New Palynological Data from Mid-Carboniferous Heath and Tyler Formations Constrain Timing of Climatic Changes and Sedimentation, Big Snowy Trough, Central Montana, USA

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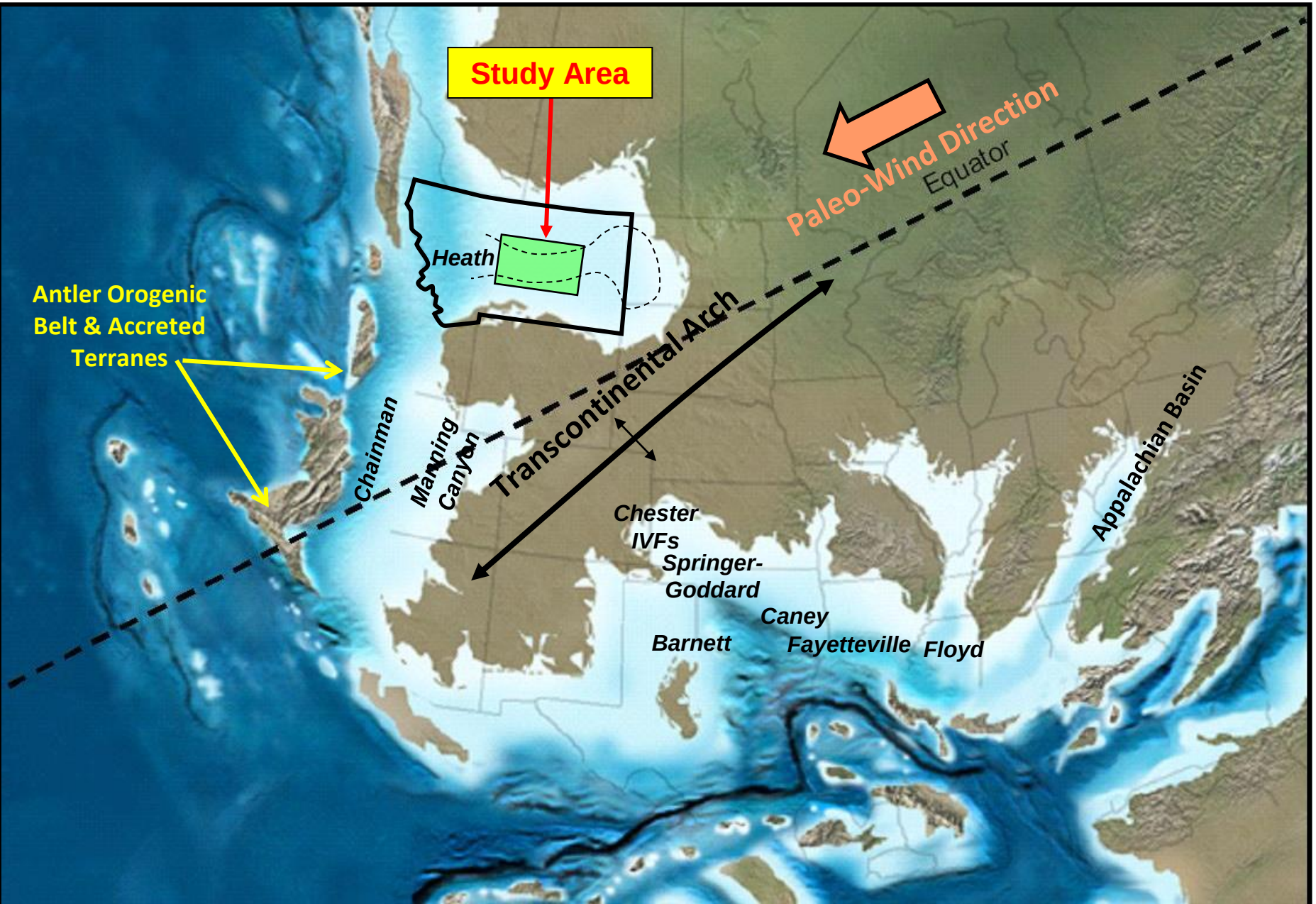
Objectives

- **Palynology - Establish more precise ages for Mid-Carboniferous marginal to non-marine strata in central Montana**
- **Confirm the presence or absence of a regional sequence boundary between the Heath and Tyler formations**
- **Constrain timing of climatic changes in central Montana and compare with timing of Gondwanan glacial advances and retreats**

Late Mississippian Paleogeography – After Blakey (2005)

North America ~ 325 MYA (late Serpukhovian / late Chesterian)



Late Mississippian Big Snowy Trough, Montana

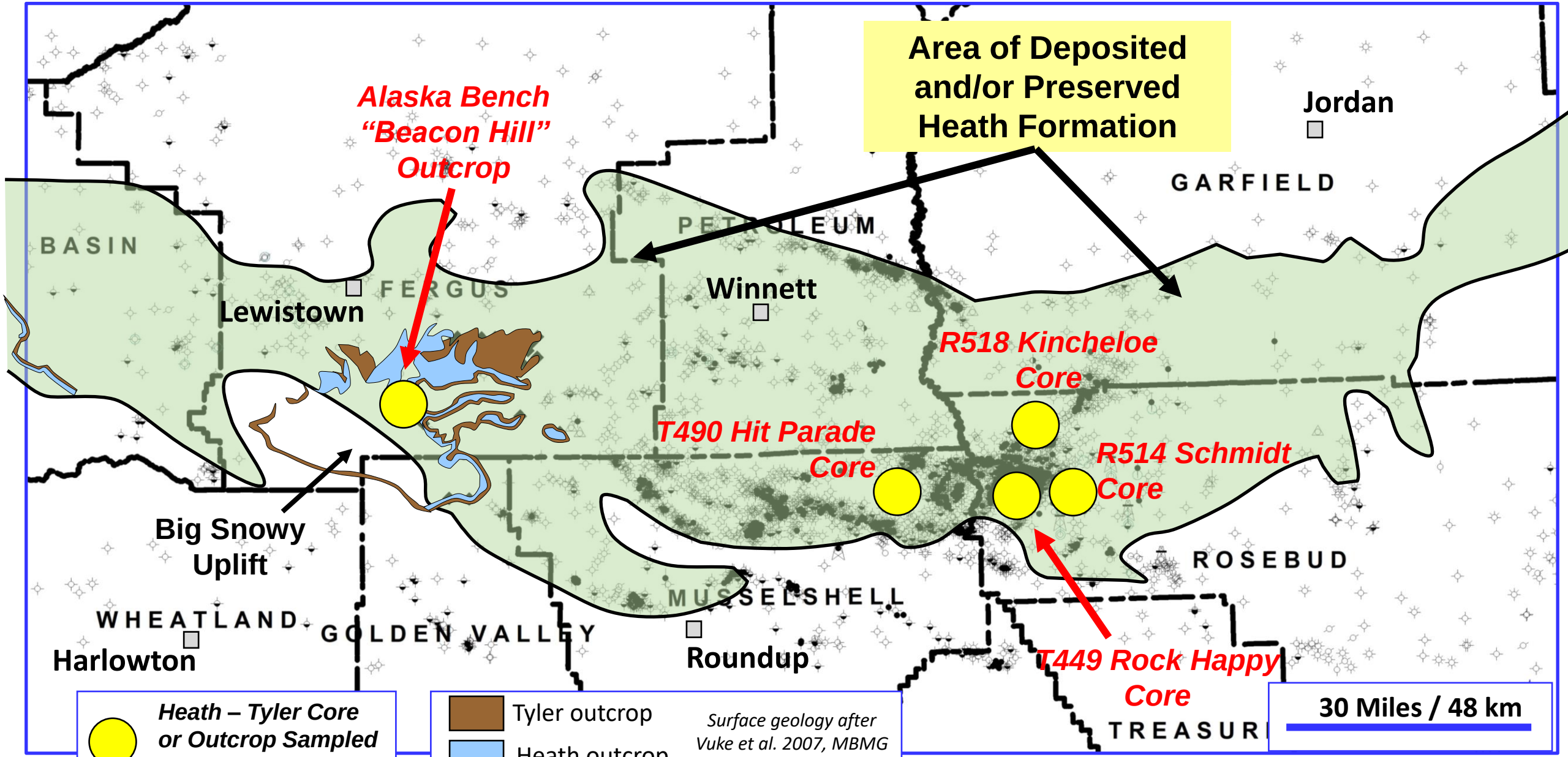
- Reactivation of Precambrian faults (Belt)
- Otter & Heath preservation & Tyler deposition and limited to Big Snowy Trough
- Tyler fluvial systems follow trough during Serpukhovian lowstand(s)

