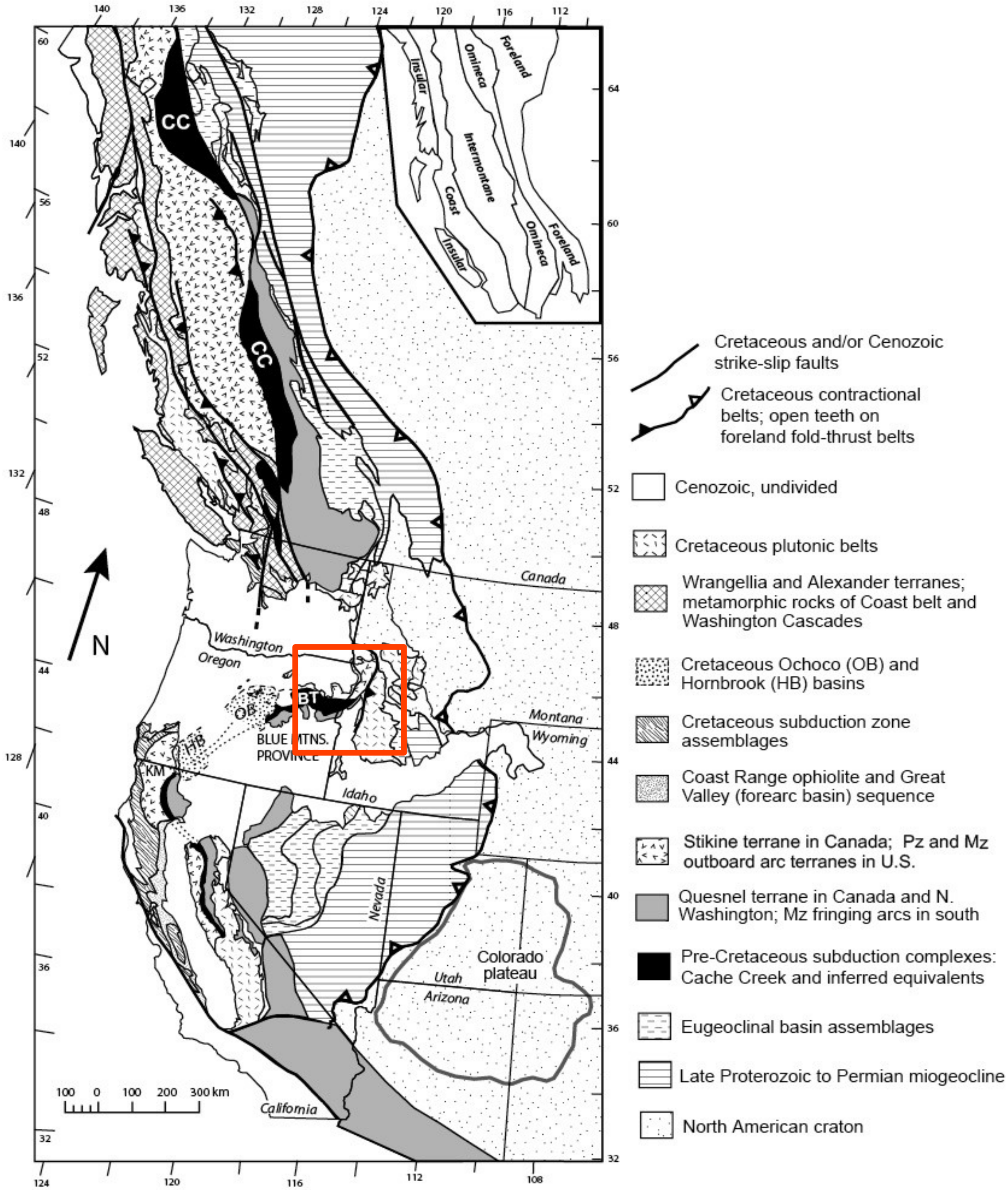
The Blue Mountains:

The Ochocos

The Wallowas

(The Strawberries)

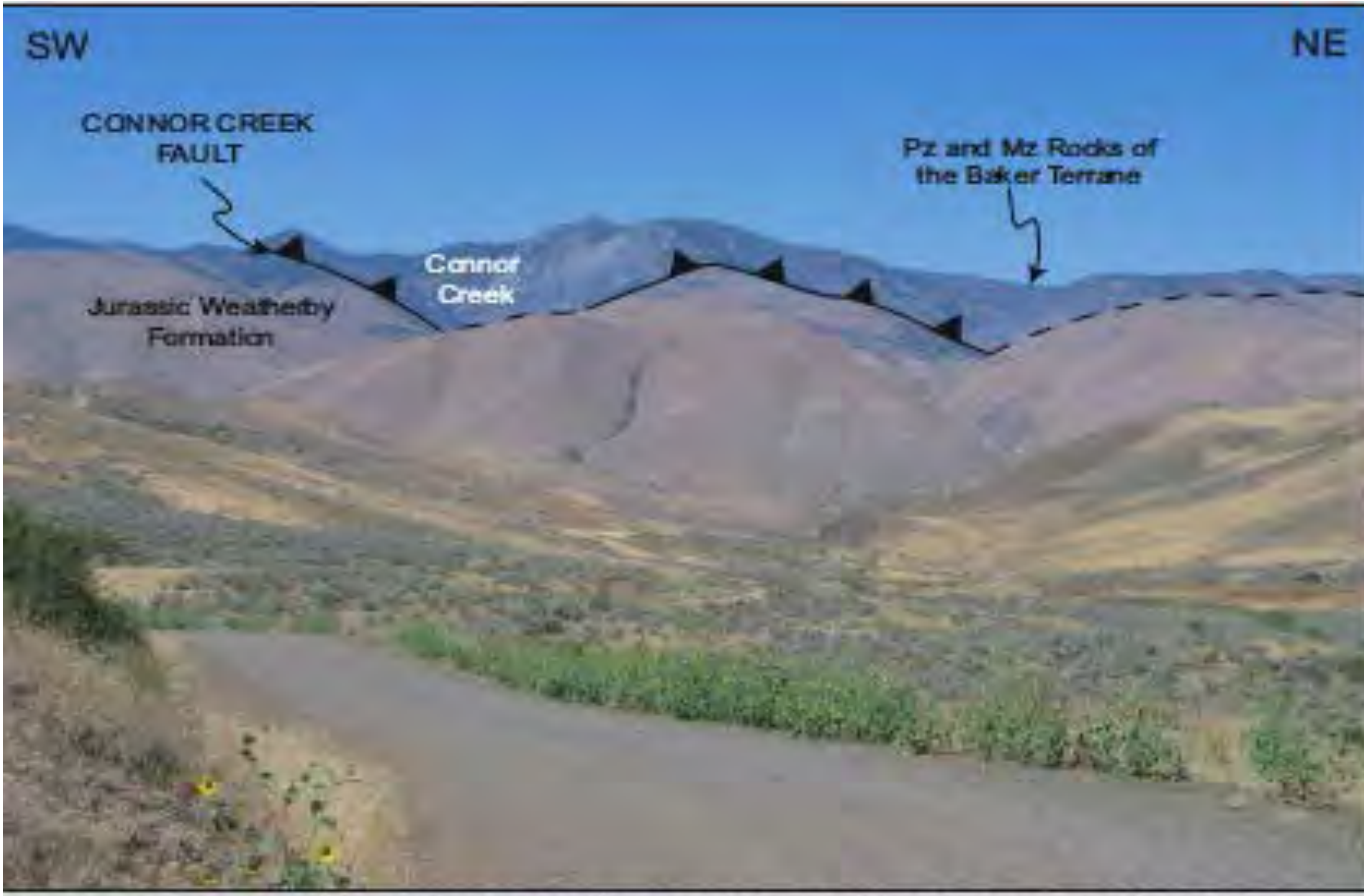
. . .



Dorsey & LaMaskin 2007

The Wallowa Mountains: Four Plutons 123-140 Ma
4
48

Hell's Canyon: Columbia River Basalt Group unconformably above Mesozoic.



View looking northwest from Washington County, Idaho into Oregon across the Snake River (hidden in foreground). Paleozoic and Mesozoic argillaceous melange, sperpentenites and mafic ophiolitic rocks overlie the Jurassic Wealtherby Formation, forearc basin volcaniclastic turbidite deposits, along the steeply northwest-dipping Connor Creek Fault.


Seven Devils Mountains, ID

Canyon Mountain Complex, south of John Day, OR
Alternating peridotite (red) and gabbro layers

13

Martin Bridge L.S.

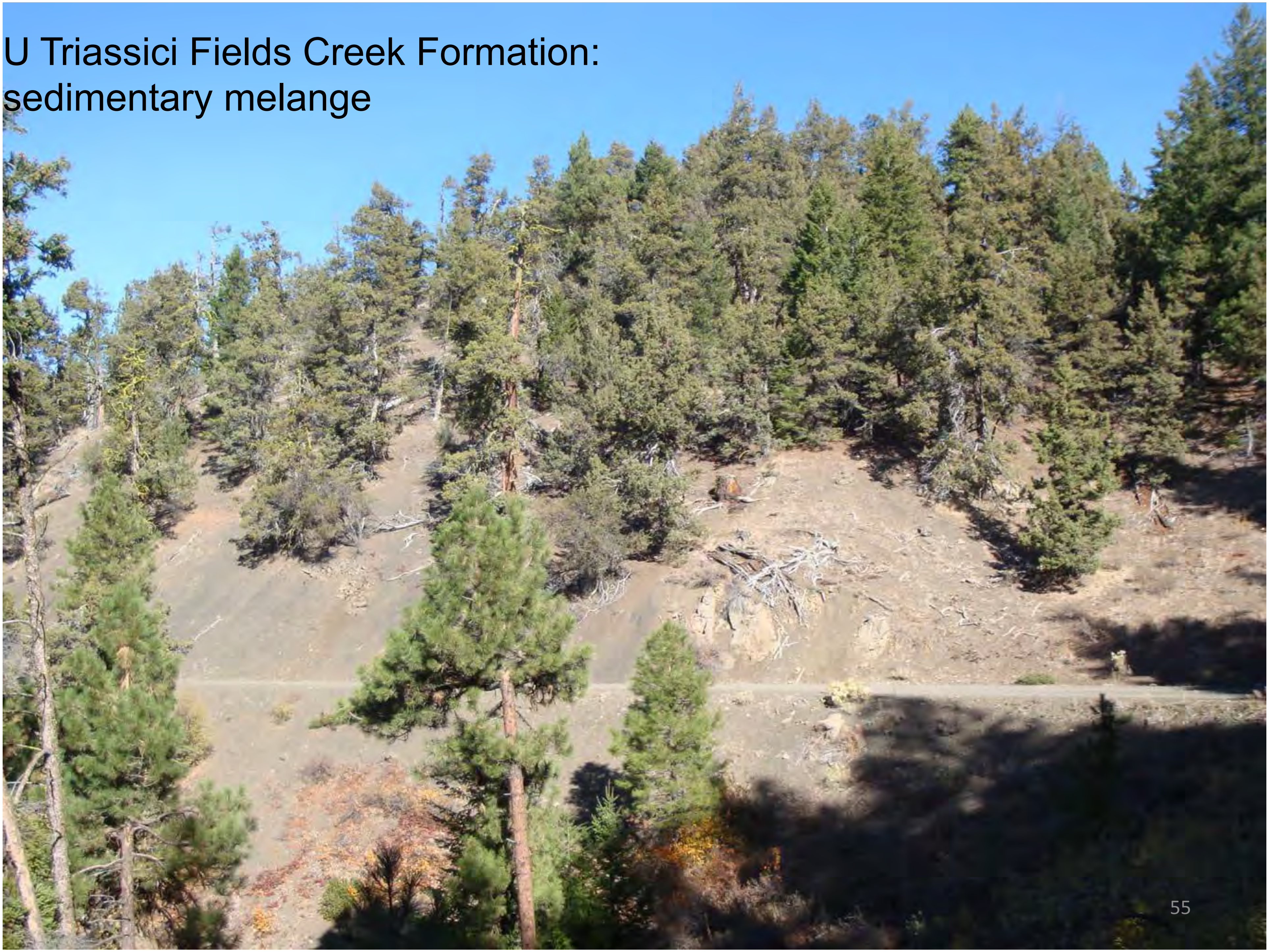
Widespread regional unit: shallow platform carbonate w/ diverse fauna (corals, sponges, crinoids) and sedimentary structures.

Records end of Mid Triassic arc volcanism … end of subduction due to collision of accretionary prisms.

11

Cement Plant near Huntington, OR
Martin Bridge Limestone was feedstock until plant closed due to mercury emissions.

U Triassici Fields Creek Formation: sedimentary melange



U Triassici Fields Creek Formation:
sedimentary melange

Vester (Carnian) and Fields Creek (Norian) Fms

Bedded turbidites, argillite, cgl, slumps, & breccias w/ large olistostromes (submarine slide blocks) ... clasts include chert, serpentine, and plutonic rocks from adjacent Baker terrane.

Unstable steep margin of tectonically active marine basin

Dickinson and Thayer (1978)

U Triassic Vester Formation: sedimentary melange

Hurwal Fm
Late Triassic - Early Jurassic

Fine-gr. turbidites & argillite, deep marine basin, partially equivalent to Martin Bridge L.S.

Excelsior Gulch Conglomerate: clasts include limestone, chert, volcanics, plutonic rx … eroded from Baker terrane T.B.
(Follo, 1986; 1992; 1994)

εNd +4 to +2, some mixing with continental clay.


Lower Jurassic Suplee Formation: marine clastic rocks
with submarine volcanic flows

M Jurassic Snowshoe Formation

146 Ma Dixie Creek Pluton

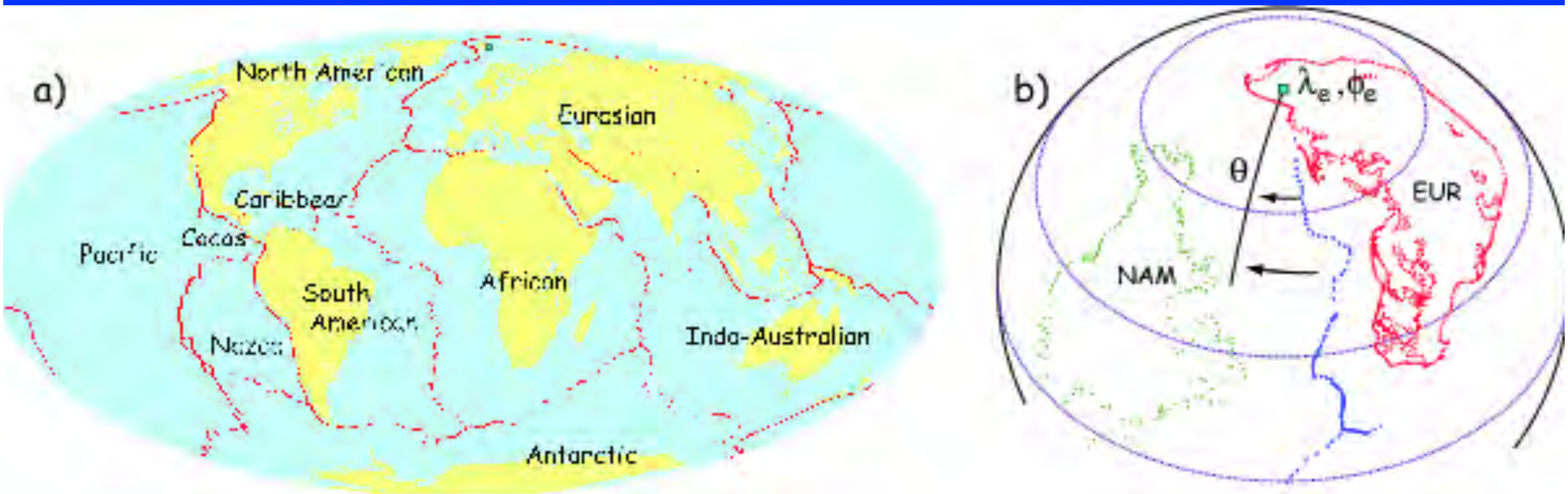
What Data Do We Use?

- Paleontology
- Lithology and Stratigraphy
- Structural Field Data
- Radiometric Age Dating
- Paleomagmatism

Paleomagnetism of Permian Wallowa Terrane

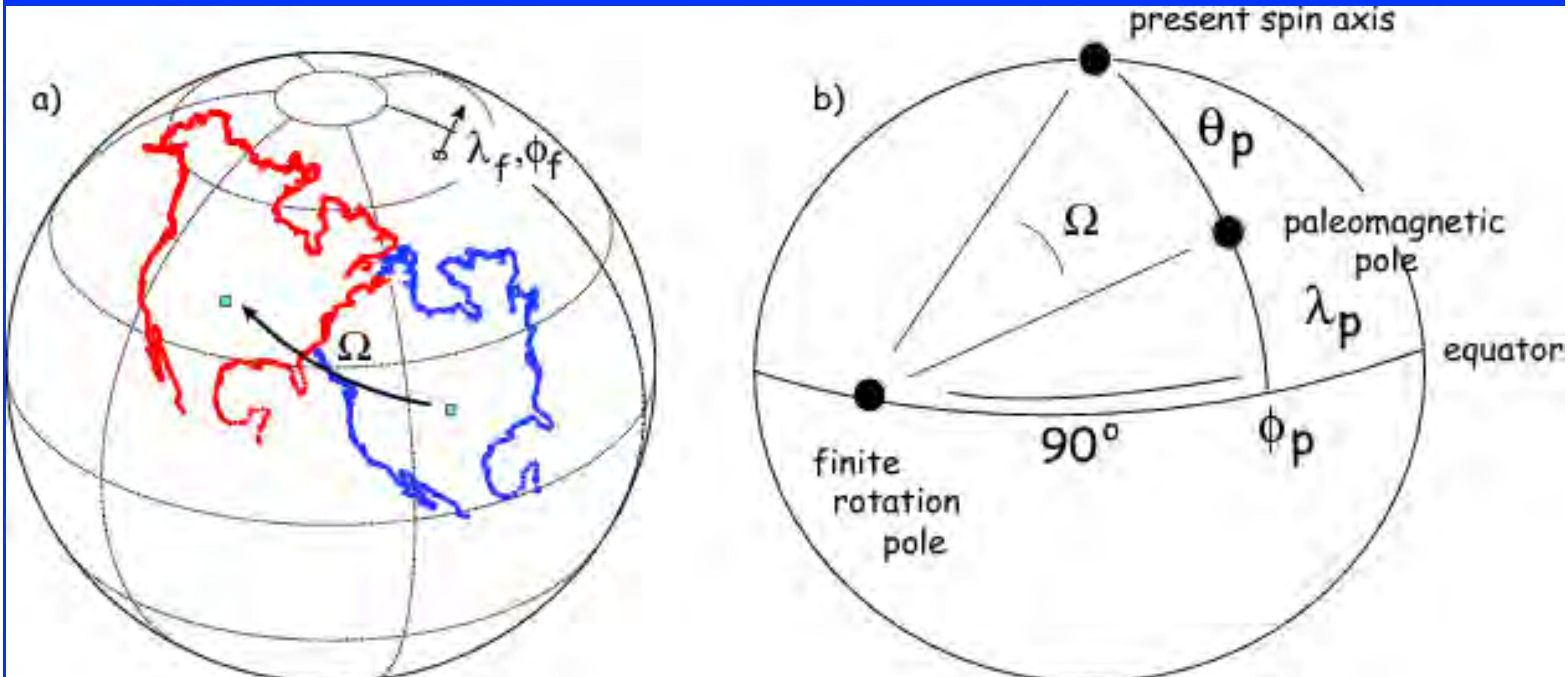
Harbert et al 1994

Some images showing plate movements on a sphere



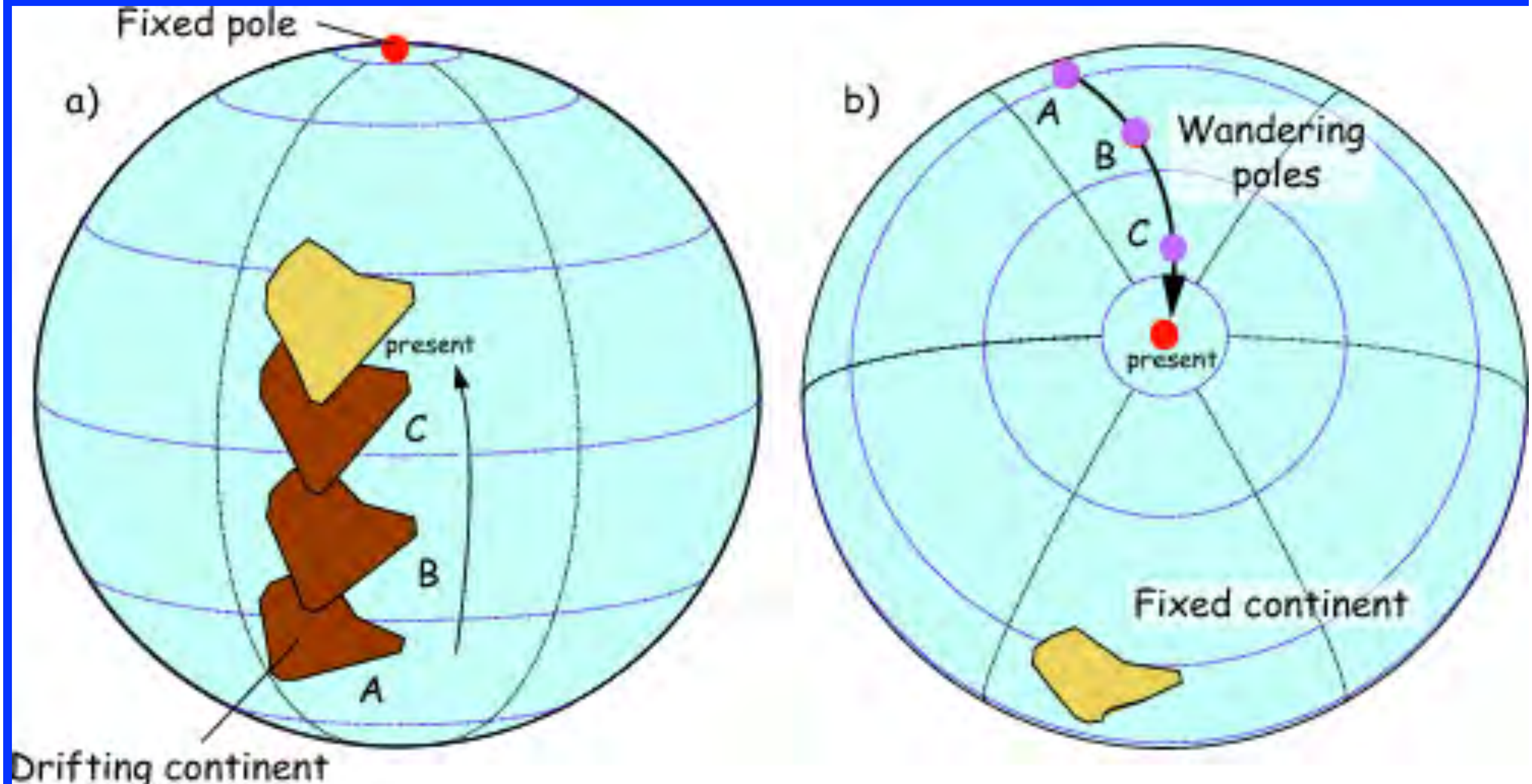
http://magician.ucsd.edu/essentials/WebBookch16.html#WebBookse101.html

