SOME KEY OBSERVATIONS PERTINENT TO THE FORMATION AND STABILIZATION OF THE WYOMING PROVINCE

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EarthScope Synthesis workshop:
4D perspective on role of Wyoming Craton in Evolution of North America
Bozeman, MT Jan. 10-13, 2019

Some key observations:

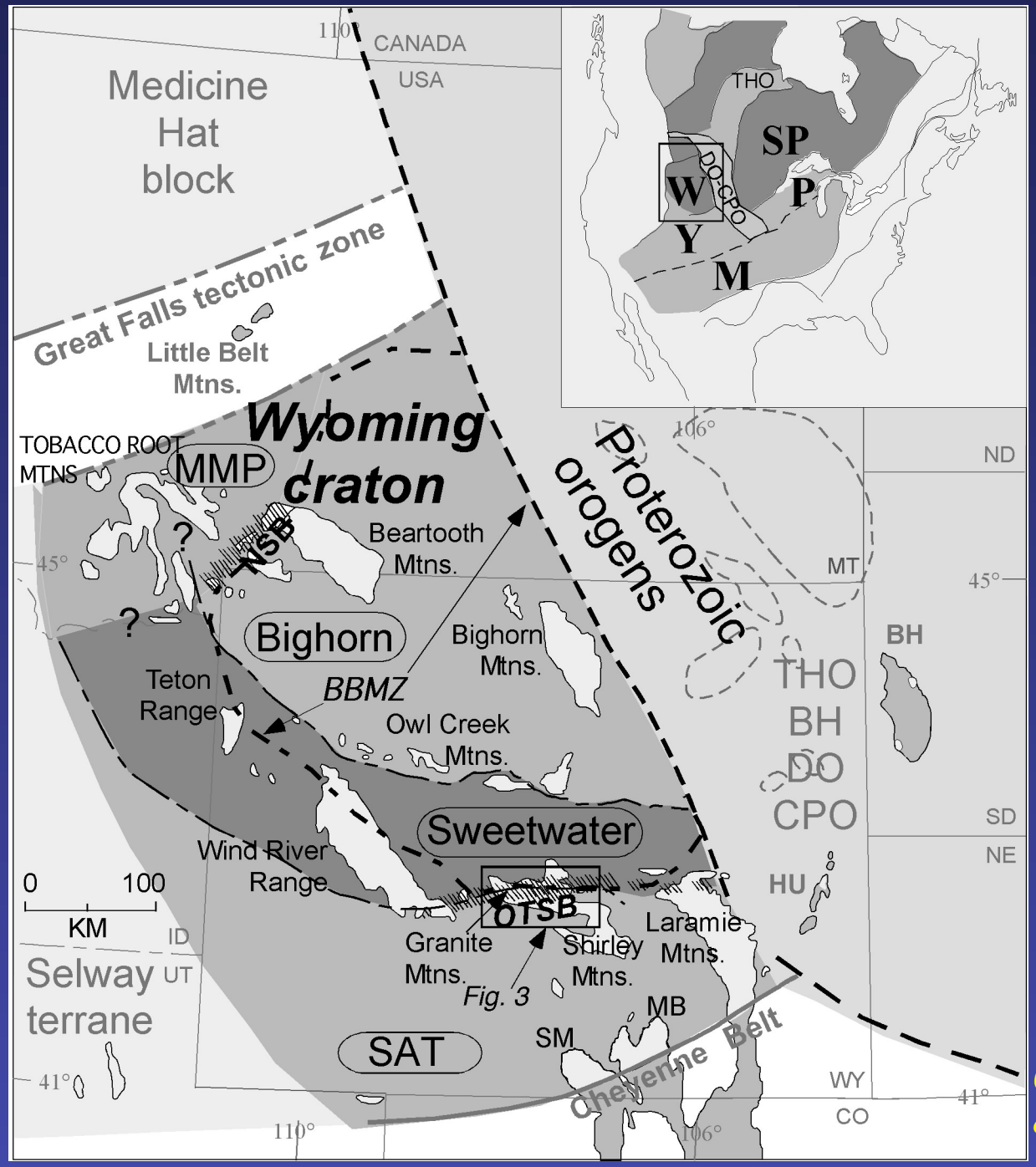
1) WY P comprises two distinct lithospheric blocks

2) Evidence for 3.3 Ga craton, not necessarily older

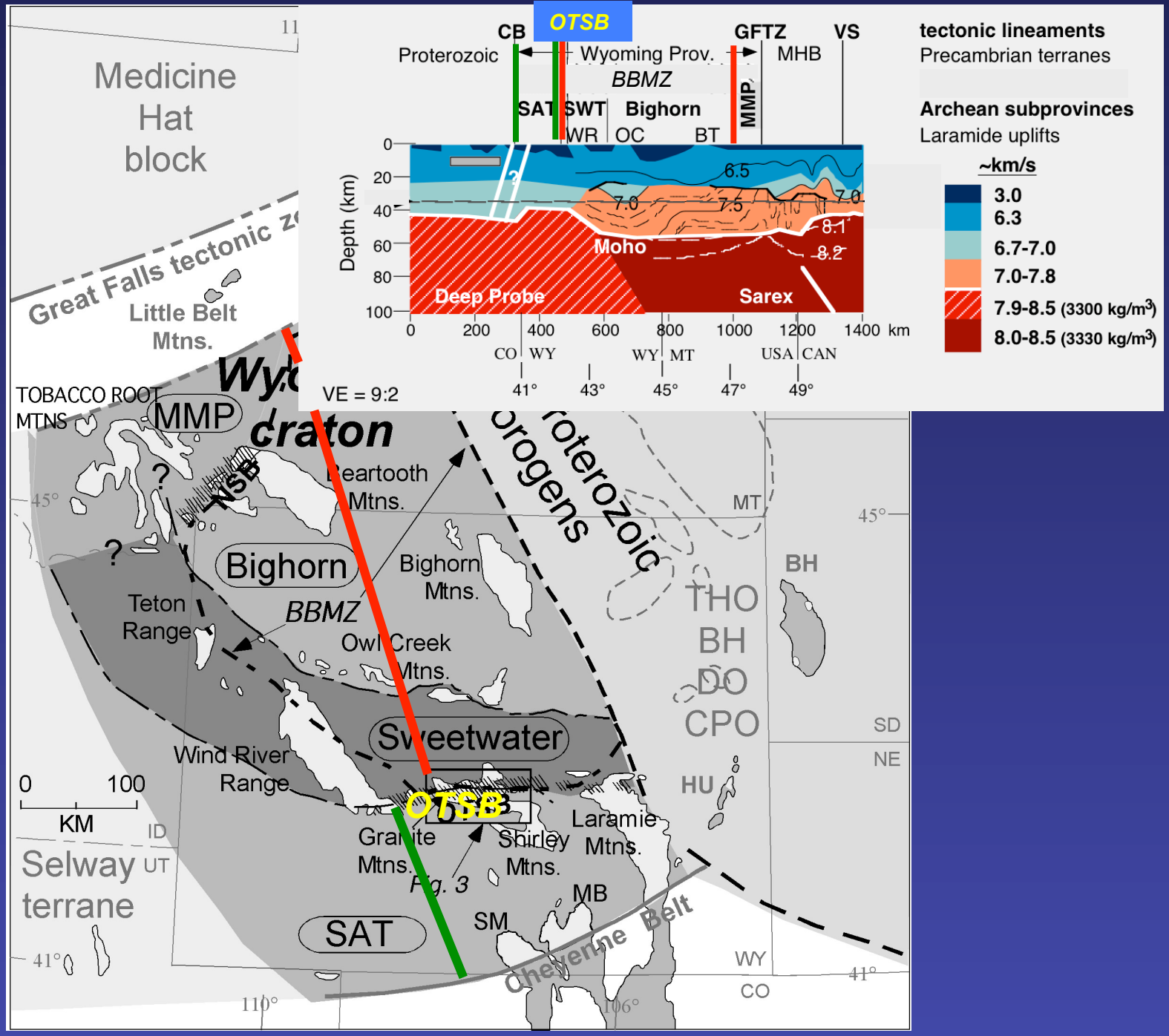
3) Exposed surface has been ≤10 km deep since Arch.

4) Eastern A-P boundary immediately east of Bighorns

1

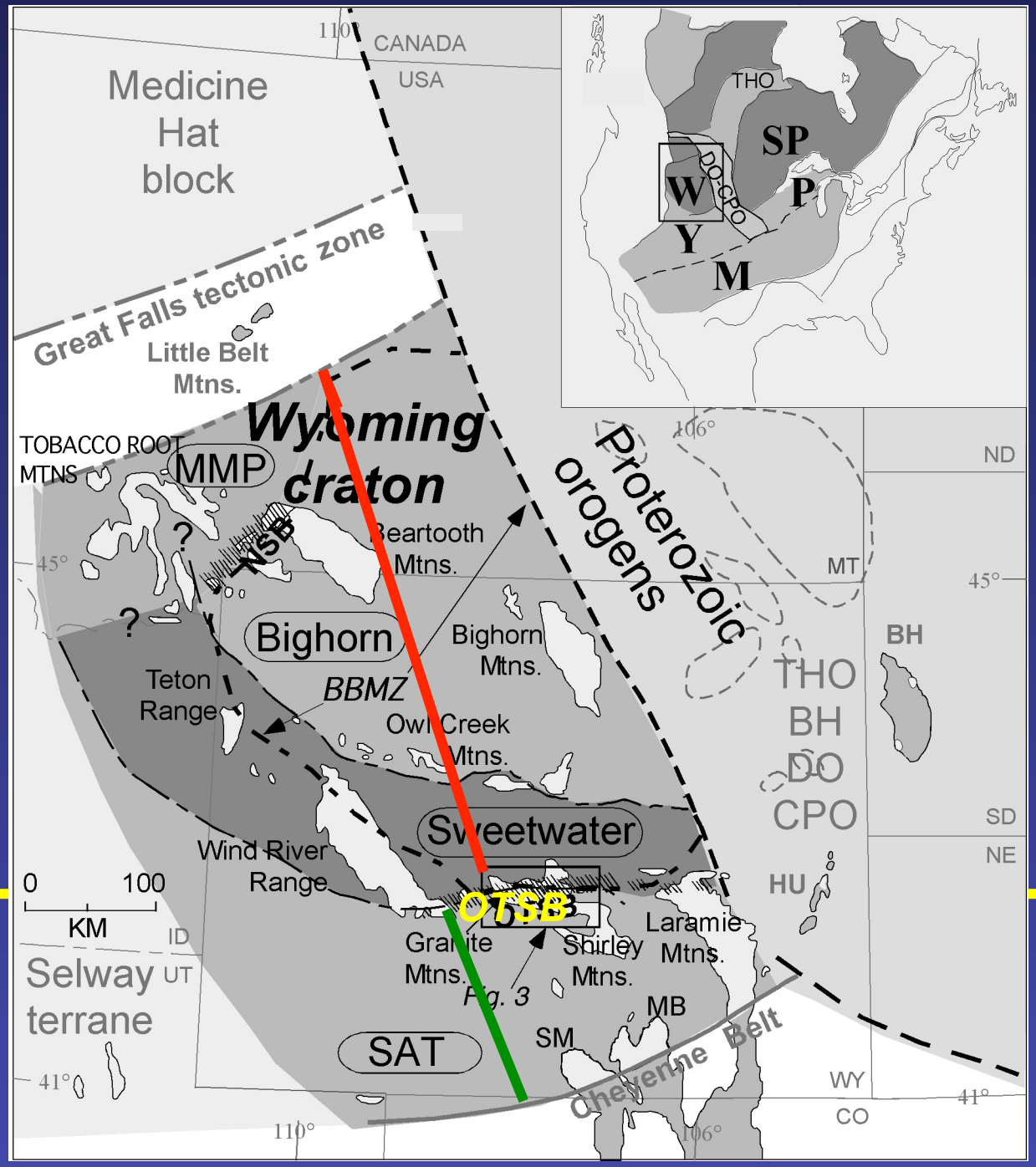


Chamberlain & Mueller, 2018


OTSB
CB
GFTZ
VS
Proterozoic
Wyoming Prov.
MHB
BBMZ
SAT
SWT
Bighorn
MMP
WR
OC
BT
Depth (km)
6.5
7.0
7.5
7.0
8.1
8.2
Moho
Deep Probe
Sarex
CO WY
WY MT
USA CAN
VE = 9:2
tectonic lineaments
Precambrian terranes
Archean subprovinces
Laramide uplifts
~km/s
3.0
6.3
6.7-7.0
7.0-7.8
7.9-8.5 (3300 kg/m3)
8.0-8.5 (3330 kg/m3)
Medicine Hat block
Great Falls tectonic zone
Little Belt Mtns.
TOBACCO ROOT MTNS
MMP
craton
Beartooth Mtns.
Bighorn
Bighorn Mtns.
Teton Range
BBMZ
Owl Creek Mtns.
Sweetwater
Wind River Range
OTSB
Granite Mtns.
Shirley Mtns.
Laramie Mtns.
Fig. 3
SAT
SM
MB
Cheyenne Belt
Proterozoic orogens
MT
BH
THO
BH
DO
CPO
SD
NE
HU
WY
CO
ID
UT
Selway terrane
0 100
KM
45°
41°
110°
106°