http://jan.ucc.nau.edu/~rcb7/garmgeolhist.html

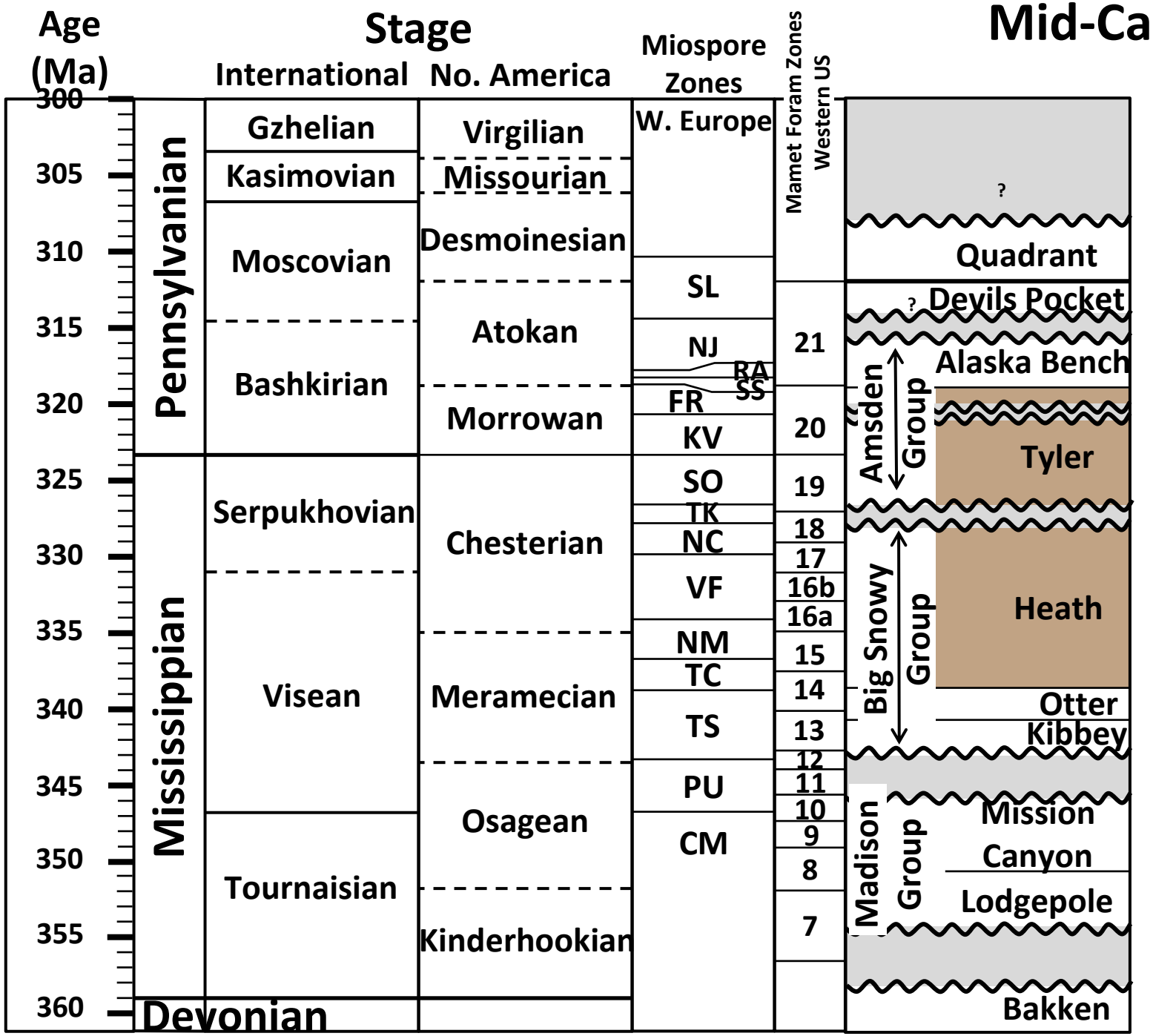
After Blakey (2005), Loucks & Ruppel (2007), and Lawton et al. (2021); Tradewinds after Abplanalp et al. (2009)

Big Snowy Trough after Maughan (1984); Derkey, et al. (1985); Nelson (1993)

Central Montana Study Area



Mid-Carboniferous Stratigraphy Central Montana



- **Study of Heath-Tyler**
- **Heath - stratigraphically highest formation in the Big Snowy Group – historically considered Chesterian in age**
- **Tyler – lower formation in Amsden Group**
- **Marginal marine & non-marine interval poorly dated using macrofossils**
- **Detrital Zircon work has not yet yielded good MDAs**

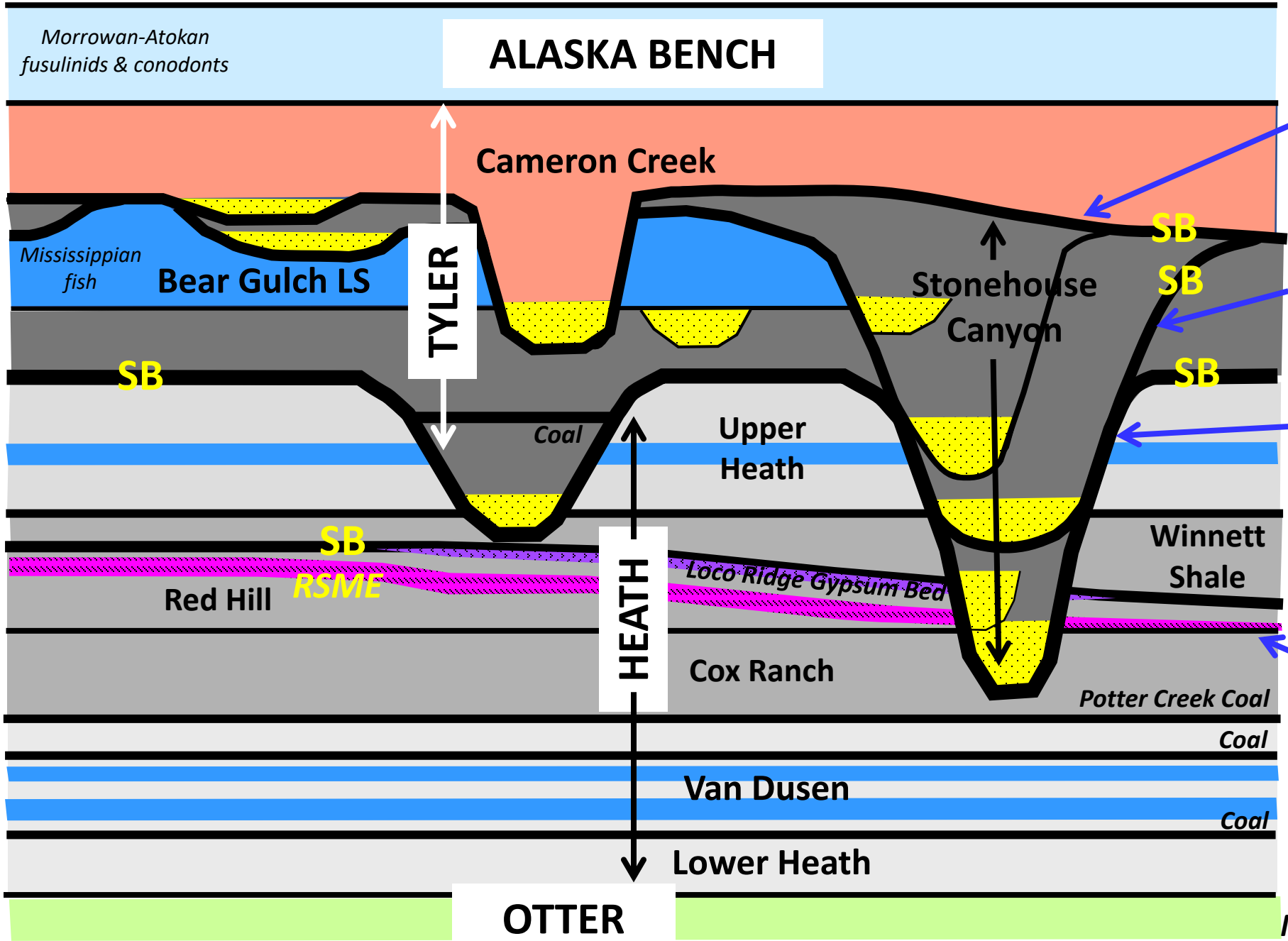
Modified from Bottjer, et al. (2019); Vuke, et al. (2007), Derkey, et al. (1985); Maughan (1984); Gutschick, et al. (1980); Maughan and Roberts (1967)

Central Montana Carboniferous Schematic Lithostratigraphic Correlation Chart

Cameron Creek Mbr. of Tyler – red mudrocks & sandstones

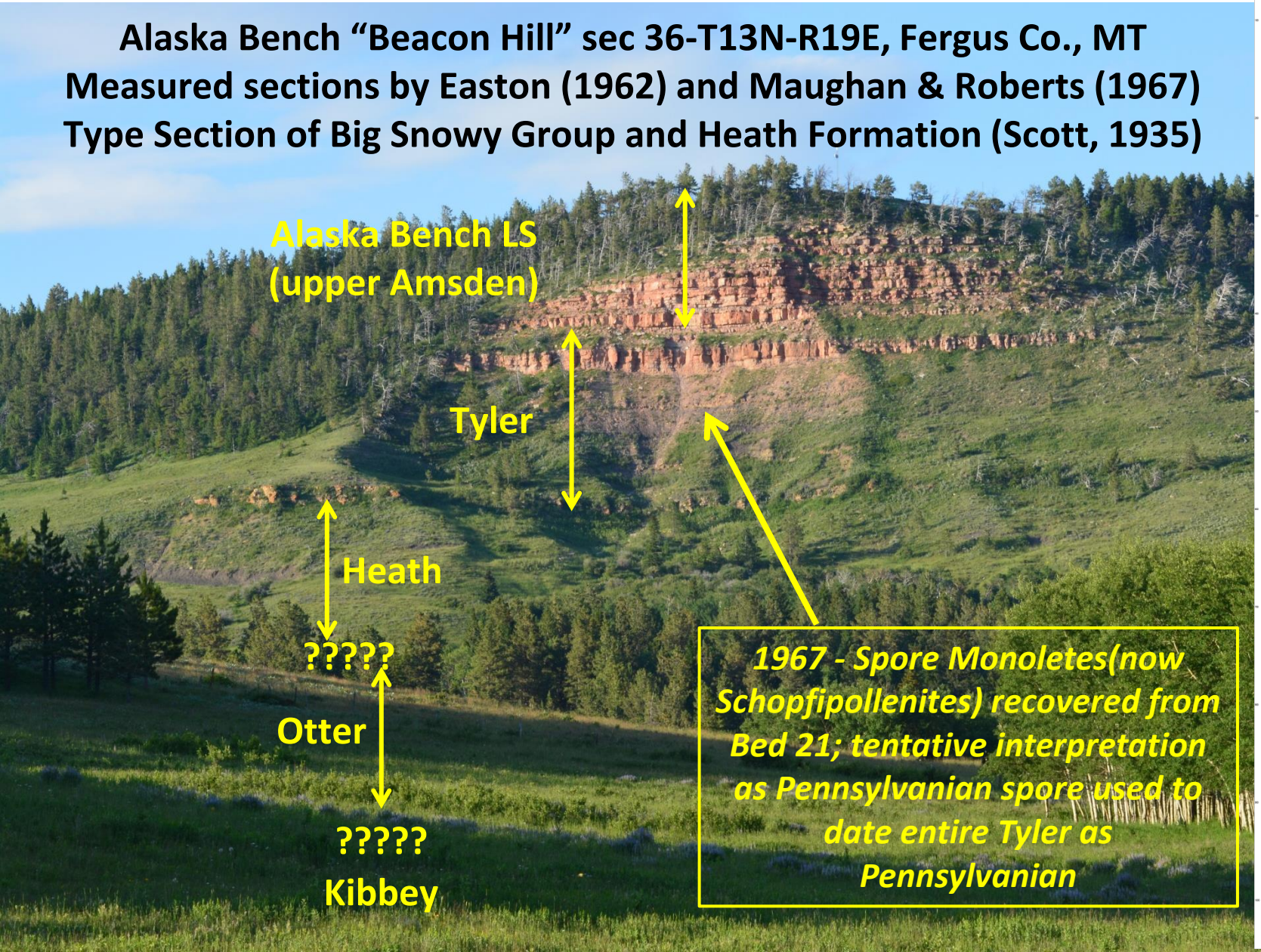
Tyler – nested incised valleys with fluvial sandstone deposits & abundant plant debris

