Terrane

- A crustal block bounded by faults
- Preserves a geologic history that is distinct from adjacent terranes
- Accreted by tectonic processes

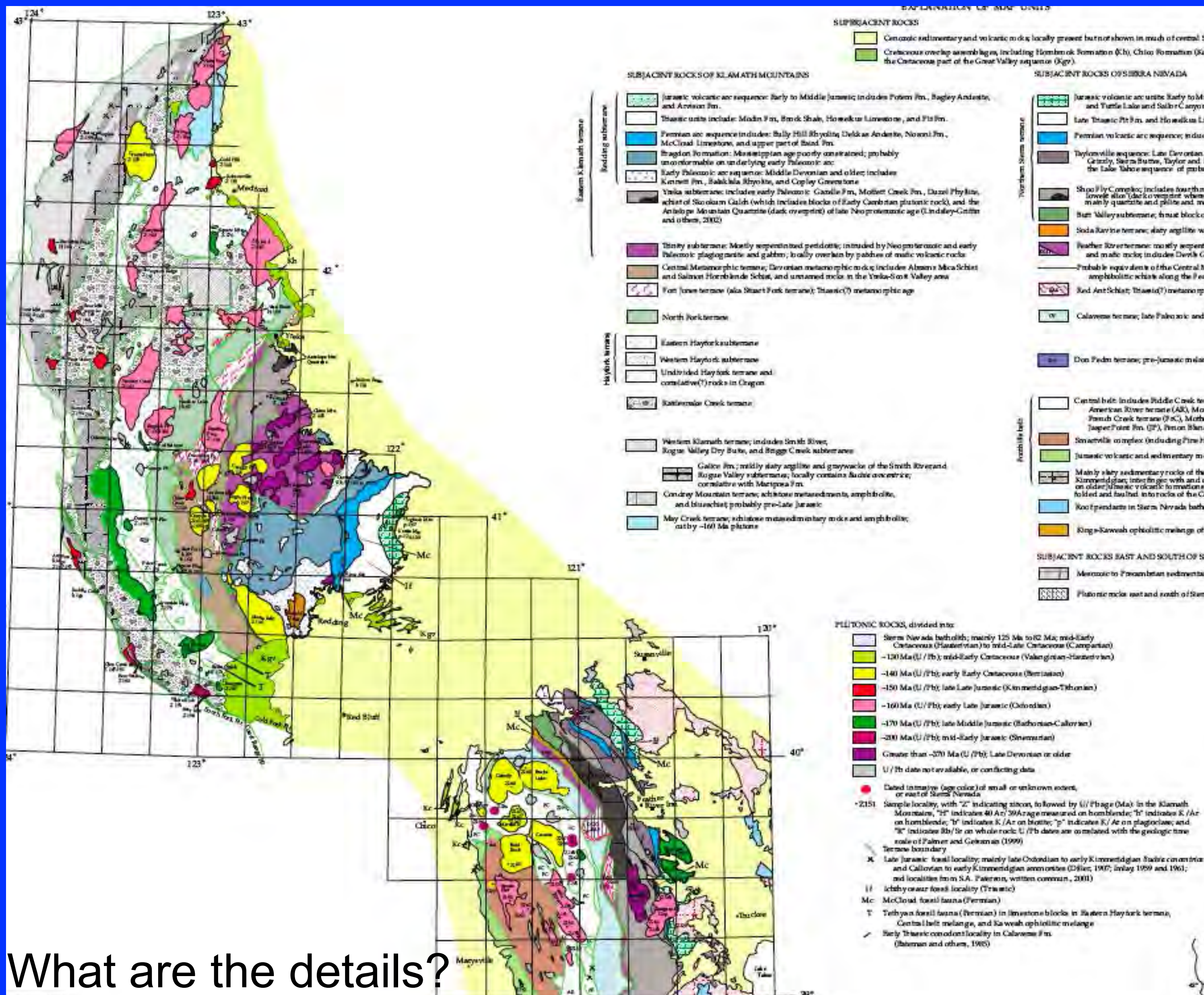
India is a Terrane within Asia

Terrane

- A crustal block bounded by faults
- Preserves a geologic history that is distinct from adjacent terranes
- Accreted by tectonic processes

What Data Do We Use?

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



What are the details?

But why worry about this?

Consider some
charts found here

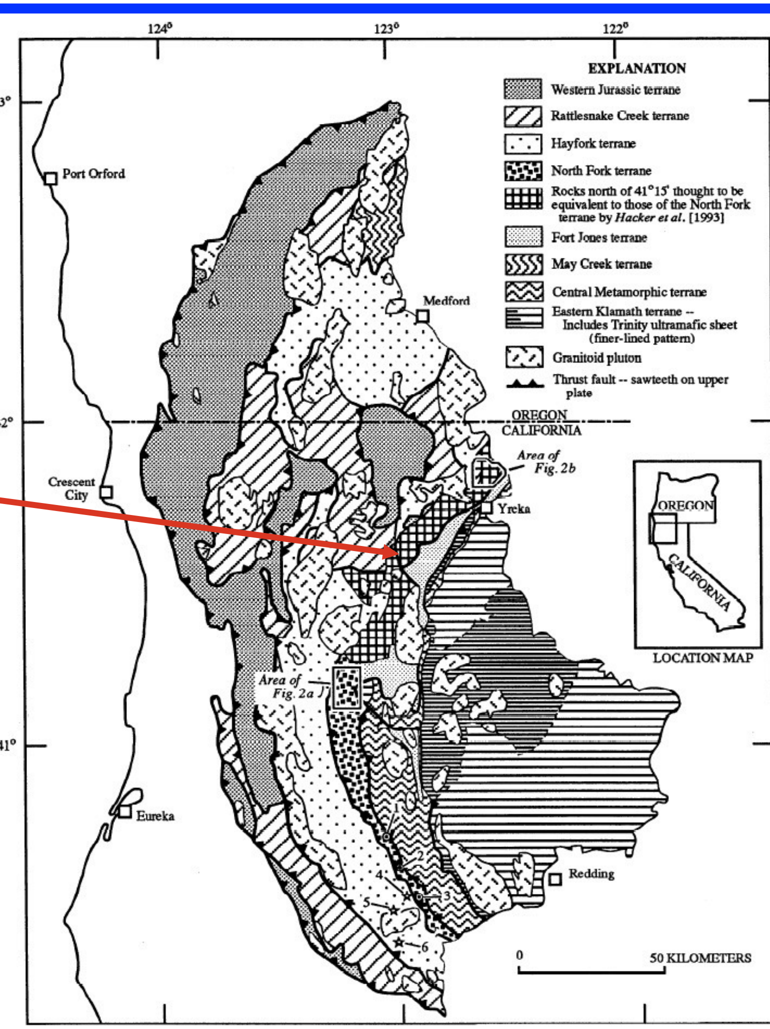
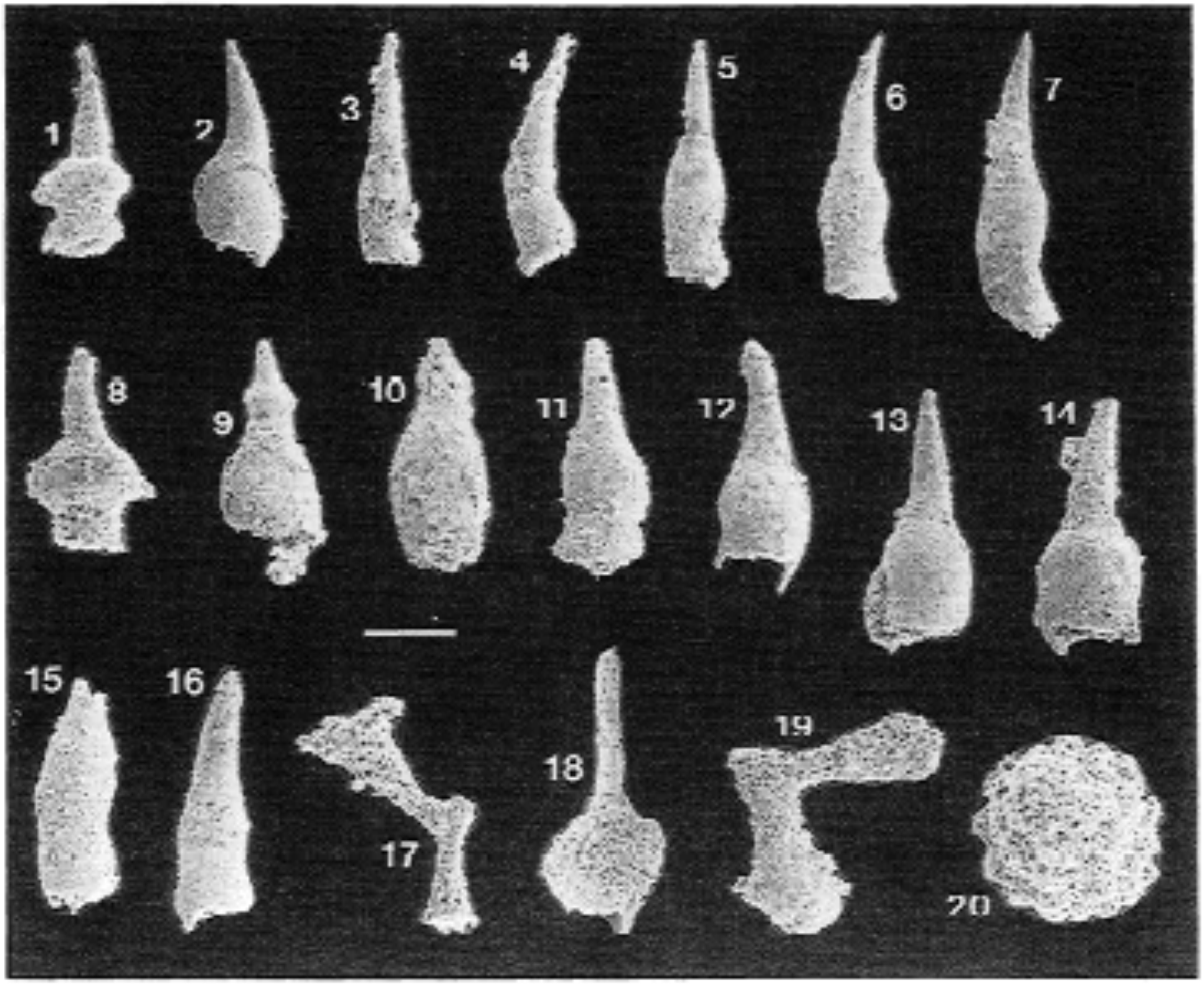


Figure 1. Sketch showing principal terranes of the Klamath Mountains province and areas sampled for paleomagnetism and paleontology. Dots are localities within the North Fork terrane with a schwagerinid fusulind fauna; stars are localities within the Eastern Hayfork terrane with a Tethyan foraminiferal fauna. Localities are 1, Mill Creek (40.71°N, 123.06°W) *Irwin* [1974] Location 1; R.C. Douglass (written communication 1972); 2, Hayfork Summit (40.61°N, 123.00°W) *Irwin* [1974] Location 4; *Luken* [1985] Location 5; 3, Brown's Creek (40.52°N, 122.94°W) R.C. Douglass, as given by *Irwin* [1972]; 4, East Fork Hayfork Creek (40.51°N, 122.98°W) *Luken* [1985] Location 12; 5, Potato Creek (40.47°N, 123.03°W) *Irwin et al.* [1985] Location 3; *Nestell et al.* [1981]; 6, Hall City Cave (40.41°N, 123.01°W) *Irwin et al.* [1985] Locations 7 and 9; *Luken* [1985] Location 24; *Nestell et al.* [1981]. Figure 1 is adapted from *Irwin* [1989] and *Hacker et al.* [1993].

Mankinen et al 1996

Paleontology Data



e 4. All figures are scanning electron photomicrographs of the radiolarians from site 2 near Willi
; fauna are assignable to the Late Permian *Follicucullus japonicus* Zone of *Ishiga* [1991]. Bar scal

Radiolarians:

Permian Age

Sub-tropical environment

Mankinen et al 1996

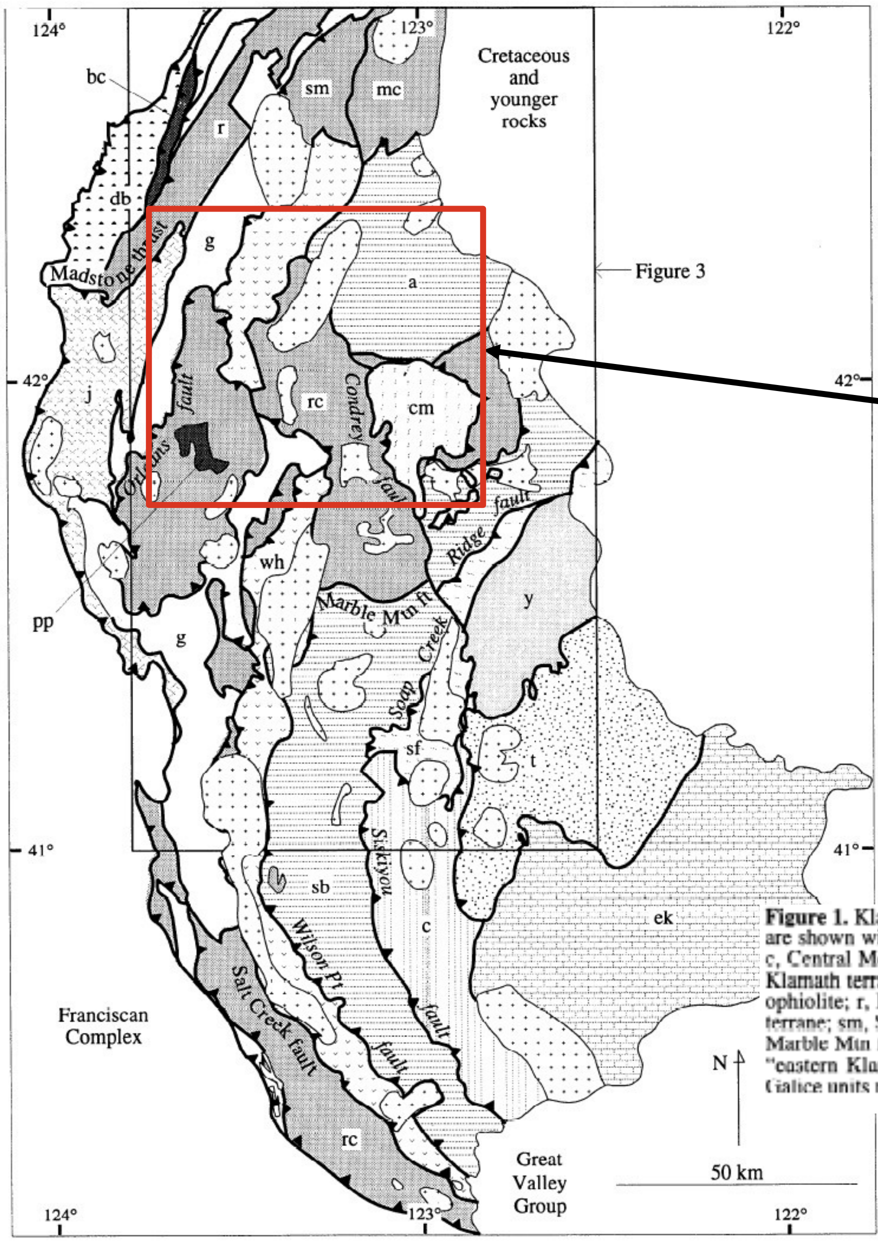
These cherts were deposited 10° north of the equator, and then moved another 10° north relative to North America.

So perhaps they sit within a terrane that later accreted to North America.

Figure 12. Dashed line shows indicated paleolatitude for deposition of Permian chert of the North Fork terrane assuming the northern hemisphere option, and the shaded area is its 95% confidence interval. Star shows the present-day position of the Klamath Mountains province.

Mankinen et al 1996

Lithology and Stratigraphy

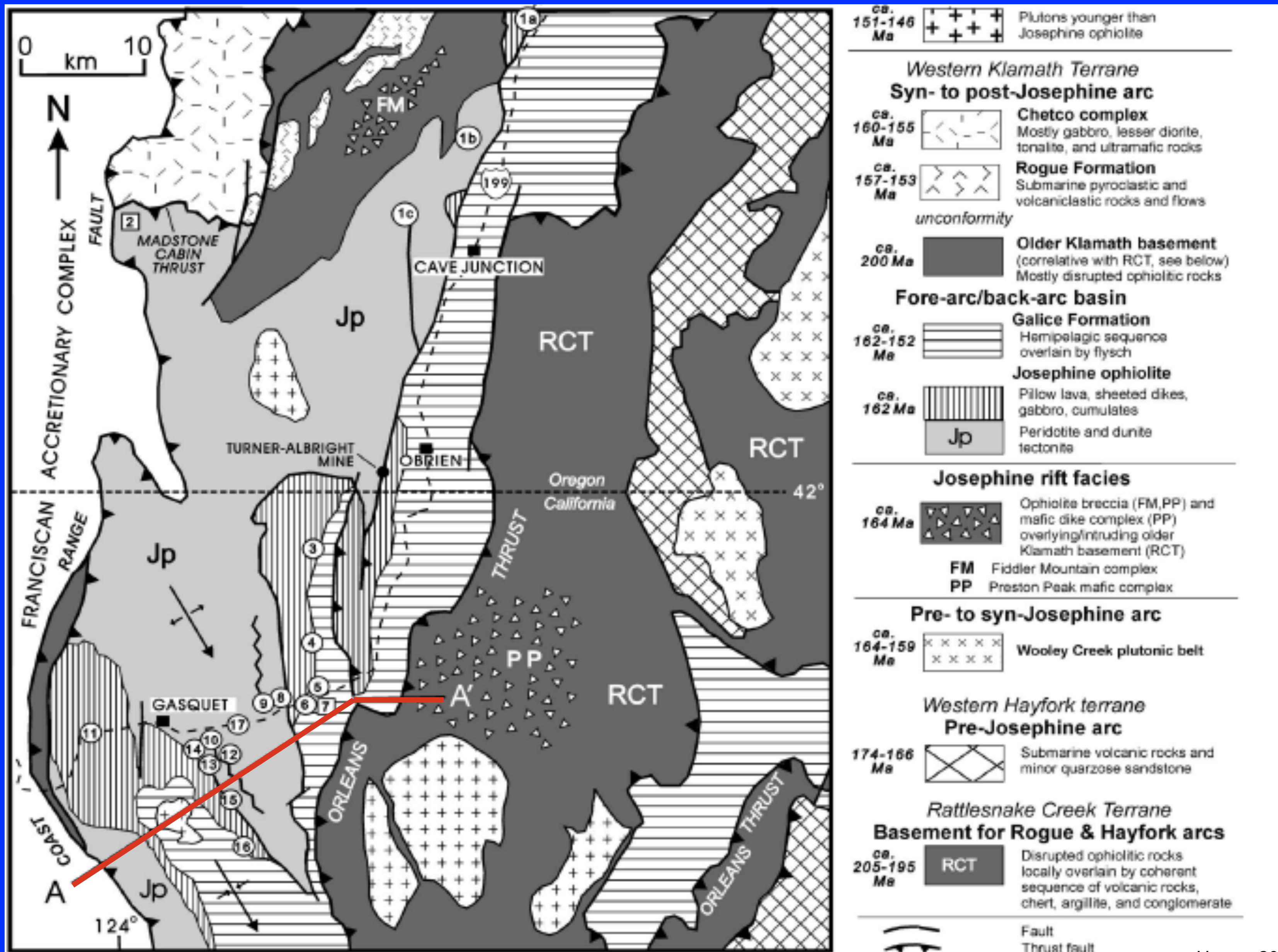


Here is a simplified map

Consider the ophiolites either side of the Cal-Or border.

