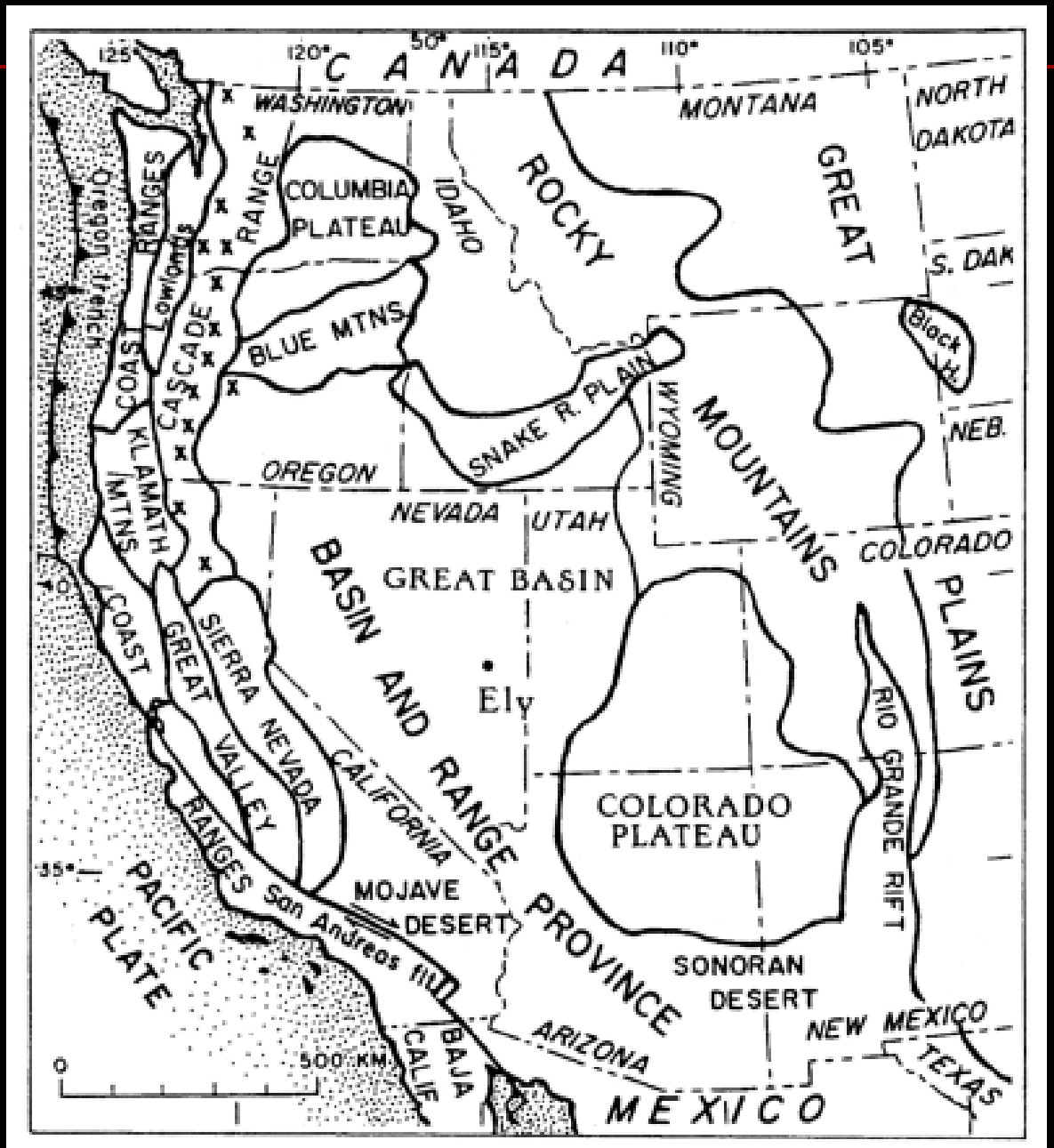
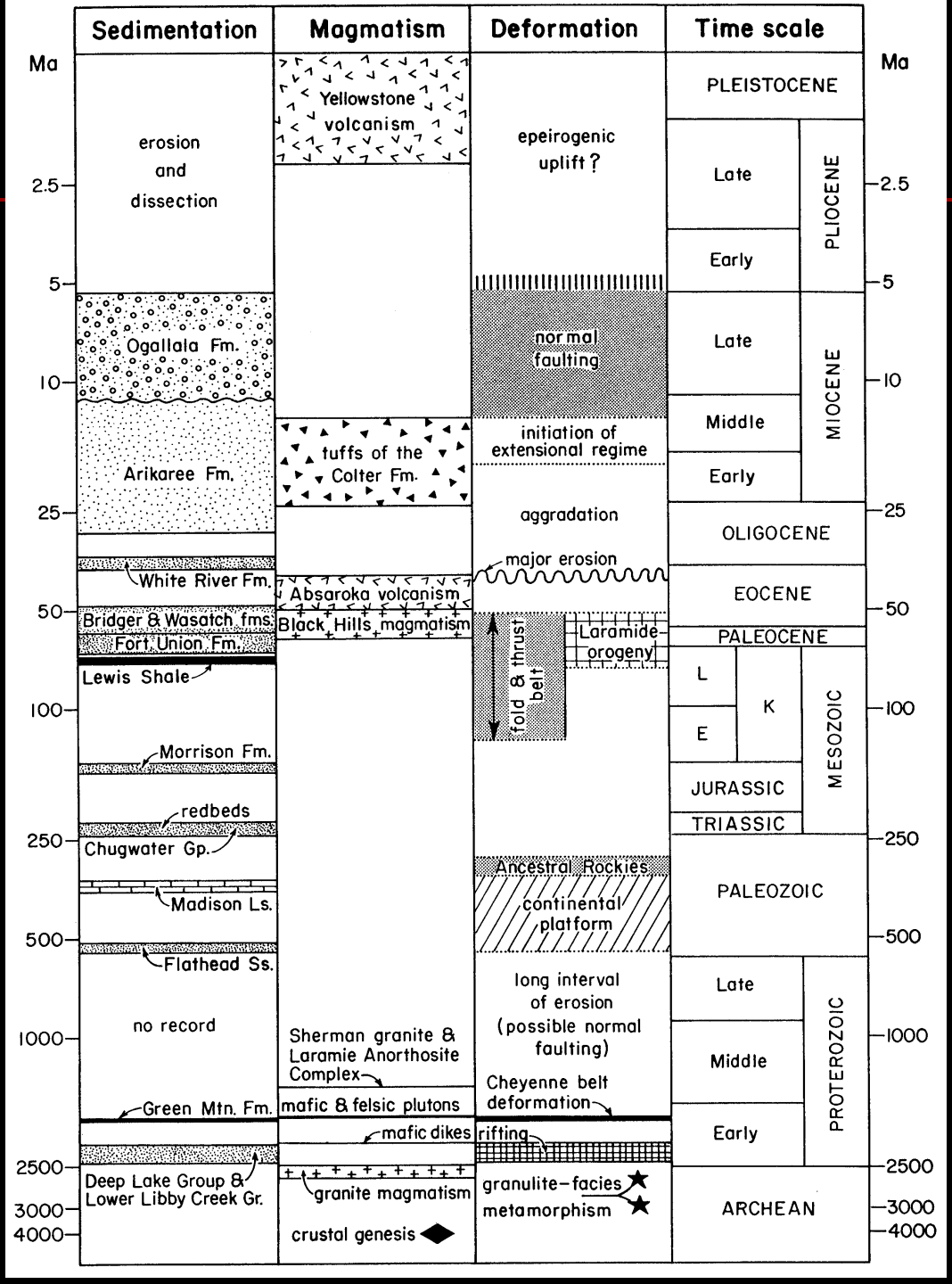
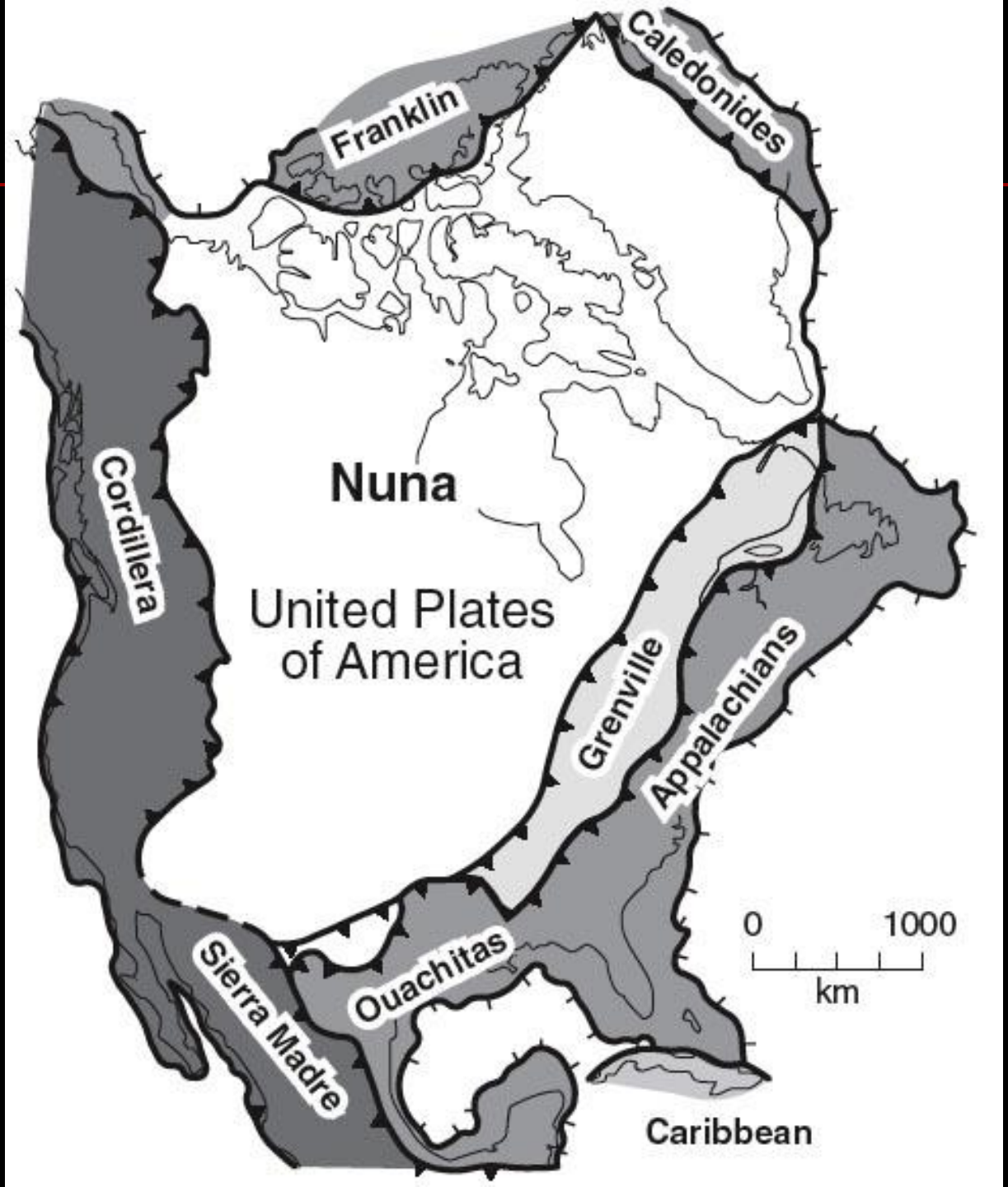
Regional geology and tectonic history of The Bighorn Mountains, WY

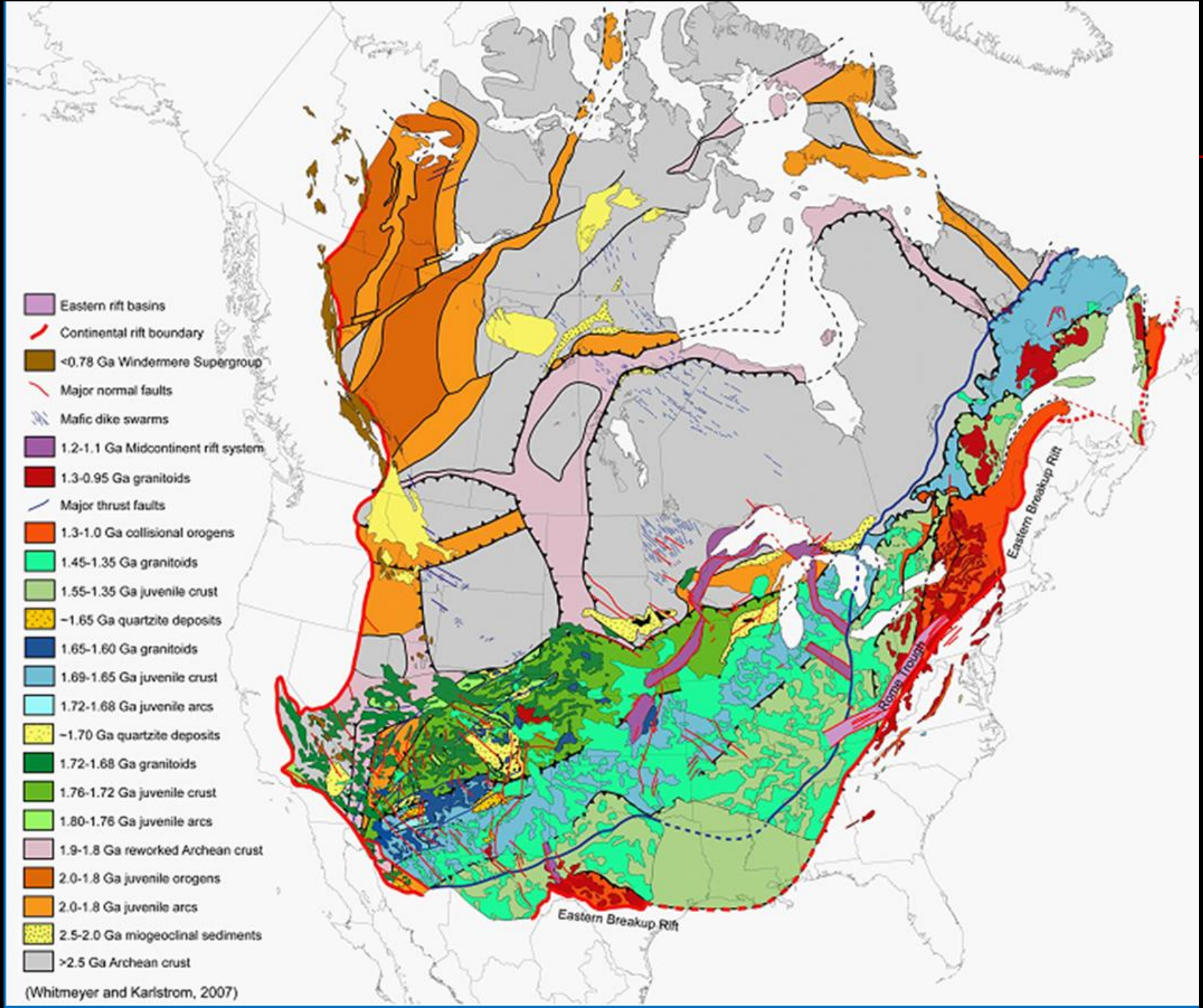
Geological Field Techniques Course

Regional physiography

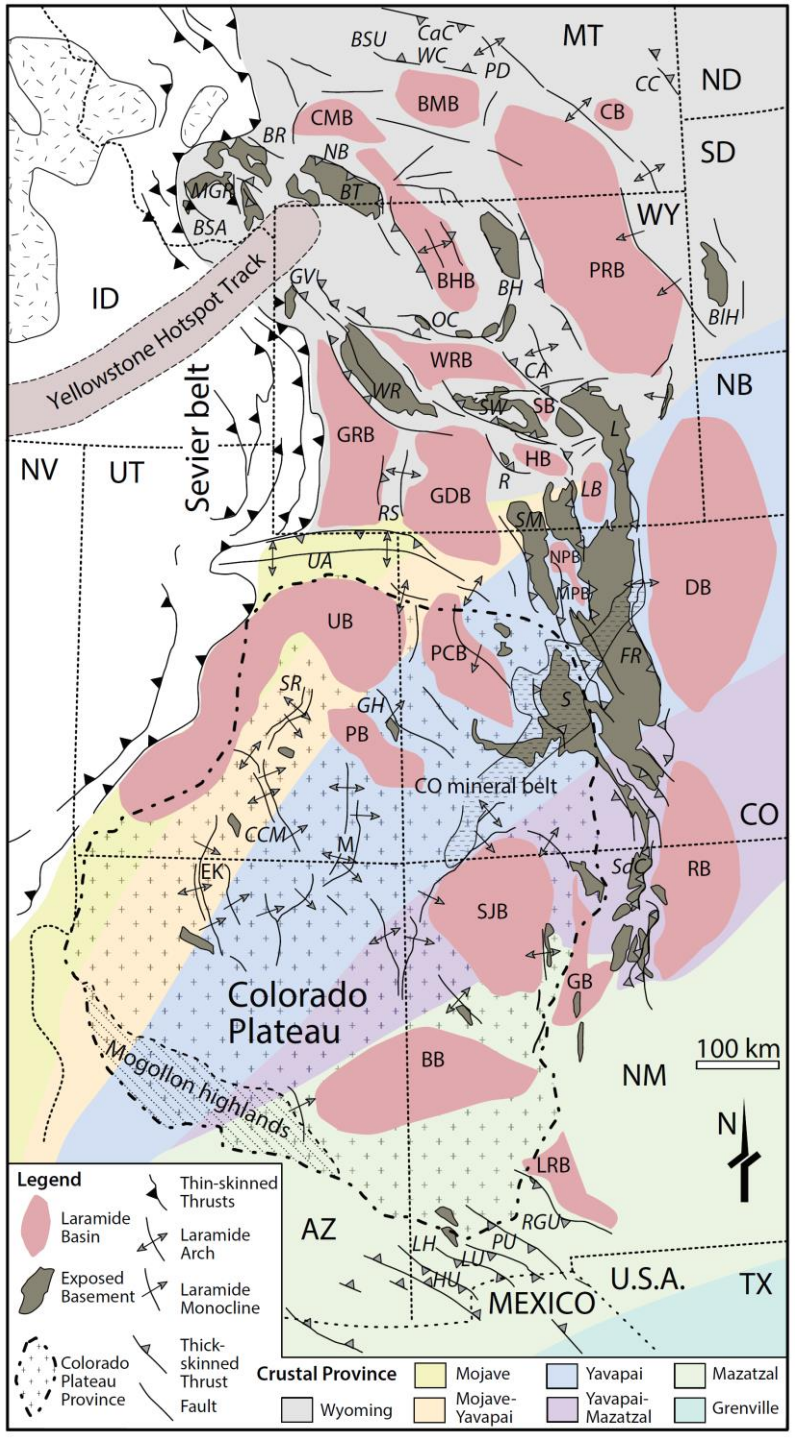



Sedimentation
Magmatism
Deformation
Time scale
Ma
Ma
erosion and dissection
Yellowstone volcanism
epeirogenic uplift?
PLEISTOCENE
Late
Early
PLIOCENE
2.5
5
Ogallala Fm.
normal faulting
Late
Middle
Early
MIOCENE
10
Arikaree Fm.
tuffs of the Colter Fm.
initiation of extensional regime
25
aggradation
OLIGOCENE
major erosion
White River Fm.
Absaroka volcanism
EOCENE
50
Bridger & Wasatch fms.
Fort Union Fm.
Black Hills magmatism
Laramide orogeny
PALEOCENE
fold & thrust belt
Lewis Shale
L
E
K
MESOZOIC
100
Morrison Fm.
JURASSIC
redbeds
TRIASSIC
250
Chugwater Gp.
Ancestral Rockies
PALEOZOIC
Madison Ls.
continental platform
500
Flathead Ss.
long interval of erosion (possible normal faulting)
Late
Middle
Early
PROTEROZOIC
no record
Sherman granite & Laramie Anorthosite Complex
1000
Cheyenne belt deformation
Green Mtn. Fm.
mafic & felsic plutons
mafic dikes
rifting
2500
Deep Lake Group & Lower Libby Creek Gr.
granite magmatism
granulite-facies metamorphism
ARCHEAN
3000
4000
crustal genesis


Franklin
Caledonides
Cordillera
Nuna
United Plates
of America
Grenville
Appalachians
Ouachitas
Sierra Madre
Caribbean
0
1000
km

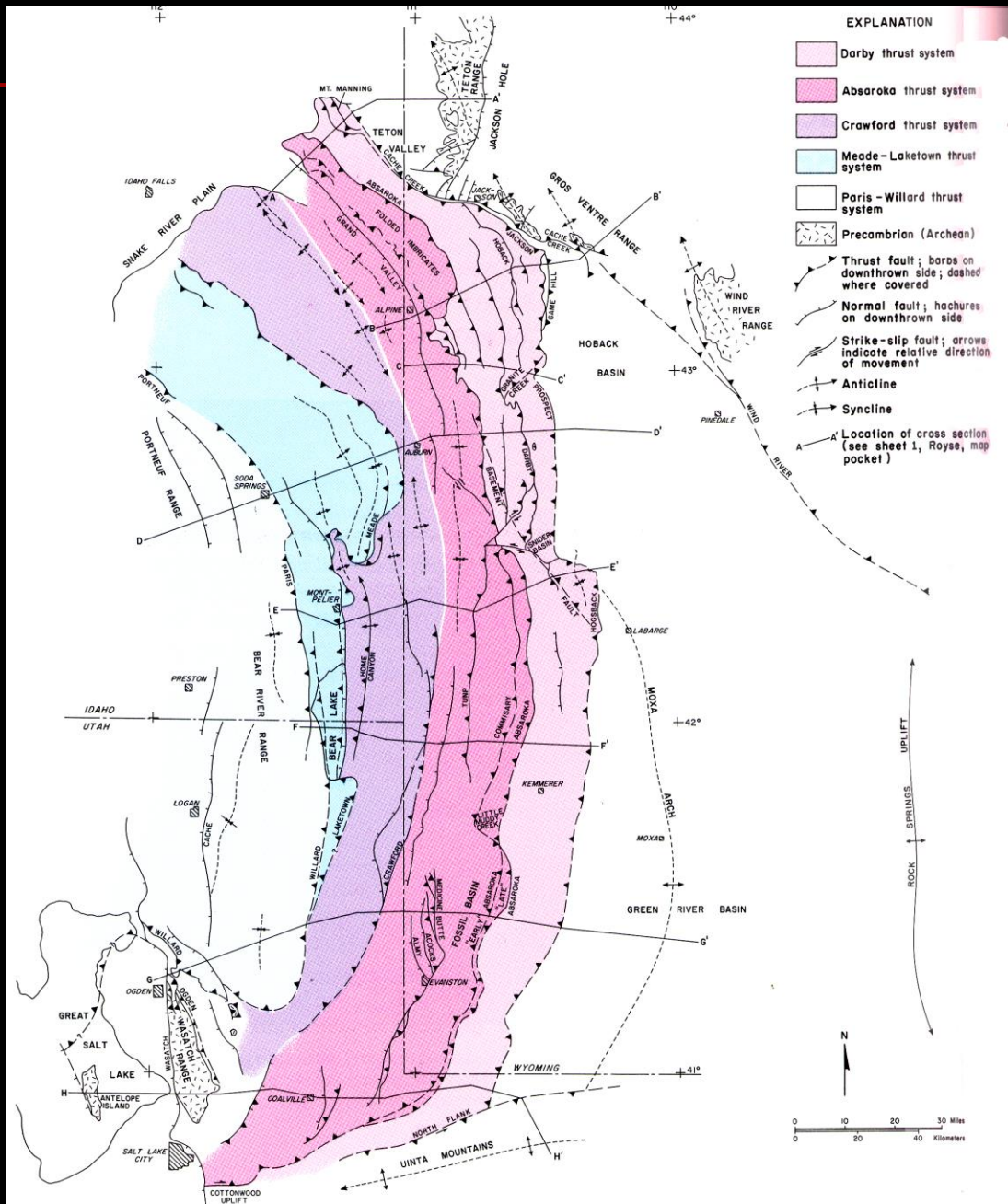

Eastern rift basins
Continental rift boundary
<0.78 Ga Windermere Supergroup
Major normal faults
Mafic dike swarms
1.2-1.1 Ga Midcontinent rift system
1.3-0.95 Ga granitoids
Major thrust faults
1.3-1.0 Ga collisional orogens
1.45-1.35 Ga granitoids
1.55-1.35 Ga juvenile crust
~1.65 Ga quartzite deposits
1.65-1.60 Ga granitoids
1.69-1.65 Ga juvenile crust
1.72-1.68 Ga juvenile arcs
~1.70 Ga quartzite deposits
1.72-1.68 Ga granitoids
1.76-1.72 Ga juvenile crust
1.80-1.76 Ga juvenile arcs
1.9-1.8 Ga reworked Archean crust
2.0-1.8 Ga juvenile orogens
2.0-1.8 Ga juvenile arcs
2.5-2.0 Ga miogeoclinal sediments
>2.5 Ga Archean crust
(Whitmeyer and Karlstrom, 2007)
Eastern Breakup Rift
Rome Trough
Eastern Breakup Rift


