Tectonic and metallogenic framework of the Canadian Cordillera

with emphasis on Yukon deposits…

Maurice Colpron

Yukon Geological Survey

Tectonics and Metallogeny

"To understand metallogeny, one must know the geologic sources of the constituents in ore minerals, appreciate the structural preparation of rock masses for ore deposition, and understand the mechanisms for ore transport and precipitation. Tectonics lies at the root of all these issues."

W.R. Dickinson (2006 - Geosphere, v. 2, p. 353)

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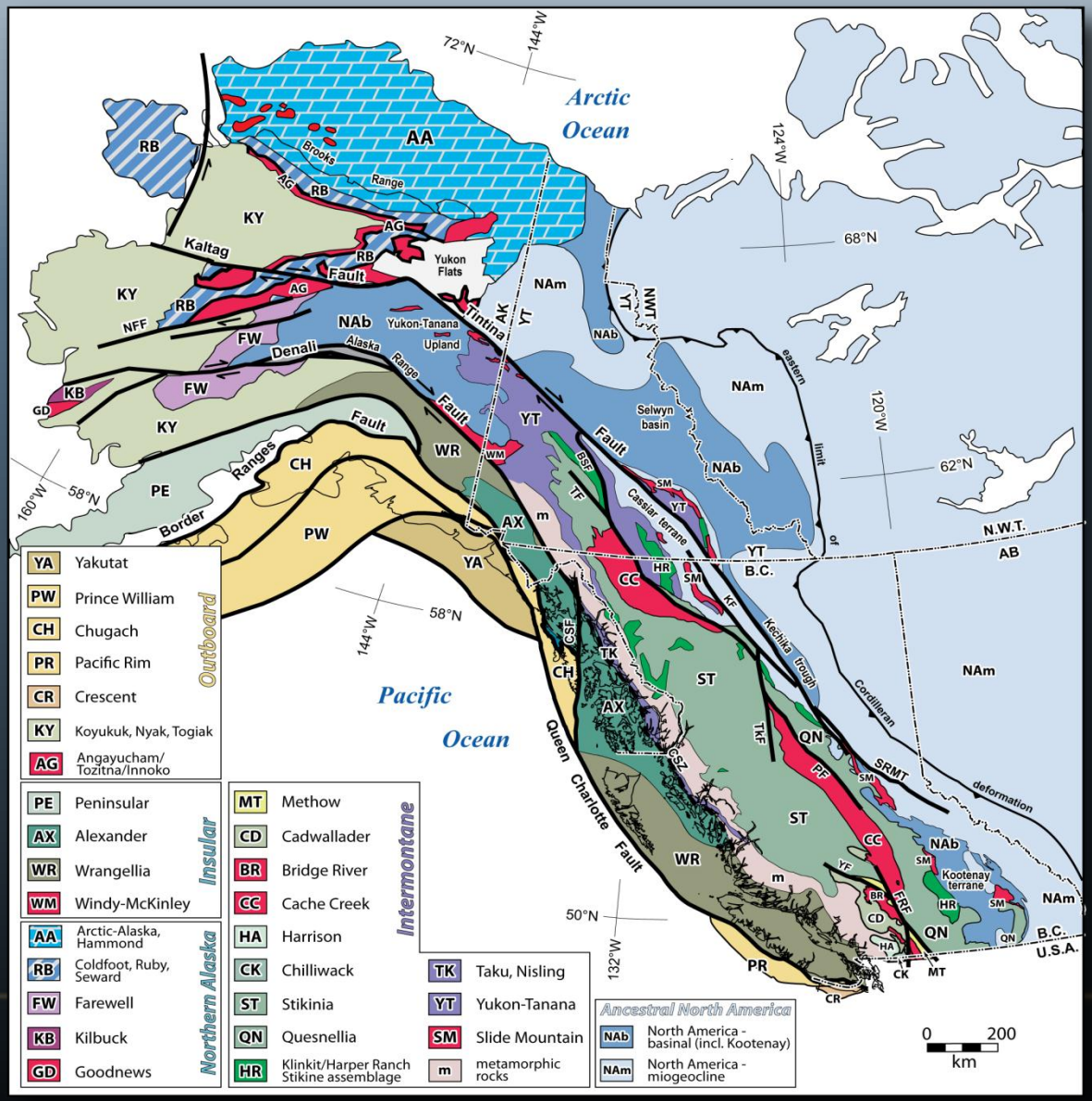
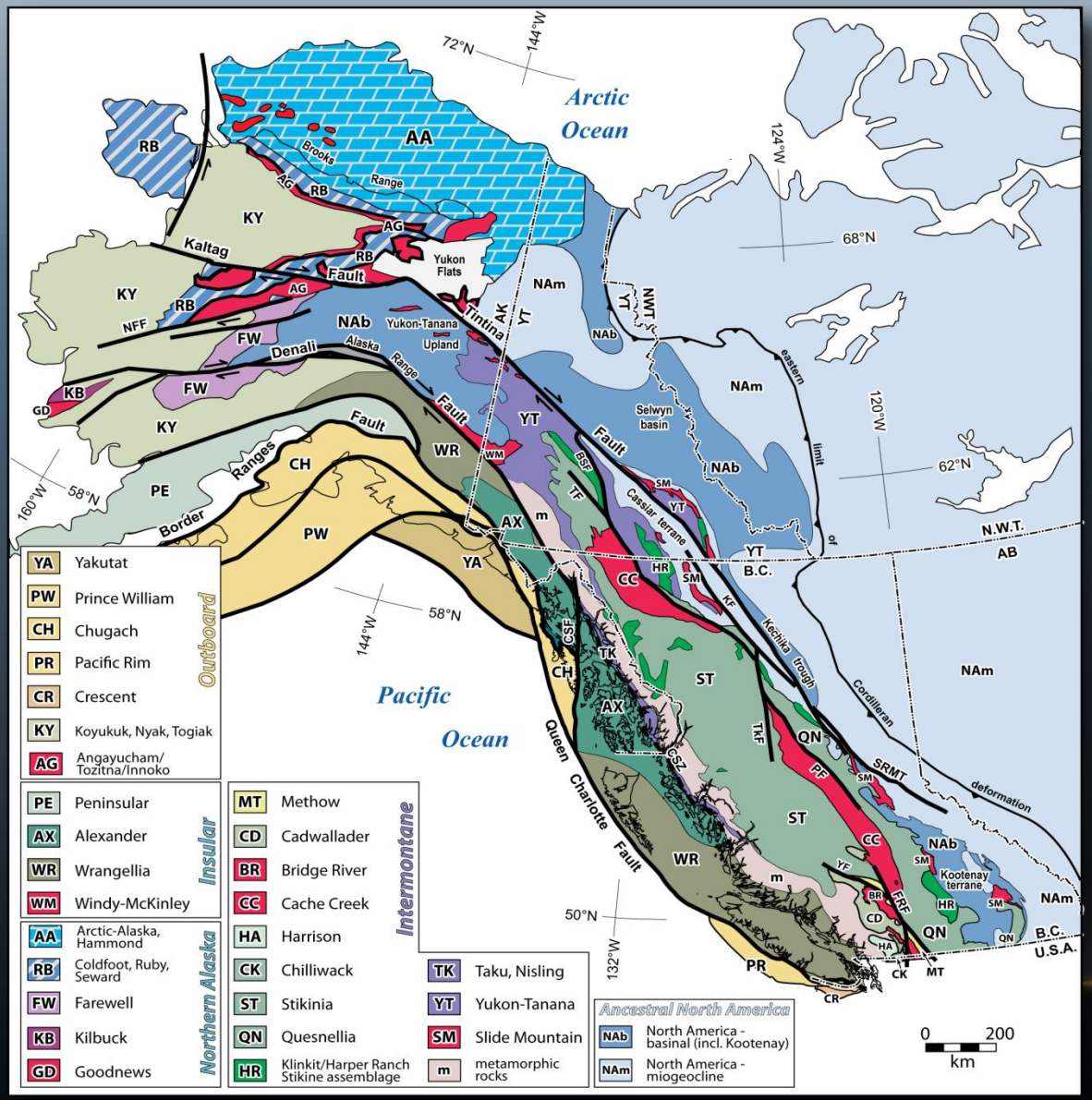
Cordilleran terranes

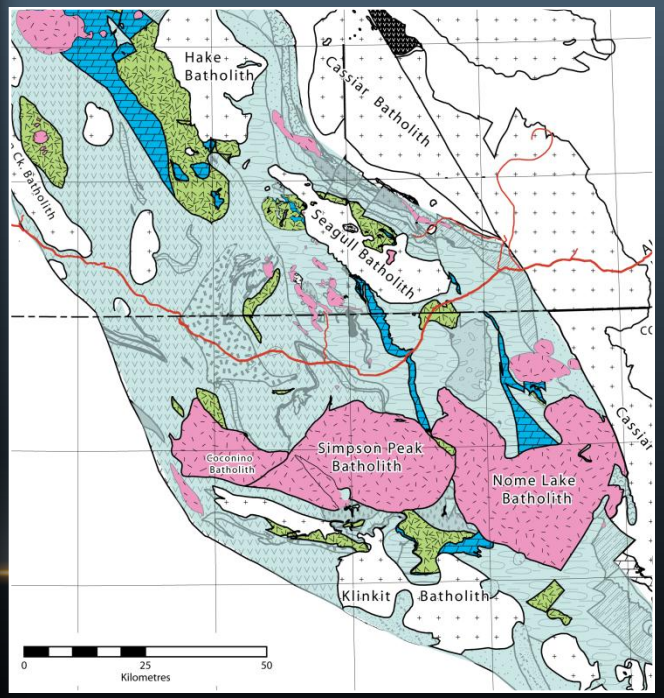


Colpron et al. (2007) – GSA Today

Terrane Linkages

- Linkages between mid-Paleozoic to early Mesozoic arc terranes of Intermontane belt

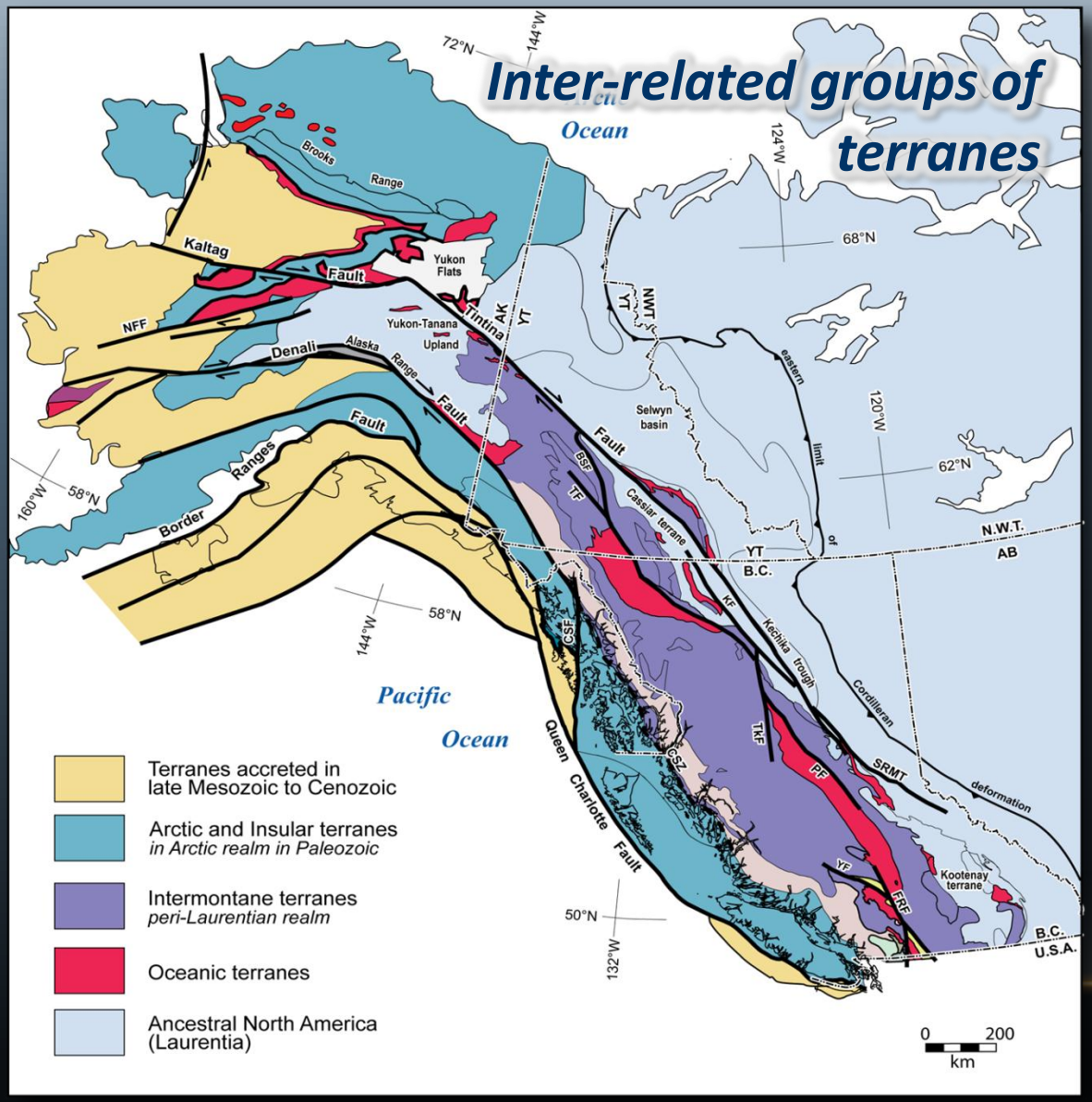




Colpron et al. (2007) – GSA Today

Roots et al. (2006)

Terrane Linkages

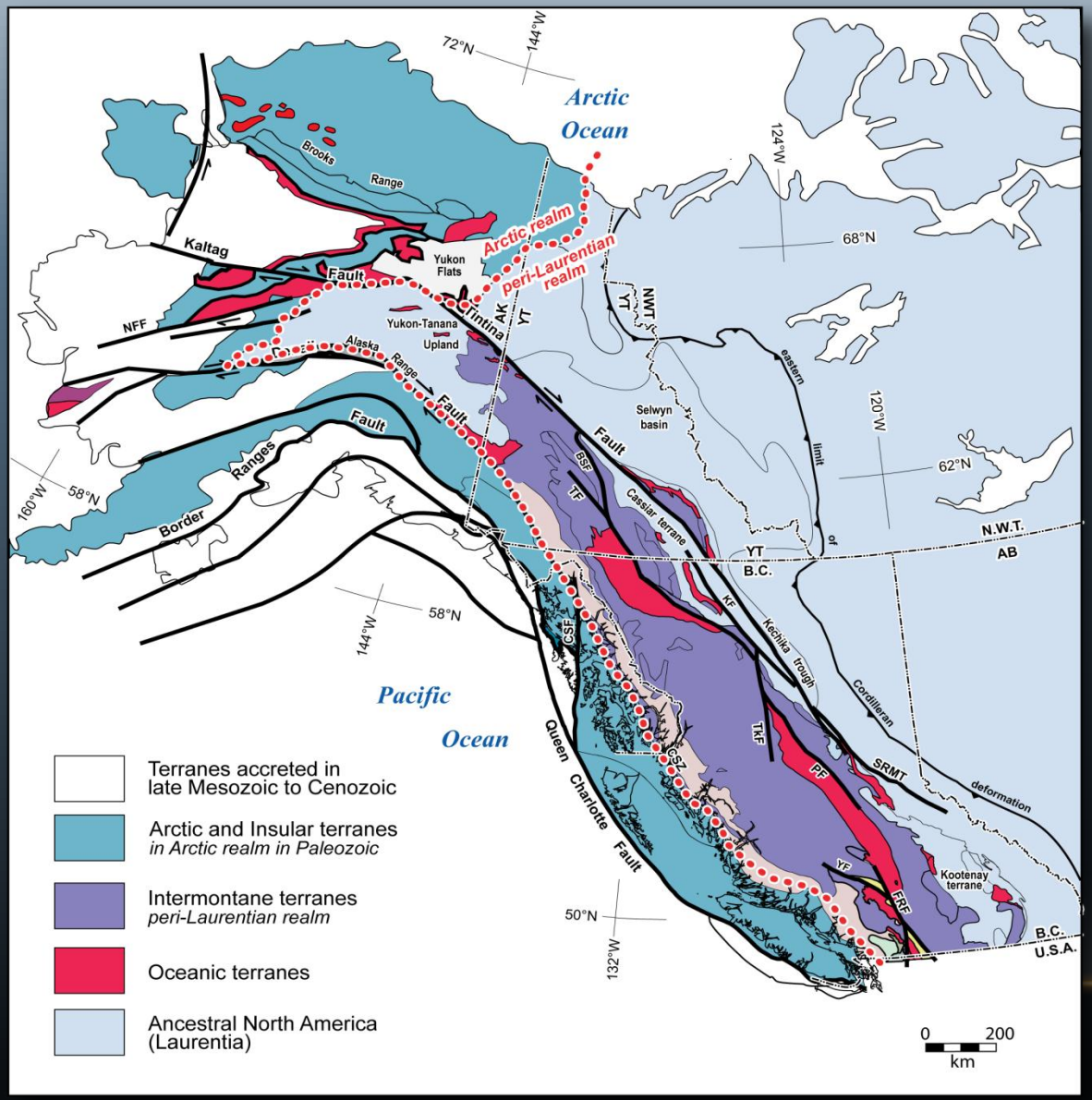


- Linkages between mid-Paleozoic to early Mesozoic arc terranes of Intermontane belt
- Evolved along western peri-Laurentian margin
- Still significant transport of some terranes

Parafusilina of the McCloud fauna

Colpron et al. (2007) – GSA Today

Terrane Origins

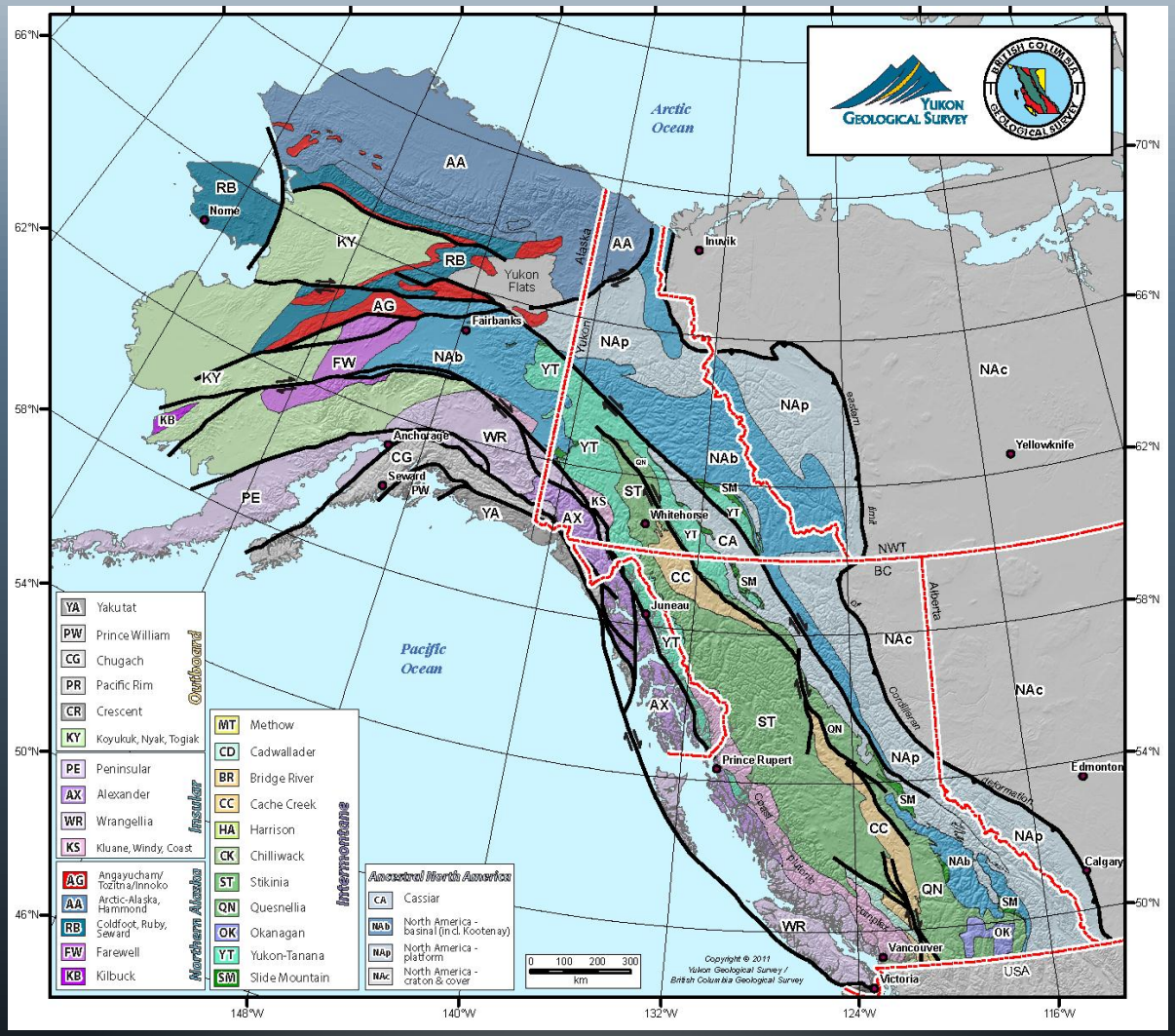


- Peri-Laurentian terranes enclose exotic Cache Creek terrane (Panthalassa)
- Outer, Arctic-Insular terranes are exotic to western Laurentia

Heceta Limestone, Alexander terrane (Silurian)

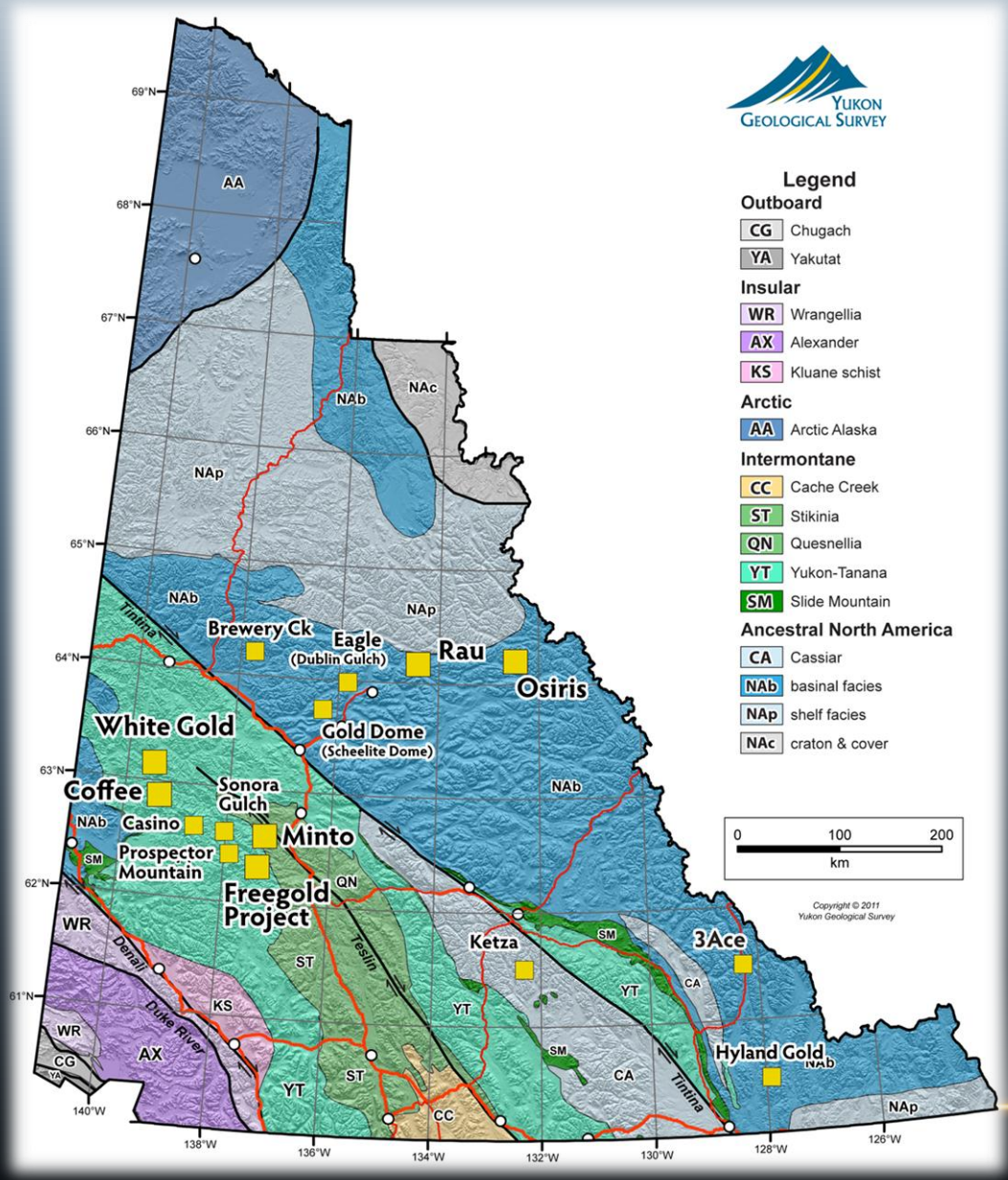
Colpron et al. (2007) – GSA Today

Digital Atlas of Terranes



GIS and graphic files available for download on YGS and BCGS websites

Yukon and
the Modern Gold Rush



- 2007-2008 discoveries in White Gold-Dawson Range
  - *e.g. White Gold, Coffee*
- 2009-2010 discoveries in the Rackla Belt and southern Selwyn basin
  - *e.g. Rau, Osiris-Conrad, 3Ace*
- Porphyry-epithermal deposits
  - *e.g. Casino, Sonora, Freegold, SW Yukon??*
- Intrusion-related Au
  - *e.g. Brewery Ck, Dublin Gulch…*