Figure 1. Klamath Mountains rock units [after *Hacker and Ernst*, 1993]. Potentially correlative terranes are shown with identical patterns. Abbreviations are a, Applegate terrane; bc, Briggs Creek subterrane; c, Central Metamorphic terrane; cm, Condrey Mountain terrane; db, Dry Butte subterrane; ek, Eastern Klamath terrane; g, Galice Formation; j, Josephine ophiolite; mc, May Creek terrane; pp, Preston Peak ophiolite; r, Rogue Formation, rc, Rattlesnake Creek terrane; sb, Sawyers Bar terrane; sf, Stuart Fork terrane; sm, Sexton Mountain terrane; t, Trinity terrane; wh, Western Hayfork terrane; y, Yreka terrane; Marble Mtn flt, Marble Mountains fault. The Yreka, Trinity, and Eastern Klamath terranes compose the "eastern Klamaths" referred to in the text, and the Dry Butte, Rogue, Briggs Creek, Josephine, and Galice units make up the western Klamath terrane.

Hacker et al 1995

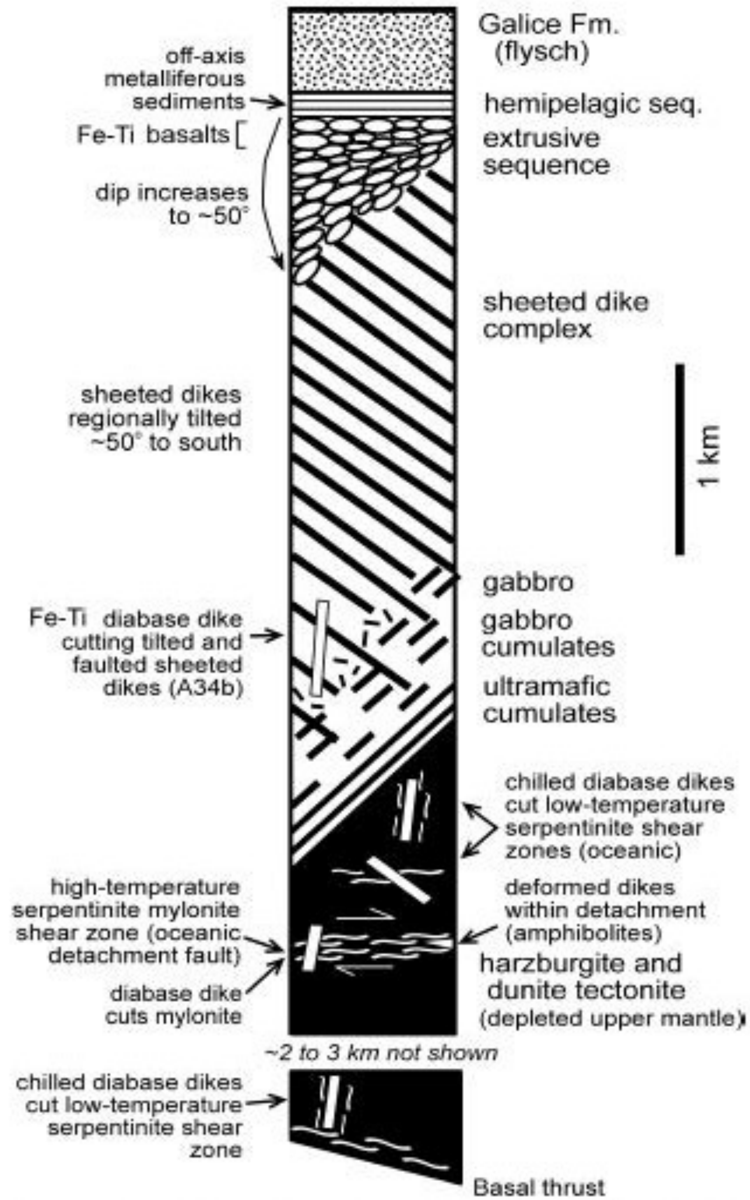


0 km 10
N
ACCRETIONARY COMPLEX
FAULT
MADSTONE CABIN THRUST
FRANCISCAN RANGE
FM
1a
1b
1c
199
CAVE JUNCTION
Jp
RCT
TURNER-ALBRIGHT MINE
OBRIEN
Oregon
California
42°
THRUST
PP
A'
A
GASQUET
ORLEANS
ORLEANS THRUST
COAST
124°
ca. 151-146 Ma
Plutons younger than Josephine ophiolite
Western Klamath Terrane
Syn- to post-Josephine arc
ca. 160-155 Ma
Chetco complex
Mostly gabbro, lesser diorite, tonalite, and ultramafic rocks
ca. 157-153 Ma
Rogue Formation
Submarine pyroclastic and volcaniclastic rocks and flows
unconformity
ca. 200 Ma
Older Klamath basement
(correlative with RCT, see below) Mostly disrupted ophiolitic rocks
Fore-arc/back-arc basin
ca. 162-152 Ma
Galice Formation
Hemipelagic sequence overlain by flysch
Josephine ophiolite
ca. 162 Ma
Pillow lava, sheeted dikes, gabbro, cumulates
Jp
Peridotite and dunite tectonite
Josephine rift facies
ca. 164 Ma
Ophiolite breccia (FM,PP) and mafic dike complex (PP) overlying/intruding older Klamath basement (RCT)
FM Fiddler Mountain complex
PP Preston Peak mafic complex
Pre- to syn-Josephine arc
ca. 164-159 Ma
Wooley Creek plutonic belt
Western Hayfork terrane
Pre-Josephine arc
174-166 Ma
Submarine volcanic rocks and minor quarzose sandstone
Rattlesnake Creek Terrane
Basement for Rogue & Hayfork arcs
ca. 205-195 Ma
RCT
Disrupted ophiolitic rocks locally overlain by coherent sequence of volcanic rocks, chert, argillite, and conglomerate
Fault
Thrust fault

Harper 2003

Ophiolite: a slice of ocean crust.

A very common sequence of rocks in the Klamaths.



2. Sequence of lithologies in the Josephine Ophiolite (modified from Harper, 1984,

Harper 2003

MANKINEN ET AL.: FAR-TRAVELLED CHERT OF THE NORTH FORK TERRANE

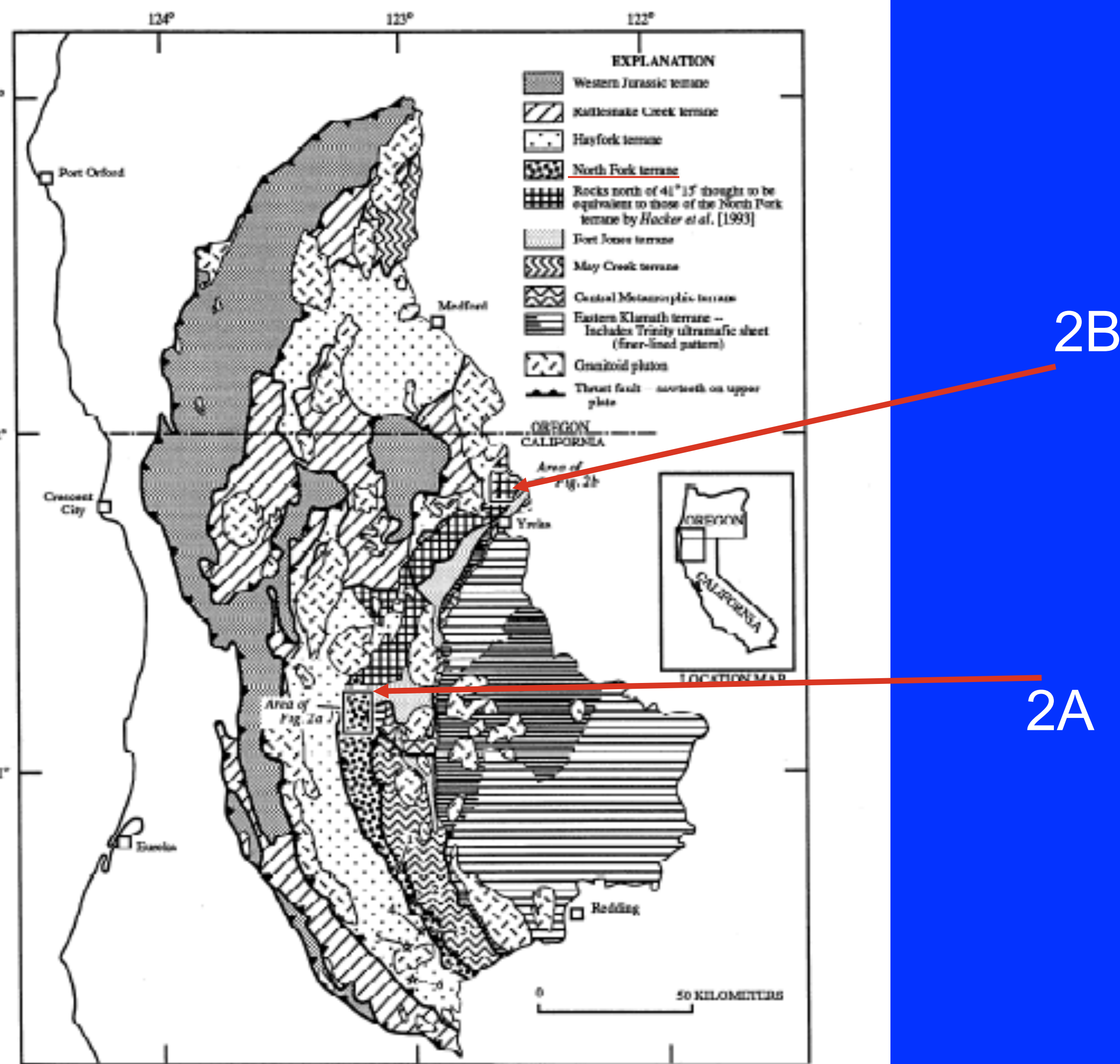
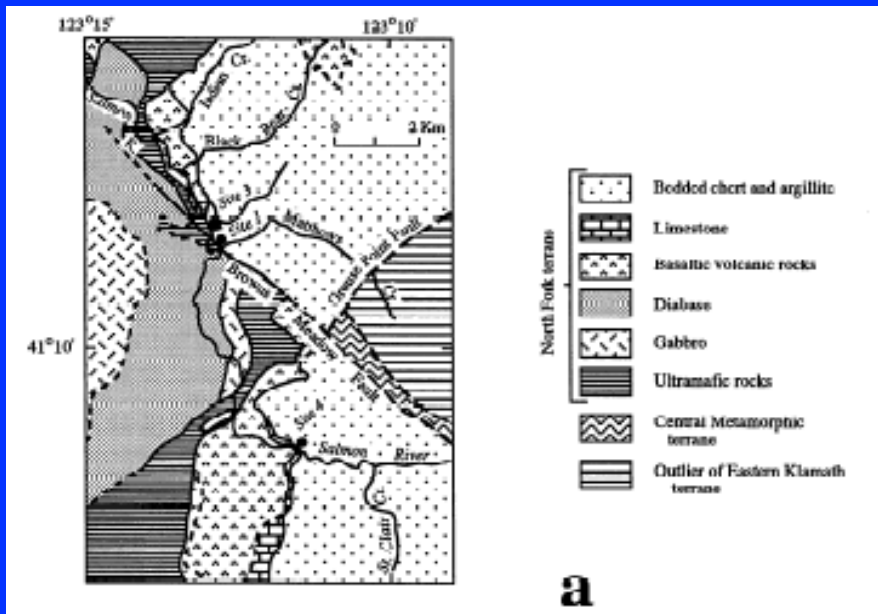


Figure 1. Sketch showing principal terranes of the Klamath Mountains province and areas sampled for paleomagnetism and paleontology. Dots are localities within the North Fork terrane with a schwagerinid fusulind fauna; stars are localities within the Eastern Hayfork terrane with a Tethyan foraminiferal fauna.

More ophiolite sequences



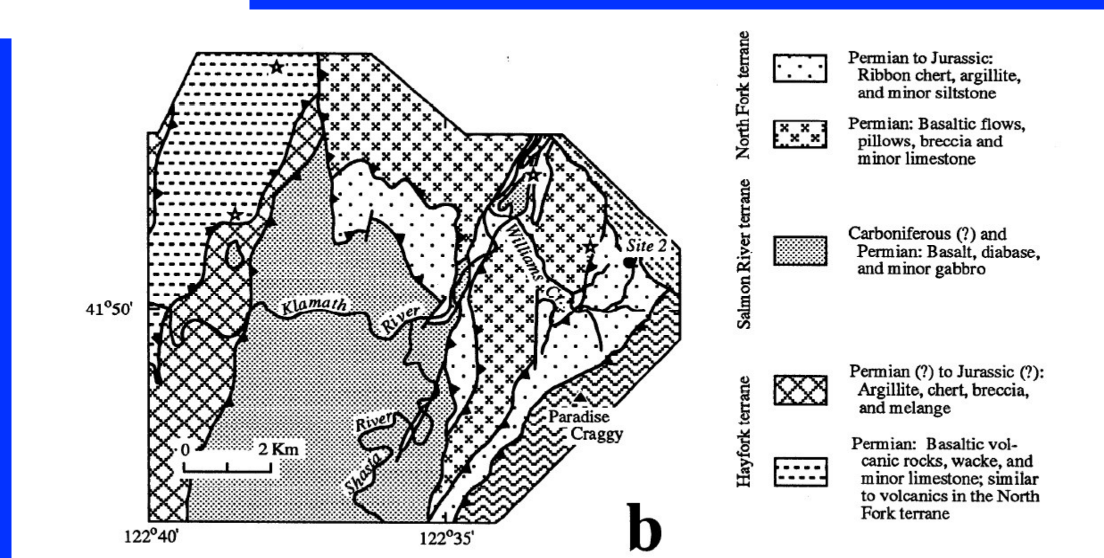
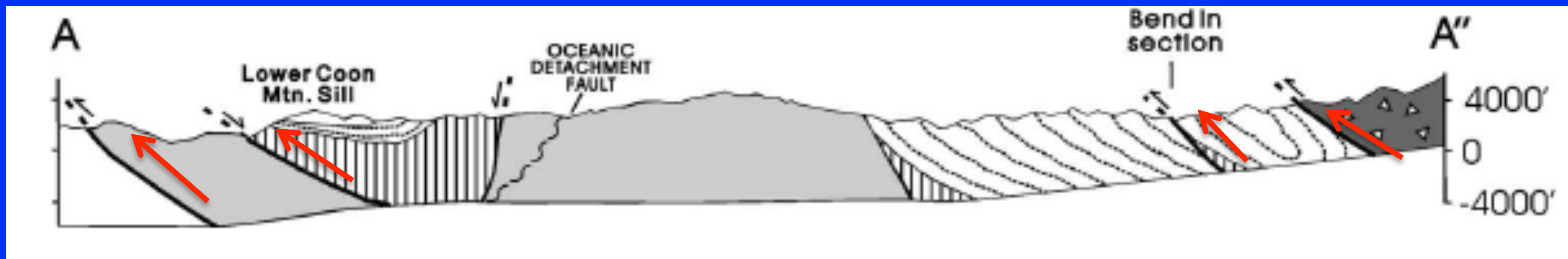
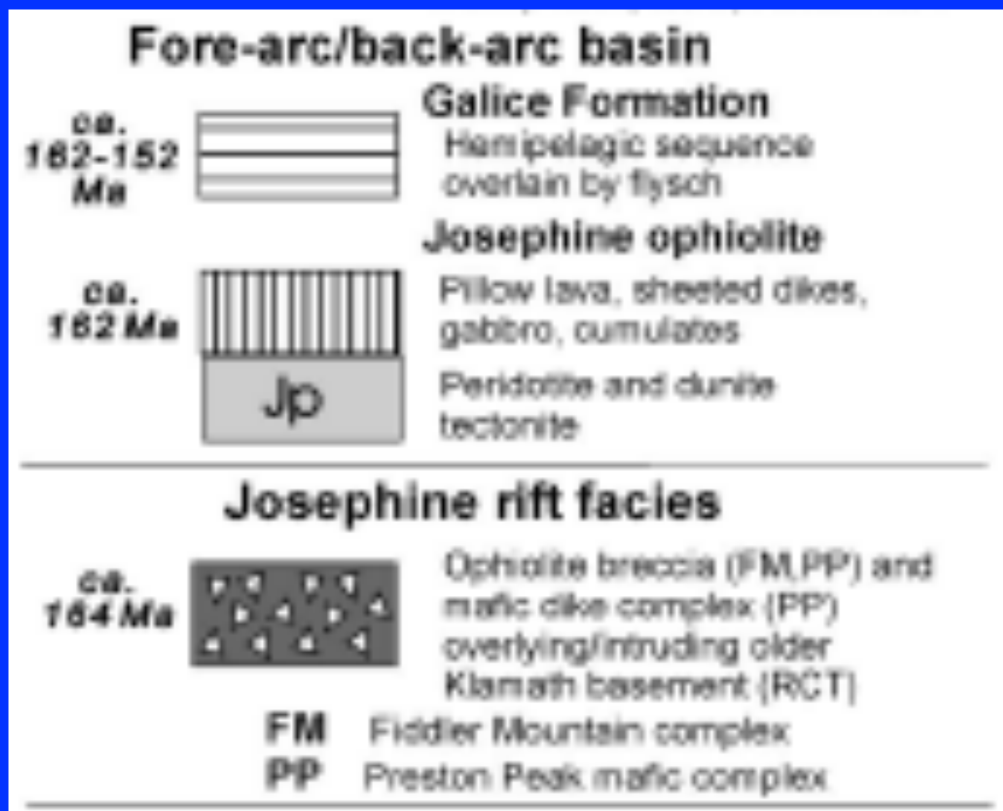


Figure 2. Maps showing areas outlined in Figure 1: (a) Salmon River area showing paleomagnetic sampling sites 1, 3, and 4; adapted from *Ando et al.* [1983] and *Davis* [1968]; (b) Klamath River area north of Yreka showing paleomagnetic sampling site 2. Stars denote locations of fossiliferous limestone discussed in text. Map and terrane assignments are adapted from *Mortimer* [1984].