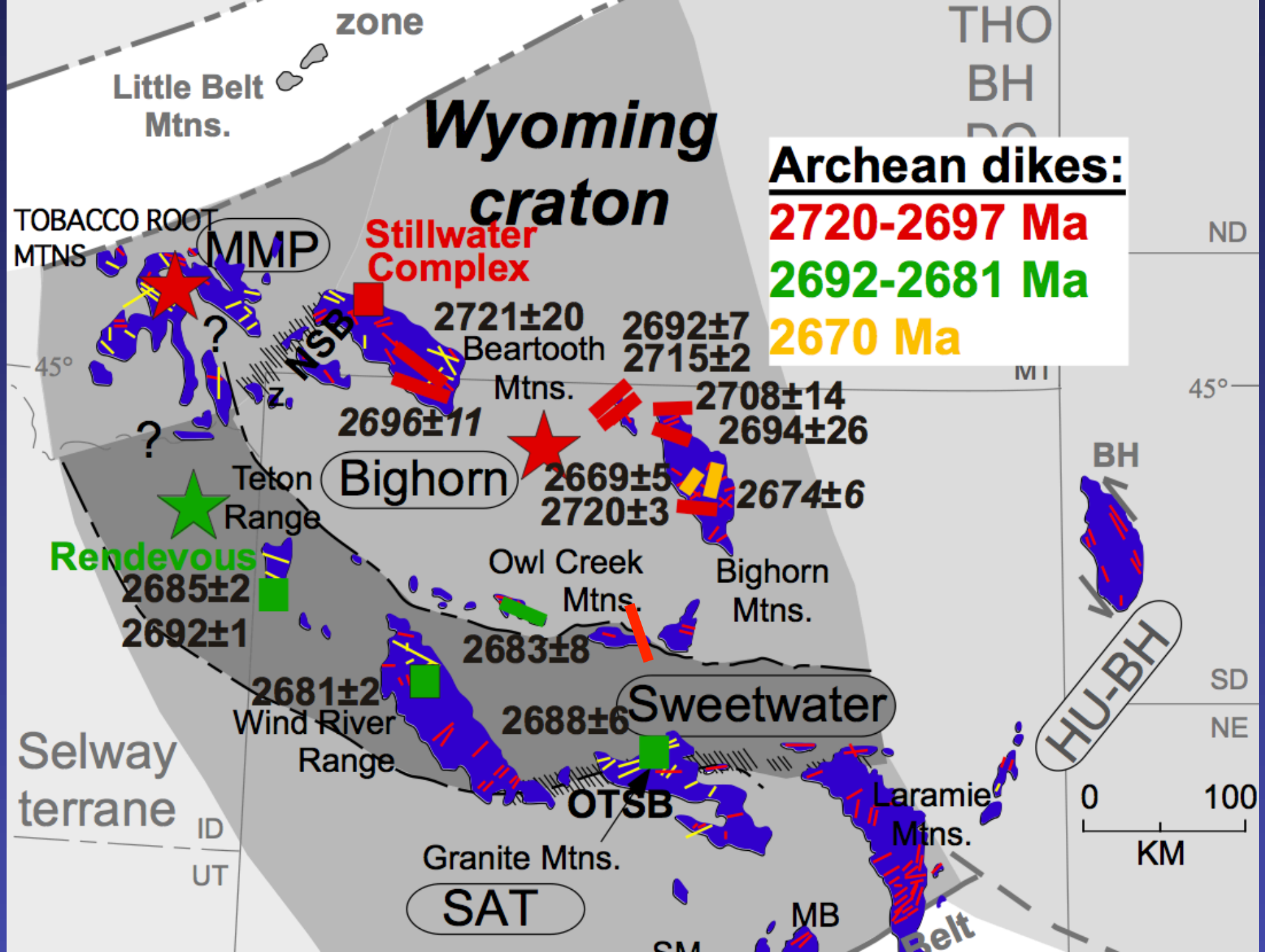
thick crust, fast lower

thin crust, no fast

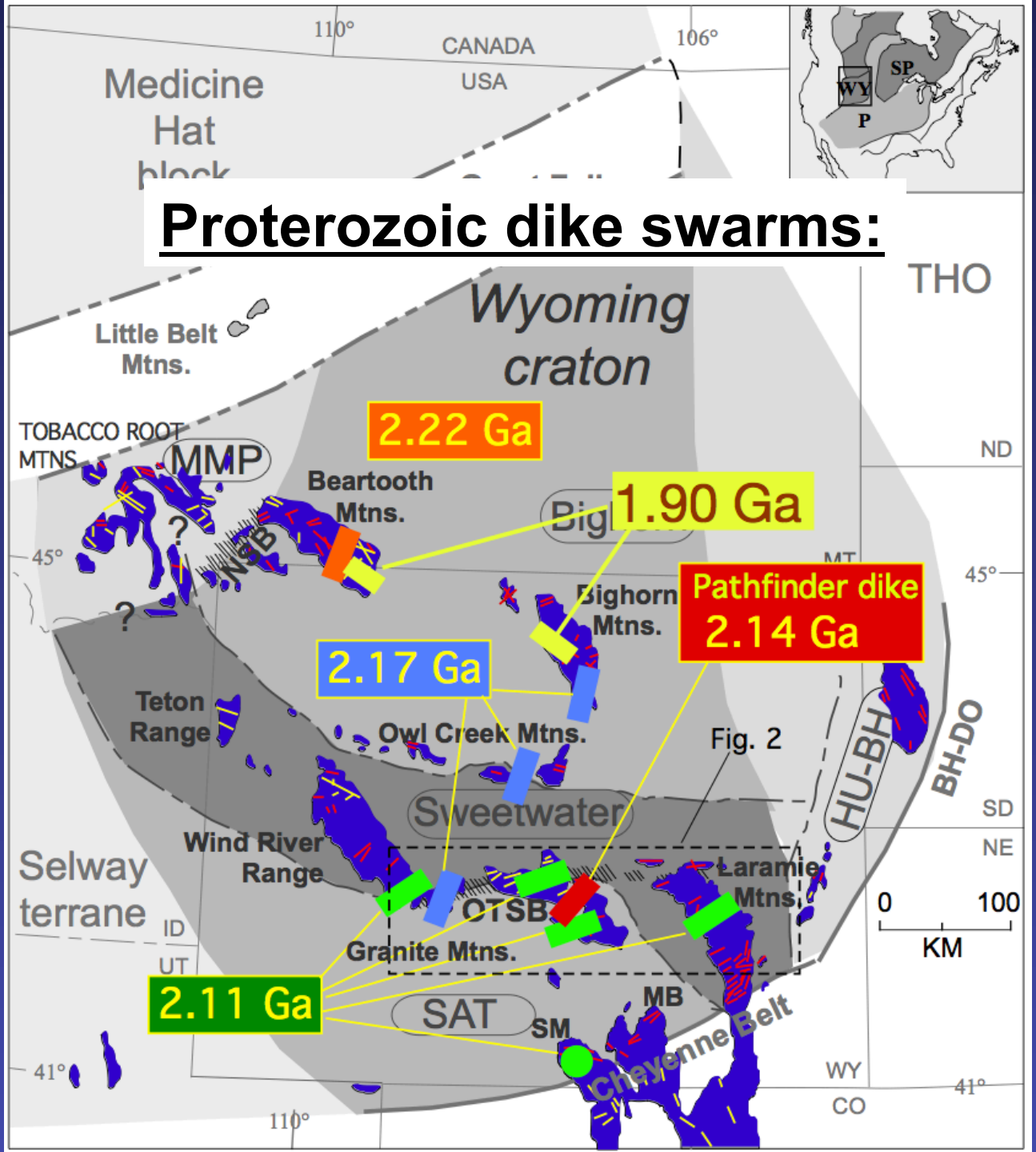


A&P mafic dikes

only P, no A

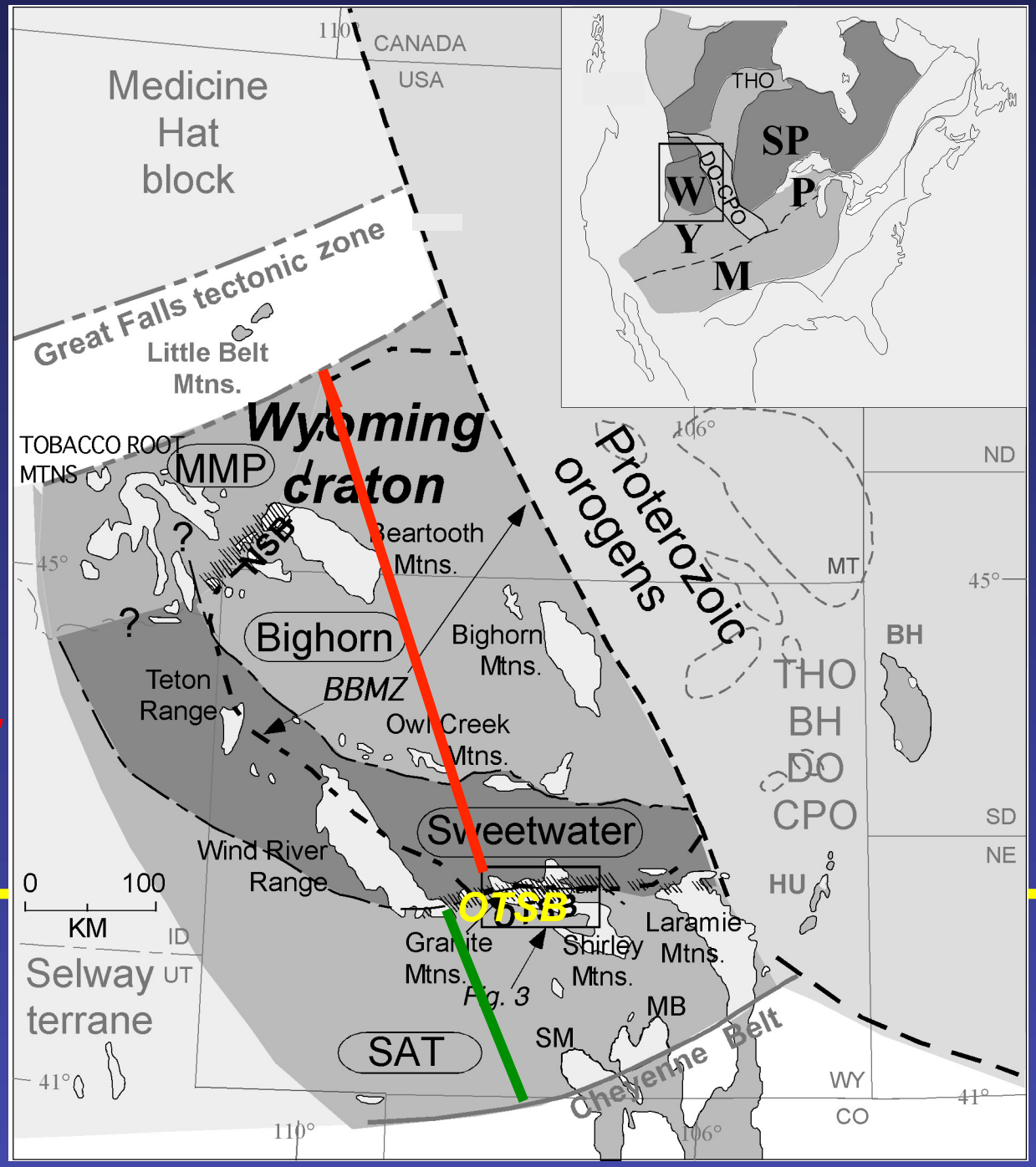

zone
Little Belt Mtns.
Wyoming craton
Archean dikes:
2720-2697 Ma
2692-2681 Ma
2670 Ma
TOBACCO ROOT MTNS
MMP
Stillwater Complex
2721±20
2692±7
2715±2
Beartooth Mtns.
NSB
2708±14
2694±26
2696±11
Bighorn
2669±5
2720±3
2674±6
Teton Range
Rendevous
2685±2
2692±1
Owl Creek Mtns.
Bighorn Mtns.
2683±8
2681±2
Wind River Range
2688±6
Sweetwater
OTSB
Selway terrane
ID
UT
Granite Mtns.
SAT
MB
Laramie Mtns.
HU-BH
BH
ND
MT
SD
NE
45°
0
100
KM

Proterozoic dike swarms:



broad magmat.

g-stone belts

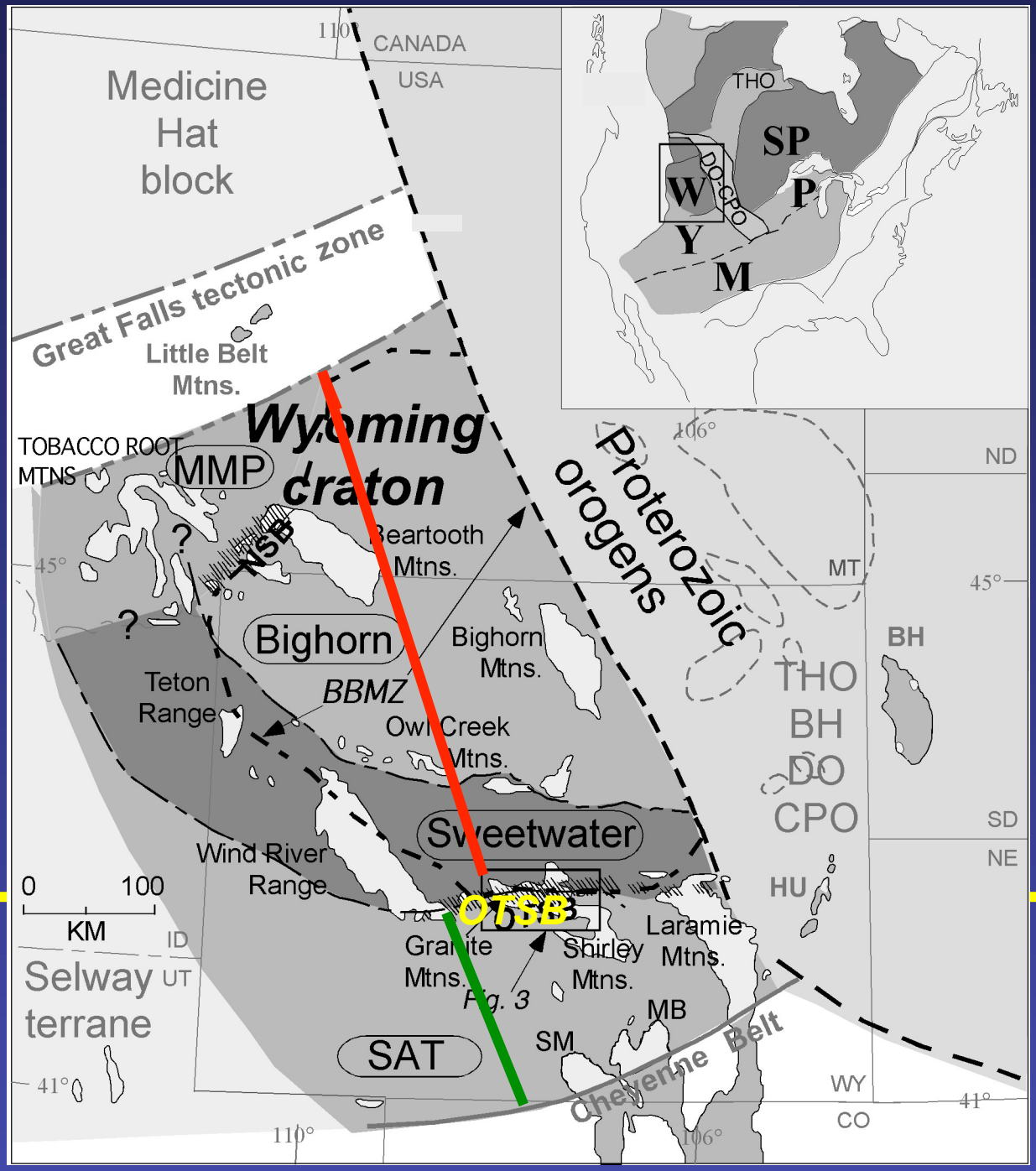


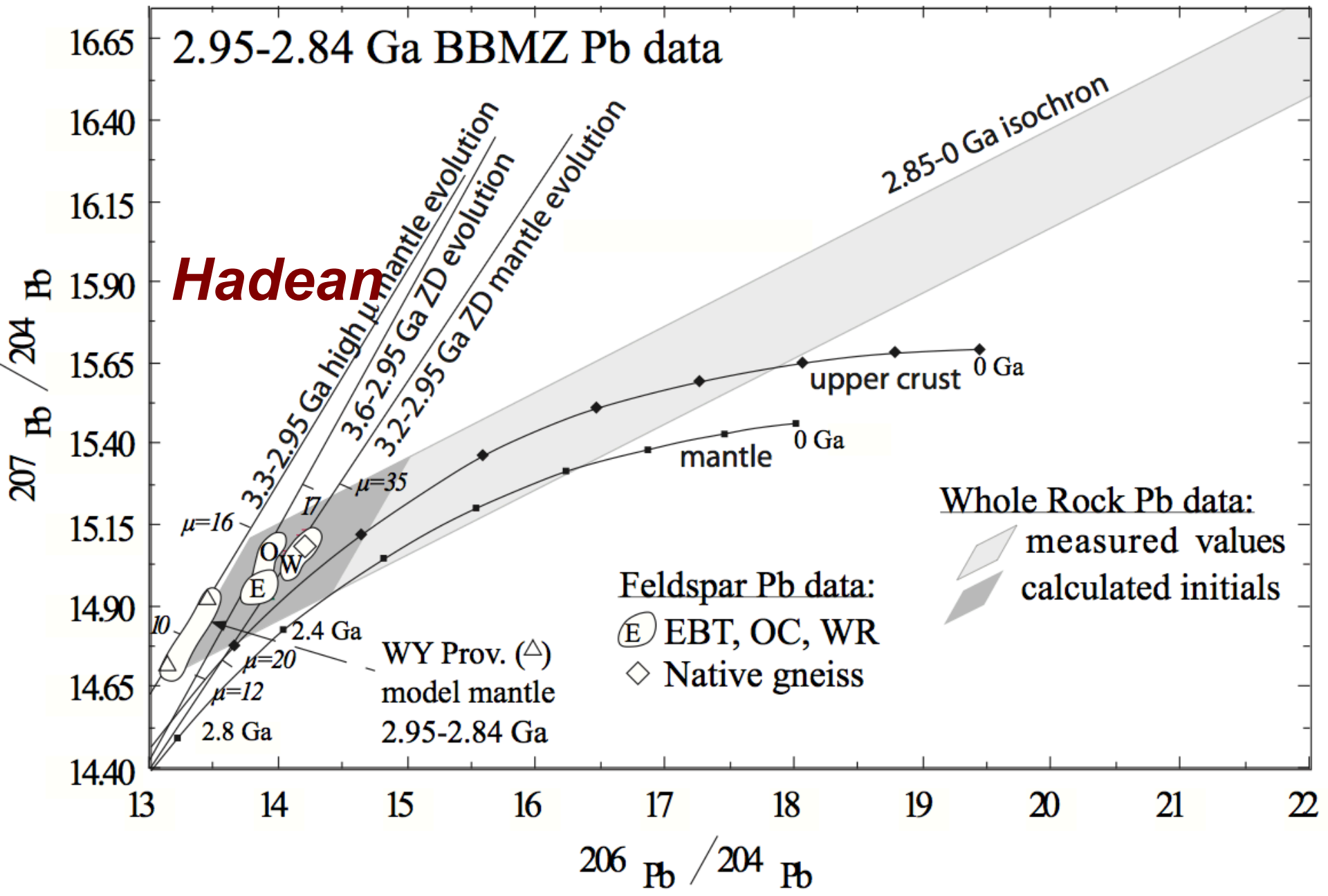
unroofed in Arch

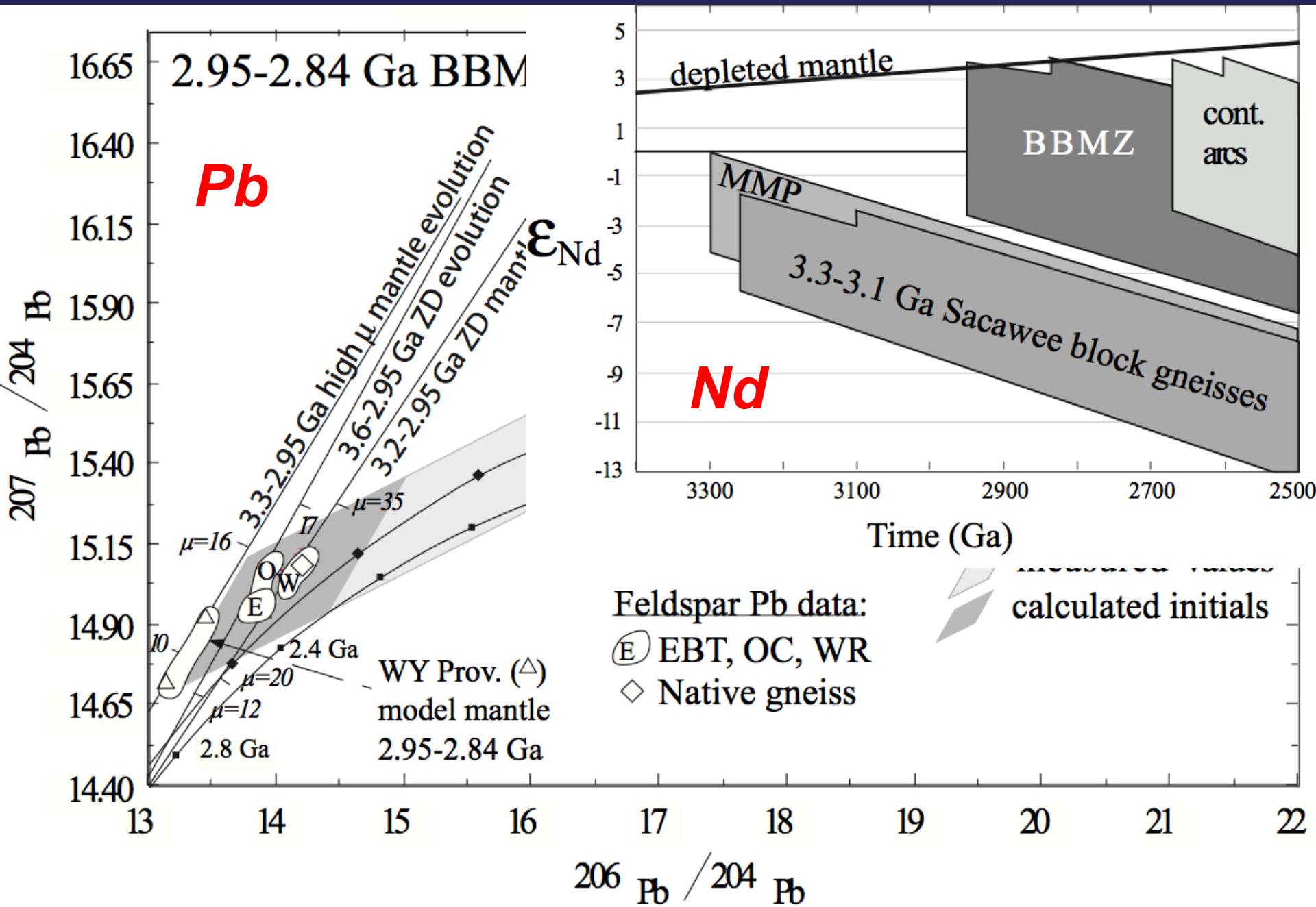
heated/ unroofed MesoP

high μ
Hadean

low μ
juv.




2.95-2.84 Ga BBMZ Pb data
Hadean
2.85-0 Ga isochron
3.3-2.95 Ga high μ mantle evolution
3.6-2.95 Ga ZD evolution
3.2-2.95 Ga ZD mantle evolution
upper crust
0 Ga
mantle
0 Ga
μ=35
μ=16
μ=20
μ=12
I7
O
W
E
I0
2.4 Ga
2.8 Ga
WY Prov. (△)
model mantle
2.95-2.84 Ga
Feldspar Pb data:
E EBT, OC, WR
◇ Native gneiss
Whole Rock Pb data:
measured values
calculated initials
207 Pb / 204 Pb
206 Pb / 204 Pb
16.65
16.40
16.15
15.90
15.65
15.40
15.15
14.90
14.65
14.40
13
14
15
16
17
18
19
20
21
22


