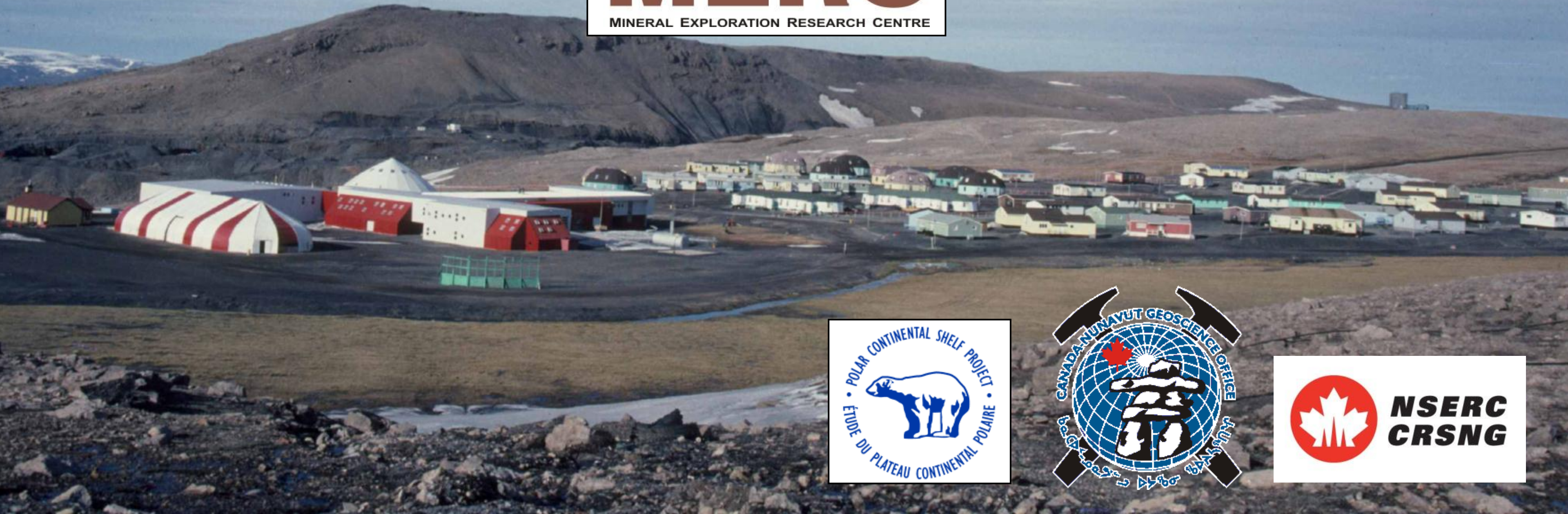
Geological evolution of the Borden Basin (Nanisivik zinc district): Implications for economic potential

E.C. Turner

Laurentian University
Université Laurentienne
MERC
Mineral Exploration Research Centre



Polar Continental Shelf Project
Étude du Plateau Continental Polaire

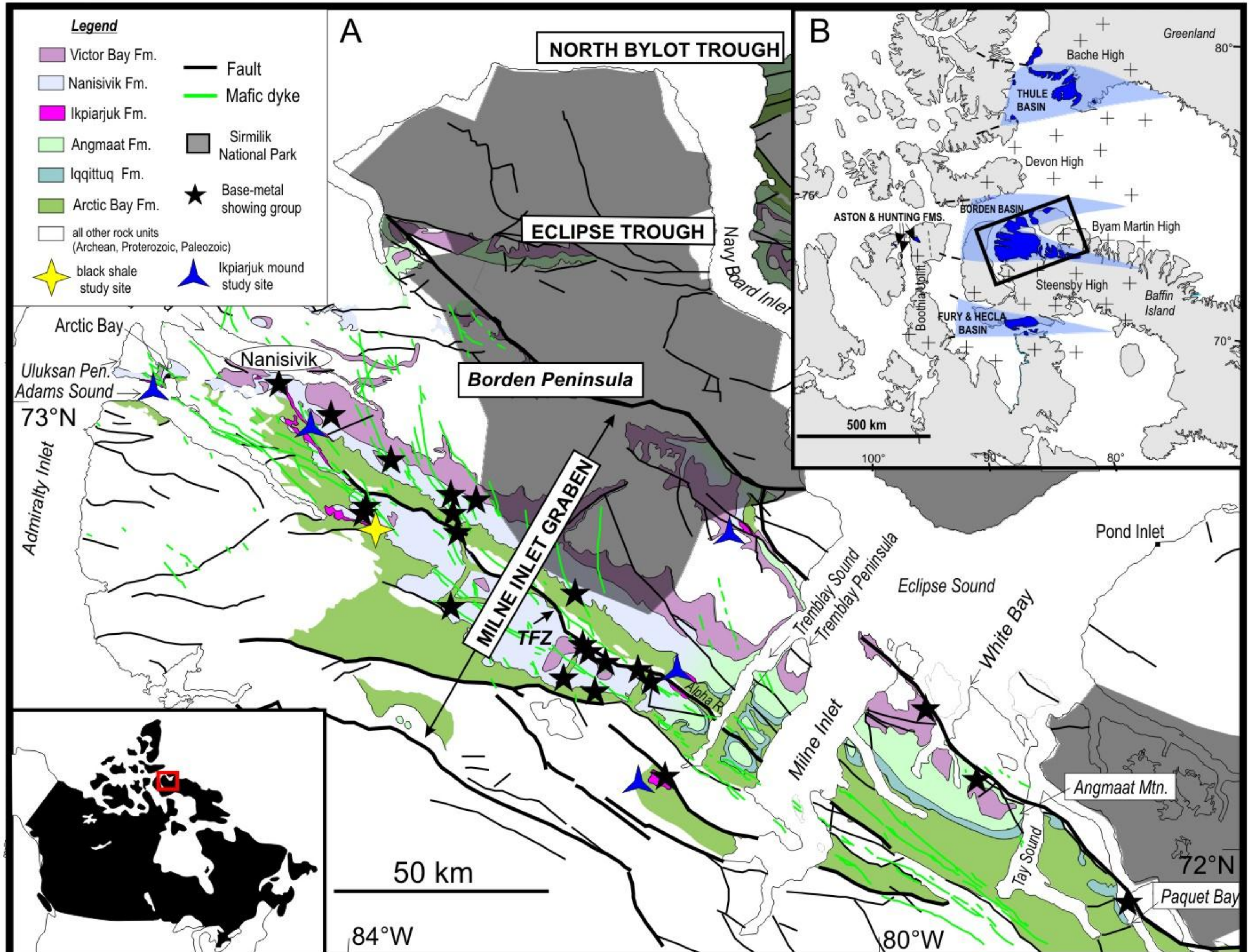
Canada-Nunavut Geoscience Office

NSERC
CRSNG

BASIC QUESTIONS TO BE ASKED ABOUT ANY KNOWN ORE DEPOSIT (IF YOU WANT TO FIND MORE)