Makinen 1995

Structural Feld relations





Harper 2003

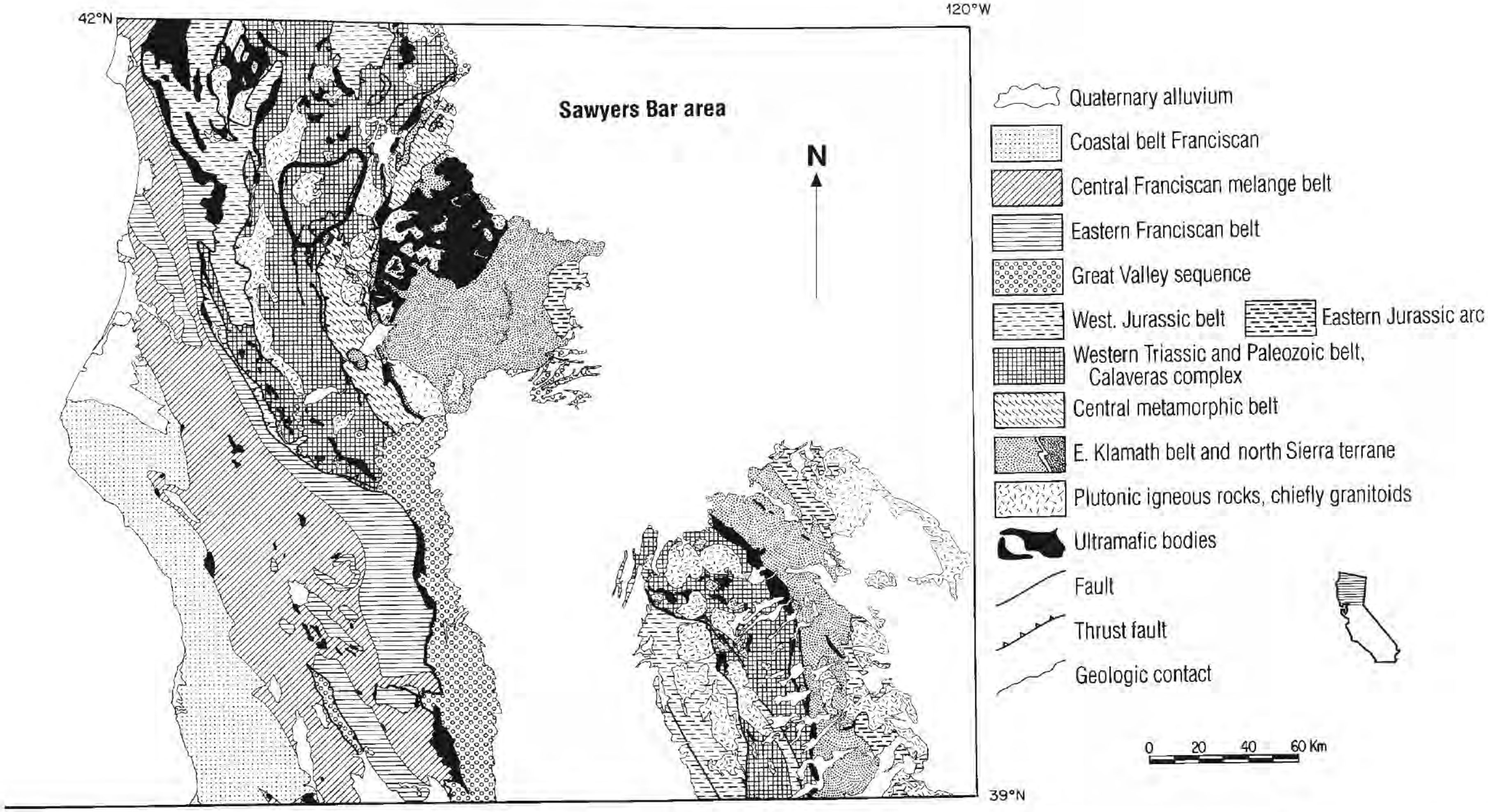
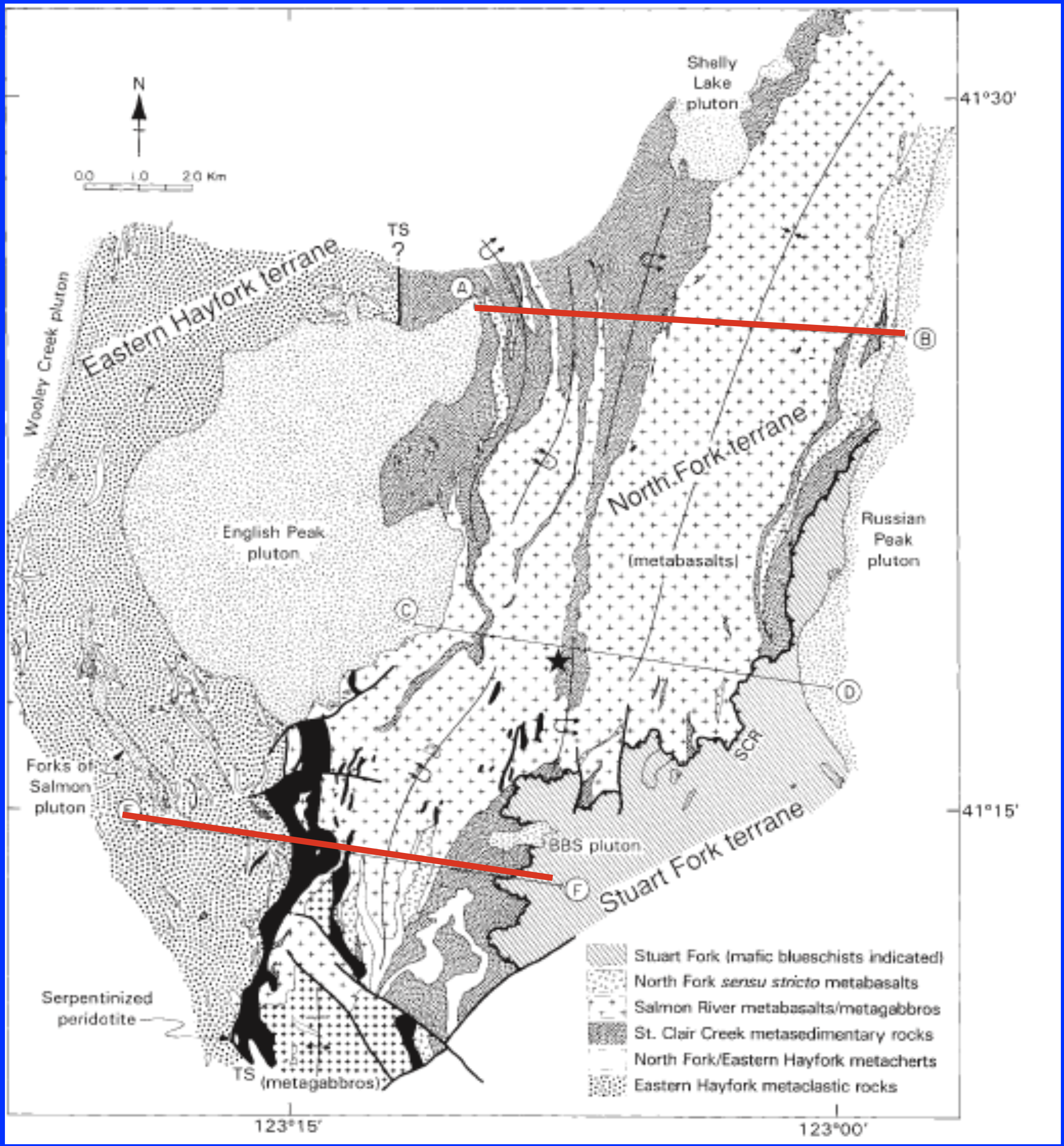
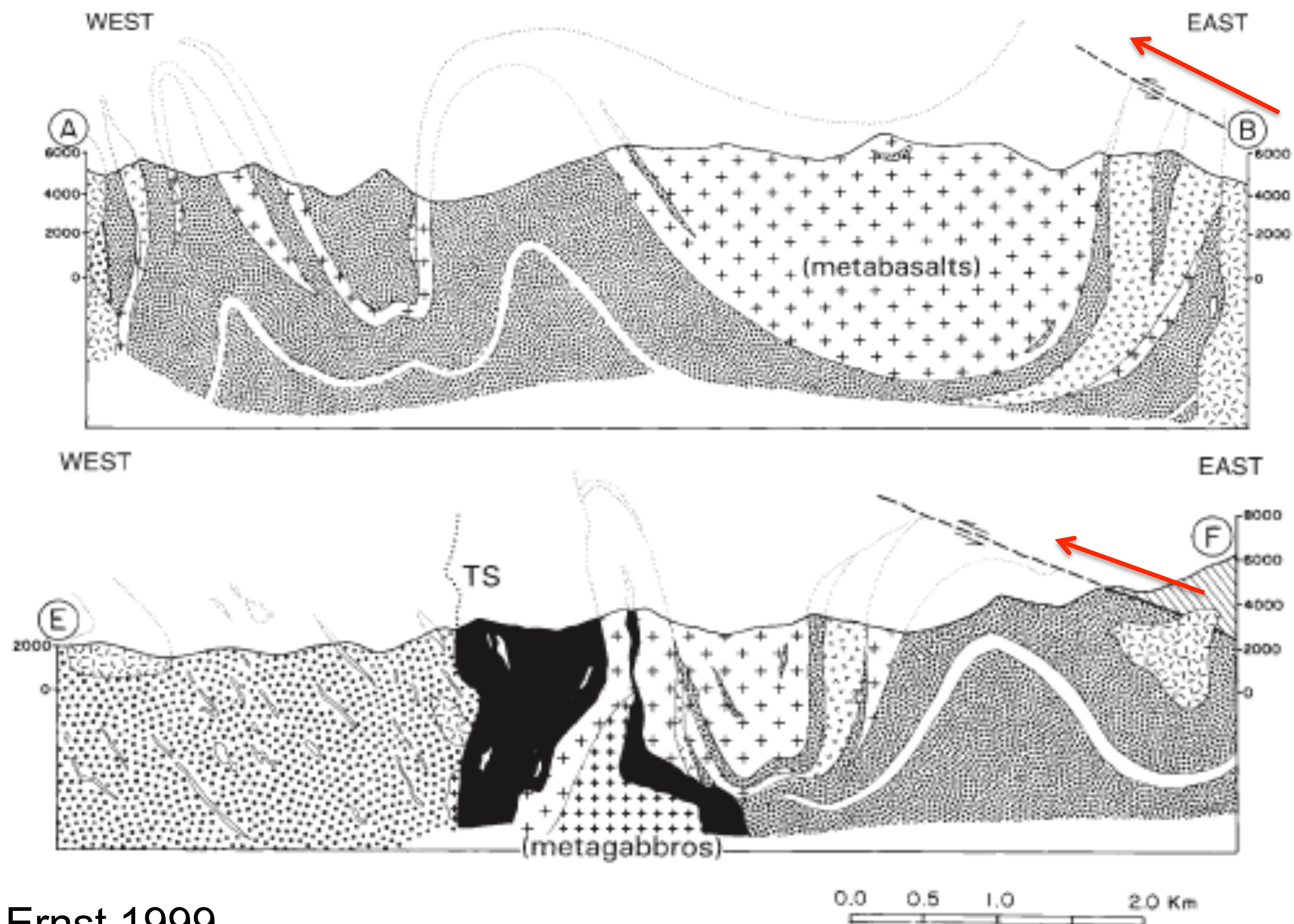


Figure 1. Geologic index map of northernmost California, after Jennings (1977) and Ernst (1983). The disposition of Sierran-Klamath-Franciscan lithotectonic belts reflects progressive seaward continental growth. For simplification in the Klamath Mountains, the Stuart Fork terrane and the Western Triassic and Paleozoic belt are combined.

Ernst 1999


N
0.0 1.0 2.0 Km
Shelly
Lake
pluton
41°30'
TS
?
Eastern Hayfork terrane
Wooley Creek pluton
A
B
North Fork terrane
(metabasalts)
English Peak
pluton
Russian
Peak
pluton
C
D
SCR
Forks of
Salmon
pluton
41°15'
BBS pluton
Stuart Fork terrane
F
Serpentinized
peridotite
TS (metagabbros)
123°15'
123°00'
Stuart Fork (mafic blueschists indicated)
North Fork sensu stricto metabasalts
Salmon River metabasalts/metagabbros
St. Clair Creek metasedimentary rocks
North Fork/Eastern Hayfork metacherts
Eastern Hayfork metaclastic rocks

Ernst 1999


WEST
EAST
A
B
6000
4000
2000
0
(metabasalts)
WEST
EAST
TS
E
F
8000
6000
4000
2000
0
(metagabbros)
0.0
0.5
1.0
2.0 Km

Ernst 1999

Radiometric Age Dates

How do
we assign
ages
to these
cross-
sections?

Hacker et al 1995

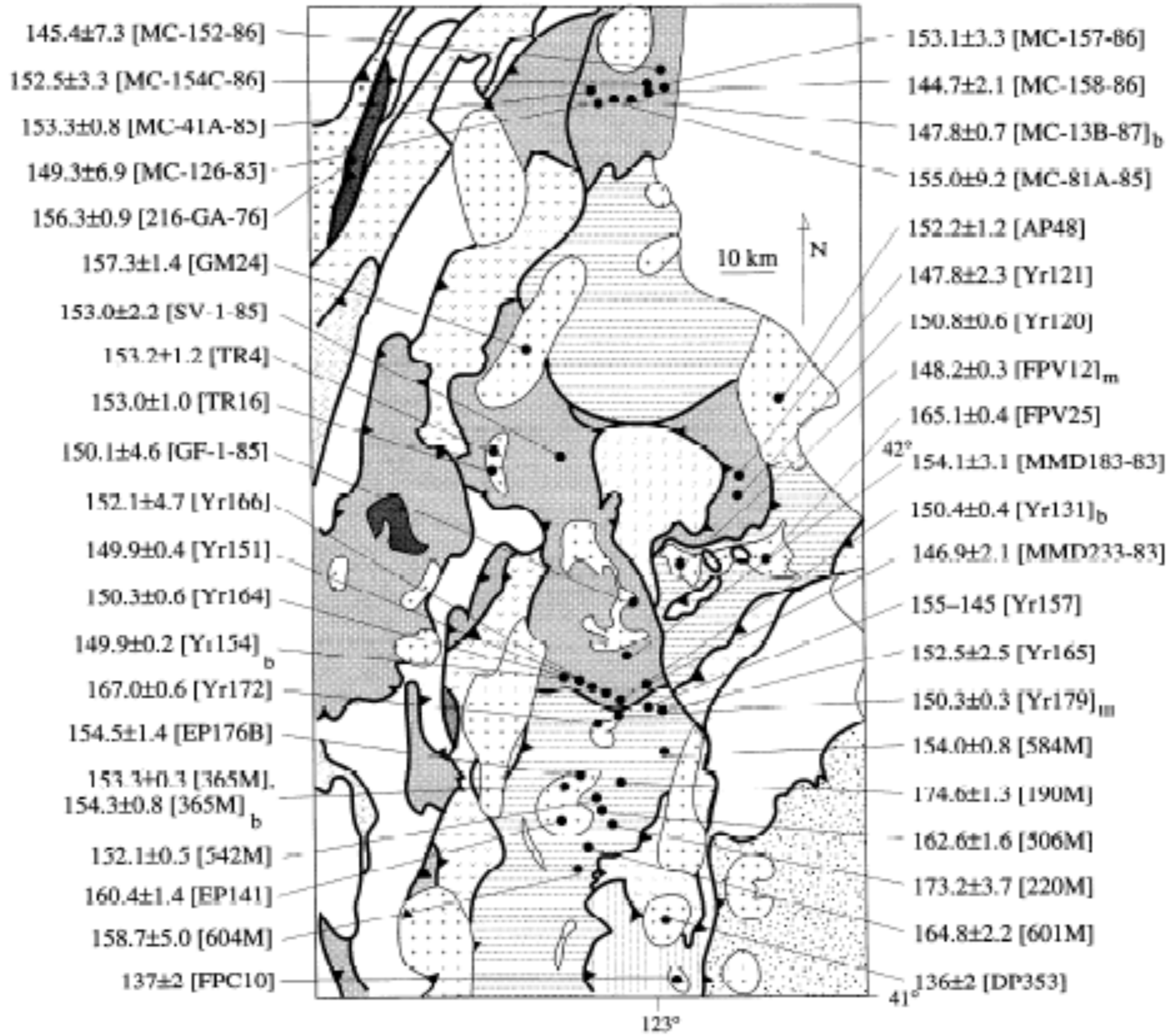


Figure 3. New $^{40}Ar/^{39}Ar$ ages; all are hornblende, except for biotite and muscovite ages labeled with b and m, respectively. See Figure 1 for location and unit names. For additional ages from this same general area, see *Hacker et al.* [1993].