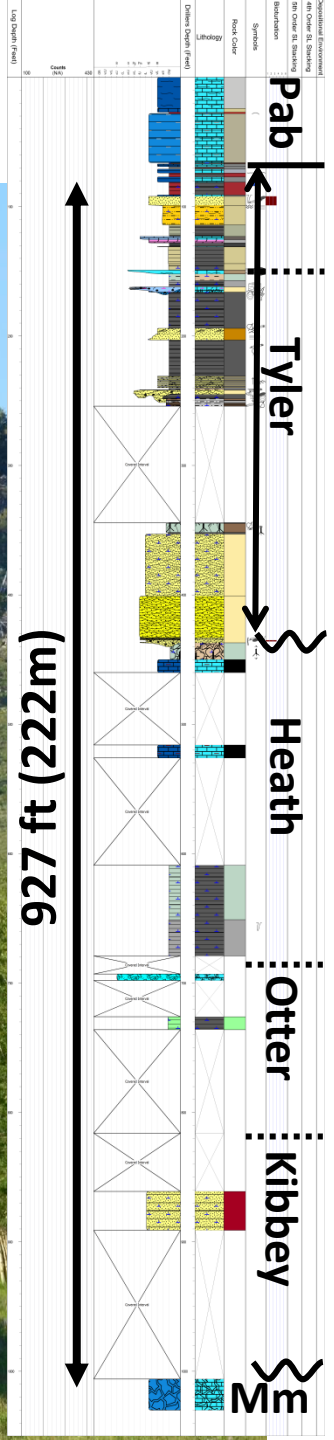
Heath – dominantly restricted shallow marine dark gray to black shale with prominent anhydrite bed



Carboniferous Stratigraphy – Definitions
HEATH-TYLER

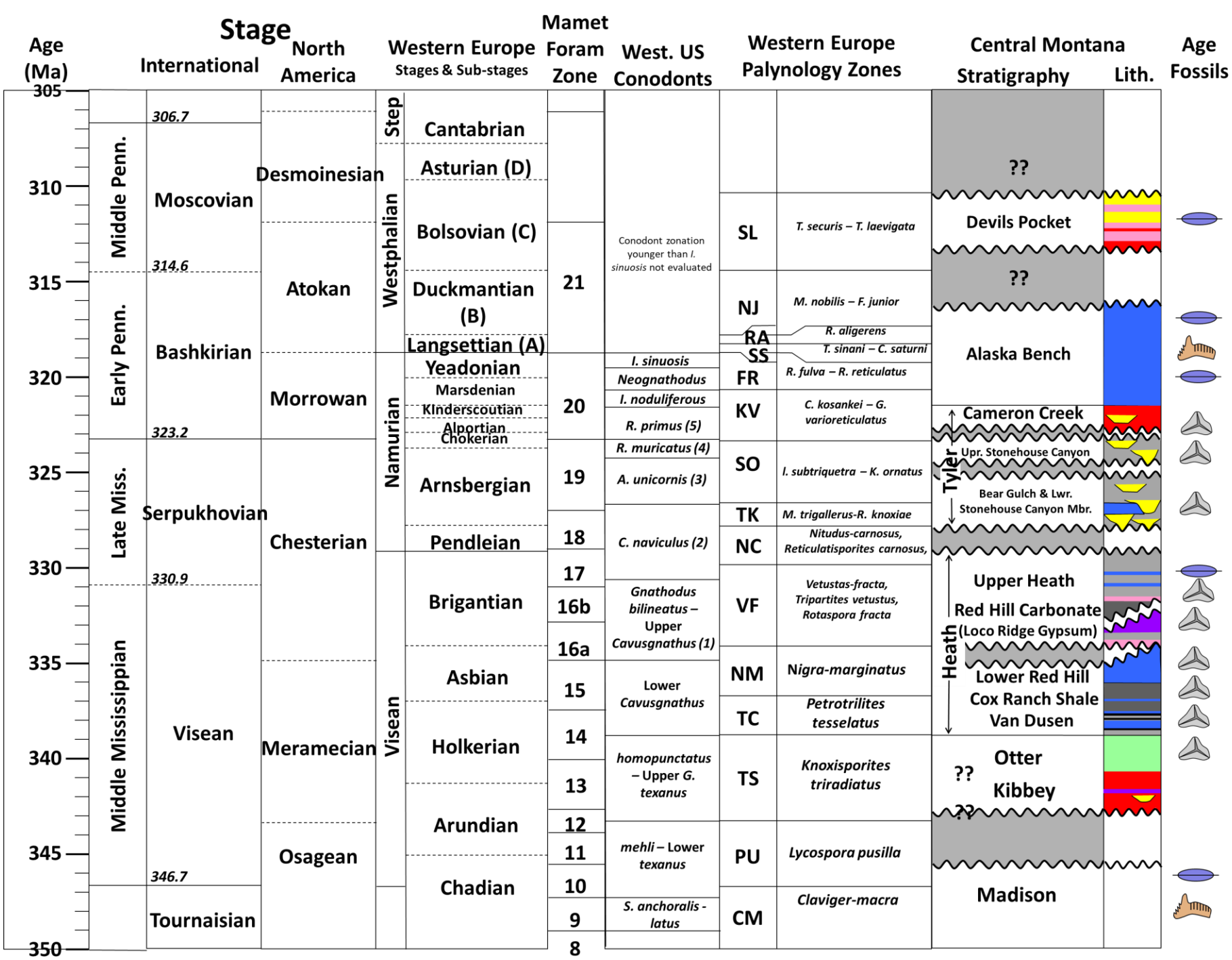
Alaska Bench "Beacon Hill" sec 36-T13N-R19E, Fergus Co., MT
Measured sections by Easton (1962) and Maughan & Roberts (1967)
Type Section of Big Snowy Group and Heath Formation (Scott, 1935)





Heath Type Section

- Defined in 1935
- 927 ft (282 m) Big Snowy Group (base Alaska Bench to top Madison)
- 74% of Heath-Otter Section (271 of 366 ft / 83 of 112 m) is COVERED INTERVAL



Carboniferous Chronostratigraphic Chart

Palynology, Foraminifera, Conodont zones

Age-Diastognic Index Fossils

- Conodonts
- Foraminifera & Fusulinids
- Palynology/Miospores

References

Global time scale, international stages, North American stages, most western Europe stages from ***Davydov et al 2012*** *Ch 23 in* ***Gradstein****, partially modified by* ***Ogg, et al., 2016***

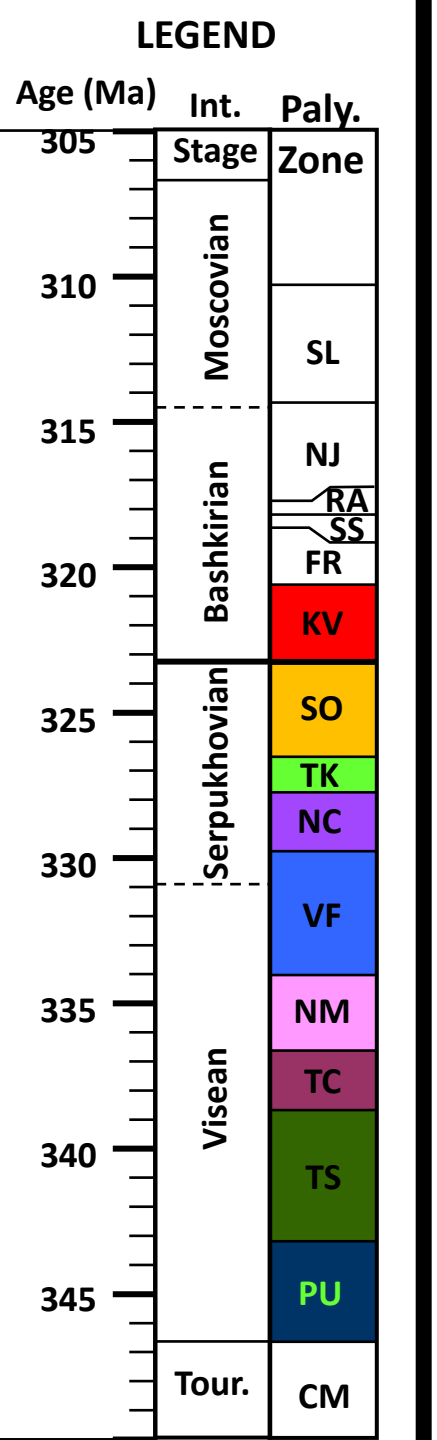
Palynology Zones for western Europe from ***diPasquo and Iannuzzi (2014)*** *and* ***McLean et al 2013***