WHY IT MATTERS

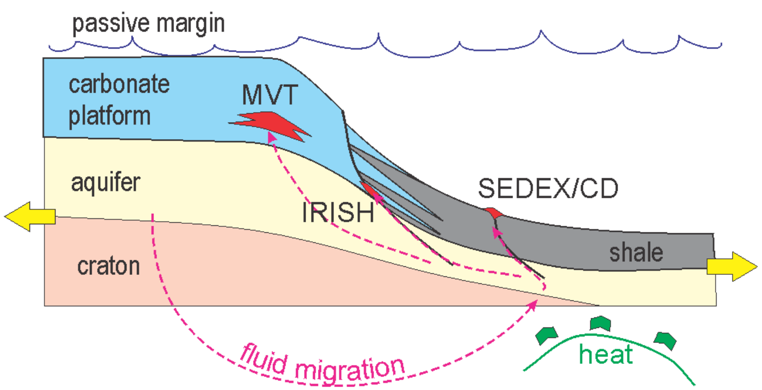
BASIC QUESTIONS		WHY IT MATTERS
1) NATURE OF HOST ROCK	→	CONTRIBUTES TO WHY AND WHERE METALS ARE CONCENTRATED
2) SPATIAL CONTROL(S) ON DISTRIBUTION OF KNOWN MINERALISATION	→	INDICATES WHERE TO LOOK FOR MORE
3) AGE OF KNOWN MINERAL DEPOSITS	→	WHEN IT HAPPENED → IDENTIFIES WHICH ROCK UNITS ARE WORTH LOOKING AT (AND WHICH ARE NOT)
4) DEPOSITIONAL AGE OF HOST ROCKS	→	INDICATES WHY METALS CAME TO BE WHERE THEY ARE
5) NATURE OF MINERALISING FLUIDS (TEMPERATURE, CHEMISTRY)	→	WHERE METALS CAME FROM AND HOW THEY CAME TO BE PRECIPITATED
6) TECTONIC SETTING	→	CONTINENTAL STRUCTURAL REGIME AT TIME OF MINERALISATION (=HOW & WHY)
7) POTENTIAL IN OTHER, RELATED ROCKS	→	WHAT HAVE WE MISSED?

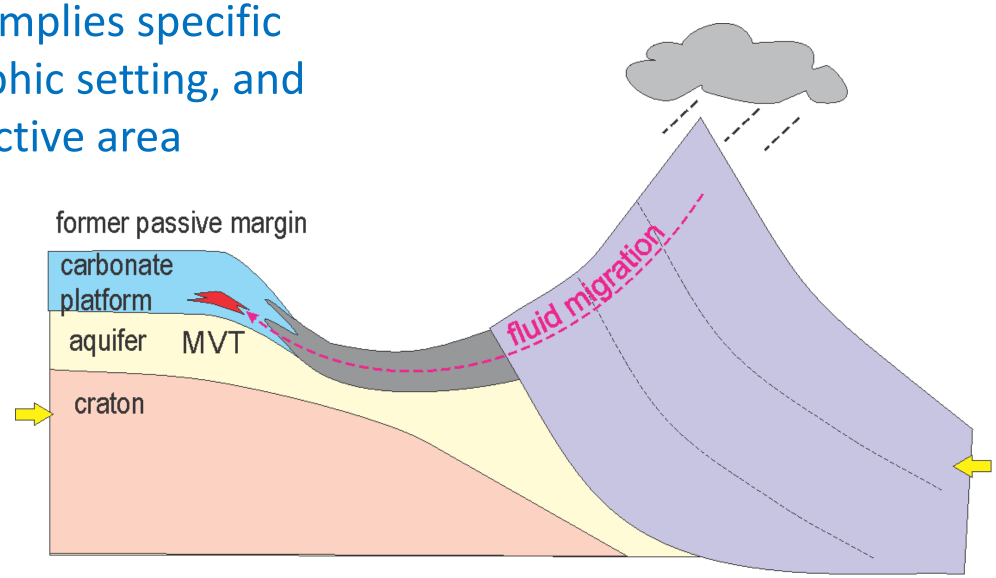

Legend
Victor Bay Fm.
Nanisivik Fm.
Ikpiarjuk Fm.
Angmaat Fm.
Iqqittuq Fm.
Arctic Bay Fm.
all other rock units (Archean, Proterozoic, Paleozoic)
black shale study site
Fault
Mafic dyke
Sirmilik National Park
Base-metal showing group
Ikpiarjuk mound study site
A
NORTH BYLOT TROUGH
ECLIPSE TROUGH
Navy Board Inlet
Arctic Bay
Nanisivik
Uluksan Pen.
Adams Sound
73°N
Admiralty Inlet
Borden Peninsula
MILNE INLET GRABEN
TFZ
Alpha R.
Tremblay Sound
Tremblay Peninsula
Eclipse Sound
Pond Inlet
White Bay
Milne Inlet
Angmaat Mtn.
Tay Sound
72°N
Paquet Bay
50 km
84°W
80°W
B
Greenland
Bache High
THULE BASIN
Devon High
ASTON & HUNTING FMS.
BORDEN BASIN
Byam Martin High
Steensby High
Baffin Island
Boothia Uplift
FURY & HECLA BASIN
500 km
100°
90°
80°
80°
76°
70°

1) NATURE OF HOST ROCK

TWO MODELS FOR CARBONATE-HOSTED Zn

- If carbonate host 'platformal', implies specific paleogeographic setting, and limits prospective area





- If carbonate host **not** 'platformal', spatial and structural constraints are less limiting