Cordilleran Tectonic Evolution

- Proterozoic intracratonic? basins
- Neoproterozoic breakup of Rodinia
- Early Paleozoic “passive” margin of western Laurentia
- Mid-Paleozoic to early Mesozoic arcs of the peri-Laurentian realm
- Mesozoic – Cenozoic convergence, transpression and continental arcs
- Still ongoing…

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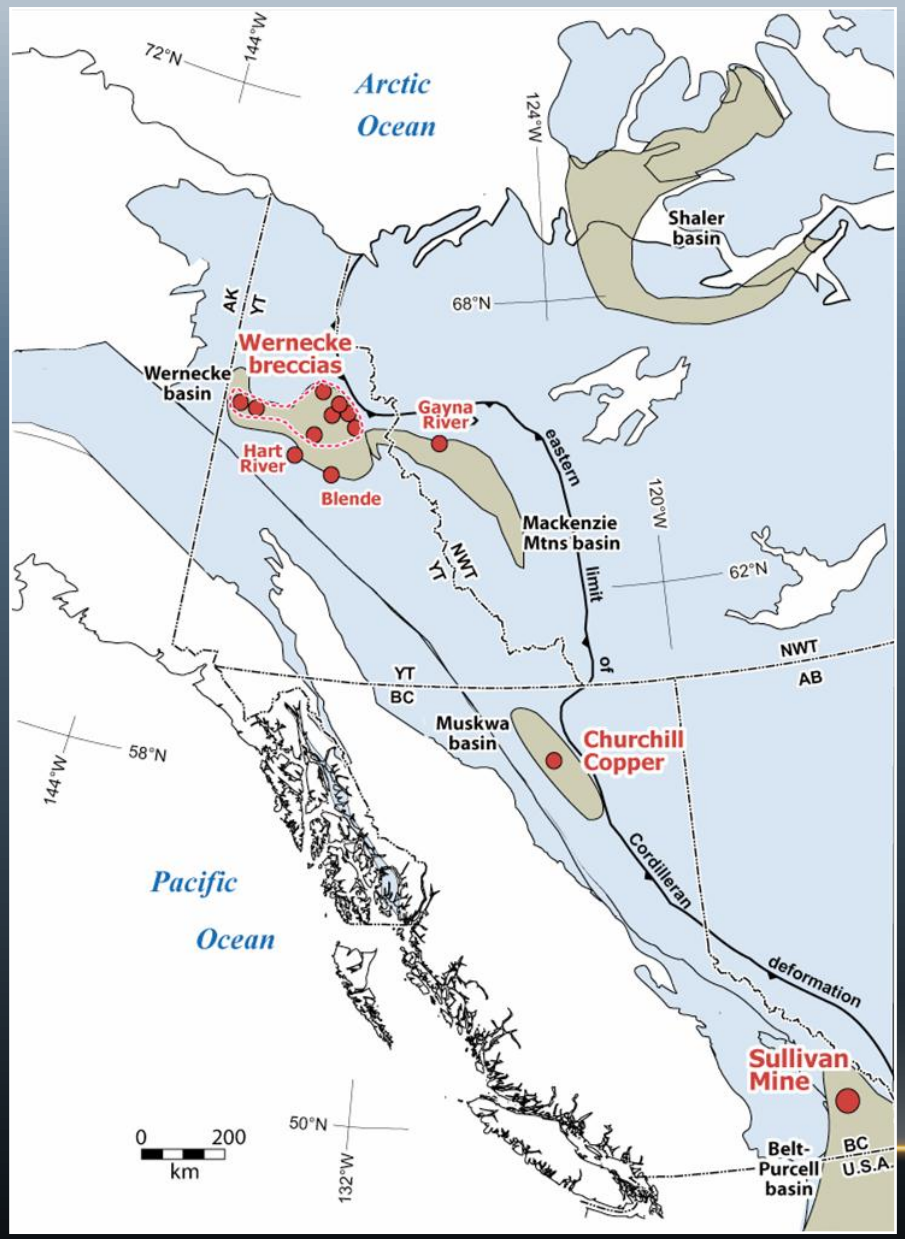
Proterozoic Basins



- Predate breakup of Rodinia
- In southern Cordillera:
  - Sullivan – 160 Mt SEDEX

Production 1914-2001
Belt-Purcell Supergroup
1.5-1.4 Ga

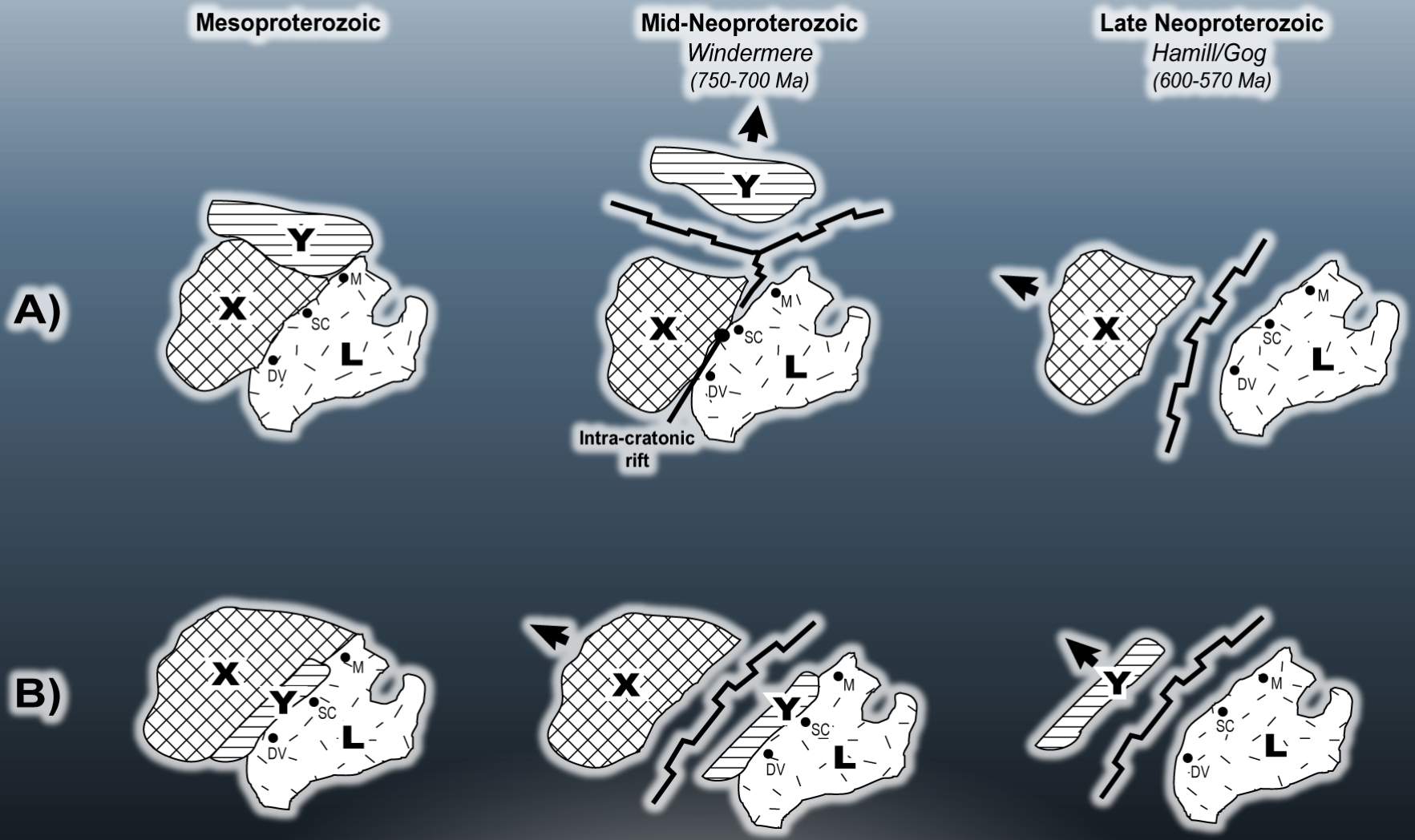
- In northern Cordillera:
  - Wernecke Breccias

IOCG? – Cu-Au-U-Co
ca. 1.6 Ga

  - Gayna River

MVT (ZN-Pb)
1.0-0.78 Mackenzie Mtn Spgp
~50 Mt of 4.7% Zn in reef mounds

Neoproterozoic Breakup of Rodinia



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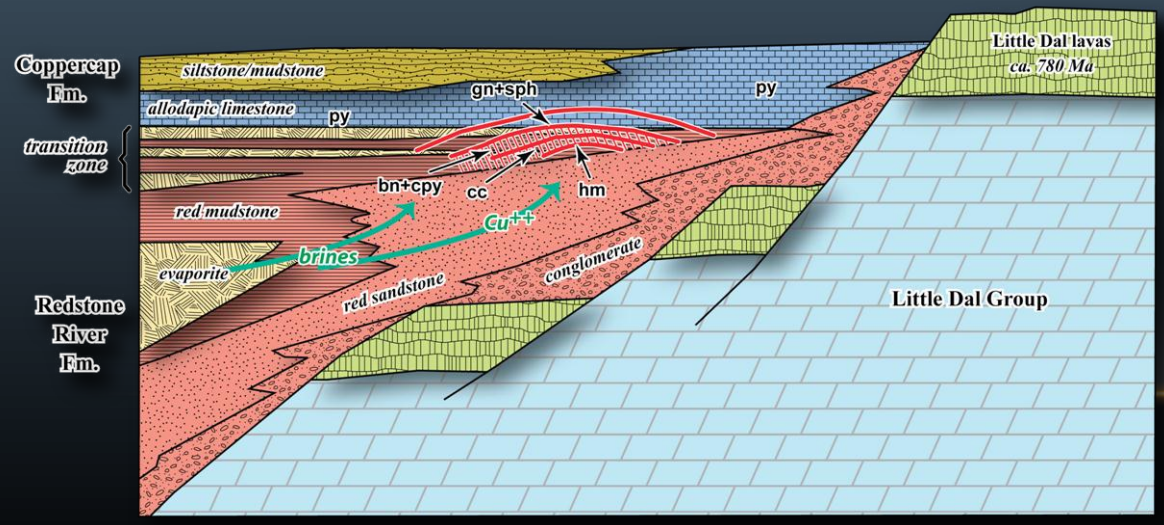
Colpron et al. (2002)

Redstone Copper Belt


Coates Lake Gp at Coppercap Mtn, NWT

- Coates Lake Group - restricted to series of half-grabens (NWT)
- Volcanic-rich rift clastics (redbeds) as source of Cu
- Transport by saline brines (evaporites)
- Mineralization occurs at ‘transition’ between redbeds and organic-rich limestone (Coppercap Fm)
- Coates Lake deposit

  ~37 Mt of 3.94% Cu and 11.3 g/t Ag

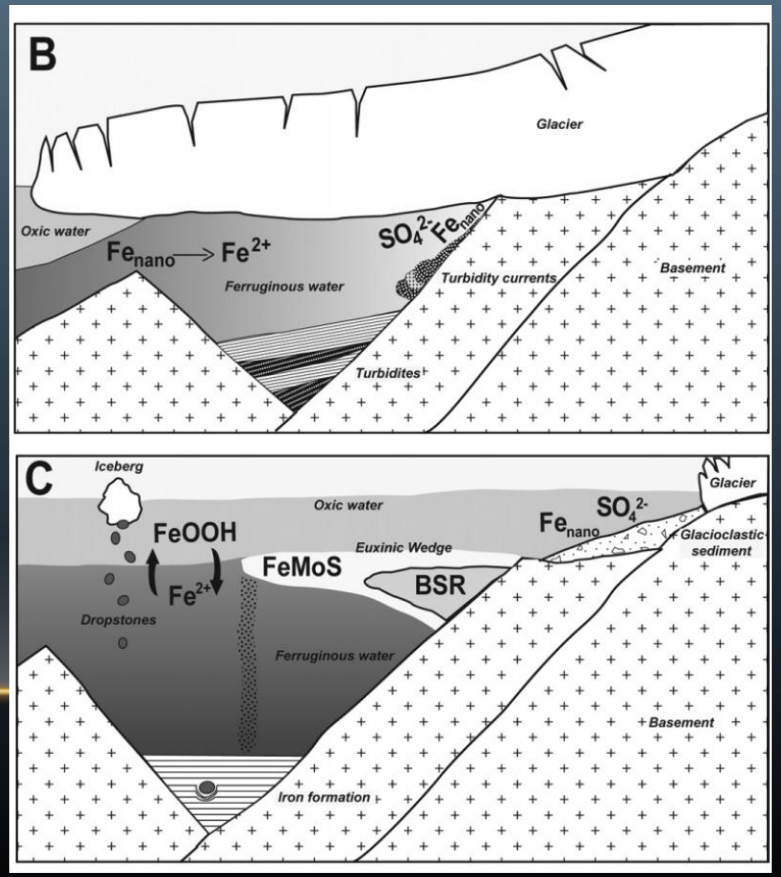


Model after Kirkham (1989, 1995)

Crest Iron

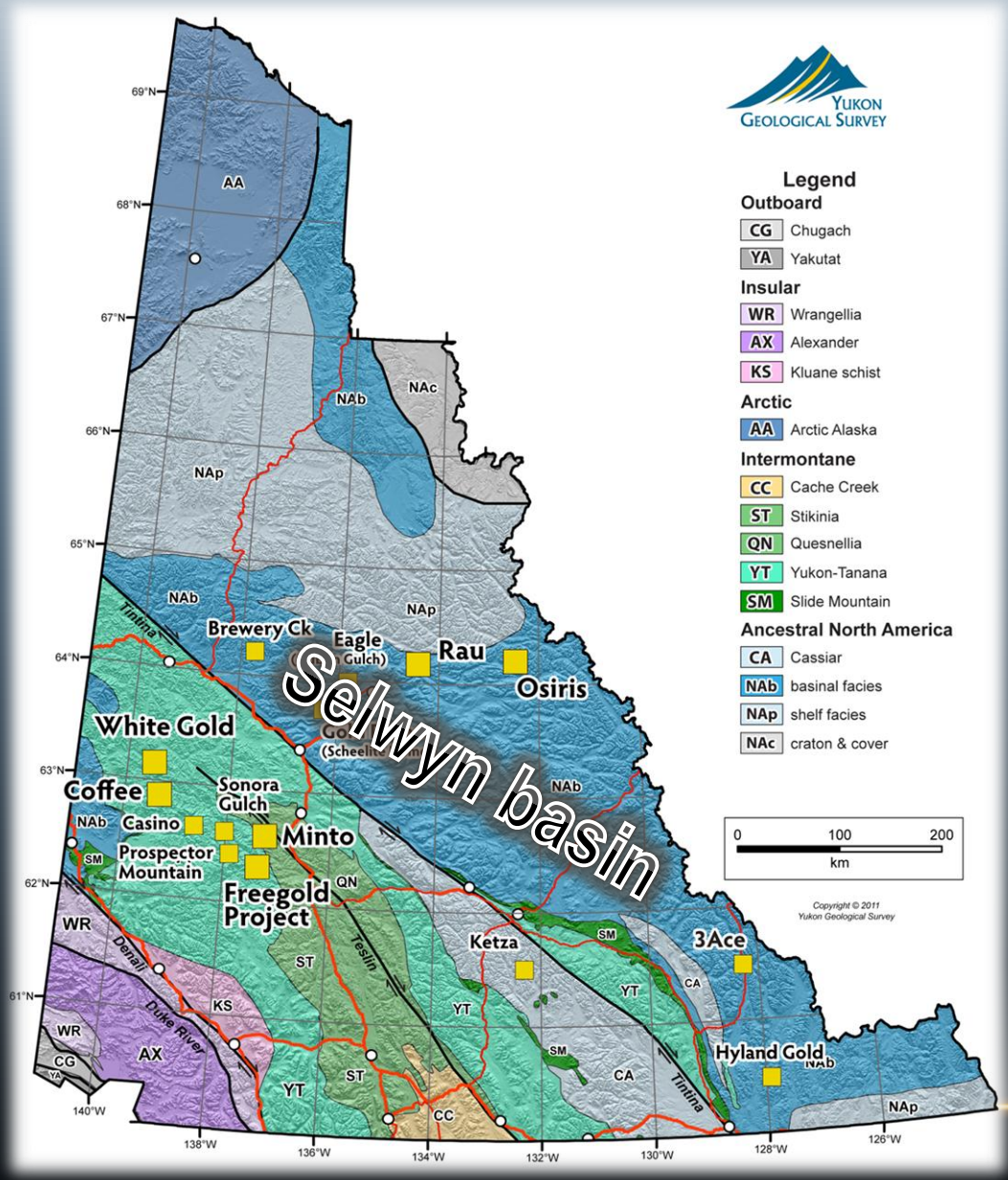
BIF at the Crest deposit, northern Yukon

- In Sayunei Fm (Rapitan Gp)
- Jasper-hematite rhythmites
- >5 Bt at Crest, but regional occurrence
- Rapid oxygenation of oceans in aftermath of Sturtian Snowball



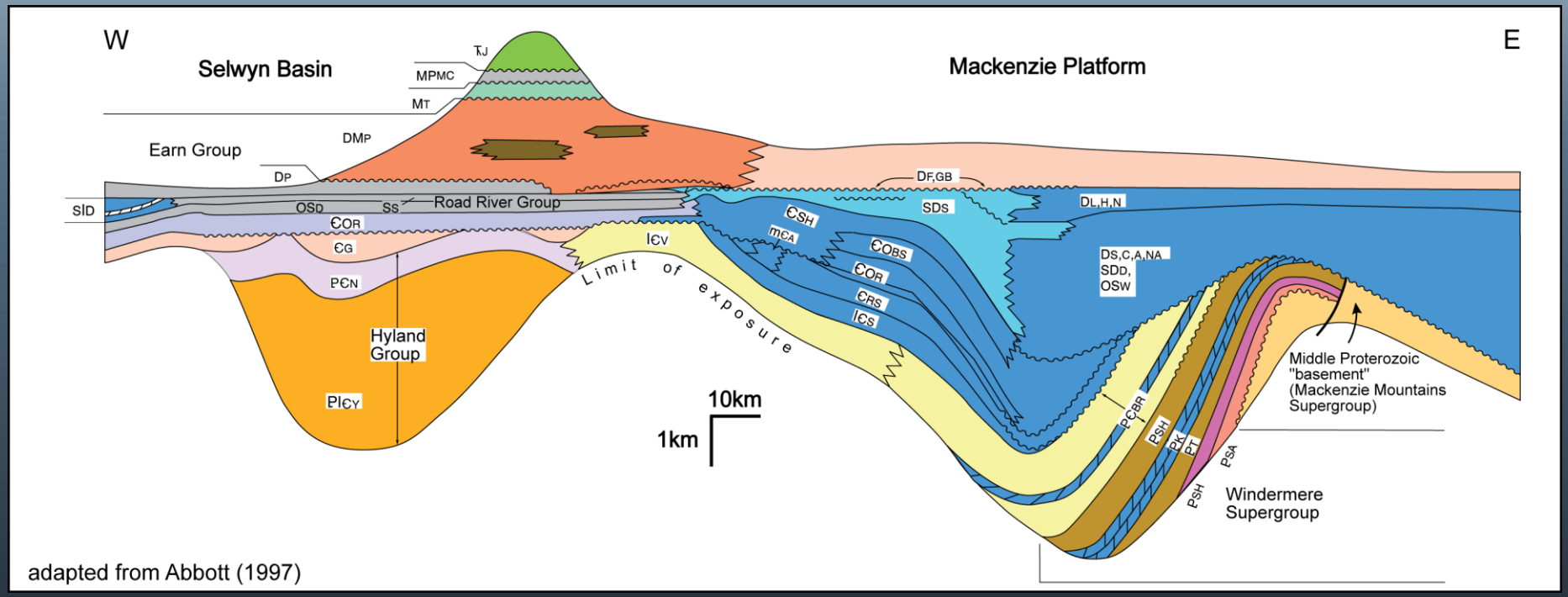
After Baldwin et al. (2012)

Selwyn Basin



- Initiated with Neoproterozoic breakup of Rodinia
- Major SEDEX deposits (Faro)
- Structurally-controlled and intrusion-related Au
- Carlin-style Au
- Fold & thrust belt
- Cretaceous transpression

Selwyn Basin Stratigraphy



adapted from Abbott (1997)

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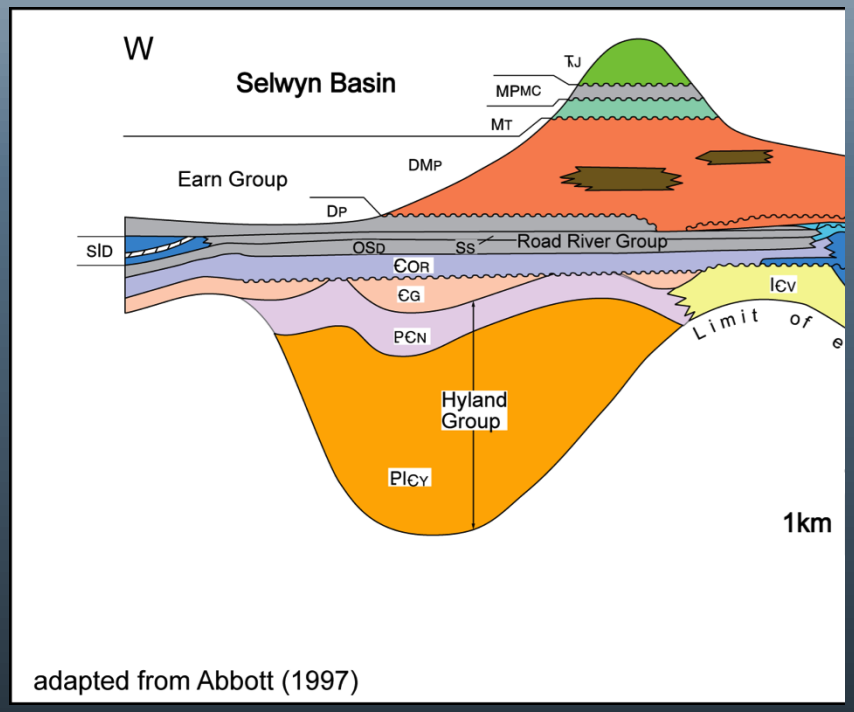
Selwyn Basin Stratigraphy



adapted from Abbott (1997)

- Initiated in Neoproterozoic with breakup of Rodinia
- Breakup unconformity in Early Cambrian
- Intermittent extension throughout early Paleozoic
- Alkalic volcanism, diatremes
- Regional Devonian unconformity (Earn Group)
- Local coarse clastic deposits – recycled from older strata

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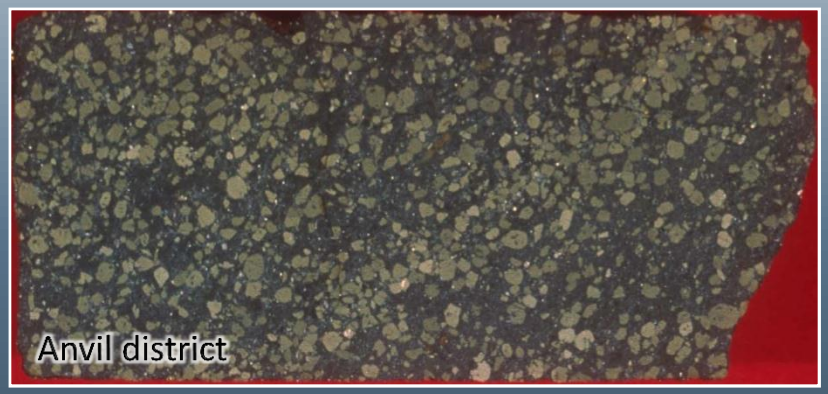
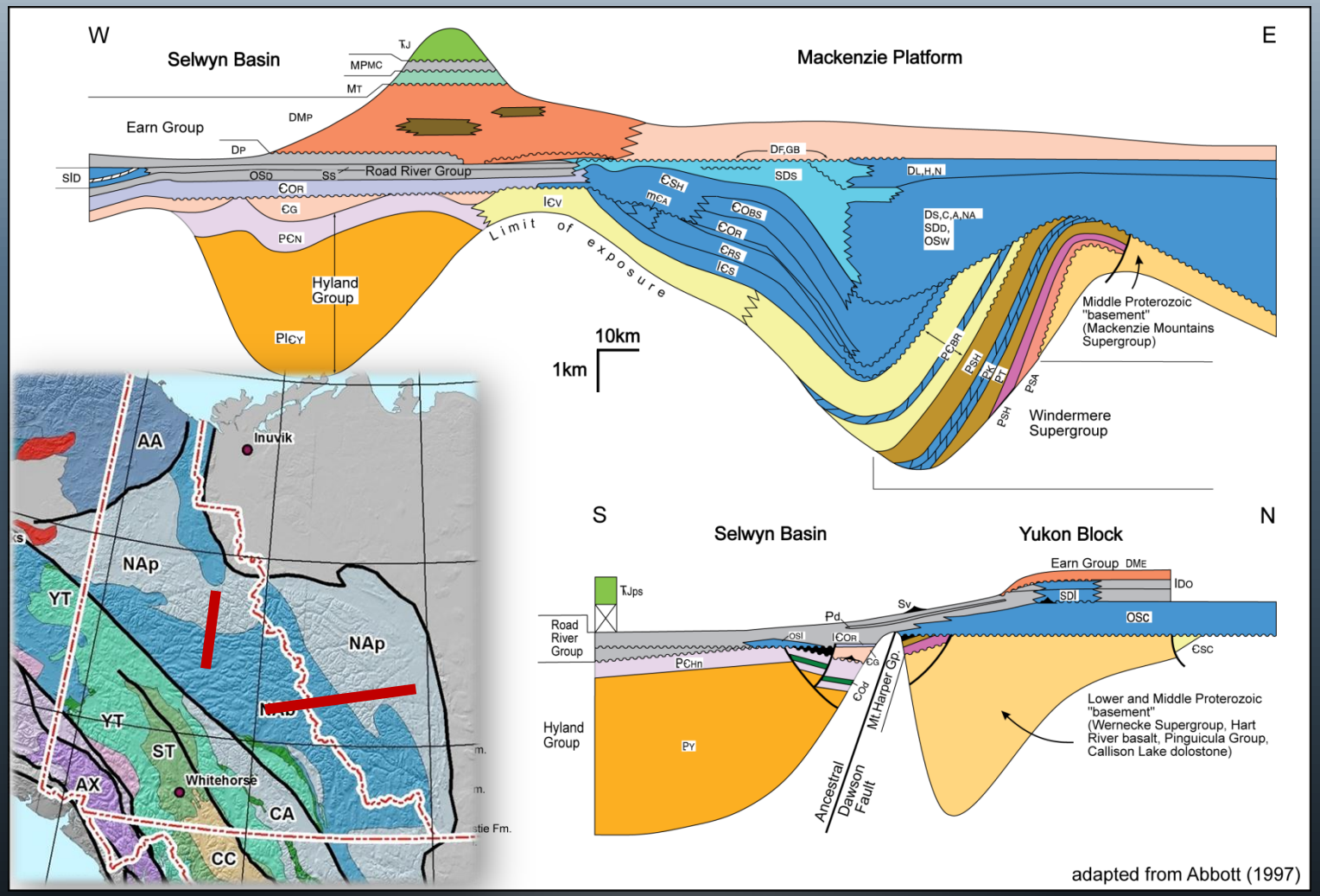
Paleozoic syngenetic mineralization



