Comparison of the Setting and Timing of Abitibi Gold Deposits with Other Large Camps in the Superior Province

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MERC PDAC
Short Course
March 03, 2018

Laurentian University / Université Laurentienne
HARQUAIL SCHOOL OF EARTH SCIENCES / ÉCOLE DES SCIENCES DE LA TERRE

Talk Outline

- **Superior Province/Abitibi Tectonic & Stratigraphic Overview**
- **Regional Controls on Abitibi Gold deposits**
- **Comparison with Hemlo Camp**
- **Comparison with Red Lake Camp**
- **Conclusions & Recommendations**

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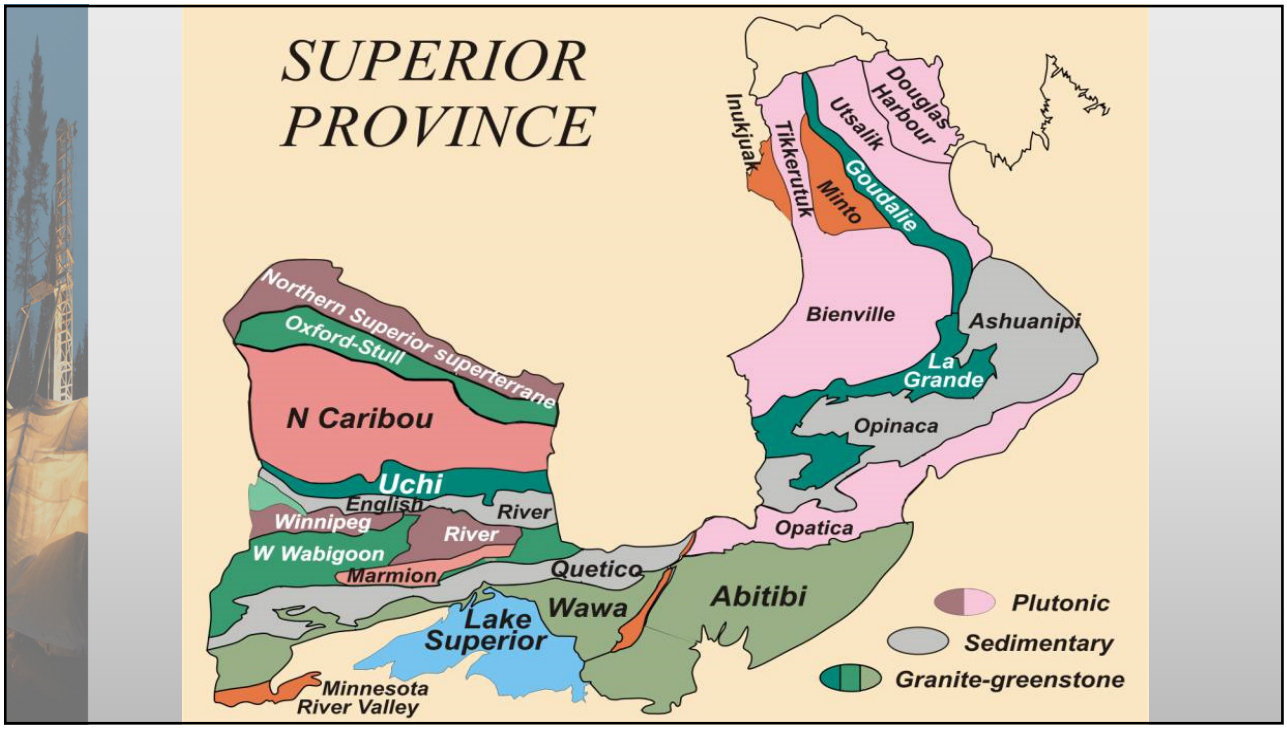
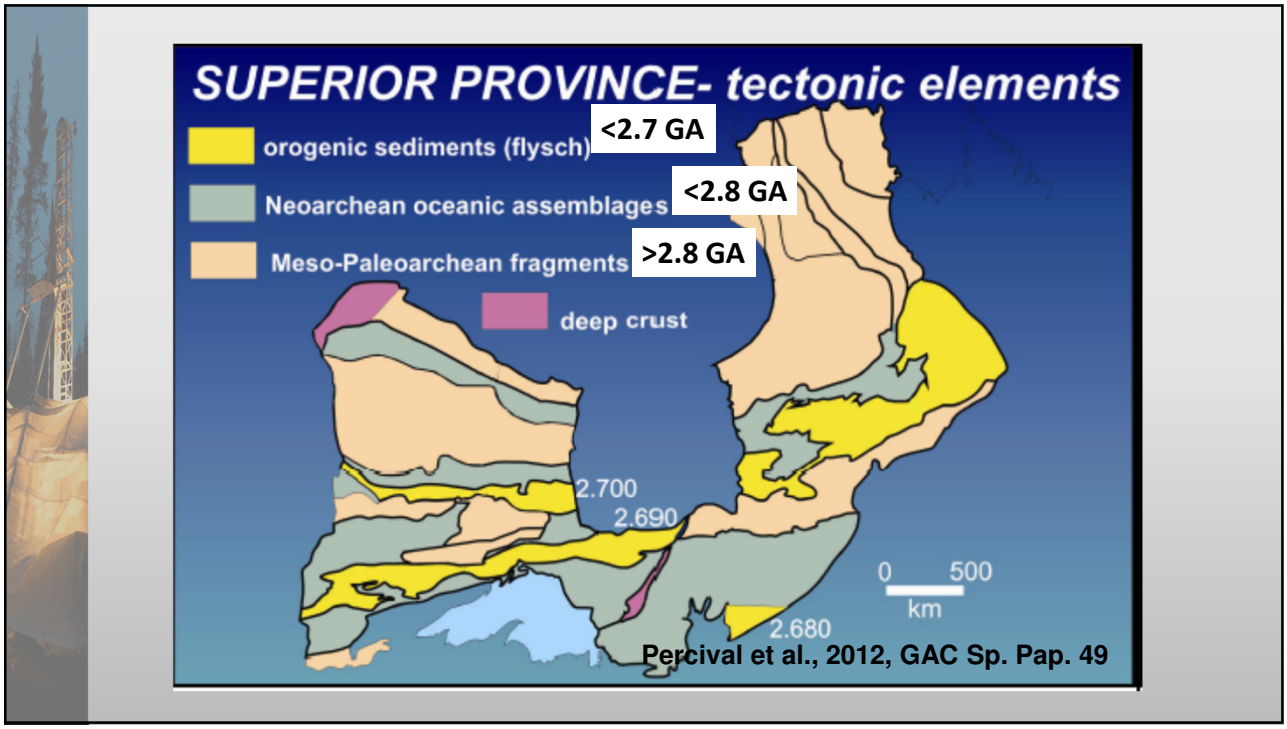
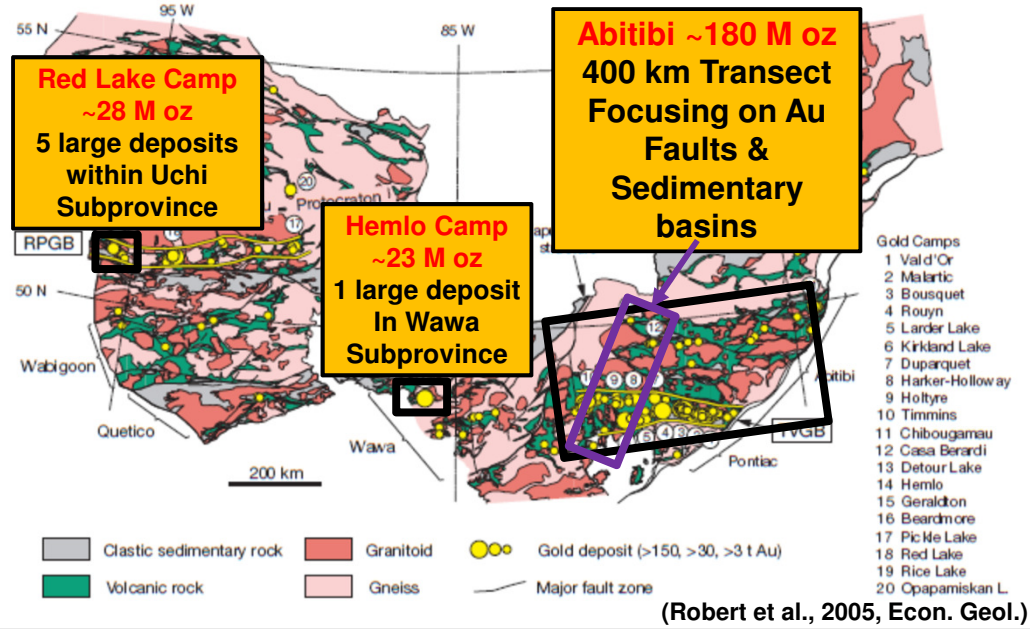

SUPERIOR PROVINCE
Inukjuak
Tikkerutuk
Douglas Harbour
Utsalik
Minto
Goudalie
Bienville
Ashuanipi
La Grande
Opinaca
Opatica
Northern Superior superterrane
Oxford-Stull
N Caribou
Uchi
English River
Winnipeg River
W Wabigoon
Marmion
Quetico
Wawa
Lake Superior
Abitibi
Minnesota River Valley
Plutonic
Sedimentary
Granite-greenstone

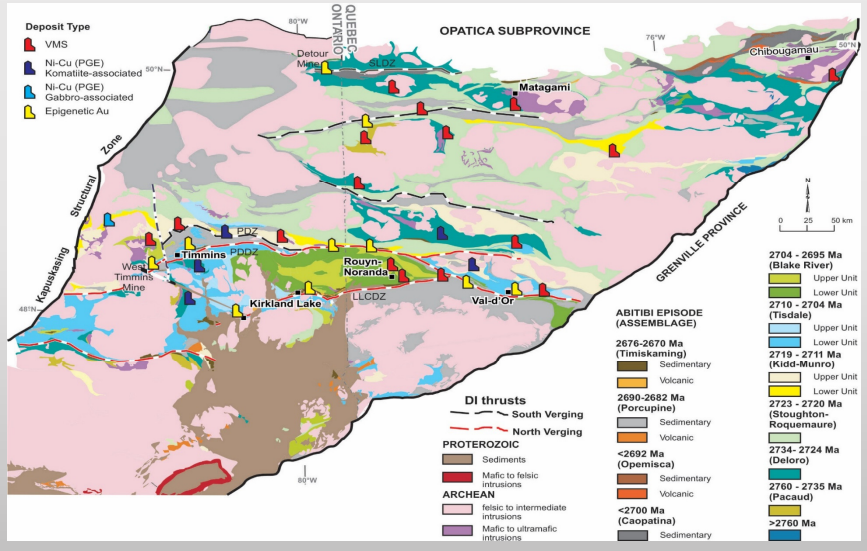

SUPERIOR PROVINCE- tectonic elements
orogenic sediments (flysch)
<2.7 GA
Neoarchean oceanic assemblages
<2.8 GA
Meso-Paleoarchean fragments
>2.8 GA
deep crust
2.700
2.690
2.680
0
500
km
Percival et al., 2012, GAC Sp. Pap. 49

Superior Craton Gold Deposits



(Robert et al., 2005, Econ. Geol.)

Abitibi Greenstone Belt Stratigraphy



Abitibi Greenstone belt extends ~800 km E-W by ~400 km N-S

-7 older volcanic assemblages 2790-2700 Ma

-4 unconformably overlying sedimentary assemblages 2700-2670 Ma

Very well endowed

~180 M oz Au

~750 Mt base metal ore produced (Cu-Zn-Au-Ag)

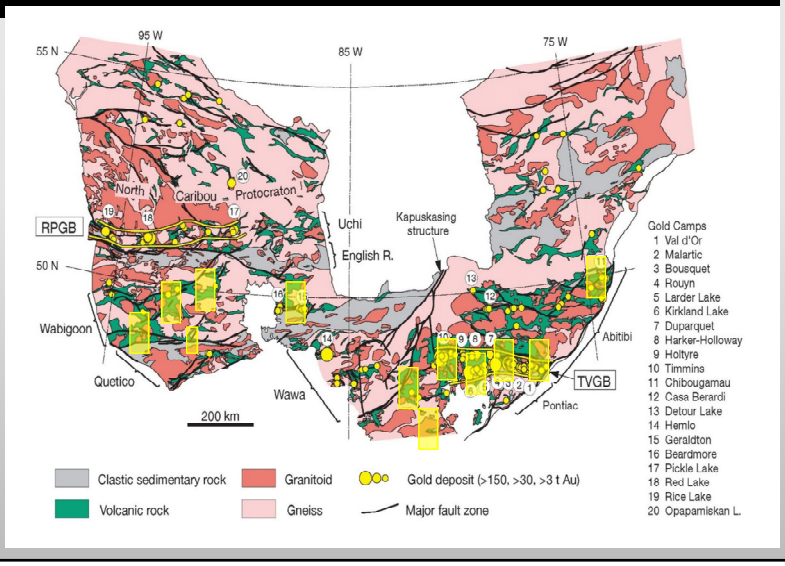
METAL EARTH: Seismic Transects

METAL EARTH MERC

Transect Scale Work

Seismic 2017
MT 2018
Geology 2017-2021
14 Transects including
-Chibougamau
-Southern Abitibi
-Cobalt
-Sudbury
-Wabigoon

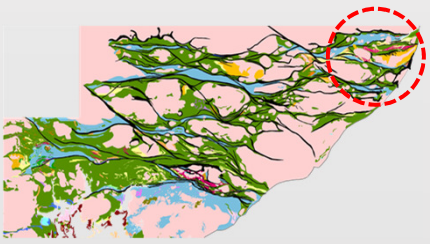
Considering endowed and less endowed areas with same level of consideration