1) NATURE OF HOST ROCK

1970s

ORE-HOSTING CARBONATE ROCKS DEPOSITED ON A CARBONATE PLATFORM

NEW

ORE-HOSTING CARBONATE ROCKS DEPOSITED IN DEEP, ANOXIC WATER

Jackson & Iannelli, 1981

Turner, 2009

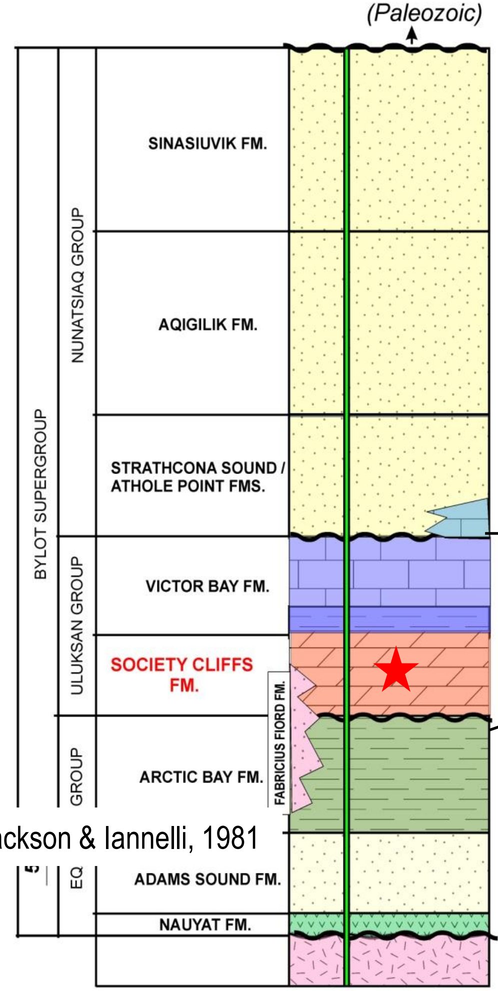
1) NATURE OF HOST ROCK

1970s ↓

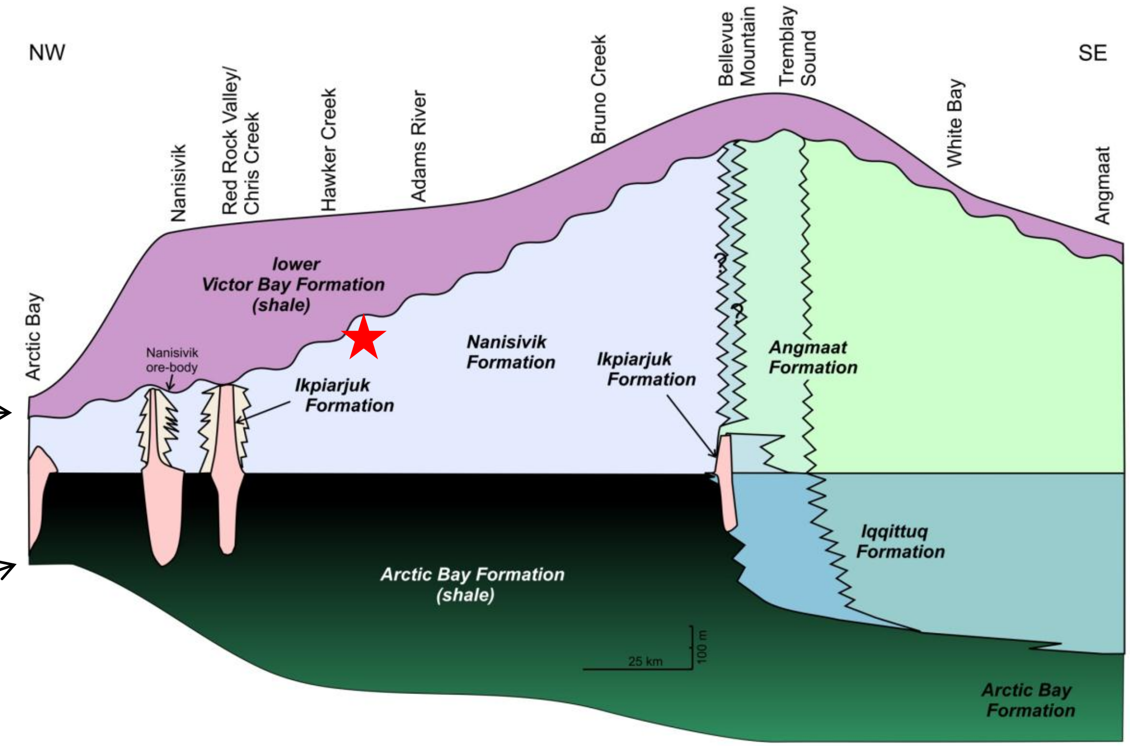
ORE-HOSTING CARBONATE ROCKS DEPOSITED ON PASSIVE MARGIN

NEW ↓

ORE-HOSTING CARBONATE ROCKS DEPOSITED IN TECTONICALLY ACTIVE, DIFFERENTIATED BASIN