Some images showing plate movements on a sphere



http://magician.ucsd.edu/essentials/WebBookch16.html#WebBookse101.html

Some images showing plate movements on a sphere



http://magician.ucsd.edu/essentials/WebBookch16.html#WebBookse101.html

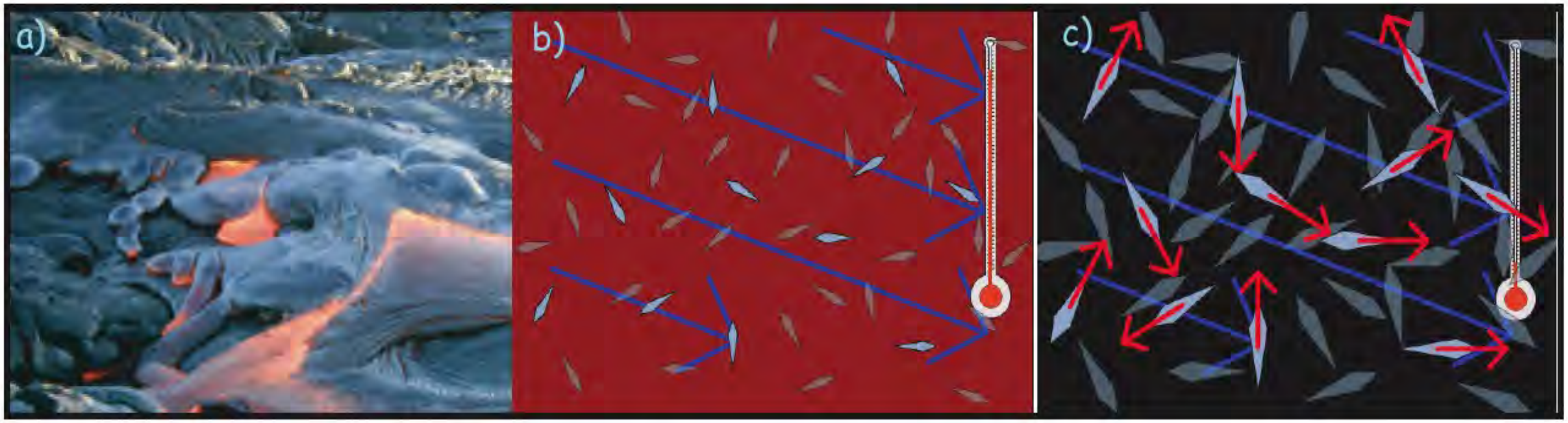


Figure 5.5: a) Picture of lava flow courtesy of Daniel Staudigel. b) While the lava is still well above the Curie temperature, crystals start to form, but are non-magnetic. c) Below the Curie temperature but above the blocking temperature, certain minerals become magnetic, but their moments continually flip among the easy axes with a statistical preference for the applied magnetic field. As the lava cools down, the moments become fixed, preserving a thermal remanence. [b) and c) modified from animation of Genevieve Tauxe available at: http://magician.ucsd.edu/Lab_tour/movs/TRM.mov.

http://earthref.org/MAGIC/books/Tauxe/2005/

5.6 Chemical Remanent Magnetization

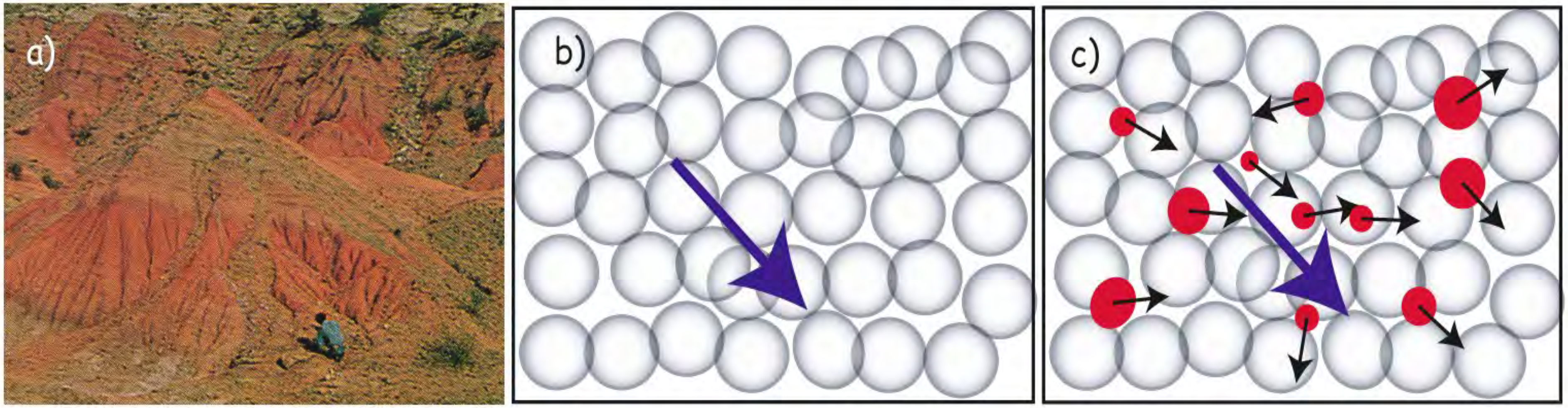


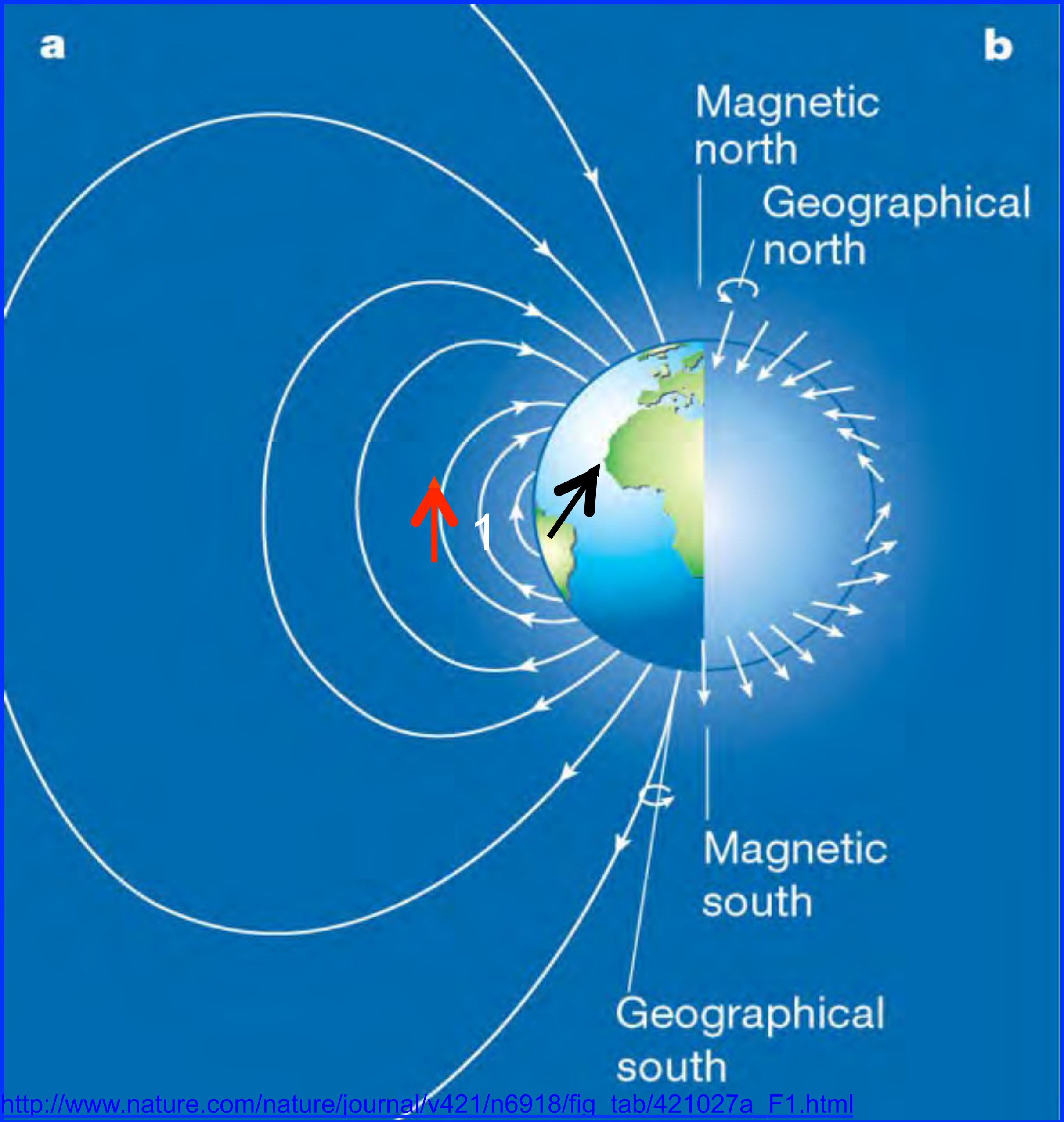
Figure 5.7: Grain growth CRM. a) Red beds of the Chinji Formation, Siwaliks, Pakistan. The red soil horizons have a CRM carried by pigmentary hematite. b) Initial state of non-magnetic matrix. c) Formation of superparamagnetic minerals with a statistical alignment with the ambient magnetic field (shown in blue).

http://earthref.org/MAGIC/books/Tauxe/2005/

Sometime in the geological past …

Magnetic Declination

Magnetic Inclination

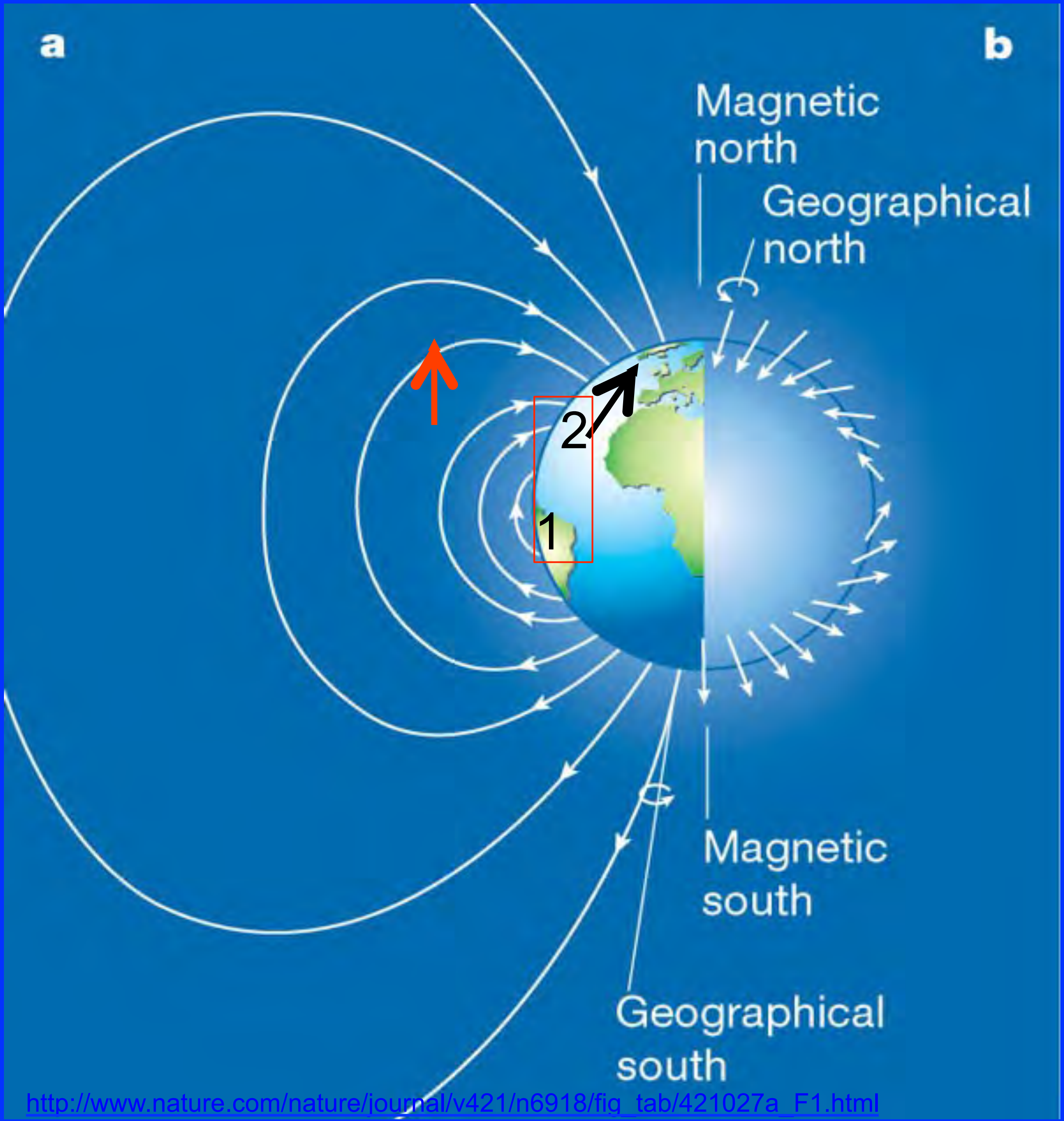


http://www.nature.com/nature/journal/v421/n6918/fig_tab/421027a_F1.html

Plate tectonics moves the plate from (1) to (2)

Magnetic Declination

Paleo-Magnetic Inclination



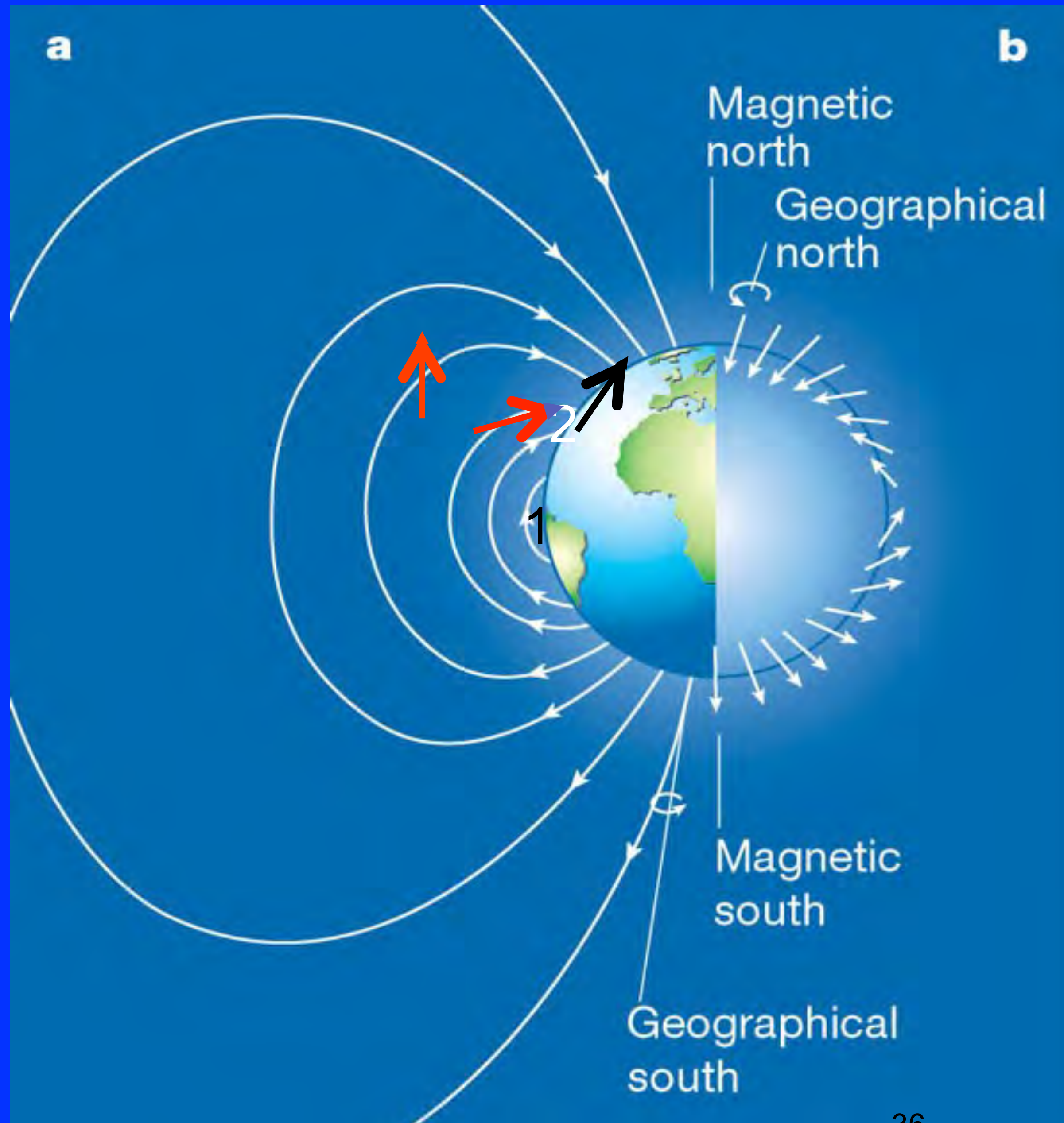
http://www.nature.com/nature/journal/v421/n6918/fig_tab/421027a_F1.html

NB difference in magnetic declinations

Magnetic Declination

Paleo-Magnetic Inclination

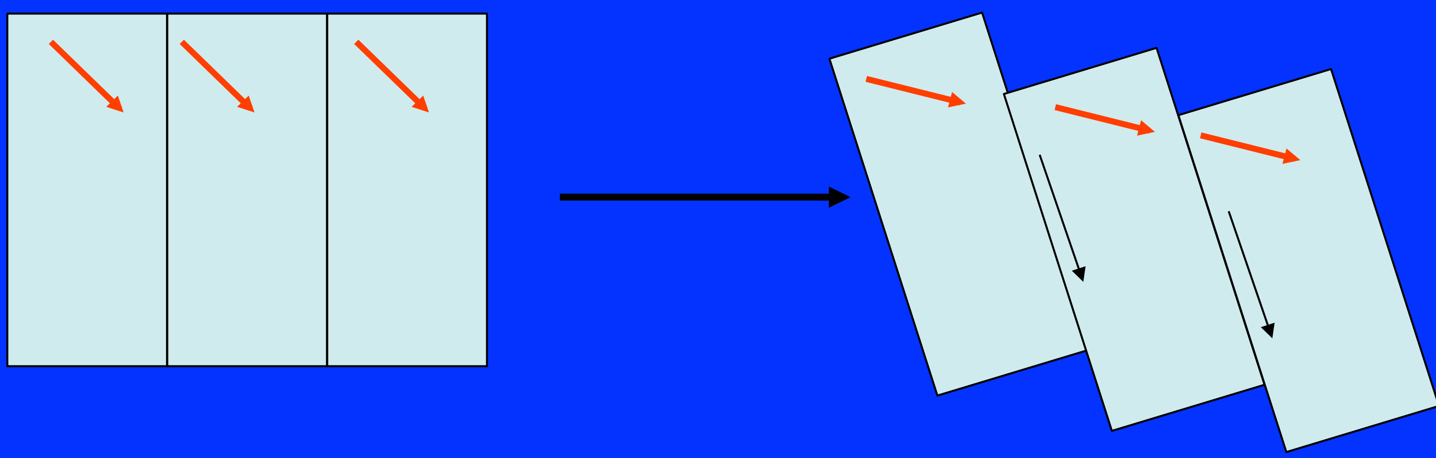
Modern Declination at (2)