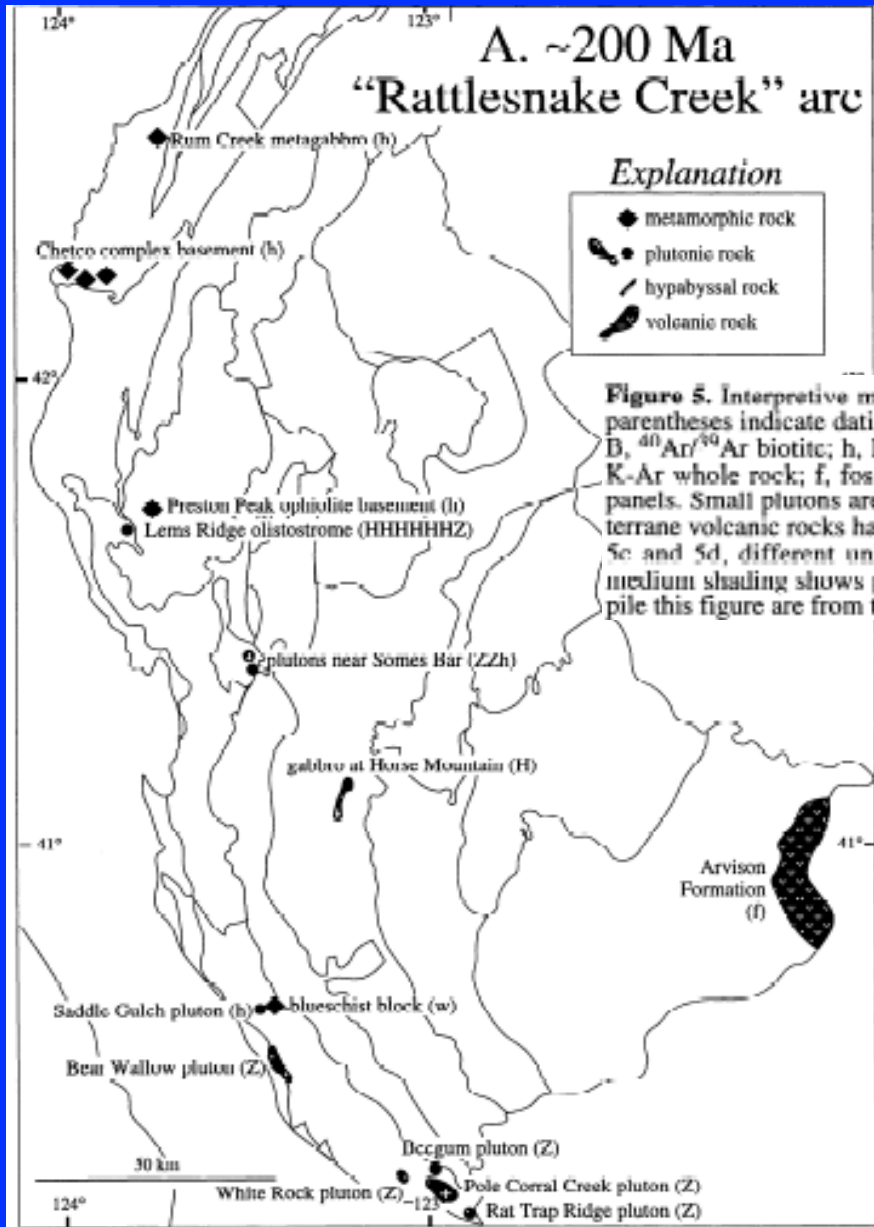
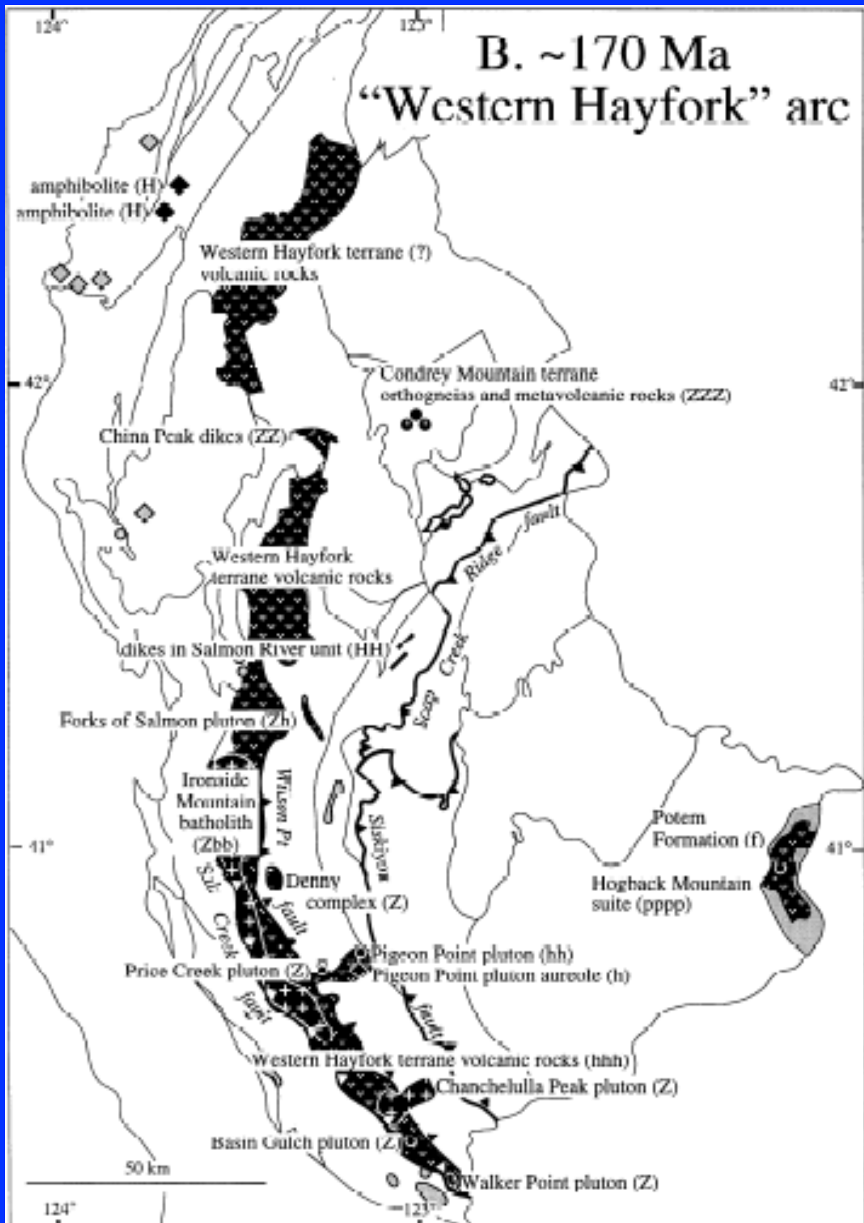
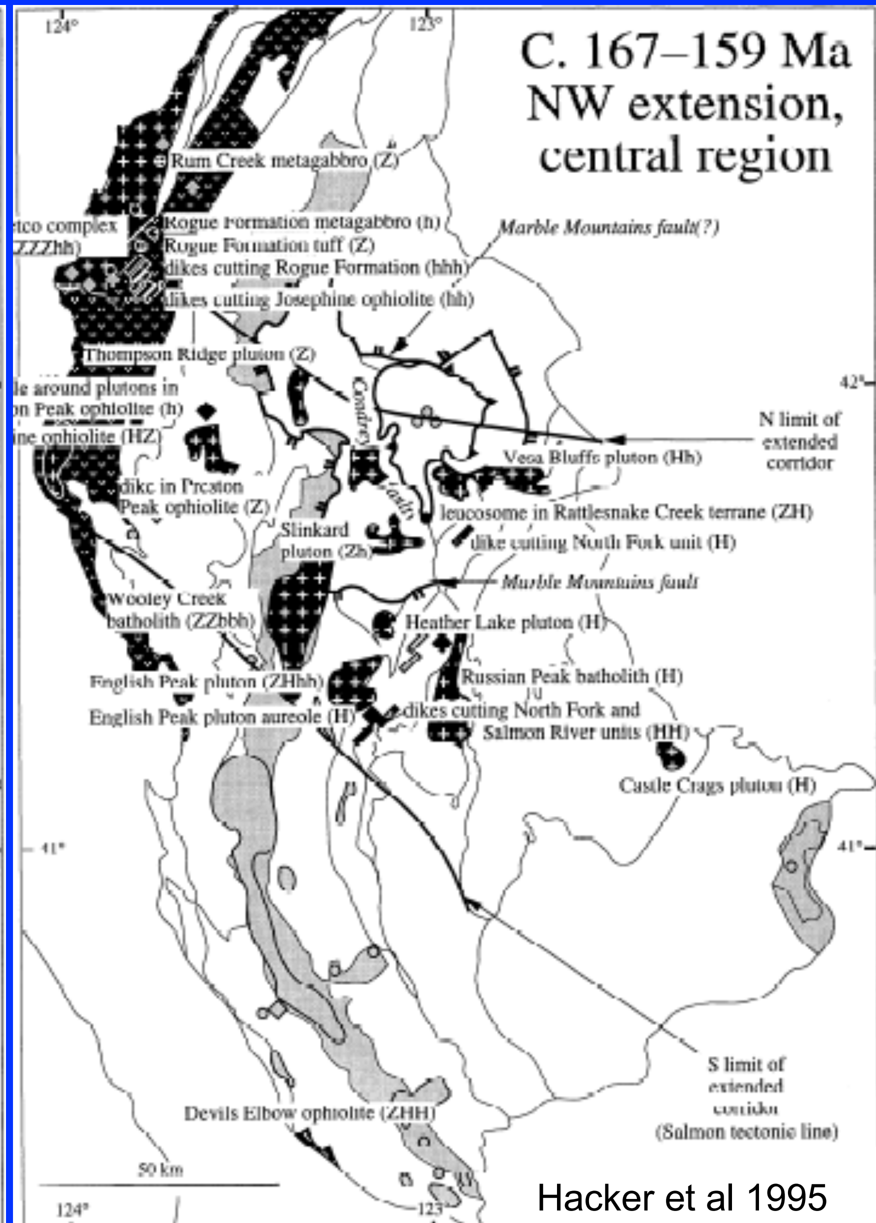


Figure 5. Interpretive maps showing intrusion, volcanism, and metamorphism in six stages. Letters in parentheses indicate dating method: Z, U/Pb zircon; H, $^{40}Ar/^{39}Ar$ hornblende; M, $^{40}Ar/^{39}Ar$ muscovite; B, $^{40}Ar/^{39}Ar$ biotite; h, K-Ar hornblende; m, K-Ar muscovite; b, K-Ar biotite; p, K-Ar plagioclase; w, K-Ar whole rock; f, fossil. After its initial appearance in black, each feature is shaded in subsequent panels. Small plutons are shown as circles. In Figure 5b, only the southern part of the Western Hayfork terrane volcanic rocks have been dated; the central and northern parts may be of different age. In Figures 5c and 5d, different units within the Rogue/Chetco arc have not been differentiated. In Figure 5e, medium shading shows plutons cooling through hornblende and mica closure to Ar. Data used to compile this figure are from this paper or summarized by *Hacker and Ernst* [1993].

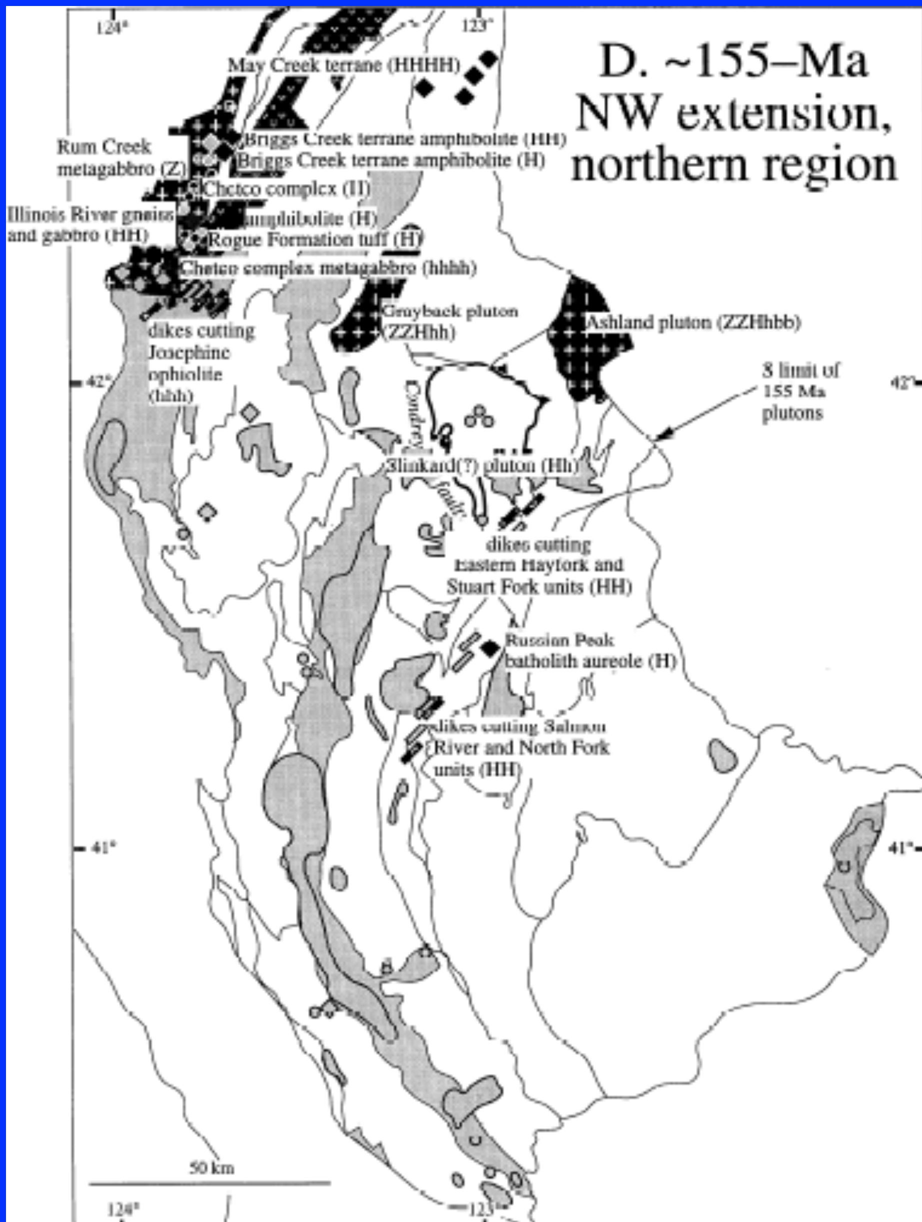
Using the age dates, we can assign ages to regional events, such as terrane collisions.