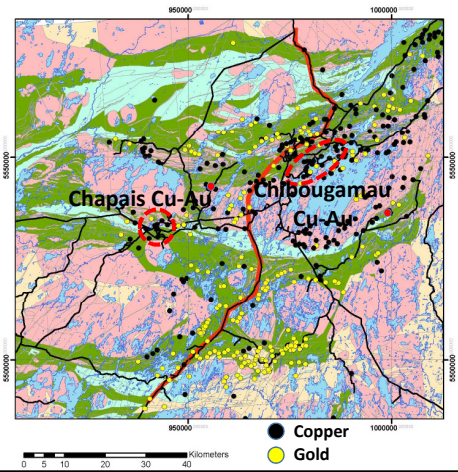


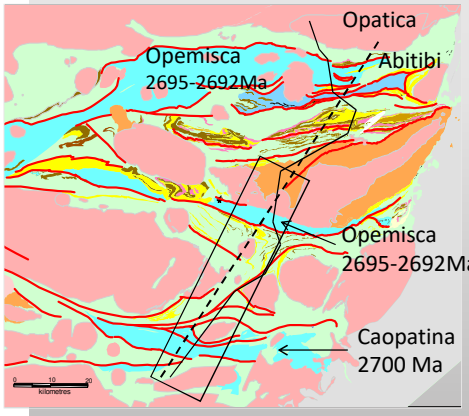
Chibougamau District

Metal Earth Seismic Transect in 2017

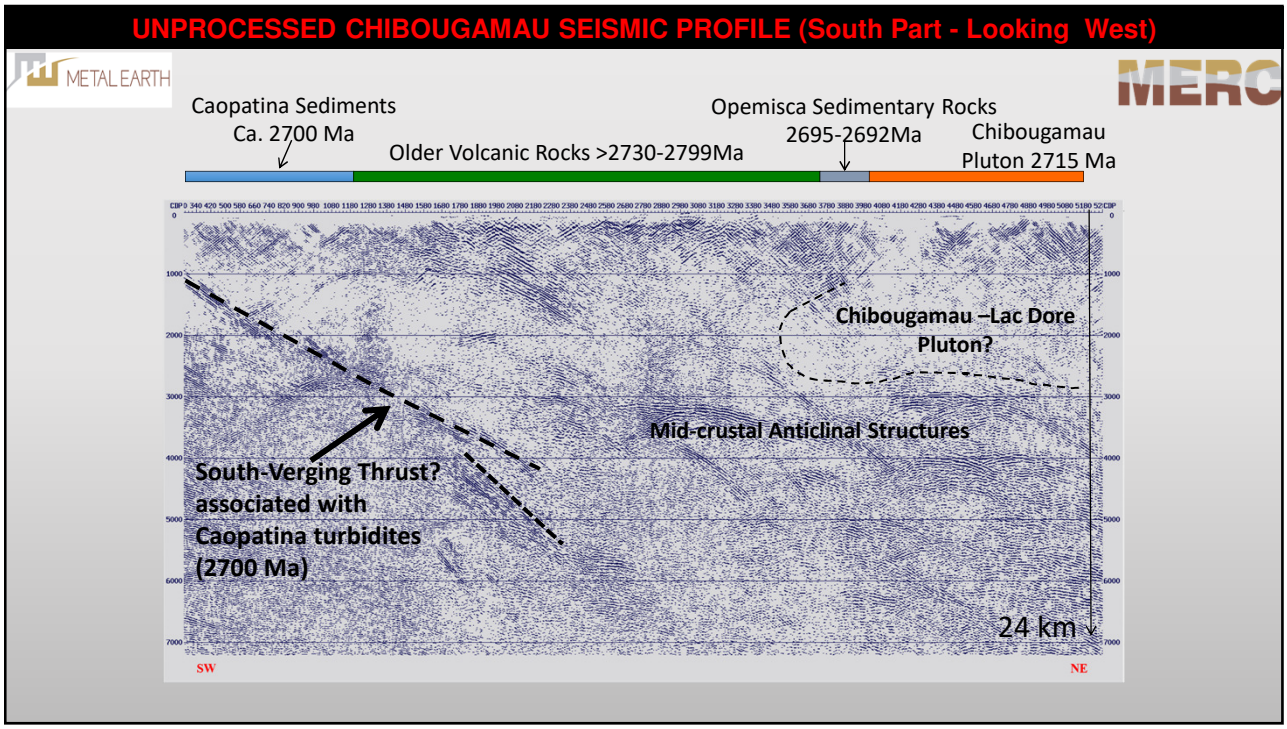
METAL EARTH

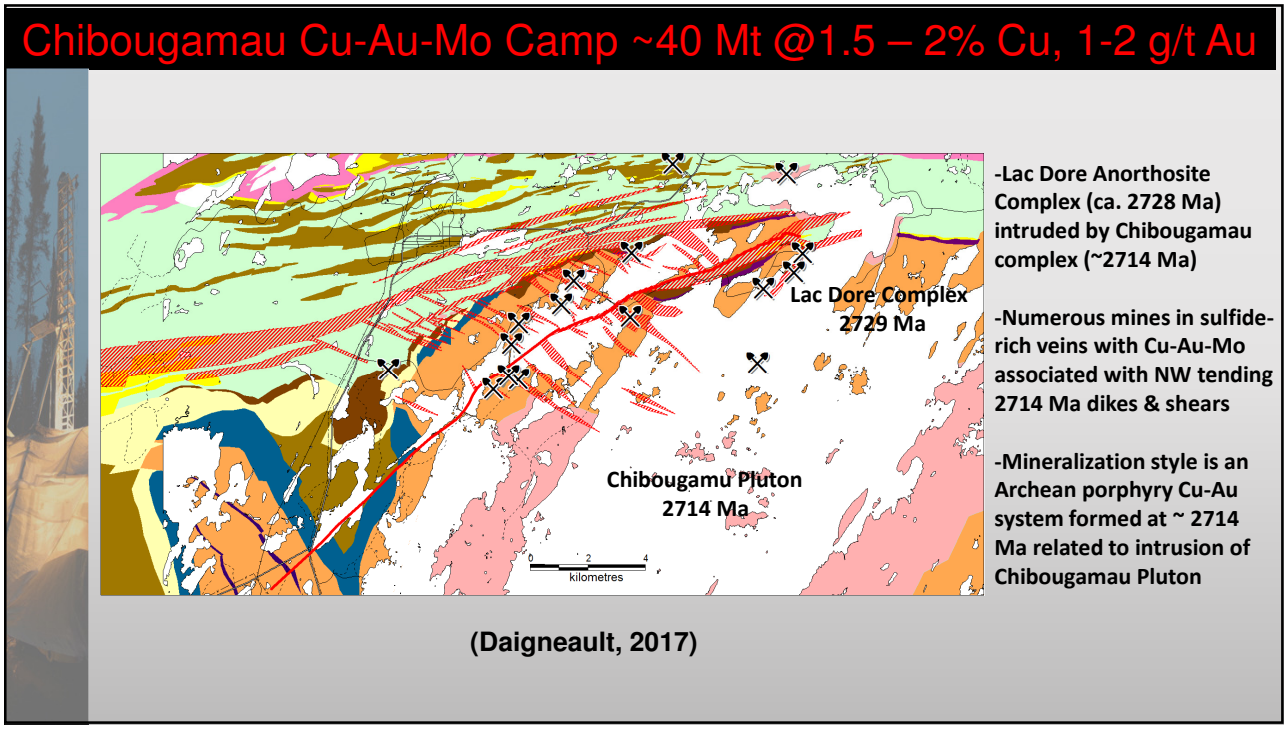


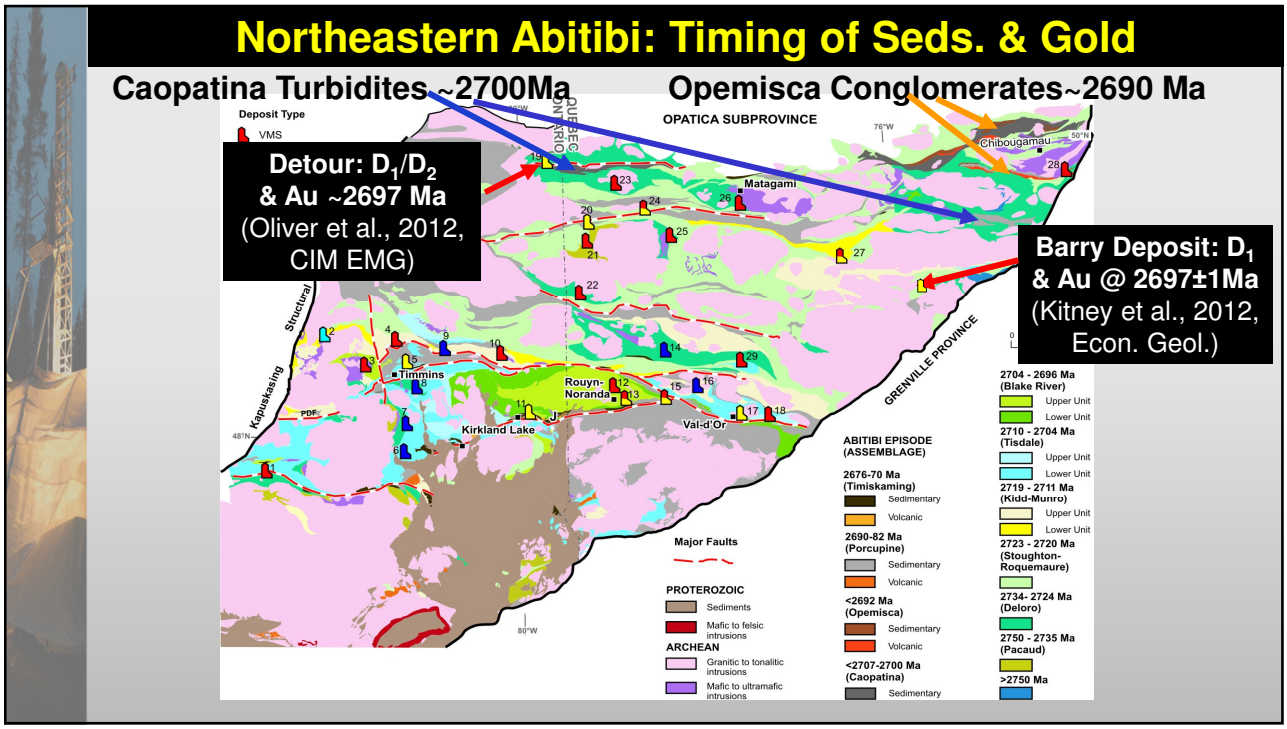


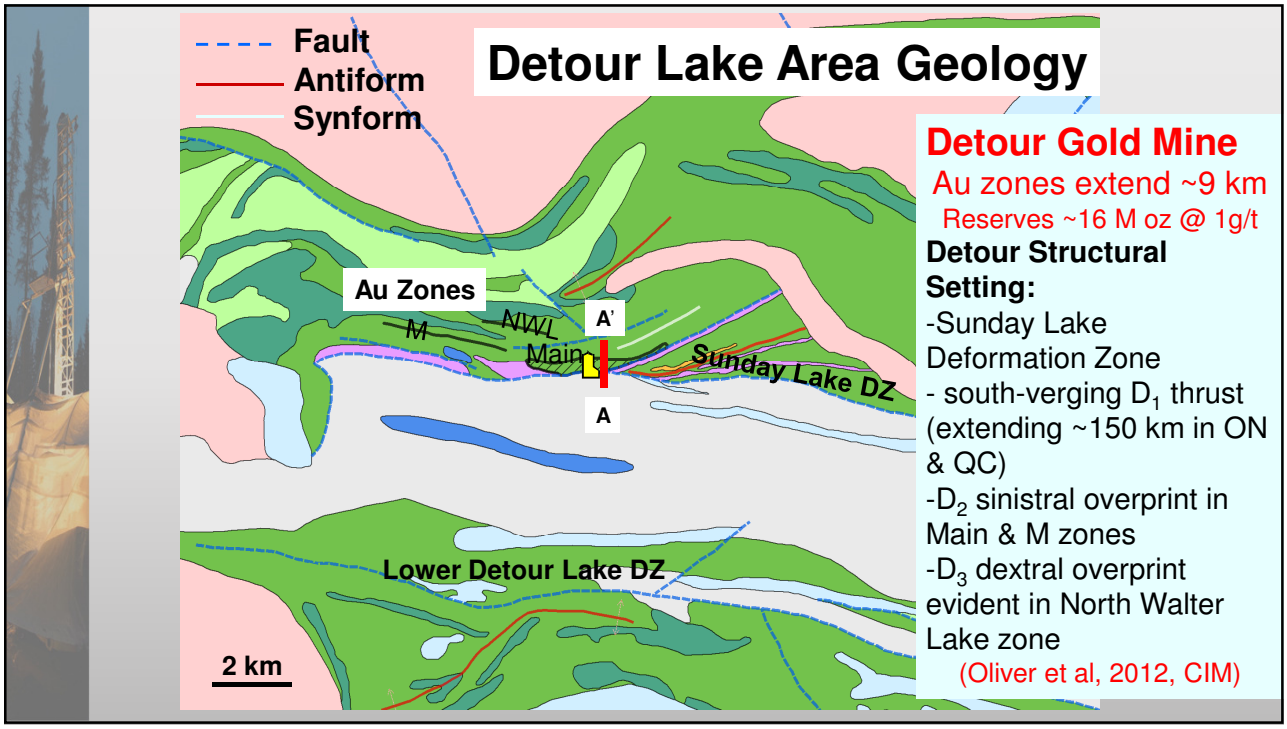


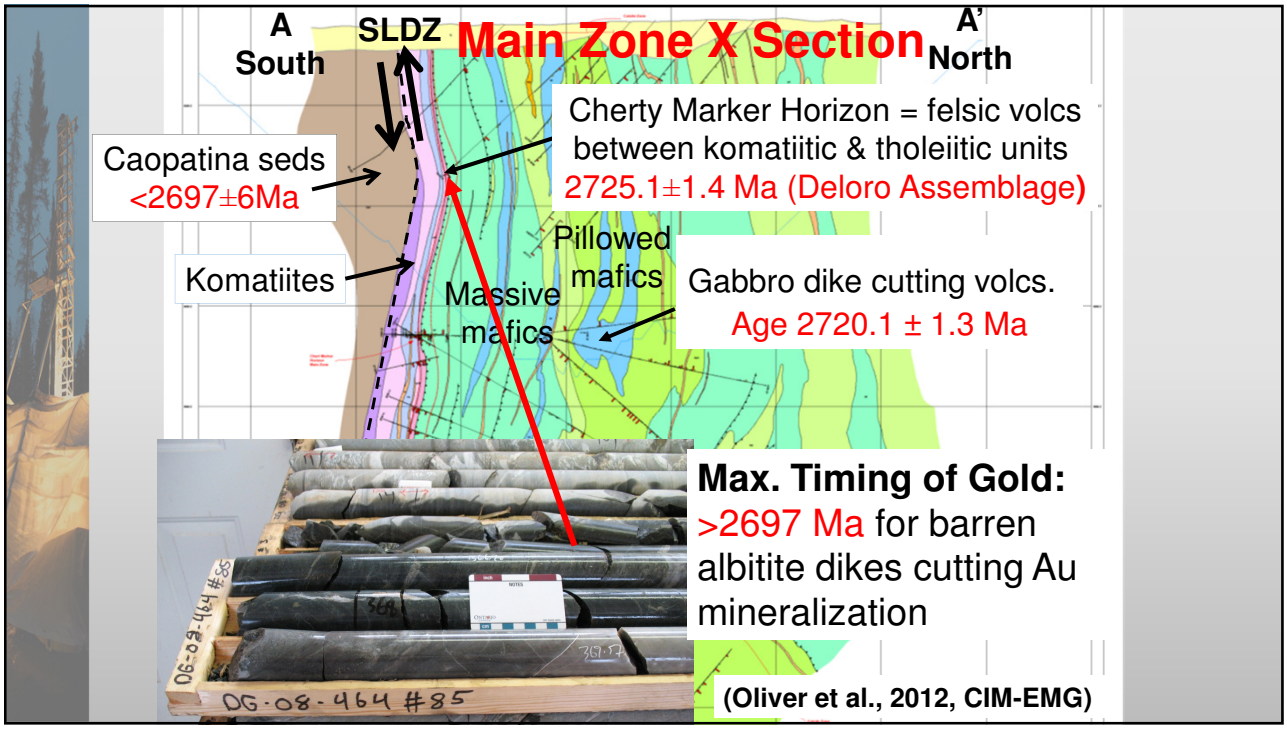
Daigneault, 2017

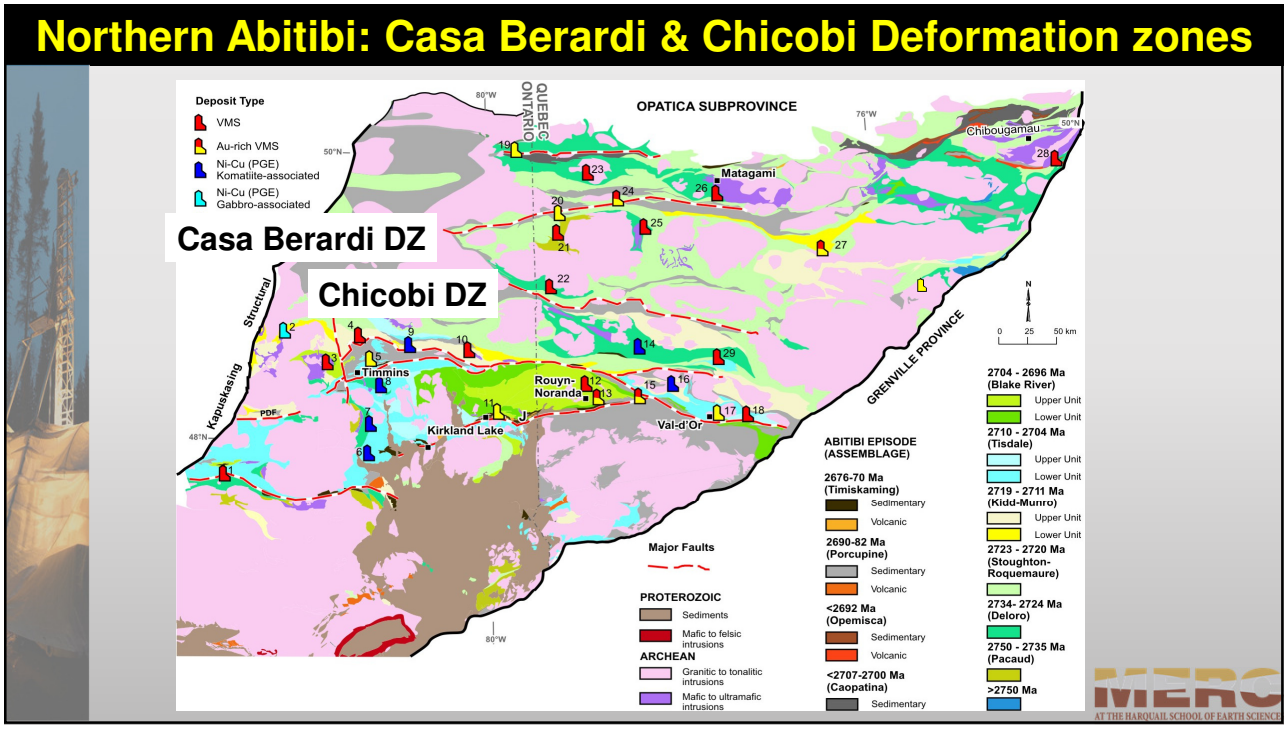

UNPROCESSED CHIBOUGAMAU SEISMIC PROFILE (South Part - Looking West)
METAL EARTH
MERC
Caopatina Sediments
Ca. 2700 Ma
Older Volcanic Rocks >2730-2799Ma
Opemisca Sedimentary Rocks
2695-2692Ma
Chibougamau
Pluton 2715 Ma
Chibougamau –Lac Dore
Pluton?
Mid-crustal Anticlinal Structures
South-Verging Thrust?
associated with
Caopatina turbidites
(2700 Ma)
24 km
SW
NE