2.95-2.84 Ga BBM
Pb
3.3-2.95 Ga high μ mantle evolution
3.6-2.95 Ga ZD evolution
3.2-2.95 Ga ZD mantle
μ=16
μ=35
μ=20
μ=12
I7
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16.65
16.40
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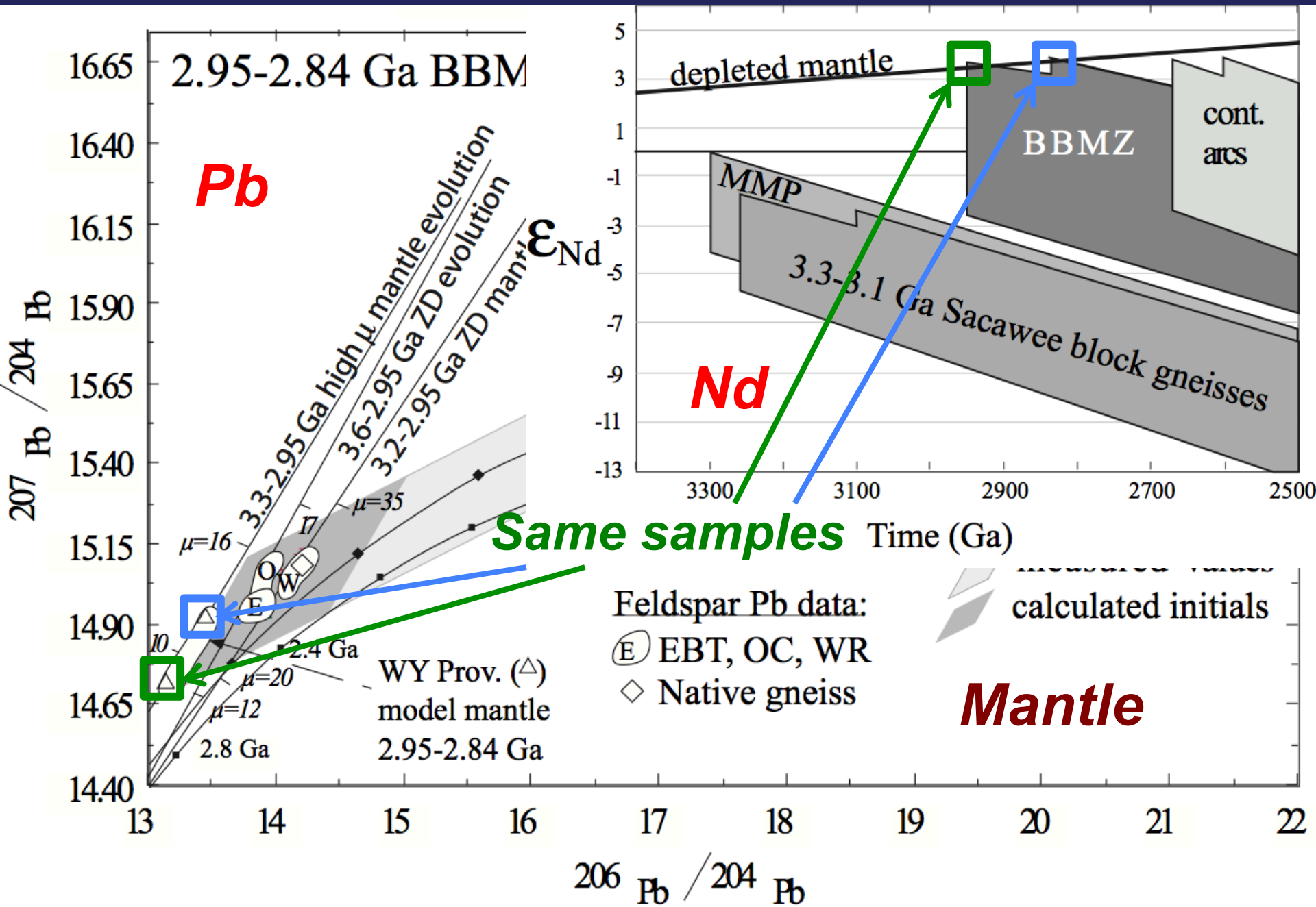
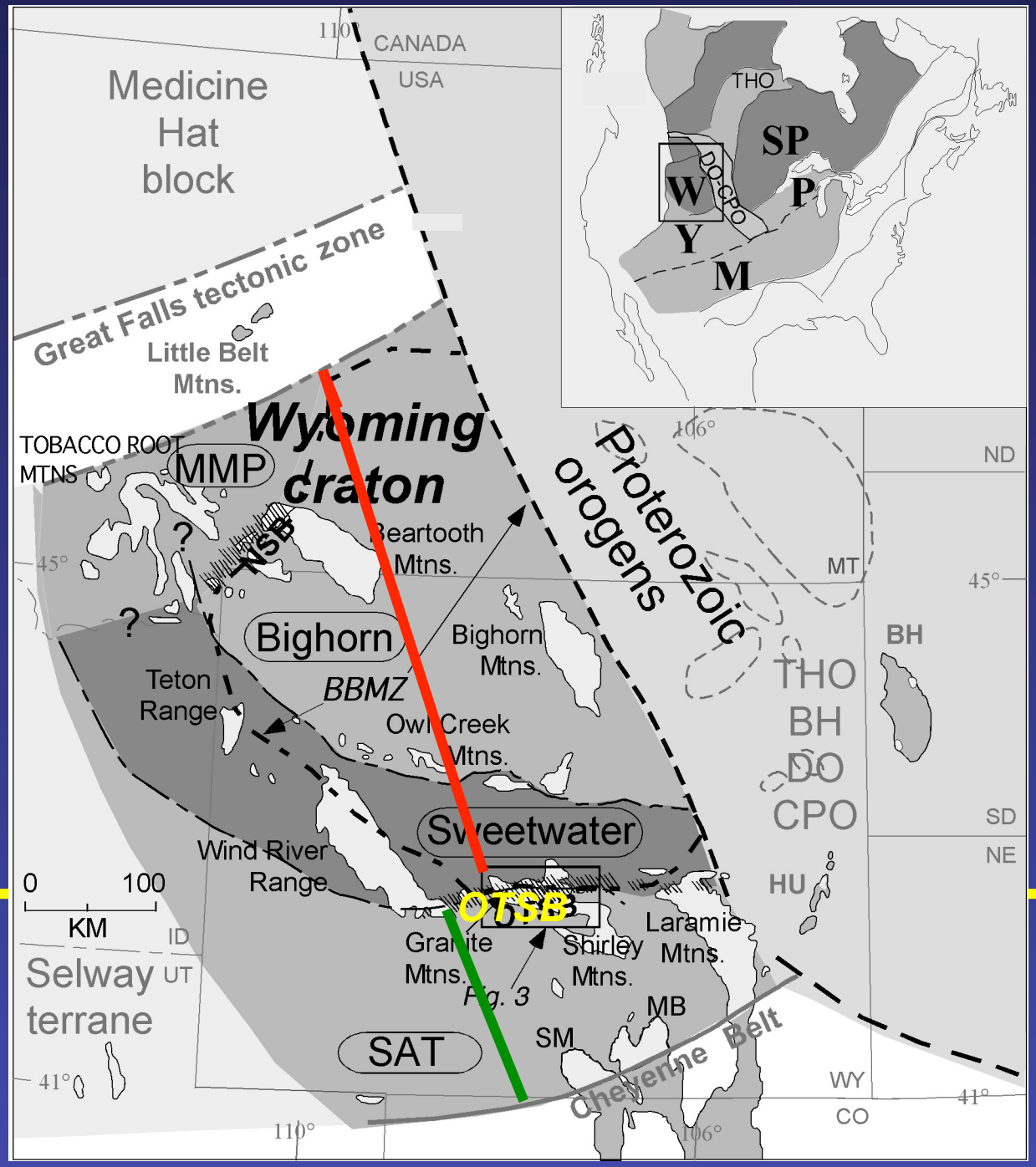
15.90
15.65
15.40
15.15
14.90
14.65
14.40
13
14
15
16
17
18
19
20
21
22
depleted mantle
BBMZ
cont. arcs
MMP
3.3-3.1 Ga Sacawee block gneisses
Nd
εNd
5
3
1
-1
-3
-5
-7
-9
-11
-13
3300
3100
2900
2700
2500
Time (Ga)


2.95-2.84 Ga BBM
Pb
Nd
Same samples
Mantle
depleted mantle
BBMZ
cont. arcs
MMP
3.3-3.1 Ga Sacawee block gneisses
Time (Ga)
3.3-2.95 Ga high μ mantle evolution
3.6-2.95 Ga ZD evolution
3.2-2.95 Ga ZD mantle
μ=16
μ=35
μ=20
μ=12
2.4 Ga
2.8 Ga
WY Prov. (△)
model mantle
2.95-2.84 Ga
Feldspar Pb data:
EBT, OC, WR
Native gneiss
calculated initials
207 Pb / 204 Pb
206 Pb / 204 Pb

high μ craton

low μ juv.

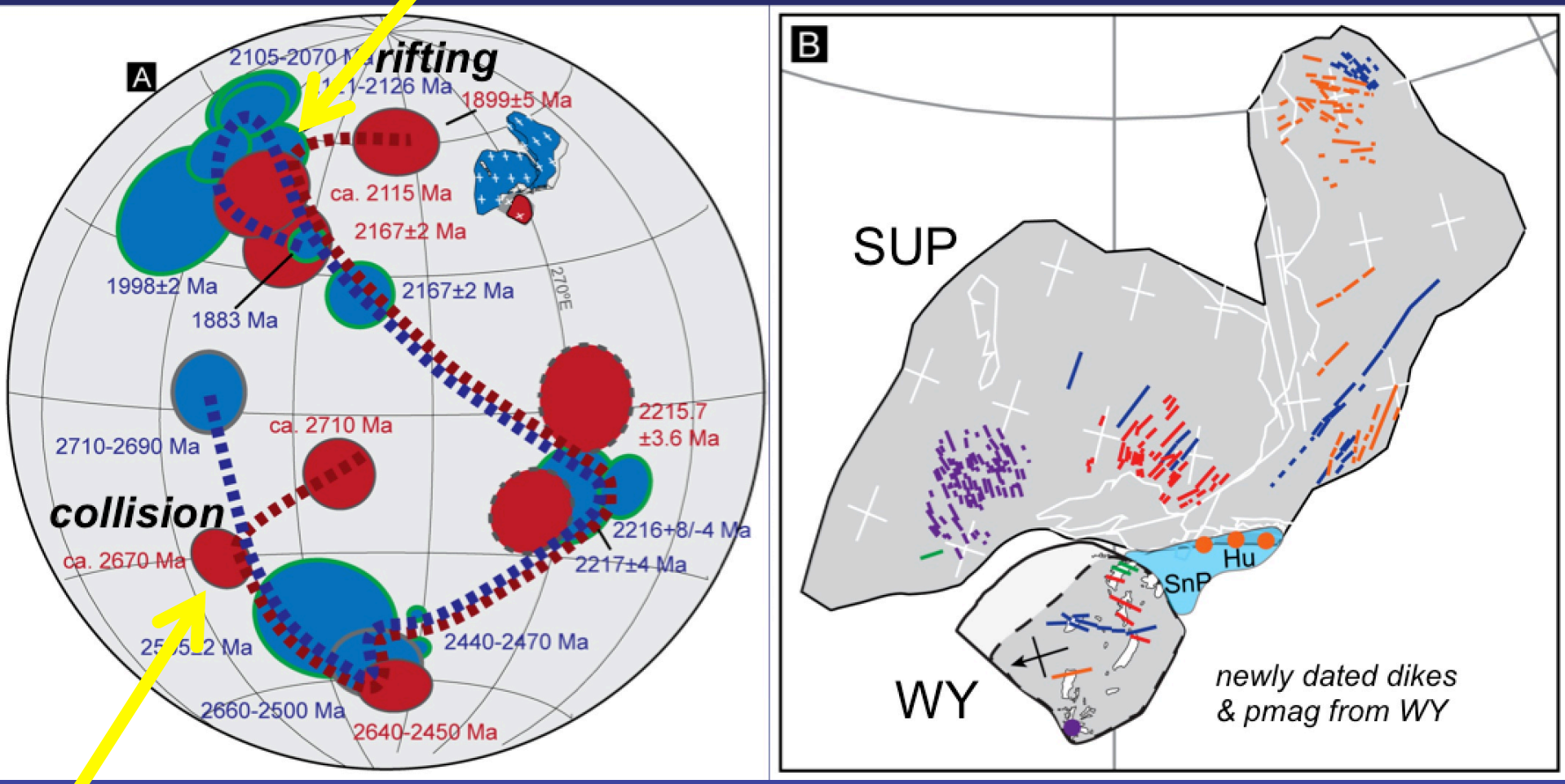


WY core

SUP

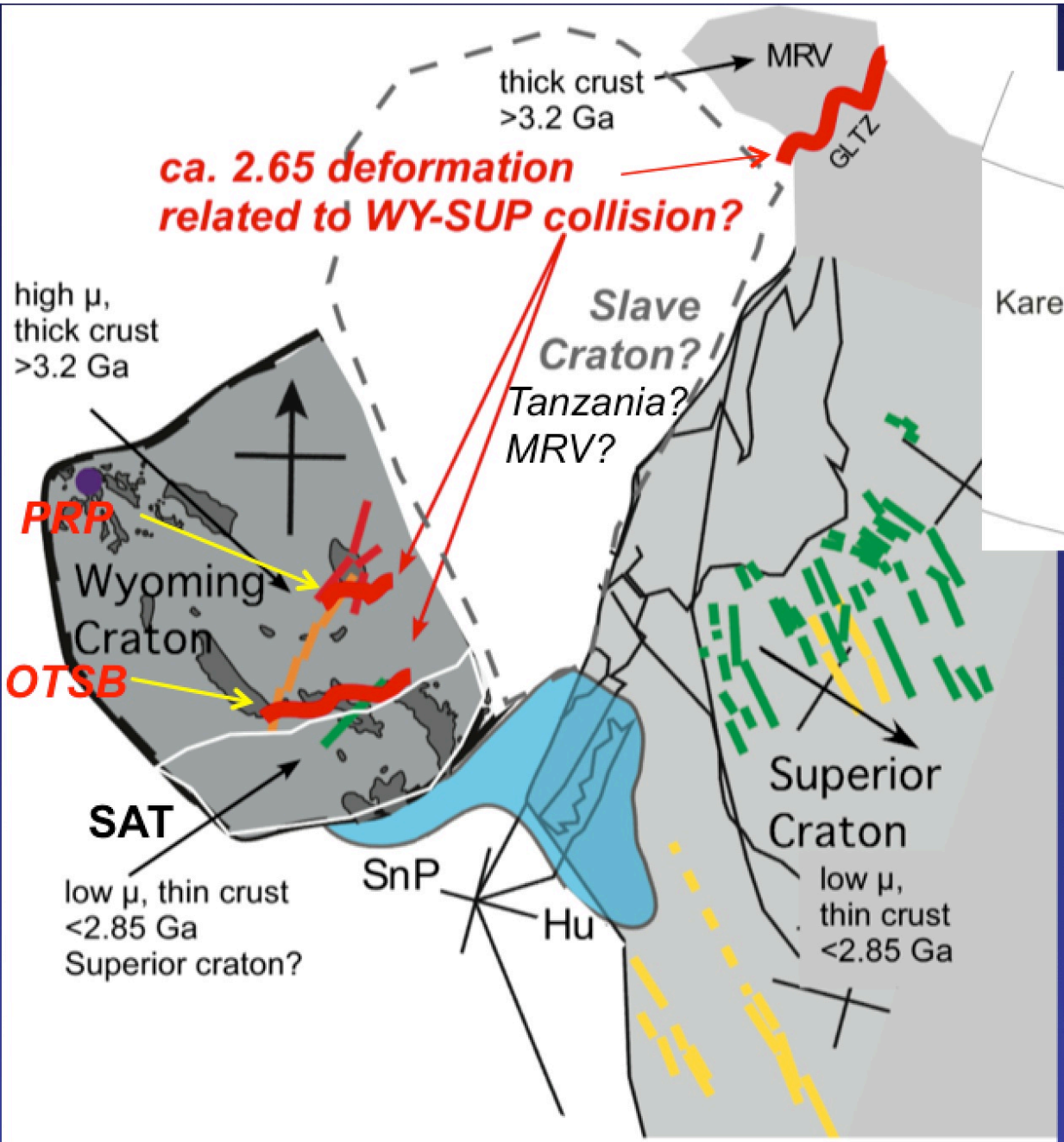
Apparent polar wander paths-WY vs SUP

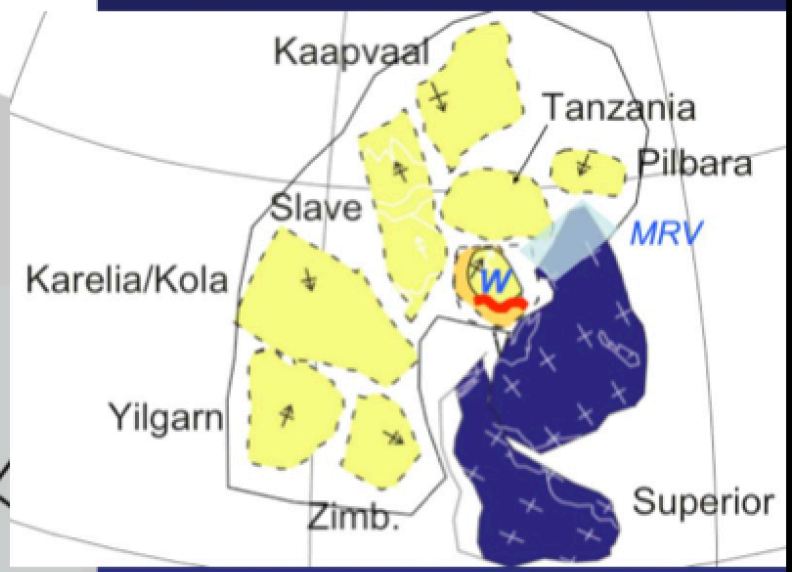
rifting ca. 2.10 Ga



collision ca. 2.67 Ga

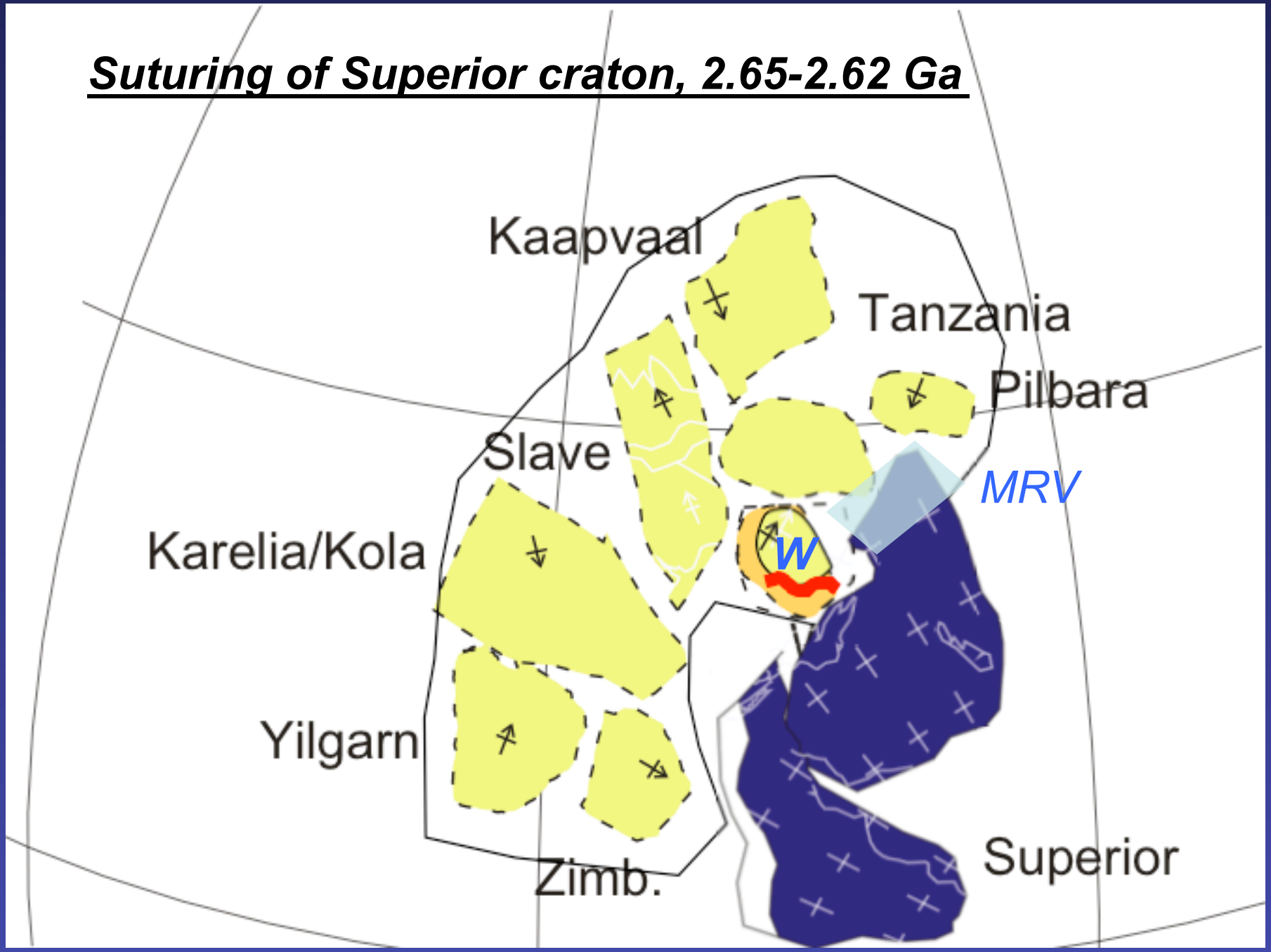
Kilian, 2015





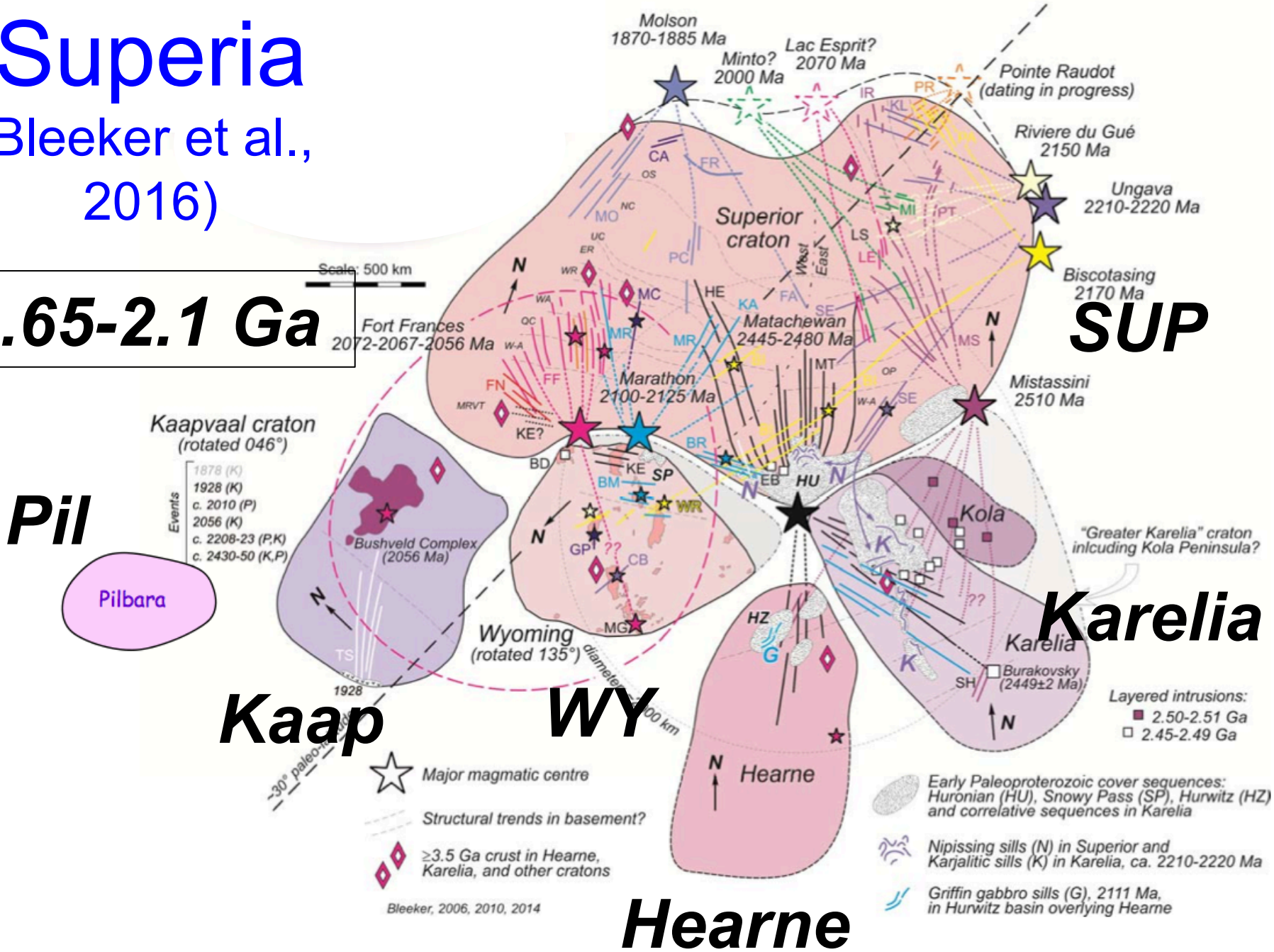
Wyoming-Superior reconstruction 2.65-2.0 Ga