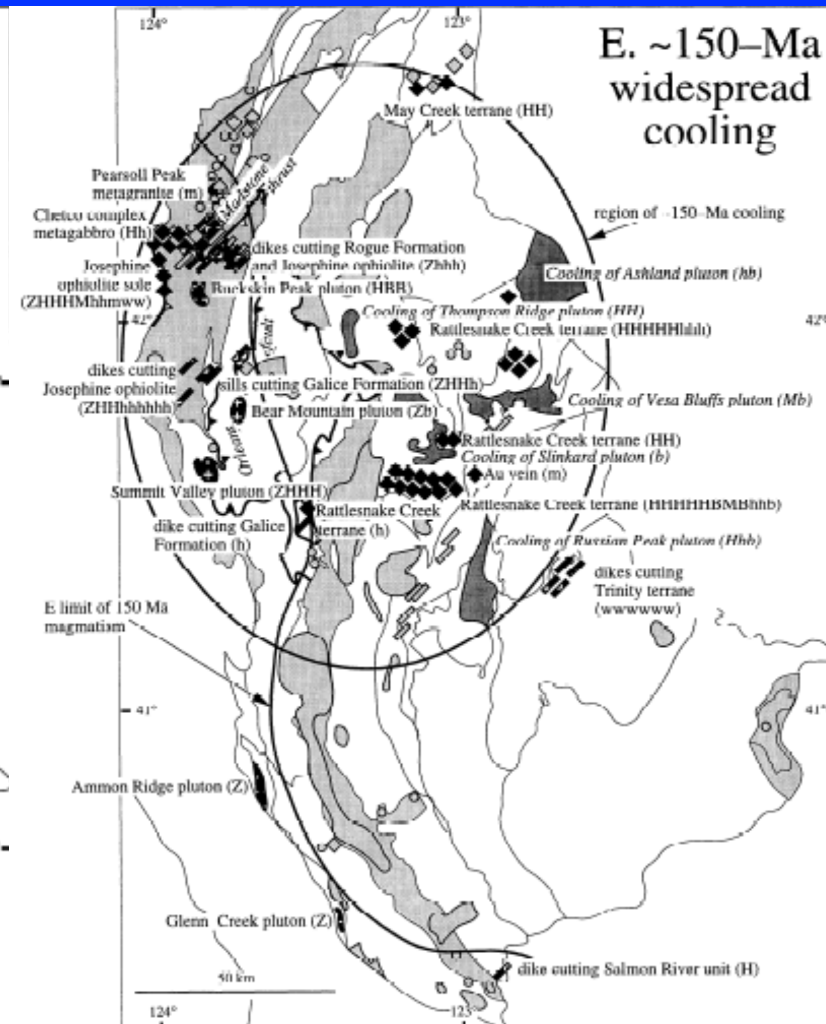
Hacker et al 1995





Hacker et al 1995





Hacker et al 1995

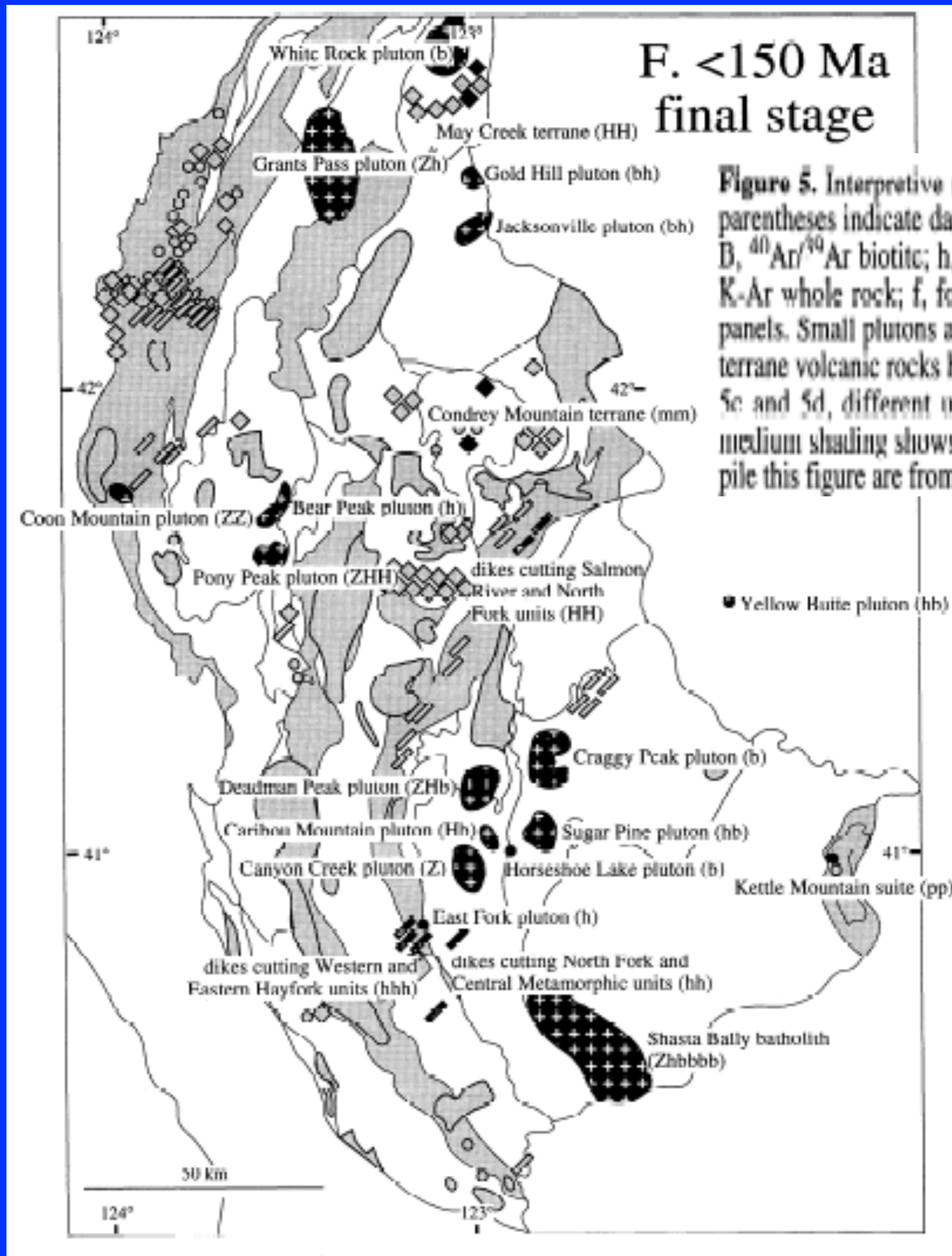


Figure 5. Interpretive maps showing intrusion, volcanism, and metamorphism in six stages. Letters in parentheses indicate dating method: Z, U/Pb zircon; H, $^{40}Ar/^{39}Ar$ hornblende; M, $^{40}Ar/^{39}Ar$ muscovite; B, $^{40}Ar/^{39}Ar$ biotite; h, K-Ar hornblende; m, K-Ar muscovite; b, K-Ar biotite; p, K-Ar plagioclase; w, K-Ar whole rock; f, fossil. After its initial appearance in black, each feature is shaded in subsequent panels. Small plutons are shown as circles. In Figure 5b, only the southern part of the Western Hayfork terrane volcanic rocks have been dated; the central and northern parts may be of different age. In Figures 5c and 5d, different units within the Rogue/Chetco are not been differentiated. In Figure 5e, medium shading shows plutons cooling through hornblende and mica closure to Ar. Data used to compile this figure are from this paper or summarized by *Hacker and Ernst* [1993].

Hacker et al 1995

W

E

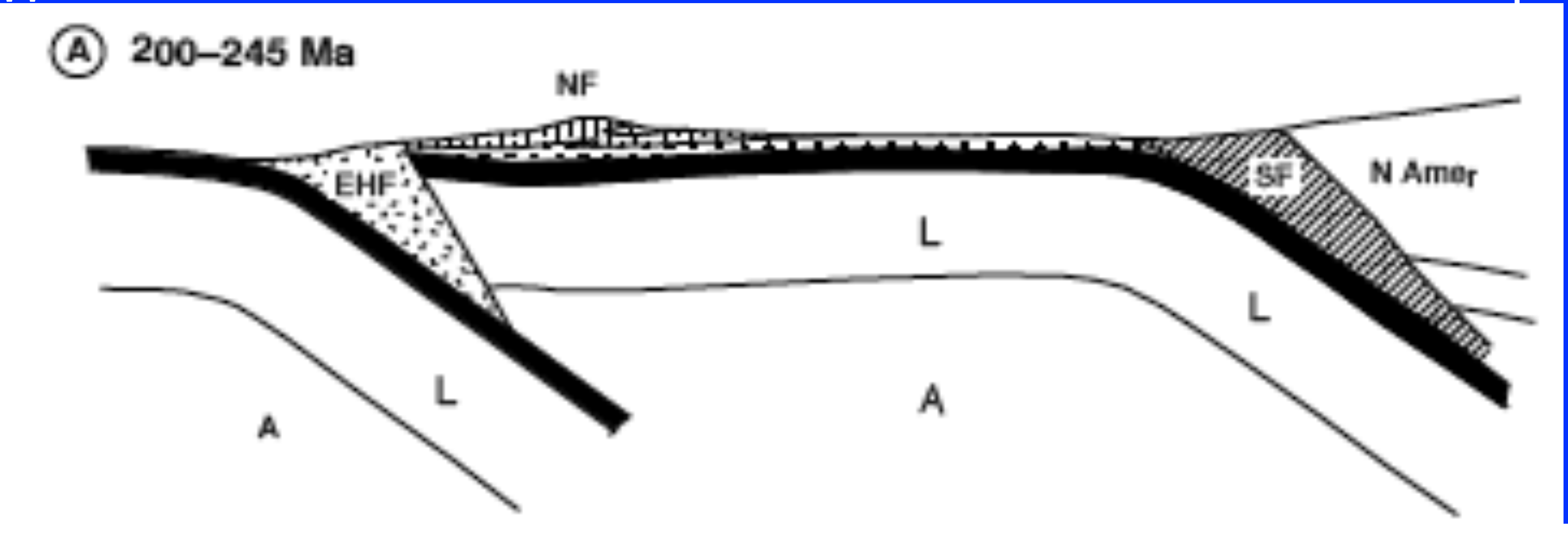


Figure 6. Speculative plate tectonic history of the central portion of the Western Paleozoic and Triassic belt, based on detailed mapping, petrotectonics, and geochemistry of the Sawyers Bar area. View is to the north. Abbreviations: A—asthenosphere; L—lithosphere; WHF—Western Hayfork terrane; EHF—Eastern Hayfork terrane; NF—North Fork terrane; and SF—Stuart Fork terrane. (A) Triassic-earliest Jurassic time; eastern subduction zone becomes inactive and Stuart Fork terrane is sequestered at midcrustal levels by ca. 227 Ma; (B) Early

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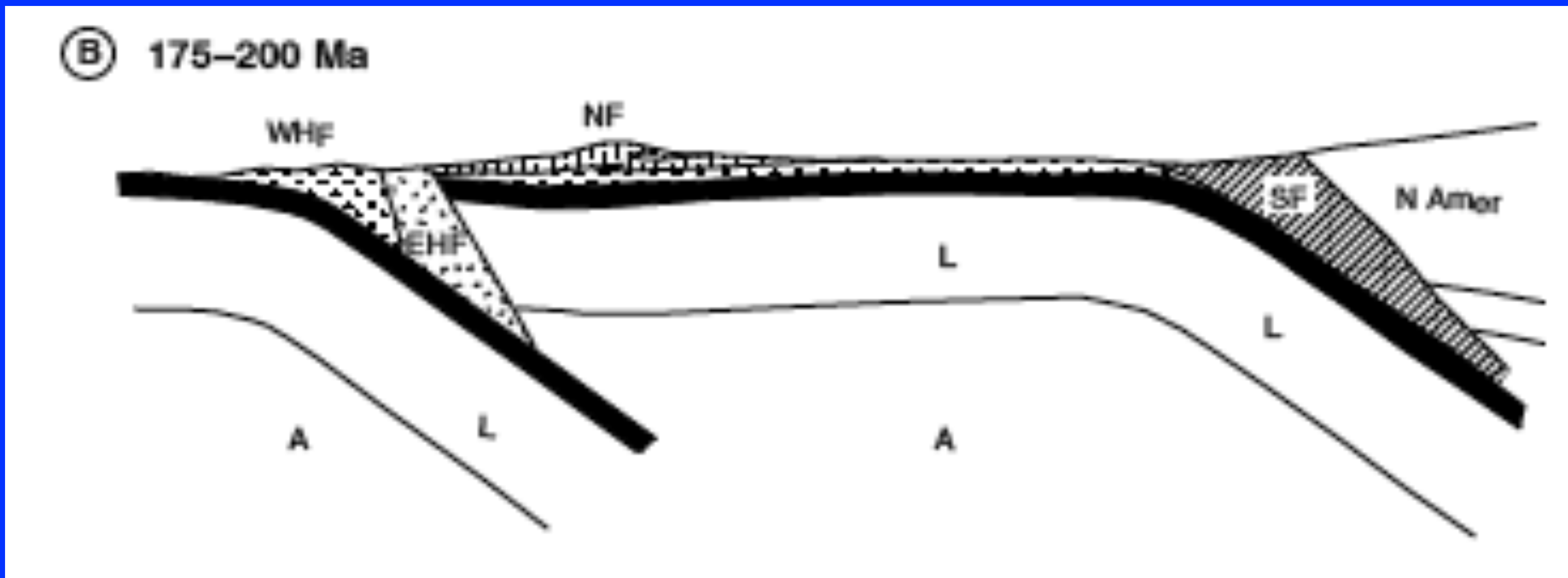
W

E



midcrustal levels by ca. 227 Ma; (B) Early and Middle Jurassic time; Western Hayfork is juxtaposed against inboard Eastern Hayfork through consumption of intervening basin or due to transpression;

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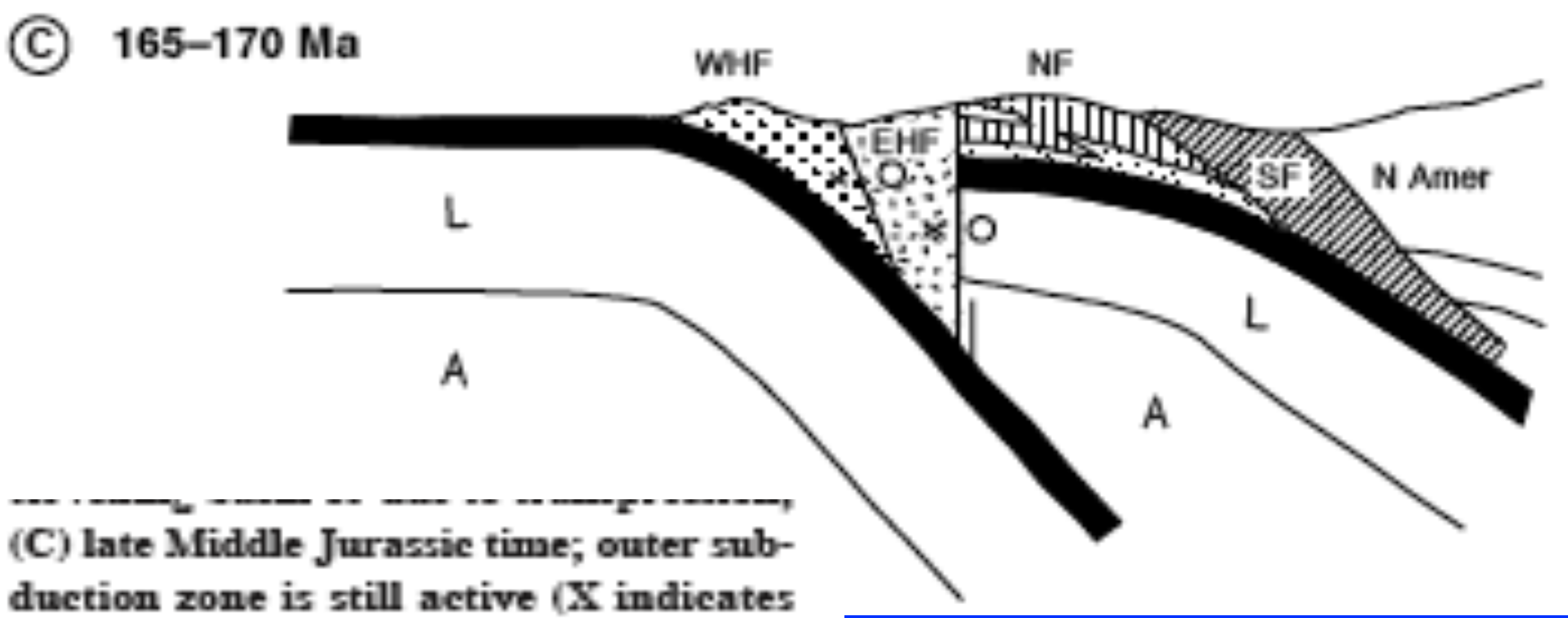
W

E



(C) late Middle Jurassic time; outer subduction zone is still active (X indicates relative movement into the plane of section, i.e., northward; bull's eye indicates relative movement out of the plane of section, i.e., southward); and (D) early Late

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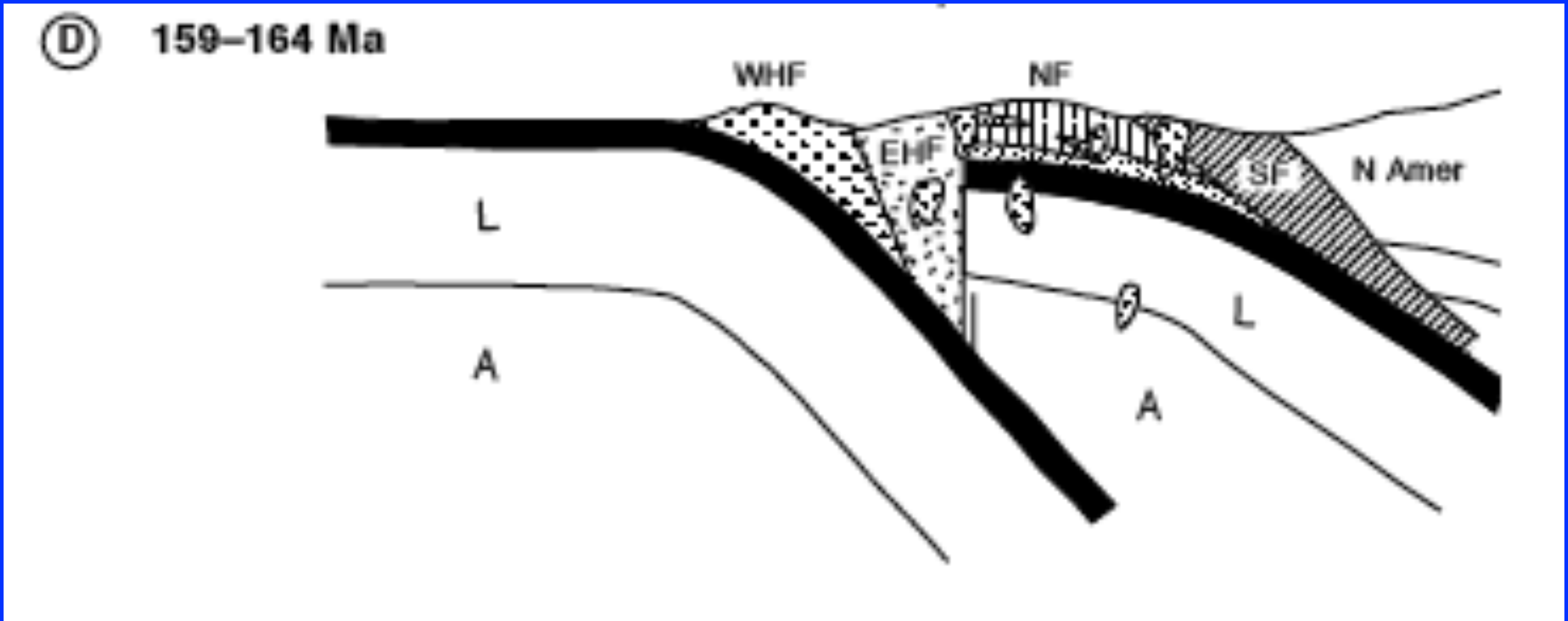

tion, i.e., southward); and (D) early Late Jurassic time; local termination of convergence and thermal relaxation. See text for discussion.