Chibougamau Cu-Au-Mo Camp ~40 Mt @1.5 – 2% Cu, 1-2 g/t Au
Lac Dore Complex
2729 Ma
Chibougamau Pluton
2714 Ma
kilometres
-Lac Dore Anorthosite Complex (ca. 2728 Ma) intruded by Chibougamau complex (~2714 Ma)
-Numerous mines in sulfide-rich veins with Cu-Au-Mo associated with NW tending 2714 Ma dikes & shears
-Mineralization style is an Archean porphyry Cu-Au system formed at ~ 2714 Ma related to intrusion of Chibougamau Pluton
(Daigneault, 2017)

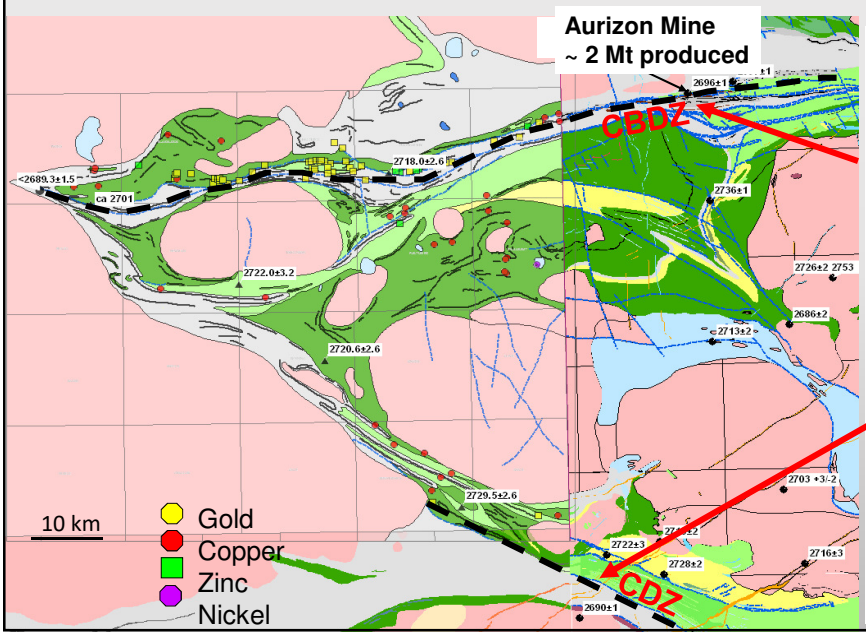

Northeastern Abitibi: Timing of Seds. & Gold
Caopatina Turbidites ~2700Ma
Opemisca Conglomerates~2690 Ma
Detour: D1/D2 & Au ~2697 Ma (Oliver et al., 2012, CIM EMG)
Barry Deposit: D1 & Au @ 2697±1Ma (Kitney et al., 2012, Econ. Geol.)
OPATICA SUBPROVINCE
Timmins
Kirkland Lake
Rouyn-Noranda
Val-d'Or
Matagami
Chibougamau
GRENVILLE PROVINCE
Major Faults
PROTEROZOIC
ARCHEAN
ABITIBI EPISODE (ASSEMBLAGE)


Fault
Antiform
Synform
Detour Lake Area Geology
Au Zones
M
NWL
Main
A'
A
Sunday Lake DZ
Lower Detour Lake DZ
2 km
Detour Gold Mine
Au zones extend ~9 km
Reserves ~16 M oz @ 1g/t
Detour Structural Setting:
-Sunday Lake Deformation Zone
- south-verging D1 thrust (extending ~150 km in ON & QC)
-D2 sinistral overprint in Main & M zones
-D3 dextral overprint evident in North Walter Lake zone
(Oliver et al, 2012, CIM)


A
South
SLDZ
Main Zone X Section
A'
North
Cherty Marker Horizon = felsic volcs between komatiitic & tholeiitic units
2725.1±1.4 Ma (Deloro Assemblage)
Caopatina seds
<2697±6Ma
Komatiites
Pillowed mafics
Massive mafics
Gabbro dike cutting volcs.
Age 2720.1 ± 1.3 Ma
Max. Timing of Gold:
>2697 Ma for barren albitite dikes cutting Au mineralization
(Oliver et al., 2012, CIM-EMG)
DG-08-464 #85


Northern Abitibi: Casa Berardi & Chicobi Deformation zones
Deposit Type
VMS
Au-rich VMS
Ni-Cu (PGE) Komatiite-associated
Ni-Cu (PGE) Gabbro-associated
Casa Berardi DZ
Chicobi DZ
QUEBEC
ONTARIO
OPATICA SUBPROVINCE
Chibougamau
Matagami
Timmins
Rouyn-Noranda
Kirkland Lake
Val-d'Or
Structural
Kapuskasing
GRENVILLE PROVINCE
Major Faults
PROTEROZOIC
Sediments
Mafic to felsic intrusions
ARCHEAN
Granitic to tonalitic intrusions
Mafic to ultramafic intrusions
ABITIBI EPISODE (ASSEMBLAGE)
2676-70 Ma (Timiskaming)
Sedimentary
Volcanic
2690-82 Ma (Porcupine)
Sedimentary
Volcanic
<2692 Ma (Opemisca)
Sedimentary
Volcanic
<2707-2700 Ma (Caopatina)
Sedimentary
2704 - 2696 Ma (Blake River)
Upper Unit
Lower Unit
2710 - 2704 Ma (Tisdale)
Upper Unit
Lower Unit
2719 - 2711 Ma (Kidd-Munro)
Upper Unit
Lower Unit
2723 - 2720 Ma (Stoughton-Roquemaure)
2734- 2724 Ma (Deloro)
2750 - 2735 Ma (Pacaud)
>2750 Ma

Burntbush Belt Map

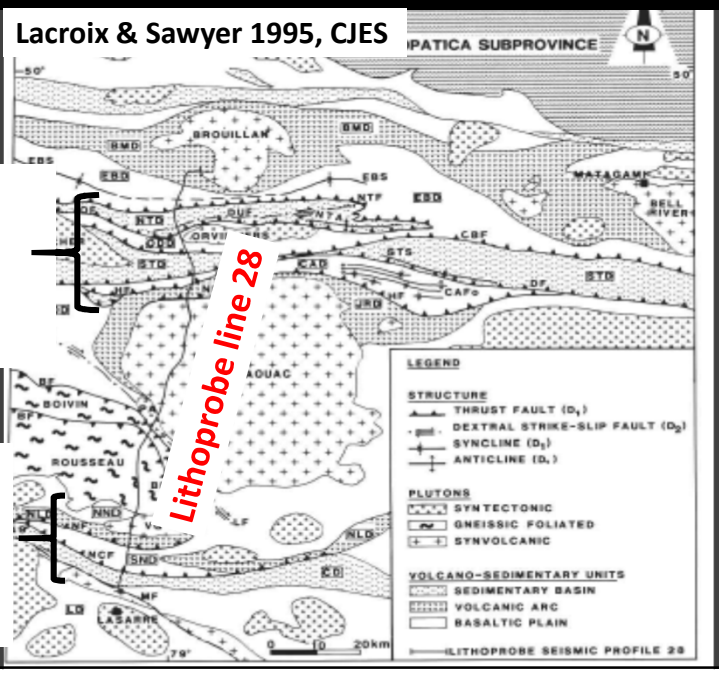


Casa Berardi DZ (CBDZ) Extends ~300 km in ON & QC, associated with 2696 Ma turbidites. Kinematics indicate early S-verging D_1 thrusting. Au veins at Casa Berardi mine associated with D_2 sinistral overprint within CBDZ (Pilote et al., 1990, CJES)

Chicobi DZ (CDZ) Extends ~ 200 km in ON & QC. D_1 S-verging thrusting associated with <2696 Ma turbidities & 2693 Ma volcs. D_2 is sinsitral overprinted by dextral D_3 (2693-2688 Ma) (Barret et al., 2013, OGS MRD 299)

Northern Abitibi: Casa Berardi & Chicobi Deformation Zones

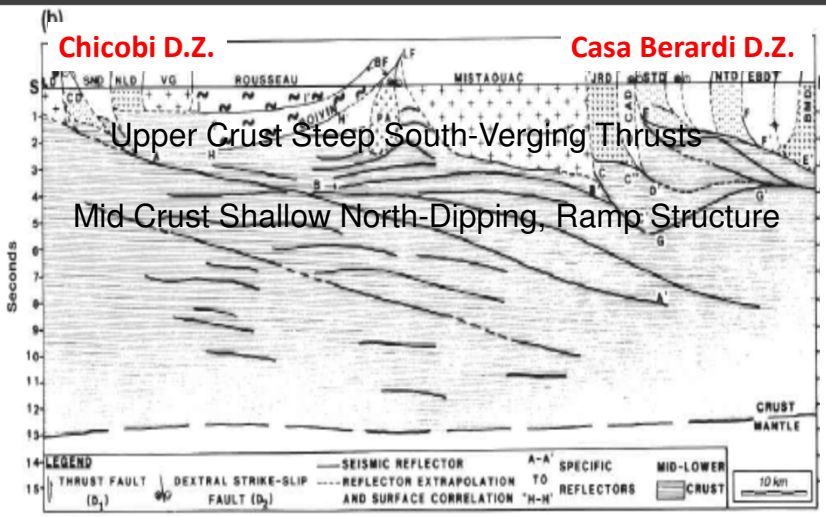
Lacroix & Sawyer 1995, CJES



Casa Berardi Deformation Zone: 6 south-verging D_1 thrusts overprinted by D_2 dextral faulting

Chicobi Deformation Zone: 2 south-verging D_1 thrusts overprinted by D_2 sinistral deformation

Line 28 seismic image of Casa Berardi & Chicobi faults systems show steep S-verging thrusts in the upper 6-9 km, underlain by a mid crustal decollement in the mid-crust (Lacroix & Sawyer, 1995, CJES)

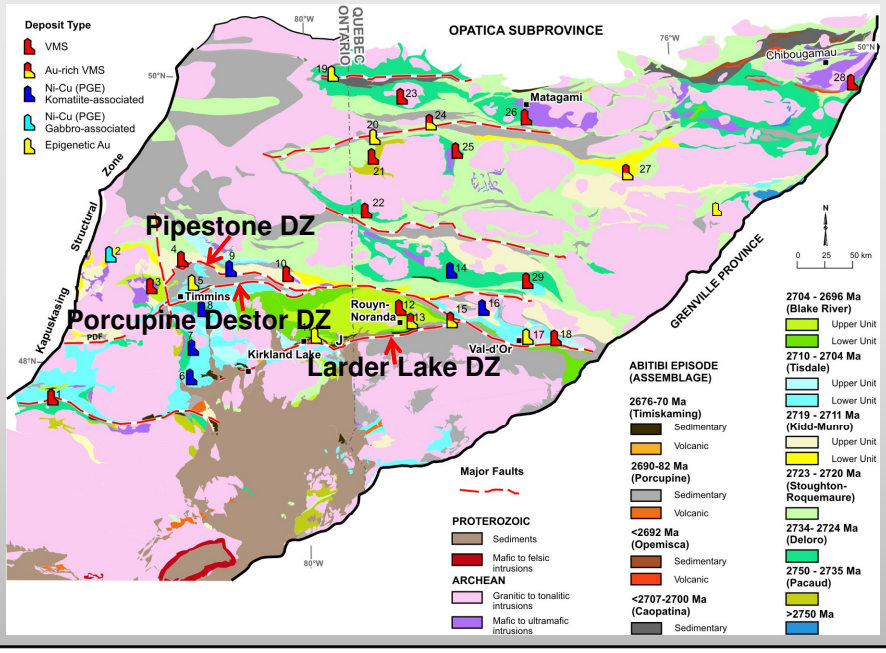


Reflection seismic interpretation in upper 9 km shows a series of steep south-verging thrusts becoming listric at depth.

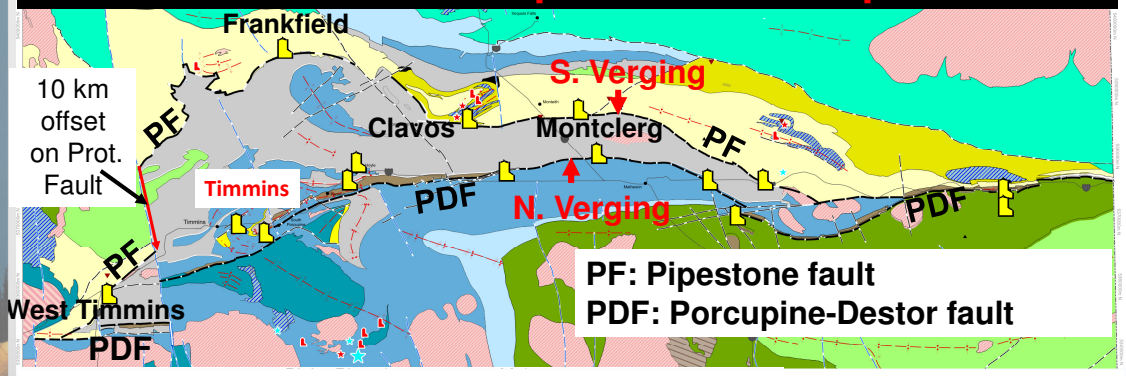
They occur above a mid-crustal decollement consisting of a 15° north-dipping ramp structure dominated by low-angle thrusts and antiformal stacks.

Interpreted as south-verging "sole thrust" crustal system, similar in structural style to Opatica subprovince to North. (Lacroix & Sawyer, 1995, CJES).

Timmins-Kirkland Auriferous Deformation Zones



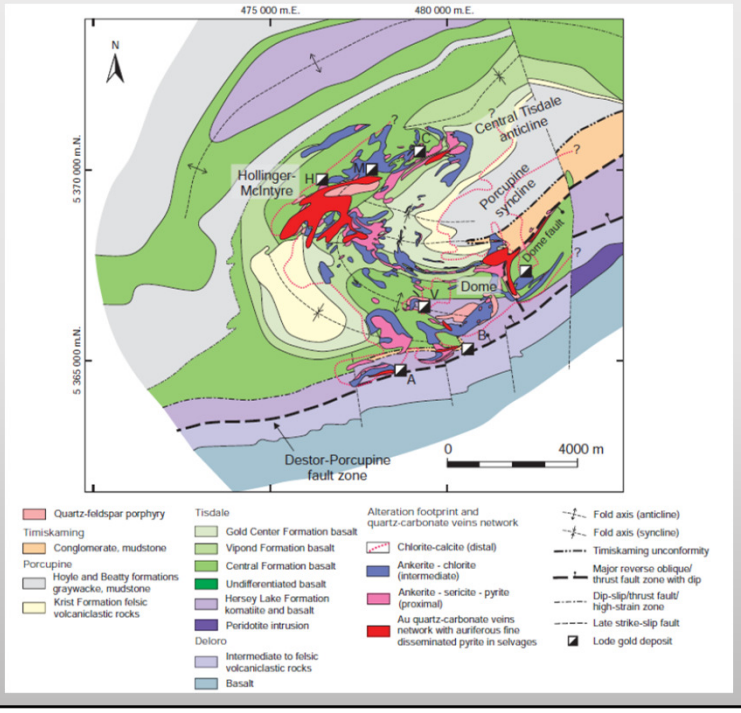
Timmins Area Gold Deposits ~75 M oz produced



Timmins Au Deposits Occurs Along Two Major Faults

North: Pipestone Deformation Zone: D_1 thrust with Kidd-Munro volcs (2720-10 Ma) thrust south over Porcupine turbidites (2690-80 Ma); Au<2680 Ma.

South: Porcupine Destor Deformation Zone: D_2 thrust associated with Timiskaming conglomerates & sandstones (2676-70 Ma); Au<2670 Ma.