N65°
N55°
N45°
N35°
W150°
W130°
Legend
Magmatic Arc
Cordilleran Fold-Thrust Belt
Laramide Province
Foreland Basin System


MT
ND
SD
WY
NB
CO
NM
AZ
NV
UT
ID
U.S.A.
TX
MEXICO
Yellowstone Hotspot Track
Sevier belt
Colorado Plateau
Mogollon highlands
CO mineral belt
BSU
CaC
WC
PD
CC
BMB
CB
CMB
BR
NB
BT
MGR
BSA
GV
BHB
BH
PRB
BlH
OC
WRB
CA
WR
SW
SB
GRB
HB
R
LB
RS
GDB
SM
NPB
UA
MPB
DB
UB
PCB
FR
SR
GH
S
PB
CCM
M
EK
Sd
RB
SJB
GB
BB
LRB
RGU
LH
PU
LU
HU
100 km
N
Legend
Laramide Basin
Exposed Basement
Colorado Plateau Province
Thin-skinned Thrusts
Laramide Arch
Laramide Monocline
Thick-skinned Thrust
Fault
Crustal Province
Wyoming
Mojave
Mojave-Yavapai
Yavapai
Yavapai-Mazatzal
Mazatzal
Grenville

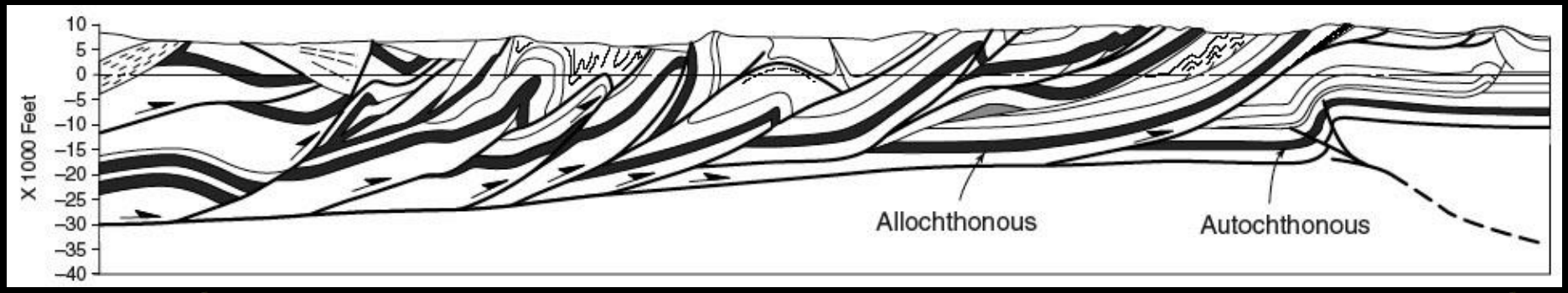
Sevier orogeny deformation style

- Thin-skinned
  - Sedimentary "cover" detached from basement

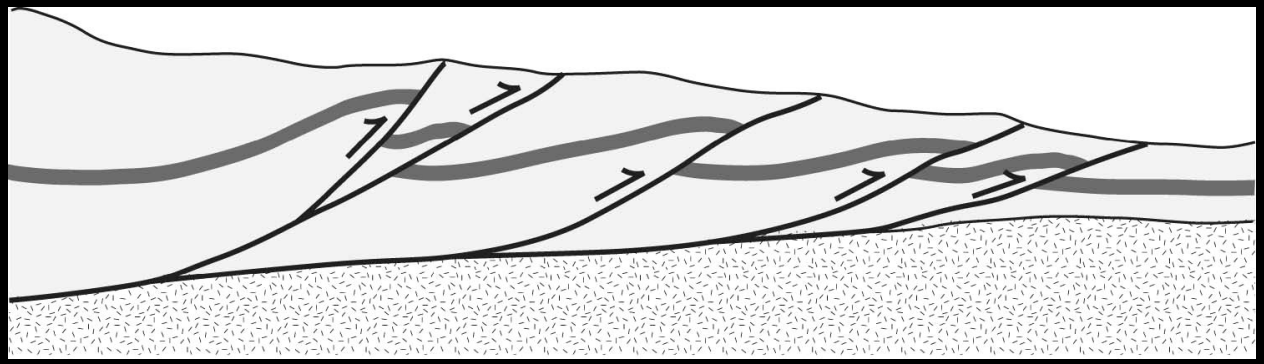


Idaho – Wyoming thrust belt

- Cross sectional view

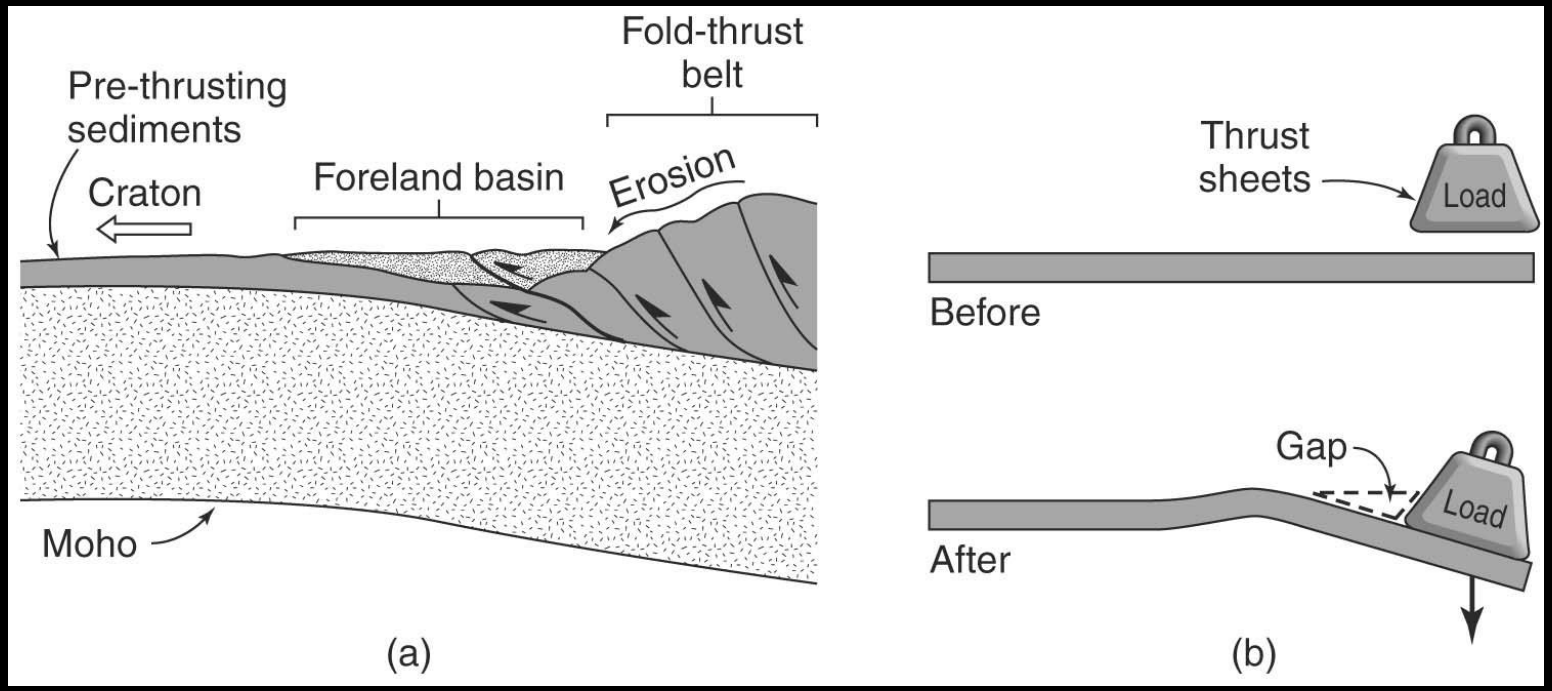


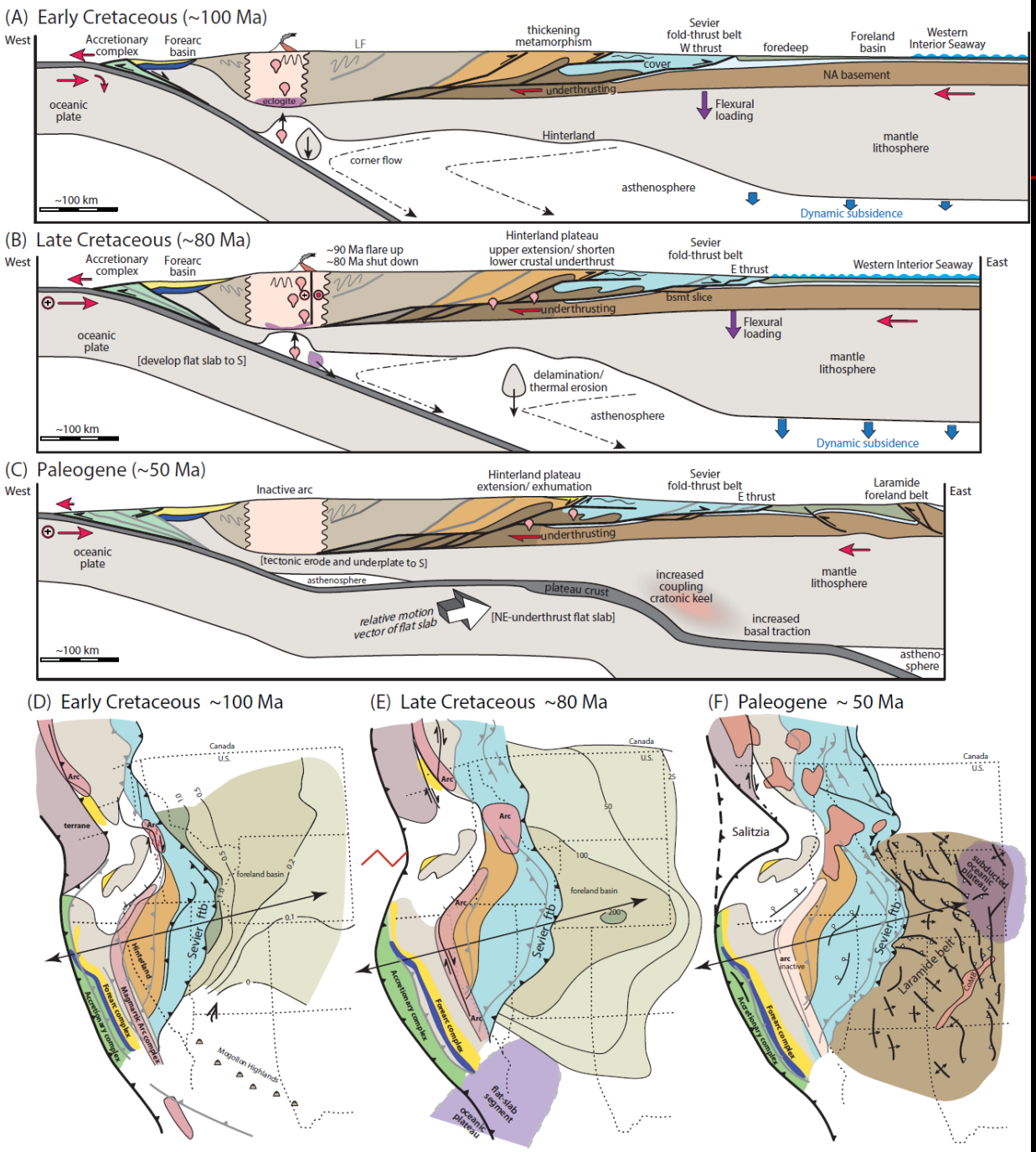
west east



Formation of foreland basins

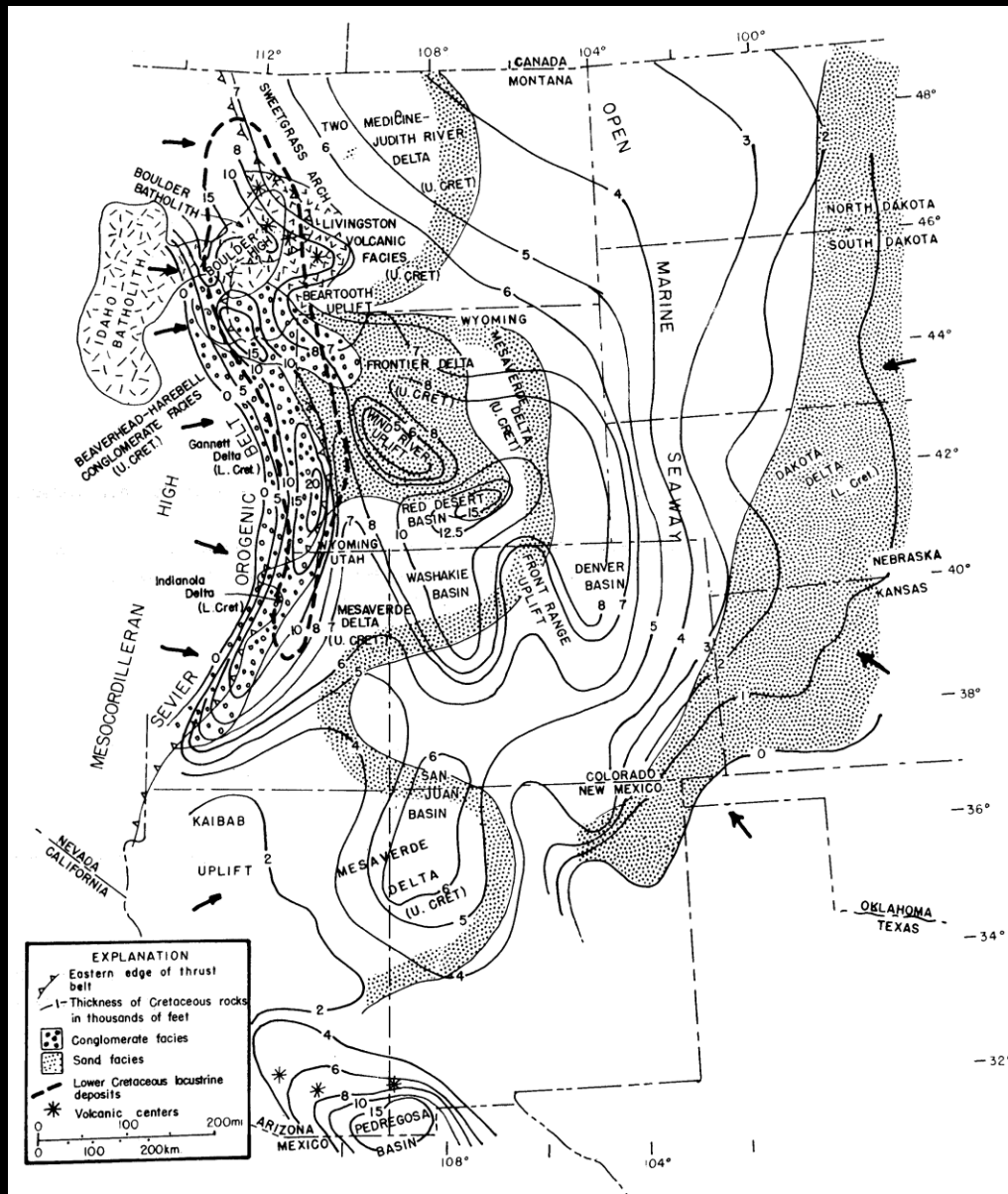
- Thickening and loading of crust causes flexure
  - Creates accommodation space to capture debris eroded from mountains

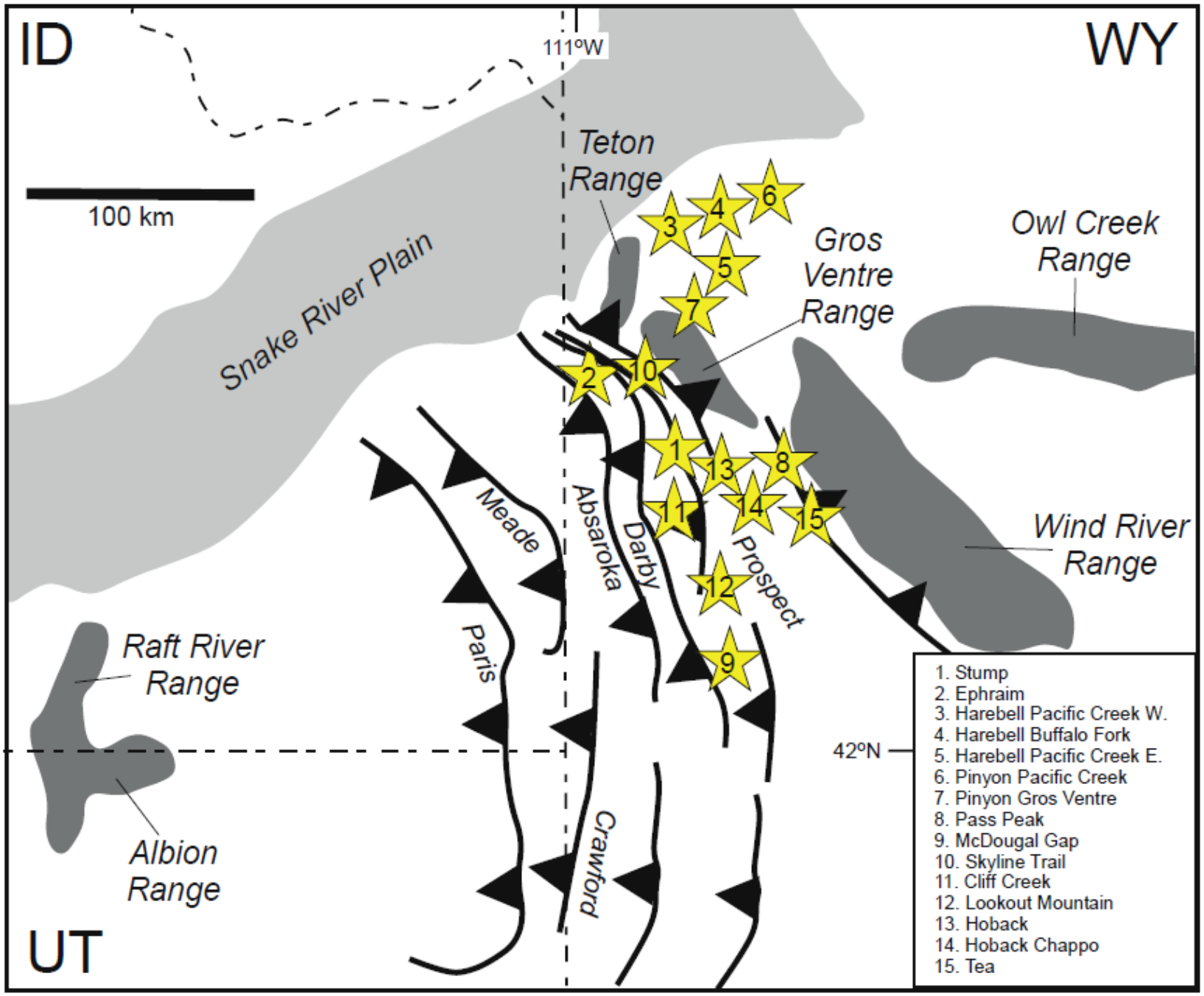


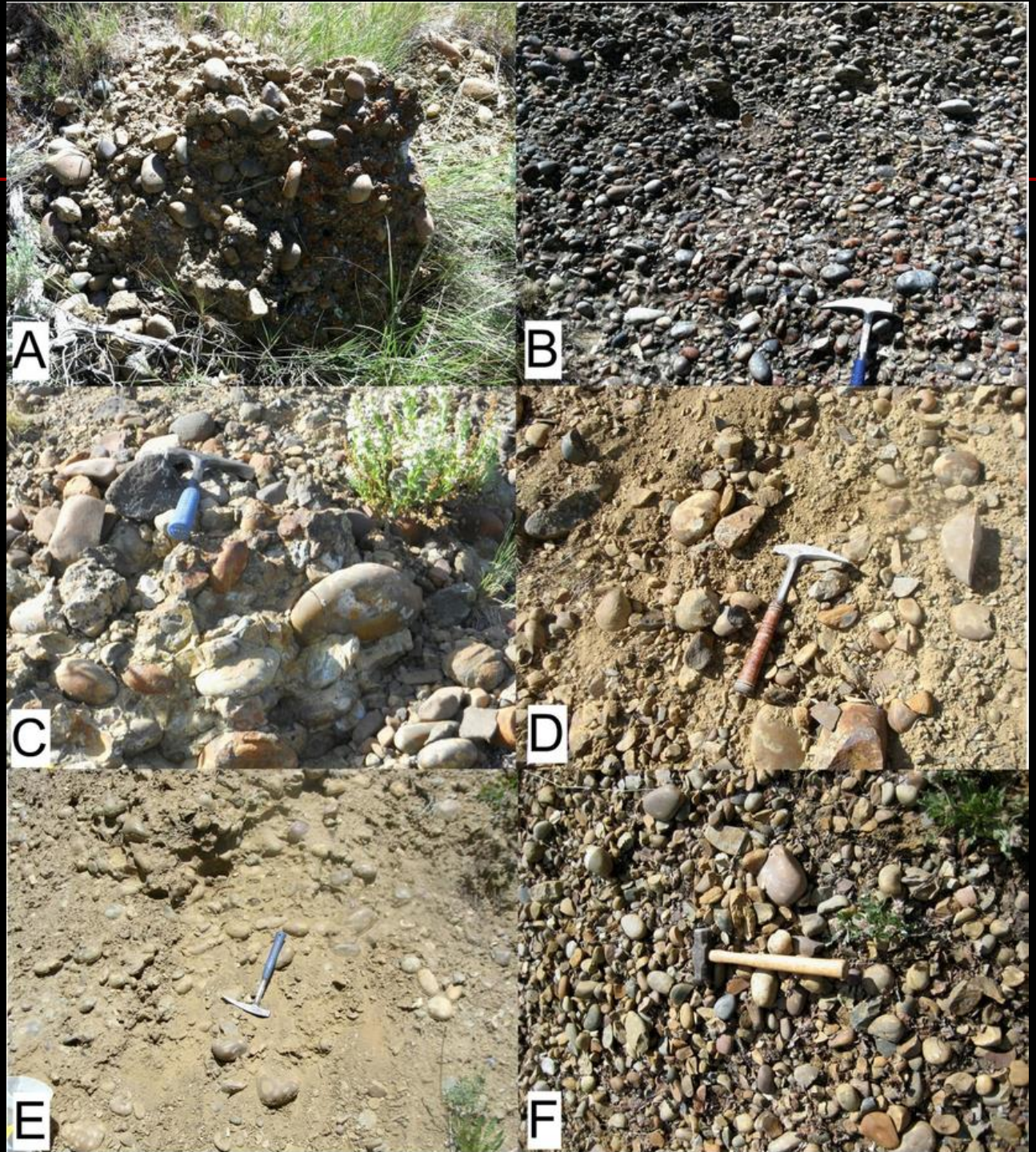

(A) Early Cretaceous (~100 Ma)
West
Accretionary complex
Forearc basin
LF
thickening metamorphism
Sevier fold-thrust belt W thrust
foredeep
Foreland basin
Western Interior Seaway
cover
NA basement
eclogite
underthrusting
Flexural loading
oceanic plate
Hinterland
mantle lithosphere
corner flow
asthenosphere
~100 km
Dynamic subsidence
(B) Late Cretaceous (~80 Ma)
West
Accretionary complex
Forearc basin
~90 Ma flare up
~80 Ma shut down
Hinterland plateau
upper extension/ shorten
lower crustal underthrust
Sevier fold-thrust belt
E thrust
Western Interior Seaway
East
bsmt slice
underthrusting
Flexural loading
oceanic plate
[develop flat slab to S]
mantle lithosphere
delamination/ thermal erosion
asthenosphere
~100 km
Dynamic subsidence
(C) Paleogene (~50 Ma)
West
Inactive arc
Hinterland plateau
extension/ exhumation
Sevier fold-thrust belt
E thrust
Laramide foreland belt
East
underthrusting
oceanic plate
[tectonic erode and underplate to S]
asthenosphere
plateau crust
increased coupling cratonic keel
mantle lithosphere
relative motion vector of flat slab
[NE-underthrust flat slab]
increased basal traction
~100 km
astheno-sphere
(D) Early Cretaceous ~100 Ma
(E) Late Cretaceous ~80 Ma
(F) Paleogene ~ 50 Ma
Canada
U.S.
Arc
terrane
foreland basin
Sevier ftb
Hinterland
Magmatic Arc complex
Forearc complex
Accretionary complex
Mogollon Highlands
flat-slab segment
oceanic plateau
Salitzia
subducted oceanic plateau
Laramide belt
arc inactive
coast