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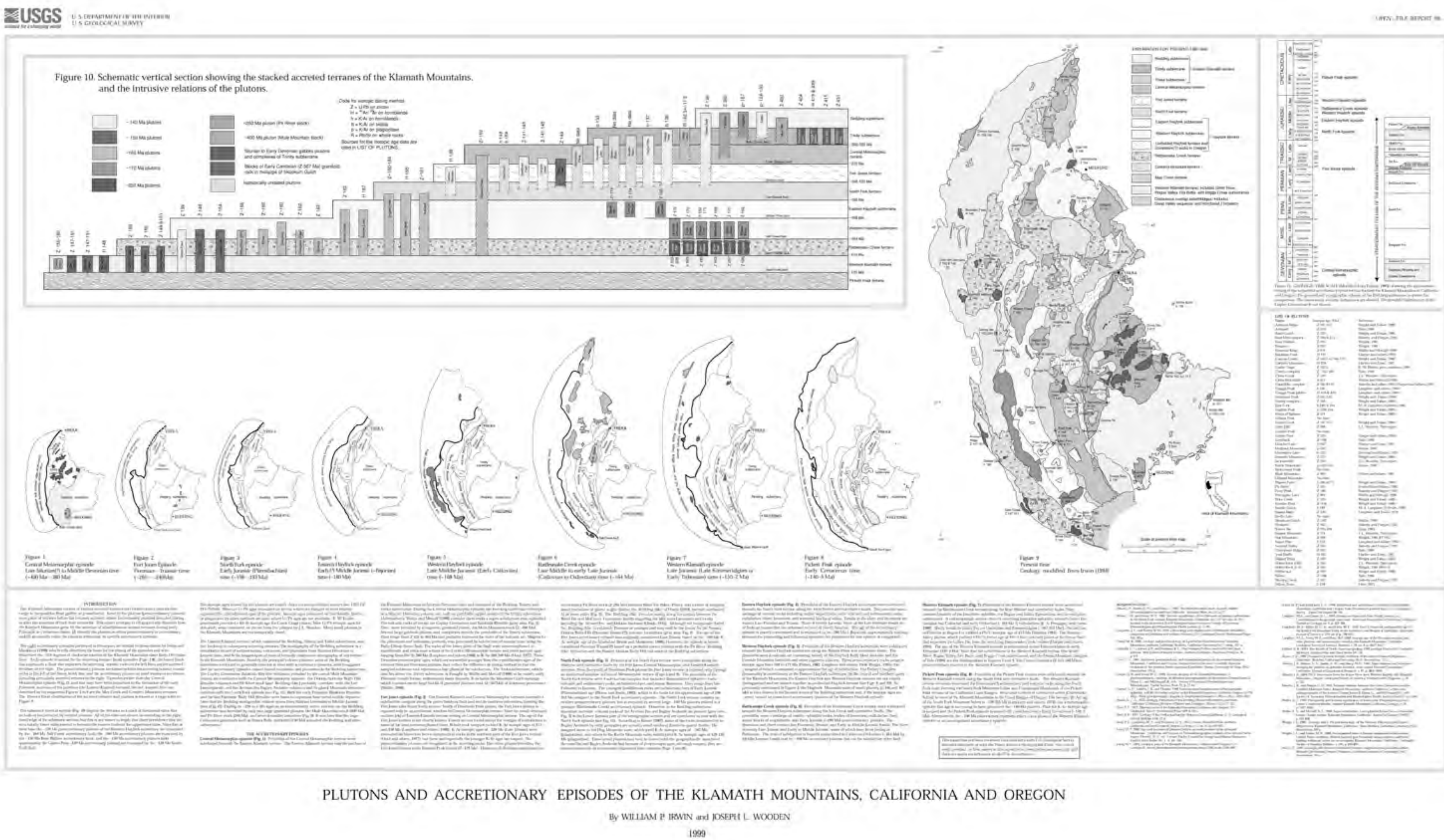
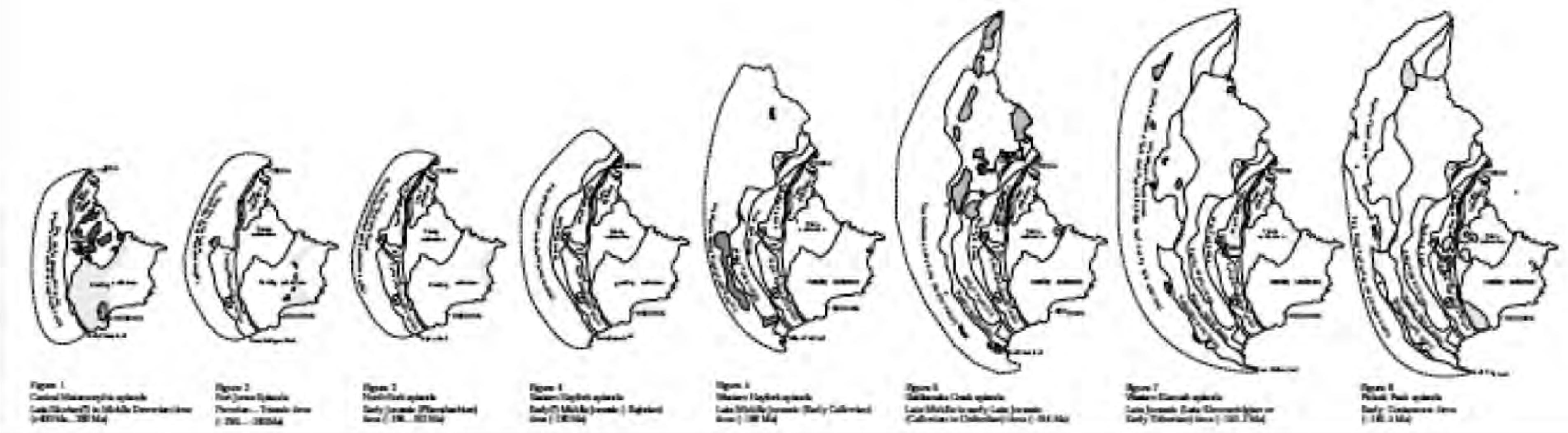
USGS OF 99-374: a history of Klamath accretion



USGS OF 99-374: a history of Klamath accretion



USGS OF 99-374: a history of Klamath accretion

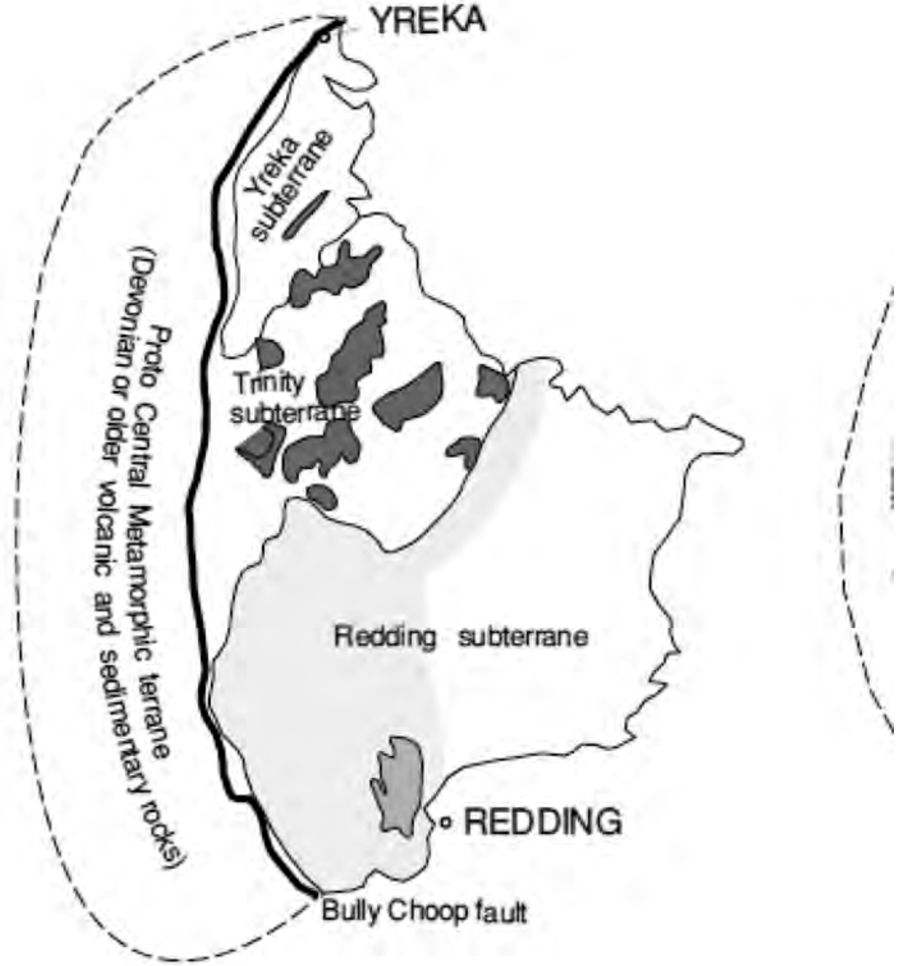


Figure 1
Central Metamorphic episode
Late Silurian(?) to Middle Devonian time
(>400 Ma—380 Ma)

USGS OF 99-374: a history of Klamath accretion

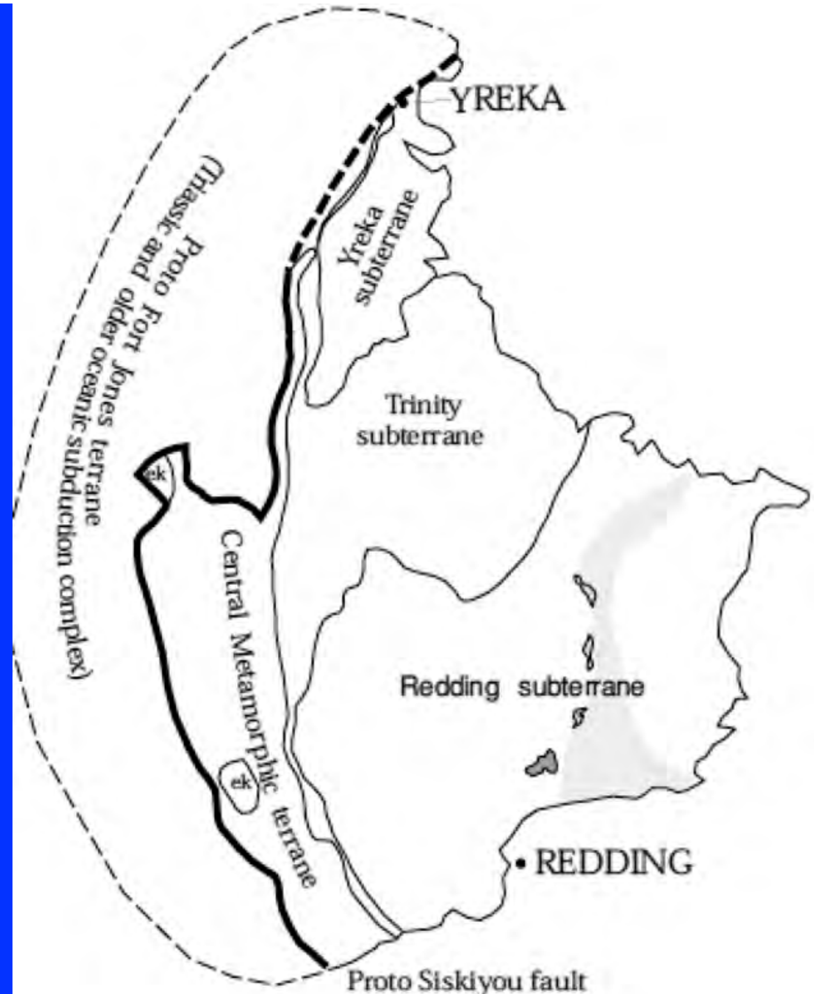


Figure 2
Fort Jones Episode
Permian—Triassic time
(~260—~240Ma)

USGS OF 99-374: a history of Klamath accretion

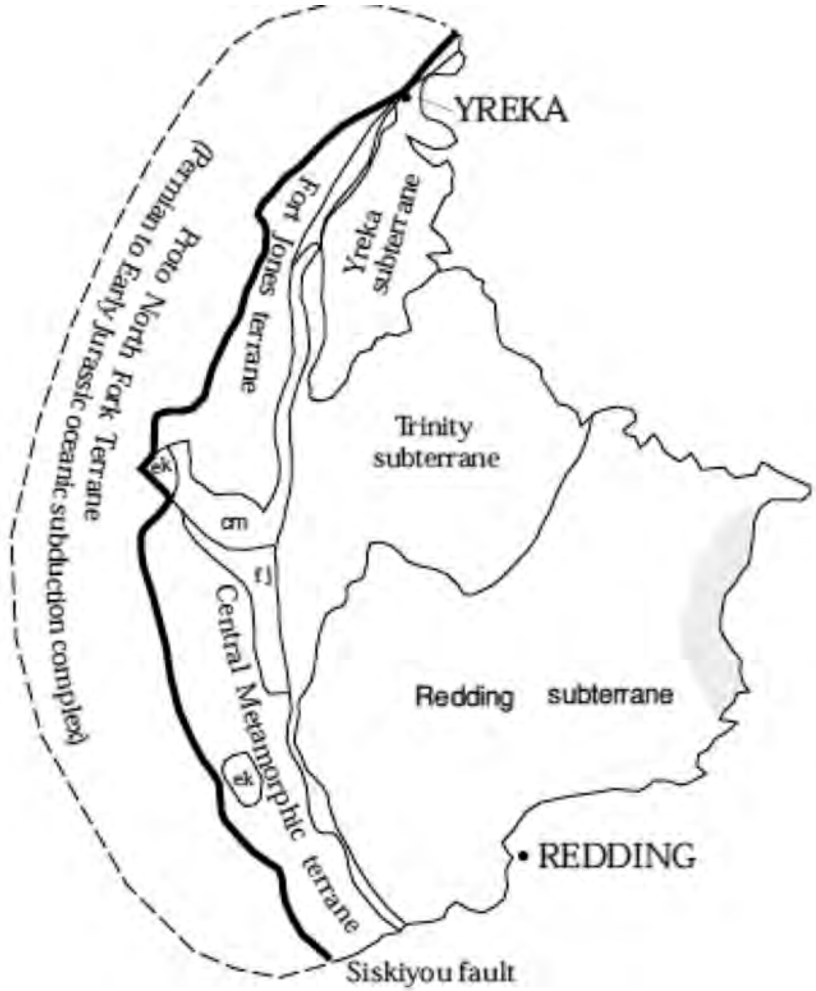


Figure 3
North Fork episode
Early Jurassic (Pliensbachian)
time (~198—193 Ma)

USGS OF 99-374: a history of Klamath accretion

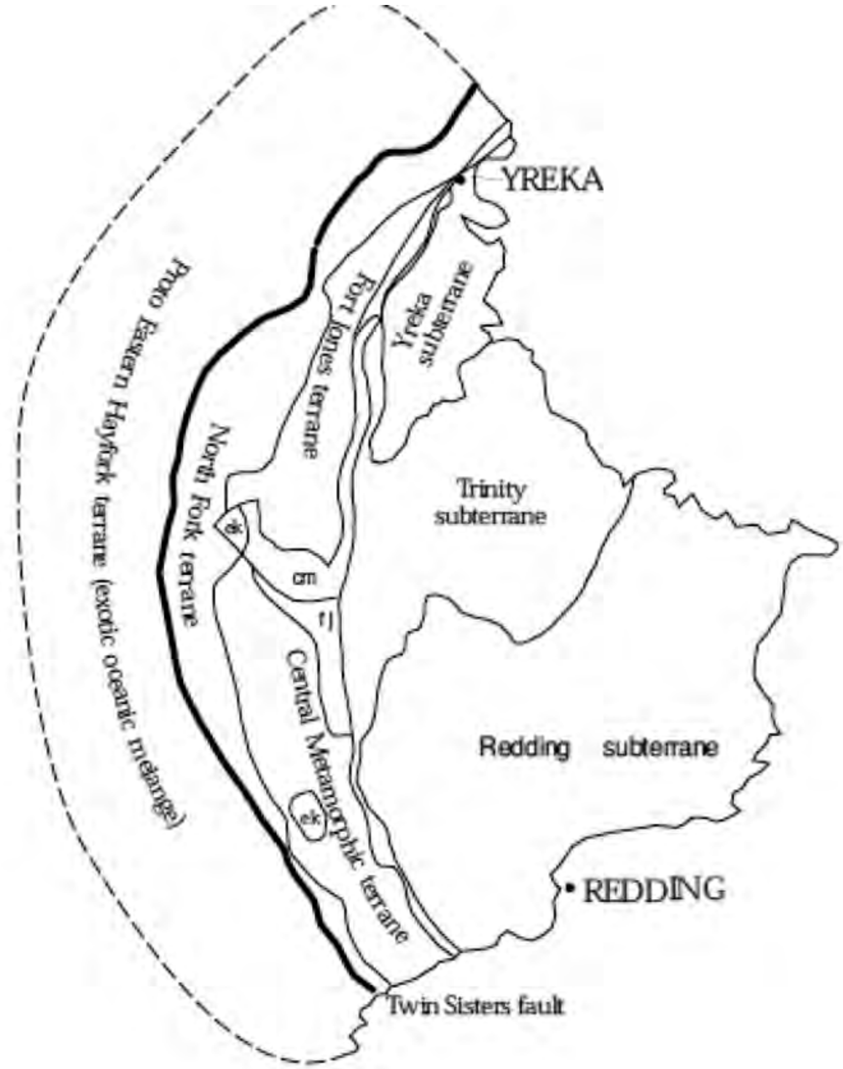


Figure 4
Eastern Hayfork episode
Early(?) Middle Jurassic (~Bajocian)
time (~180 Ma)