- SEDEX deposits in Cambrian-Ordovician shale
- Anvil District (Faro):
  - *Total of 120 Mt of Zn-Pb ore in 5 deposits*
  - *Hosted in Cambrian strata – at contact between Mount Mye and Vangorda formations*
- Howards Pass (Selwyn Project):
  - *Nearly 400 Mt of Zn-Pb ore*
  - *Hosted in Active member – top of Duo Lake Formation (Ordovician-Silurian)*

Variations in platform-basin transition



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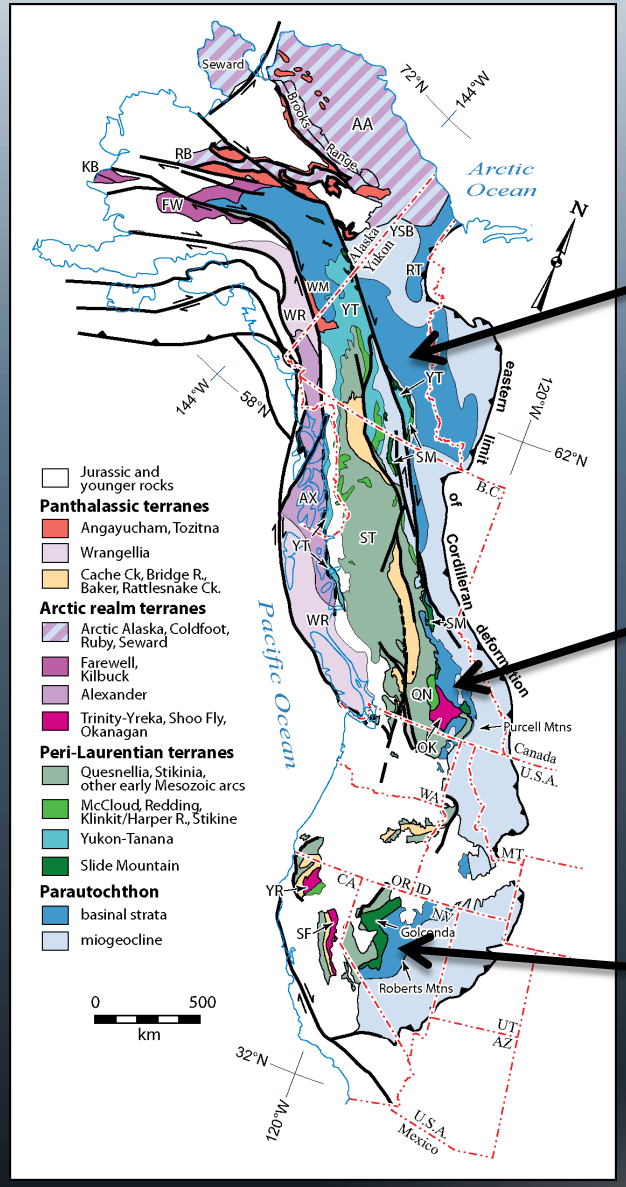
Pan-Cordilleran Connections



Selwyn Basin

Kootenay terrane

Roberts Mountain allochthon

Colpron & Nelson (2009, 2011)

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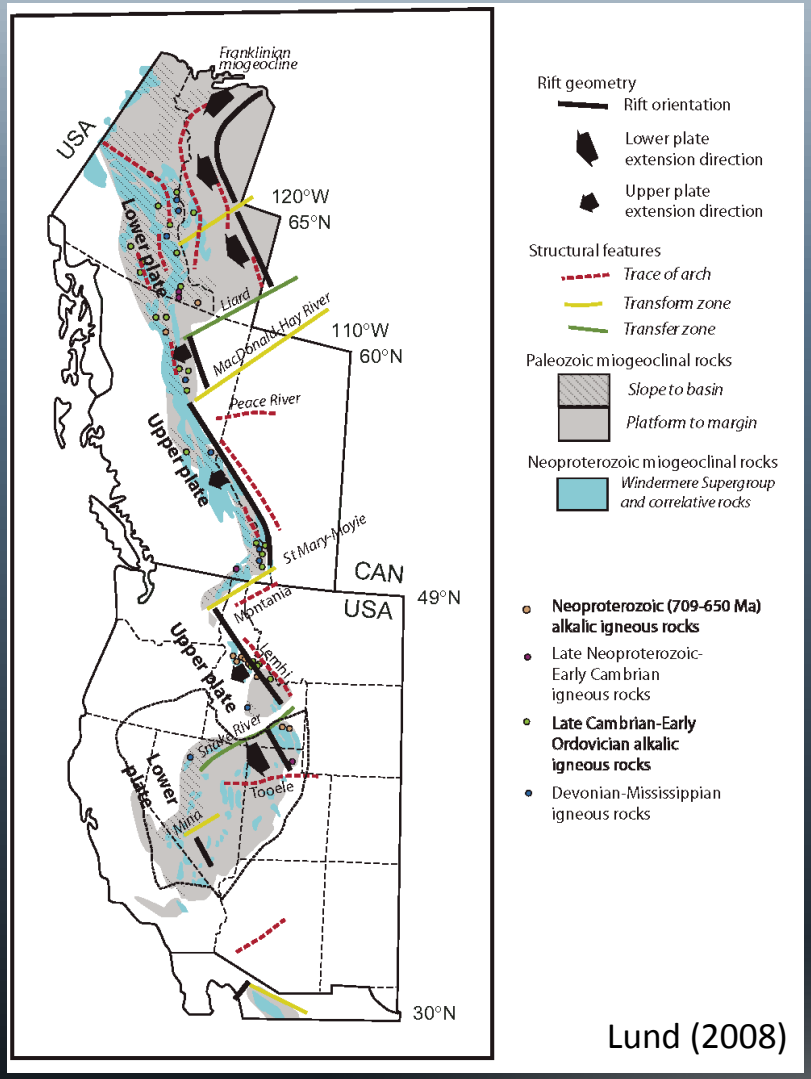
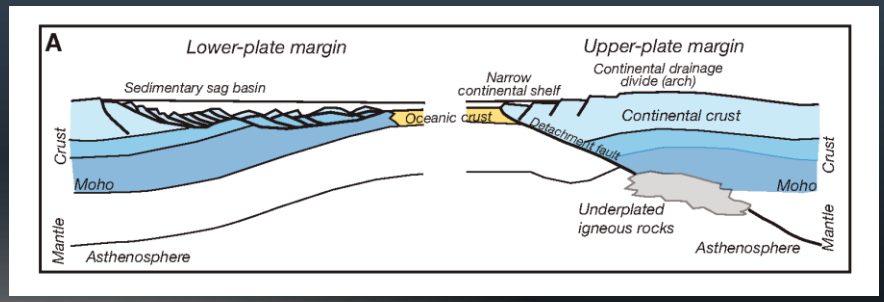
Pan-Cordilleran Connections



Lund (2008)

- Both Selwyn basin and RMA occupy 'lower plate' positions along rifted margin
- Intermittent Paleozoic extension
- Slope to basinal facies
- Both experienced Devonian-Mississippian tectonism – **BUT**…
  - *RMA = contraction – Antler*
  - *Selwyn = extension (back-arc rift?)*



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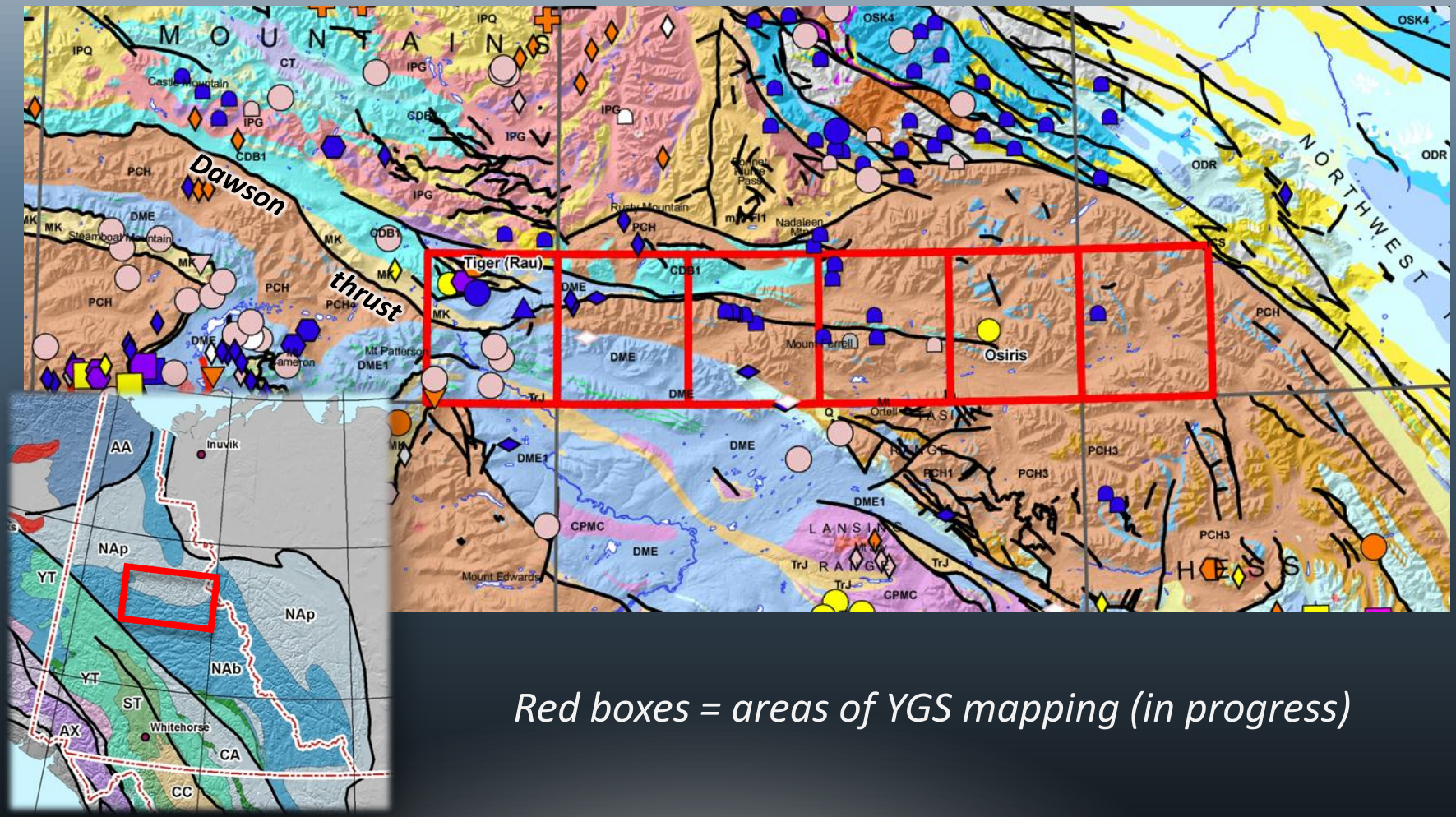
Dawson Thrust



Red boxes = areas of YGS mapping (in progress)

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Dawson Thrust

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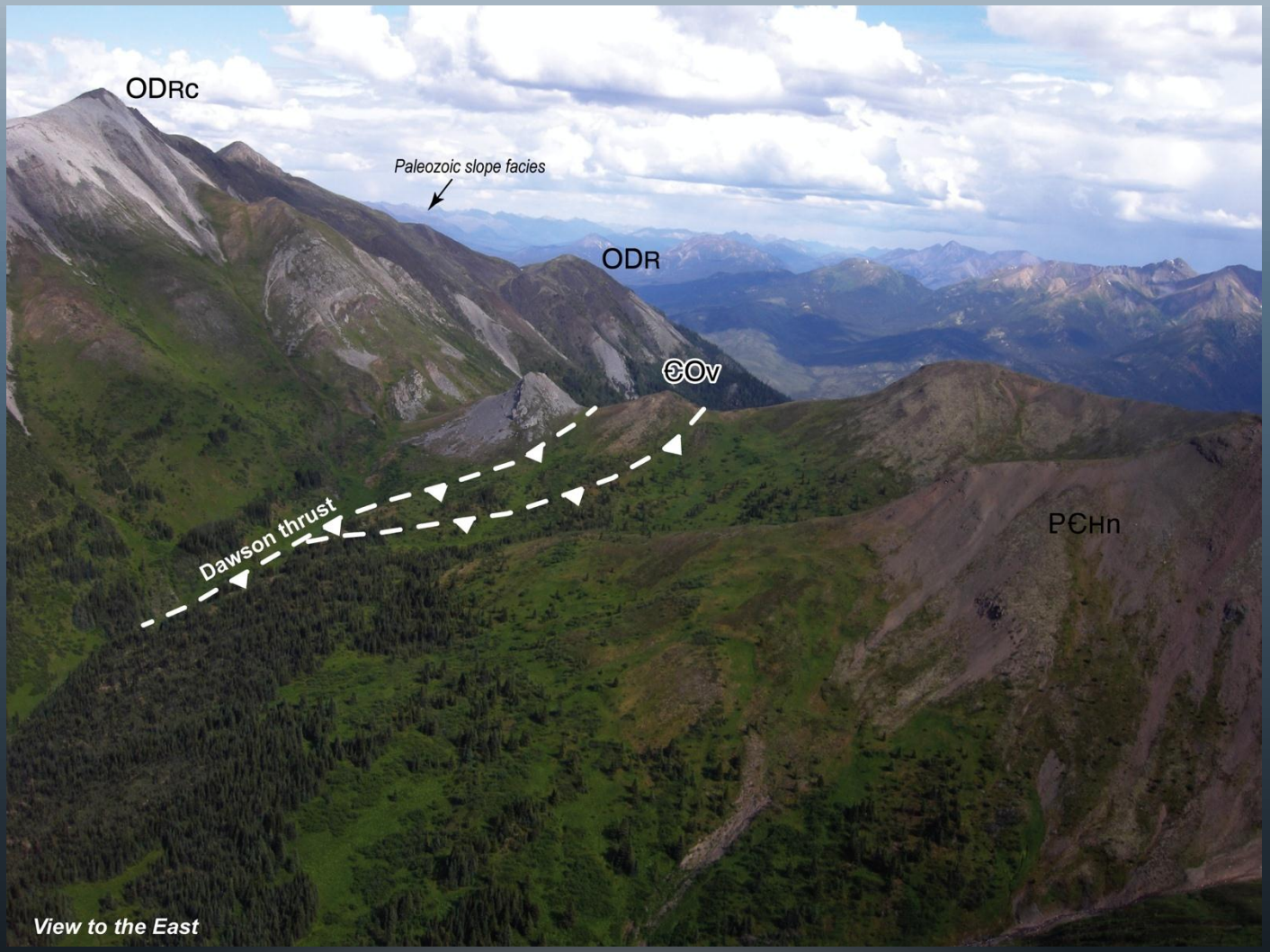
Dawson Thrust



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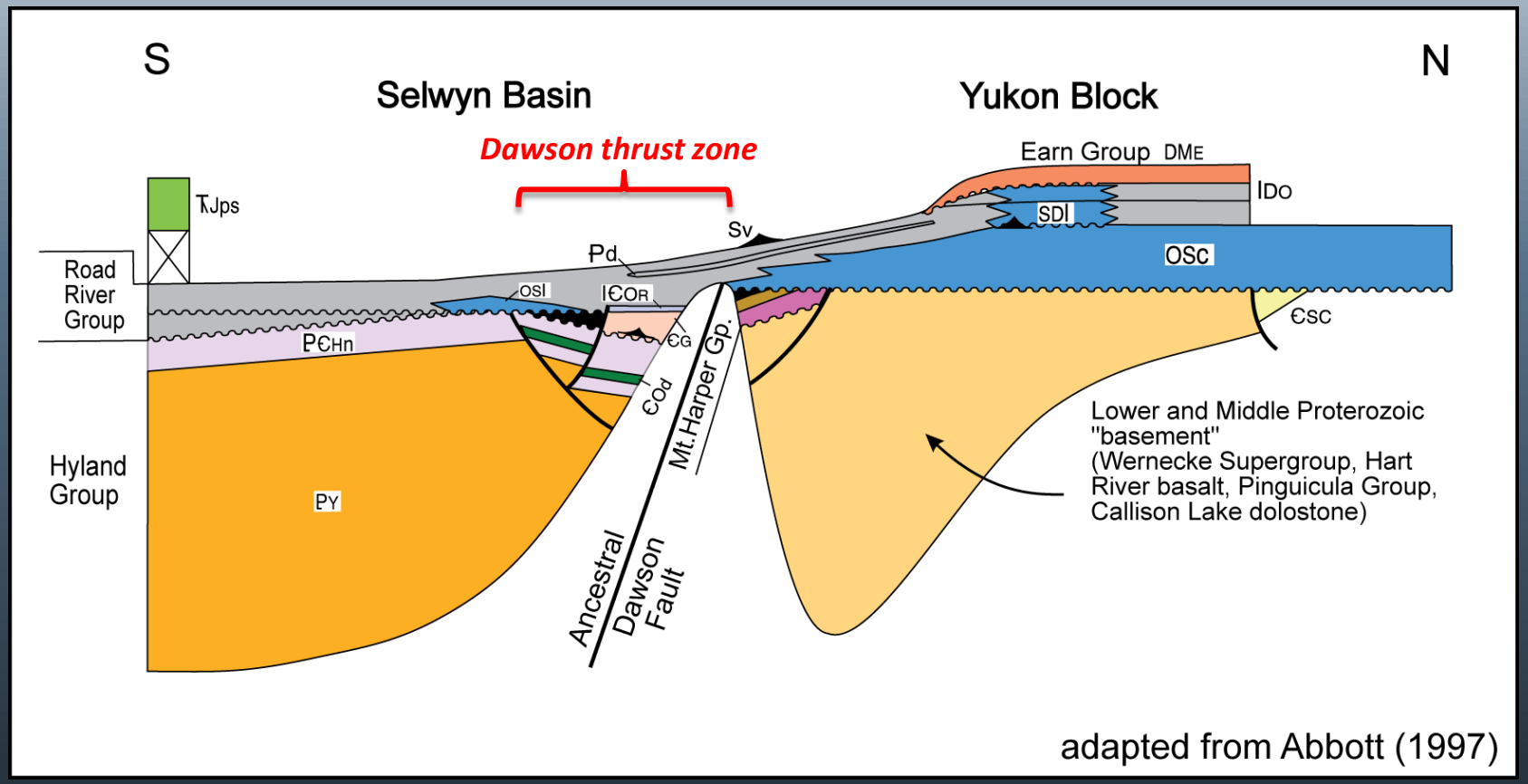
Ancestral Dawson Fault



- *Paleozoic magmatic rocks mainly found near Dawson fault*
- *Important facies changes across the Dawson fault zone*

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Carlin-type mineralization

ATAC Resources – Osiris Zone

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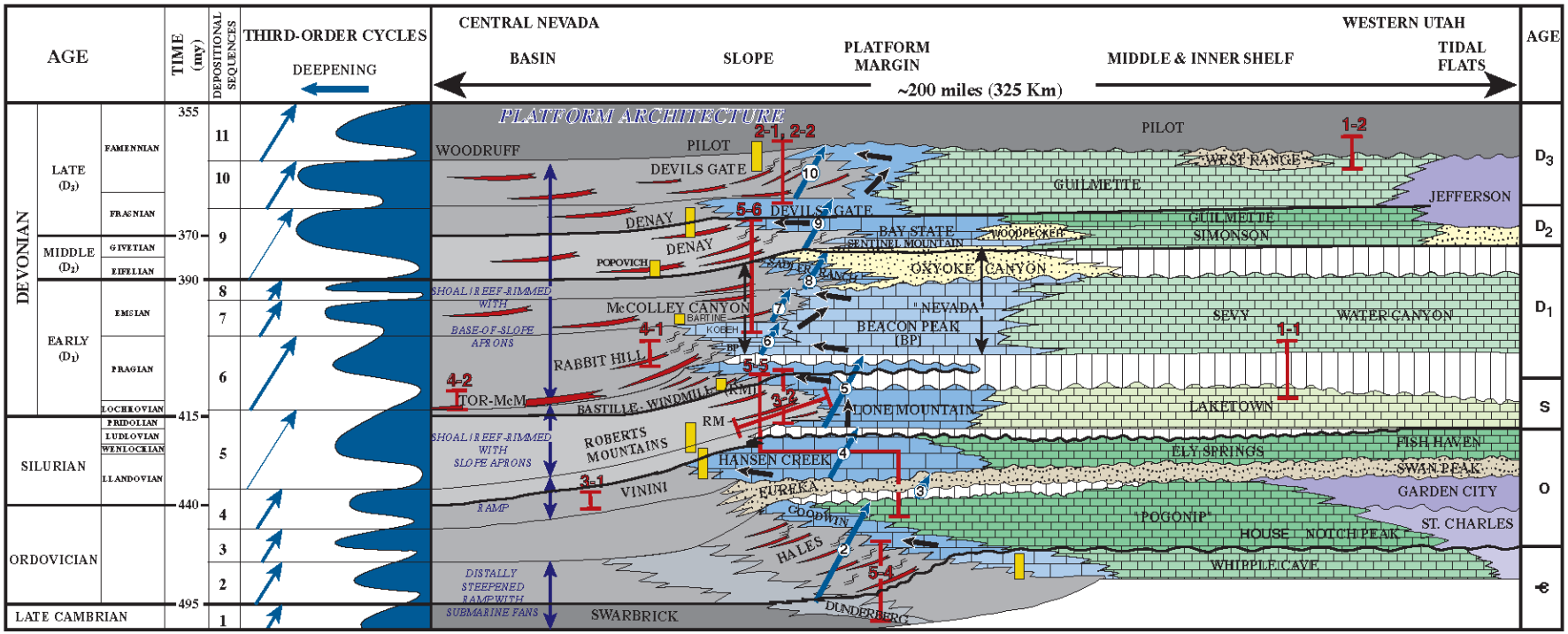
Stratigraphic controls in Carlin trend



STRATIGRAPHIC OCCURRENCES OF GOLD

PROGRADING

RETROGRADING

AGGRADING

1-1 FIELD STOP DAY 1, STOP1

SLOPE AND BASIN

TURBIDITE/DEBRIS FLOWS

SLUMPS

PLATFORM MARGIN

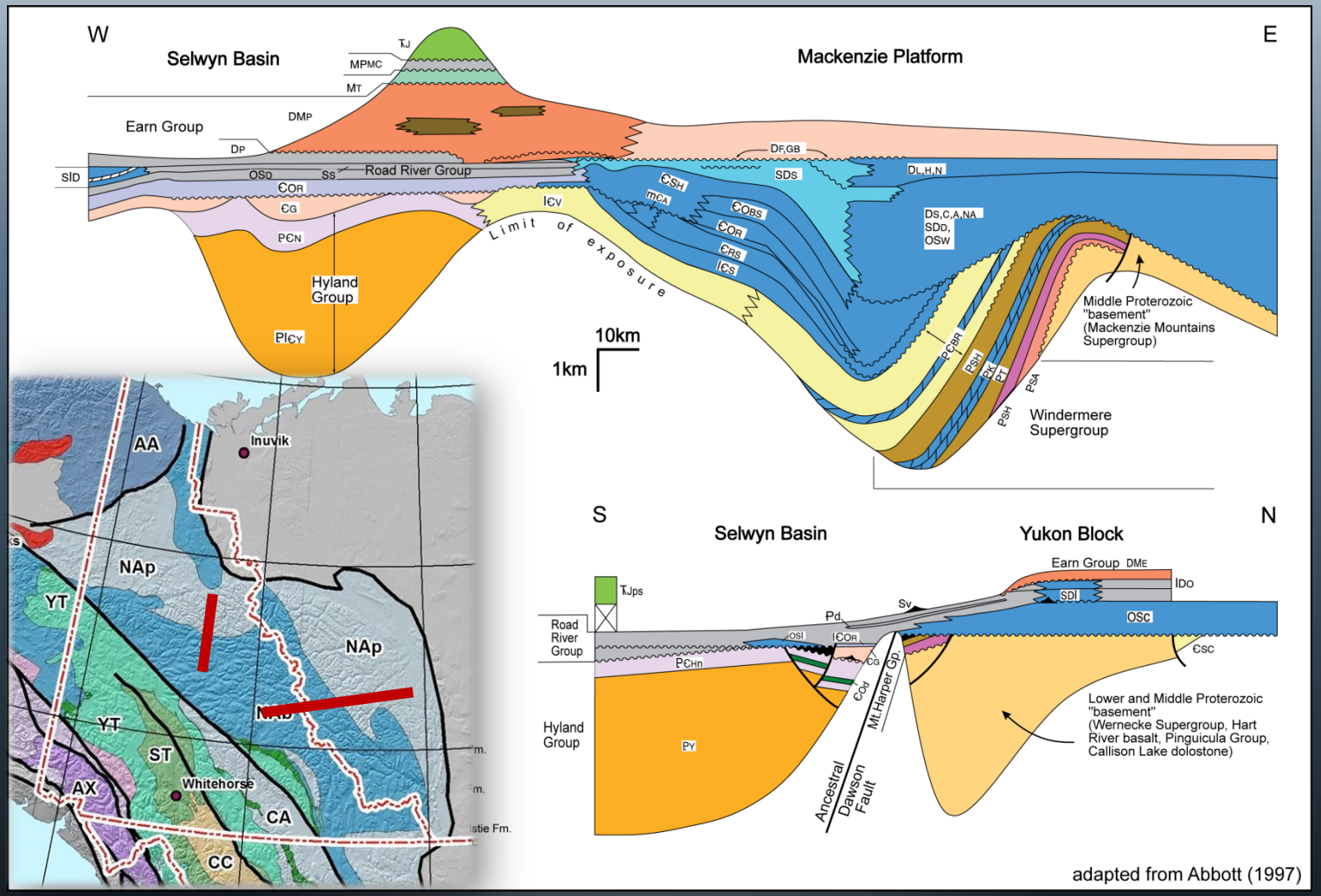
MIDDLE AND INNER SHELF

TIDAL FLATS

SILICICLASTIC SANDSTONE

Cook & Corboy (2004)