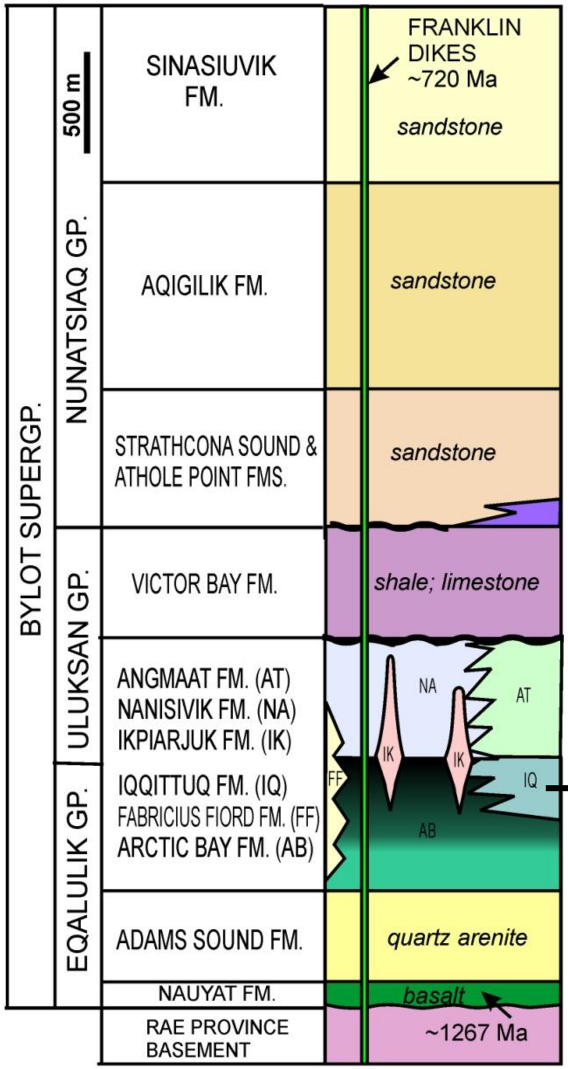


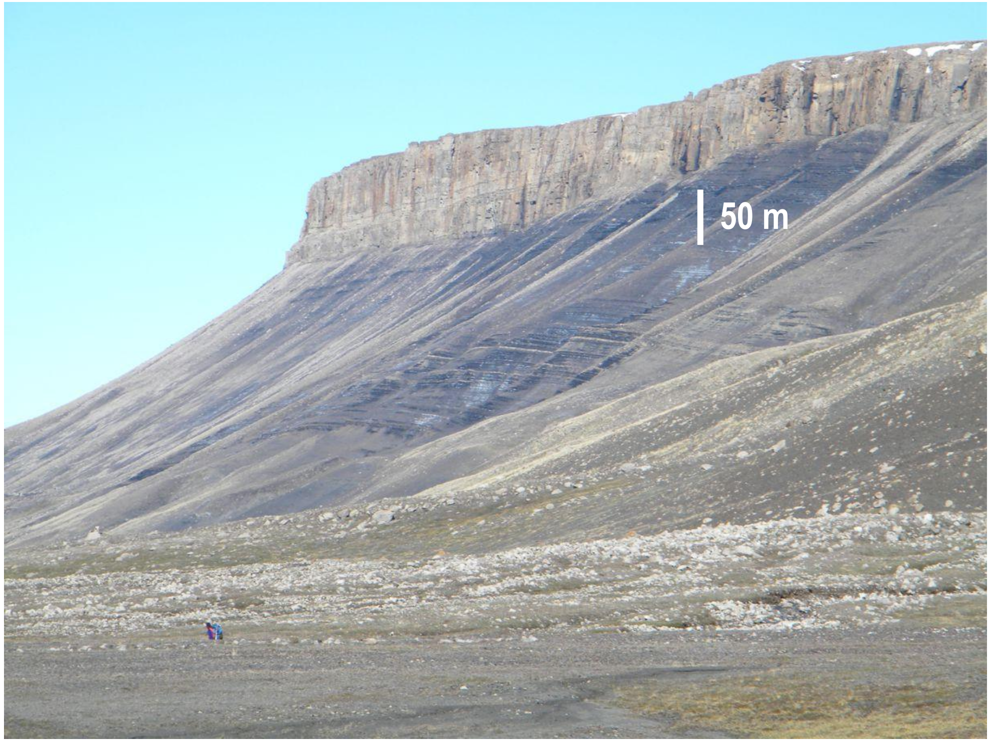
Jackson & Iannelli, 1981



Turner, 2009

2) DEPOSITIONAL AGE OF HOST ROCKS



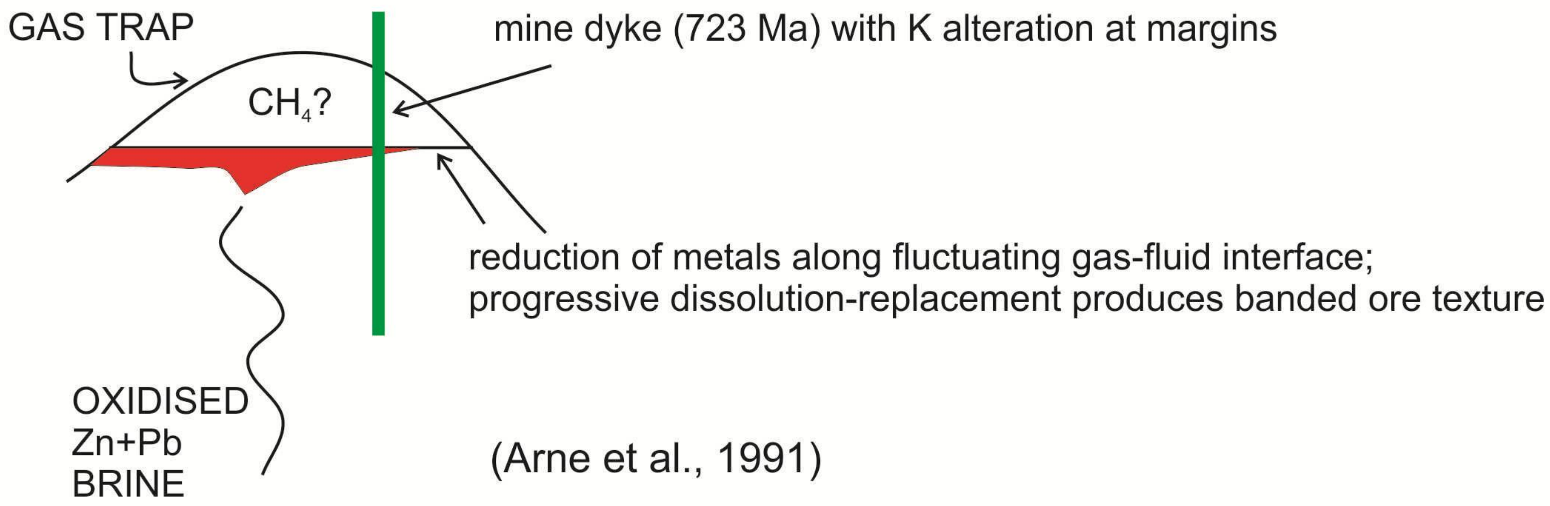


Arctic Bay Formation:

- depositional age **1092 ±59 Ma** (U-Th-Pb whole rock)
- **~200 m.y. YOUNGER** THAN PREVIOUSLY THOUGHT
- **CONTEMPORANEOUS** WITH **ASSEMBLY OF RODINIA**