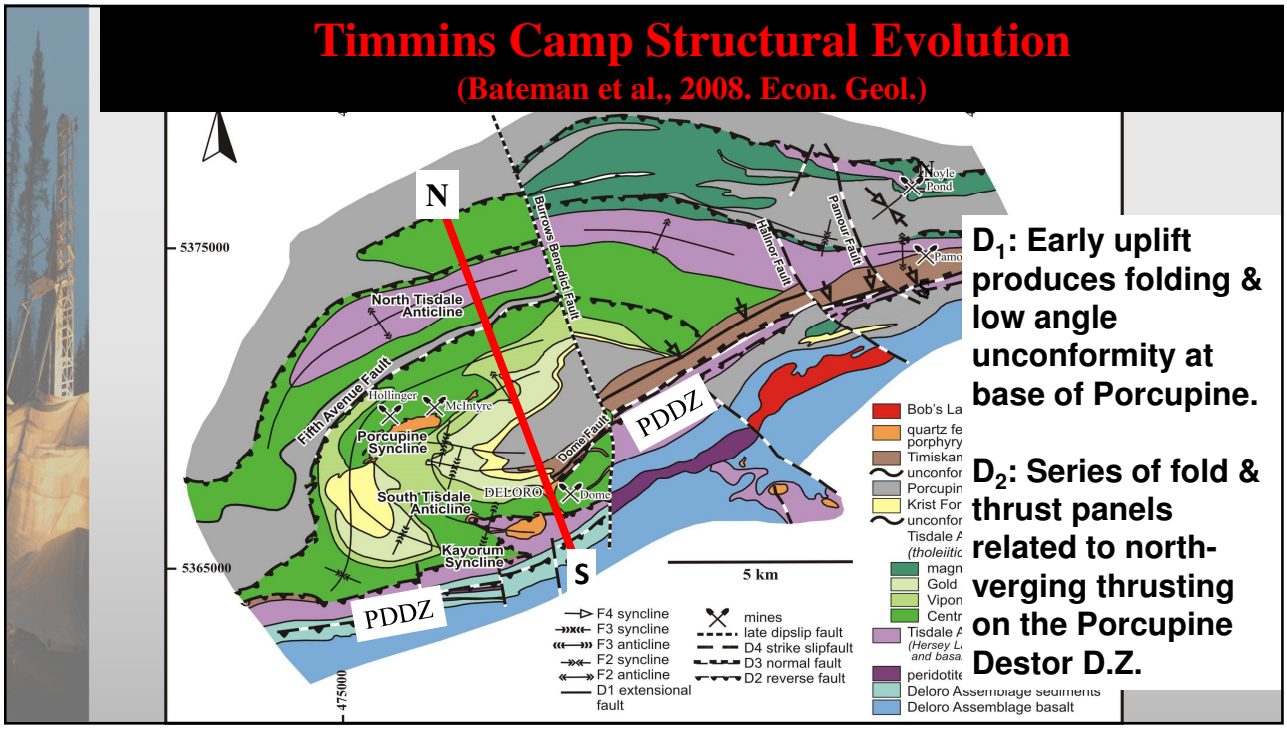


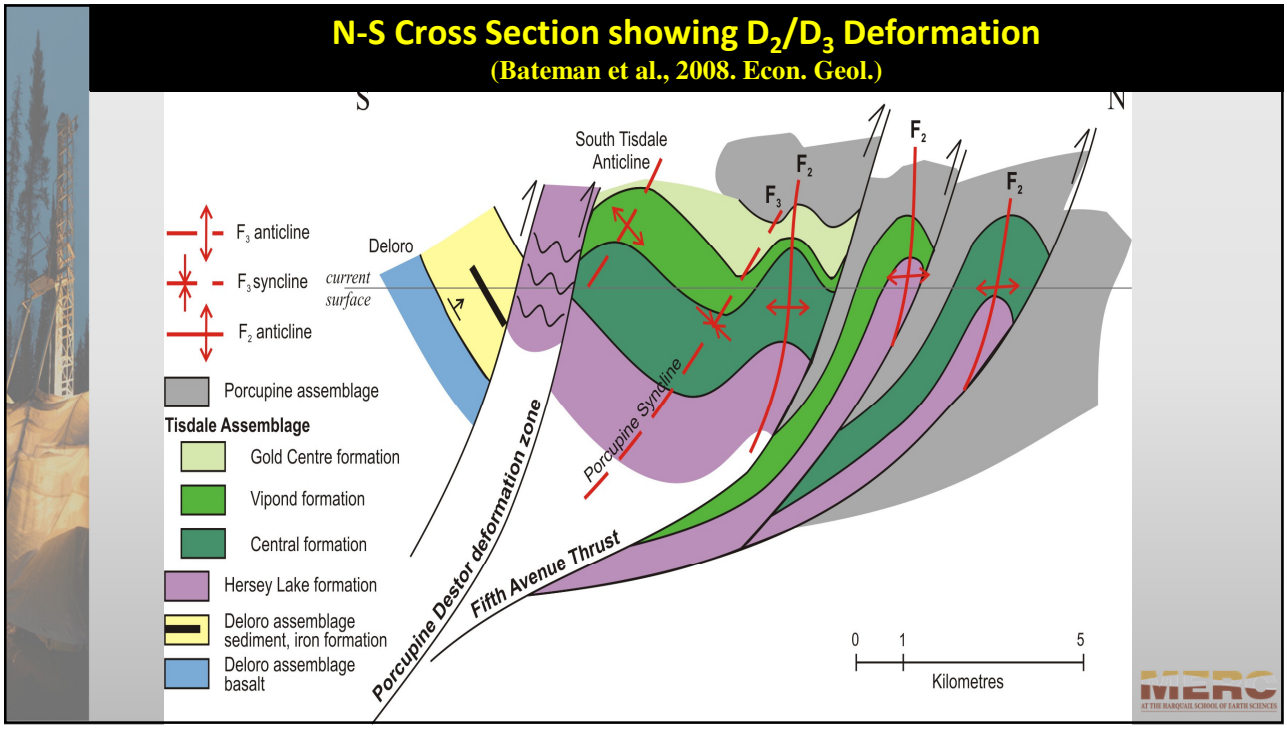
Map of the Timmins Gold Camp Showing the Main Gold & Alteration Zones

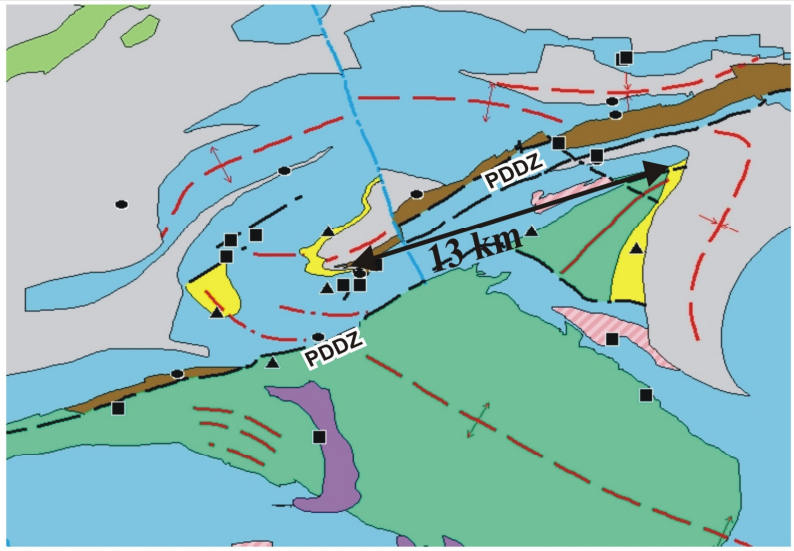
- Chlorite-calcite (distal)
- Ankerite - chlorite (intermediate)
- Ankerite - sericite - pyrite (proximal)
- Au quartz-carbonate veins network with auriferous fine disseminated pyrite in selvages

The alteration footprint extends over several km^2 & is characterized by distal chlorite-calcite, intermediate ankerite-chlorite & proximal ankerite-sericite-pyrite, all with variable amounts of quartz & albite

(Dubé et al., 2017, Rev. Econ. Geol.)


Timmins Camp Structural Evolution
(Bateman et al., 2008. Econ. Geol.)
N
S
5375000
5365000
475000
North Tisdale Anticline
Fifth Avenue Fault
Hollinger
McIntyre
Porcupine Syncline
South Tisdale Anticline
DELORO
Dome
Dome Fault
Kayorum Syncline
Burrows Benedict Fault
Halinor Fault
Pamour Fault
Noyle Pond
PDDZ
PDDZ
5 km
F4 syncline
F3 syncline
F3 anticline
F2 syncline
F2 anticline
D1 extensional fault
mines
late dipslip fault
D4 strike slipfault
D3 normal fault
D2 reverse fault
Bob's La
quartz fe
porphyry
Timiskan
unconfor
Porcupin
Krist For
unconfor
Tisdale A
(tholeiitic
magn
Gold
Vipon
Centr
Tisdale A
(Hersey L
and basa
peridotite
Deloro Assemblage sediments
Deloro Assemblage basalt
D1: Early uplift produces folding & low angle unconformity at base of Porcupine.
D2: Series of fold & thrust panels related to north-verging thrusting on the Porcupine Destor D.Z.


N-S Cross Section showing D2/D3 Deformation
(Bateman et al., 2008. Econ. Geol.)
S
N
South Tisdale Anticline
F2
F3
F2
F2
F3 anticline
F3 syncline
F2 anticline
Deloro
current surface
Porcupine assemblage
Tisdale Assemblage
Gold Centre formation
Vipond formation
Central formation
Hersey Lake formation
Deloro assemblage sediment, iron formation
Deloro assemblage basalt
Porcupine Syncline
Porcupine Destor deformation zone
Fifth Avenue Thrust
0
1
5
Kilometres



D_3: 13 km sinistral displacement on PDDZ opened dilational jog resulting in deposition of Timiskaming sediments (2676 to 2670 Ma), folding & Au mineralization event

D_4: Dextral movement on PDDZ, folding, faulting of & Au mineralization event

Timing of Deformation & Gold in Timmins
(Bateman et al., 2008, Econ. Geol.)

➢ **Early Stage Au (D_1/D_2) (uneconomic):**

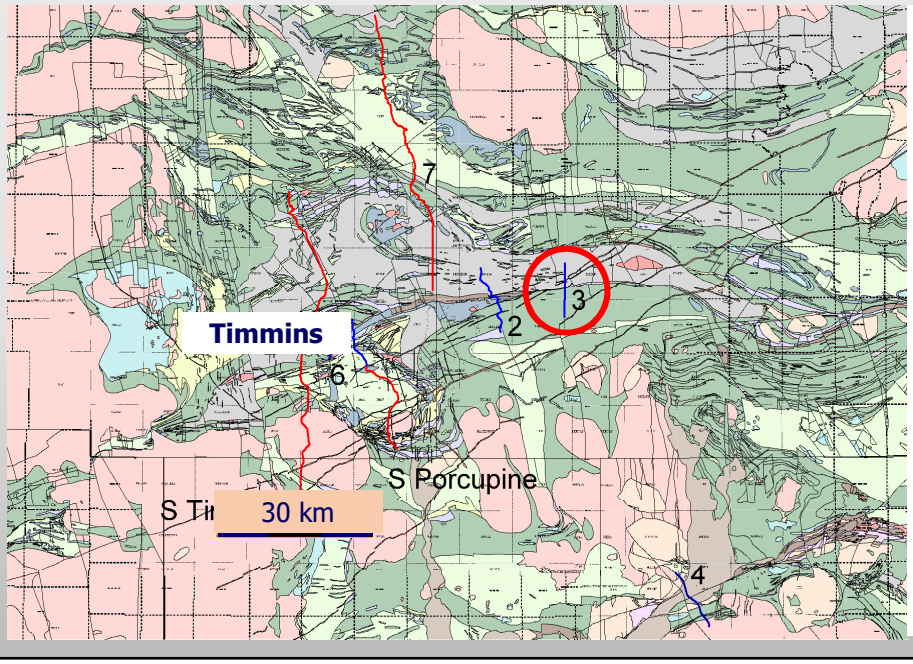
Pre-Timiskaming (>2676 Ma): Au in ankerite vein clasts in conglomerates

➢ **Main Stage Au (D_3/D_4) (~70 Moz):**

Post-Timiskaming (<2670 Ma)

- Cu-Mo-Au stockwork (eg. McIntyre Re-Os moly age of 2672 +/- 6 Ma)
- Au veins in hanging wall anticlines (Hollinger-McIntyre, Dome – Re-Os moly age at Dome of 2670 +/- 10 Ma).

Discover Abitibi Seismic Profiles (Snyder et al., 2008, Econ. Geol.)



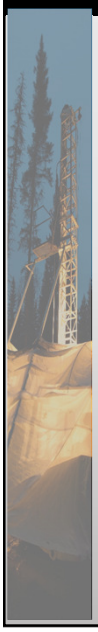
Map of seismic reflection profiles:

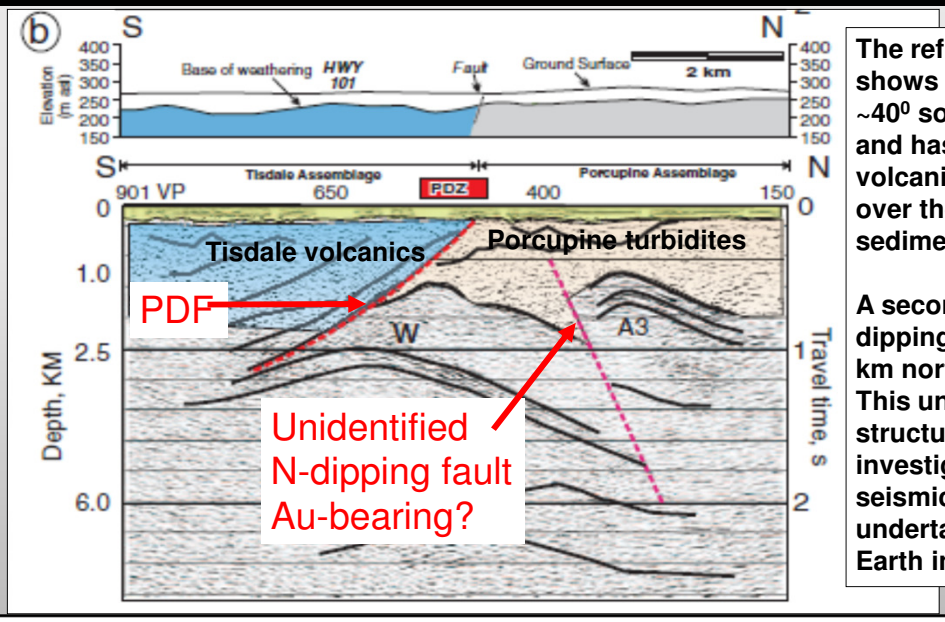
-Red lines regional parameters (40 km depth)

-Blue line high-resolution parameters (8-10 km depth)

-red circle 10 km Shillington high-resolution line

Shillington High Resolution Seismic line
(Snyder et al., 2008, Econ Geol.)

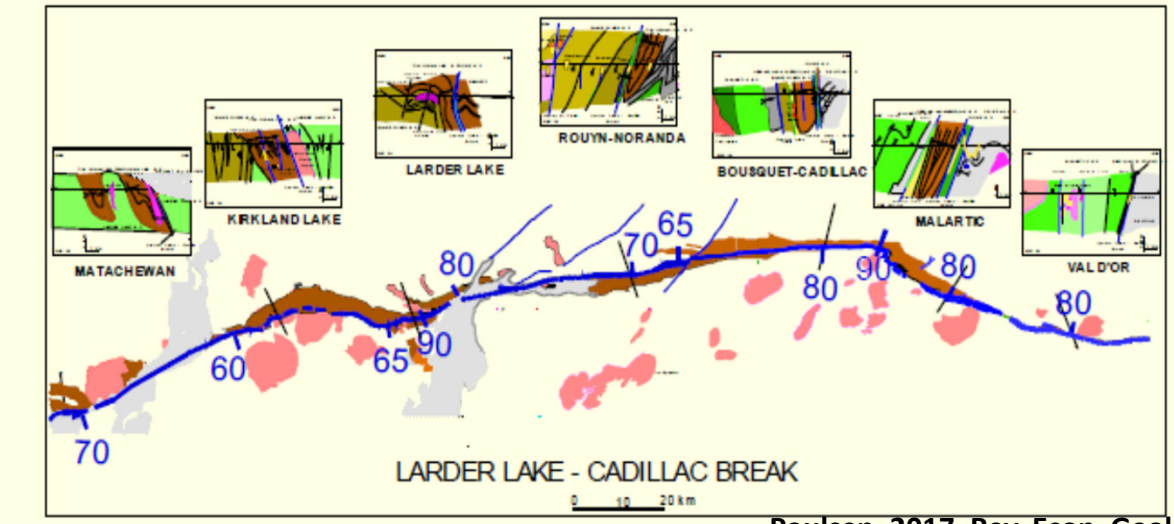




The reflection Image shows the PDF dips ~40^0 south in this area and has thrust Tisdale volcanics northwards over the Porcupine sediments.

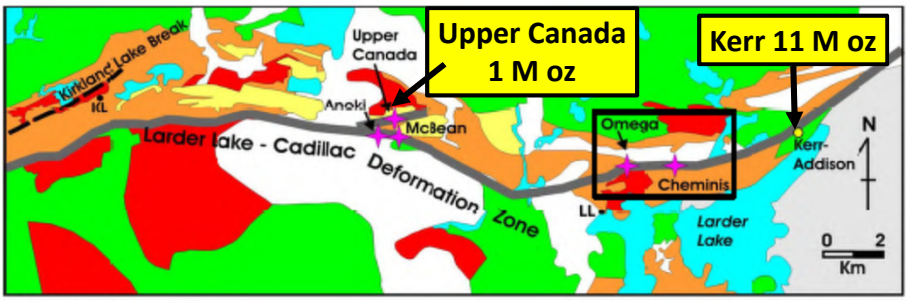
A second steeply north-dipping fault occurs 2 km north of the PDF. This unidentified structure will be further investigated by new seismic lines to the east undertaken by Metal Earth in 2017.

Larder-Cadillac Break: D2 thrust proximal to 7 mining camps (~110 M oz Au) along a 250 km strike length from Matachewan to Val d'Or
D2 Thrust strikes NE & dips S in west, but changes to NW strike with N dip in east



Poulsen, 2017, Rev. Econ. Geol.