USGS OF 99-374: a history of Klamath accretion

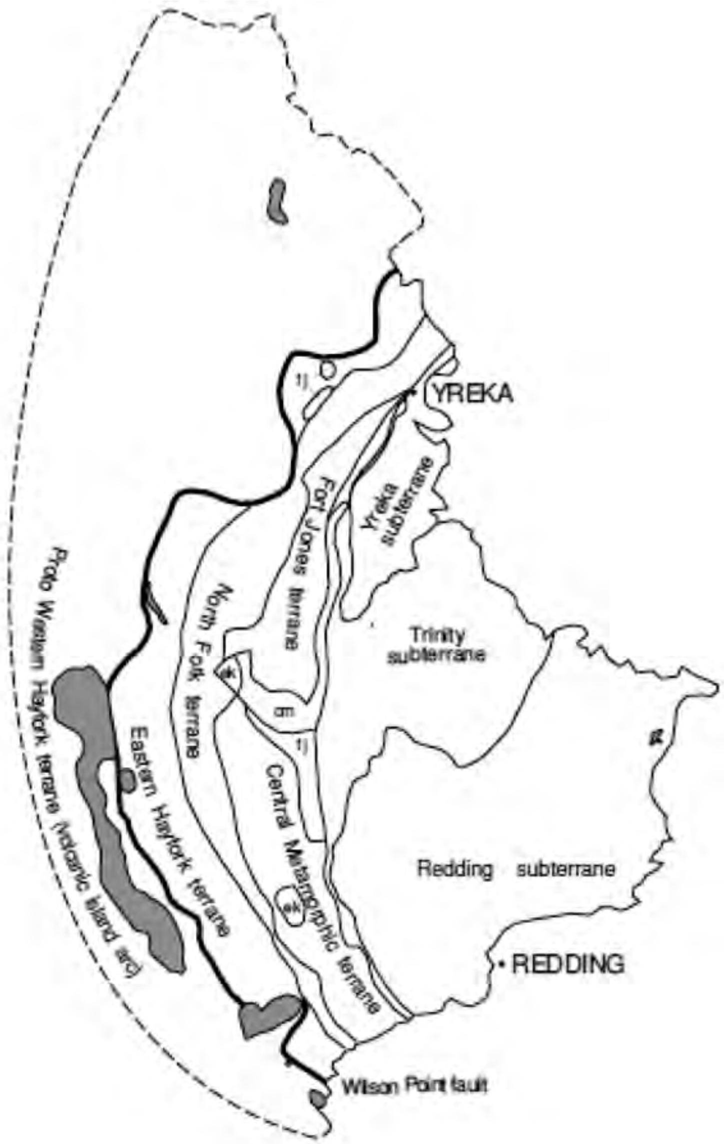


Figure 5
Western Hayfork episode
Late Middle Jurassic (Early Callovian) time (~168 Ma)

USGS OF 99-374: a history of Klamath accretion

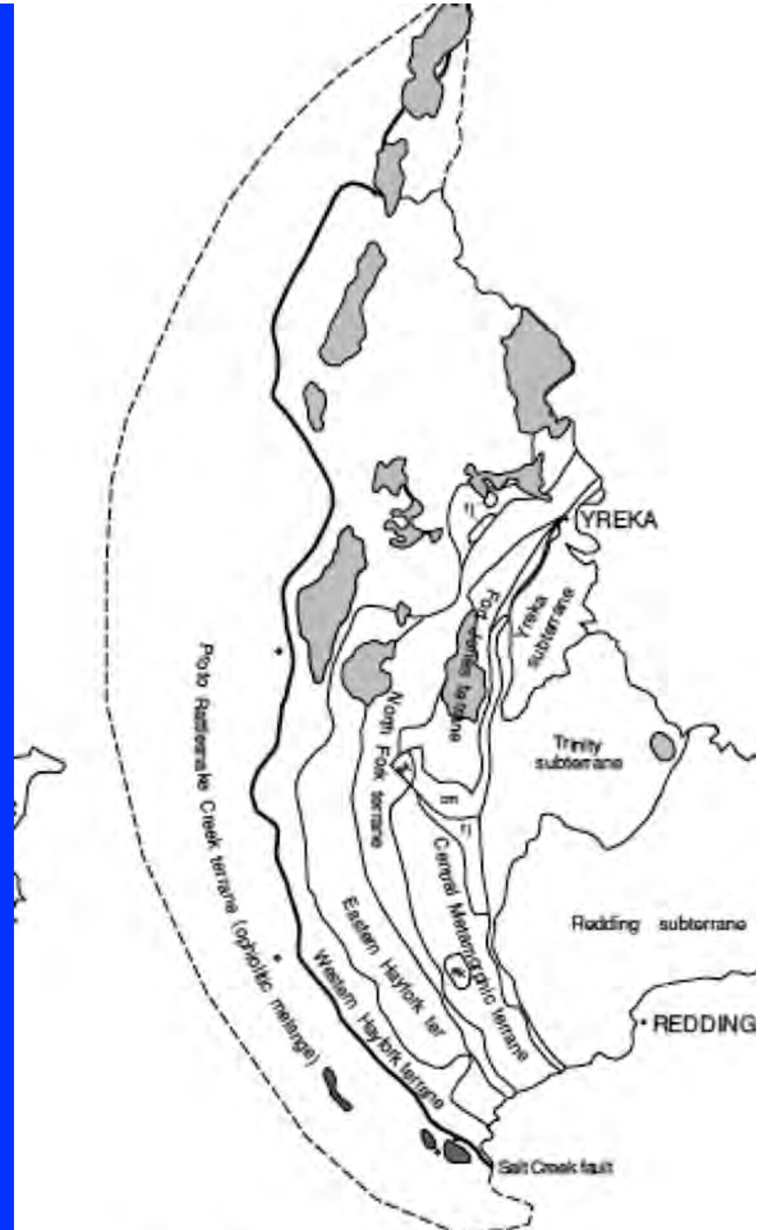


Figure 6
Rattlesnake Creek episode
Late Middle to early Late Jurassic
(Callovian to Oxfordian) time (~164 Ma)

USGS OF 99-374: a history of Klamath accretion

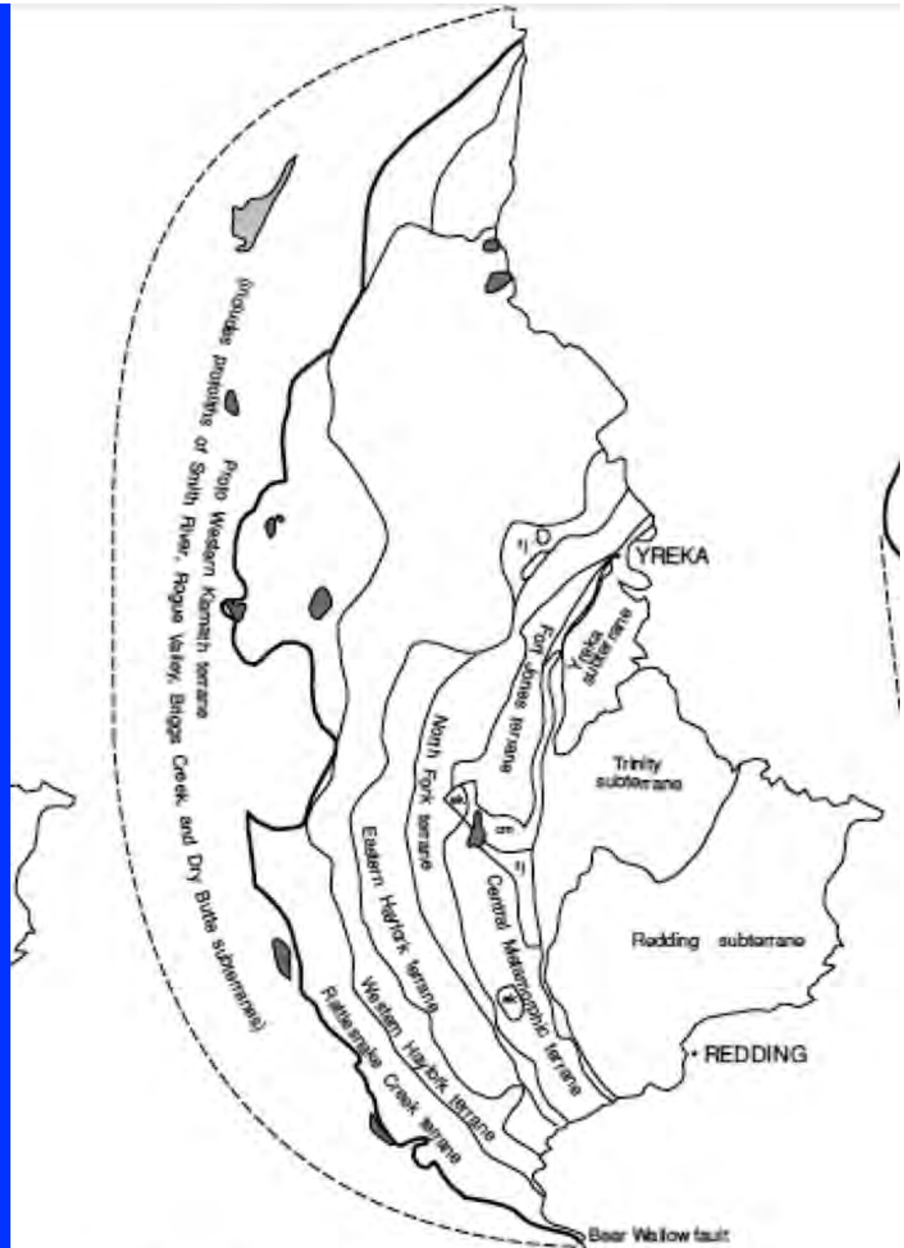


Figure 7
Western Klamath episode
Late Jurassic (Late Kimmeridgian or Early Tithonian) time (~150–2 Ma)

USGS OF 99-374: a history of Klamath accretion

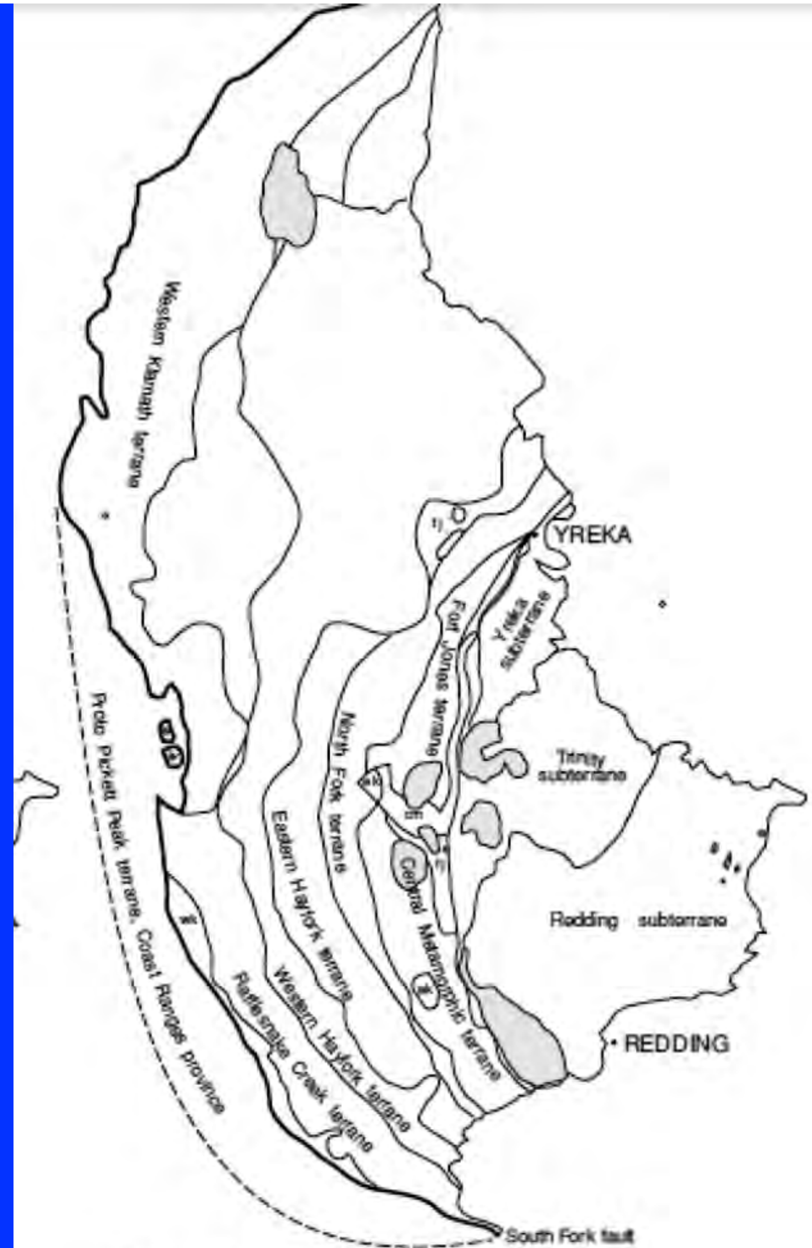


Figure 8
Pickett Peak episode
Early Cretaceous time
(~140–5 Ma)

USGS OF 99-374: a history of Klamath accretion

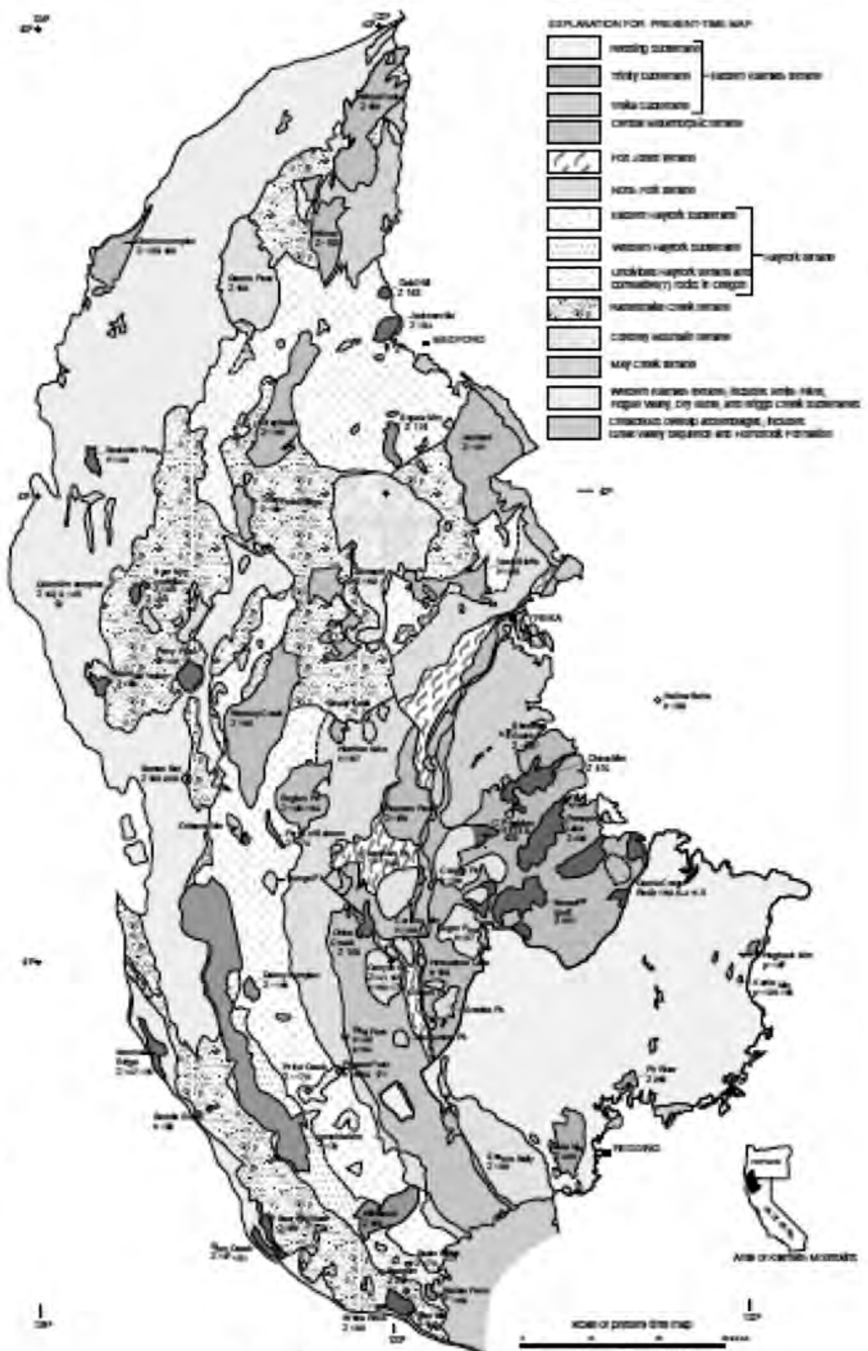
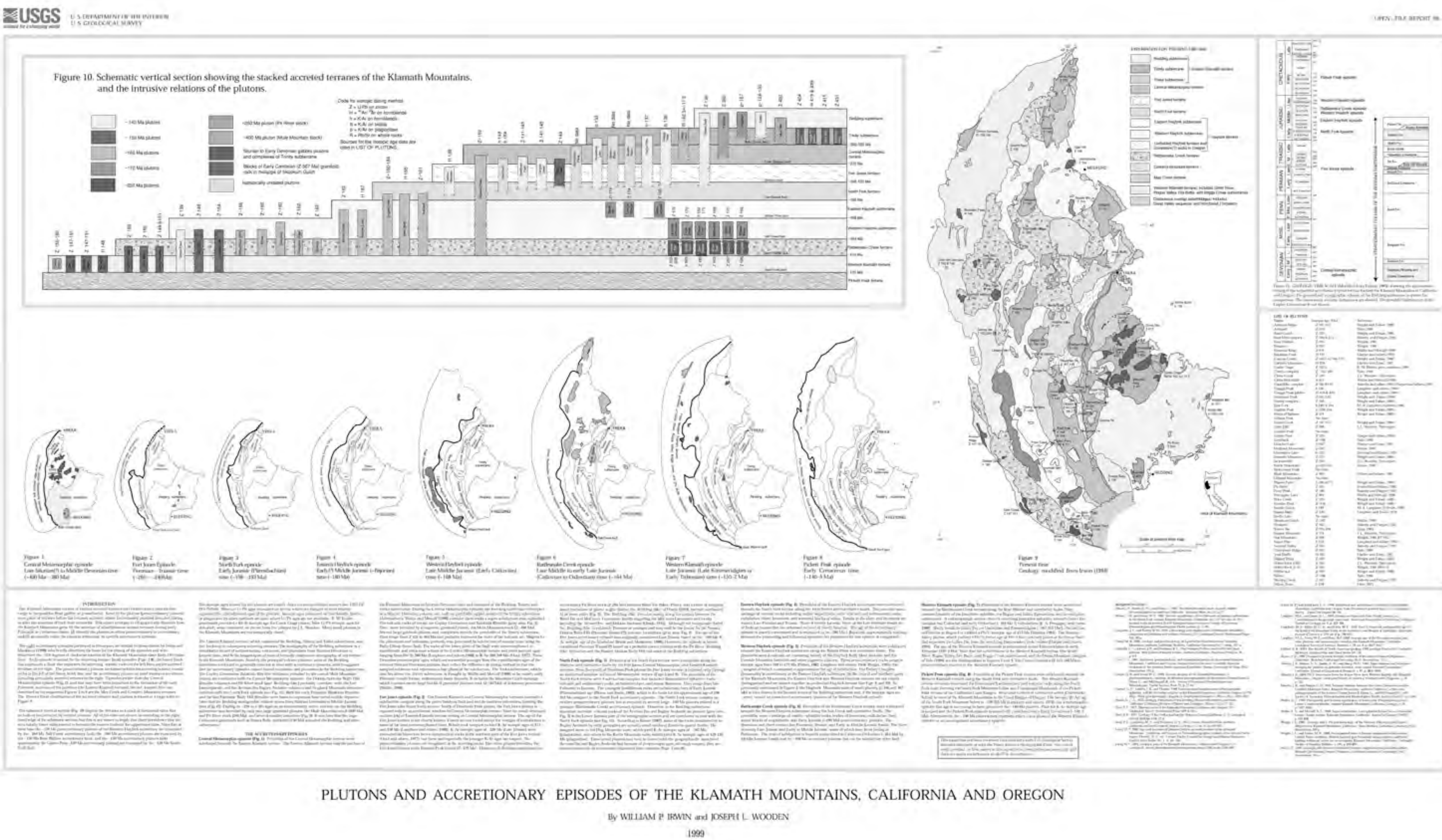


Figure 9
Present time
Geology modified from Irwin (1994)

USGS OF 99-374: a history of Klamath accretion



USGS OF 99-374: note the use of granites to assign ages.

