GEM

Northeast Thelon region geoscience framework - new maps and data for uranium in Nunavut

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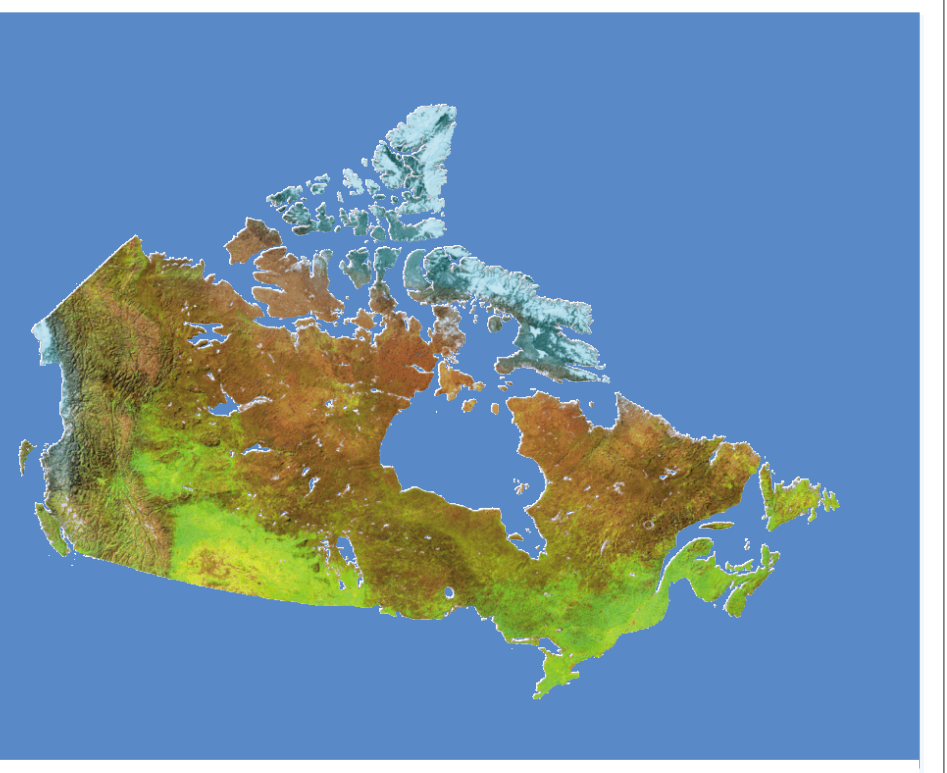
B. Leblon, D. Lentz, A. LaRocque, Y. Shelat; **Concordia:** J. Patterson; **U of O:** A. Enright and C. Stieber; **Poitiers:** T. Riegler. (Institutions detailed at bottom).



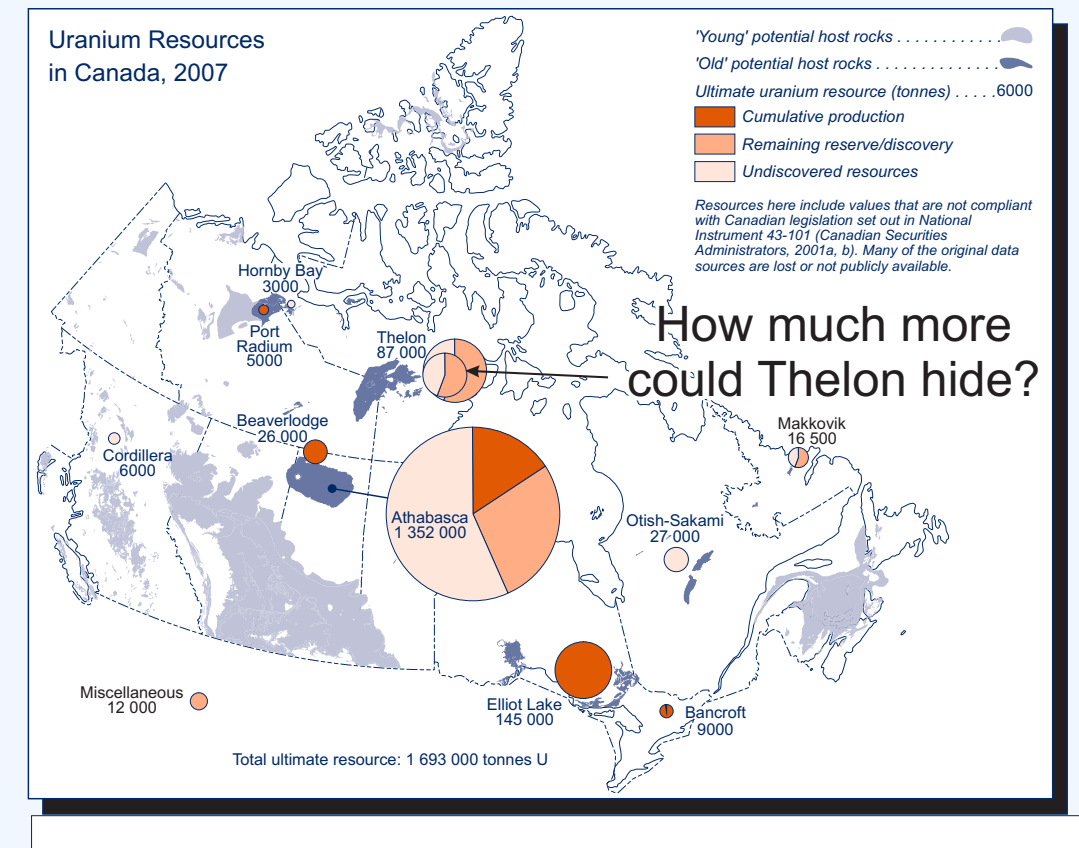
Why, how, where & what did we learn?

WHY Geomapping for Energy and Minerals (GEM)?
- Provide information in northern Canada to guide investment decisions by private sector exploration companies, and for governments and land owners to inform land-use decisions with respect to mineral and energy resource development.

HOW does the Northeast Thelon GEM project work? (Fig. 2)
- Shared existing Industry data + new GSC geophysical-geological data from work on the land, + a wealth of legacy data are providing new geophysical and compositional knowledge of rock units, their structural and alteration histories related to U and other potential commodities. These help test the hypothesis.

•WHAT have we learned and gained so far? Examples shown in this poster include:
- Fundamentally clarified Neoarchean through Paleoproterozoic stratigraphy,
- Added a regional first phase of isoclinal recumbent folds and thrusts,
- Recognized the spatial association of 1.75 Ga Nueltin granite with U deposits
- Gained complete airborne geophysical coverage at <½ cost to taxpayer
- Added >1000 gravity stations along strategic transects for modelling in 3-D.

WHAT questions remain? Many including:
- Alteration haloes:
  - What types of illite & chlorite are in and around Kiggavik?
  - Apatite 1670 Ma = distal part of U ore system or barren system? Age of ore?
  - Difference between regional and deposit specific illite?
- Amer Group beneath Thelon Fm:
  - Conductors or stratabound U horizons more prospective, or both?
  - How important is pre-weathering recrystallization?
- Favourable geochemical hosts for unconformity U:
  - Which Archean strata are best - just Neoarchean Sequence 3?
  - Are proto U deposits associated with Nueltin contact zones?
  - How important is Pitz Volcanic associated U (Miller & LeCheminant)


Uranium Resources in Canada, 2007
'Young' potential host rocks
'Old' potential host rocks
Ultimate uranium resource (tonnes) 6000
Cumulative production
Remaining reserve/discovery
Undiscovered resources
Hornby Bay 3000
Port Radium 5000
Thelon 87 000
Beaverlodge 26 000
Cordillera 6000
Athabasca 1 352 000
Otish-Sakami 27 000
Makkovik 16 500
Miscellaneous 12 000
Elliot Lake 145 000
Bancroft 9000
Total ultimate resource: 1 693 000 tonnes U