Structural Controls on Au in Larder Area



Huronian Supergroup

Timiskaming assemblage (2677-2669 Ma)

Syenitic intrusions

Sandstone and conglomerate

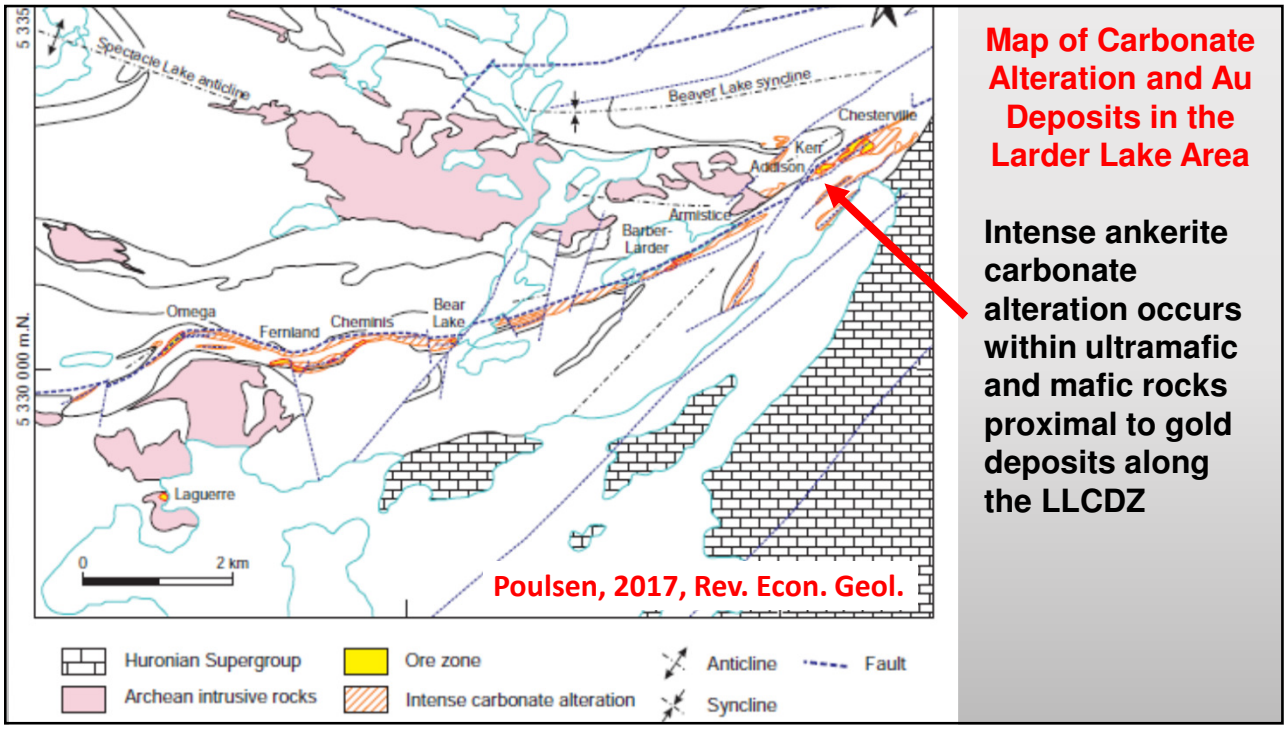
Alkalic pyroclastics and flows

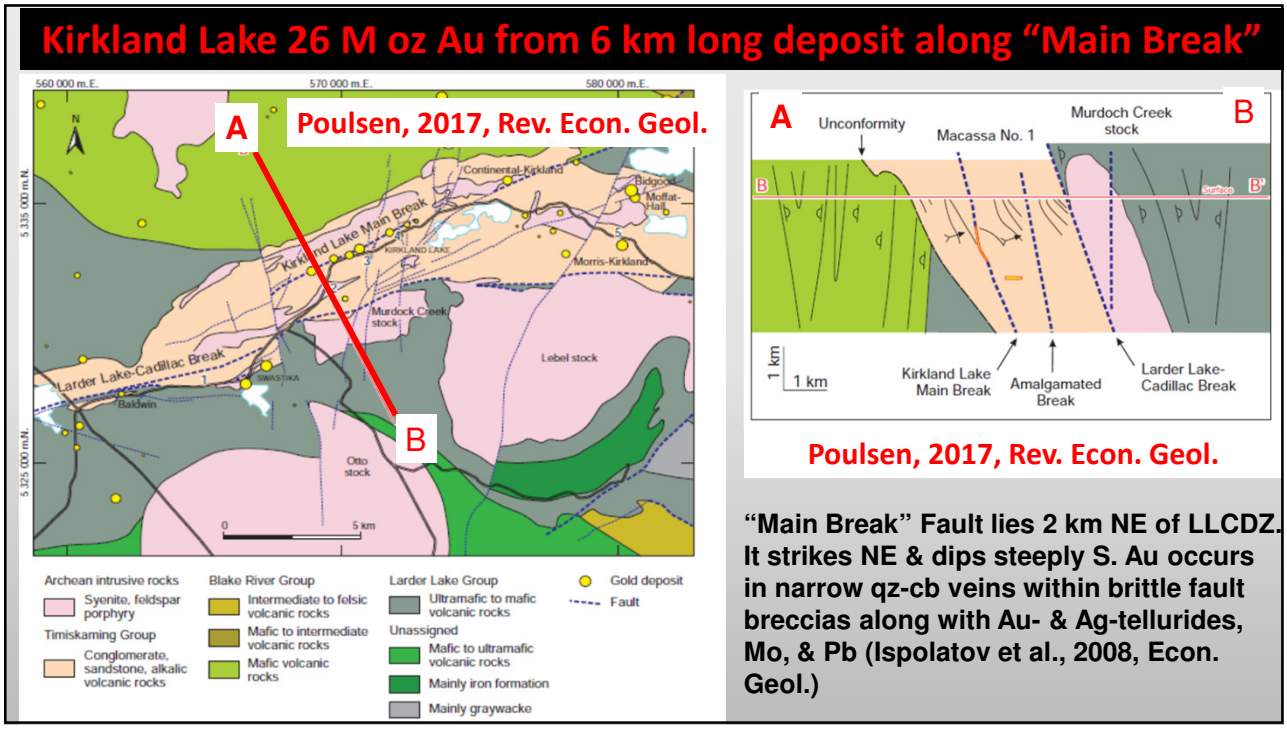
Tisdale, Kinojevis, Blake River assemblages (2710-2696 Ma)

Mafic volcanic rocks

The Kerr-Addison, Omega, Cheminis, Upper Canada, & McBean deposits all formed during D_2 ductile deformation associated with the Larder Lake-Cadillac deformation zone.

Au is associated with disseminated sulfides and qz-cb veining along with regionally extensive carbonate hydrothermal alteration
(Lafrance, 2015, CJES)

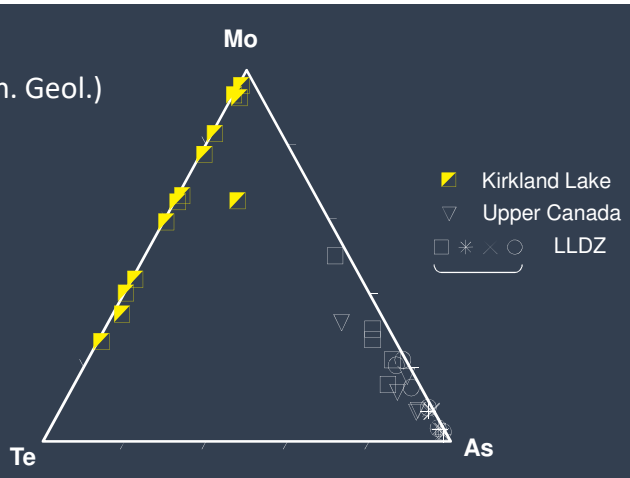

Map of Carbonate Alteration and Au Deposits in the Larder Lake Area
Intense ankerite carbonate alteration occurs within ultramafic and mafic rocks proximal to gold deposits along the LLCDZ
Spectacle Lake anticline
Beaver Lake syncline
Chesterville
Kerr Addison
Armistice
Barber-Larder
Omega
Fernland
Cheminis
Bear Lake
Laguerre
5 335 000 m.N.
5 330 000 m.N.
0
2 km
Poulsen, 2017, Rev. Econ. Geol.
Huronian Supergroup
Archean intrusive rocks
Ore zone
Intense carbonate alteration
Anticline
Syncline
Fault

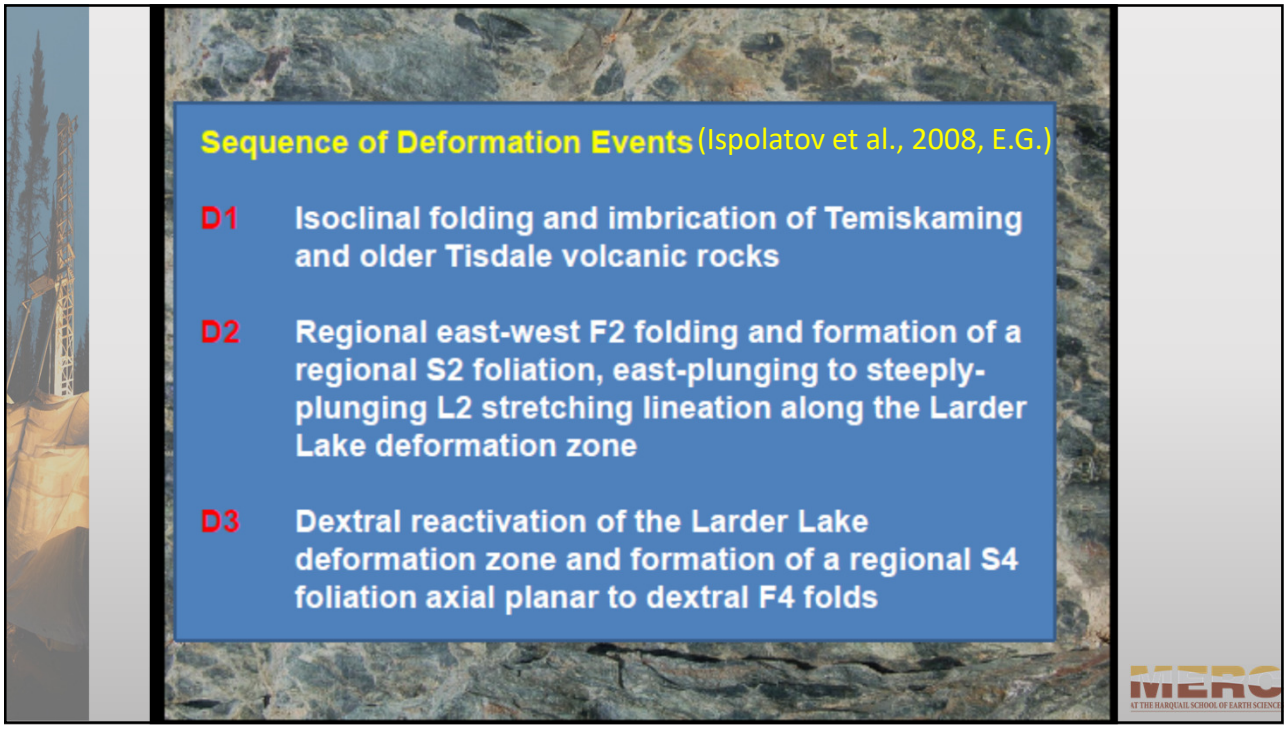

Kirkland Lake 26 M oz Au from 6 km long deposit along "Main Break"
560 000 m.E.
570 000 m.E.
580 000 m.E.
A
B
Poulsen, 2017, Rev. Econ. Geol.
Kirkland Lake Main Break
Larder Lake-Cadillac Break
Murdock Creek stock
Lebel stock
Otto stock
Morris-Kirkland
Bidgood
Moffat-Hall
Continental-Kirkland
Baldwin
SWASTIKA
KIRKLAND LAKE
0
5 km
Archean intrusive rocks
Syenite, feldspar porphyry
Timiskaming Group
Conglomerate, sandstone, alkalic volcanic rocks
Blake River Group
Intermediate to felsic volcanic rocks
Mafic to intermediate volcanic rocks
Mafic volcanic rocks
Larder Lake Group
Ultramafic to mafic volcanic rocks
Unassigned
Mafic to ultramafic volcanic rocks
Mainly iron formation
Mainly graywacke
Gold deposit
Fault
A
B
Unconformity
Macassa No. 1
Murdoch Creek stock
Surface
1 km
Kirkland Lake Main Break
Amalgamated Break
Larder Lake-Cadillac Break
Poulsen, 2017, Rev. Econ. Geol.
"Main Break" Fault lies 2 km NE of LLCDZ. It strikes NE & dips steeply S. Au occurs in narrow qz-cb veins within brittle fault breccias along with Au- & Ag-tellurides, Mo, & Pb (Ispolatov et al., 2008, Econ. Geol.)

Kirkland / Larder Au geochemistry:

-Main Break Au associated with telluridies and molybdenite;
high Te (Te>Au), Mo & low As
-Main Break is distinct from Upper Canada & LLDZ deposits

(Ispolatov et al, 2008, Econ. Geol.)





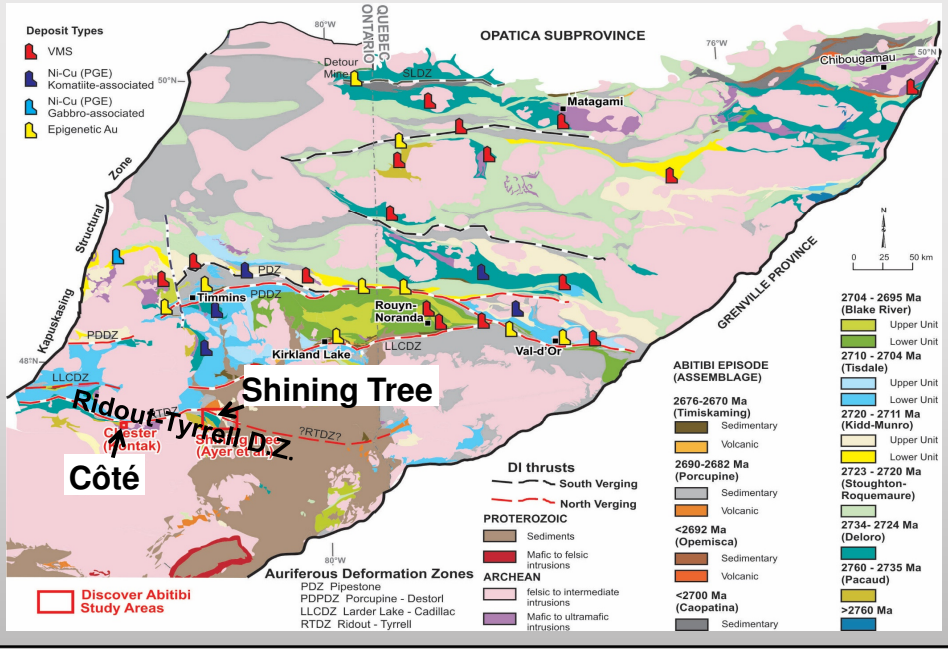
Larder-Kirkland Timing of Deformation & Gold

Conclusions

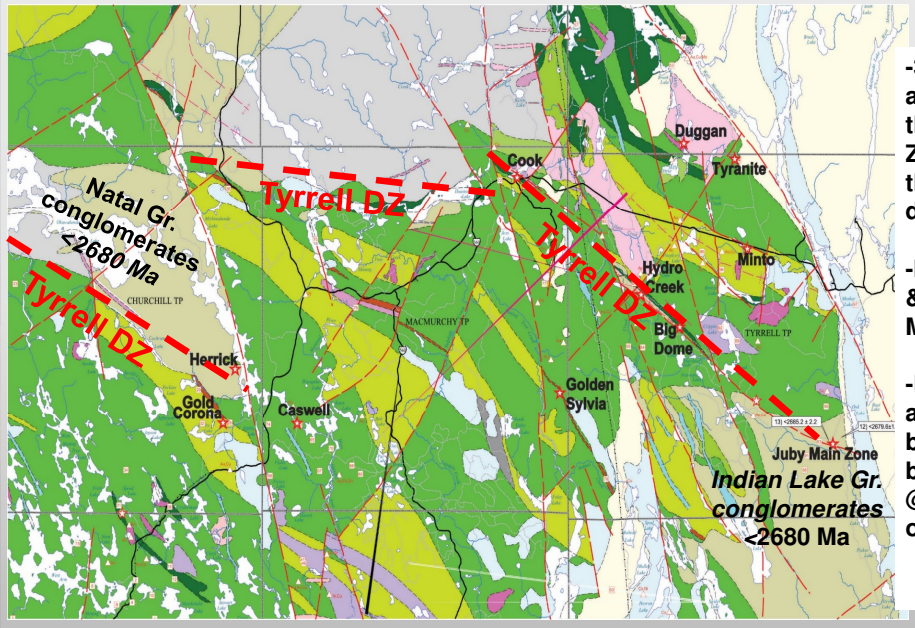
- Gold mineralization along the Larder Lake deformation zone was emplaced syn-D2 in a wide ductile corridor of deformation with strong ankerite alteration.
- Gold at Kirkland Lake is associated with Te & Mo in brecciated quartz veins emplaced in syn-D4, sericitized, brittle faults.
- Mineralization is coeval with a long-lived alkalic magmatic system.