Turner, & Kamber 2009

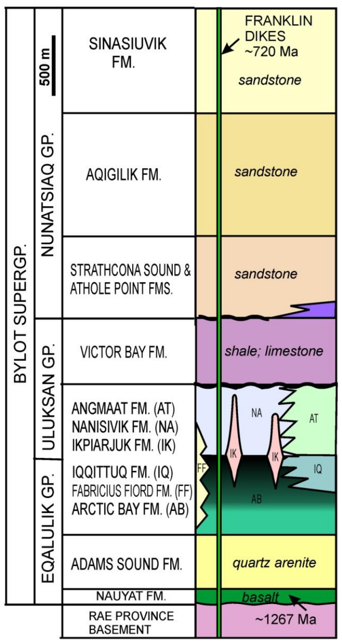
3) SPATIAL CONTROL(S) ON DISTRIBUTION OF KNOWN MINERALISATION

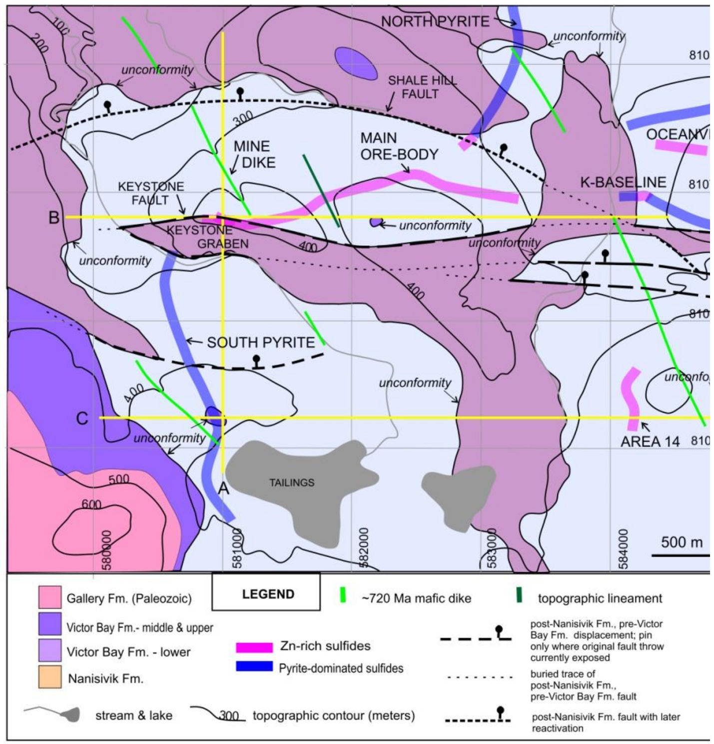


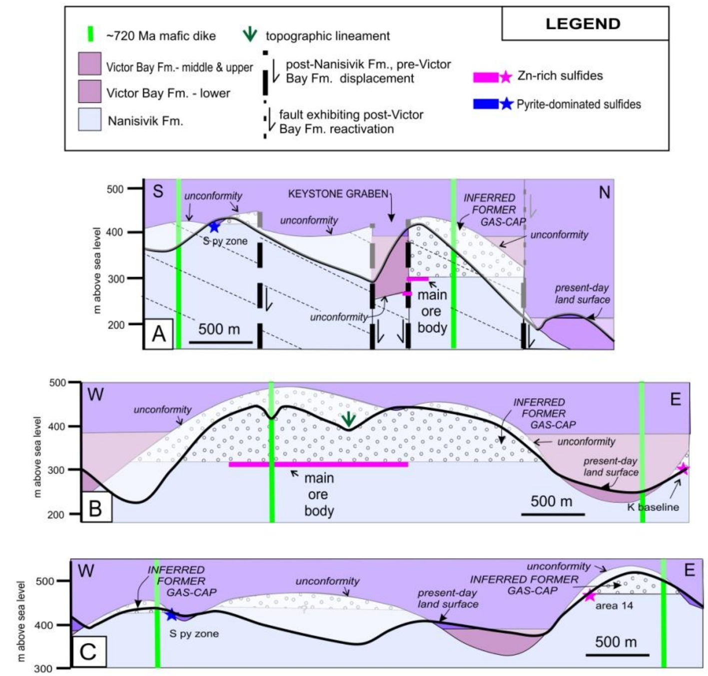
3) SPATIAL CONTROL(S) ON DISTRIBUTION OF KNOWN MINERALISATION

1970s → UNDETERMINED

NEW ↓







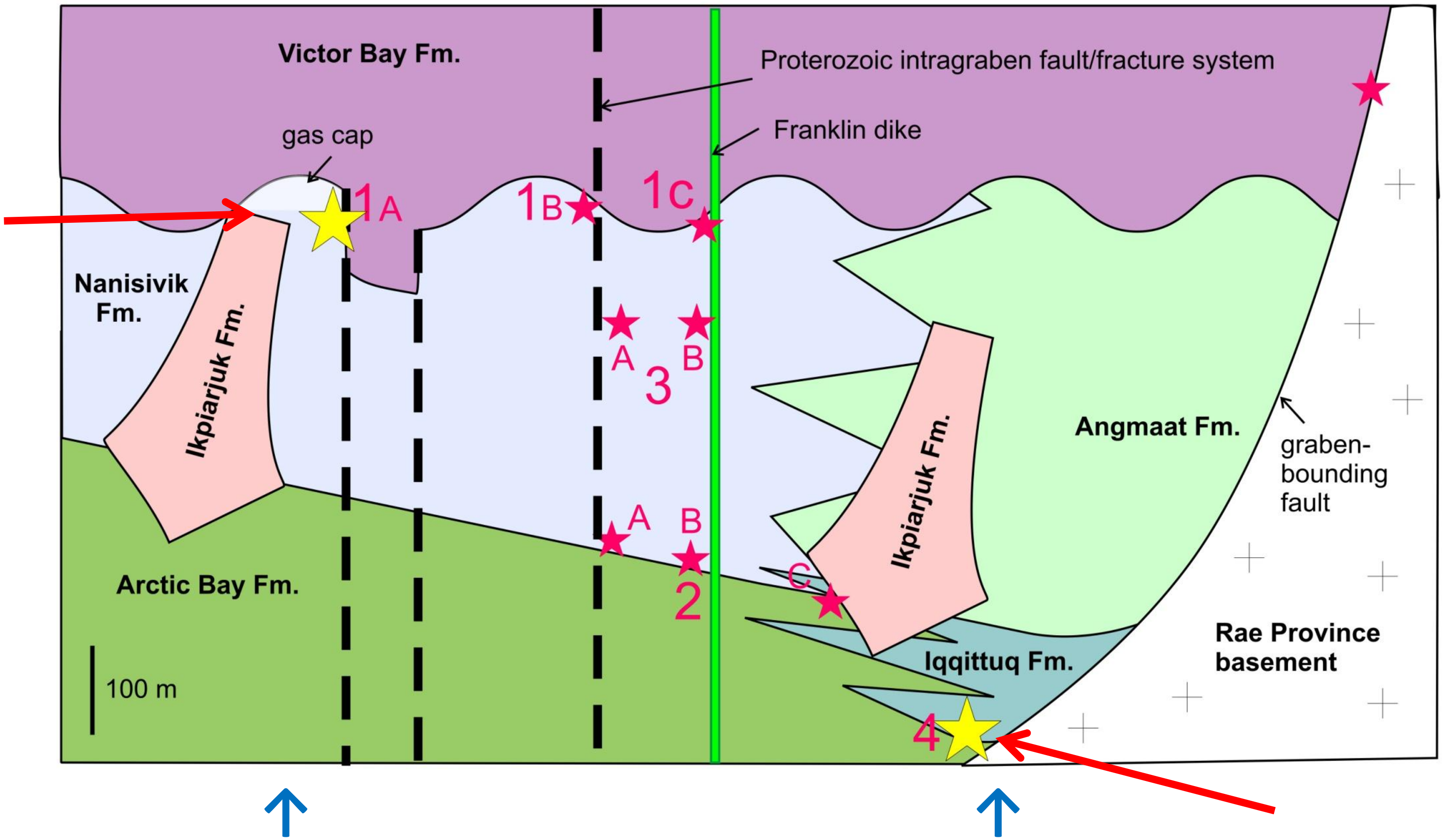
Nanisivik orebody's location is constrained by

1) shape of unconformity (gas trapped under convexities in unconformity)

2) ± faults

Turner 2011

3) SPATIAL CONTROL(S) ON DISTRIBUTION OF KNOWN MINERALISATION



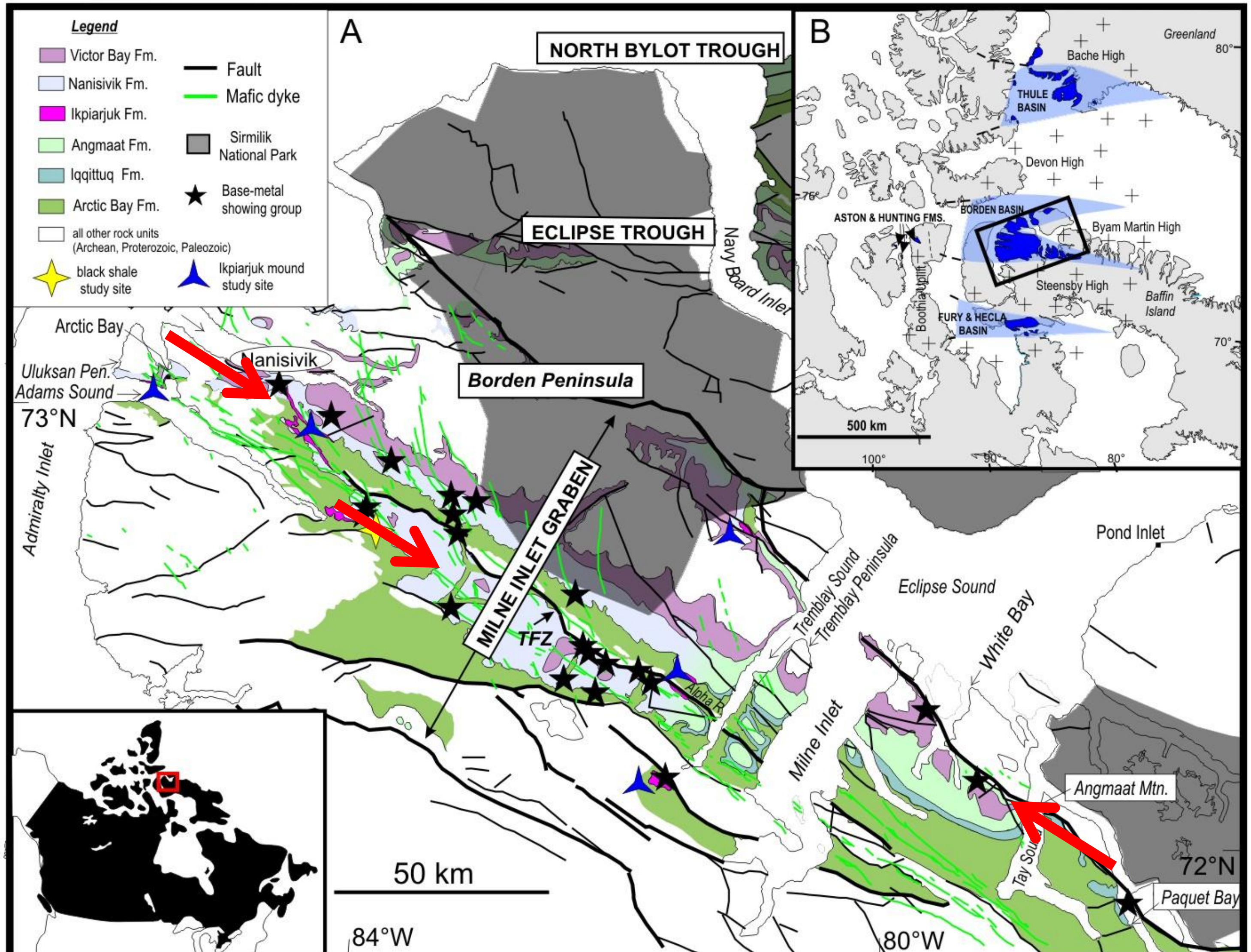
1) Erosional hills ± horsts buried by shale later become hydrocarbon traps that provide reductant for metals