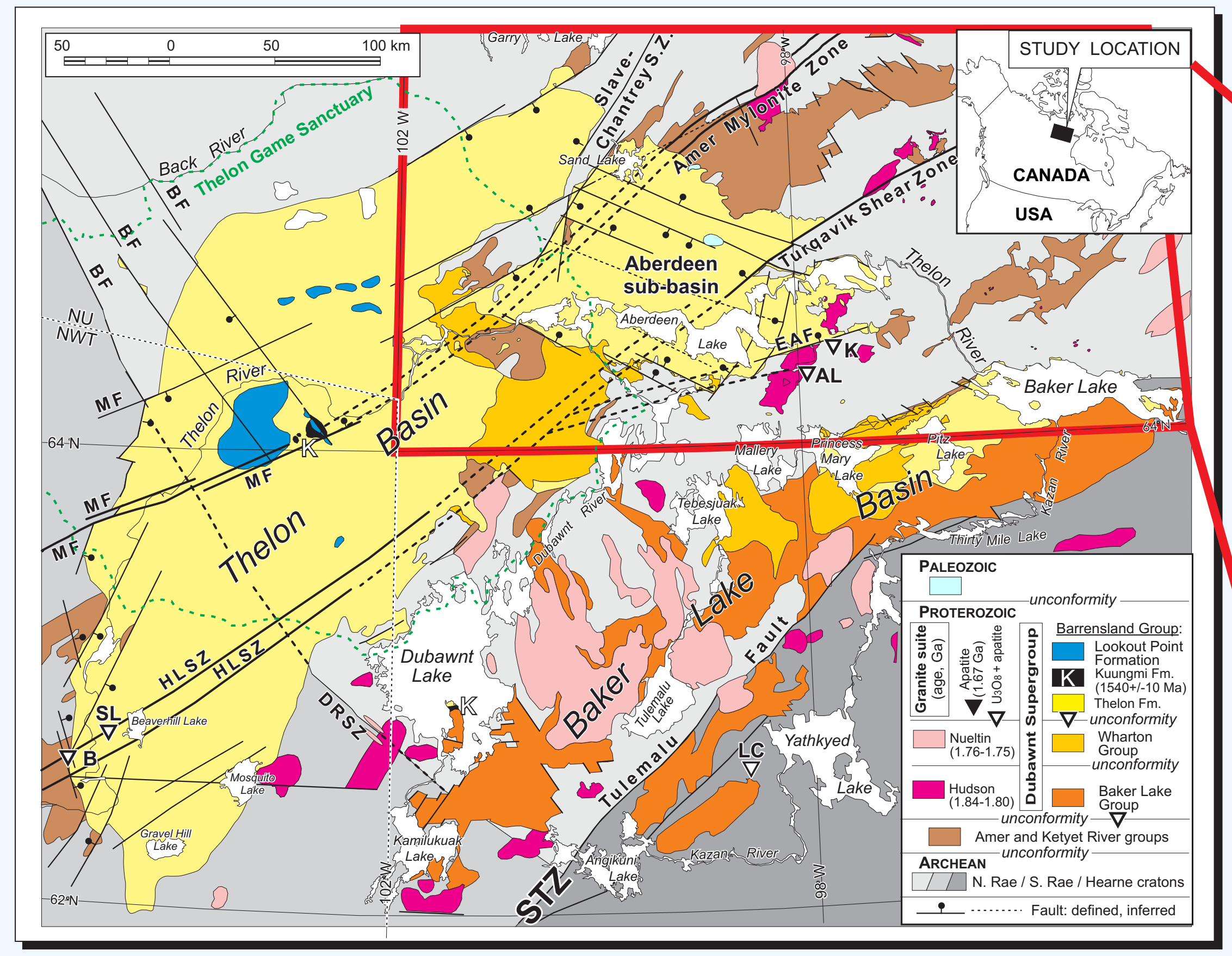
How much more could Thelon hide?

HYPOTHESIS - WHERE & HOW MUCH:
- In comparison with east Athabasca, do Thelon, western frontier Athabasca & other late Paleoproterozoic northern basins & basement have untapped U?

TESTS:
- Apply the eastern Athabasca Basin unconformity U Model
- Extrapolate U source & key basement units beneath basins by improved mapping, geophysics and satellite data.
- Track and date basin development; U-related alteration, sources & pathways.

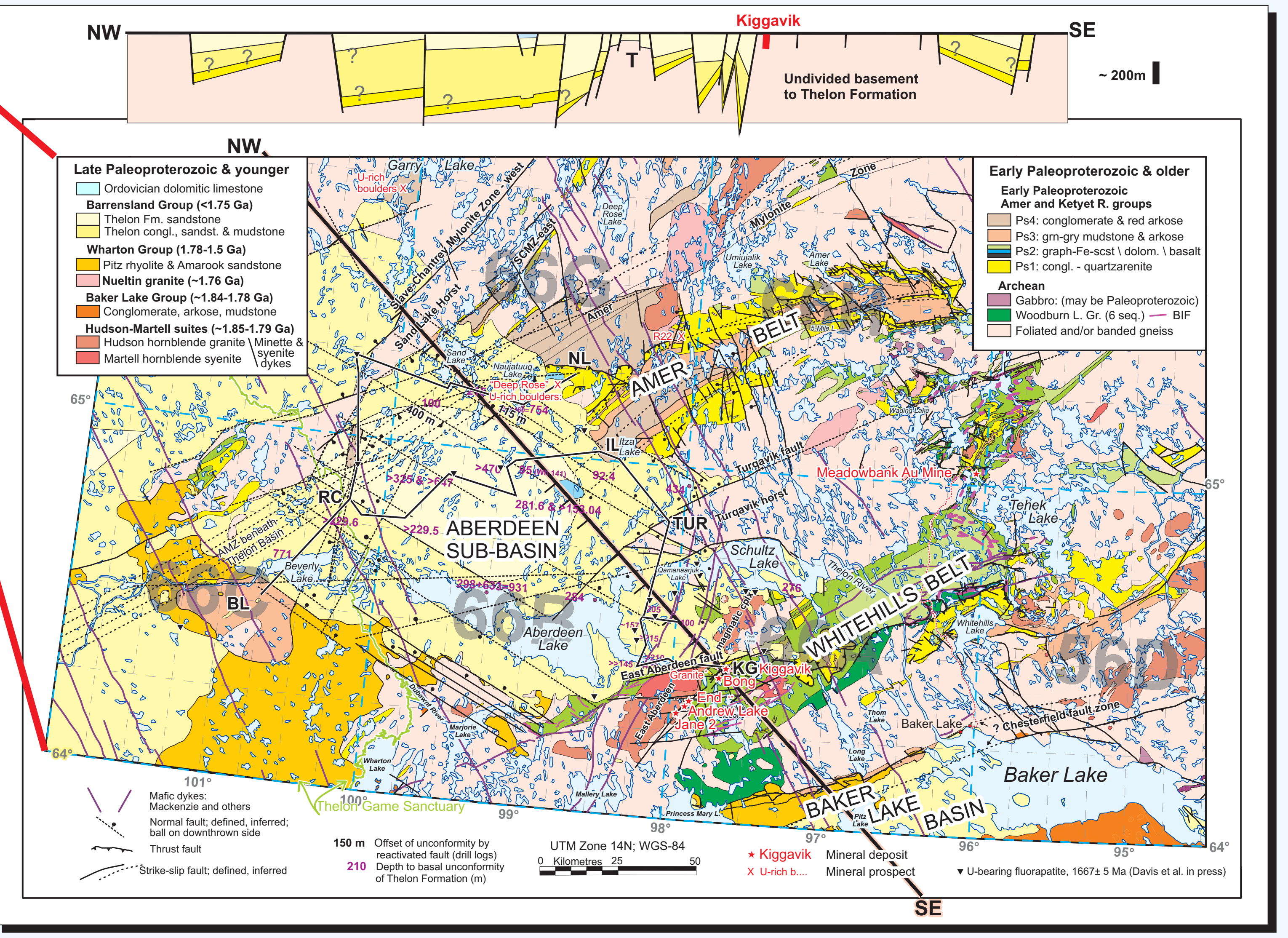
OUTPUTS: series of 1:50,000 scale geophysical, geological and surficial materials maps + government and journal papers with new metallogenic knowledge

Fig. 1: Location & Geology, Thelon - Baker Lake region

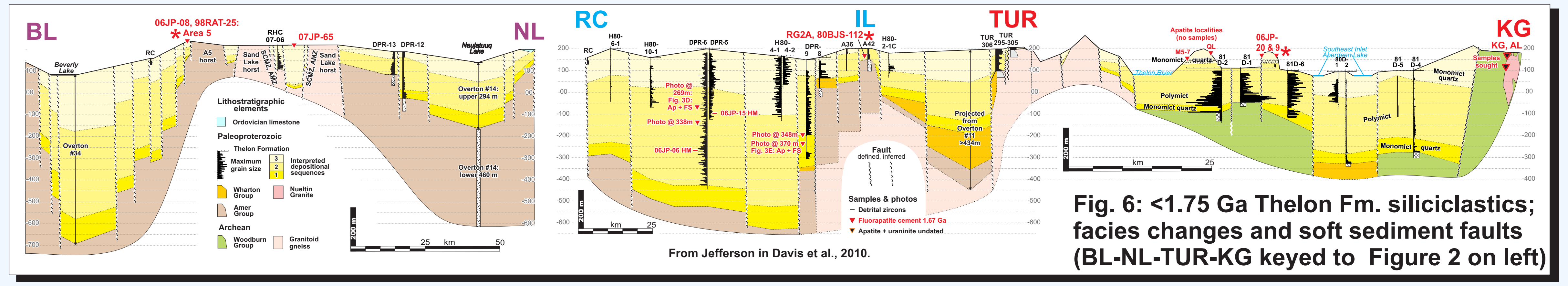

STUDY LOCATION
CANADA
USA
50 0 50 100 km
Garry Lake
Back River
Thelon Game Sanctuary
Slave-Chantrey S.Z.
Amer Mylonite Zone
Sand Lake
Aberdeen sub-basin
Turqavik Shear Zone
Thelon River
Aberdeen Lake
EAF
K
AL
Baker Lake
NU NWT
BF
MF
Thelon River
K
Thelon Basin
HLSZ
SL
B
DRSZ
Dubawnt Lake
Baker Lake Basin
Tulemalu Lake
Yathkyed Lake
LC
STZ
Kazan River
Mallery Lake
Princess Mary Lake
Pitz Lake
Tebesjuak Lake
Thirty Mile Lake
Beaverhill Lake
Mosquito Lake
Gravel Hill Lake
Kamilukuak Lake
Angikuni Lake
64°N
62°N
102°W
98°W
PALEOZOIC
unconformity
PROTEROZOIC
Granite suite (age, Ga)
Apatite (1.67 Ga) U3O8 + apatite
Dubawnt Supergroup
Barrensland Group:
Lookout Point Formation
Kuungmi Fm. (1540+/-10 Ma)
Thelon Fm.
unconformity
Wharton Group
unconformity
Nueltin (1.76-1.75)
Hudson (1.84-1.80)
Baker Lake Group
unconformity
Amer and Ketyet River groups
unconformity
ARCHEAN
N. Rae / S. Rae / Hearne cratons
Fault: defined, inferred

The Thelon R. - Baker L. region overlies several Archean basement cratons. North & South Rae were sutured along the Dubawnt River shear zone (DRSZ), Hearne along the Snowbird Tectonic Zone (STZ). New aeromagnetic data connect reactivated shear zones prospective beneath Thelon Basin: Amer (AMZ) with MacDonald (MF), Howard (HLSZ) with Turqavik whose East Aberdeen splays (EAF) localize the Kiggavik Trend deposits (K, AL) at intersections with northerly faults.