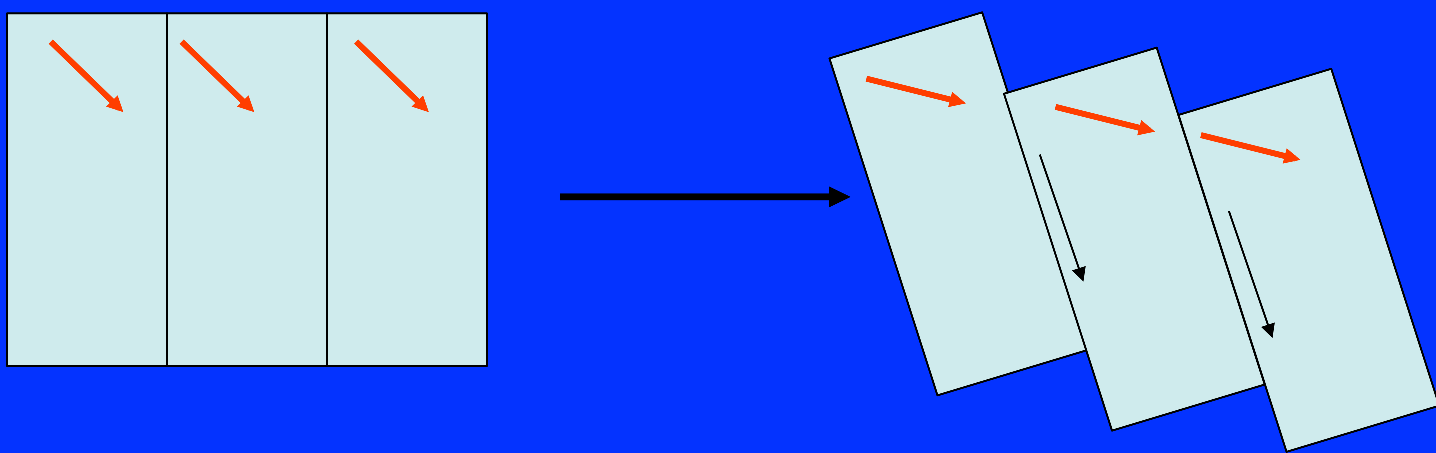
36

http://www.nature.com/nature/journal/v421/n6918/fig_tab/421027a_F1.html

But there are problems:

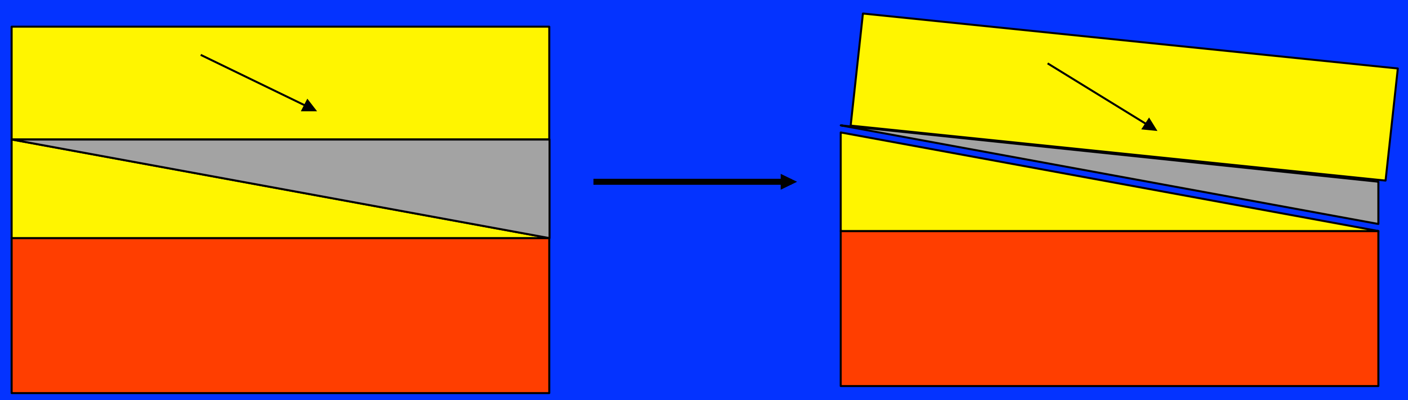


But there are problems:

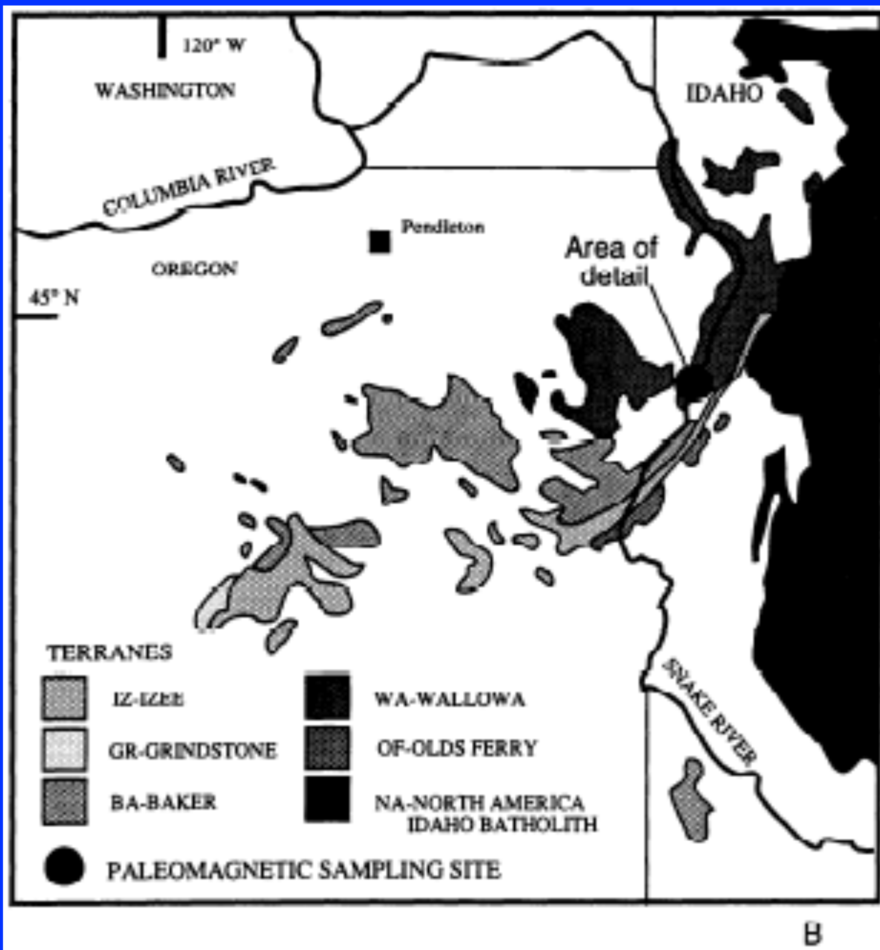


Tectonic deformation will change the measured paleo-inclination. Here faulting leads us to infer the faulted blocks were deposited at a southern paleo-location, where inclinations are not as steep.

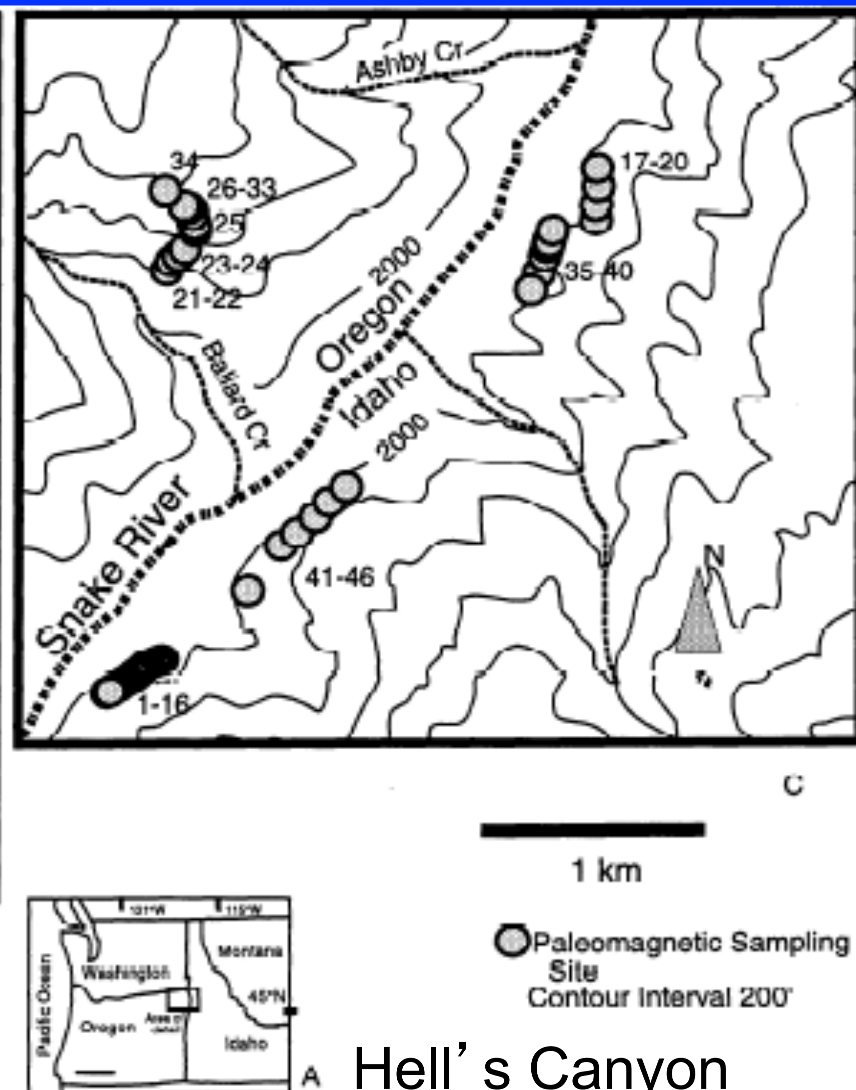
There are problems



Differential compaction of sediments leads to change in measured paleo-inclination in the overlying beds.

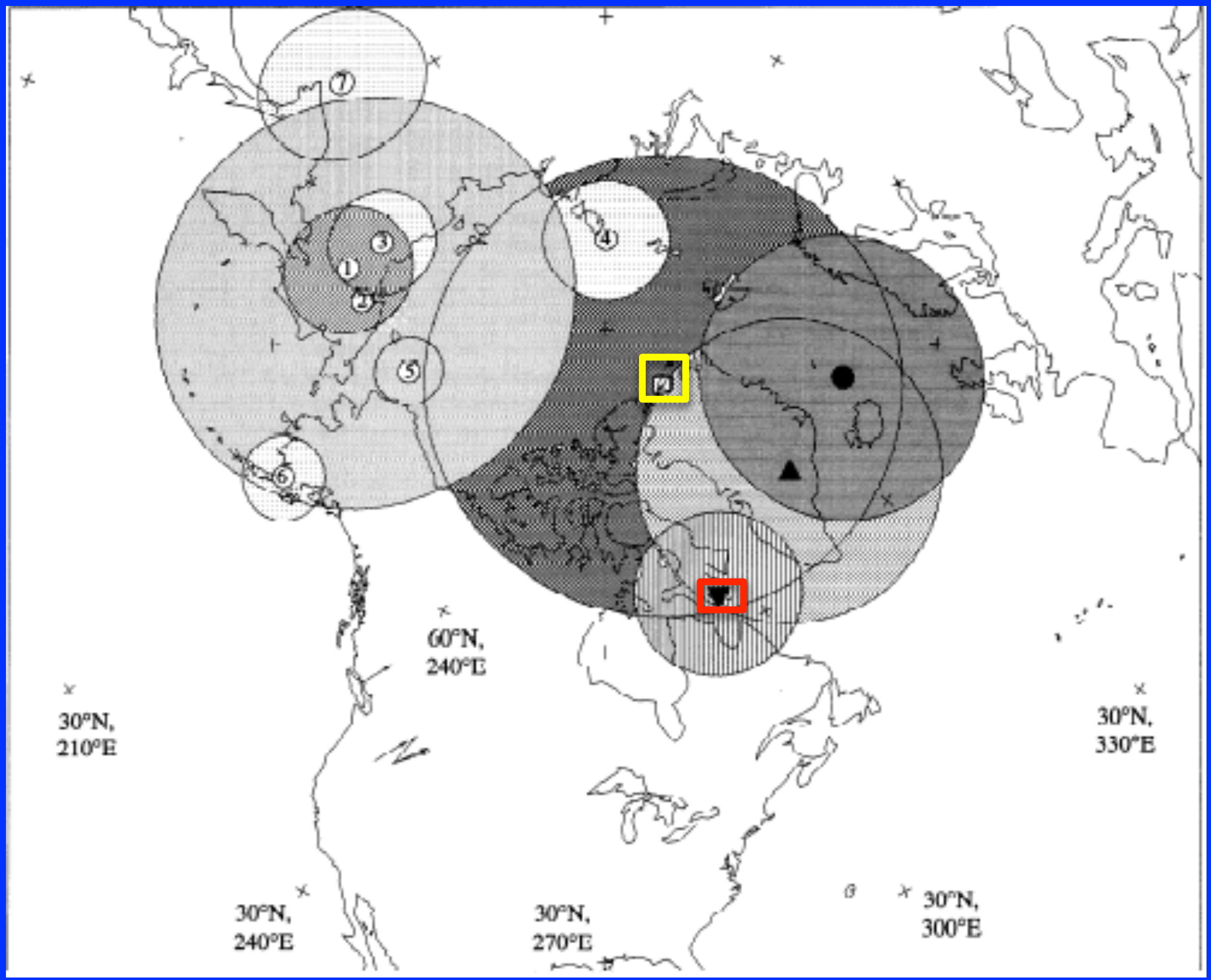


Regional geology



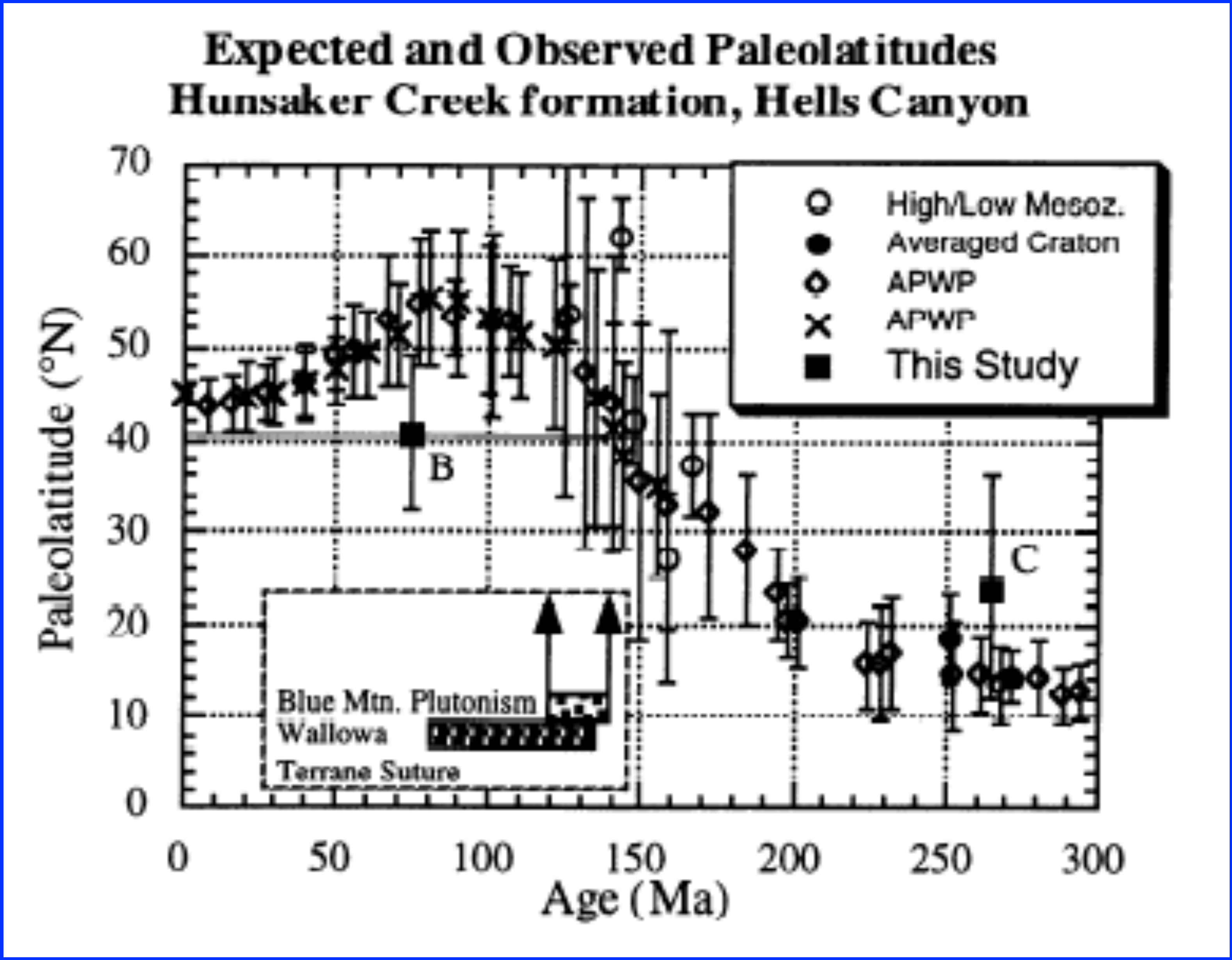
Hell's Canyon sites

Harbert et al 1994

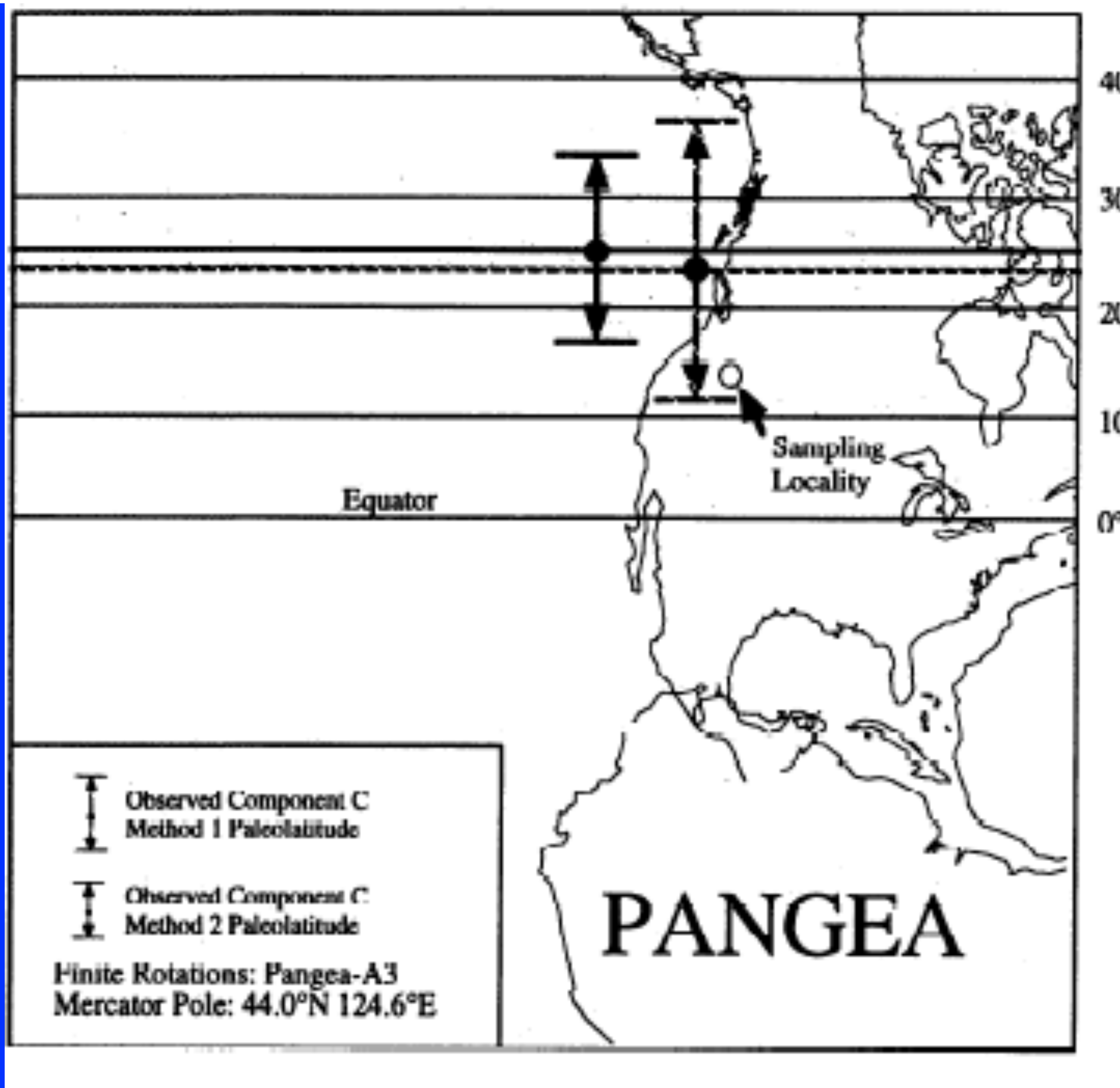


Open square: Paleo-pole this study nb error circle
1=135MA, 2=131MA, 3-7=OTHER POLES
Inverted triangle=Blue Mt L Jur-E Cret
pole

Harbert et al 1994



Harbert et al 1994

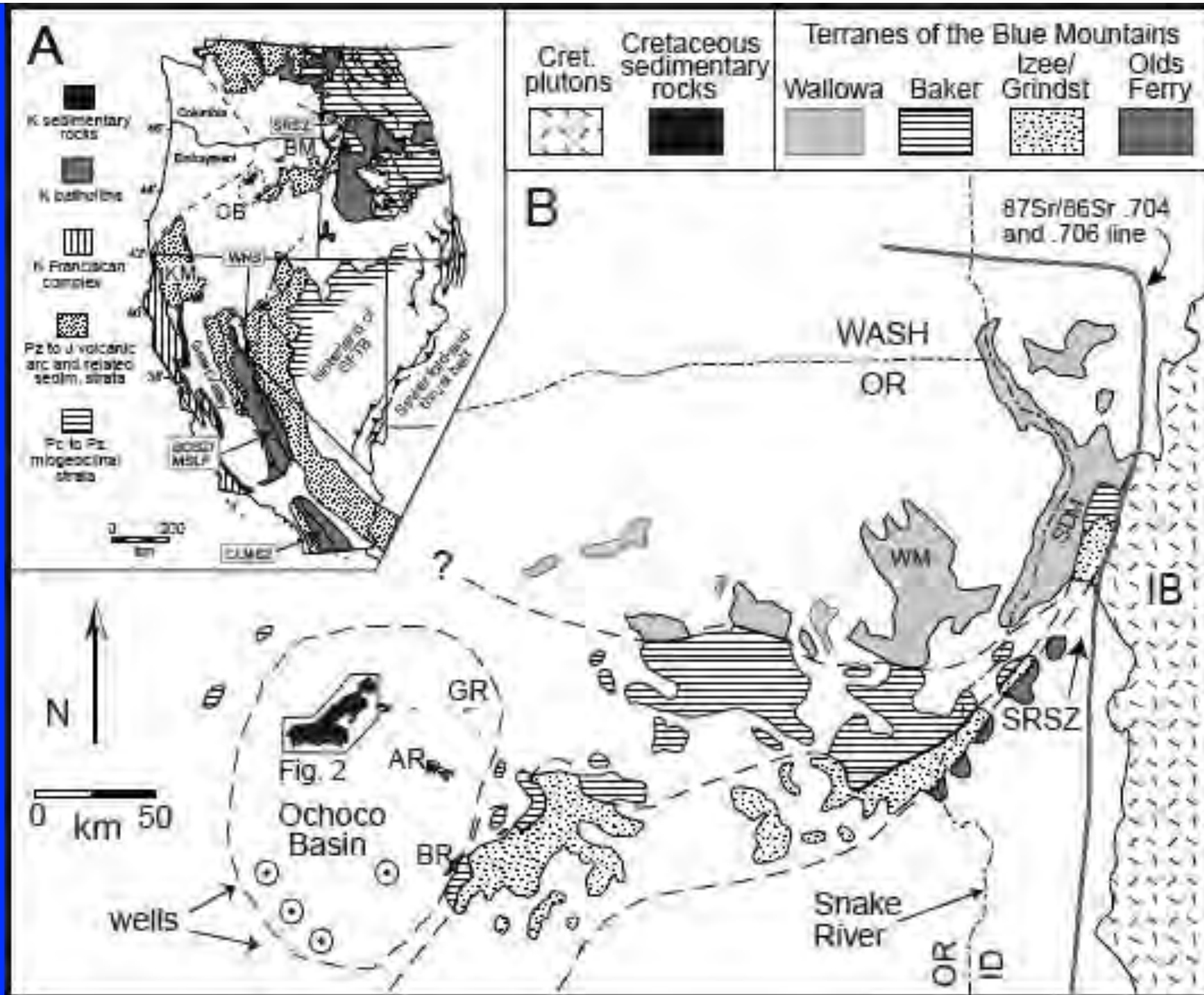


Permian Paleo-pole and Hell's Canyon Permian paleo-poles: this study suggests Wallowa Terrane formed to NORTH of its present location.

