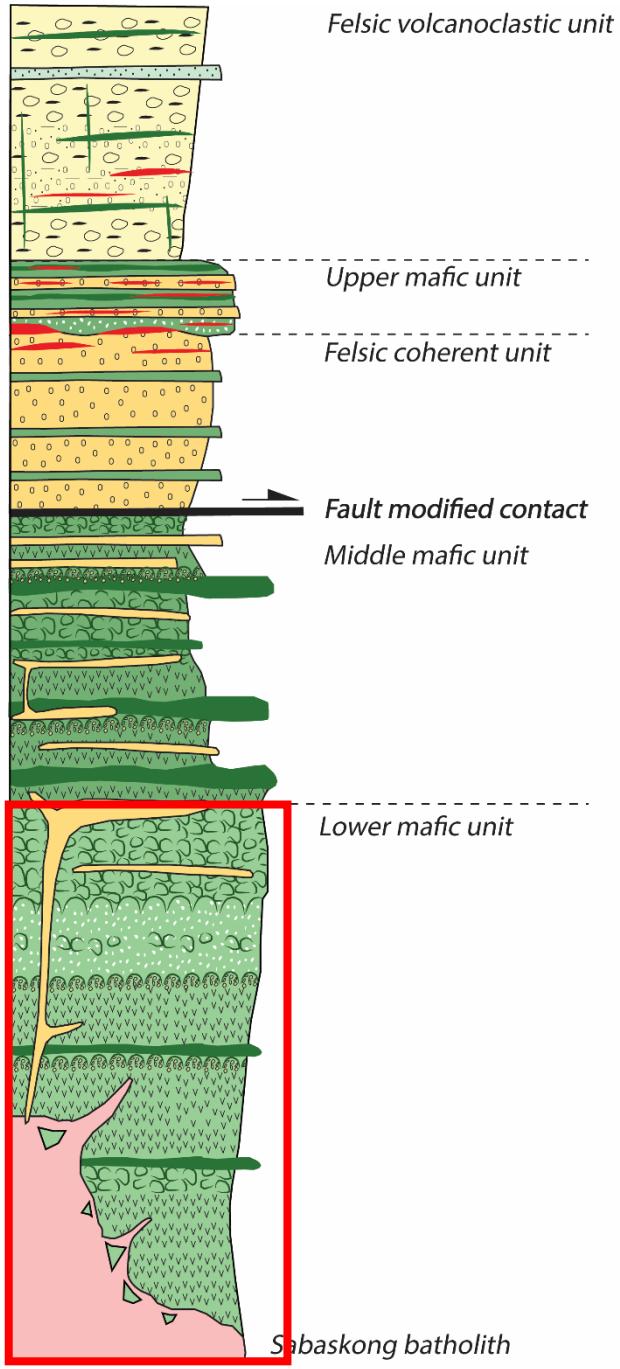


- Existence of an old (2820-2880 Ma) gneissic continental crust underlying the RRGB
- Reworking of the gneissic basement during magmatic events (2700-2720 Ma) related to the formation of the RRGB

Volcanic stratigraphy of the RRGB:



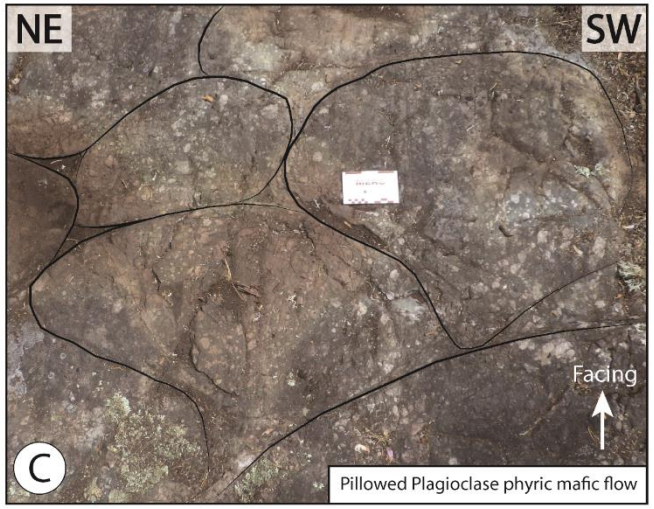




- Adjacent to Sabaskong batholith
- Massive and pillowed mafic flows
- Plagioclase and amphibole phyric mafic flows (stratigraphic marker)

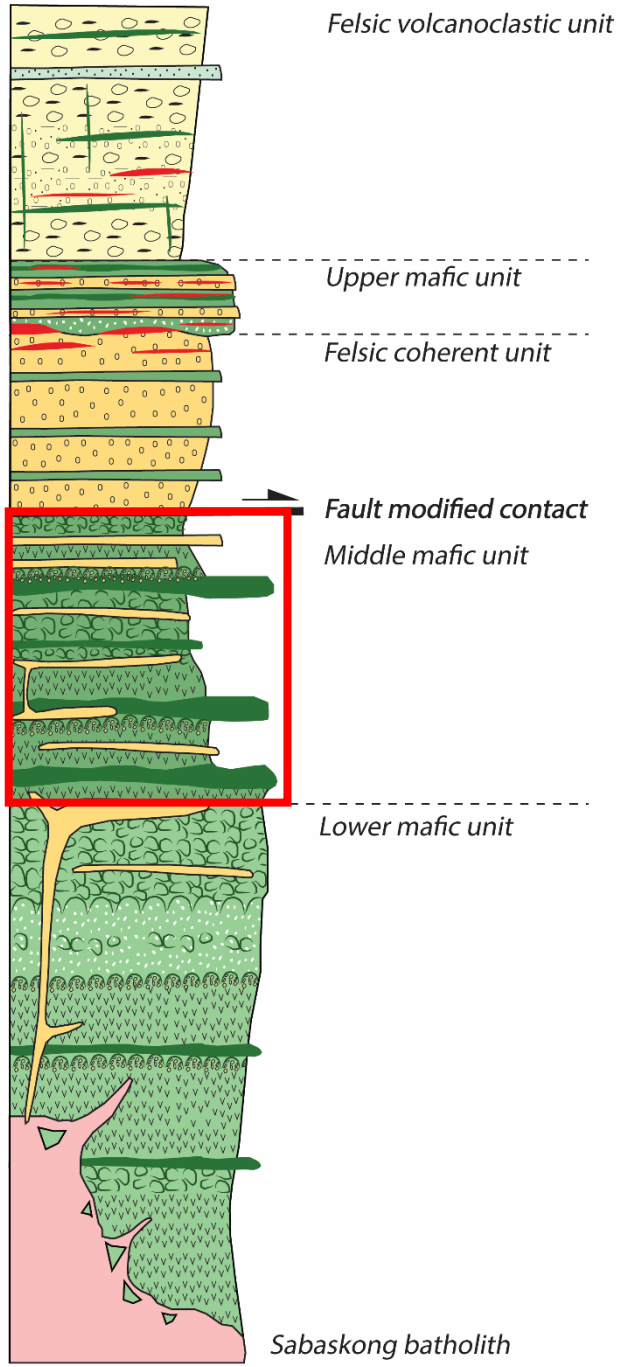
Stratigraphy of the RRGB:

I- Lower mafic unit

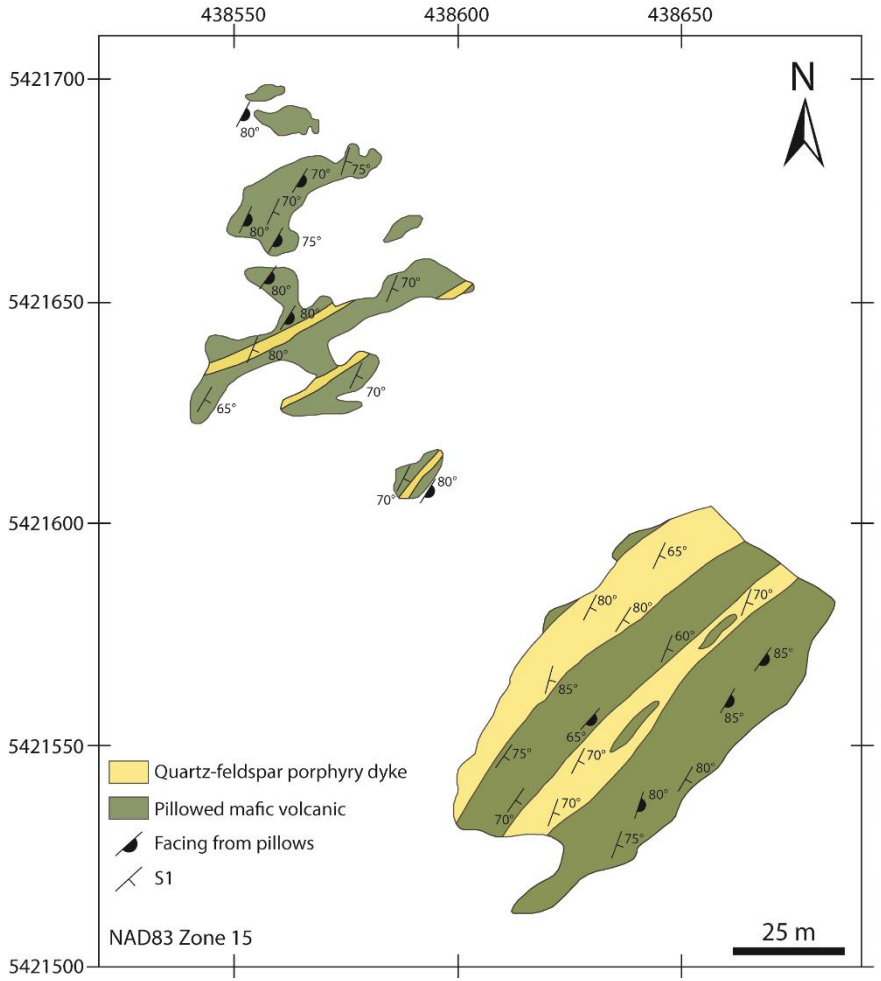


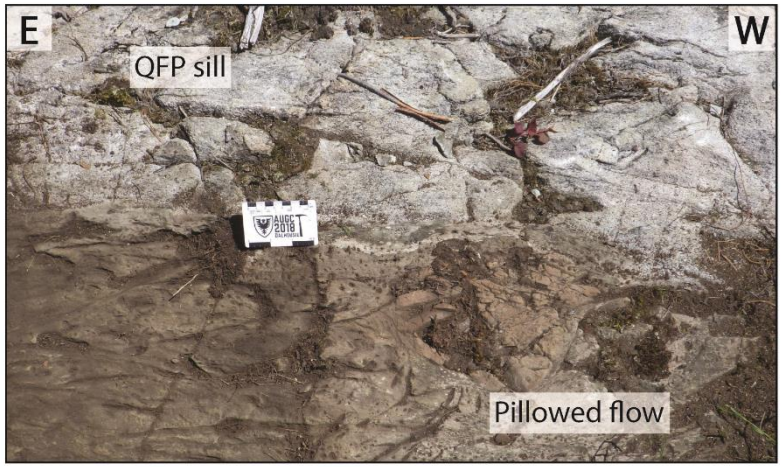
Stratigraphy of the RRGB:

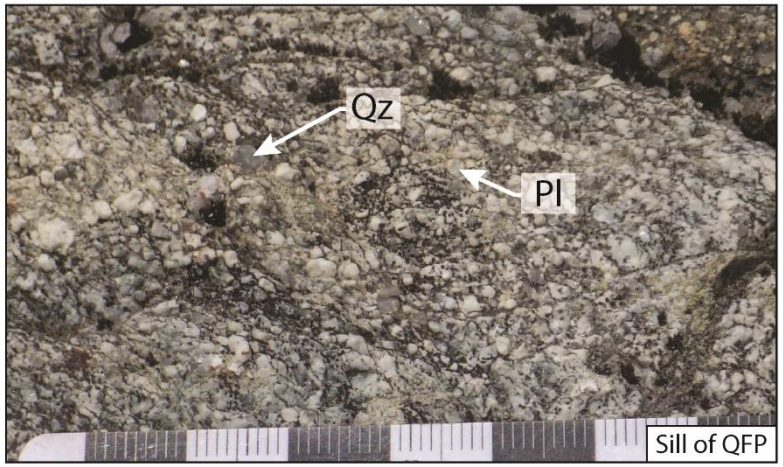
II- Middle mafic unit

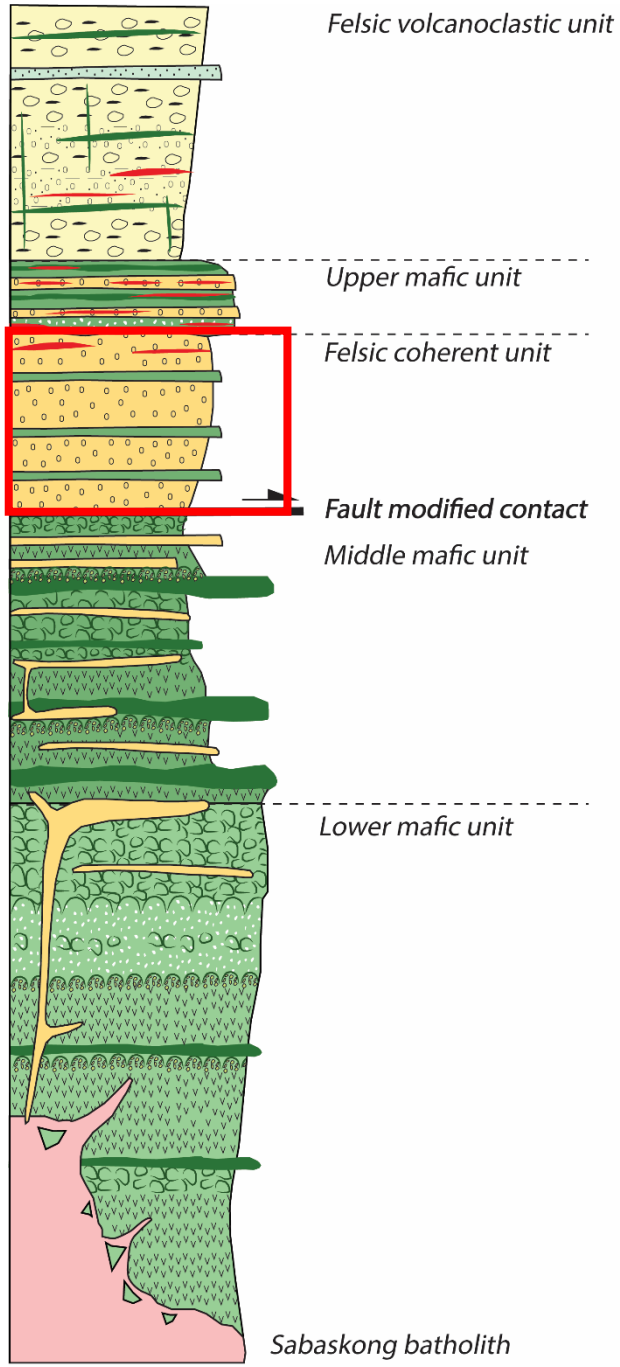


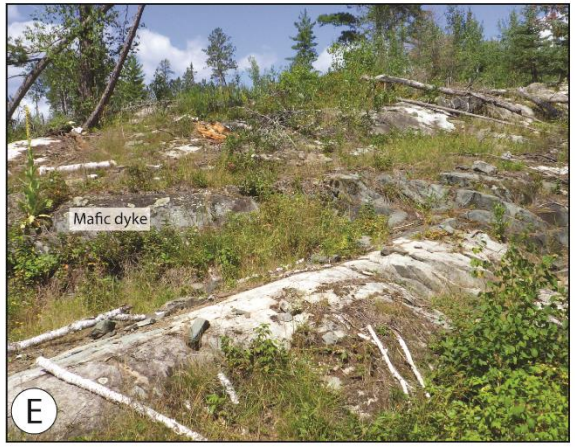
- Magnetic break with the lower mafic unit
- Massive basaltic flows with minor pillowed flows
- Felsic dikes and sills
- Numerous Gabbro sills







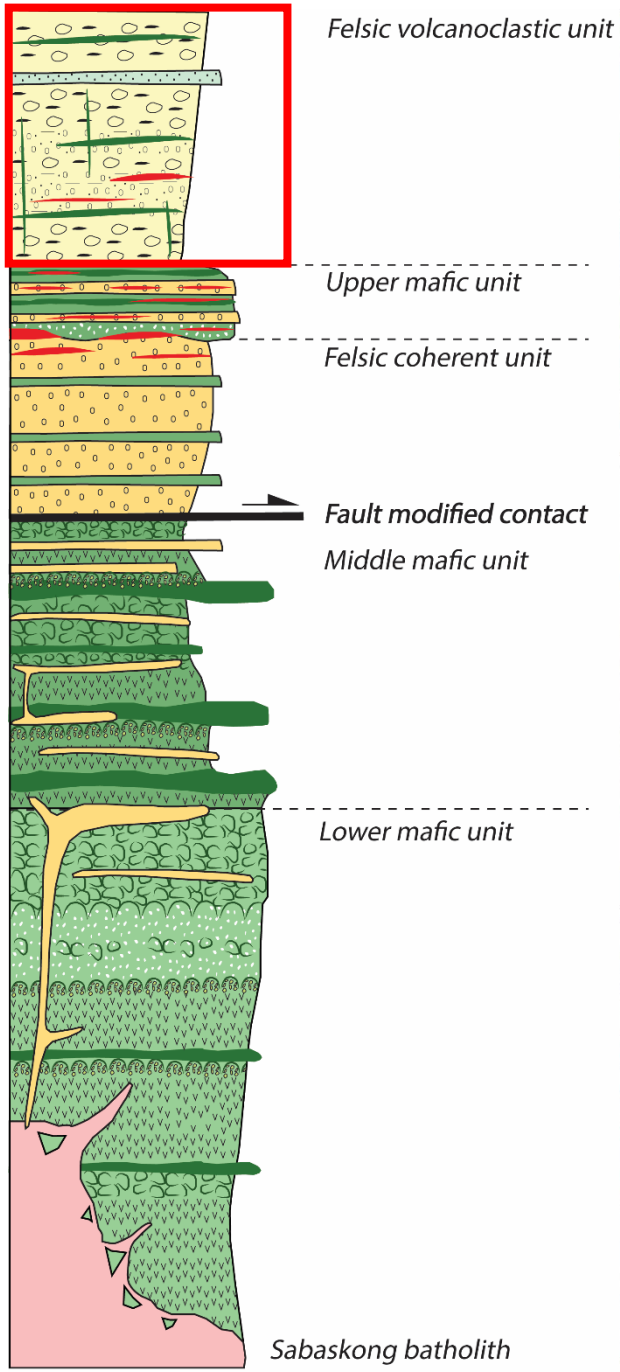




Stratigraphy of the RRGB:

III- Coherent felsic unit

- Fault modified contact with mafic unit
- Quartz-feldspar phyric felsic coherent bodies
- Flows and lobes locally observed
- Occurrences of mafic sills and dikes