Fig. 2: Geology, Northeast Thelon Basin & surrounding region

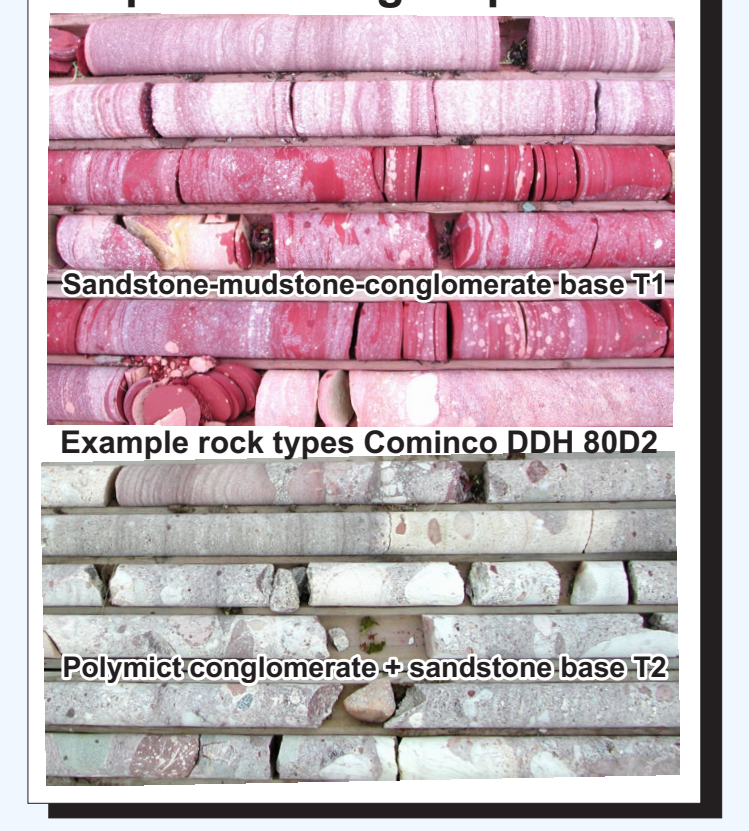

NW
Kiggavik
SE
T
Undivided basement to Thelon Formation
~ 200m
Late Paleoproterozoic & younger
Ordovician dolomitic limestone
Barrensland Group (<1.75 Ga)
Thelon Fm. sandstone
Thelon congl., sandst. & mudstone
Wharton Group (1.78-1.5 Ga)
Pitz rhyolite & Amarook sandstone
Nueltin granite (~1.76 Ga)
Baker Lake Group (~1.84-1.78 Ga)
Conglomerate, arkose, mudstone
Hudson-Martell suites (~1.85-1.79 Ga)
Hudson hornblende granite
Martell hornblende syenite
Minette & syenite dykes
Early Paleoproterozoic & older
Early Paleoproterozoic Amer and Ketyet R. groups
Ps4: conglomerate & red arkose
Ps3: grn-gry mudstone & arkose
Ps2: graph-Fe-scst \ dolom. \ basalt
Ps1: congl. - quartzarenite
Archean
Gabbro: (may be Paleoproterozoic)
Woodburn L. Gr. (6 seq.) BIF
Foliated and/or banded gneiss
Garry Lake
U-rich boulders
Slave-Chantrey Mylonite Zone - west
SCMZ-east
Sand Lake horst
Mylonite
Zone
66C
NL
AMER BELT
Deep Rose Lake
U-rich boulders
IL
RC
AMZ beneath Thelon Basin
ABERDEEN SUB-BASIN
Turqavik fault
TUR
Turqavik horst
Meadowbank Au Mine
Tehek Lake
Schultz Lake
66B
BL
Beverly Lake
Aberdeen Lake
East Aberdeen fault
Granite
Bong
KG Kiggavik
End
Andrew Lake
Jane 2
WHITEHILLS BELT
66A
Baker Lake
Chesterfield fault zone
56D
BAKER LAKE BASIN
Thelon Game Sanctuary
65°
64°
101°
100°
99°
98°
97°
96°
95°
Mafic dykes: Mackenzie and others
Normal fault; defined, inferred; ball on downthrown side
Thrust fault
Strike-slip fault; defined, inferred
150 m Offset of unconformity by reactivated fault (drill logs)
210 Depth to basal unconformity of Thelon Formation (m)
UTM Zone 14N; WGS-84
0 Kilometres 25 50
Kiggavik Mineral deposit
U-rich b.... Mineral prospect
U-bearing fluorapatite, 1667± 5 Ma (Davis et al. in press)

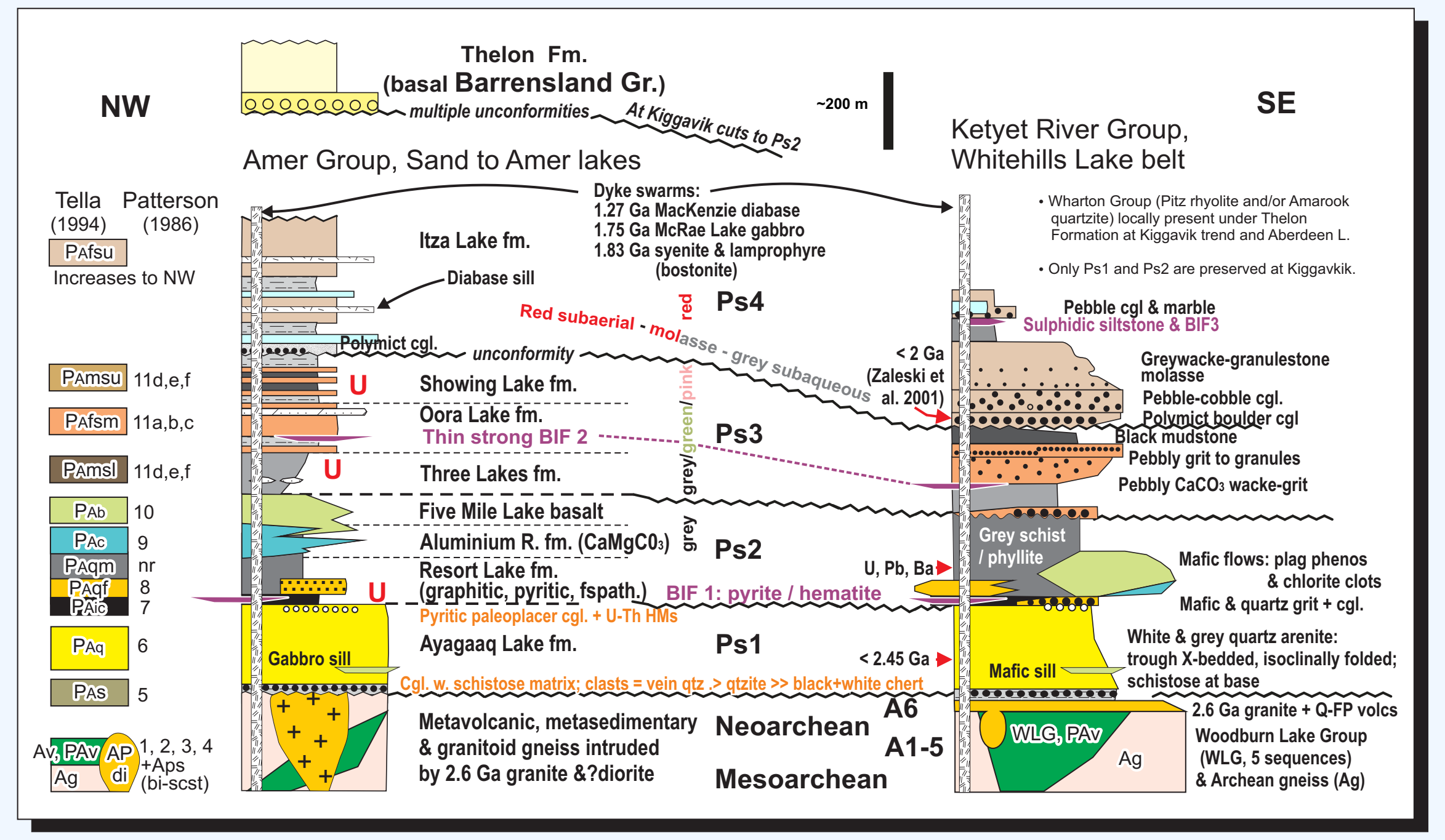
Neoarchean through late Paleoproterozoic stratigraphy; Paleoproterozoic orogeny through brittle transextension: much to be tested and integrated