Cretaceous foreland basin

- Sediment sources and crustal loading patterns revealed by stratigraphic thickness and facies variations




ID
WY
UT
111°W
42°N
100 km
Teton Range
Snake River Plain
Gros Ventre Range
Owl Creek Range
Wind River Range
Raft River Range
Albion Range
Meade
Absaroka
Darby
Prospect
Paris
Crawford
1. Stump
2. Ephraim
3. Harebell Pacific Creek W.
4. Harebell Buffalo Fork
5. Harebell Pacific Creek E.
6. Pinyon Pacific Creek
7. Pinyon Gros Ventre
8. Pass Peak
9. McDougal Gap
10. Skyline Trail
11. Cliff Creek
12. Lookout Mountain
13. Hoback
14. Hoback Chappo
15. Tea


A
B
C
D
E
F

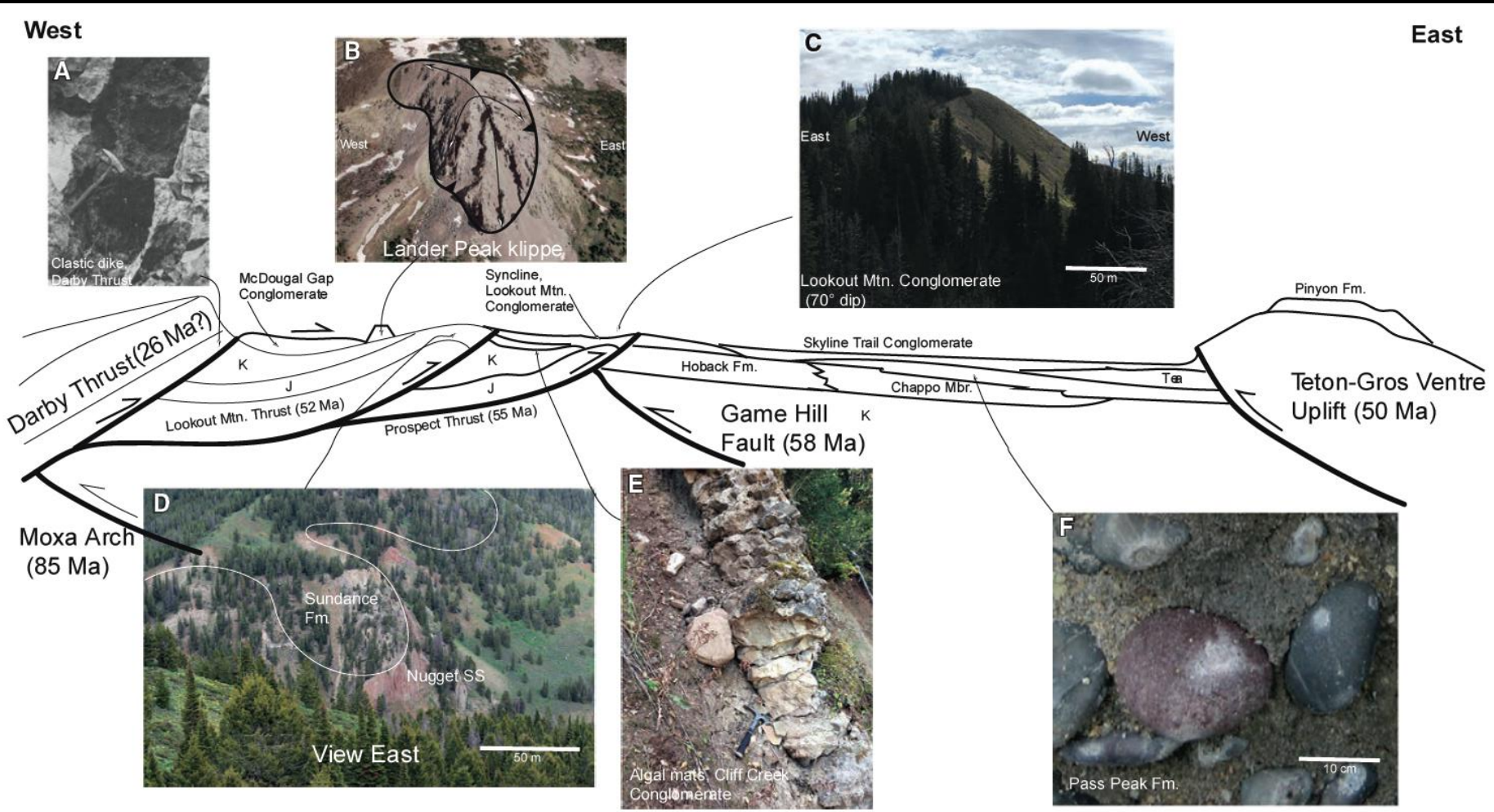
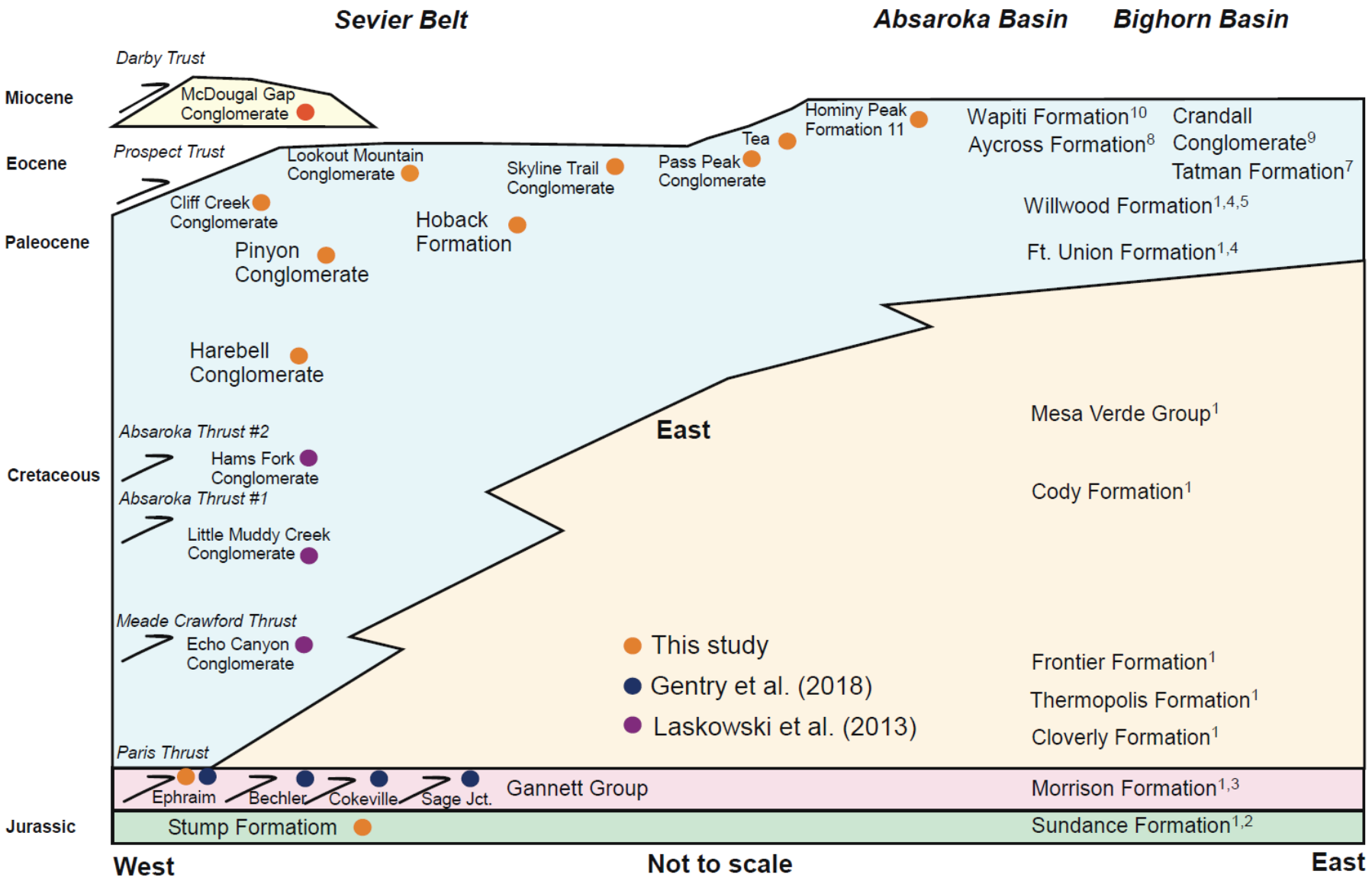
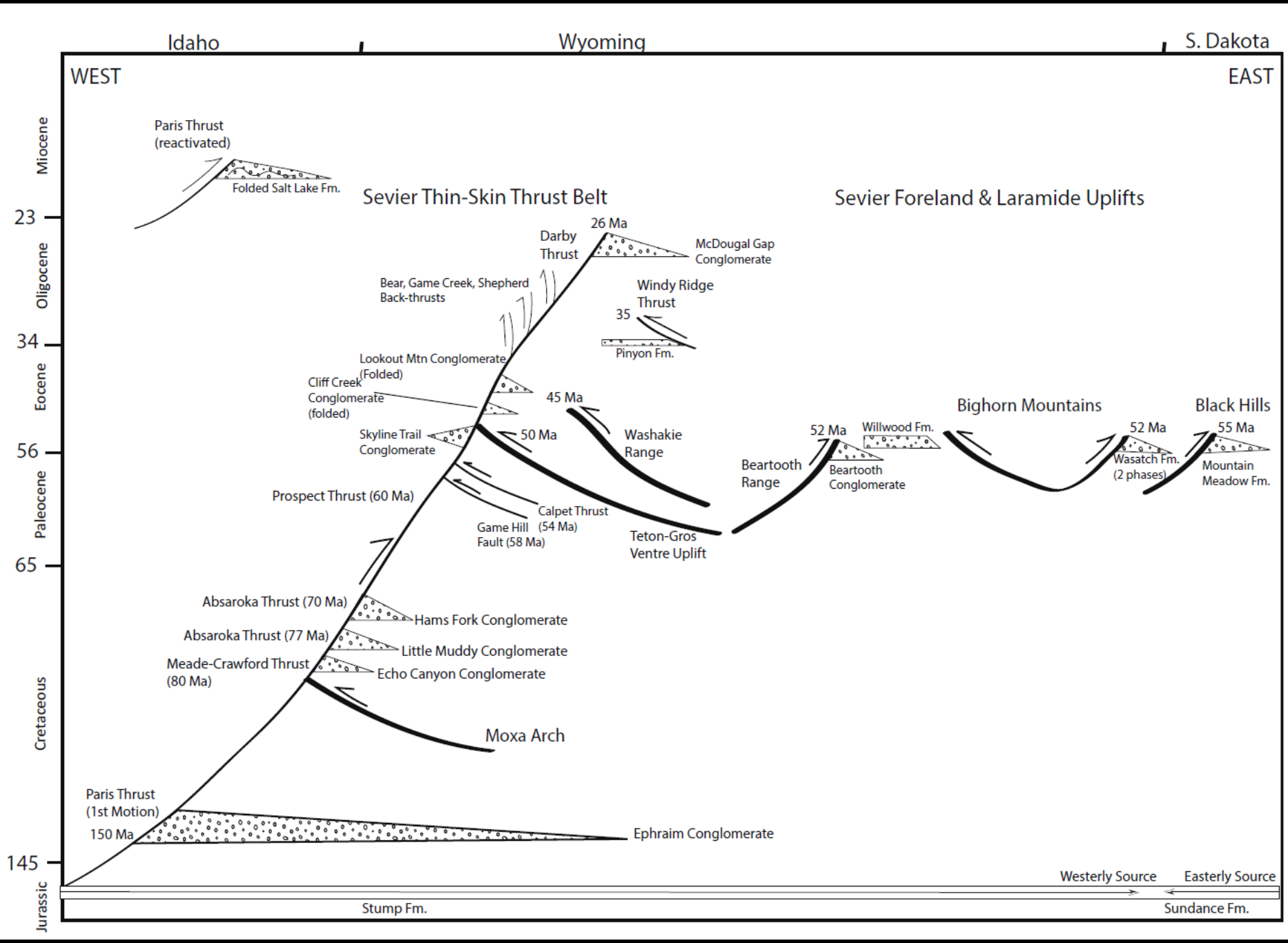
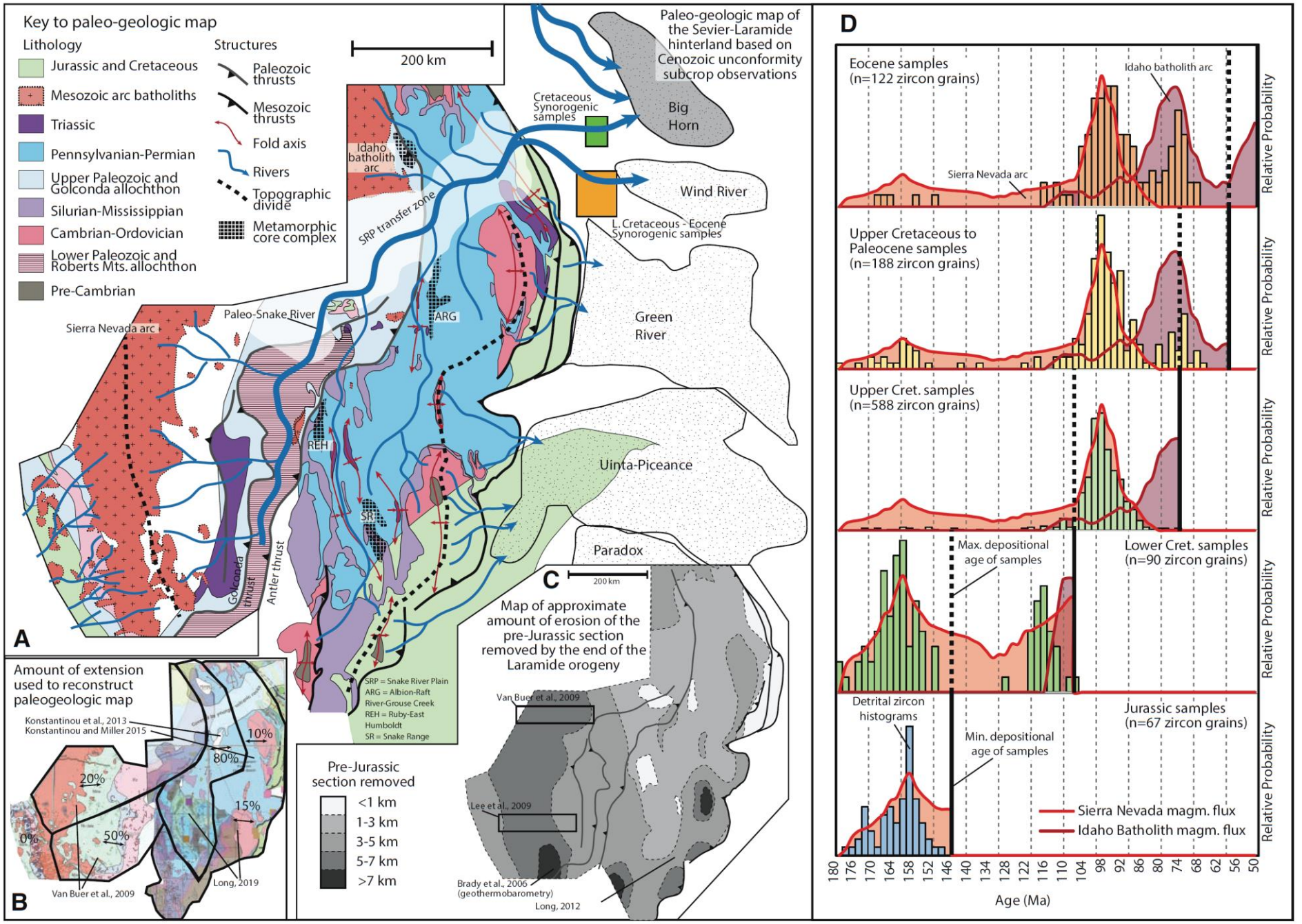
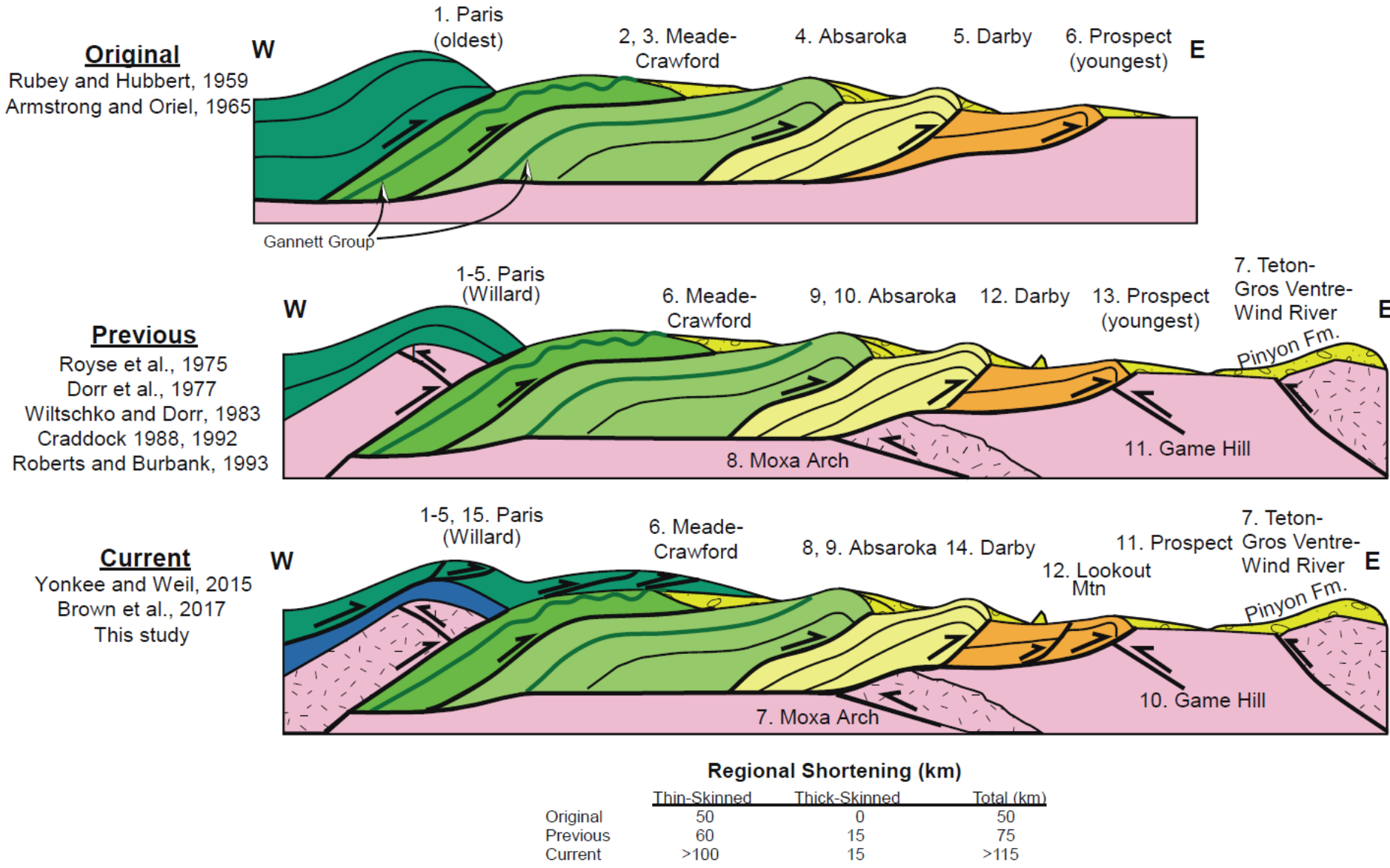


Figure 12. Schematic representation of the field relations of the synorogenic sedimentation along the eastern front of the Sevier belt and the out-of-sequence timing of thrust fault motions. (A) Clastic dike injected upward from the Darby thrust. (B) Lander Peak klippe (Madison Limestone) is the only klippe in the Sevier belt, and it is complexly deformed and overlies the McDougal Gap Conglomerate. (C) Secondary motion on the Prospect thrust formed a syncline in the Eocene Lookout Mountain Conglomerate, including 70° dips. (D) Jurassic strata in the upper plate of the Lookout Mountain thrust. SS—Sandstone. (E) Motion on the Lookout Mountain (Bear) thrust, with vertical barrel folds, also overthrust the Eocene Cliff Creek Conglomerate, rotating stromatolites to a vertical orientation. (F) Clast-on-clast pressure-solution pits are found in many quartzite clasts in the Eocene Pass Peak Formation in the Green River basin. J—Jurassic; K—Cretaceous.