Suturing of Superior craton, 2.65-2.62 Ga



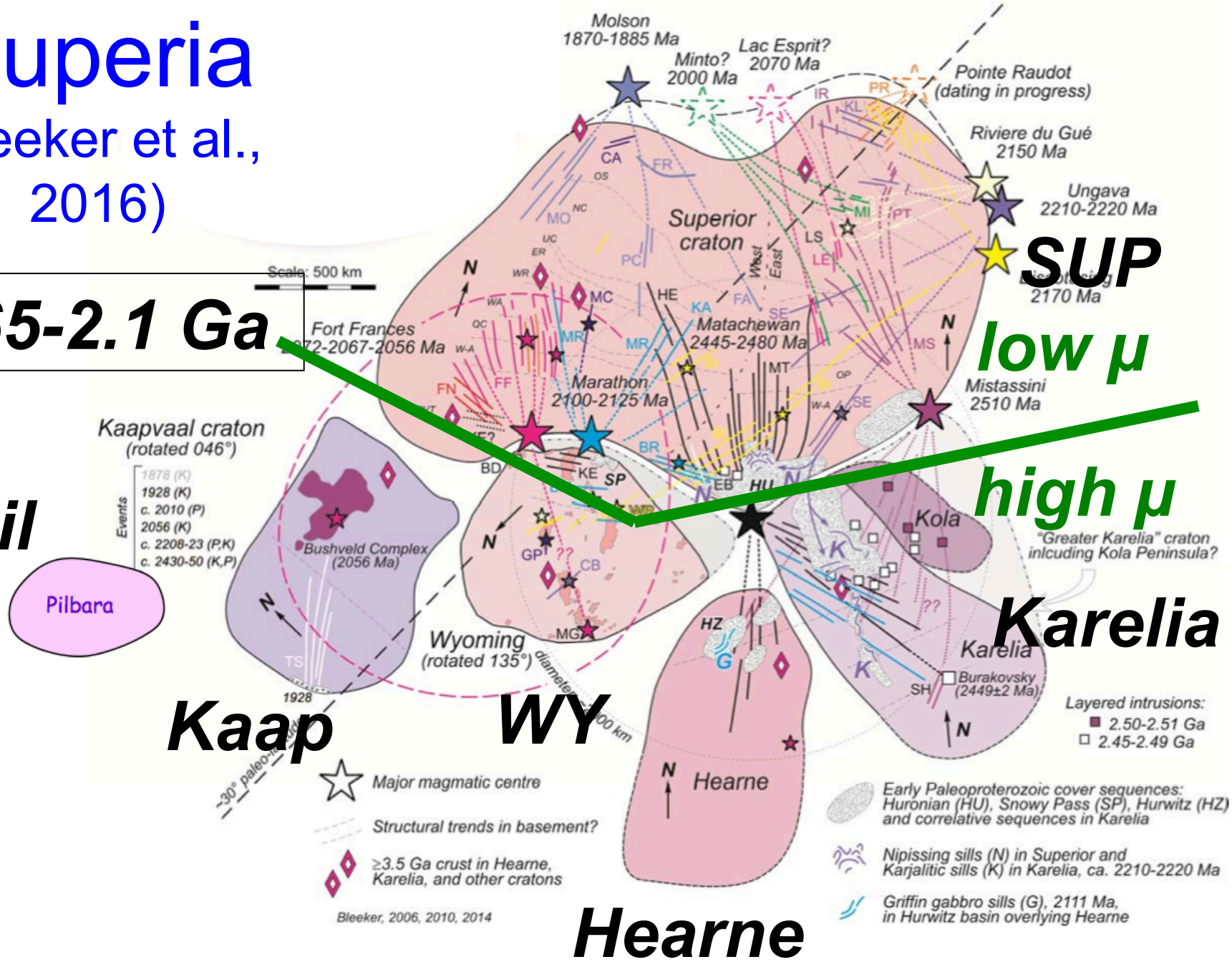
Superia
(Bleeker et al., 2016)

2.65-2.1 Ga



Superia
(Bleeker et al., 2016)

2.65-2.1 Ga



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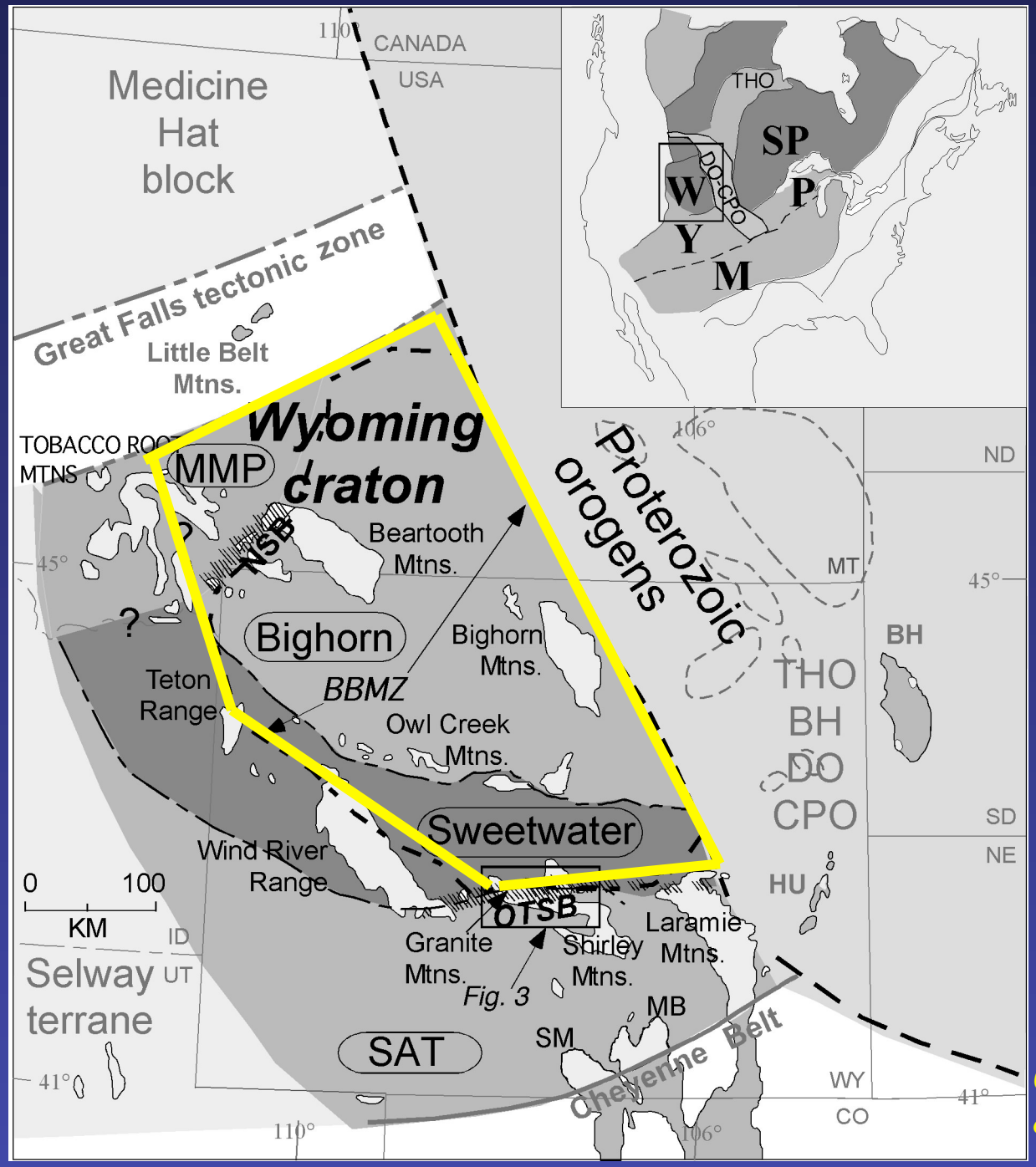
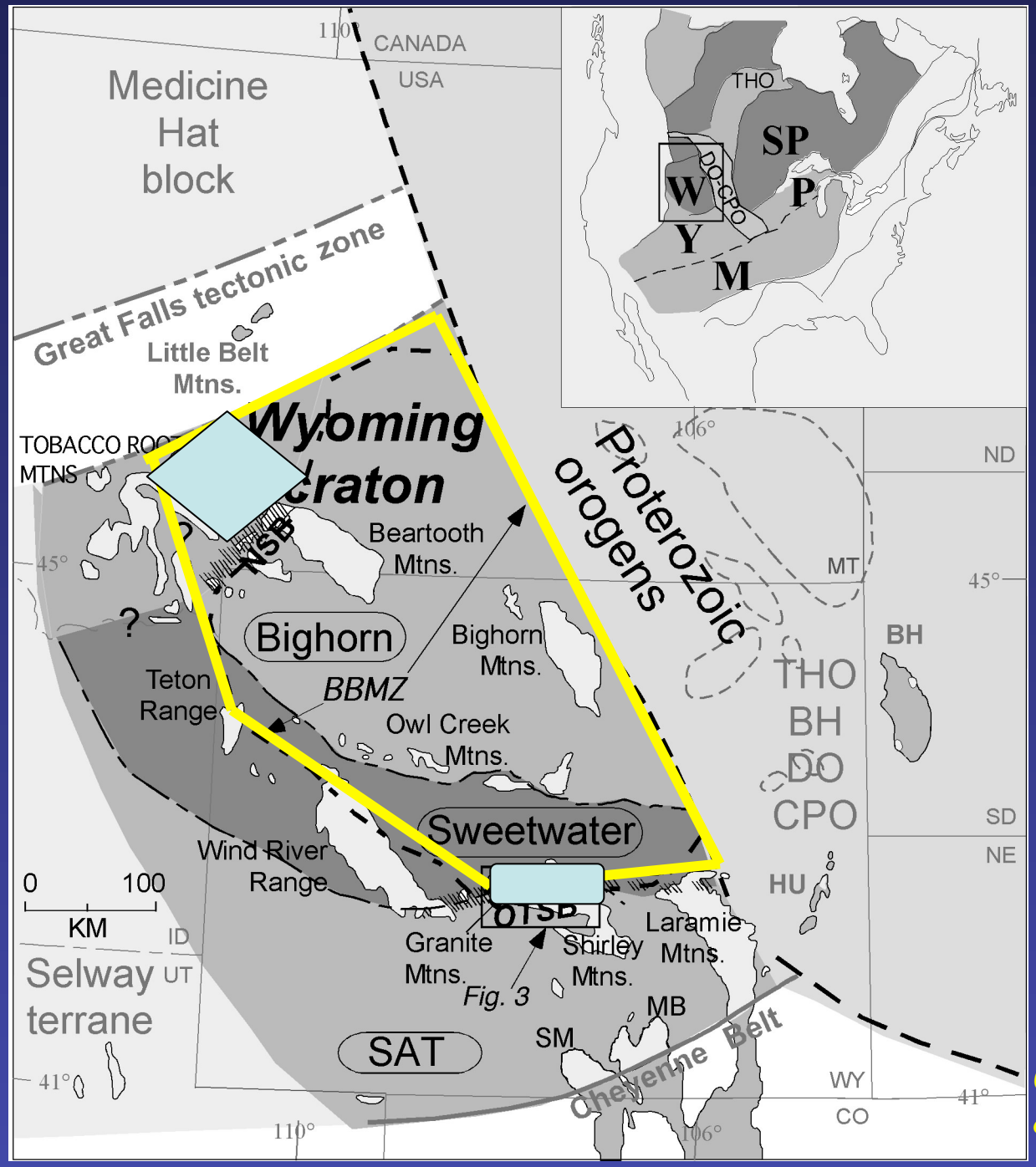
2



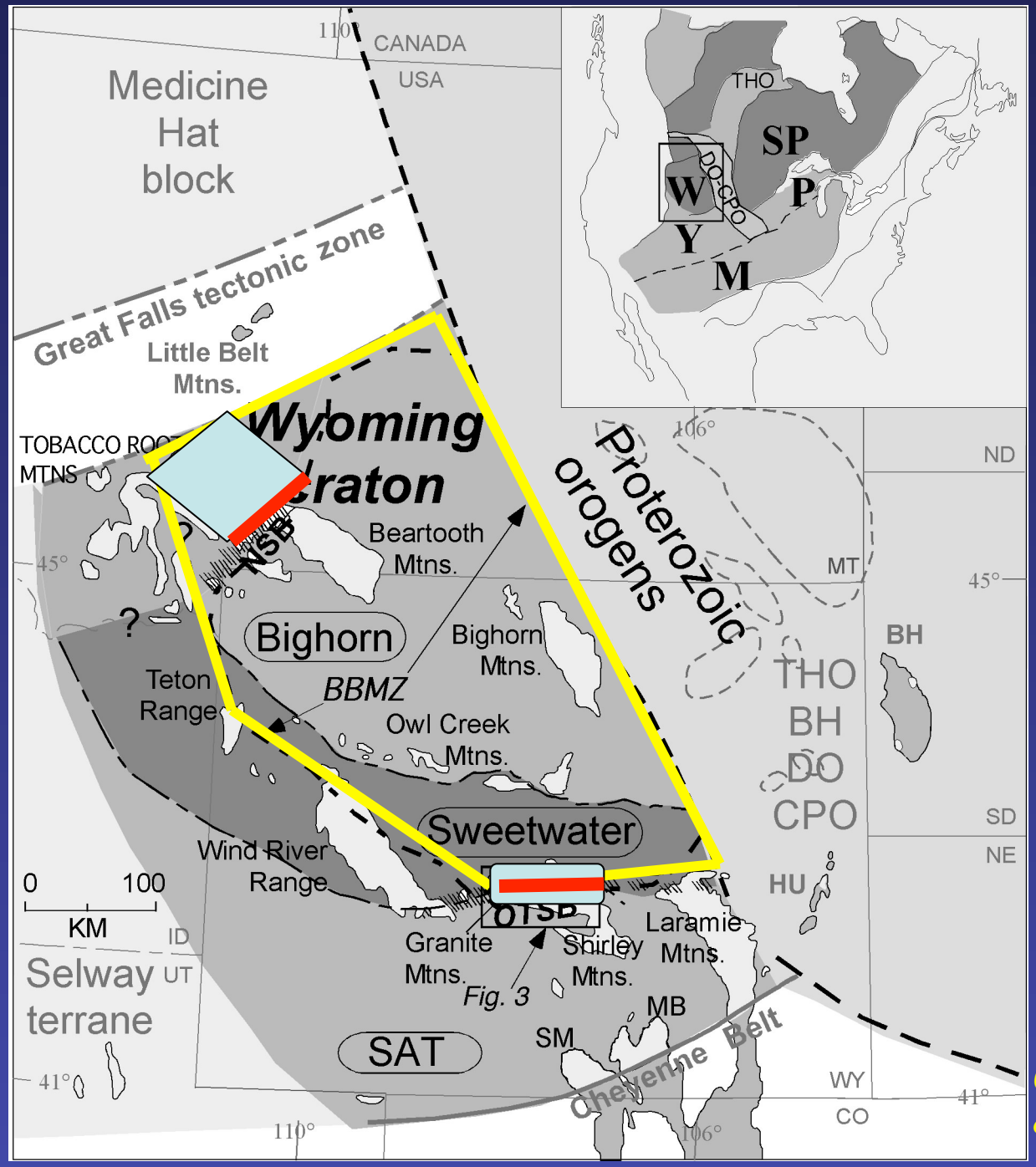
Possible 3.3 Ga craton

Chamberlain & Muller, 2018



Terranes With >3.3 Ga comp.

Chamberlain & Muller, 2018



Terranes With >3.3 Ga comp.