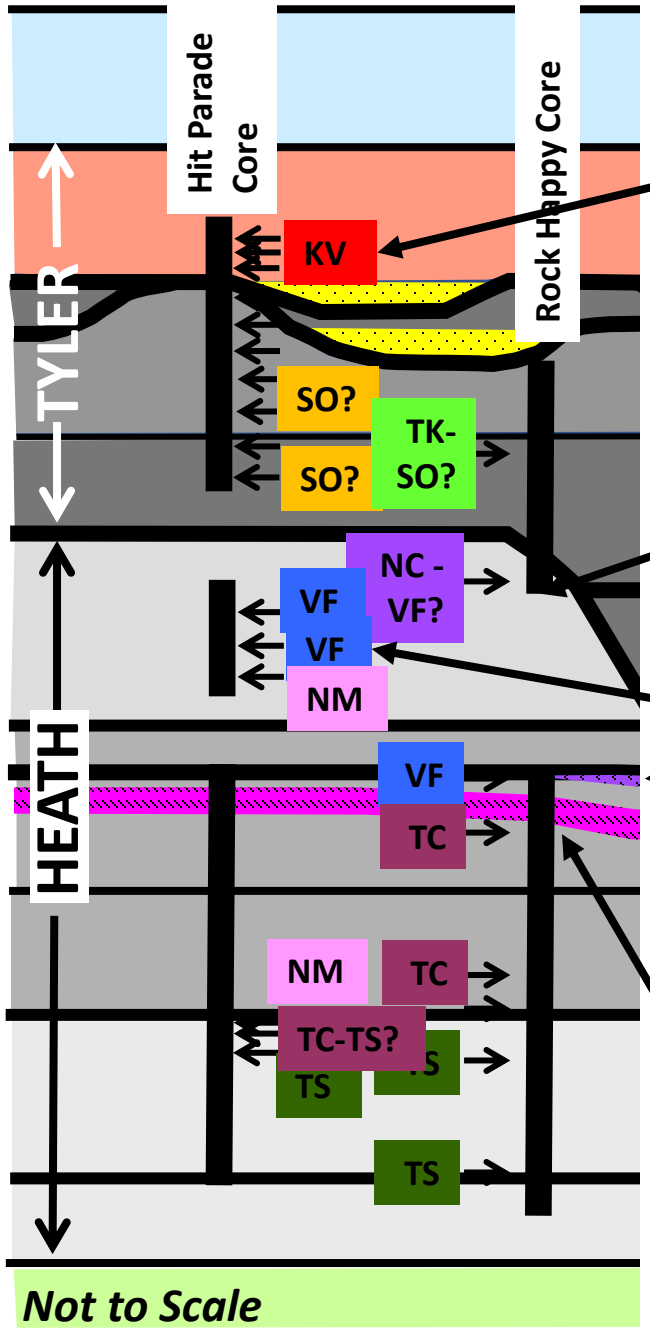
Visean Subdivisions from ***diPasquo & Iannuzzi (2014)*** *and* ***McLean etal 2013***

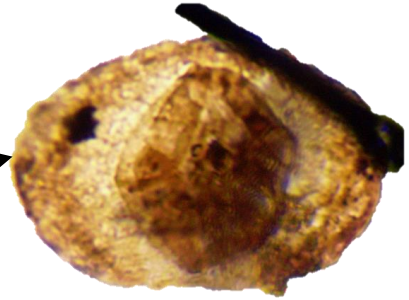
Western US Conodont zones based on ***Abplanalp, et al, 2009****;* ***Poole and Sandberg, 1991; Lane and Stratka, 1975***

Central Montana stratigraphy based on results of this study

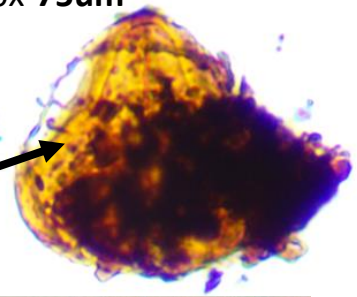
Palynology Results – Examples of Some Key Miospores



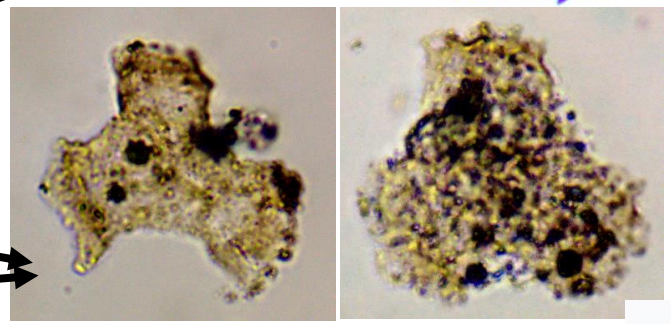




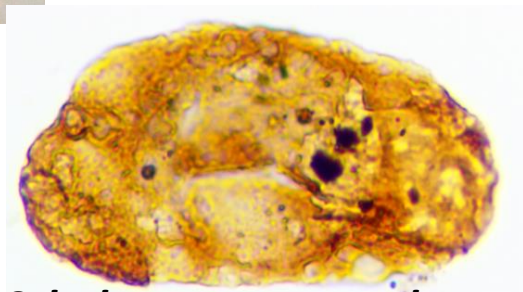
Potonieisporites densus
KV zone – BASHKIRIAN – PENN
Hit Parade CIC2336-1-HF-trab-25-110-40x-**75um**



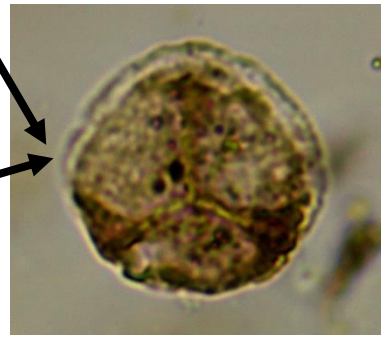
Rotaspora fracta
VF zone – BRIGANTIAN- LATEST VISEAN (range VF to TK)
Rock Happy smpl. 7-1+25-40x-34-113-**42um**



Tripartites vetustus
VF Zone - BRIGANTIAN - LATE VISEAN (range VF to TK)
Hit Parade smpl. 6 (also Rock Happy smpl. 6, & others), **50 µm**

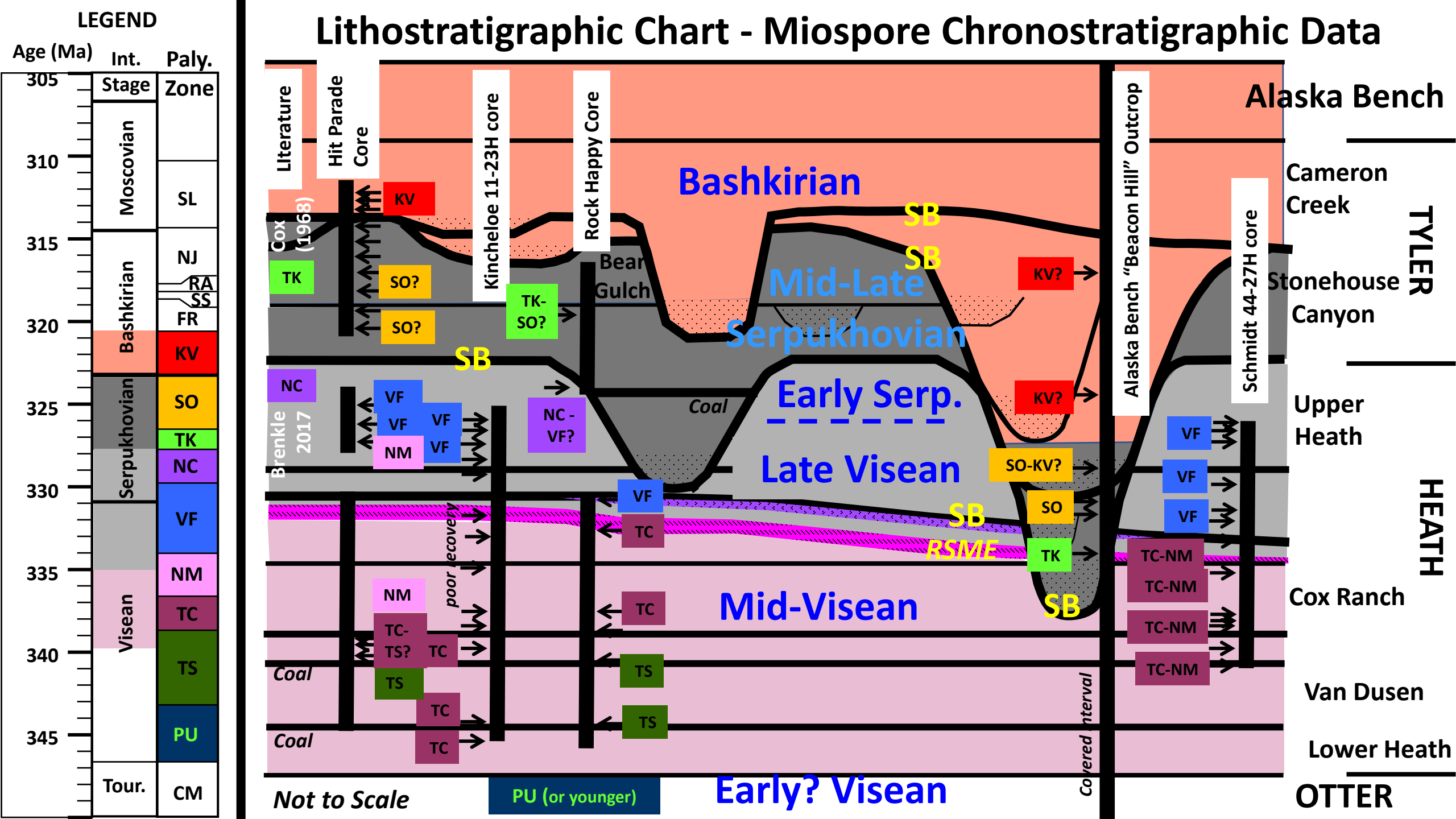


Schulzospora campyloptera
FAD TC zone - **MID-VISEAN TO EARLY SERPUKHOVIAN** (range TC - TK zone)
Rock Happy UI693- sample 7-1+25-40x-37-108-**83um**



Lycospora pusilla
VISEAN OR YOUNGER
(Range PU to Penn)
Rock Happy smpl. 5 (present in all samples), **26 um**

Lithostratigraphic Chart - Miospore Chronostratigraphic Data



Central Montana Carboniferous Paleoclimates

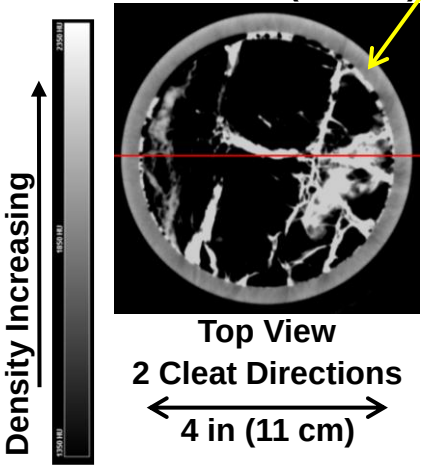
Mid-Visean Lower Heath

(Van Dusen zone, TC paly zone)