Selwyn Basin



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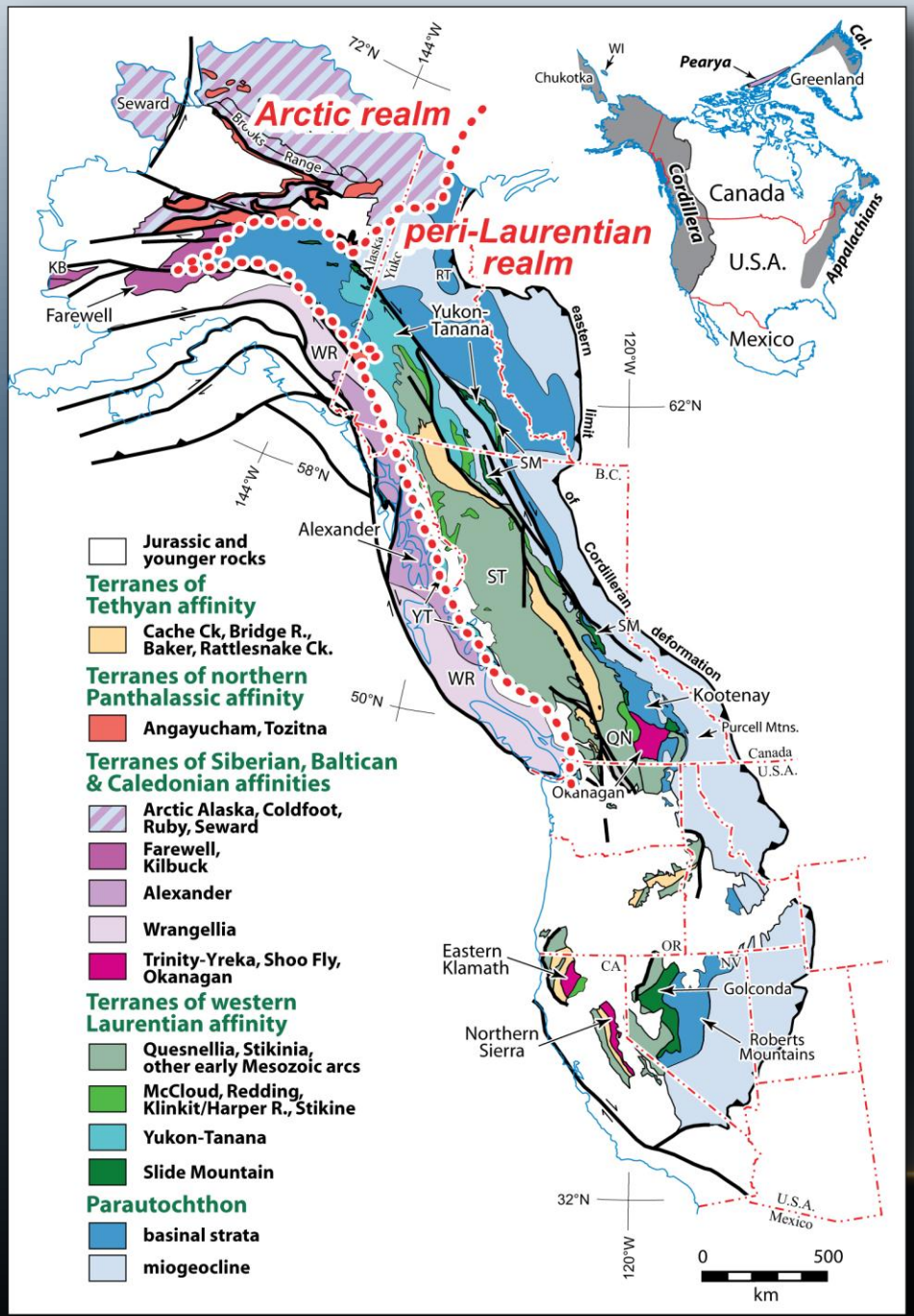


Arctic realm terranes

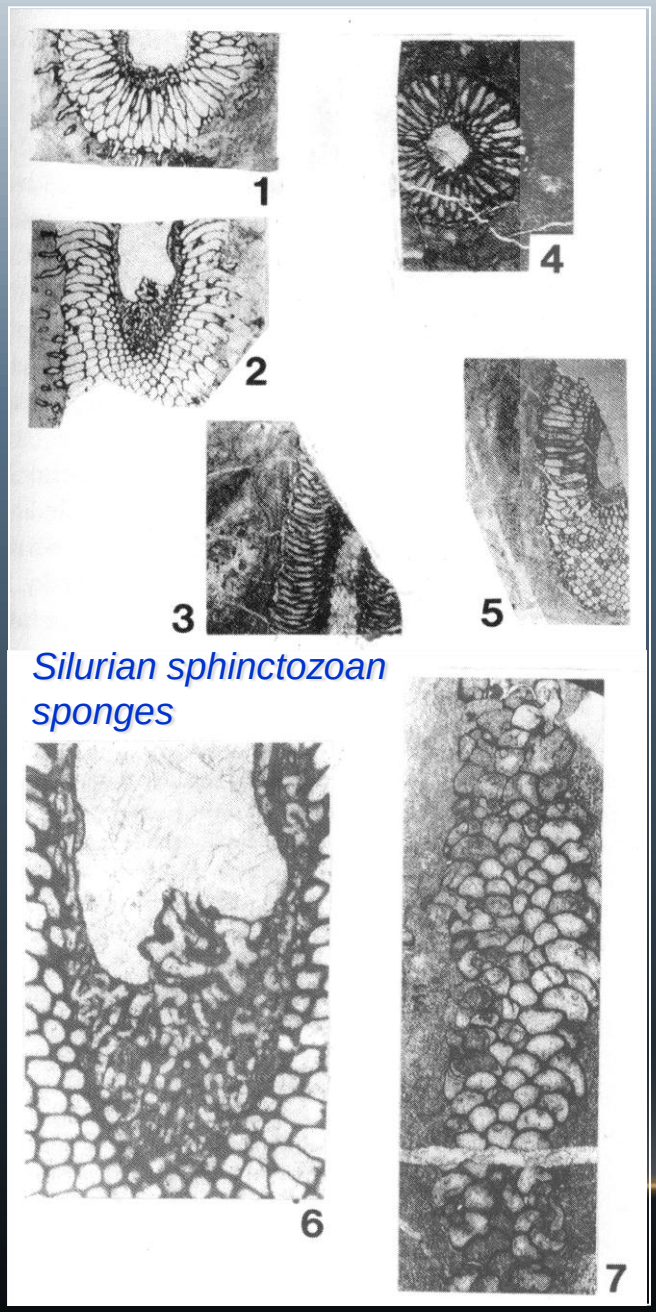
- Affinities with northern Caledonides, Timanides, Urals
- Neoproterozoic rocks of North Altlantic affinities
- Alexander terrane:

  VMS – Niblack (Ordovician-Silurian); Greens Creek, Windy Craggy (Triassic)
- Wrangellia:

  built on Alexander starting in Devonian

  Ni-Cu-PGE – Wellgreen (Triassic)

Terranes of Siberian-Caledonian-Baltican affinities



Silurian sphinctozoan sponges

- Fossil affinities with Siberia, and in some cases Baltica
- Evidence of 920-980 Ma magmatism
- Neoproterozoic and Ordovician-Silurian arcs
- Detrital zircons = Baltica, NE Laurentia

Blodgett et al. (2002) - GSA Special Paper 360

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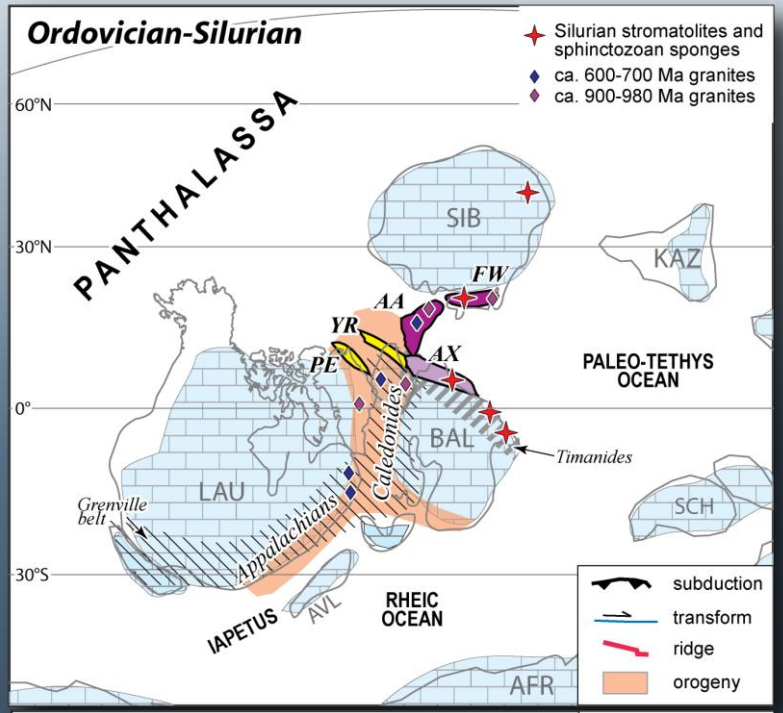
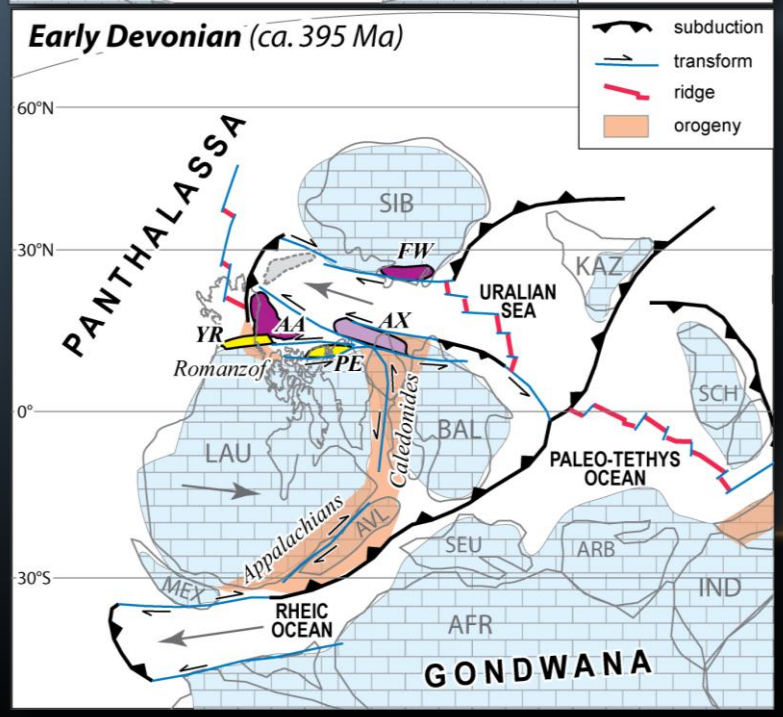
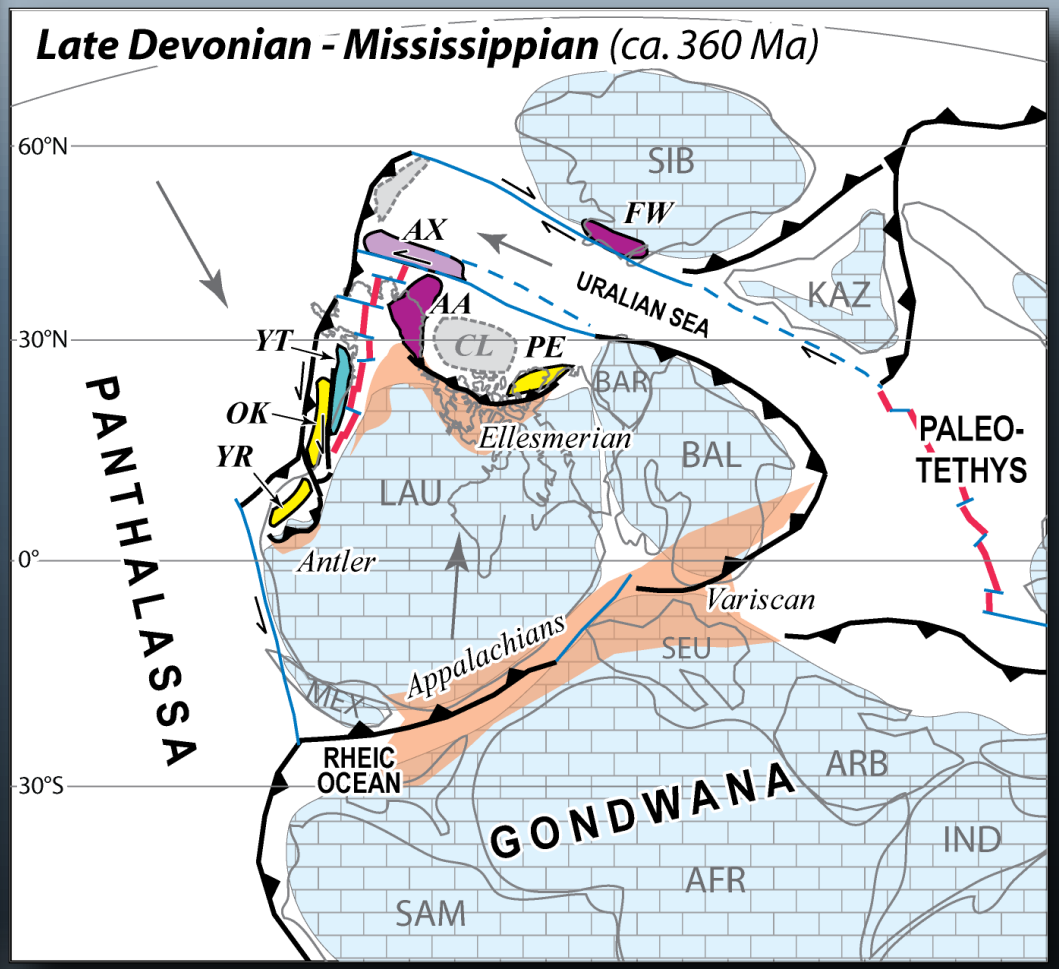
A Paleozoic NW Passage

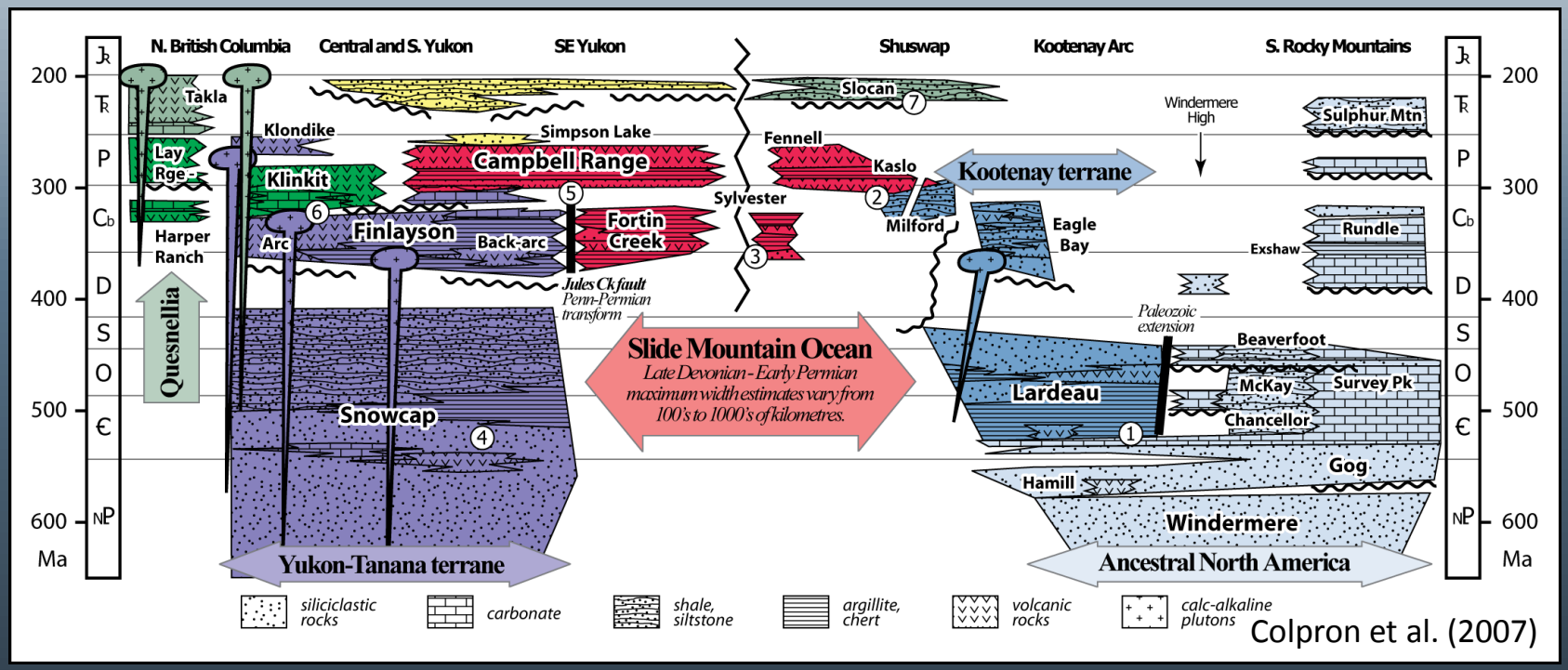






Colpron & Nelson (2009) – GSL Special Publications 318
Colpron & Nelson (2011) – GSL Memoirs 35

Devonian Active Margin



Colpron et al. (2007)

- Rifting in Selwyn basin (Earn), magmatism and syngenetic sulphides
- Onset of arc magmatism in Yukon-Tanana terrane
- Backarc rifting of Slide Mountain

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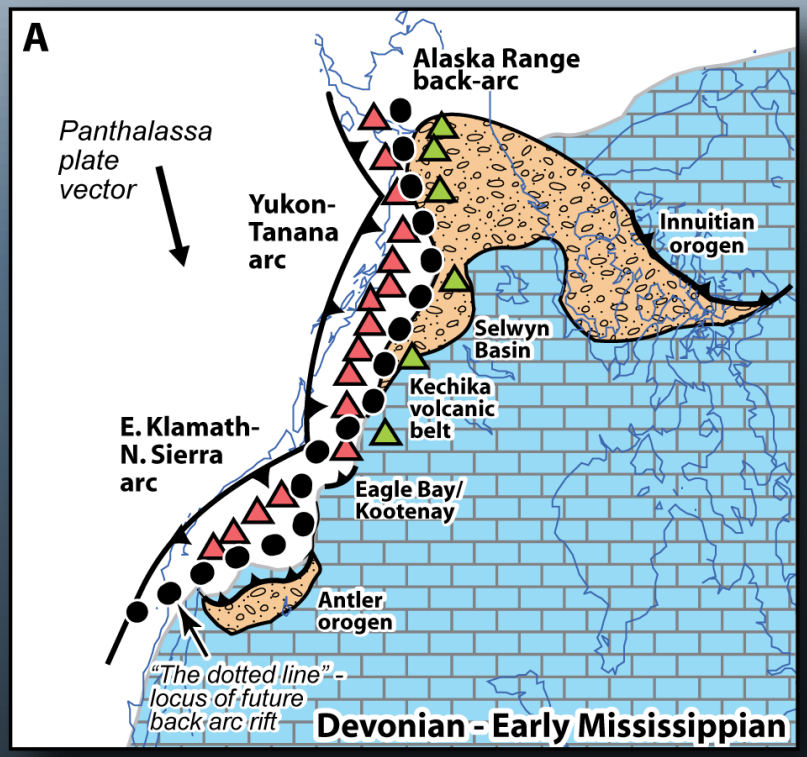
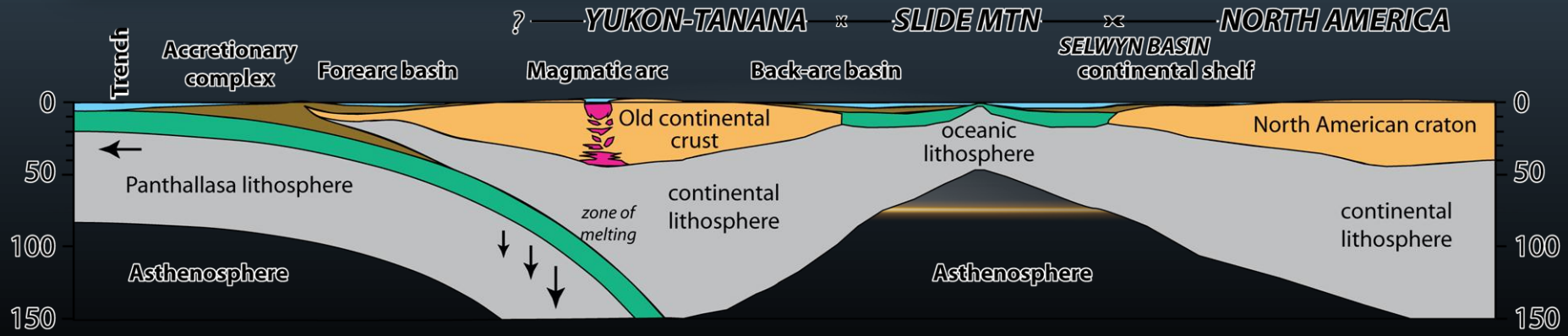
Devonian Active Margin

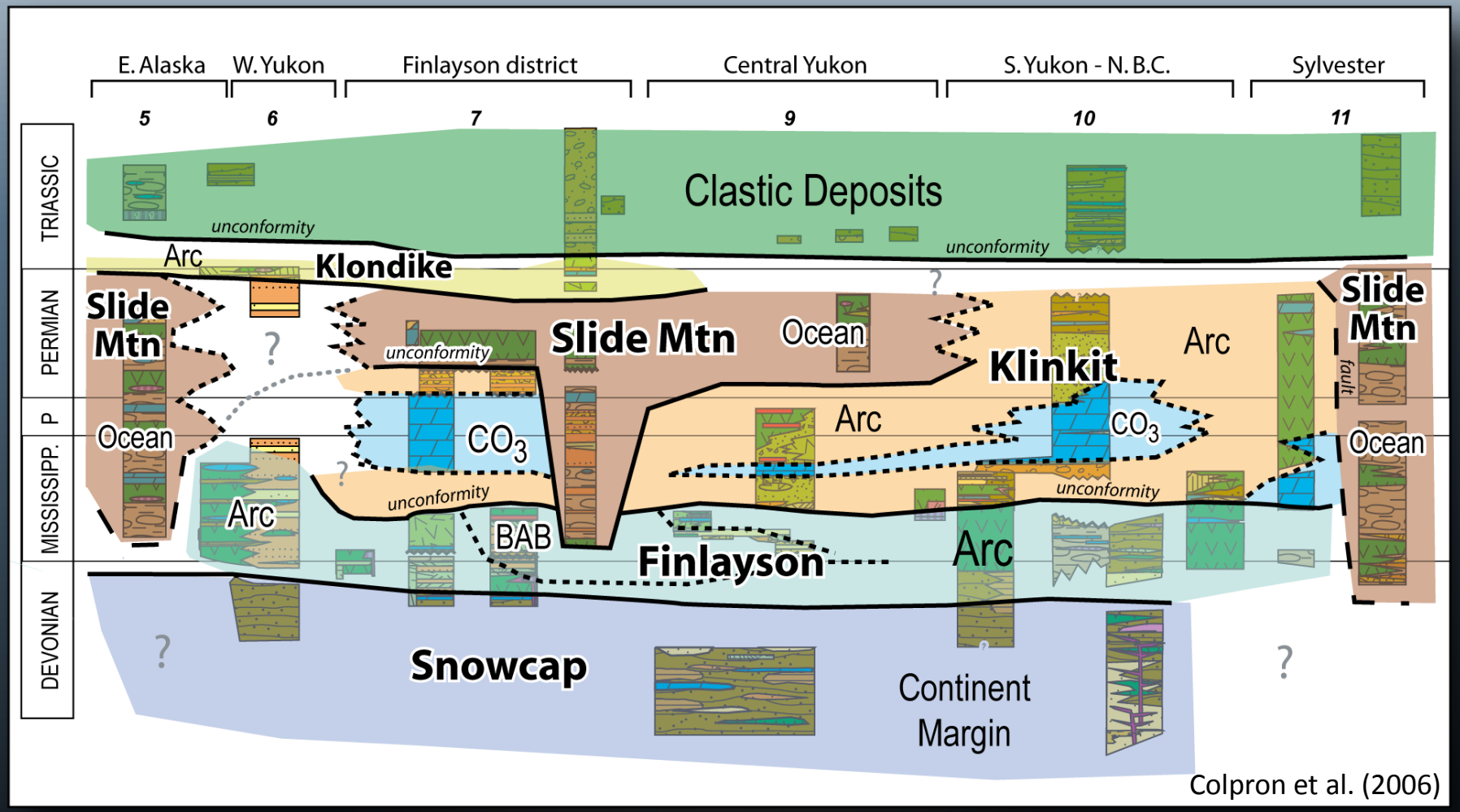


- Yukon-Tanana – Active Arc
  L Devonian-E Permian
- Slide Mtn – Backarc Rift
  L Devonian-Permian
- Eagle Bay & YT Upland (AK) – Remnant Arc
  L Devonian-E Mississippian