Harbert et al 1994

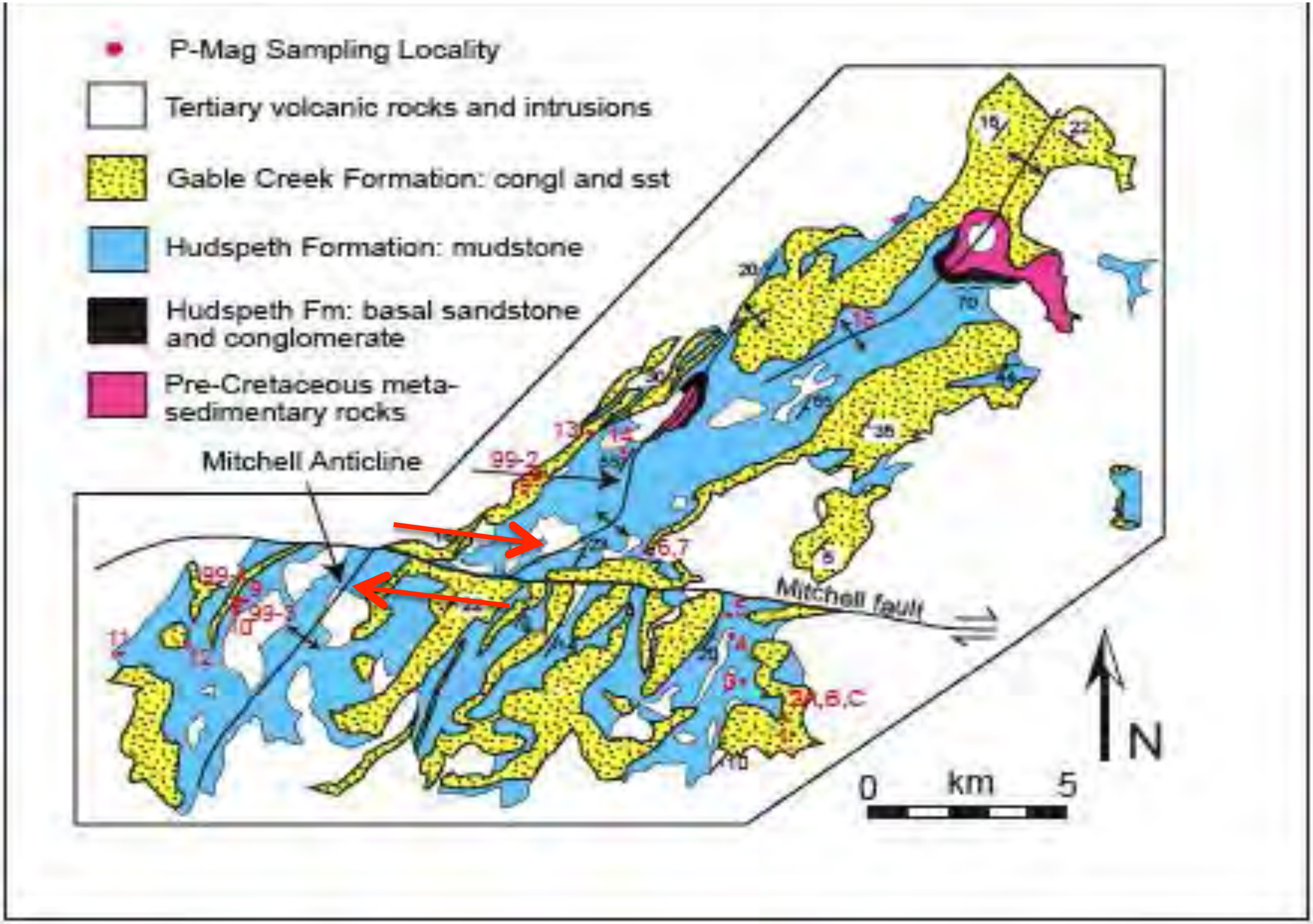
Cretaceous Tectonics of the Ochoco Basin: Paleomagnetism

Housen and Dorsey 2005



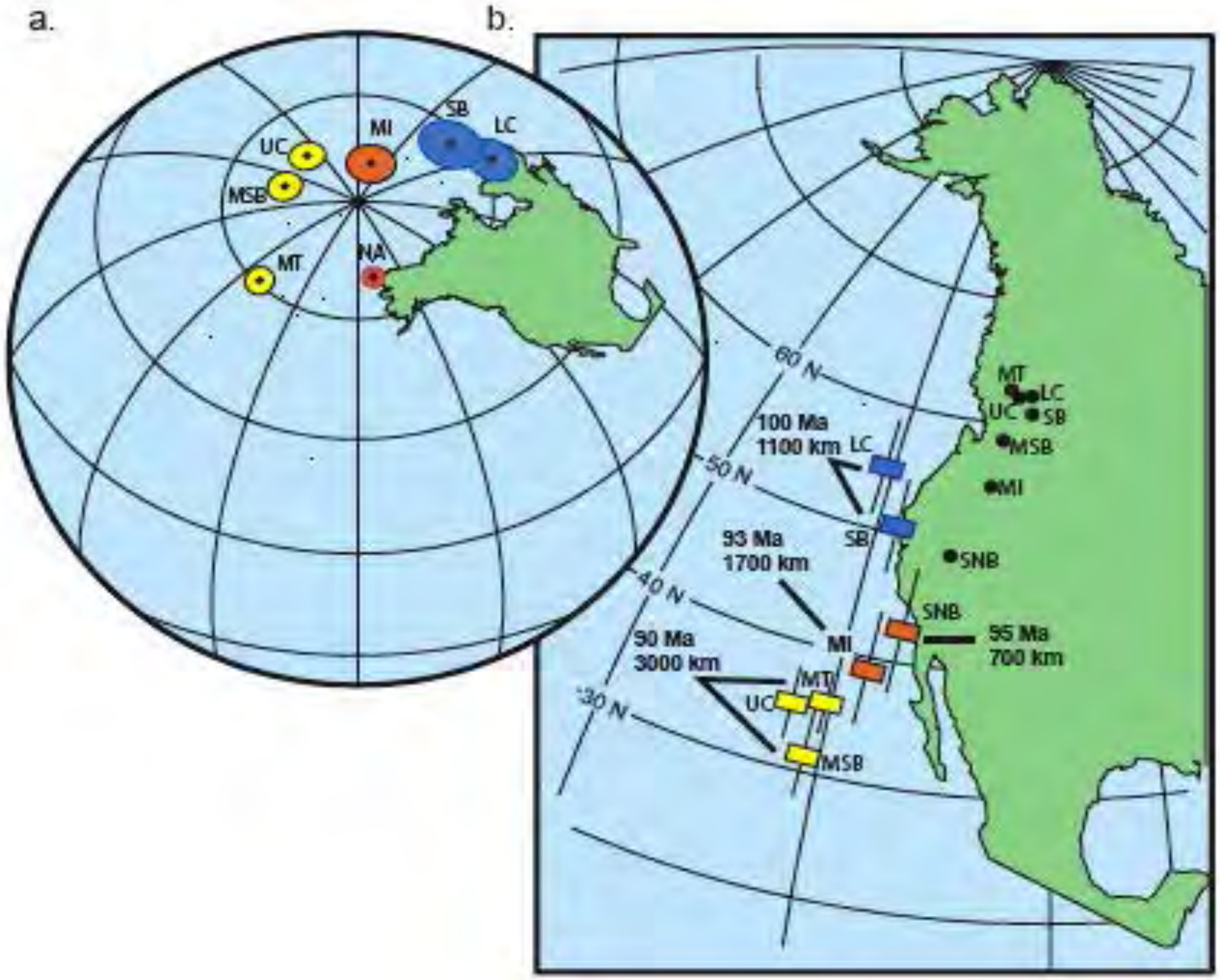
Pre-Tertiary geology: nb. “Columbia Embayment”

Housen and Dorsey 2005



Housen and Dorsey 2005

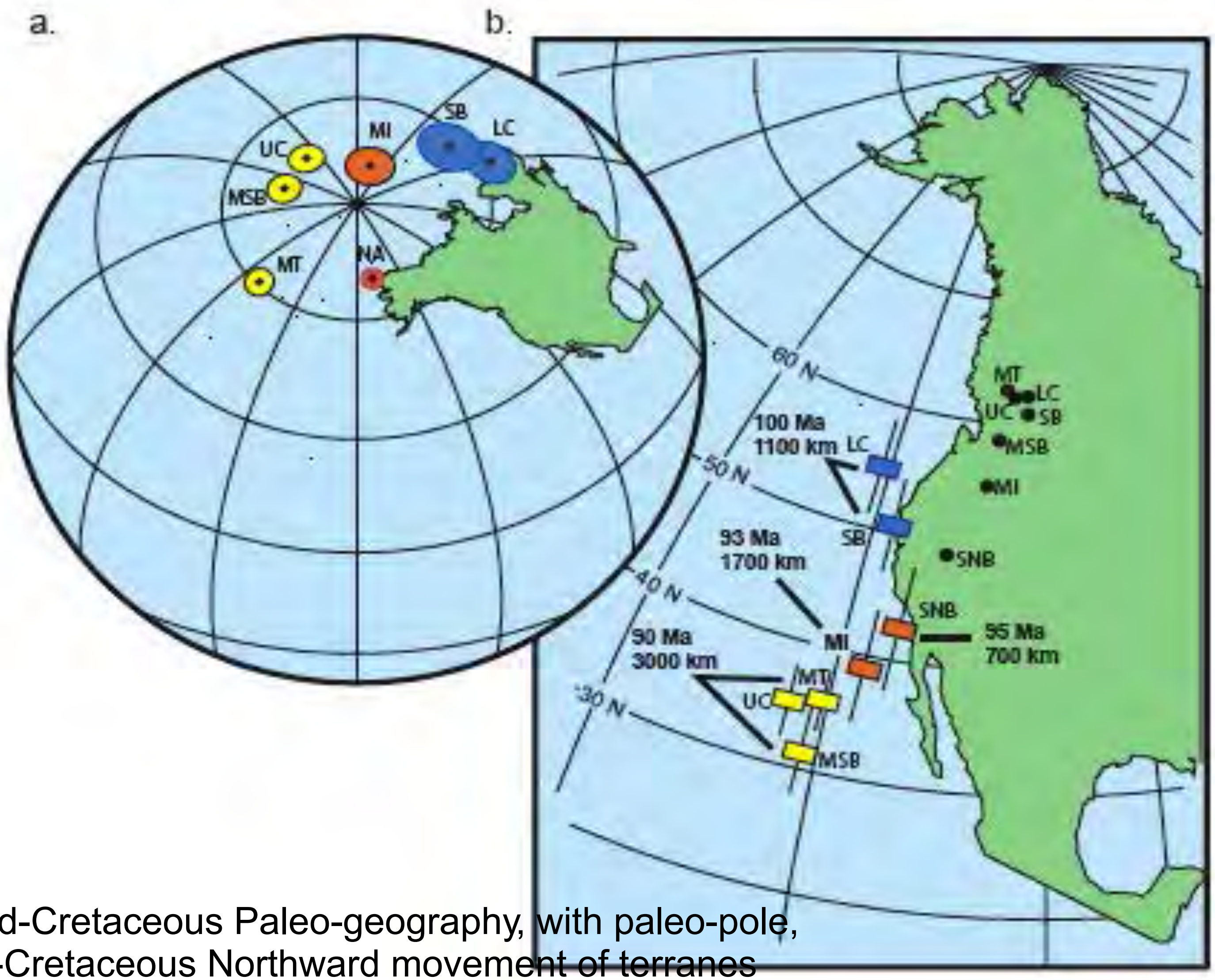
a. Paleomagnetic poles
MI=this study,
yellow=Insular Terranes
blue=Intermontane terranes



b. Mid-Cretaceous Paleo-geography, with paleo-pole,
Post-Cretaceous Northward movement of terranes

Housen and Dorsey 2005

a. Paleomagnetic poles M=this study, yellow=Insular Terranes blue=Intermontane terranes



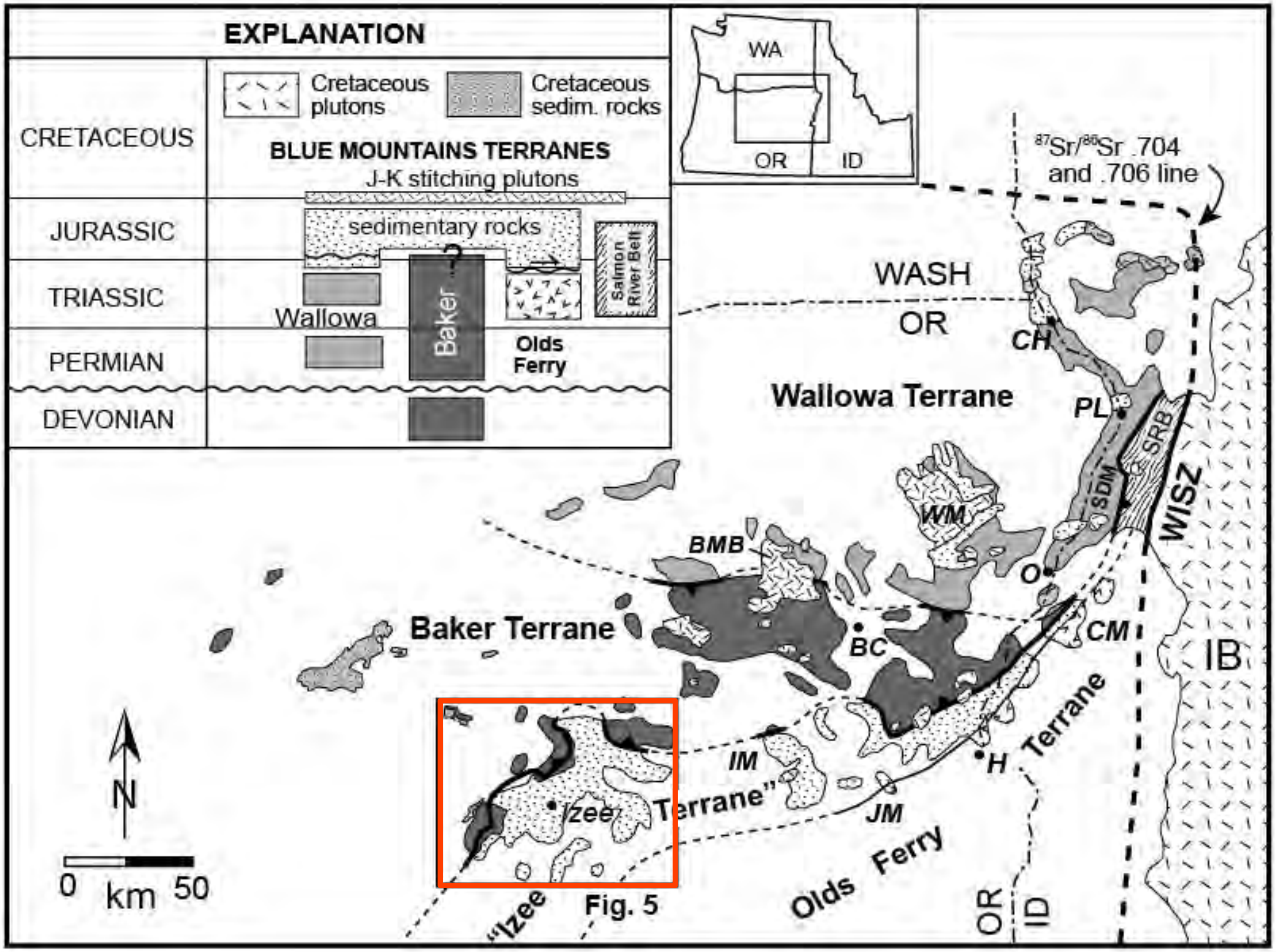
b. Mid-Cretaceous Paleo-geography, with paleo-pole, Post-Cretaceous Northward movement of terranes

These data suggest the Blue Mountains have moved NORTh 1760 +/- 460 km, and Rotated 37° +/- 7.3° since 93 Ma

Housen and Dorsey 2005

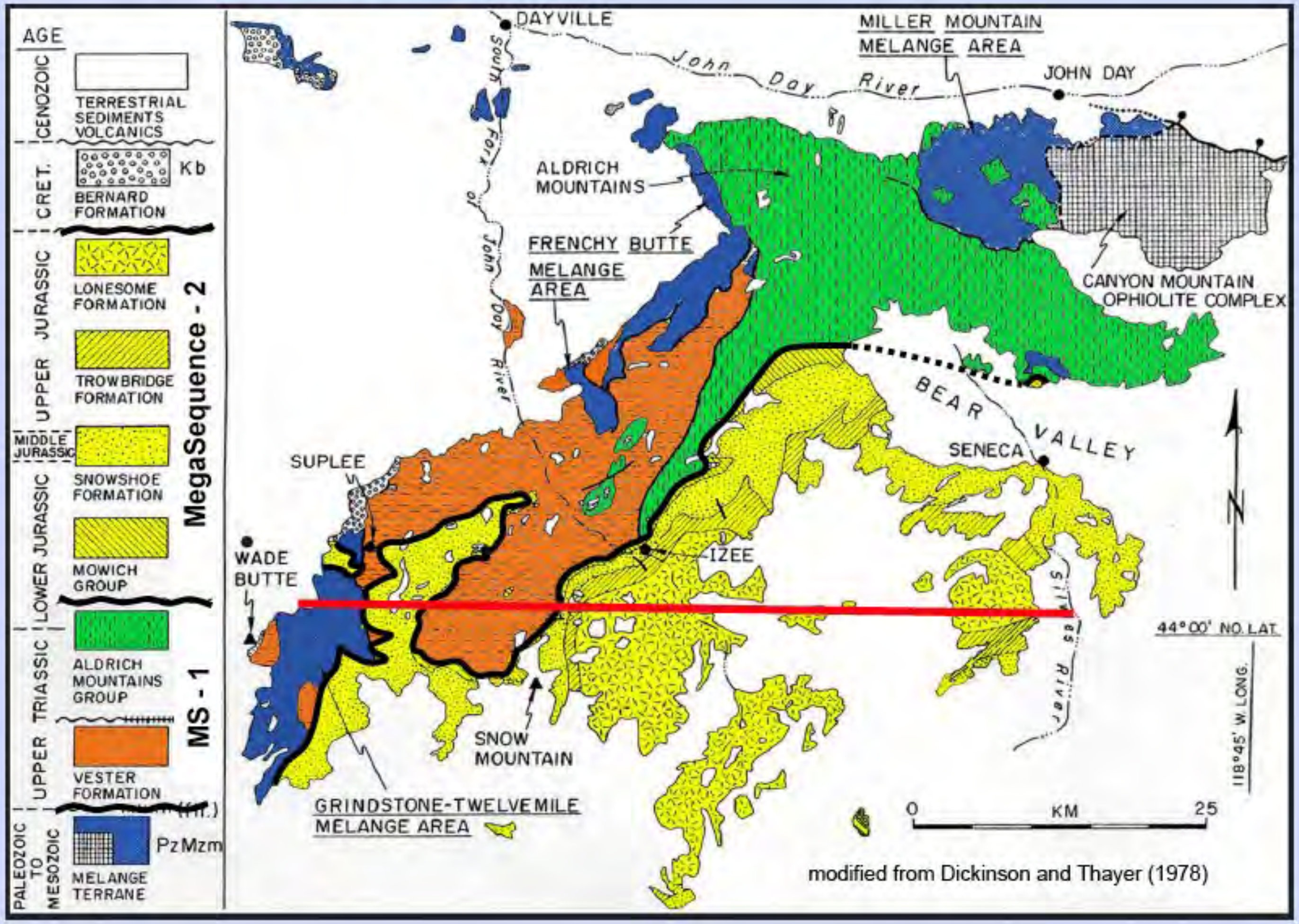
Basinal response to Triassic-Jurassic Collisional Tectonics in the Blue Mountains Province, Northeastern Oregon

