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J.W. Lydon

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Tectonic evolution of the Belt-Purcell basin: implications for the metallogeny of the Purcell anticlinorium

J.W. Lydon

INTRODUCTION.

This open file contains the slides of a talk given at the Minerals South Conference held in Cranbrook, British Columbia on October 27-30, 2009 organized by the East Kootenay Chamber of Mines. The slides of the original talk have been augmented by additional notes and a reference list for citations on the slides.

The talk released, in graphical form, new information on:
1. Age dating of detrital zircons of Mesoproterozoic sedimentary rocks of the western limb of the Purcell anticlinorium.
2. A stratigraphic profile for sulphur isotopes of diagenetic sulphides of the Purcell Supergroup in British Columbia.
3. Lead isotopes of Zn-Pb-Ba deposits on the western limb of the Purcell anticlinorium.

These new data give cause for a re-assessment of stratigraphic correlation of upper Purcell strata between the eastern and western limbs of the Purcell anticlinorium. In turn, the reassessment points to the possible existence of a major synsedimentary fault system that affected strata of the Dutch Creek Formation. This fault system could have importance for exploration for Zn-Pb deposits.

In view of the great interest shown by mineral explorationists in the content of the talk at the Minerals South Conference, the information is released as an open file so that it would be readily available to a wider audience.

CONTEXT OF INVESTIGATIONS.

The Mesoproterozoic Purcell Supergroup of southeastern British Columbia and the equivalent Belt Supergroup in the adjacent U.S.A. is an intracontinental rift filled by marine and fluviatile sediments (SLIDE 01). Rocks of the rift basin have an unusually high metal endowment resulting from both Mesoproterozoic and Jurassic-Cretaceous metallogenetic events. Mineral deposit types (SLIDE 01, SLIDE 12) include synsedimentary seafloor massive sulphides of both the Sedex (e.g. Sullivan, B.C.; Sheep Creek, Montana) and Besshi (e.g. Blackbird, Idaho) types; syndiagenetic disseminated sulphides of both the Cu (e.g. Spar Lake, Montanore, and Rock Creek, Montana) and Zn-Pb types (e.g. Star, Canam, B.C.); post-lithification Pb-Zn-Ag veins (e.g. Coeur d'Alene district, Idaho); Mesozoic porphyry deposits (e.g. Butte, Montana) as well as major historical production of placer gold (Lydon, 2007). In southeastern British Columbia, the Purcell Supergroup outcrops in the Purcell anticlinorium, and with its outstanding record of past mineral production, the Purcell

Supergroup has been a prime focus of the Cordilleran Project of the Geological Survey of Canada's Targeted Geoscience Initiative (TGI-3) program. The purpose of this program has been to provide a new geoscience infrastructure for areas with established base metal mining communities.

The major base metal producer of the Belt-Purcell basin in Canada has been the Sullivan deposit, which at the time of its closure at the end of 2001, was Canada's longest-lived continuous mining operation and had produced Zn-Pb-Ag ores worth nearly $30 billion in terms of average 1996-2005 metal prices adjusted for inflation to 2005 Canadian dollars (Lydon, 2007). Sedex deposits, of which Sullivan is an example, are sea floor hydrothermal Zn-Pb-(Cu) sulphide deposits and are a prime exploration target because of their characteristic large tonnages. Most Sedex deposits occur in sediments that accumulated during the sag phase of intracontinental or epicontinental rifts (Lydon, 1996). Sullivan is one of the few exceptions and occurs in sediments that accumulated during the early rifting stage of the rift cycle. Mineral exploration within the Purcell anticlinorium over the past several decades has focused on finding another Sullivan-type deposit. Exploration strategies have generally been based on a "Sullivan model", so that nearly all exploration expenditure for Sedex deposits has been targeted towards the Aldridge Formation, which forms the rift-fill in the lower part of the Purcell Supergroup (SLIDE 01), to the neglect of the upper part of the supergroup that represents the sag phase of the Belt-Purcell rift.

An emphasis of the Cordilleran Project of the TGI-3 program was to investigate whether there is any evidence to encourage exploration for base metal deposits in the rift sag sequence of the Purcell Supergroup, particularly in those strata younger than the lavas of the Nicol Creek Formation. In the Purcell anticlinorium, these strata have been collectively referred to as the Dutch Creek Formation Formation (Walker, 1926) but on the eastern limb of the Purcell anticlinorium they have been divided into the Sheppard, Gateway, Phillips and Roosville formations (Höy, 1993 and references therein). This open file summarizes some of these investigations.

SCIENTIFIC SUMMARY

Sedex deposits are spatially associated with synsedimentary faults (e.g. Lydon, 1996). In the Belt-Purcell basin, major synsedimentary faults are metallotects. For example, the Lewis and Clark line, a zone of major Mesozoic strike-slip, dip-slip and oblique-slip faulting, has origins in antecedent Mesoproterozoic faults (e.g. Wallace et al., 1990) that control Ag-Pb mineralization of the Coeur d'Alene Ag-Pb-Zn district (Mauk and White, 2004) and along which also occur the Spar Lake red bed Cu-Ag district, the Blackbird Cu-Co district and the Sheep Creek Sedex deposit (SLIDE 01A and SLIDE 12). The timing of the Sullivan deposit is related to a tectonic event which suddenly deepened the northern part of the basin (Höy et al., 2000). An understanding of the tectonic evolution of the Belt-Purcell basin is therefore one of the keys to understanding its metallogeny, which in turn may lead to identifying new mineral exploration targets.

At a continental scale, the Belt-Purcell basin accumulated in the distal foreland of a Cordilleran-type orogen that formed the southern continental margin of Laurentia, from which much of its detritus was derived (Link et al., 2007) (SLIDES 03 through 07). However, north of the Lewis and Clark line, especially in the western part of the basin, most of the detritus was derived from a western continent containing abundant 1490-1640 Ma magmatic rocks. Magmatic rocks of this age are rare in the North America - the North American magmatic gap of van Schluss et al., (1993) (SLIDES 08 through 10). Interpretation of the Belt-Purcell basin as a pull-apart basin along a strike-slip or oblique-slip convergent margin of Laurentia with this western continent (Ross and Villeneuve, 2003) (SLIDES 11 and 12) gives different context to tectonic events than the interpretation of the basin as a passive rift e.g. Chandler (2000).

Synsedimentary faulting within the Dutch Creek Formation has been recognised by mapping abrupt changes in thickness of lithological units (Höy, 1993; Gardner, 2008). Much of this synsedimentary faulting took place during deposition of the Sheppard and Gateway formations (SLIDE 13). These tectonic disturbances are reflected in the sulphur isotope excursions of diagenetic sulphides (SLIDE 14). The aggregate difference in thickness of post-Aldridge and pre-Mount Nelson stratigraphic units between the Northern Hughes Range and the Purcell Mountains is about 2.5 km. Assuming that this difference in sediment thickness has been accommodated by vertical movement on synsedimentary faults then at least 2.5 km of vertical movement took place across the eastern walls of the pull-apart basin (or rhombochasm) after deposition of the Aldridge Formation but prior to deposition of the Mount Nelson Formation (SLIDE 13). Major vertical movements, identified by prominent synsedimentary faults and at least one unconformity, are recognized at the stratigraphic levels and at the approximate ages indicated on Slide 13. The aggregate amount of displacement decreases with decreasing age. The displacement is about 2.5 km at the base of the Creston; about 1.8 km at the top of the Kitchener, 1.5 km at the top of the Nicol Creek, and about 0.2 km at the base of the Roosville, and of course 0.0 km at the base of the Mount Nelson which is the youngest Mesoproterozoic stratigraphic level considered here and is used as a horizontal datum in SLIDE 13.

The amount of stratigraphic displacement of the boundary between diagenetic pyrrhotite and diagenetic pyrite across the same synsedimentary faults of the eastern walls of the rhombochasm is also about 2.5 km (SLIDE 15), the boundary being within the Creston Formation in the Purcell Mountains but in the lower part of the Middle Aldridge in the Northern Hughes Range. The plane marking the upper limit of diagenetic pyrrhotite is concordant with bedding and of regional extent (SLIDES 16 and 17), and is interpreted to represent a horizontal hydrologic boundary between pore fluids of contrasting density and chemical composition at the time of diagenesis. The stratigraphic displacements along this paleo-horizontal plane indicates that at the time the diagenetic Py-Po signature was imprinted on the rocks, there had been a post-Aldridge vertical displacement of 2.5 km between strata of the Purcell Mountains and strata of the Northern Hughes Range. This is the amount of post-Aldridge and pre-Mount nelson vertical movement across the eastern margin of the rhombochasm calculated from differences in thickness of stratigraphic units between the two areas, and indicates that the diagenetic sulphide signature was being imprinted at depth while the uppermost part of the Dutch Creek Formation was being deposited. The formation of diagenetic pyrrhotite at the time of depositionof upper Dutch Creek Foramtion strata implies that highly reduced pore fluids, similar to those that formed the Sullivan deposit, still existed at a depth of about 5 km within the rhombochasm on the eastern limb of the Purcell anticlinorium (SLIDE 18). These fluids represent a hydrothermal reservoir with potential to form Sedex deposits in the Dutch Creek Formation.

The only significant mineralization that has been mapped as being in the Dutch Creek Formation are Zn-Pb±Ba deposits in carbonate rocks on the western limb of the Purcell anticlinorium (see

SLIDE 23). Ores of the larger of these deposits, the Mineral King and the Legion, are typically laminated and reminiscent of the characteristic laminated textures of Sedex deposits. However, the rocks are highly deformed, and the lamination may be gneissic or mylonitic textures caused by extreme tectonic flattening or shearing.

The high degree of deformation of the host rocks makes correlation of them with the stratigraphy on the eastern limb of the Purcell anticlinorium problematical, and strata of the western limb of the Purcell anticlinorium have been separated as the Coppery Creek and La France Creek groups (Reesor, 1996). The new detrital zircon data from the western limb of the Purcell anticlinorium indicates that clastic rocks immediately below the host carbonate to the Zn-Pb±Ba deposits were derived from the western continent (SLIDE 19). Missing are rocks containing detrital zircons of syn-Belt-Purcell age in the 1445-1380 Ma Range, typical of the Dutch Creek Formation on the eastern limb of the Purcell anticlinorium (Gardner, 2008) and the stratigraphically equivalent Missoula Group elsewhere in the Belt-Purcell basin (Ross and Villeneuve, 2003). However, detrital zircon signatures for the Mount Nelson Formation, which immediately overlies the host carbonates, are identical to the Mount Nelson on the eastern limb of the Purcell anticlinorium (SLIDE 20). These detrital zircon data suggest a substantial hiatus below the Mount Nelson Formation on the western limb of the Purcell anticlinorium (SLIDE 21), or, alternatively, an unrecognized bedding parallel fault near the base of the Mount Nelson which suppresses the outcrop of Dutch Creek Formation. If a depositional hiatus, and the carbonates hosting the Zn-Pb±Ba deposits are equivalent to the Kitchener Formation, then a synsedimentary fault system with a ~4 km vertical displacement is implied. This magnitude of vertical displacement on this synsedimentary fault system may have been great enough to produce a hydraulic head sufficient to cause sea floor discharge of the hydrothermal reservoir contained in Creston and older rocks (SLIDE 22). The trace of the synsedimentary fault zone would be approximately between the trace of the Hall Lake fault and the Redding Creek fault (SLIDE 23).

Lead isotopes of galena (SLIDE 24) in the (SLIDE 23) indicate a mixture of lead segregated from uranium and thorium during the Mesoproterozoic and lead segregated from uranium and thorium during the lower Paleozoic (SLIDE 25). Lead isotope ratios of the Paleozoic end member are very similar to Zn-Pb deposits that are hosted in Cambrian carbonates elsewhere in southeastern British Columbia and Washington State. Most of these deposits also contain barite. The major difference between these deposits and those on the western limb of the Purcell anticlinorium may be the much higher degree of deformation of the latter (SLIDE 26). All these deposits occur within a narrow, linear, north-south corridor nearly 200 km long (SLIDE 27). This corridor also contains the suggested Dutch Creek synsedimentary fault zone. The longevity of this linear feature in controlling faulting during the Mesoproterozoic, controlling fluid flow during the lower Paleozoic and controlling the location of faults during Jurassic-Cretaceous thrusting suggests that the fault reflects a structure in the basement to Mesoproterozoic rocks. This basement structure is now hundreds of kilometres to the west because of the eastward translation of Mesoproterozoic and younger cover rocks with respect to the basement during Jurassic-Cretaceous thrusting.

CONCLUSIONS AND IMPACTS.

New detrital zircon ages and a new stratigraphic sulphur isotope profile of the Purcell Supergroup both support the interpretation of a major synsedimentary fault system along the western limb of the Purcell anticlinorium involving about 4 km of vertical displacement during deposition of the Sheppard and/or Gateway Formations.

Geological maps of the western limb of the Purcell anticlinorium need to be revised in light of these new data that indicate the Dutch Creek Formation is missing in that area.

Lead isotope ratios of galena from Zn-Pb±Ba deposits on the western limb of the Purcell anticlinorium indicate that these deposits are part of a lower Paleozoic metallogenic event that produced carbonate-hosted Zn-Pb deposits along a metallotect that extends from near Creston to the Kicking Horse Pass in the Rocky Mountains. The metallotect probably reflects a structure in the Paleoproterozoic-Archean crystalline basement because of the longevity of its geological influence.

ACKNOWLEDGEMENTS.