BL
06JP-08, 98RAT-25: Area 5
RHC 07-06
07JP-65
DPR-13 DPR-12
Naujatuuq Lake
NL
Beverly Lake
RC
A5 horst
Sand Lake horst
SCMZ
AMZ
Overton #34
Overton #14: upper 294 m
Overton #14: lower 460 m
Lithostratigraphic elements
Ordovician limestone
Paleoproterozoic
Thelon Formation
Maximum grain size
Interpreted depositional sequences
Wharton Group
Nueltin Granite
Amer Group
Archean
Woodburn Group
Granitoid gneiss
25 km 50
RC
IL
RG2A, 80BJS-112
TUR
H80-6-1
H80-10-1
DPR-6 DPR-5
H80-4-1 4-2
DPR-9 8
A36 A42
H80-2-1C
TUR 306
TUR 295-305
Photo @ 269m: Fig. 3D: Ap + FS
06JP-15 HM
Photo @ 338m
06JP-06 HM
Photo @ 348m
Photo @ 370 m
Fig. 3E: Ap + FS
Fault defined, inferred
Samples & photos
Detrital zircons
Fluorapatite cement 1.67 Ga
Apatite + uraninite undated
Projected from Overton #11 >434m
km 25
Apatite localities (no samples)
06JP-20 & 9
M5-7
QL
Monomict quartz
81 D-2
81 D-1
81D-6
Southeast Inlet Aberdeen Lake
80D-1 2
81 D-5
81 D-4
KG
KG, AL
Samples sought
Thelon River
Polymict
Monomict quartz
200 100 00 -100 -200 -300 -400 -500 -600

From Jefferson in Davis et al., 2010.

Fig. 6: <1.75 Ga Thelon Fm. siliciclastics; facies changes and soft sediment faults (BL-NL-TUR-KG keyed to Figure 2 on left)


3 upward fining sequences
Sandstone-mudstone-conglomerate base T1
Example rock types Cominco DDH 80D2
Polymict conglomerate + sandstone base T2


NW
Thelon Fm. (basal Barrensland Gr.)
multiple unconformities
At Kiggavik cuts to Ps2
~200 m
Ketyet River Group, Whitehills Lake belt
SE
Amer Group, Sand to Amer lakes
Tella (1994)
Patterson (1986)
PAfsu
Increases to NW
Dyke swarms:
1.27 Ga MacKenzie diabase
1.75 Ga McRae Lake gabbro
1.83 Ga syenite & lamprophyre (bostonite)
Itza Lake fm.
Diabase sill
Red subaerial - molasse - grey subaqueous
red
Ps4
Polymict cgl.
unconformity
PAmsu 11d,e,f
PAfsm 11a,b,c
PAmsl 11d,e,f
PAb 10
PAc 9
PAqm nr
PAgf 8
PAic 7
PAq 6
PAs 5
Av PAv AP Ag di 1, 2, 3, 4 +Aps (bi-scst)
U
Showing Lake fm.
Oora Lake fm.
Thin strong BIF 2
Ps3
grey/green/pink
Three Lakes fm.
Five Mile Lake basalt
Aluminium R. fm. (CaMgCO3)
grey
Ps2
Resort Lake fm.
(graphitic, pyritic, fspath.)
BIF 1: pyrite / hematite
Pyritic paleoplacer cgl. + U-Th HMs
Gabbro sill
Ayagaaq Lake fm.
Ps1
< 2.45 Ga
Cgl. w. schistose matrix: clasts = vein qtz > qtzite >> black+white chert
Metavolcanic, metasedimentary & granitoid gneiss intruded by 2.6 Ga granite &?diorite
Neoarchean
Mesoarchean
A6
A1-5
Whorton Group (Pitz rhyolite and/or Amarook quartzite) locally present under Thelon Formation at Kiggavik trend and Aberdeen L.
Only Ps1 and Ps2 are preserved at Kiggavik.
Pebble cgl & marble
Sulphidic siltstone & BIF3
< 2 Ga (Zaleski et al. 2001)
Greywacke-granulestone molasse
Pebble-cobble cgl.
Polymict boulder cgl
Black mudstone
Pebbly grit to granules
Pebbly CaCO3 wacke-grit
Grey schist / phyllite
U, Pb, Ba
Mafic flows: plag phenos & chlorite clots
Mafic & quartz grit + cgl.
White & grey quartz arenite: trough X-bedded, isoclinally folded; schistose at base
Mafic sill
2.6 Ga granite + Q-FP volcs
WLG, PAv
Ag
Woodburn Lake Group (WLG, 5 sequences) & Archean gneiss (Ag)

STRUCTURE

Dextral reactivated faults offset 1.75 Ga Nueltin granite & McRae Lake diabase

~1.83 Ga Hudson granite stitched & offset by mylonite

The orogen was eroded into NW foreland basins 1st folded late D2.

Major basement uplift SE of STZ drove NW-vergent D2 refolding.

Regional sequences Ps1-Ps2-Ps3 were deformed into Archean-cored nappes and thrusts before 1.92 Ga.

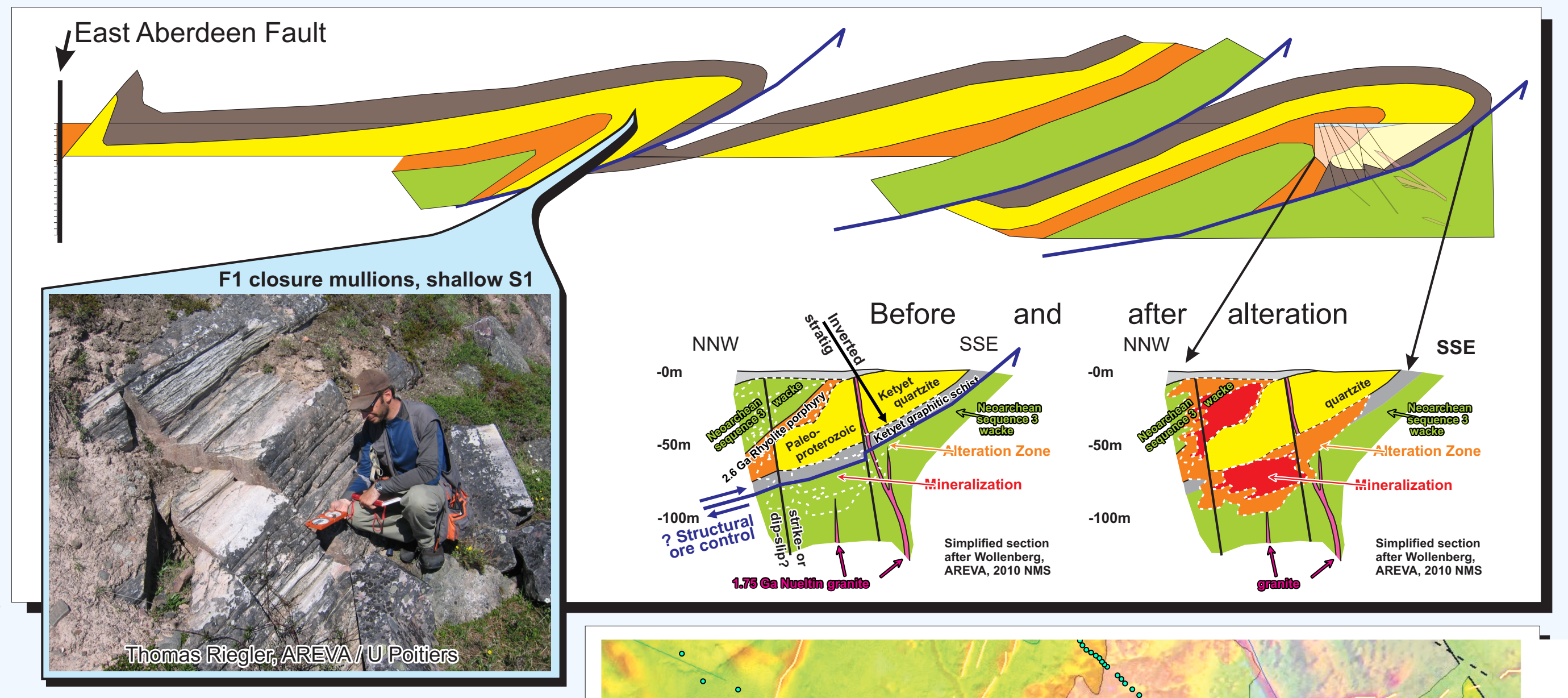
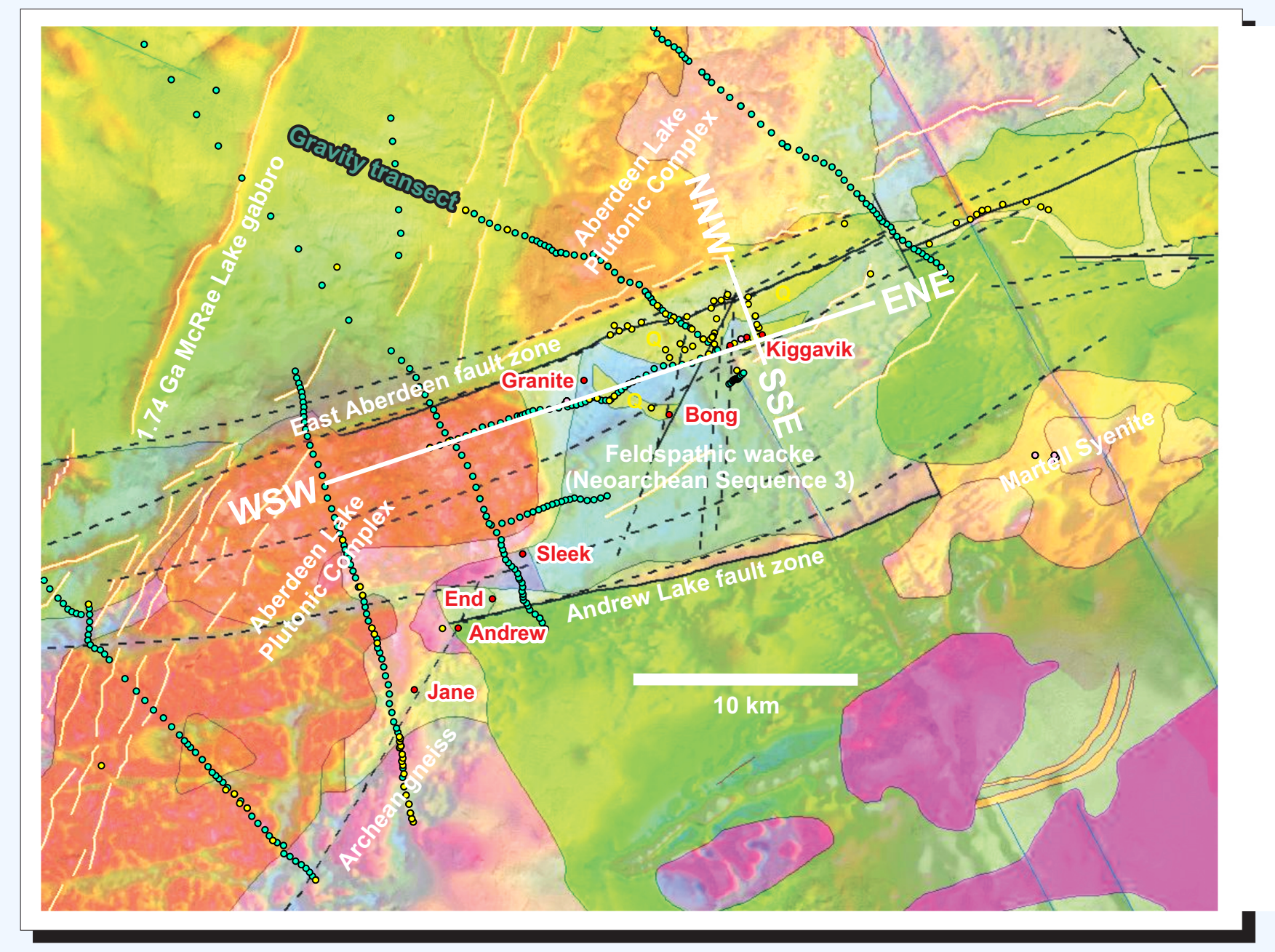