(Ispolatov et al., 2008, E.G.)

Southern Abitibi: Ridout-Tyrrell Deformation Zone



Southern Abtibi: Shining Tree Belt

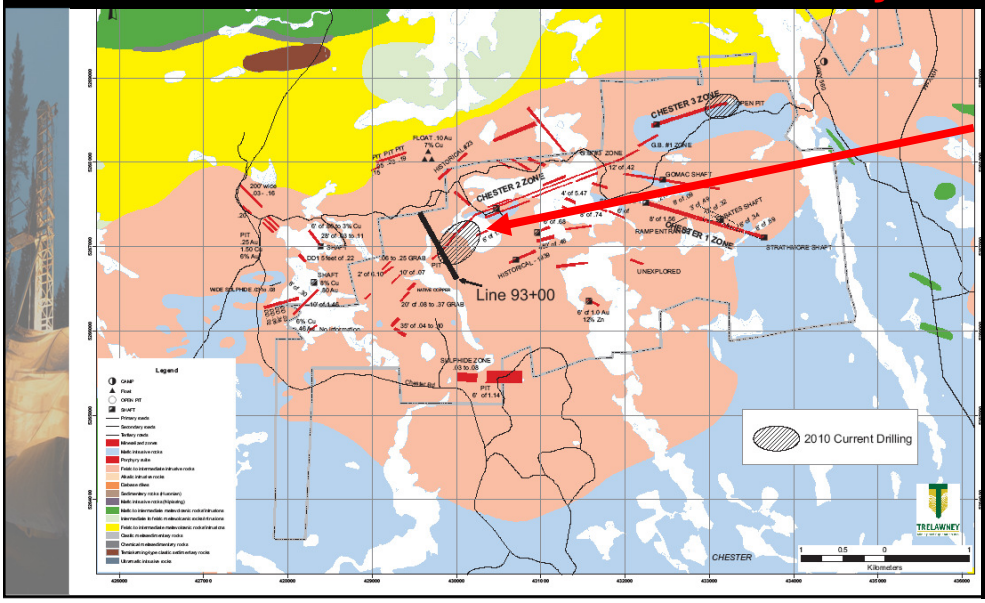


-3 Au deposits occur along the eastern part of the Tyrrell Deformation Zone, a north-verging D_2 thrust overprinted by D_3 dextral shearing

-Main stage Au is syn-D_3 & postdates a 2676±2 Ma felsic dike

-D_4 deformation occurs as late, N-trending brittle faults with Au in brecciated qz-cb veins @ 2640+/-11 Ma based on a Re-Os moly age (Ayer et al., 2013, OGS MRD 294)

Côté Gold Deposit ~3 km South of Ridout-Tyrrell Deformation Zone in SE Swayze Belt



-Large tonnage, low grade deposit with reserves of ~ 8 M oz @ 1 g/t

-Intrusion-related Au+Cu porphyry-style deposit formed @ ~2740 Ma

(Kontak et al., 2013, OGS MRD 294)

Côté Deposit

•Centred on a diorite-tonalite intrusive complex;
•Tonalite formed carapace to diorite with later breccia injection from an evolved dioritic melt;
•Brittle structures control focus of breccias, alteration and mineralization.

Features indicate a high-crustal level setting.

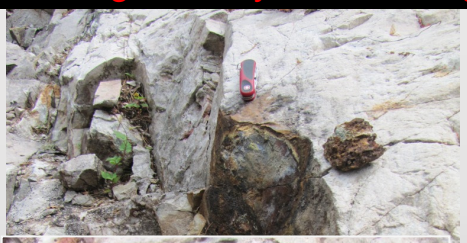
What about absolute age constraints?

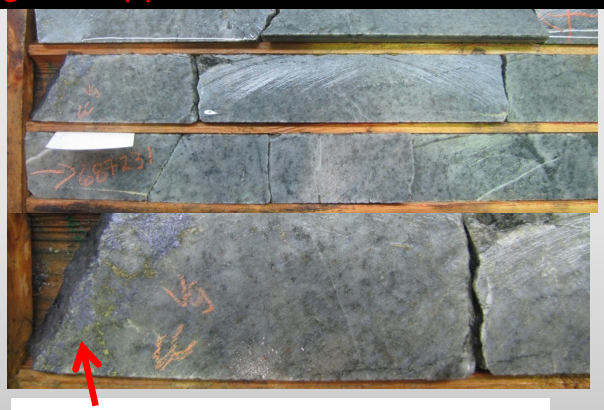
Côté Deposit:

U-Pb zircon ages of intrusion and Re-Os ages of magmatic-hydrothermal gold-copper mineralization

Tonalite U-Pb Zircon age 2741 ± 1 Ma

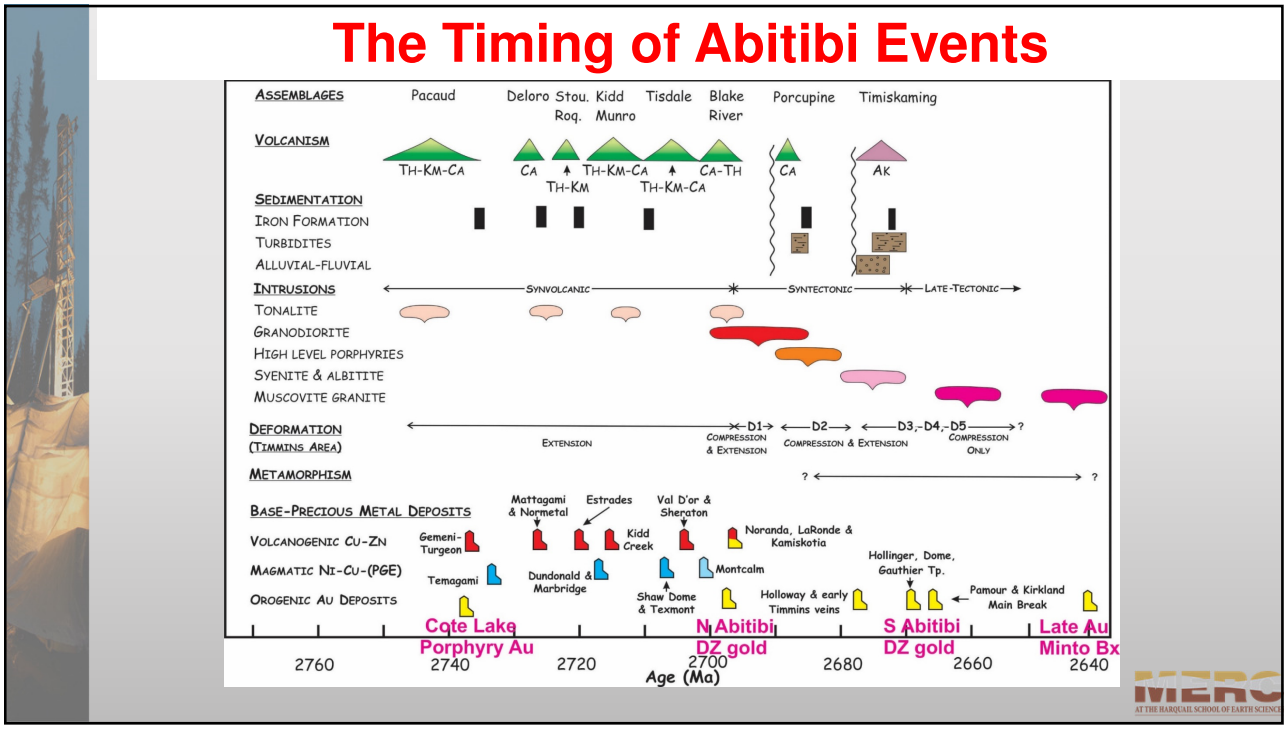
Re-Os Moly age 2737 ± 7 Ma

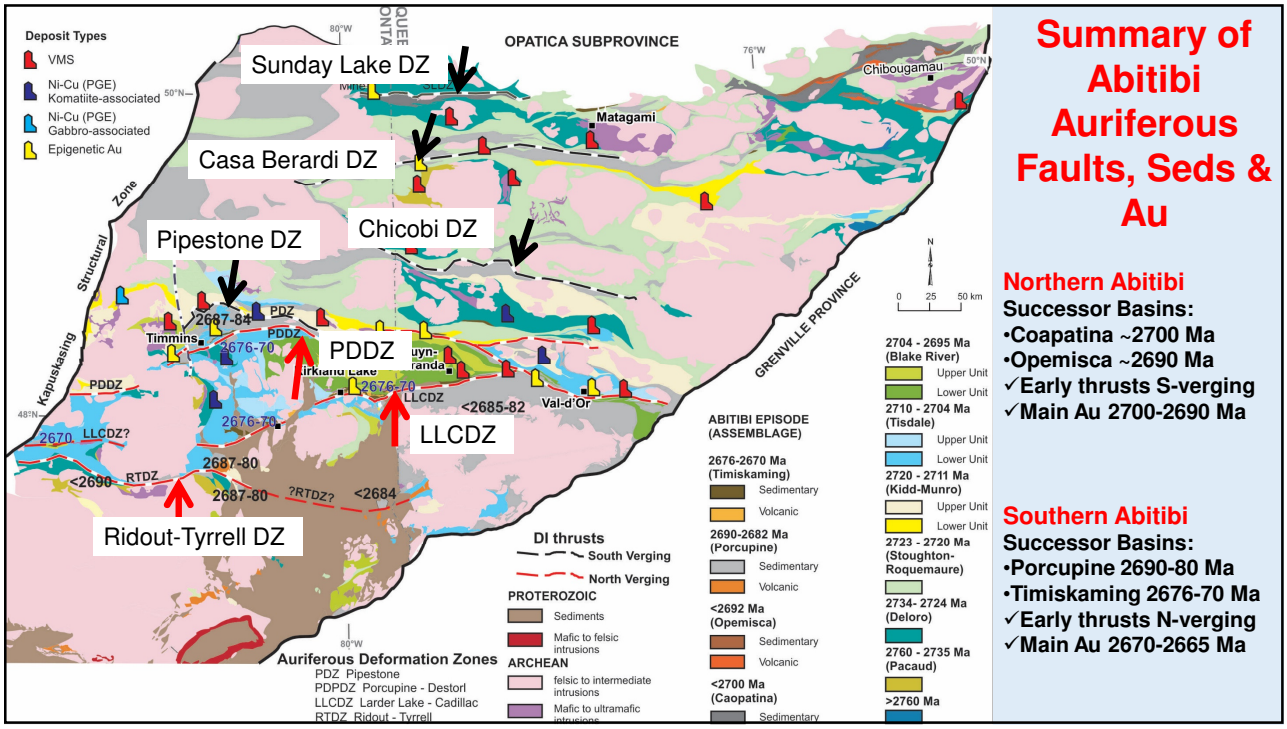




Moly with Au in diorite; Re-Os age = 2741 ± 7 Ma (DDH E-09-01)

(Kontak et al., 2013, OGS MRD 294)



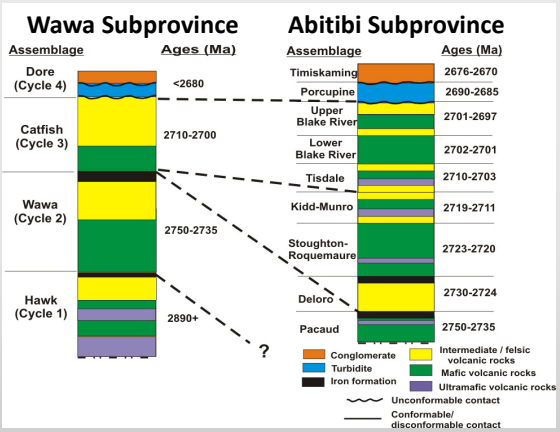


Summary of Abitibi Auriferous Faults, Seds & Au

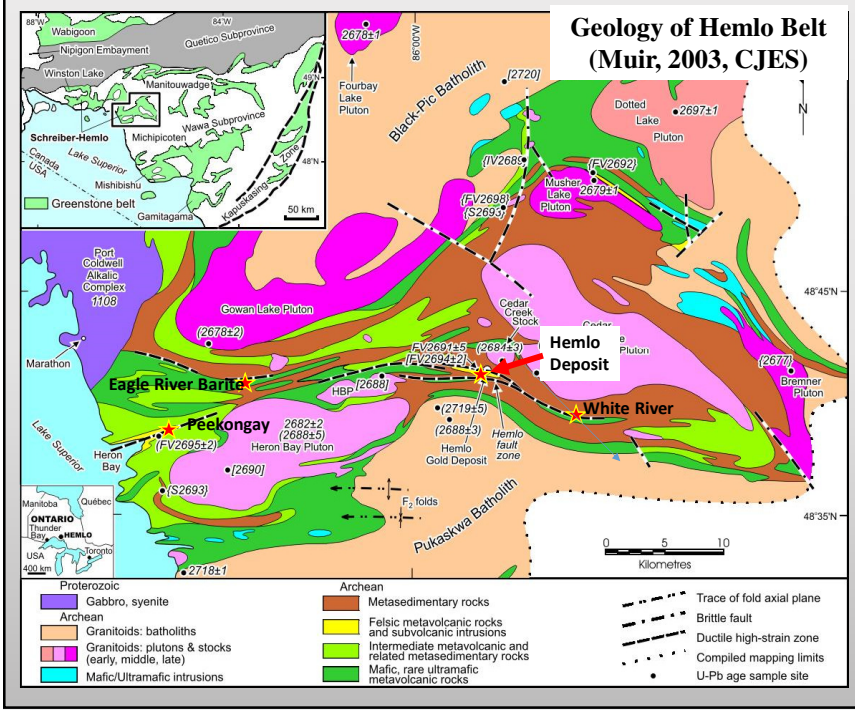
Northern Abitibi
Successor Basins:
- **Coapatina ~2700 Ma**
- **Opemisca ~2690 Ma**
- **✓Early thrusts S-verging**
- **✓Main Au 2700-2690 Ma**

Southern Abitibi
Successor Basins:
- **Porcupine 2690-80 Ma**
- **Timiskaming 2676-70 Ma**
- **✓Early thrusts N-verging**
- **✓Main Au 2670-2665 Ma**

Comparison of Abitibi and Hemlo Gold Camps



- **Upper stratigraphic units in Abitibi & Wawa have similar lithlogies & ages (i.e. 2.76-2.68 Ga).**
- **One difference in the Wawa area is the presence of a ~2.9 Ga lowermost unit representing a stratigraphic gap (unconformity ?) of >100 Ma.**

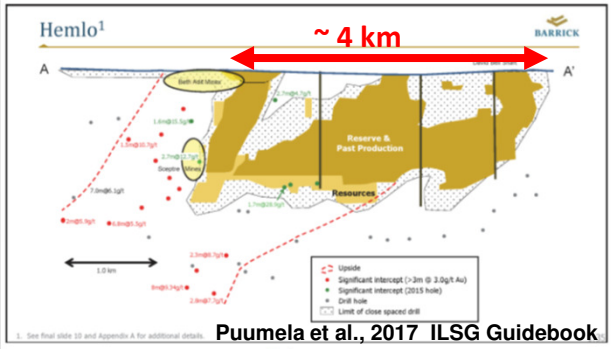


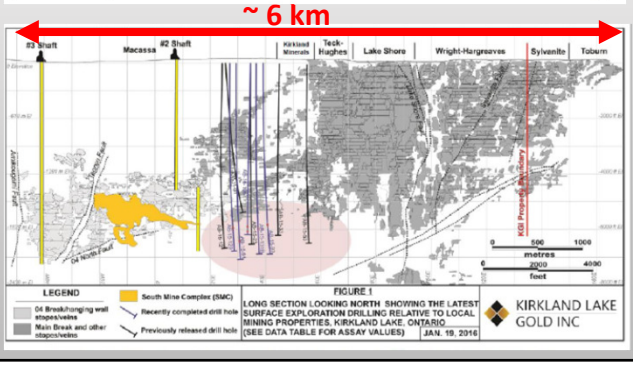
Hemlo Deposit Setting

The Hemlo deposit occurs within a 2693-2685 Ma succession of clastic seds. & felsic volcs, underlain by older >2720 Ma (undated) mafic volcs, intruded by 2720 Ma tonalitie batholiths to N & S

The deposit occurs at a jog (change from NE to NW strike) in the Lake Superior deformation zone, a over 50 km auriferous deformation zone

The mineralization consist of broad replacement zones with disseminated sulfides in amphibolite facies sediments and volcanics



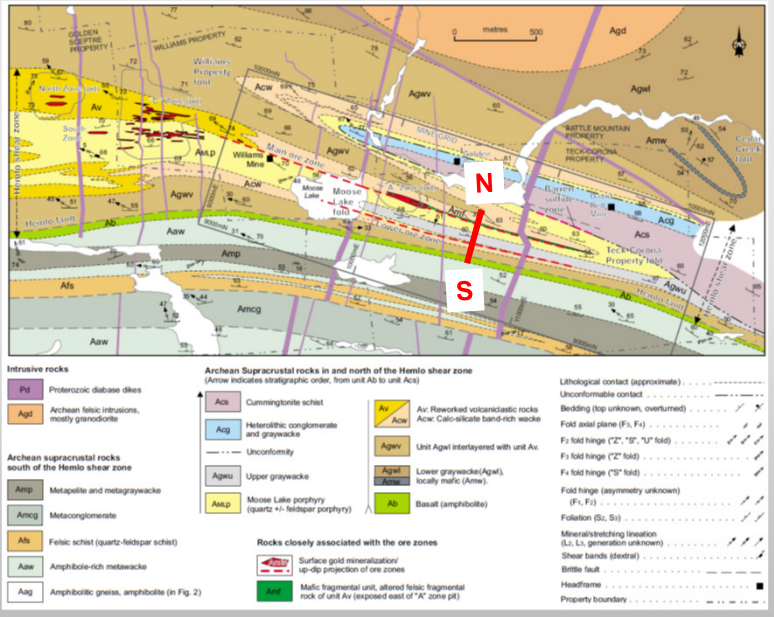


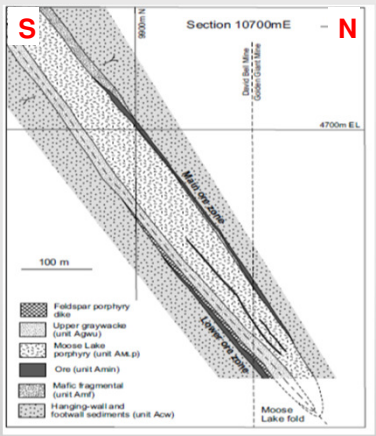
Comparison of Hemlo and Kirkland Lake Long. Sections

Hemlo ~23 M oz Au over 4 km strike length. The ore zone strikes W & plunges steeply W, but changes to a WNW strike with a shallower western plunge in the east. Au is associated with Mo, As, Sb, Hg, Ba & V (magmatic association?).