2) Lowest carbonate unit at graben margin

BEST KNOWN MINERALISATON IS IN 2 SETTINGS

Turner 2011

3) SPATIAL CONTROL(S) ON DISTRIBUTION OF KNOWN MINERALISATION

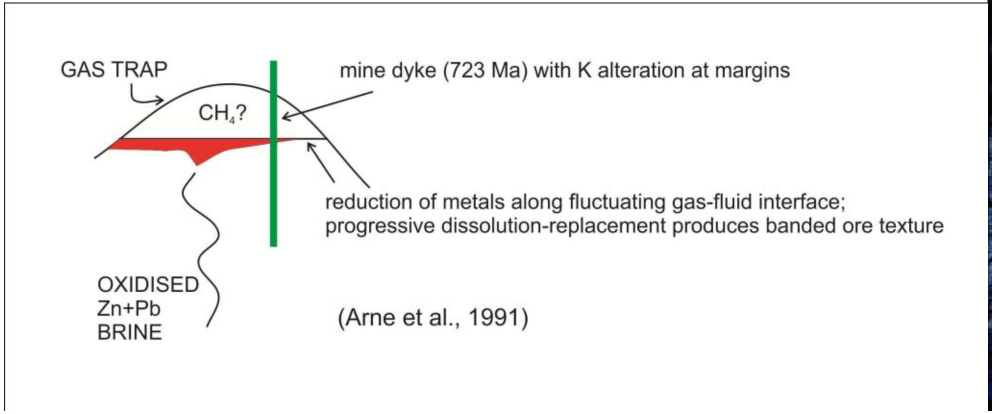


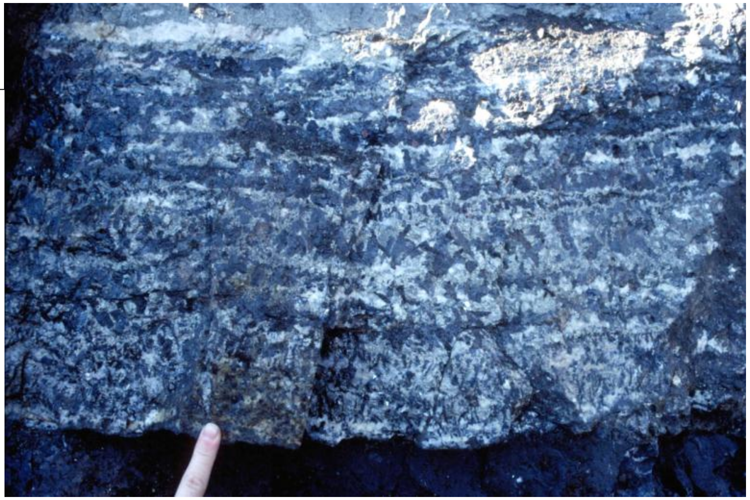
4) AGE OF KNOWN MINERAL DEPOSITS

1970s - 2004 → Nanisivik

461 Ma Ar-Ar orthoclase Sherlock et al., 2004
800-600 Ma Pb-Pb galena Olson, 1984
1095 Ma paleomag Symons et al., 2000
1100 Ma Rb-Sr sphal Christensen et al., 1993

NEW → 1105±24 Ma Re-Os pyrite
(late Mesoproterozoic)
Hnatyshin et al., 2011





- contemporaneous with deposition of upper Bylot Supergroup (Nunatsiaq Group)
- contemporaneous with assembly of supercontinent Rodinia
- excludes all younger rocks in area from consideration

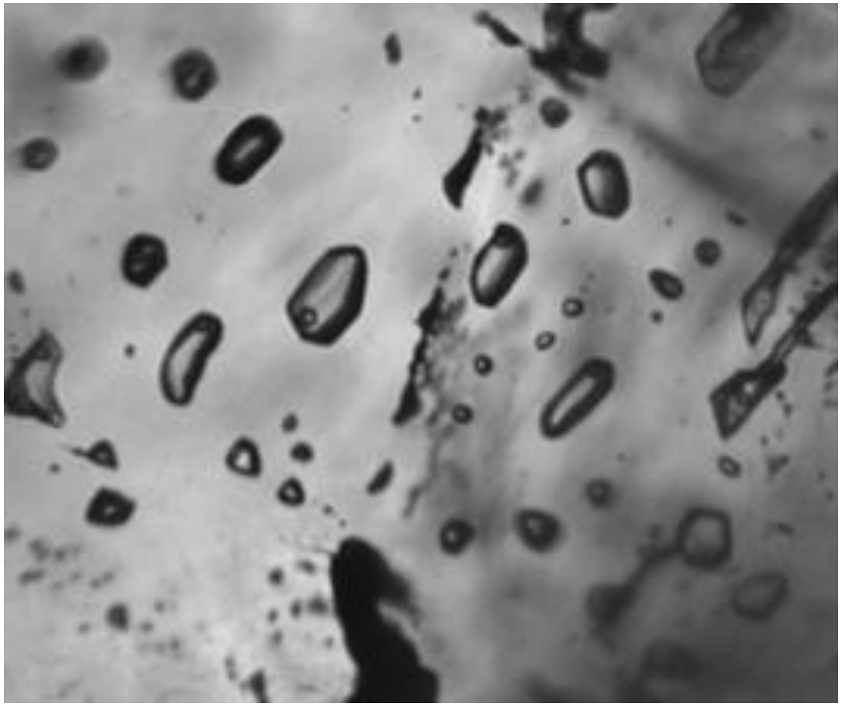
5) NATURE OF MINERALISING FLUIDS (TEMPERATURE, CHEMISTRY)

1970s-80s
↓

- Unusually high T (>200°C)
- Interpreted as ‘anomalous’ relative to ‘normal’ MVT deposits

NEW
↓

1) Th indicate ‘normal’ temperature (**<100°C**)
   - typical MVT
2) Solutes Na-Ca-Mg
   - mineralising fluid could not produce K alteration; not necessary for ore to post-date dyke
3) Th increases toward mine dyke (flincs reset by intrusion)
   - dyke post-dates ore; deposit is >723 Ma)