East Aberdeen Fault
F1 closure mullions, shallow S1
Thomas Riegler, AREVA / U Poitiers
Before and after alteration
NNW
SSE
-0m
-50m
-100m
Inverted stratig
Neoarchean sequence 3 wacke
2.6 Ga Rhyolite porphyry
Paleo-proterozoic
Ketyet quartzite
Ketyet graphitic schist
Alteration Zone
Mineralization
? Structural ore control
dip-slip? strike- or
1.75 Ga Nueltin granite
granite
quartzite
Simplified section after Wollenberg, AREVA, 2010 NMS

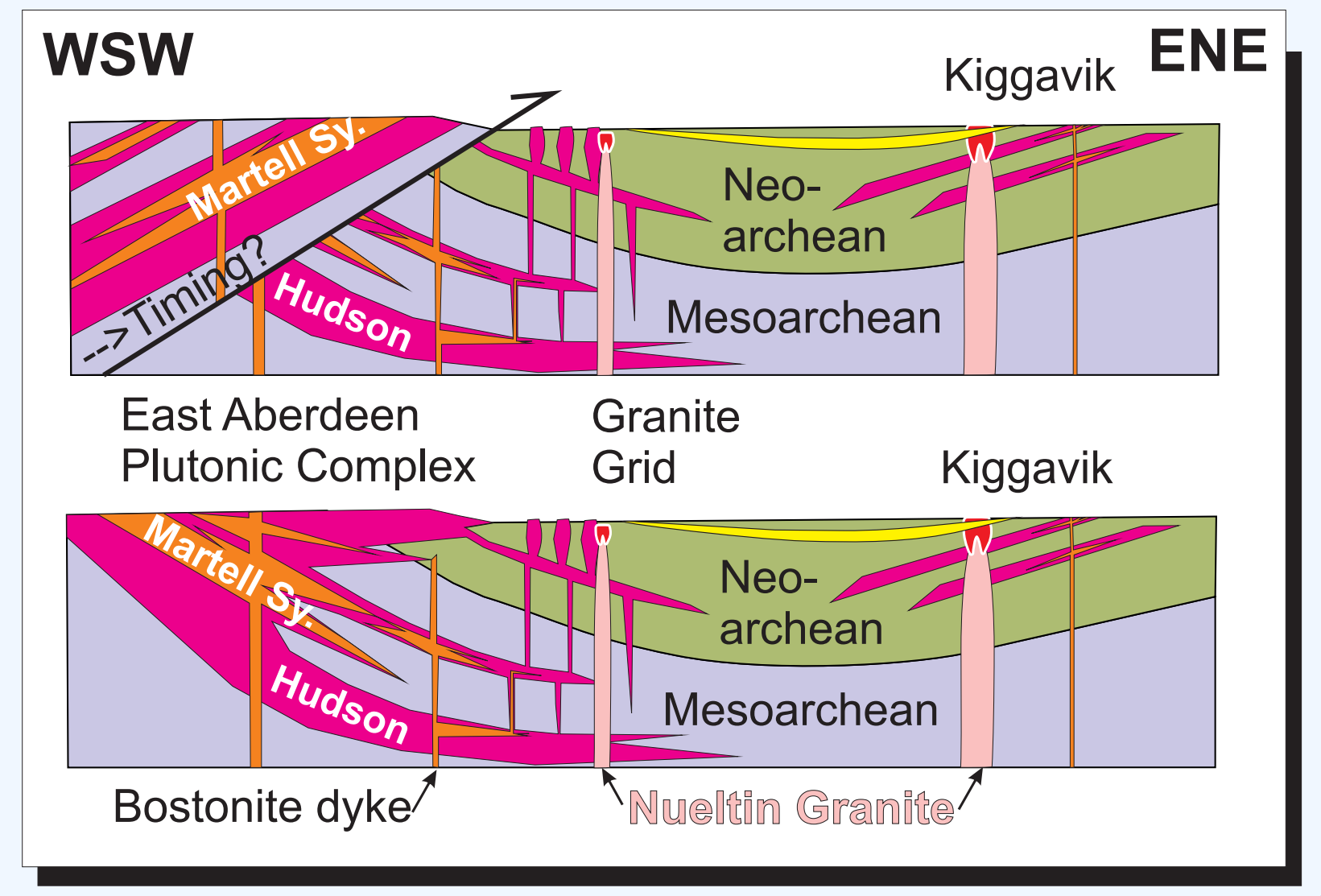
Fig. 7: Early Paleoproterozoic (<2.5 to >1.8 Ga) Amer and Ketyet groups: sequences, lithostratigraphy and structure now closely correlated.

Fig. 9: Applying to ore what we have learned:

A. Nappes & thrusts as part of the structural setting for Kiggavik E.

B. Ideas to test by mapping & modeling: **e.g. is the East Aberdeen plutonic complex thrust over the Kiggavik Trend or does it intrude?**


Gravity transect
1.74 Ga McRae Lake gabbro
Aberdeen Lake Plutonic Complex
NNW
ENE
SSE
Kiggavik
Granite
Bong
East Aberdeen fault zone
WSW
Feldspathic wacke (Neoarchean Sequence 3)
Martell Syenite
Aberdeen Lake Plutonic Complex
Sleek
End
Andrew
Andrew Lake fault zone
Jane
Archean gneiss
10 km


WSW
Kiggavik
ENE
Martell Sy.
-->Timing?
Hudson
Neo-archean
Mesoarchean
East Aberdeen Plutonic Complex
Granite Grid
Kiggavik
Martell Sy.
Hudson
Neo-archean
Mesoarchean
Bostonite dyke
Nueltin Granite

Summary

- Tectonic and uranium attributes of Thelon Basin compare with, but differ in subtle ways from the graphitic metapelite-dominated basement setting for world class deposits of the Athabasca basin.
- The two basins developed along parallel but separate, west-flowing "big river" systems draining the interior of Nuna.
- Ages of diagenesis, hydrothermal events & uranium minerals differ by 10s of Ma.
- Thelon's deposits are spatially associated with 1.75 Ga Nueltin granite & Pitz rhyolite
- Intersecting reactivated faults are key in both basins; basement nappes may also!
- Alteration (e.g. chlorite, illite, hematite, +/- quartz, fluorapatite) differs in detail.