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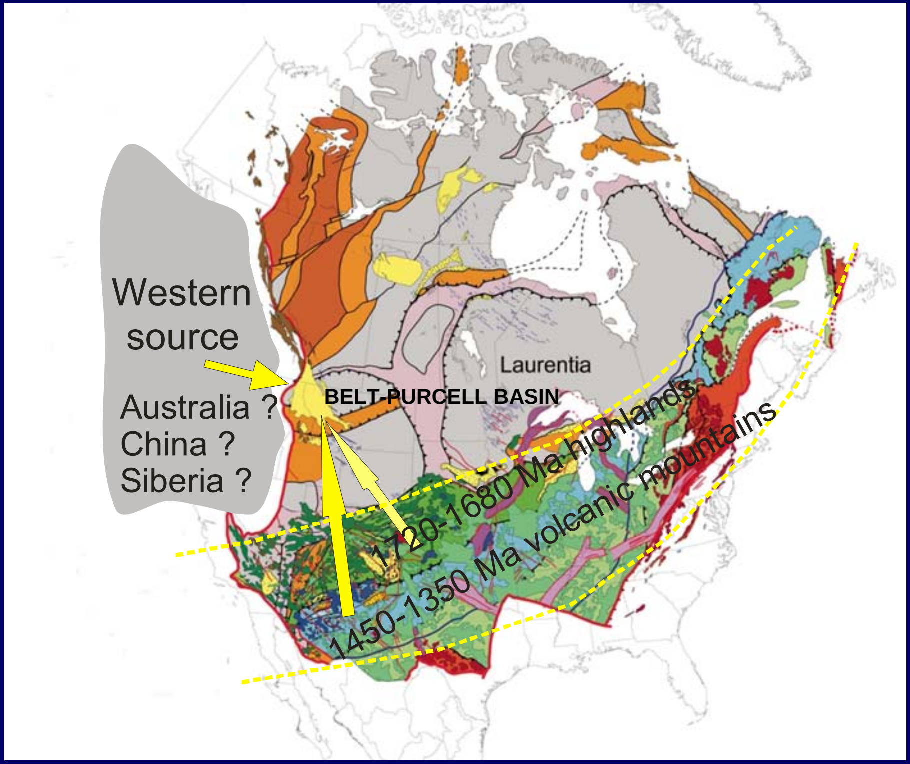
Geological Survey of Canada Open File 6411

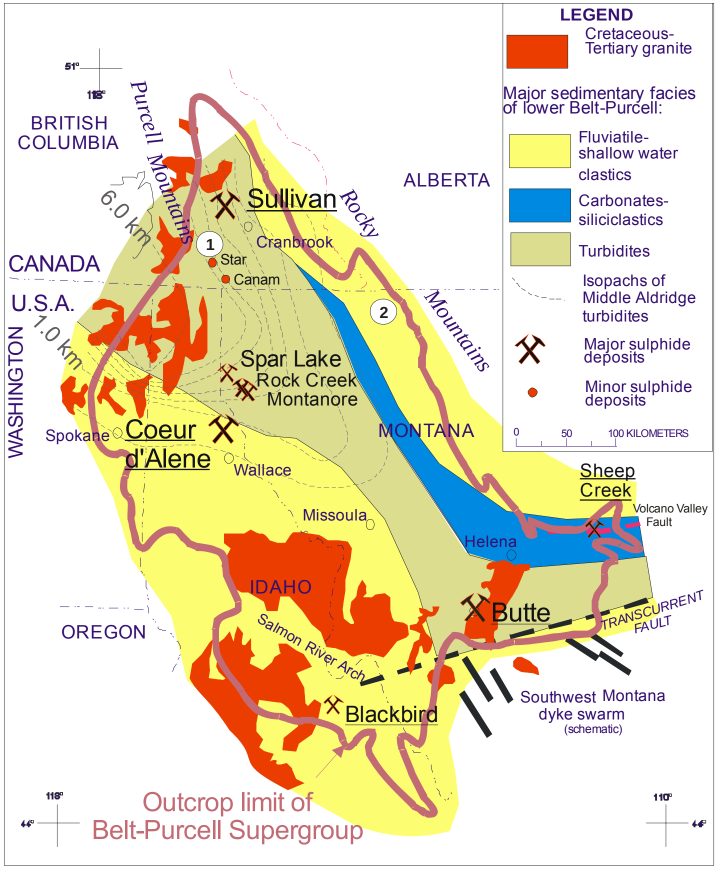
Tectonic evolution of the Belt-Purcell basin: Implications for Metallogeny of the Purcell Anticlinorium



John W. Lydon
Geological Survey of Canada, Ottawa.

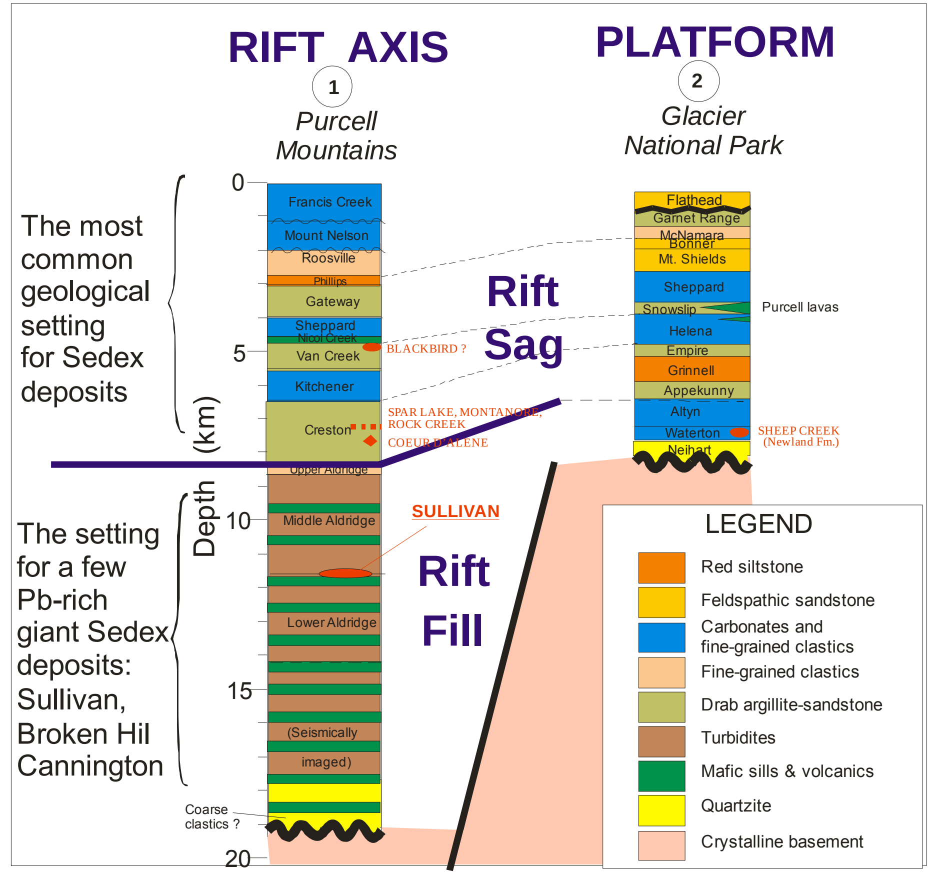
Minerals South Conference, Cranbrook, October, 2009

A. Map of Belt-Purcell Basin



Outcrop extent of the Belt-Purcell Basin, the locations of major mineral deposits, and the simplified distribution of sedimentary facies of the lower part of the Belt-Purcell Supergroup (i.e. Aldridge-Pritchard formations and stratigraphic equivalents). Numbers refer to profiles in B.

B. Stratigraphic profiles of Belt-Purcell Basin



A major emphasis of TGI-3 work has been to better understand the geological evolution and metallogeny of the rift sag sequence

After Lydon, 2007

SLIDE 01

MAIN POINT

There are converging lines of evidence to suggest a major, north-trending Mesoproterozoic fault system along the western edge of the Purcell anticlinorium, and that this fault system became a lower Paleozoic metallotect.

OUTLINE OF TALK

- 1. Review Proterozoic tectonic evolution of Laurentia and initiation of Belt-Purcell basin – a back-arc basin.

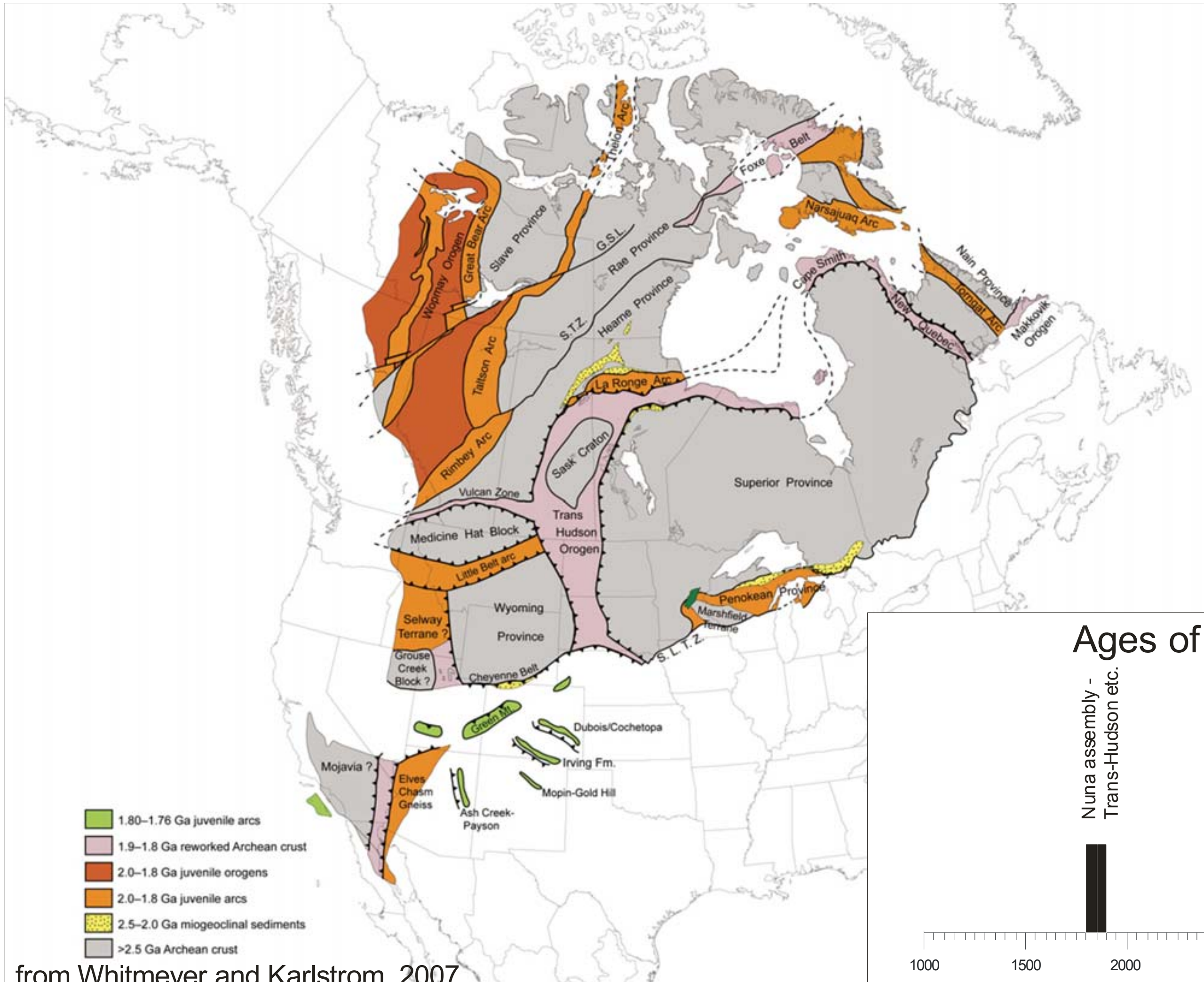
- 2. Review architecture and evolution of Belt-Purcell basin, based on evidence from:
  - detrital zircon ages,
  - synsedimentary faulting
  - sulphur isotopes of diagenetic sulphides.

- 3. Using these constraints, show that during the upper part of the Purcell Supergroup the Purcell rhombochasm must have a major north-trending synsedimentary fault system along what is now the western edge of the Purcell anticlinorium.

- Discuss interpretation of Pb isotopes of Zn-Pb deposits which occur near this suggested fault system.

SLIDE 02

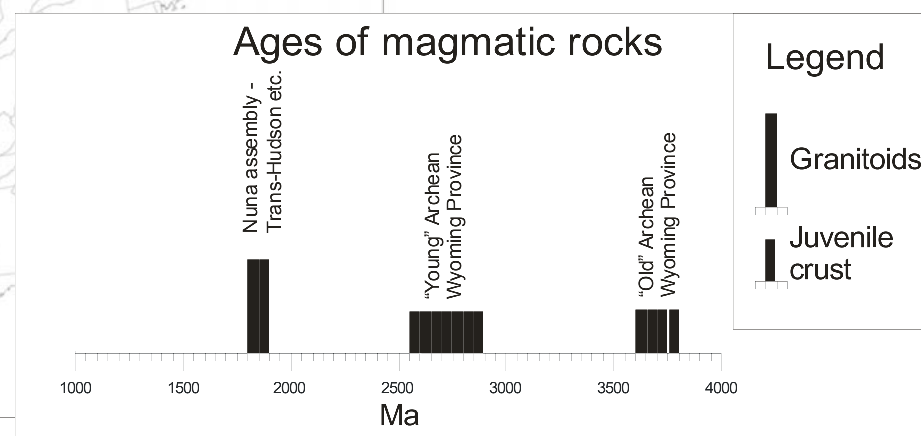
Tectonic evolution of Belt-Purcell Basin - Pre-1800Ma



from Whitmeyer and Karlstrom, 2007.

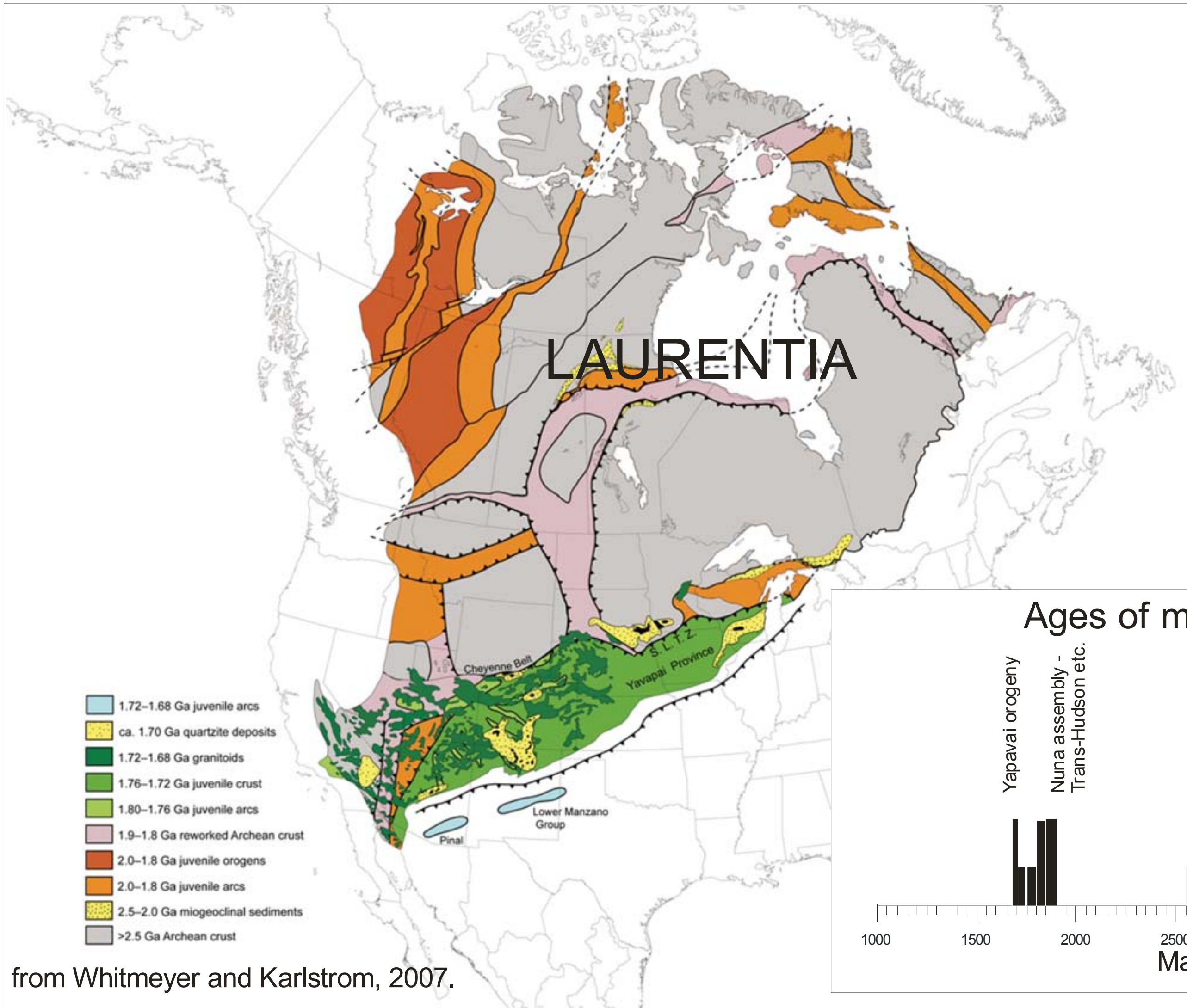
Belt-Purcell basin deposited on a basement of Archean and Paleproterozoic rocks of Nuna supercontinent.