Late Arch. sutures

Chamberlain & Muller, 2018

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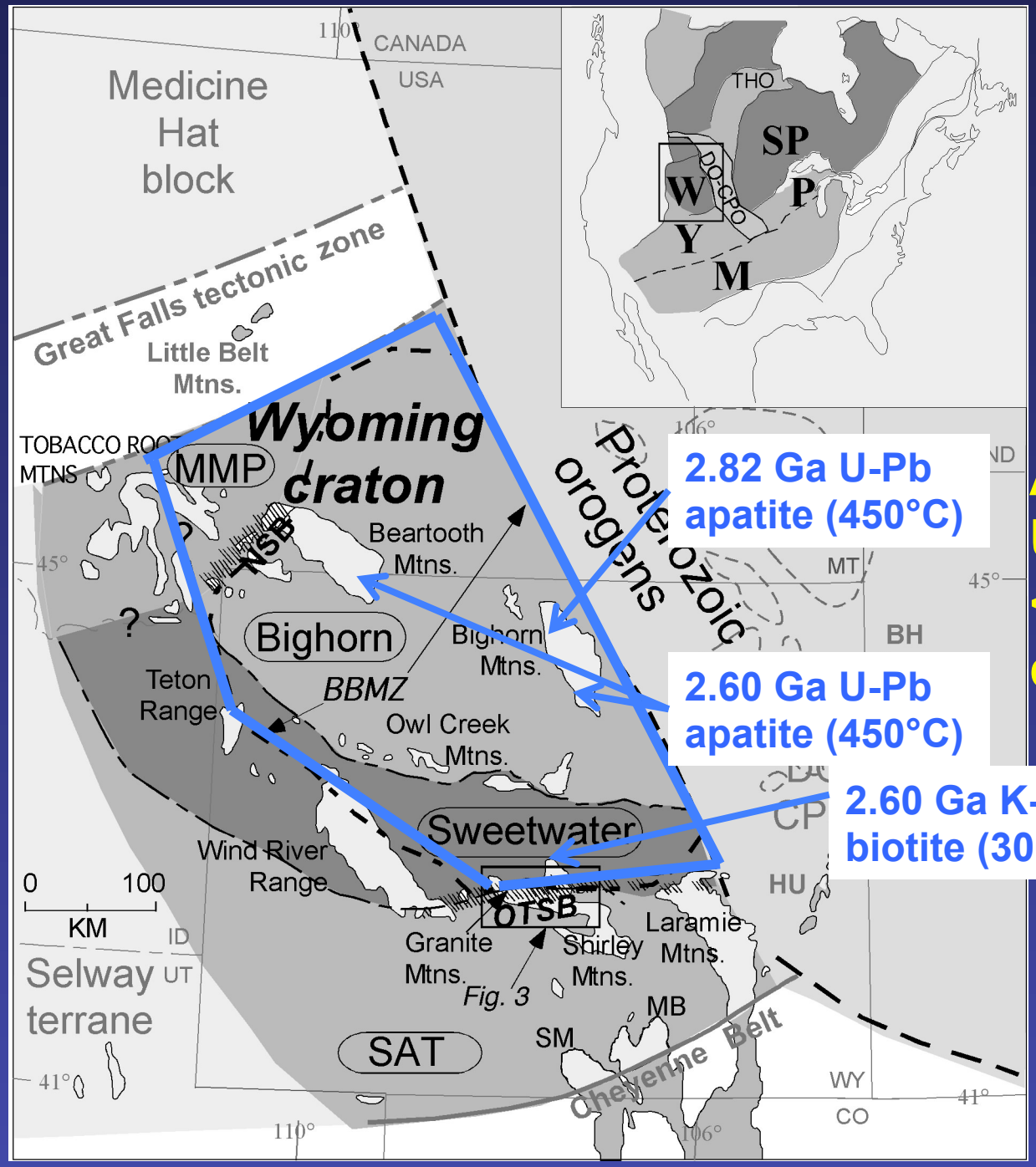
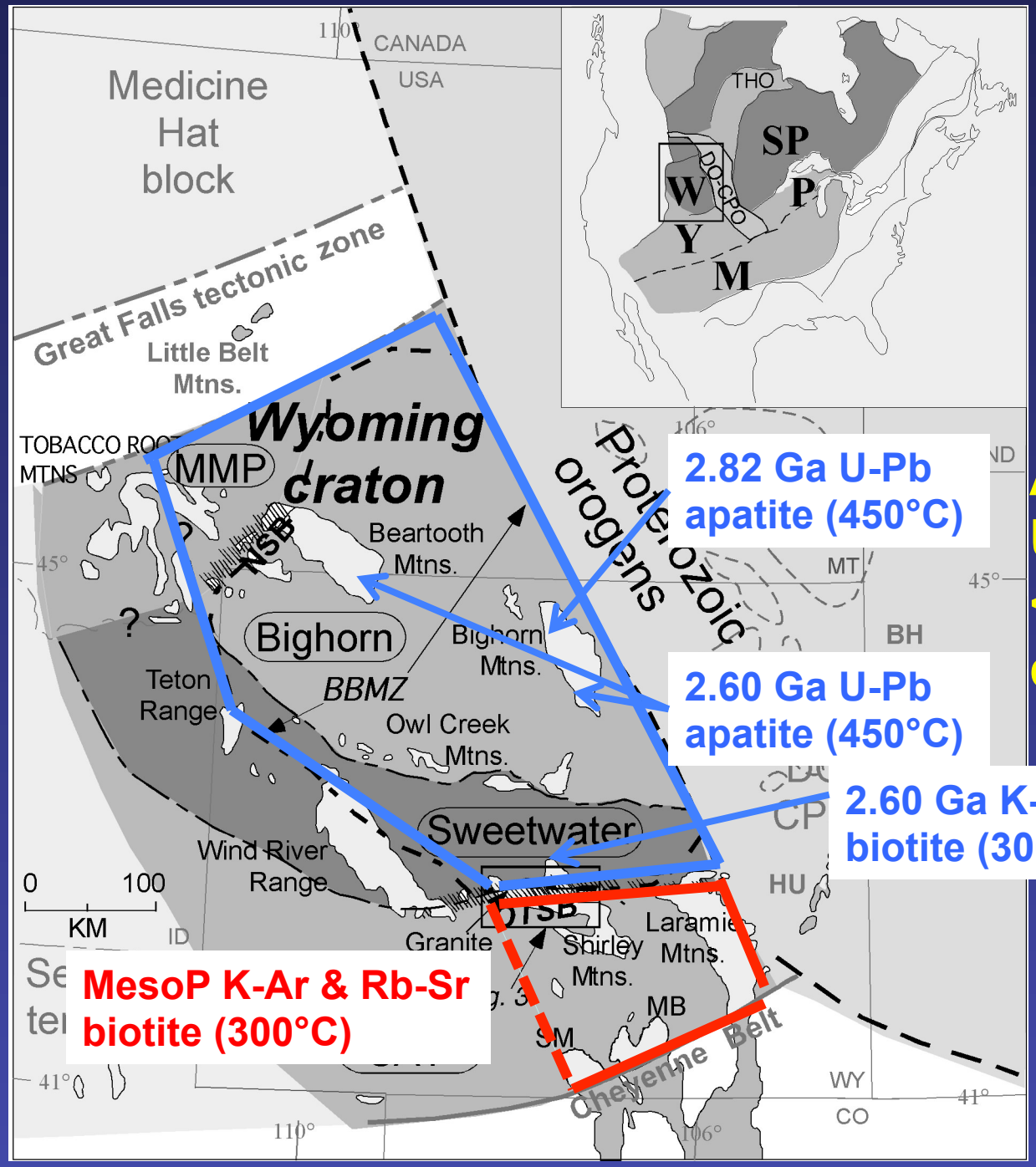


Arch. Unroofing, <10 km depth since



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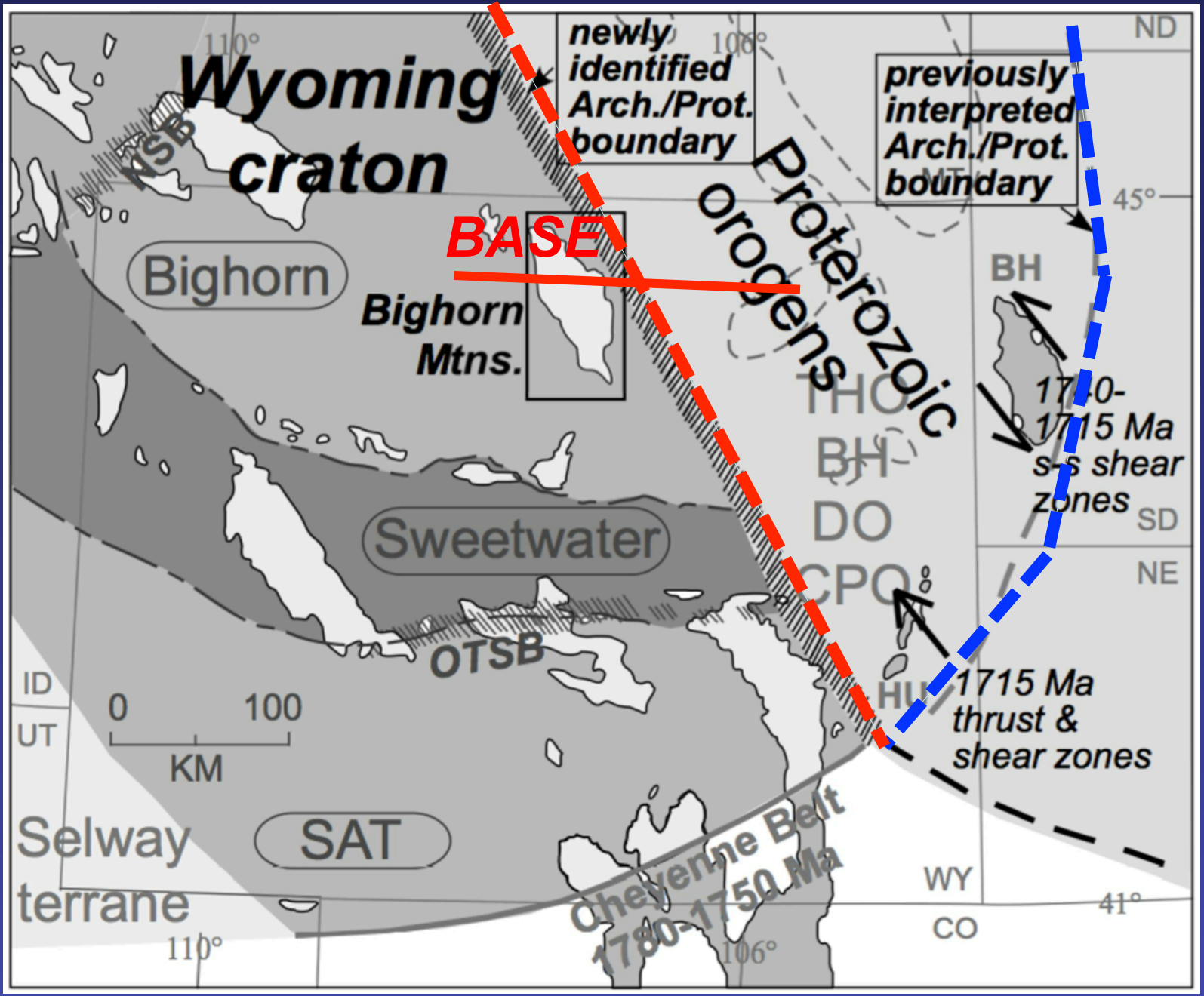
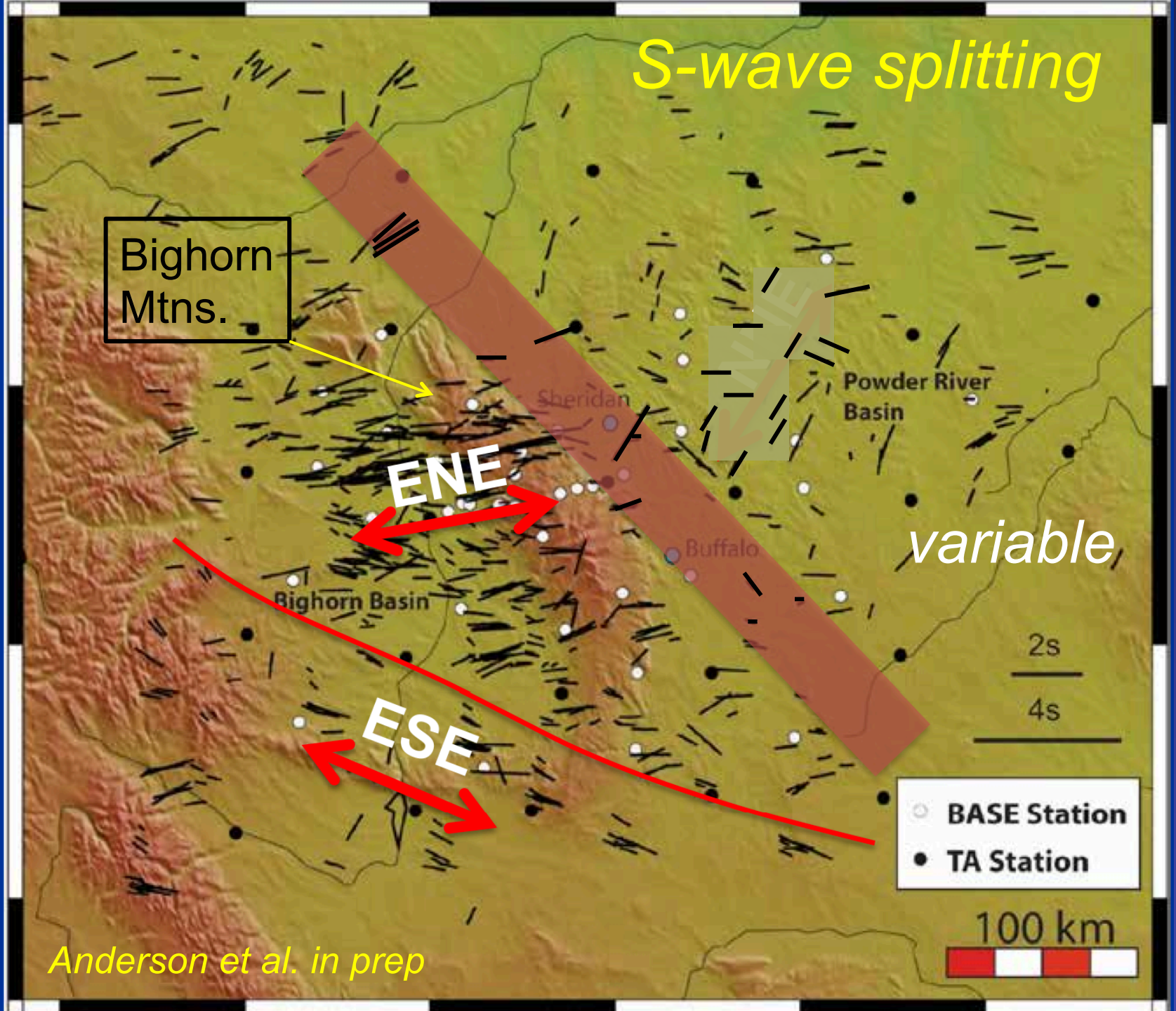
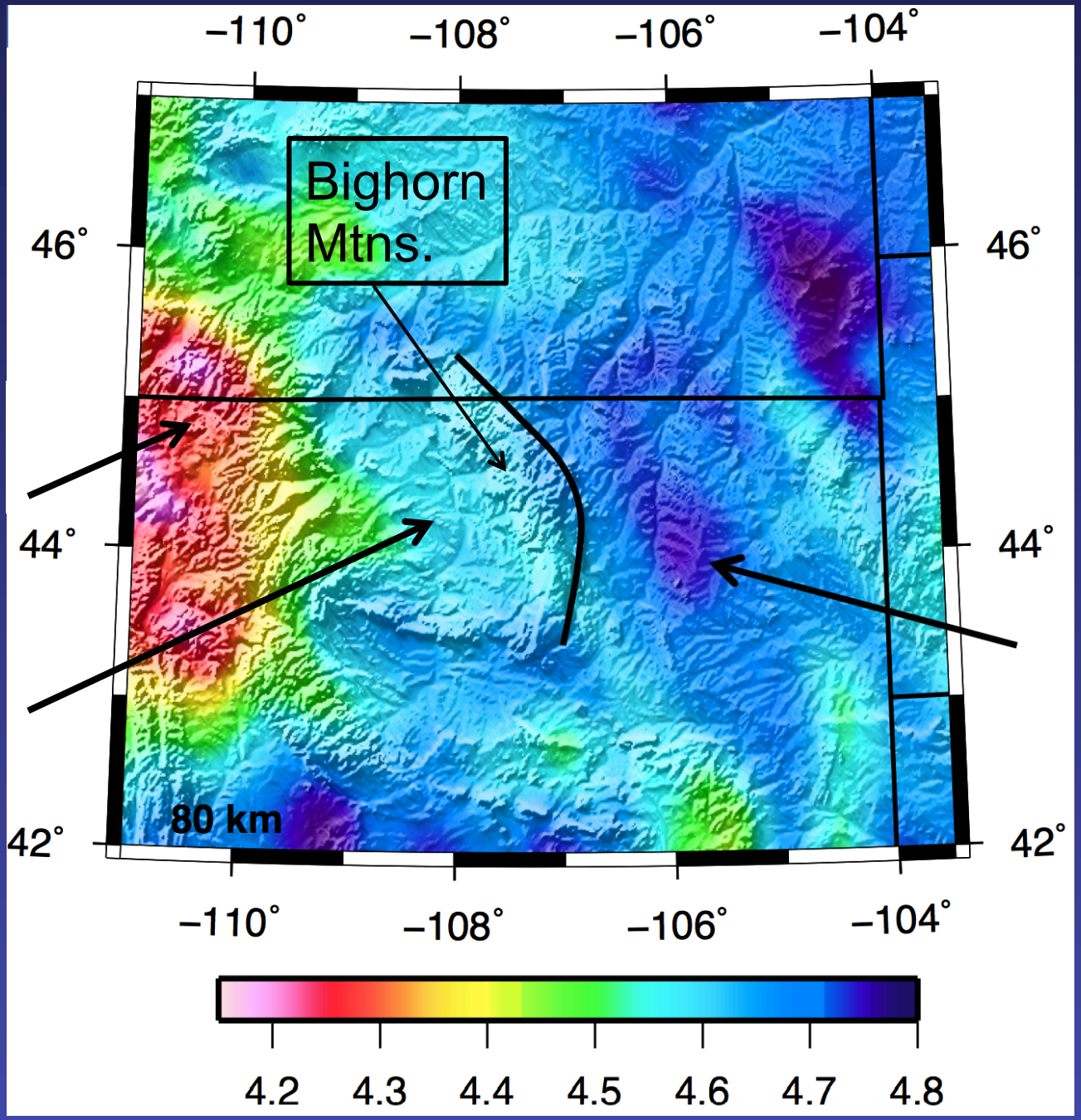
4



Worthington et al., 2016


S-wave splitting
Bighorn Mtns.
Sheridan
Powder River Basin
ENE
Buffalo
variable
Bighorn Basin
2s
4s
ESE
BASE Station
TA Station
100 km
Anderson et al. in prep

S-Wave Tomo. 80 km (BASE)



Yellowstone

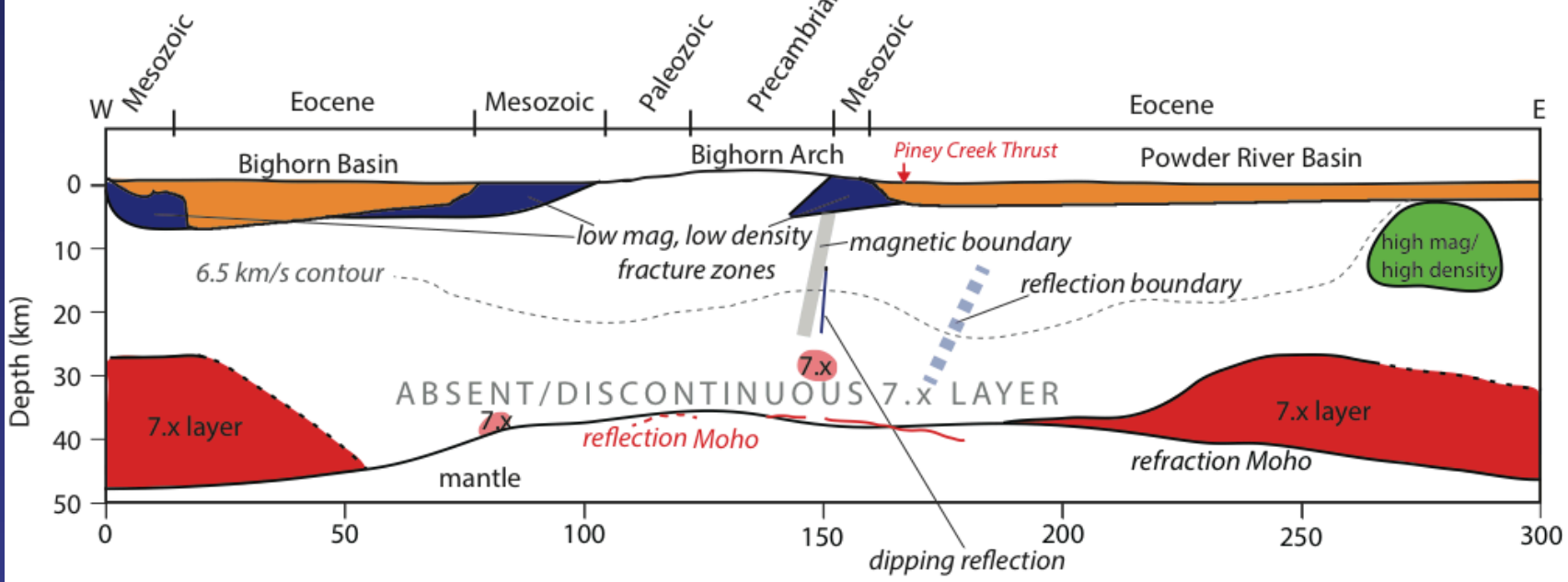
Archean

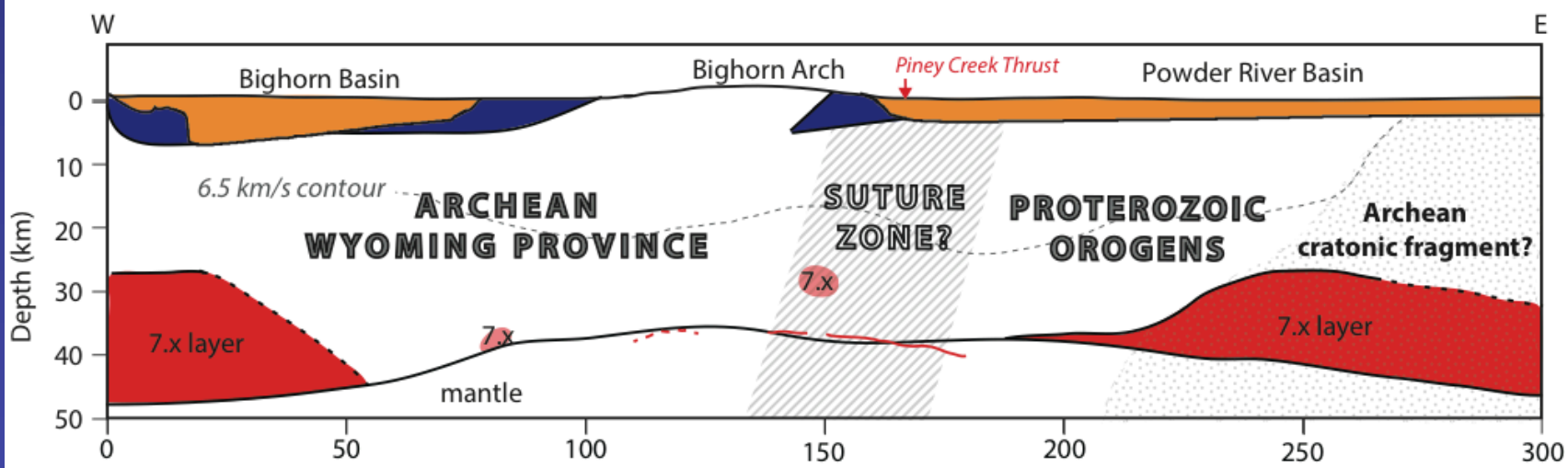
Protero.