Colpron et al. (2007)



Yukon-Tanana terrane



Colpron et al. (2006)

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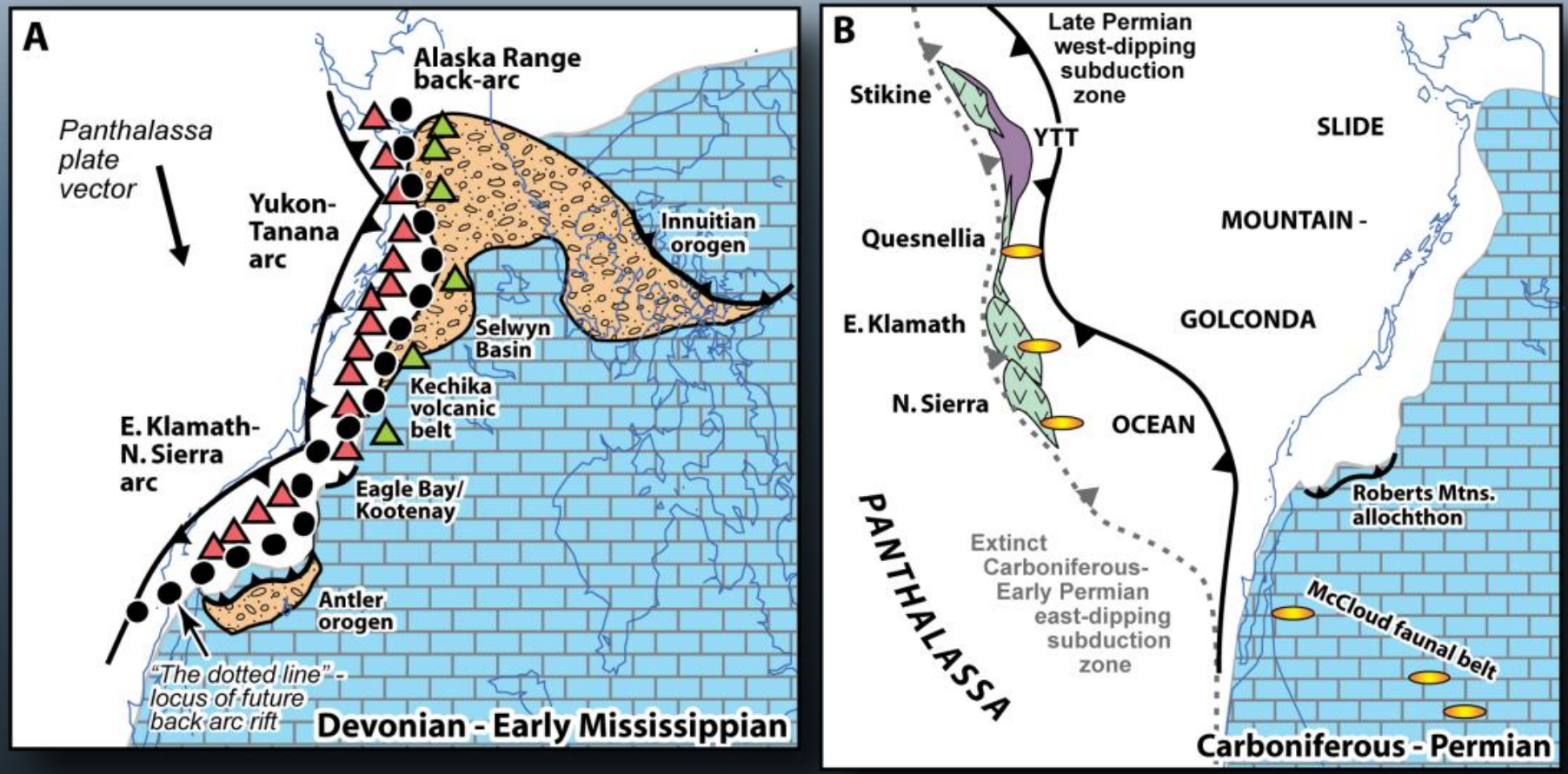
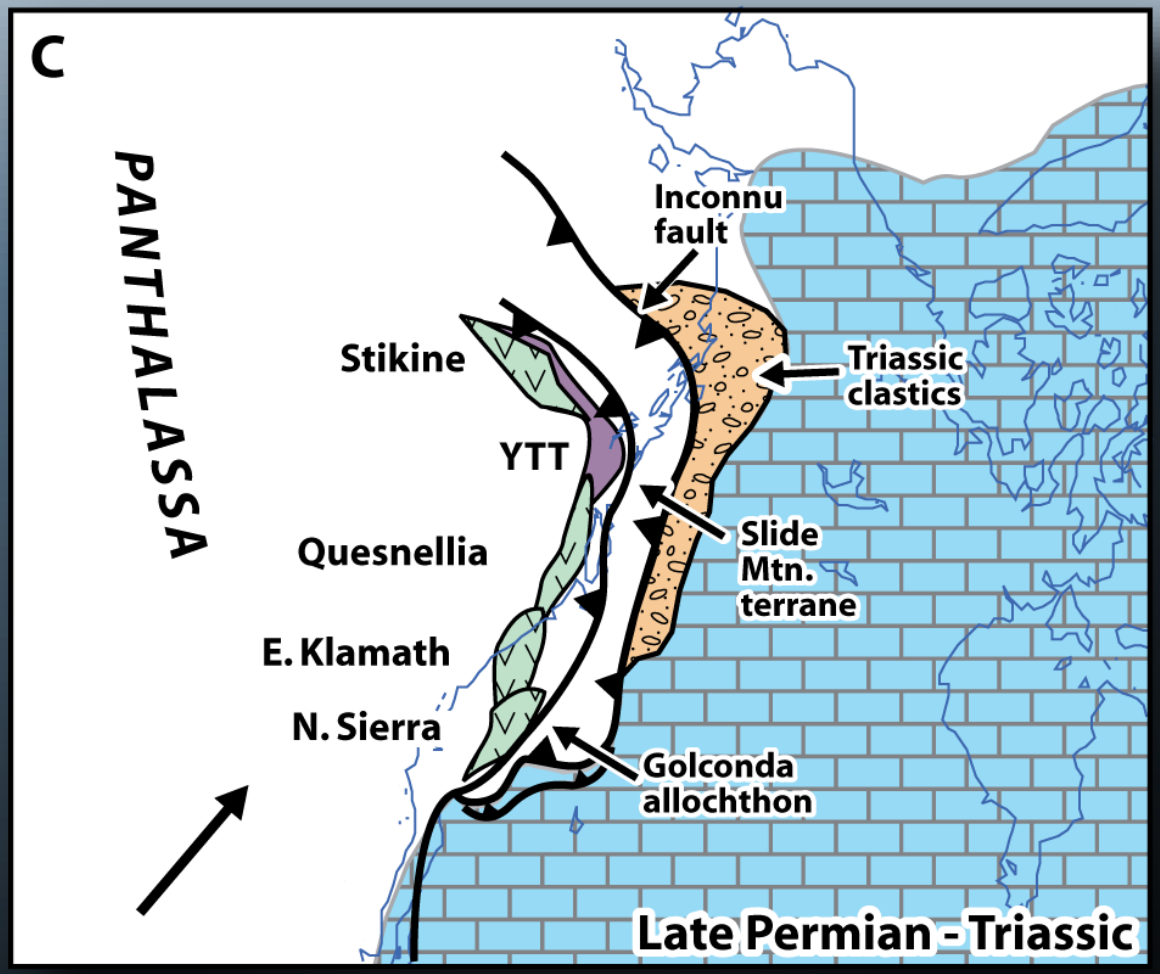
Devonian-Carboniferous Tectonics



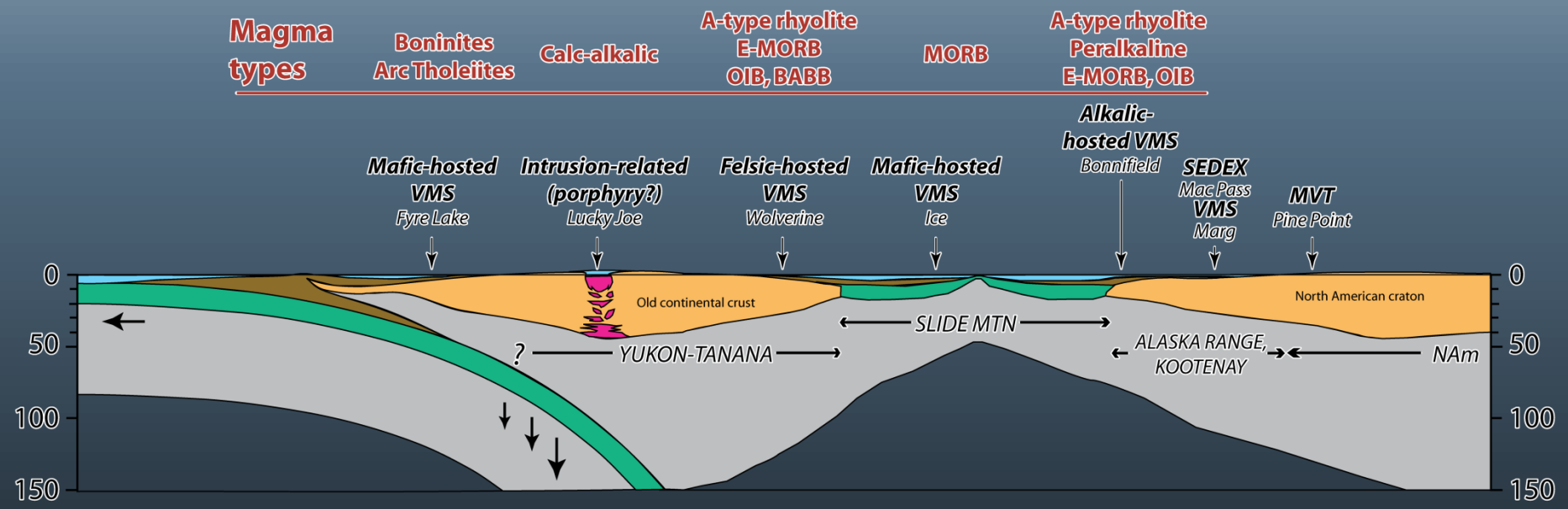
Colpron et al. (2007)

Permo-Triassic



Colpron et al. (2007)

Devonian-Carboniferous Metallogeny



After Nelson et al. (2002)

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Wolverine Mine

- Mineralization hosted in Early Mississippian black phyllite and felsic metavolcanic rocks of Yukon-Tanana terrane
- 346-356 Ma, Wolverine Lk Gp
- 2 coalesced seafloor mounds
- 3 types of mineralization:

  Stringer sulphide veins
  Semi-massive replacement
  Banded massive sulphide

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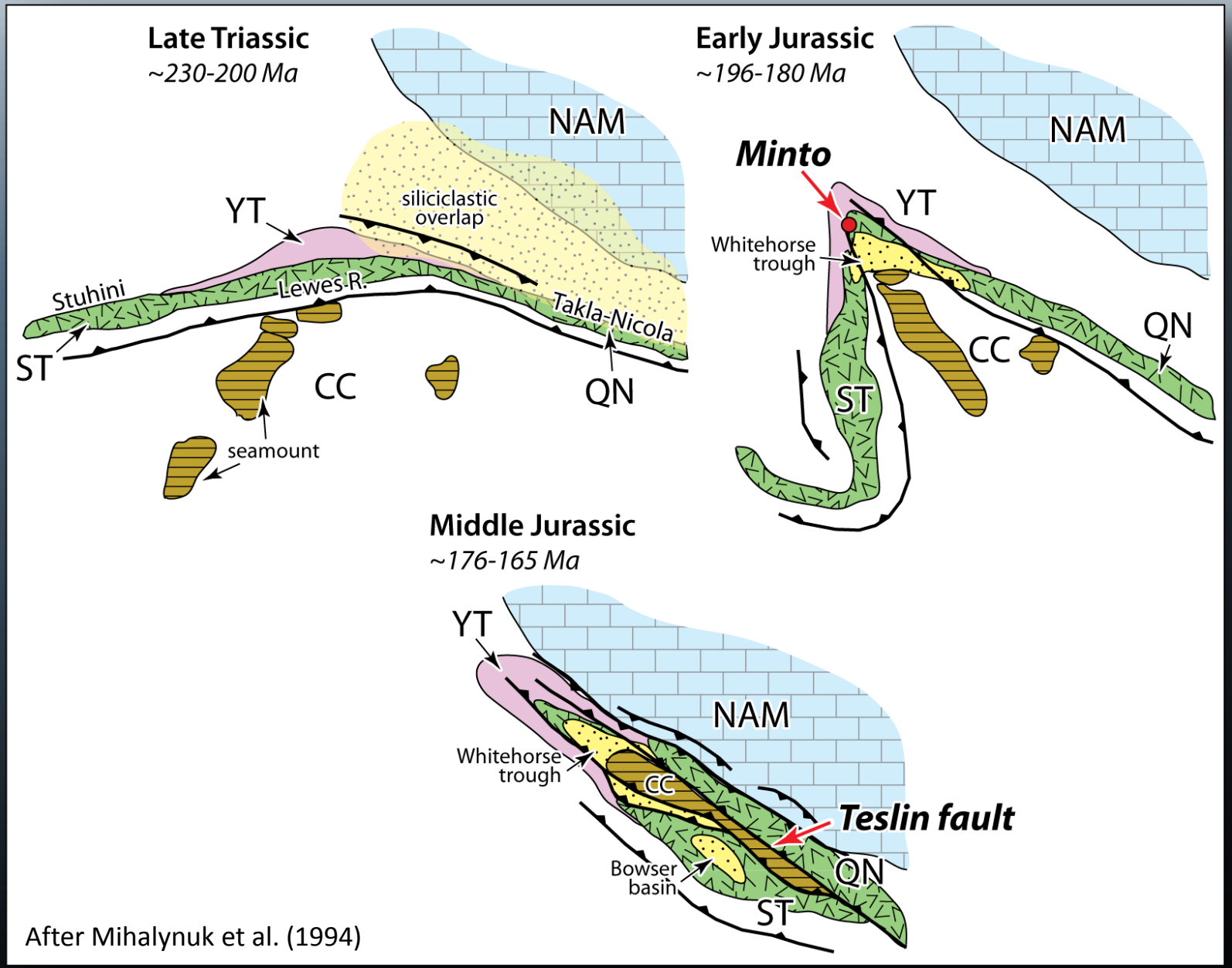
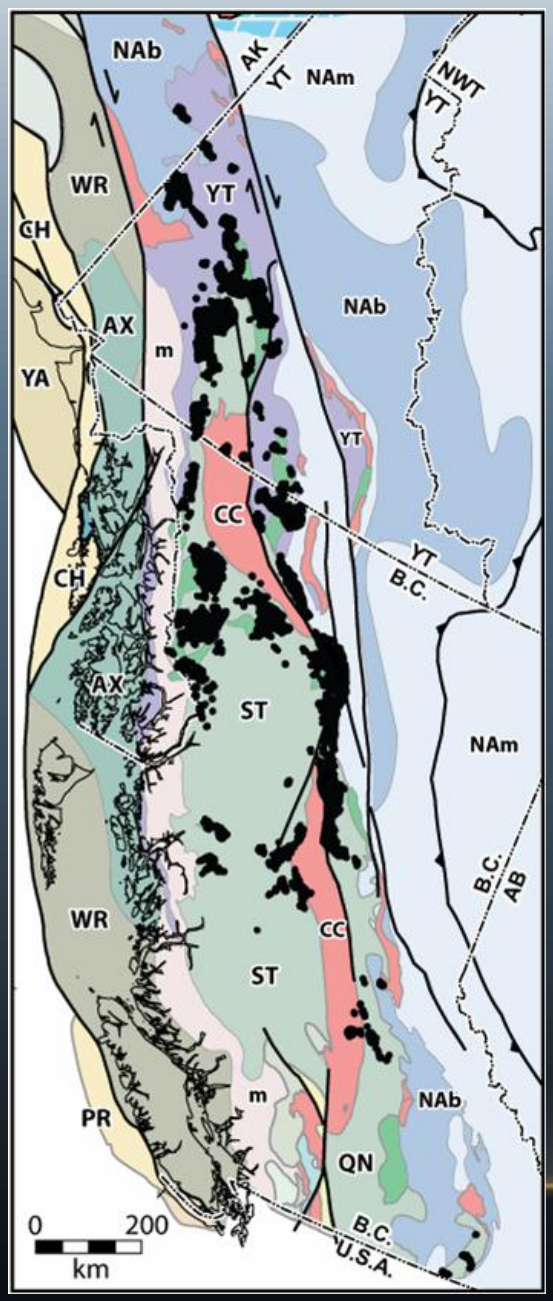


After Mihalynuk et al. (1994)



Early Mesozoic Porphyries

- Cu-Au & Cu-Mo porphyry deposits
- Most important group of deposits in B.C.

  Highland Valley *- producer since 1972; 1355 Mt @ 0.43% Cu*

  Kemess south *- ~200 Mt @ 0.22% Cu, 0.63 g/t Au*

  Galore Ck *- 540 Mt @ 0.557% Cu, 0.45 g/t Au, 0.3 g/t Ag (proven/probable)*
- Associated with L Triassic – E Jurassic plutons of Quesnellia and Stikinia
- Suite extends in Yukon, where plutons intrude Yukon-Tanana terrane
- Host of Minto Mine and Carmacks Copper deposits

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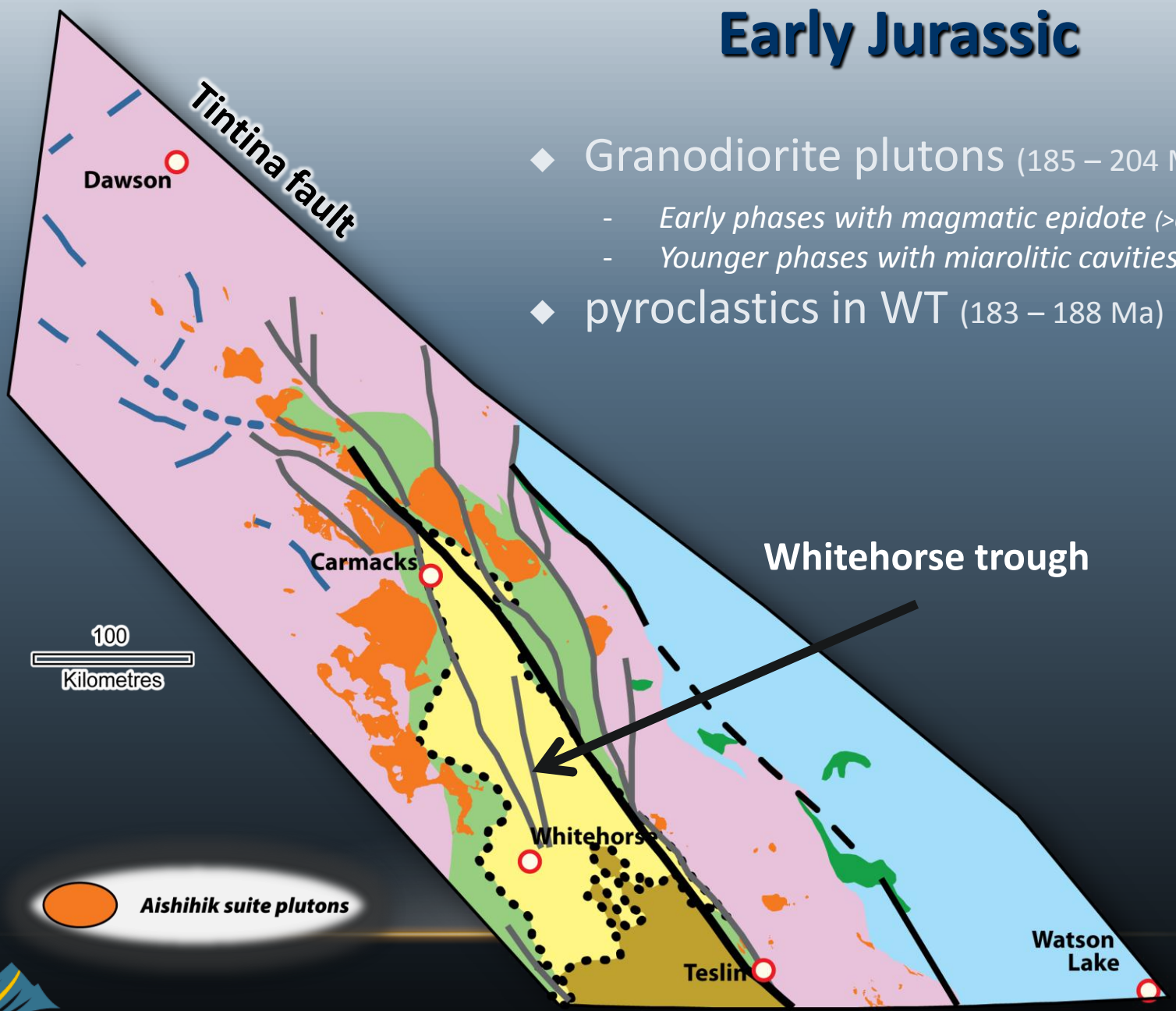
Early Jurassic

- Granodiorite plutons (185 – 204 Ma)
  - *Early phases with magmatic epidote (>6 kbar)*
  - *Younger phases with miarolitic cavities (<2 kbar)*
- pyroclastics in WT (183 – 188 Ma)