Sevier Belt
Absaroka Basin
Bighorn Basin
Darby Trust
McDougal Gap Conglomerate
Prospect Trust
Lookout Mountain Conglomerate
Skyline Trail Conglomerate
Pass Peak Conglomerate
Tea
Hominy Peak Formation 11
Wapiti Formation[10]
Aycross Formation[8]
Crandall Conglomerate[9]
Tatman Formation[7]
Willwood Formation[1,4,5]
Ft. Union Formation[1,4]
Cliff Creek Conglomerate
Hoback Formation
Pinyon Conglomerate
Harebell Conglomerate
East
Mesa Verde Group[1]
Cody Formation[1]
Absaroka Thrust #2
Hams Fork Conglomerate
Absaroka Thrust #1
Little Muddy Creek Conglomerate
Meade Crawford Thrust
Echo Canyon Conglomerate
This study
Gentry et al. (2018)
Laskowski et al. (2013)
Frontier Formation[1]
Thermopolis Formation[1]
Cloverly Formation[1]
Paris Thrust
Ephraim
Bechler
Cokeville
Sage Jct.
Gannett Group
Morrison Formation[1,3]
Stump Formatiom
Sundance Formation[1,2]
Miocene
Eocene
Paleocene
Cretaceous
Jurassic
West
Not to scale
East

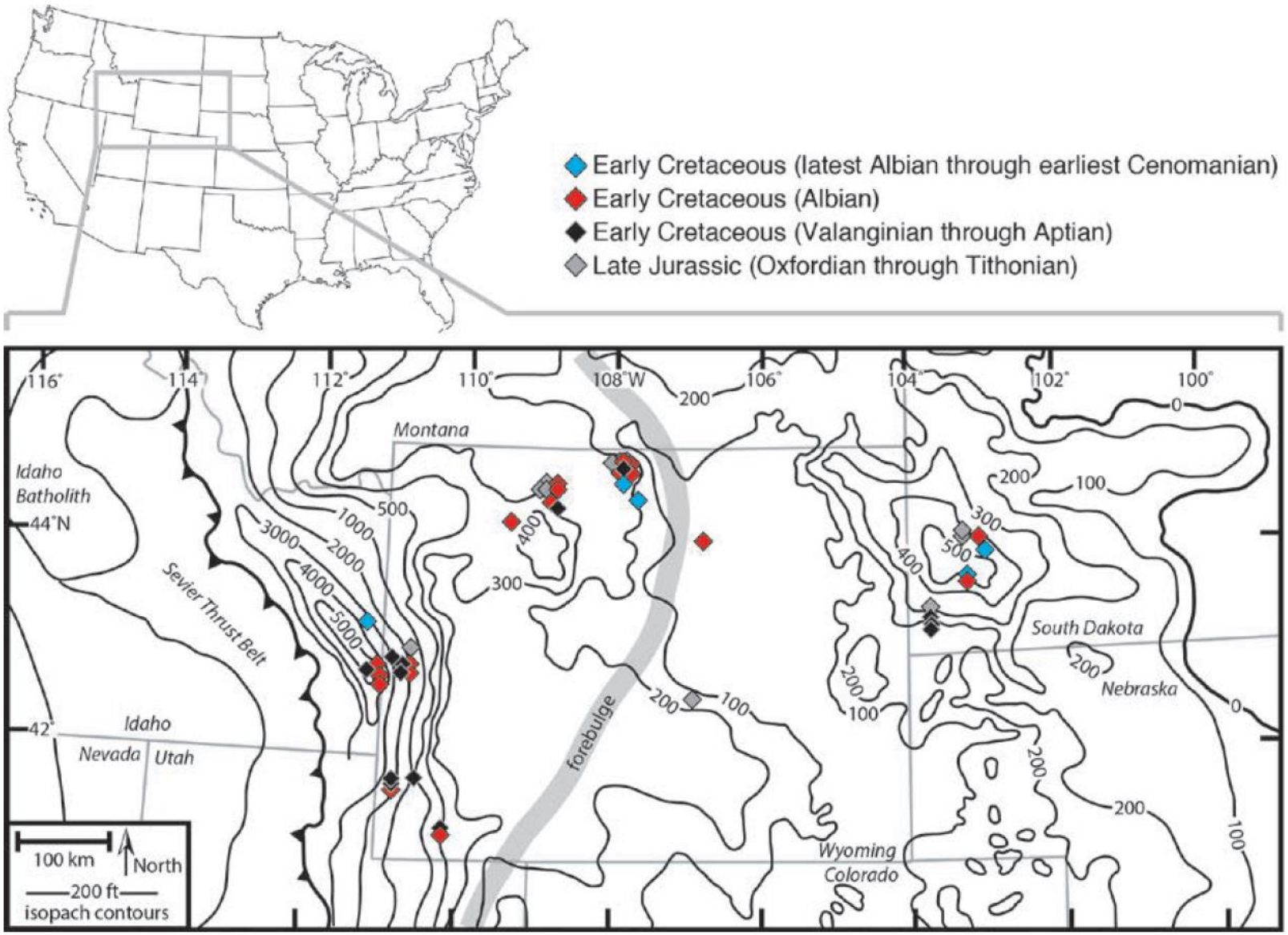

Idaho
Wyoming
S. Dakota
WEST
EAST
Miocene
23
Oligocene
34
Eocene
56
Paleocene
65
Cretaceous
145
Jurassic
Paris Thrust
(reactivated)
Folded Salt Lake Fm.
Sevier Thin-Skin Thrust Belt
Sevier Foreland & Laramide Uplifts
26 Ma
Darby
Thrust
McDougal Gap
Conglomerate
Bear, Game Creek, Shepherd
Back-thrusts
Windy Ridge
Thrust
35
Pinyon Fm.
Lookout Mtn Conglomerate
(Folded)
Cliff Creek
Conglomerate
(folded)
45 Ma
Bighorn Mountains
Black Hills
Skyline Trail
Conglomerate
50 Ma
Washakie
Range
52 Ma
Willwood Fm.
Beartooth
Range
Beartooth
Conglomerate
52 Ma
55 Ma
Wasatch Fm.
(2 phases)
Mountain
Meadow Fm.
Prospect Thrust (60 Ma)
Calpet Thrust
(54 Ma)
Game Hill
Fault (58 Ma)
Teton-Gros
Ventre Uplift
Absaroka Thrust (70 Ma)
Hams Fork Conglomerate
Absaroka Thrust (77 Ma)
Little Muddy Conglomerate
Meade-Crawford Thrust
(80 Ma)
Echo Canyon Conglomerate
Moxa Arch
Paris Thrust
(1st Motion)
150 Ma
Ephraim Conglomerate
Westerly Source
Easterly Source
Stump Fm.
Sundance Fm.

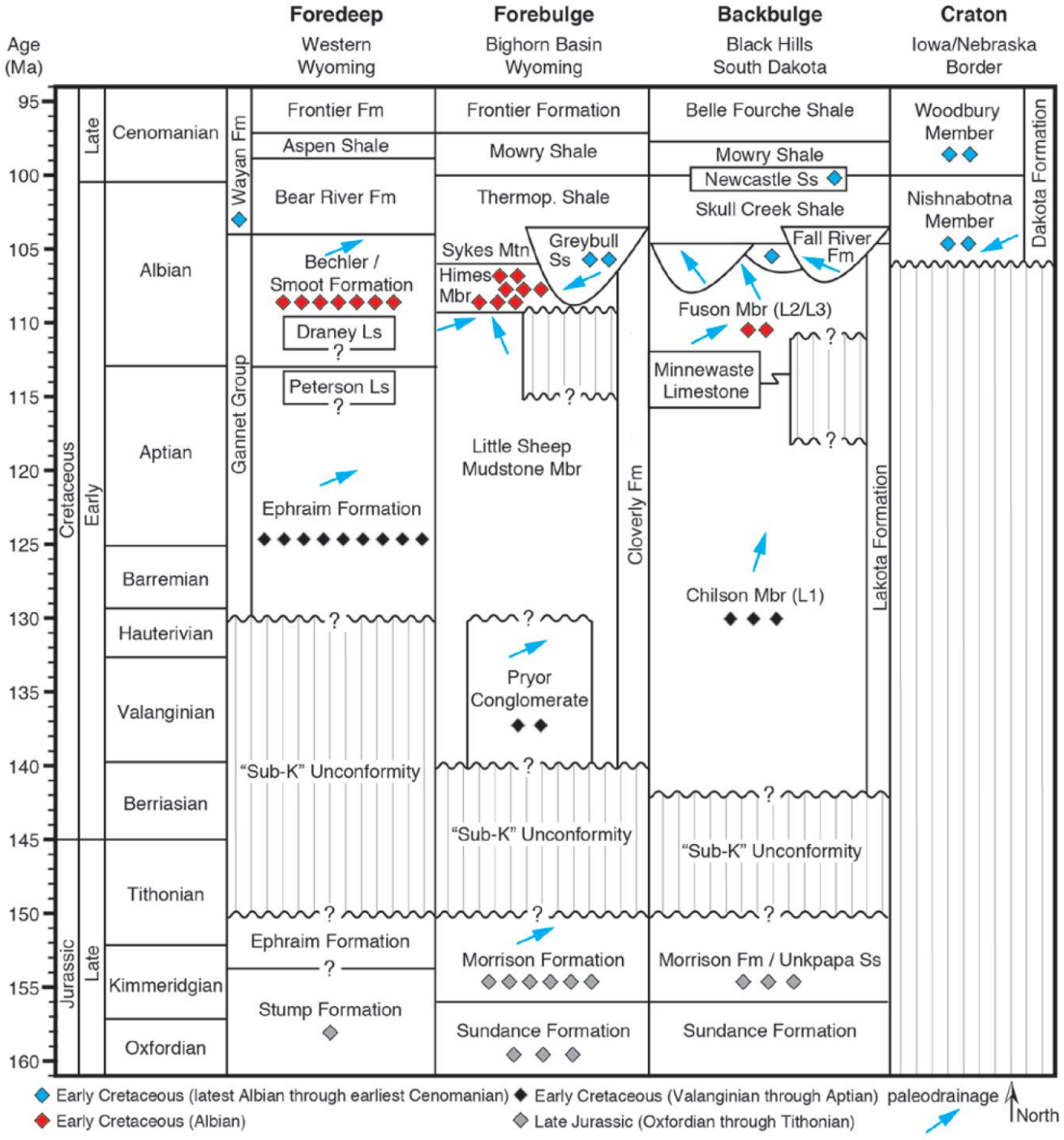

Key to paleo-geologic map
Lithology
Jurassic and Cretaceous
Mesozoic arc batholiths
Triassic
Pennsylvanian-Permian
Upper Paleozoic and Golconda allochthon
Silurian-Mississippian
Cambrian-Ordovician
Lower Paleozoic and Roberts Mts. allochthon
Pre-Cambrian
Structures
Paleozoic thrusts
Mesozoic thrusts
Fold axis
Rivers
Topographic divide
Metamorphic core complex
200 km
Paleo-geologic map of the Sevier-Laramide hinterland based on Cenozoic unconformity subcrop observations
Cretaceous Synorogenic samples
Big Horn
Wind River
L. Cretaceous - Eocene Synorogenic samples
Green River
Uinta-Piceance
Paradox
Idaho batholith arc
SRP transfer zone
Sierra Nevada arc
Paleo-Snake River
ARG
REH
SR
Golconda thrust
Antler thrust
A
SRP = Snake River Plain
ARG = Albion-Raft River-Grouse Creek
REH = Ruby-East Humboldt
SR = Snake Range
Amount of extension used to reconstruct paleogeologic map
Konstantinou et al., 2013
Konstantinou and Miller 2015
10%
80%
20%
15%
0%
50%
Van Buer et al., 2009
Long, 2019
B
C
200 km
Map of approximate amount of erosion of the pre-Jurassic section removed by the end of the Laramide orogeny
Van Buer et al., 2009
Lee et al., 2009
Brady et al., 2006 (geothermobarometry)
Long, 2012
Pre-Jurassic section removed
<1 km
1-3 km
3-5 km
5-7 km
>7 km
D
Eocene samples (n=122 zircon grains)
Idaho batholith arc
Sierra Nevada arc
Upper Cretaceous to Paleocene samples (n=188 zircon grains)
Upper Cret. samples (n=588 zircon grains)
Max. depositional age of samples
Lower Cret. samples (n=90 zircon grains)
Detrital zircon histograms
Min. depositional age of samples
Jurassic samples (n=67 zircon grains)
Sierra Nevada magm. flux
Idaho Batholith magm. flux
Relative Probability
180 176 170 164 158 152 146 140 134 128 122 116 110 104 98 92 86 80 74 68 62 56 50
Age (Ma)

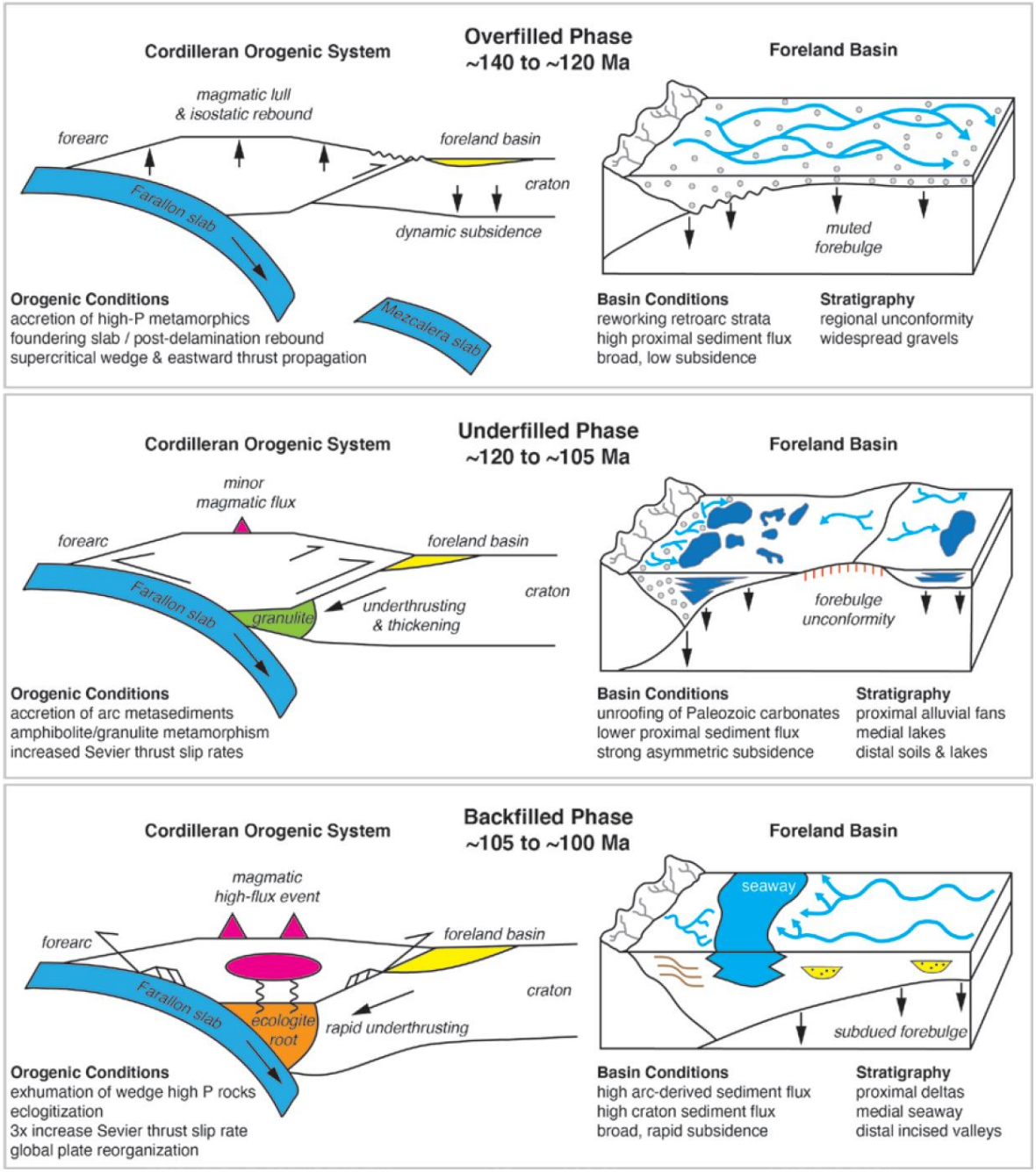


Regional Shortening (km)

	Thin-Skinned	Thick-Skinned	Total (km)
Original	50	0	50
Previous	60	15	75
Current	>100	15	>115


Early Cretaceous (latest Albian through earliest Cenomanian)
Early Cretaceous (Albian)
Early Cretaceous (Valanginian through Aptian)
Late Jurassic (Oxfordian through Tithonian)
116°
114°
112°
110°
108°W
106°
104°
102°
100°
Montana
Idaho Batholith
44°N
Sevier Thrust Belt
forebulge
South Dakota
Nebraska
42°
Idaho
Nevada
Utah
Wyoming
Colorado
100 km
North
200 ft
isopach contours


Foredeep
Western Wyoming
Forebulge
Bighorn Basin Wyoming
Backbulge
Black Hills South Dakota
Craton
Iowa/Nebraska Border
Age (Ma)
95
100
105
110
115
120
125
130
135
140
145
150
155
160
Cretaceous
Late
Early
Jurassic
Late
Cenomanian
Albian
Aptian
Barremian
Hauterivian
Valanginian
Berriasian
Tithonian
Kimmeridgian
Oxfordian
Wayan Fm
Gannet Group
Frontier Fm
Aspen Shale
Bear River Fm
Bechler / Smoot Formation
Draney Ls
?
Peterson Ls
?
Ephraim Formation
?
"Sub-K" Unconformity
?
Ephraim Formation
?
Stump Formation
Frontier Formation
Mowry Shale
Thermop. Shale
Sykes Mtn
Himes Mbr
Greybull Ss
?
Little Sheep Mudstone Mbr
?
Pryor Conglomerate
?
"Sub-K" Unconformity
?
Morrison Formation
Sundance Formation
Cloverly Fm
Belle Fourche Shale
Mowry Shale
Newcastle Ss
Skull Creek Shale
Fall River Fm
Fuson Mbr (L2/L3)
Minnewaste Limestone
?
?
Chilson Mbr (L1)
?
"Sub-K" Unconformity
?
Morrison Fm / Unkpapa Ss
Sundance Formation
Lakota Formation
Woodbury Member
Nishnabotna Member
Dakota Formation
Early Cretaceous (latest Albian through earliest Cenomanian)
Early Cretaceous (Albian)
Early Cretaceous (Valanginian through Aptian)
Late Jurassic (Oxfordian through Tithonian)
paleodrainage
North


Overfilled Phase
~140 to ~120 Ma
Cordilleran Orogenic System
Foreland Basin
magmatic lull
& isostatic rebound
forearc
foreland basin
craton
Farallon slab
dynamic subsidence
muted
forebulge
Mezcalera slab
Orogenic Conditions
accretion of high-P metamorphics
foundering slab / post-delamination rebound
supercritical wedge & eastward thrust propagation
Basin Conditions
reworking retroarc strata
high proximal sediment flux
broad, low subsidence
Stratigraphy
regional unconformity
widespread gravels
Underfilled Phase
~120 to ~105 Ma
Cordilleran Orogenic System
Foreland Basin
minor
magmatic flux
forearc
foreland basin
craton
Farallon slab
granulite
underthrusting
& thickening
forebulge
unconformity
Orogenic Conditions
accretion of arc metasediments
amphibolite/granulite metamorphism
increased Sevier thrust slip rates
Basin Conditions
unroofing of Paleozoic carbonates
lower proximal sediment flux
strong asymmetric subsidence
Stratigraphy
proximal alluvial fans
medial lakes
distal soils & lakes
Backfilled Phase
~105 to ~100 Ma
Cordilleran Orogenic System
Foreland Basin
magmatic
high-flux event
forearc
foreland basin
craton
Farallon slab
eclogite
root
rapid underthrusting
seaway
subdued forebulge
Orogenic Conditions
exhumation of wedge high P rocks
eclogitization
3x increase Sevier thrust slip rate
global plate reorganization
Basin Conditions
high arc-derived sediment flux
high craton sediment flux
broad, rapid subsidence
Stratigraphy
proximal deltas
medial seaway
distal incised valleys