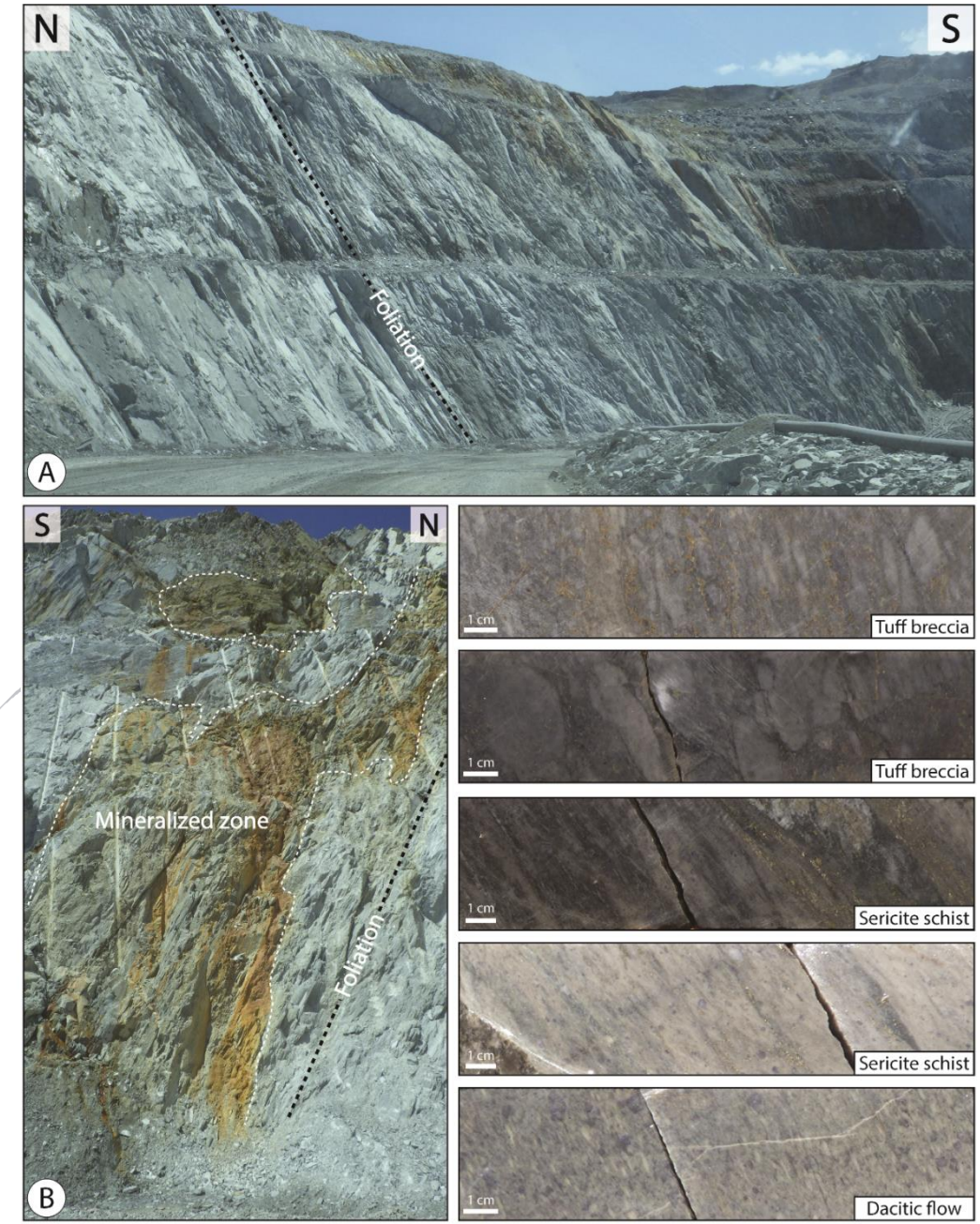


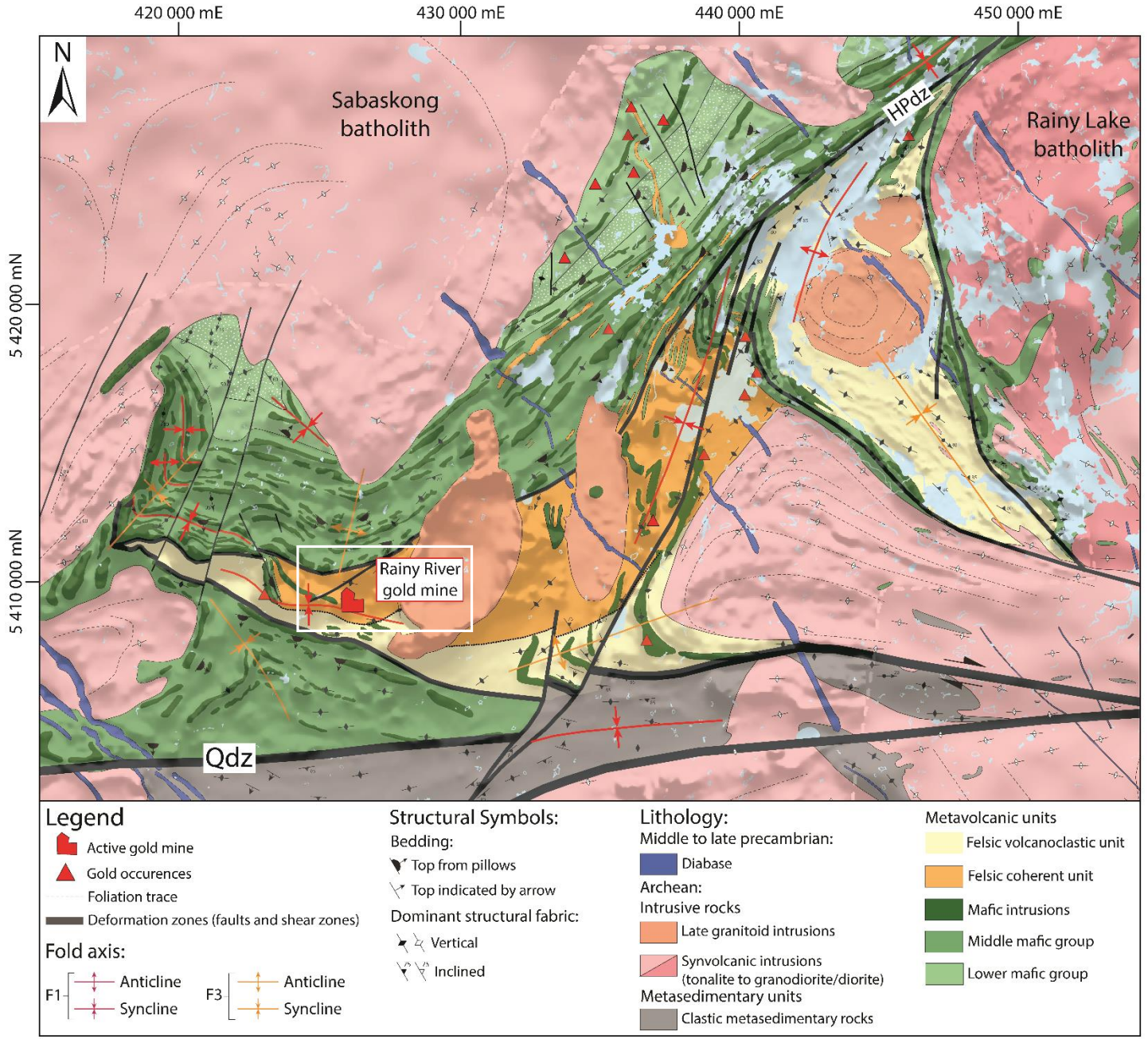
Stratigraphy of the RRGB:

IV- Volcanoclastic felsic unit

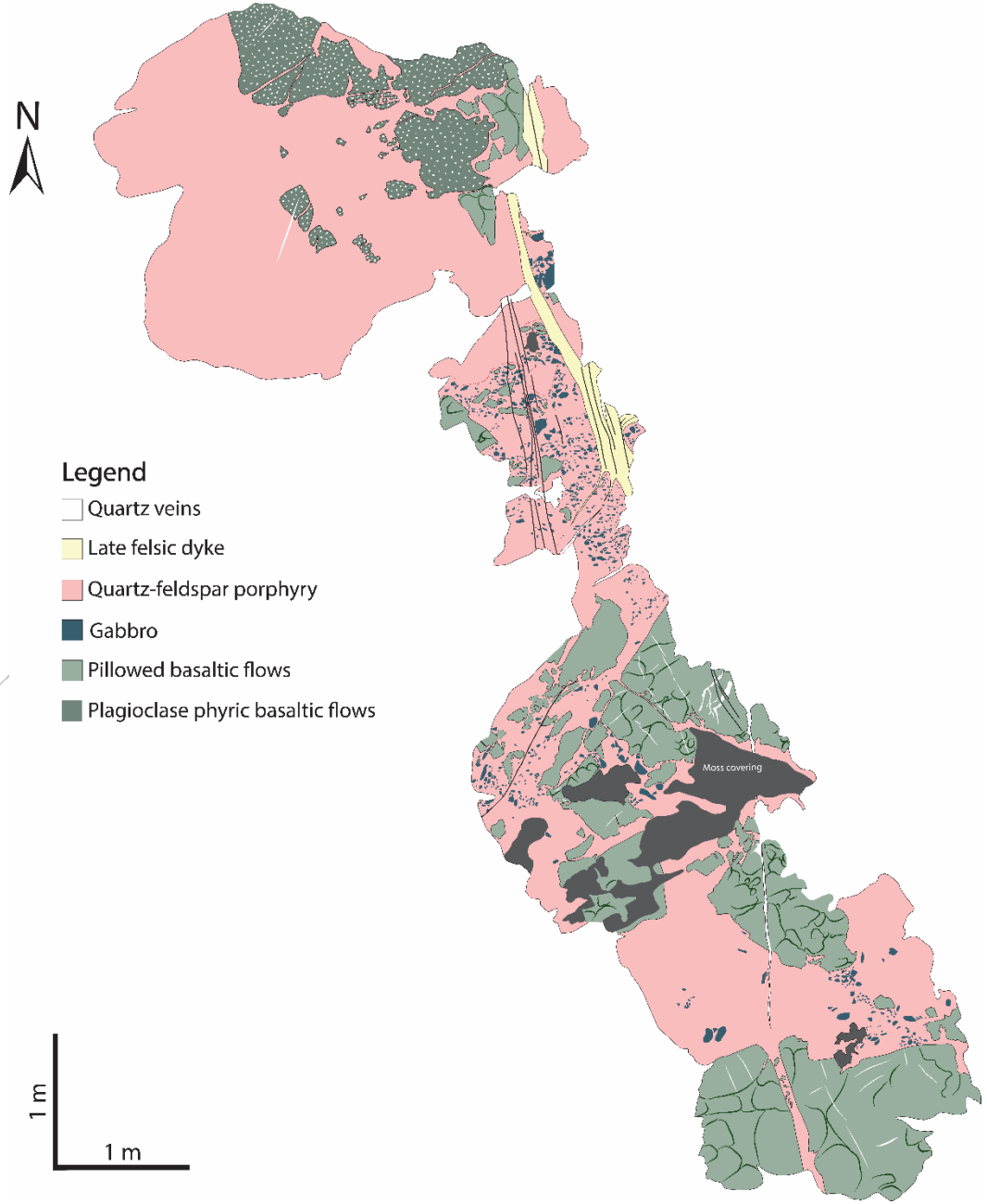
- Burditt Lake and Pinewood Lake volcanoclastic units are composed of the same lithofacies assemblages
- Tuff breccia, crystal-rich tuff and lapilli tuff
- Clasts of coarse-grained QFP surrounded by fine-grained matrix
- Mafic clasts occur in tuff breccia layers
- Sandstone layer interlayered with tuff breccia = submarine environment of deposition

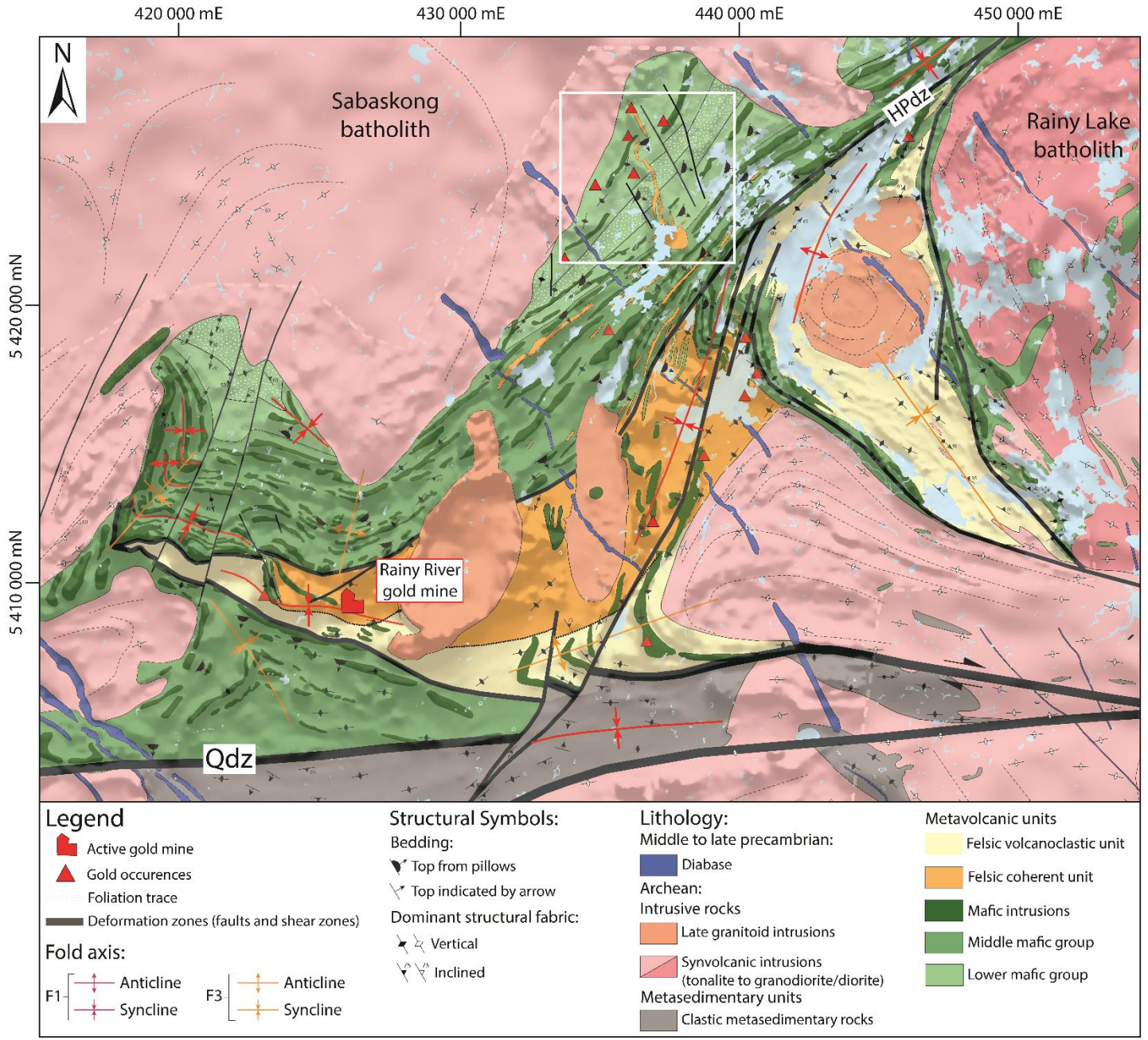
Synvolcanic Au-Ag sulphide mineralization (Rainy River gold mine)





Synvolcanic Au-Ag sulphide mineralization (Off Lake)





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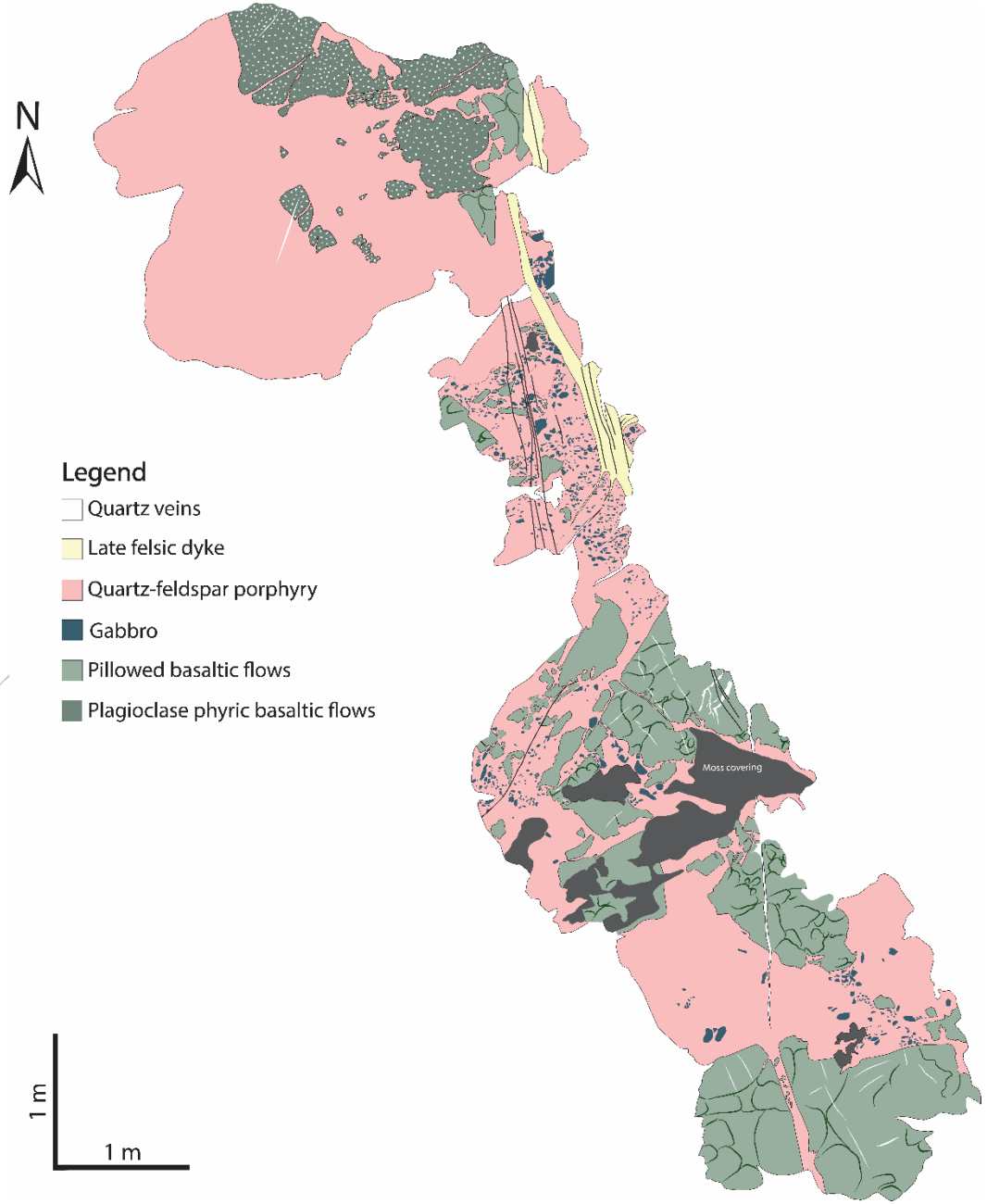
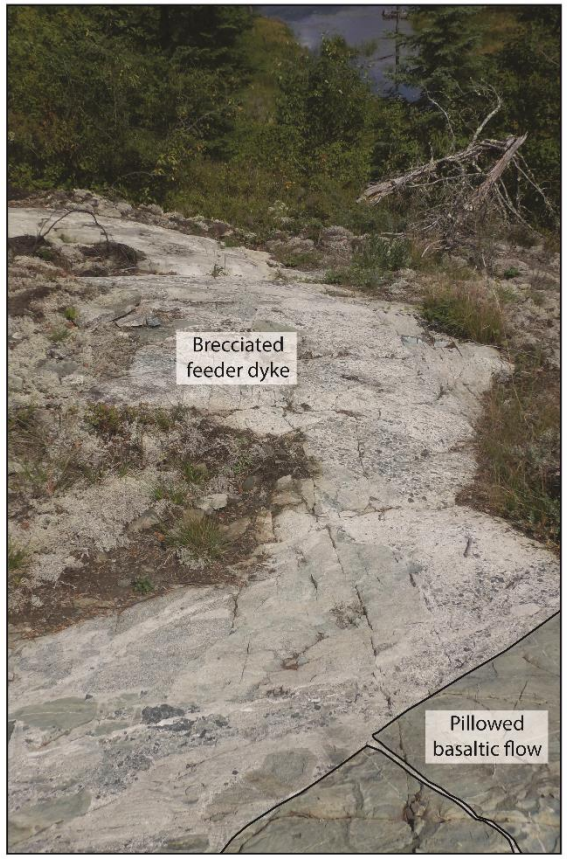
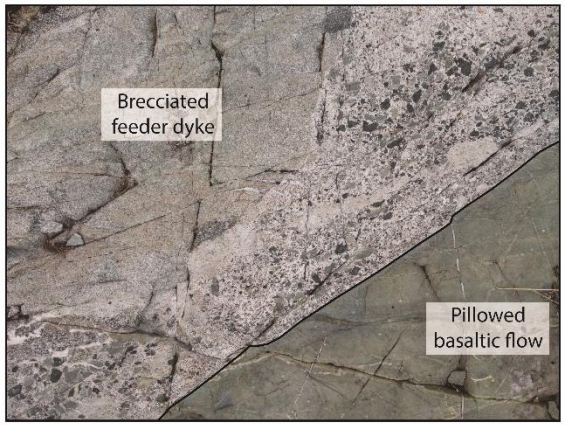
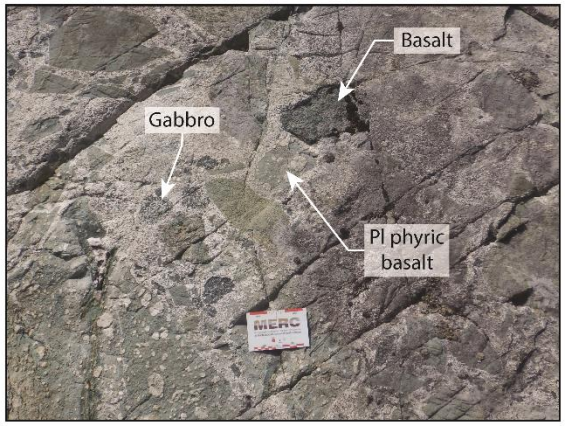
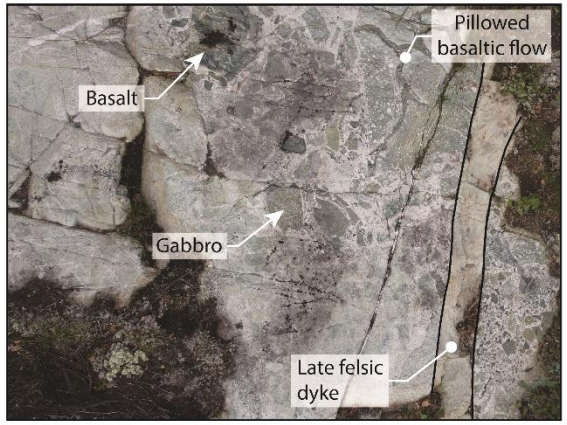