Kirkland Lake ~26 M oz Au over 6 km strike length. The ore zone strikes ENE with shallow plunge to W. Au occurs in narrow qz-cb veins in brittle D4 faults. Au is associated with Te, Mo, & Pb, (magmatic association?)

Hemlo Deposit Area Map and Cross Section (Davis and Lin, 2003, E.G.)





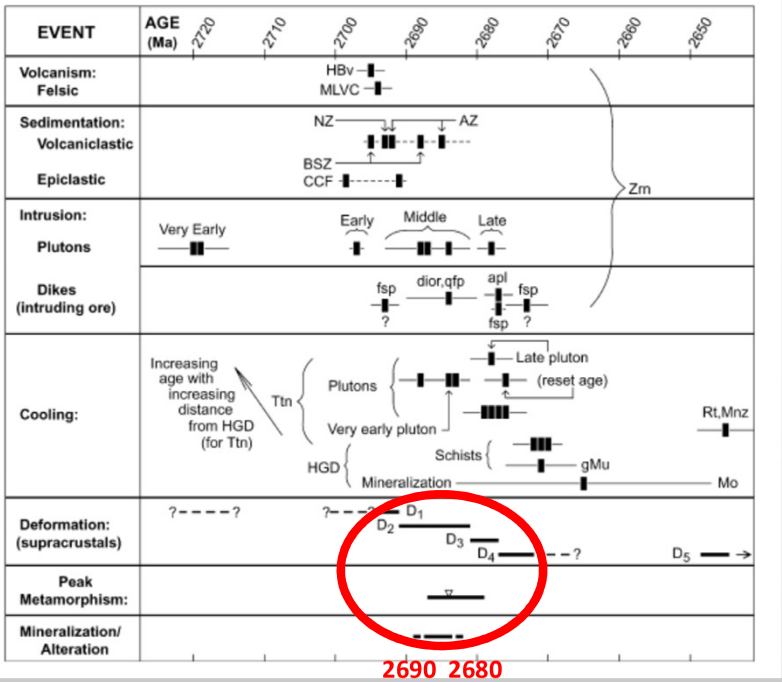
Structural History:

-D_1 early thrusting, fabric only locally preserved

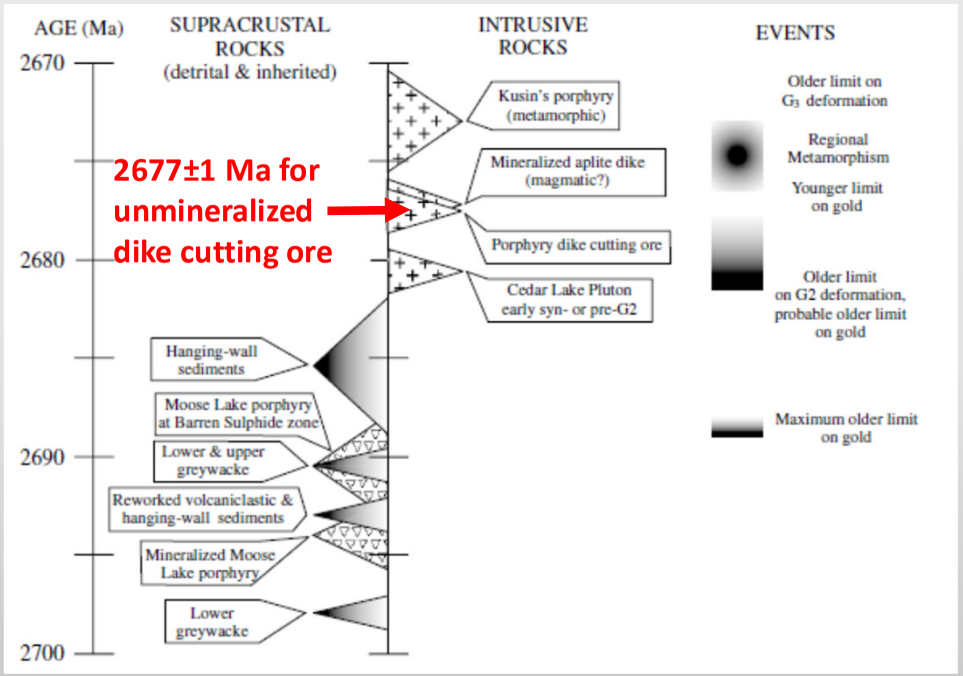
-D_2 sinistral kineamatics with tight folds & shearing parallel to stratigraphy

-D_3 crenulation folding overprints Au

Comparison of Timing of Hemlo Deformation and Gold

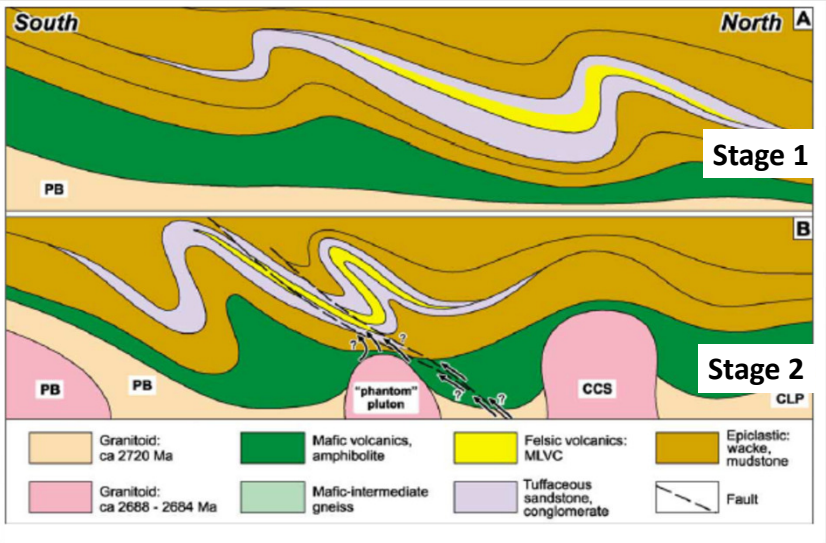


Gold is syn-D_2 & pre-D_3 @ 2690-2680 Ma & peak metamorphism is post-ore @ 2678-76 Ma. (Muir, 2002, Ore Geol. Rev.)



Gold is pre-D_2 & D_3 @ 2680-2677 Ma. Maximum age of Au @ 2677±1 Ma for barren dike cutting ore. (Davis and Lin, 2003, Econ. Geol.)

Model for formation of the Hemlo Gold Deposit (Muir, 2002, OGR)



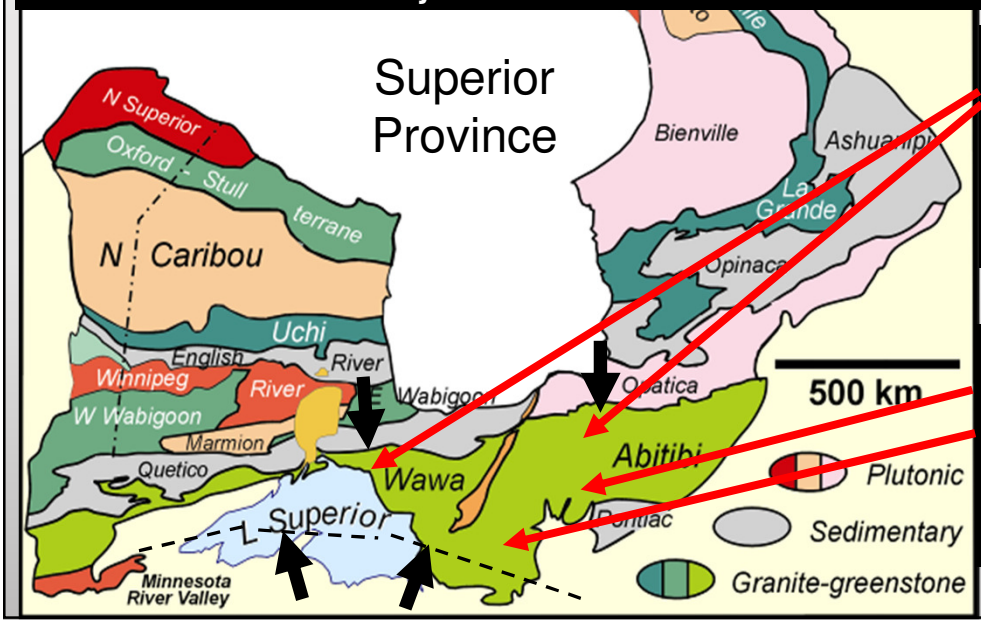
-D_1: N-S compression & south verging thrusting resulting in deposition of 2695-2685 Ma clastics & felsic volcs.
-D_2: NE-SW transpression & sinistral deformation resulted in NE-NW jog & pathway for hydrothermal fluids & Au @ ~2680 Ma

Similarities of Hemlo Deposit to Northern Abitibi faults

-South-verging thrusting
- Deposit associated with 2695-2685 Ma clastics & volcanics
-No evidence for Timiskaming assemblage rocks @2676-2670 Ma
-Age of main stage Au @ 2680 Ma is older than 2670-2665 Ma in S. Abitibi

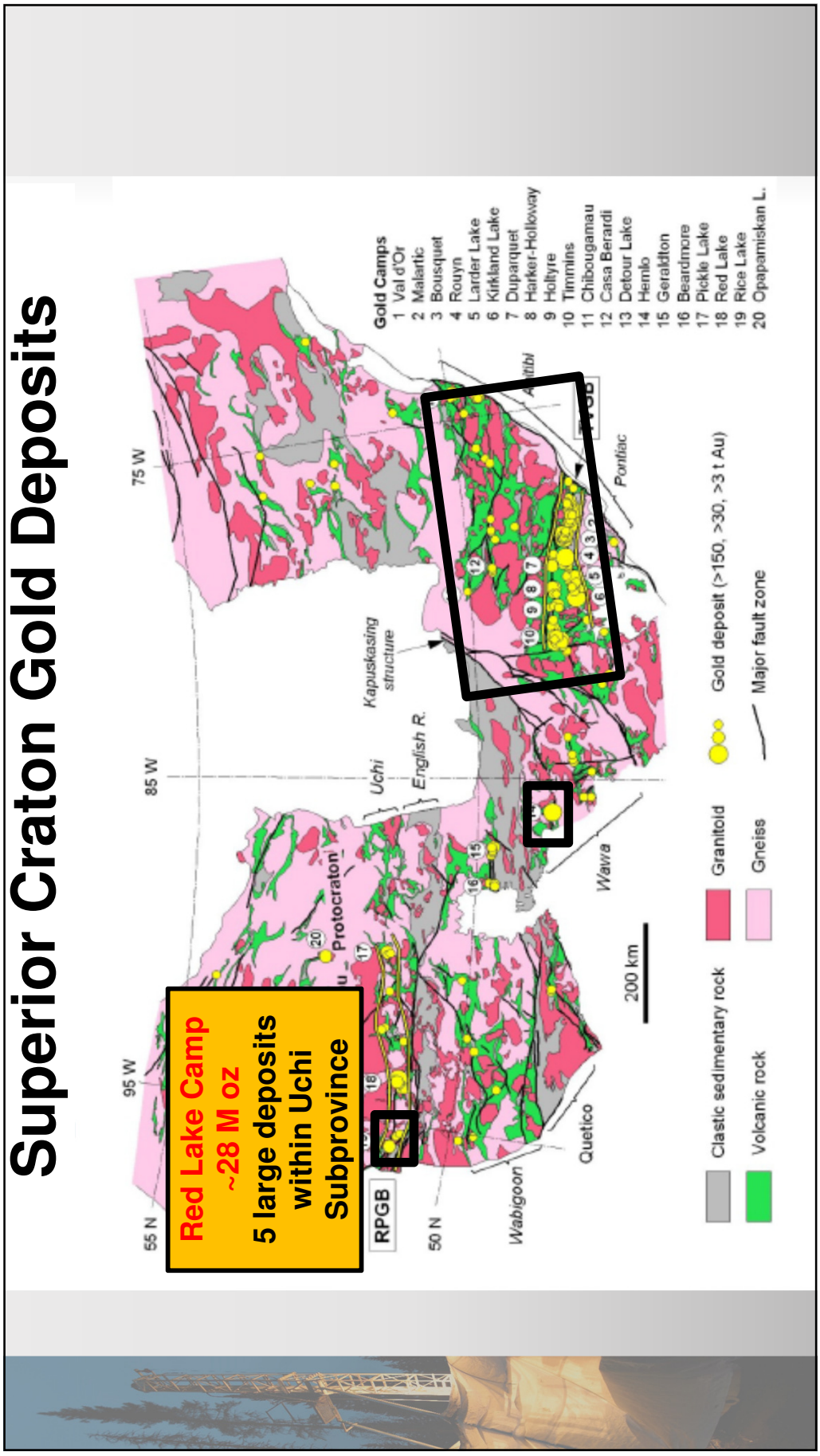
Model for Orogenic Gold in Southern Superior

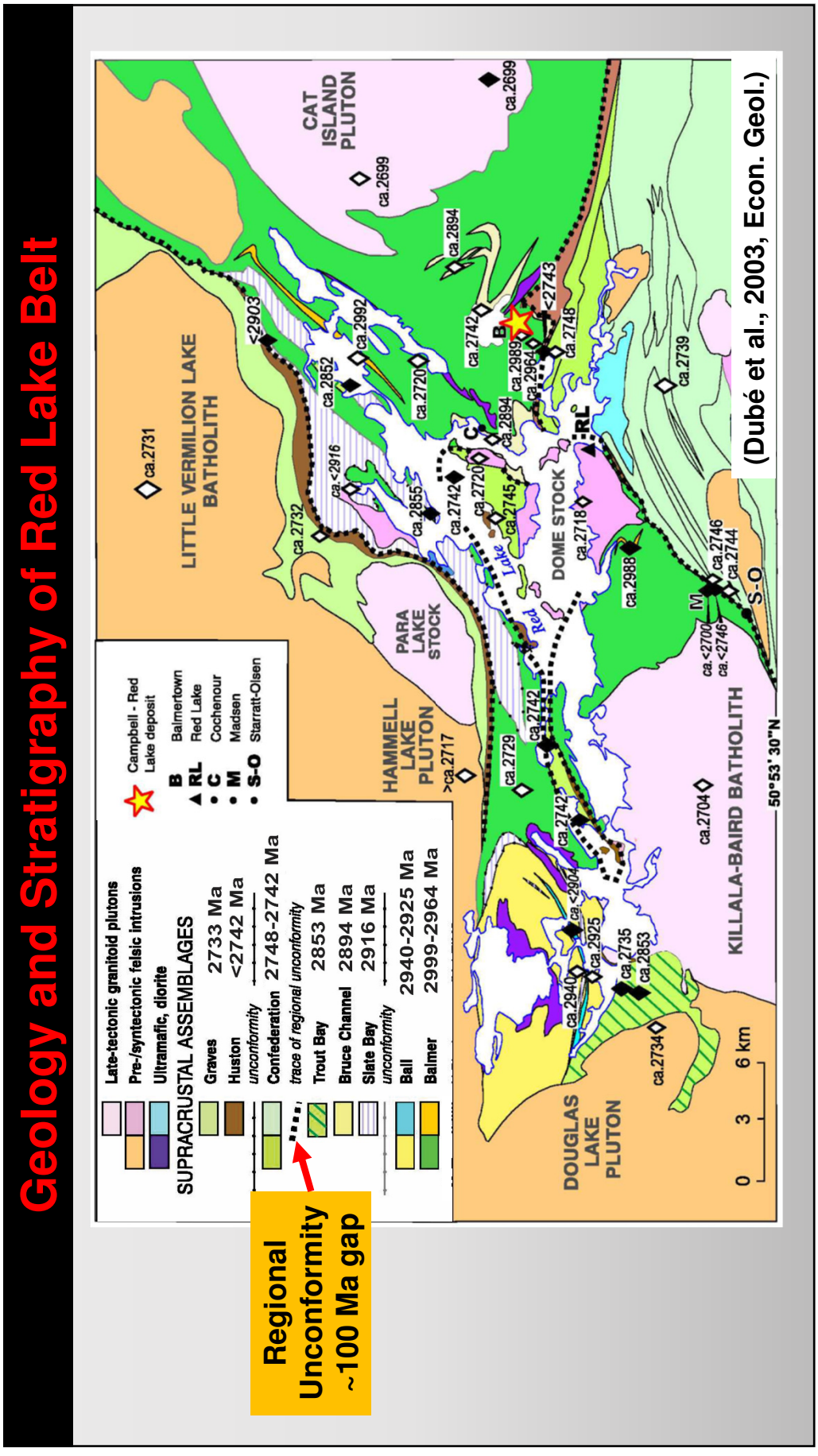
Late Accretionary Faults were Conduits for Gold-bearing Fluids