Tectonic configuration - onset Laramide

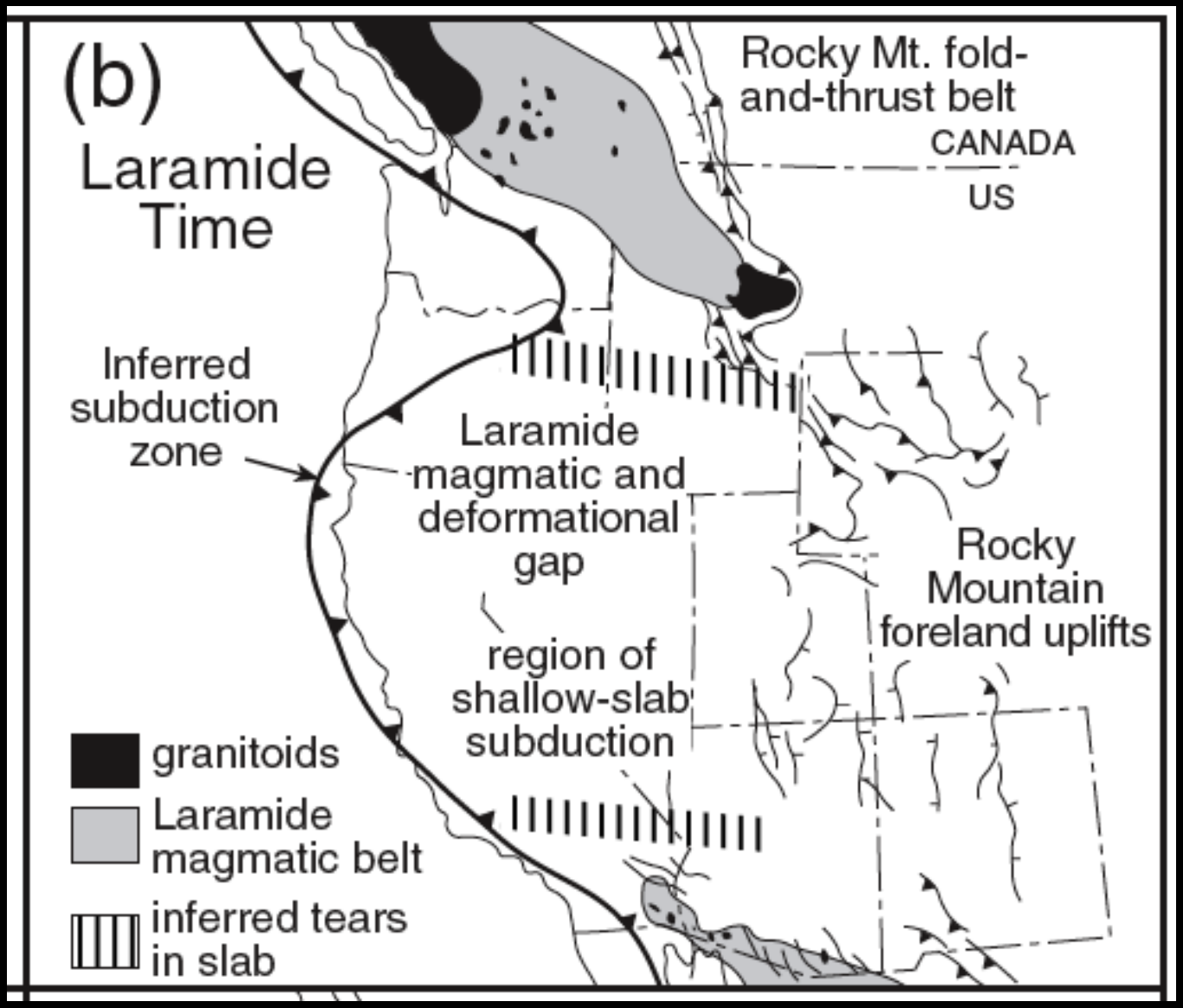
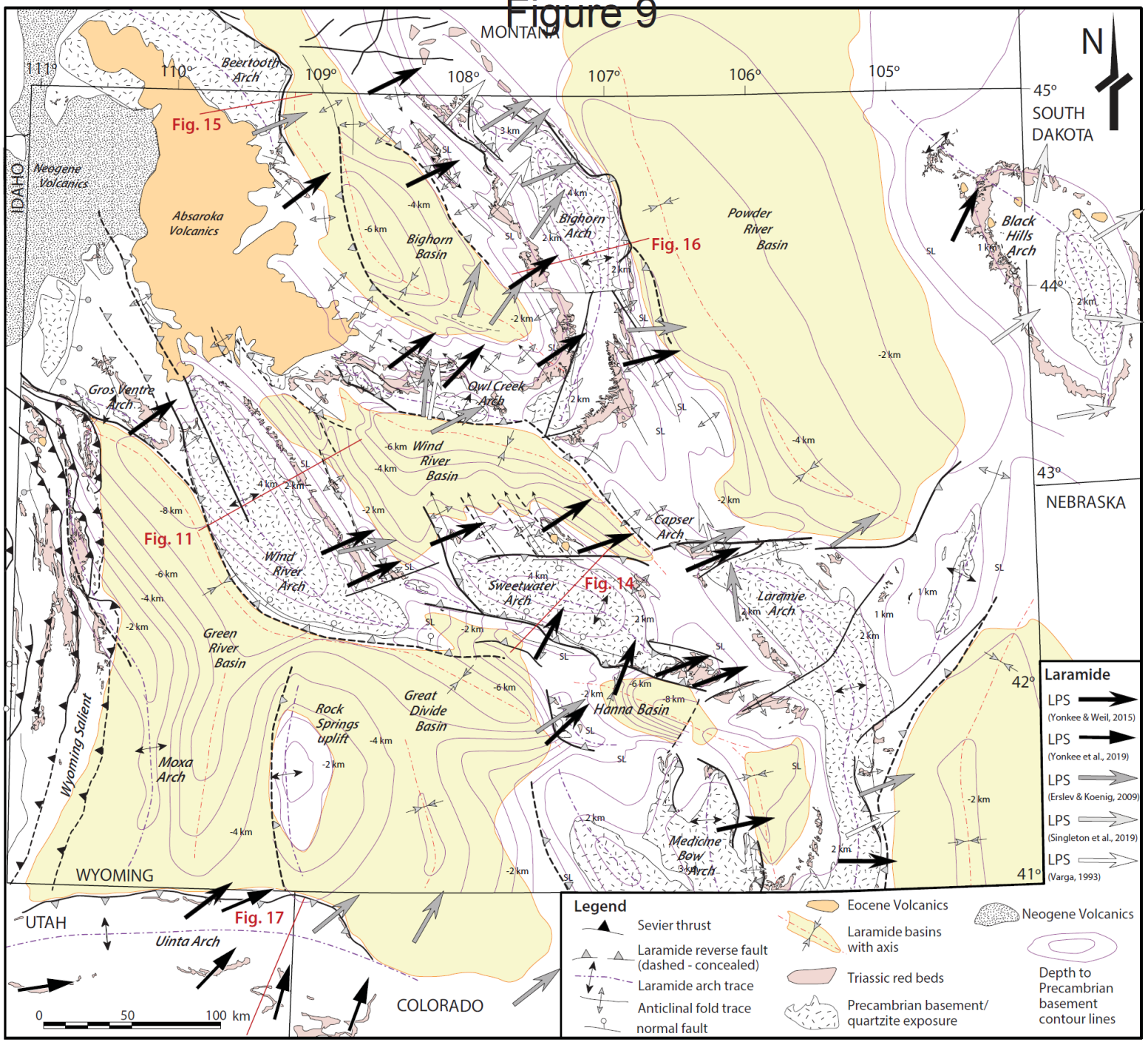
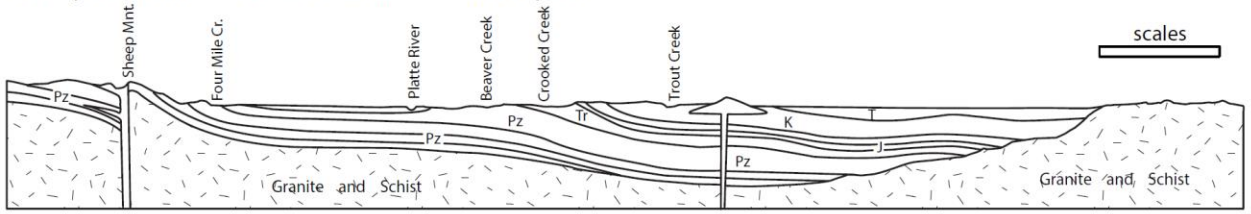


Figure 9

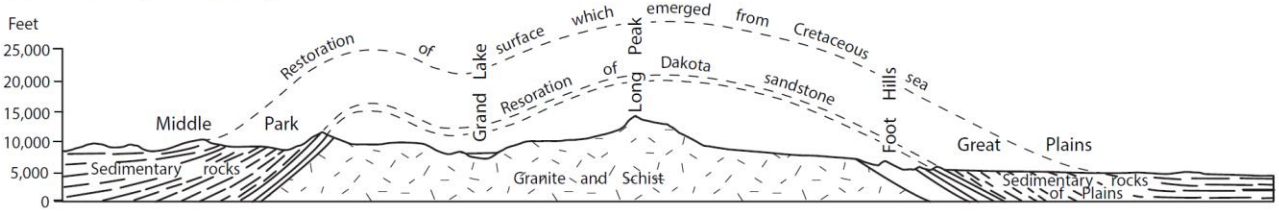

MONTANA
N
111°
110°
109°
108°
107°
106°
105°
45°
44°
43°
42°
41°
SOUTH DAKOTA
NEBRASKA
IDAHO
WYOMING
UTAH
COLORADO
Beartooth Arch
Neogene Volcanics
Absaroka Volcanics
Bighorn Basin
Bighorn Arch
Powder River Basin
Black Hills Arch
Gros Ventre Arch
Owl Creek Arch
Wind River Basin
Wind River Arch
Sweetwater Arch
Capser Arch
Laramie Arch
Green River Basin
Wyoming Salient
Rock Springs uplift
Great Divide Basin
Hanna Basin
Medicine Bow Arch
Moxa Arch
Uinta Arch
Fig. 15
Fig. 16
Fig. 11
Fig. 14
Fig. 17
0 50 100 km
Laramide
LPS (Yonkee & Weil, 2015)
LPS (Yonkee et al., 2019)
LPS (Erslev & Koenig, 2009)
LPS (Singleton et al., 2019)
LPS (Varga, 1993)
Legend
Sevier thrust
Laramide reverse fault (dashed - concealed)
Laramide arch trace
Anticlinal fold trace
normal fault
Eocene Volcanics
Laramide basins with axis
Triassic red beds
Precambrian basement/ quartzite exposure
Neogene Volcanics
Depth to Precambrian basement contour lines

Laramide basement uplifts

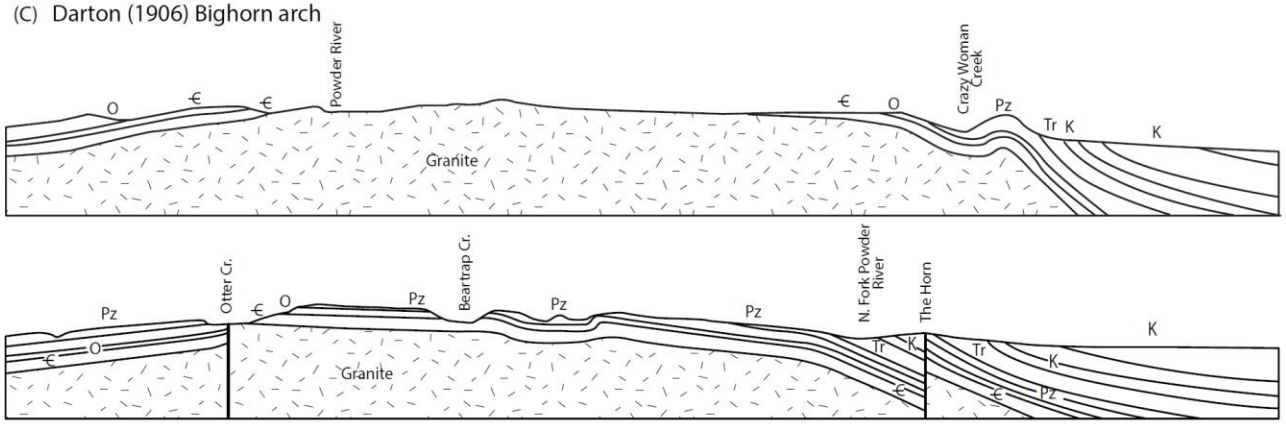
(A) Hayden (1877)- South Park basin and basement uplifts



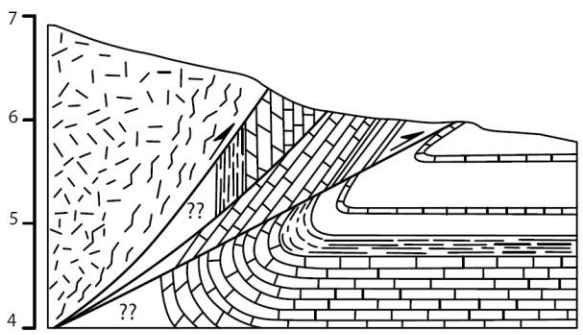
(B) Lee (1917) - Front Range



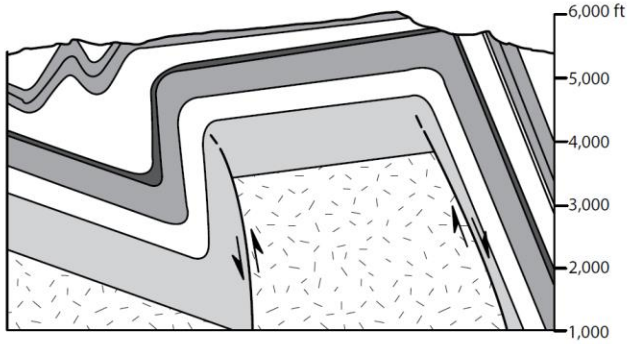
(C) Darton (1906) Bighorn arch



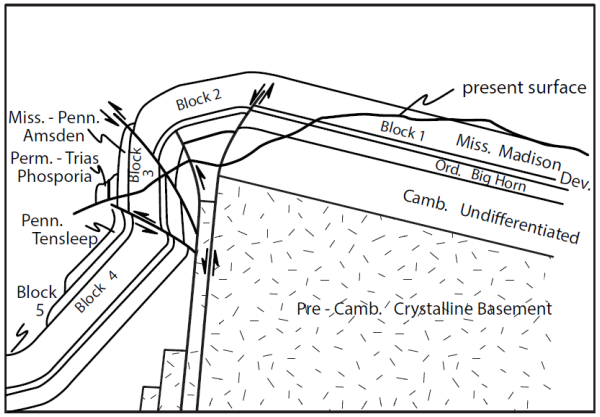
(D) Blackstone (1940) - Pryor Moutnains arch



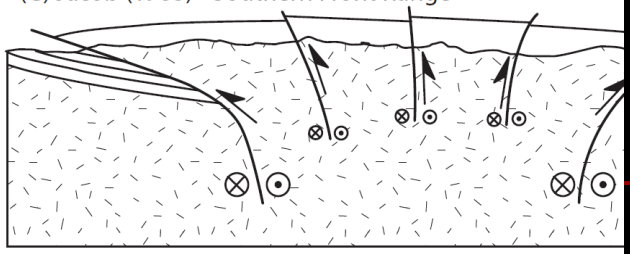
(E) Mathews and Work (1978) - Rabbit Mountain, CO



(F) Stearns or Maththews (1978) Rattlesnake Mountain

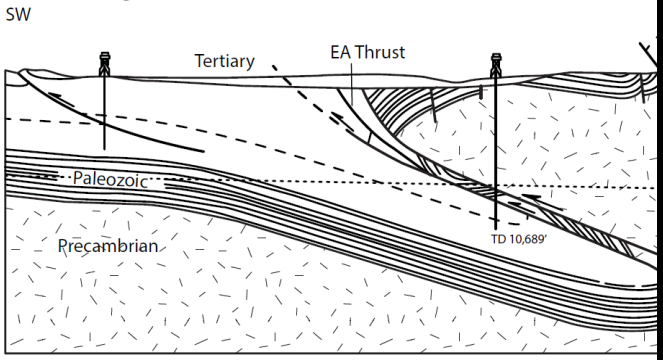


(G) Jacob (1983) - Southern Front Range

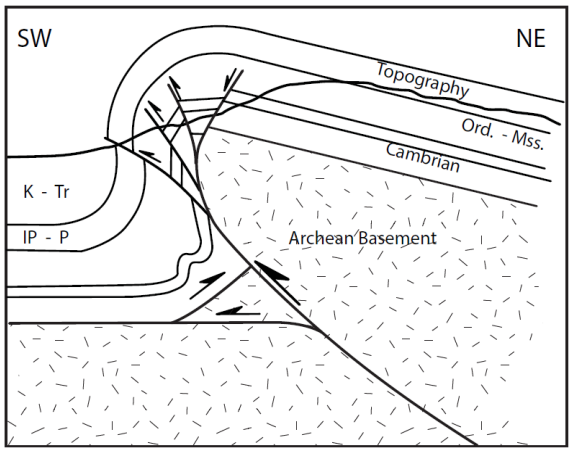


(H) Sales (1968) - General arch model

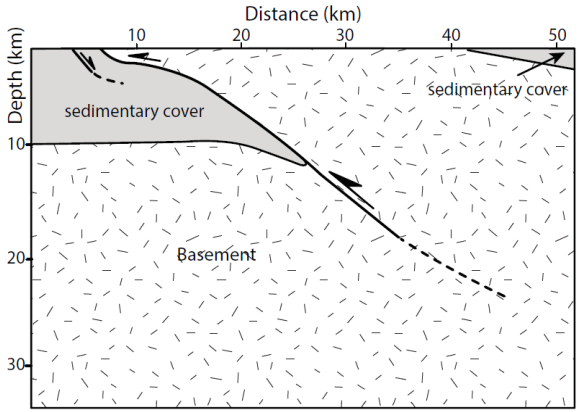
(I) Berg (1962) - Owl Creek arch

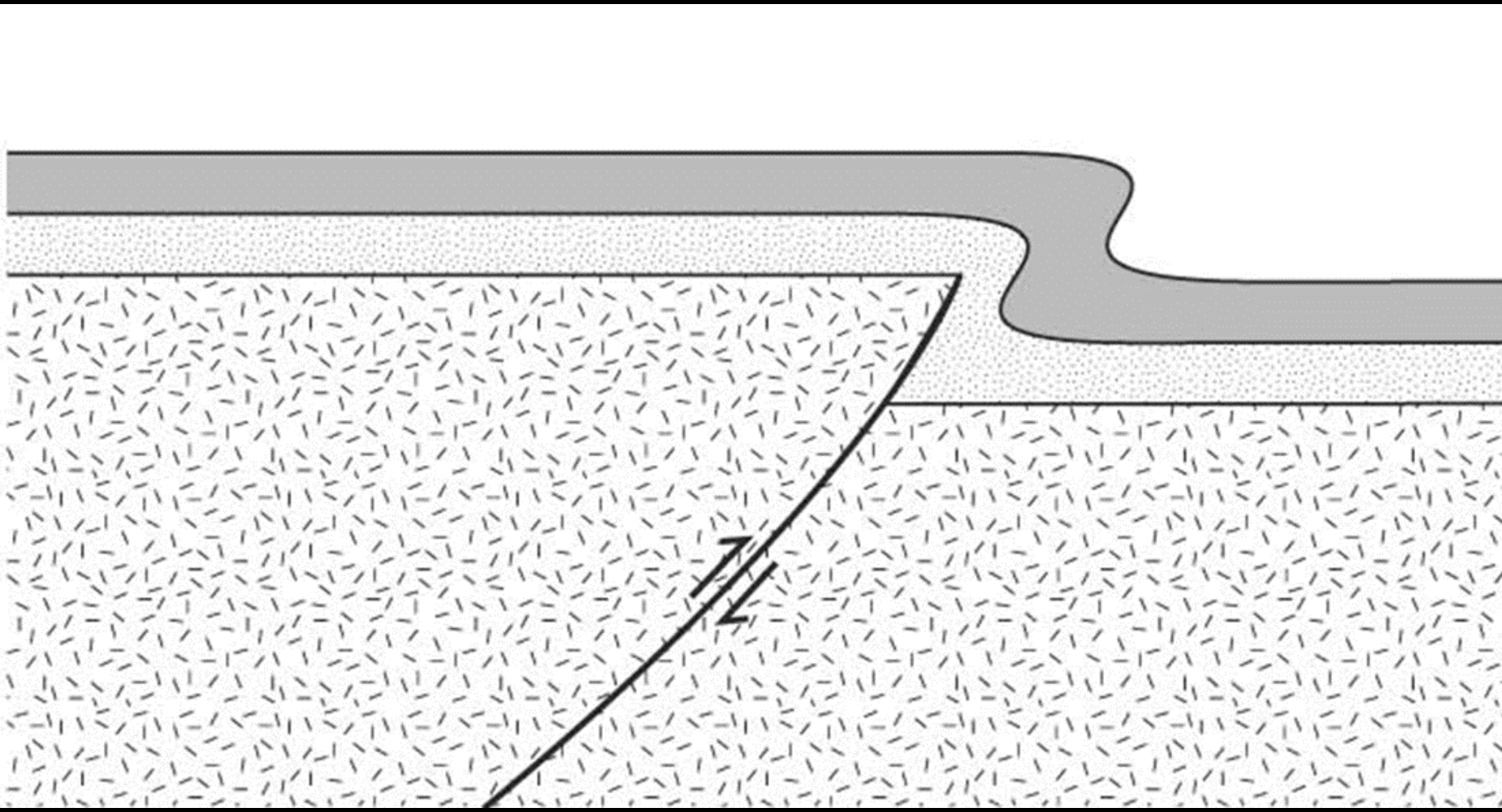


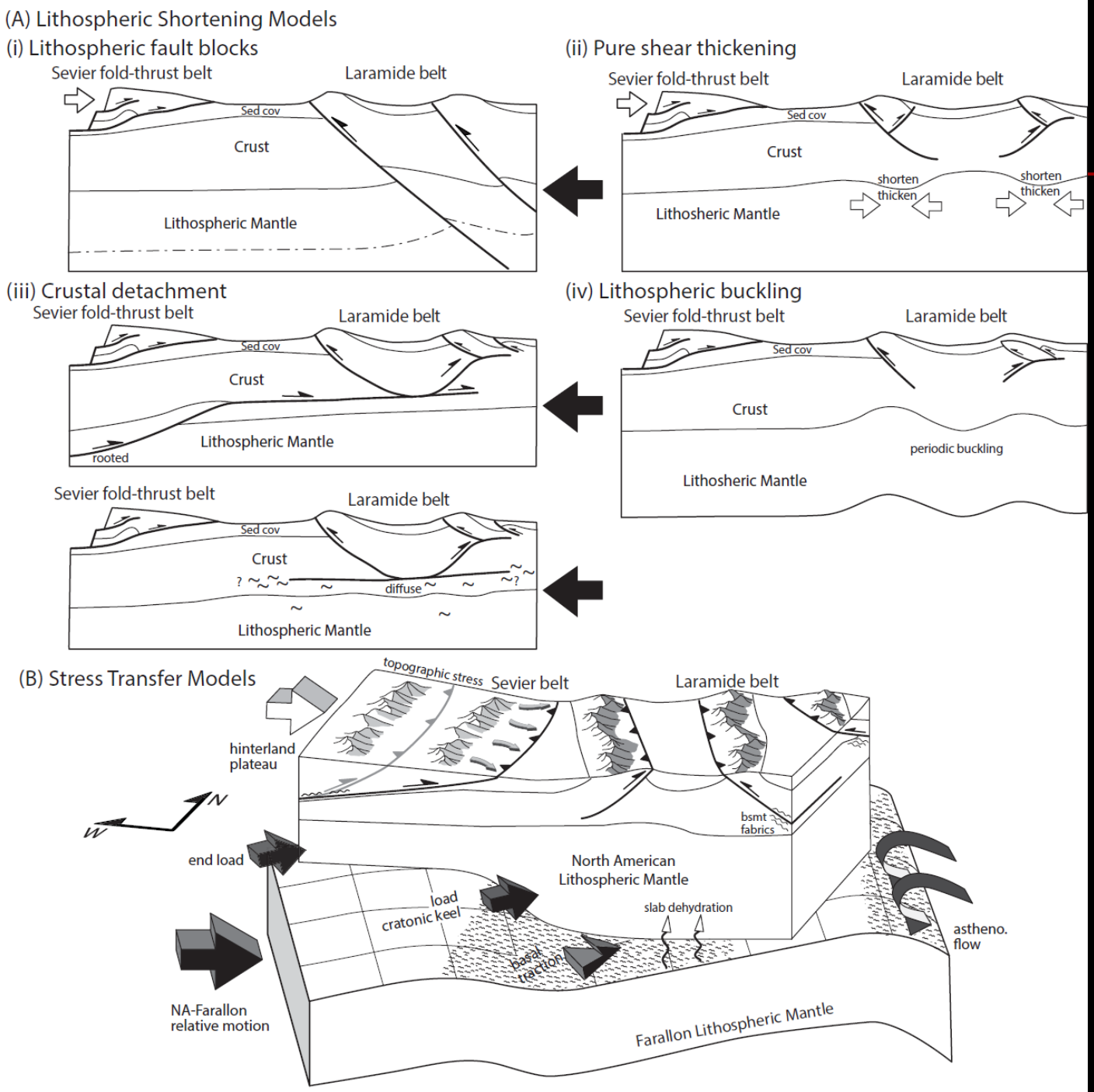
(J) Erslev (1986) - Rattlesnake Mountain