Assembly of Nuna supercontinent complete by 1800 Ma



SLIDE 03

Tectonic evolution of Belt-Purcell Basin - 1680 Ma

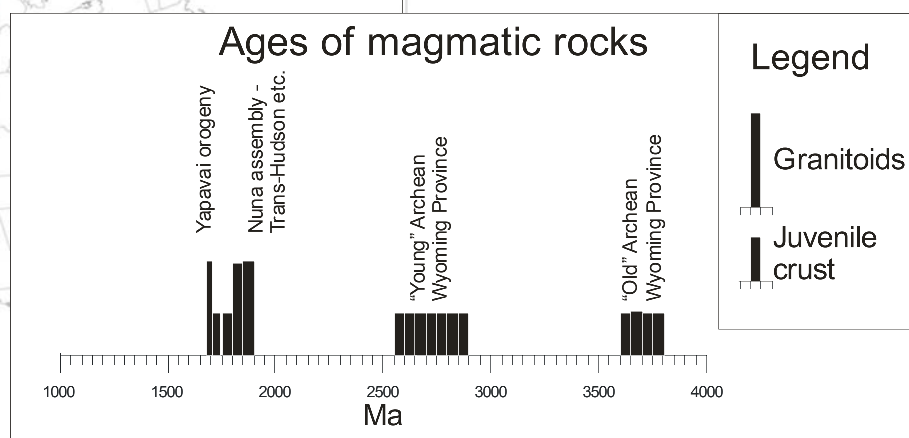


from Whitmeyer and Karlstrom, 2007.

After 1800 Ma, Nuna supercontinent expand by accretion along the south-eastern margin of Laurentia.

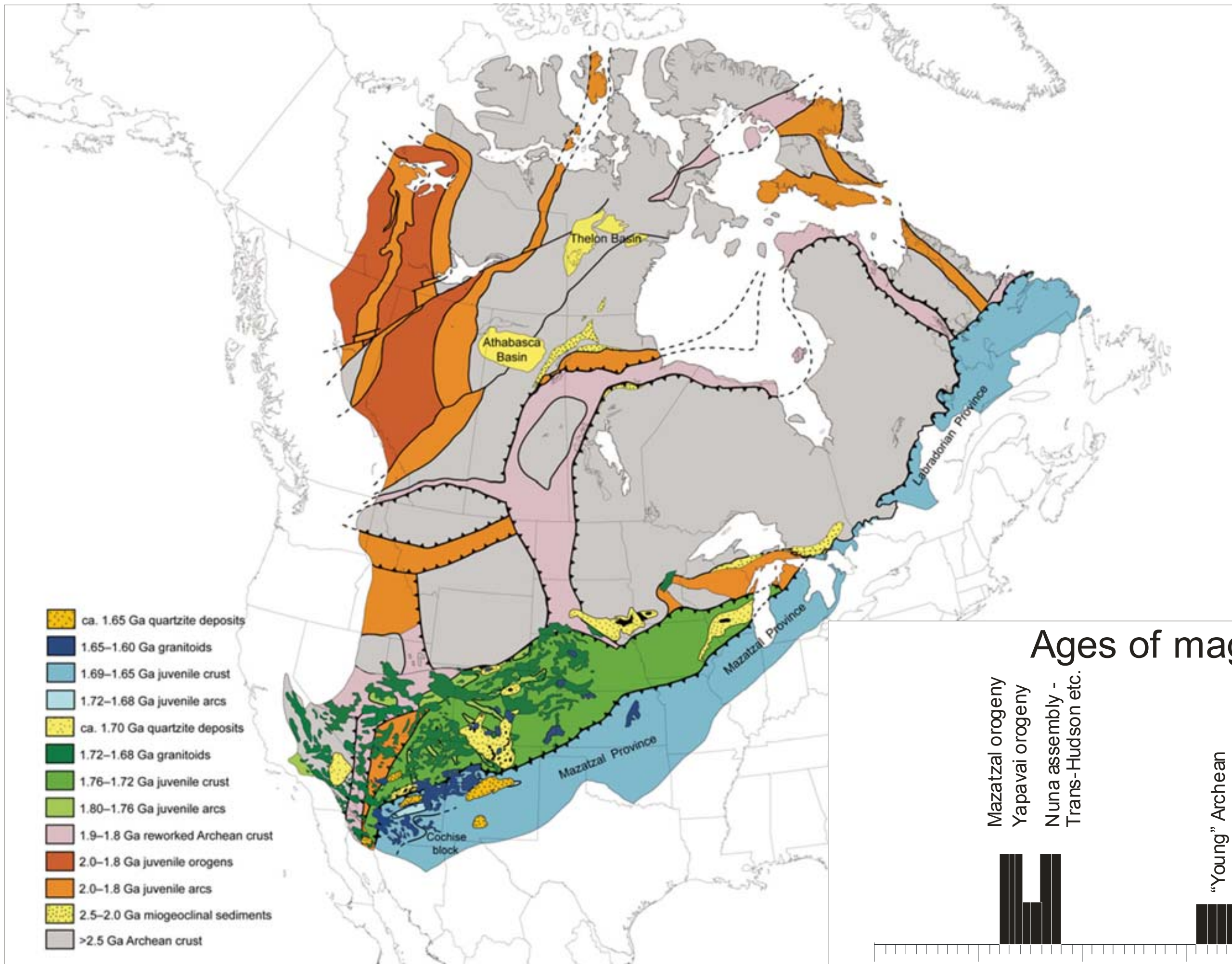
First major event is accretion of 1.8-1.7 Ga juvenile crust during the 1.71--1.68 Ga Yavapai orogeny.

Most granitoids in west



SLIDE 04

Tectonic evolution of Belt-Purcell Basin - 1600 Ma

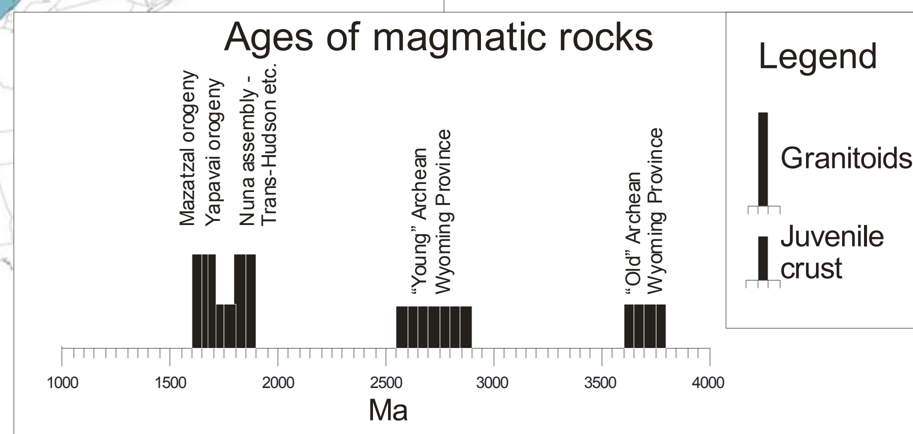


from Whitmeyer and Karlstrom, 2007.

Second major event is accretion of 1.7-1.6 Ga juvenile crust during the 1.65-1.60 Ga Mazatzal orogeny.

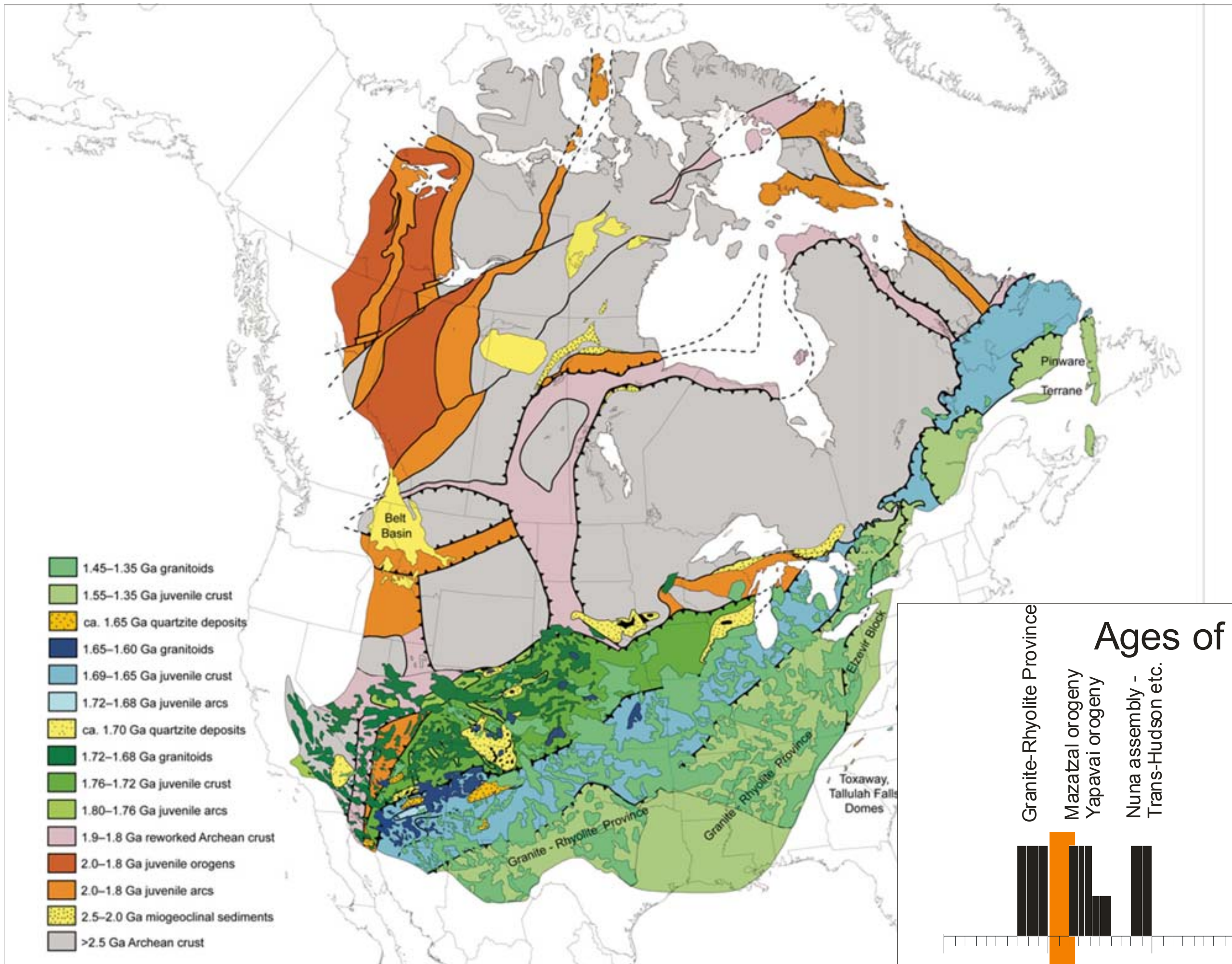
Again, most granitoids in west.

Last major tectonic event on south-east margin of Laurentia prior to initiation of Belt-Purcell basin at ~1.5 Ga



SLIDE 05

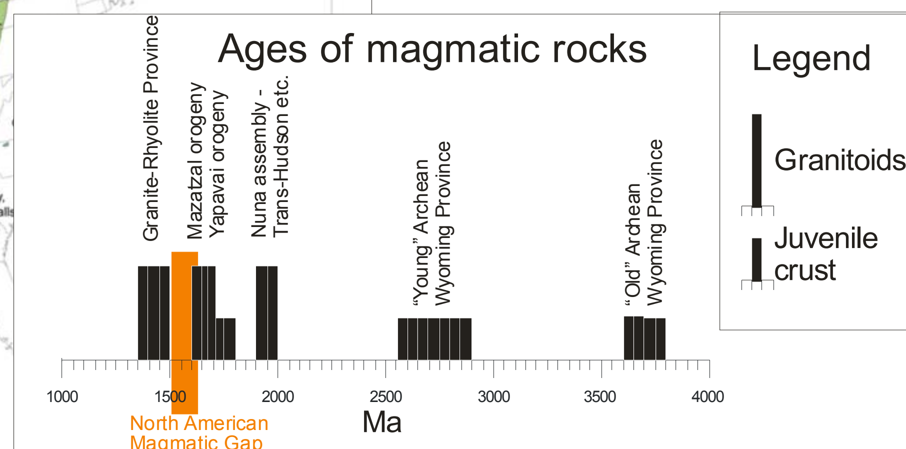
Tectonic evolution of Belt-Purcell Basin - 1435 Ma



from Whitmeyer and Karlstrom, 2007.

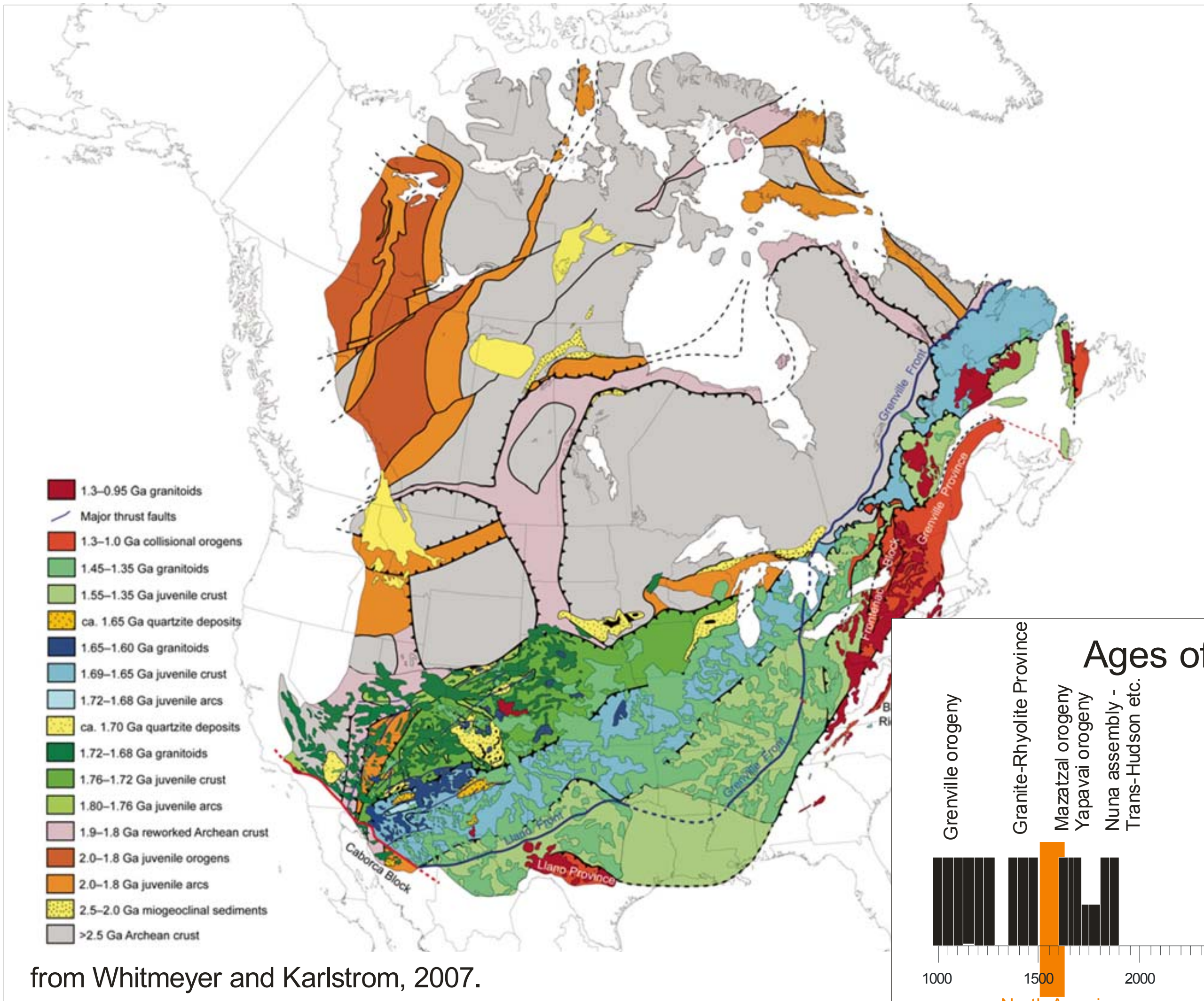
Third major event is accretion of 1.5-1.4 Ga juvenile crust during 1.48-1.35 Ga magmatism and metamorphism of the Granite-Rhyolite Province.