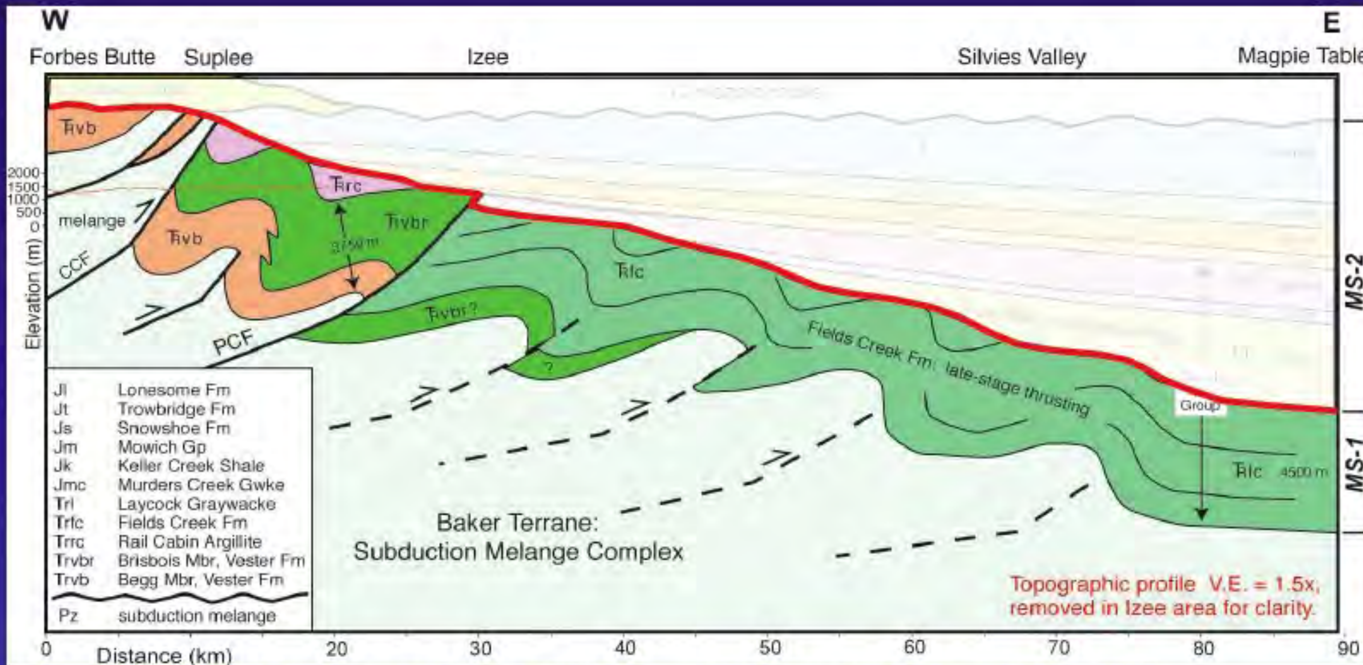
Dorsey and LaMaskin
2007



EXPLANATION
CRETACEOUS
JURASSIC
TRIASSIC
PERMIAN
DEVONIAN
Cretaceous plutons
Cretaceous sedim. rocks
BLUE MOUNTAINS TERRANES
J-K stitching plutons
sedimentary rocks
Wallowa
Baker
Olds Ferry
Salmon River Belt
WA
OR
ID
$^{87}Sr/^{86}Sr$ .704 and .706 line
WASH
OR
CH
Wallowa Terrane
PL
SRB
SDM
WISZ
WM
BMB
O
Baker Terrane
BC
CM
IB
IM
H
Terrane
"Izee Terrane"
JM
Olds Ferry
OR
ID
N
0 km 50
Fig. 5

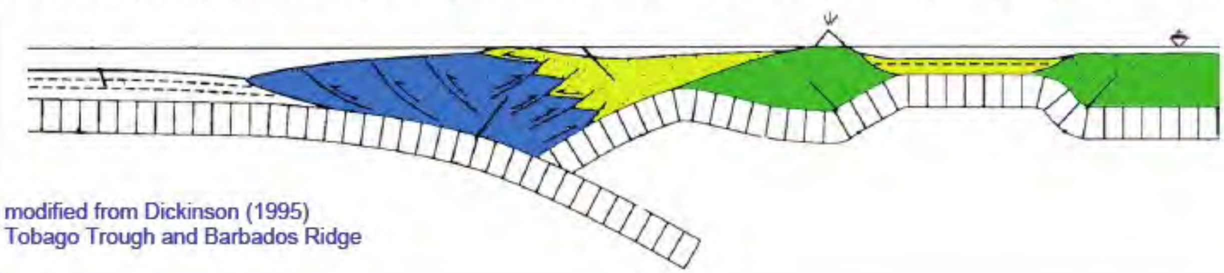
Izee-Suplee area





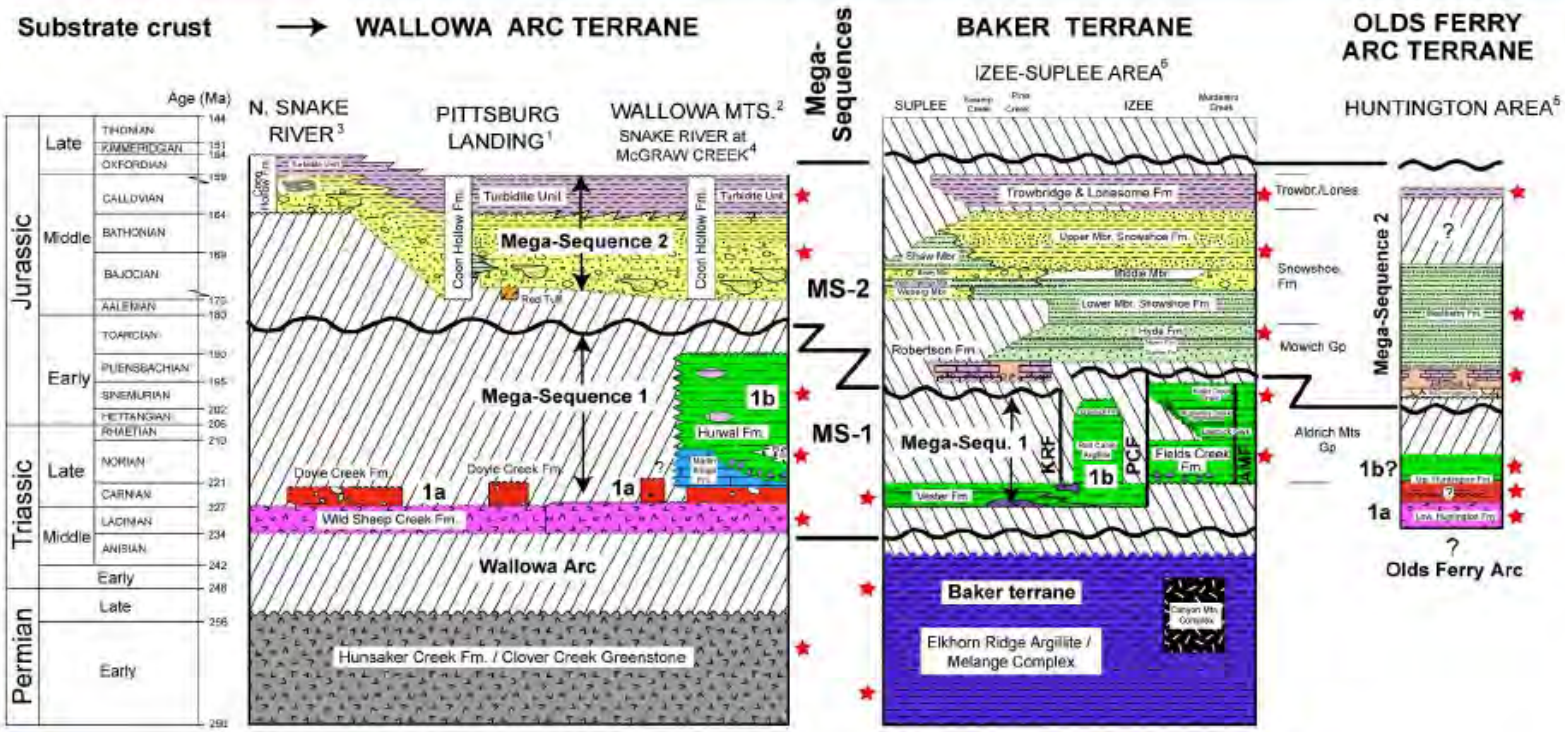
Constructed using data from Dickinson and Thayer (1978), Dickinson and Vigrass (1965), Brown and Thayer (1966)

Dickinson (1979): backthrusting on edge of accretionary prism above "normal" east-dipping subduction zone



modified from Dickinson (1995)
Tobago Trough and Barbados Ridge

Stratigraphy of the Blue Mountains



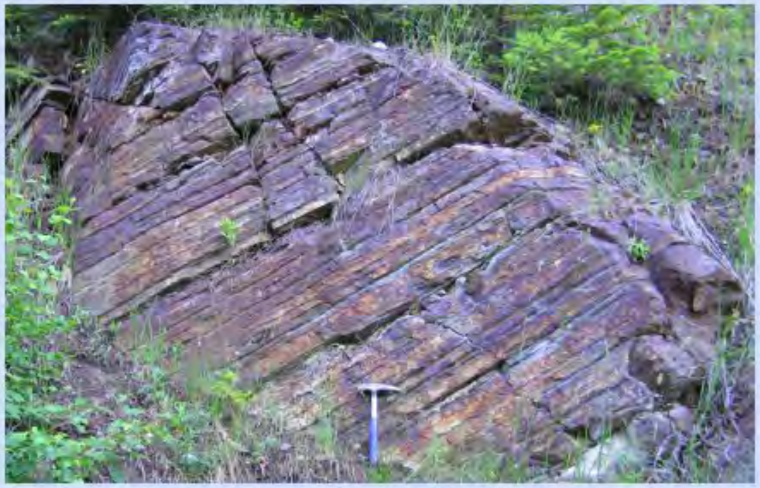
★ indicates positions of samples to be collected for provenance analysis

- Norian shallow- to deep-water carbonate facies
- Carnian calcareous volcaniclastic sandstone and conglomerate
- Middle to Upper Triassic volcanic rocks
- Upper Paleozoic peridotite, pyroxenite, and gabbro
- Pz to Lower Jurassic radiolarian chert, argillite, and subduction melange
- Lower to Middle Jurassic shale and siltstone
- Lower Jurassic volcaniclastic sandstone
- Lower Jurassic conglomerate
- Lower Jurassic isolated carbonate mound/biohermal strata
- Upper Triassic to Lower Jurassic shale, siltstone, and turbidites
- Middle to upper Upper Jurassic shale and sandstone
- Middle Jurassic shale
- Middle Jurassic sandstone and shale
- Middle Jurassic sandstone and conglomerate

1. White et al. (1992); White (1994); White and Vallier (1994)
2. Follo (1992; 1994)
3. Vallier (1977); Goldstrand (1994)
4. Vallier (1974, 1977)
5. Brooks et al. (1976); Brooks (1979a)
6. Dickinson and Vigrass (1965); Dickinson and Thayer (1978); Dickinson (1979); Imlay (1986); Taylor and Guex (2002)

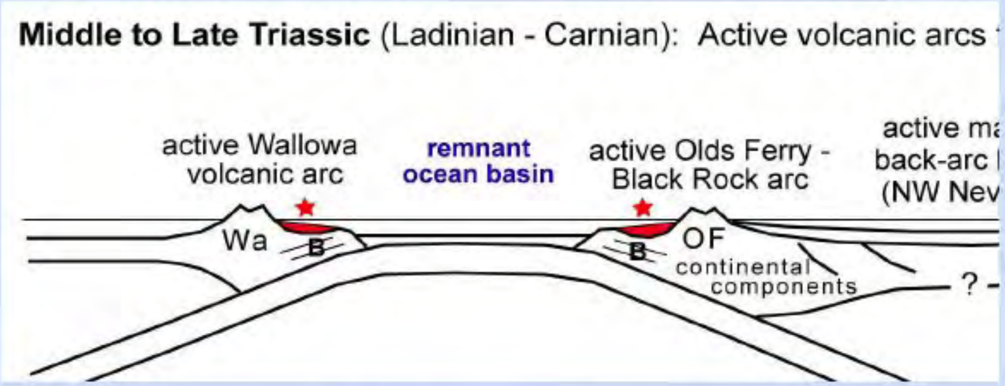
compiled by Todd LaMaskin

Doyle Creek Formation: forearc basin strata



fine-grained marine turbidites and ...

coarse volcaniclastic sst & pebble cgl

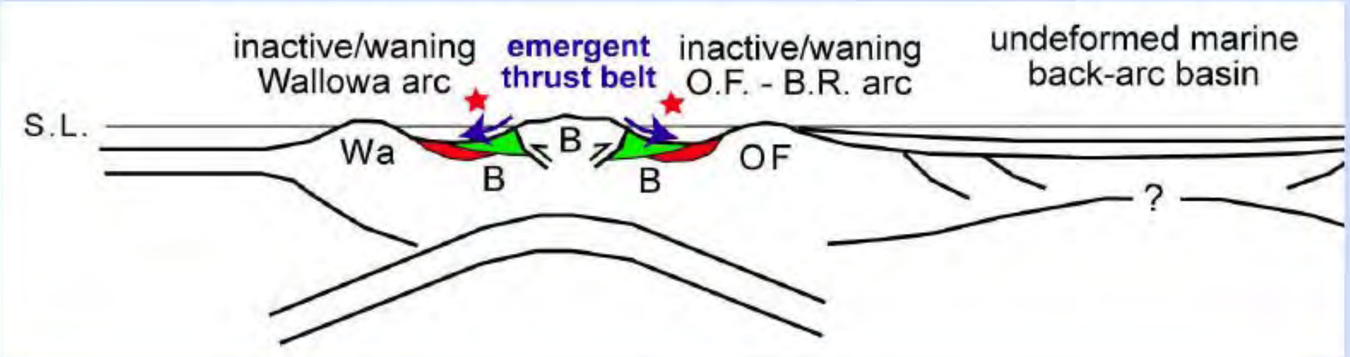


εNd +7 (new results from Vervoort's lab), indicates juvenile crust with no continental input.

Transition to Hurwal Fm

Carbonate turbidites record deepening and foundering of carbonate platform … why?

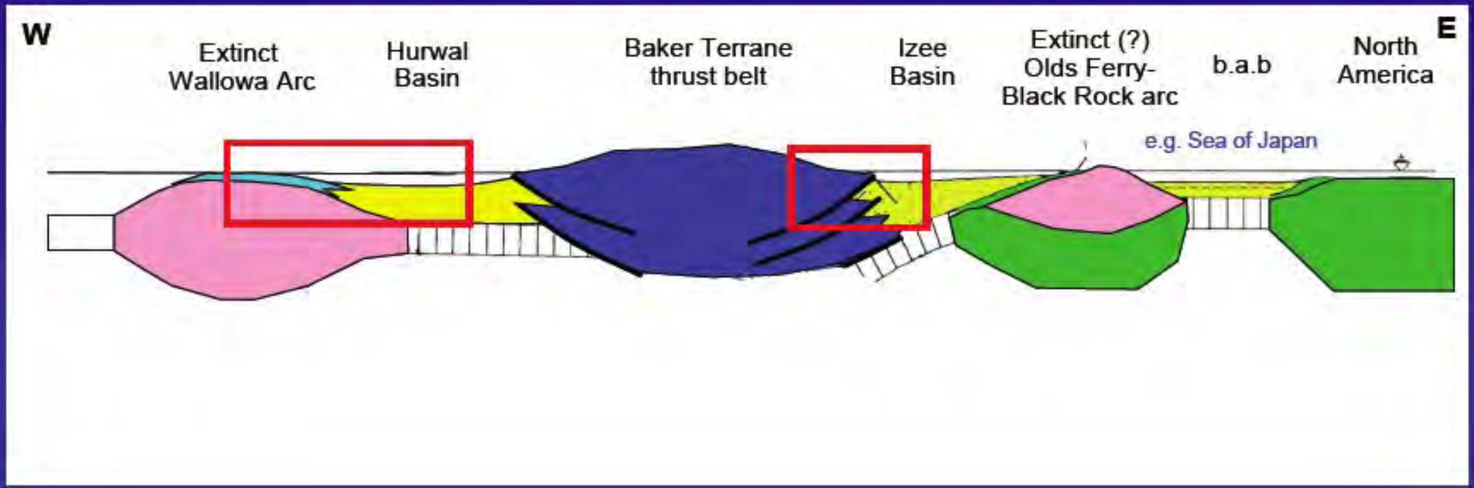
Rise and fall of the Martin Bridge LS may record migration of a flexural bulge due to loading in the Baker terrane thrust belt.

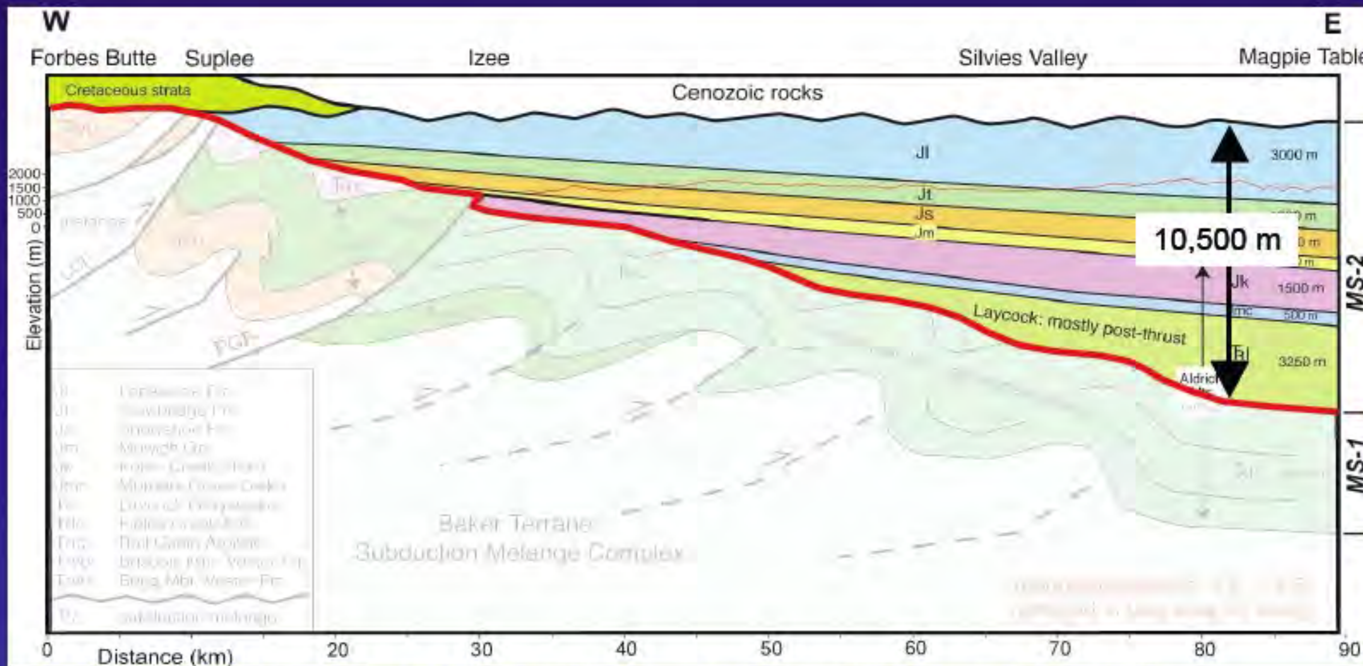


Late Triassic

Dickinson (1979): backthrusting above "normal" east-dipping subducting plate

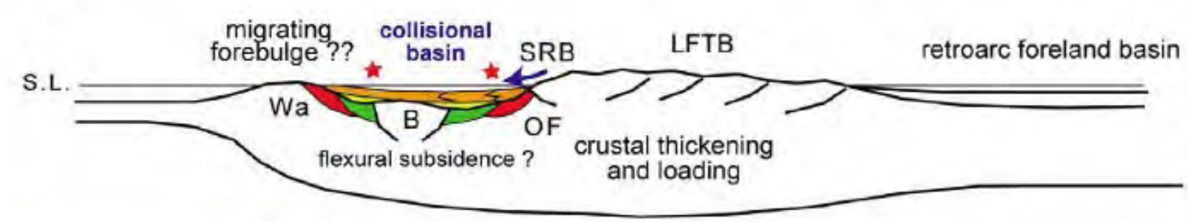
Alternate Hypothesis: doubly vergent Baker t. thrust belt and flanking flexural basins