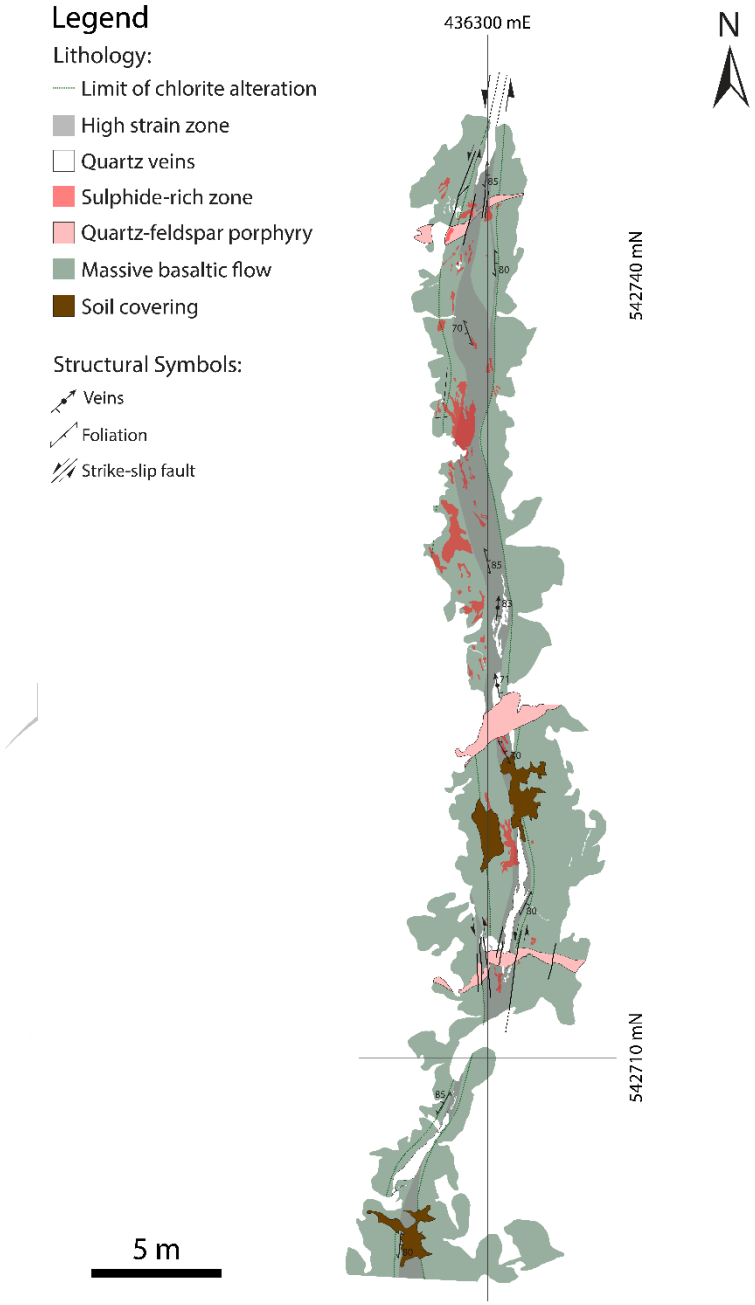


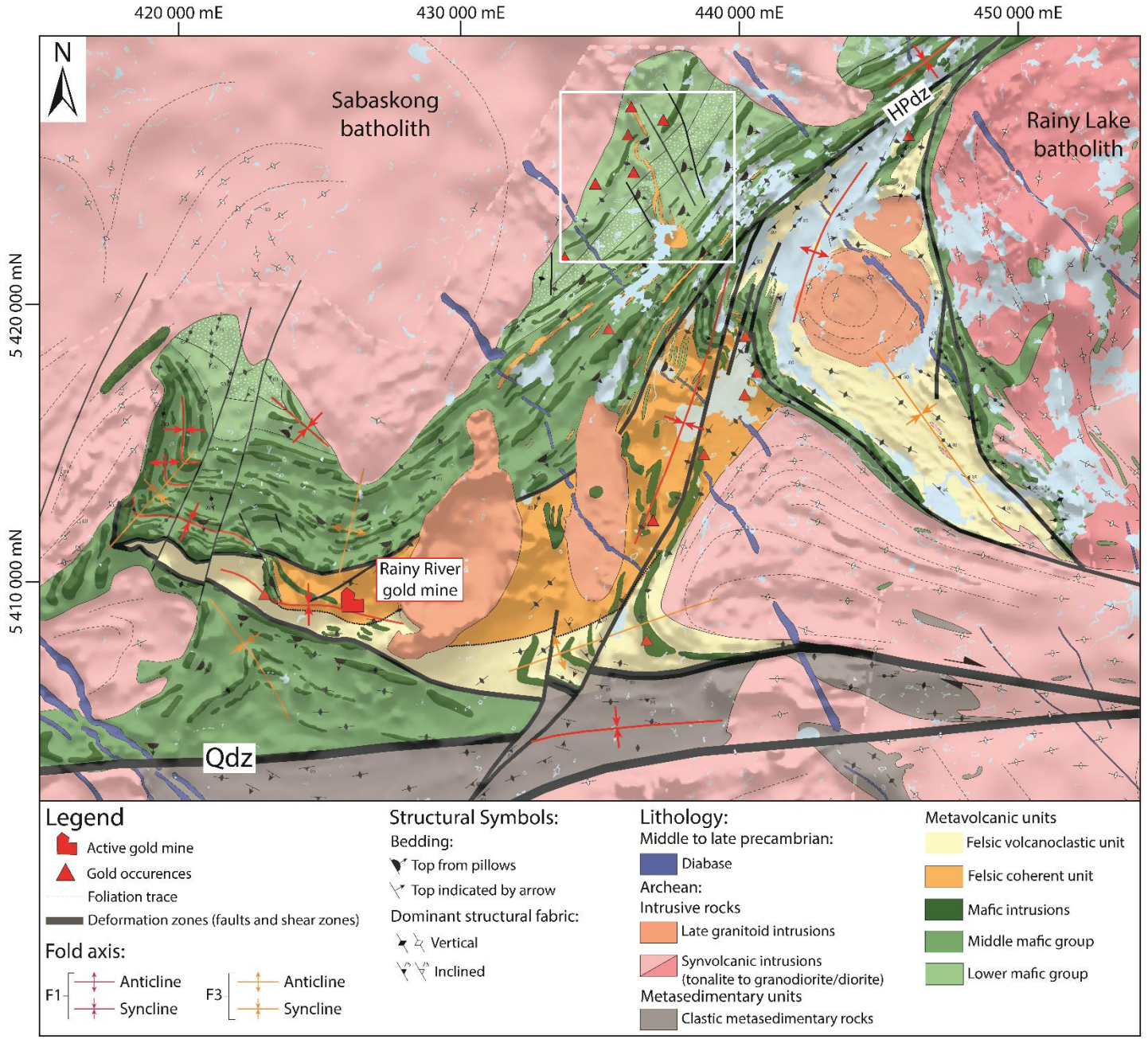






Synvolcanic Au-Ag sulphide mineralization (Off Lake)





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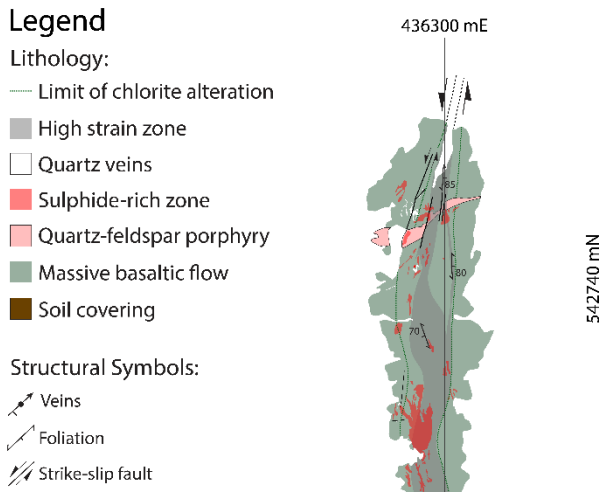
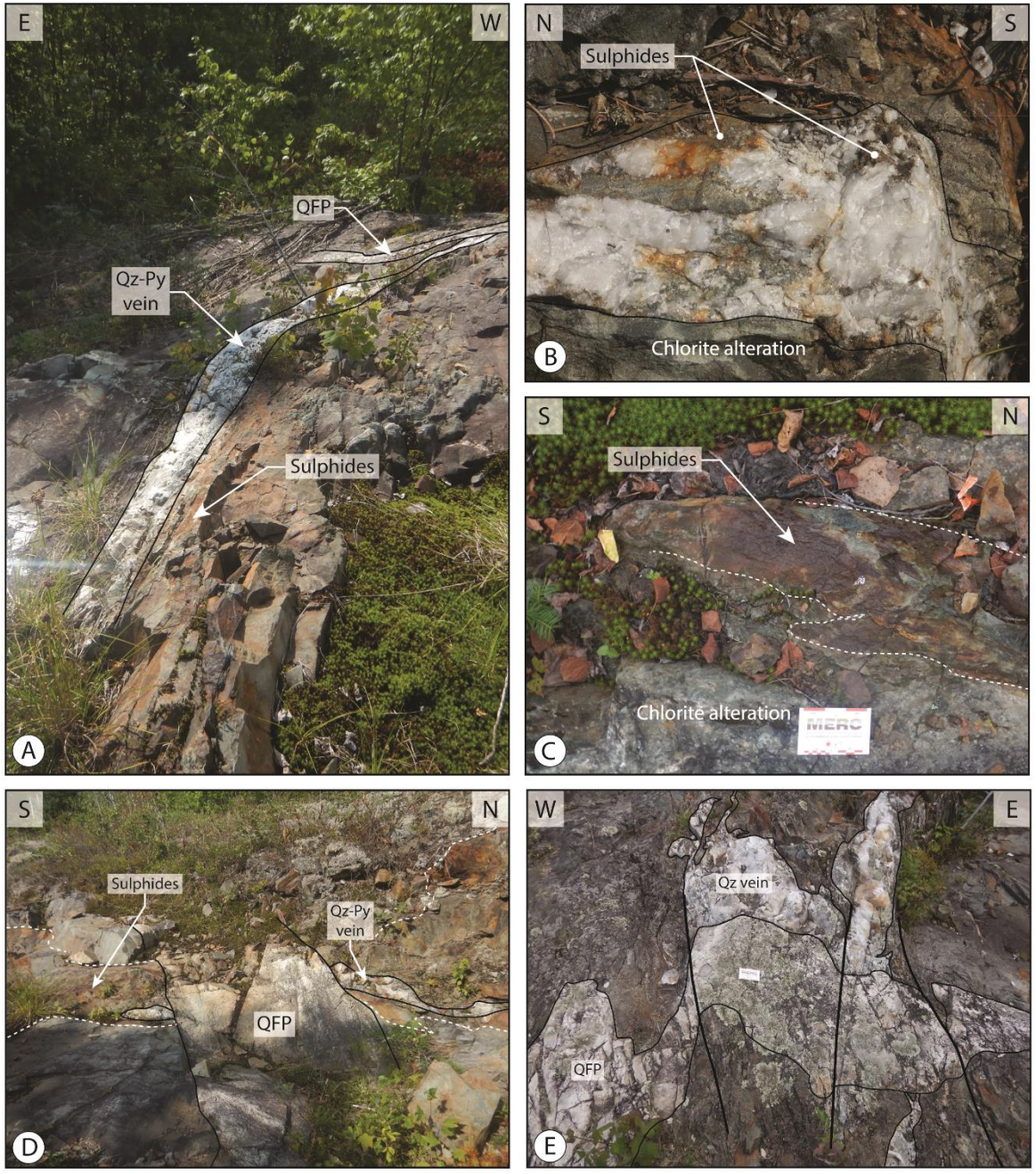
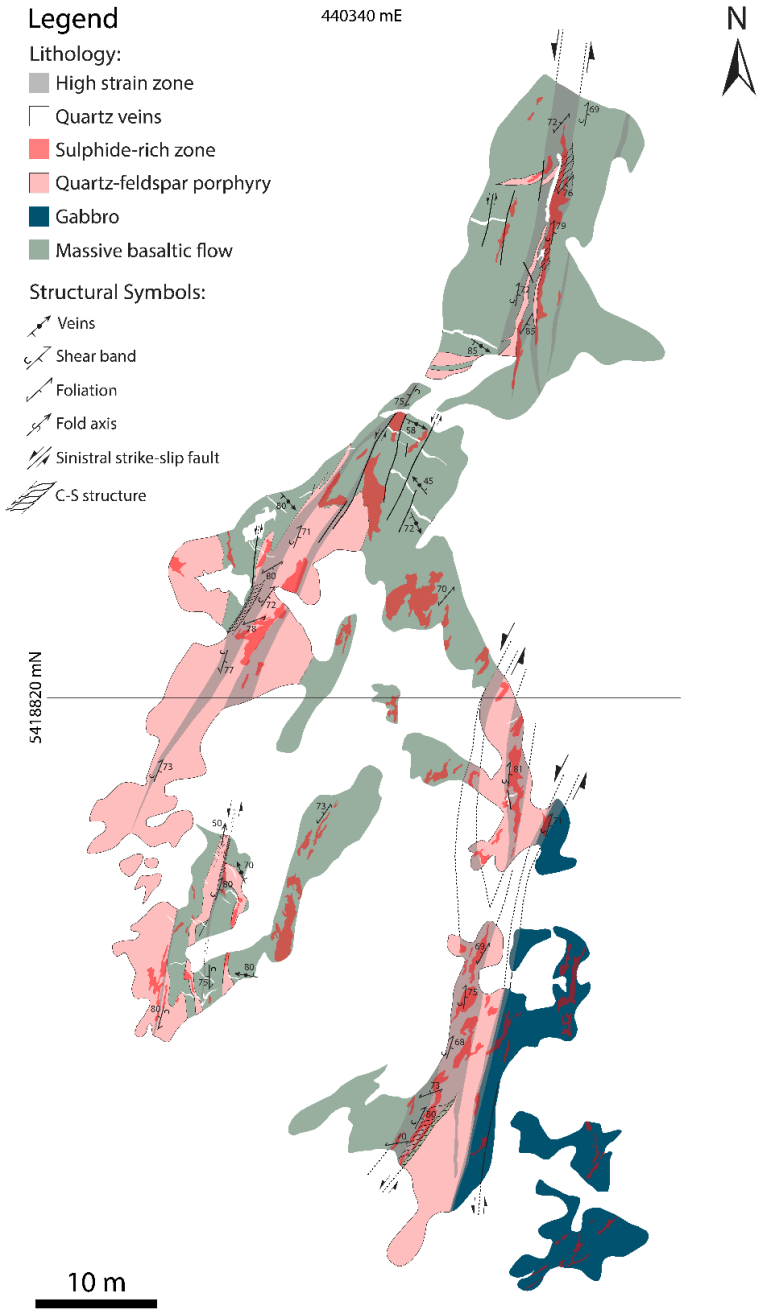
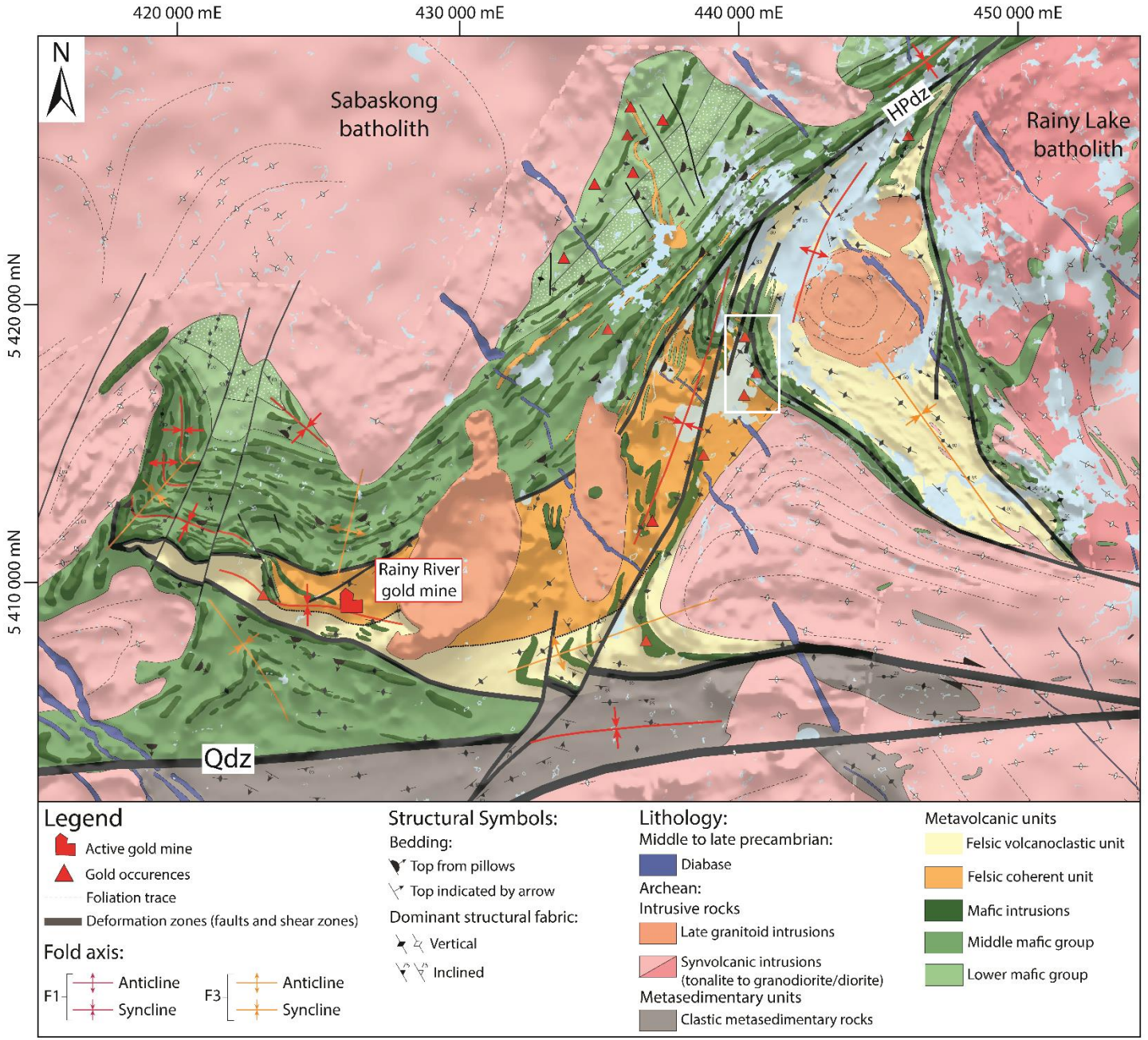




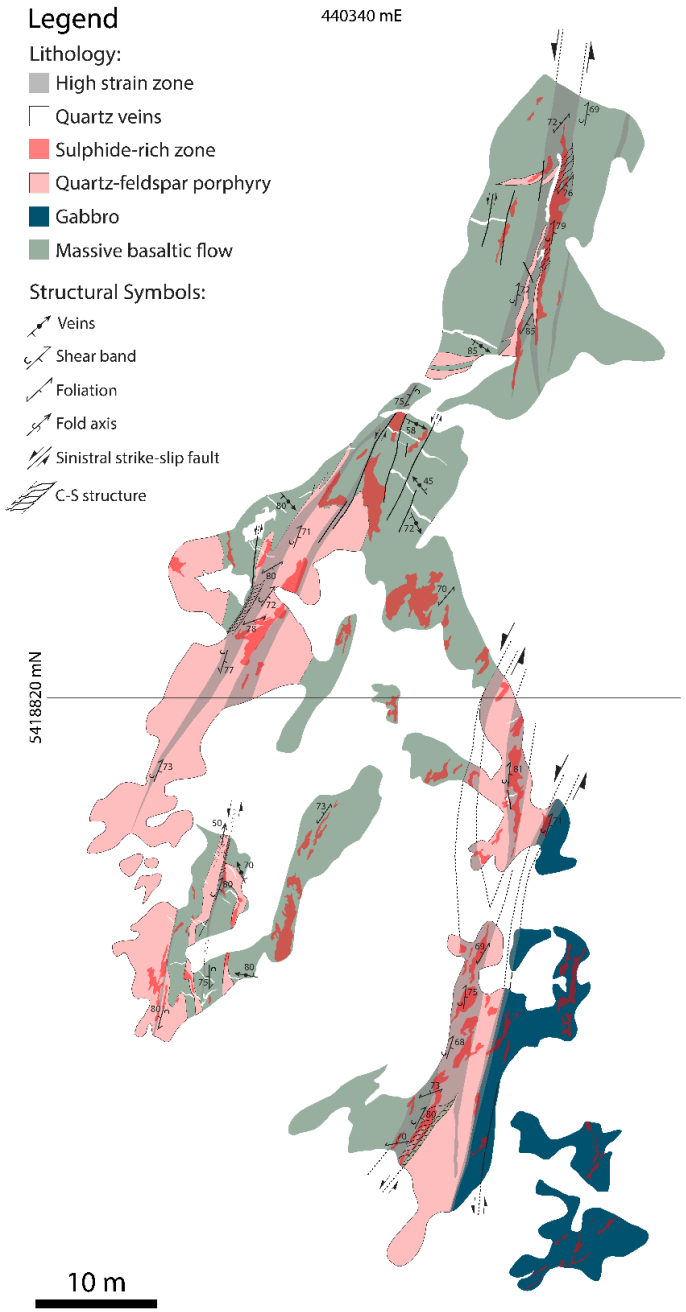
- Qz-Chl-Tur-Py veins
- Chl-Ep alteration
- Mineralized veins crosscut by QFP dikes/sills
- Deep hydrothermal system connecting the Sabaskong synvolcanic tonalite intrusion and the Au-Ag sulphides mineralization of Off Lake

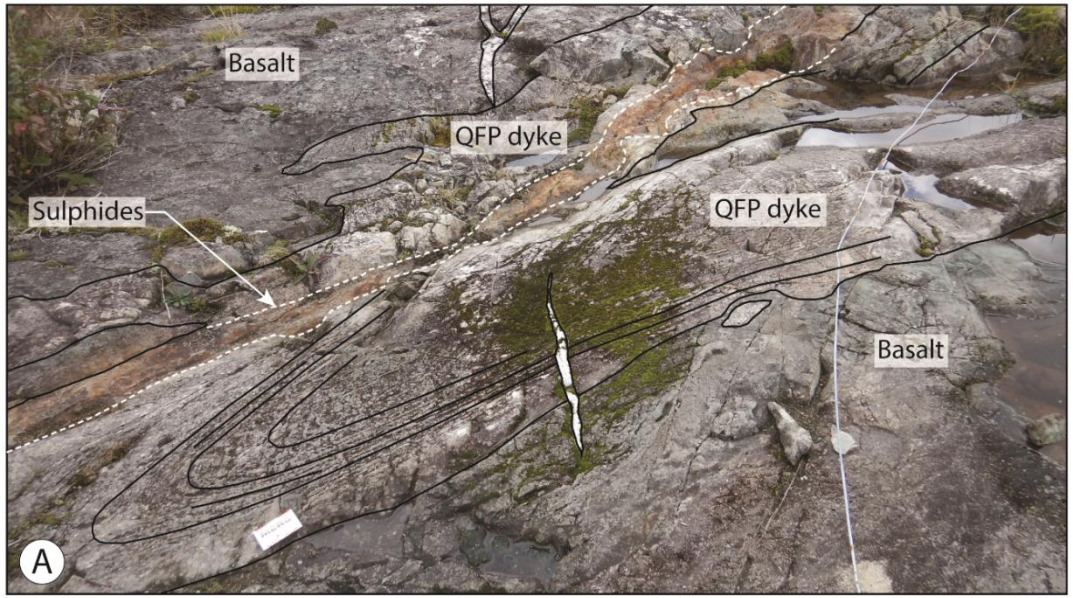
Synvolcanic Au-Ag sulphide mineralization (Off Lake)