Note the "North American Magmatic Gap" (Van Schmus et al., 1993) at 1.64-1.49 Ma.



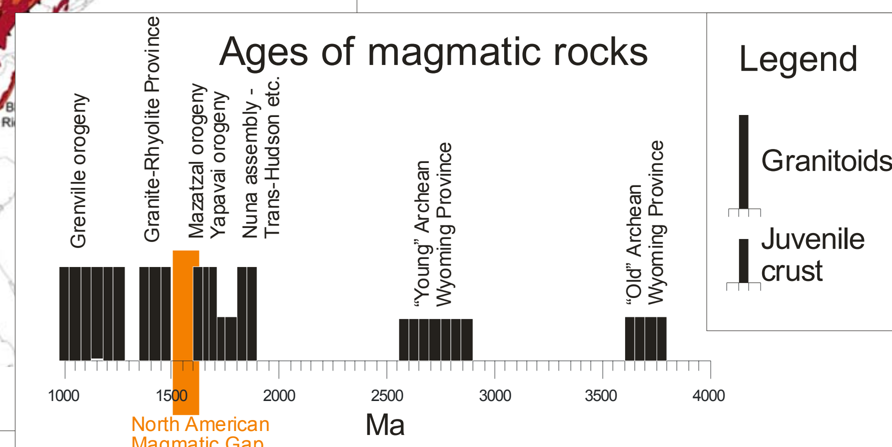
SLIDE 06

Tectonic evolution of Belt-Purcell Basin ~1000 Ma



from Whitmeyer and Karlstrom, 2007.

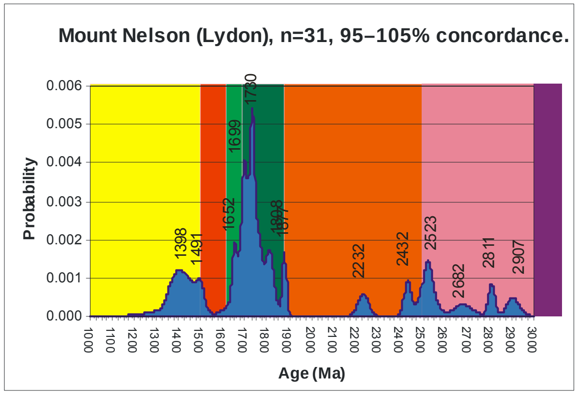
The final Proterozoic accretionary events on the southeast margin of Nuna are the 0.95 - 1.3 Ga continent-continent collisions of the Grenville orogeny to form the Rodinia supercontinent.



SLIDE 07

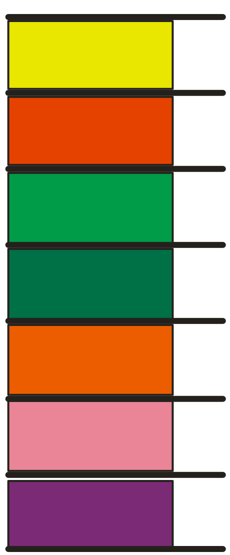
GROUPING OF DETRITAL ZIRCON AGES

Example:



Grouping of probability peaks for detrital zircon for all data for Belt-Purcell sedimentary rocks according to their overall frequency of association produces groups that closely correspond to age groupings of recognized magmatic events.

Age of detrital zircons



1000 Ma

Syn-sedimentary magmatism; Granite-Rhyolite Province; Western continent.

1498 Ma

Western continent - North American magmatic gap.

1615 Ma

Mazatzal Province magmatism.

1686 Ma

Yavapai Province magmatism.

1800 Ma

Mojave Province; Trans-Hudson and other Paleproterozoic orogens of Laurentia

2500 Ma

Arbitary division of Paleoproterozoic from Archean of Laurentia

3000 Ma

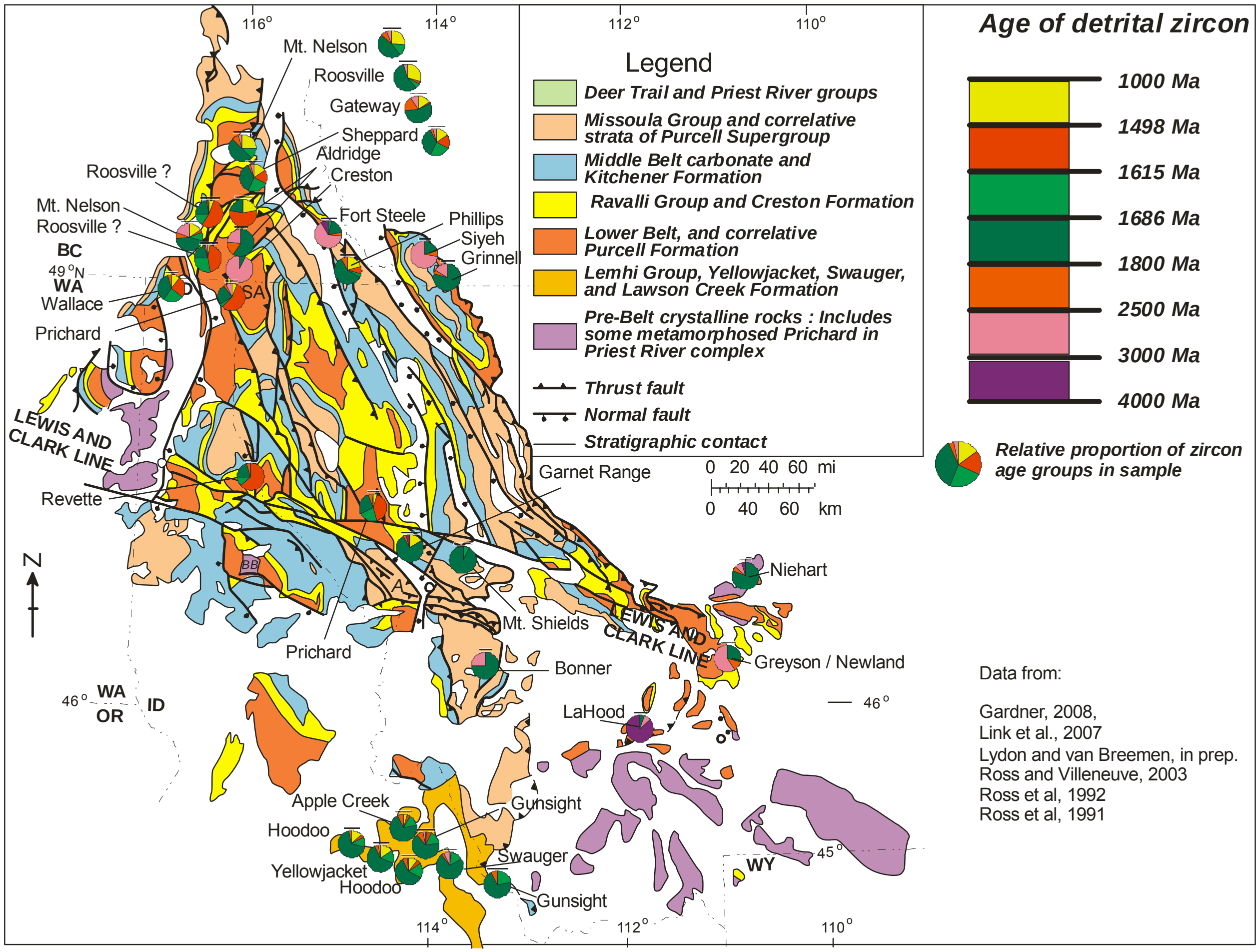
Arbitary division of Archean of Laurentia

4000 Ma

SLIDE 08

Geological Map of Belt-Purcell Basin

(after Winston and Link, 1993)



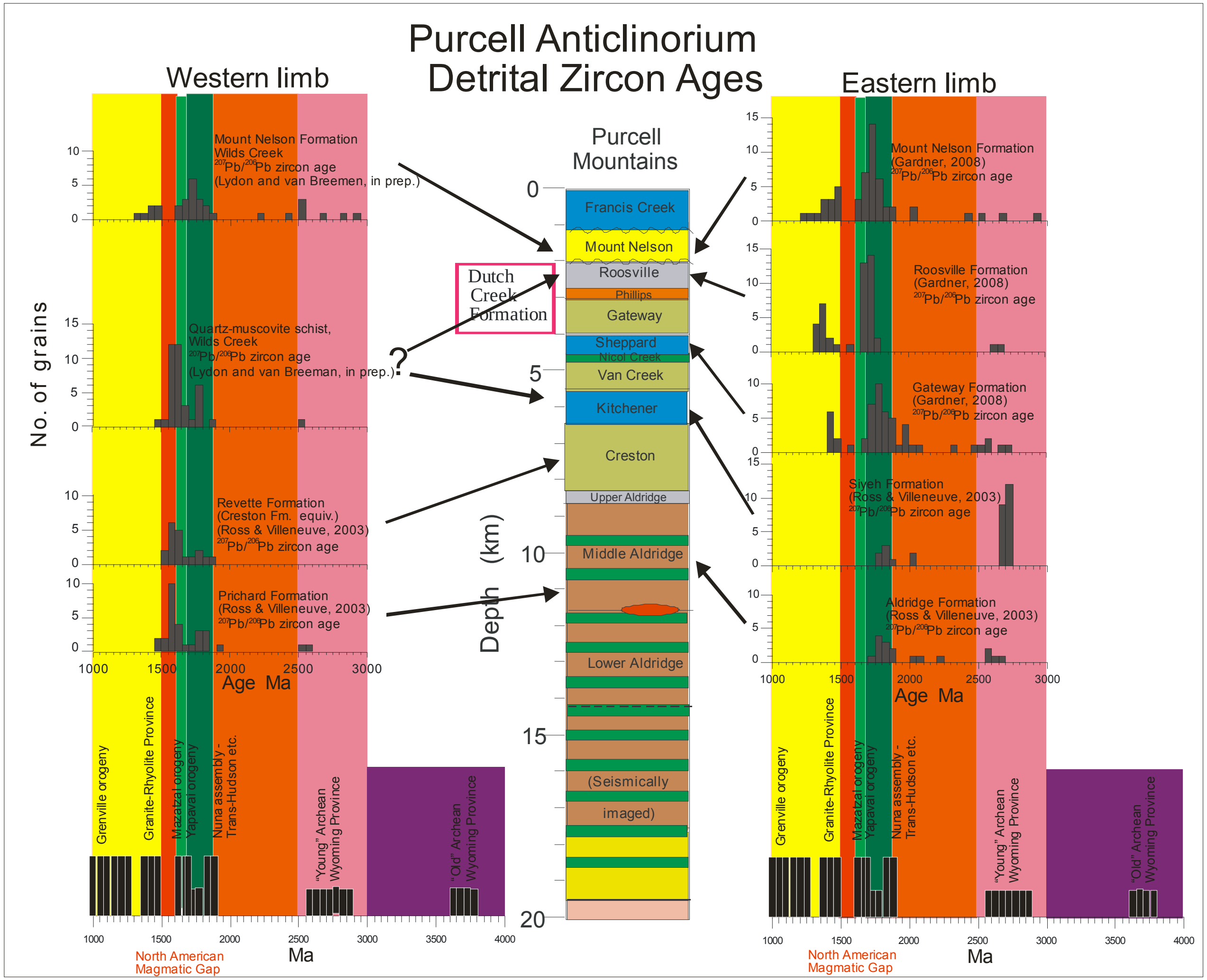
Detrital zircon sample locations and sediment provenance

Detritus derived from the western source occurs mainly in the western part of the basin.

Ratio of 1686-1800 Ma (Yavapai age) to 1615-1685 Ma (Mazatzal age) zircons is <2:1 for detritus from the western source but >3:1 for other detritus.

Abundant zircons with synsedimentary ages occcur mainly in Missoula Group and correlative strata.

SLIDE 09

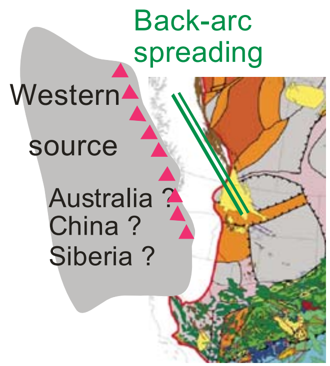


Ages of detrital zircons on eastern limb match basement rocks to the southeast and south of Belt-Purcell basin (Archean Wyoming Province; "Trans-Hudson" age Solway Terrain and Little Belt arc); and rocks of the Mazatzan and Yavapai provinces. Detrital zircons from the contemporaneously volcanically active Granite-Rhyolite province are abundant in theSheppard Formation and younger strata.

Ages of detrital zircons on western limb are predominantly within the "North American magmatic gap) and indicate a volcanically active source to the west of the Belt-Purcell basin, that is not part of Laurentia.

SLIDE 10

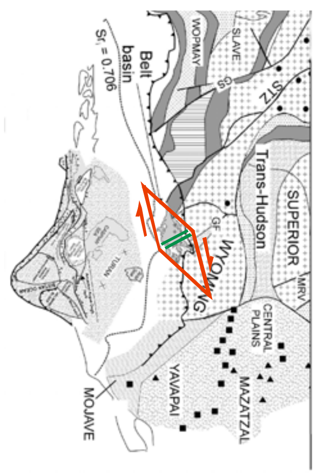
Tectonic significance of Belt-Purcell basin



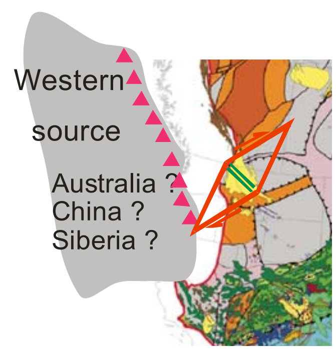
No magmatic or tectonic event along south-eastern margin of Laurentia during the interval 1500-1485 Ma, to initiate the Belt-Purcell basin, though there is a connection in that the first magmatism in Granite-Rhyolite province coincides with 1468 Ma Moyie Sill event in the Middle Aldridge.