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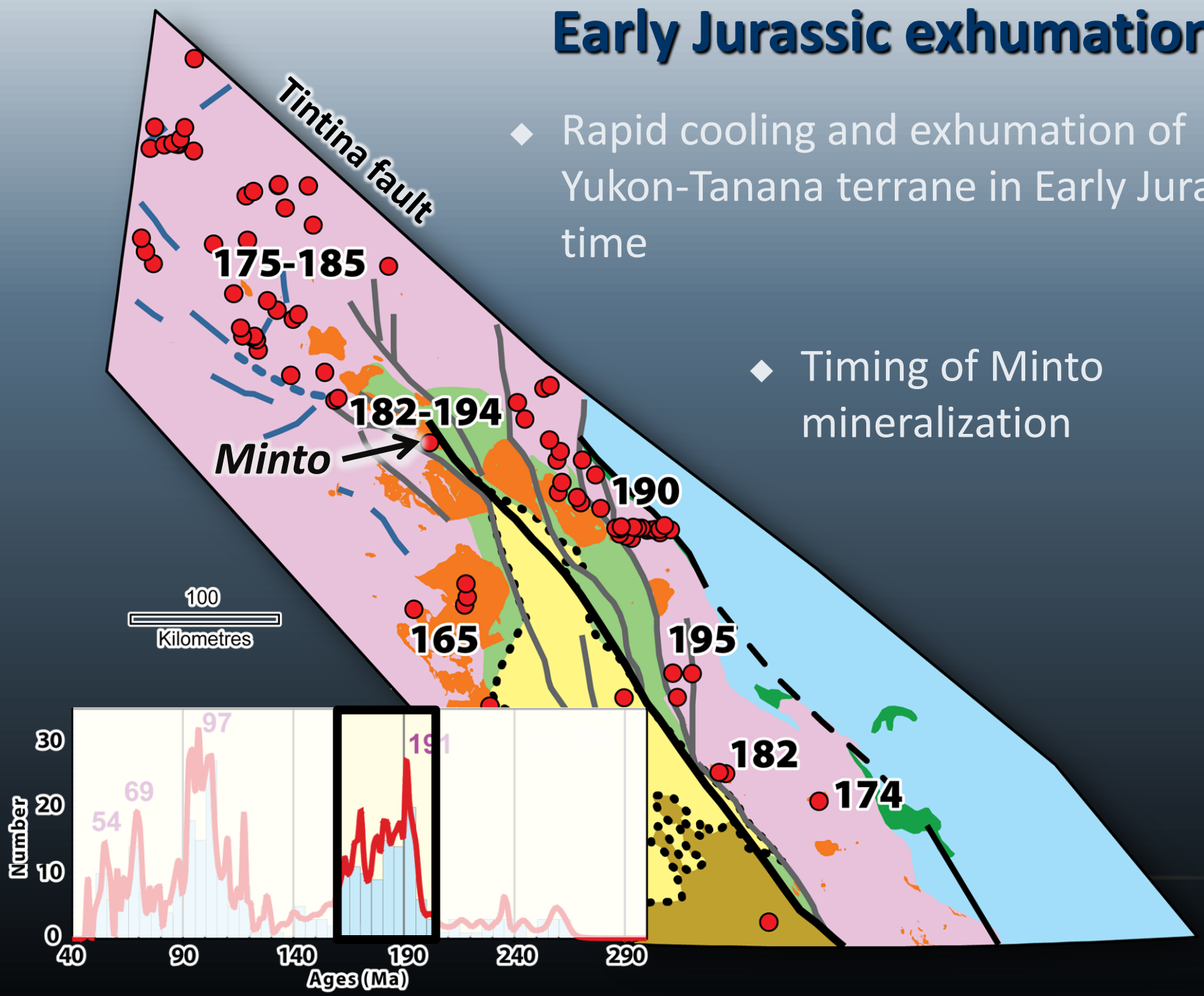
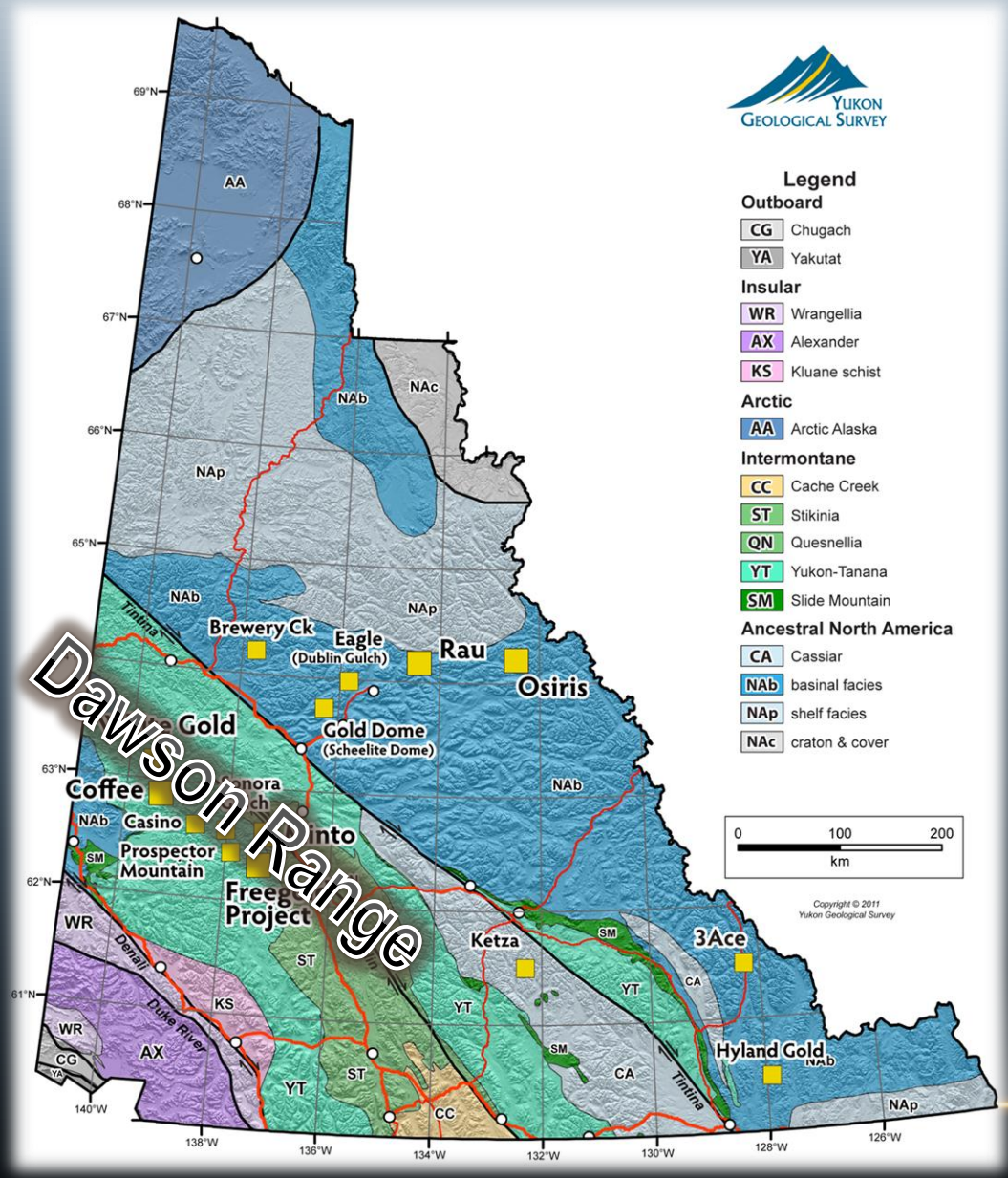
Early Jurassic exhumation

- Rapid cooling and exhumation of Yukon-Tanana terrane in Early Jurassic time
- Timing of Minto mineralization



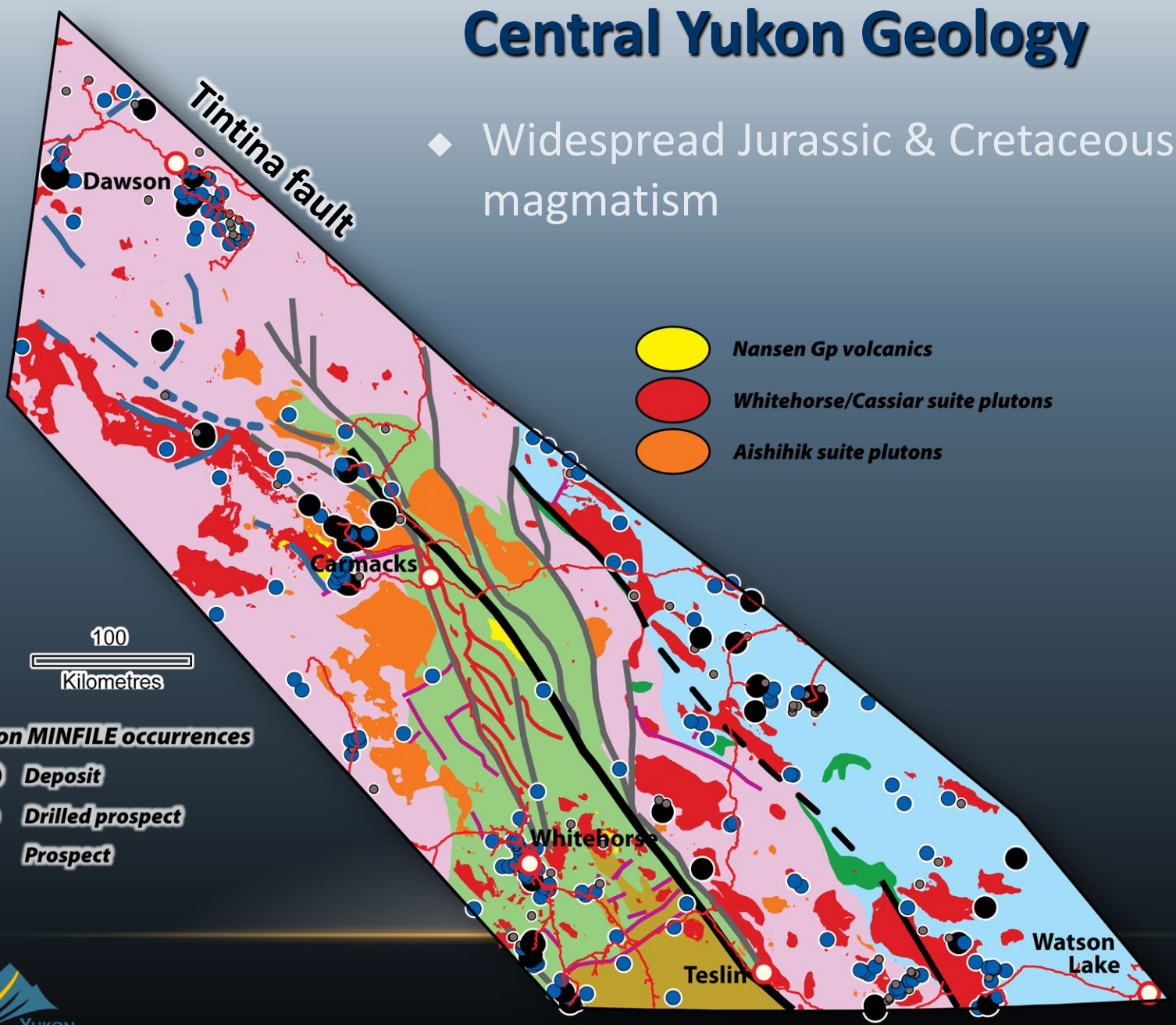
White Gold
Dawson Range



- Yukon-Tanana ‘basement’
- Jurassic, mid- and Late Cretaceous magmatism
- Permo-Triassic regional deformation
- Jurassic exhumation
- Cretaceous (and younger?) faulting

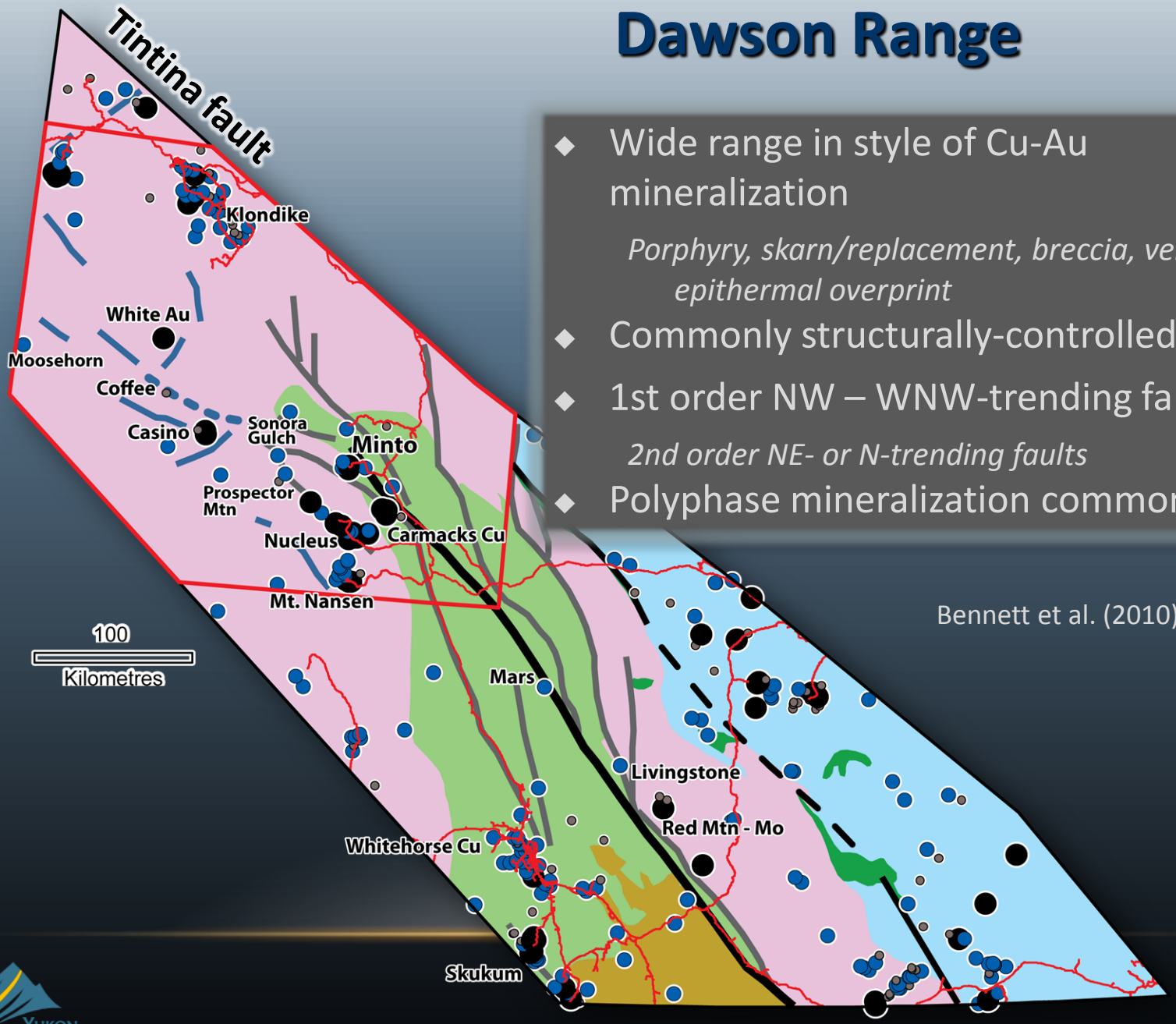
Central Yukon Geology

- Widespread Jurassic & Cretaceous magmatism



Yukon Geological Survey

Dawson Range

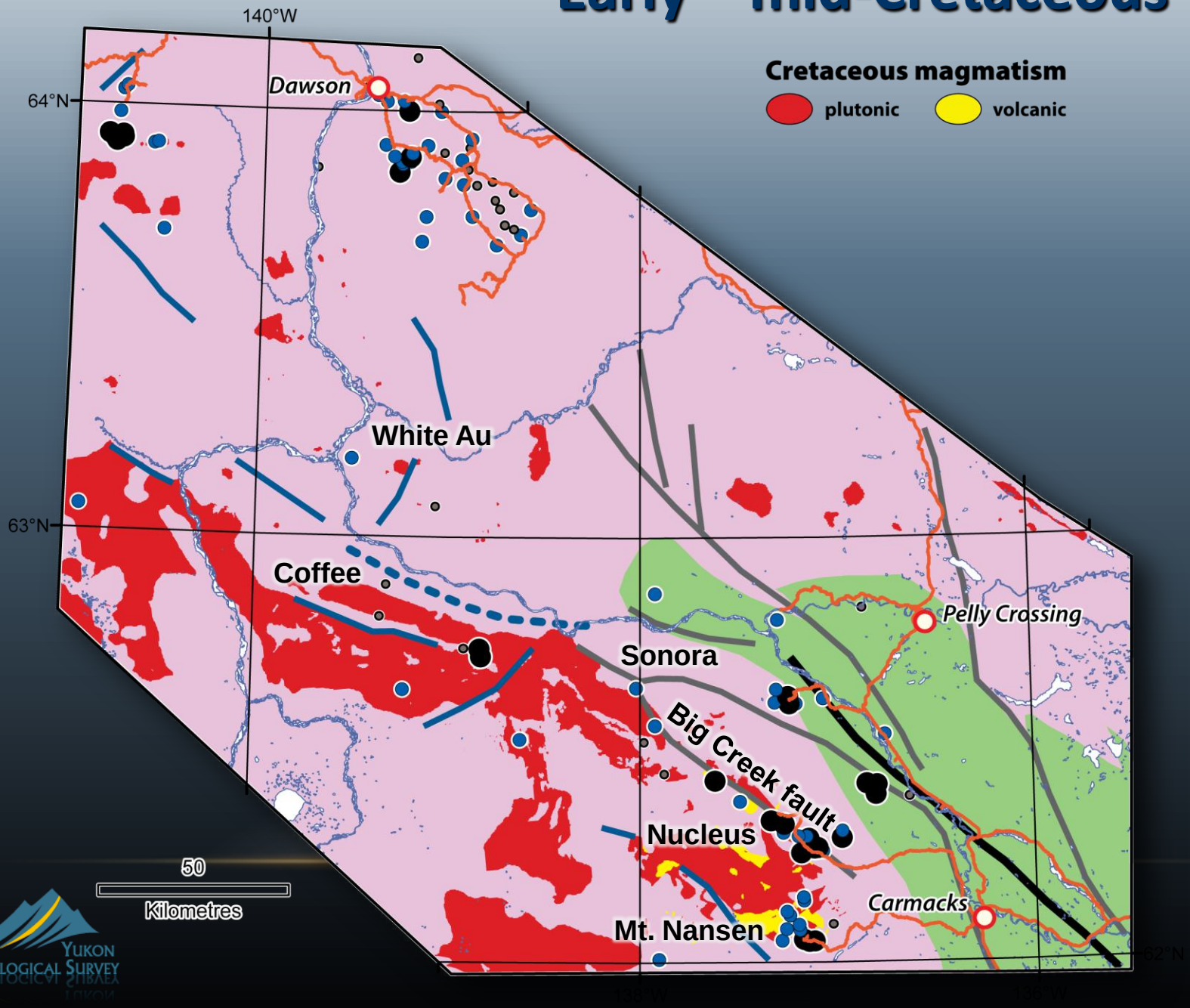


- Wide range in style of Cu-Au mineralization
  - *Porphyry, skarn/replacement, breccia, veins, epithermal overprint*
- Commonly structurally-controlled
- 1st order NW – WNW-trending faults
  - *2nd order NE- or N-trending faults*
- Polyphase mineralization common

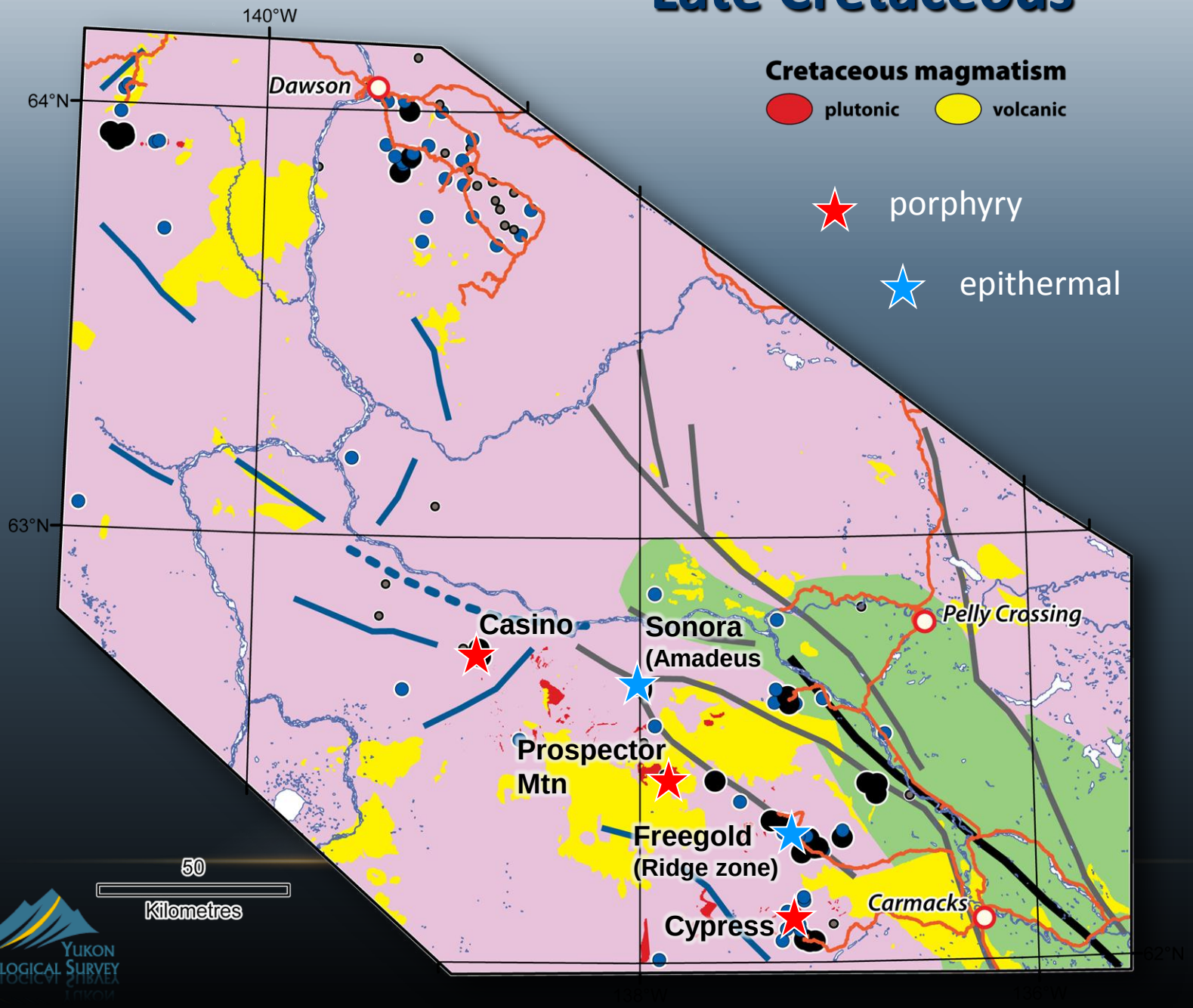
Bennett et al. (2010)

Yukon Geological Survey

Early – mid-Cretaceous



Late Cretaceous



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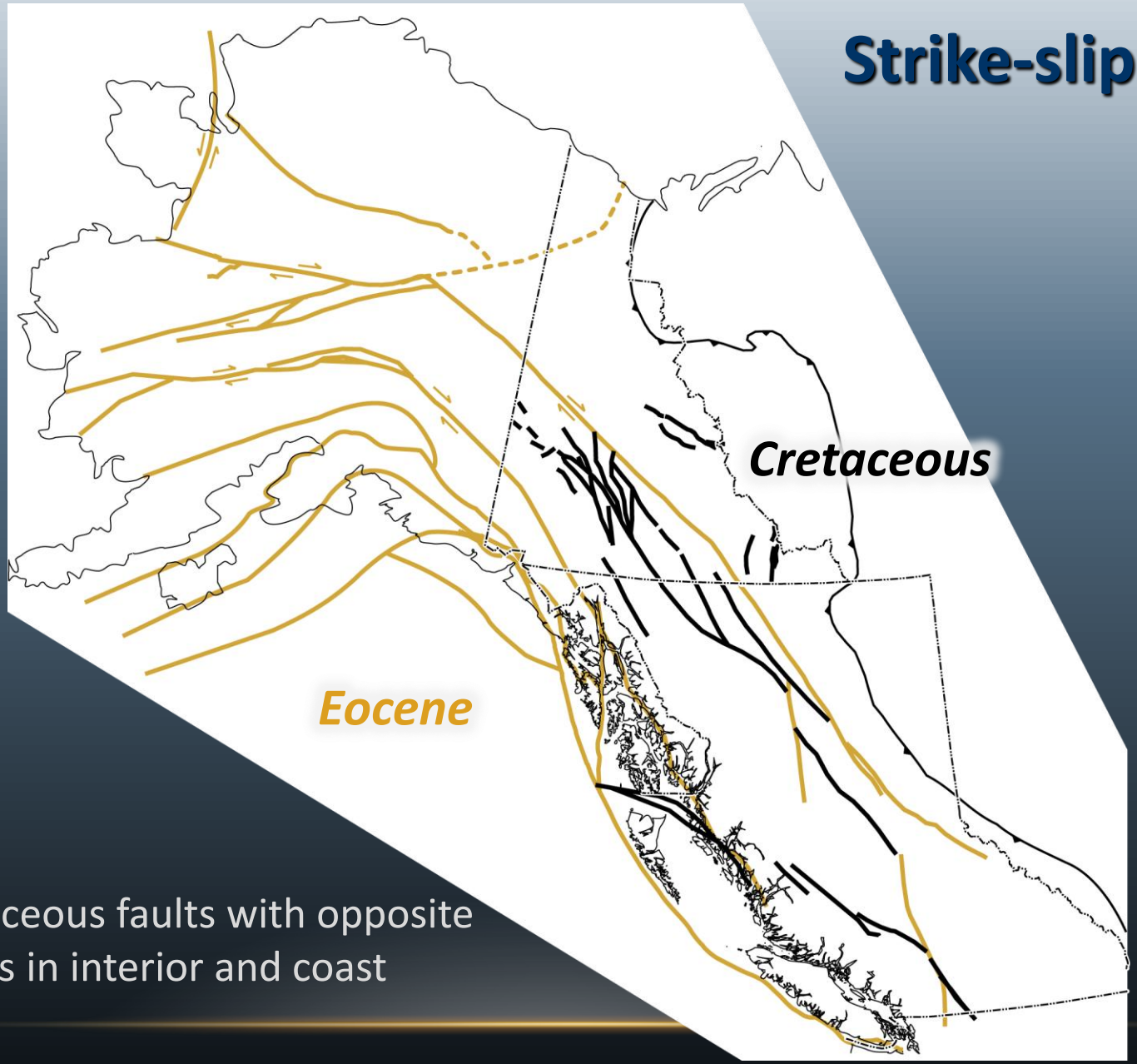
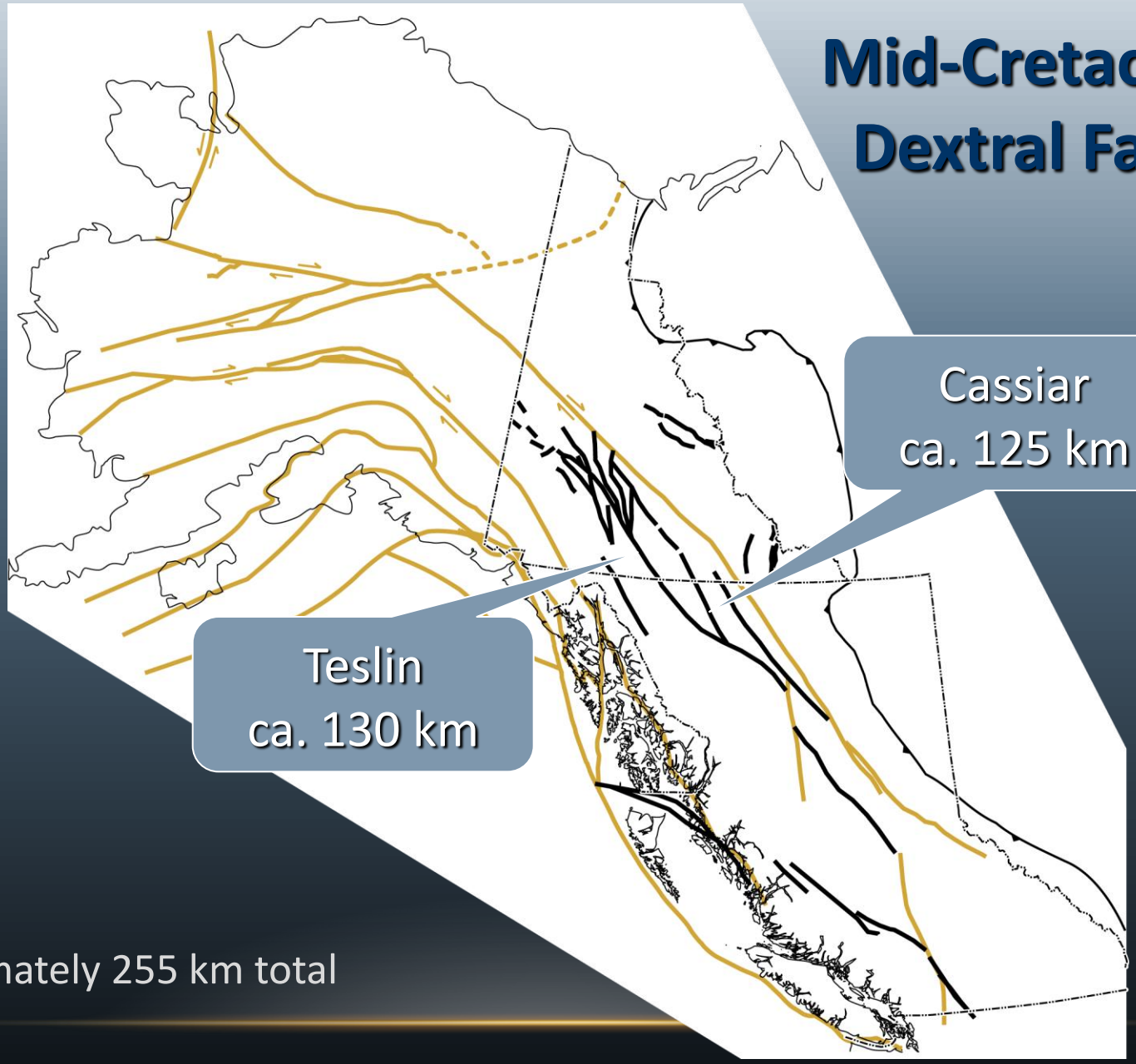
Strike-slip Faults