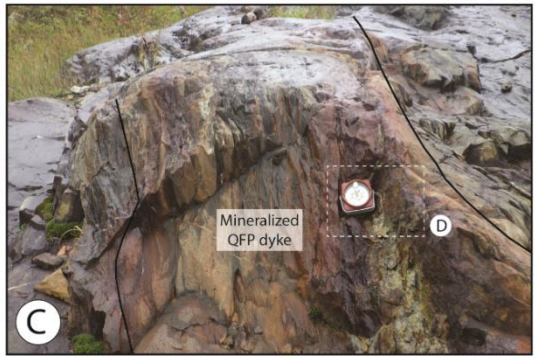


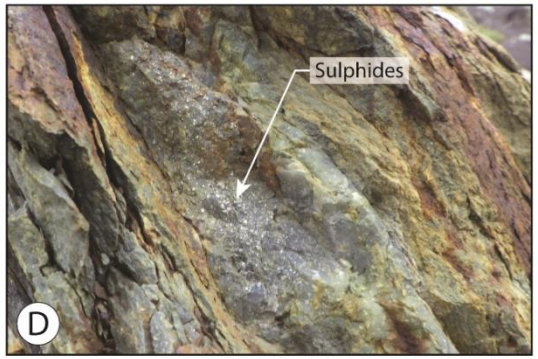


Synvolcanic Au-Ag sulphide mineralization (Off Lake)

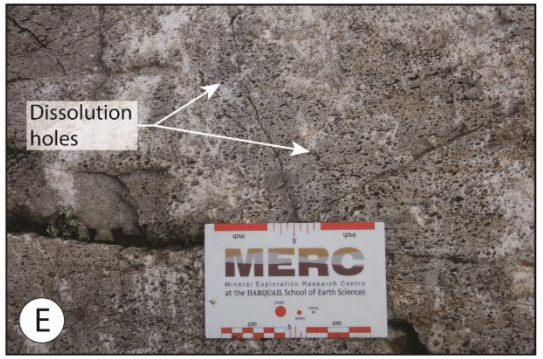


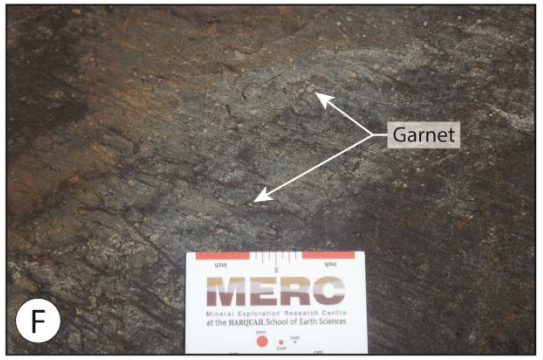




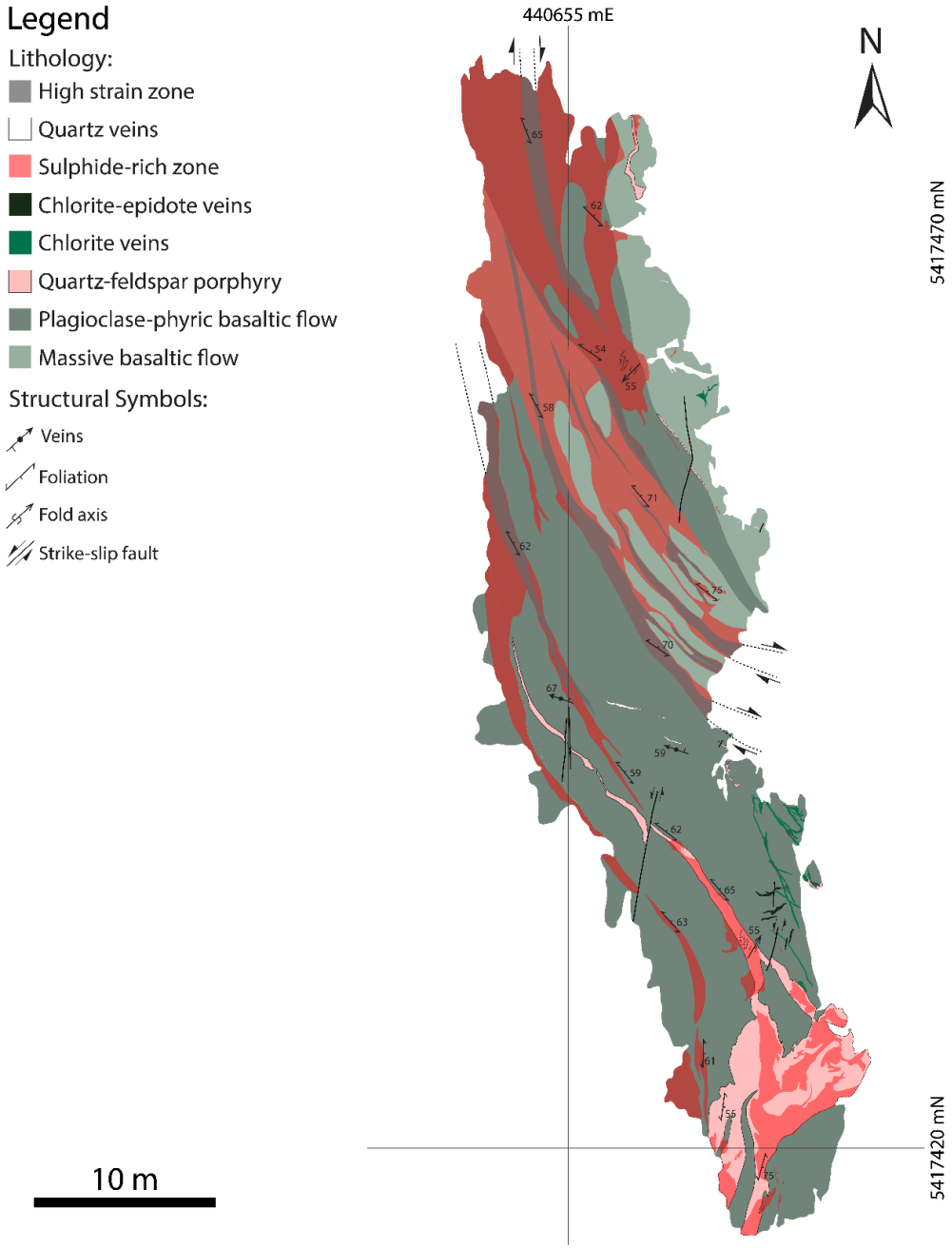


- Py-Cpy-Sp occurrences at the top of the felsic coherent unit (roof of rhyolitic cryptodome)
- Veinlets and disseminated sulphides mainly hosted by sills/dikes of QFP
- Chlorite-sericite alteration overprinted by Bt-Grt-Ky assemblage (metamorphism)



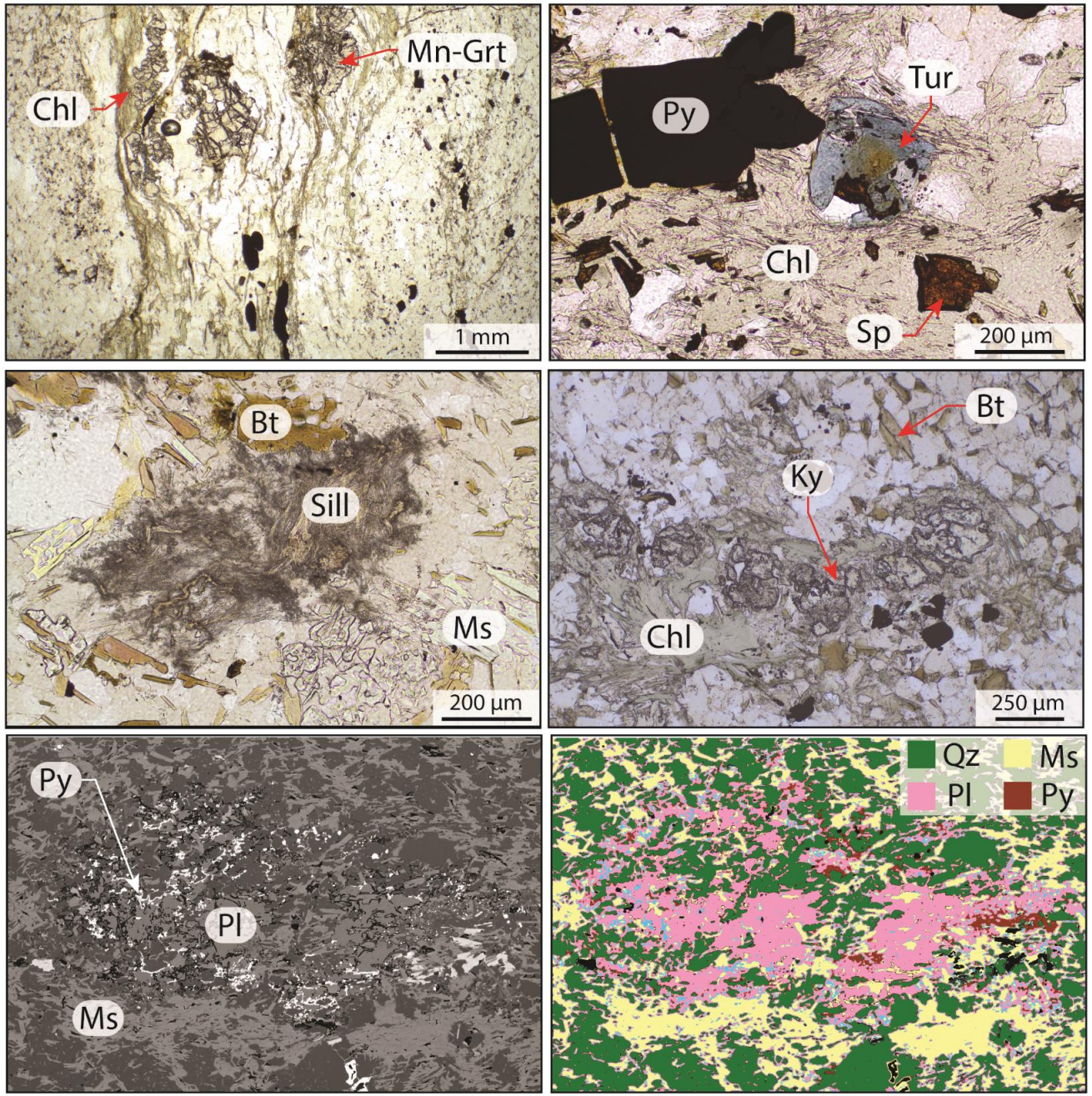


Synvolcanic Au-Ag sulphide mineralization (Off Lake)



- Py-Cpy-Sp occurrences at the top of the felsic coherent unit (roof of rhyolitic cryptodome)
- Occurences of sulphides layers in bedding of basaltic flows
- Chlorite veinlets and intense chlorite-epidote alteration

Alteration related to the Au-Ag mineralization (Off Lake)



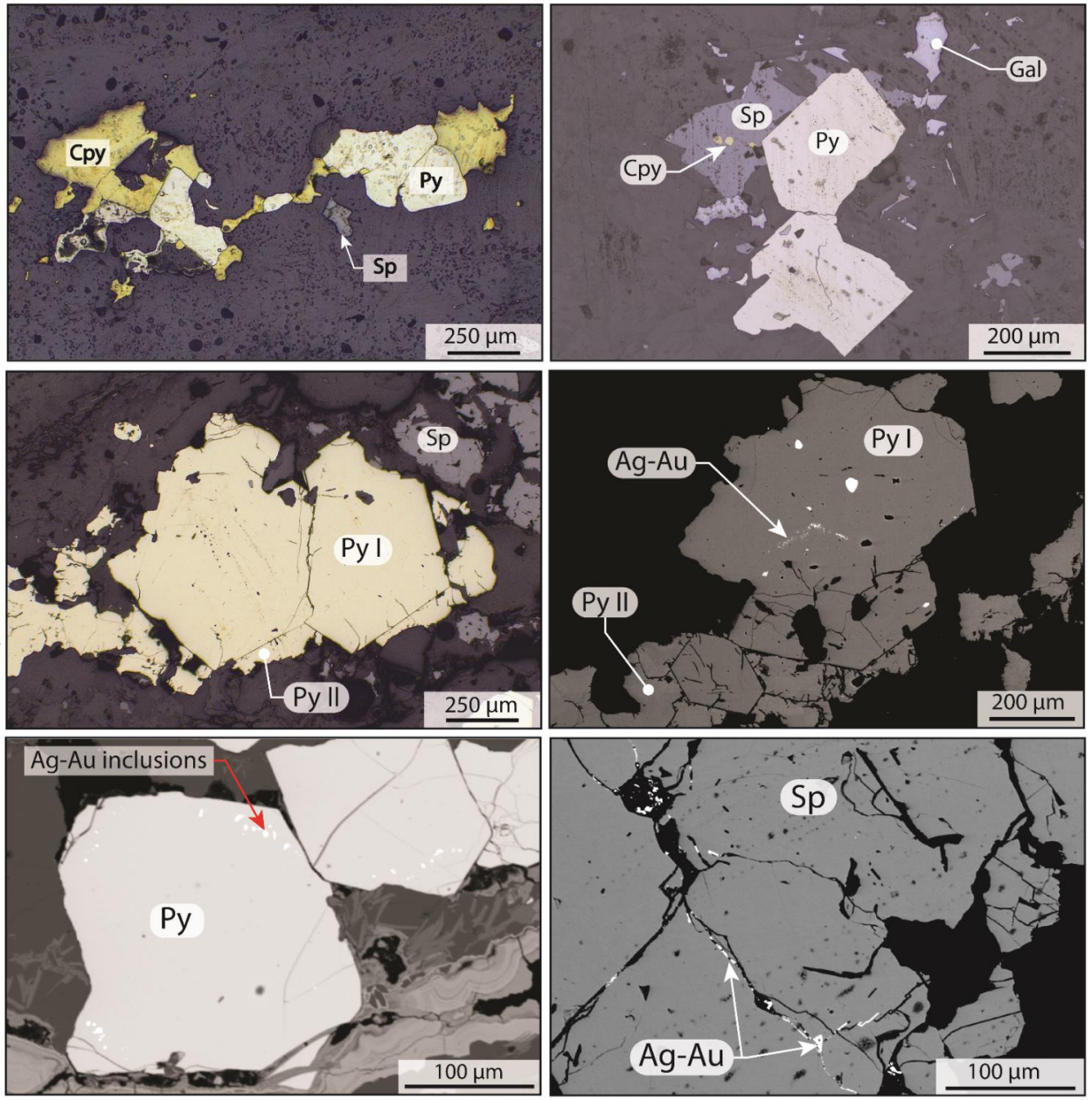
- Chlorite-sericite-epidote-tourmaline alteration
- Alteration assemblages overprinted by Bt-Grt-Sill-Ky assemblage (metamorphism)
- Aluminosilicates

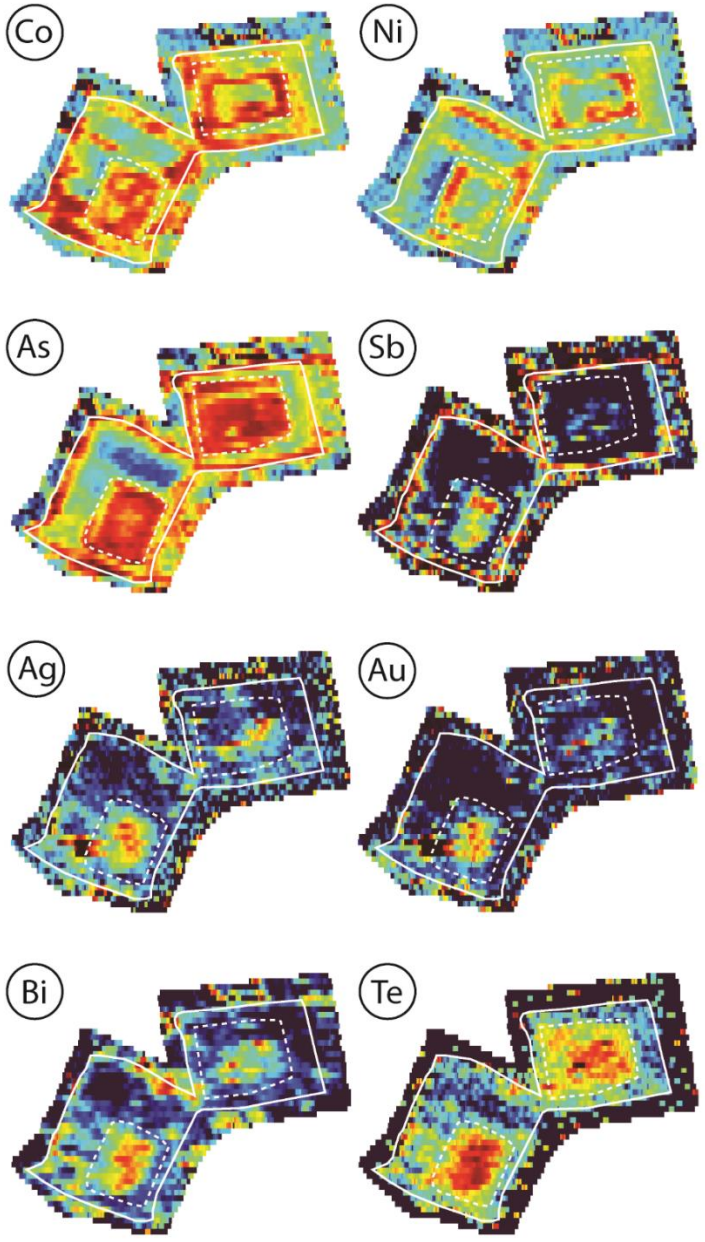
= metamorphism of argillic alteration assemblage

- Dissolution holes and hydrolysis of plagioclase consistent with argillic alteration (acidic fluids)
- Similar alteration assemblages described by Pelletier et al., 2016 for the Rainy River gold deposit

= Same hydrothermal system

Textural characteristics of the Au-Ag mineralization (Off Lake)

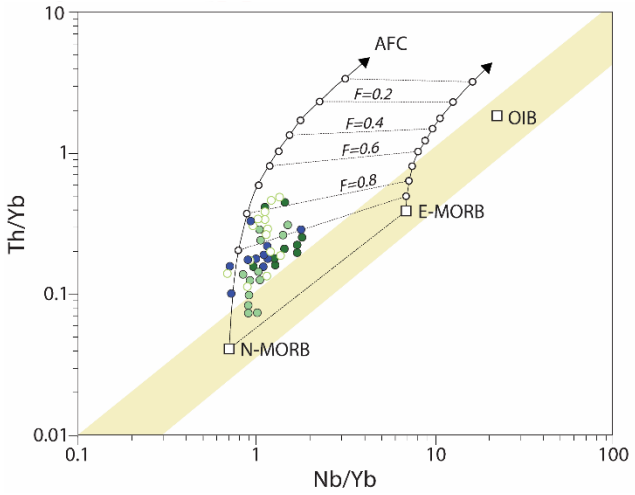


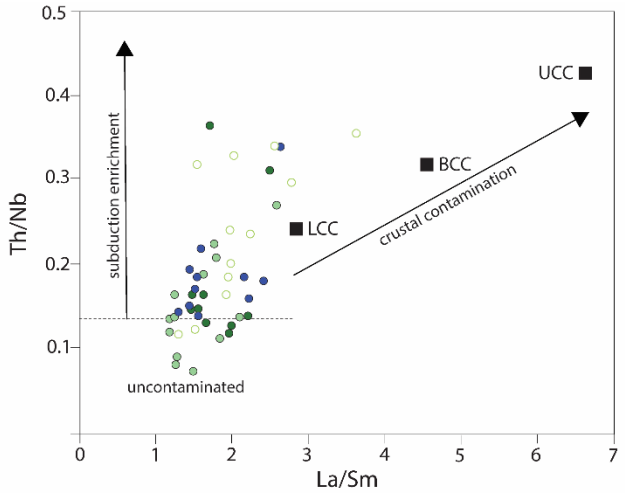


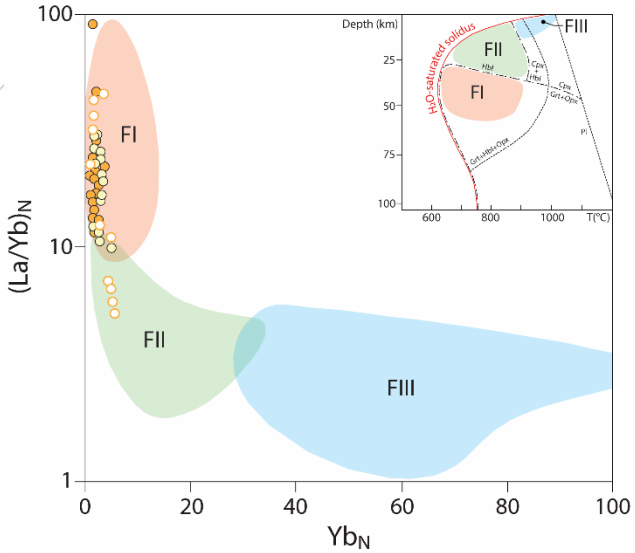
- Base metals sulphides:
  - Py-Po-Sp-Cpy-Gal
- Ag-Au inclusions in pyrite
- Remobilization of Au in fractures during deformation related to the HPdz
- Au and Ag correlated with As, **Bi, Te** and Sb

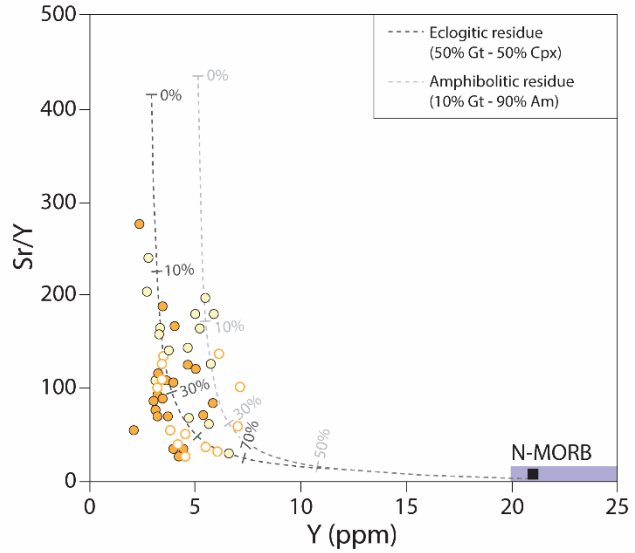
= Magmatic fluids input?