IR image of FIA of ~20 µm fluid inclusions in sphalerite

Hnatyshyn et al, 2011

6) POTENTIAL IN OTHER, RELATED ROCKS

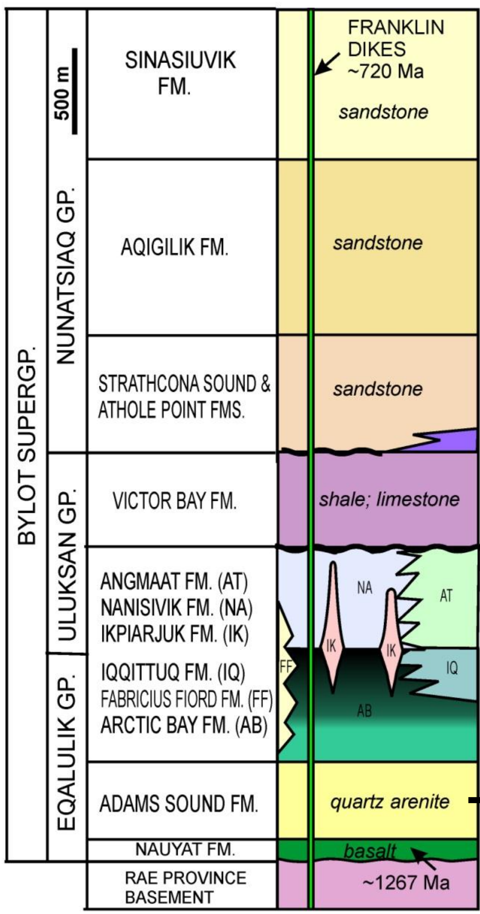
1970s-2002

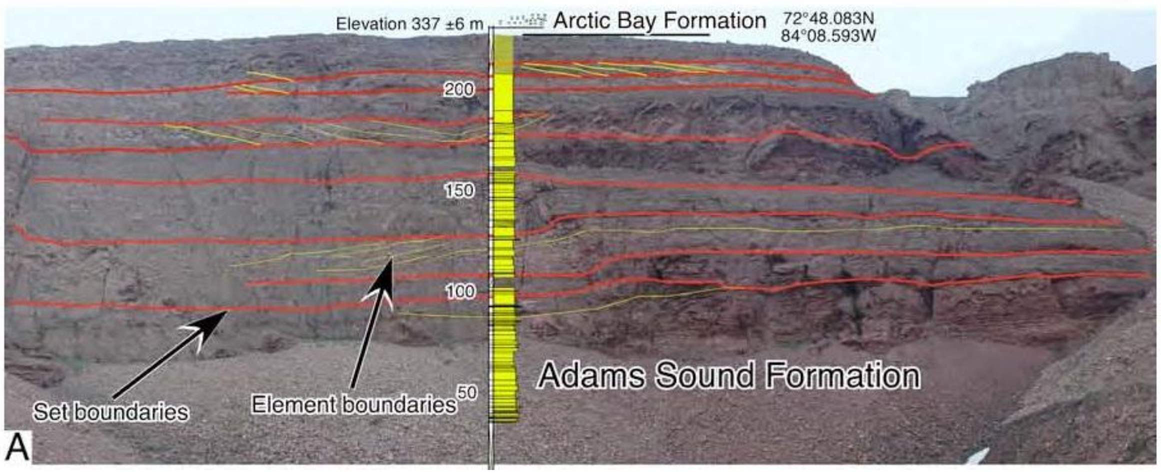
↓

UNKNOWN

NEW

↓





Adams Sound Formation (quartz arenite)

•little potential for unconformity-type U

(rock cemented early & too compositionally mature)

Long & Turner 2012

6) POTENTIAL IN OTHER, RELATED ROCKS

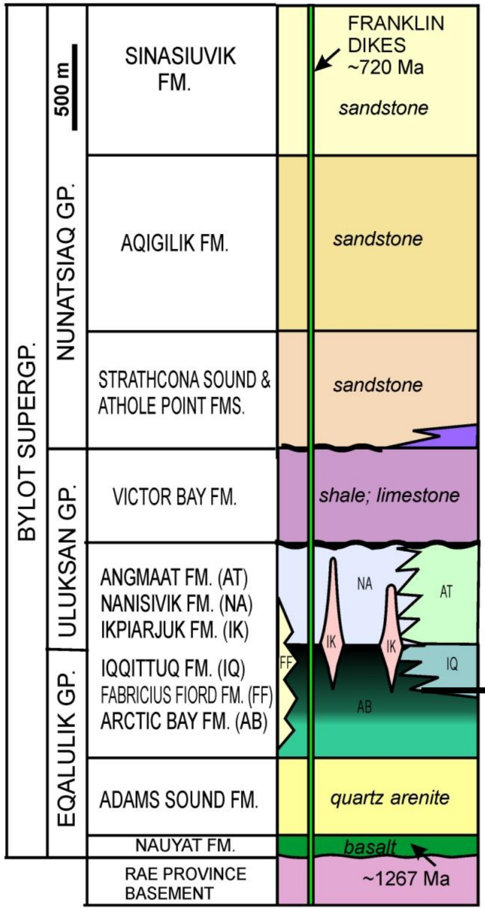
1970s-2002

↓

UNKNOWN

NEW

↓



Arctic Bay Formation (black shale)

•Geochemically appropriate for SEDEX/CD

(euxinic basin water & known sea-floor venting)

Turner & Kamber 2012

7) TECTONIC REGIME AT TIME OF MINERALISATION

1970s-2002 → UNKNOWN

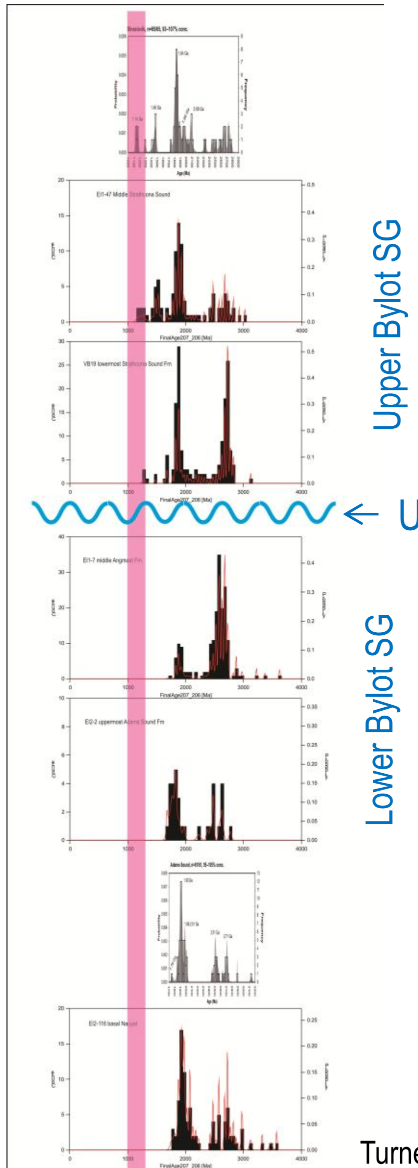
NEW ↓

- 1.1 Ga zircon come from orogenies associated with amalgamation of supercontinent Rodinia