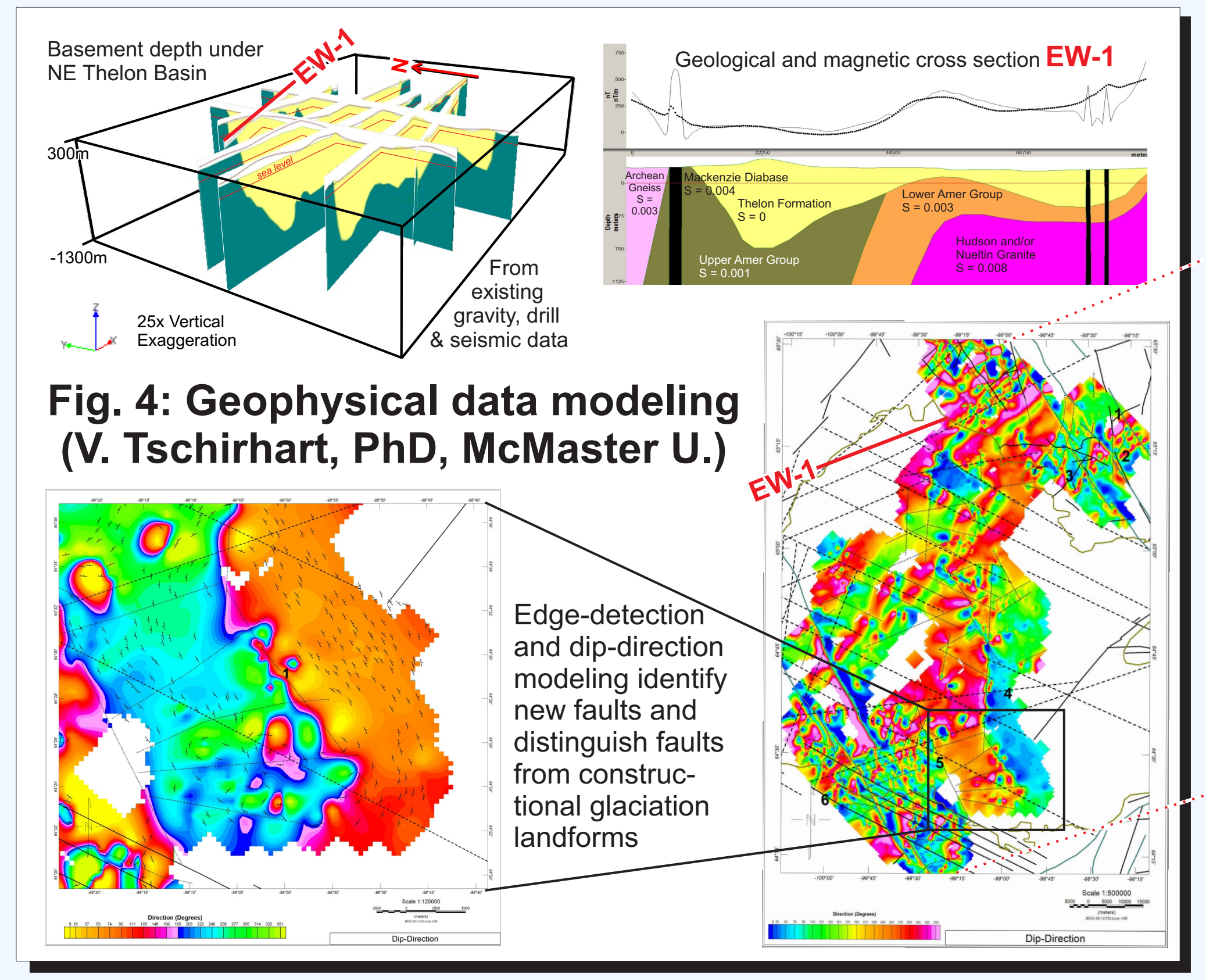

Basement depth under NE Thelon Basin
EW-1
N
300m
sea level
-1300m
25x Vertical Exaggeration
From existing gravity, drill & seismic data
Geological and magnetic cross section EW-1
Archean Gneiss S = 0.003
Mackenzie Diabase S = 0.004
Thelon Formation S = 0
Lower Amer Group S = 0.003
Upper Amer Group S = 0.001
Hudson and/or Nueltin Granite S = 0.008
EW-1
Direction (Degrees)
Dip-Direction

Fig. 4: Geophysical data modeling (V. Tschirhart, PhD, McMaster U.)

Edge-detection and dip-direction modeling identify new faults and distinguish faults from constructional glaciation landforms

Fig. 3: Geophysical consortium contributions and new field data stations

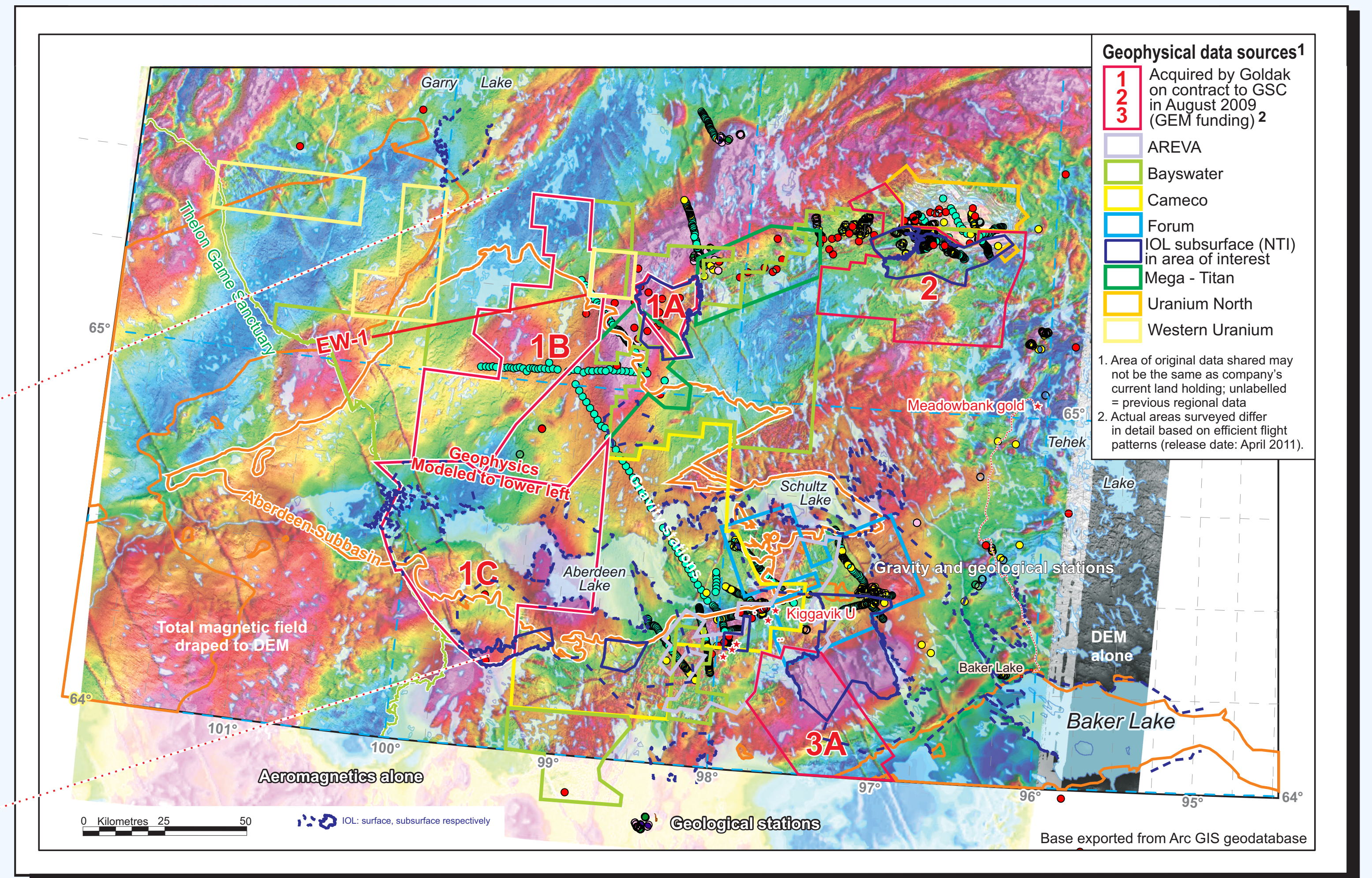
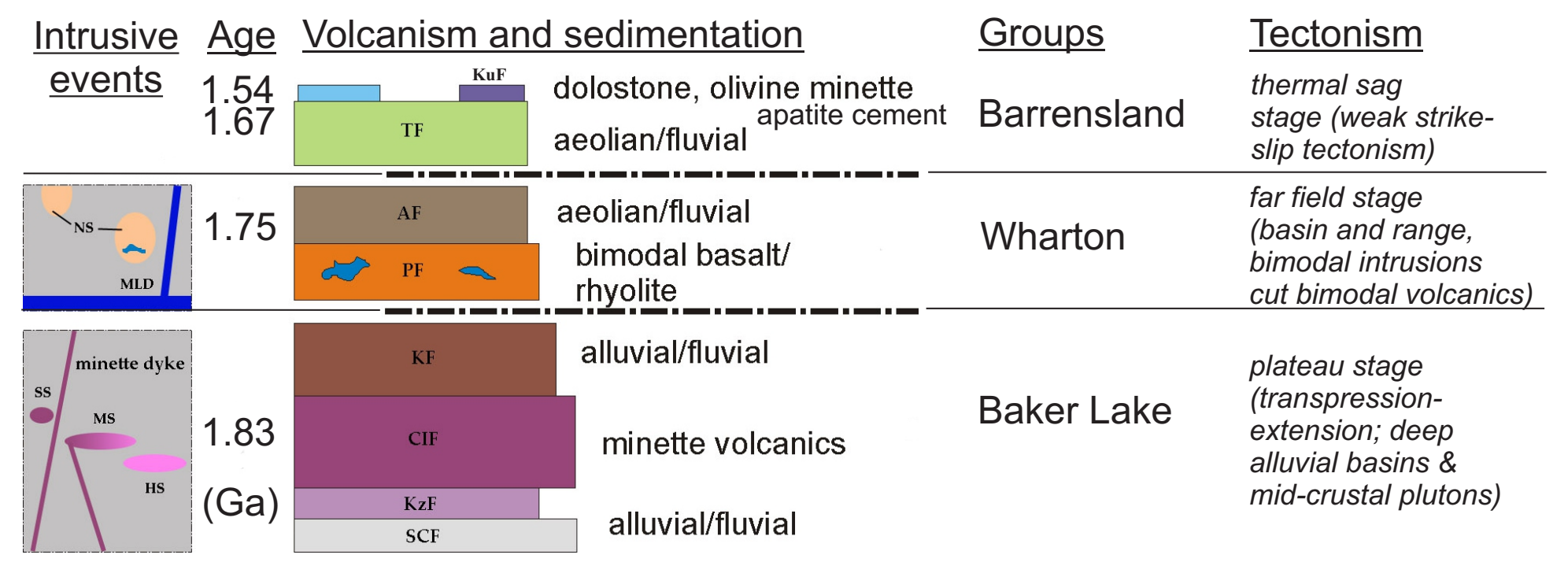
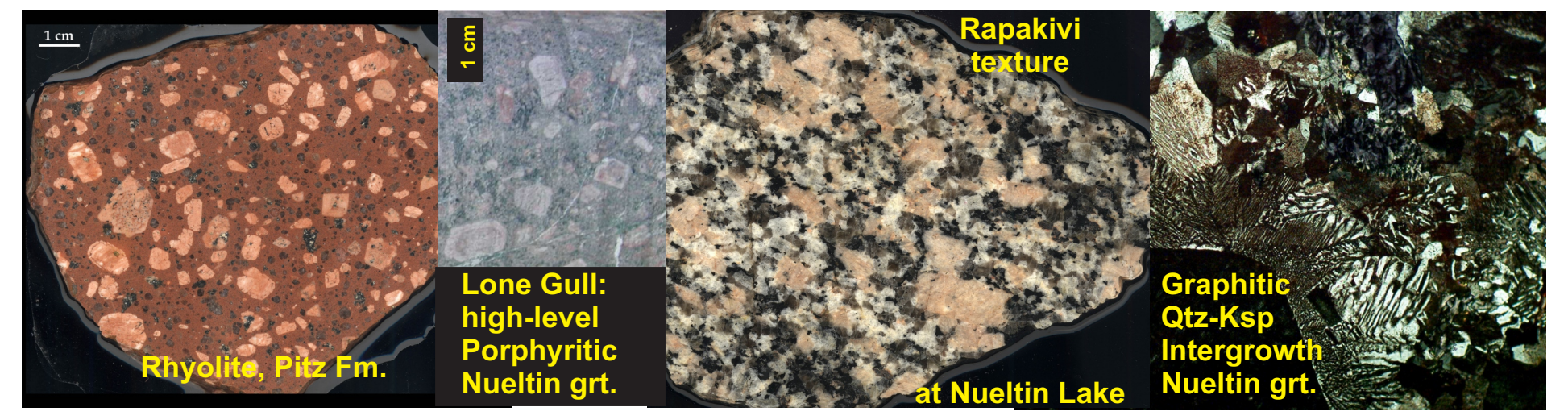