(K) Smithson et al. (1979) - Wind River Range

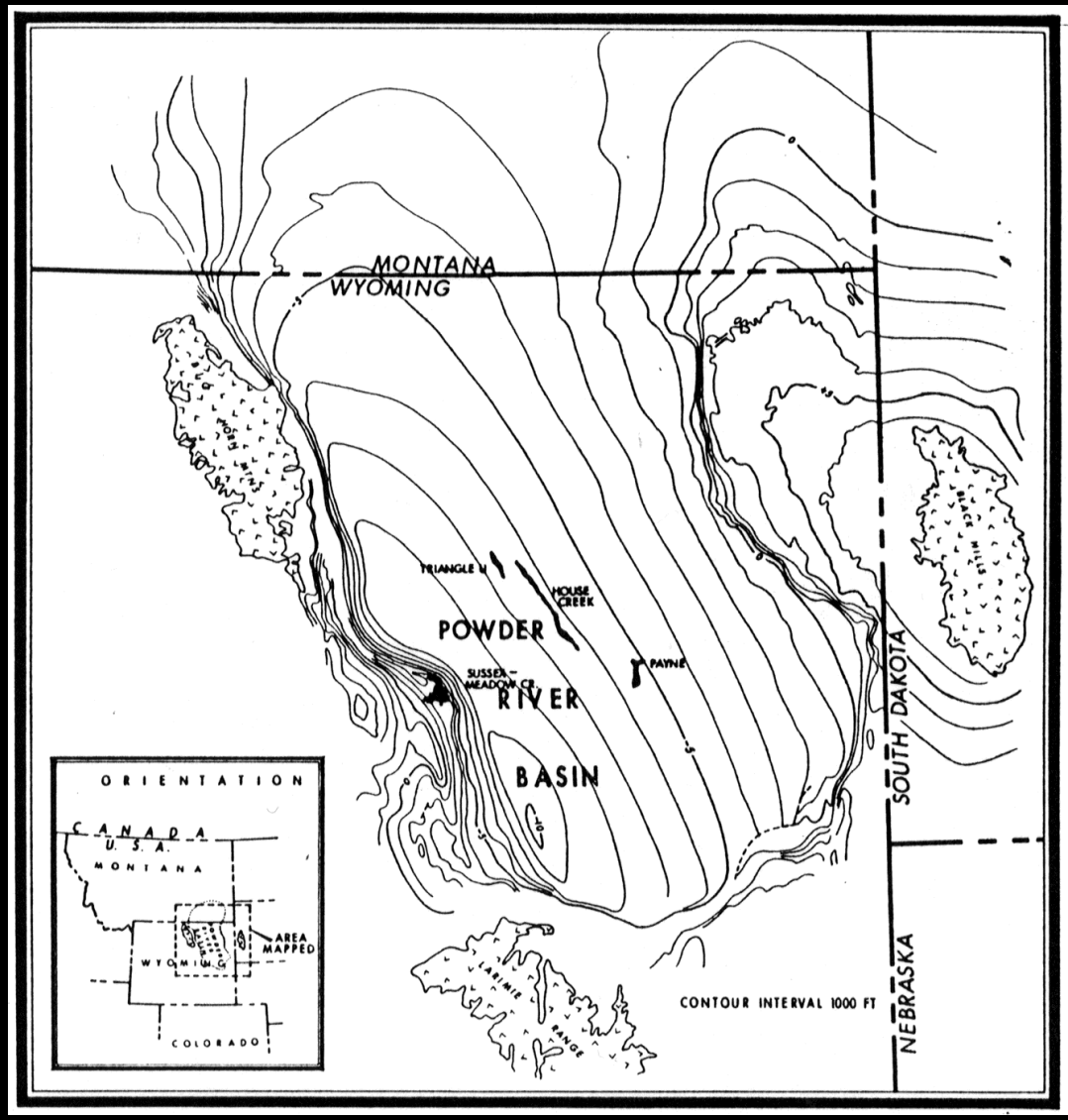





(A) Lithospheric Shortening Models
(i) Lithospheric fault blocks
Sevier fold-thrust belt
Laramide belt
Sed cov
Crust
Lithospheric Mantle
(ii) Pure shear thickening
Sevier fold-thrust belt
Laramide belt
Sed cov
Crust
shorten
thicken
shorten
thicken
Lithosheric Mantle
(iii) Crustal detachment
Sevier fold-thrust belt
Laramide belt
Sed cov
Crust
Lithospheric Mantle
rooted
Sevier fold-thrust belt
Laramide belt
Sed cov
Crust
diffuse
Lithospheric Mantle
(iv) Lithospheric buckling
Sevier fold-thrust belt
Laramide belt
Sed cov
Crust
periodic buckling
Lithosheric Mantle
(B) Stress Transfer Models
topographic stress
Sevier belt
Laramide belt
hinterland plateau
N
W
bsmt fabrics
end load
North American Lithospheric Mantle
load
cratonic keel
slab dehydration
basal traction
astheno. flow
NA-Farallon relative motion
Farallon Lithospheric Mantle

Geometry of Laramide basins

- Asymmetric
  - Basin axes close to uplift margins
  - Facies and thickness changes indicate uplifts were sediment sources



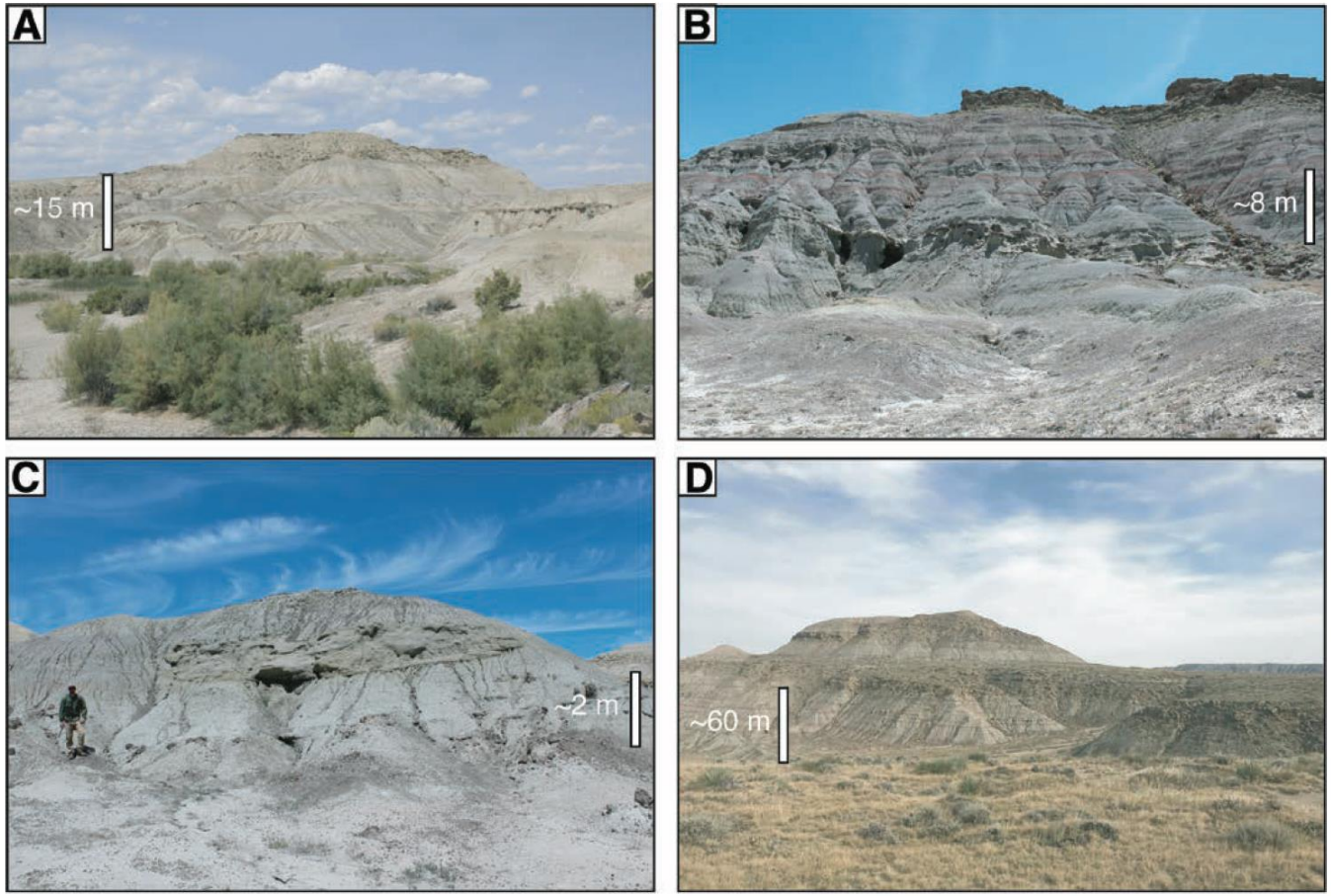
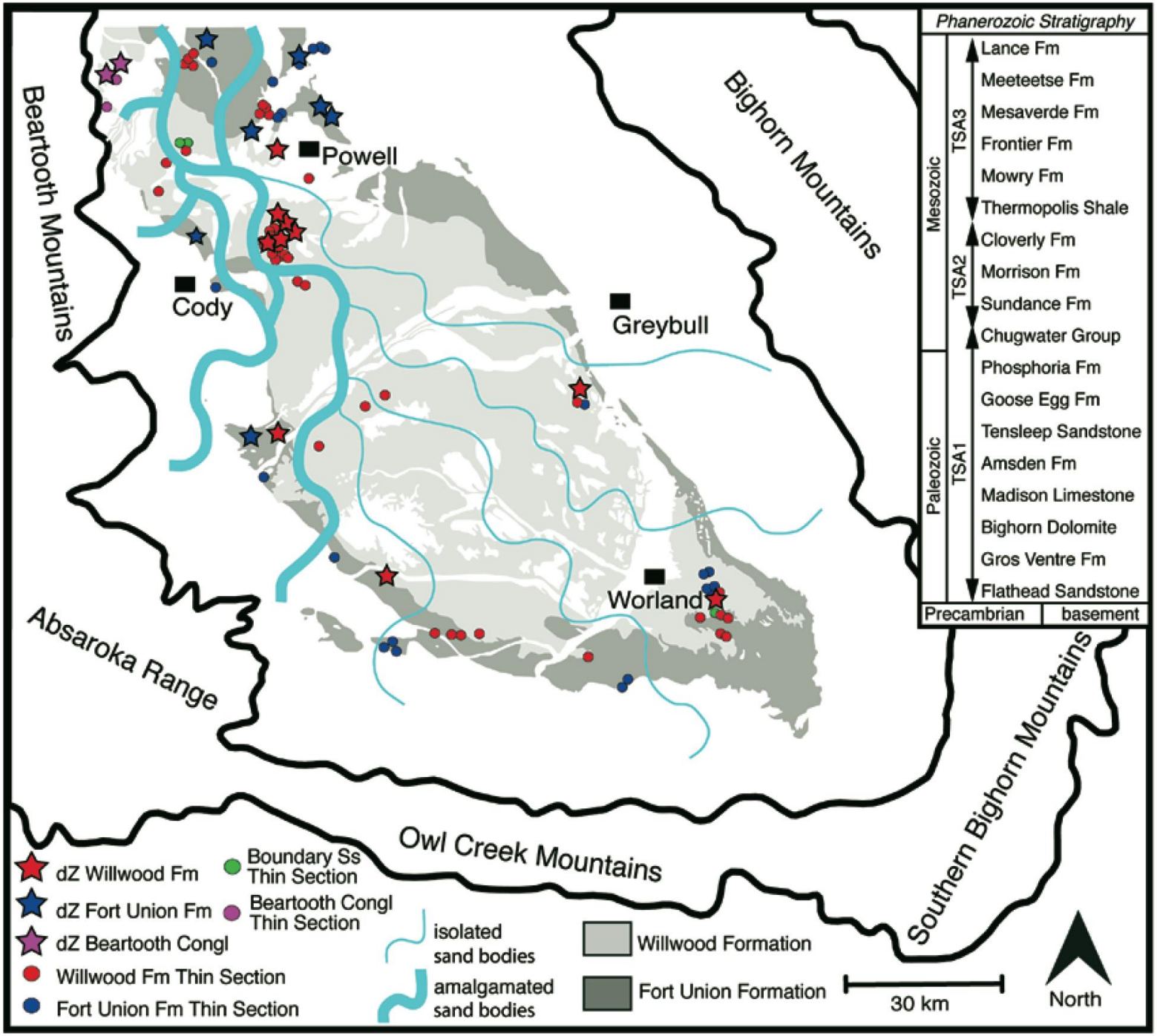
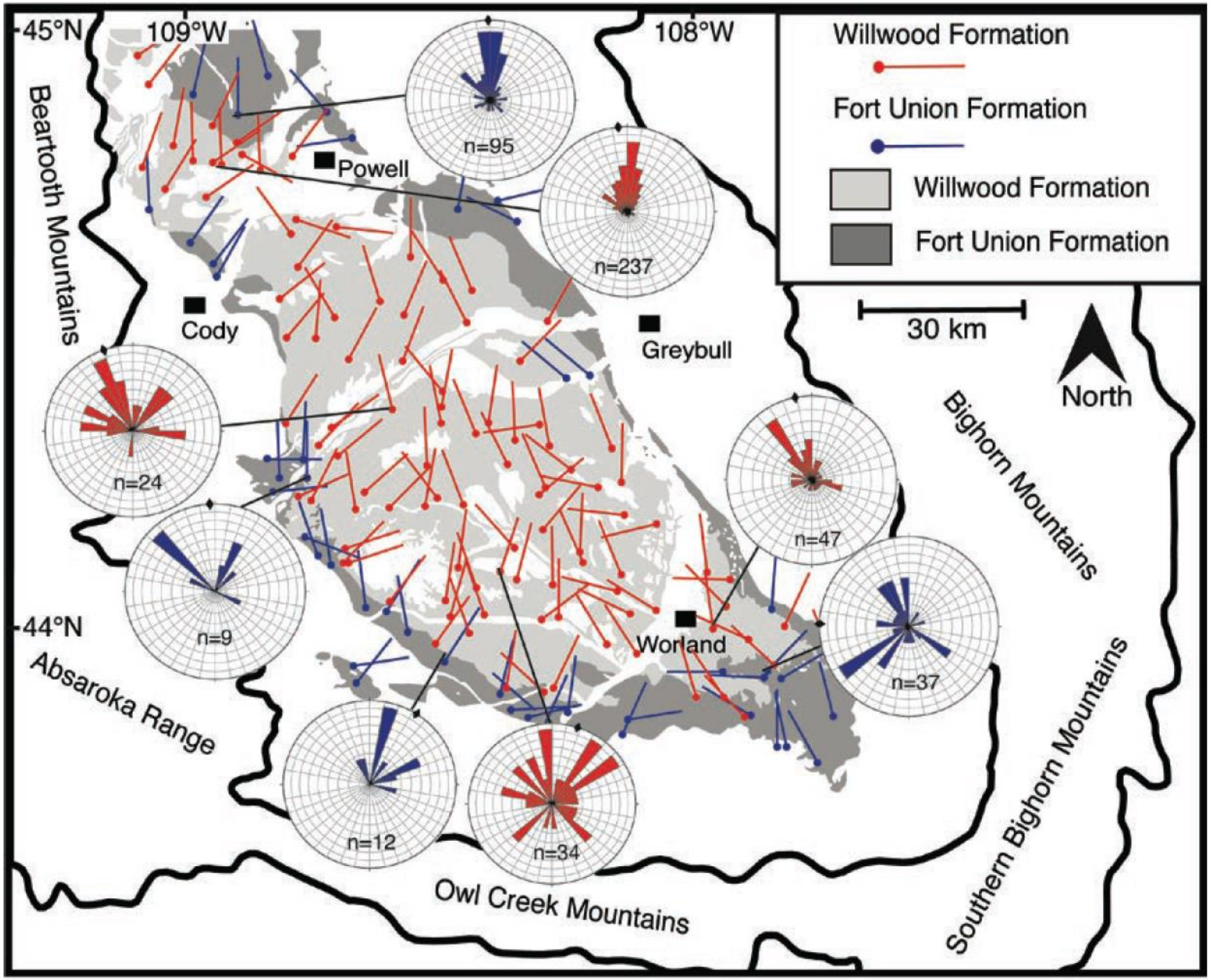
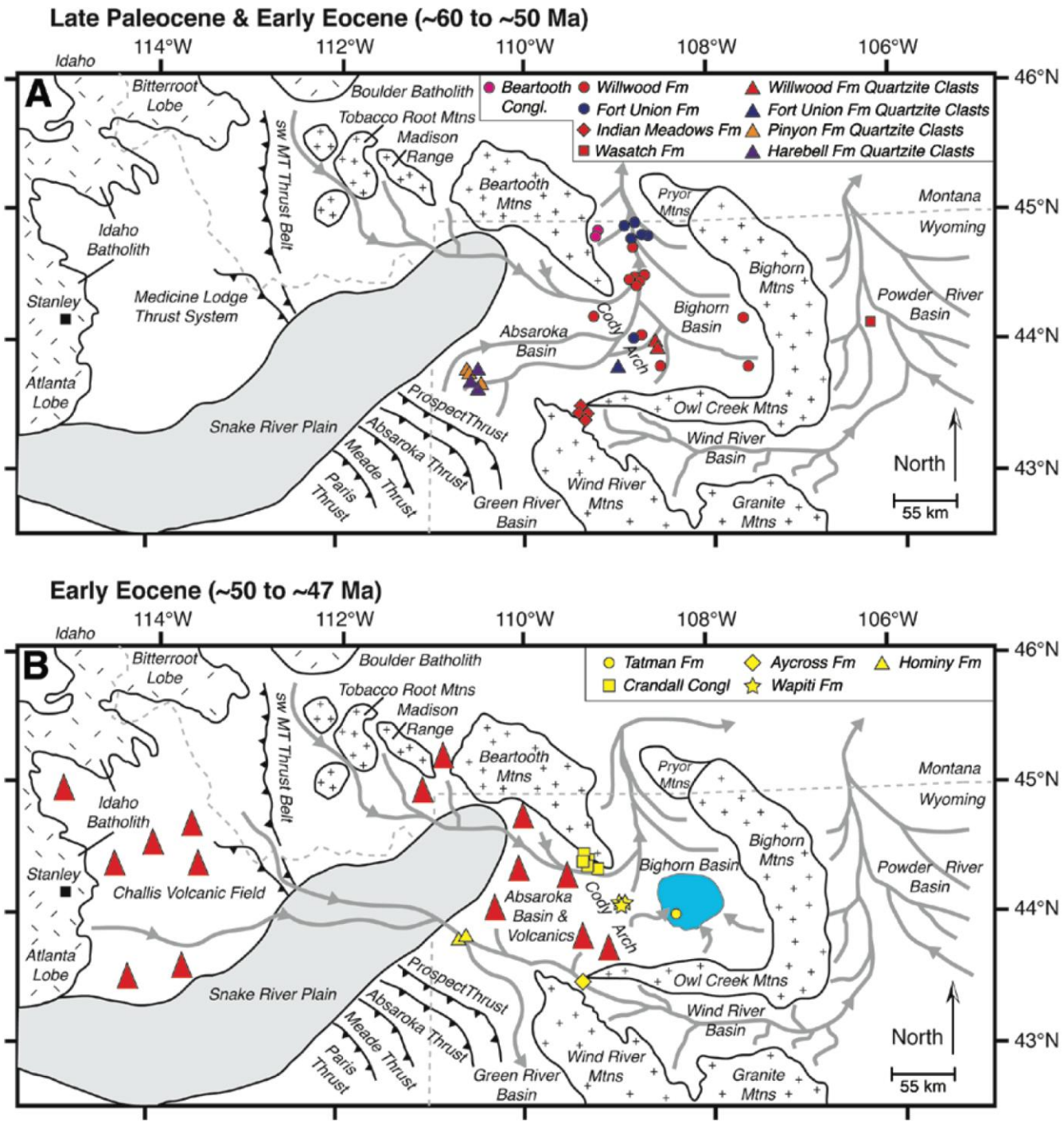
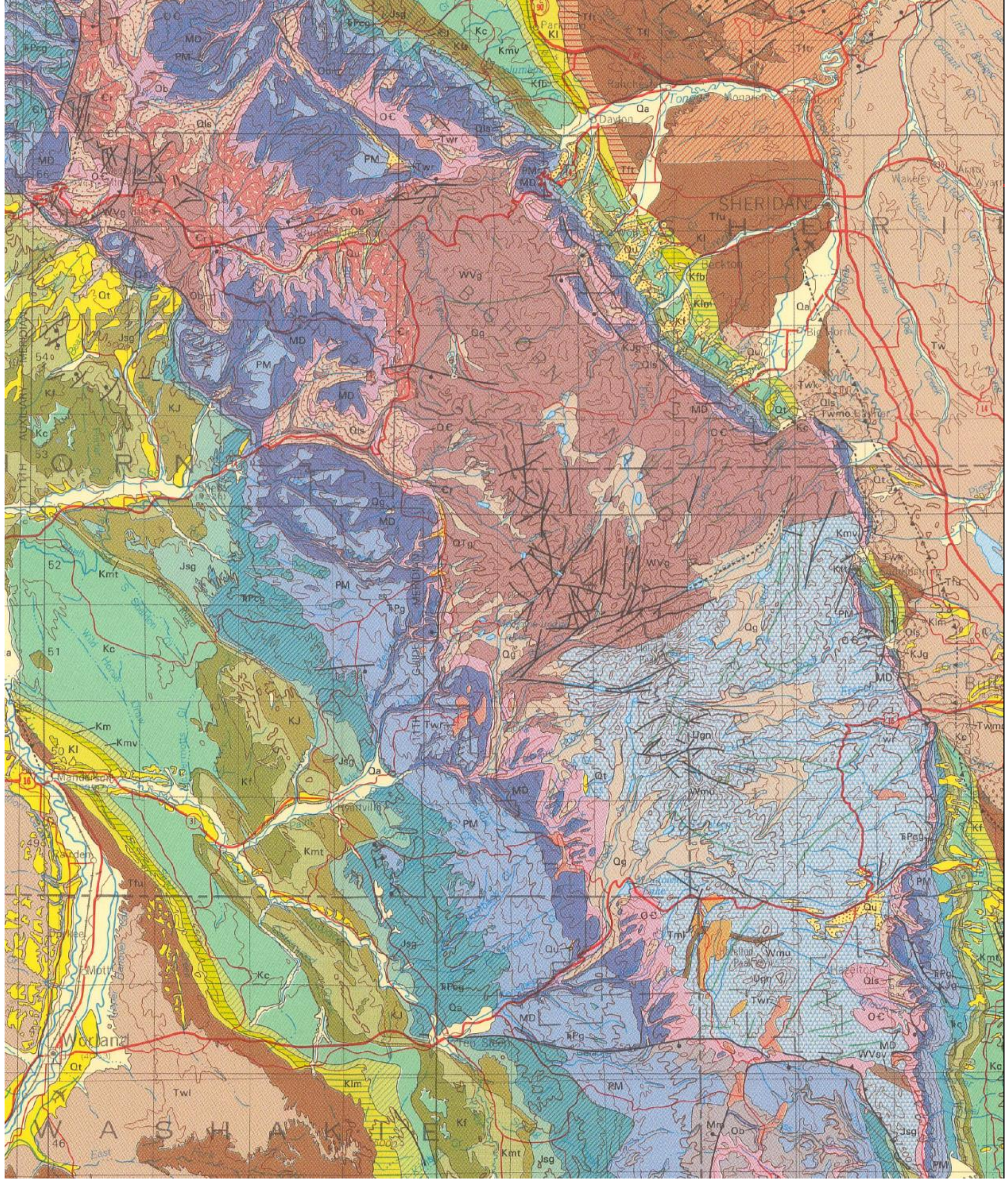