Rifting more like to be back-arc spreading associated with the approach of the volcanically active Western Source that supplied zircons as young as 1450 Ma.

Strike-slip pull-apart basin (rhombochasm)



Belt-Purcell basin likely a pull-apart basin along a back-arc strike-slip fault system. (Ross and Villeneuve, 2003)

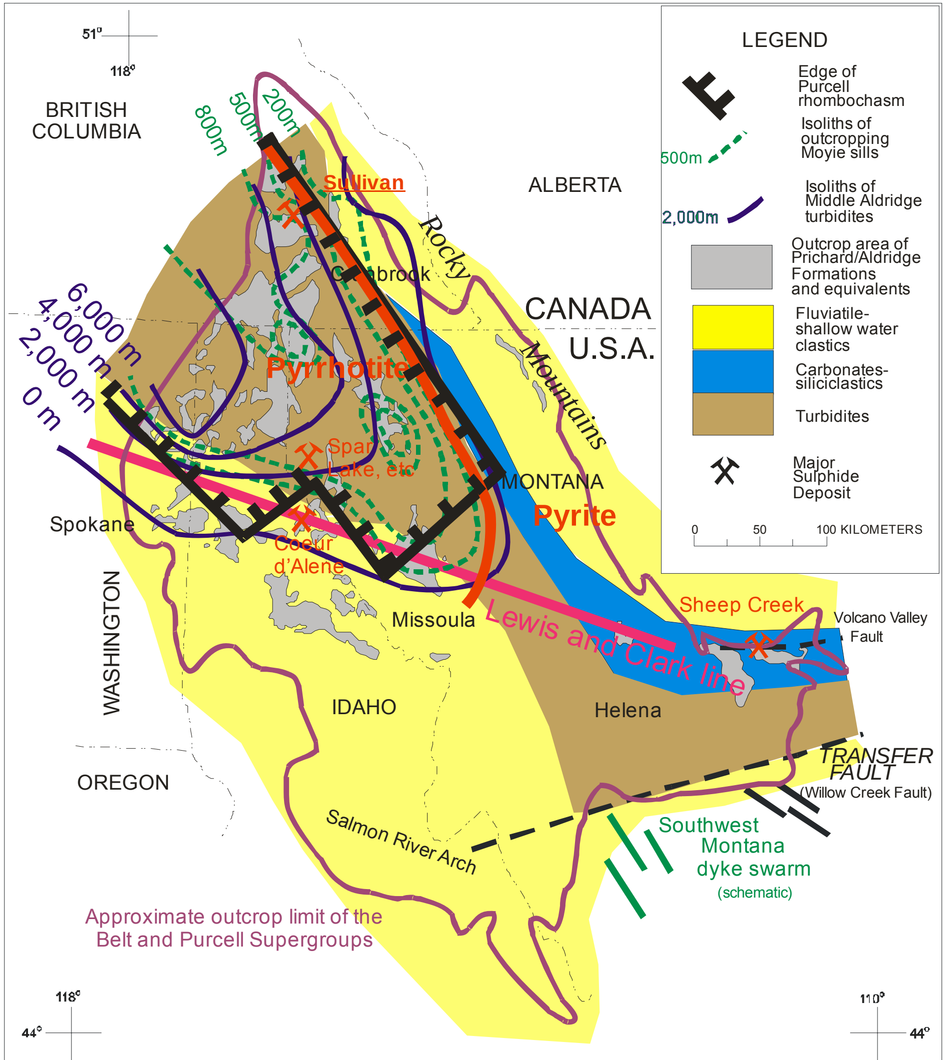


....though considering inferred orientation of extention, strike-slip motion was likely along structural grain of basement (i.e. orientaion of Moyie, St. Mary's, etc. faults)

Belt-Purcell basin is a back arc basin where spreading centres have been segmented by strike-slip transfer faults controlled by the structural grain of the basement

Belt-Purcell basin

Major sedimentary facies of lower part of Belt-Purcell supergroup



Interpretation of the thickest part of the rift-fill sequence as an infilled rhombochasm gives an explanation to:

Isoliths of Middle Aldridge turbidites.

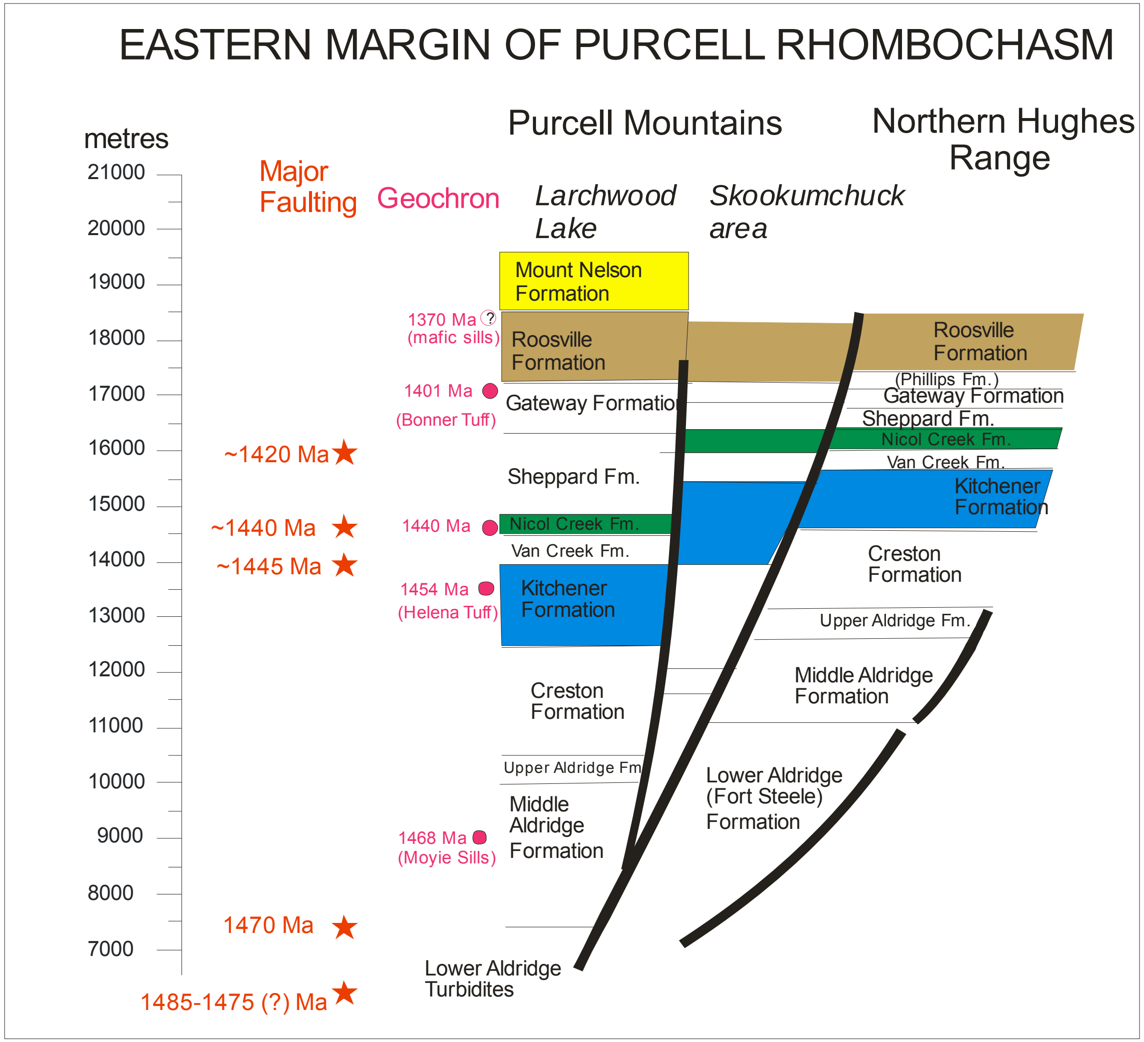
Isoliths of outcropping Moyie Sills

Distribution of Pyrrhotite versus Pyrite as the dominant diagenetic iron sulphide.

Note: southern boundary of suggested rhombochasm closely coresponds to Lewis and Clark line of structural complexity with Mesoproterozoic antecedents.

SLIDE 12

MAJOR SYNSEDIMENTARY FAULTING



Timing of major tectonic pulses reflected by abrupt thickness changes across synsedimentary faults

RIFT SAG STAGE

~1420 Ma
Thickness changes in Sheppard and Gateway. ~2.0 km vertical movement

~1445-50 Ma
Thickness changes in Kitchener and Van Creek; unconformity at base of Sheppard.

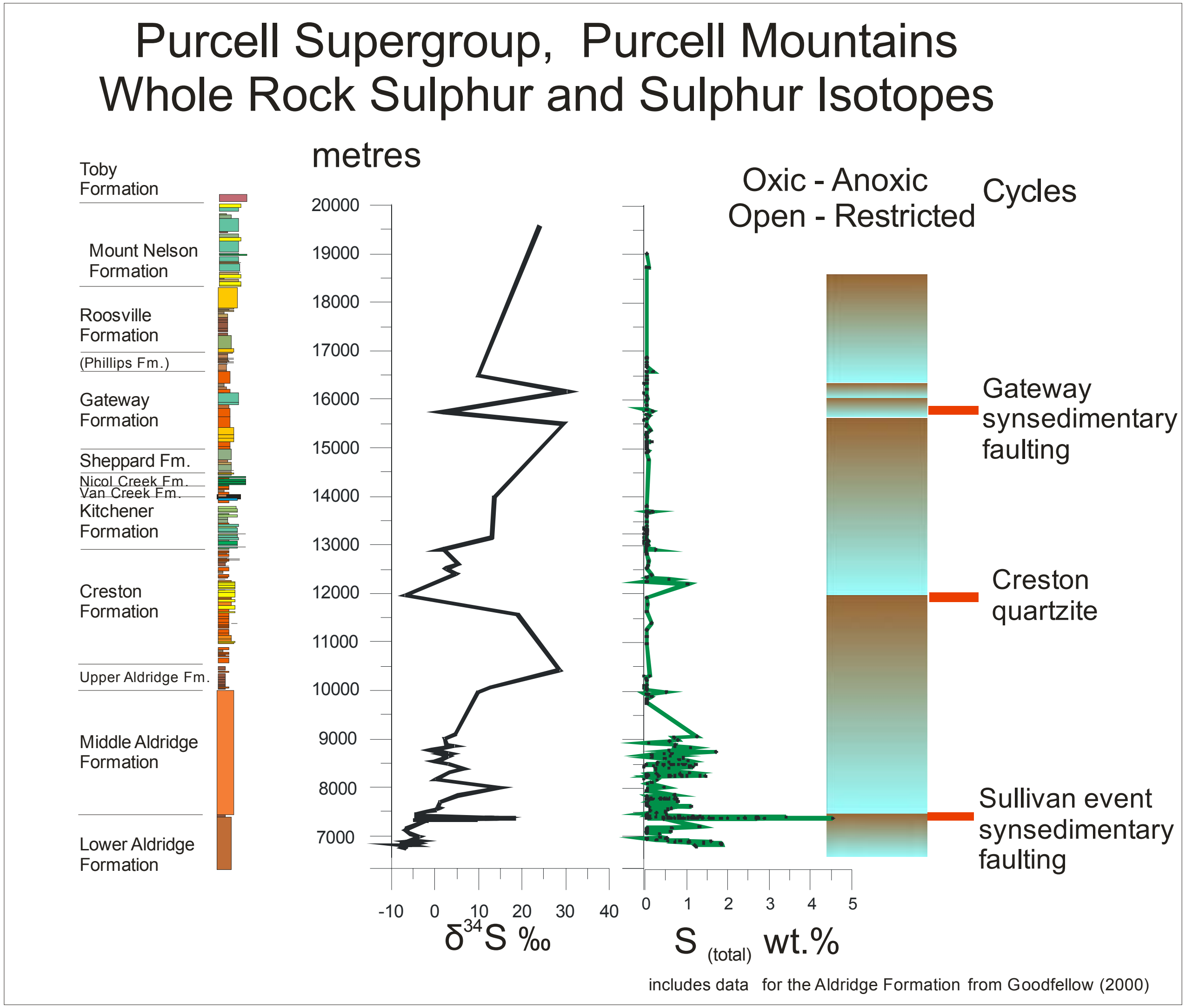
MAIN RIFTING STAGE

~1470 Ma
~2.0 km of vertical movement and eastward expansion of rhombochasm to accommodate Middle and Upper Aldridge. SULLIVAN formed

1485-1470 Ma
Cumulative 5-7 km of vertical movement to accommodate Lower Aldridge turbidites

Total post-Aldridge and pre-Mount Nelson vertical movement on synsedimentary faults = 2.5 km
(measured by the difference in aggregate thickness of post-Aldridge and pre-Mount Nelson stratighaip units in the Northern Hughes Range and correlative strata in the Purcell Mountains)

SLIDE 13



Tectonic events reflected by excursions of sulphur isotopes of diagenetic sulphides.

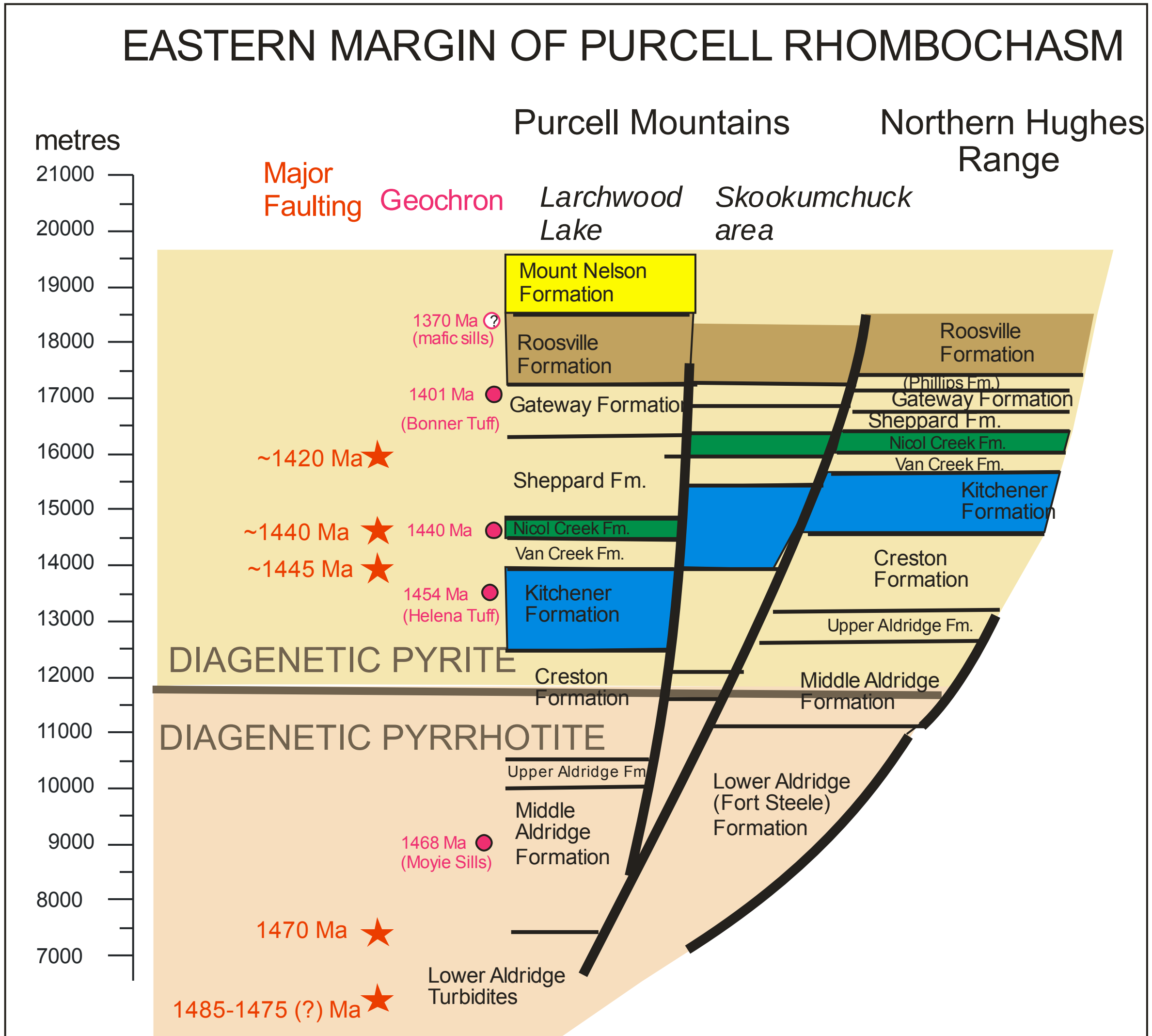
Note excursions in Gateway Formation (at ~1420 Ma)

Tectonic events cause reorganization of sea water circulation patterns which are reflected in diagenetic sulphide sulphur isotope excursions as water column changes from restricted to open circulation conditions.