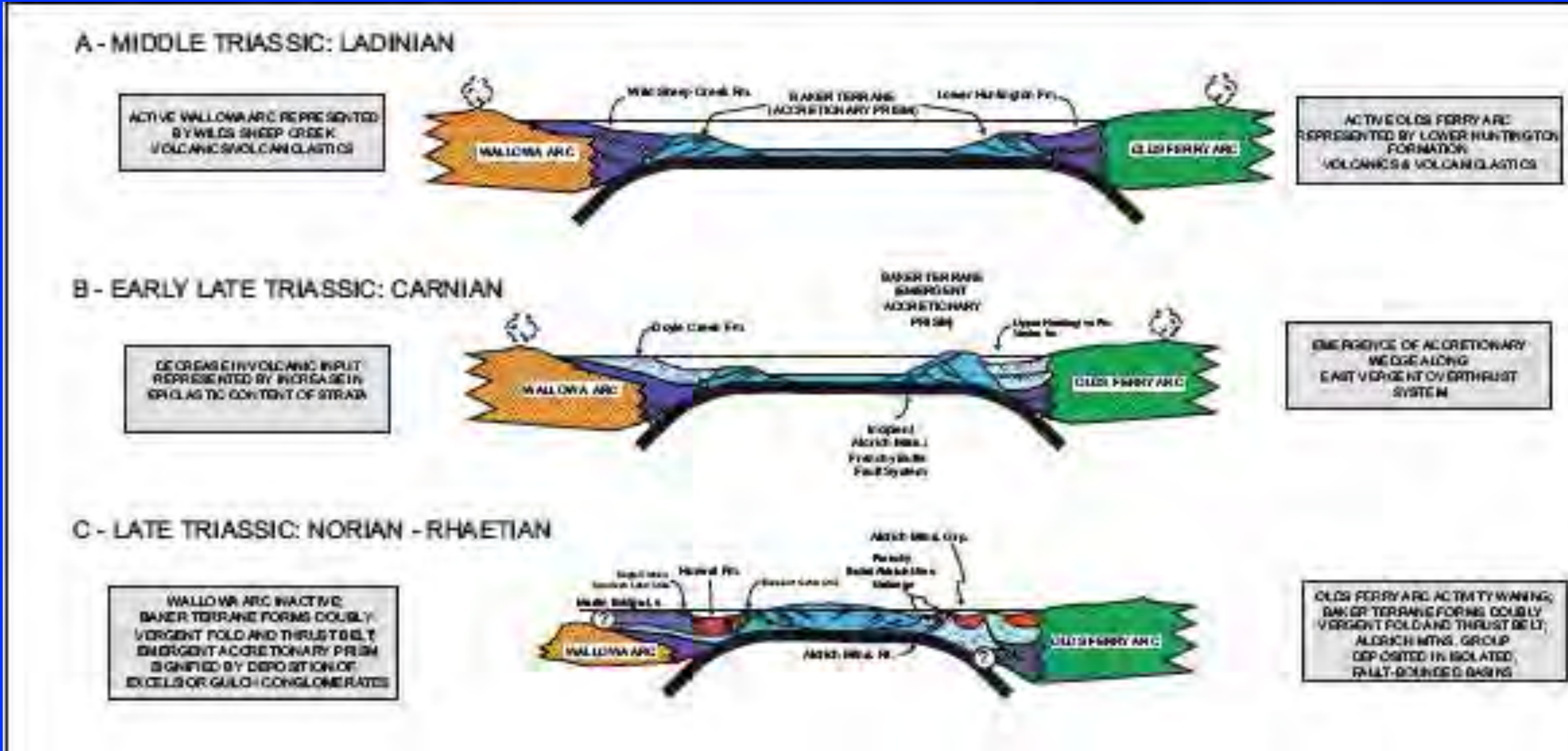




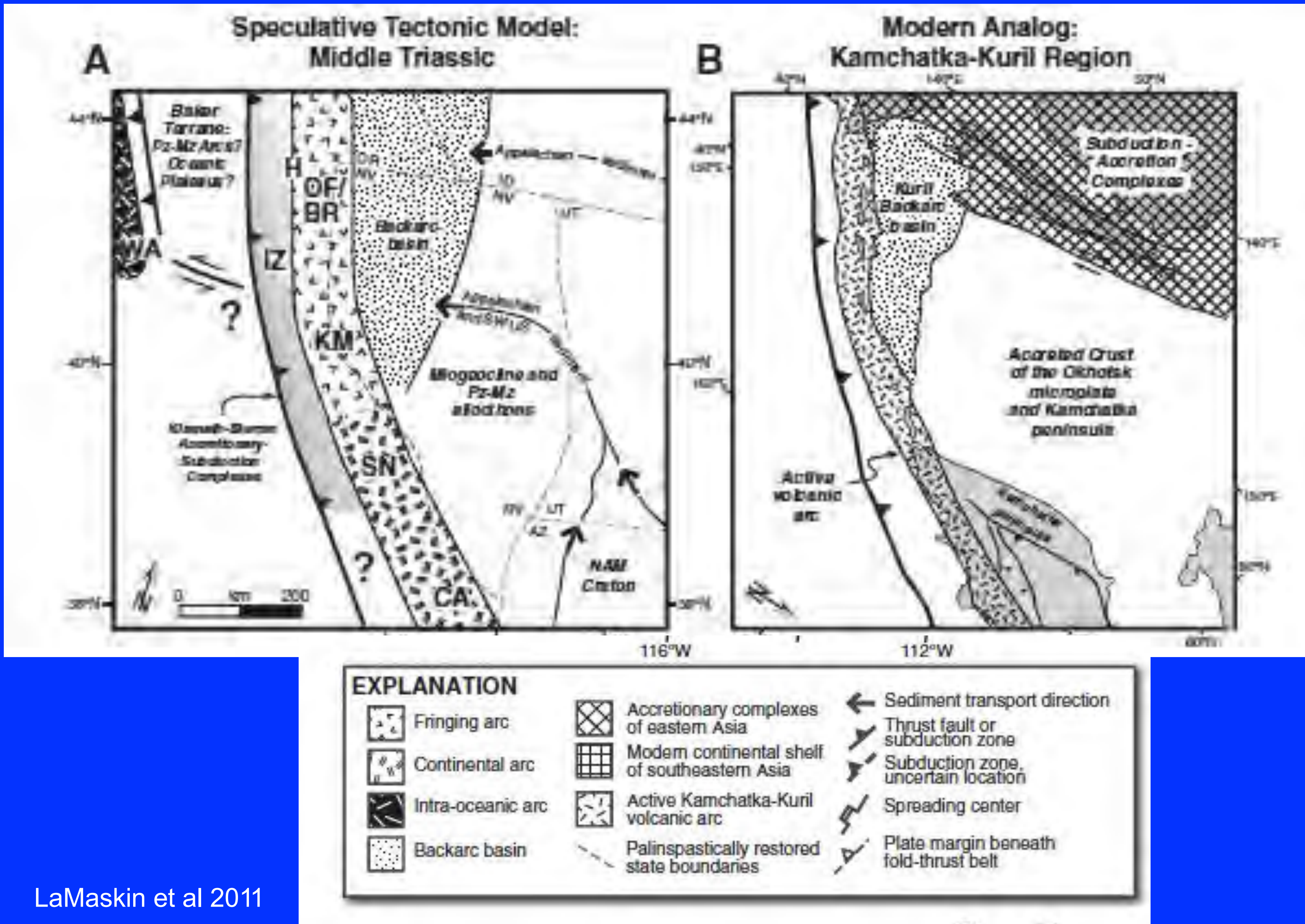
Constructed using data from Dickinson and Thayer (1978), Dickinson and Vigrass (1965), Brown and Thayer (1966)

Early to Late Jurassic: growth and subsidence of collisional basin; thick overlap assemblage

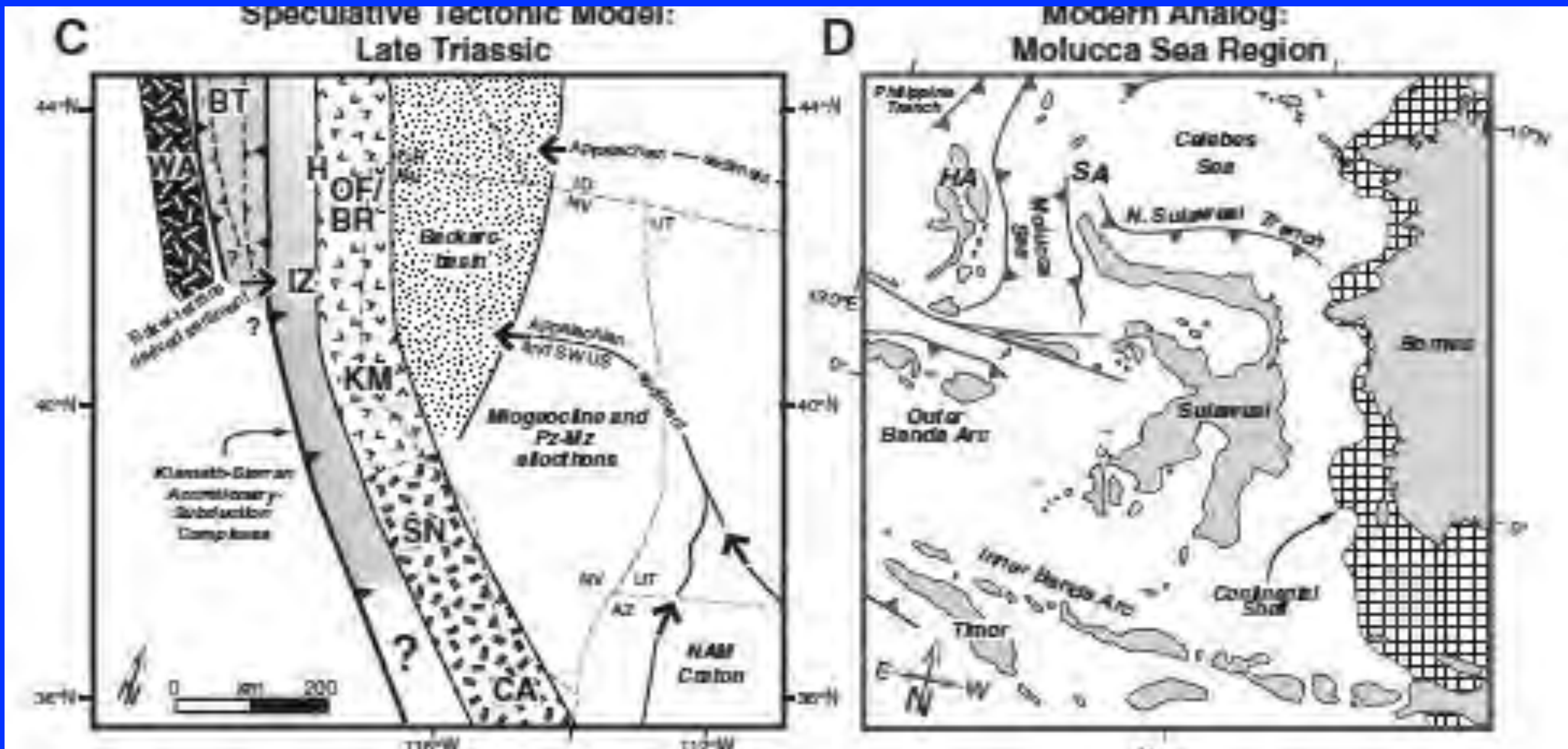


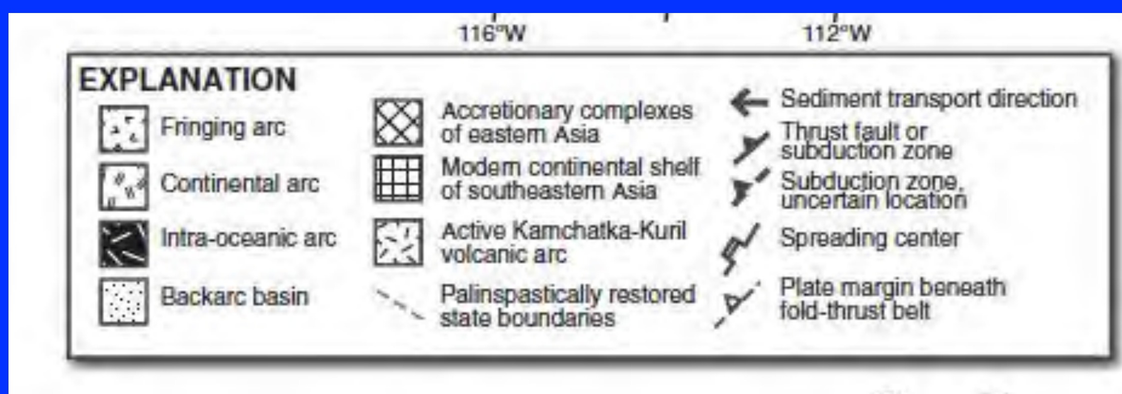

A - MIDDLE TRIASSIC: LADINIAN
ACTIVE WALLOWA ARC REPRESENTED BY WILDS SHEEP CREEK VOLCANICS/VOLCANICLASTICS
WALLOWA ARC
BAKER TERRANE (ACCRETIONARY PRISM)
Lower Huntington Fm.
OLDS FERRY ARC
ACTIVE OLDS FERRY ARC REPRESENTED BY LOWER HUNTINGTON FORMATION VOLCANICS & VOLCANICLASTICS
B - EARLY LATE TRIASSIC: CARNIAN
DECREASE IN VOLCANIC INPUT REPRESENTED BY INCREASE IN EPICLASTIC CONTENT OF STRATA
WALLOWA ARC
BAKER TERRANE EMERGENT ACCRETIONARY PRISM
OLDS FERRY ARC
EMERGENCE OF ACCRETIONARY WEDGE ALONG EAST VERGENT OVERTHRUST SYSTEM
C - LATE TRIASSIC: NORIAN - RHAETIAN
WALLOWA ARC INACTIVE; BAKER TERRANE FORMS DOUBLY VERGENT FOLD AND THRUST BELT; EMERGENT ACCRETIONARY PRISM SIGNIFIED BY DEPOSITION OF EXCELSIOR GULCH CONGLOMERATES
WALLOWA ARC
OLDS FERRY ARC
OLDS FERRY ARC ACTIVITY WANING; BAKER TERRANE FORMS DOUBLY VERGENT FOLD AND THRUST BELT; ALDRICH MTNS. GROUP DEPOSITED IN ISOLATED, FAULT-BOUNDED BASINS


D - EARLY JURASSIC: PLEINSBACHIAN
TRANSGRESSION OF HURWAL FM AND BURNT RIVER SCHIST BASINAL STRATA OVER MARTIN BRIDGE PLATFORM
WALLOWA ARC
CONTINUED FAULTING/DEFORMATION, PRE-MOWICH UNCONFORMITY MAY REPRESENT REGIONAL PARTITIONING OF COLLISIONAL STRAIN.
E - MIDDLE JURASSIC
MIDDLE JURASSIC EROSION AND THRUSTING? UPLIFT OF WALLOWA ARC SYSTEM FOLLOWED BY GRADUAL FOUNDERING AND SUBMERGENCE OF ARC CRUST; DEPOSITION OF TRANSGRESSIVE COON HOLLOW FM.
WALLOWA ARC
GRADUAL FOUNDERING AND SUBMERGENCE OF ARC CRUST SUBSIDENCE AND GROWTH OF COLLISIONAL BASIN
F - LATE JURASSIC
FINAL COLLISION AND THRUSTING OF BAKER TERRANE OVER ARC TERRANES
FINAL COLLISION AND THRUSTING OF BAKER TERRANE OVER ARC TERRANES



LaMaskin et al 2011





LaMaskin et al 2011

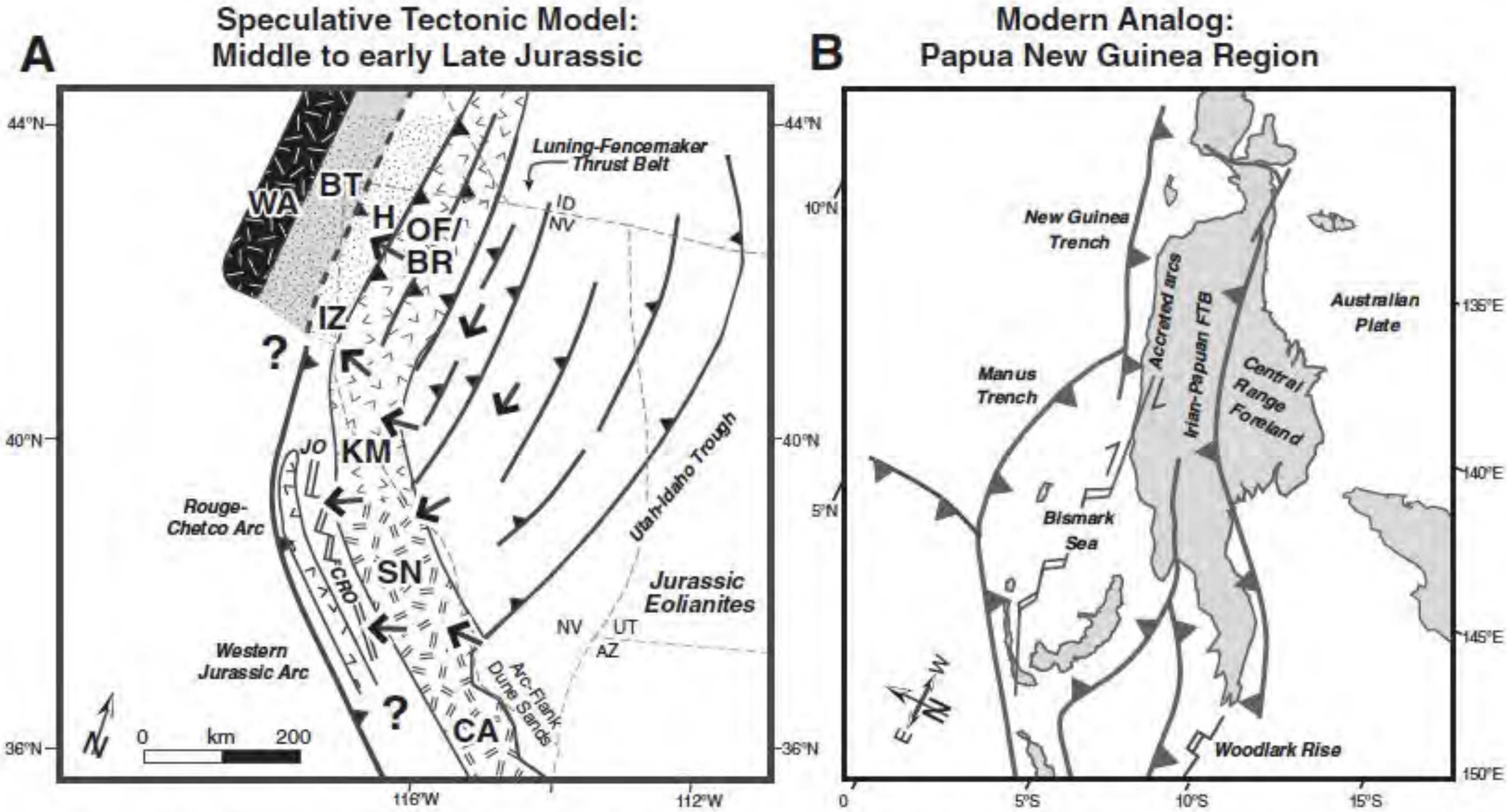


Figure 15. Proposed tectonic models for central western North America during Middle to early Late Jurassic time. See Figure 14 for explanation of symbols and abbreviations used. Palinspastic base in A is modified from Wyld et al. (2006). Rocks of the Blue Mountain Province have been restored ~400 km to the south. (A) Middle to early Late Jurassic time. Sediment deposited in the John Day region is derived from (1) tectonic closure, uplift, and erosion of the Triassic backarc basin and formation of the Luning-Fencemaker fold-and-thrust belt, and/or (2) mixed arc and erg dune sands. Similar sediment is deposited in the intra-arc Josephine–Galice (JO) and Coast Range–Basal Great Valley basins (CRO). (B) Proposed modern analog of the Papua New Guinea region modified from Cloos et al. (2005). Note north arrow and flipped E-W arrows. Accretion of the Melanesian arcs has resulted in formation of the Irian-Papuan fold-and-thrust belt (FTB) and

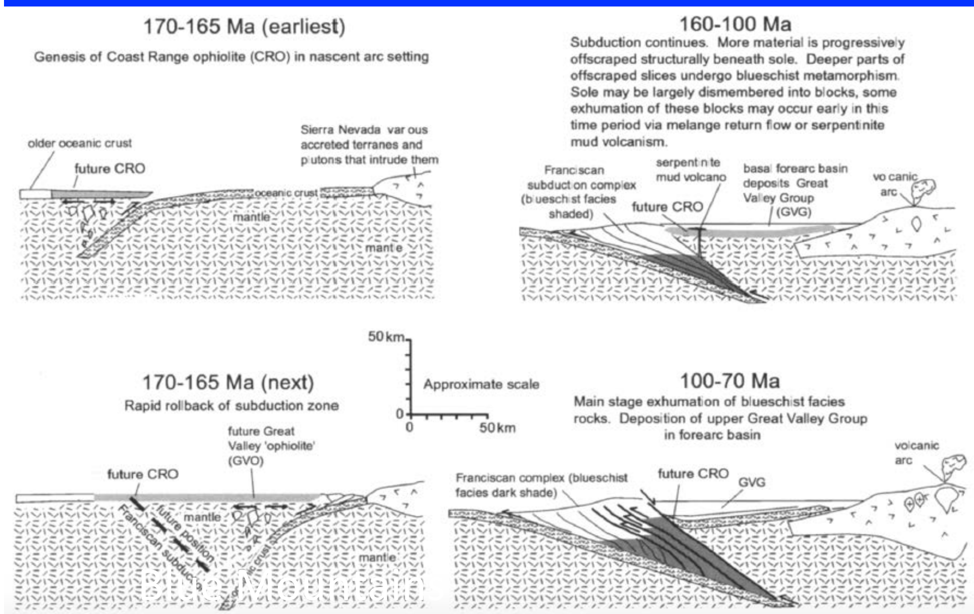
LaMaskin et al 2011

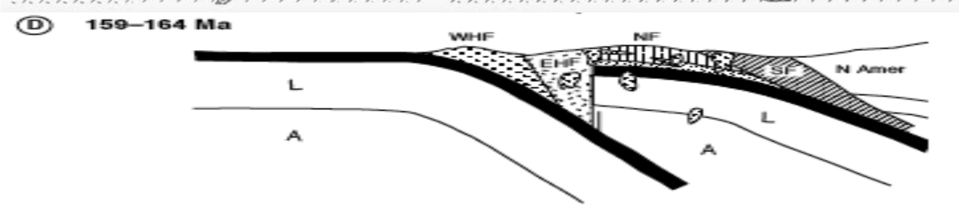
Data used in terrane analysis

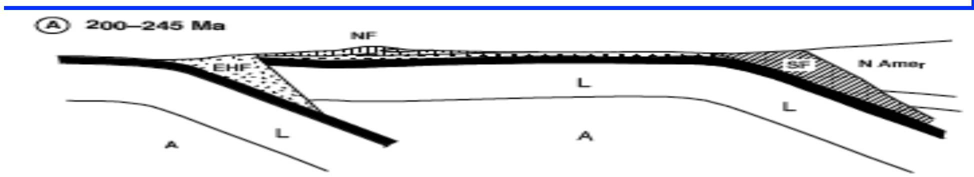
- Stratigraphy
- Paleontology
- Geochemistry
- Igneous rock correlations
- Age dating
- Structural relations
- Paleomagnetism