Petrogenesis of the RRGB and sources of melt:







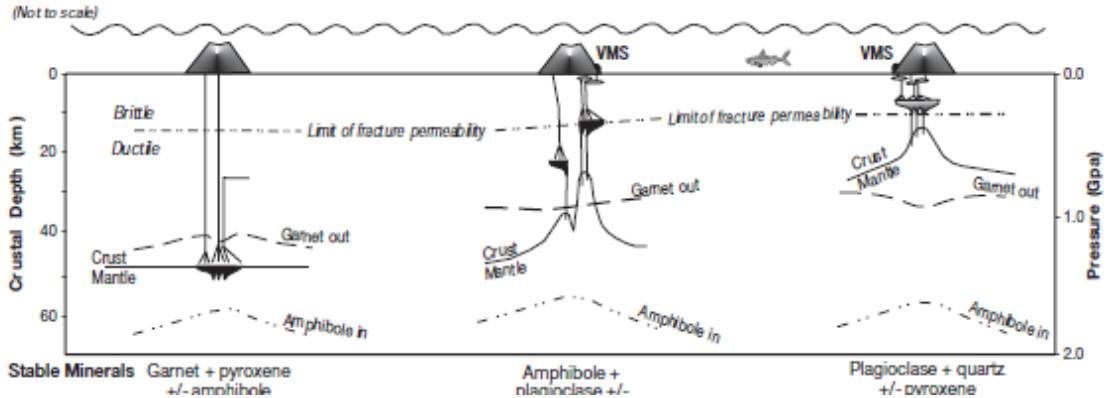


- Assimilation of lower gneissic crust during mafic volcanism
- FI rhyolite
- Sr rich melt = absence of Plagioclase at the source

= deep source of melt (garnet stability field)

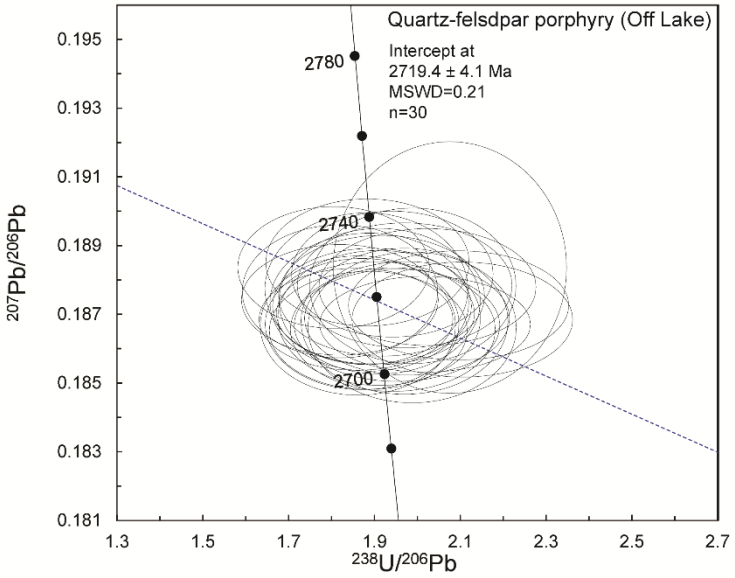
= thick crust and reworking/assimilation of lower gneissic crust during arc-volcanism

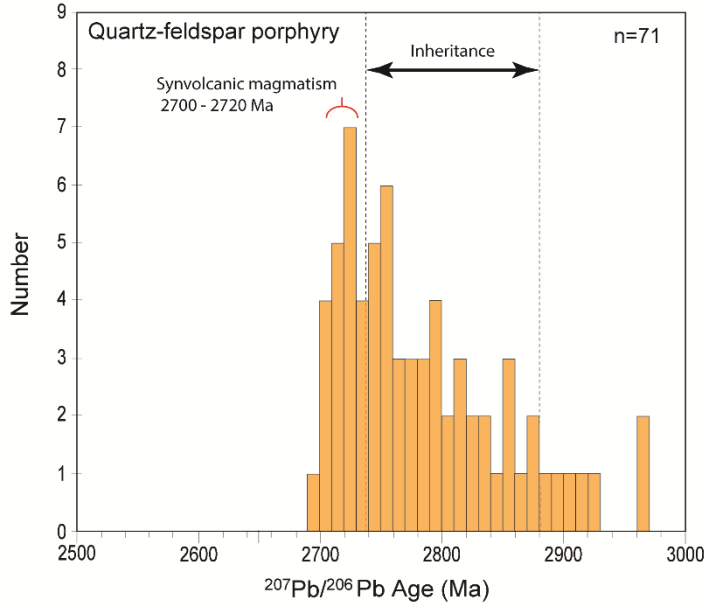
- Context not favorable for the formation of conventional VMS deposit
- **Magmatic fluids input to form the Rainy River deposit?**

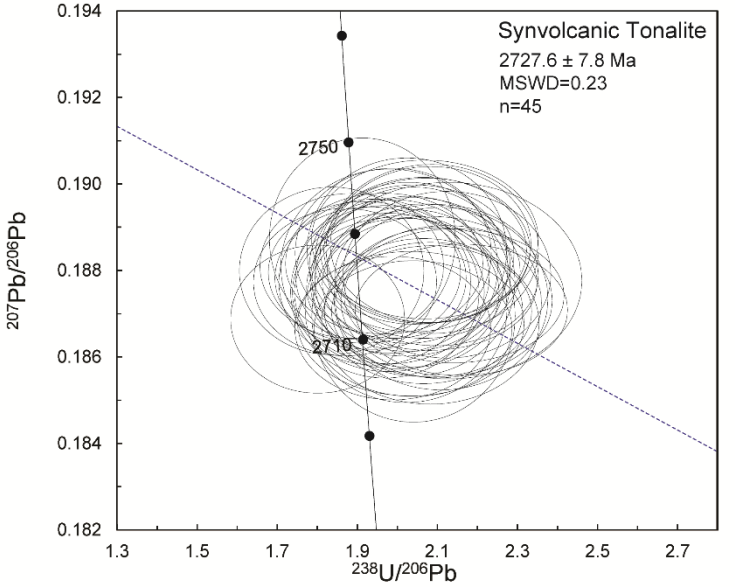


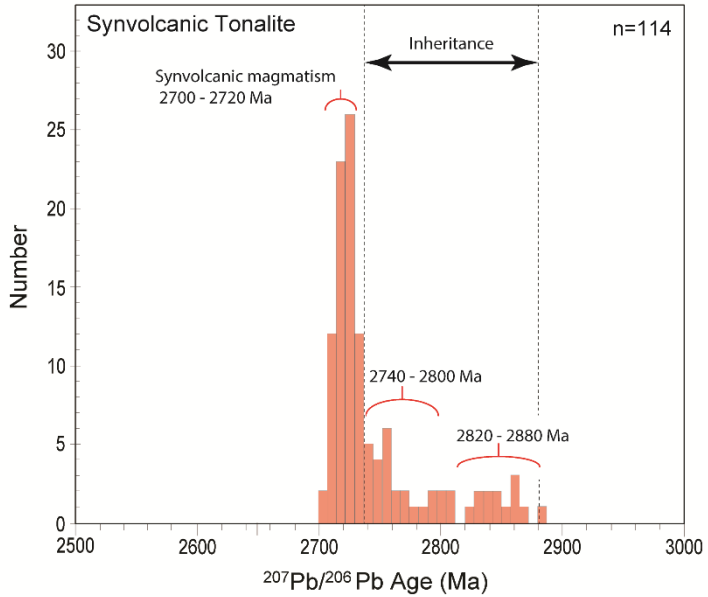
Hart et al., 2004

Timing of the felsic volcanism related to the Au-Ag sulphide mineralization



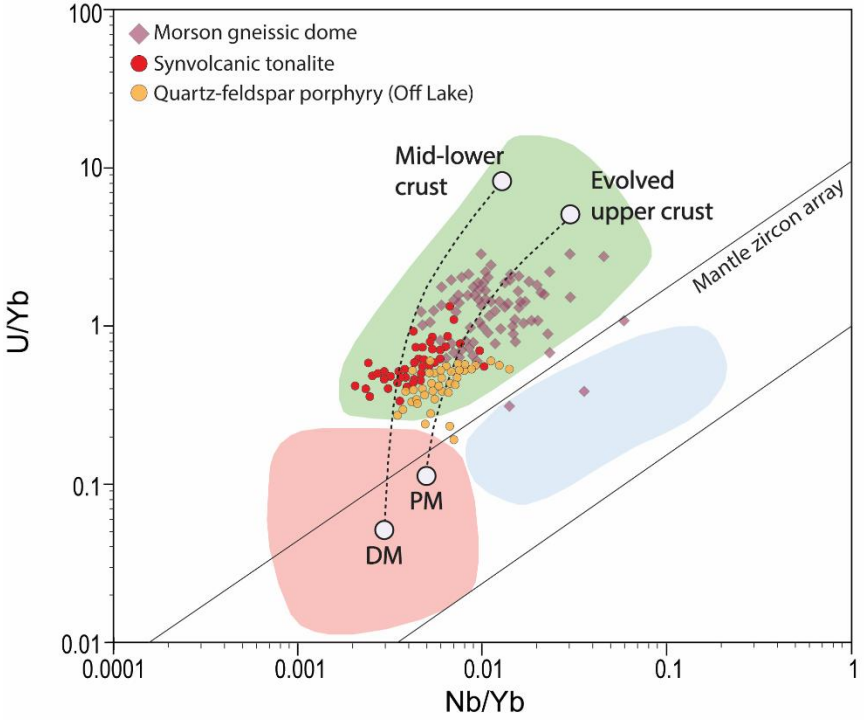




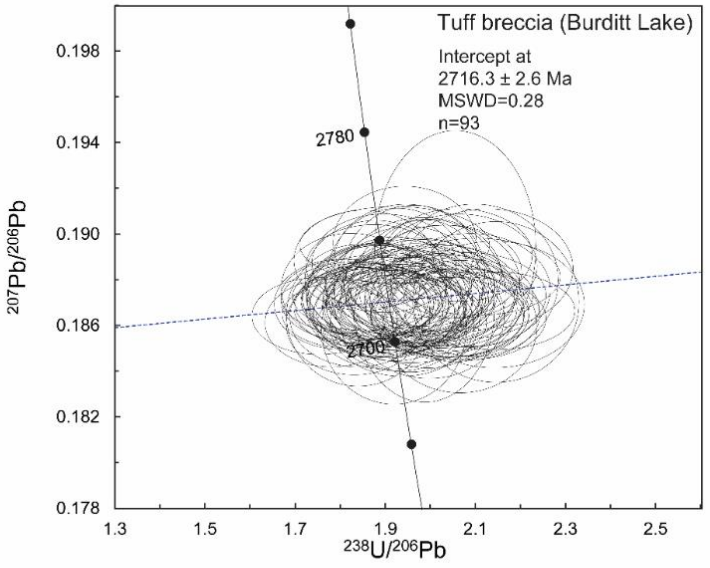


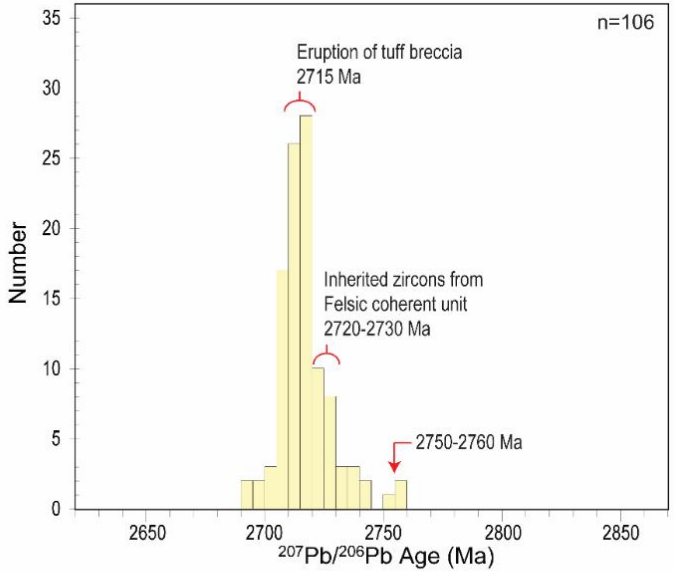
- Felsic coherent unit and synvolcanic tonalite-granodiorite intrusion of the Sabaskong batholith are coeval (2719-2727 Ma)
- Presence of inherited zircons (2750-2880 Ma)
- Mixing trend between evolved crustal signature and mafic component

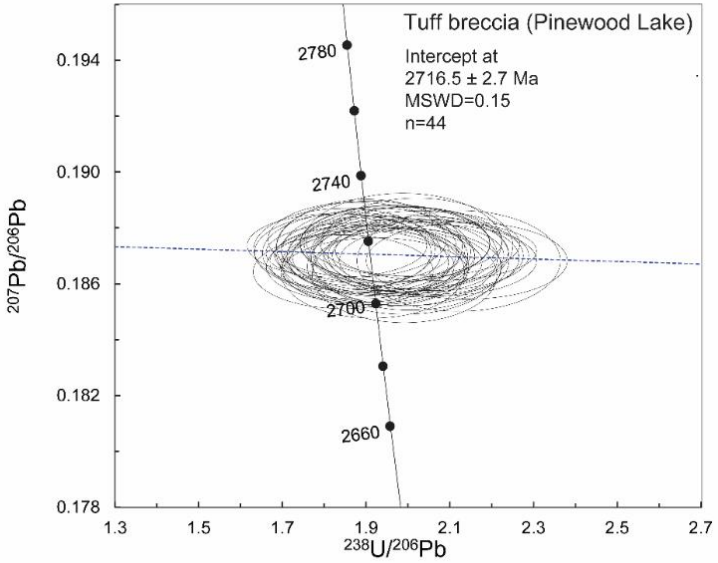
= **assimilation of deep gneissic crust**

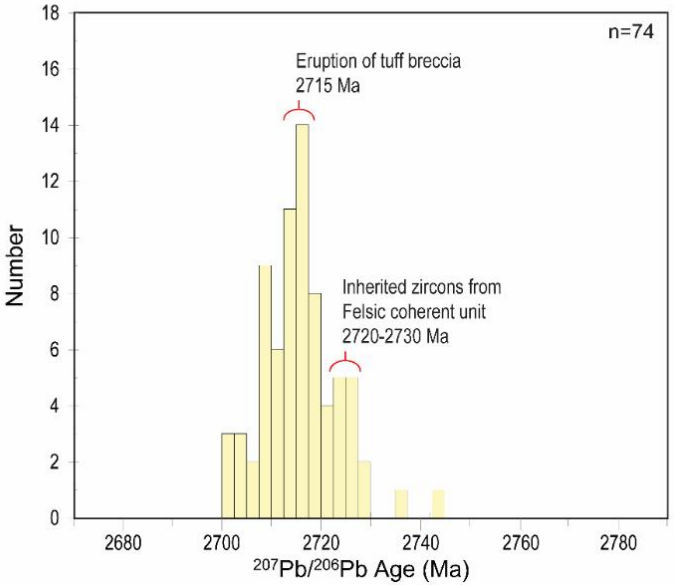


Timing of the felsic volcanism related to the Au-Ag sulphide mineralization









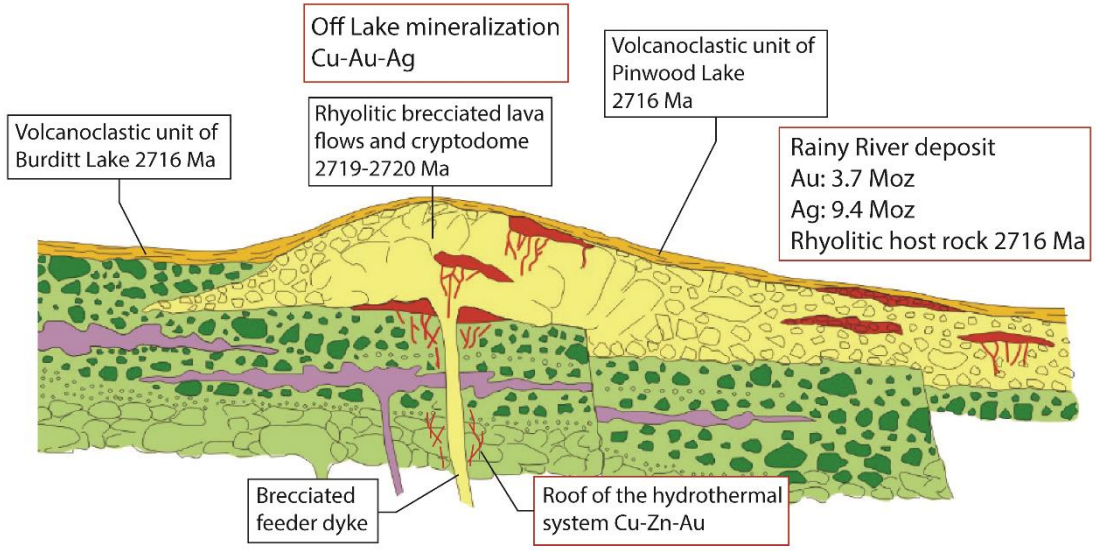
- Deposition of the felsic volcanoclastic units of Burditt and Pinewood Lake are coeval (2715-2716 Ma)

= Similar to ages of the felsic volcanic unit of the Rainy River gold deposit (2716 ± 1 Ma) (Hamilton 2008, Pelletier et *al.* 2015)

= Mineralization of Off Lake and Rainy River are related to the same volcanic center

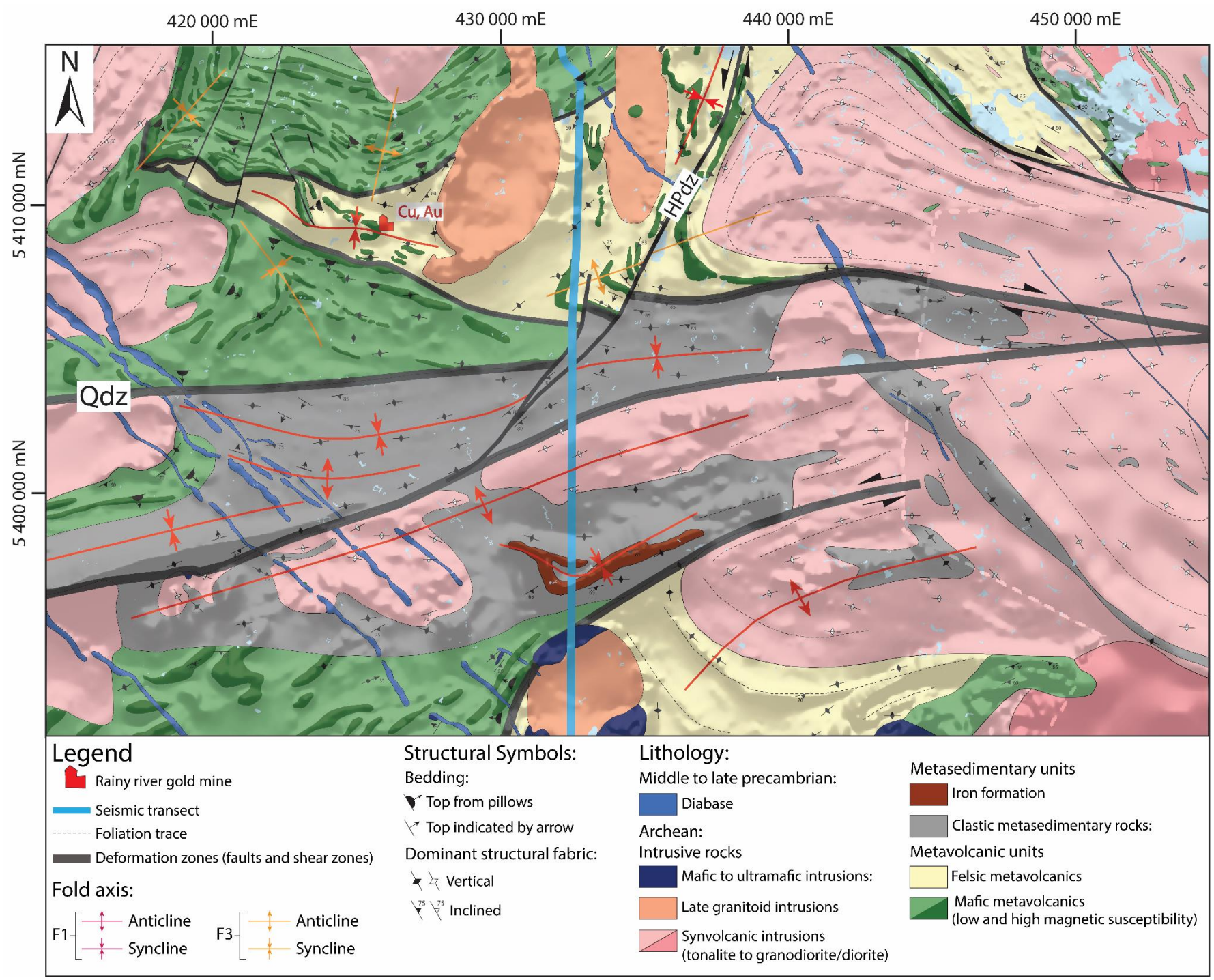
- Minimum lifespan of the felsic volcanism ~5 Ma (2721-2716 Ma)
- Short-lived volcanic system