Garry Lake
Thelon Game Sanctuary
EW-1
1A
1B
2
65°
Meadowbank gold
Tehek Lake
Geophysics Modeled to lower left
Aberdeen-Subbasin
Gravity transect
1C
Aberdeen Lake
Schultz Lake
Kiggavik U
Gravity and geological stations
Total magnetic field draped to DEM
DEM alone
Baker Lake
Baker Lake
3A
64°
101° 100° 99° 98° 97° 96° 95° 64°
Aeromagnetics alone
0 Kilometres 25 50
IOL: surface, subsurface respectively
Geological stations
Geophysical data sources1
1 2 3 Acquired by Goldak on contract to GSC in August 2009 (GEM funding) 2
AREVA
Bayswater
Cameco
Forum
IOL subsurface (NTI) in area of interest
Mega - Titan
Uranium North
Western Uranium
1. Area of original data shared may not be the same as company's current land holding; unlabelled = previous regional data
2. Actual areas surveyed differ in detail based on efficient flight patterns (release date: April 2011).
Base exported from Arc GIS geodatabase

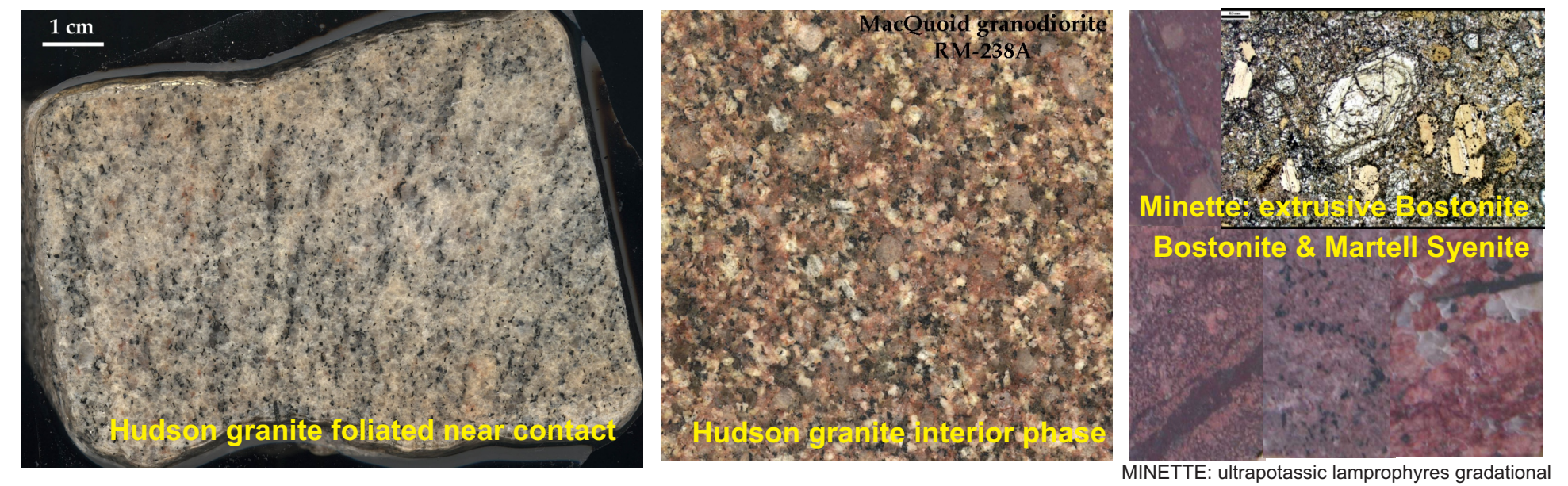
Fig. 5: Paleoproterozoic magmatism & Dubawnt Supergroup


Intrusive events
Age
Volcanism and sedimentation
Groups
Tectonism
1.54
1.67
KuF
TF
dolostone, olivine minette
apatite cement
aeolian/fluvial
Barrensland
thermal sag stage (weak strike-slip tectonism)
NS
MLD
1.75
AF
PF
aeolian/fluvial
bimodal basalt/ rhyolite
Wharton
far field stage (basin and range, bimodal intrusions cut bimodal volcanics)
minette dyke
SS
MS
HS
1.83
(Ga)
KF
CIF
KzF
SCF
alluvial/fluvial
minette volcanics
alluvial/fluvial
Baker Lake
plateau stage (transpression-extension; deep alluvial basins & mid-crustal plutons)


1 cm
Rhyolite, Pitz Fm.
1 cm
Lone Gull: high-level Porphyritic Nueltin grt.
Rapakivi texture
at Nueltin Lake
Graphitic Qtz-Ksp Intergrowth Nueltin grt.