Note degassing of Moyie sills which adds sulphur of ~0.0‰ composition to rock.

SLIDE 14

PYRRHOTITE-PYRITE DIAGENETIC SULPHIDE TRANSITION

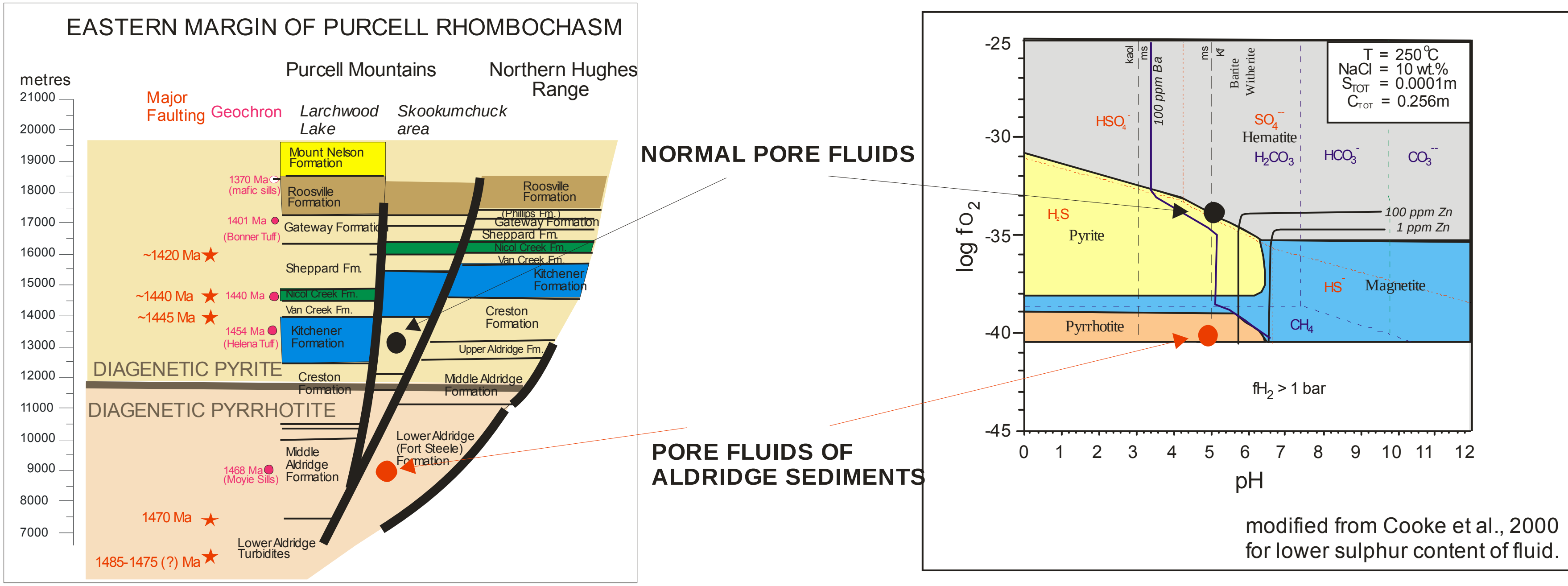


The aggregate thickness of post-Aldridge and pre-Mount Nelson stratigraphic units in the Purcell Mountains is about 2.5 km greater than the aggregate thickness of correlative strata in the NorthernHughes Range.

This difference in aggregate thickness of stratigraphic units is about the same as the amount of stratigraphic displacement of the boundary between diagenetic pyrrhotite and diagenetic pyrite in the Northern Hughes Range and Purcell Mountains respectively (i.e. across the Rocky Mountain Trench fault or approximately the eastern margin of the rhombochasm).

Is this coincidence or does it have metallogenetic implications ?

SLIDE 15



The interface between pyrrhotite-dominant and pyrite-dominant diagenetic sulphides marks the interface between pore fluids of contrasting chemical composition.

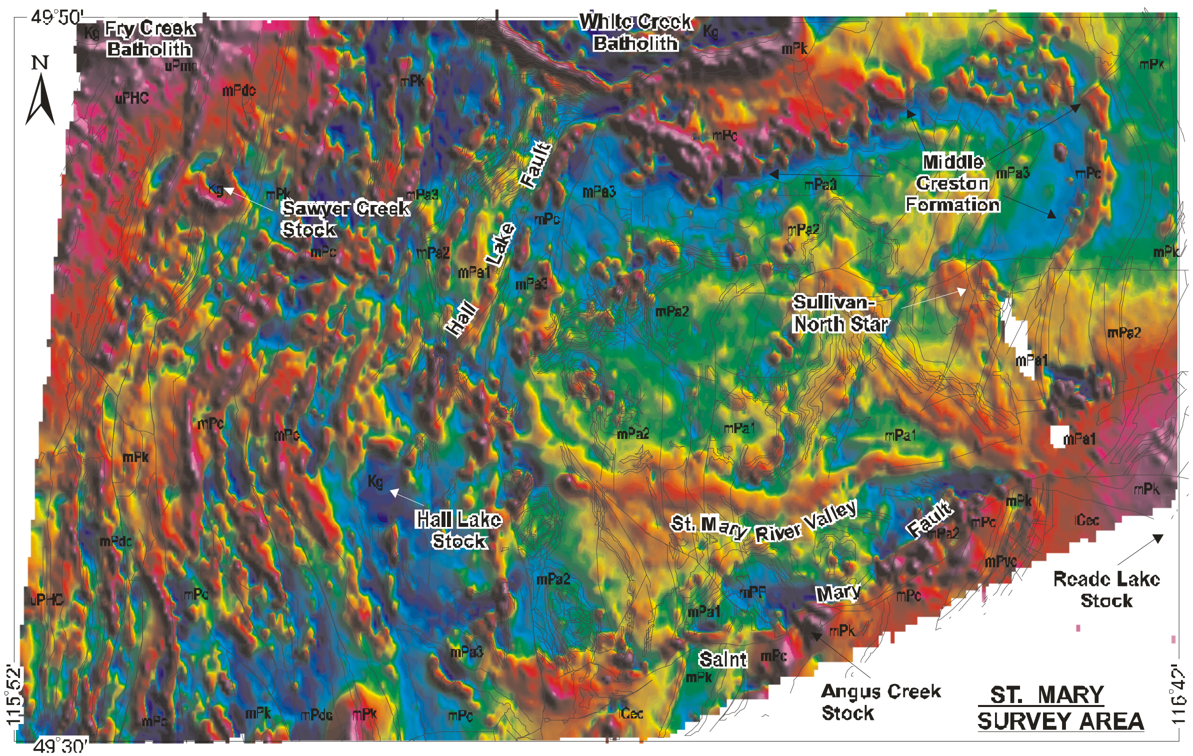
The interface migrates stratigraphically upwards as sediments of the basin gradually compact.

The reduced basinal pore fluids, with which pyrrhotite was stable, were likely the ore fluids that formed Sullivan and other Mesoproterozoic Zn-Pb deposits of the Belt-Purcell basin.

Note that at low total sulphur content, magnetite is stable at the boundary between pyrrhotite and pyrite.

SLIDE 16

STRATAL MAGNETITE ZONE OF CRESTON FORMATION



From Lowe et al., 2000

0 20km

Also see Thomas and Brown, 2009.

The middle part of the Creston Formation, at the pyrrhotite to pyrite transition, is magnetite-rich, and is a prominent feature on aeromagnetic maps.

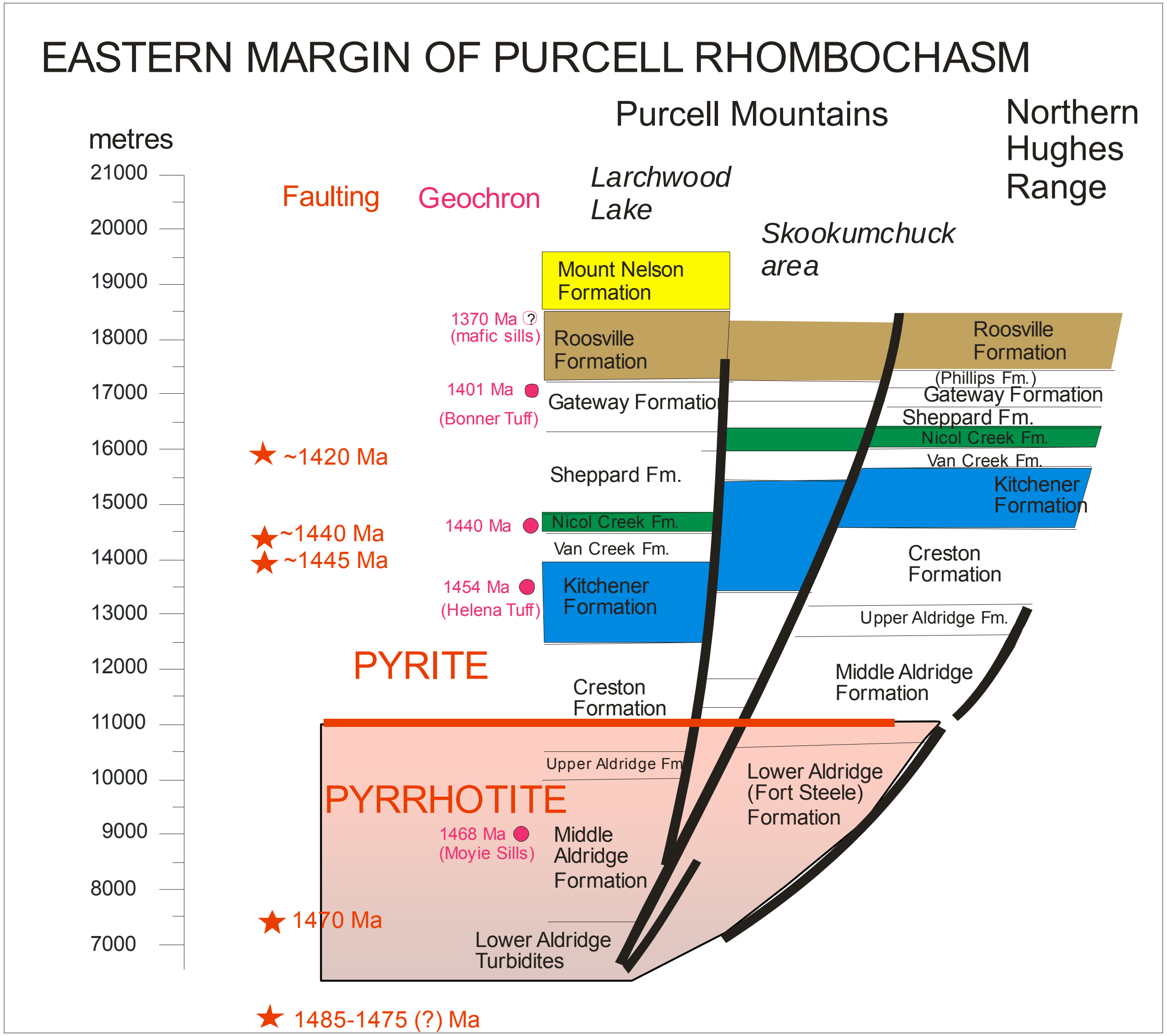
The magnetite zone is of regional extent.

The magnetite zone is essentially conformable with lithological units.

The magnetite zone, and the pyrrhotite-pyrite boundary are therefore consistent with reflecting the horizontal interface between stratal hydrochemical domains formed by pore fluids of contrasting density and chemical composition in a sedimentary basin during burial and compaction prior to any tectonic folding.

SLIDE 17

AN UPPER PURCELL HYDROTHERMAL RESERVOIR ?