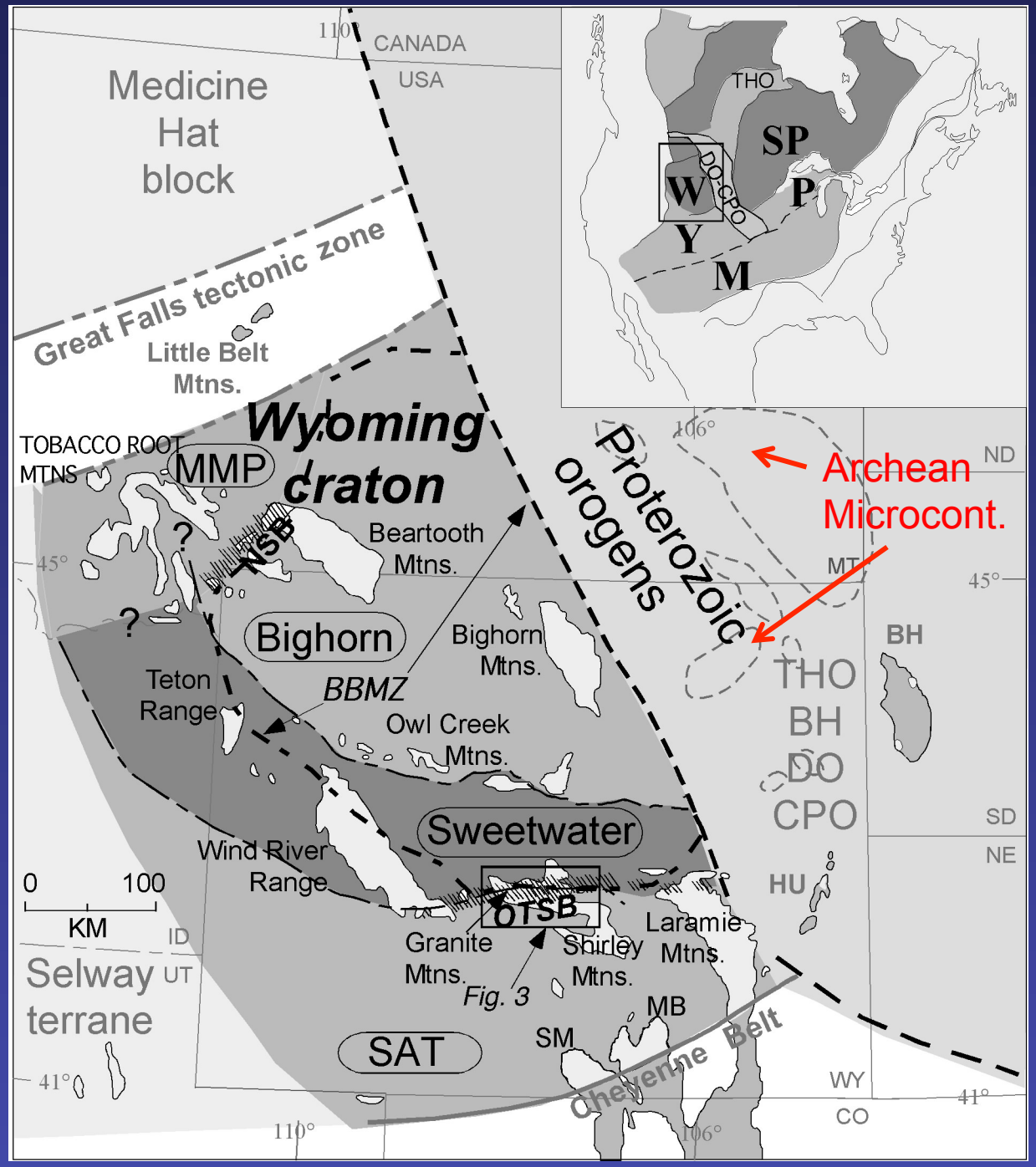
Yeck 2015

BASE interpretation

Worthington et al., 2015







aeromag. highs = Archean microcont.

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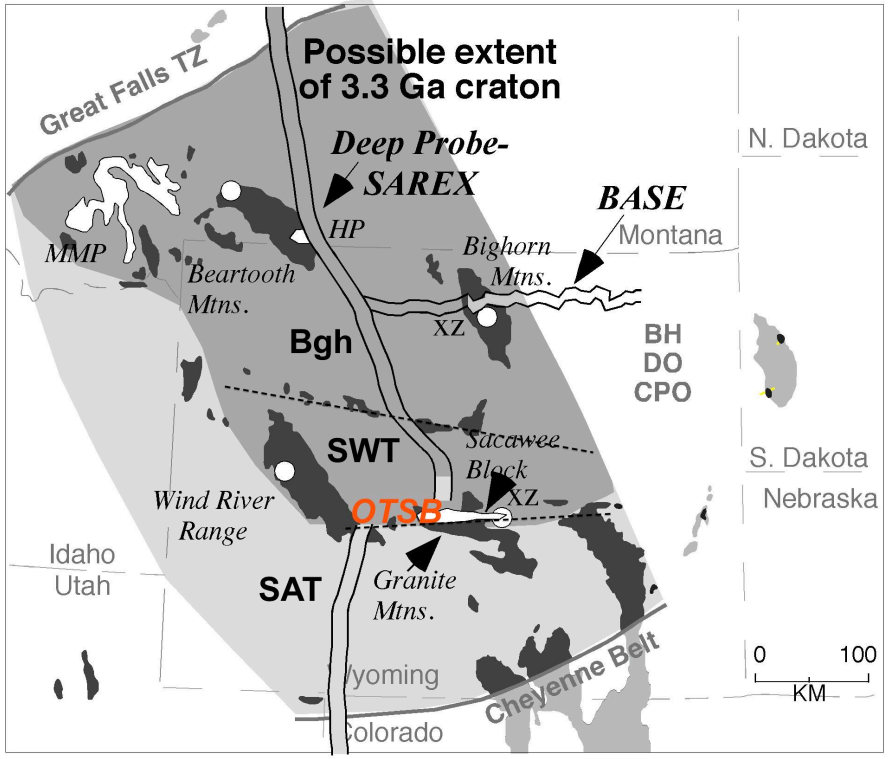
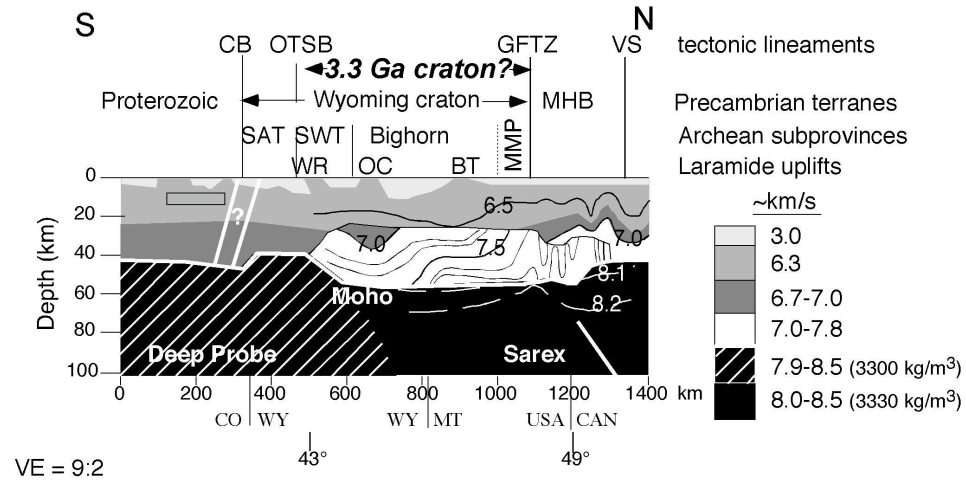
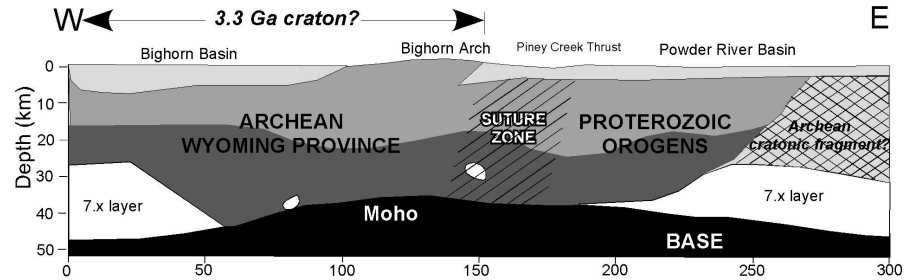
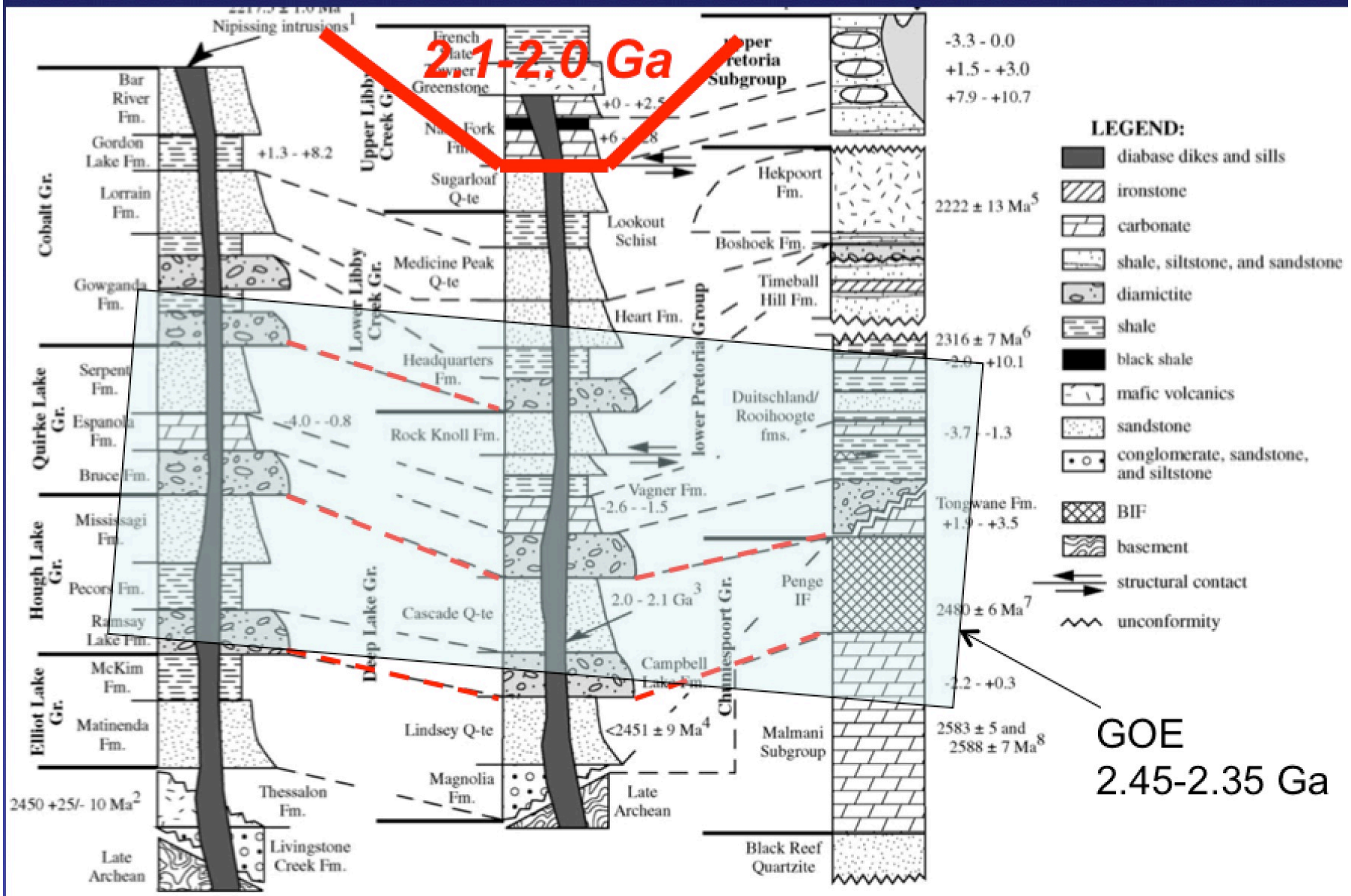
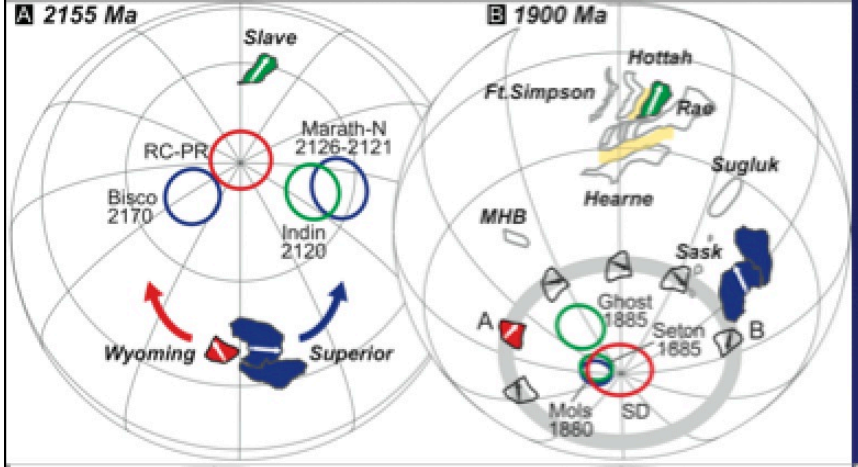

Possible extent of 3.3 Ga craton
Great Falls TZ
Deep Probe-SAREX
BASE
N. Dakota
Montana
HP
MMP
Beartooth Mtns.
Bighorn Mtns.
XZ
Bgh
BH
DO
CPO
SWT
Sacawee Block
S. Dakota
Nebraska
Wind River Range
OTSB
XZ
Idaho
Utah
SAT
Granite Mtns.
Wyoming
Colorado
Cheyenne Belt
0 100
KM

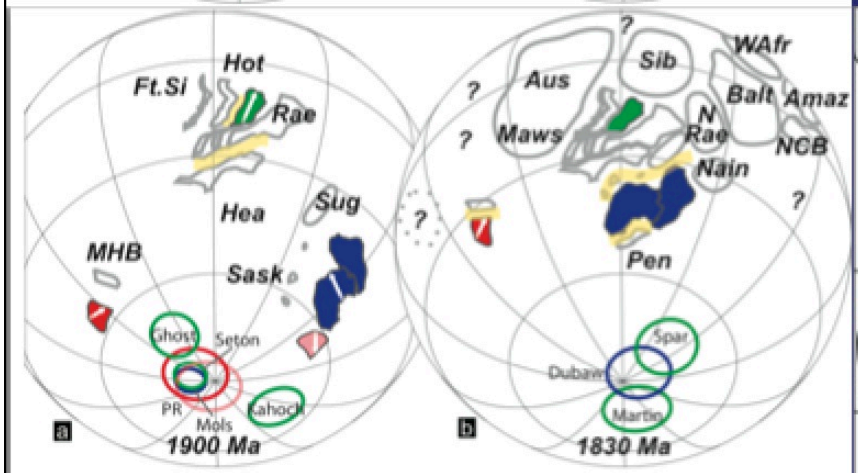

S
N
CB OTSB
GFTZ
VS
tectonic lineaments
3.3 Ga craton?
Proterozoic
Wyoming craton
MHB
Precambrian terranes
Archean subprovinces
Laramide uplifts
SAT SWT
Bighorn
WR OC BT
MMP
Depth (km)
6.5
7.0
7.5
7.0
8.1
8.2
Moho
Deep Probe
Sarex
~km/s
3.0
6.3
6.7-7.0
7.0-7.8
7.9-8.5 (3300 kg/m3)
8.0-8.5 (3330 kg/m3)
0 200 400 600 800 1000 1200 1400 km
CO WY
WY MT
USA CAN
43°
49°
VE = 9:2

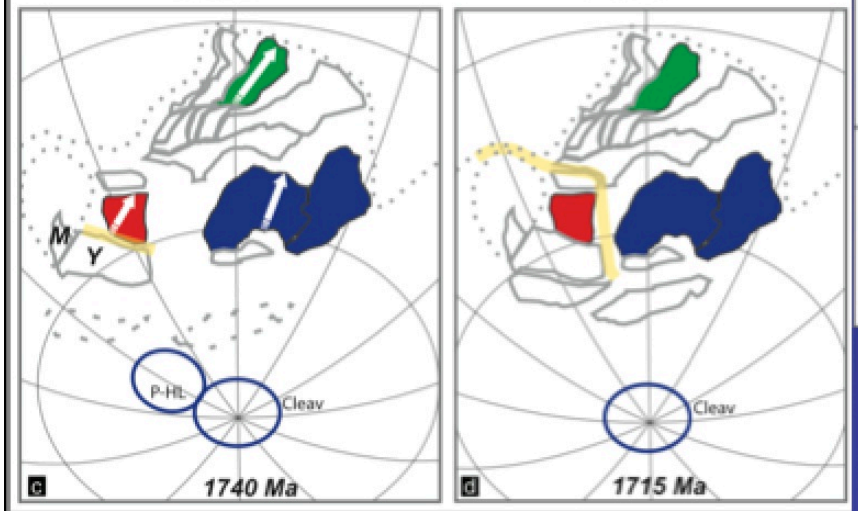

W
3.3 Ga craton?
E
Bighorn Basin
Bighorn Arch
Piney Creek Thrust
Powder River Basin
Depth (km)
ARCHEAN WYOMING PROVINCE
SUTURE ZONE
PROTEROZOIC OROGENS
Archean cratonic fragment?
7.x layer
7.x layer
Moho
BASE
0 50 100 150 200 250 300