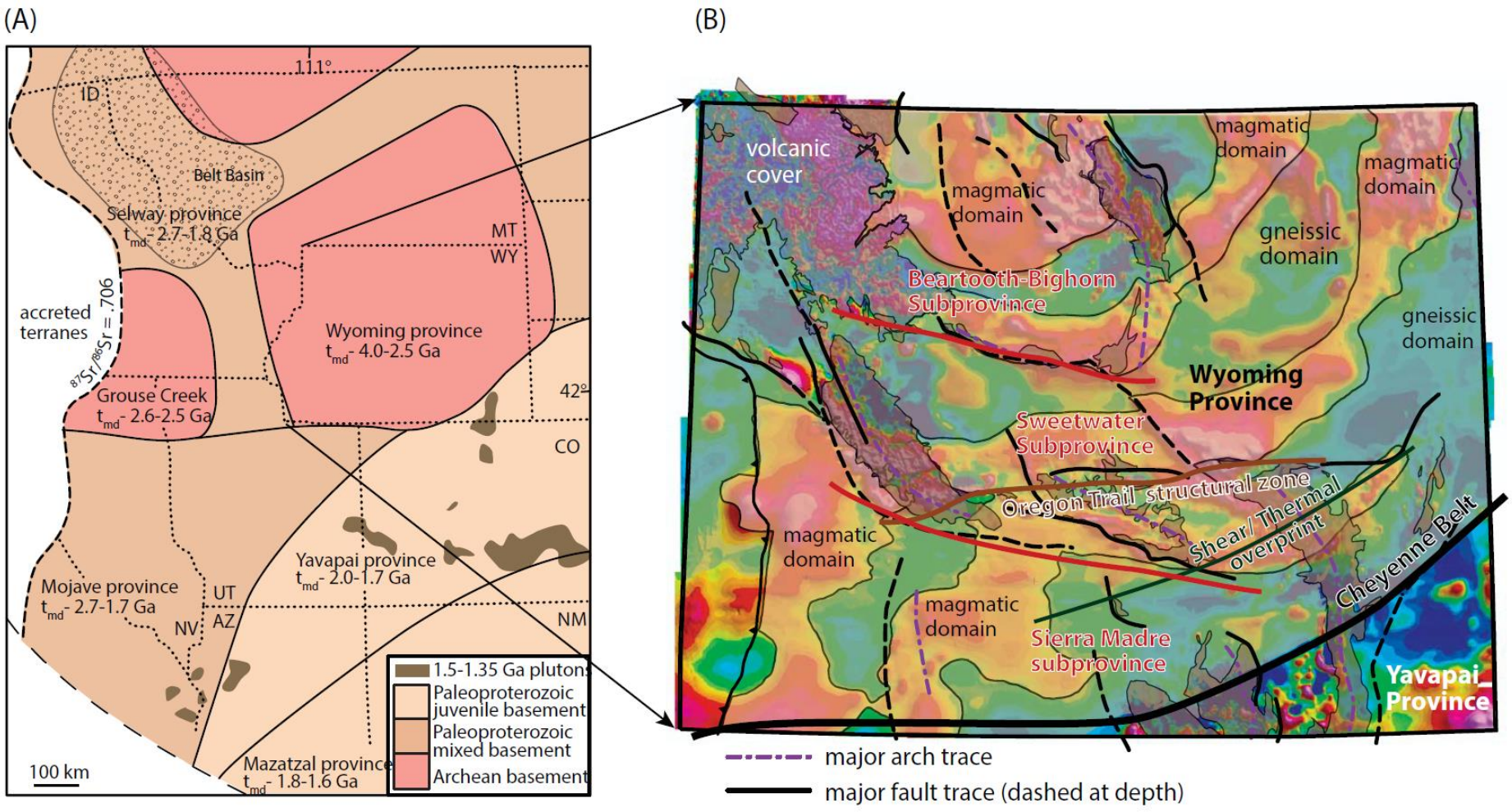
Figure 2. Representative outcrop photographs: (A) Drab overbank strata and sheet sand bodies within the Fort Union Formation, (B) red bed overbank strata and sheet sand bodies in the Willwood Formation, (C) isolated fluvial sand body, (D) sheet sand bodies associated with the Paleocene-Eocene thermal maximum in the northern Bighorn Basin, and (E) conglomeratic, amalgamated sand bodies in the Willwood Formation of the southwestern basin.


Beartooth Mountains
Bighorn Mountains
Absaroka Range
Owl Creek Mountains
Southern Bighorn Mountains
Powell
Cody
Greybull
Worland
Phanerozoic Stratigraphy
Mesozoic
Paleozoic
TSA3
TSA2
TSA1
Lance Fm
Meeteetse Fm
Mesaverde Fm
Frontier Fm
Mowry Fm
Thermopolis Shale
Cloverly Fm
Morrison Fm
Sundance Fm
Chugwater Group
Phosphoria Fm
Goose Egg Fm
Tensleep Sandstone
Amsden Fm
Madison Limestone
Bighorn Dolomite
Gros Ventre Fm
Flathead Sandstone
Precambrian
basement
dZ Willwood Fm
dZ Fort Union Fm
dZ Beartooth Congl
Willwood Fm Thin Section
Fort Union Fm Thin Section
Boundary Ss Thin Section
Beartooth Congl Thin Section
isolated sand bodies
amalgamated sand bodies
Willwood Formation
Fort Union Formation
30 km
North


45°N
109°W
108°W
Willwood Formation
Fort Union Formation
Willwood Formation
Fort Union Formation
Beartooth Mountains
Powell
n=95
n=237
Cody
Greybull
30 km
North
n=24
n=47
Bighorn Mountains
n=9
44°N
Worland
n=37
Absaroka Range
n=12
n=34
Owl Creek Mountains
Southern Bighorn Mountains


Late Paleocene & Early Eocene (~60 to ~50 Ma)
A
114°W
112°W
110°W
108°W
106°W
46°N
45°N
44°N
43°N
Idaho
Bitterroot Lobe
Boulder Batholith
Tobacco Root Mtns
Madison Range
sw MT Thrust Belt
Beartooth Mtns
Pryor Mtns
Montana
Wyoming
Idaho Batholith
Stanley
Medicine Lodge Thrust System
Bighorn Mtns
Bighorn Basin
Powder River Basin
Absaroka Basin
Cody Arch
Atlanta Lobe
Snake River Plain
Prospect Thrust
Absaroka Thrust
Meade Thrust
Paris Thrust
Green River Basin
Owl Creek Mtns
Wind River Basin
Wind River Mtns
Granite Mtns
North
55 km
Beartooth Congl.
Willwood Fm
Fort Union Fm
Indian Meadows Fm
Wasatch Fm
Willwood Fm Quartzite Clasts
Fort Union Fm Quartzite Clasts
Pinyon Fm Quartzite Clasts
Harebell Fm Quartzite Clasts
Early Eocene (~50 to ~47 Ma)
B
Tatman Fm
Crandall Congl
Aycross Fm
Wapiti Fm
Hominy Fm
Challis Volcanic Field
Absaroka Basin & Volcanics


SHERIDAN
Dayton
Worland
W A S H A K I E


(A)
(B)
111°
ID
Belt Basin
Selway province
t_{md} - 2.7-1.8 Ga
MT
WY
accreted terranes
$^{87}Sr/^{86}Sr$ = .706
Wyoming province
t_{md} - 4.0-2.5 Ga
Grouse Creek
t_{md} - 2.6-2.5 Ga
42°
CO
Yavapai province
t_{md} - 2.0-1.7 Ga
Mojave province
t_{md} - 2.7-1.7 Ga
UT
NV
AZ
NM
100 km
Mazatzal province
t_{md} - 1.8-1.6 Ga
1.5-1.35 Ga plutons
Paleoproterozoic juvenile basement
Paleoproterozoic mixed basement
Archean basement
volcanic cover
magmatic domain
magmatic domain
magmatic domain
gneissic domain
Beartooth-Bighorn Subprovince
gneissic domain
Wyoming Province
Sweetwater Subprovince
Oregon Trail structural zone
Shear/Thermal overprint
Cheyenne Belt
magmatic domain
magmatic domain
Sierra Madre subprovince
Yavapai Province
major arch trace
major fault trace (dashed at depth)

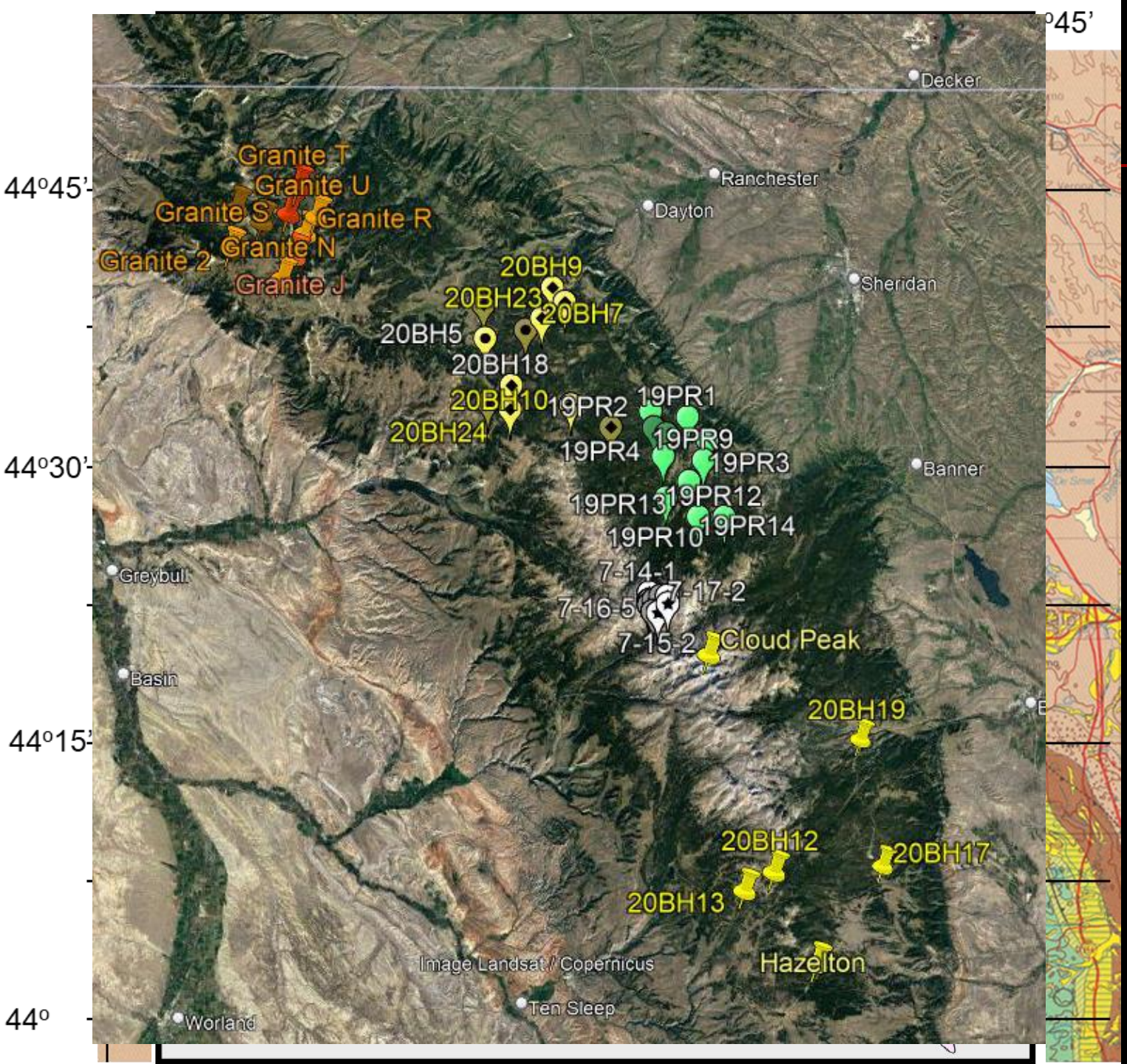

A.
B.
C.
D.
E.
F.

Who's fault is that?

Michelle Dafov is currently a geoscientist at ExxonMobil in Houston, where she is working in the carbonate reservoir performance team within ExxonMobil's Research and Technology Development organization. She completed a B.Sc. geosciences degree at the University of Arizona, Tucson, Arizona. Her current role involves implementing new research and technology that enhances our understanding of how carbonate reservoirs perform to various business units across the company which are presently working on carbonate assets.

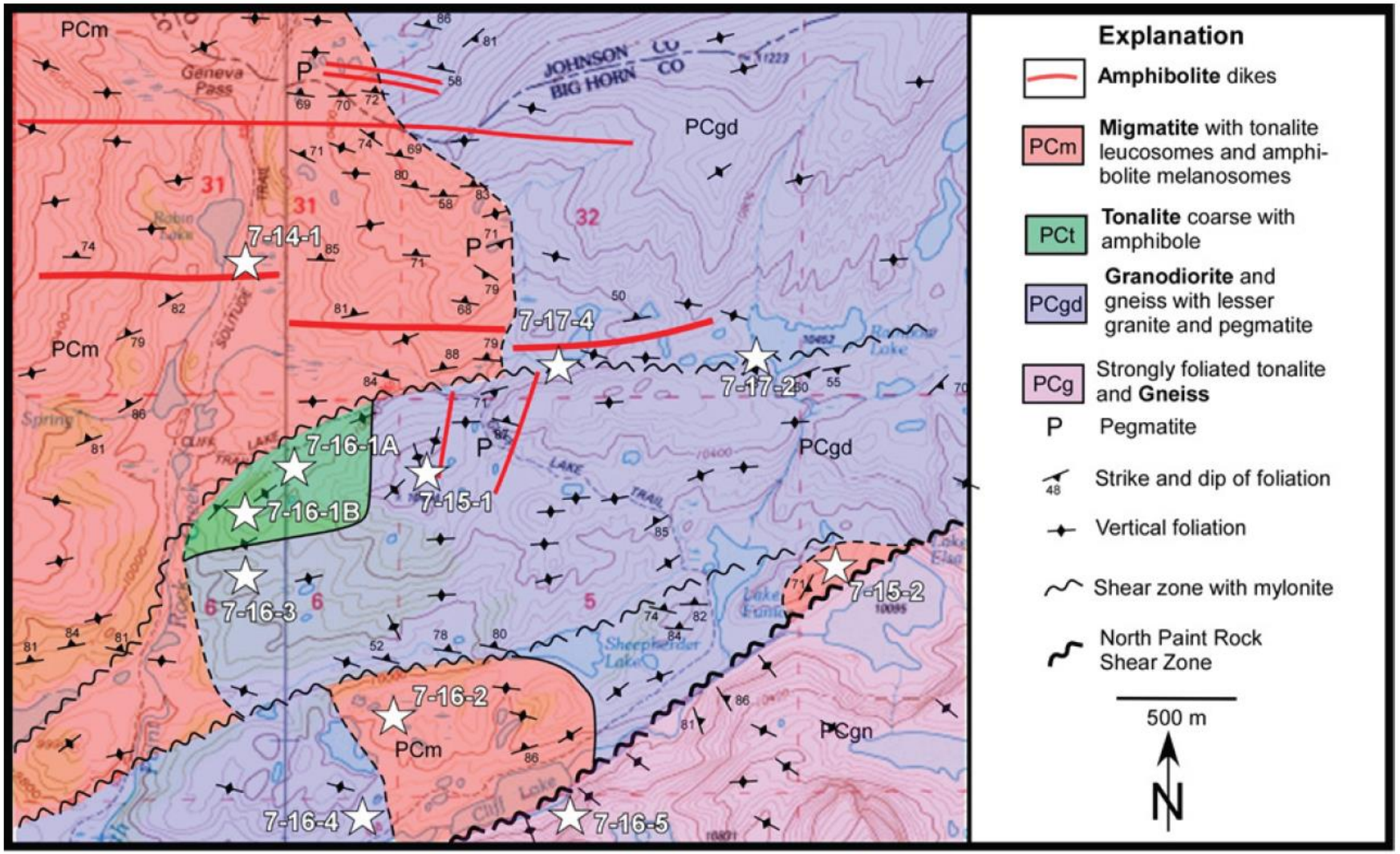
Dad, I'm looking for a project…..

John Malone is currently pursuing a Masters of Science Degree in Geology at the University of Wisconsin Milwaukee, where he is studying clastic sedimentology with Dr. John Isbell. He completed a B.A. geology degree from Augustana College, Rock Island, Illinois. His research focuses on using stratigraphic, sendimentologic, and geochronologic studies to unravel and define the extent of glaciogenic strata during the late Paleozoic ice age.

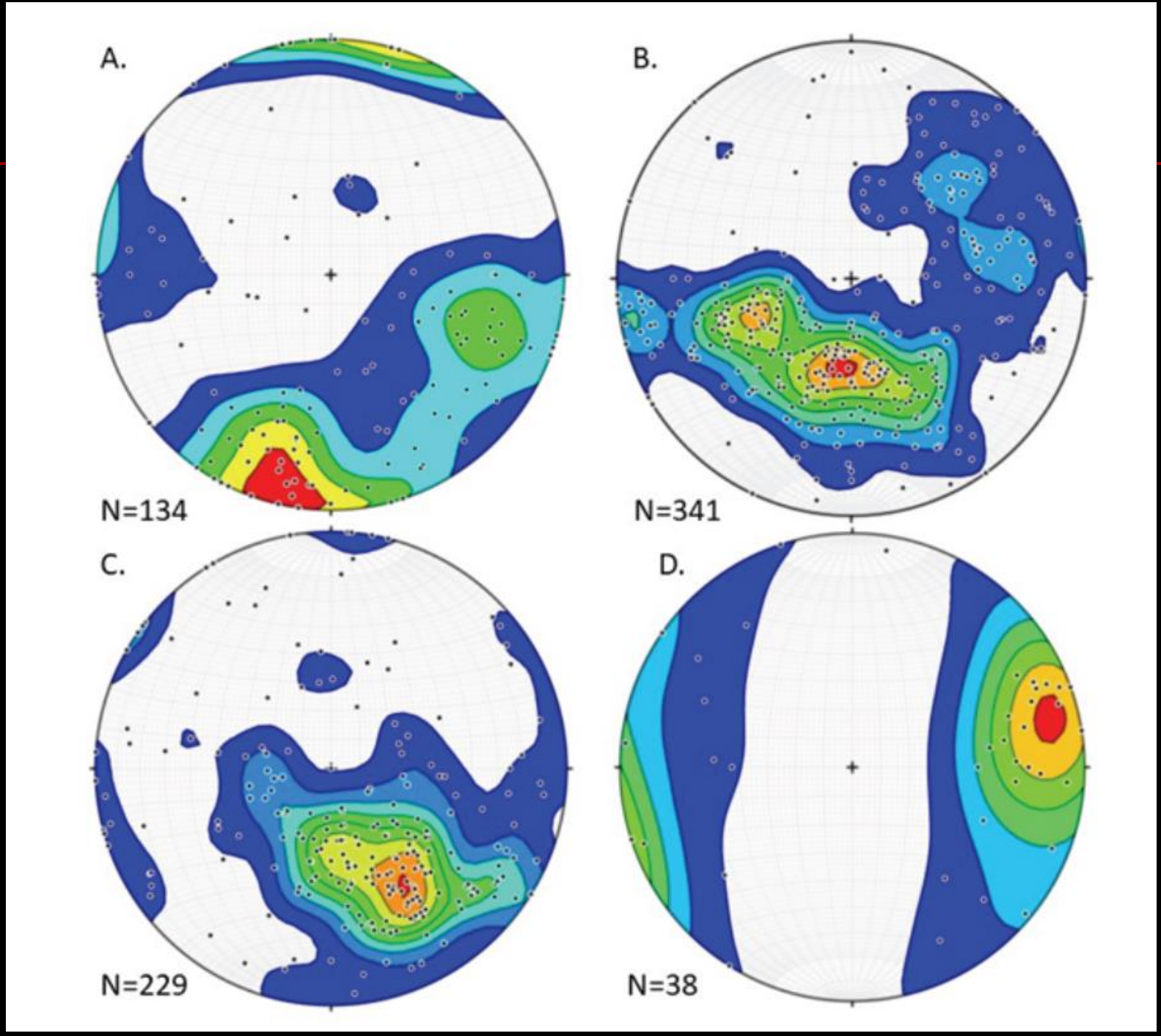

45’
Decker
Granite T
Granite U
44°45’
Granite S
Granite R
Granite N
Granite 2
Granite J
Ranchester
Dayton
Sheridan
20BH9
20BH23
20BH7
20BH5
20BH18
20BH10
19PR2
19PR1
20BH24
19PR4
19PR9
44°30’
19PR3
Banner
19PR13
19PR12
19PR14
19PR10
7-14-1
Greybull
7-17-2
7-16-5
7-15-2
Cloud Peak
Basin
20BH19
44°15’
20BH12
20BH17
20BH13
Image Landsat / Copernicus
Hazelton
Ten Sleep
44°
Worland


A.


B.