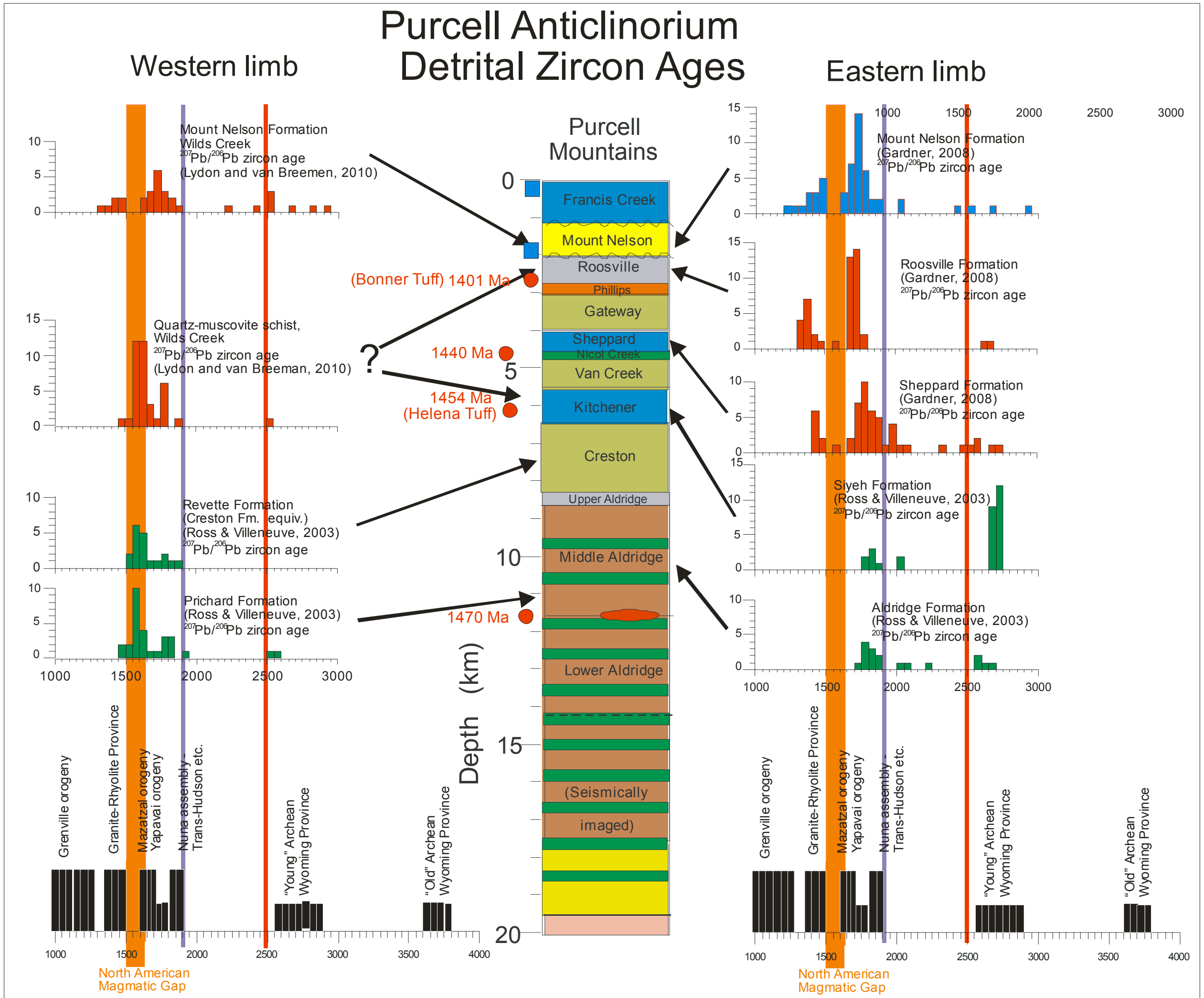


If interpretation is correct, at ~1420 Ma a formational reservoir of reduced, presumably metalliferous fluid still existed at a depth of about 5 km below the contemporaneous sea floor.

Too deep for Sheppard-Gateway synsedimentary faulting to bring to the sea floor ?

.....or an exploration target ?

SLIDE 18



Western limb enigma

Sequence of tectonic events on western limb of Purcell anticlinorium is more enigmatic.

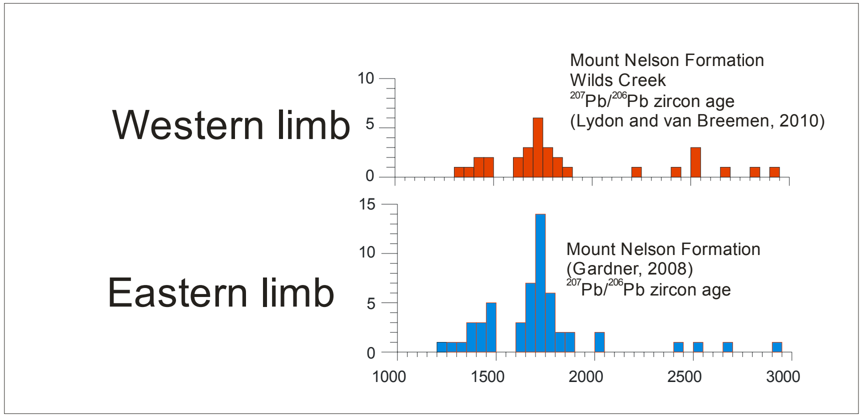
All rocks below Mount Nelson Formation were derived from the western source.

Only one out of 230 zircons from western source samples has an age < 1440 Ma (1404±37 Ma).

Does this mean that there was no magmatism in western source after 1440 Ma or else all pre-Mt. Nelson rocks on western limb are older than ~1440 Ma (i.e. older than Nicol Creek) ?

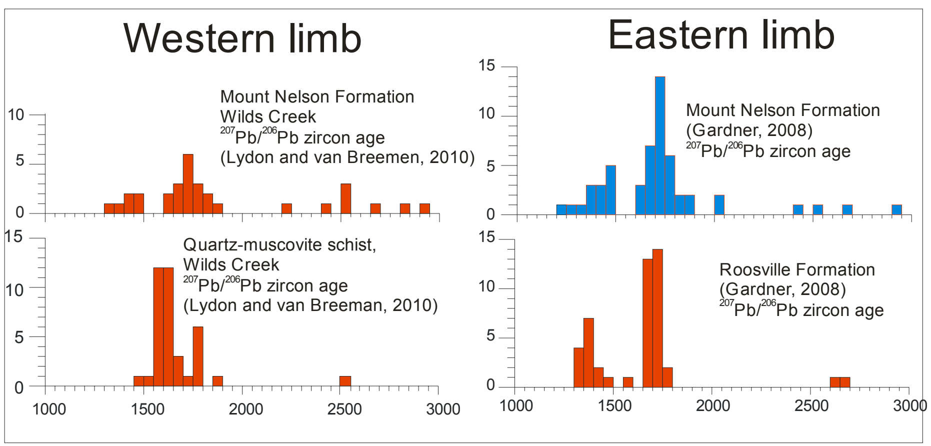
SLIDE 19

Lower Contact of Mount Nelson Formation



Detrital zircon profiles of Mount Nelson Formation are identical for both the eastern and western limbs of the Purcell anticlinorium.

Both have a provenance from the same southern source as Sheppard through Roosville rocks on the eastern limb of the Purcell anticlinorium

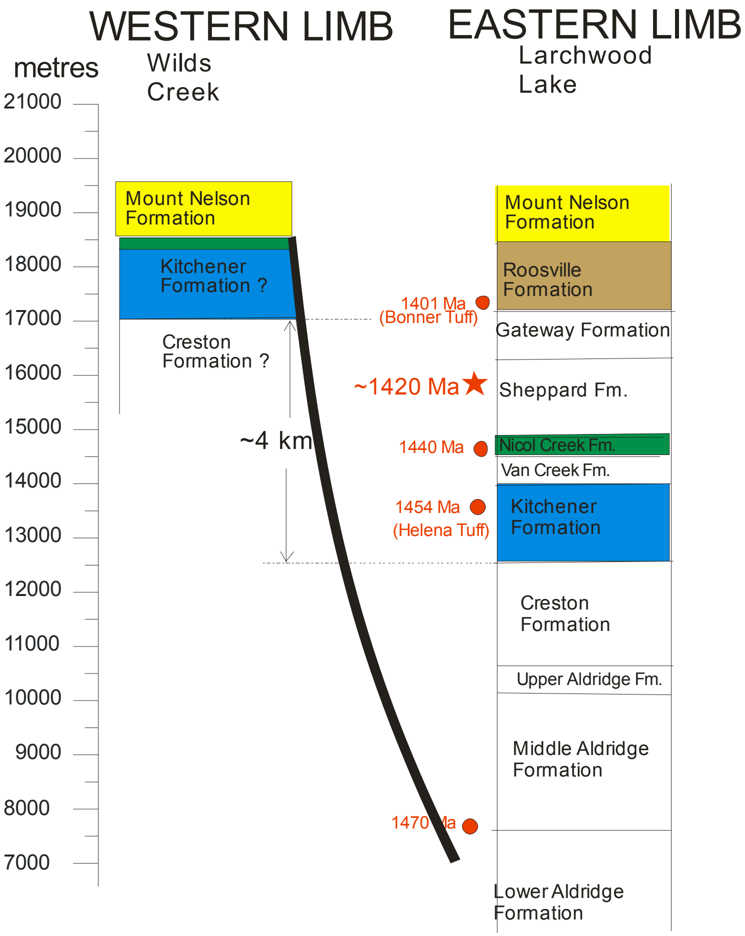


Contact between Mount Nelson Formation and immediately underlying rocks on western lim marks an abrupt change for the provenance of sediments.

Did western source suddenly disappear ?

In contrast, on the eastern limb the contact is gradational and the detrital zircon profile of the Mount Nelson Formation continues the Sheppard through Roosville evolution of decreasing age of youngest zircons. There is no indication of a sub-Mount Nelson major tectonic event.

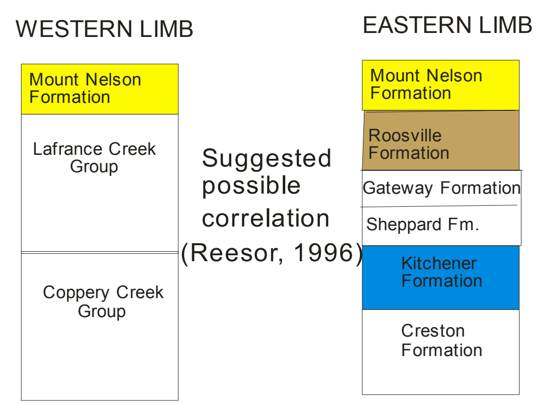
SLIDE 20



The youngest pre-Mount Nelson tectonic event is that which caused ~1.5 km of vertical displacement in the Sheppard and Gateway formations at ~1420 Ma.

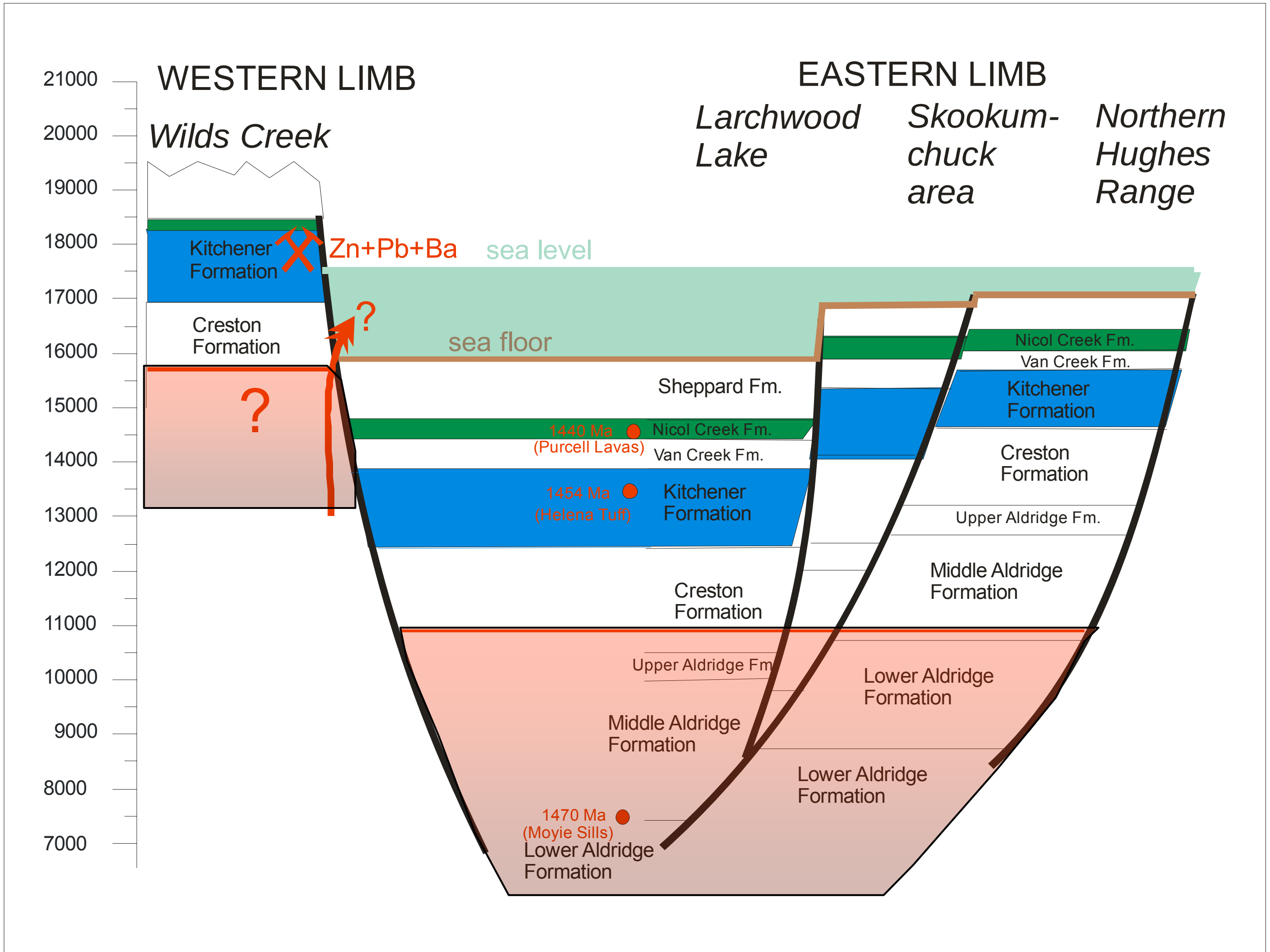
Vertical displacement to cause an hiatus, such that the Mount Nelson rests on Nicol Creek / Kitchener Formation in the area that is now the western limb of the Purcell anticlinorium would require a vertical movement of ~4 km.

An hiatus explains:
1. The lack of detrital zircons younger than1440 Ma in pre-Mount Nelson rocks on the western limb.
2. The difficulty in correlating sub-Mount Nelson rocks with the stratigraphic sequence of the eastern limb of the Purcell anticlinorium



SLIDE 21

SCHEMATIC CROSS-SECTION PURCELL BASIN ~ 1320 Ma

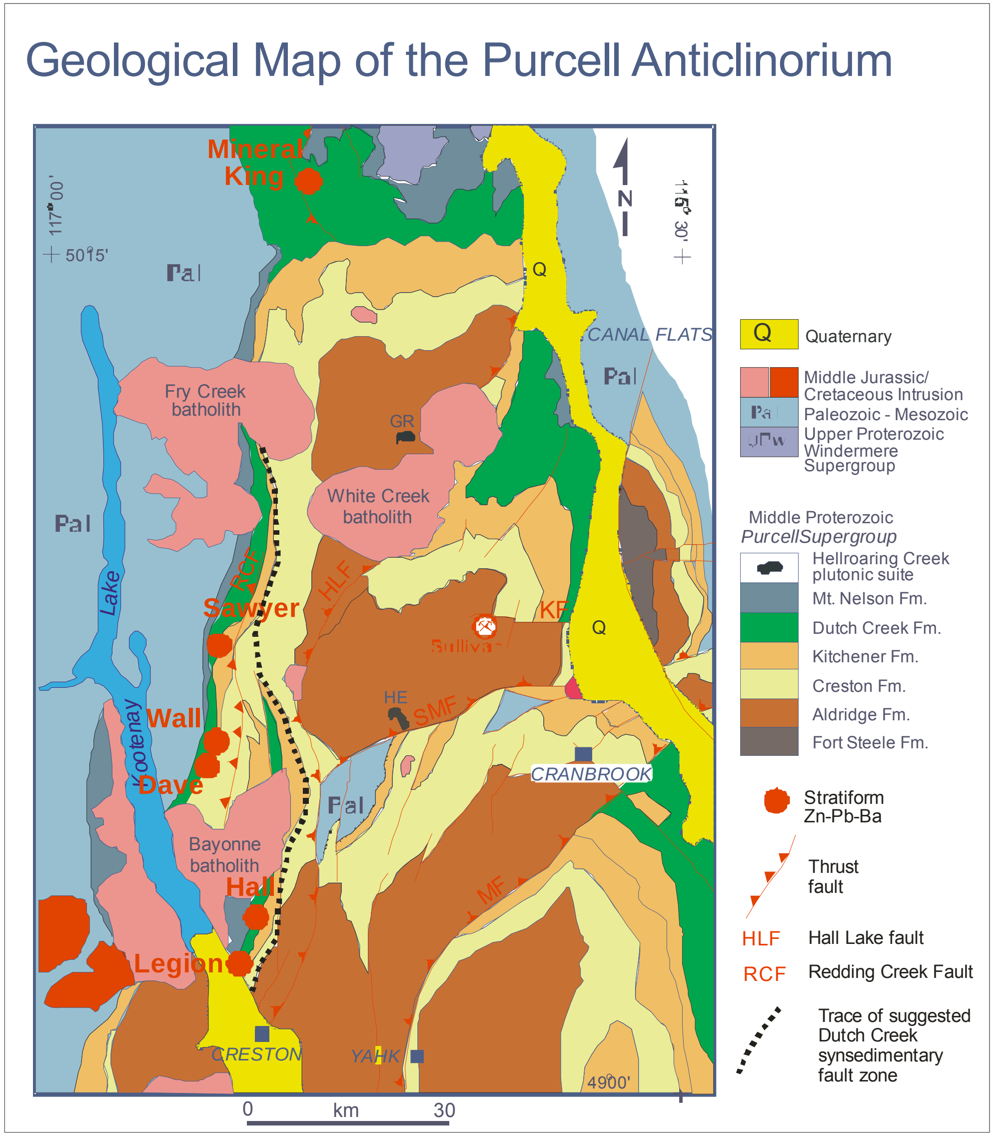


A vertical displacement of ~4 km could create the hydraulic head necessary for the expulsion of the reduced fluid reservoir on to the sea floor of the Gateway Formation.