mid-Cretaceous faults with opposite kinematics in interior and coast

Yukon Geological Survey

Mid-Cretaceous Dextral Faults

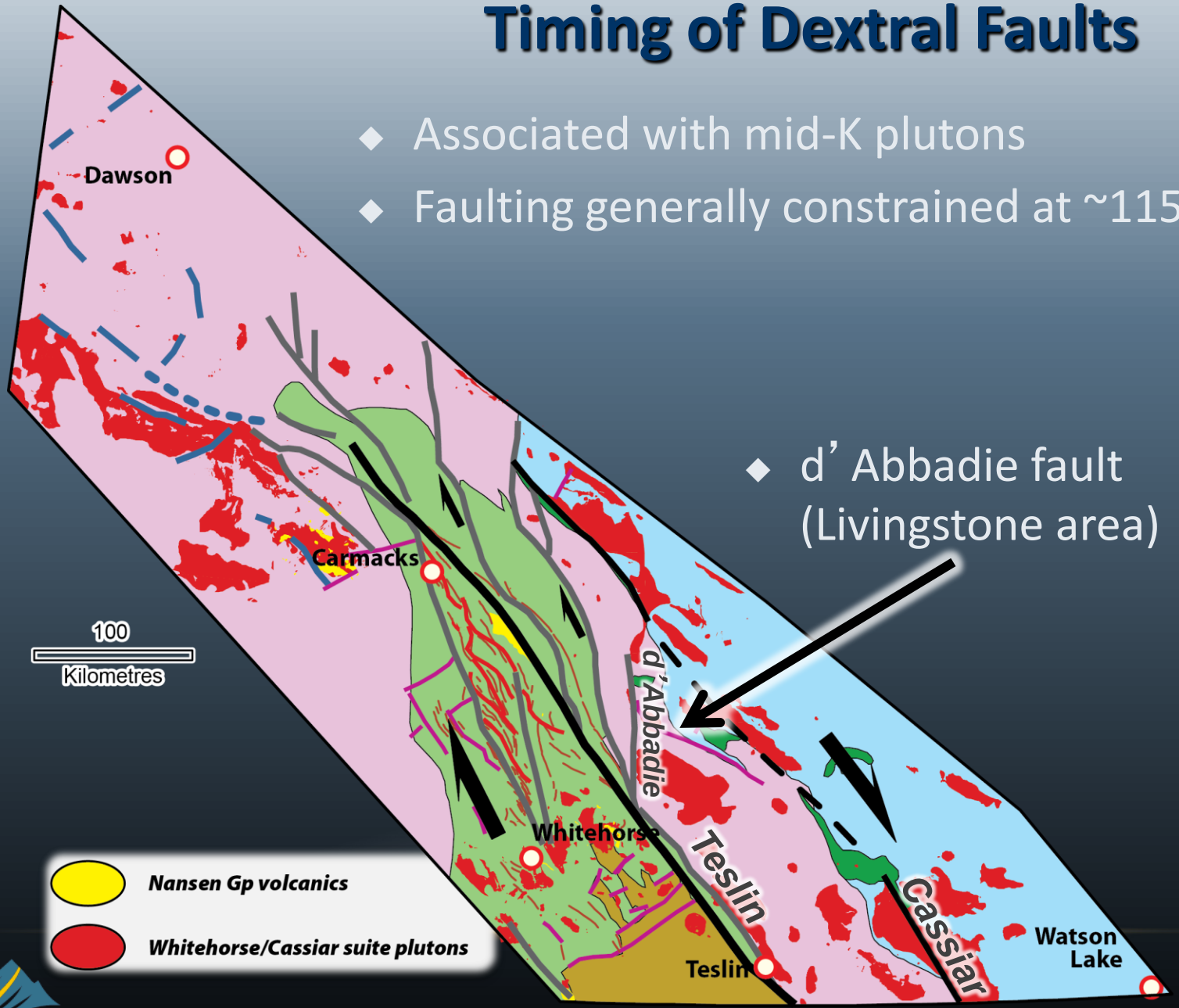


Approximately 255 km total

Yukon Geological Survey

Timing of Dextral Faults

- Associated with mid-K plutons
- Faulting generally constrained at ~115-95 Ma



- d'Abbadie fault (Livingstone area)

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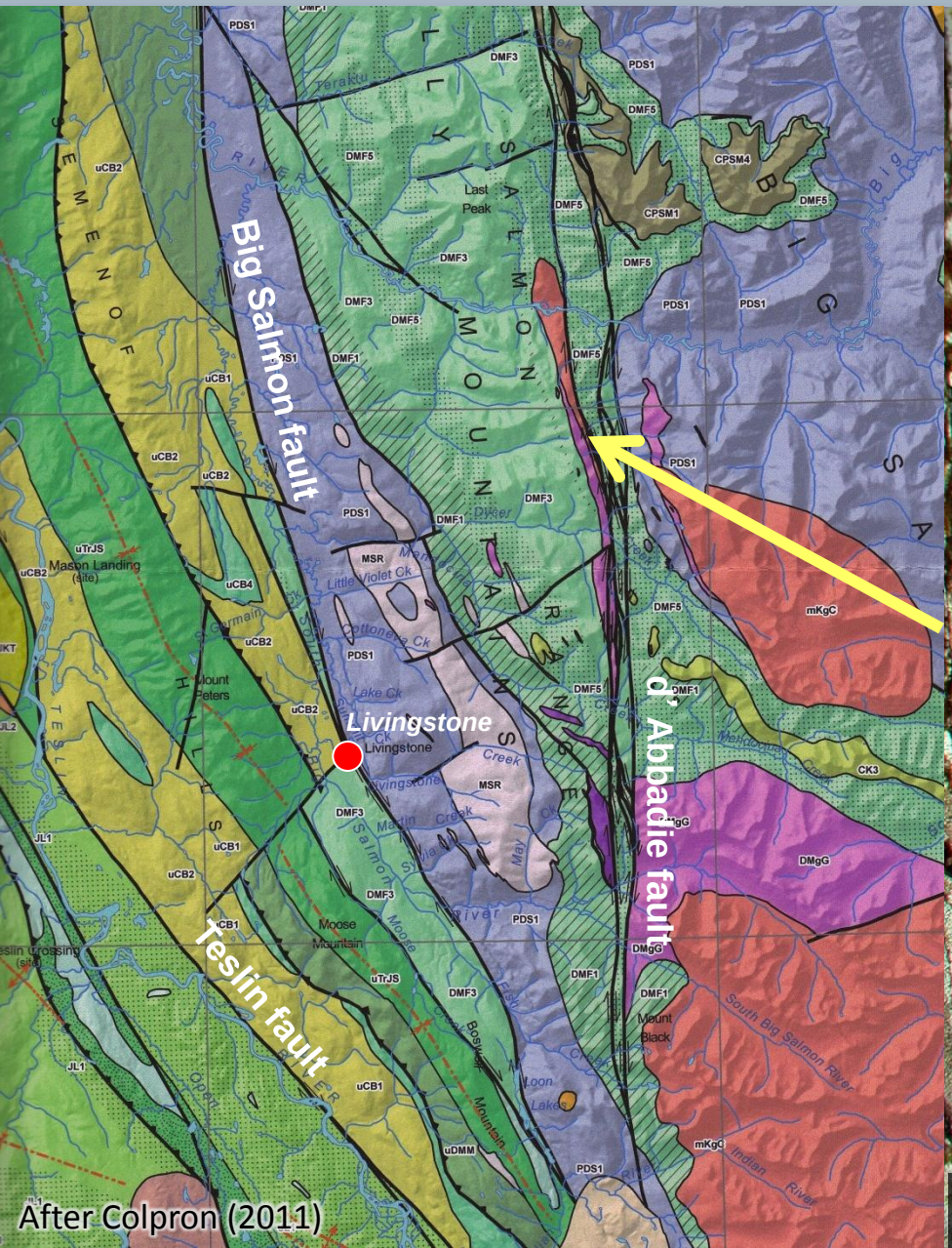
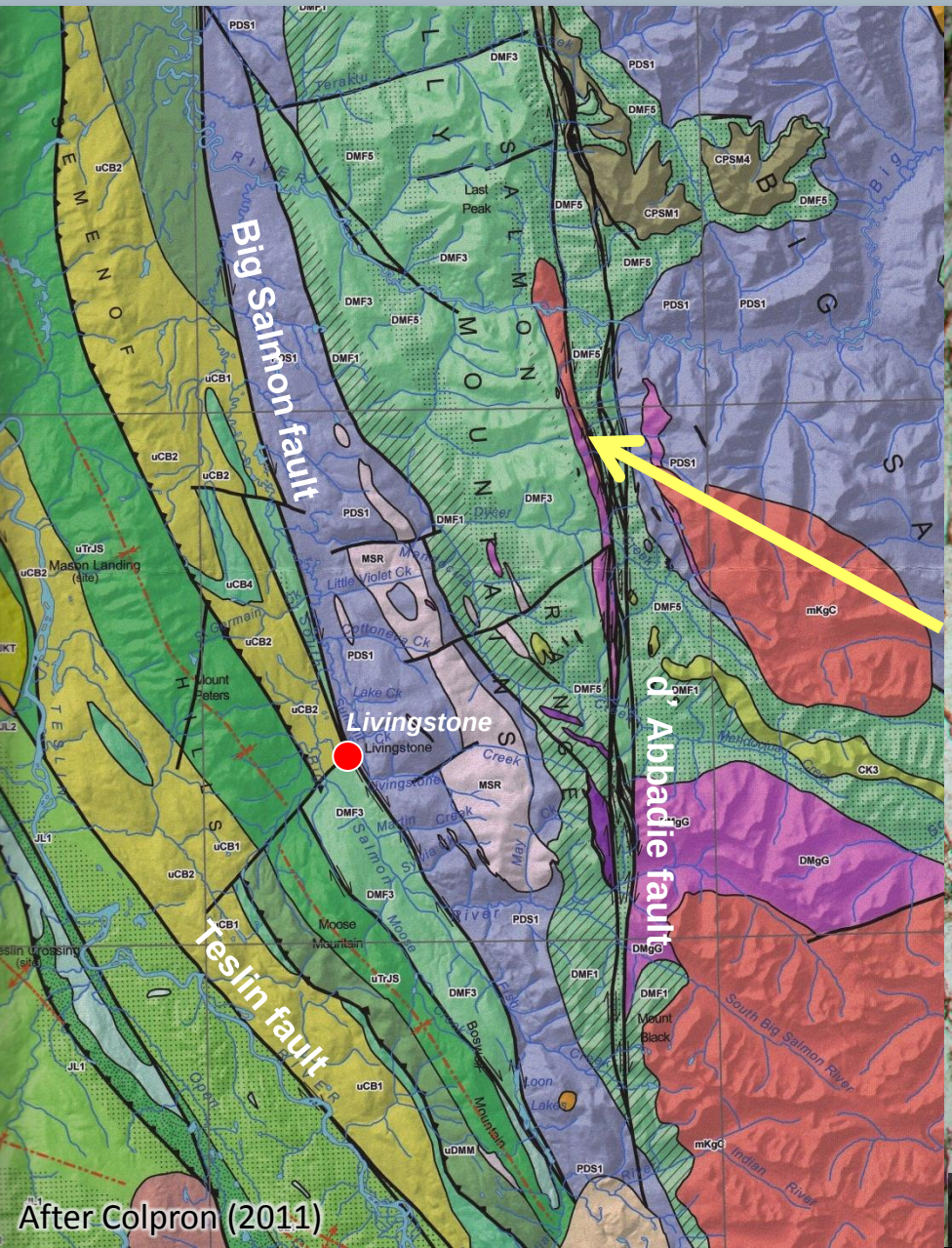
d'Abbadie fault



After Colpron (2011)

d'Abbadie fault



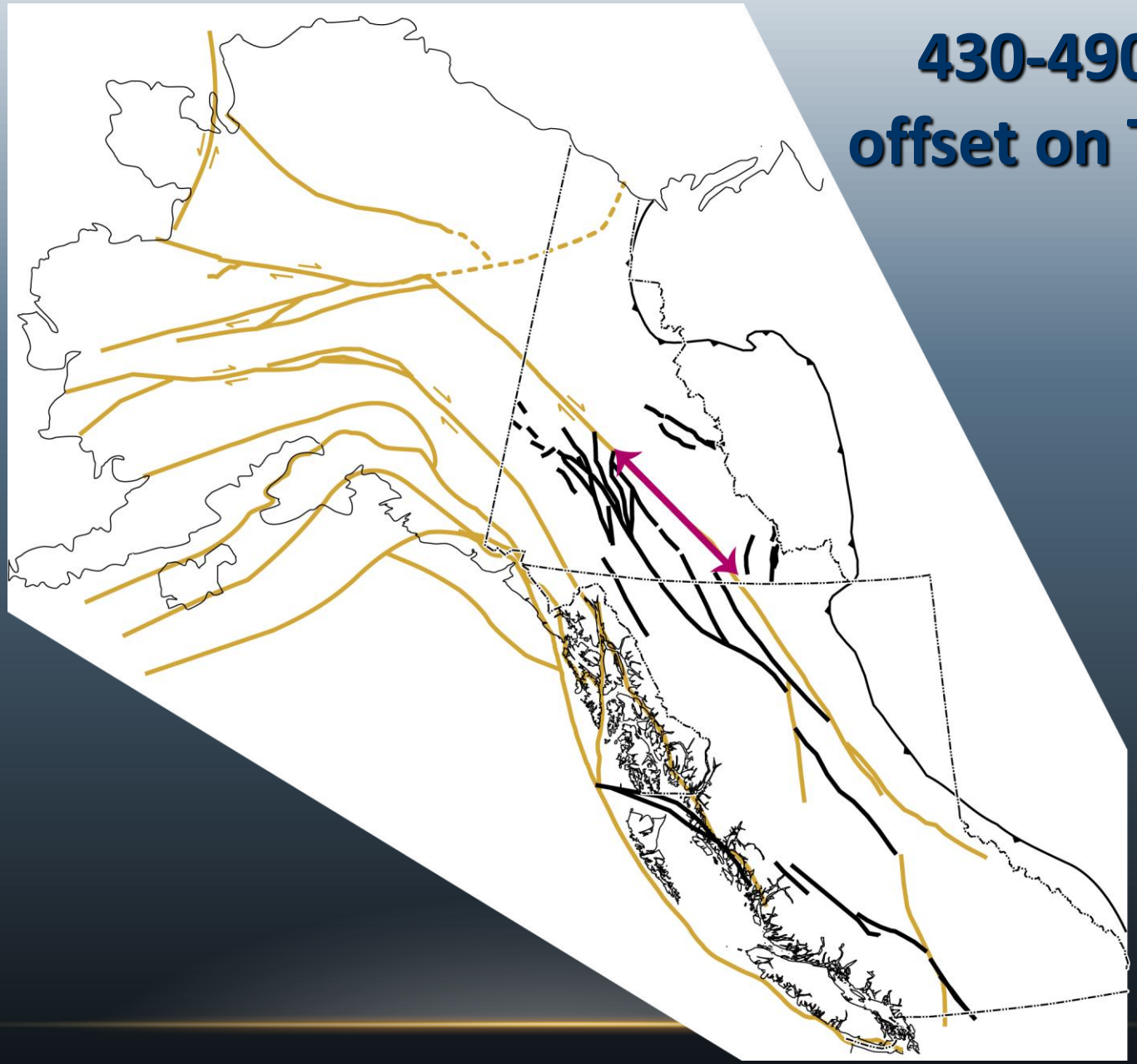
d' Abbadie fault

Last Peak granite *ca. 96 Ma*

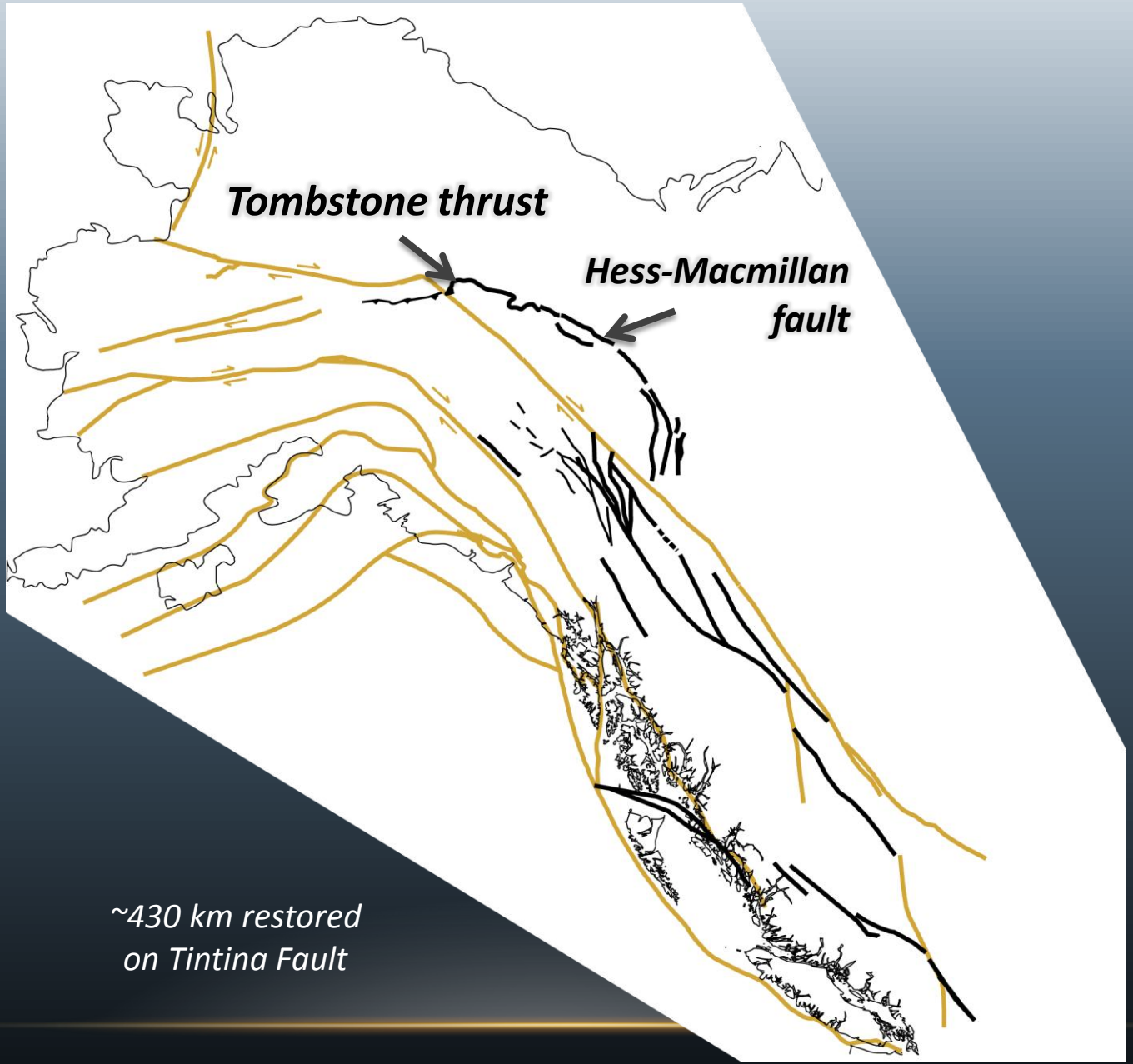
50,000 oz placer Au

Overall brittle regime

430-490 km offset on Tintina

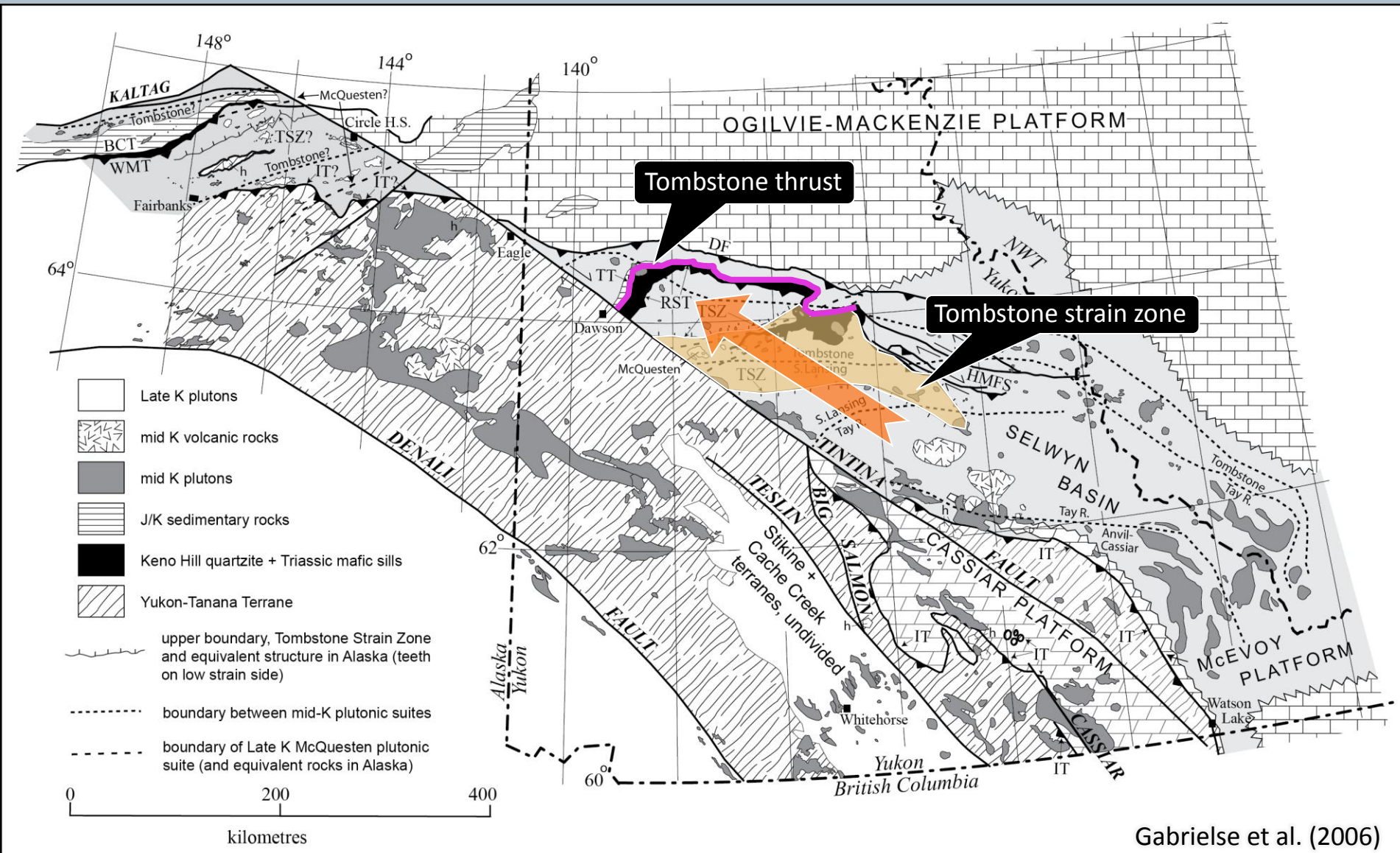


Yukon Geological Survey



Yukon Geological Survey

Tombstone thrust

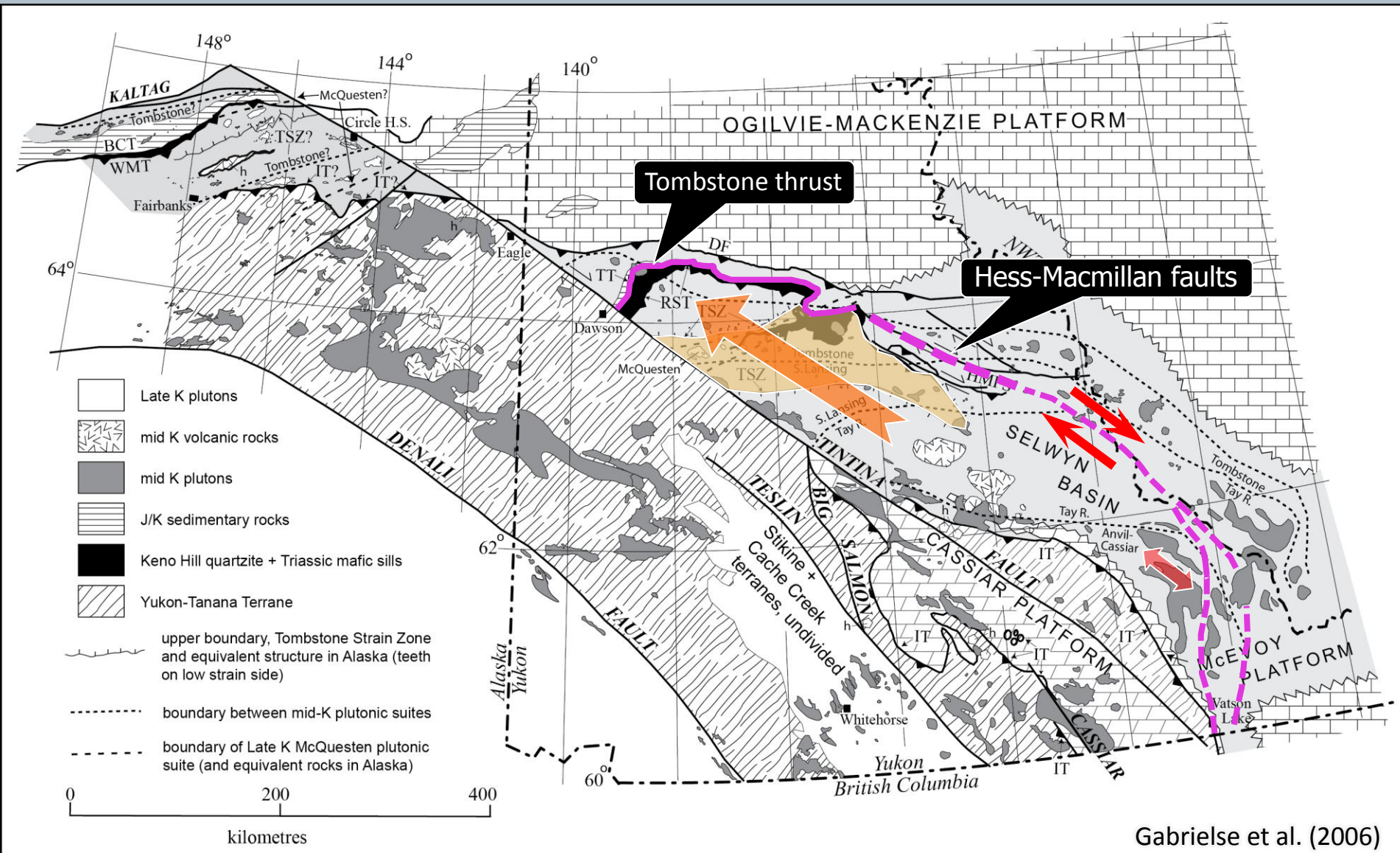


Gabrielse et al. (2006)