= short-lived hydrothermal system



Modified from Gibson et al., 2005

Mather syn-orogenic basin and the Quetico deformation zone

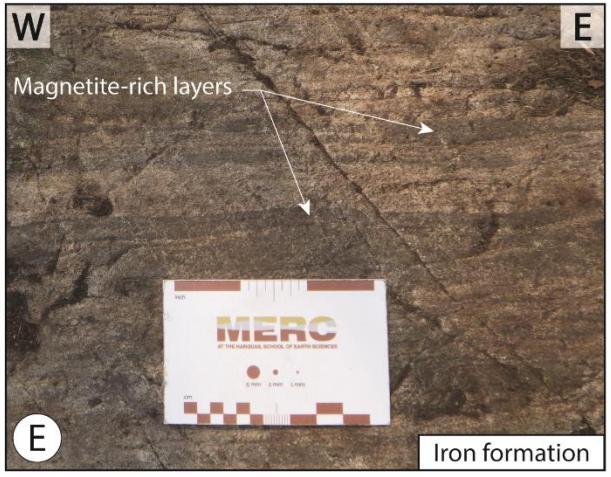


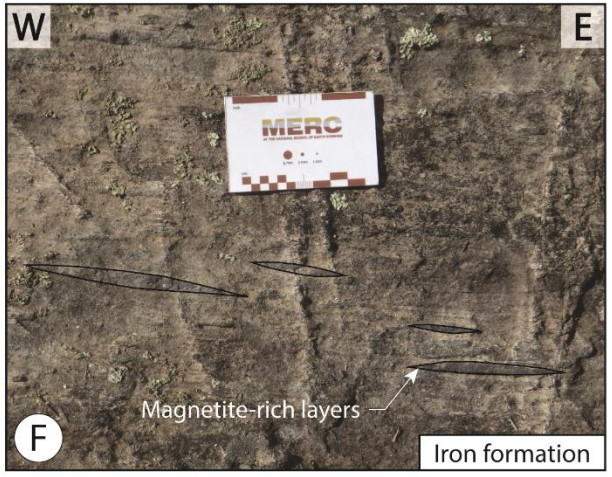
- Mather sedimentary basin bounded to the North by the Quetico deformation zone
- South contact with volcanic units corresponds likely to an unconformity (map relationship)
- Syn-tectonic intrusions crosscut the sediments

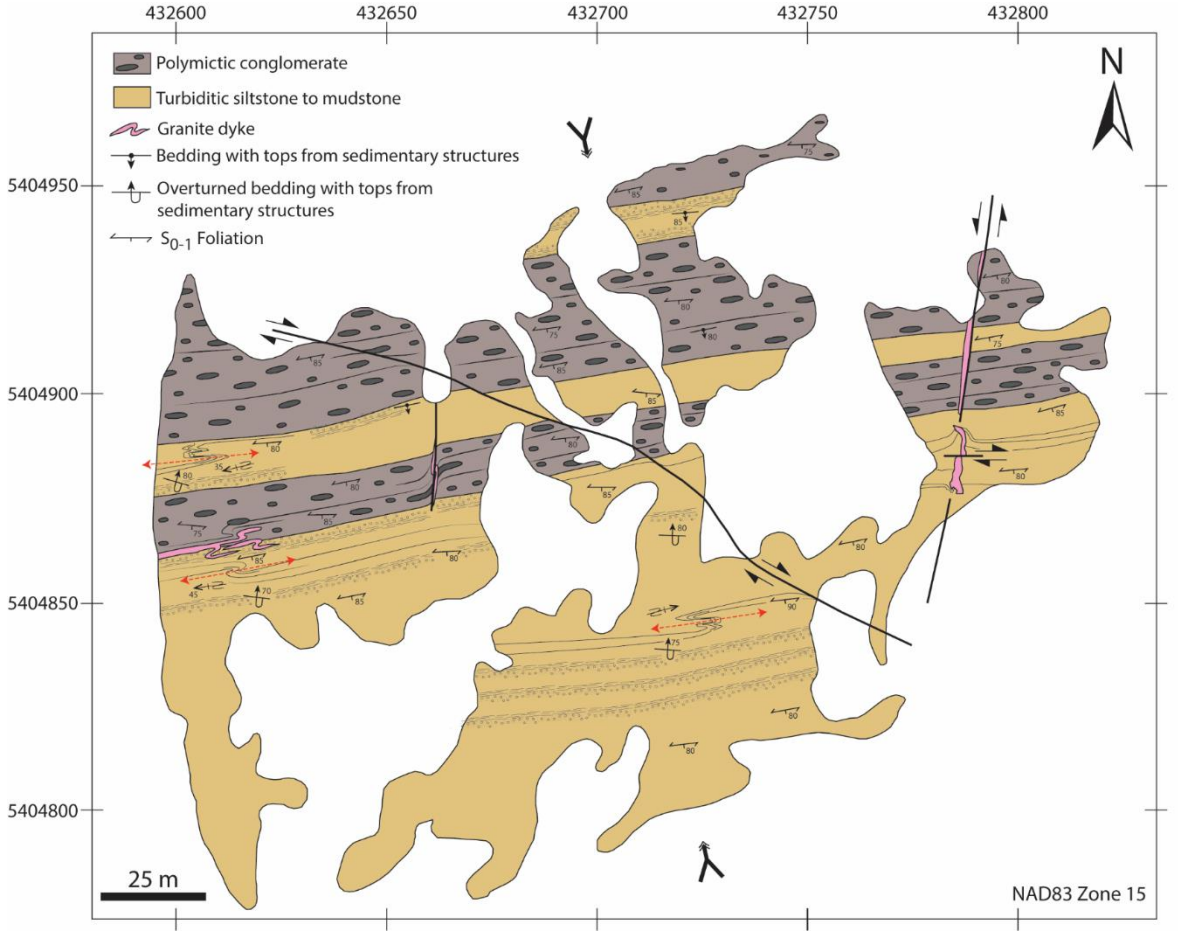
Mather sedimentary basin:

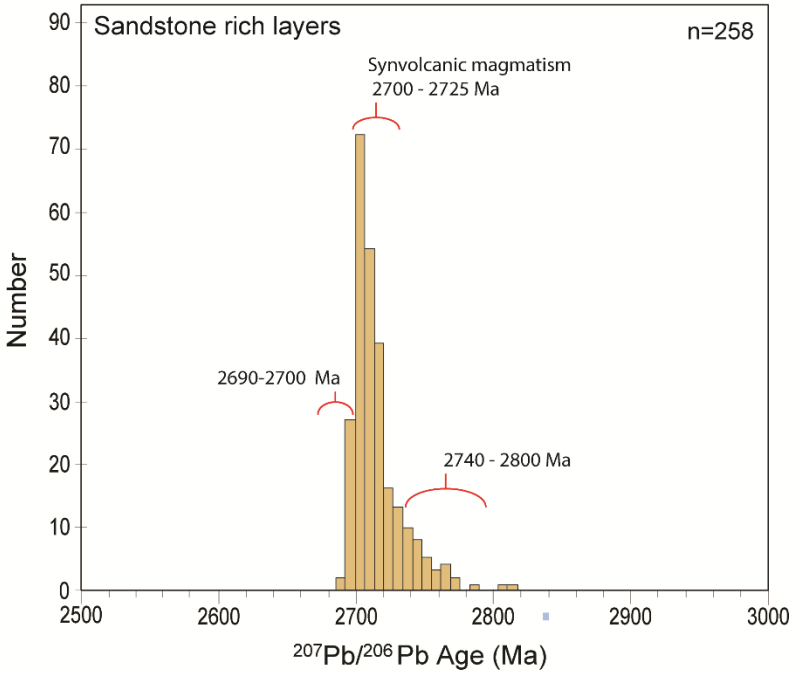
Facies association

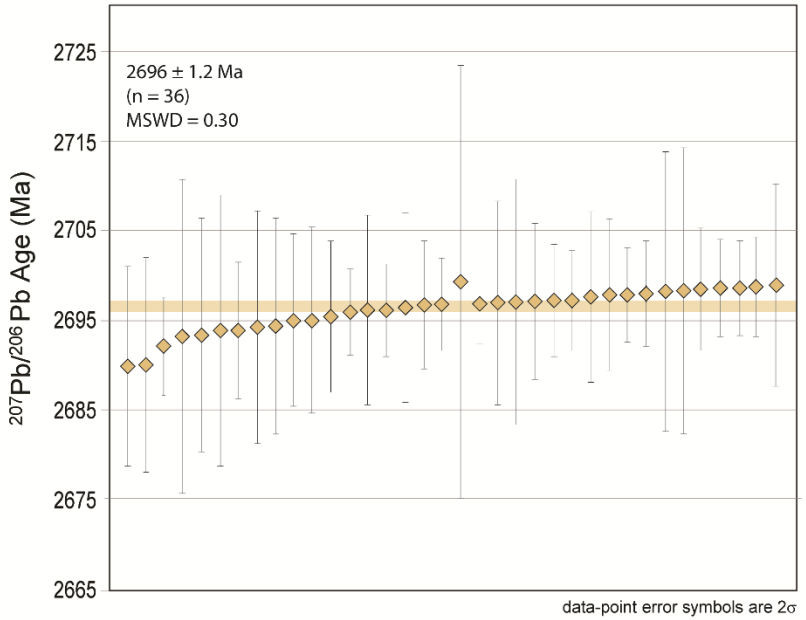
- Conglomerate–sandstone–silt/mudstone association
- Marine environment
- **Porcupine association**



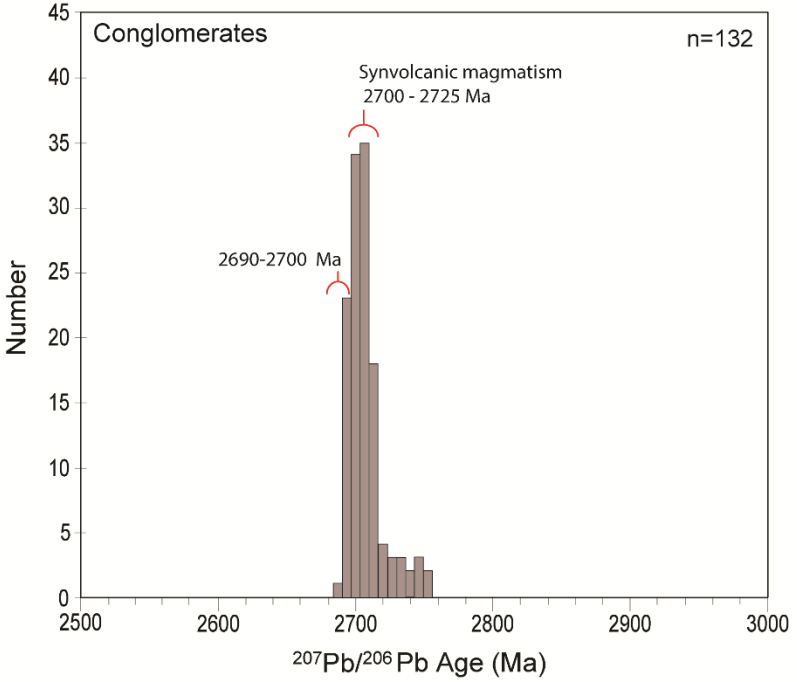


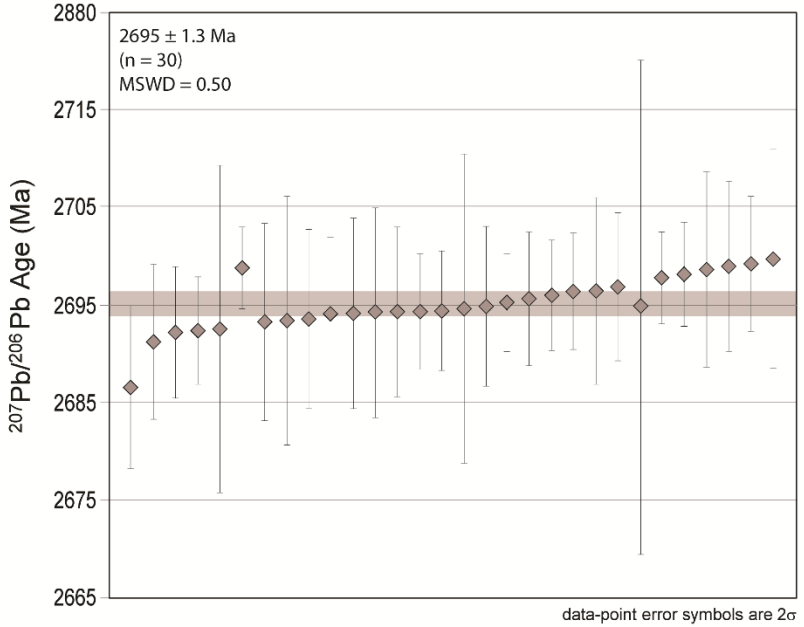


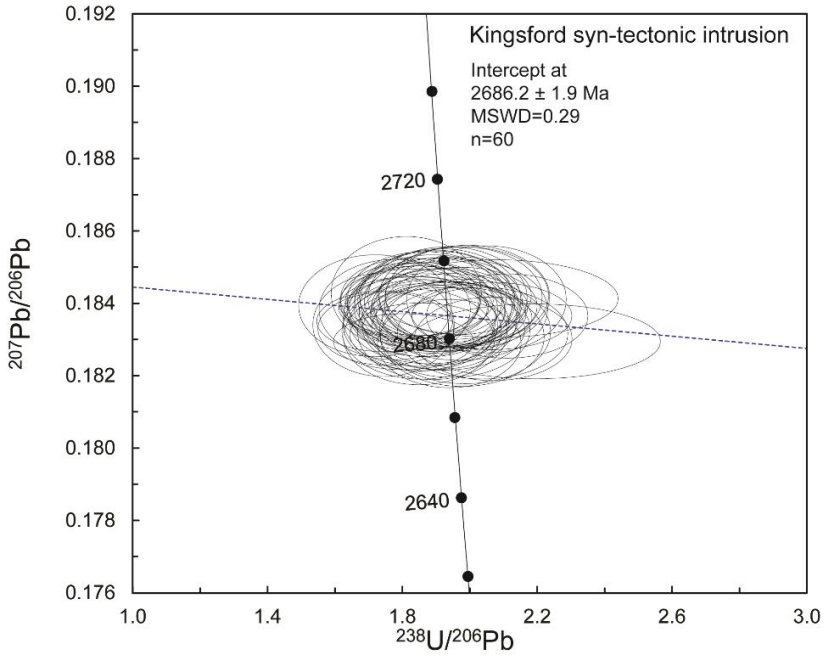


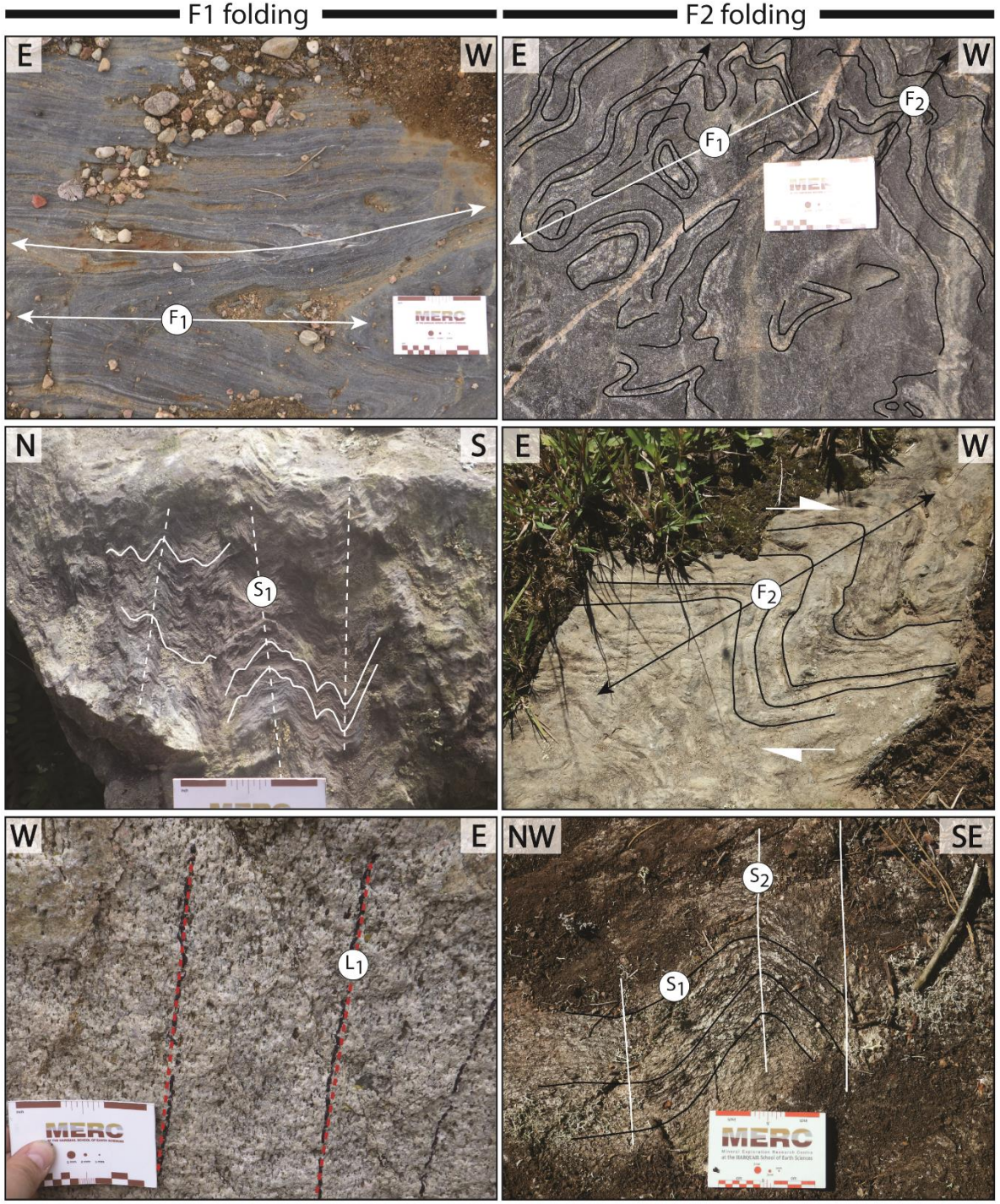


- Sedimentation brackets between 2695-2696 Ma and 2686 Ma
- Age of sedimentation similar to Quetico sediments 2709–2688 Ma (Davis et *al*. 1990)
- Proximal sources of sediments
- Uplift of the Wabigoon subprovince and formation of synorogenic basins



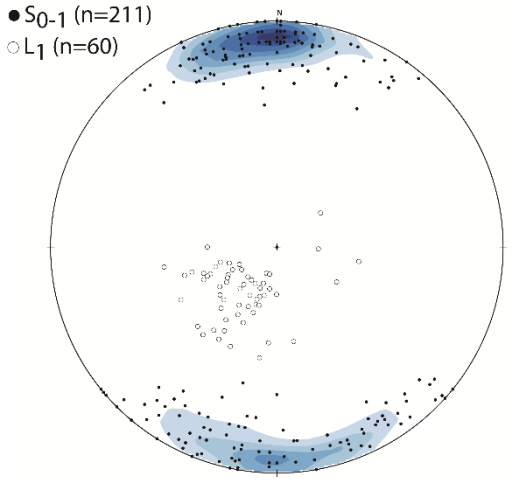


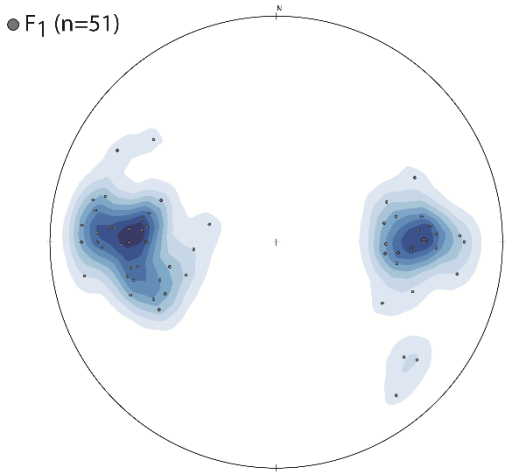




➢ F_1 folding:

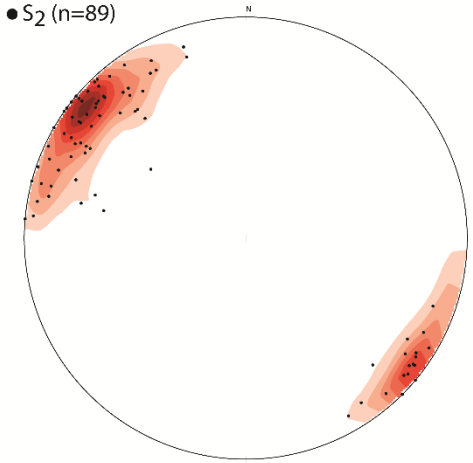
- Tight isoclinal folds
- E-W subvertical axial plane foliation
- Steeply plunging West L_1 stretching
- **N-S shortening**