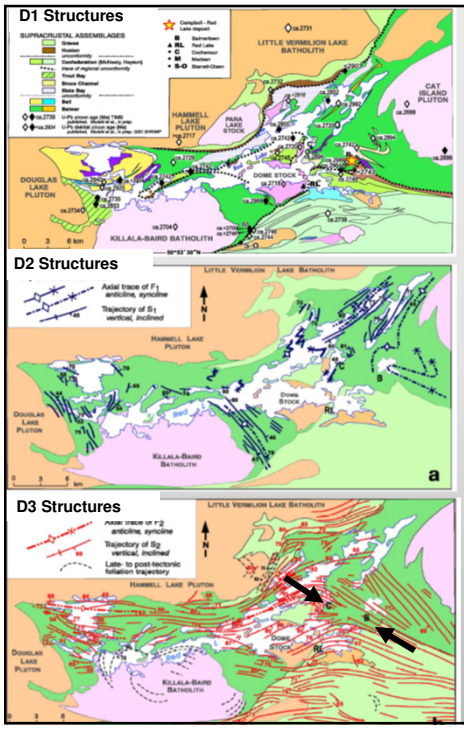


N. Abitibi-Wawa collision with older terranes to N resulted in S-verging DZs & Au~2.70-2.68 Ga.

S. Abitibi collision with an older terrane from the S resulted in N-verging DZs & Au ~2.67-2.66 Ga


Superior Craton Gold Deposits
Red Lake Camp
~28 M oz
5 large deposits
within Uchi
Subprovince
RPGB
Gold Camps
1 Val d'Or
2 Malartic
3 Bousquet
4 Rouyn
5 Larder Lake
6 Kirkland Lake
7 Duparquet
8 Harker-Holloway
9 Holtyre
10 Timmins
11 Chibougamau
12 Casa Berardi
13 Detour Lake
14 Hemlo
15 Geraldton
16 Beardmore
17 Pickle Lake
18 Red Lake
19 Rice Lake
20 Opapamiskan L.
Clastic sedimentary rock
Volcanic rock
Granitoid
Gneiss
Gold deposit (>150, >30, >3 t Au)
Major fault zone
200 km
Protocraton
Uchi
English R.
Kapuskasing structure
Wawa
Quetico
Wabigoon
Pontiac
55 N
50 N
95 W
85 W
75 W


Geology and Stratigraphy of Red Lake Belt
Late-tectonic granitoid plutons
Pre-/syntectonic felsic intrusions
Ultramafic, diorite
SUPRACRUSTAL ASSEMBLAGES
Graves 2733 Ma
Huston <2742 Ma
unconformity
Confederation 2748-2742 Ma
trace of regional unconformity
Trout Bay 2853 Ma
Bruce Channel 2894 Ma
Slate Bay 2916 Ma
unconformity
Ball 2940-2925 Ma
Balmer 2999-2964 Ma
Campbell - Red Lake deposit
B Balmertown
RL Red Lake
C Cochenour
M Madsen
S-O Starratt-Olsen
Regional Unconformity ~100 Ma gap
LITTLE VERMILION LAKE BATHOLITH
CAT ISLAND PLUTON
PARA LAKE STOCK
HAMMELL LAKE PLUTON
DOME STOCK
KILLALA-BAIRD BATHOLITH
DOUGLAS LAKE PLUTON
Red Lake
0 3 6 km
50°53' 30"N
(Dubé et al., 2003, Econ. Geol.)



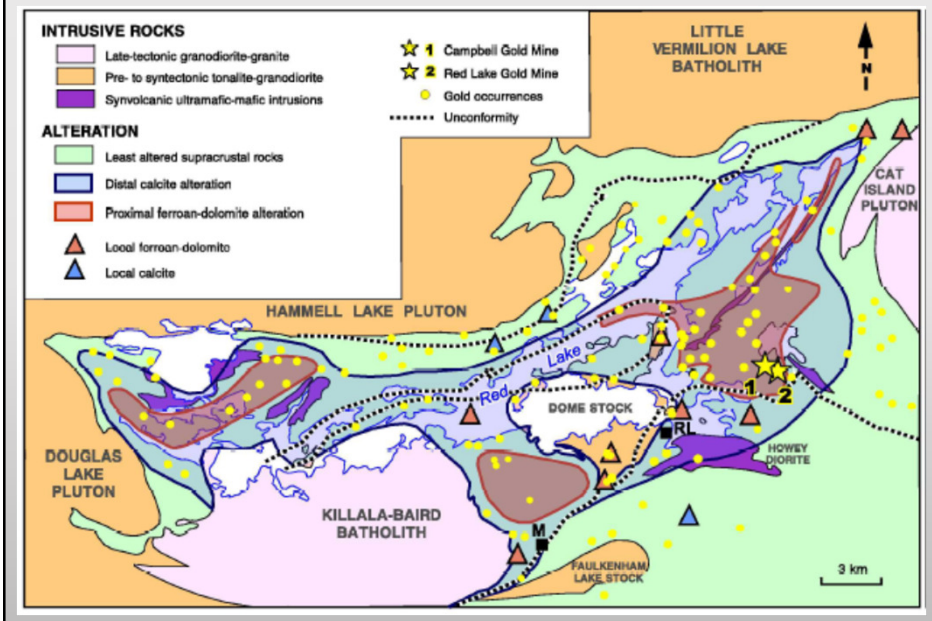
Red Lake Structural History
(Sanborn-Barrie et al., 2004, GSC Open File 4594)

D1: a non-penetrative, early (pre-2748 Ma) event involving folding and overturning of the Mesoarchean assemblages & a regional unconformity

D2: (ca. 2733-2742 Ma) involved east-west shortening and resulted in a north-trending foliation, axial planar to the F2 folds

D3: (ca. 2720-2700 Ma) resulted in E-NE foliation & refolding F2 folds. A deflection of S3 around the McKenzie stock and a SE striking high strain zone, hosting the major gold deposits "Mine Trend" extends from Cochenour to Balmertown.

Red Lake Alteration & Gold Deposits Map

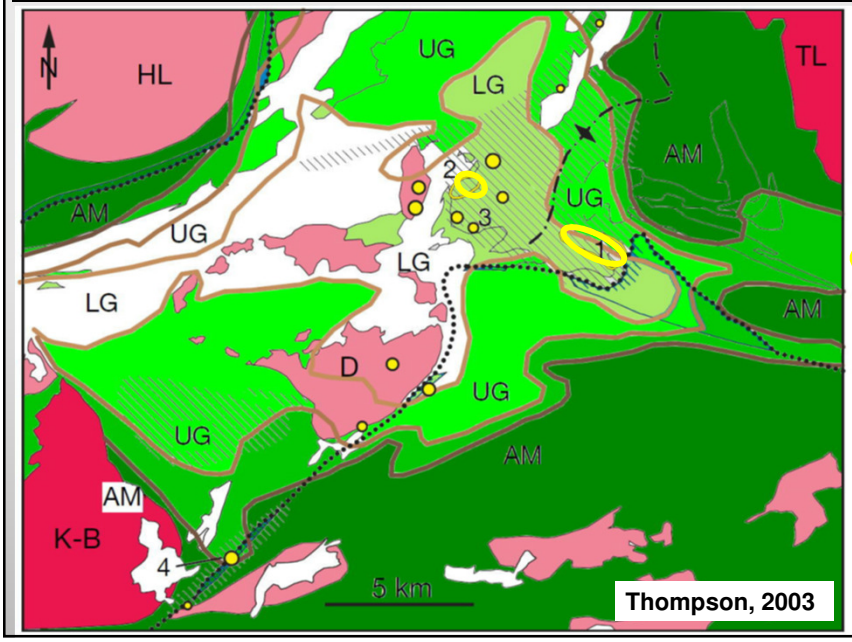


Two types of regional hydrothermal alteration envelopes with spatial relationship to Au:
1) Distal alteration of widespread calcite & weak potassic & chloritization
2) Proximal alteration of ferroan-dolomite & intense potassic alteration

Over 95% of the Au deposits are within ½ km of the regional Mesoarchean-Neaoarchean unconformity, within the proximal alteration envelopes

(Sanborn-Barrie et al., 2004, GSC Open File 4594)

Red Lake Metamorphic Metamorphic Map



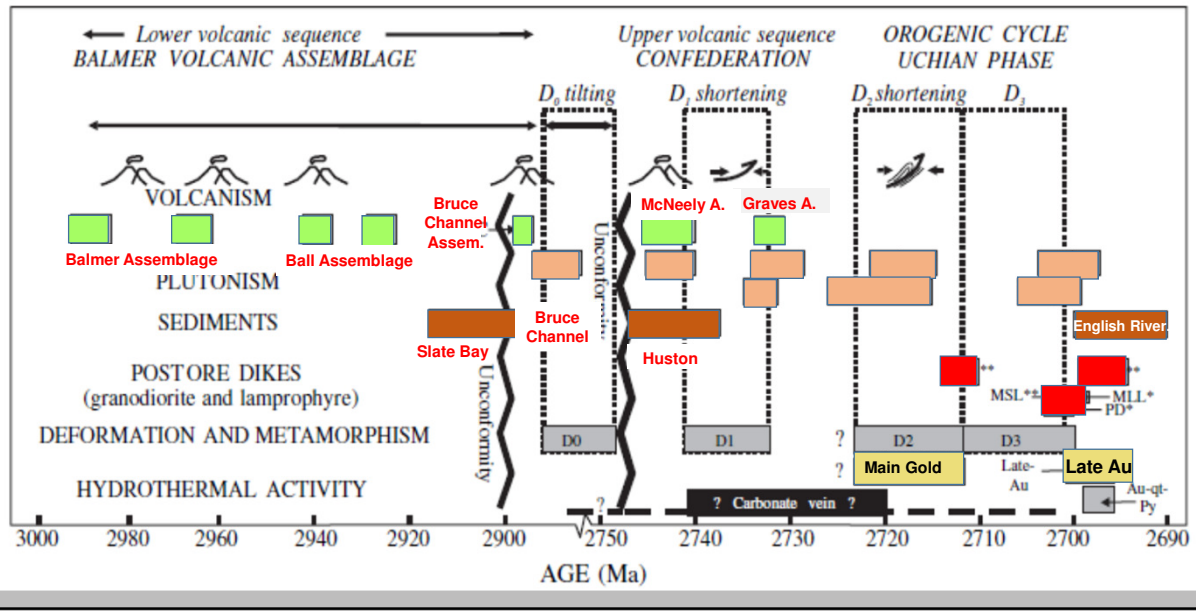
- Lower greenschist
- Upper greenschist
- Lower amphibolite
- Amphibolite
- Mesoarchean-Neoarchean Regional unconformity
- Gold deposits: 1 Campbell-Red Lake, 2 Cochenour. 3 Wilmar, 4 Madson

Metamorphic zone boundaries favourable for Au deposits:

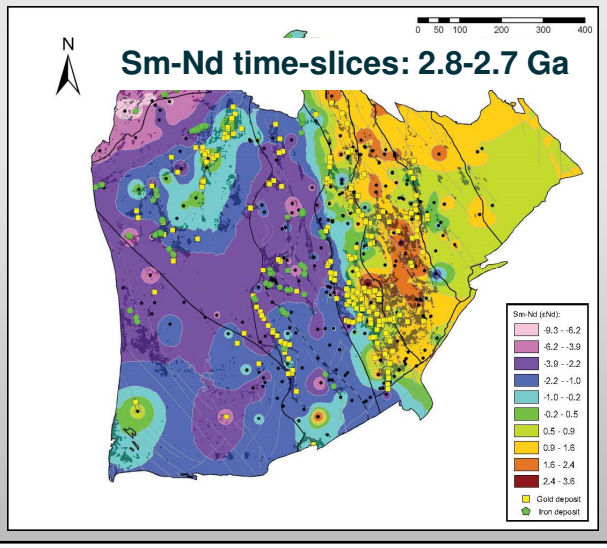
1) Lower to Upper Greenschist (e.g. Campbell, Red Lake & Cochenour)
2) Upper Greenschist-Amphibolite (e.g. Madson & Sharrett-Olsen

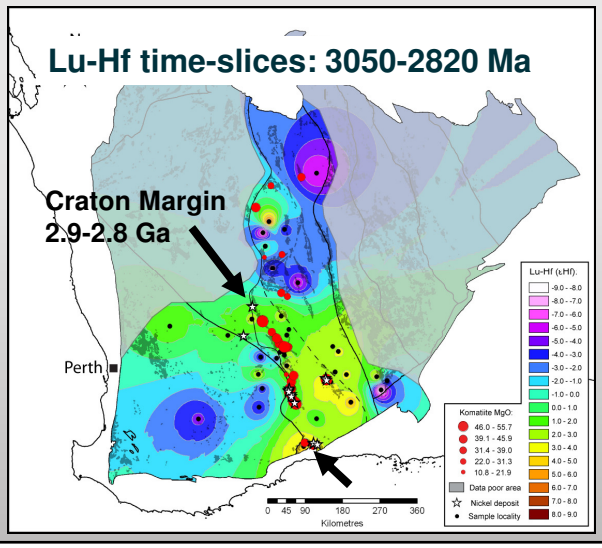
Thompson, 2003. OGS OFR 6122)

Timing of Events and Gold in the Red Lake Greenstone Belt
(Dube et al., 2003, Econ. Geol.)



Nd and Hf isotope studies from the Yilgarn Craton indicate many gold (& Ni) deposits are proximal to terrane boundaries: 2.8-2.7Ga (left) & 2.9-2.8 Ga (right) (Mole et al., 2013, Geol. Soc. Lon.)





Summary & Recommendations

Early Porphyry Style Mineralization

- **Archean Porphyry Au ± Cu in upper crustal intrusions (Côté & Chibougamau, Troilus) - represents a less explored target. Exploration focus on high level diorite & tonalite intrusive complexes & breccias.**

Abitibi-Wawa Orogenic Au Deposits

- **Related to faults associated with terrane collisions: with Opatica Terrane to the north @ 2.70 Ga & Minnesota River Terrane from the south @ 2.67 Ga**

- **Terrane Collisions resulted in crustal uplift, regional scale faulting, unconformities & late sedimentary/volcanic successor basins**

Conclusions & Recommendations

- Au deposited from hydrothermal fluids, localized within the regional faults (eg. Detour, Kerr, Hemlo) & 2nd order splay faults (eg. Dome, Hollinger, Kirkland Main Break)
- Faults in proximity to late, unconformable successor basins with turbidites, conglomerates, calc alkaline volcanics ± mantle-derived magmas/fluids/alkali intrusions or volcanics
- Exploration focus on contacts between brittle, ductile & Fe-rich lithologies (seds/mafic/ultramafic volcanics, felsic intrusions, etc.) flextures in regional faults; (eg. Hemlo, Larder Lake), proximal alteration facies (eg. ankerite, sericite, biotite, kspar)
- In Northern Superior (eg. Red Lake) regional faults appear to be less important. Focus should be on contacts between Mesoarchean-Neoarchean terranes, unconformities & conglomerates, proximal alteration facies (eg. ankerite, sericite, biotite, kspar) and transisition zones between metamorphic facies (low to upper greenschist & greenschist to amphibolite)

MERC Mineral Exploration Research Centre AT THE HARQUAIL SCHOOL OF EARTH SCIENCES

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HARQUAIL SCHOOL OF EARTH SCIENCES ÉCOLE DES SCIENCES DE LA TERRE

Thank You

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MERC PDAC
Short Course
March 03, 2018

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