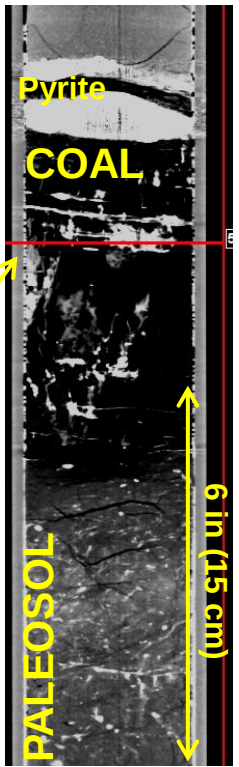
- 4-6 regionally correlative 5th order sequences in 83 ft. interval (25.4m), coal at base, paleosol at top of each
- Sub-humid & cyclic

CT Scan Potter Creek Coal

Lucky Strike 10-4H
Garfield Co, MT
5086.4-5087.3 ft (1550-1551 m)
Slice at 5086.6 ft (1550 m)



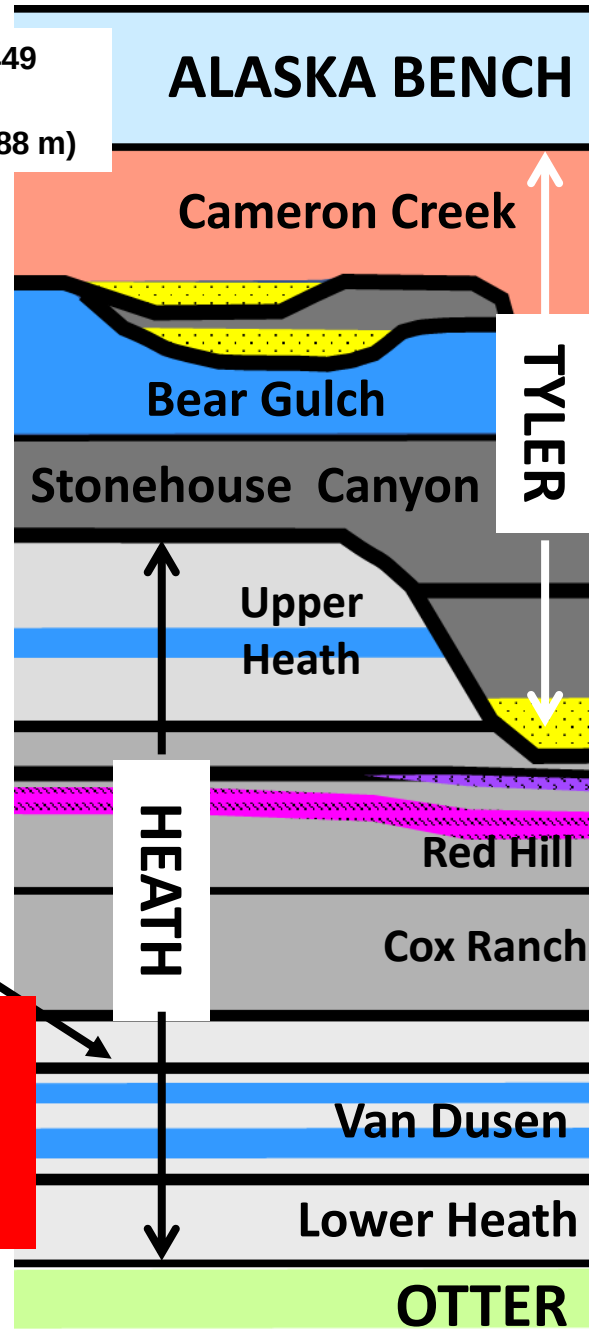
Top View
2 Cleat Directions
4 in (11 cm)



Curl 23-14 NDIC 16581
McKenzie Co, ND
8260-8264 ft (2518-2519 m)

Rock Happy 33-3H T449
Rosebud Co, MT
5204-5209 ft (1586-1588 m)

1 ft (30 cm)



SUB-HUMID & CYCLIC

ARID

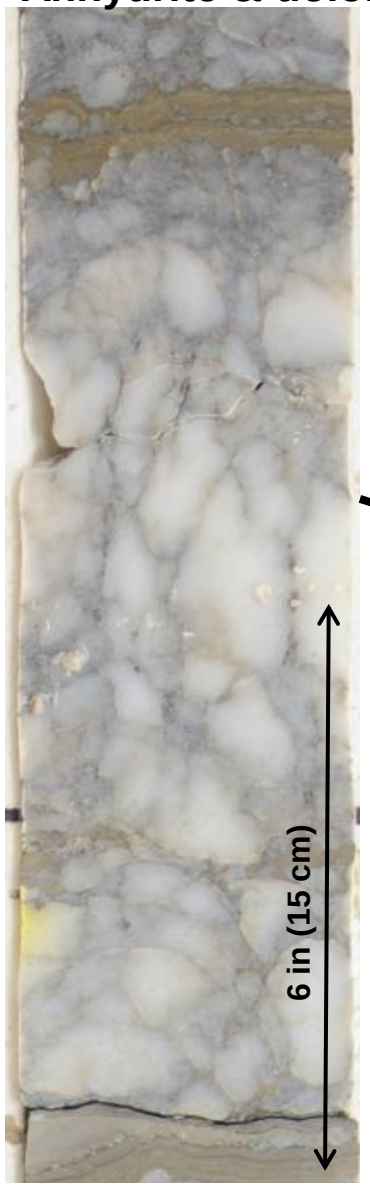
Central Montana Carboniferous Paleoclimates

Late Visean Middle Heath

(Cox Ranch – Red Hill zones, TC-NM-VF paly zones)

- Forced regression overlain by shallow marine dolostones, dolomitic microbialites, & supratidal anhydrites
- Very arid climate

Anhydrite & dolomite



Schmidt 44-27H R514
4946 ft (1508 m)

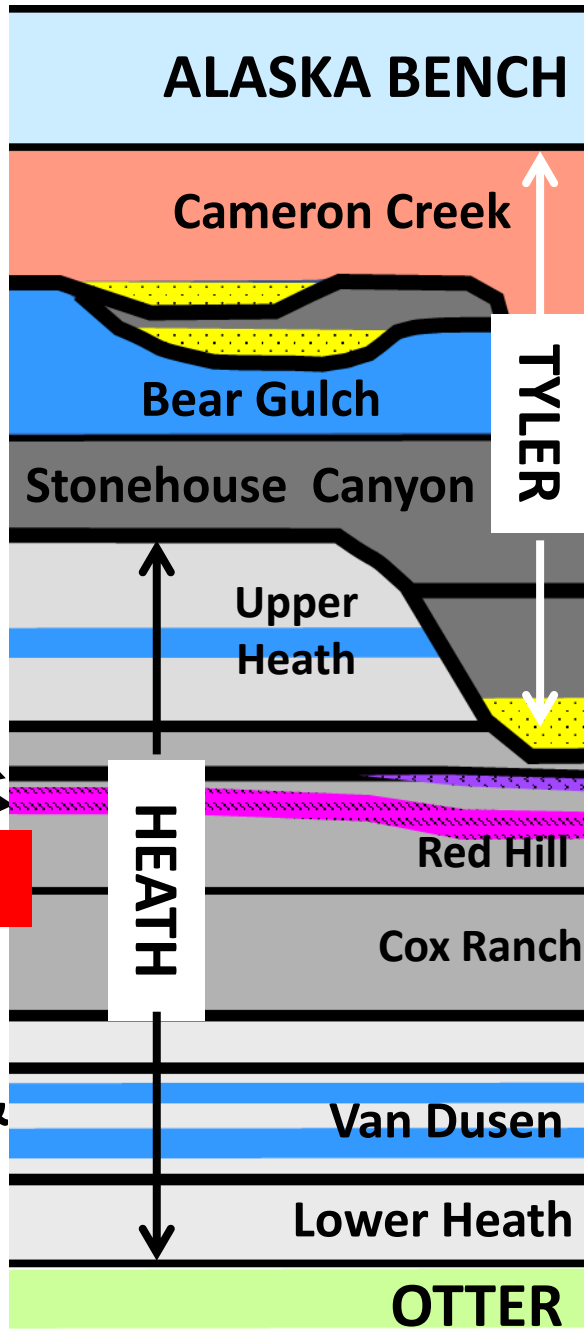
Subtidal dolomite

Rock Happy 33-3H T449
5061 ft (1543 m)

ARID

SUB-HUMID & CYCLIC

ARID



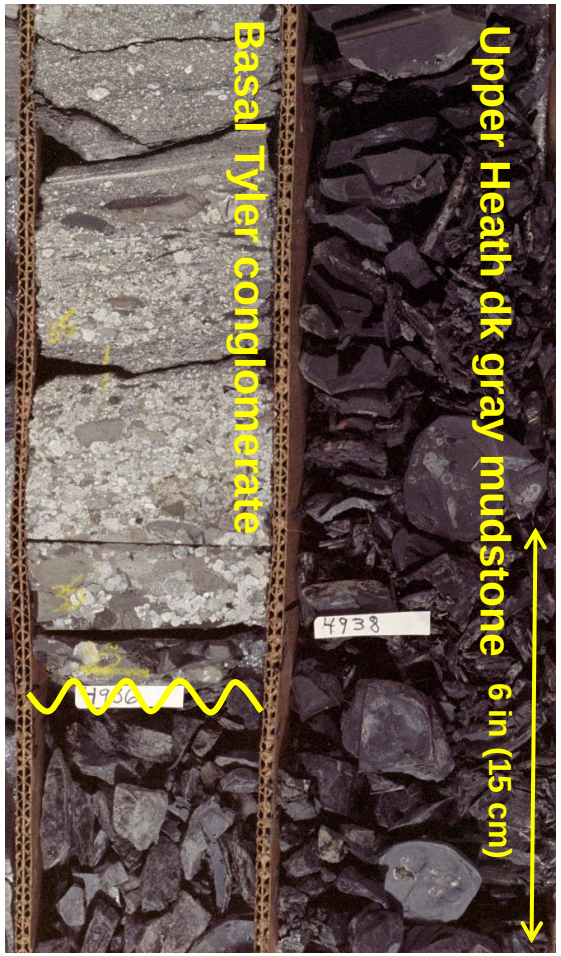
Central Montana Carboniferous Paleoclimates