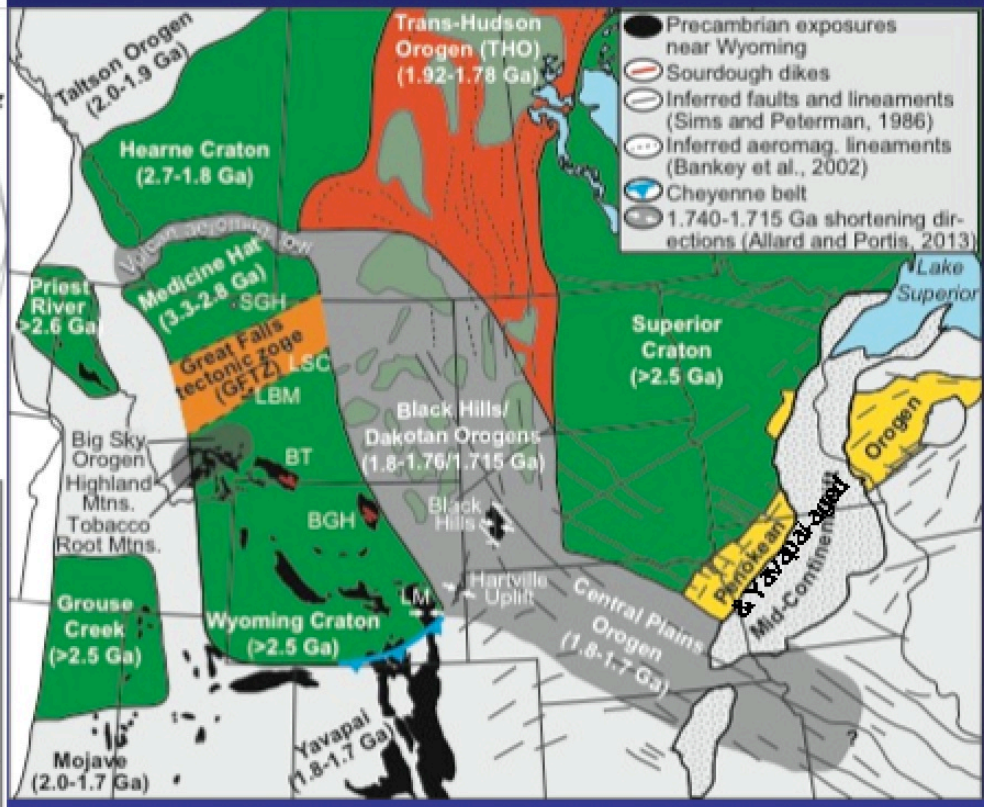
Huronian SUP | Snowy P. WY | Transvaal Kaap




A 2155 Ma
Slave
RC-PR
Marath-N
2126-2121
Bisco
2170
Indin
2120
Wyoming
Superior
B 1900 Ma
Hottah
Ft.Simpson
Rae
Sugluk
Hearne
MHB
Sask
A
Ghost
1885
Seton
1885
B
Mols
1880
SD


Hot
Ft.Si
Rae
Hea
Sug
MHB
Sask
Ghost
Seton
PR
Mols
Kahoch
a
1900 Ma
Sib
WAfr
Aus
Balt
Amaz
Maws
N
Rae
NCB
Nain
Pen
Spar
Dubawnt
Martin
b
1830 Ma

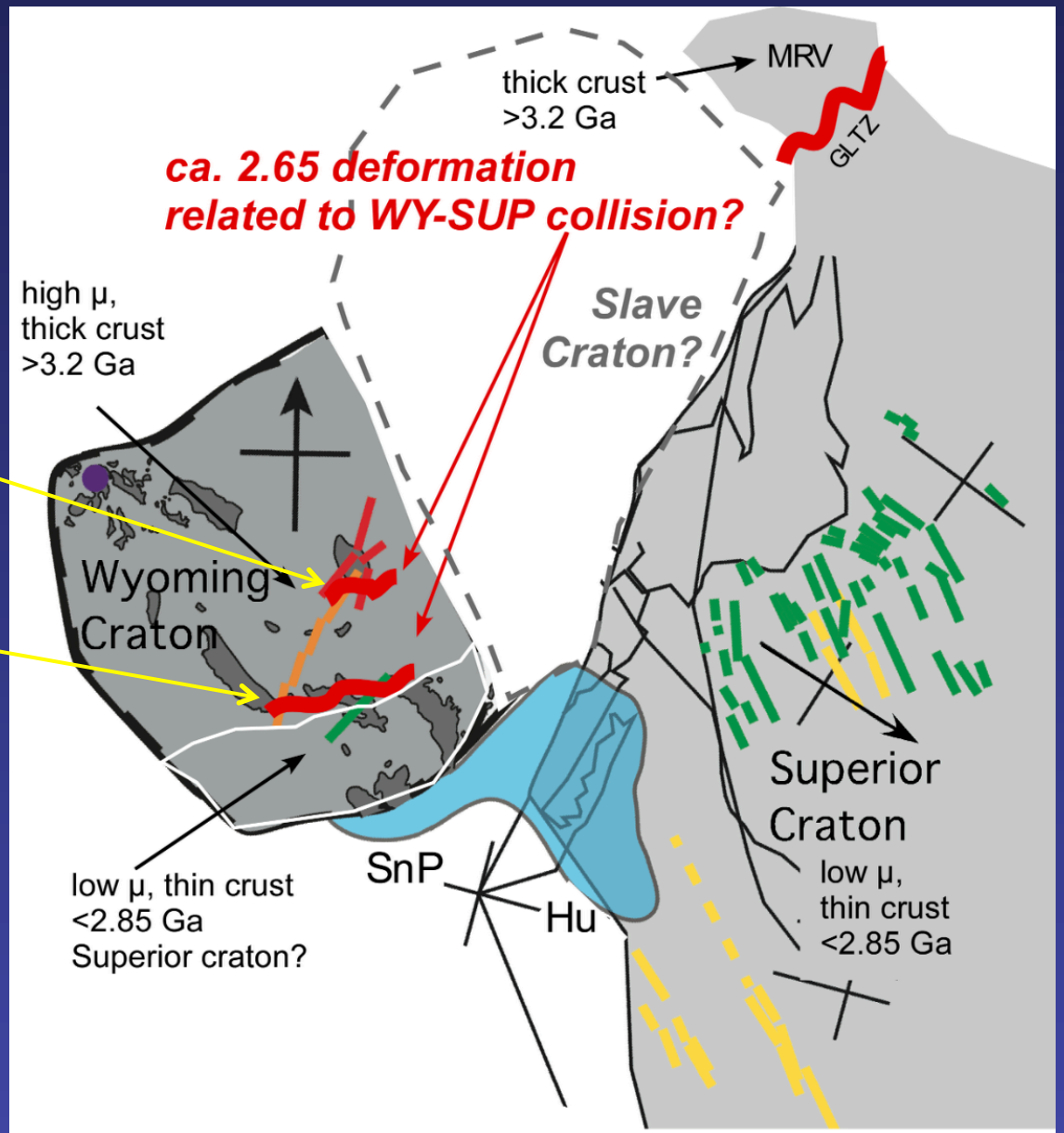

M
Y
P-HL
Cleav
c
1740 Ma
Cleav
d
1715 Ma


Taltson Orogen
(2.0-1.9 Ga)
Trans-Hudson
Orogen (THO)
(1.92-1.78 Ga)
Precambrian exposures near Wyoming
Sourdough dikes
Inferred faults and lineaments (Sims and Peterman, 1986)
Inferred aeromag. lineaments (Bankey et al., 2002)
Cheyenne belt
1.740-1.715 Ga shortening directions (Allard and Portis, 2013)
Hearne Craton
(2.7-1.8 Ga)
Medicine Hat
(3.3-2.8 Ga)
SGH
Priest
River
>2.6 Ga
Great Falls
tectonic zone
(GFTZ)
LSC
LBM
Lake
Superior
Superior
Craton
(>2.5 Ga)
Black Hills/
Dakotan Orogens
(1.8-1.76/1.715 Ga)
Big Sky
Orogen
Highland
Mtns.
Tobacco
Root Mtns.
BT
BGH
Black
Hills
Orogen
Hartville
Uplift
LM
Grouse
Creek
(>2.5 Ga)
Wyoming Craton
(>2.5 Ga)
Central Plains
Orogen
(1.8-1.7 Ga)
Mid-Continent
Yavapai
(1.8-1.7 Ga)
Mojave
(2.0-1.7 Ga)

2.67-2.62 Ga shear zones:

PRP sz

OTSB

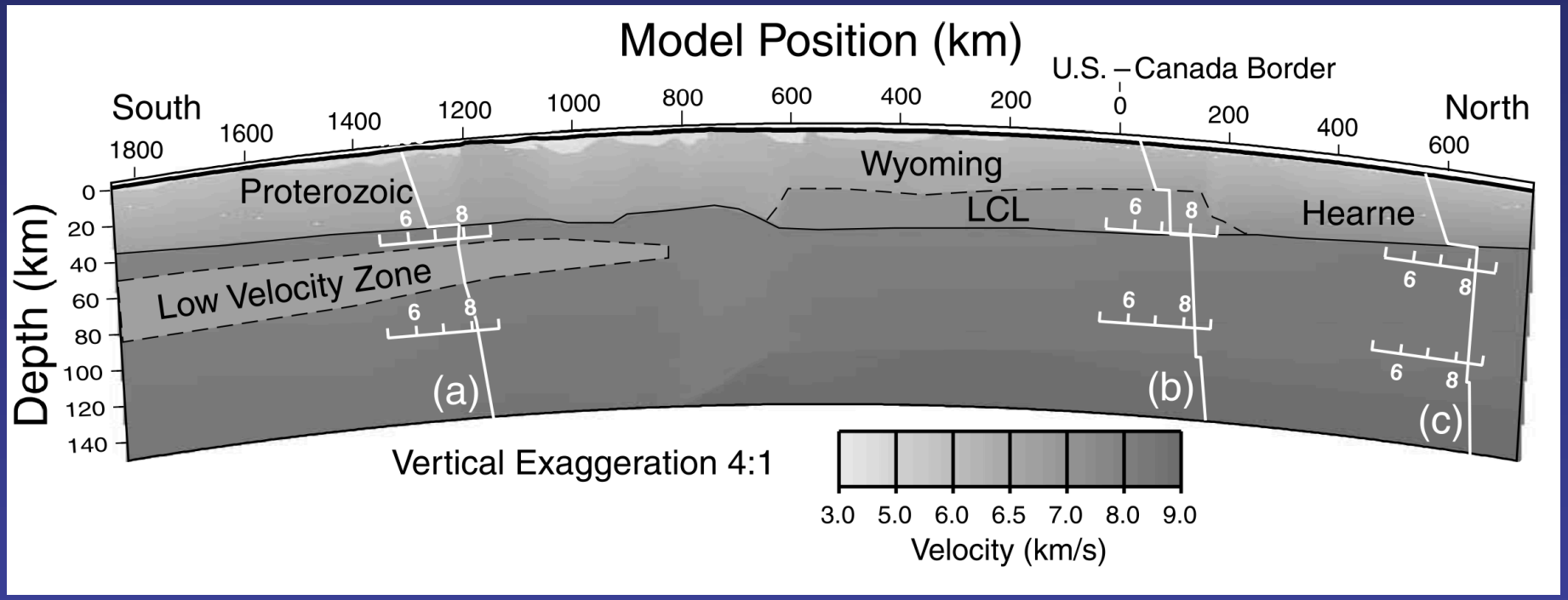


Wyoming-Superior reconstruction 2.65-2.0 Ga

Adapted from Kilian et al., 2015

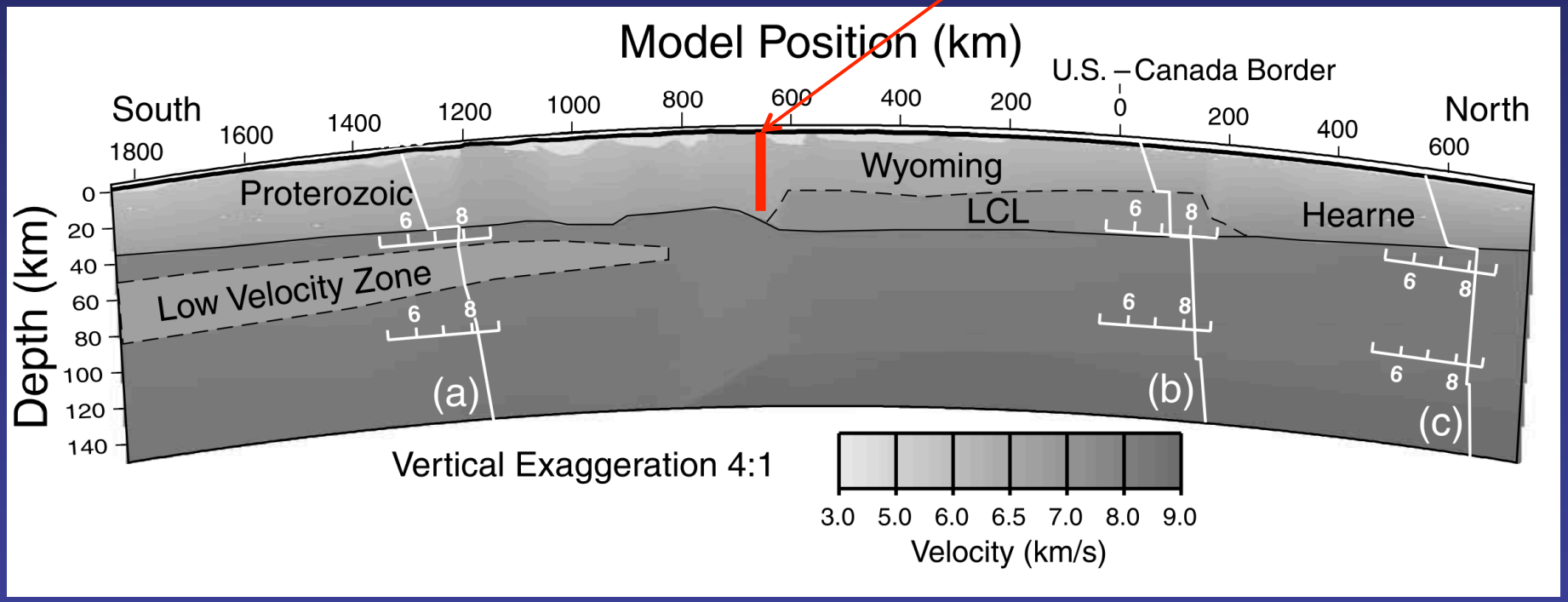
Parker et al., 2015

Deep Probe velocity model



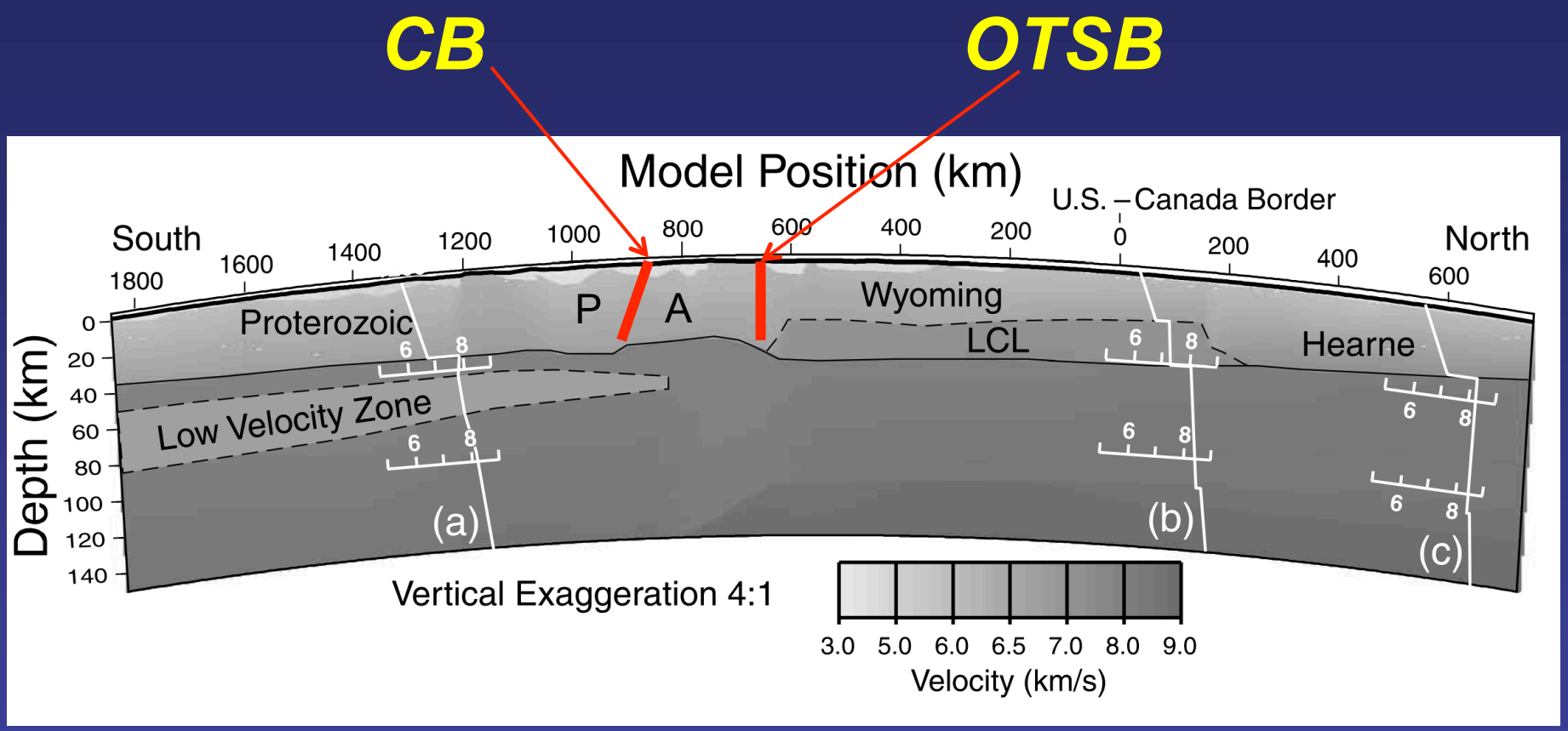
Gorman et al., 2002

Deep Probe velocity model



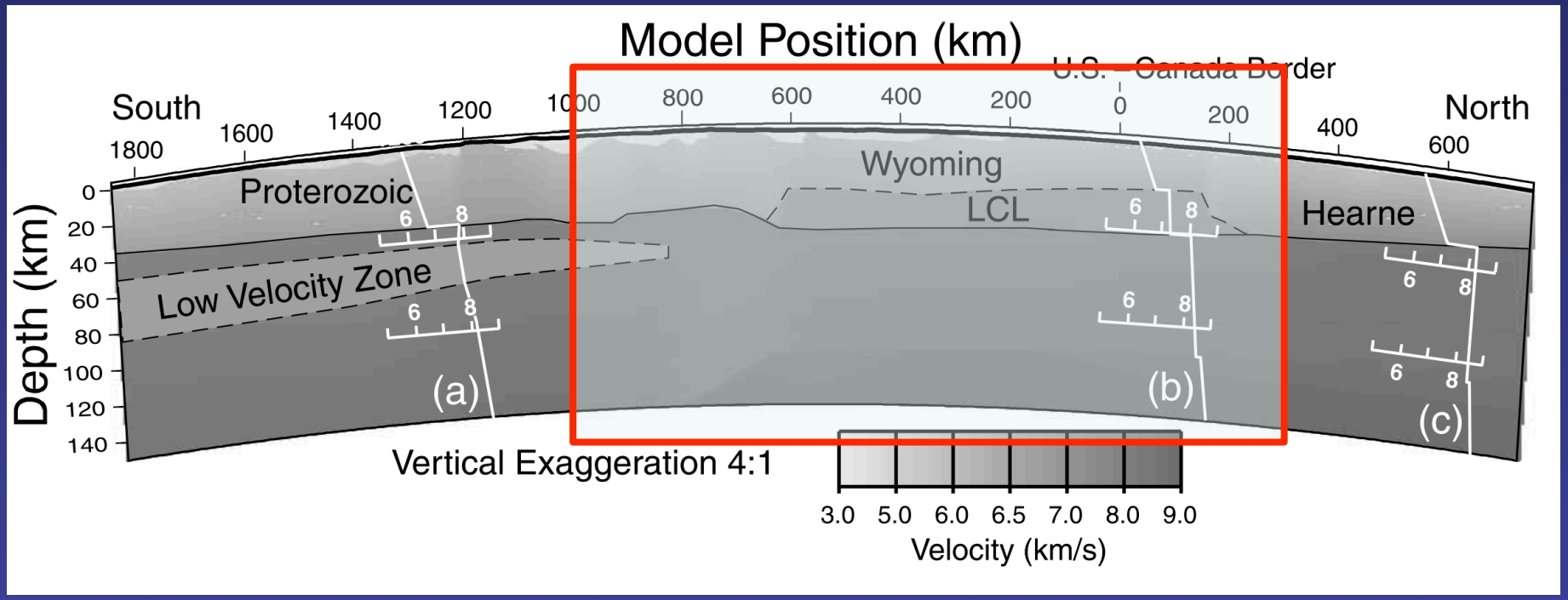
Gorman et al., 2002

Deep Probe velocity model



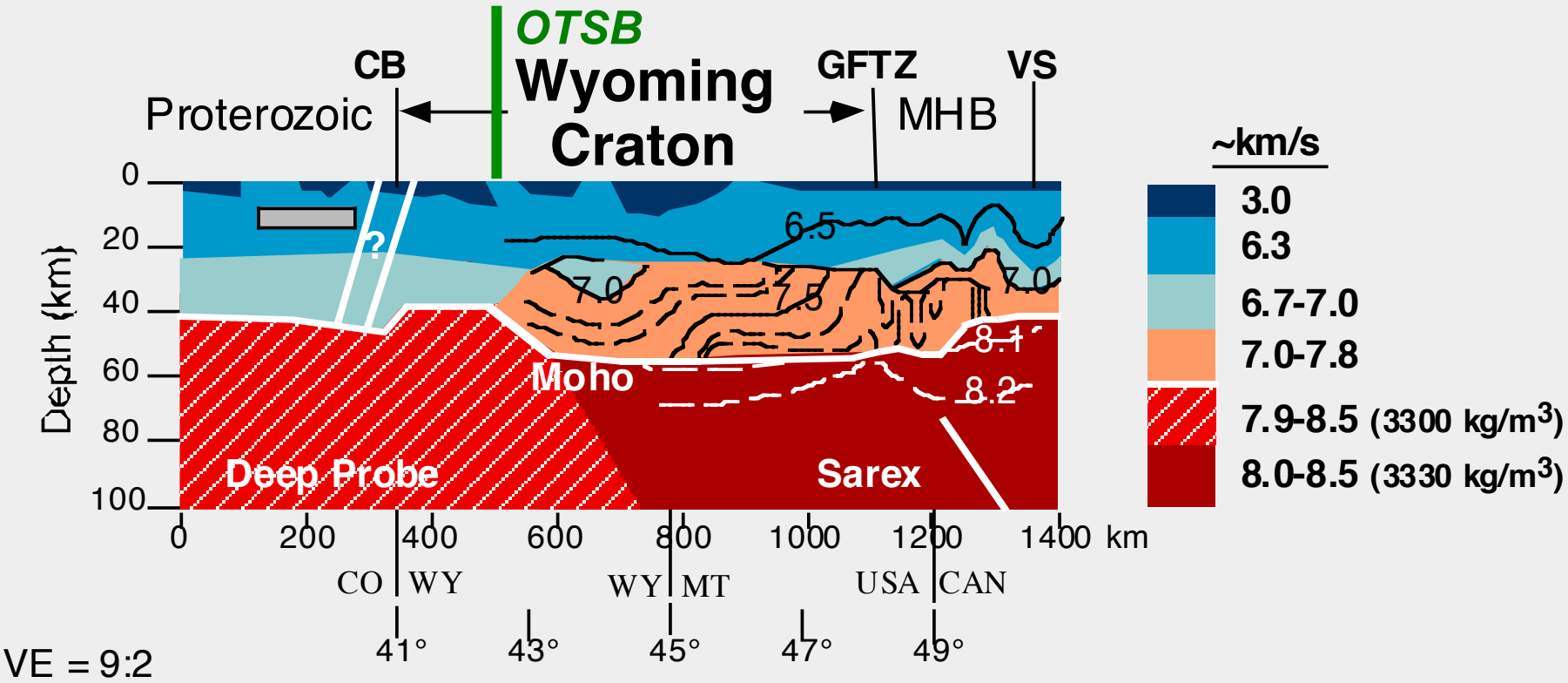
Gorman et al., 2002

Deep Probe velocity model

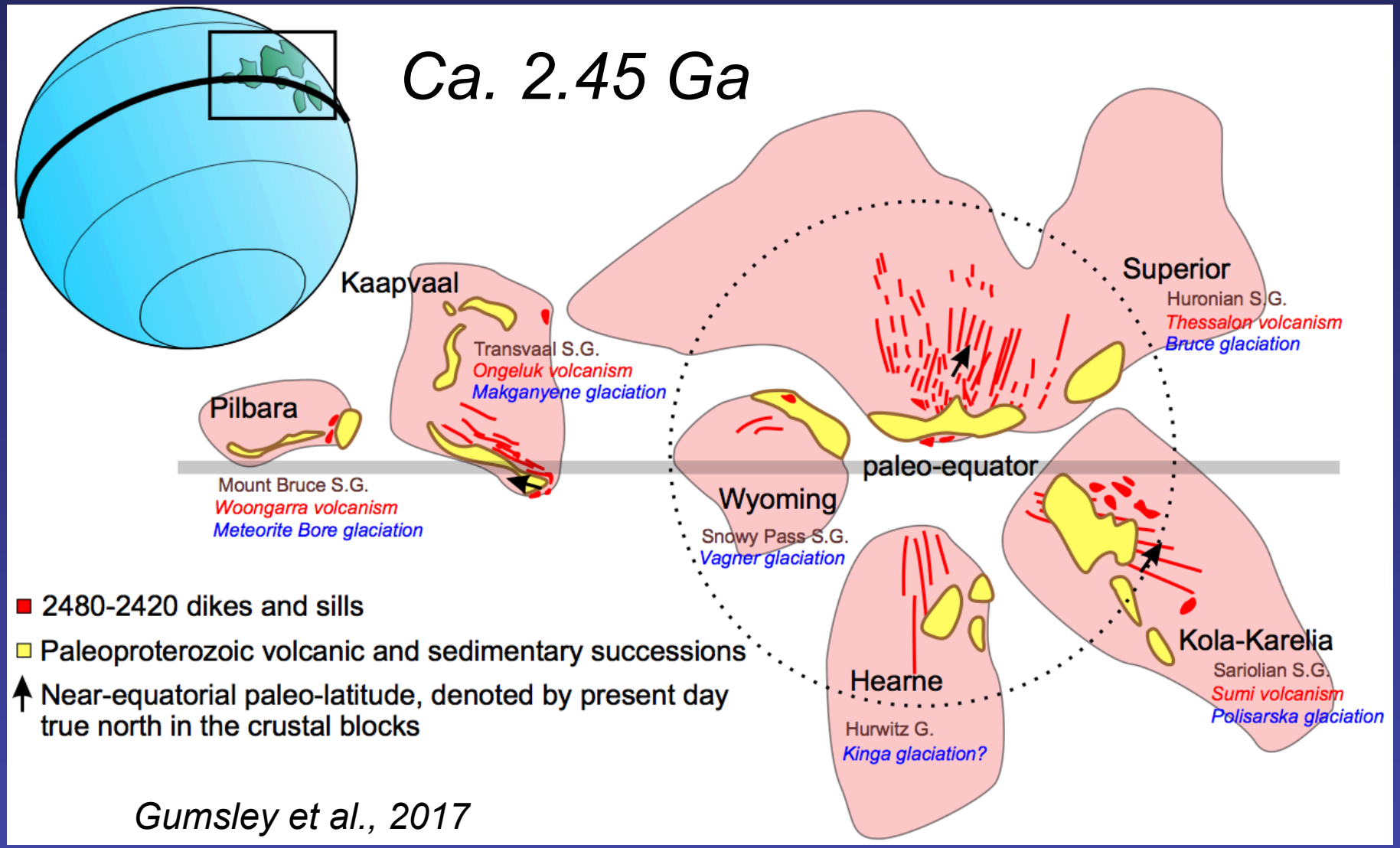


Gorman et al., 2002

Deep Probe transect

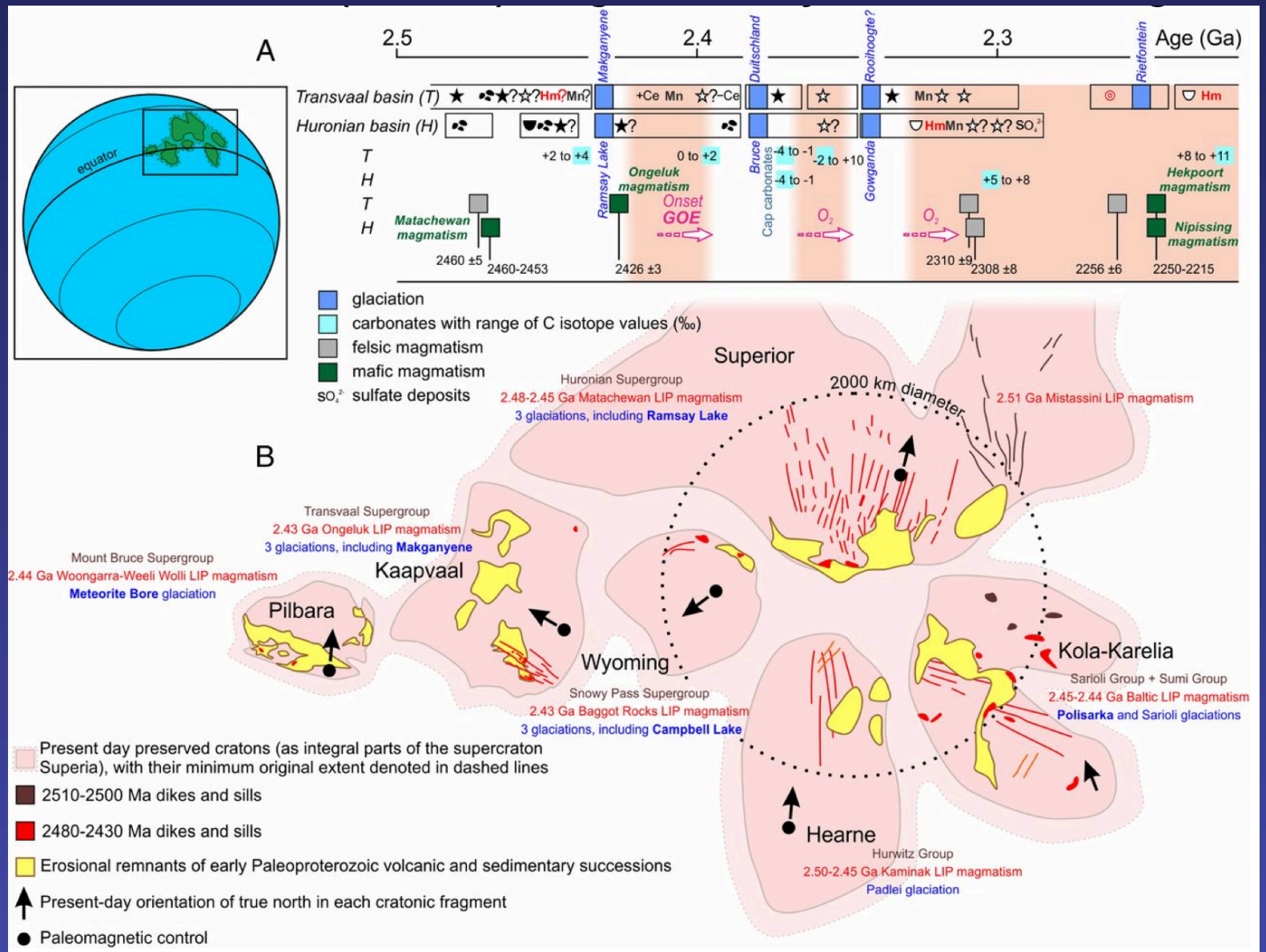


adapted from Chamberlain et al. (2003), Snelson et al. (1998) and Gorman et al. (2002)



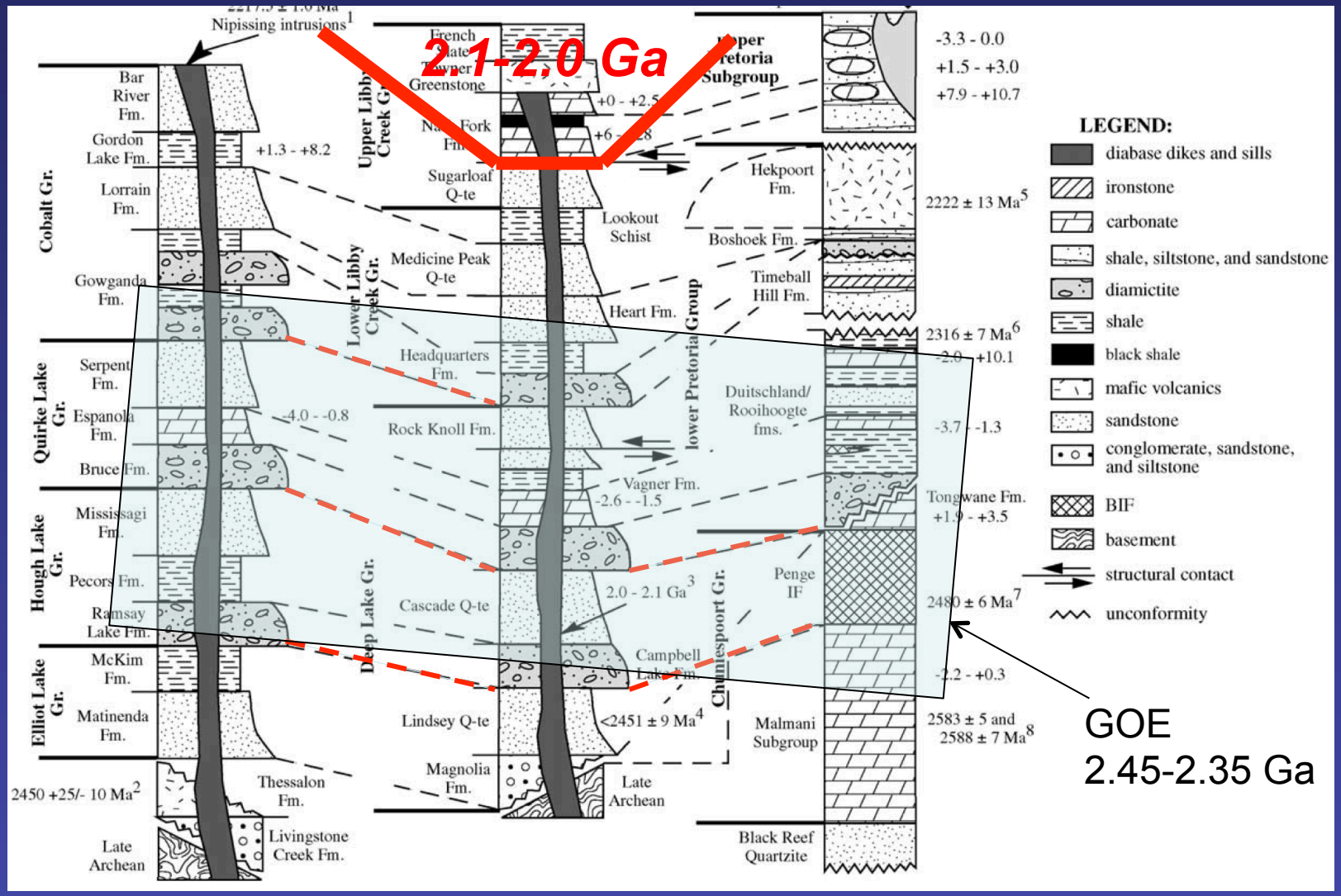
Gumsley et al., 2017

GOE Ca. 2.45-2.35 Ga

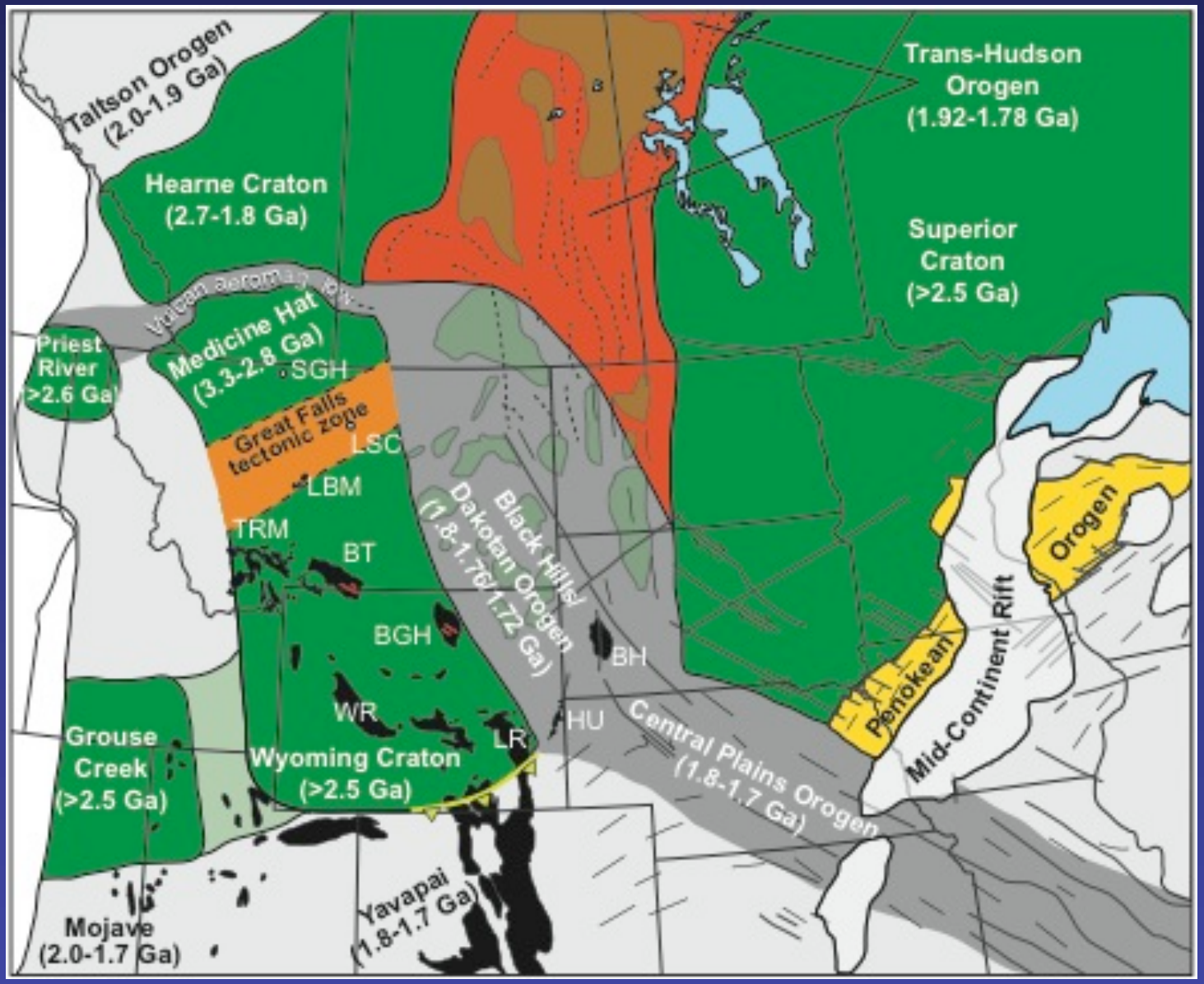


Ashley P. Gumsley et al. PNAS
doi:10.1073/pnas.1608824114

Huronian SUP Snowy P. WY Transvaal Kaap



Bekker et al., 2005



Kilian et al., 2016