NW-directed transport of Tombstone thrust sheet

Yukon Geological Survey

Tombstone thrust

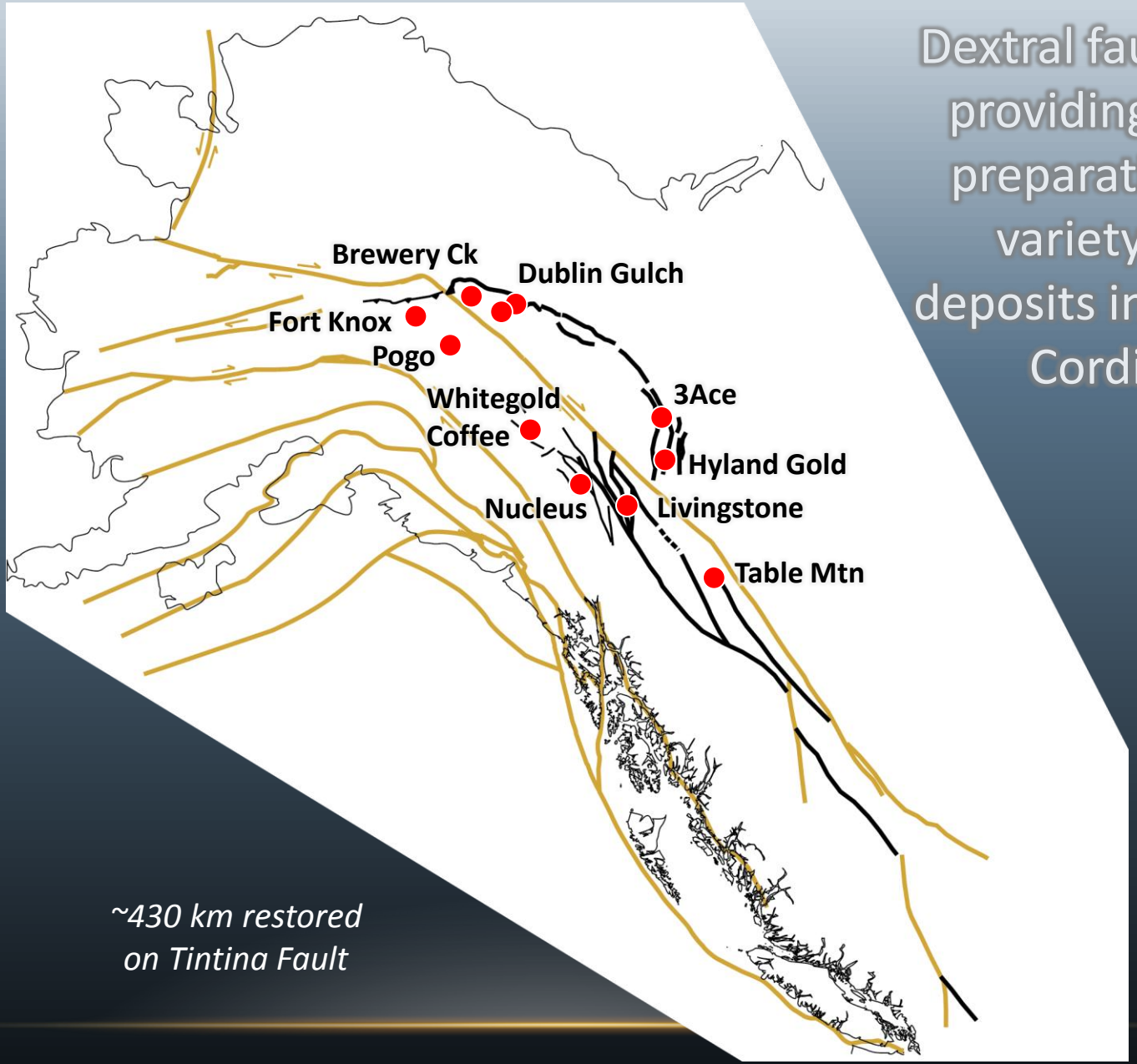


Gabrielse et al. (2006)

NW-directed transport of Tombstone thrust sheet

Yukon Geological Survey

Dextral fault system providing ground preparation for a variety of Au deposits in northern Cordillera



~430 km restored on Tintina Fault

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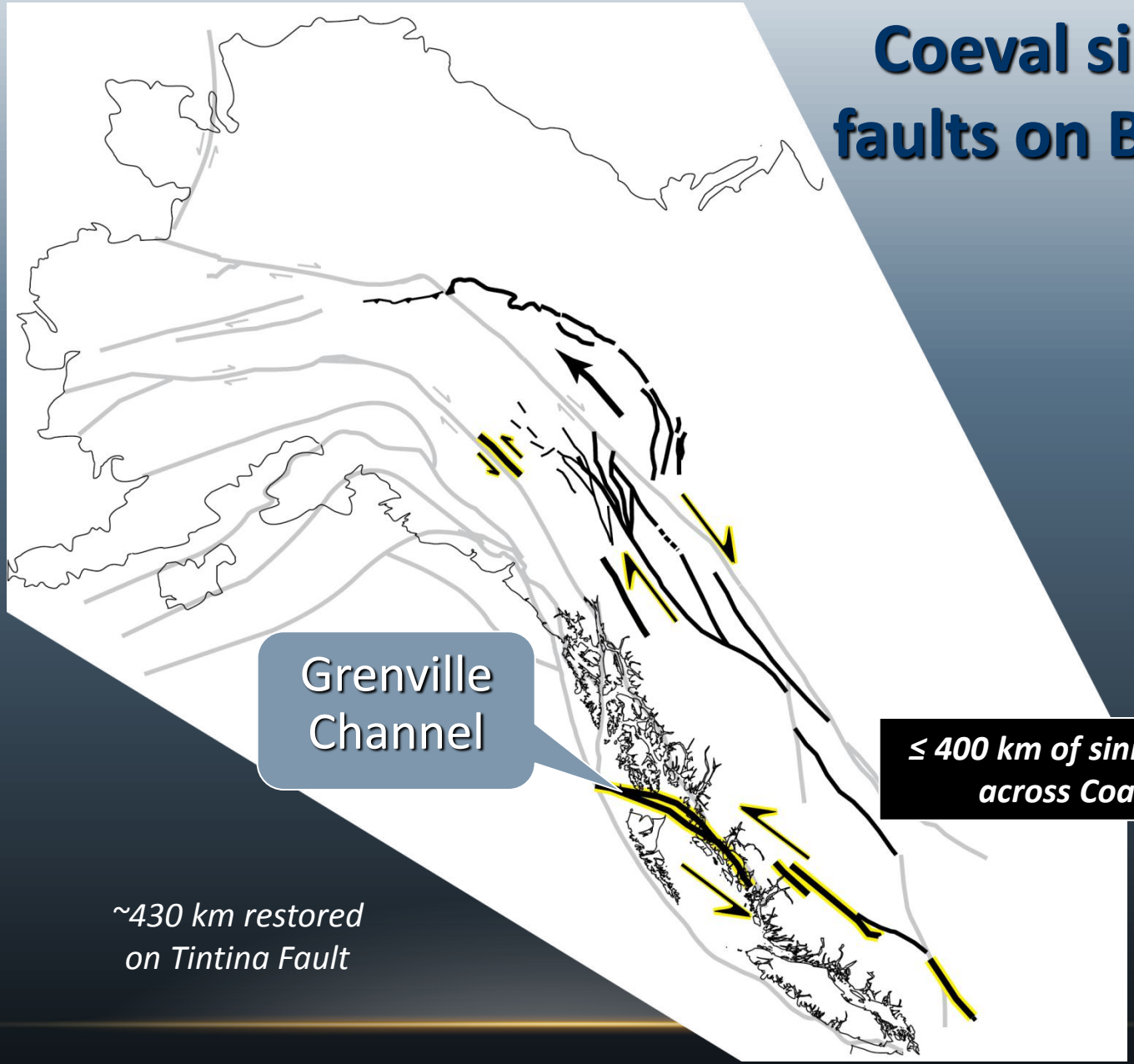
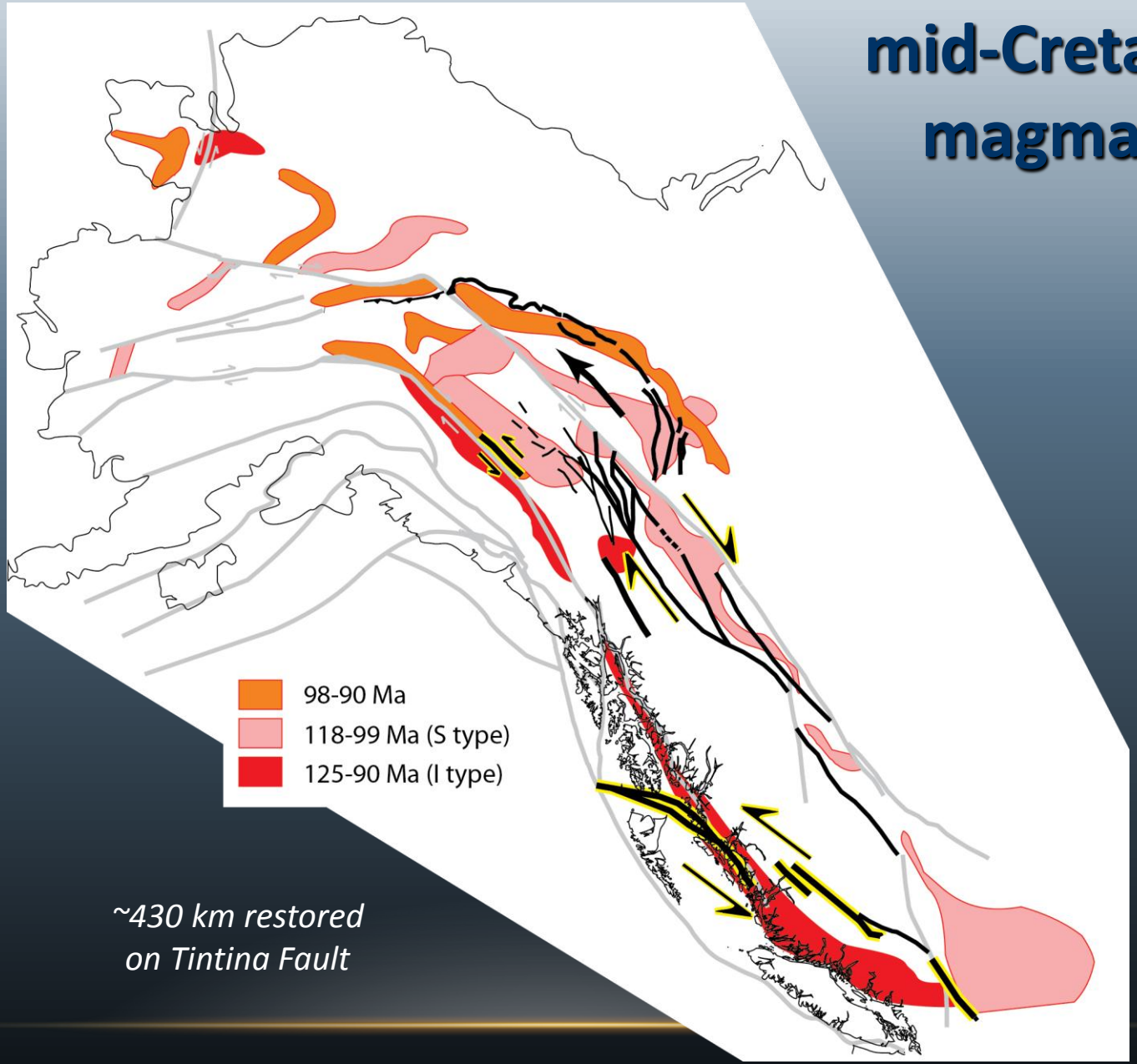
Coeval sinistral faults on BC coast



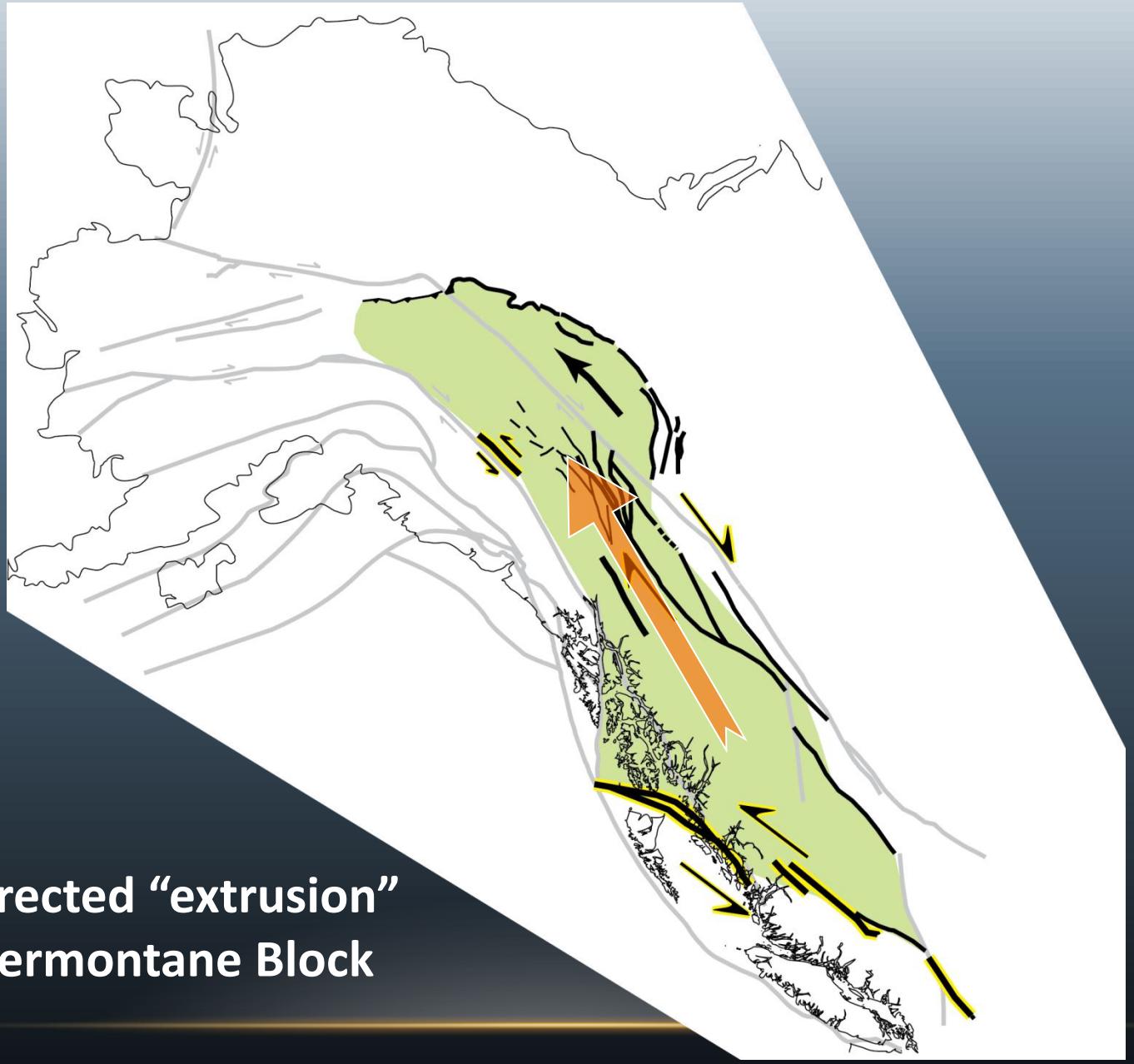
Yukon Geological Survey

mid-Cretaceous magmatism



~430 km restored on Tintina Fault

Yukon Geological Survey



NW-directed “extrusion” of Intermontane Block

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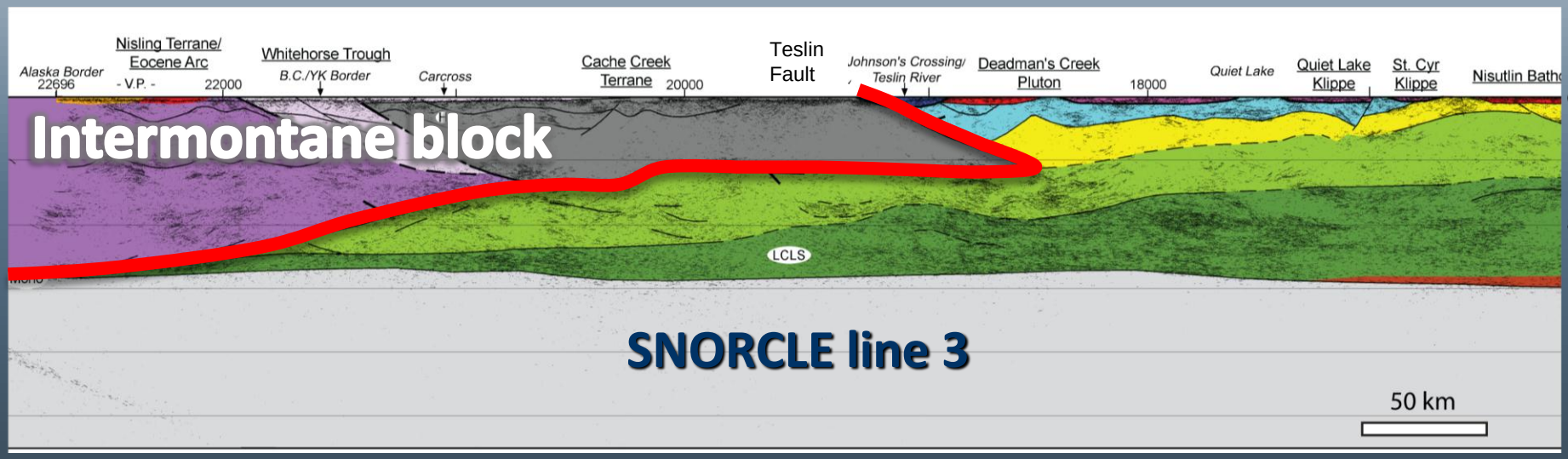
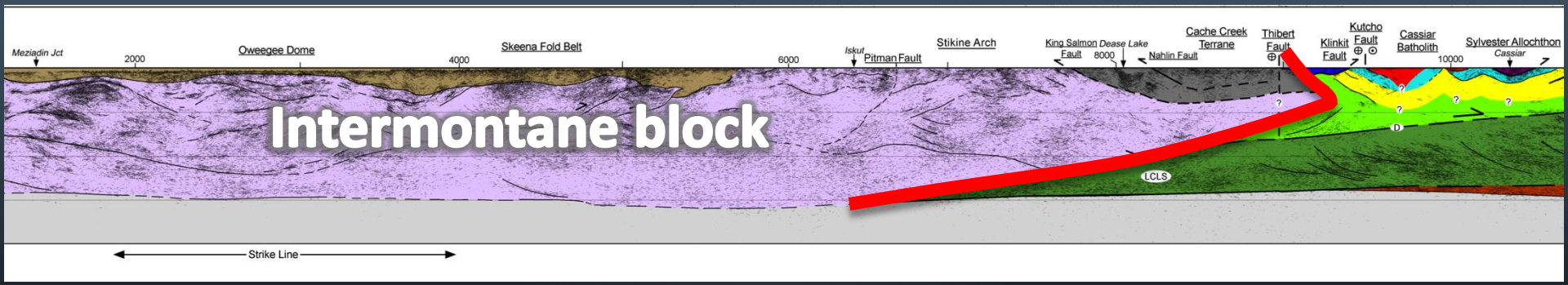
Lithoprobe SNORCLE



SNORCLE line 3



SNORCLE line 2a

Yukon Geological Survey

Cook et al. (2004) - Tectonics

Tectonics and Metallogeny of the British Columbia, Yukon, and Alaskan Cordillera, 1.8 Ga to the Present

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Abstract

The northern Cordilleran Orogen of western Canada and Alaska comprises rocks that
of tectonic history, from cratonization of the Laurentian continental core to current subd
off the west coast today. Evolving tectonic styles, ranging from Proterozoic intracrat
Paleozoic rifting through the construction of Mesozoic and younger intraoceanic and cor
the wide variety of metallogenetic styles that define the mineral wealth of the northern C

The northern Cordillera is made up of five large-scale tectonic provinces: the Laure
margins; allochthonous terranes of the peri-Laurentian realm, that represent offshore rifte
and ocean basins formed in a setting similar to the modern western Pacific province; the
group of crustal fragments that originated in the Arctic realm between Laurentia and Sibe
arately southwards to impinge on the outer peri-Laurentian margin in Mesozoic time; an
ranes, Mesozoic to Cenozoic accretionary prisms that developed along an active Pacific p
tion much like the present one. Each tectonic province carries its own metallogenetic s
accretionary magmatic arcs and compressional and extensional tectonic regimes have als
eral deposit suites. Seafloor hotspring deposits forming presently along the Juan de Fuca
of British Columbia show the continuation of Cordilleran metallogeny into the foreseeab

Résumé

La partie nord de l'orogène de la Cordillère, qui s'étire le long de la côte Ouest du C
des roches témoignant d'une évolution tectonique longue de plus de 1,8 milliard d'anné
tion du noyau continental laurentien, cette évolution se poursuit de nos jours par le dépl
subduction et coulissage. Des styles tectoniques en évolution, depuis la formation d
Protérozoïque jusqu'à la distension continentale au Paléozoïque puis à l'édification d'arcs
marge continentale au Mésozoïque et plus récemment, ont engendré toute une gamme de
minant la richesse minérale du nord de la Cordillère.

La Cordillère septentrionale comprend cinq grandes provinces tectoniques : le craton l
mées; les terranes allochtones du domaine péri-laurentien, constitués de fragments conti
par rifting et dispersés au large, d'arcs et de bassins océaniques formés dans un cadre
province du Pacifique occidental; les terranes arctiques et insulaires, un groupe de fra
domaine arctique entre la Laurentie et la Sibérie, transportés séparément vers le sud et
laurentienne au Mésozoïque; et les terranes du Pacifique d'accrétion tardive, constitués
du Mésozoïque au Cénozoïque, qui se sont formés le long d'une marge active de la plaqu
configuration très semblable à la marge actuelle. Chacune de ces provinces présente une
lui est propre. Les arcs magmatiques post-accrétionnaires et les régimes tectoniques de c
en outre engendré d'importantes successions de gîtes minéraux. Les dépôts de sourc