Mid-Serpukhovian – Early Bashkirian Tyler

(Stonehouse Canyon Mbr., TK-SO-KV paly zones,

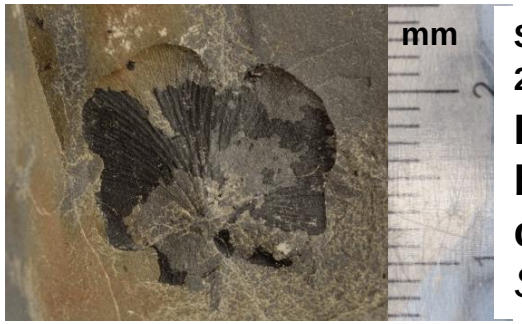
- Basal erosion with > 400 ft. (129m) relief
- Abundant plant and wood fragments – more humid environment
- Active fluvial processes, transport of sand & pebbles

Basal Tyler Sandstone, Beacon Hill, Alaska Bench, Sec. 36 T13N R19E, Fergus Co., MT



Rock Happy 33-3H T449
4936 ft (1505 m)

Lepidodendron
Smith #6-1 S615
8235 ft (2510 m)

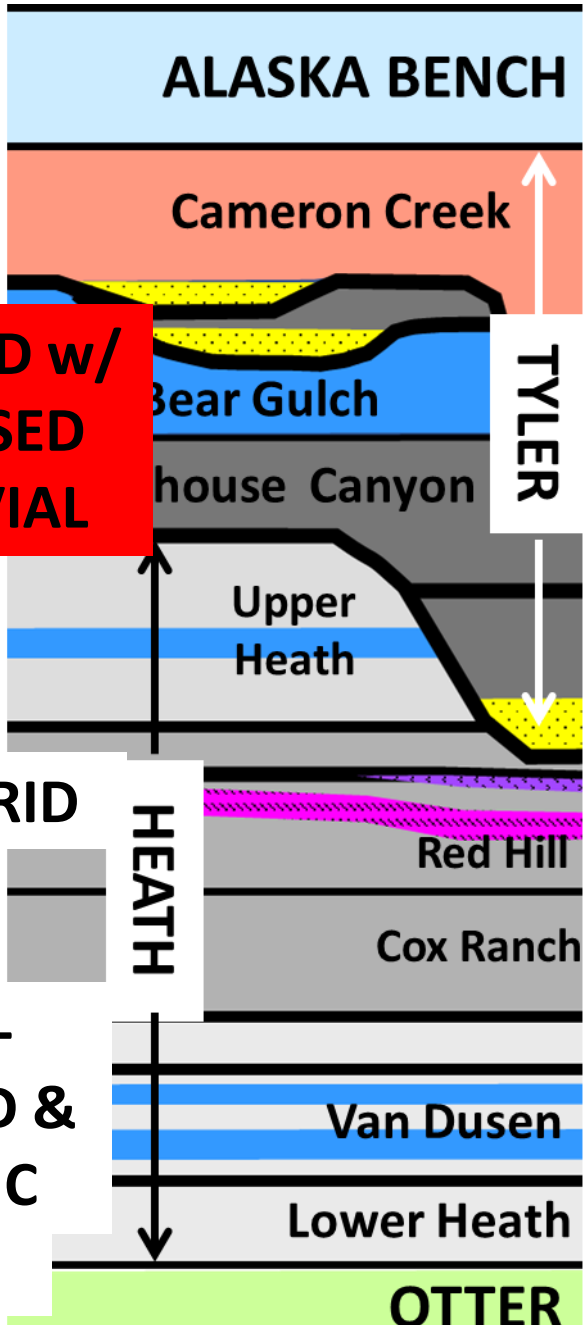


Stoiberg #14C-14 T260
2627 ft (801 m)
Palm-like Leaves on bedding plane, silty claystone, probably *Sphenophyllum*

HUMID w/ INCISED FLUVIAL

ARID

SUB-HUMID & CYCLIC ARID



Central Montana Carboniferous Paleoclimates

Bashkirian Tyler
(Cameron Creek Mbr., KV paly zone)

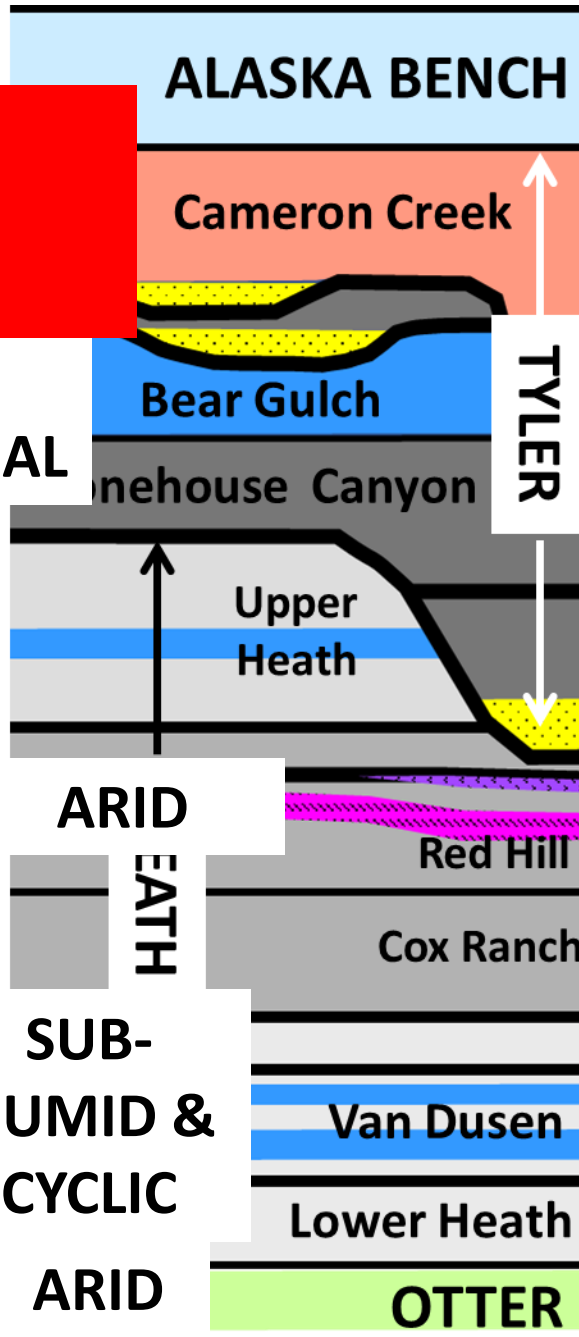
- Fluvial channels with fine-coarse sand, oxidized wood fragments
- Laminated red & gray mudrocks
- Alternating wet & dry seasons

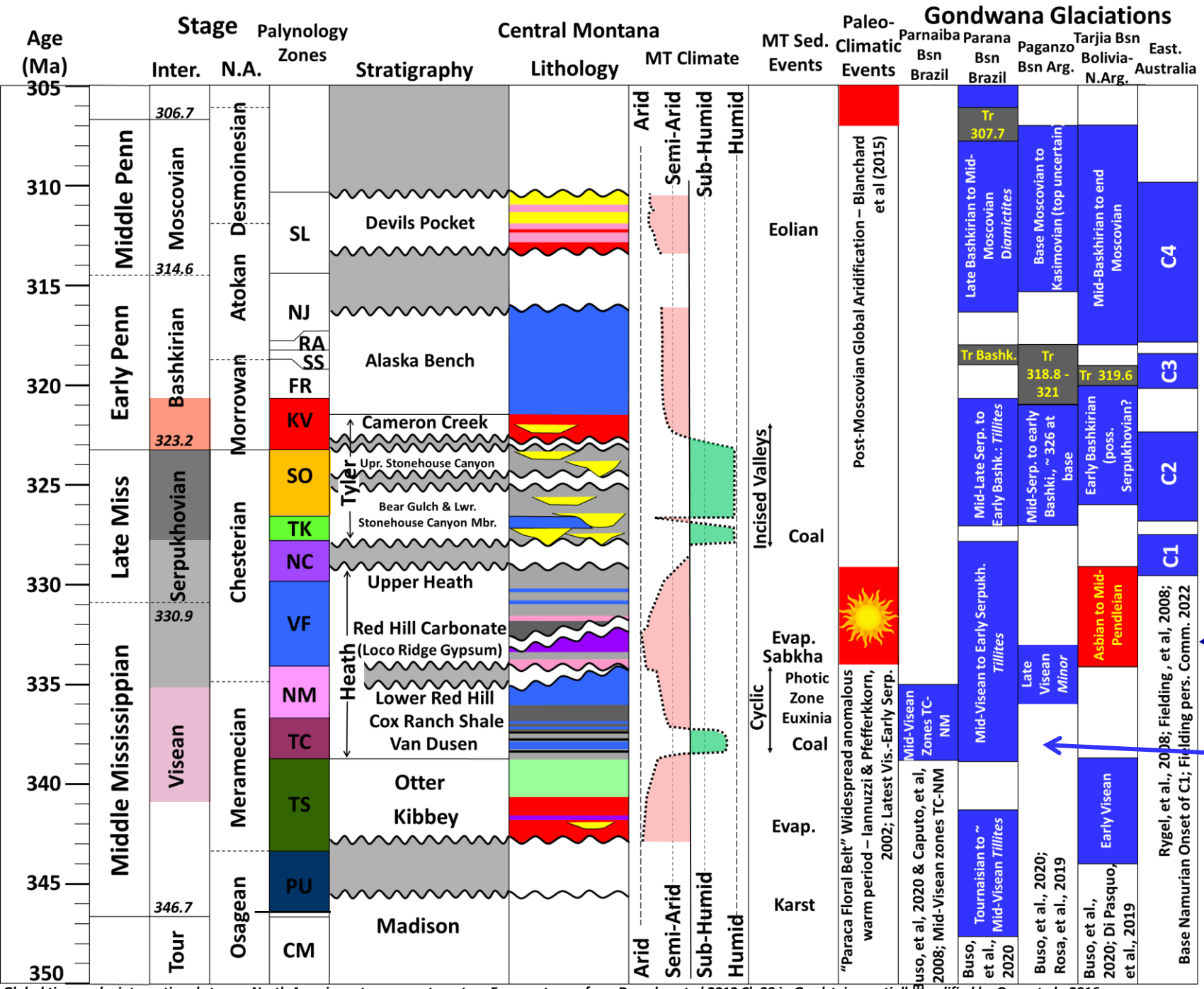
Hit Parade #31-3H T490
4230-4236 ft (1289-1292 m)

WET- DRY SEASONAL OXIDIZED

HUMID w/ INCISED FLUVIAL

Oxidized Lepidodendron Strobilus
Alaska Bench "Beacon Hill"
T13N-R19E-36
Bed 13





Global Implications & Conclusions

Bashkirian Seasonal wet & dry climate → onset of Gondwanan glacial maximum

Early Serpukhovian wet humid climate → onset of major Gondwanan glaciations

Late Visean Arid (anhydrite) → widespread Gondwanan warm period & glacial retreat

Mid-Visean cyclicity + humid climate → minor glacial advances in Gondwana?