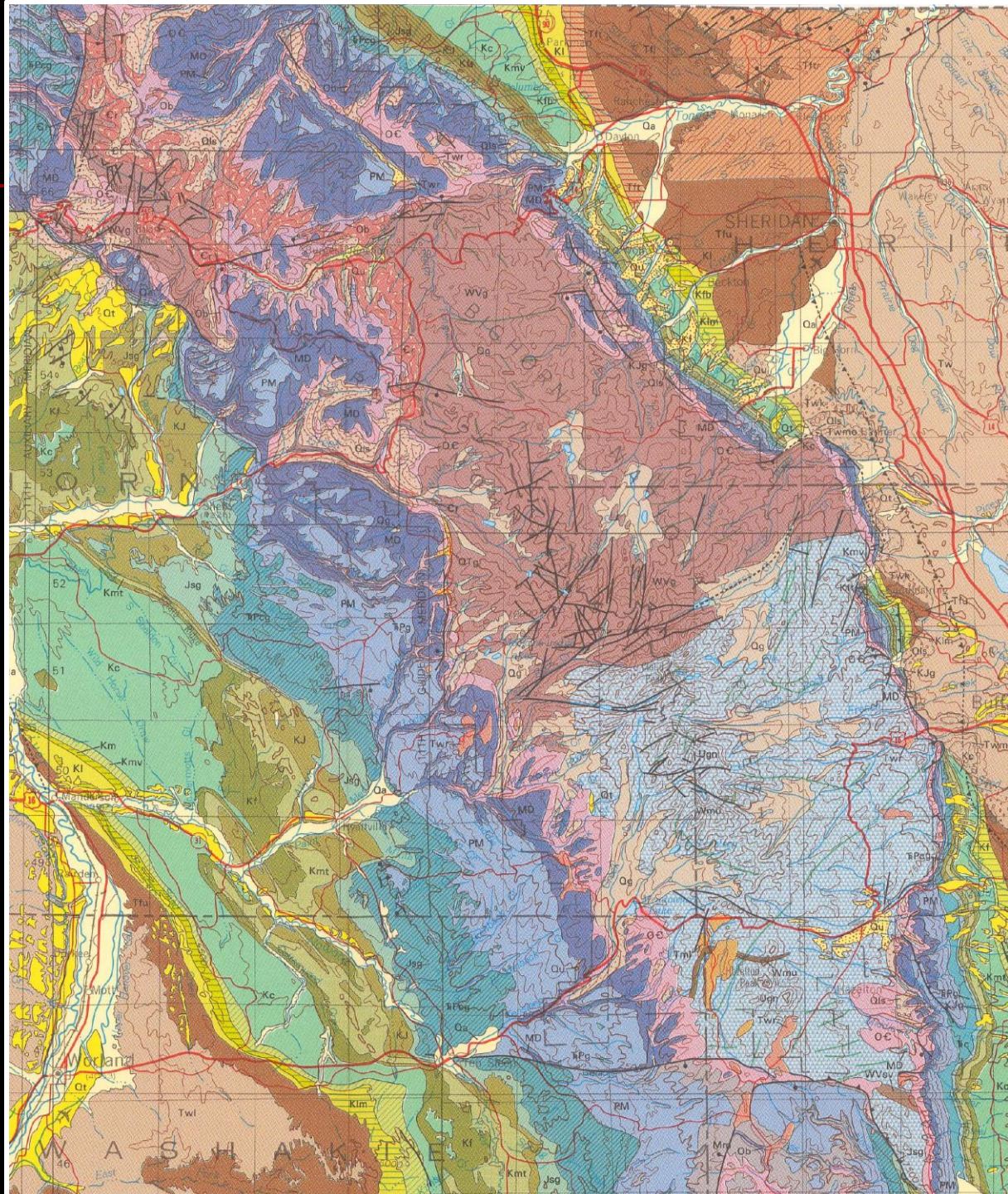

PCm
Geneva Pass
P
JOHNSON
BIG HORN
CO
PCgd
31
32
7-14-1
7-17-4
7-17-2
PCm
7-16-1A
7-16-1B
7-15-1
PCgd
7-16-3
7-15-2
7-16-2
PCm
PCgn
7-16-4
7-16-5
Explanation
Amphibolite dikes
PCm
Migmatite with tonalite leucosomes and amphibolite melanosomes
PCt
Tonalite coarse with amphibole
PCgd
Granodiorite and gneiss with lesser granite and pegmatite
PCg
Strongly foliated tonalite and Gneiss
P
Pegmatite
Strike and dip of foliation
Vertical foliation
Shear zone with mylonite
North Paint Rock Shear Zone
500 m
N

lite

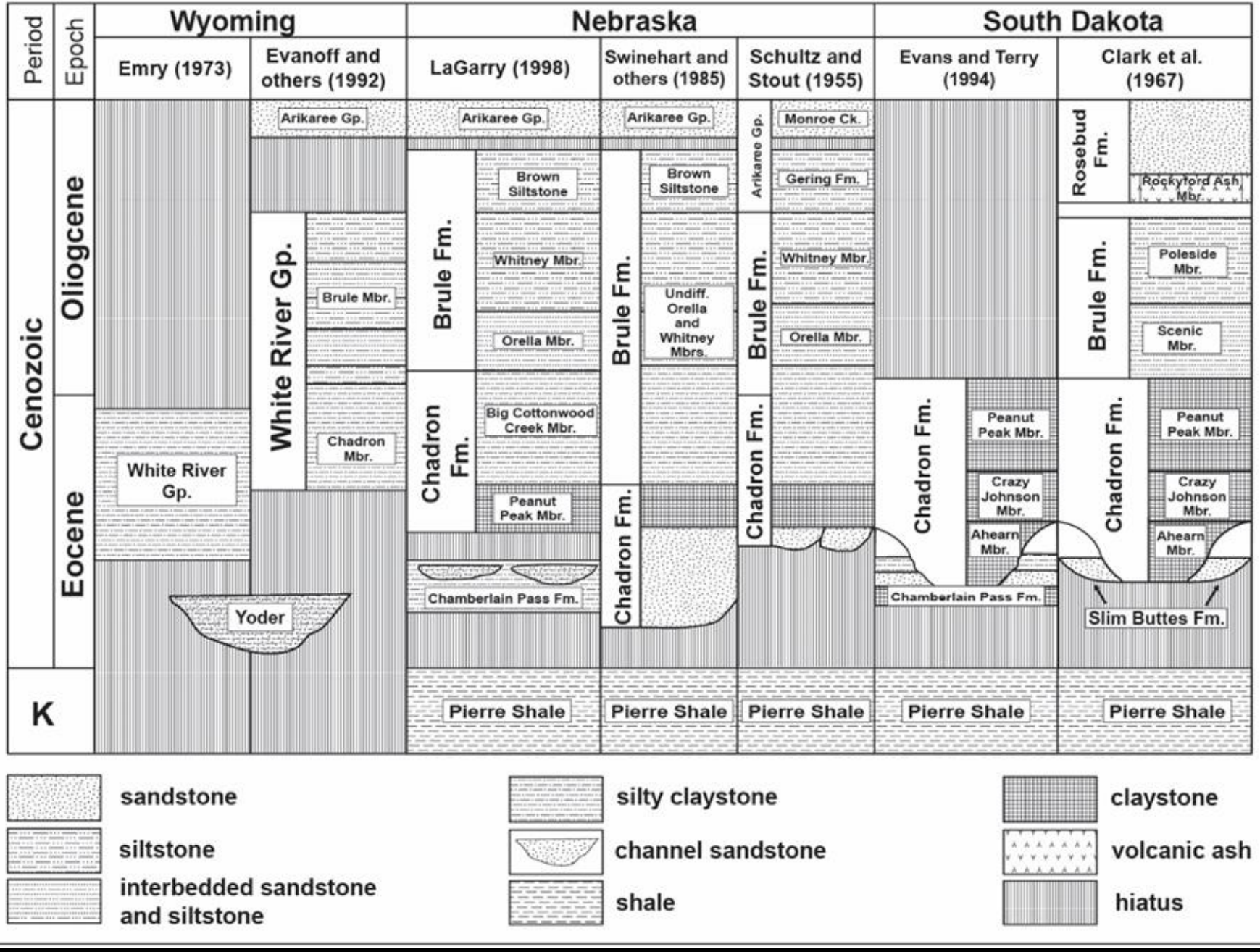

A.
N=134
B.
N=341
C.
N=229
D.
N=38

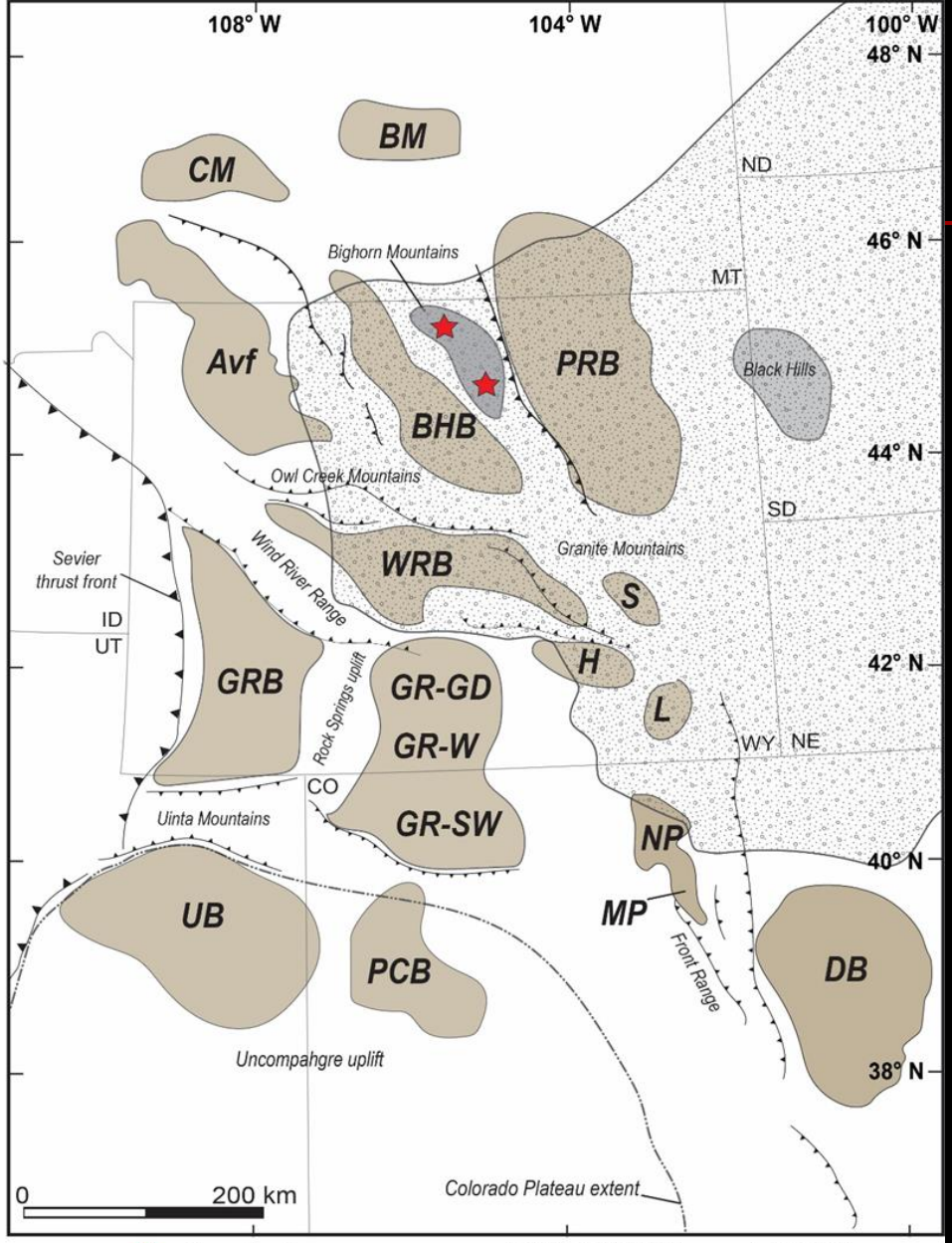
Dad, I’m looking for a project…

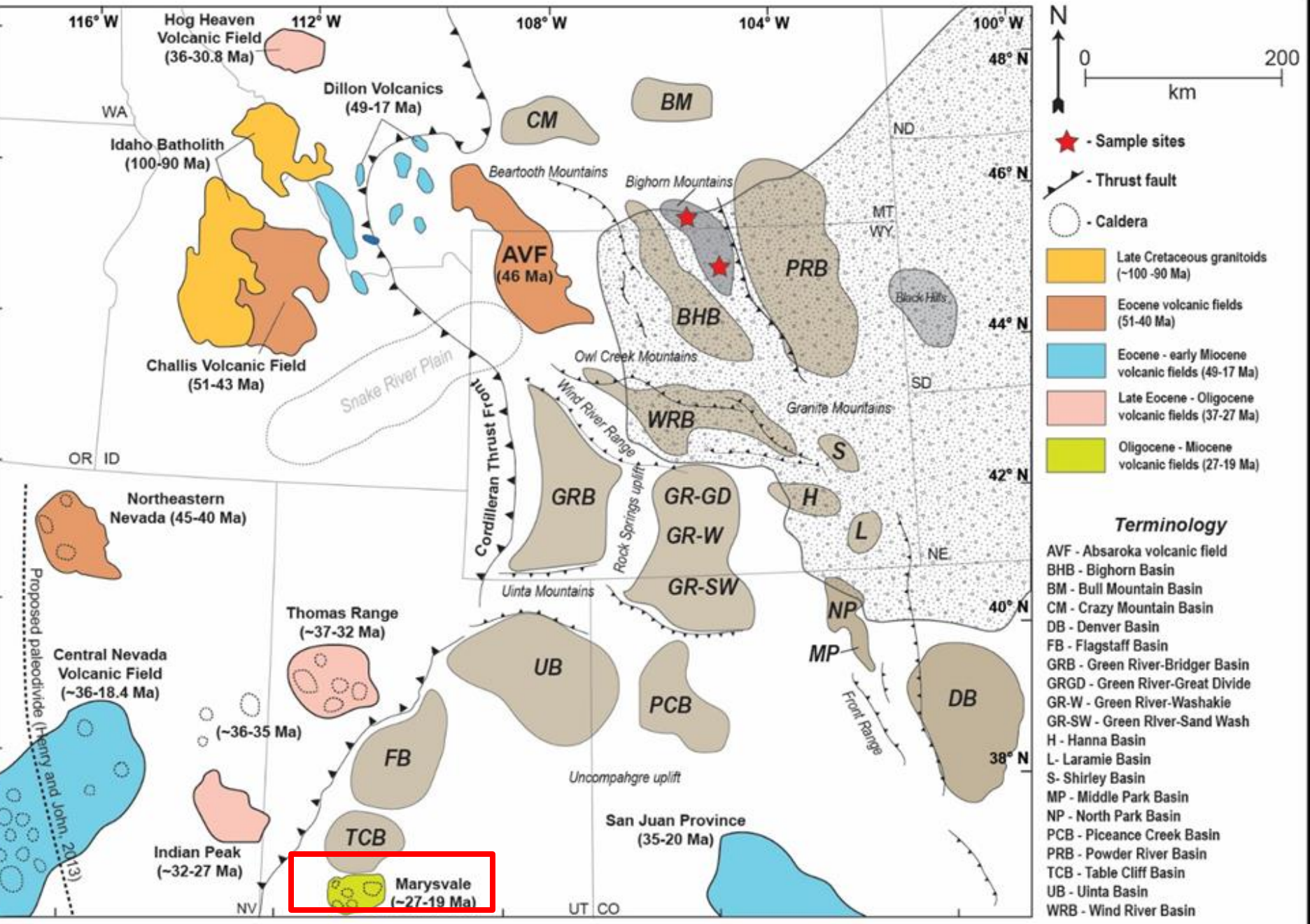
Dad, I’m looking for another project…




A
B

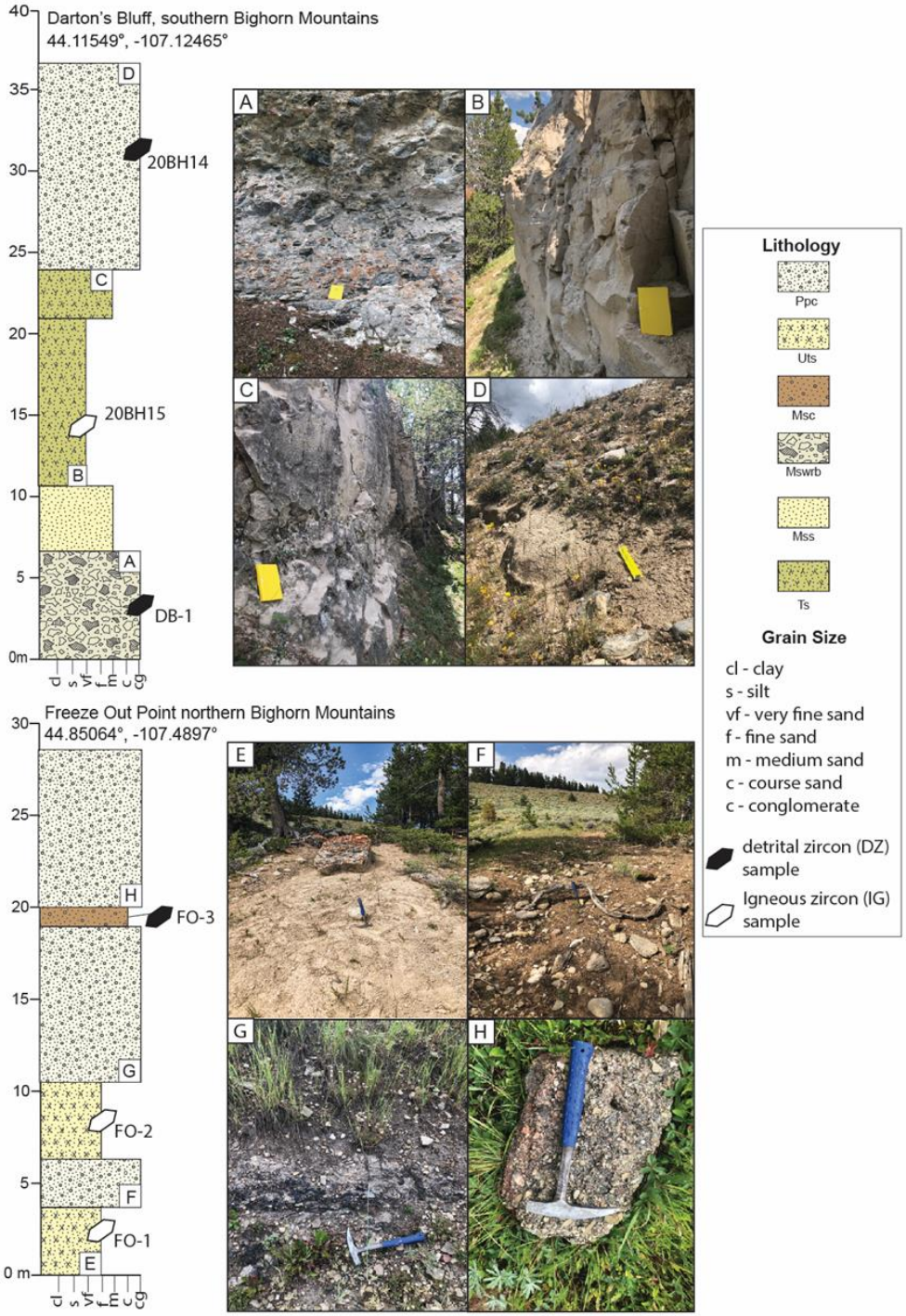

Period
Epoch
Wyoming
Nebraska
South Dakota
Emry (1973)
Evanoff and others (1992)
LaGarry (1998)
Swinehart and others (1985)
Schultz and Stout (1955)
Evans and Terry (1994)
Clark et al. (1967)
Cenozoic
Oligocene
Eocene
K
Arikaree Gp.
White River Gp.
Brule Mbr.
Chadron Mbr.
Brule Fm.
Brown Siltstone
Whitney Mbr.
Orella Mbr.
Undiff. Orella and Whitney Mbrs.
Chadron Fm.
Big Cottonwood Creek Mbr.
Peanut Peak Mbr.
Chamberlain Pass Fm.
Yoder
Pierre Shale
Monroe Ck.
Gering Fm.
Crazy Johnson Mbr.
Ahearn Mbr.
Rosebud Fm.
Rockyford Ash Mbr.
Poleside Mbr.
Scenic Mbr.
Slim Buttes Fm.
sandstone
siltstone
interbedded sandstone and siltstone
silty claystone
channel sandstone
shale
claystone
volcanic ash
hiatus


108° W
104° W
100° W
48° N
46° N
44° N
42° N
40° N
38° N
ND
MT
SD
WY
NE
CO
ID
UT
BM
CM
Avf
BHB
PRB
WRB
S
H
L
GRB
GR-GD
GR-W
GR-SW
NP
MP
UB
PCB
DB
Bighorn Mountains
Black Hills
Owl Creek Mountains
Granite Mountains
Wind River Range
Sevier thrust front
Rock Springs uplift
Uinta Mountains
Front Range
Uncompahgre uplift
Colorado Plateau extent
0
200 km
- Sample sites
- Thrust fault
Extent of the White River Group deposition (Larson and Evanoff, 1998)
Avf - Absaroka volcanic field
BHB - Bighorn Basin
BM - Bull Mountain Basin
CM - Crazy Mountains
DB - Denver Basin
GRB - Green River-Bridger Basin
GRGD - Green River-Great Divide
GR-W - Green RIver-Washakie
GR-SW - Green RIver-Sand Wash
H - Hanna Basin
L- Laramie Basin
S- Shirley Basin
MP - Middle Park Basin
NP - North Park Basin
PCB - Piceance Creek Basin
PRB - Powder River Basin
UB - Uinta Basin
WRB - Wind River Basin

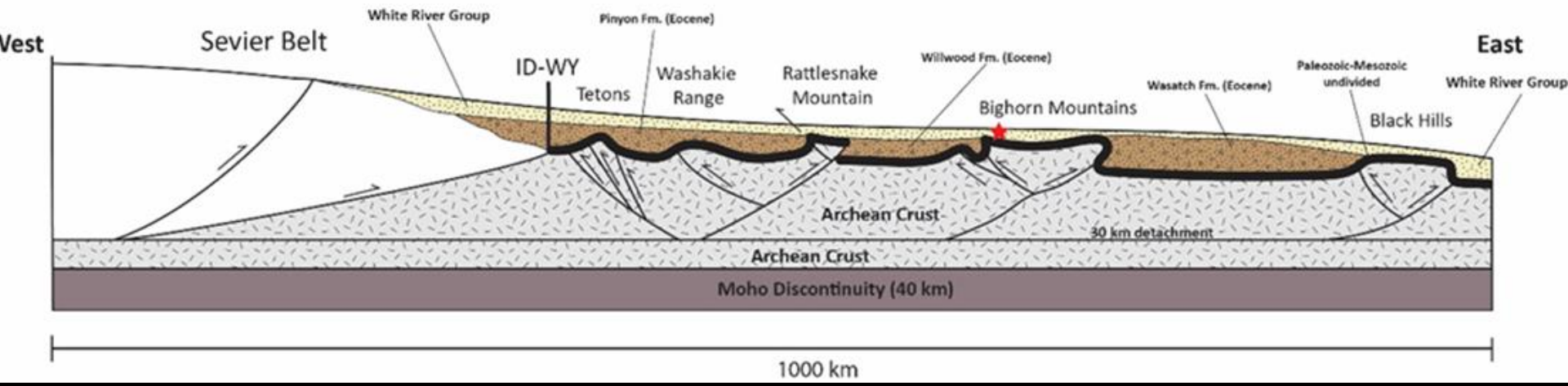


Terminology

AVF - Absaroka volcanic field
BHB - Bighorn Basin
BM - Bull Mountain Basin
CM - Crazy Mountain Basin
DB - Denver Basin
FB - Flagstaff Basin
GRB - Green River-Bridger Basin
GRGD - Green River-Great Divide
GR-W - Green River-Washakie
GR-SW - Green River-Sand Wash
H - Hanna Basin
L- Laramie Basin
S- Shirley Basin
MP - Middle Park Basin
NP - North Park Basin
PCB - Piceance Creek Basin
PRB - Powder River Basin
TCB - Table Cliff Basin
UB - Uinta Basin
WRB - Wind River Basin


Darton's Bluff, southern Bighorn Mountains
44.11549°, -107.12465°
40
35
30
25
20
15
10
5
0m
D
C
B
A
20BH14
20BH15
DB-1
cl s vf f m c cg
A
B
C
D
Freeze Out Point northern Bighorn Mountains
44.85064°, -107.4897°
30
25
20
15
10
5
0 m
H
G
F
E
FO-3
FO-2
FO-1
cl s vf f m c cg
E
F
G
H
Lithology
Ppc
Uts
Msc
Mswrb
Mss
Ts
Grain Size
cl - clay
s - silt
vf - very fine sand
f - fine sand
m - medium sand
c - course sand
c - conglomerate
detrital zircon (DZ) sample
Igneous zircon (IG) sample

Oligocene


Vest
Sevier Belt
White River Group
Pinyon Fm. (Eocene)
ID-WY
Tetons
Washakie Range
Rattlesnake Mountain
Willwood Fm. (Eocene)
Bighorn Mountains
Wasatch Fm. (Eocene)
Paleozoic-Mesozoic undivided
Black Hills
East
White River Group
Archean Crust
30 km detachment
Archean Crust
Moho Discontinuity (40 km)
1000 km