Mesozoic Subduction on the Cordilleran Margin

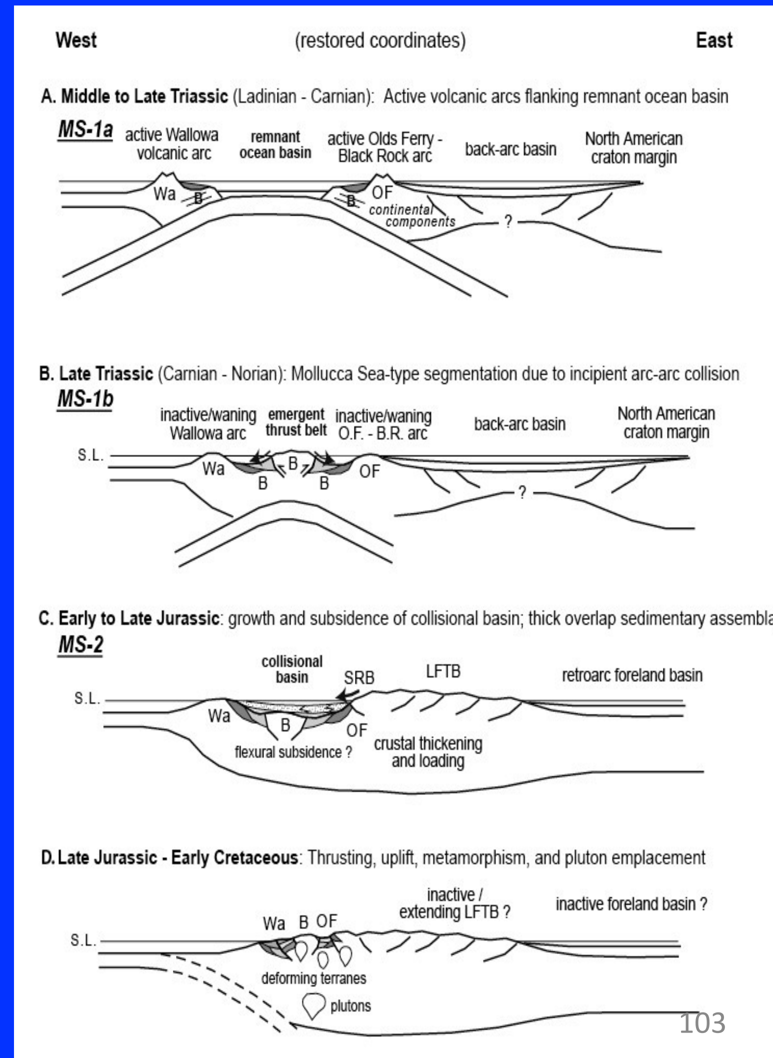
Western Sierras







Klamaths



What is the relationship between the Blue Mountain and Klamath Provinces?

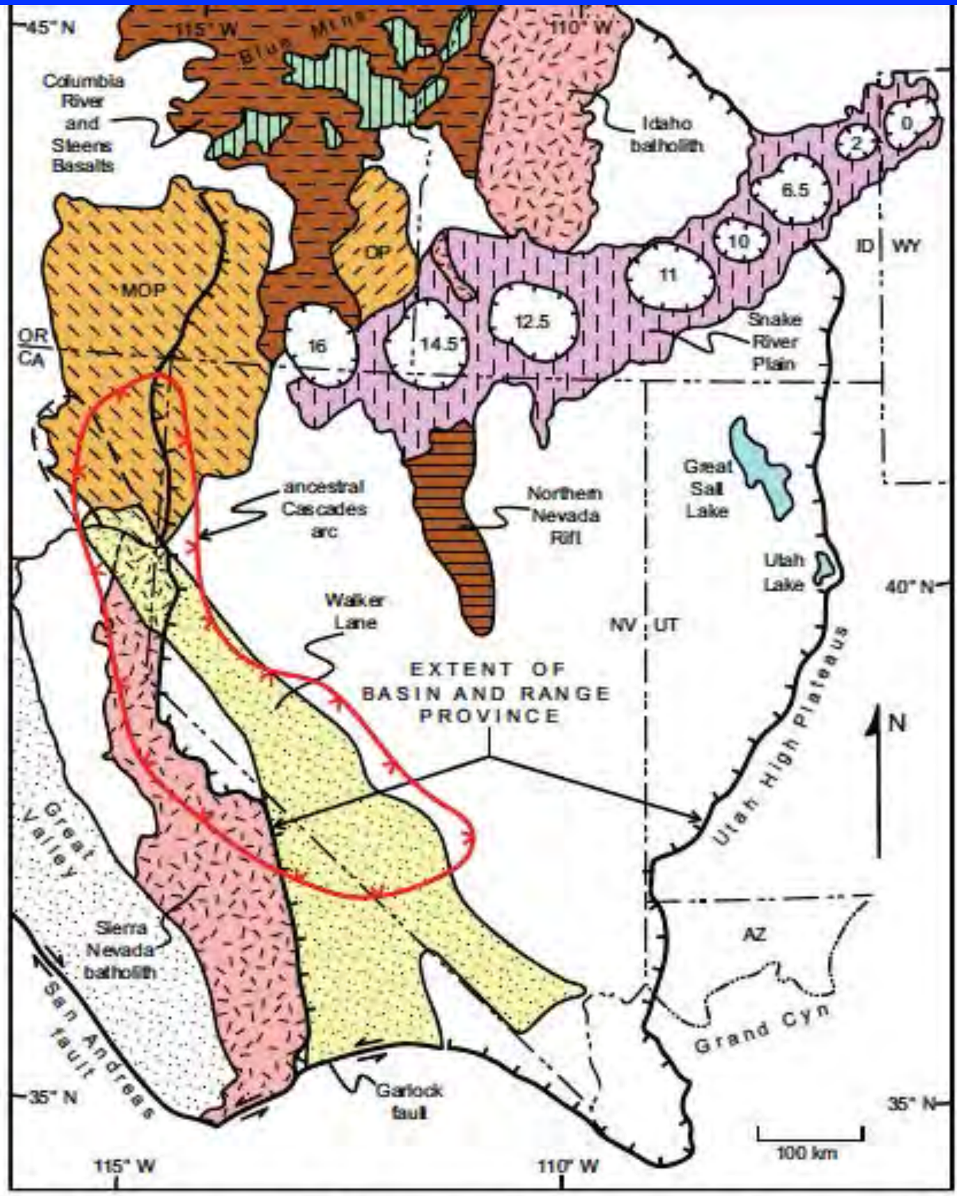


Figure 1. Modern geography of Neogene (<20 Ma) tectonomagmatic features within and adjacent to the Great Basin (coextensive in Nevada and Utah with the Basin and Range province). Walker Lane of distributed dextral transform shear and transrotation after Faulds

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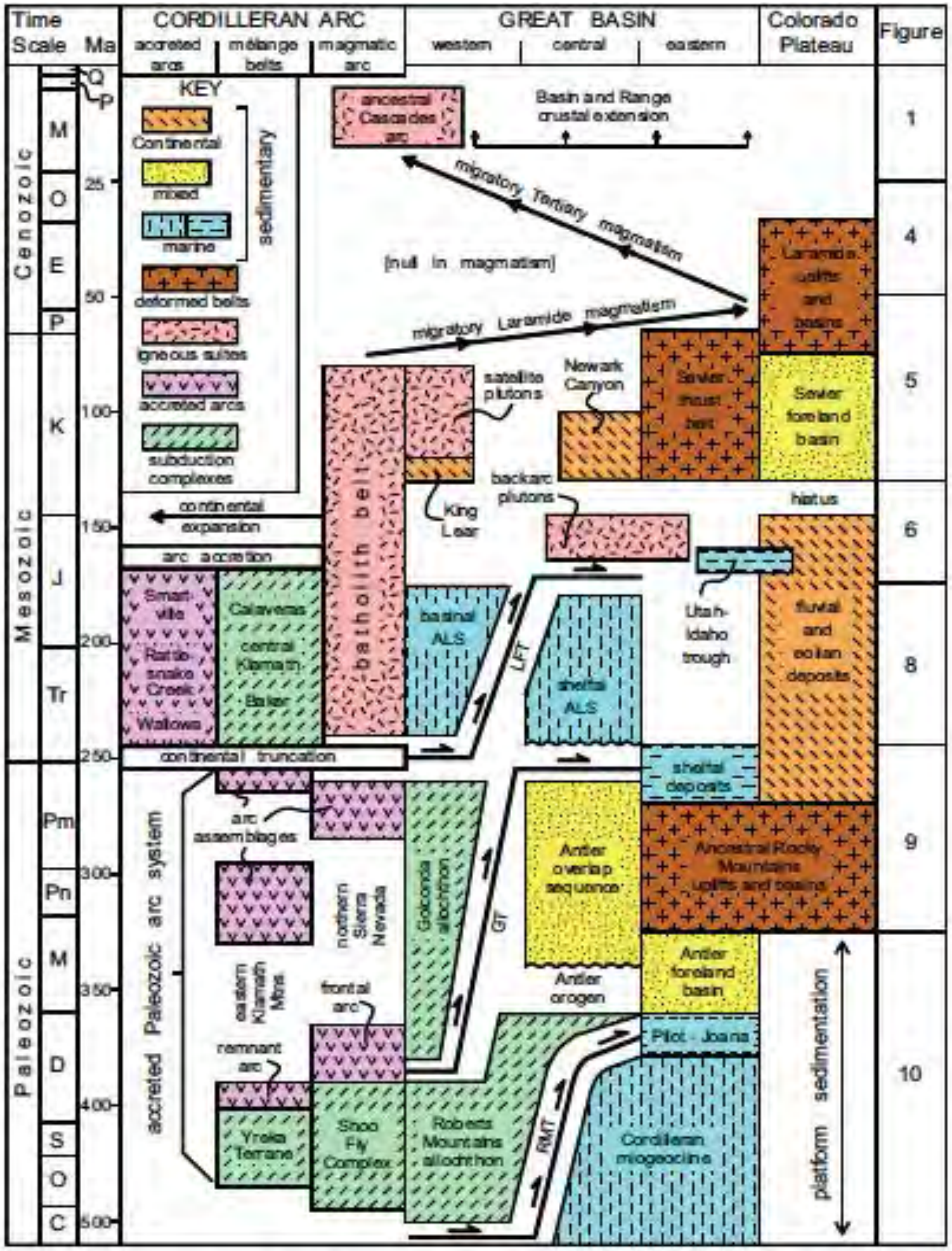

Figure 2. Chronostratigraphic diagram of lithic assemblages in the Great Basin and adjoining regions to the west (left) and east (right). Time scale (note scale changes at 50 Ma and

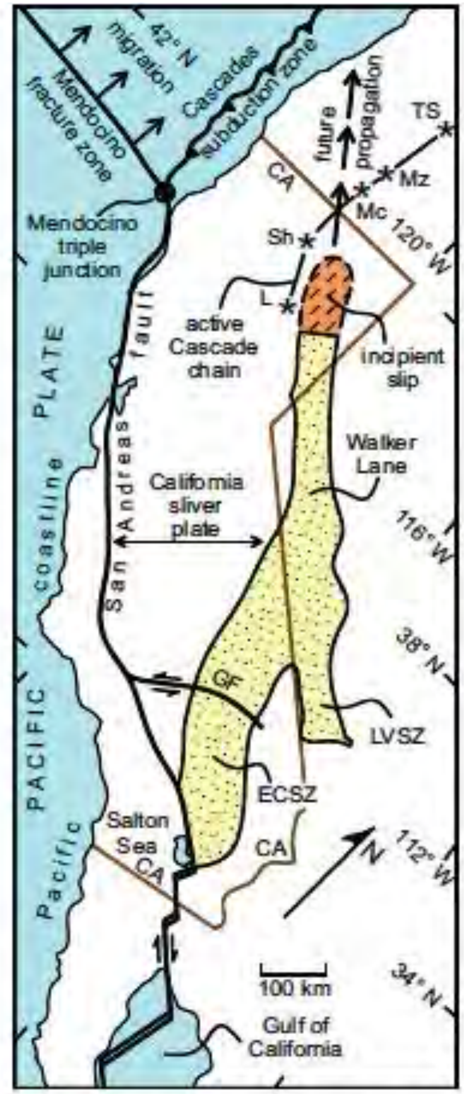

Figure 3. Geodynamic relations of the Walker Lane to the San Andreas transform fault. Heavy double lines are spreading centers linked to opening of the Gulf of California. Asterisks are Quaternary High Cascades volcanoes (L—Lassen Peak; Mc—Mount McLoughlin; Mz—Mount Mazama; Sh—Mount Shasta; TS—Three Sisters). Heavy

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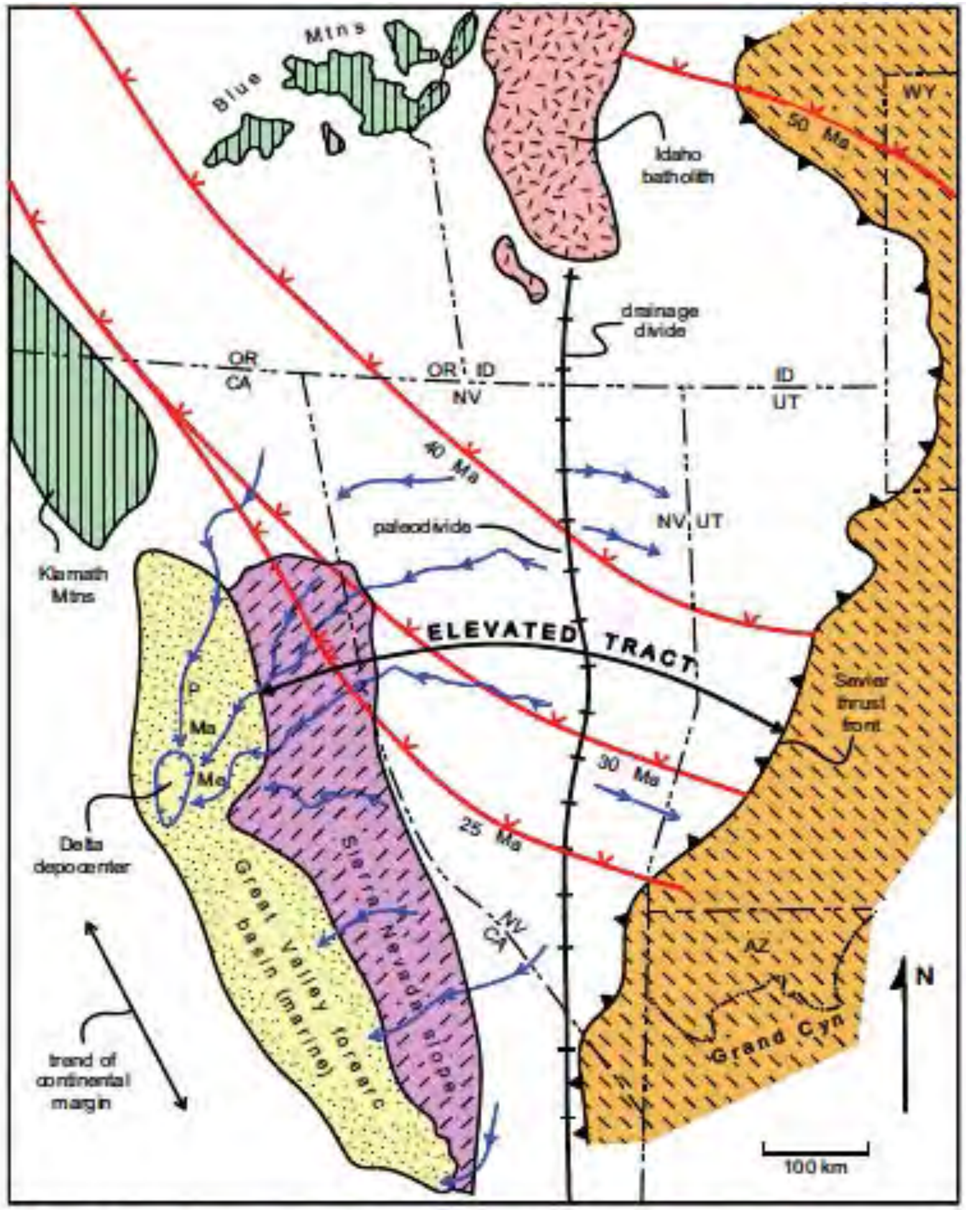

Figure 4. Early Eocene to Early Miocene (50–20 Ma) tectonomagmatic relations across the site of the younger Great Basin prior to Neogene Basin and Range extension. The elevated tract (curving double-headed arrow) included the Sierran slope, Nevadaplano, and Sevier thrust belt. Barbed blue lines denote principal paleodrainages including terrestrial paleovalleys of the Nevadaplano (Henry, 2008; Henry et al., 2012) linked locally to submarine canyons (Ma—Markley; Me—Meganos; P—Princeton) leading into the Delta depocenter (Dickinson et al., 1979) of the Great Valley forearc basin. Red lines are successive volcanic

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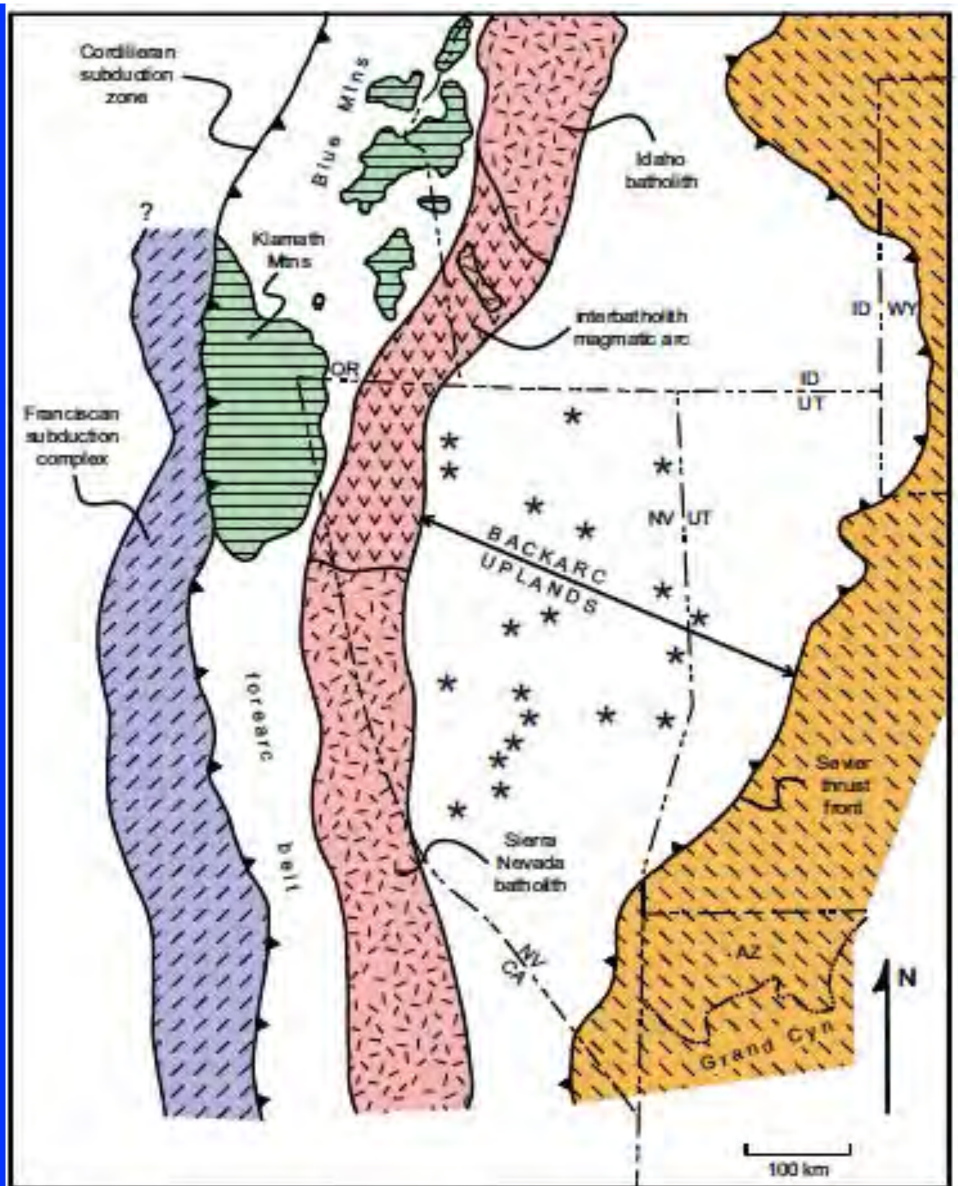