1760-1750 Ma Nueltin granite & Pitz rhyolite: associated with Kiggavik U deposits

1840-1800 Ma granite & syenite: crustal melts mixed with bostonite (lamprophyre)


1 cm
Hudson granite foliated near contact
MacQuoid granodiorite RM-238A
Hudson granite interior phase
Minette: extrusive Bostonite
Bostonite & Martell Syenite

MINETTE: ultrapotassic lamprophyres gradational to lamproite; cpx-phlog-sanidine (olivine, magnetite, leucite, alkali amphibole)

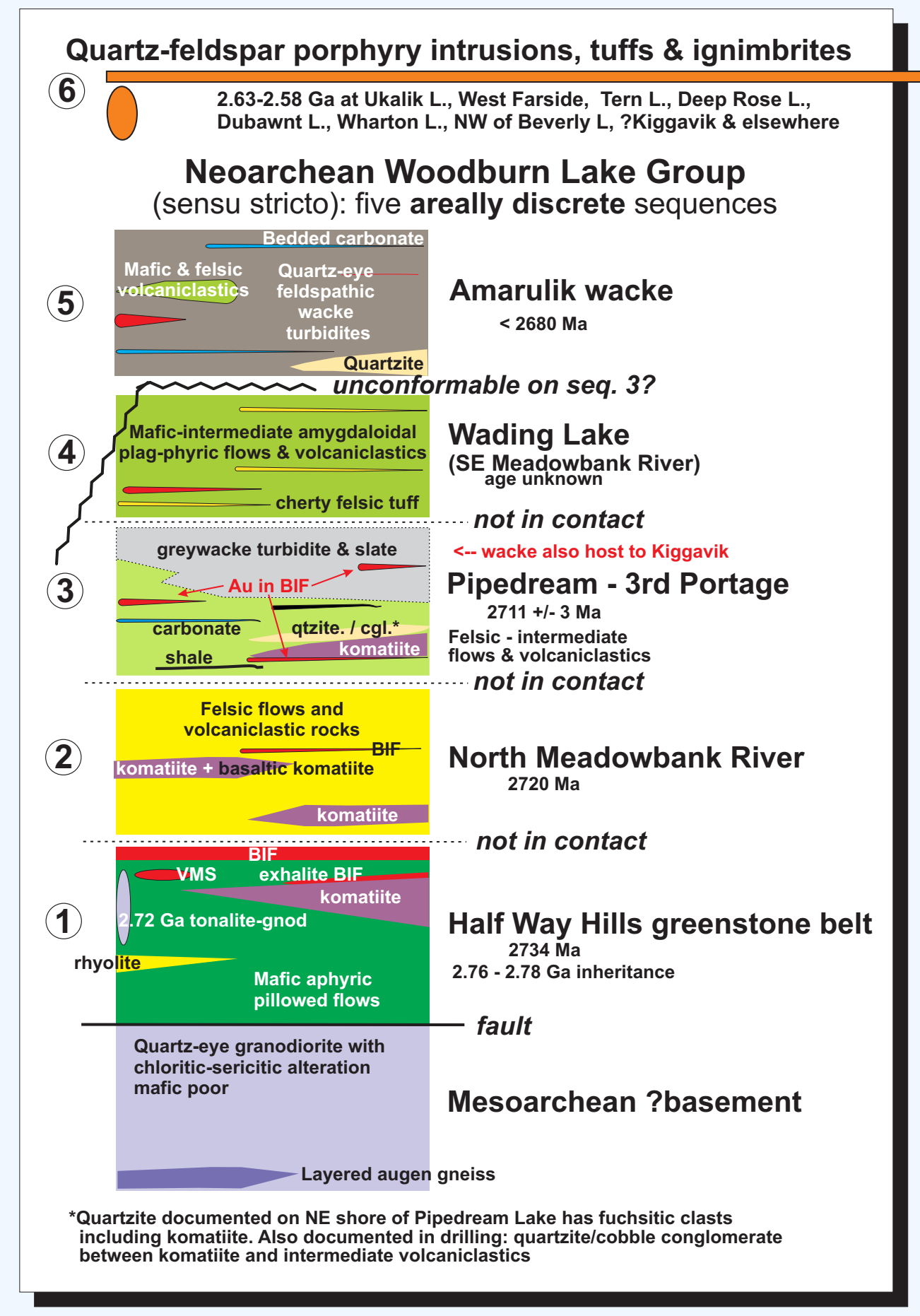
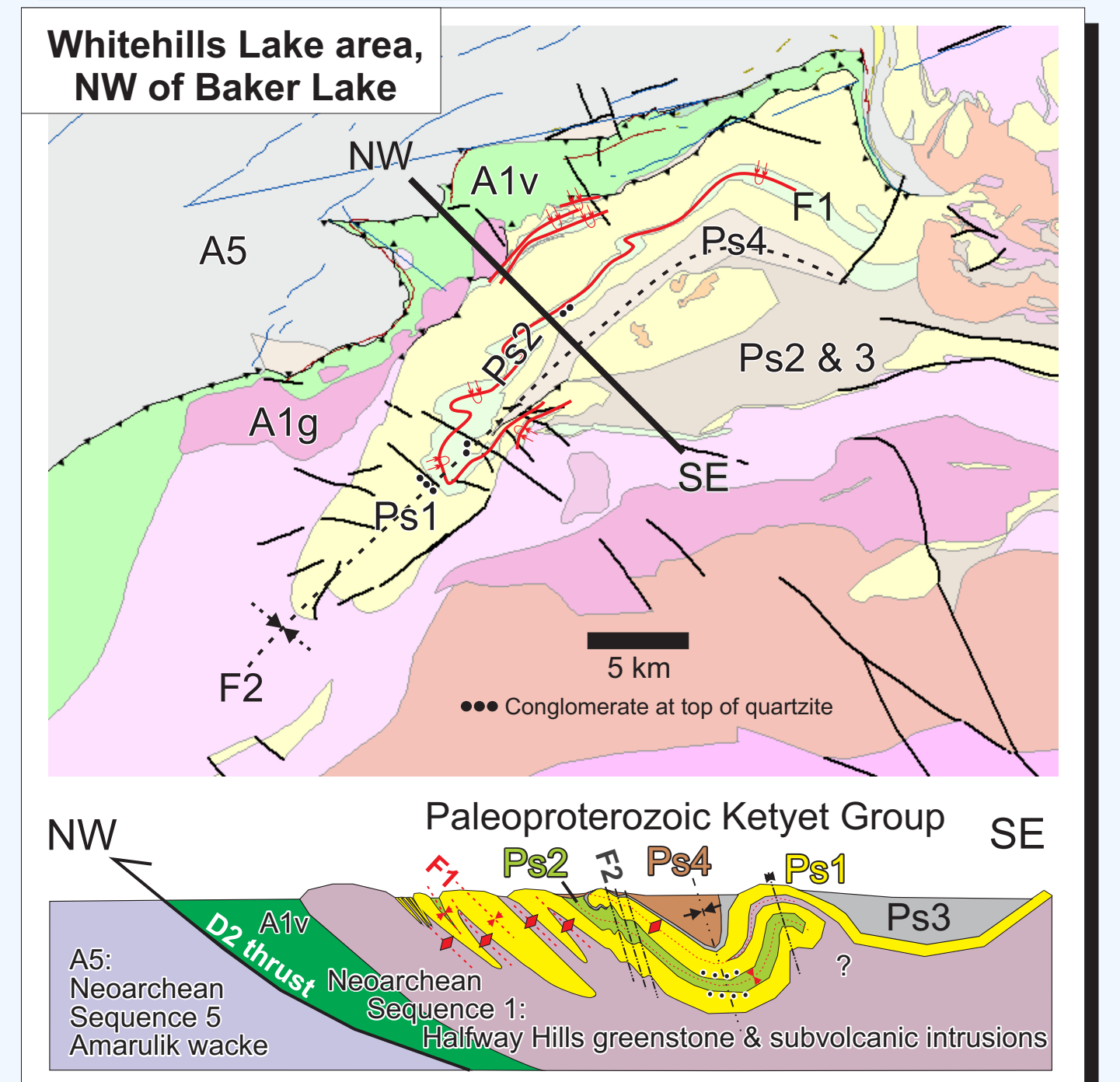

Quartz-feldspar porphyry intrusions, tuffs & ignimbrites
6
2.63-2.58 Ga at Ukalik L., West Farside, Tern L., Deep Rose L., Dubawnt L., Wharton L., NW of Beverly L, ?Kiggavik & elsewhere
Neoarchean Woodburn Lake Group (sensu stricto): five areally discrete sequences
5
Bedded carbonate
Mafic & felsic volcaniclastics
Quartz-eye feldspathic wacke turbidites
Quartzite
Amarulik wacke < 2680 Ma
unconformable on seq. 3?
4
Mafic-intermediate amygdaloidal plag-phyric flows & volcaniclastics
cherty felsic tuff
Wading Lake (SE Meadowbank River) age unknown
not in contact
3
greywacke turbidite & slate
<-- wacke also host to Kiggavik
Au in BIF
carbonate shale
qtzite. / cgl.*
komatiite
Pipedream - 3rd Portage 2711 +/- 3 Ma
Felsic - intermediate flows & volcaniclastics
not in contact
2
Felsic flows and volcaniclastic rocks
BIF
komatiite + basaltic komatiite
komatiite
North Meadowbank River 2720 Ma
not in contact
1
BIF
VMS exhalite BIF
komatiite
2.72 Ga tonalite-gnod
rhyolite
Mafic aphyric pillowed flows
Half Way Hills greenstone belt 2734 Ma 2.76 - 2.78 Ga inheritance
fault
Quartz-eye granodiorite with chloritic-sericitic alteration mafic poor
Mesoarchean ?basement
Layered augen gneiss
*Quartzite documented on NE shore of Pipedream Lake has fuchsitic clasts including komatiite. Also documented in drilling: quartzite/cobble conglomerate between komatiite and intermediate volcaniclastics

Fig. 8: Areally distinct Meso- to Neoarchean lithostructural sequences

Intensely deformed with the Paleoproterozoic

Rhyolite NE of Kiggavik


Whitehills Lake area, NW of Baker Lake
NW
A1v
F1
A5
Ps4
Ps2
Ps2 & 3
A1g
SE
Ps1
F2
5 km
Conglomerate at top of quartzite
NW
Paleoproterozoic Ketyet Group
SE
F1
Ps2
F2
Ps4
Ps1
Ps3
A1v
D2 thrust
A5: Neoarchean Sequence 5 Amarulik wacke
Neoarchean Sequence 1: Halfway Hills greenstone & subvolcanic intrusions

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