DETRITAL ZIRCON GEOCHRONOLOGY OF BYLOT SG

Contain ~1.1 Ga zircon

Do not contain ~1.1 Ga zircon

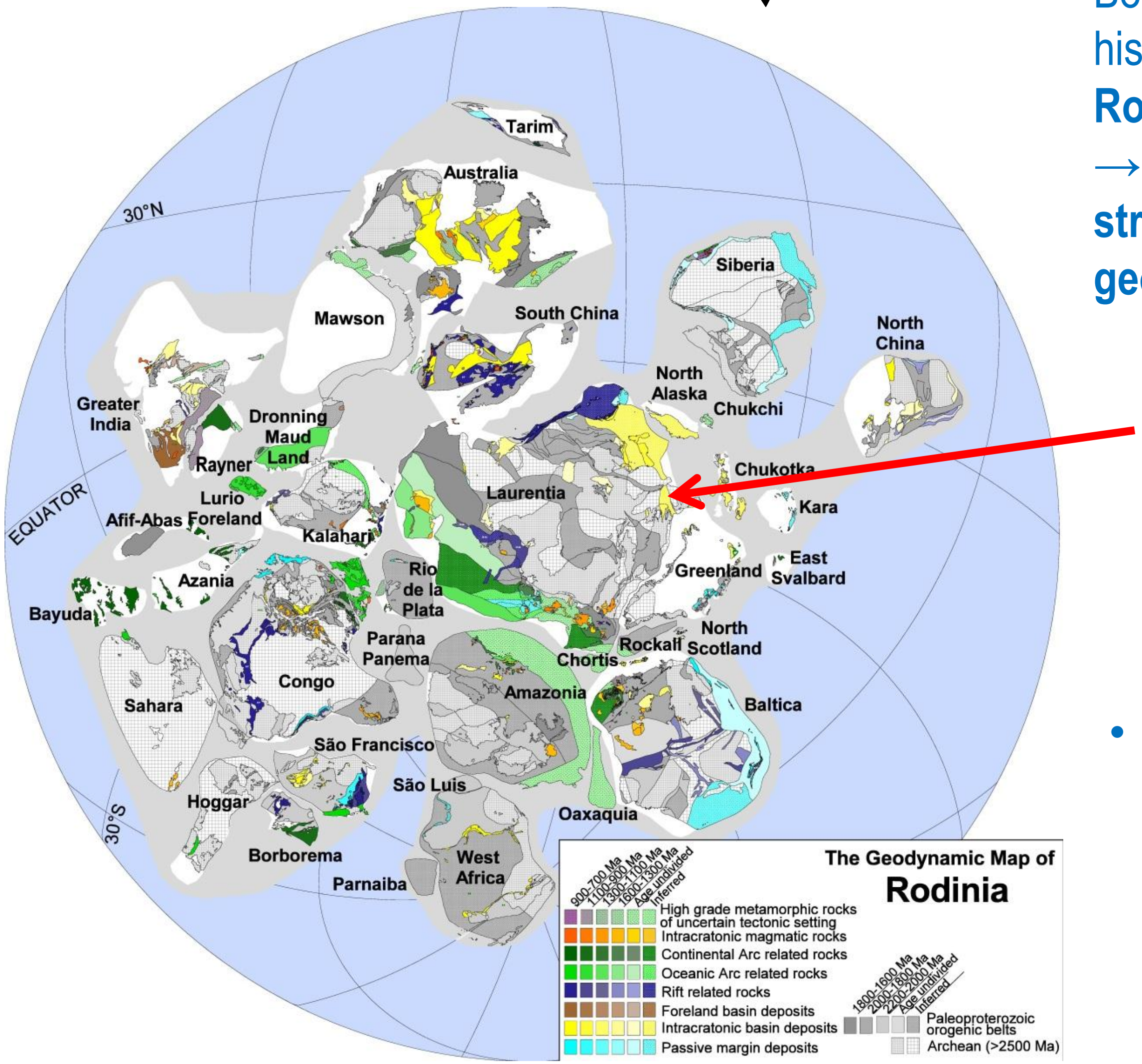


Turner et al., in prep.

7) TECTONIC REGIME AT TIME OF MINERALISATION

1970s-2002⟶ UNKNOWN

NEW ↓



Li et al., 2008

- Borden Basin depositional history spans onset of **Rodinia-related** orogeny ⟶ explains basin's **stratigraphic and geometric complexity**

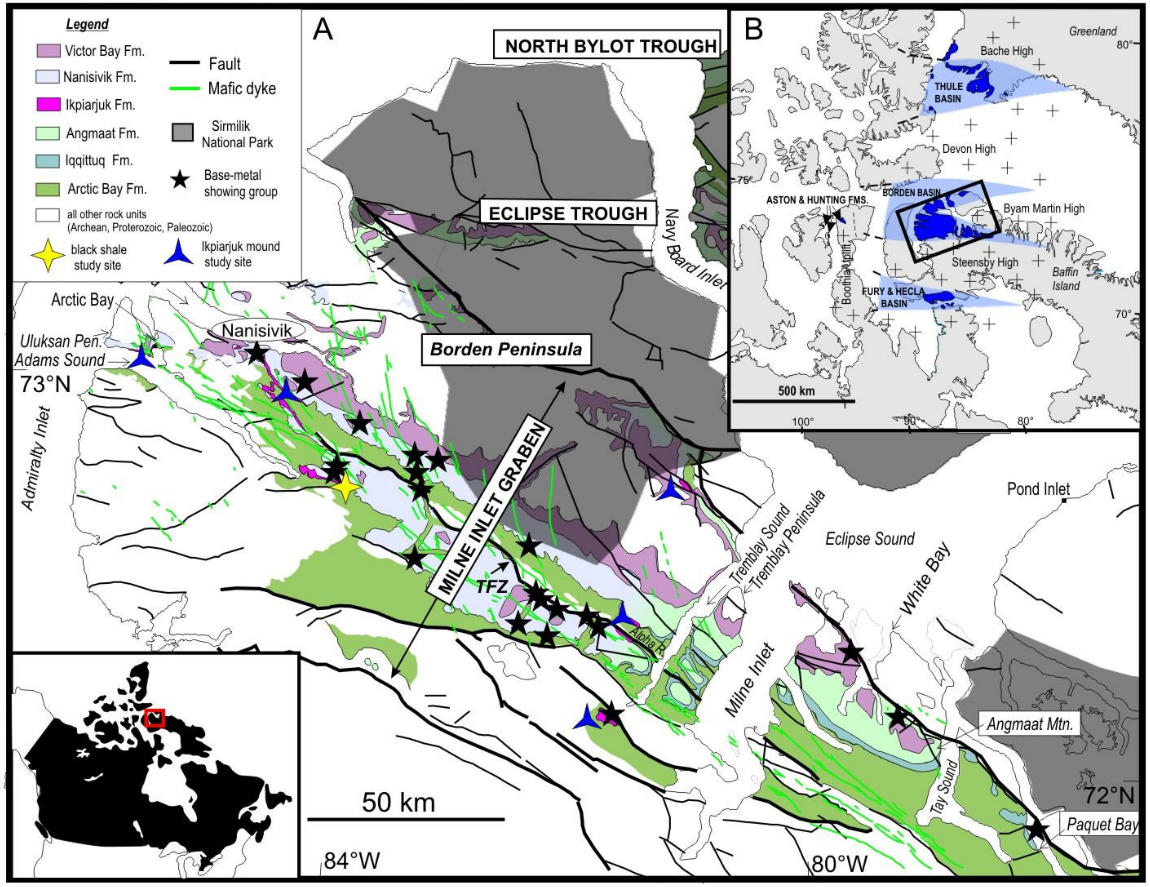
- Fluid migration and **Nanisivik mineralisation** early & probably Rodinia-related

NEW KNOWLEDGE IN LAST 5 YEARS:

1) ORIGIN AND DEPOSITIONAL AGE OF HOST ROCK (WHY; WHERE)
2) BASIN AGE AND TECTONIC CONTEXT (WHY)
3) GEOLOLGIC SETTING OF KNOWN Zn (WHERE; HOW)
4) TIMING OF MINERALISATION (WHEN)
5) NATURE OF FLUID AND METAL (WHY)
6) POTENTIAL IN RELATED ROCKS (WHAT ELSE IS THERE)

ITEMS TO ADDRESS:

1) METALLOGENY OF DISTRICT
2) POTENTIAL FOR BLIND MINERALISATION UNDER UNCONFORMITY
3) POTENTIAL FOR METALLIFEROUS SEA-FLOOR VENTING DURING BLACK SHALE DEPOSITION



Collaborators:

R. Creaser (University of Alberta) – Re-Os geochronology
D.G.F. Long (Laurentian University) – terrigenous clastic sedimentology
B.S. Kamber (Trinity College Dublin) – shale geochemistry & geochronology
D.J. Kontak (Laurentian University) – fluid inclusion microthermometry & decrepitate chemistry
J. Petrus (Laurentian University) – detrital zircon geochronology
R. Rainbird (GSC-Ottawa)) – detrital zircon geochronology
N. Rayner (GSC- Ottawa)) – detrital zircon geochronology

Students:

K. Hahn
D. Hnatyshyn
R. Morden
K. Pavan

Field:

J. Beaulieu
T. Chevrier
B. Gammon
C. Gilbert
J. Mathieu
R. Morden
J. Taylor
F. Turner
R. Yehia

Financial & logistical support:

POLAR CONTINENTAL SHELF PROJECT
ÉTUDE DU PLATEAU CONTINENTAL POLAIRE
CANADA-NUNAVUT GEOSCIENCE OFFICE
NSERC
CRSNG