Figure 5. Early Cretaceous to Paleogene (130–50 Ma) tectonomagmatic relations spanning the intermountain region (Great Basin and environs) depicted on paleogeography after Sevier thrusting and late Mesozoic forearc displacements, but before Basin and Range extension. Batholith belt shown for ≥75 Ma. Asterisks denote isolated Laramide (≤75 Ma) plutons (Stewart, 1980; Barton, 1990; du Bray, 2009; Hintze and Kowallis, 2009) emplaced during the inland sweep of magmatism associated with shallow slab descent beneath the Cordillera. Isolated exposures of Lower Cretaceous (Fig. 2) and Upper Cretaceous to Eocene strata in Nevada (Vandervoort and Schmitt, 1990; Martin et al., 2010; Druschke et al., 2011) are not

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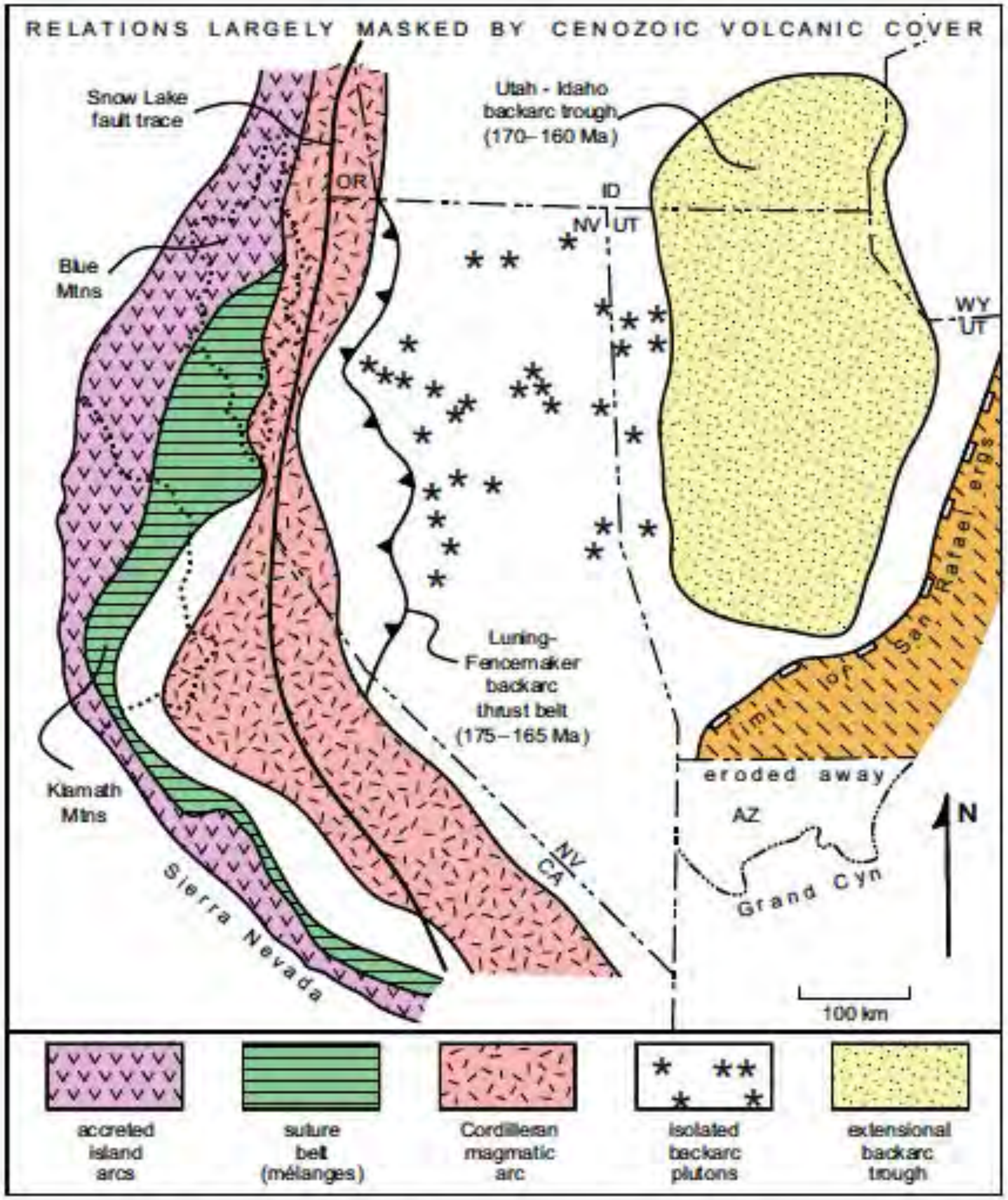

Figure 6. Middle Jurassic to Early Cretaceous (175–130 Ma) tectonomagmatic relations from the Sierra Nevada to the Colorado Plateau depicted on paleogeography before Sevier thrusting and Cretaceous dextral slip along the Snow Lake fault (dotted outlines show

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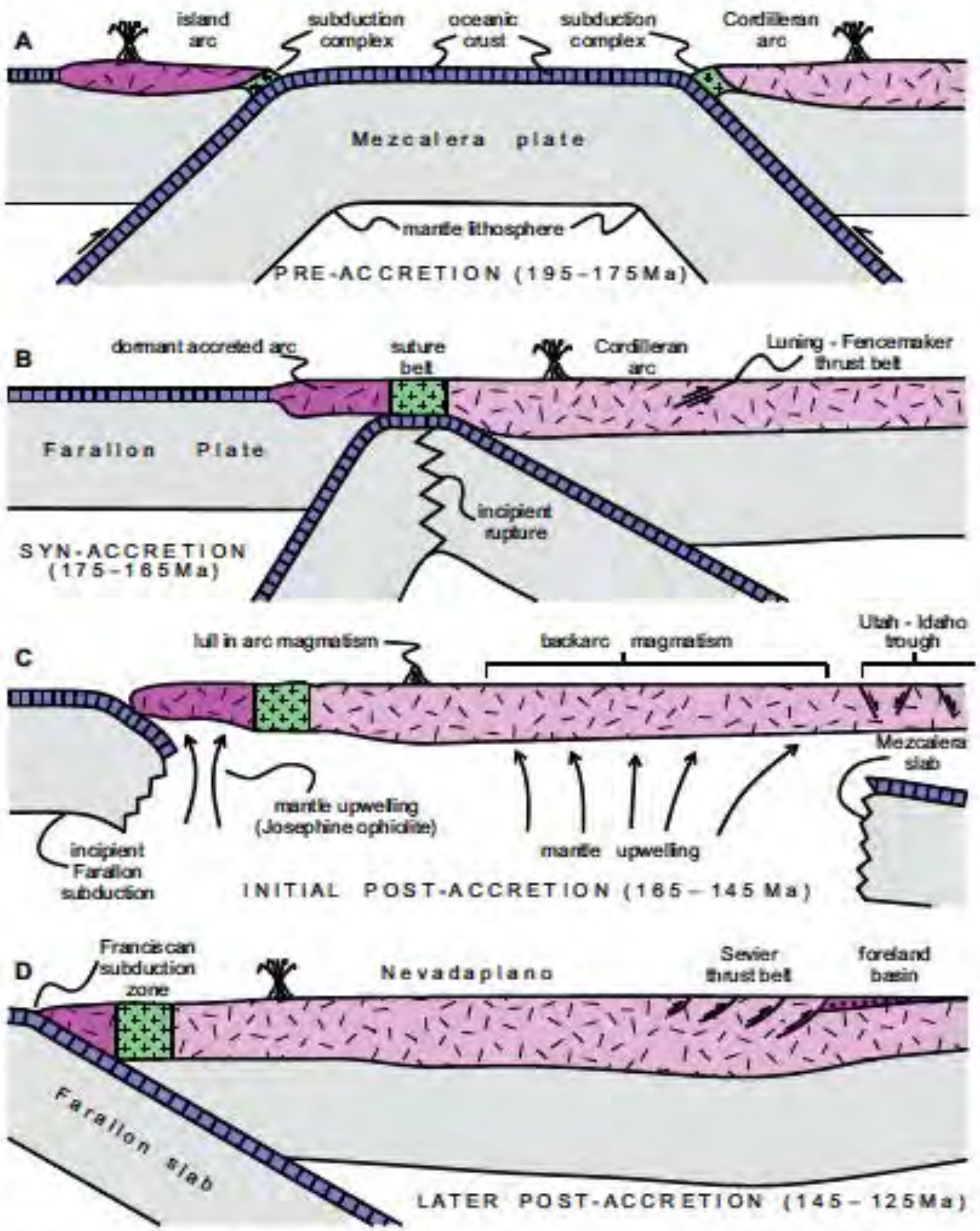

Figure 7. Speculative geodynamic scenario (sequential events A–D) for middle Mesozoic arc accretion, transient backarc thrusting, widespread backarc plutonism, and backarc extensional tectonism at the latitude of the Great Basin and Klamath Mountains (as restored palinspastically). Mezcalera plate after Dickinson and Lawton (2001) and Sigloch and Mihalynuk (2013).

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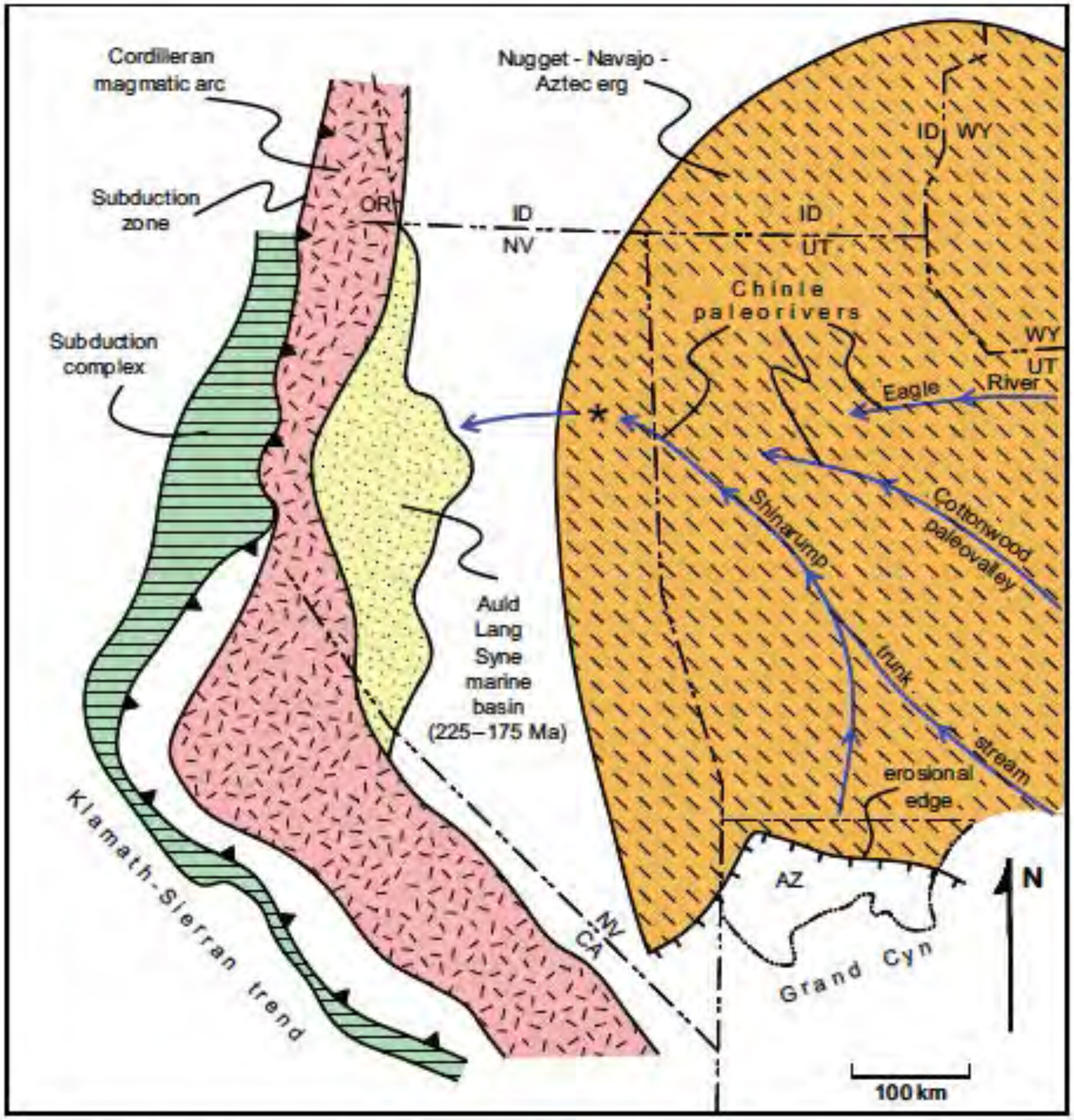

Figure 8. Middle Triassic to Early Jurassic (245–175 Ma) tectonomagmatic relations across the intermountain region. Asterisk denotes Currie outlier (Stewart, 1980, his figures 33 and 35) of Mesozoic Colorado Plateau stratigraphic units. Extent of erg after Dickinson and Gehrels (2010). Chinle paleorivers after Dickinson et al. (2010). See Figure 1 for the states shown (boundaries distorted) and Figure 2 for the time span depicted.

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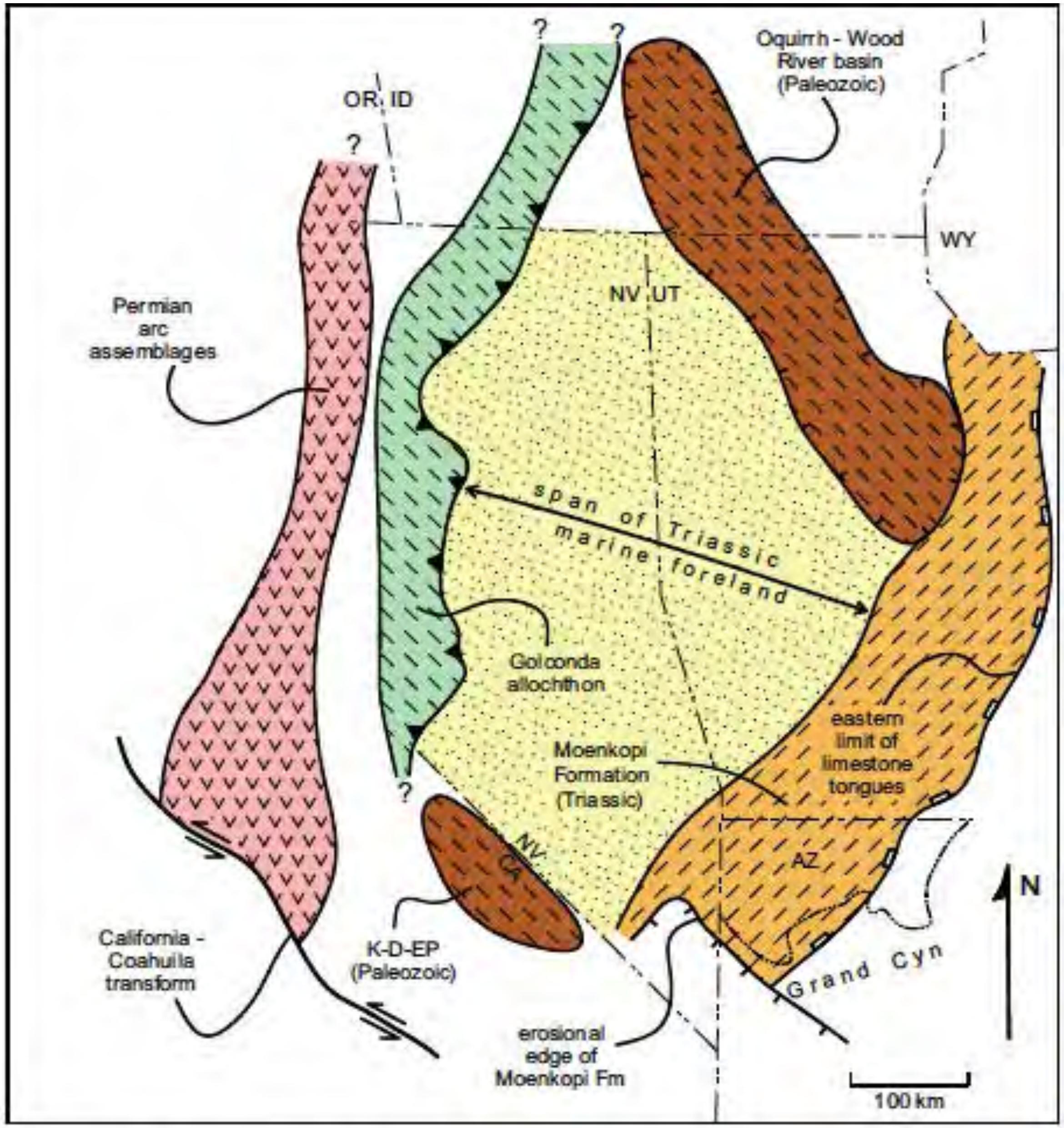

Figure 9. Mississippian to Early Triassic (325–245 Ma) tectonomagmatic relations across the intermountain region. Selected late Paleozoic depocenters: Oquirrh–Wood River basin (Geslin, 1998; Hintze and Kowallis, 2009); Keeler–Darwin–El Paso (K-D-EP) basin cluster (Stevens et al., 1997, 2005; Stevens and Stone, 2007). See Figure 1 for the states shown (boundaries distorted) and Figure 2 for the time span depicted.

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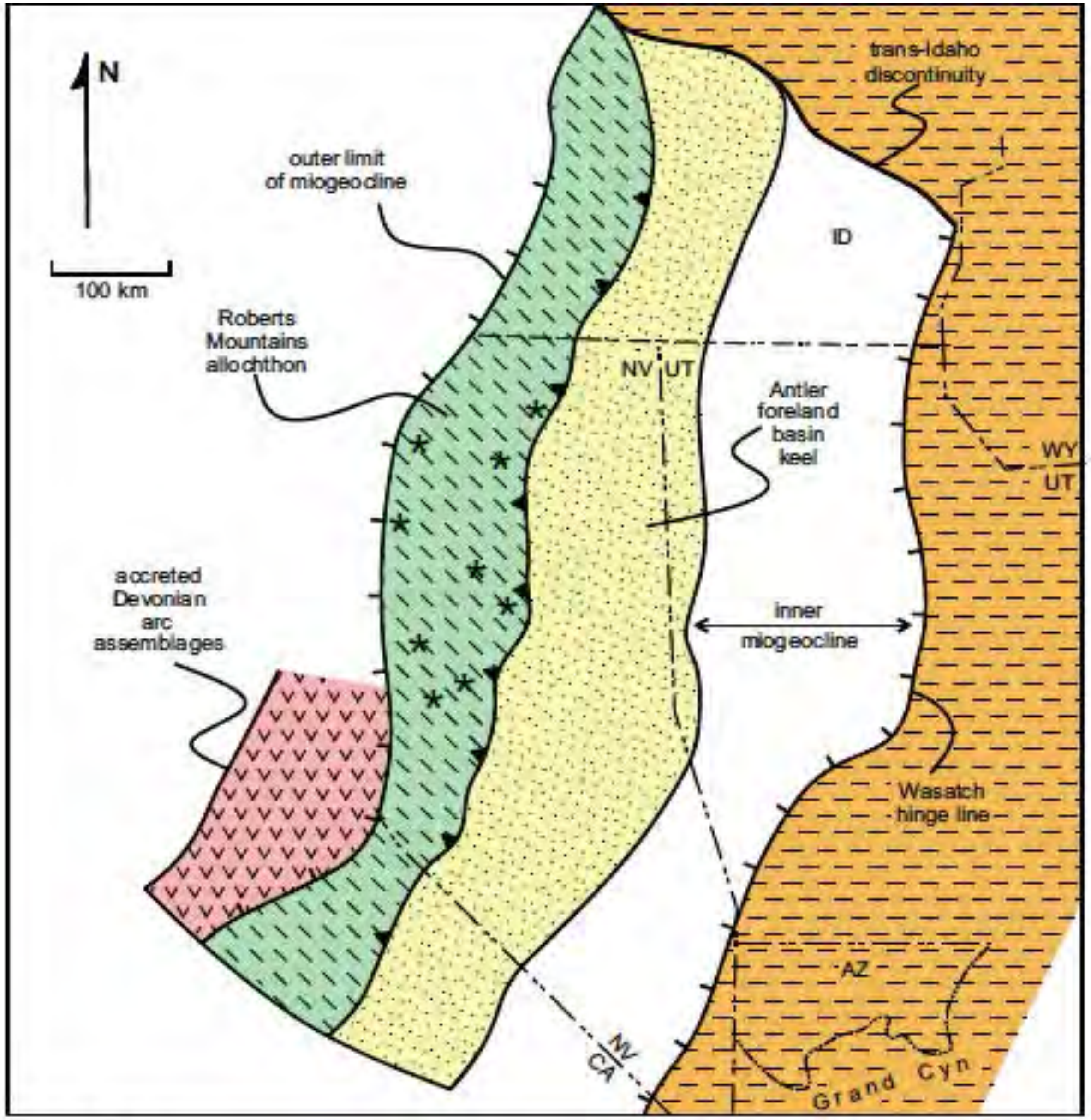

Figure 10. Early Cambrian to Mississippian (520–325 Ma) tectonomagmatic relations across the intermountain region. Asterisks denote fensters of miogeoclinal strata exposed beneath the overthrust Roberts Mountains allochthon. The trans-Idaho discontinuity is adapted after Yates (1968). See Figure 1 for the states shown (boundaries distorted) and Figure 2 for the time span depicted.