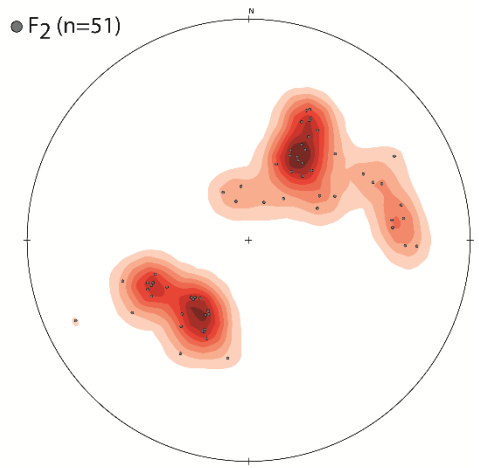


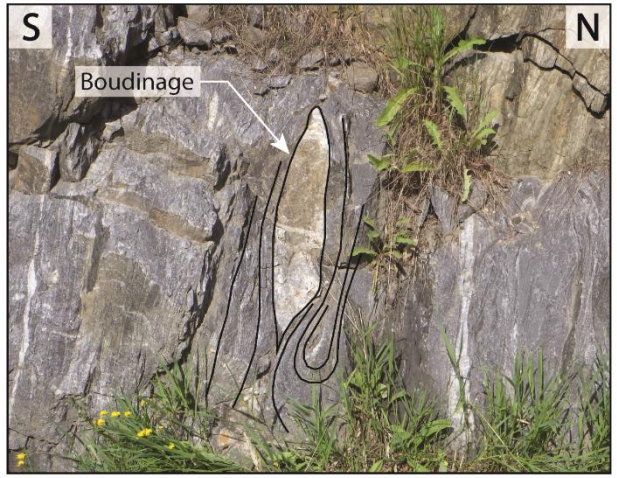


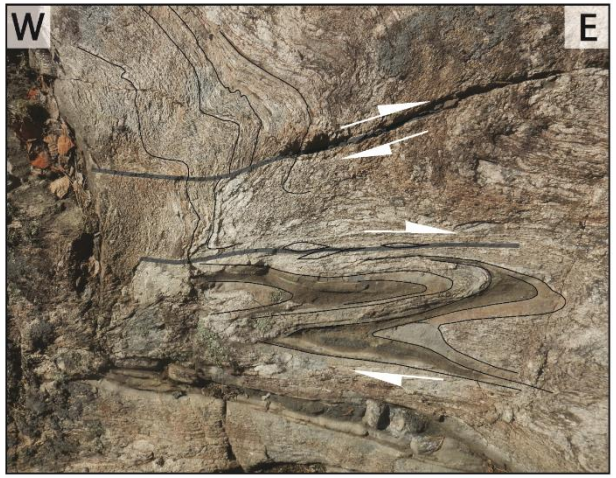
➢ F_2 folding:

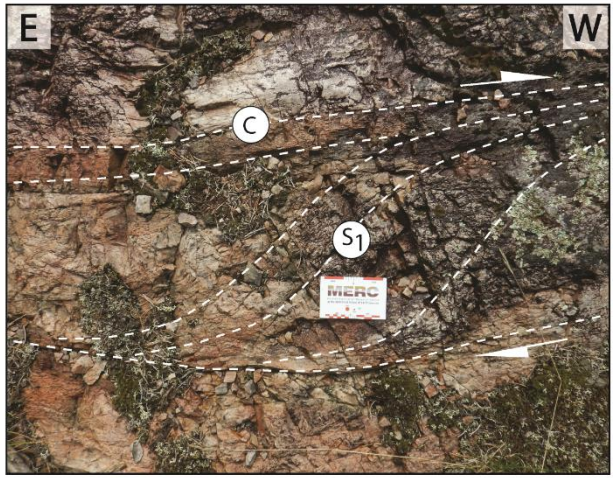
- Open Z-folds
- NE-SW S_2 crenulation cleavage
- **Transpressive deformation with a dextral sense of shearing**

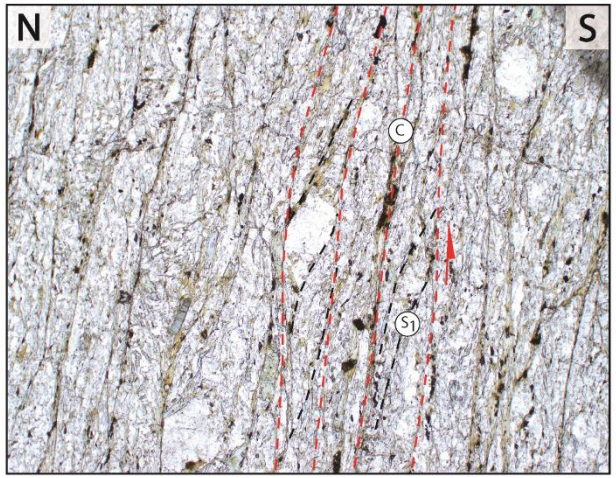




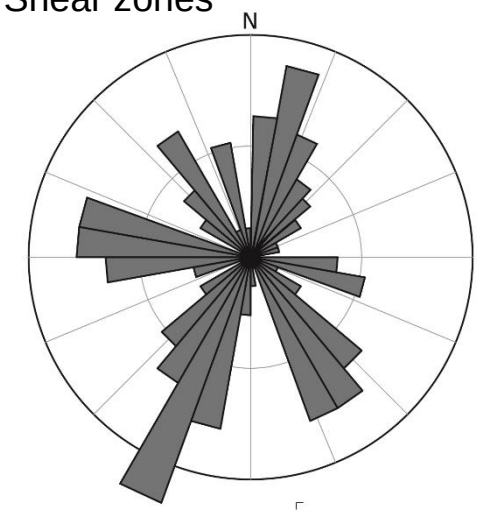


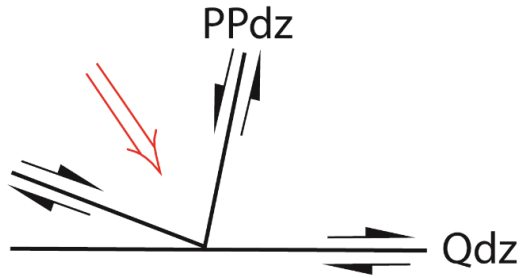


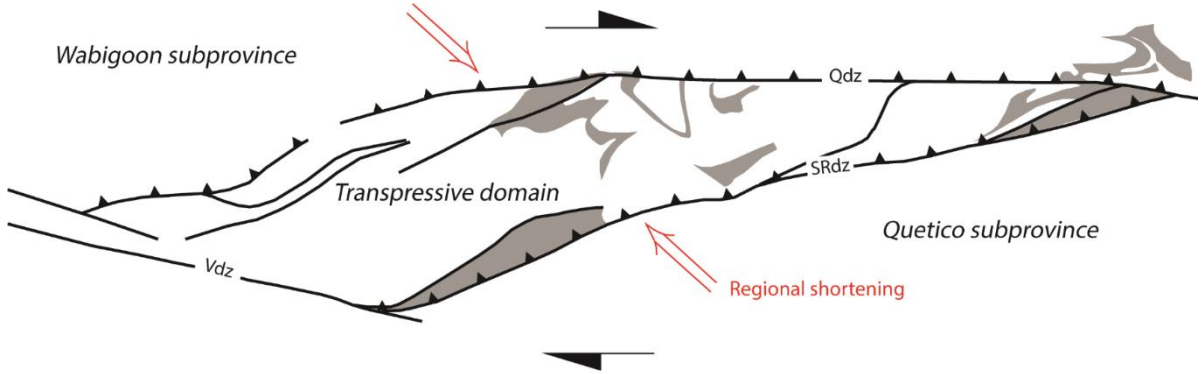




Shear zones



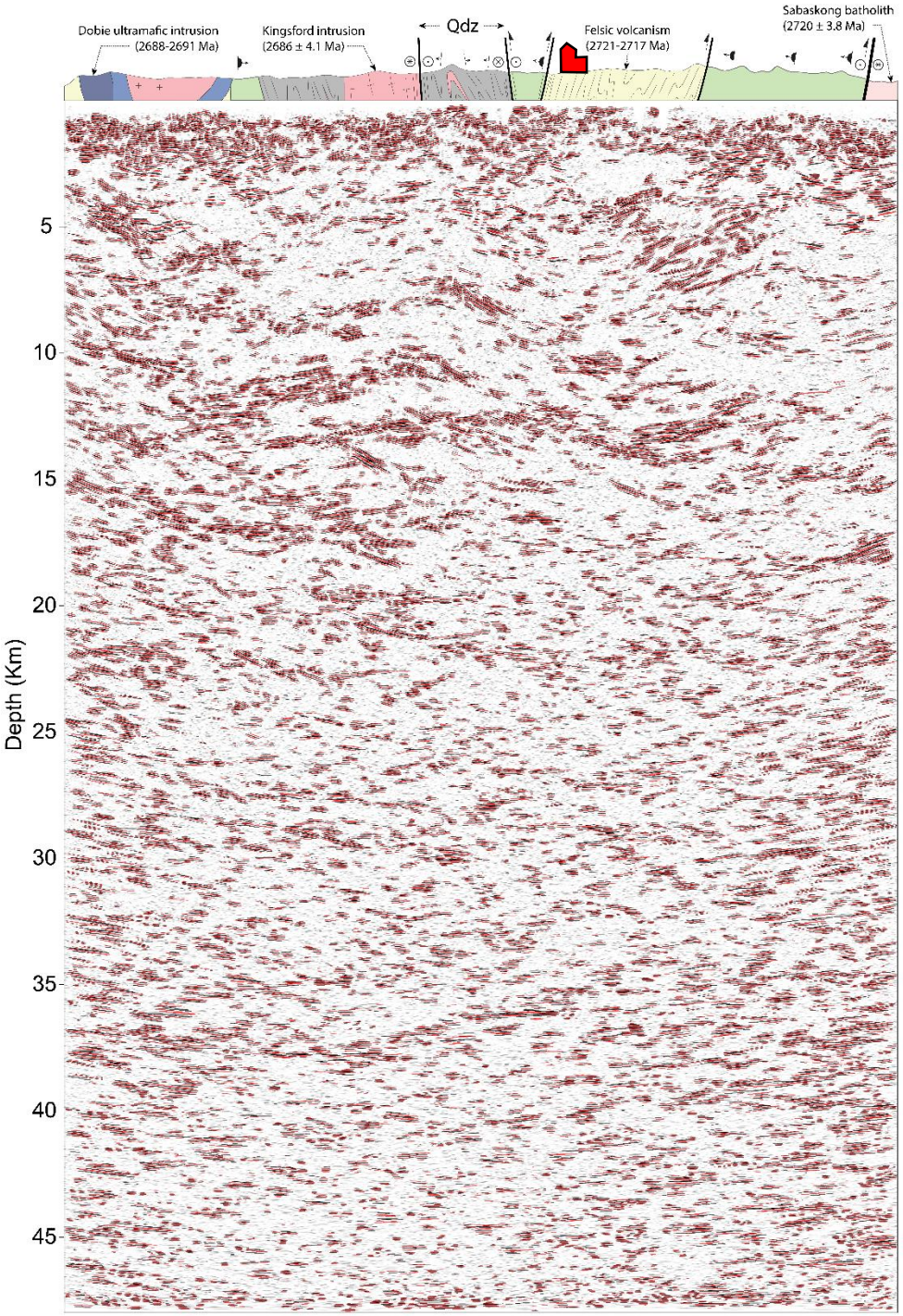


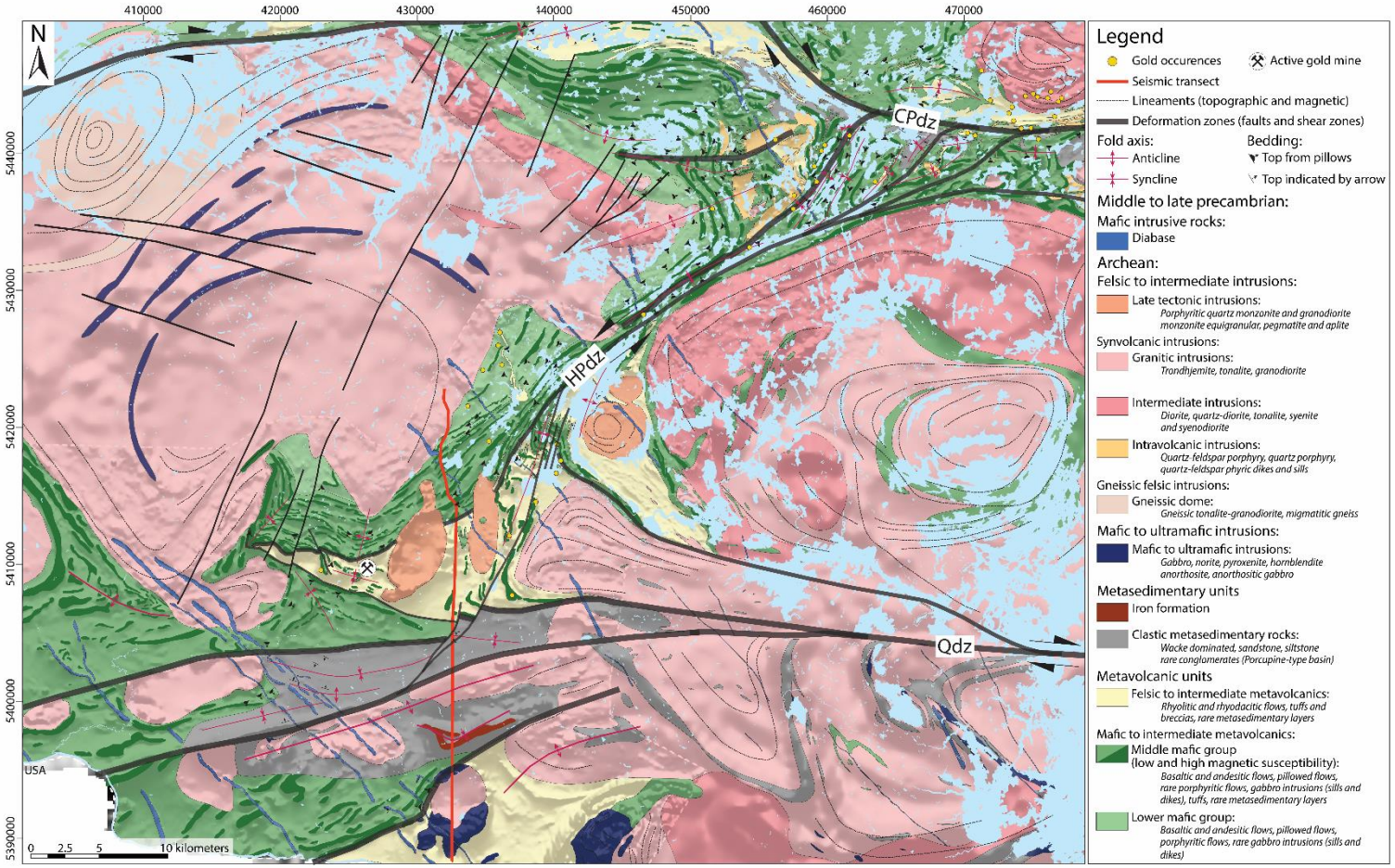


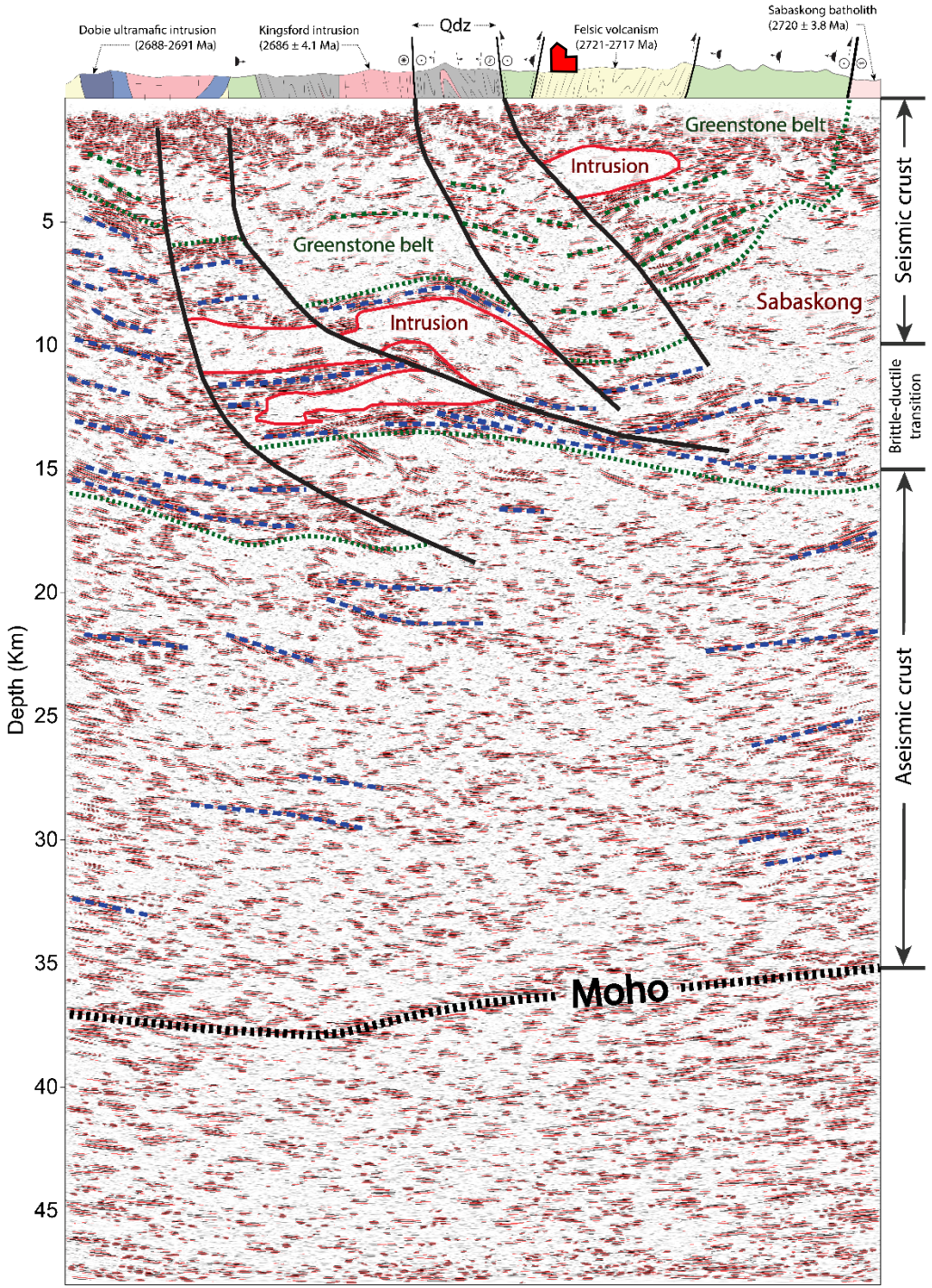
Quetico deformation zone

- Conjugate shear zones
- Qdz: Mylonitic corridor; absence of carbonates alteration and gold occurrences
- **Transpressive deformation with a dextral sense of shearing**

Crustal architecture of the RRGB using geological and geophysical data







Upper crust:

- Weak seismic reflectivity
- Reflectors (sills/dikes?) dip toward to the S in the northern part and toward to the N in the southern part (Dome-and-keel structure?)
- Lower limit of the RRGB at ~5-9 km

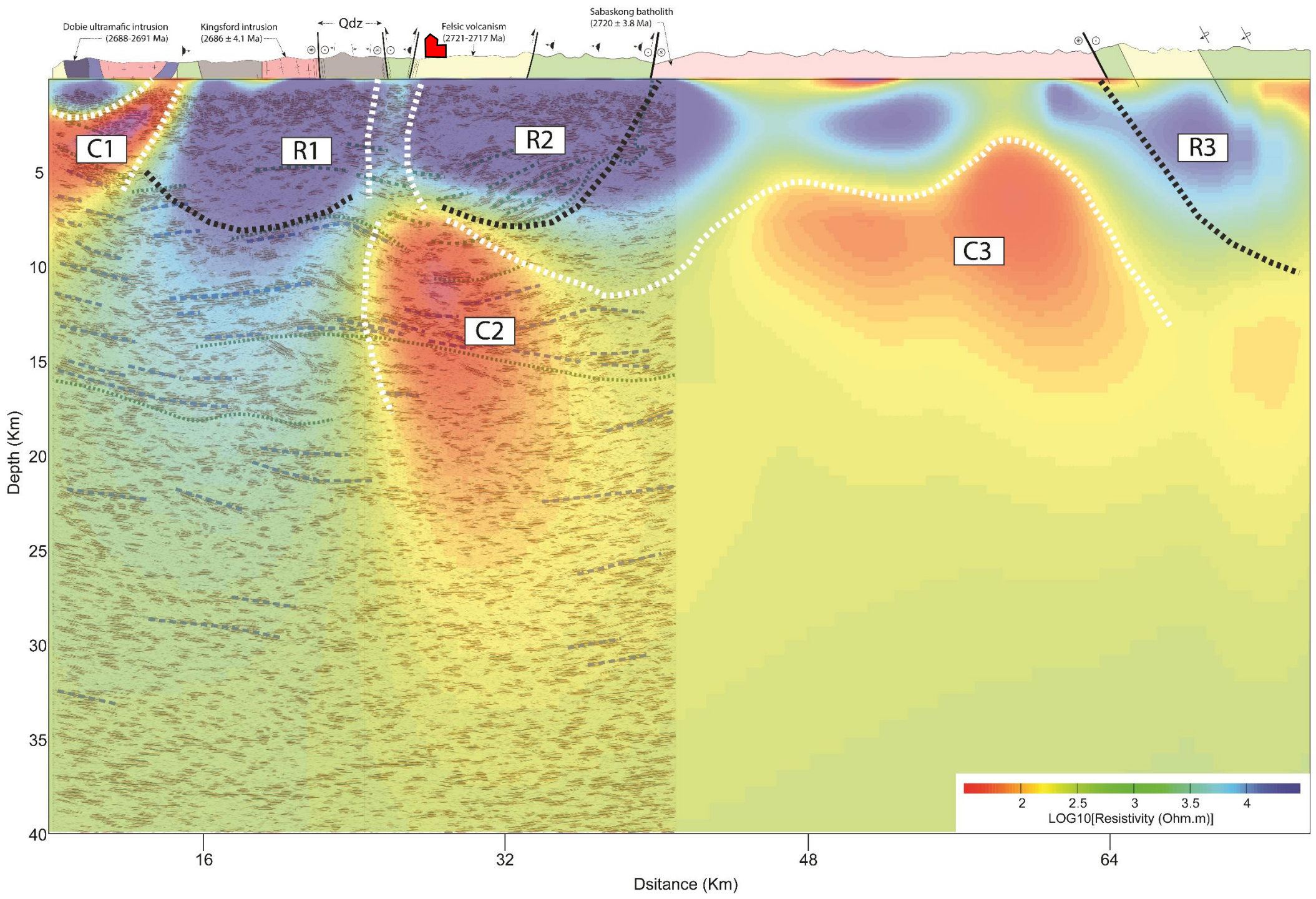
Middle crust:

- Reflective crust between 9 and 15 km
- Less reflective domains = probable intrusions
- Interlayered mafic and TTG gneiss
- Depth extent of faults ~12-15 km

Lower crust:

- Weak seismic reflectivity
- Subhorizontal reflectors
- Ductile homogeneous crust?
- Moho at ~37 km

Crustal architecture of the RRGB using geological and geophysical data

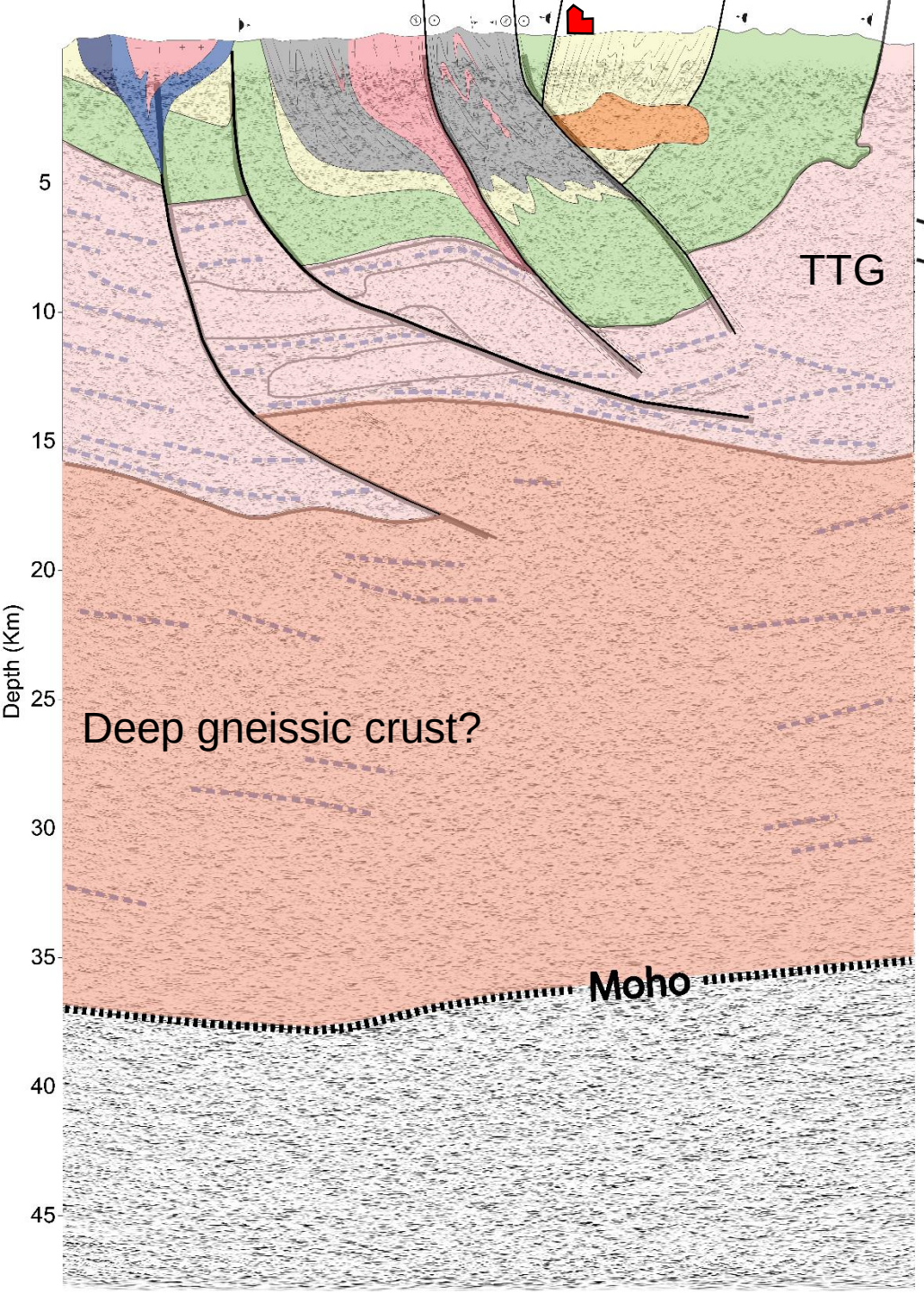


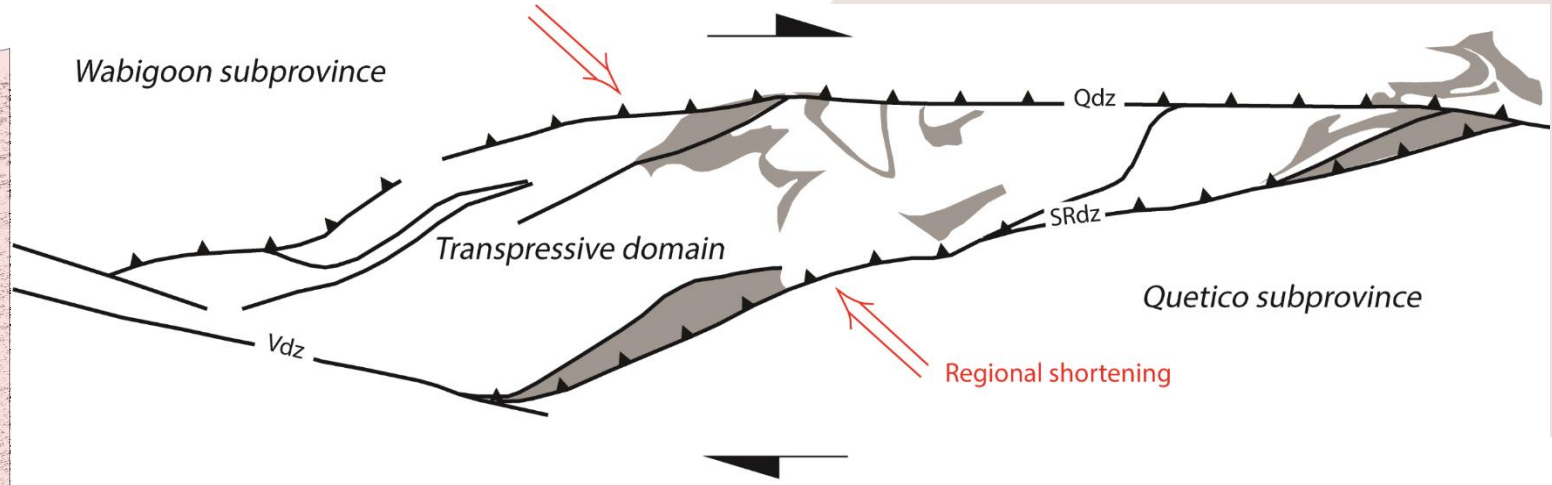
Upper crust:

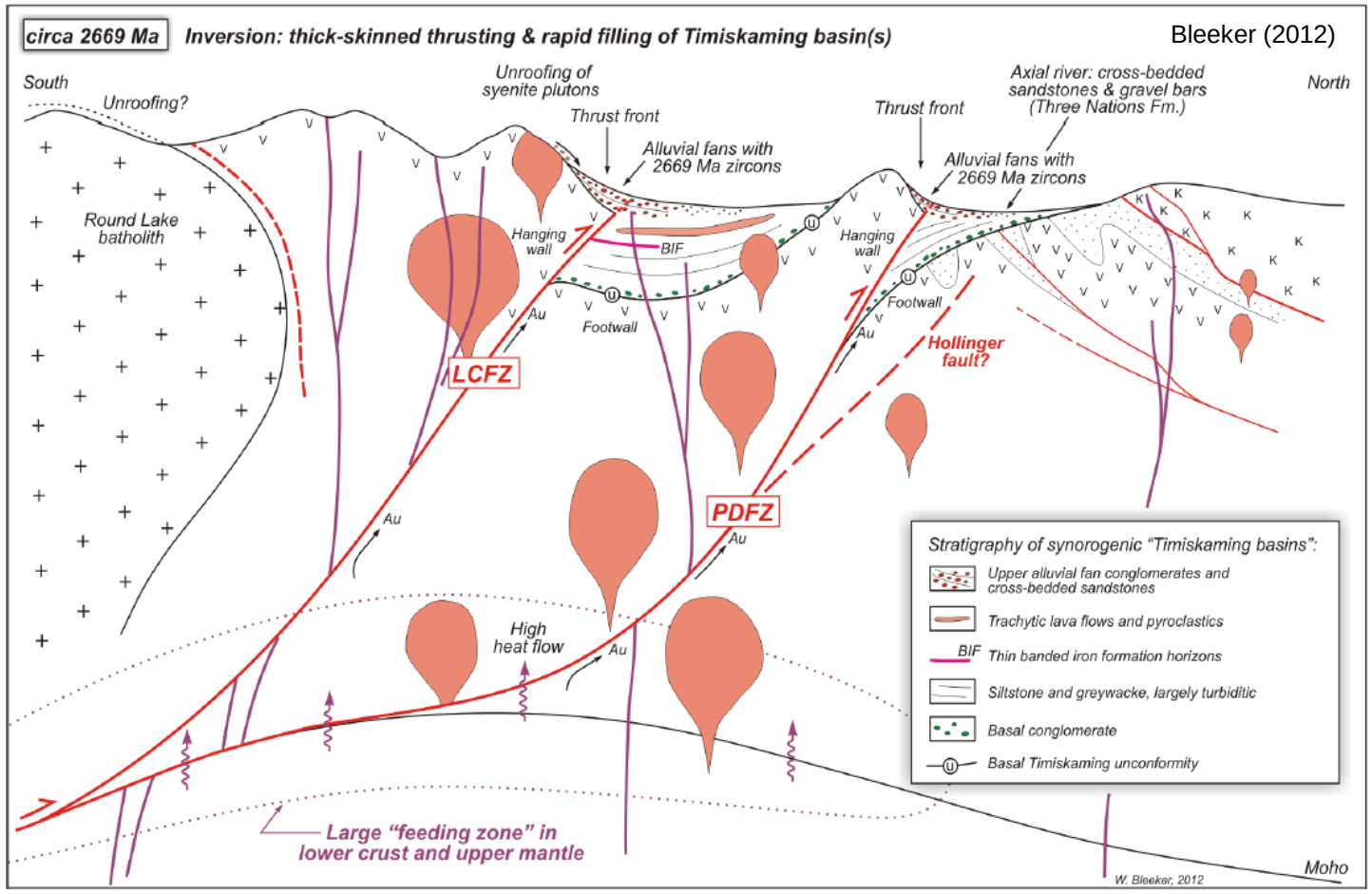
- Resistive crust (R1, R2 and R3 anomalies)
  = Greenstone belts
- Subvertical relatively conductive corridor = Extension of the Qdz at depth?
  = Implication for the Rainy River deposit?
- Conductive zone to the South (C1)
  = Ni-Cu Dobie ultramafic intrusion

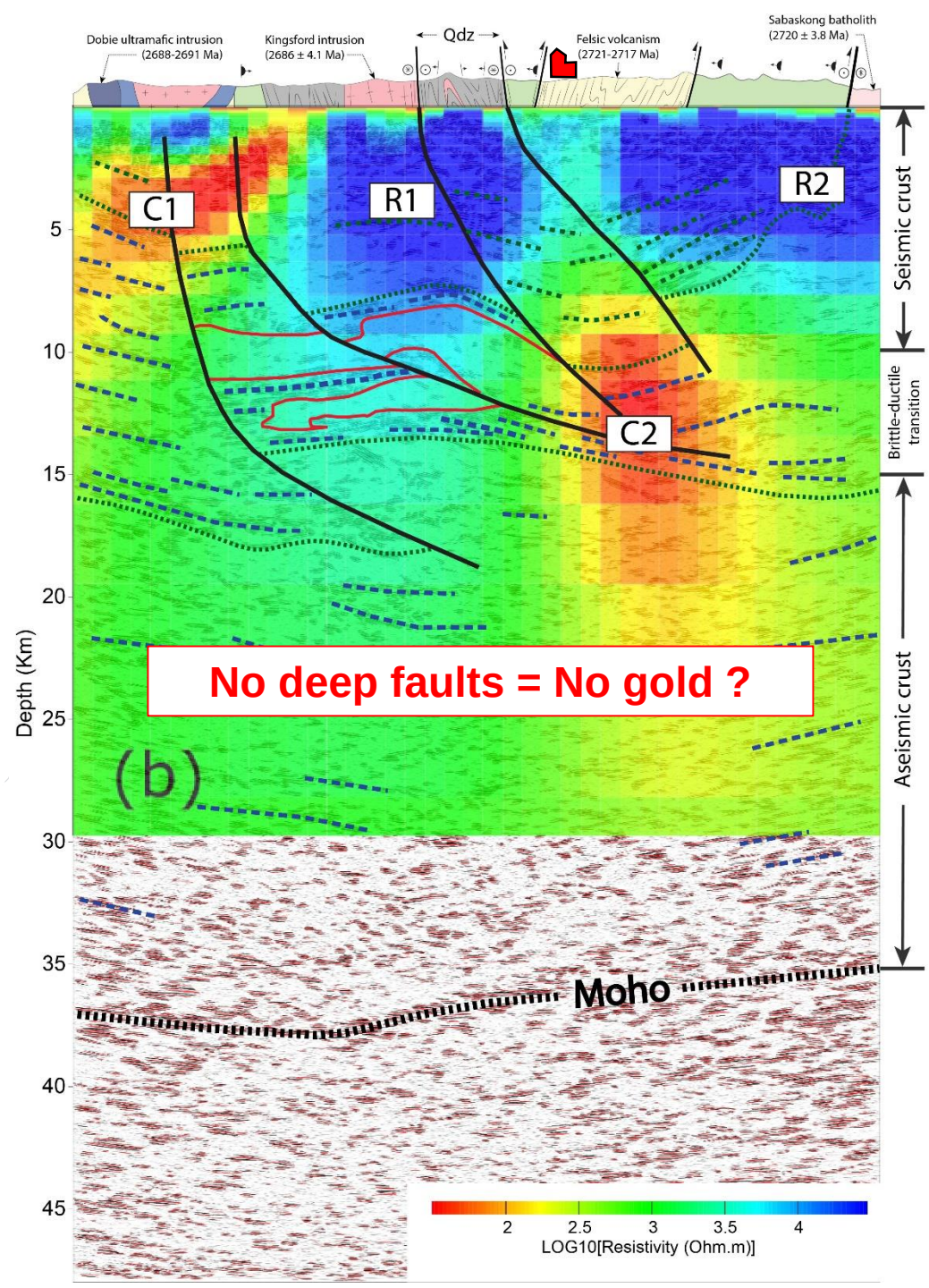
Middle and lower crust:

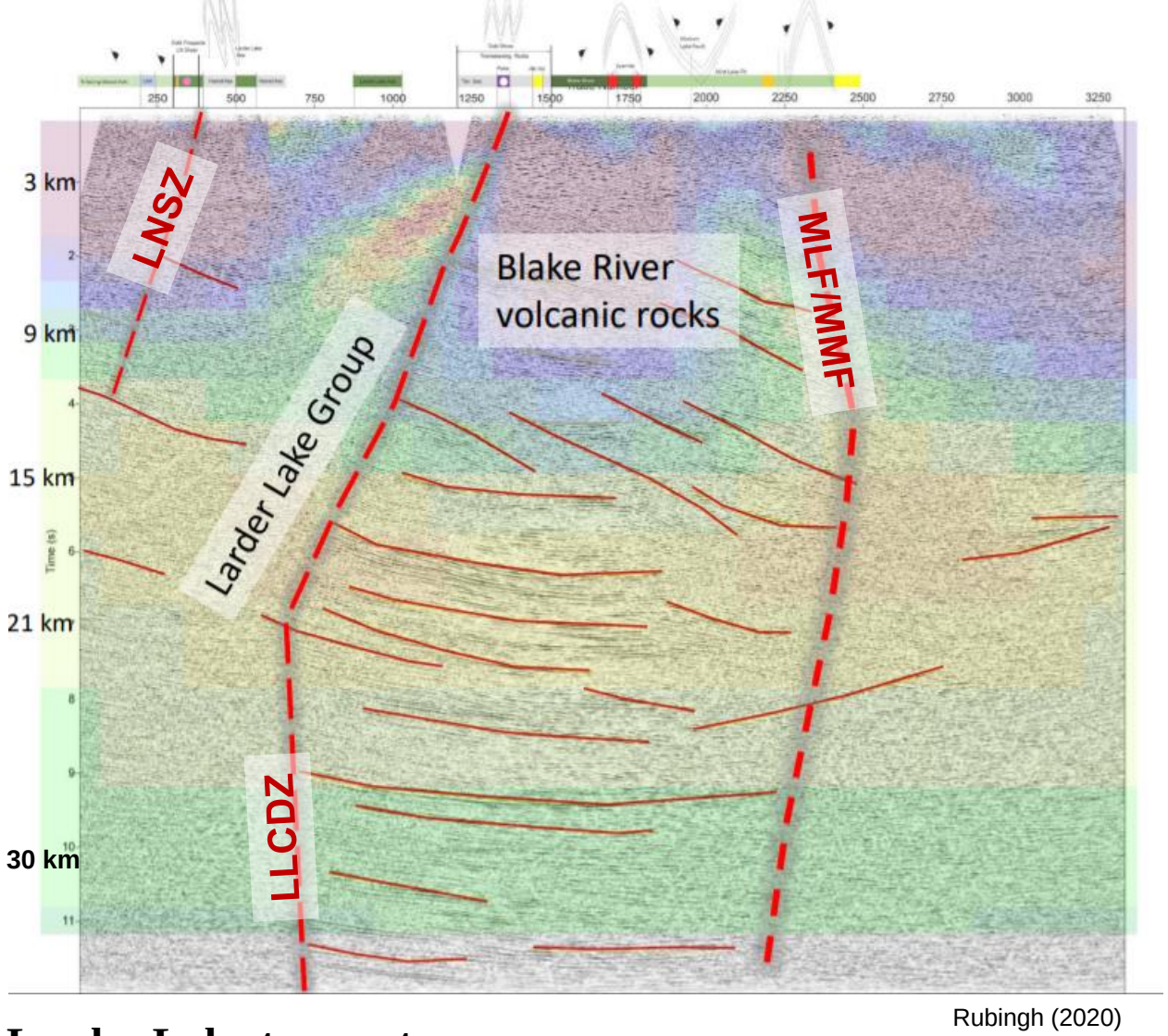
- Conductive crust
  = TTG gneiss
- Conductive anomaly (C2 and C3)
  = Gneissic domes?


Depth (Km)
5
10
15
20
25
30
35
40
45
TTG
Deep gneissic crust?
Moho


Wabigoon subprovince
Qdz
SRdz
Transpressive domain
Quetico subprovince
Vdz
Regional shortening


circa 2669 Ma
Inversion: thick-skinned thrusting & rapid filling of Timiskaming basin(s)
Bleeker (2012)
South
Unroofing?
Round Lake batholith
Unroofing of syenite plutons
Thrust front
Alluvial fans with 2669 Ma zircons
Axial river: cross-bedded sandstones & gravel bars (Three Nations Fm.)
North
Hanging wall
BIF
Footwall
Au
LCFZ
PDFZ
Hollinger fault?
High heat flow
Large "feeding zone" in lower crust and upper mantle
Moho
Stratigraphy of synorogenic "Timiskaming basins":
Upper alluvial fan conglomerates and cross-bedded sandstones
Trachytic lava flows and pyroclastics
Thin banded iron formation horizons
Siltstone and greywacke, largely turbiditic
Basal conglomerate
Basal Timiskaming unconformity
W. Bleeker, 2012





Rubingh (2020)

Larder Lake transect:

- Large gold deposits (11Moz Kerr Addison) associated with the main LLCDZ.
- Strong iron carbonate alteration, quartz and quartz – carbonate veins
- **The LLCDZ can be traced up to 30 km on the seismic section**

Summary

Morson gneissic dome:

- Exhumation of old gneissic crust (2820 Ma) underlying the Rainy River Greenstone belt
- Gneissic crust was reworked during magmatic events related to the formation of the RRGB (2750-2700 Ma)
- Exhumation of the gneissic dome related to transpressive deformation induced by a NW-SE regional shortening consistent with structures observed in the RRGB

Rainy River Greenstone Belt:

- Off Lake and Rainy River mineralizations belong to the same volcanic center
- Short-lived volcanic system ~4-5 Ma (2720-2716 Ma)

Mather sedimentary basin:

- Porcupine synorogenic basin
- Sedimentation occurred between 2696 ± 1.2 Ma - 2686 ± 1.2 Ma
- Proximal sources of sediments

Quetico deformation zone:

- Wide E-W mylonitic corridor
- No carbonates alteration and gold mineralization
- Moderate conductive corridor = moderate alteration and fluid flow
- Limited depth extension of the Qdz (~12 km) can explain the absence of economic gold mineralization?

METAL EARTH

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