Warming, glacial retreat

Gondwanan glaciations

Global time scale, international stages, North American stages, most western Europe stages from Davydov et al 2012 Ch 23 in Gradstein, partially modified by Ogg, et al., 2016
Palynology Zones for western Europe from diPasquo and Iannuzzi (2014) and McLean et al 2013; Visean Subdivisions from diPasquo & Iannuzzi (2014) and McLean etal 2013

CONCLUSIONS

- **Palynological interpretations determine that the Heath ranges from mid-Visean to early Serpukhovian, and the Tyler is mid-Serpukhovian to early Bashkirian.**
- **The Mississippian-Pennsylvanian boundary is within the upper Stonehouse Canyon Member of the Tyler, stratigraphically above the Bear Gulch Limestone**
- **Lithofacies document an episodic change in climate from arid to sub-humid to arid to very wet and humid.**
- **Climatic changes in central Montana correspond to climatic changes and glacial advances/retreats in Gondwana**
- **Next Steps - Incorporate new age determinations and climatic interpretations into detrital zircon analyses (humid/fluvial vs arid/aeolian processes) – Devon Orme at Montana State**

To experience the Heath-Tyler lithofacies in person, attend our short course core workshop at the GSA Rocky Mountain Section meeting in May 2023!

Thank You!

ACKNOWLEDGEMENTS

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Devon Orme

Chance Ronemus

Sophie Black

Multiple Landowners that allowed access to private lands

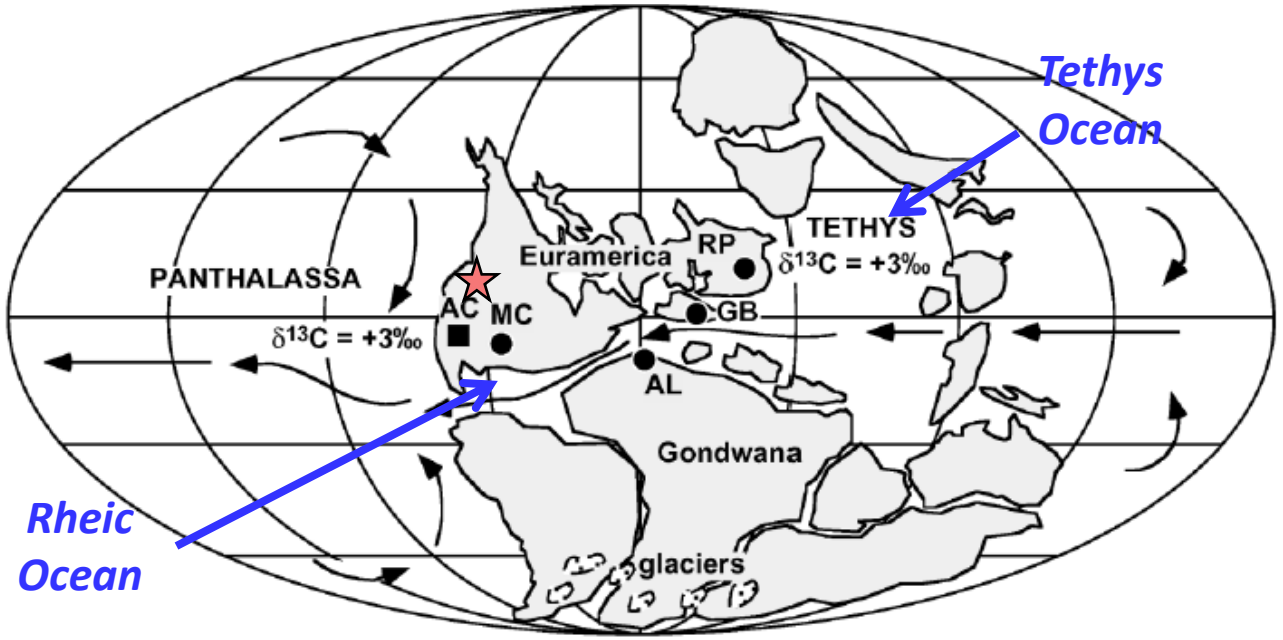
View to North from Sacajawea Peak in the Bridger Range, southwestern Montana

Late Paleozoic Ice Age Caused by Closure of Rheic Ocean?

Does new data reveal the timing of closure of the Rheic Ocean?

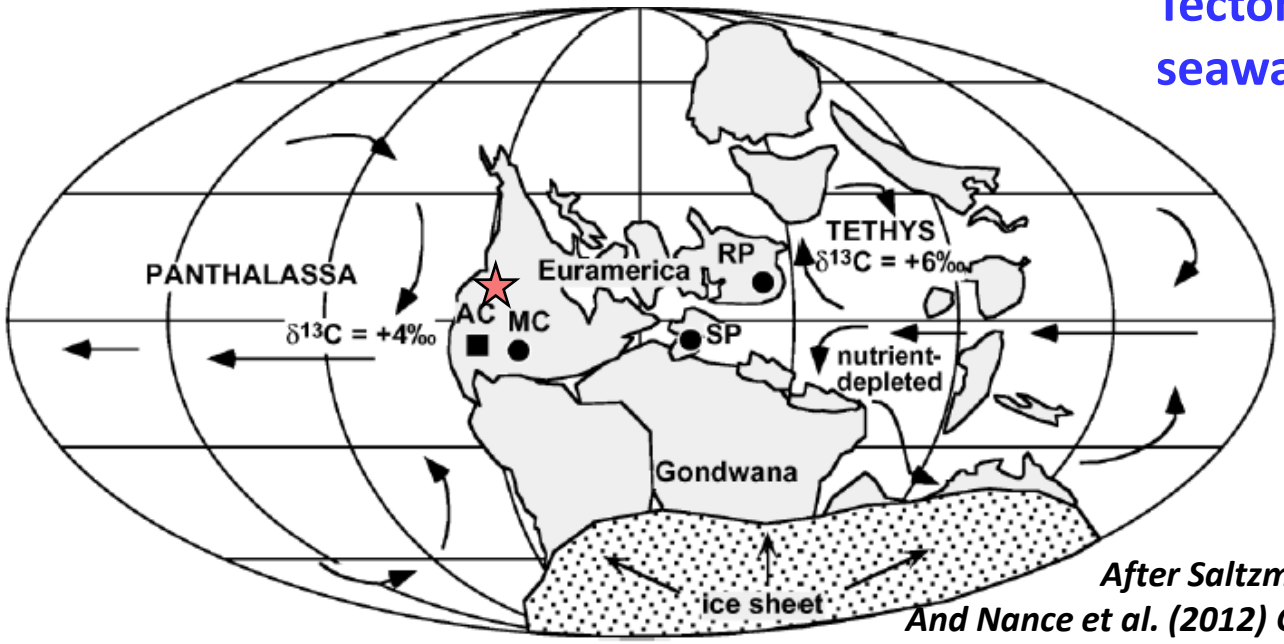
How did closure of the Rheic Ocean affect North American climate?

~ 340 Ma Meramecian (mid-Visean)



Subequatorial current flows between Gondwana & Laurussia

~ 320 Ma Morrowan (mid-Bashkirian)