Only mineralization known in the general area are the Zn-Pb±Ba deposits mapped as being in the Dutch Creek Formation, but on this section would be in the Kitchener Formation

SLIDE 22

Zn-Pb-Ba deposits on western limb of Purcell anticlinorium mapped as being in the Dutch Creek Formation



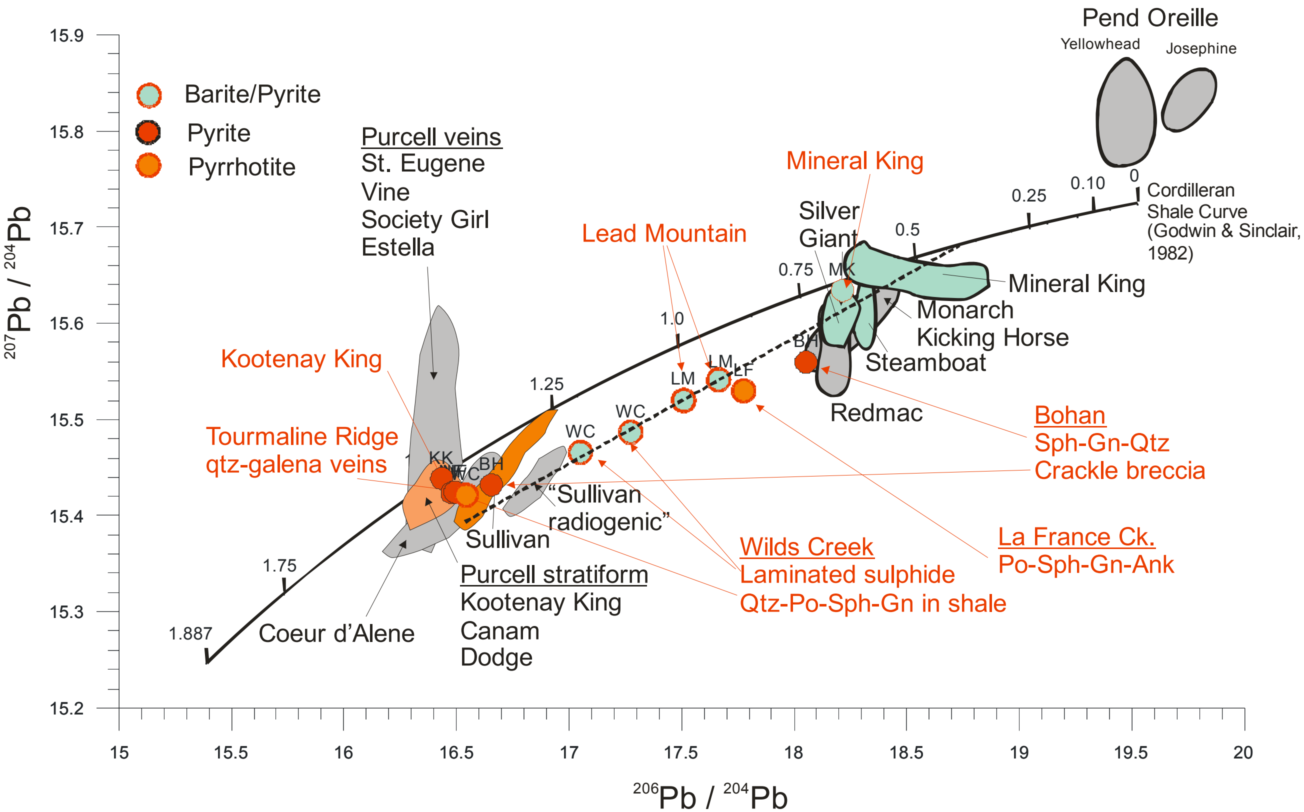
Zn-Pb-Ba deposit in dolomitic and black argillite host rocks on western limb of Purcell anticlinorium.

Host rocks mapped as Dutch Creek Formation

Largest deposit is Mineral King (2.1 mt @ 4.12%Zn 1.76%Pb mined)

SLIDE 23

LEAD ISOTOPES OF DEPOSITS ON WESTERN LIMB OF PURCELL ANTICLINORIUM COMPARED TO OTHER DEPOSITS OF BELT-PURCELL BASIN AND ADJACENT AREAS



Data suggests:

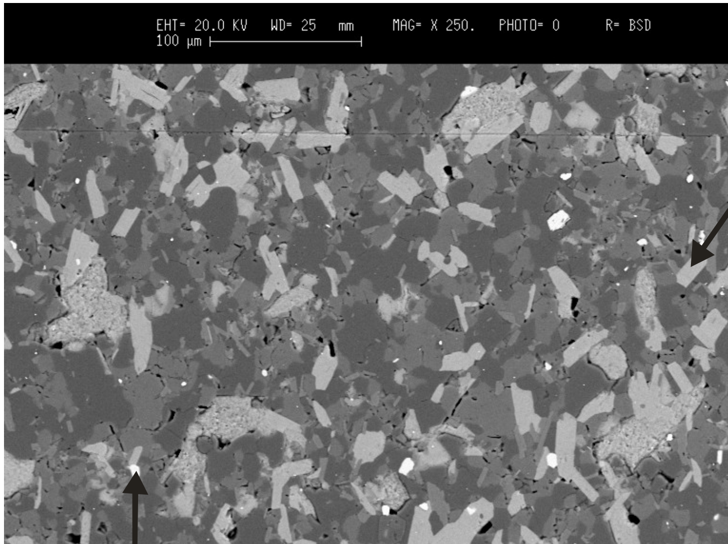
1. Mineral King and Wilds Creek deposits are the same metallogenetic event as Silver Giant, Steamboat, Lead Mountain, Monarch-Kicking Horse, etc.

2. Lead in these deposits were derived from two components in local source rocks:

a) **Silicate Pb** (contained, along with U and Th, in silicate minerals) leached from source rocks at ~400 Ma.

b) **Sulphide lead** (contained in galena formed during Mesoproterozoic burial metamorphism or hydrothermal events) .

Datafor mineral deposit fields from:
Godwin and Sinclair (1982).
Paul Ransom (Pers. Com.)
Beaudoin (1997)
Marshall et al,(2000)
St. Marie and Kessler (2000)

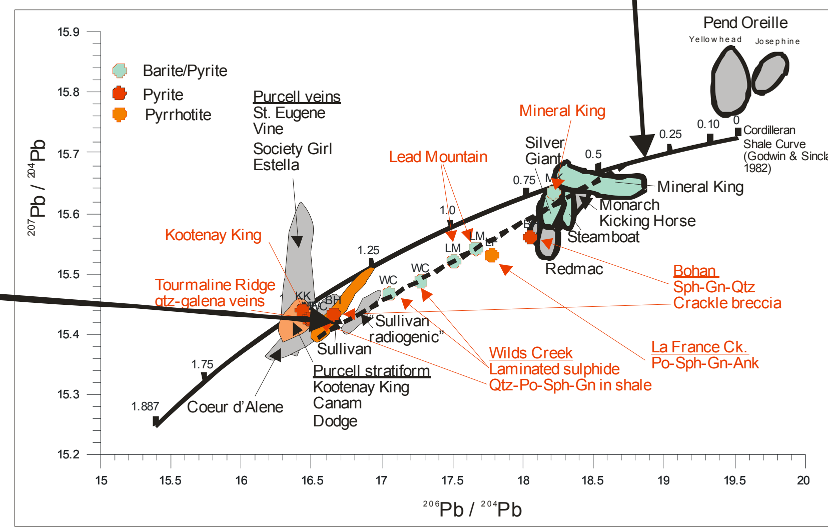


Pb isotopes in silicate minerals evolve along "shale" curve

Concentrated by:

Saline pore waters of sedimentary basins during smectite-illite transition

Mid to late stage leaches of circulating hydrothermal fluids



Pb isotopes in sulphide minerals remain "frozen" to time of burial metamorphism

Concentrated by:

Metamorphic segregations in quartz veins;

Initial leaches of circulating hydrothermal fluids

Pb in Zn-Pb±Ba deposits derived from a mixture of pore waters of Paleozoic sedimentary basins and Pb leached from Mesoproterozoic basement.

SLIDE 25

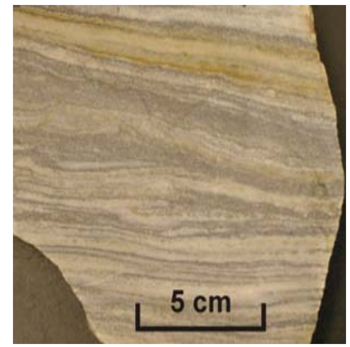
Western limb of Purcell anticlinorium is a transition into the Kootenay arc.

Undeformed

Deformed

<u>Lead Mountain</u>

Barite cementing red-weathering carbonate breccia



<u>Mineral King</u>

Laminated barite, carbonate, sphalerite, galena.

Kootenay Arc penetrative Mesozoic deformation

<u>Lead Mountain</u>

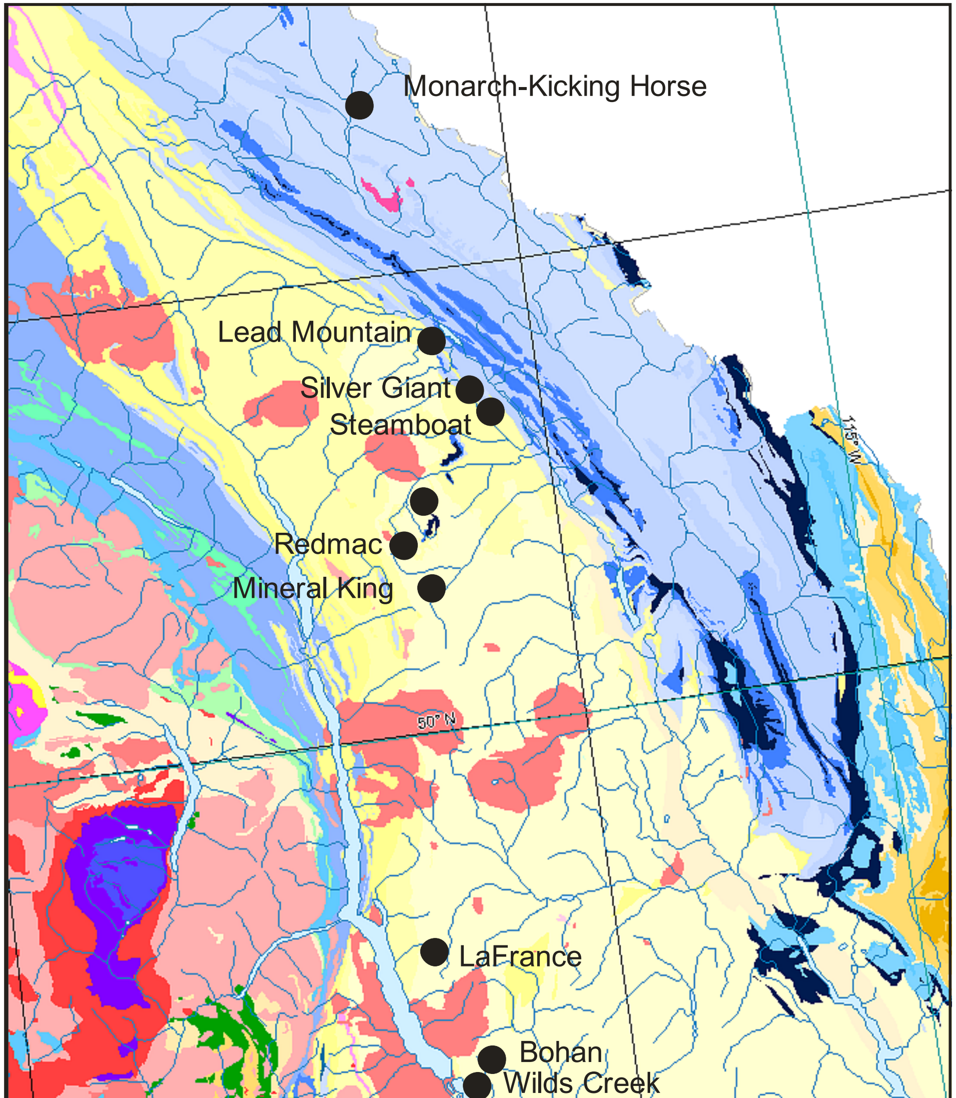
Sphalerite, galena, pyrite, barite infilling open spaces in carbonate breccia

<u>Wilds Creek</u>

Laminated carbonate, pyrite, sphalerite, barite

SLIDE 26

Zn-Pb±Ba deposits of south-eastern British Columbia with measured Pb isotope ratios



Zn-Pb±Ba deposits of western limb of Purcell anticlinorium are on the same metallotect as Monarch-Kicking Horse, Lead Mountain etc.

Further evidence that all belong to the same lower Paleozoic (Ordovician ?) metallogenetic event ?

SLIDE 27

CONCLUSIONS

Consideration of the tectonic evolution of the Belt Purcell basin and detrital zircon data suggests that there is an hiatus below the Mount Nelson Formation on the western limb of the Purcell anticlinorium.

Absence of the Dutch Creek Formation on the western limb implies a major synsedimentary fault system, approximately along an antecedent Hall Lake fault, that coincides with timing of synsedimentary faulting in the Sheppard and Gateway formations.

The eastern side of this fault system has potential for mineralization because its vertical displacement of ~ 4 km could have created the hydraulic head for upflow of reduced metalliferous formational waters.

Zn-Pb-Ba deposits on the western limb of the Purcell anticlinorium have Pb isotope signatures that collectively suggest an Ordovician (?) metallogenetic event that has remobilized Mesoproterozoic sulphides.

SLIDE 28

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