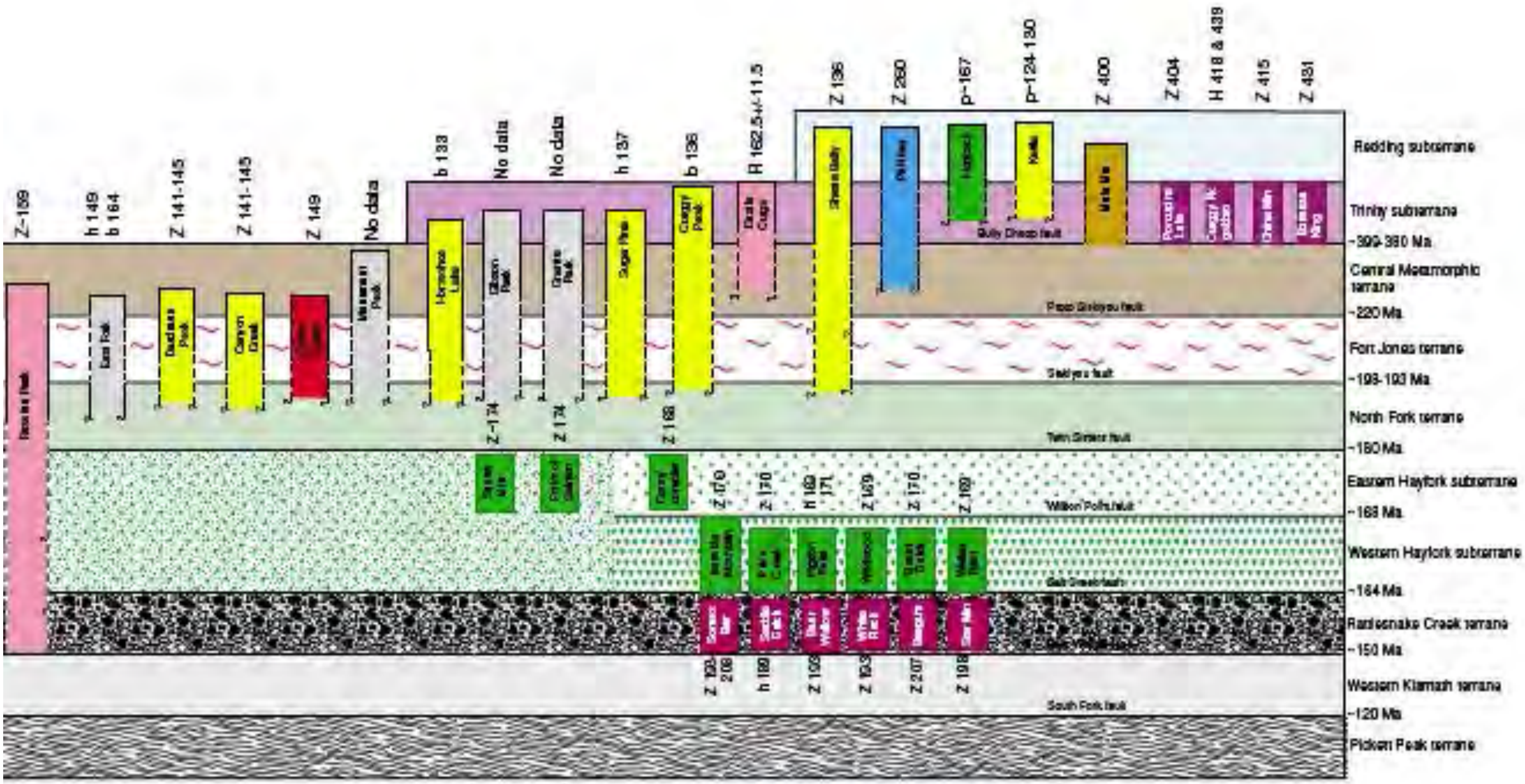
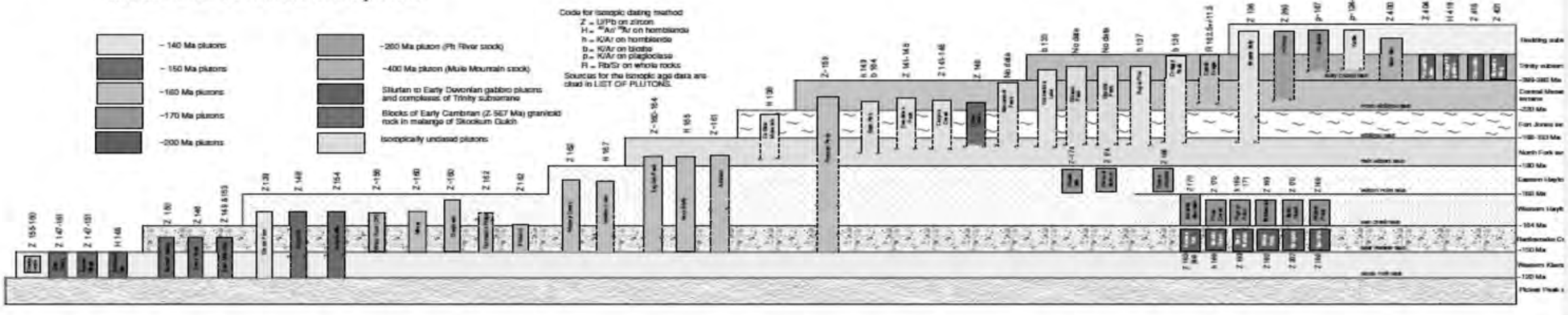


Figure 10. Schematic vertical section showing the stacked accreted terranes of the Klamath Mountains, and the intrusive relations of the plutons.



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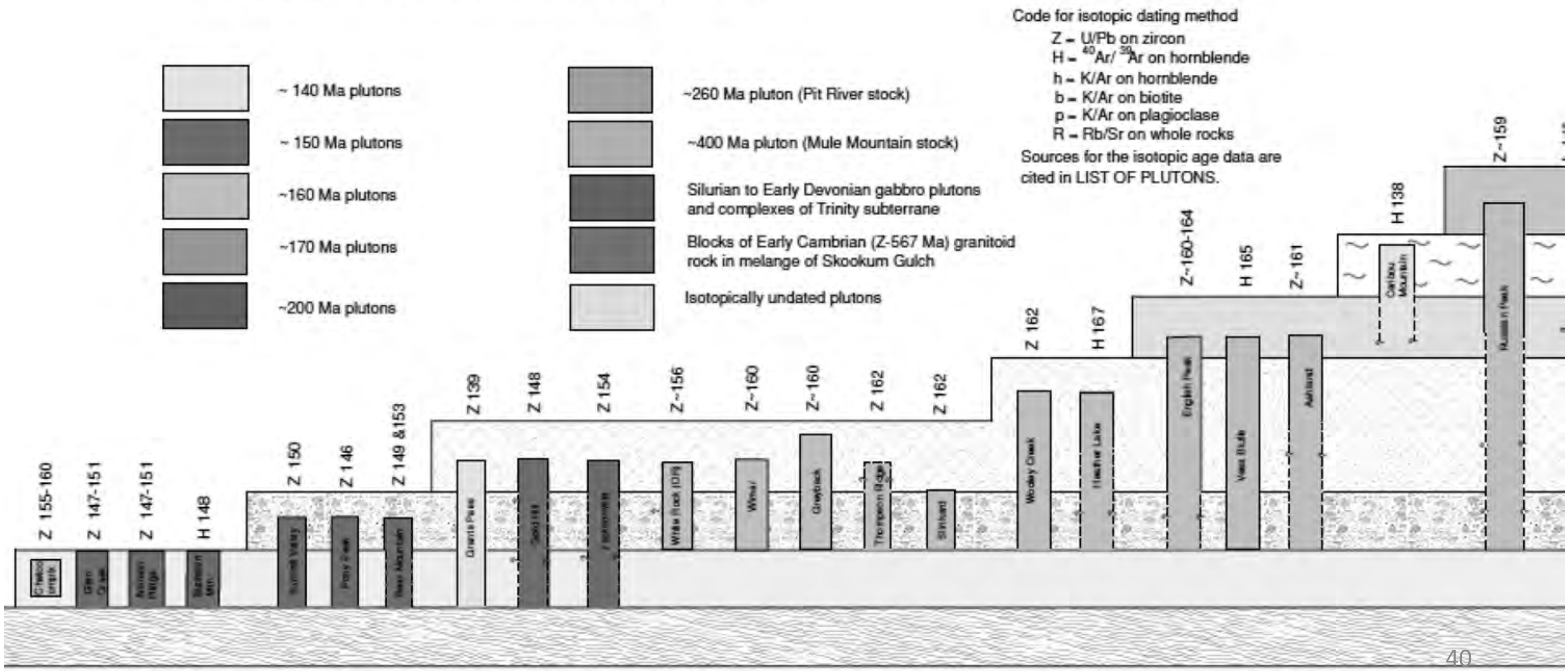
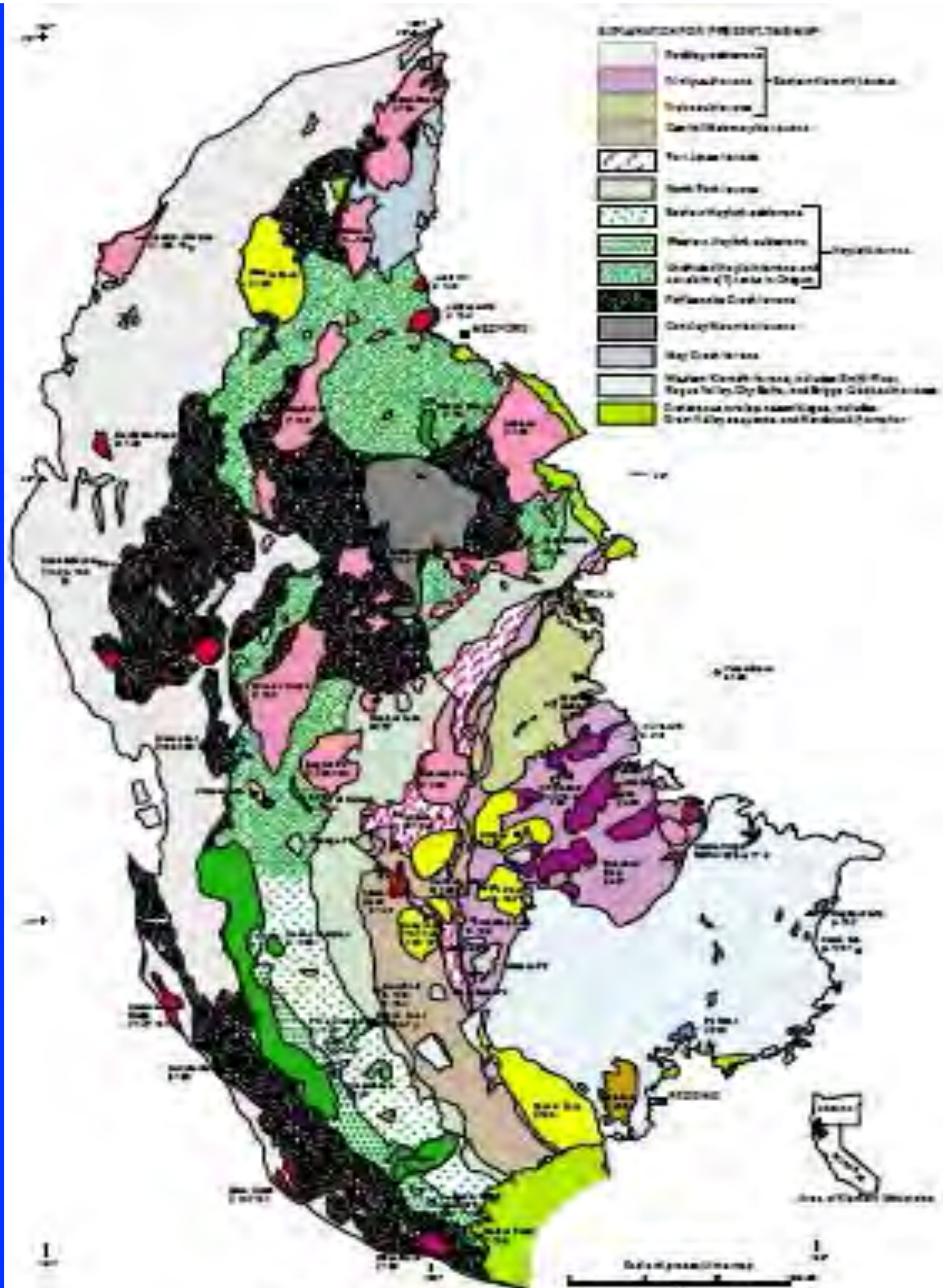
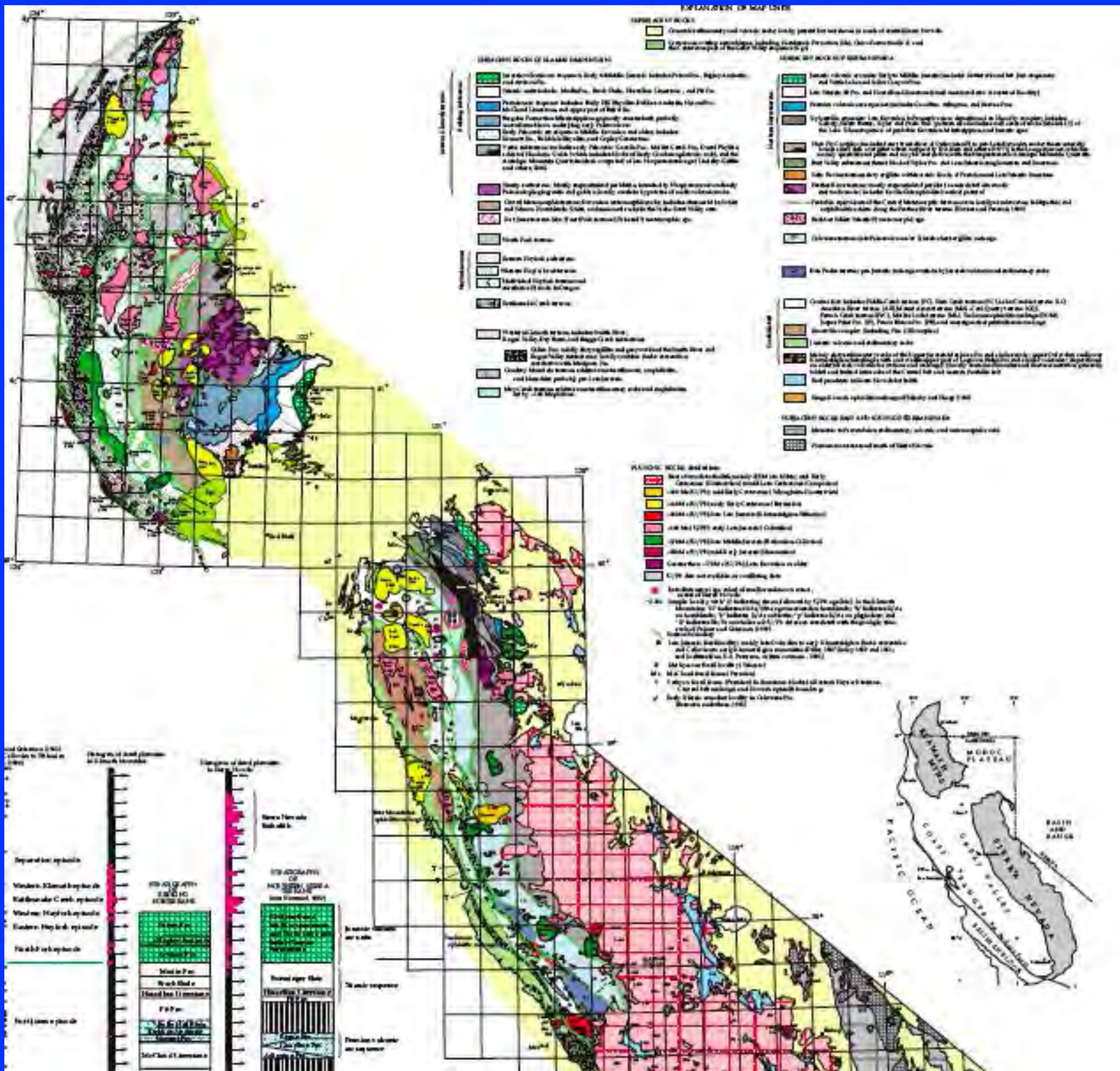


USGS
OF 99-374





The Klamaths

And

The Sierras

A Proposed Correlation

The Klamath Mountains

- Four distinct thrust-bound major terranes
- Many sub-terranes
- Range from Permian to Cretaceous
- Evidence to infer multiple subduction zones
- A long-lived zone of continental growth
- Similar to the Sierra Nevada
- Related to Blue Mountains and other northern regions


YOUR G.P.S.
IS WRONG
DEAD END