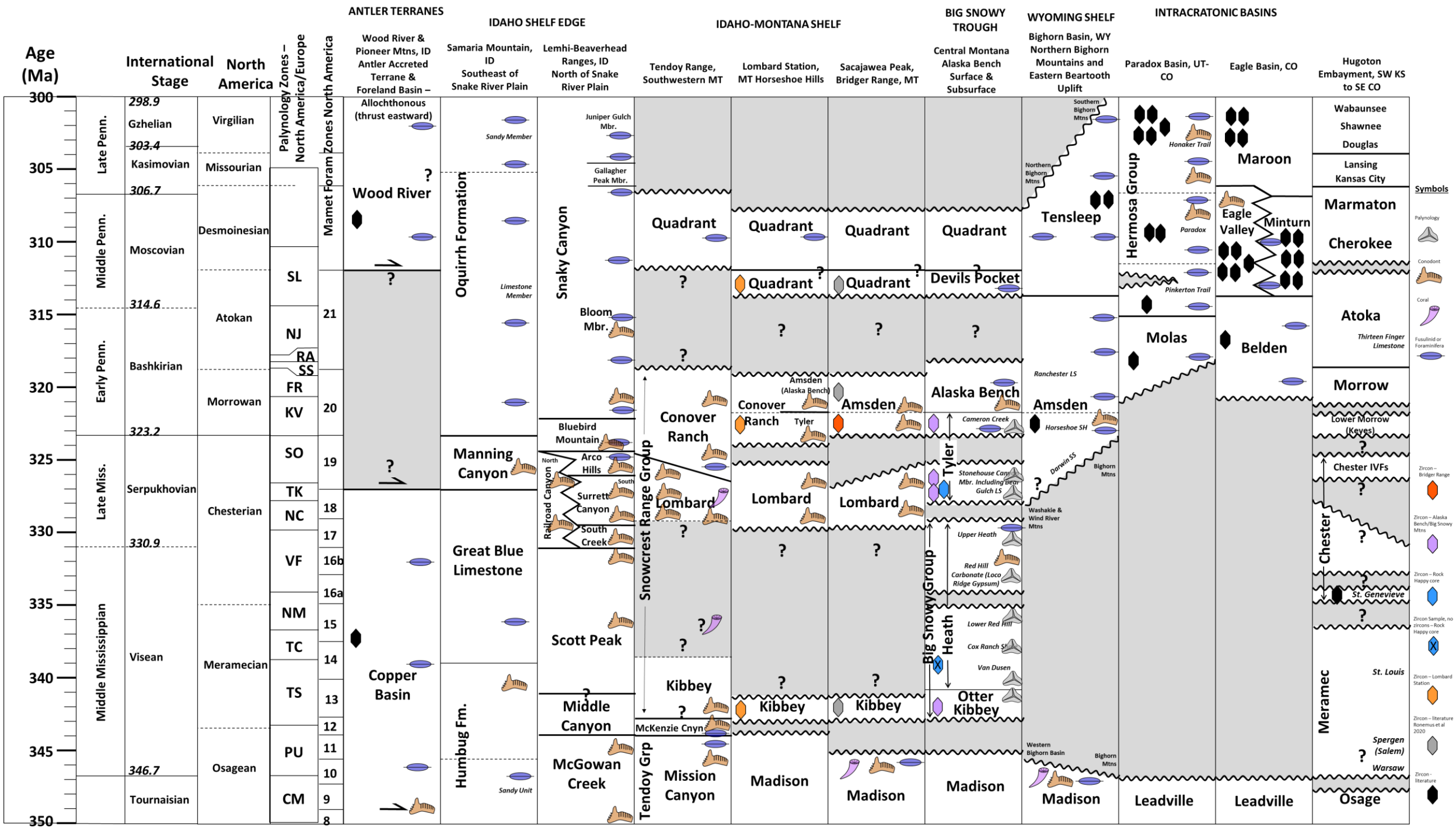


Tectonic closure of seaway cuts off current

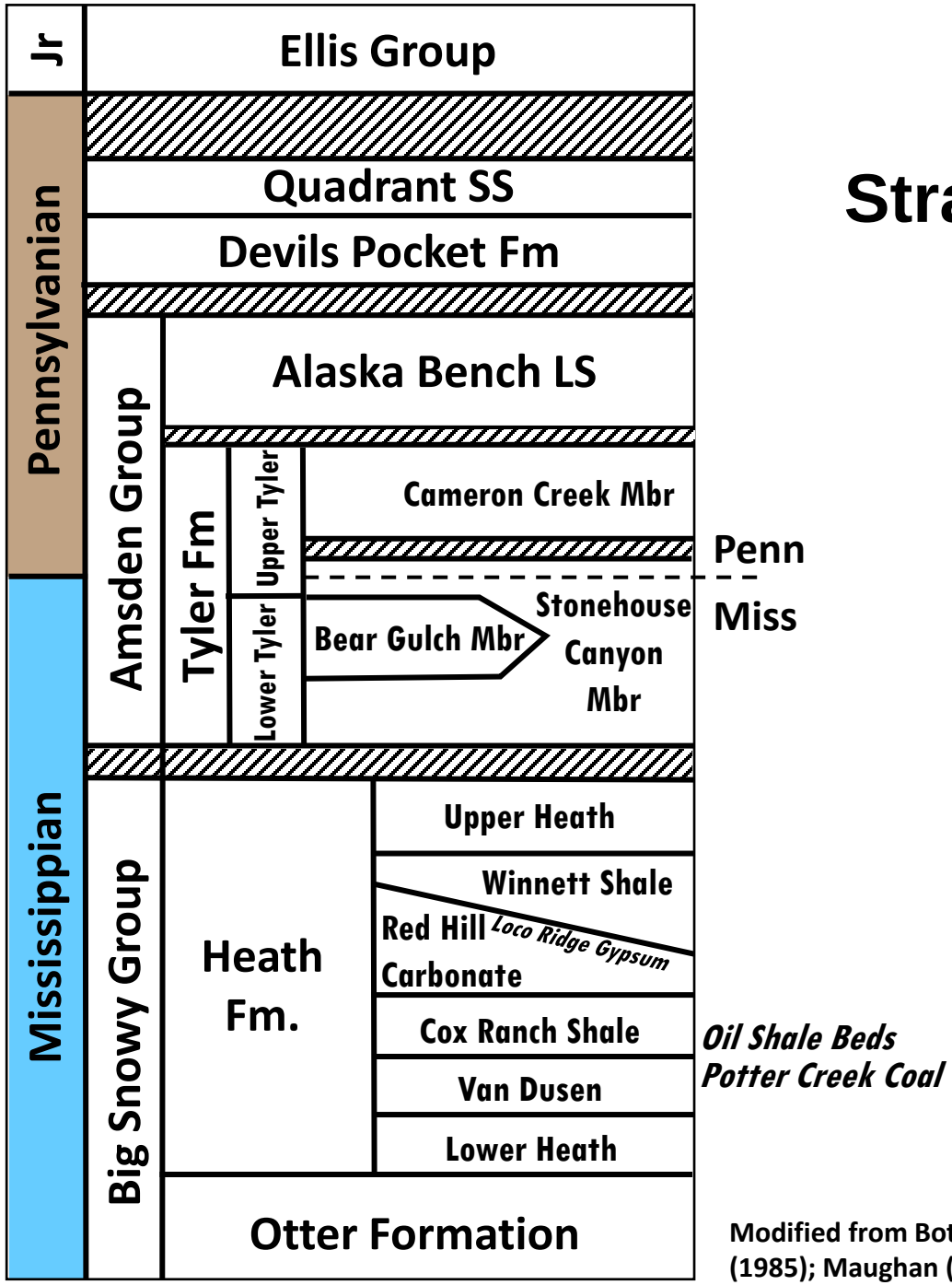
AC = Arrow Canyon, Nevada, Miss.-Penn. GSSP
MC = Midcontinent USA
RP = Russian Platform
GB = Great Britain
AL = Algeria
SP = Spain

★ *Approximate position of central Montana*

After Saltzman (2003) Geology v.31, p.151-154
And Nance et al. (2012) Geoscience Frontiers v3, p. 125-135


Age (Ma)
International Stage
North America
Palynology Zones – North America/Europe
Foram Zones North America
ANTLER TERRANES
Wood River & Pioneer Mtns, ID Antler Accreted Terrane & Foreland Basin – Allochthonous (thrust eastward)
IDAHO SHELF EDGE
Samaria Mountain, ID Southeast of Snake River Plain
Lemhi-Beaverhead Ranges, ID North of Snake River Plain
IDAHO-MONTANA SHELF
Tendoy Range, Southwestern MT
Lombard Station, MT Horseshoe Hills
Sacajawea Peak, Bridger Range, MT
BIG SNOWY TROUGH
Central Montana Alaska Bench Surface & Subsurface
WYOMING SHELF
Bighorn Basin, WY Northern Bighorn Mountains and Eastern Beartooth Uplift
INTRACRATONIC BASINS
Paradox Basin, UT-CO
Eagle Basin, CO
Hugoton Embayment, SW KS to SE CO
300
305
310
315
320
325
330
335
340
345
350
Late Penn.
Middle Penn.
Early Penn.
Late Miss.
Middle Mississippian
298.9
Gzhelian
303.4
Kasimovian
306.7
Moscovian
314.6
Bashkirian
323.2
Serpukhovian
330.9
Visean
346.7
Tournaisian
Virgilian
Missourian
Desmoinesian
Atokan
Morrowan
Chesterian
Meramecian
Osagean
SL
NJ
RA
SS
FR
KV
SO
TK
NC
VF
NM
TC
TS
PU
CM
Mamet
21
20
19
18
17
16b
16a
15
14
13
12
11
10
9
8
Wood River
Oquirrh Formation
Sandy Member
Limestone Member
Manning Canyon
Great Blue Limestone
Humbug Fm.
Sandy Unit
Copper Basin
Juniper Gulch Mbr.
Gallagher Peak Mbr.
Snaky Canyon
Bloom Mbr.
Bluebird Mountain
Arco Hills
North
South
Railroad Canyon
Surrett Canyon
South Creek
Scott Peak
Middle Canyon
McGowan Creek
Quadrant
Snowcrest Range Group
Conover Ranch
Lombard
Kibbey
McKenzie Cnyn
Tendoy Grp
Mission Canyon
Amsden (Alaska Bench)
Conover Ranch
Tyler
Amsden
Lombard
Kibbey
Madison
Devils Pocket
Alaska Bench
Cameron Creek
Stonehouse Canyon Mbr. including Bear Gulch LS
Upper Heath
Red Hill Carbonate (Loco Ridge Gypsum)
Big Snowy Group
Heath
Lower Red Hill
Cox Ranch Sh
Van Dusen
Otter
Kibbey
Madison
Southern Bighorn Mtns
Northern Bighorn Mtns
Tensleep
Ranchester LS
Amsden
Horseshoe SH
Darwin SS
Bighorn Mtns
Washakie & Wind River Mtns
Western Bighorn Basin
Bighorn Mtns
Madison
Hermosa Group
Honaker Trail
Paradox
Pinkerton Trail
Molas
Leadville
Maroon
Eagle Valley
Minturn
Belden
Leadville
Wabaunsee
Shawnee
Douglas
Lansing
Kansas City
Marmaton
Cherokee
Atoka
Thirteen Finger Limestone
Morrow
Lower Morrow (Keyes)
Chester IVFs
Chester
St. Genevieve
Meramec
St. Louis
Spergen (Salem)
Warsaw
Osage
Symbols
Palynology
Conodont
Coral
Fusulinid or Foraminifera
Zircon – Bridger Range
Zircon – Alaska Bench/Big Snowy Mtns
Zircon – Rock Happy core
Zircon Sample, no zircons – Rock Happy core
Zircon – Lombard Station
Zircon – literature Ronemus et al 2020
Zircon - literature

Mid-Carboniferous Central Montana Stratigraphic Correlation Chart



- Top of Heath = Sequence Boundary, Overlain by Tyler Formation
  - *New high-resolution palynology*
  - *Detrital Zircon analyses of Kibbey, Tyler, and Quadrant in progress*
- Bear Gulch Limestone & most of Stonehouse Canyon Member of Tyler = Mississippian Age (Serpukhovian - Chester)
- Informal Subdivisions within Heath
  - *Updated stratigraphic architecture and nomenclature in progress*

Modified from Bottjer, et al. (2019); Derkey, et al. (1985); Maughan (1984); Maughan and Roberts (1967)